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SAVANNAH RIVER PLANT
ENGINEERING AND DESIGN HISTORY

VOLUME II
#100-R,P,L,K & C AREAS

ENGINEERING DEPARTMENT
E. I. DU PONT DE NEMOURS & CO. (INC.)
Wilmington, Delaware

Prime Contractor
For
UNITED STATES ATOMIC ENERGY COMMISSION

U.S. CONTRACT NO. AT(07-2)-1

DU PONT PROJECT 8980

JANUARY, 1957

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SAVANNAH RIVER PLANT

PROJECT 8980

ENGINEERING AND DESIGN HISTORY

VOLUMES AND TITLES

- VOLUME I - ADMINISTRATION
- VOLUME II - #100 AREAS
- VOLUME III - #200 AREAS
- VOLUME IV - #300/700 AREAS AND GENERAL SERVICE
FACILITIES
- VOLUME V - #400 AREA
- VOLUME VI - POWER AND ELECTRICAL FACILITIES
(ALL AREAS)

SAVANNAH RIVER PLANT - PROJECT 8980
ENGINEERING AND DESIGN HISTORY
OF
#100-R,P,L,K & C AREAS

VOLUME II

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PLOT PLAN - 100-R AREA
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PLOT PLAN - 100-L AREA
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PROJECT 8980

#100R AREA

ENGINEERING AND DESIGN HISTORY

OF

#100-R,P,L,K & C AREAS

SAVANNAH RIVER PLANT

I - DESCRIPTION AND DEVELOPMENT OF #100 AREAS

Five reactor areas, designated as #100 Areas, were provided in this project and assigned the letters R,P,L,K and C. Each area was equipped with a reactor building and completely integrated supporting facilities. Design, construction and start-up of operations progressed in the sequence indicated above.

Major production facilities are similar in all areas; however, to the fullest extent possible, simplifications and improvements were introduced, as the design progressed, in the interest of lower cost and more effective operation.

The accelerated schedule for completion of the reactors had a substantial effect on the design. A chart showing the sequence of research, development, design and construction for Building #105 is presented on page 25.

Reliable basic data were not available in the early stages of design, making it necessary to provide allowances in layout for decisions to be made at a later date. Consequently, the first area, #100-R, represented the largest investment since it was equipped with a river water clarification plant of 80,000 g.p.m. capacity and a reactor building substantially larger than those in the remaining areas. This area also included a facility for drum storage of heavy water, Building #122-R, not provided in other areas. A plot plan of the #100-R area is shown on page 11.

Concurrent with the design of the first #100 Areas, engineering and laboratory investigations were conducted by representatives of both the Engineering and Operating Departments to determine the degree of treatment required for use of Savannah River water in reactor cooling. The impact of these studies was reflected immediately in the design of the second area, #100-P, by a reduction in water clarification facilities to 4000 g.p.m. capacity supplying only clarified water for general power and service use, the remaining 76,000 g.p.m. to be supplied to the reactors as raw river water.

Reactor buildings #105-R and P are identical in arrangement with minor reductions in the size of the disassembly area introduced for the P Area. Greater familiarity with the process requirements aided by firm decisions on requirements for supporting facilities made possible a major change in layout in Building #105 between the P and L Areas. This improved layout was adopted for the remaining three areas and represented a substantial reduction in building size, consolidation of many services, and more effective utilization of building space. A plot plan of the L Area is presented on page 13.

An even greater departure from the general #100 Area plans was introduced in the C Area. By this time assurance of reliable purchased power and ability to appraise the power generation capabilities on the site resulted in the elimination of power generating equipment in this area. Accordingly, steam generating facilities were provided only for general process and heating loads, representing a major reduction in power plant investment. Cooling tower requirements for turbine operation were also eliminated.

The earliest concepts of reactor design pointed to the need for developing special fabricating techniques to secure the precise tolerances required for satisfactory assembly and operation of critical reactor components. Early in 1951 arrangements were completed with New York Shipbuilding Corp., Camden, New Jersey, to fabricate and erect a full-scale prototype reactor, from which test results were quickly translated into shop procedures for the production unit. The prototype reactor was subsequently modified to conform to latest design details and erected in Building #105-K. This test program, designated as the NYX Program, is described in detail in Section X of this volume.

Many significant design improvements were incorporated in the C Area reactor complex based on extended calculations, test programs at NYS, and experience in the fabrication of the earlier equipment.

The net result of these major changes in the C Area was a substantially lower investment and higher potential reactor capacity than that for any other #100 Area.

Early in the program the AEC arranged consultation with the Defense Department and the Air Force with respect to the location and dispersal of facilities on the site. As a result, at the suggestion of the U.S. Air Force, the reactor areas were arranged along a horseshoe curve with no permanent facilities located inside this pattern. Basic AEC requirements established a minimum separation of 2-1/2 miles between each of the five reactor areas, a distance of 3 miles from a

passenger carrying railroad, and 6 miles from the site property line. Within the limits of these broad criteria, area locations were selected to obtain optimum topographical conditions. Sites were selected and allocated for a total of seven areas providing two locations for future expansion. Principal area locations are shown on the site plan on page 9.

Plans for the five #100 Areas included provisions for each area to be self-sufficient during extended emergency periods. Four of the five areas contained power generating capacity equivalent to the area demand for production. The #100-C Area depended upon outside sources of electric power for full production. All areas were dependent upon river water supplied from a system of underground lines radiating from two pump houses located on the river. The selection of ideal #100 Area sites provided for the gravity return of cooling water effluent from each area to the river through natural drainage channels.

It was the initial intent of the Engineering Department to subcontract the design of all SRP facilities including the reactor areas, the work to be coordinated and directed by du Pont Design Division personnel. With this objective, negotiations were conducted for several months with Ebasco Services, Inc., with the intent of assigning to them the responsibility for the utilities and reactor areas. However, no satisfactory agreement had been reached by November, 1950, when the decision was made by Engineering Department management that the reactor process design assignment would be assumed by the du Pont Design Division. The design of all principal utilities was assigned subsequently to Gibbs & Hill, Inc., New York City. In September, 1951, the design of the heavy water purification wing of Building #105 was assigned to the Blaw-Knox Company because of the similarity of these facilities to the canyon design in the #200 Areas which had already been subcontracted to the Blaw-Knox Company and was well under way.

The design of administrative and service facilities in the #100 Areas was assigned to Voorhees Walker Foley & Smith of New York City, whose effort included site layout, grading, roads, railroads, administrative, laboratory, and service facilities in all areas. The du Pont Engineering effort, in addition to participating in reactor development and design, included the responsibility for coordination of du Pont design with the subcontractors' work associated with the five reactor areas. Refer to page 20 for Building List and design assignment.

#100 AREA BUILDING LIST

<u>Building Number</u>	<u>Name</u>	<u>Areas in which building is located</u>	<u>*Design by</u>
105	Reactor	CKLPR	Du. & B-K
106	Process Water Storage	CKLPR	Du Pont
107	Cooling Water Effluent Sump	CKLPR	G. & H.
108-1,2	Engine Houses	CKLPR	G. & H.
108-3	Fuel Unloading Facilities	CKLPR	G. & H.
109	Purge Water Storage Basin	CKLPR	Du Pont
110	Gas Storage	CKLPR	B-K
122	Process Storage Building	R only	VWF&S
151-1,2	Primary Substation	CKLPR	G. & H.
152	Secondary Substation	CKLPR	G. & H.
183-1	Clarification Plant (Cooling Water)	R only	G. & H.
183-2	Filter and Softener Plant	CKLPR	G. & H.
183-4	Clarification Plant (Misc. Services)	CKLP	G. & H.
184-1	Power House	CKLPR	G. & H.
184-2	Service Building	C	G. & H.
185	Cooling Towers	KLPR	G. & H.
186	Cooling Water Reservoir	CKLPR	G. & H.
188	Ash Disposal Basin	KLPR	G. & H.
190	Cooling Water Pump House	CKLPR	G. & H.
501	Fence and Road Lighting	CKLPR	G. & H.
503	Distribution Lines	CKLPR	G. & H.
505	Fire Alarm Systems	CKLPR	G. & H.
506	Telephone Cable and Instru- ments	CKLPR	G. & H.
507	Safety Alarm System	CKLPR	G. & H.
601	Standard Gauge Track	CKLPR	VWF&S
603	Roads	CKLPR	VWF&S
604	Walks	CKLPR	VWF&S
605	Fences	CKLPR	VWF&S
607	Septic Tanks	CKLPR	VWF&S
613	Parking Area	CKLPR	VWF&S
697	Site Work and General Grading	CKLPR	VWF&S
698	Landscaping	CKLPR	VWF&S
701-1	Area Gate House & Patrol Headquarters	CKLPR	VWF&S
701-2,3	Gate House	CKLPR	VWF&S
704	Office and Shops Building	CKLPR	VWF&S
711	Steel and Pipe Storage	CKLPR	VWF&S
801	Pipe Supports	CKLPR	Du Pont
802	Steam Lines	CKLPR	Du Pont
808	Chlorine Lines	CKLPR	Du Pont
809	Ash Sluicing Lines	KLPR	Du Pont
901	Water Lines	CKLPR	Du Pont
903	Sanitary Sewers	CKLPR	VWF&S
904	Process Sewers	CKLPR	Du Pont
907	Storm Sewers	CKLPR	VWF&S

* B-K - Blaw-Knox Company
 G. & H. - Gibbs & Hill
 VWF&S - Voorhees, Walker, Foley & Smith

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II - DEVELOPMENT OF BUILDING #105 DESIGN

FUNCTIONS

Building #105 in each of the five #100 Areas performs the same basic function of irradiating elements in a heavy-water moderated, heavy-water cooled reactor using uranium as a fuel. The principal supporting functions performed in the building to support the reactor operation are listed below:

1. In the assembly area, fuel elements and target materials to be irradiated are cleaned, loaded into foils, inspected, flow-tested, and stored prior to loading into the reactor.
2. The process area devoted to the main reactor complex includes the reactor tank, shielding and related accessories, heavy-water circulating pumps, piping and heat exchangers, radiation monitoring systems, reactor control equipment and special equipment for charging and discharging the reactor.
3. In the disassembly area the materials after irradiation, as well as the depleted fuel elements, are aged, disassembled, and loaded into casks for shipment to another plant area, all operations being performed under water by remote mechanisms.
4. The purification area contains equipment for the continuous purification of the heavy water moderator and helium blanket gas during reactor operation.
5. Various types of service facilities located throughout the building include operating control rooms, heating and ventilating equipment, electrical power distribution facilities, change rooms, offices, and miscellaneous facilities peculiar to reactor operation.

Connected to the reactor building by underground passages are two adjacent buildings, #108-1 and #108-2, which house standby and emergency power facilities (see Volume VI - Power Facilities). Equipment in these buildings includes emergency diesel electric power generation and water pumping facilities which permit operations to be self-sustaining during interruptions in the normal power supply. Both Buildings #105 and #108 are of blast resistant construction to further

insure their integrity under either earthquake or other disaster conditions. Buildings #105-L, K and C include certain noncritical areas which, for economic reasons, were not enclosed with blast resistant construction.

DESIGN PHILOSOPHY

The nuclear reactor in Building #105 is the core of the #100 Area, and all sections of the building as well as the other #100 Area buildings and facilities were designed and located to serve it most efficiently. Consequently the development of the reactor dictated, to a large extent, the scope of work for the balance of the area. This history outlines consecutive steps in design development of the building and equipment to acquaint the reader with the reasoning behind the design of the completed facilities.

Three documents prepared in 1950 record the early concept of the reactor. The first, dated August 9, 1950, was prepared by the Technical Group of the du Pont Atomic Energy Division and described the "Pi-Pile". This was followed on October 23, 1950, by "#100 Area - Preliminary Scope of Work" issued by AED's Process Group. The Design Division's engineering concept of AED's scope was detailed in an unissued letter by Design to Ebasco dated November 7, 1950. These documents will be referred to from time to time.

Design development of the reactor proceeded concurrently with the development of its closely integrated auxiliaries: the D₂O pumps, heat exchangers and piping; control mechanisms; charging and discharging equipment; and the arrangement of the building to house this equipment and other directly supporting facilities. In connection with significant development steps, frequent reference will be made to dates to acquaint the reader with the time intervals involved.

A chronological review of the design and construction schedules for the #100-R Area demonstrates the effort made to achieve the earliest possible start-up by simultaneously pursuing research and development, design, equipment procurement and construction. The chart on page 25 shows the overlapping of the research and prototype development work at NYX and CMX, the design and construction activities and a few key decisions. It may be noted that the decision to use vertical control rods instead of horizontal rods was made only a few weeks before building excavation was started. While the NYX testing was still in progress, the R Area reactor was shipped to SRP by the New York Shipbuilding Corporation. Furthermore, almost one-half of Building #105-R was built before the decision was made to abandon the R1 actuator system in favor of the R2 system. Fuller

BUILDING #105-R SEQUENCE

Research - Development - Design - Construction

- NOTE:
1. Vertical control rods adopted
 2. R2 control rod actuator system adopted
 3. Initial shipment to SRP
 4. Criticality

appreciation of these overlapping activities will be realized after reading the development history of these design phases. This procedure was not as obvious in the #100-P Area since many drawings prepared for the R Area were duplicated for P Area. The #100-L, K and C Area efforts, however, again demonstrated this practice.

PROCESS BASIC DATA

Preparing for the design and construction of the new Atomic Energy Commission plant, du Pont used available AEC reports and data to study three fuel-moderator combinations.

1. A heavy water moderated, natural water cooled, natural uranium system.
2. A heavy water moderated, heavy water cooled, natural uranium system.
3. A natural water moderated, natural water cooled, enriched uranium system.

The second alternative represented a basic system which had been recommended to the Commission by its Argonne National Laboratory, and this type was finally selected. In the analysis, however, there appeared to be a number of possible improvements to the Argonne scheme, and in reporting its decision on August 9, 1950, the du Pont AED Technical Group described a modification which it called the "Pi-Pile". The proposal offered these additional and very desirable features: a highly flexible control system; the use of producer material in control rods; multiple fuel element loading; and the use of downward coolant flow by employing a header system to permit lattice changes, reduce the heavy water inventory, and simplify flow monitoring. Multiple loading was abandoned later, but the other features were incorporated in design.

Very little basic data as such was contained in this early document, but it did mention a coolant flow of 70,000 g.p.m. for a power level of 315 MW. Subsequent discussions referred to investigations of single fuel element channels on 5-inch triangular lattice positions and the possibility of trefoils, or clusters of three elements, on 6-1/2-inch triangular lattice positions.

A second document, the preliminary scope of work for design, dated October 23, 1950, more fully presented the reactor concept and gave additional design data. It proposed a design for a reactor fueled by natural uranium with a nominal output of 300 MW but, since other fuels and producer materials might in the future be used, a large premium

was to be placed on flexibility. It pointed out that the number of fuel channels might vary between 1000 and 1600, their arrangement in clusters as trefoils or quatrefoils being a strong possibility. The document also described three fuel zones: the "flattened" core, the "buckled" zone, and the producer blanket. At this time a hexagonal lattice with a pitch of $9\frac{3}{16}$ inches between fuel positions, coolant annuli ranging from $\frac{1}{8}$ -inch to $\frac{1}{4}$ -inch, and a maximum fuel sheath temperature of 80 deg. C. were being considered. The scope of work at this time called for two reactors.

Later, in evaluating prospective sites, principally from a cooling water standpoint, a six-reactor plant with a total of 1800 MW was used as a criterion. However, after a site had been selected in December, 1950, it was decided that five reactors would be built, each in a separate area.

The accompanying table summarizes interesting basic data and reflects the development as AEC firmed its requirements and du Pont in turn translated product requirements into physical concepts.

As development of a reactor design progressed from August, 1950, through the spring of 1951, four very significant decisions were reached.

1. The study to determine the lattice, or relative position of elements within the reactor, involved nuclear physics calculations with heavy emphasis on minimizing moderator volume requirements. The lattice finally selected has fuel and control rod positions on a 7-inch triangular pitch and includes two zones; a central flat zone in which each control rod position is surrounded by six fuel positions in a hexagonal array; and a buckled zone containing fuel positions but no control rods. Initially, there was also a peripheral producer blanket zone, the rods of which were not cooled by forced convection, but this was replaced by additional fuel positions.
2. Two types of possible fuel loadings were developed, both involving natural uranium, cylindrical fuel slugs in aluminum jackets. For a "plutonium loading" a 1-inch diameter slug was selected, and for a "tritium loading", so-called because it permitted production of a larger amount of tritium at the expense of some plutonium, the slug diameter was reduced to $\frac{3}{4}$ -inch.

SEQUENCE OF PROCESS DESIGN DATA CHANGES

28

	<u>Sept. 1950</u>	<u>Oct. 1950</u>	<u>Nov. 1950</u>	<u>Jan. 1951</u>	<u>Final and date of selection</u>
Lattice	5" Single - 6.5 Trefoil	9-3/16"	9"	-	7" March 1951
Fuel Tubes	-	1100-1600 channels	1100-1600 channels	516 Q-foils	606 Q-foils March 1951
Annulus width	1/4"	1/8"-1/4"	1/8"	1/8"	1/8"
Sheath temp., °C. max.	80	-	-	80	80
Power, MW	315	300	300	350	368
Safety rods	-	-	-	-	66 July 1951
Control rods	30	3 types	30 horiz.	-	427 vertical May 1951
Tank Dia., ft.	12' est.	17	17	-	16' 2-3/4" May 1951
D ₂ O Circ., g.p.m.	70,000	-	40,000	60-65,000	76,000 April 1951
Purif. rate, g.p.m.	-	3	3	-	30 July 1951

3. Calculations set the number of fuel tubes at 606, each containing four channels. In addition, 67 positions in the lattice were allotted for control rods and gas tubes. In all, there are 673 lattice positions.
4. At first the control system was to consist of 30 horizontal rods mounted radially around the reactor tank. As design progressed, this arrangement was modified to include vertical "striped" and "lightning" rods as well as horizontal rods. The latter were completely abandoned in May, 1951, in favor of vertical rods. As finally designed the system has 61 control rod positions, each consisting of a seven-channel tube (septifoil) containing two cadmium rods and five producer rods of Li-Al alloy, two of which are half-length. Some consideration was also given to the use of thorium for producer rods instead of the Li-Al alloy, but this provision was not included in original designs.

OPTIMIZATION OF COOLING FACILITIES

Determining factors in the design of the cooling system were the temperature of the river water and the maximum allowable temperature of the fuel element. At high power levels the temperature of the moderator leaving the fuel channels can become a limitation. For design calculations the mean annual temperature of the Savannah River water was set at 21 deg. C., records indicating that the average summer temperature would be 31 deg. C. and the winter temperature, 10 deg. C. In arriving at a sheath temperature, the strength and corrosion properties of aluminum were considered as well as the central metal temperature limitation which is dictated by a change in the crystal structure of uranium that occurs at 650 deg. C. Design was based on a maximum sheath temperature of 80 deg. C. In optimizing calculations of the cooling system these factors were, of course, closely related to the power level, heavy and light water circulation rates and volume, slug diameter, cooling annulus width, heat exchanger surface and reactor size as well as a number of second-order variables.

Since the object was to arrive at a cooling system design that would require minimum investment and minimum annual costs consistent with good nuclear engineering, the Design Division, in October, 1950, pointed out the need for complete heat transfer calculations covering a number of variables. To make such calculations an interdepartmental group was formed and began its work with the following reactor conditions.

Total number of tubes - 2064, including 506 Q-tubes.

Active length of canned uranium column - 14 feet or 20 slugs.

Slug diameter - 1.08 inches O.D.

Efficiency - 73 per cent.

Maximum sheath temperature - 80 deg. C.

Flux distribution - 6 inches - chopped cosine.

Ratio of reactor to fuel power - 1.05, five per cent of heat generated in the moderator.

To match these data with suitable annual cost factors, water pumping and heat exchanger costs and heavy water costs were estimated. The following annual cost factors, based on a 10-year estimate, were adopted.

Reactor, including moderator but excluding fuel	- \$13,350,000
Cooling water, delivered to pumps	- \$1,880,000 plus \$35/g.p.m.
Heavy water inventory	- \$5.60/lb.
Heavy water pumping	- \$88/theor. hp.
Cooling water pumping in area	- \$73.50/theor. hp.
Heat exchanger surface	- \$1.55/sq. ft.

As the study progressed the effect of variations in efficiency, sheath temperature, annulus velocity, and D₂O and H₂O flows was determined. It became evident that additional information was required and, in November, 1950, this need was summarized as follows.

"It will be necessary to know, at an 80 deg. C. maximum sheath temperature, the variation with:

1. Minimum investment in heat exchangers, circulating pumps and external water system.
2. Minimum internal volume of heavy water circuit.
3. Minimum operating cost (variable).
4. Minimum pumping horsepower of the following values:

- a. Number of fuel tubes.
- b. Diameter of fuel slug.
- c. Length of fuel slug.
- d. Inside diameter of fuel tube.
- e. Coolant velocity in fuel tubes.
- f. Pressure drop through fuel tubes.
- g. Water film temperature near fuel sheath.
- h. Heat transfer coefficient from fuel sheath to water.
- i. Fuel tube inlet temperature.
- j. Number, length and diameter of heat exchanger tubes.
- k. Heat exchanger tube-side pressure drop.
- l. Heat exchanger coefficient of heat transfer.
- m. Fouling factors in heat exchanger.
- n. Log-mean-temperature-difference in heat exchanger.
- o. Tube-side volume in heat exchanger.
- p. Velocity across tubes on shell side of heat exchanger.
- q. Theoretical pumping horsepower at 80 per cent efficiency.
- r. Water plant flow and pressure drop across heat exchanger."

The first set of data, marked Series 4, was reported by the group in early January, 1951, and evaluated the use of 1/4-inch O.D. heat exchanger tubing. Later in January a second report, Series 5, evaluated the effects of fouling coefficients, winter and summer temperatures, annulus velocity, 1/4-inch and 1/8-inch O.D. tubes and 1/2-inch cored tubes, and higher sheath temperature and efficiency. By the end of that month the group concluded that cored tubes merited additional study. The use of unclarified river water in the exchangers was also receiving attention. After an evaluation of several cases based on heat exchangers with 1/2-inch cored tubes, this type was selected for plant use.

It was generally concluded, as a result of these extensive studies that, for the 1-inch slug loading and with a mean annual power level of 350 MW, the heavy water circulation rate should be 69,000 g.p.m. The secondary coolant flow was set at 76,000 g.p.m. and the total heat exchanger surface for each building was established at 400,000 sq. ft.

Subsequently the peripheral producer blanket concept was abandoned in favor of fuel positions at lattice points in this region, and there was some adjustment of the pattern to fit it to the circular tank. As a result of these changes the number of fuel channels increased from 2064 to 2424 and the heavy water circulation rate was boosted to 76,200 g.p.m. No changes were made in the heat exchanger surface. To conserve power and heavy water during initial operation, the cooling water flow through the heat exchangers was cut to 60,000 g.p.m.

A decision in April, 1951, to install only six exchangers or a total of 200,000 sq. ft. for initial operation in the R Area led to additional calculations which indicated that the nominal pile power should be reduced to 323 MW with the 80 deg. C. maximum sheath temperature retained. In May, the AEC advised that initial operation of the first two reactors would emphasize plutonium production rather than tritium, but that flexibility for tritium production was still a necessary part of the program. In line with these instructions, it was agreed that development work on the 3/4-inch slugs should be deferred and priority given to a design for the first two reactors based on the use of 1-inch slugs.

Although the nominal power level of a reactor was specified in early 1951 as 368 MW, it was recognized at the time that power levels of 650 to 680 MW might some day be attained. Accordingly, the design of the shielding facilities and other permanent features was based on a power level of 700 MW. By September 1951, basic data on the heat loads to be absorbed in the tank wall and thermal shields became available. Because a tritium loading causes a higher level of radiation to the shield than a plutonium loading, this was used as the basis for calculations. From this data the temperature rises to be expected in the tank structure and the shields were calculated so that stress analyses could be made.

DESIGN DEVELOPMENTS - L & K AREAS

A discussion of possible basic design changes for the third, fourth and fifth reactors was held in June 1951, and led to the conclusion that the determining factors would be

higher power levels and the use of enriched or depleted fuel. Later, it was decided to conduct reactor studies, aimed especially at a design change for the L Area, that would yield a higher power with reduced investment costs by relaxing certain requirements. The following table contains the design basis used in these studies. Column I represents the final R and P designs, Column II the power that might be achieved by the same design as R and P by allowing a higher sheath temperature and higher pile efficiency. Columns III and IV represent the power gains made by increasing the specific surface of the fuel elements.

Case	I	II	III	IV
<u>Design Basis</u>				
Type of fuel housing	Q-foil	Q-foil	S-foil	Tube
Type fuel element	Cyl. Slugs	Cyl. Slugs	Cyl. Slugs	Flat Plates
Dia. fuel elements (in.)	1	1	0.75	0.2" thick
No. of effective tubes (as Q-tubes)	1,861	1,861	1,861	1,861
Total tubes	2,424	2,424	2,424	2,424
Max. sheath temp. °C.	80	95	120	120
Cooling water temp. °C.	21	21	21	21
Coolant velocity, ft./sec.	25	25	25	25
Efficiency, per cent	73	85	85	85
HX Area, sq. ft.	400,000	400,000	400,000	400,000
<u>Derived Conditions</u>				
Moderator flow, g.p.m.	76,000	76,000	76,000	76,000
Cooling water flow, g.p.m.	60,000	60,000	84,000	100,000
Outlet moderator temp., °C.	46	67	83	97
Axial fuel temp. °C.	300	480	480	190
Annual avg. power, MW	363	630	1,000	1,400

After a four-month study it was decided in February 1952, to proceed on the basis of a power level of 1000 MW, as in Case III, insofar as design of the reactor tank structure, shielding and moderator piping were concerned. Shielding calculations were also made on the basis of 1400 MW. In the meantime, it had been decided that because of the limited supply of D₂O only six exchangers would be installed in each of the #100 Areas for initial start-up.

Provisions were to be made for the ultimate installation of 12 in each area, the number dictated by over-all economic considerations.

In March 1952, it was concluded on the basis of experimental work at CMX that untreated raw river water could be used in the heat exchangers and design changes necessary for use of this type of water were initiated. The CMX test runs had shown that the dirt coefficient in the exchangers assumed in the original optimization calculations would not be encountered in practice. This raised the over-all heat transfer coefficient from 323 to 500 p.c.u./ (sq. ft.) (hr.) ($^{\circ}\text{C.}$) with a corresponding decrease in the maximum sheath temperature for a given power level.

#100-C AREA DESIGN

Actual design of the C Area began in September, 1952, when a document was prepared which outlined the differences in basic data between the C Area and the L and K Areas.

1. The building arrangement was to be readily adaptable to handling flat plate fuel elements.
2. Initial moderator flow would be 85,000 g.p.m. with some provision to be made for a future flow of 120,000 g.p.m.
3. The reactor would have an integral heavy water reflector.
4. The reactor structure and thermal shield were to be designed for a maximum power level of 2000 MW with a moderator exit temperature of 95 deg. C. if, by this change, the cost was not unduly increased.
5. The cooling water supply line from the river was to be 66 inches in diameter with a capacity of 96,000 g.p.m. Consideration was to be given to a possible future flow of 140,000 g.p.m.

Later work more specifically described the reflector as 12 to 18 inches thick and the fuel element as composed of a 3.5-inch O.D. tube with an 0.06-inch wall in which five fuel plates would be contained, each 0.18-inch thick, 3.25-inch wide, and 14 feet long. The aluminum sheath of each plate would be 0.03-inch thick. The fuel tube itself would be extruded with two chord-wise membranes in such a way that the five plates separated by ribs could be placed between them.

Further information developed in October included data on heat fluxes into the shield.

Reactor Area	R-P	L-K	C	C
Reflector thickness, in.*	0	0	18	18
Power, MW	700	1400	700	2000
Max. heat entering inner wall of shield, B.t.u./ (sq.ft.)(hr.)	22,100	44,200	10,200	29,100
Max. heat leaving inner wall of shield, B.t.u./ (sq.ft.)(hr.)	17,300	34,600	6,800	19,400

These figures were later revised as follows:

Power output	700	1400	700	2000
Reflector thickness, in.*	0	0	18	18
Max. heat generated, B.t.u./ (sq.ft.)(hr.)	7,100	14,200	4,400	12,500

Use of a chopped cosine distribution on the side wall with an average to maximum ratio of 0.7 was agreed upon.

*Actually the effective reflector in R, P, L, and K is approximately three inches thick.

Additional design data for the C reactor were developed in December of 1952.

	<u>Present Design</u>						<u>Potential Plates</u>		
	<u>Slugs</u>			<u>Plates</u>					
H ₂ O, °C. to HX	10	21	31	10	21	31	10	21	31
H ₂ O Flow, 1000 g.p.m.	75	75	75	75	75	75	130	130	130
D ₂ O, °C. to HX	44	50	55	56	60	63	88	92	95
D ₂ O Flow, 1000 g.p.m.	85	85	85	85	85	85	120	120	120
HX, arrangement	-	-	-	-	-	-	Parallel		
HX, number	6	6	6	6	6	6	12	12	12
Fuel, sheath, °C.	80	80	80	80	80	80	130	130	130
Power, MW	510	430	360	710	590	490	2,020	1,850	1,670

The three columns under each heading refer to winter, mean annual, and summer conditions, respectively.

By February 1953, it was possible to outline the design basis for the C Area which, in part, was as follows:

1. C Area will start up with 1-inch diameter fuel slugs. It is expected that flat plate elements will be substituted a short time after start-up.
2. The reactor will be provided with a D₂O reflector outside the tube pattern which will require increasing the radius of the tank wall about 14 inches.
3. Twelve of the positions in the buckled zone used for fuel tubes in the other reactors will be allocated to control rods in C Area.
4. Maximum average power level with slugs is to be 430 MW and the ultimate maximum average is to be on the order of 2000 MW.
5. Ultimate moderator flow has been specified as 120,000 g.p.m. Consideration is being given to ultimate flows as high as 150,000 g.p.m. Initial flow is to be 85,000 g.p.m. Cooling water flow is to be 75,000 g.p.m. initially with an ultimate flow of 130,000 g.p.m.
6. Six heat exchangers will be installed initially. Ultimately, six more heat exchangers will be added in parallel with the first six.

From February to November a number of important decisions were made. Twelve new control positions were specified, making a total of 73 for the C Area, plus 13 additional safety rods to cope with the higher flux in the outer region of the reactor. In August, it was decided to install 12 heat exchangers for start-up in the C Area and by November it had been decided to increase the heavy water flow rate to 90,000 g.p.m. or 15,000 g.p.m. per pump.

LM LOADING

The possibility of producing larger quantities of tritium in the L Area reactor was reviewed in March of 1953. Discussions centered on a revised loading, called "LM", which would consist of Q-tubes in which three channels would contain enriched uranium fuel slugs and the fourth would contain a "producer rod" of Li-Al alloy. Some of the control rods would continue to be Li-Al as before. Actually, little additional basic data for reactor design was required since the new loading would primarily affect the design of the Q-tube top fittings, and the discharging, disassembly and shipping facilities. Through the following months alternative loading patterns were considered, aimed at reducing the hazard of nuclear accidents in the reactor and, in January 1954, a revised scope of work for the LM program was developed. This included the following details.

PROCE

DISASSEMBLY AREA

1. Loading to be a striped pattern in standard Q-tubes, each channel of the Q-tube containing nine enriched fuel slugs and six Li-Al alloy slugs.
2. Fuel slugs to be 1.085 inches in diameter and 12.435 inches long. Target slugs to be 1.085 inches in diameter and 6.218 inches long.
3. The fuel alloy composition to be five per cent enriched uranium in aluminum; the target alloy composition to be approximately 4.5 per cent lithium in aluminum.
4. The reactor to have two flow zones:

	No. Q-tubes	Flow Per Channel
Zone I	456	30.5 g.p.m.
Zone II	150	24.5 g.p.m.

Although the LM program was originally considered for the L Area, it was subsequently expanded in scope so that any area might be considered for this loading. However, in late 1954 the proposed loading of target elements was changed from Li-Al alloy to thorium.

Except for some work with experimental quantities, the thorium program was shelved in 1955. During the year, small amounts of LM (enriched) fuel were used for experimental purposes.

DEVELOPMENT OF BUILDING DESIGN

GENERAL ARRANGEMENT

The design of Building #105 is functional, its purpose being to house the reactor and its auxiliaries. It is of blast-resistant construction and incorporates shielding necessary to protect personnel from radiation. In each of the five #100 Areas the reactor is placed near the center of the structure with the assembly, purification and disassembly equipment arranged around the reactor room to permit smooth material flow in a minimum amount of space. An important aspect of design, particularly in the early areas, was the necessity for making provision for conditions and facilities which were still under development.

The most important arrangement problems centered about the location of the reactor with its heat exchangers and pumping facilities, the loading and unloading of the reactor components, and the control methods to be used. By

October, 1950, the Atomic Energy Division of the du Pont Explosives Department had formed a very tentative conception of the building's layout, and the Engineering Department Design Division had in turn prepared the first set of study arrangement drawings, numbered W-130000 to W-130003 inclusive.

These early arrangements showed a building of irregular shape, about 440 feet long by 320 feet wide, extending from approximately 40 feet below ground level to 50 feet above. Horizontal control rod mechanisms were located at the -19 foot level with the heavy water pumps at the -38 foot level. The heat exchangers were arranged vertically and located between two concentric concrete shields.

The design featured the bulk handling of sector-shaped plenums carrying Q-tubes, a component handling method more fully described in the section on the development of the reactor design. Transfer buggies supporting the plenum sectors were to be loaded with the Q-tubes, flow tested and inspected, and then lowered into a canal through which they could be moved under water into the reactor room where they would be lifted and dried. This canal served also as a gas lock between the assembly area and the reactor room in which, by original design, a helium atmosphere was to be maintained.

During a discharge cycle, the D₂O lines would be disconnected and the plenum assemblies with their components would be removed from the reactor by a 15-ton crane. These assemblies then would be placed on the transfer buggies and moved through the gas lock canal into the disassembly area, which at that time was referred to as a "fish pond". Newly loaded plenum sections could then be brought into the reactor room from the assembly area.

It was believed originally that after a reasonable aging period the plenum chambers could be re-used, and for this reason the early building design included provisions for moving the plenums from the disassembly area back into the assembly area.

Among other design features of the building at this time were a lead curtain to protect maintenance workers on the crane while the reactor was in operation; a liquid scram tank in a pit below the -38 foot level; and a tube between the control rod room and "fish pond" through which "hot" control rods could be moved into the disassembly area for storage and later shipment as target material. With this plan the disassembly, or "fish pond", area contained approximately 4,000,000 gallons of water.

To transport irradiated fuel and target material to off-plant destinations and to other plant areas, a spur of the plant railroad system was located adjacent to the building.

After reviewing these arrangement drawings, AED submitted a number of comments which helped to clarify the objectives of design. It was pointed out that, since the cost of a reactor is small compared with that of attendant facilities, it would be desirable to make provisions in each area for a second reactor. This was to be done in such a way that existing general facilities could readily be used. It was also stated that the lead curtain shield would be inadequate, and in its place a room separated from the reactor room by concrete walls from five to six feet thick would be necessary for crane maintenance.

AED further suggested that, with a tight top shield, a helium atmosphere in the reactor room could be eliminated. No particular objection was raised to the buggy handling scheme, but the drying problem involved could not be overlooked, nor could the probable difficulty in disassembling the pie-shaped plenum section under water and at depths of from 25 to 35 feet. A top plenum chamber for coolant downflow and a fixed top shield, both under review by Design at that time, appeared to AED to offer more definite advantages. A number of miscellaneous details also were reviewed by AED and alternative designs were proposed.

These comments, supplemented by further discussions, resulted in the second set of study arrangement drawings in December, 1950. These are numbered from W-130028 to W-130035 inclusive and W-130037. Several distinctive developments were made in the second study.

One side of the building was kept free of structures or equipment which would prevent the installation of additional equipment or a second reactor. In the R and P Areas, the first to be constructed, this plan was retained but the L, K and C Areas were built without this provision.

Further developments placed the assembly and disassembly areas on opposite sides of the reactor with the reactor room turned 90 degrees to improve material handling. The combined shield and plenum sector assembly was abandoned in favor of a full, circular, fixed shield with which separate sector-shaped plenum assemblies, having "gun barrels" extending from the bottom, were to be used. Cars were still required to move these plenum assemblies into and out of the reactor room.

Heat exchangers still were to be mounted vertically and, if these had to be replaced at any time, they were to be lifted through the reactor room floor and ceiling. At the -20 foot elevation a square room surrounding the reactor contained a circular track for a coffin required when horizontal control rods or their rechargeable cores were discharged. The heavy water pumps were located at the -32 foot level, the influent and effluent cooling water lines at the -48 foot level, and the scram tank pit at the -60 foot level.

Maximum height of the building at that time was estimated to be 76 feet, since there was no provision for vertical control rods. Offices, control rooms and service areas were stacked beside the reactor room. Also, for the first time, blast resistant construction was indicated.

The question of blast-resistant construction for the key buildings of the plant had been proposed by the AEC very early in the project and led to a du Pont investigation of its feasibility and cost. From a series of discussions between the AEC, du Pont and Air Force personnel, from opinions expressed by industrial specialists and consultants, and from tests of detonation effects on building materials grew a building code issued by du Pont in January, 1951. Its specific recommendations, detailed in "Classes of Construction" in Volume I of this history, were adopted for plant-wide use and played a large part in the architectural design of the reactor building.

On the basis of this second study, concrete drawings were started for construction and are numbered from W-130100 to W-130147. Seven of these were issued eventually as field construction drawings.

At this time pile supports under all foundations were stipulated. The geometry of the building, as then designed, created a load concentration in the center, or process section, amounting to a soil bearing pressure of approximately 10,000 pounds per square foot. The ability of the soil to carry such a load was seriously questioned and, in the absence of complete soil study information, pile design was evolved which placed 40-ton piles on approximately 3-foot centers. However, later changes in building geometry and complete soil structure information made it possible to eliminate the use of these piles.

Despite the progress made in the second general arrangement of the reactor building, the positioning of the heat exchangers and the methods proposed for their removal posed obvious difficulties.

In preparing a third set of arrangement drawings in February 1951, more details throughout the building were given design attention and the heat exchangers, for the first time, were placed horizontally. More specifically, the reactor room was made narrower since the exchangers were no longer to be lifted through the room; the size of the building was better defined; the horizontal control rods were arranged peripherally around the reactor; single Q-tube handling replaced bulk charging and discharging; and preliminary crane handling methods for the pumps, motors and heat exchangers were proposed which forced the lowest floor level down to the -86 foot elevation and the scram tank pits to -106 feet. Pumping of heavy water was to be done in two stages, one pump receiving suction from the reactor and pumping the moderator through the heat exchangers and a second pump supplying the necessary coolant pressure to the plenum. Reactor development, however, had not yet reached the point where the solid bottom in the reactor and the "bird cage" monitor array could be abandoned in favor of the bottom shield and monitor pins.

AED's major objections - and these were shared by Design - were the magnitude of the building volume and the necessarily large inventory of heavy water. As a result, numerous discussions were held to evaluate single versus dual pump arrangements, alternative piping arrangements to reduce D_2O volume, and alternative heat exchanger and motor handling to reduce building size. By March of 1951, agreement had been reached on a number of such improvements and a revised set of drawings was issued.

The building depth was reduced from -86 feet to -40 feet by rearranging the horizontal control rods into a compact assembly, by moving the heat exchangers up to the -20 foot level, by providing a dolly and power truck instead of a crane to handle the pumps and motors, and by mounting the heat exchangers on railroad trucks. The exchangers then could be moved into and out of the building by a transfer car and a hoist. This was to be a dual layout with six exchangers, a transfer car, and a hoist on opposite sides of the reactor.

The tube-sheet type bottom shield replaced the former solid tank bottom, and a pin room was added under the reactor. Single heavy water pumps were planned to reduce moderator inventory. Notable progress was made in the design of shielding windows which would give control and crane room personnel the required view of the reactor room. For the first time steel shielding doors were included in the design to separate the crane maintenance area from the reactor room. At this stage the building extended only 55 feet above grade.

General approval of this arrangement was given by AED, but it was recommended that further reductions should be attempted in building volume and additional efforts made to reduce the moderator inventory through piping changes. The location of the scram tanks in pits at the -60 foot elevation was particularly unattractive at this time.

In a very significant design change, the horizontal control rods were abandoned in favor of vertical rods. This permitted a much more compact design of the center section of the building. The scram tanks also were relocated. Further definition of the building above the 55-foot level was coordinated with the development of the actuator system for vertical control of the reactor. A longitudinal section view, page 63, and a cross-section view of the building elevation, page 61, present the center section of Building #105-R essentially as it was finally constructed. Page 65 is a plan view showing the arrangement at the +15 foot elevation. The adjoining building areas, namely, assembly, disassembly and purification, are discussed in later sections of this report.

The design of the reactor building for the R Area was adopted for the P Area with a few major exceptions. By the time this second area was being constructed, changes in material handling and some process improvements had made it possible to eliminate one bay from the assembly area and three bays from the disassembly area. Although the compression of the disassembly area layout, made in January 1952, caused a five-week delay in delivery of the drawings to the Construction Division, the savings in building cost more than justified the overtime required by the field to make up the time lost.

To meet the overall construction schedule no additional alterations could be made in the R and P Areas, but it became evident, as requirements were better defined, that a still more compact arrangement might be made at substantially lower costs. However, it appeared that time would permit no major change before construction of the C Area. Looking toward that possibility, a design engineer was assigned, early in 1952, to develop alternative plans for Building #105-C. These study efforts were so successful that by April an entirely new building arrangement could be submitted for AED approval. This not only made sizable reductions in building volume but also proposed Class III construction for several major sections of the building. Building volume of this condensed layout was 2,600,000 cubic feet less than in the P Area and 2,700,000 cubic feet less than the R Area. Substantial equipment savings also were projected.

The following major changes were presented in the new design. The large canal from the reactor room to the disassembly area was deleted; 44,000 square feet of floor space were eliminated from the lower portion of the building; the reactor room was made 36 feet shorter; heat exchanger transfer cars were eliminated; two special glass windows were omitted; the instrument and crane control rooms were combined; an elevator was eliminated; and several areas of the building were converted to Class III construction.

Because the expected savings were so substantial, AED and Design were eager to employ the new arrangement as soon as possible. Schedule reviews between Design and Construction followed and resulted, in May 1952, in the adoption of the arrangement for the L, K and C Areas.

The provision for a second reactor was eliminated, permitting the disassembly area to be moved to the end of the reactor room so as to permit a direct flow of discharged materials into the temporary tube storage basin. The fan room was made Class III and the assembly area, a major part of which had been designed as Class III, was moved to a portion of the space previously occupied by the disassembly area. Allocation of office and personnel facilities was changed and a Class III personnel area was constructed as a wing to the main building. In this manner both sides of the reactor room exterior were cleared and the area could be designed in such a way that the heat exchangers could be lifted directly to ground level by removing concrete slabs over each unit. For this purpose a special boom crane was built by modifying a standard crawler crane. With the transfer car area eliminated, the lower portion of the building could be greatly reduced in size. The plot plan and elevations are shown on pages 75 and 77.

Alterations to the assembly, disassembly and purification areas, occurring with this redesign, are described in the history sections dealing with those areas.

ASSEMBLY AREA

The set of arrangement drawings issued in December, 1950, placed the assembly and disassembly areas on opposite sides of the reactor, and this principle was retained for the R and P Areas. As previously described, the concept, then current, centered on the use of sector-shaped plenum sections with "gun barrels". The assembly area building arrangement reflected this in the car handling system required for the plenum sections. By February 1951, however, the individual Q-tube handling scheme had been adopted and all development work ceased on the sector plenums.

With the adoption of the single Q-tube handling method the assembly process could be defined more clearly and was resolved generally into the following steps: receive and store individual components and clean them when necessary; assemble components into foils; flow test and inspect completed assemblies; store completed assemblies until needed for the reactor; and transport them out of storage to the presentation conveyor.

Actually, early in 1951, there was still no firm basis on which details of the assembly process could be established or even where it might best be carried out. There were many unanswered questions on the mechanical stability of the rods, Q-foils and S-foils and the feasibility of transporting them. At this time it was believed that all control rods would have to be tested in the #300 Area where they were fabricated. It was also thought that as many as five per cent of the fuel assemblies would require testing in Building #305 in that area. Some attention, therefore, was given to the location of the assembly facilities for fuel rods in both the #100 and #300 Areas and control rod assembly facilities in the #300 Areas. As design of the components progressed and knowledge of their character increased, it was decided that all assembly activities should be carried out in the #100 Areas. In the assembly procedure adopted, the control, 35W5, and blanket rods are delivered from Building #320-M in aluminum sheaths ready for insertion in the S-foils. Some empty and loaded quatrefoils and septi-foils occasionally are sent from the #100 Areas to Building #305-M for testing.

From the beginning of building and equipment design two basic considerations were paramount. Scrupulous cleanliness was a vital requirement since the introduction of foreign contaminants into the reactor might have extremely serious consequences. Also, the close mechanical tolerance imposed on all elements for efficient operation and successful repetitive handling into and out of the reactor required careful inspection and flow testing of each assembled element. A typical assembly area was expected to process over 2500 quatrefoil assemblies a year and, because of this number, the operations in the area were mechanized as much as possible to reduce manual labor.

It should be noted here that, in accordance with conventional du Pont Engineering Department commercial practice, the mechanical development and design of the components, fuel handling machines, control rod actuators and machines required for assembly and disassembly, had been assigned by the Design Division to the Development Engineering Division. DED, in turn, subcontracted this work to the American Machine & Foundry Company. Later the similarity

of design in the purification area to some aspects of the #200 Area design, on which the Blaw-Knox Company was a sub-contractor, led to the assignment of the purification area design to Blaw-Knox. All work on the design of the building and the design and procurement of equipment, other than the above, however, was carried out by the du Pont Design Division. In some cases prototype equipment was installed in the R Area with conventionally procured equipment provided for the P, L, K and C Areas.

The physical arrangement and dimensions of the assembly area were governed partially by its relationship to the adjoining process area. The latter, being designed concurrently with the assembly area, appeared to require a rectangular layout with the tank in the approximate center. To the north of the tank in the R Area would be the exit point for materials moving into the disassembly area, and to the south would be the entrance point for materials from the assembly area. The south wall of the assembly area was placed beyond this entrance to the process area but as close as possible to keep the adjoining purification area near the reactor moderator system.

As mentioned previously, it was decided to keep one side of the building free for any additional facilities that might be required. In the R Area this free side is to the north. Thus contained both to the north and south, the assembly area developed to the east as design was firmed.

By May of 1951, a much better understanding of the assembly process had resulted from progress in the design of components and from close examination of several suggested assembly methods. New arrangement drawings were issued in which the assembly area contained four bays each approximately 60 feet wide and 186 feet long. Final storage was in the south side of the bay nearest the reactor, with parts inspection and parts storage on the north side of the bay. In the two adjoining bays were areas for tube storage and cleaning, storage of material to and from Building #305, tube inspection, sleeve assembly, parts cleaning, a locked room for slug storage and accountability, an office, and space for solvent storage and ventilating equipment. The northeast corner of the easternmost bay contained the receiving area, crated tube storage, S-foil and fuel inspection, and space for storage of pallets and new, crated sleeves. Final assembly at this time consisted of attaching sleeves to loaded quatrefoils. The sleeves were to be received from the disassembly area after aging sufficiently for safe handling. Tube loading was to be done vertically from a mezzanine, with the roof level raised over the mezzanine.

Despite the attention given to the use of a mezzanine in tube loading, the plan was in many respects unsatisfactory. All material to be used in the assembly process had to be lifted from the floor level to the mezzanine and, in turn, any materials not used had to be returned to floor level. Also, the handling and transfer of the loaded assemblies to and from the various stations presented problems of excessive building height for vertical insertion or complicated switching for side insertion.

In June, 1951, another arrangement, quite similar to that eventually adopted for construction, was completed. At that time the receiving area was placed in the southeast corner of the building and the arrangement of the final storage bay was altered to place the fan room on the north wall. Assembly was to take place on the main floor level in a location on the north side of the center bays. During loading and testing, the top of the tube would be at the main floor level, the tube extending through a floor slot into a 20-foot deep basement. At the end of the floor slot a drop section of the overhead monorail system would pick up the components from a transfer dolly and transport them into final storage. The points at which the monorail entered both the final storage room and the reactor room were to be closed by sliding steel doors. With this arrangement the assembly area occupied a space 255 feet long and 180 feet wide.

Through this design period it had been contemplated that the stainless steel sleeve which formed the upper end of the fuel tube assembly would be re-used, since only the lower portion of the sleeve would become radioactive as a result of its exposure to neutrons in the reactor. However, the problems incident to handling the "hot" sleeves through cleaning, inspection and re-assembly began to mount until it was decided that this re-use was impractical. The alternative of discarding the sleeves after one use was equally impractical from the point of view of economic design.

This major problem was solved by separating the fuel tube into two sections, namely the sleeve and the Q-foil. The sleeve, now known as the semi-permanent sleeve, was considered to be a part of the reactor and would remain there unless the Q-foil and sleeve could not be separated by the discharge crane. As a result of this change only the Q-tube and its components had to be processed through the assembly area and loaded into the reactor.

A third major redesign of the area was completed in July 1951, and this, with but a few important revisions, became the design as constructed. Containing an area of approximately 35,000 square feet in a layout of 186 feet

by 191 feet, it reflected the many steps that had been taken to compress process and storage requirements. A much earlier design had included over 90,000 square feet. Chief contributors to this space economy were the elimination of large transfer facilities for the components; the elimination of storage and remote assembly of permanent sleeves; the simplification of the washing, testing and assembly procedure; a reduction in the number of loading lines; the adoption of the monorail system for single tube handling; the reduction of total storage capacity to 1.2 of a reactor charge; and the reduction of the unassembled component inventory.

In late 1951 a comparison had been made between the investment cost of five assembly areas of the R Area design and the cost of two "producing" areas plus three abbreviated "receiving and storage" areas. The latter scheme showed sizable savings in building costs, but these were offset by material increases in operating cost. The designs adopted for the later areas were to realize some of the advantages of both schemes.

In the P Area one complete bay was removed without compromising construction schedules. Container handling was simplified by the elimination of one crane system and the transfer rail car through the use of a crane to unload truck shipments directly to the storage areas. The floor plan of the assembly area in Building #105-P is shown on page 67.

In the L, K and C Areas the bays containing receiving, storage and assembly were placed in a Class III structure, with final storage and the component presentation point continuing in a Class I structure. Layout of the area also was altered to conform to the new arrangement of the main building.

PROCESS AREA

Housing the principal process equipment, the main building structure, known as the process area, lies between the assembly and disassembly areas and extends from -40 feet to approximately 150 feet above grade. It contains the reactor and its auxiliaries, the control equipment, the charging and discharging facilities, and offices, change rooms and service equipment rooms.

Because the development of a design for Building #105 had to be concerned primarily with the location of the reactor and its closely associated equipment, the sequence of general building development was essentially that of the process area. The reader is referred to the preceding "General Arrangement" section of this history.

DISASSEMBLY AREA

In submitting basic data on the disassembly area to the Design Division, the Atomic Energy Division included two stipulations which controlled the design development of both building and equipment. First, waterfilled basins were to be used for the storage and disassembly of discharged fuel elements and, second, a minimum of 10 feet of water should be maintained over any single element to shield operators from radioactivity.

The arrangement drawings issued in December 1950, although they presented only a preliminary disassembly scheme, did show the general orientation of the area with respect to other portions of Building #105 which prevailed until design was completed. Process developments that followed caused extensive changes in building design.

The first actual arrangement of the area, issued in April 1951, utilized a space 186 feet wide by 325 feet long. Disassembly operations and the monorail system for both disassembly and storage were located in a north-south direction. The bay nearest the reactor room, approximately 60 feet wide and extending the depth of the wing, was devoted to rack storage facilities. The two adjoining bays contained the emergency disassembly area along the north wall and the area for the transfer of racks from the trans-out vehicle to the disassembly cranes. The south portion of these two bays was devoted to empty bucket storage, the blanket rod disassembly machine, the control rod disassembly machine and the two fuel tube disassembly machines. Here the monorail system connected to the crane system which extended almost the entire length of the building along the south wall. The remaining two and one-half bays contained the wet storage basin, the transfer area, a machinery repair and service area, and a large area for processing re-usable parts. This included a wash and inspection area and a storage, loading and office area.

Space required for storage of the several types of components was calculated on the basis of a discharge at approximately 45-day intervals. For the fuel slugs, which represented the largest single item to be stored, this indicated a minimum capacity of two and one-half charges. It was at first estimated that a storage bucket would contain 275 slugs, which meant that a total of 380 buckets were necessary for the 104,400 slugs to be stored. For all materials, some of which had to be stored for as much as 24 months, it was estimated that 1140 buckets were required, each using 18 inches of monorail track. In addition there would be a number of component parts stored as units on hangers. These included the sleeves, caps, plugs, support

rings, springs and orifice plates of the quatrefoils, and the sleeves and shield plugs of the blanket rods. Sleeves and rod extensions of the vertical control rods were to be stored as individual items. Calculations placed the number of hangers required for this parts storage at 1200.

By the end of April the sector-shaped plenum section concept, with its associated multiple component handling in racks, had been abandoned in favor of single component handling. A new layout, prepared in May, provided for this single component handling and included a more complete monorail system, eliminated a number of cranes, and enclosed a part of the disassembly area in a Class III structure. An evaluation was made of the possible cost reduction resulting from this rearrangement.

Occupying an area approximately 144 feet by 315 feet, this new plan changed the storage and disassembly arrangement from a north-south to an east-west flow. Foil and rod storage were placed in the bay nearest the reactor room while the emergency disassembly area, the disassembly machines and the baler were located in the adjoining bay. A third bay provided for the storage of empty buckets and of buckets containing fuel and producer slugs. The transfer area separated the Class I portion of the building from the Class III portion which contained facilities for wet storage and the inspection, washing and dry storage of parts to be shipped to the assembly area for re-use. An enclosed monorail system connected the Class I portion with the Class III portion.

However, when estimates were made of the savings achieved by partial Class III construction, it was decided that they did not justify the surrender of blast protection.

A third building arrangement was prepared in July of 1951 and became the basis for construction even before many of the details had been worked out. The new arrangement returned the building to Class I construction throughout, incorporated an enclosed dry cave area for the disassembly of producer rods, and retained the provisions for sleeve disassembly and storage. The area required was set at approximately 187 feet by 316 feet, and these dimensions were used for excavation and foundation construction. Almost simultaneously with the completion of the first drawings and their release to the field came the decision to use semi-permanent sleeves which would remain in the reactor room. As a result of this and other later changes, the building in the R Area contains space for tube and bucket storage somewhat in excess of the redefined basic requirements.

When the Design Division was developing the final arrangement of the area, the required capacity of tube storage had been set at 1200 hangers. Before completion of the building the elimination of O-ring changing facilities and the reduction of hanger lengths to 11-1/2 inches combined with the changes in the spacing of building columns increased the capacity to 2030 hangers.

The basin now devoted to bucket storage was sized to take care of 800 buckets and the two-year storage of sleeves. The adoption of the semi-permanent sleeves increased the capacity of the basin to 1870 buckets, each containing either 250 fuel slugs or aluminum scrap for disposal.

Early in 1952 a hot laboratory was added to the dry cave design for the remote weighing, measuring and examination of dry fuel slugs. The underwater microscope for examination of canned fuel slugs after their removal from Q-foils was also added at this time.

In designing the building, special attention had to be given to the retention of a large volume of water in concrete basins below ground level. This in itself was not an unusual or difficult problem but, in the case of the disassembly area basin, other factors made the selection of a water-proofing method extremely important. First, the water table in the R Area was above the level of the basin floors; second, other important portions of the building were at levels below that of the disassembly area; third, visibility throughout the basins had to remain as nearly perfect as possible. The choice of a suitable basin lining plus the choice of wall and floor finishes for this and other portions of the building are described under "Special Finishes" in another section of this history.

Through the elimination of space originally intended for the storage of sleeves and stainless steel parts, the disassembly area in Building #105-P was made approximately 14,000 square feet smaller than that in the R Area. General layout and flow of materials are the same in the two areas. In the L Area the large canal was omitted by shifting the disassembly area clockwise 90 degrees about the main part of the building and making minor adjustments in the length and capacity of storage lanes. In general, the K and L Areas are similar. Pages 69 and 71 show the differences in floor plans of the disassembly areas in Buildings #105-P and #105-L.

The C Area design is distinct in that it includes modifications of the L and K Area design to accommodate long fuel elements which may be used at a future date. These can be processed through the disassembly area and

shipped from the transfer station which also was re-designed to permit long element handling. Page 73 presents the floor plan in Building #105-C.

PURIFICATION AREA

In preliminary data furnished to the Design Division in 1950, the Atomic Energy Division briefly described the purpose of the purification area as the maintenance of moderator purity. This was to be accomplished by two methods. As the heavy water produced unwanted gaseous decomposition products during reactor operation and as air accumulated in the reactor, these gases would be entrained by a helium blanket continuously sweeping over the surface of the moderator and carried to the purification area. There the helium would be processed to recover the heavy water and the D₂O decomposition products. At the same time the heavy water itself could be expected to pick up varying quantities of light water from the air, particles resulting from corrosion of elements in the reactor and, in extreme cases, highly radioactive material caused by the failure of a slug can. To remove these a small stream of moderator would be continuously circulated through a combination of filtration, distillation and ion exchange equipment.

In a tentative design for the reactor building prepared in October of 1950, only space allocations for the purification facilities were made and very little specific design effort was expended on this phase of the work until late summer of 1951. At that time the process equipment had been defined sufficiently to permit building arrangement drawings to be prepared.

In this layout the cell-type construction visualized for this facility plus the remote handling of cell vessels, made the design closely comparable to some features of Building #221-F; hence it became desirable to have the work done by the same engineering organization. By such an approach a uniformity of design and procurement could be achieved at the lowest cost and the accumulated design experience could be applied most effectively. In September a contract was initiated with the Blaw-Knox Company, the #200 Area design subcontractor, to execute the design and procurement for the purification area.

To save time, Blaw-Knox was requested to continue development of the proposed arrangement, with du Pont design to supply completed process flow diagrams. The purification area work at Blaw-Knox continued as a responsibility of the Design Division which assisted by assigning a full-time liaison process engineer and designers and giving specialist assistance when requested.

The first layout of the area made by du Pont and turned over to Blaw-Knox, utilizing ideas from Hanford buildings, contained labyrinthed cells, a central pipe alley and two cranes, one remotely operated. With the main floor at Elevation 3 feet 6 inches, the instrument control room, electrical control room and chemical and analytical laboratory facilities were placed next to the reactor area and over the heat exchanger transfer tunnel. To the east, the four moderator purification cells adjoined the assembly area, and across a corridor over the pipe alley were the gas purification, drying and refrigeration rooms. The south portion of the area contained storage facilities for helium, oxygen, moderator resin and catalyst. The distillation equipment was located on the exterior of the building at the southeast corner. Outside loading and unloading were planned for both helium and oxygen, and also for the trailer which would be used to transport the lead cask containing equipment pieces to be discarded.

Space for this lead cask was to be provided in each of the moderator purification cells. When an equipment piece was to be moved, the remotely controlled 5-ton crane would disconnect all equipment couplings or fasteners and place the equipment in the cask. Then the 50-ton roof-mounted crane would remove the cell covers, lift the cask from the cell and transport it to the trailer. The 5-ton crane was to be equipped with pendant controls, and operations would be observed through shielding windows between the cells and the corridor.

As design progressed it became evident that several aspects of this preliminary layout could be improved. The labyrinth design imposed a penalty in space utilization; with redesign the second crane could be eliminated; and the outside loading of the cask trailer could conflict with truck movements into the assembly area. Also, the use of shielding windows and a pendant controlled crane was an untried method in cell operation.

To incorporate these improvements a second layout was completed early in 1952 and approved for construction. The labyrinth entrances to the four cells were eliminated to permit the inclusion of an enclosed trailer area. Observation windows in the cells were removed and an optical system added to the 5-ton crane to facilitate remote operation. With the cask-carrying trailer accessible to the cell crane, the roof-mounted crane could be eliminated. By that time, plans for helium shipment and storage had been changed, removing these facilities from Building #105. This cleared the way for a rearrangement of the south portion of the purification area placing the resin preparation area and the two identical gas purification rooms across from the

cells and the trailer loading space. The refrigeration and gas drying equipment was located south of the resin preparation area.

A north-south corridor was added to improve equipment handling and personnel access to the area. By shortening the railroad track south of the building by 30 feet, a ramp was constructed leading from grade level to the new corridor level in order to permit fork truck movement between the trailer space and the inside of the building.

Although the structure has a multiple-level design, there are only two principal floors - the main floor at elevation 3 feet 6 inches and the basement at minus 9 feet 6 inches. Basement space is devoted to cell tunnels, a hot tunnel, cold pipe space, and an air supply duct. A portion of the ground under this area is composed of fill compacted after excavation for the main building. To save additional filling and compacting costs it was decided to make the cold pipe space four or five feet deeper than necessary. Since this space covers an area approximately 37 feet wide and 100 feet long, a considerable saving resulted.

Throughout design of the building, calculations of shielding wall and door thicknesses were based on a safe exposure level of 1 mr./hr. Against this, the maximum radiation level anticipated was estimated to be the concentration of one slug's activity within one vessel or at one fixed point. This activity was judged to be 3×10^8 Roentgens per eight hours. For the necessary protection, concrete cell walls were made 4 feet 6 inches thick. Other walls as well as ceilings and floors were sized proportionately depending on the radiation level anticipated in the lines and in the several pieces of equipment. Where little personnel traffic was expected, the level of exposure was raised to 10 mr./hr. In the trailer loading area a door 11-1/4 inches thick would have been necessary to give a 1 mr./hr. level outside the door. To reduce the door thickness, weight and cost, an exposure level of 10 mr./hr. outside the door was accepted and the thickness reduced to an equivalent of 8-3/4 inches. Interlocks are installed on the door to prevent its opening at any time radioactive material is being transferred by the crane to the lead cask.

The design of the L and K Areas was initiated in June 1952, on the basis of a scope reduced from R and P by the elimination of resin preparation, the chemistry laboratory, mass spectrometry laboratory and the counting room, all of which were service facilities. One process improvement, the substitution of desiccant beds for refrigeration in the gas drying operations, was introduced. In addition, the location of the purification area was changed to permit

greater freedom in the layout of the main structure. Although the extensive redesign of the purification area building was justified by these changes, there was a distinct advantage in retaining almost intact the detailed development of the individual process units, gas rooms and cell areas. In the redesign, however, it was advisable to eliminate some congestion that appeared around the distillation equipment and in the hot pipe tunnel of the R and P buildings.

Several abbreviated layouts were prepared, differing mainly in orientation of the cell block to the main building and other parts of the purification area. The distillation facilities were modified by locating much of the service equipment in the basement and the instrument and electrical control rooms were more advantageously placed near the center of the process area. These, actually, became only intermediate arrangements although design of the L and K Areas was carried to the point where foundations could be poured to grade in the L Area. Design proceeding simultaneously on the C Area had, by that time, evolved a much more desirable arrangement, and this was adopted immediately for both the L and K Areas.

In basic data for the C Area, submitted to the Design Division in January 1953, AED proposed a radical change in the moderator clean-up process. The following advantages and design objectives were cited.

1. Removal of certain fission products from the moderator, which ion exchange resins are unable to remove completely, so as to permit quicker resumption of pile operation after a slug rupture.
2. Relative simplicity of operation by streamlining cell piping and reducing the frequency of drying and removing cell equipment before burial.
3. Investment reduction by the substitution of simpler optic and equipment handling facilities.

Design personnel analyzed the new process carefully and, in February, countered with the following suggestions.

1. Continue the use of the filtration-ionization principle installed in R, P, L and K Areas, but add provisions for removing, through the isotopic still system, any materials unaffected by the resin bed.
2. Remove and install cell equipment by methods similar to those contemplated for the evaporation process.

3. Simplify cell layout and piping by including the filters in the removable jumpers to and from the deionizer.

This system retained all the potential investment reduction of the evaporation process without the penalty of increasing the power facilities, and accomplished it with the use of only two cells instead of five. Furthermore, building volume and equipment costs could be substantially less than with the evaporation process.

In early March 1953, AEC concurred with the recommended alternative because of its greater flexibility and probable reduced cost. Design was at that time requested to evaluate the substitution of direct vision, shielded windows in the cell walls and the elimination of optics from the remotely operated crane, as well as other schemes for equipment arrangement.

In mid-March Design presented three schemes, none economically superior to the other, but recommended that the third be adopted as the most flexible.

1. Provide liquid-filled windows for vision; purchase a simplified crane of conventional design without shielded cab or optics, the crane to be controlled from window locations; reduce height over cell area about 15 feet from that in the L Area design.
2. The same as Scheme 1 but involving no change in roof elevation, thus providing for possible future installation of a Hanford-type crane as used in the R and P Areas.
3. Same as Scheme 2 except for providing initially the Hanford-type crane then on order, but omitting the optics, shielded cab, and related auxiliaries although retaining provisions for their future installation.

AED concurred in the recommendation.

The economics of the new purification area plan were so attractive that an immediate investigation was started on the possibility of installing it in the L and K Areas. Through the cooperation of the Construction Division in waiting for revised designs and the Blaw-Knox Company in producing revised foundation and building designs promptly, the lower cost and simplified design was constructed in the L, K and C Areas.

BUILDING #105 - COMPARISON OF BLDG. AREAS IN SQ. FT.

	<u>R</u>	<u>P</u>	<u>L</u>	<u>K</u>	<u>C</u>
Assembly	39,857	30,586	30,958	30,958	30,958
Process Area	344,136	344,136	295,972	295,972	296,988
Disassembly	94,784	67,864	61,772	61,772	68,202
Purification	23,597	23,597	16,774	16,774	16,774
Total	502,374	466,183	405,476	405,476	412,922

BUILDING #105 - COMPARISON OF BLDG. CUBAGE (CU. FT.)

Assembly	1,572,037	1,164,646	1,234,484	1,234,484	1,234,484
Process Area	6,740,211	6,740,211	5,422,158	5,422,158	5,447,558
Disassembly	2,233,836	1,714,645	1,501,496	1,501,496	1,234,168
Purification	587,000	587,000	462,000	462,000	462,000
Total	11,133,084	10,206,502	8,620,138	8,620,138	8,378,210
Total (Estimate Basis)	12,450,000	11,485,000	9,000,000	9,000,000	8,950,000

PLATE	DESCRIPTION	REFERENCE
346	BOB END TONGS	W15639
347	UTILITY TONGS	W152207
418	POLE TONGS	W153651
1842	UTILITY CARRIER	D-26608

[illegible]

W131827

THIS DRAWING HAS BEEN PREPARED BY S.I. IN PART TO COMPLY WITH THE REQUIREMENTS OF THE SAVANNAH RIVER PLANT AND TO BE USED FOR THE DESIGN AND CONSTRUCTION OF THE BUILDING. ALL INFORMATION IS BASED ON THE DATA FURNISHED BY THE CLIENT. THE ENGINEER ASSUMES NO RESPONSIBILITY FOR THE ACCURACY OF THE DATA OR THE RESULTS OF THE DESIGN.

SAVANNAH RIVER PLANT
BUILDING NO 105-P
DISASSEMBLY AREA
KEY PLAN
ARRANGEMENT

REVISIONS	DATE	BY	CHKD	APP'D	REVISIONS	DATE	BY	CHKD	APP'D	REFERENCE STANDARDS	REFERENCE DRAWINGS	FILE NO.
ADDED 4' X 5' X 8' ADDITIONAL DISASSEMBLY AREA	1/15/50	J.E.	J.E.	J.E.	REVISION 1 - SEE REVISION 2	1/15/50	J.E.	J.E.	J.E.	W-1316/5	KEY SECTIONS	8980
ADDED REF TO DETAIL 'A'	1/15/50	J.E.	J.E.	J.E.	REVISION 2 - SEE REVISION 3	1/15/50	J.E.	J.E.	J.E.	W-1316/6	ROOF PLAN	1-4-51
					REVISION 3 - SEE REVISION 4	1/15/50	J.E.	J.E.	J.E.	W-1317/3	FLOW DIAGRAM	1-4-51
					REVISION 4 - SEE REVISION 5	1/15/50	J.E.	J.E.	J.E.	W-1315/6	PLAN - MONORAILS & CRANES	2-4-52
					REVISION 5 - SEE REVISION 6	1/15/50	J.E.	J.E.	J.E.	W-1315/9	ARCHITECTURAL & CIVIL	2-4-52
					REVISION 6 - SEE REVISION 7	1/15/50	J.E.	J.E.	J.E.	W-1317/5	PIPELINE DIAGRAM	2-4-52
					REVISION 7 - SEE REVISION 8	1/15/50	J.E.	J.E.	J.E.	W-1315/8	ELECTRICAL	2-4-52
					REVISION 8 - SEE REVISION 9	1/15/50	J.E.	J.E.	J.E.	W-1316/1	VENTILATION	2-4-52
					REVISION 9 - SEE REVISION 10	1/15/50	J.E.	J.E.	J.E.			
					REVISION 10 - SEE REVISION 11	1/15/50	J.E.	J.E.	J.E.			
					REVISION 11 - SEE REVISION 12	1/15/50	J.E.	J.E.	J.E.			
					REVISION 12 - SEE REVISION 13	1/15/50	J.E.	J.E.	J.E.			
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					REVISION 84 - SEE REVISION 85	1/15/50	J.E.	J.E.	J.E.			
					REVISION 85 - SEE REVISION 86	1/15/50	J.E.	J.E.	J.E.			
					REVISION 86 - SEE REVISION 87	1/15/50	J.E.	J.E.	J.E.			
					REVISION 87 - SEE REVISION 88	1/15/50	J.E.	J.E.	J.E.			
					REVISION 88 - SEE REVISION 89	1/15/50	J.E.	J.E.	J.E.			
					REVISION 89 - SEE REVISION 90	1/15/50	J.E.	J.E.	J.E.			
					REVISION 90 - SEE REVISION 91	1/15/50	J.E.	J.E.	J.E.			
					REVISION 91 - SEE REVISION 92	1/15/50	J.E.	J.E.	J.E.			
					REVISION 92 - SEE REVISION 93	1/15/50	J.E.	J.E.	J.E.			
					REVISION 93 - SEE REVISION 94	1/15/50	J.E.	J.E.	J.E.			
					REVISION 94 - SEE REVISION 95	1/15/50	J.E.	J.E.	J.E.			
					REVISION 95 - SEE REVISION 96	1/15/50	J.E.	J.E.	J.E.			
					REVISION 96 - SEE REVISION 97	1/15/50	J.E.	J.E.	J.E.			
					REVISION 97 - SEE REVISION 98	1/15/50	J.E.	J.E.	J.E.			
					REVISION 98 - SEE REVISION 99	1/15/50	J.E.	J.E.	J.E.			
					REVISION 99 - SEE REVISION 100	1/15/50	J.E.	J.E.	J.E.			

ENGINEERING DEPARTMENT
W131827

NA NO	DESCRIPTION	REFERENCE
317	UTILITY TOWER	W-112209
356.2	UTILITY CARRIER	D-126605

A
(W-138079)

[illegible]

SAVANNAH RIVER PLANT
BUILDING NO 105-L
DISASSEMBLY AREA
KEY PLAN
ARRANGEMENT

THIS DRAWING SUPERCEDES W-132078

REVISIONS	DATE	BY	REVISIONS	DATE	BY	REFERENCE STANDARDS	REFERENCE DRAWINGS
01	11-1-78	W-132078	01	11-1-78	W-132078	KEY SECTIONS - DISASSEMBLY	W-132078
02	11-1-78	W-132078	02	11-1-78	W-132078	ROOF PLAN - DISASSEMBLY AREA	W-132078
03	11-1-78	W-132078	03	11-1-78	W-132078	PLAN - MONORAIL & CRANE	W-132078
04	11-1-78	W-132078	04	11-1-78	W-132078	CONCRETE - FOUNDATION PLANS	W-132078
05	11-1-78	W-132078	05	11-1-78	W-132078	VENTILATION	W-132078
06	11-1-78	W-132078	06	11-1-78	W-132078	ELECTRICAL	W-132078
07	11-1-78	W-132078	07	11-1-78	W-132078	ARCHITECTURAL	W-132078
08	11-1-78	W-132078	08	11-1-78	W-132078	FLOW DIAGRAM	W-132078
09	11-1-78	W-132078	09	11-1-78	W-132078	PIPING DIAGRAM	W-132078

W-132078

ENGINEERING DEPARTMENT
W-132078

EQUIPMENT NOT SHOWN
USED IN THIS AREA.

NAME	RESIDENCE	AREA CODE
NY	WILLIAMSON	914-867
NY	WILLIAMSON	914-867
NY	WILLIAMSON	914-867

[illegible]

W134454

SAVANNAH RIVER PLANT
BUILDING N° 105 C
DISASSEMBLY AREA
KEY PLAN
EQUIPMENT ARRANGEMENT

REV.	REVISIONS	DATE	BY	CHKD.	REFERENCE STANDARDS	REFERENCE DRAWINGS	DATE
0590	MOVED STAIRS ADDED PLATFORM	1-12-63	W-134454			W134455 DISASSEMBLY AREA KEY SECTIONS	1-12-63
0590	W-6 WASHING 18" x 18" 8" 8"	1-12-63	W-134454			W134456 DISASSEMBLY AREA ROOF PLAN	1-12-63
0590	W-6 WASHING 18" x 18" 8" 8"	1-12-63	W-134454			W134457 FLOW DIAGRAM-SLUDGE/LOW ILLUMIN	1-12-63
0590	W-6 WASHING 18" x 18" 8" 8"	1-12-63	W-134454			W134458 PLAN-MANORAIL CRANES	1-12-63
0590	W-6 WASHING 18" x 18" 8" 8"	1-12-63	W-134454			W134459 PIPING DIAGRAM	1-12-63
0590	W-6 WASHING 18" x 18" 8" 8"	1-12-63	W-134454			W134460 ELECTRICAL LIGHTING POWER	1-12-63
0590	W-6 WASHING 18" x 18" 8" 8"	1-12-63	W-134454			W134461 VENTILATION	1-12-63
0590	W-6 WASHING 18" x 18" 8" 8"	1-12-63	W-134454			W134462 ARCHITECTURAL & CIVIL	1-12-63
0590	W-6 WASHING 18" x 18" 8" 8"	1-12-63	W-134454			W134463 INSTRUMENTS	1-12-63

W134454
SAVANNAH RIVER PLANT
BUILDING N° 105 C
DISASSEMBLY AREA
KEY PLAN
EQUIPMENT ARRANGEMENT
1-12-63
W-134454

ASSEMBLY AREA
QUARTER FOR FINAL STORAGE
PURIFICATION AREA
FAR ROOM FOR MAINTENANCE

ROAD
TRUCK

1950
1951

W-130037	EQUIPMENT	ARREST PLAN	-40' 0"
W-130026			70' 0"
W-130028			+0' 0" SH 1
W-130029			+10' 0" SH 2
W-130047			+18' 0" SH 1
W-130080			+15' 0" SH 8
W-132717			+30' 0" SH 1
W-132718			+30' 0" SH 8
W-133333			+64' 0" SH 1
W-133336			+64' 0" SH 1
W-133771			+66' 0" MORE
W-130056			CROSS SECTION
W-130054			LONGITUDINAL SECTION
W-130055	PLOT	PLAN	
W-133335	PLOT	PLAN	ELEVATIONS

N-153/91	CLEAR LEDGE & CABLE TRANSFER	1-PLAYS
N-153/02		SECTIONS
N-150754	PUMP RM. OBSERV. WINDOW	ADJST.
N-150772		ASSY.
N-150674	CONTROL RM.	ADJST.
N-150675		ASSY.

D-114834	PUMP RM. OBSERV. WINDOW	FRAME
D-114837	"	SASH
D-114862	"	DETAILS
D-14824	CONTROL RM.	FRAME
D-114836	"	SASH
D-114835	"	DETAILS
D-112774	LIFTING DEVICE FOR	3000 H.P. MOTOR

W 139 083	PERSONNEL
W 144 199	PURIFICATION
W 137 878	ASSEMBLY
W 137 340	DIESEL BLDG 108 14
W 137 790	DIESEL BLDG 108 96
W 139 738	PUMP ROOM 108 96
W 139 078	DISEASSEMBLY
W 139 874	106 L
W 149 786	107 L
W 133 960	109 L

NOTE.
ALL ELEVATIONS SHOWN ARE TOP OF ROOF
CONCRETE SLAB EXCEPT AS NOTED
OTHERWISE

U102485

[illegible]

SAVANNAH RIVER PLANT
PROCESS AREA - BLDG 705L
FLOT PLAN
ARRANGEMENT

3-3

[illegible]

8280

1.30-0

21/04/2014

1991

100. *Asplenium*

442195-1076-31 P. 104

W 192055

[illegible]

W122387

THIS MESSAGE WAS DECLASSIFIED BY 1
ON PART IN REFERENCE 4 ON THE INFORMATION AND
REVIEWED THE FACT THAT THE FBI HAS THE SOURCE
ON INFORMATION WITHOUT THE SOURCE PERSONNEL
OF THE FBI. ALL INFORMATION IS SUBJECT TO THE
PART INCLUDING VARIOUS 3 THE SOURCE. SMALL
THEY ARE SUBJECT TO THE FBI.

SAVANNAH RIVER PLANT
PROCESS AREA BLDG. 105-L
PLOT PLAN ELEVATIONS
EQUIP. ARR'GT.

[illegible]

CONTRIBUTIONS OF SPECIALIST DESIGN GROUPS

ARCHITECTURAL AND CIVIL

The Site Survey Report, recommending the location of the new plant at its present location, supplied the following information.

"The surface of the manufacturing area is covered with a rather loose wind-blown sand, varying from two to ten feet in depth. Below this is the Barnwell Formation, generally considered to be about 80 to 150 feet thick. It is said to dip southward at nine feet per mile. Below the Barnwell is the McBean Formation said to be 50 to 100 feet thick and to consist of soft limestone, clay marls and sands. A few clay lenses were found. The Tuscaloosa sands, 250 to 500 feet thick, underly the McBean. Pre-Cambrian crystalline rock lies at a depth of 500 to 750 feet below the surface.

"Occasional sink holes scattered throughout the area indicate openings of an undetermined nature and consequent settlement. The U.S. Geological Survey's reports on the area mention calcareous deposits at the base of the Barnwell as a possible solution or cavernous zone which may have caused the local subsidences. In an attempt to answer this question, thirteen core holes were drilled in possible building areas. The suspected calcareous deposits were found below the Barnwell in a band trending north-south near Greenland; and in three holes limestone up to 60 feet thick was found. In one hole the limestone was only 82 feet below the surface. In most of the holes the limestone found was a few inches thick to depths of 125 feet below the surface. None of the limestone was found to be cavernous, probably because it is too weak to support caves. Although no pervious calcareous beds were located in the drilling, the marl-like limestone found in three holes may in other forms have contributed to the subsidences."

SOIL INVESTIGATION

At the outset of this project, it was apparent that a thorough knowledge of the subsoil conditions would be necessary in the immediate vicinity of all major buildings on the project. This need arose from the peculiar combinations of load, size of structures, stringent limitation on allowable building settlements, prevention of plant waste seepage, and geological factors induced by the surface depressions or "sinks" already disclosed in preliminary borings made before site selection.

A recommended procedure for a thorough foundation investigation was drawn up by personnel of the du Pont Engineering Research Laboratory in December 1950. These recommendations were followed to a large extent in the subsequent work. ERL also recommended the establishment of a board of consultants composed of prominent foundation and geological engineers. In executing this recommendation it was found that there existed no commercial organization of sufficient size to handle the work in the time required. The most practical solution was to utilize the facilities of the U.S. Army Corps of Engineers or the Bureau of Reclamation. The former was favored because of its acquaintance with the area and the existence of several laboratories in the South Atlantic Region. In December, the Corps of Engineers agreed to undertake the work. Periodic meetings of the board of consultants were held to review the foundation explorations and analyses. Field conditions, laboratory results and analyses as they developed were studied also.

The soil deposits consisted generally of combinations of sand and clay. A few random, poorly cemented, sand layers were found at depths of 100 feet or more. Evidence of solution of calcareous materials was found at depths ranging from 100 to 200 feet; the results being reflected in surface sinks and subterranean channels. Much of the area was covered with a crust of desiccated sandy clay up to 30 feet in thickness which had a higher strength than the underlying material. Bedrock was found to be at depths ranging from 700 to 1200 feet. Ground water varied from nine feet to 60 feet below the surface.

A seismic survey revealed that soils at foundation level generally had sonic velocities of 2000 to 4000 feet per second compared with the velocity of basement rock, at depths of 700 to 1200 feet, of 18,000 feet per second. Velocities of deep lying clay layers could not be determined because they were marked by overlying high velocity materials.

Soil at the sites of reactor buildings was explored in the following manner. The first holes drilled were three to five split spoon drillings to determine ground resistance. In a second step, five additional holes were drilled approximately 150 feet apart. A number of the second holes were for undisturbed samples of underlying soils on which laboratory tests were made for strength, settlement and other characteristics. In a third step, fish tail holes were drilled on a grid of 50-foot spacing to determine whether or not there were any soft pockets below the earth crust at depths up to 200 feet. The soft pockets are strata of calcareous soils resulting from prehistoric marine deposits. When a soft pocket was found, the spacing was decreased to determine the extent of the pocket. As a final step, grout was pumped

into the pocket until it was filled, as indicated by a refusal to accept more grout. This grouting pattern covered the full area of the building and extended to a line roughly 100 feet outside the building lines.

Based on results of laboratory and field tests, an investigation was made of the probable behavior of the various parts of the structure with reference to settlement and shear failure of the soil under the proposed loads. In the R and P Areas, the load on the main supporting mat of the structure is 443,000,000 pounds. With the mat measuring 280 feet by 290 feet, the average soil pressure is 5450 pounds per square foot. In the L, K and C Areas the load is 314,000,000 pounds distributed over an area of 170 feet by 250 feet for an average soil pressure of 7400 pounds per square foot.

The positioning of the main mat under the principal part of the building required considerable calculation to make the center of gravity of the loads coincide with the center of gravity of the mat. This was difficult because of the shifting nature of a large segment of the live load. However, the centers of gravity were so close to being coincident that the variation in soil pressure over the whole mat was 10 per cent in one set of buildings and 13 per cent in the other. In connection with this foundation study, careful records were kept of the amount of rebound of the subgrade as it was relieved of the load during excavation and the amount of settlement encountered as the load was applied during construction. Rebounds averaged 2 inches and settlements 3 inches for a net average settlement of 1 inch.

The structure was designed for blast conditions equivalent to the detonation of a 125 kiloton bomb 1-1/4 miles from the building and 2000 feet above ground zero. The equivalent earthquake design specified by most building codes is much less severe than this blast criterion. To make certain the building could withstand earthquake, the following specifications were observed: buildings were checked for resistance to a force "F" which is equal to $0.1 \times$ total dead load (including equipment operating weight) plus one-half the live load. In addition, the building code used in designing the plant was the Uniform Building Code published by the Pacific Coast Building Officials Conference which specifies that buildings more than 25 feet high shall be designed for lateral forces.

DRAINAGE

Three drainage systems serve each of the #100 Areas. The storm sewer system is designed to collect the normal roof and surface water run-off resulting from a 2-year storm frequency of five inches of rain per hour for a period of ten minutes. This system discharges into tributaries of the Savannah River. The sanitary system collects all sanitary wastes and disposes of them in septic tanks. All wastes not collected in these systems are carried into the process waste system which has the principal function of channeling process cooling water beyond the area boundary and discharging it into river tributaries. An auxiliary portion of this system was installed to handle the overflow from the supply reservoir in the event of an emergency. Because of the flow volume in the process system, the trunk lines range from 60 to 72 inches in diameter and are constructed of either reinforced concrete or steel pipe with neoprene lining. In most cases all sewer systems converge outside the area fence at a common headwall or outfall structure discharging into an open earth canal leading to the various creeks.

In four of the #100 Areas there was no question of the tributary to be used in process drainage. Steel Creek serves both the #100-P and L Areas, Pen Branch the K Area and Four Mile Creek the C Area. In the R Area, however, either Four Mile or Lower Three Runs Creeks could be used. For the former it would have been necessary to pump the water to a high point from which it could flow by gravity into the creek. Direct discharge to Lower Three Runs was possible but the plan made it advisable to purchase additional bordering land since the stream reached the river outside of AEC property. An evaluation of the alternative established definite operating economies in the use of Lower Three Runs, and the necessary land was purchased.

HEATING, VENTILATING AND AIR CONDITIONING

When the reactor building developed into a concrete enclosed structure without windows or louvers and, of course, subject to localized quantities of radiation, it became evident that ventilation would be very important. The first set of study arrangement drawings issued in October, 1950, reflected this and allocated about 13,000 square feet of space plus a stack for the purpose.

Continuing ventilation studies eventually led to the decision to develop two main systems. One, known as the "pump room system", would include the pump room, motor rooms, heat exchanger rooms, observation and instrument rooms at the -40' level, and the transfer corridors and

miscellaneous rooms contained in the lower levels of the building. The second system, known as the "main tank room system", would ventilate the reactor room and the crane wash area as well as several auxiliary rooms at the 0.0' level. Smaller fan supply rooms and air conditioning units were to be located throughout the building to meet specific needs of other rooms or areas. Before final design of the latter system was approved, air flow patterns through a simulated model of the reactor room were studied to assure design requirements.

To serve both air supply and equipment removal, a deepwell extending from grade level to -40', was included in the design at the south end of the center section of Building #105-R. Air supply fan rooms and air exhaust rooms for the pump room system were placed near the deepwell. Additional fan equipment was located next to the deepwell at Elevation 0.0' to supply the crane maintenance and transformer rooms.

Air supply and exhaust equipment for the main tank room system was placed at the +48' level, the supply room to the north, the three exhaust rooms to the south in R Area.

Since the blast protection features of Class I construction would be defeated by air intakes located in walls of the building, either wells at grade level or specially designed reinforced concrete intakes on the roof of the building, known as "blast-tees", were employed.

The design for all air handling systems in the building was based on the following premises.

1. Where possible, air is re-used for ventilation or heat removal in subsequent areas before it is discharged from the building. In the air conditioning systems the maximum amount of air is recirculated with a minimum amount of outside air added to meet ventilation requirements.
2. All portions of the system are based on a maximum summer temperature outdoors of 95 degrees F. dry bulb and a winter minimum of 20 degrees F.
3. The systems have been kept as small as possible consistent with the requirements for good air flow pattern and the limitations placed on temperature rises within the building.
4. To keep the cost of the system to a minimum, no excessive safety factors are included.

5. All heating is by steam coils installed in the fan rooms and operated in conjunction with the air supply system.
6. Where possible, the corridors and doorways are used as "ducts" to distribute air to various parts of the building.

PUMP ROOM PATTERN

The -40 ft. fan room, adjacent to the deepwell at the south end of the building, see Page 63, contains two 135,000 c.f.m. fans, one a spare, complete with heating coils and filters. Automatic controls start the idle fan and open or close respective fan dampers when the operating pressure in the discharge duct for the system falls below a predetermined minimum static pressure. Identical duct systems are installed for the various rooms on each side of the reactor. The main flow, 94,500 c.f.m., is first delivered to the motor room, is sent to the heat exchanger room above by 12 axial vane fans set in the walls of the motor room, and then is drawn down through the grating floor of the exchanger room to the pump room. Ductwork installed near the floor of the pump room carries exhaust air to the -40 ft. exhaust fan rooms. These two rooms, each containing a 120,000 c.f.m. fan, can operate separately, one being a spare. Each fan has a suction and discharge water seal to permit maintenance work on one fan without hazard from the operating fan. Other areas or rooms serviced by the -40 ft. fan room include the -20 ft. south center area, the supply and exhaust fan rooms themselves, the seal pump room, transmitter room, several corridors below grade, the horizontal tank room, valve pit room, and the area containing the circulating pumps. All discharge from the system is to the stack.

MAIN TANK ROOM PATTERN

This system maintains an air flow of approximately 100,000 c.f.m. from adjacent areas at Elevation 0.0' and above toward the main tank room and the crane wash area.

Several unusual ventilation problems existed in the reactor room. The temperature of the air in the room had to be kept above the dew point during both summer and winter. Air motion in the room had to dilute, diffuse and remove moisture, vapor and fumes. Pocketing of fumes had to be prevented by sweeping with air all the inside surfaces of the room.

To meet requirements, supply and exhaust plenums were located outside the east and west walls of the room, see page 61. Supply nozzles spaced on 6-foot centers were constructed in the wall at the angled, underside of the crane ledge at approximately the 28 ft. level. Pressure in the supply system forces air currents from each of these nozzles approximately 34 feet into the room causing a horizontal flow of air across the floor and inducing a vertical flow of air up the east and west walls of the room. At the same time a vertical flow is induced in the center of the room. Exhaust air is pulled from the room by duct connections spaced on 6-foot centers located just below the ceiling line on each side of the room.

Total supply to both the reactor room and crane wash area is 97,000 c.f.m. giving an air change every five minutes. The exhaust system has a capacity of 119,000 c.f.m. to insure leakage of air from other areas into these rooms.

The supply room on the north end of the building, see page 63, at the 48 ft. level contains three 61,500 c.f.m. fans, one a spare. These are equipped with filters and heating coils. Air intake is from a "blast-tee" on the roof. The exhaust area at the south side of the building contains three 85,200 c.f.m. fans, one a spare, each in its own room and provided with suction and discharge water seals which are filled when a fan is to undergo repair or maintenance. Discharge is to the stack.

OTHER FACILITIES

The crane control area on the east side of the reactor room is supplied by the 12,000 c.f.m. conditioning capacity installed in the fan room at Elevation 15' in the northwest corner of the assembly area. Of the total, 4400 c.f.m. is supplied to the main level and 7600 c.f.m. to the 15 ft. level. About 11,000 c.f.m. of the total flow is recirculated, and the remainder is drawn from the outside. The balance of 1000 c.f.m. flows to the west side control area through the north corridor at the 15 ft. level.

Air conditioning equipment with a total capacity of 37,400 c.f.m. is installed at Elevation 0'-0" in the southwest corner of the process area to supply the control room and office area on that side of the reactor room. The main floor is fed 17,800 c.f.m., the fan room, 1000 c.f.m., and the 15' level, 18,600 c.f.m. Recirculation from the fan room is 1000 c.f.m., from the main floor, 12,200 c.f.m., and from the 15' level, 15,400 c.f.m., for a total of 28,600 c.f.m. Toilet and shower rooms are exhausted with an

8000 c.f.m. flow, and the hood of the Health Physics laboratory with 800 c.f.m. for a total exhaust of 8800 c.f.m. Make-up air of 7800 c.f.m. is drawn from the outside and the 1000 c.f.m. balance is led from the east side system through the north corridor.

The crane repair room receives a total of 46,400 c.f.m. from a fan system located in the southeast corner of the room to maintain a positive pressure relative to the crane wash area and the reactor room.

The general assembly area is supplied conditioned air from the central station air conditioning unit. A separate fan system is installed for the receiving area. Since the air for the final storage room must be clean and the room kept at a positive pressure, air drawn from the general area is double-filtered before it is admitted to the storage room.

The disassembly area is served by a fan room located at the 15 ft. level along the north wall of the building. Approximately 80,000 c.f.m. is supplied in the summer and 45,000 c.f.m. in the winter. Of the total circulation, 7400 c.f.m. is supplied to the transfer area and 6000 c.f.m. to the dry cave. In the latter case the air is double filtered before discharge through a "blast-tee".

Ventilation of the purification area is achieved by 8000 c.f.m. supplied to the cells through a pipe trench and drawn from the main pump room pattern. This is supplemented by 15,800 c.f.m. supplied to the corridors in the area by the supply fans in the crane repair room. The supply spills into the cells and is exhausted with all cell air through ducts installed in the cell ceilings. The laboratories are air conditioned and the counting room has its independent conditioning system to maintain 75°F. and 45% relative humidity conditions at all times.

In the original design 20,000 c.f.m. was to be supplied from the main tank room system through ducts to the actuator tower. A pair of exhaust duct risers with dampers at the +110, 120 and 130-foot levels removed the spent air. Pressure in this part of the building was to be positive relative to the reactor room below to prevent a reverse flow of air up through the numerous holes in the various actuator deck plates. During early operation, a temperature rise of 34°F. was noted in the more centrally located packages. Peripherally located packages developed a much smaller temperature rise. At the same time some personnel discomfort was experienced in the tower structure. To eliminate this discomfort and to provide additional cooling to the motor packages, a 6000 c.f.m. air conditioning unit was installed at the 110-foot level, holes were drilled in the 120-foot deck under

the motors, a plenum was installed under the 120-foot deck and this was connected with an additional fan to the air conditioning system. Continuing studies of operating conditions had, by the fall of 1953, indicated that with forced outside air to the special plenum under the motor packages and a better balancing of the ventilating system, there was, under normal conditions, no need for the air conditioning unit.

EMERGENCY OPERATION

Through any emergency period, a minimum amount of air must be supplied to and exhausted from a few rooms in the building. This is assured by providing emergency diesel service on the supply and exhaust fans of the reactor room system, the pump room system, a supply fan for each of the control fans, the supply fan for the final storage room of the assembly area, and the exhaust fan in the dry cave of the disassembly area.

STACK

The du Pont Engineering Service Division calculated as 200 feet the stack height required to disperse safely the tritiated water vapor released during operations. In the interests of economical building construction a 150-foot stack was designed to be mounted on the +55-foot level of the building and adjacent to the reactor room exhaust fan room.

Stack calculations were based on:

1. A maximum air discharge of 220,000 c.f.m.;
2. A process liquid release of approximately 40 lb./hr. during reactor charging periods; and
3. A tolerable concentration of 5×10^{-5} microcuries per cc. of air.

Since Gibbs & Hill, a design subcontractor, was purchasing concrete stacks for all the power houses it was decided to combine these stack orders to reduce costs. Gibbs & Hill thus handled procurement details with du Pont and the vendor executing the design. The stacks are unlined, have a 16-foot inside diameter at the top, and are designed for temperatures up to 200°F. and a maximum wind force of 25 p.s.i. They can withstand the same blast forces as the building.

Arrangements in Building #105-P do not materially differ from the above description.

For Buildings #105-L, K and C the reorientation of the areas did not change the ventilation approach but did affect the physical location of some apparatus.

A large machinery space was allocated at the 0.0' level adjacent to the rearranged assembly area to house the -40' supply and exhaust fans, the refrigerating machines, the assembly air conditioning system, and final storage filtered supply system. The supply and exhaust air to the -40' spaces was carried by a system of ducts and risers connecting the areas served with the ventilation equipment in this machine space.

The Class III personnel area was provided with supply and exhaust ventilation systems each handling about 38,000 c.f.m. for summer temperature control with two speed motors to permit steam economies in winter at lower fan deliveries. Exhaust is to atmosphere. The three offices of the Health Physics group in this area were air conditioned in addition to the above.

The consolidated control room at the +15' level was equipped as in Buildings #105-R and P with the same air conditioning apparatus located in a +34' level apparatus room directly over the central control room. The supply air quantity is 28,700 c.f.m. The lunch room and men's toilet are exhausted to atmosphere with a 4700 c.f.m. exhaust fan. Air is exhausted from the women's toilet by a fan taking 1300 c.f.m. from that room along with 1000 c.f.m. from a hood over the battery rack in the motor generator room at the 0'-0" level.

A detailed tabulation of air flow quantities, temperature limitations, rates of change and relative area pressures is contained in Exhibit C of the Appendix.

ELECTRIC POWER

Reference to Volume VI of this history, covering the power and electrical facilities of the Savannah River Plant, will acquaint the reader with the important position occupied by the #100 Area process buildings in the development of the design of the service facilities for the plant. The locations of the electric power generating stations; the arrangement of the extensive, high-voltage transmission network; the locations and bus arrangements of the power-pool switching stations; the capacity of the paralleled transformer linking each #100 Area with the inter-area

power network; the local area ring-bus power distribution system using underground cable and double bus-tie circuit breakers; the heavy, Class I construction of the houses protecting the vital area distribution switchgear; the overall design of the river water pumping, distribution and reservoir systems supplying large quantities of water to the #100 Areas--all these features point up the importance attached to providing for each #100 Area a highly dependable supply of electricity and water.

There were four broad areas of electrical design and development work involved in the Building #105 effort. Power supply, lighting, instrument supply, and communications are the categories which, while they were coordinated, were developed as essentially independent designs.

ELECTRIC POWER DISTRIBUTION

It was recognized early in the development that the characteristics of the electric power supply required for the large moderator pump drives were markedly different from those required for other utilization equipment within the #105 Building. The problems of supply in these two types of load were therefore divorced.

The development of a reliable supply for the six 3000 hp. pump drive motors in each #105 Building is discussed in Volume VI, and the selection of the motors and the development of "on-line" power supply and auxiliary drive motors for these pumps are discussed in the "on-line power and water supply" section of this #100 Area volume. Each of the main pump drive motors is supplied directly and independently from the area 13.8-kv. ring-bus through a circuit breaker (housed in a Class I building) and an underground feeder cable.

Two additional underground primary feeders were provided to supply the general power requirements of Building #105. Each feeder is a continuous, unspliced cable having sufficient capacity to carry all of the building loads. One feeder is connected to the area 13.8-kv. distribution system through a circuit breaker housed in Primary Substation, Building #151-1. The other feeder ties in at Primary Substation, Building #151-2. In the #100-R, P, L and K Areas, the former building is a transformer station associated with the pool of plant power - the transmission network; the latter is a switch house associated with the electrical generators in the Power House, Building #184. In the #100-C Area, which does not have local power generation, each of the primary substations contains a large transformer of sufficient capacity to carry the entire area load.

The general power and lighting requirements of Building #105 were estimated to total 5000 to 6000 kv.-a. connected load, with the operating load expected to reach 3500 to 4000 kv.-a. The largest single items of load were the heating and ventilating fan drives, as large as 150 and 200 hp. The magnitude of the total load and the size of the larger individual units indicated the desirability of a 480 volt, 3-phase distribution system, served through a number of load center unit substations which would transform the 13.8-kv. primary service to 480 volts and distribute power at this voltage.

Fifteen hundred kv.-a. was selected as the largest economic load center unit substation in this voltage range, and a total of four such units were selected for each Reactor Building. Each substation is fed by either of the 13.8-kv. primary feeders, which loop through all substations to provide a dual power supply at each location. Each substation is equipped with two 15 kv. manually-operated air-break interrupter switches for selection of primary power source.

The unit substations are interconnected through a secondary loop system with manually-operated bus tie circuit breakers at each substation. Thereby each substation can be fed from either of two other substations in the event of transformer failure.

The 480 volt secondary switchgear of each substation is split into two sections which are physically separate, but electrically connected. The first section is the "normal power" section which feeds less critical equipment; the second section is the "emergency power" section which feeds all essential equipment. In normal operation both sections are fed from the substation transformer. If the normal supply fails, both sections are disconnected automatically from the transformer and the emergency power section only is fed from a standby 1000 kv. diesel generator in Building #108-1 or #108-2. Each diesel generator is connected to supply emergency power to two unit substations, and a bus tie is installed between the two generators to provide a maximum of flexibility.

The design of the secondary distribution system from the unit substations to the utilization equipment followed conventional du Pont practice except for the following features. Motors larger than 50 hp., which might be required to operate on a diesel-generator supply, are provided with reduced voltage starters to minimize the starting duty on the diesel. Unusual attention was given to the coordination of circuit protective devices to assure minimum disturbances from short-circuits. In general, duplicate items of equipment, such as pumps and fans, are supplied from different unit substations to provide maximum continuity of essential services.

LIGHTING

Power for lighting is distributed from 480 volt, 3-phase distribution panels which are located in the transformer rooms and are energized by individual substation feeders. Lighting feeders serve individual 10, 15, and 25 kv.-a., 3-phase, 4-wire lighting transformers located at strategic points throughout the building. Approximately 10 per cent of the general and all of the process lighting requirements are served from the emergency power sections of the unit substations.

Lighting requirements in the main process area called for a monochromatic light source in order to permit undistorted viewing through thick glass observation windows. No commercial units were available to meet the requirements for intensity, limited mounting space, and weatherproof enclosure. Working closely with a vendor, a unit having a special and totally new mounting and enclosure was designed for a dual unit sodium vapor lamp.

SPECIAL POWER SUPPLY FOR INSTRUMENTS AND ROD CONTROL

Under emergency operation, precipitated by a power failure at one or more unit substations, the standby 1000 kw. diesel generators in Buildings #108-1 and #108-2 start automatically and pick up the load on the emergency power section of the affected substation. However, due to the time required to start the diesel, there is a 10 second lag between the loss of normal power and the availability of diesel generator power.

Since continuity of power is essential for instrumentation and actuator circuits, an additional system provides continuity of service independent of building power continuity.

A system consisting of a.c. to d.c. motor generator sets, a large storage battery, and d.c. to a.c. motor-alternator sets was supplied. There are two sets of rotary equipment, each with 62-1/2 kv.-a. capacity, one for instrument service and one for actuator service. A 640 ampere-hour storage battery is connected to float on the d.c. bus of the conversion system. In normal operation the generating equipment is driven by motors connected to the unit substations; in emergency service, the storage battery supplies power to drive the motor-alternators. Automatic voltage and frequency controls are incorporated in the over-all control system.

INSTRUMENT POWER SUPPLY

Instrument power is distributed through panels located in or near heavy instrumentation load areas of the process section of the building. The branch circuits of these panels are very lightly loaded to minimize the effects of a loss or disturbance of any one circuit.

In the central control room each section of gage board has an assigned distribution circuit for solenoid valves, relays, instrument motor drives and other power components. Ultra-sensitive instruments which utilize very low powered signals are supplied from a separate distribution panel. This isolation was necessary to avoid pick-up of pulses reflected in the circuits by relay or solenoid operation. Special methods were required to provide adequate isolation and shielding of the instrument circuits between the remote signal transmitters and the signal amplifiers.

The accurate operation of the vital and sensitive instruments required for safe control of the process demanded an electric power supply that was not only dependable, but which also had extremely stable voltage and frequency characteristics. These quality requirements had far reaching effects upon the design development of the instrument power supply electrical system.

COMMUNICATIONS

During the early stage of development of the design, a floor area of approximately 100 sq. ft. was allocated in Building #105 for communications equipment. This area was more than doubled after the total communications requirements were developed. These requirements were established by conference with the Operating Department and included the following systems: Bell Telephone System for general contact between buildings within an area, between areas within the plant, and with the external Bell System; Building #105 Private Automatic Telephone Exchange having an executive loud speaking feature; Sound Powered Systems for process and maintenance control functions; Process Amplified Intercom Systems; Evacuation Safety Alarm and Emergency Paging System.

The #100 Areas are connected to the Plant Bell Telephone System by a 100-pair trunk line from the Central Exchange, Building #702-A. Cable pairs taken from this trunk line enter each #100 Area through area switching equipment housed in Patrol Headquarters, Building #701-1. A 10-pair underground cable is directed from that point to the #105 Building where it is terminated in a distribution box

inside the building. From this box, lines are run to individual instruments installed in personnel occupied areas throughout the building.

To obtain a completely integrated private phone exchange, one vendor was chosen to supply all equipment, power supply, telephone instruments, wiring and installation. The system is known as the PAX and has all necessary capacity for outgoing line expansion. As originally installed, the local trunk lines are equipped with sufficient connector switches to permit a total of twenty simultaneous conversations. The direct line executive units are located in the supervisor's office and at the main operating console. Besides being able to place and receive calls through the exchange, a direct line unit can call any one of a selected group of twenty-two stations without dialing.

This is accomplished through the use of selector keys on a master cabinet. Either a normal telephone instrument or a microphone and speaker arrangement can be employed by the direct line user.

Sound powered telephone equipment was selected as a satisfactory, yet inexpensive, means for providing communications between personnel engaged in cooperative tasks during operating, maintenance and instrument calibration activities. As its descriptive designation indicates, this equipment is self-sufficient and readily portable and was used extensively during the construction, installation and testing phases prior to start-up. Fifteen separate systems were installed. Some of these systems extend beyond Bldg. #105 to tie together equipment locations in other buildings that are associated with a given function. The functions and general locations of these systems are indicated by their designations.

System No. 1	Process Cooling Water
Systems No. 2 & 3	Back-up for Intercom Between Loading and Unloading Machine Operators
System No. 4	Independent Contact Between Bldg. #105 Central Control Room and Bldg. #184 Power House Control Room
Systems No. 5 & 10	General Building Process Coverage
System No. 6	Actuator System Control
System No. 7	120-ton Crane Control
System No. 8	120-ton Crane Manipulation

Systems No. 9, 11, and 13	Instrument Calibration
System No. 12	G.P. Robot Manipulation
System No. 14	Loading Machine Control and Maintenance
System No. 15	Unloading Machine Control and Maintenance

To provide communication with those locations where personnel must have complete freedom of movement, three systems of amplified speech intercom were provided. These systems are used during loading and unloading of the reactor; between precision crane operators and operators at the deposit and exit points; and in the purification area between the main control room operator, crane operator and the truck port. A microphone which is connected to the loading and unloading intercom system is located beside the observation window for the supervisor's use.

A safety alarm system is among the plant communications facilities described in Volume VI. In addition to transmitting evacuation alarms and air raid warnings, this system can be used in each area to issue instructions to personnel and for emergency paging. Safety alarm broadcasting can originate in each #100 Area from Bldg. #701 or #105. The main amplification equipment for the system is also located in these two buildings. The heavy concrete section of the former building houses a duplicate set of system controls and becomes the communications center during air raids or other emergency conditions.

MISCELLANEOUS CONTRIBUTIONS

In addition to the broad areas of electrical design activity covered in the above sections, electrical specialist engineers were deeply involved in the design and development of unique electro-mechanical devices and systems, such as: rod controls, precision cranes, hoists for the telescoping forest and the shield doors, conveyors and other materials handling, and manipulation equipment. Assistance was also given to the instrument specialist group in the development of graphic panels and instrument wiring schemes. These miscellaneous facilities are discussed in other sections of this volume.

The size and complexity of Bldg. #105 and its facilities can be expressed a number of ways - yards of concrete, miles of pipe, feet of wire. A total quantity of wire equivalent to over 900,000,000 feet of single conductor wire was installed in the five #105 Buildings.

POWER

The principal power requirements of Building #105 are chiefly electrical, but some process and heating steam as well as compressed air are required. Only in the design of the river cooling water system did the design of power facilities have any appreciable effect on Reactor Building design.

Of necessity, the definition of requirements for steam, water, air and electricity changed as design of production facilities developed. In late January 1951, the utility requirements for Buildings #105, #110 and #115 were first evaluated:

Steam - Process	5,000 lb./hr.
Steam - Heating (winter maximum)	10,000 lb./hr.
Electric - Installed hp.	18,500 b.hp.
Water - Heat Exchangers	80,000 g.p.m.
Water - Service	1,000 g.p.m. av.

Four months later the over-all requirements were re-estimated after the building design for the R Area was basically agreed upon, the major equipment items were known, and the service demands more accurately developed:

Steam - Process	2,500 lb./hr.
Steam - Heating (winter maximum)	10,000 lb./hr.
Electric - Installed hp.	20,500 b.hp.
Water - Heat Exchangers	74,000 g.p.m.
Water - Service	7,500 g.p.m. av.

The installed horsepower estimate included 2400 b.hp. for d.c. back-up power required for main pump drives.

One month later the water requirements were further specified:

	<u>Present</u>	<u>Future</u>
Reactor cooling, g.p.m.	60,000	75,600
Services incl. shields	8,000	8,000
Air conditioning	1,000	1,000
Total clarified water, g.p.m.	69,000	84,600
Disassembly basin, g.p.m.	2,000	2,000
Total filtered water, g.p.m.	2,000	2,000

These data resulted in current and future #100 Area river water requirements of 78,000 and 94,000 g.p.m. respectively. Each area initially was to have a clarification plant large enough to process the entire influent.

The determination of requirements proceeded through the balance of 1951 and were next officially recorded in February 1952. The following tabulation represents the final requirements as they were established at that time.

<u>Water</u>	<u>Initial</u>	<u>Future</u>
Reactor cooling, g.p.m.	62,100	75,600
Misc. cooling incl. shields	5,000	5,000
Service water	6,000	6,000
Total Bldg. #105 requirements, g.p.m.	69,100	86,600
Total area requirements, g.p.m.	80,000	94,000

<u>Steam</u>	<u>Winter</u>	<u>Summer</u>
20 p.s.i. ga. Process, lb./hr.	12,000	12,000
20 p.s.i. ga. Service	36,850	4,500
	48,850	16,500
175 p.s.i. ga. Process, lb./hr.	5,200	5,200
175 p.s.i. ga. Miscellaneous	1,000	1,000
	6,200	6,200

<u>Electric</u>	<u>Winter</u>	<u>Summer</u>
Main pumps, kw.	16,200	16,200
Miscellaneous and lighting	2,200*	2,200
	18,400	18,400

*Connected load 4850 kw.

In addition, two 1000 kw. quick-starting, diesel-driven a.c. generators were installed in Buildings #108-1 and 2 to supply emergency power in the event of loss of a.c. power external to Building #105. The emergency load to be carried was estimated to be an average of 1390 kw. but with a total connected load of 3550 kw.

INSTRUMENTATION

Before any design work was started on Building #105 it was evident that instrumentation associated with reactor operation would have to be closely grouped to give control from a location preferably overlooking the reactor room. Actual space requirements were indefinite and remained to be worked out with the architectural and process design groups. As the building's design evolved, the instrumentation was largely centered in an instrument room near the base of the reactor at the -40' level and in a control room at the 15' level. Orientation and location of these rooms were flexible and through successive design stages did change considerably, although they remained close to the reactor.

CONTROL ROOM

As soon as observation window locations in the walls of the main process room were determined, the control room was located so that a semi-circular panel board layout with a console in the center faced the reactor room window. At that time the control room was flanked on one side by an auxiliary instrument room and on the other by a record room and an office.

It became increasingly apparent, however, that much more panel space was needed and the auxiliary instrumentation was assigned to a room at the zero level originally intended for the flow and temperature monitoring equipment. Later, as design improvements and simplifications were made, a major portion of this auxiliary instrumentation was eliminated. After a number of intermediate arrangements were studied, a final layout was approved in which the office and record room were consolidated at the center of the control room wall away from the reactor. A glass partition in the office provides a complete view of the control room. The working area within the control room, which has instrument panels lining the four walls, is approximately 26 feet by 86 feet. The console no longer faces the shielding window but, instead, overlooks the trim and monitor panels since it was eventually concluded that the reactor operator would, during operation, in no way rely on the view of the reactor room afforded by the window. Views of the control room as constructed in the R and P Areas are shown on pages 99 and 101.

In the redesign of Building #105 for the L Area in which the sides of the reactor room were kept free of adjoining structures, the main and crane control rooms were combined and placed above the disassembly area. A single observation window is located at an angle which provides a complete view of the reactor room.

INSTRUMENT ROOM

During the early development period when the "Pi-Pile" was receiving design attention, it was planned to bring temperature leads out of the top of the reactor. Also, the measurement of flows in individual fuel tubes was to be made at the inlet to the tube. Since so many instrument leads would be located at the top of the reactor in this scheme, space was allocated at the zero level of the building for the necessary instrumentation. This plan was changed in a later design in which leads were brought out through a seal in the bottom of the reactor and carried approximately 70 feet to an instrument room at the -56 foot

level. When the reactor design was changed finally to include a bottom shield with monitor pins, the space directly under the reactor was converted into a pin room to permit easy access to the monitor pins and associated connections. Scram tanks which had been located near the reactor were moved to a more remote area, and an instrument room could then be located close to the reactor base at the -40 foot level. For the multi-port rotary sampling valve then planned for activity monitoring, a part of the instrument room was enclosed to give the isolation and special ventilation required to offset the danger of possible moderator leakage. When the multi-port valve was eliminated, the enclosed space was used for other instrumentation added to the scope of work very late in the project.

Space originally allotted for flow and temperature measuring equipment at the zero level was, for a short time, retained for transducers. These were eventually placed at the -40 foot level. After auxiliary instrumentation originally planned for this space was eliminated, the motor generators and other electrical equipment necessary for crane operation were installed. This room is directly under the crane control room.

OBSERVATION ROOM

A small space at the -40 foot level under the discharge canal from the reactor room was provided for control and instrumentation for the main pump system. It also included the moderator leak detection equipment.

In addition to the changes in the instrument control and crane control rooms previously noted in the L, K and C designs, the electrical equipment was located in other parts of the building and the centralized equipment room was eliminated. A larger instrument room was designed for these three buildings containing not only duplicates of the equipment installed in the R and P Areas but including also equipment previously installed in the pump observation room. Separate pump observation space was thereby eliminated.

**BUILDING 105-CENTRAL CONTROL ROOM
HYDRAULIC CONTROL PANELS**

**BUILDING 105-CENTRAL CONTROL ROOM
REACTOR CONTROL CONSOLE**

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III - DEVELOPMENT OF BUILDING #105 EQUIPMENT DESIGN

GENERAL

This section discusses the engineering development of the major equipment items designed and fabricated for installation in the various areas of Building #105. In nearly all cases the equipment described is novel or differs substantially from any commercial counterpart. The "Description of Facilities", contained in the latter part of this history, presents a complete list of major standard and special equipment.

For additional details and illustrations on assembly and disassembly area equipment, the control rod actuators, and the charging and discharging machine masts and grippers, reference is made to the "Engineering and Design History" prepared by the American Machine and Foundry Company. The history of the "NYX Program" prepared by du Pont and included as Section X of this volume, and the "Fabrication and Testing History - Prototype and Production Units", prepared by the New York Shipbuilding Corporation as a separate report, give design, fabrication and testing details on the reactors.

It is suggested that the reader refer to the appropriate "Description of Facilities" and "Description of Process" sections of this history to obtain the complete pattern of the various areas in the building.

ASSEMBLY AREA

Facilities were developed for this area to receive, clean, inspect and assemble components as required. The bulk of the special equipment was developed by the American Machine and Foundry Co. as a subcontractor of the Development Engineering Division.

FUEL TUBE ASSEMBLY

The complete fuel tube assembly was pictured originally as a continuous column extending from a locating instrument pin on the bottom plate of the reactor through the tank, the top shield, and the plenum chamber with the whole column supported from the plenum. Since it could be handled as a completely assembled column, this made possible the remote charging and discharging of the reactor. The fuel column could be assembled and disassembled outside the reactor room in appropriate areas of the building. Essential elements of

the continuous assembly were similar in function to those finally adopted, i.e., fuel column, flow distributors, supporting sleeve, shield plug, a latch securing the column in the reactor, and provision for remotely handling the component with the charge-discharge machine.

A major change from this concept resulted from research which indicated that the upper stainless steel elements of the assembly would not, within a reasonable aging period, be reusable because the radiation level would not permit manual assembly. The component therefore was redesigned with a support sleeve and shield plug that was separate from the fuel tube and could be retained in the reactor or reactor room. Although this introduced some additional complications in the programming of the charge-discharge machine, it was preferred to the alternative of remote assembly or to the expense of discarding these elements after each charge.

From this redesign the fuel column evolved into an arrangement of three independent elements, represented on the left on page 111. These consist of first, the semi-permanent sleeve, a cylinder about six feet long, extending through the tubes of the plenum and the top tube sheet. Supported by a ring flange resting on the top of each plenum tube, it serves as the support column for the fuel tube which is inserted in the sleeve and rests on an inside rim at the bottom of the sleeve. Water from the plenum flows into the fuel tube through matching slots in the plenum tube and sleeve with the annulus between the sleeve and the plenum tube sealed by O-rings above and a piston ring below the slots. The second element is the fuel tube quatrefoil with its top adapter, piston orifices and charge machine pickup knob. The third element is the upper shield plug assembly which is latched to engage the sleeve and hold against a plenum pressure of 250 p.s.i. Leakage between the assembly and the sleeve is prevented by O-rings. Included in the shield plug assembly is a filter screen through which all coolant must flow before entering the fuel tube.

Some of these elements presented only conventional design problems; others entailed considerable study and development effort. Among the latter was the sealing of components against moderator loss. Because of the intense radiation present at the lower end of the semi-permanent sleeve, only metal could be used and the components were sealed at that point with piston rings. Small quantities of moderator leak past these rings but this small amount serves to remove heat from the sleeves. The upper seals, on the other hand, were required to be tight against permanent loss of moderator. For this application, O-rings seemed an ideal choice because they permitted easy insertion and removal of components by remote means.

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REACTOR COMPONENTS-SECTIONS

When subjected to tests at NYX, however, the rings first selected allowed small quantities of water to seep past them and a development program was then initiated to study such variables as squeeze, hardness, material composition, the use of one or two rings, surface finish, and tolerances in the dimensions of the molded rubber. As an illustration of the tenuous nature of this problem, and typical of the many difficulties in achieving complete success in a design, none of the test O-rings would leak when subjected to simulated process conditions. For this reason the evaluation was extended on the basis of statistical evidence accumulated from the performance of several hundred rings installed in the NYX reactor.

The solution finally reached appeared to have only relative advantages over others. Two rings were to be used instead of one and a heavier squeeze, a higher degree of dimensional tolerance and surface finish, and a softer ring were specified. Candidate ring materials were limited to those having the insertion characteristics of a designated compound. It appeared likely that with these altered specifications it would be necessary to use a lubricant to reduce insertion forces but no general agreement on this was attained.

Subsequent events further illustrate the problems that can be associated with complex mechanical design. When components with these seals were being placed subsequently in the reactor at the plant, it was found that the insertion force required was beyond the capacity of the charge-discharge machine. As an alternative to lubrication and the attending possibilities of contaminating the moderator, a second program was undertaken to select an O-ring material offering less resistance to insertion. This resulted in a specification for a ring material that could be successfully inserted by the crane.

During operation of the reactor, critical information on coolant flow through the fuel tubes must be constantly relayed through instruments to the control panel. In the flat bottom plate of the early reactor design, prior to the addition of the bottom tube sheet, there was a pattern of fixed locating pins drilled to accommodate a pressure tap and thermocouples for pressure, temperature and activity monitoring. The bottom end fitting of each quatrefoil was to contain metering orifices to develop characteristic pressure signals. When the reactor design was changed to include a bottom tube sheet, this monitoring function evolved without change in principle into a long shielded element mounted through the tubes of the bottom tube sheet to engage, with a sliding fit, the quatrefoil bottom fitting containing the orifices. A mating allowance of one inch was provided at this point for thermal and mechanical movement and slight differences in length of quatrefoil.

FUEL TUBE

As design of the several types of components was undertaken, initial emphasis quite logically was placed on the reactor fuel tube element. Attention was given first to a plain aluminum tube in which the 1-inch slugs would be separated and centered longitudinally by airfoil-shaped, finned spacers. A uniform annulus of 1/8-inch around the slugs was planned as a cooling water channel. Discussions were started with extrusion specialists of the Special Air Corps Facilities at Adrian, Michigan, and resulted in the design and construction of a single tube arrangement, samples of which were subjected to simulated flow conditions at the Engineering Research Laboratory. Fuel tube designs also were studied for nominal 3/4-inch fuel slugs. Before long, however, the 1-inch slugs were selected for initial operation at the plant since these favored the production of plutonium over tritium which, at the time, was the AEC objective.

Without much difficulty, samples of 1-inch and 3/4-inch bevelled spacers were produced by die casting, and sufficient quantities were shipped to Argonne National Laboratory and NYX for special tube assemblies then being tested. Later, development work on the spacers ceased when internally ribbed quatrefoils were adopted for production use.

For the obvious advantages offered in handling, a quatrefoil or integral four-tube design had in the meantime been proposed and Adrian was requested to initiate extrusion work on this design. It is illustrated on page 111, second from the left. The first of these quatrefoils, made of 2S aluminum, was produced in January of 1951, with other extrusions of higher tensile 63S aluminum in February. Since a second source of quatrefoils was highly desirable, it was decided then to start work at the New Kensington, Pa. Plant of the Aluminum Company of America on a parallel basis.

Through this period progress was also being made in the design of other parts of the fuel tube. The top and bottom end fittings for the quatrefoil were designed and fabricated and, in meetings with Alcoa, a method of welding the fittings to the special tube shape was selected that insured strong, leak-proof joints. Preliminary ERL tests had indicated the need for some means of steadying the top slugs in the fuel column to reduce vibration and possible damage to the Q-foil tube. At first, springs were considered to eliminate this vibration and also to allow for a thermal growth of approximately 1-1/4 inches in the slug column. When requirements for this thermal growth were increased, in May of 1951, to from four to six inches, the concept of piston orifices was evolved.

After repeated extrusion efforts, enough experience had been accumulated at both the Adrian and Alcoa plants to demonstrate that the one-inch plain quatrefoil could be produced by extrusion to nominal dimensions and then sizing in a final draw operation. It was on this basis that a production order was placed on Alcoa for the foils necessary for the NYX test.

The early efforts to load plain tubes with slugs and spacers made it apparent that the spacers would introduce complications in the loading operation and the hazard of channel wall damage. This, however, was not entirely unexpected and earlier proposals had suggested the use of a Q-foil having ribs integral with the inside diameter of the channel. Extrusion difficulties anticipated in the production of such tubes made it advisable to try the plain foils first and utilize these for the NYX tests. Active investigation of this alternative was initiated and the first extrusion die for a concentric 1-inch ribbed Q-foil was completed in July, 1951, for the Adrian facilities. Since that plant was then closed by a strike, the die was modified to fit an extrusion press available at the Reynolds Plant at Grand Rapids. Extrusion efforts proceeded also at Alcoa and later at Adrian.

Through August of 1951 the procurement of Q-foil extrusions continued to be very critical as it was to remain in certain measure until mid-1954. At Adrian and Reynolds attempts had been made to extrude the tube without subsequent sizing operations. This proved unsatisfactory and Reynolds revised its method and tried extruding to slightly less than the correct size with slight expansion of the tubes following. The first length of ribbed quatrefoil produced by this means was not within dimensional tolerances but the results did offer some encouragement. Unfortunately, operating management changes during this period plagued the Air Corps facilities at Adrian where extrusion efforts were centered. The plant's control passed successively from Reynolds to Mack Industries and finally to the Bohn Aluminum Company. Inevitably the development program at that location was confused. New dies were eventually completed there for the ribbed Q-foil extrusion and the promise of success was enough by the end of November to result in an agreement that the reactor in the #100-R Area would be loaded with 1-inch ribbed foils. Because there seemed to be sufficient unknowns in this type of assembly, on the other hand, the cost of providing a full complement of plain Q-foils as a standby appeared justified.

In the intervening months Alcoa had been working on its

purchase order for plain Q-foils but, by the first of November, had completed only about 100 such extrusions in pre-pilot lots that were satisfactory from a dimensional and finish standpoint. These had been produced by individual hand maneuvering. During November 1951, Alcoa did achieve production runs of the plain foils and the extrusions required for the NYX test were completed.

As a further contribution to improved cooling within the reactor, it was suggested at about this time that the slugs should be placed slightly off center in the tube. The validity of the proposal was such that development of the 1-inch eccentric ribbed Q-foil was expedited by diverting a 1-inch plain Q-foil die that had been initially fabricated by Alcoa on its production order. This development program, in December 1951, was given priority over all other commitments. An initial push of these foils was made by Alcoa in January 1952, but the results were unfavorable and the die had to be modified. Additional efforts with the revised dies and new draw tools in February and March failed to produce full length pieces meeting specified tolerances.

Up to this point all foils of the new design had a rectangular rib section which it was believed would provide a minimum aluminum cross section and maximum annular flow area. Tolerances on the rib circle were specified as plus or minus .0025-inch at the top of the rib which is the point of highest wear in the extrusion die. As wear increased in the die it became necessary in the drawing operation to remove more and more of the rib tips and the result generally was a rough, dimensionally irregular surface. By March, Alcoa was satisfied that the rectangular ribs could not be drawn to the specified rib circle and initiated the development of tools for shaving or broaching the ribs to size. Through 1952, and until the end of 1953, only sporadic success attended the development of this inherently high-cost, low-yield operation.

Q-foil procurement remained on an uncertain basis until the middle of 1953, when Alcoa was directed to develop a Q-foil with a trapezoidal rib section on which tolerances in the rib circle were relaxed to plus or minus .004-inch. This tolerance Alcoa felt could be reasonably achieved by extrusion and drawing to size without a final broaching operation. This course was successful and production swung over to the new process early in 1954.

CONTROL CLUSTERS

The original conception of reactor control included the use of both horizontal and vertical rods somewhat similar to the Hanford pattern. Considerations leading to the adoption of vertical control rods to be inserted through the top plenum and tube sheet have been described elsewhere in this history.

Arranged through the central zones of the R Area reactor are 61 control cluster positions laid out in the center of a hexagon formed by the fuel rod positions. Each of these clusters contains seven rods of three different types all of which are housed within a septifoil and subject to position adjustment by the control rod actuator system. Two of the seven rods are half-length lithium-aluminum producer rods employed to control the neutron flux in the axial direction. The other five rods are full length rods and are the primary controllers of reactor activity. Two made of cadmium are, under normal operating conditions, fully withdrawn and three, made of a lithium-aluminum alloy, may be held within the reactor during the operation cycle. The use of five rods instead of a single rod of five times the strength was selected because of the reduced disturbance of axial flux distribution caused by rod adjustments.

Design and fabrication of the control rod cluster assemblies presented problems similar to those associated with the fuel tube development, the manufacture of the thin-walled septifoil extrusions causing the greatest concern. Development of the extrusion, (page 111, fourth from left), was initiated with that of the quatrefoil under the direction of the Development Engineering Division. Efforts at Adrian, Michigan, were directed toward producing a one-piece, seven cavity section, and those at Alcoa toward a two-piece section composed of a single cavity ribbed core over which could be drawn a cylindrical sheath. Production quantities were all accomplished by Alcoa using the two-piece design.

Other elements in the control rods required proportionately less design effort. The lithium-aluminum rods, nominally 1-inch in diameter, are supplied by the #300 Area with the #100 Area furnishing only the rod extensions to the actuator latches. The cadmium rods, which are a cadmium plated core within a stainless steel sheath, were fabricated by the Wilmington Shops. These are identical to the safety rods except for the rod extension. Some thought was given to a cadmium foil wrapped core for these rods but the plated core was a preferred design.

SAFETY RODS, THIMBLES, 35W5 RODS AND BLANKET CLUSTERS

Arranged within the hexagonal pattern of 673 primary lattice positions are 165 positions for small components, (page 111). These include 66 safety rods, 39 instrument rods, and 60 35W5 rods. There is also a pattern of blanket clusters, (page 111, third from left), essentially secondary producer components, which can be substituted for the quatrefoil fuel components in the outer ring of the reactor lattice. The small components, nominally 1-inch in diameter, are guided into place in the reactor tank by long perforated sleeves known as thimbles.

The safety rods are cadmium plated rods with an active length and design identical to the solid control rods. Safety rod extensions to the actuator latches are fitted with a lead collar to cushion the plenum against the impact of a rod in free fall.

Safety rod thimbles were originally planned as solid tubular sleeves constructed of aluminum with an O-ring to seal against tank pressure. The thimbles, it was found, were very susceptible to leaks as a result of pinhole corrosion. In tests at NYX it was demonstrated that when flooded from a pinhole leak, the thimble would snub the fall of a safety rod beyond tolerable limits. To allow the escape of water, the thimble design was changed to include perforations but this in turn reduced the maximum working pressure of the circulating gas blanket to the depth of the liquid seal provided by the plenum and gas chamber. Two solutions were studied. Prototype solid thimbles of corrosion resistant zirconium were successfully fabricated by the Bridgeport Brass Company. A hollow safety rod was designed by the Development Engineering Division which because of its reduced cross-section is not as readily snubbed as it falls free into a flooded solid thimble. Only extensive operating experience can determine the merits of these alternatives.

The 35W5 rods are bismuth producer rods of a design similar to the control rods but with rod extensions designed for gripper pick-up by the precision cranes. They are inserted in thimbles perforated for water circulation and free conduction of heat. Each rod is sealed in its thimble by an O-ring and the thimble is sealed in its plenum tube by a second ring. When these producer rods are not to be used during reactor operation, the openings in the plenum are sealed with solid plugs.

Two types of instrument rods, inserted in thimbles, are used in the reactor, one to measure neutron flux and the other tank water temperature. After installation of the rods, connections with the recorders are made manually at the top of the rod. At the time of discharge these are clipped by hand and the rods are pulled out by the precision crane.

Blanket clusters are a hybrid containing elements of both the quatrefoil and septifoil designs. They house seven rods within a septifoil extrusion, are fitted with a quatrefoil type bottom end to mate with a monitor pin and have a septifoil top fitting. The rods have the same design as the control rods but do not have the rod extension and are fitted for gripper pick-up at about the same elevation as a quatrefoil. For down-flow cooling the semi-permanent sleeve, plug and spiral shield are the same for the blanket clusters as for the quatrefoil. An orifice plate is mounted directly beneath the screen and between the upper plug and the spiral shield to restrict the flow to specified values.

SHIPPING CONTAINERS

In view of the value of the aluminum extrusions and the need for straightness and absence of imperfections, it became necessary to develop special shipping containers for use between the vendor's plant and the Savannah River Plant and also for use between areas within the plant. Several suggested designs were considered, from strong metal containers for single extrusion shipments to larger, light weight containers for a number of extrusions.

To resolve the problem, a purchase order was issued to the du Pont Wilmington Shops for the construction of experimental containers. After an acceptable prototype had been constructed, a commercial fabricator was given a purchase order for the 24 containers required.

The adopted design, which accomodates either quatre-foils or septifoils, is approximately 38 inches by 34 inches by 16 feet 6 inches long. It is steel-framed, constructed of marine or exterior 3/8-inch plywood, with removable end panels and a sliding top. The 56 tubes are nested in sponge rubber-lined sections and are held in place by hinged top plates secured by thumbscrews and barrel bolts.

Two different designs are used for the shipment of control rods and loaded quatrefoils between plant areas. The control rod box, with a capacity of 18, is a structural steel form with a steel plate cover, a hinged plate at one end and plastic spacers fitted to secure the rods in the box, whereas the quatrefoil box, designed for only one tube, consists of two bent steel shapes bolted together. Both are equipment pieces charged to Building #305-M.

STORAGE

When plans were abandoned for the rack storage fixtures, a very simple and flexible storage method was adopted. All tube and rod containers are placed directly on the floor in the large storage area adjacent to receiving. A locked room is provided for the slugs. Small parts storage is either in boxes on the floor or in standard storage fixtures.

INSPECTION FACILITIES

Before the aluminum extrusions are released from the vendor's shops a complete inspection has assured a product that meets specifications. This inspection includes a chemical analysis of the heat producing the billets for the extrusion, a four-point check on wall thicknesses, a plug inspection of inside diameters, "go-no-go" check on tube ends, a visual inspection for roughness, scratches and other surface imperfec-

tions, and tests for straightness, twist and tube length. Hydrostatic tests also are performed. As a result it is necessary in the assembly area to inspect the extrusions only for damage that might have occurred during shipment. This includes a visual inspection of the tube and checks with "go-no-go" gages on tube diameters.

Similarly, the small parts have been carefully inspected before shipment to Building #105 and therefore require only visual inspection and tolerance checks. The inspection gages for the tubes and small parts were designed specially but involved no major problems. Inspection benches are of standard design.

CLEANING

Throughout all operations in the assembly area cleanliness is stressed constantly. Specifications for the cleaning procedures were based on a desired end result in the reactor of a maximum D₂O conductivity of 1 micromho. This in turn corresponded to .5 p.p.m. of solids calculated as NaCl. With a total pile moderator system containing approximately 44,000 gallons, this meant a total permissible ionic impurity of 100 grams. If all 673 loaded quatrefoils were charged at one time the total permissible contamination for each quatrefoil would be 0.13 grams as NaCl. Contamination by dust or organic dirt and greases would be limited per tube to approximately 0.1 gram.

To achieve this cleanliness the materials received by the area are carefully cleaned by the vendor or the on-plant producer, shipped in special containers and in covered vehicles. If not degreased before arrival at the area, they are vapor degreased prior to assembly. Care is taken to remove any adhering chemical.

No development work was necessary on degreasing equipment, but a study was made of various methods of cleaning to determine which would be most satisfactory. These included: degreasing alone, degreasing followed by an alkali rinse and drying; degreasing followed by an alkali rinse, an acid rinse and drying; degreasing followed by an acid rinse and drying; an alkali rinse, acid rinse and drying. An immersion vapor degreasing cycle was selected.

The degreaser is a liquid, liquid-vapor tank with a rated production load of 3000 pounds of aluminum parts per hour. All parts to be cleaned are placed in a basket which is lowered into the "boiling" liquid tank for one minute or until the parts have reached the temperature of the trichloroethylene solvent. The basket is transferred to a second tank, immersed, and then raised to the vapor section for

final rinse by the condensation of vapors on the parts. The degreaser has an over-all length of 27 feet, a width of 6 feet, and a height of 9 feet. A solvent recovery still is beside it on the first floor and two solvent storage tanks, a solvent pump, and a still pump are located in a pit beneath the degreaser.

PORTABLE TUBE RACK

After cleaning, the extrusions are placed in this rack for transport to the loading station. Composed of five "A" frames, the rack is of all-welded aluminum construction and is mounted on rubber tired castors. It is designed to carry ten quatrefoils or septifoils which rest on sockets arranged in pyramid form, five on each side of the rack. The sockets are surfaced with neoprene to prevent scratching the aluminum surfaces.

This rack replaced an earlier design of a vertical model intended to transport 30 tubes. It was felt that a horizontal transporting method would more easily give the stable support required.

Q-TUBE LOADING MACHINE

The initial approach to loading a quatrefoil was to assemble a column of the slugs and parts in a horizontal trough and then push the column into one of the four tubes of the foil. At that time the quatrefoil was a smooth bore design and finned spacers were used between the slugs. Actual experience with this method uncovered serious disadvantages. It was found that the finned spacers badly gouged the tubes because of the combination of thrust pressure and the weight of the materials being inserted. This situation could not be tolerated due to the fact that the wall thicknesses of the tubes had been carefully calculated to effect maximum heat transfer and to withstand the maximum erosion effects resulting from the high velocity of the cooling water passing through. Faced with these problems, designers turned their attention to vertical loading and found it to be a more satisfactory method.

One of the vertical machines tried out on a jury rig basis was a hydraulic loading machine. In this equipment, with flow upward in all channels, it was necessary to load fuel slugs simultaneously in all four tubes to prevent hydraulic imbalance which permitted one slug to drop too fast. The experiment was not very successful and the concept was dropped. The main difficulties were "dancing" of the slugs and a resulting tendency to "hang up" plus an adverse time loading factor.

The dry-type machine that was eventually accepted,

prototyped, tested at NYX, and installed with improvements consisted of a three-cable arrangement supporting the fuel column as it was lowered into the tube. The cables were wound around a drum and restrained from moving downward by a worm gear box which had a weighted lever attached to the worm gear shaft. Action of the lever gradually increased as the load increased on the cables. When a column was loaded an adapter at the bottom end of the cables was pulled down, the cables disengaged and retracted through the annuli of the tube.

Three machines were completed first as manually-operated machines. Later five machines were manufactured with motor drives, the parts necessary to adapt the three earlier models being sent to the field for assembly.

After this mechanical loading machine was installed in the R Area and assembly of the initial reactor charge had begun, difficulties were experienced with the cables and drums. The AED Works Technical Section therefore initiated a study in June, 1953, on a simplified hydraulic loading method. A prototype was fabricated and installed in the R Area which, with refinements resulting from operating experience, became the model for hydraulic units installed in other assembly areas.

This machine is designed to load a single tube of the quatrefoil at a time. Mounted in the floor, it consists of a revolving head and overflow basin at the top and a metal connecting tube with a fitting at the lower end in which a foil guide is located. This is essentially a metal cup on which the bottom end fitting of the foil rests. Water is introduced through the center of the foil guide, is pumped up through the foil, overflows into the collecting basin, drains to a storage tank and is recycled. A 25 g.p.m. gear pump provides the hydraulic pressure.

The indexed revolving head carries three tapered plugs which seat over three tubes of the foil leaving only one open for loading. Pieces are introduced manually to the tube and restrained in their fall by the upward flow of water.

Q-TUBE FINAL TEST FIXTURE

Pre-assembly mechanical inspection of components was provided to eliminate dimensionally substandard elements. To evaluate both the fit and hydraulic performance of the completed fuel tube assembly a functional test also has to be made. As originally conceived, in May 1951, the hydraulic test was to combine a relatively stringent leakage test and a flow test having wide rejection limits. As the design of the fuel element crystallized, the test fixture design

evolved into a device which, in sequence and semi-automatically, would perform a leak test and flow test, and wash and dry the tube and record the results of the flow test. The latter combined three measurements in one operation: measurement of total flow resistance; measurement of balance of flow between individual channels; and calibration of the orifice holes in the end fitting. By this design the desired functions were performed with a minimum operating time and floor space.

In this tester the Q-tube was lowered vertically into the center of two small plenum chambers. These chambers, one at the top and one at the bottom of the tube, sealed to the foil by inflatable rubber gaskets around the tube, leaving the center portion clear for inspection for leaks. The pressure at the top and bottom chambers was controlled to simulate reactor conditions.

A prototype of the test fixture, utilizing somewhat simplified instrumentation, was installed at NYX and used during 1952 to test the Q-tubes installed in the test reactor. It became apparent from NYX experience that a combination fixture of this type could not give the precise test measurements ultimately required when the plant reactors were operated at high power levels. However, since the reactors were to operate initially at lower levels and there was a strong possibility that fuel types would be changed, it was agreed early in 1952 that one of the combination fixtures with minor improvements would be installed in each assembly area.

After some operating experience had been obtained with the fixture, more accurate units in which the test functions were separated were installed early in 1954. One unit tests the uniformity of flows in single channels and the other checks total flow and the pressure drop through the bottom fitting. The original test station was retained for its drying function only.

The single channel flow tester is designed to measure the flow resistance of a single loaded channel prior to adding the top adapter and the piston orifices. The Q-foil is supported beneath the top fitting on a seal ring plate. Three channels are plugged and a cover chamber bolted down against the seal plate. Measurement is made of the single channel flow and the pressure in the head chamber. The water flow passes through the foil into a bottom pan from which it drains to the circulating water return tank.

The total flow tester is a vertical tank of 10-inch diameter pipe in which the Q-foil is submerged. The top pressure head simulates a semi-permanent sleeve, supporting the Q-foil fitted with an O-ring in the adapter piston ring groove to

seal the flow from by-passing the channels. The bottom of the tank is fitted with a monitor pin nose. Measurement is made of the total flow, the pressure above the piston orifices, and the bottom fitting pressure drop at the monitor pin.

A third hydraulic test station installed in the R Area only is designed to calibrate monitor pins of the metering pin design as adopted for the K and C Areas. In design it resembles the total flow station turned upside-down to facilitate the insertion of monitor pins from the operating floor. A test length of Q-foil is fitted through the bottom flange of the tank in inverted arrangement. The monitor pin is inserted in the Q-foil bottom end fitting and as water flows up through the foil a measurement is made of flow and monitor pin differential pressure.

Q-TUBE ASSEMBLY LAG RACK

The lag rack temporarily holds the assembled quatrefoils until they can be tested and placed on storage hangers. A structural steel frame with a stainless steel support plate and stainless steel head guide, the rack projects over an opening in the floor.

TIPPING TABLE

Originally intended to raise rather fragile elements from a horizontal to a vertical position, the tipping table evolved into an equipment piece capable of raising boxed full, solid, half and 35W5 rods to a vertical position. It is used also to raise or lower loaded fuel tubes scheduled for shipment to Building #305 or received from that building and those tubes found in testing to be defective.

A long narrow steel table supported on trunnions centered in bearings on a base frame, it projects for half its length over an opening in the floor. When tipped to the vertical this end drops into the floor slot. Power is supplied by a one horsepower motor through a 1575 to 1 gear reducer.

Control rod boxes containing 18 rods are placed on the table, the cover and ends are removed from the boxes, the rods are pulled out approximately six inches and the rod extensions are attached. When one layer of the rods has been fitted with the extensions, a multiple gripper is attached and a spacing clip placed on the lower end of the rods. The table is tipped to the vertical and a hoist lifts the rods from the box and transports them to the revolving rack.

REVOLVING RACK

This rack provides interim storage for components removed from shipping containers and awaiting sequence selection for delivery to final storage. Approximately 23 feet high, mounted at the -20 foot level, and projecting above the main floor, it is a cylindrical frame with 12-sided top and bottom plates. Each side contains four or five component sockets to give a total of 54 for the rack. The rack can be rotated manually with an indexing arm positioning any selected side. Rods are placed on the rack by the multiple gripper operated from a monorail hoist. For removal a storage hanger, lowered by an elevator, is attached to a rod and the unit is moved into final storage.

Development of the rack passed through several stages. Square, rectangular and circular stationary and portable racks were considered as well as rotating but stationary racks at various building elevations. To eliminate the need for stairs and platforms the rack was mounted at the -20 foot level. For a time a combination revolving rack and wash station with a swivel jib crane on top of the rack was considered as an alternative design. This was abandoned although space was provided for the addition of a wash spray and drying booth should this prove necessary. The adopted design offers the maximum in storage capacity, compactness and freedom in selecting charge components.

FUNCTIONAL GAGES

Because of the difficulties experienced in inserting assembled components in the NYX test reactor, functional gages were provided to eliminate any similar difficulty in loading reactors at the plant.

Gage No. 1. simulates a permanent sleeve of the plenum chamber and top tube sheet of the reactor and is located in the floor slot near the tipping table. This is used to check the fit of the semi-permanent sleeves, plugs, spiral shields and muffs.

Gage No. 2 simulates the bottom part of the semi-permanent sleeves of the quatrefoils with the monitor pin at the bottom of the tank and includes a ring in the center. One gage is installed between the loading machine and the quatrefoil lag rack in each of the loading lines. This gage checks the straightness and length of loaded quatrefoils and blanket septifoils.

Gage No. 3 consists of a top section, which simulates the large permanent sleeve in the process tank, and a two-piece bottom section, which can be used to simulate the cup

in the process tank which holds the lower end of the small component thimbles or as a holding device for the lower end of the septifoil. It is located in the floor opening near the revolving rack. Into this gage can be slipped the components necessary to check the fit of control rods, safety rods, 35W5 rods and thimbles.

Gage No. 4 consists of three sections. The top section simulates the bottom part of the semi-permanent sleeves used for control septifoils. The bottom section simulates the up-flow cooling pin and the center section is a ring located midway between the top and bottom sections. It is installed adjacent to Gage No. 1 in the floor slot near the tipping table and is used to check the straightness of the septifoil to be used for control rod clusters, the fit between the muff and septifoil, and the ease with which control rods can be inserted in the assembly.

MONORAIL SYSTEM AND STORAGE HANGERS

When assembly and testing are completed, the reactor components are placed on hangers and moved into final storage to await reactor charging.

Since the charging crane mast grippers can only move in the "Z" direction (i.e. up and down), the components to be loaded into the reactor must be presented so that they can be lifted off their hangers with a vertical lift of a few inches. It was therefore necessary to present the component outboard of the trolley from which it is suspended so the gripper chuck could "come down" on the pickup knob of the component without fouling the trolley. The hanger is a T section approximately 22 feet long supported from a three-wheel trolley. Two carrier wheels ride on top of the American monorail track while the third or rear wheel rides on the under side. The center wheel is hinged on a four-inch radius to permit pushing a hanger around curves in the track layout. On the front of the T section are two brackets which hold and support the element being stored outboard of the trolley, and these can be changed to accommodate different components. The weight reaction of the load and hanger is taken by a down thrust on the front wheel and an upward thrust of the rear wheel. The middle wheel serves as a safety feature to retain the hanger on the track in case of wheel malfunction.

Considerable difficulty was experienced in developing these hangers. At first a cam follower rolling on the under side of the track was used, but tests at NYX indicated that the cam developed too much pressure against the track when the hanger was being pushed backwards. For this reason the cam was replaced by a third wheel and the swiveling action was added to the trolley.

As the system was designed and installed originally, the hangers were to be pushed manually forward and backward. After some use, however, it was found that the hangers were sensitive to track misalignment and would "hang up" at sharp curves. It appeared that successful and safe movement of the hangers would result from a strengthening of all track and supports and the use of a motive power nearer the rail level. Consequently all heavily traveled rail was replaced with stronger girder type rail; a turntable was installed to replace three switches; small radius curves were replaced with large radius curves; and the track supporting structure was strengthened to accomodate compression and bending as well as tension loadings. In addition, the system was equipped with electric monotractors which are mounted on the track and can both push and pull the hangers. Each is essentially a motor-driven rubber tire pressing on the underside of the rail with enough force to prevent slippage. Control is by a pendant cord at floor level.

As a further improvement, the final storage area crane was motorized and provided with a captive mule to handle all backward movements of the hangers.

As the system is now normally used, all movements of the hangers in the assembly area are by monotractors while in the storage area only backward movements are by monotractors. All forward movements in the storage area are still accomplished manually by pushing on the bottom of the hanger.

Operation of the hoists in the assembly area revealed two deficiencies: one, that the hoist unit should be self-propelled instead of manually pulled to permit safer and easier handling; two, that the hoist should be equipped with a constant hook center to permit easier centering of the hoists and to help prevent scratching of elements when inserted in assembly equipment and gages. Four new hoists were purchased incorporating these features and the remaining hoists were reworked to the new hoist design.

The final storage portion in the R Area was designed to handle 1095 hangers involving about 2000 feet of monorail track with a manually operated monorail transfer crane operating down the center of the room. In response to requests from AED, the P Area was designed for 879 hangers on 1800 feet of track, and the L, K and C Areas for 951 hangers on 1600 feet of track.

GRIPPER PICK-UP STATION

Facilities were required to transfer the loaded hangers into the reactor room, to a point where the charging crane could pick them up, and return the empty hanger. The reactor

room is uninhabitable during the combined charging and discharging operation, hence hangers must be moved in and out of the room by mechanical means. The reactor room entry consists of a narrow slot in the wall backed up outside the room by a concrete radiation barricade about 8 feet back from the slot. This barricade was a factor in the equipment design.

The selected design was an electric motor-driven chain conveyor in which a cam actuated mechanical arm engaged the loaded hanger, moved it through the slot to a point where the component could be picked up by the charging crane. Empty hangers were conveyed in the same way but diverted to another rail, spray washed and then pushed into final storage. This design replaced more elaborate equipment considered, including five station presentation tracks and five station pivoting tracks. These would have been much more expensive and would have increased the quantity of equipment required in the reactor room.

Difficulties in the R, P, and L Areas with this design led to the replacement in all areas of the monorail and chain conveyor by an articulated motorized unit operating on a monorail track. The hangers are transferred manually from the incoming track by a swing bridge switch into the fork of the pusher unit. Each hanger is then pushed into the reactor room to a new precision holding fixture at the pick-up point for component removal by the charging crane. On return the empty hangers are indexed at the swing bridge to the outgoing track. The conveyor machinery in this scheme is always outside the barricade for servicing, also the power unit can be detached for full manual operation, if desired.

PROCESS AREA

Facilities were designed for this section of the building to produce irradiated materials in heavy water moderated, heavy water cooled reactors using uranium as a fuel. Supporting facilities were required to circulate the heavy water, remove nuclear heat from the coolant, control the reactor, charge and discharge the reactor and monitor the reactor.

Because these supporting facilities have many ramifications they are discussed in this history as systems rather than as individual pieces of equipment.

REACTOR

The Savannah River Plant production units are heterogeneous thermal reactors in which aluminum encased fuel is arranged vertically on a 7-inch triangular spacing in a cylindrical tank. Heavy water moderates and cools the reactors which operate normally on natural uranium. Flexibility in design, however, permits the use of other fuels and the production of several types of fissionable or fusionable materials. In contrast, the Hanford units are graphite piles in which the canned slugs, cooled by light water, are positioned horizontally.

Analyses of reactor design began on the basis of the following proposals. The top shield could be divided into six sectors by a supporting spider and could serve as a jig for the insertion and removal of large numbers of fuel elements in a single operation. Below each leg of the spider, and extending to the bottom of the reactor there would be a gap in the lattice into which control rods could be inserted horizontally. As many as thirty such rods could be placed in a hexagonal array with six rods on each of five levels.

The tank could be made circular, hexagonal or octagonal, but a circular tank might best accommodate a symmetrical hexagonal lattice. Each 60-degree sector of the top shield would be further subdivided radially into two or three zones. In normal operation each shield section carrying fuel producer elements would be inserted and removed as a unit. Reactor materials would probably be limited to stainless steel for long-term corrosion resistance.

The first design studies on the reactor incorporated these major features and served as a basis for numerous discussions of technical problems and design improvements.

Before much progress could be achieved, however, an important decision had to be made on the direction of coolant flow. The Argonne National Laboratory of the AEC had done much exploratory work on the design of a heavy water moderated, heavy water cooled reactor using natural uranium, and had prepared theoretical data largely responsible for the selection of the type of reactor to be constructed for the Savannah River Plant. In the Argonne scheme the heavy water was pumped up through channels around the fuel columns to remove heat generated by reaction. This was joined with moderator in the tank, circulated through heat exchangers and returned to the fuel columns as coolant. It became evident, however, that a downflow system offered distinct improvements. In October 1950, the adoption of a downflow system was agreed upon, eliminating the following disadvantages of an upflow system.

1. Heavy water coolant coming out near the top of the fuel tube and mixing with the moderator in the tank would flow downward with such velocity that it would seriously interfere with the removal of gases resulting from dissociated moderator.

2. Any serious deformation of guides at the top of the plenum chamber, which would be located at the bottom of the reactor, would result in a major shutdown.

3. Any components or material falling out of a tube into the plenum would be extremely difficult to remove.

4. The aluminum fuel tubes would be weak at the point where coolant was ejected through radial slots.

Through October and November, alternate design ideas were explored and, by December, 1950, study drawings containing the major features agreed upon were prepared. The reactor had a 17-foot O.D. and was 17 feet high between the underside of the top shield and the flat bottom of the tank. The distance between the top poison plate and the instrument plate or false bottom was approximately 14 feet 9 inches. This accommodated a uranium column 14 feet long.

The separate plenum contained six sections but the top shield was designed as one piece. Projecting from the bottom of each plenum section and welded to it were the "gun barrels" in which the fuel tubes were to be suspended in the tank. Each plenum section, carrying from 50 to 100 fuel tubes, would be positioned or removed by a crane. The plenum supported hydraulic drives for clusters of "striped" control rods and arranged around the periphery of the tank were nozzles for 30 side rods at six radial points and at five elevations.

Inclusion of a false bottom in the reactor was intended only to support the instrumentation required at the outlet of each fuel tube. Precisely located on the plate under each plenum and top shield hole were stainless steel "noses" which positioned the lower end of the fuel tube and supported four thermocouples and one sample tube. The thermocouples measured effluent cooling water temperatures. The sample tube detected any mobile fission products indicating a ruptured slug. Flow in each fuel tube was determined by a pressure connection at the top of the tube.

Supported below the false bottom were thermocouples and sample tubing. Much of the 6-inch space between the false and true tank bottoms would be occupied by instrumentation leads.

In the second major design decision the sector plenum

concept was abandoned in favor of a one-piece fixed plenum with provisions for individual fuel tube charging and discharging. Difficulties anticipated in handling the plenum sections had chiefly led to this decision.

Several variations of the one-piece plenum were investigated. Some thought was given to a combined plenum and top shield but it was felt that satisfactory fabrication of such a complex assembly would be difficult. Placement of the top shield above the plenum was studied also but discarded because of the difficulties it would present in charging and discharging operations.

Through the first three months of 1951 alternative designs for many parts of the reactor were studied. Continuing efforts to develop a satisfactory method of conducting instrument leads from the bottom of the tank to the zero floor level developed obvious shortcomings in the system. Maintenance of the thermocouples and instrument leads was practically impossible without unloading the reactor, removing the bottom and completely replacing it with a false bottom previously fitted with all instrument leads. The removal of the large radioactive bottom plate also posed a major problem.

This led directly to the third major decision. The false bottom was discarded and a bottom shield similar to the top shield was adopted in which unit instrumentation for fuel tubes would be designed for easy maintenance.

The fourth important decision, the use of liquid cooled top and bottom shields, followed.

Of the many materials that can be used for nuclear shielding a particularly efficient combination is alternate layers of hydrogenous material and iron. Dense forms of these offer decided advantages from the viewpoint of space occupied and the cost of materials. Iron can, of course, be handled readily as can hydrogen in the form of water or masonite. In some applications, as at Hanford, masonite can be laminated effectively with steel. Selection of either masonite or water for the top and bottom shields at SRP carried some disadvantages. If masonite were used, all fluid leakage into the shield would have to be prevented to eliminate the likelihood of masonite swelling to the point of rupturing the shields. If water were used, the shield would have to be tight enough to prevent contamination of the heavy water in the reactor by light water from the shield. A combination shield of iron and water was considered the more desirable and offered the alternative of using heavy water in the shield should contamination become a problem.

To achieve the necessary combination of 50 per cent steel and 50 per cent water, the shields were designed as large-

diameter cylinders perforated by a number of tubes welded to both faces and parallel to the cylinder axis. All spaces between the tubes in the cylinder were filled with 1/4-inch diameter by 1/4-inch long stainless steel Raschig rings. During reactor operation the voids in and around the hollow rings are filled by circulating deionized light water which is heated by the absorption of neutrons and gamma rays and is then cooled in heat exchangers through which river water circulates.

As reactor design progressed serious concern developed over the fabrication of the complex shield and plenum weldments. To secure a reliable and experienced fabricator's opinions, du Pont approached the Combustion Engineering Company which had assisted in similar problems at Hanford. In March 1951, the design problems involved in reactor fabrication were explained to Combustion personnel and later two men from that company spent several days studying design details with du Pont engineers. Combustion reported that the design appeared practical and suggested the use of a mock-up to determine the extent of distortion in the final tube pattern from that theoretically established. Hydrostatic testing of the plenum and tube sheet at one and one-half times the design pressure was considered practical. Use of solid stainless steel in the weldments rather than clad materials was recommended to insure sound joints. Suggestions also were submitted on X-raying, plenum support, stress relieving and hole boring after final assembly.

In response to CE offers to review fabricating drawings, these were forwarded in March and comments received in mid-April. Although the reply was concerned with design details, it reiterated the value of a mock-up in checking tube sheet shrinkage.

The benefits to be derived from a comprehensive mock-up program became increasingly apparent. Its purpose would be to establish reactor fabrication methods, demonstrate the feasibility of fabrication, determine the dimensional tolerances obtainable in fabrication and confirm both the hydraulic and mechanical performances of the reactor and related equipment. AEC concurred in the need, and the test work became known as the NYX program. The reader is referred both to DPXN-200 for a summary of the test results of this program, and to the reports covering 37 related subjects. Titles of these reports appear in the Appendix to this volume as Exhibit M.

A preceding section of this history, devoted to "Process Basic Data", reviews the lattice variables considered and the number of fuel tubes required for optimum operation. The selection of a tube pattern was influenced by physics calculations, the instrumentation arrangement and the requirements

for irradiating the 35W5 rods. In the study drawing issued in January 1951, there were 576 large tubes on the 7-inch triangular spacing, but this was shortly increased to 606. Still later the number was increased to 673 when it developed that the material to be irradiated in the blanket tubes had to be cooled. For uniformity, flexibility, and ease of fabrication these holes were then increased to the diameter of the large fuel holes.

Several changes in the number of reactor openings took place later. When the use of horizontal rods was discarded, 55 fuel tube positions were assigned as control rod positions. These are located in a hexagonal pattern over the core of the reactor. This number was increased to 61 in July of 1951. Still later six large holes in the top shield were set aside to permit the release of gases produced by the dissociation of moderator, into the helium gas space between the plenum and top shield. Had this not been done, all gas bubbles would have had to rise through the annuli between the semi-permanent sleeves and the top shield tubes. Also required were 165 small holes interspersed on a regular pattern among the large holes to accommodate safety rods, instrument rods and 35W5 rods.

In April 1951, the New York Shipbuilding Corporation at Camden, New Jersey, was selected as the fabricator of the five reactors for the plant and as the site for the mock-up and test program. A history of the "NYX Program" gives information of interest on many phases of this work and is included as Section X of this volume.

With the fabricator selected, a series of design and procurement meetings was immediately scheduled to acquaint the NYS personnel with reactor design. Permitting full discussion of possible fabrication techniques, details of design, procurement, specifications on stainless steel and tubes as well as many other design and fabrication problems, these meetings proved invaluable. Since many details of the reactor design were still incomplete, it was possible to include NYS recommendations for over-all improvement in design quality, ease and speed of fabrication, and the effective use of existing machine tools and the skills of NYS craftsmen.

During April and early May of 1951, many discussions were held on the development of a building design, control rod designs, and a piping layout that would minimize the D₂O holdup. Physical interferences offered by the horizontal control rods prevented the development of many desirable building arrangements and led to the adoption of vertical control rods. This became an approved design feature, the fifth major step in reactor development. It not only simplified design of the lower part of the building but also served better the physics requirements of the reactor since the rods were then parallel to the fuel elements.

The sixth and last major step affecting the first production reactor was the decision to use up-flow cooling in the septifoils. Heavy water leaving the top of the septifoils could then blend with the moderator in the tank, flow down through spaces in the poison plate around the tubes and prevent overheating of the moderator. The fact that approximately 5 per cent of the heat released in the reactor is generated in the moderator had been recognized in a previous design by including side nozzles in the main influent lines. These directed a small heavy water stream to the space between the top shield and the poison plate. Achieving the same result with septifoil upflow cooling was a much preferred design.

The development of hundreds of design details involving tolerances, welds, metal thicknesses and miscellaneous fabrication methods proceeded vigorously through 1951 and part of 1952.

Page 135 presents a view of the reactors built for the NYX program and the R, P, and L Areas at the plant. A number of detailed improvements were made later to the NYX unit and it was installed in the K Area.

Several comprehensive references have been prepared which give details of the NYX program. The New York Shipbuilding Corporation history, "Fabrication and Testing History - Prototype and Production Units", records in detail the fabrication activities. The Material and Equipment Section of the du Pont Construction Division has compiled, for future use, a manual of the fabricating procedures employed on the reactors. This contains step-by-step procedures for the fabrication, fit-up, and assembly of the plenum, shield and tank weldments. Detailed job descriptions and photographs of the work in progress are included. Fabrication operations peculiar to the C Area reactor are described. The manual also brings together such general information as du Pont drawing lists, NYS drawings for tools, jigs and fixtures, welding specifications and typical work schedules.

Final inspection reports on these assemblies have been compiled to record the more important "as fabricated" dimensions as determined by inspectors. Exact pattern dimensions, tube bore diameters and tank diameter are typical data contained in these files. Also on file are the critical "as erected" dimensions compiled at the plant by the Construction Division. These pertain principally to the clearances and alignment between major parts of the reactor, the relative position and orientation between major parts of the reactor, and the exact location of the reactor within the building. In this file, too, are check measurements made on the weldments at SRP to ascertain whether or not any deleterious

1 PIECE PLE

HORIZONTAL HEAT EXCHANGERS

ARRANGEMENT
REACTOR, PROCESS PUMP
AND HEAT EXCHANGER

changes had been caused by shipping, handling and erection maneuvers.

As constructed, the plenum chamber is a hollow disc weldment approximately 17 feet in diameter and 1-foot thick. There are 673 5-1/4-inch O.D. tubes and 165 2-inch O.D. tubes passing through both faces of the disc. Each tube extends through and is welded to each face. In addition, six large tapered nozzles are welded at 60-degree peripheral intervals around the disc. The over-all diameter of the disc and its extended nozzles is approximately 25 feet. All plate material is of substantial thickness and the entire plenum structure is designed for an internal pressure of 250 p.s.i. The 673 large tubes are arranged in a 7-inch triangular pitch pattern. The 165 small tubes, on the other hand, are arranged in a hexagonal pattern around specified large tubes.

The top shield is a similar tube and tube sheet weldment approximately 18 feet 9 inches in diameter by 3 feet 4 inches deep. It contains the same number of large and small tubes welded through the top and bottom faces in a pattern which identically matches that of the plenum. When the plenum is mounted on the top shield, all holes are in alignment. A 1-inch thick deflector or poison plate is bolted to the bottom of the lower tube sheet with a 1-inch clearance between the two. Space in the top shield between the tubes and the weldment body is filled with approximately 50 tons of 1/4-inch stainless steel Raschig rings.

The bottom shield is essentially the same as the top shield except that the 673 large tubes have a 4-inch O.D. and the 162 small tubes are not required.

In assembling the reactor the bottom shield, top shield and plenum are precisely aligned, one above the other, with a vertical distance of approximately 15 feet between the top of the bottom shield and the bottom of the top shield. This space is enclosed by the reactor "tank" which consists of heavy stainless steel plate continuously welded to the bottom shield and extending up to and around the top shield. The main tank diameter is 16-feet, 2-3/4-inches.

Maintenance of the 7-inch triangular pitch pattern in the plenum, top shield and bottom shield not only within the elements themselves but in relation to each other created the main fabrication problems. The amount of welding on each part was extensive.

As had been agreed, following a recommendation by Combustion Engineering, a mock-up was fabricated at NYX primarily to determine the amount of welding shrinkage in a tube sheet and plenum. The 8-foot diameter mock-up used actual tube

sizes, plate thicknesses and final welding thicknesses. It showed that the 7-inch pitch could be expected to shrink .021-inch in the plenum, .014-inch in the top shield, and .007-inch in the bottom shield. Since there was no welding in the deflector plate no shrinkage occurred. To offset this anticipated shrinkage the tube sheets for the shields and plenum were laid out in an exploded pattern to give a 7-inch triangular pitch pattern after welding.

Precise vertical alignment of the tubes in the plenum and top shield created the second major fabrication problem. To provide the necessary nuclear shielding and allow easy insertion and removal of reactor components, true alignment after installation at the plant had to be assured. This problem had been recognized and it was generally believed that all tube holes would have to be rebored with the plenum and top shield tightly fastened together. For this operation large vertical or horizontal boring mills would be required and efforts were made to locate these machines. It was found, however, that this "line" boring could be accomplished by use of radial drills mounted around the horizontally placed reactor sections. With the arms of these drills swinging out over the plenum and top shield, which were keyed together, it was possible to align a number of holes simultaneously. This would not have been possible with other types of mills. Precise alignment of tubes in the bottom shield was not as critical, the tolerance there being held to within 1/64-inch of the corresponding holes in the plenum and top shield.

After line boring of the R plenum was completed, several tubes were found to be outside of tolerance on bore diameter and finish. This was not entirely unexpected and, according to plan, the faulty tubes were removed and new tubes welded in place. Effects of this welding spread to adjacent tubes, however, and produced an "out-of-roundness" beyond specifications. Rather than perpetuate the chain reaction of replacement and distortion, it was decided to hone the deformed tubes to an acceptable roundness. The increase in bore diameter, .010-inch, required to accomplish this was then made universal by honing all the other tubes in the pattern. The increased diameter, 4.385-inch, plus .005 or minus .000-inch for the large tubes and the 1.505-inch plus .005 or minus .000-inch for the small tubes, was adopted as standard for all areas. To avoid any likelihood of further increases in the P, L, K and C units, the final .010-inch in bore diameter was not honed until faulty tubes had been replaced.

In planning the fabrication of the tube sheets and plenum, all concerned had naturally preferred seamless tubing. As procurement progressed, however, it appeared doubtful that enough seamless for all units could be obtained without seriously affecting the fabrication schedules, and for that reason

both welded and centrifugally cast tubes were purchased to supplement the supply of seamless. Each of the three types was used in the fabrication of the R unit bottom shield.

During the final inspection of this section in April 1952, cracks were detected in some of the welded tubes and a critical examination was then made to determine their cause and extent. At the conclusion of metallurgists' studies it was agreed that cast tubes could be used to replace the defective tubes. It was decided that if, after this replacement, the shield satisfactorily passed a test with 1000 p.s.i. hydraulic pressure inside the tubes and a Freon test with 30 p.s.i. on the shell side, it would be acceptable. The shield passed the tests and was shipped to SRP in August 1952. The soundness of the "X" unit, under fabrication during this period, was not doubted since only seamless tubing was being used.

Hydraulic testing of the "X" reactor began in May, 1952, and in August splitter vane failures in the plenum nozzles were discovered. In this reactor, vertical staybolts had been installed between the top and bottom triangular plates of the plenum nozzles. Inlet water passed these staybolts at high velocities and, to prevent excessive turbulence, they had been streamlined by welded shrouds. When the shrouds gave way under hydraulic testing, a much stronger construction was then substituted. In the R and P plenums solid splitter vanes were installed to streamline coolant flow.

One other significant factor in reactor design was disclosed by this hydraulic testing. After the initial pumping run was completed, orientation measurements were made and compared with measurements made before pumping. These data proved that the relative position of the plenum and top shield had shifted by .020-inch. The exact cause could not be determined but there was a general belief that the three tongue and groove indexing guides were not rigid enough or had too much clearance. Three more guides were added to restrict any possible movement.

Throughout the duration of the NYX tests many minor items of design and performance were noted and incorporated in the reactor design, fabrication, erection and inspection.

REACTOR STRESS CALCULATIONS

One of the principal considerations in the design of a nuclear reactor and in the evaluation of a design for its potential power level is the investigation of stresses in the reactor. Temperatures, pressures and weights affect the reactor structure and critically influence many design features.

Temperature problems arise, first, from the exchange of heat between the reactor structure and coolant streams and, second, from heat developed in all parts of the reactor structure by the capture of neutrons and gamma rays.

Pressure problems are limited primarily to the system that distributes cooling water to individual fuel columns under sufficient pressure to prevent "boiling disease" and overcome pressure drops incident to the high heat transfer rate required to cool the uranium fuel. Although the helium in the blanket gas system is maintained at a relatively low pressure, the area of application is large enough to build up a total force that does affect design.

The third stress results from the weight of the components carrying the uranium fuel. In each of the Savannah River Plant reactors there are approximately 100 tons of these components. In addition, the weight of the moderator, reactor shields and plenum chamber must be carefully considered.

Design of each of the SRP reactors was based on the following unit weights:

Plenum chamber	21 tons
Top shield, including water	108 tons
Tank	14 tons
Bottom shield, including water	115 tons
Thermal shield, including water	170 tons
Moderator	111 tons
Semi-permanent components, including sleeves, shield plugs, and monitor pins	100 tons
Nuclear charge	104 tons

Early calculations recognized three types of lattice positions: fuel, control and blanket. These positions were the basis of the original three "cases" or representative calculations of power, circulation rates and other pertinent data. Case III, plutonium production without a producer blanket, became the design basis.

After the over-all size, general arrangement and some details of the reactor had been settled by consideration of the factors discussed above, design began on structural details and progressed through the following steps.

1. Development of a detailed concept for each part of the reactor.
2. Computation of temperatures produced throughout the reactor during the various conditions of operation.
3. Computation of stresses and distortion produced by the combined effects of temperature, pressure and weight.
4. Comparison of calculated stresses with safe working values for the materials used, and comparison of calculated strains with limits beyond which interference of parts occur.
5. Modification of the design concept to reduce stresses or strains where they appeared to exceed safe practice.

Through 1951, especially in the spring and summer, the reactor concept developed rapidly. The effort was partly spurred by the need for shop drawings of the prototype at New York Shipbuilding Corporation. In January of that year work was started on evaluating alternative top shield and plenum structures. In both cases the basic requirement was a high degree of rigidity to minimize deflection and adequate strength to withstand an internal pressure of 250 p.s.i. in the plenum. Preliminary scouting calculations were issued in February covering most of the design features.

The first complete temperature survey was issued at the end of October and, with this data and that on pressures and weights, it was possible to pinpoint those parts of the structure where stresses or strains warranted detailed analysis. Several minor changes were found advisable but these did not delay fabrication of the NYX unit or the R Area unit on which work had been started.

These analyses had emphasized that in reactors of the SRP design several effects on reactor structure could be expected from the temperatures, gas pressure, and the fuel and moderator weight.

1. The bottom shield will bow upward since its top plate is much warmer than its bottom plate. The weight of the shield itself, the moderator, and the gas pressure imposed is not sufficient to counteract the temperature effect. The bottom shield also expands radially and vertically.
2. The tank wall expands vertically to compress the expansion joint. It also expands radially.
3. The top shield deflects downward due to its own weight, the weight of the plenum and the fuel load. In addition, its bottom plate is warmer than its top plate, hence the deflection is increased by temperature.

4. The plenum deflects to match the curvature of the top shield on which it rests. Gas pressure tends to buoy the plenum. The temperature of the plenum is uniform throughout. Curvature and differential radial expansion produce a misalignment between tubes of the plenum and those of the top shield, tending to "pinch" the internal sleeves which pass through both plenum and shield tubes.

The importance of measuring the temperatures of critical reactor parts and their motion became clear during late 1951 and early 1952. For this purpose it was decided to install thermocouples at strategic locations and also to provide means for measuring the movement of critical parts. A complete description of these facilities is found in the history section devoted to instrumentation.

During the third quarter of 1951 much thought was given to the potential power capabilities of the SRP design. A basis for reactor studies to be applied to the L, K and C Areas was set up. A table of key data from four assumed cases is reproduced here for reference in discussions which follow on design.

Case I on the accompanying table, similar to Case III mentioned previously, was the nominal design basis for the R and P Areas. Case II represents the "maximum" conditions for which the R and P reactors were to be designed. It should be noted that the power levels are annual averages based on the mean annual temperature of Savannah River water. During the summer months when the river temperature exceeds 21 deg. C. average, power would be curtailed to keep sheath temperatures below the listed maximum. During the winter months a power output above the given annual average could be realized.

It is evident from the following table that an increased power level is obtainable from one or more of the following changes; increasing the permissible sheath temperature; increasing the effective heat transfer surface to volume ratio of fuel elements to prevent a rise of the sheath or axial fuel temperature; increasing the quantity of coolant and cooling water flows; or by improving "efficiency". The net result of any power level increase is an increase in the operating temperature of the various parts of the reactor.

Results of the L, K and C reactor studies were reviewed in February, 1952. The temperature and stresses reported were for a 700 MW maximum power level which corresponded to Case II but converted to winter operating conditions. Stresses were calculated at 19,800 p.s.i. for the expansion joint and 7300 p.s.i. at the juncture of the tank wall and the upper plate of the bottom shield with gas pressure super-

POTENTIAL POWER LEVELS OF REACTORS

<u>Case</u>	I	II	III	IV
Design Basis				
Type Fuel Tube	Q-foil	Q-foil	S-foil	Tube
Type Fuel Element	Cyl. Slugs	Cyl. Slugs	Cyl. Slugs	Flat Plates
Size Fuel Element(In dia.)	1	1	0.75	0.2 in. thick
Effective tubes (as Q-foil tubes)	1,861	1,861	1,861	1,861
Total Tubes	2,424	2,424	2,424	2,424
Max. Sheath Temp. (°C.)	80	95	120	120
Inlet Water Temp.(°C.)	21	21	21	21
Coolant Velocity (Ft/sec.)	25	35	25	25
Efficiency (%)	73	85	85	85
Pfd. HX Area (Sq.Ft.)	400,000	400,000	400,000	400,000
Derived Conditions:				
Moderator Flow (g.p.m.)	76,000	76,000	76,000	90,000
Cooling Water Flow (g.p.m.)	60,000	60,000	84,000	100,000
Outlet Water Temp. (°C.)	44	61	67	75
Inlet Mod. Temp. (°C.)	31	38	37	43
Outlet Mod. Temp. (°C.)	46	67	83	97
Axial Fuel Temp. (°C.)	300	480	480	190
Annual Avg. Power (MW)	363	630	1,000	1,400

imposed. When these results were discussed it was found that the stress in the bottom joint would be three times higher, or 21,600 p.s.i., if the blanket tubes at the outer lattice points carried a target material. Under such operating conditions, with elevated temperatures existing in all parts of the reactor, the coolant flowing from the blanket tubes would impinge cold D₂O against the lower tank wall.

Late in February, 1952, the basic requirement for the L and K Area reactor design was set at 1000 MW with an outlet D₂O temperature of 83 deg. C. This corresponded to Case III in the previous table.

Using a temperature survey calculated for 1400 MW operation, Case IV, and temperatures interpolated between the 700 MW and 1400 MW levels, stress summaries were prepared for both 1400 MW and 1000 MW operation. At 1000 MW, calculations indicated a stress of 28,800 p.s.i. in the bottom joint with cold water jetting against the tank wall. Stress in the expansion joint was calculated to be 24,500 p.s.i.

Meanwhile fatigue tests had been made on weld specimens simulating the bottom joint. Results were so favorable that the calculated stress at 1000 MW was no longer regarded as excessive. Sample welds were stressed to 30,000 p.s.i. and flexed 2-1/2 to 7-1/2 million cycles without failure while a sample stressed to 40,000 p.s.i. withstood 483,000 cycles before interruption by failure in metal adjacent to the weld.

In late March, the R bottom weld design was accepted for the P, L and K reactors, recognizing that the pattern of reactor loading was a factor at high power levels. The replacement of the expansion joint in the P, L and K units by a "double convolution" joint, then under preliminary study, was decided upon. Detailed stress calculations comparing the double and single convolution designs resulted in a recommendation that the single convolution joint be used in the first four reactors since the 10 per cent lower stress obtained was not worth the greater fabricating complications and additional welding required. Of the 24,500 p.s.i. stress computed for the single convolution, 5500 p.s.i. was attributable to an assumed 5 p.s.i. gas pressure, which by this time had been relegated to use at times when thermal stresses were insignificant. The recommendation was accepted in May, 1952.

The following month a summary was made of the proposed L and K Area reactor designs, but an opinion on fuel element types, pressure drop and flow reversal was reserved since data on these had not been developed to the point where they could be accurately evaluated.

Stresses in the lower tank wall continued to be investigated. The following table illustrates clearly the higher stresses incident to the jetting of cold water against the lower tank wall with blanket loading. In a "no blanket" operation it is assumed that bulk moderator temperatures prevail at this point. The expansion joint and the major part of the tank wall are not affected by jetting. The table also shows the substantial stress resulting from the 5 p.s.i. helium gas pressure.

BENDING STRESS COMPARISON
(p.s.i.)

MW Level	<u>700</u>	<u>1,000</u>		<u>1,400</u>	
Cold Water Jetting	No	No	Yes	No	Yes

Bottom "T" Weld:

Weight + Liquid	+7,400	+7,400	-7,400	+9,400	+9,400
Wt. + Liq. + Temp.	+9,200	+7,800	-28,800	+9,100	-32,400
Wt. + Liq. + T + 5 PSI Gas	+12,100	+10,700	-25,900	+12,600	-29,000

Expansion Joint:

Cold Spring (.153")	-18,800	-18,800	-18,800
CS + Liquid	-16,500	-16,500	-16,500
CS + Liq. + Temp.	+15,600	+19,100	+22,600
CS + Liq. + T + 5 PSI Gas	+21,000	+24,500	+28,000

Note:

Positive figures denote tensile stress; negative figures denote compressive stress.

All the stress calculations for the reactor studies had been made for specific cases, i.e., certain power levels and the structural conditions pertinent to those levels. The need for an equally detailed but less specific approach was recognized. To fulfill this need a report (DPE-772) was prepared in which "the stresses and deformation characteristics of the reactor in Buildings #105 R,P,L,K and C are discussed" and the theoretical formulas and charts are presented for

calculating them over a wide range of operating conditions. Their relation to the motion indicator and thermocouple readings is treated in detail so that the latter may be properly interpreted. The ultimate objective is a reliable means of knowing the mechanical effects of the operating conditions as they affect the operability and safety of the unit". It is believed that the information presented in this report, supplemented with actual operating data, will permit accurate extrapolation of the stresses and deformation at incrementally higher power levels.

Late in September of 1952, the design basis for the C Area was outlined in which two significant changes were noted. First, the building was to be adaptable to flat plate fuel elements. Second, the initial moderator flow was to be 85,000 g.p.m. but provisions were to be made for an ultimate flow of 120,000 g.p.m. Intimations of a request for a heavy water reflector were confirmed in October when a 12-inch to 18-inch wide reflector was included in the design. The design basis of a 2000 MW power level was established in February 1953, with natural uranium fuel to be used for plutonium production.

Just prior to this time, the design basis for the R, P, L, and K reactors and the expected basis of the C reactor were reviewed. The data presented were as follows. In this table Cases I through IV are as previously described and are tabulated here for comparison with Case V.

<u>Item</u>	<u>I</u>	<u>II</u>	<u>III</u>	<u>IV</u>	<u>V</u>
Power, MW*	363	630	1000	1400	2000***
Foil	Q	Q	S	B**	B**
Slug, O.D.	1"	1"	3/4"	.2"thk.	.2" thk.
Sheath, °C.	80	95	120	120	130
D ₂ O Vel.	25	35	25	25	25
Axial, °C.	300	480	480	190	-
Eff., %	73	85	85	85	85
D ₂ O Flow, M g.p.m.	76	76	76	90	120
H ₂ O Flow, M g.p.m.	60	60	84	100	130
D ₂ O In, °C.	31	38	37	43	39
D ₂ O Out, °C.	46	67	83	97	92
H ₂ O In, °C.	21	21	21	21	21
H ₂ O Out, °C.	44	61	67	75	75

* Annual average

** B tube for flat plate elements

*** 430 - Initial with slugs

590 - Initial with plates

2000 - Potential with plates

#100-C AREA REACTOR DESIGN

It was apparent from previous stress studies that a reactor of the R,P,L and K design could not be operated at the 2000 MW objective for the C Area without exceeding stress and strain values generally agreed to be safe. Other considerations, too, dictated changes in reactor design. An increase in tank diameter was necessary to accommodate the larger reflector, and larger tank outlet nozzles were needed to permit the ultimate flow of 120,000 g.p.m. Design changes made specifically to reduce stresses and distortion were as follows.

1. The offset expansion joint was replaced with a rolled, convoluted or bellows-type joint designed to absorb the tank wall growth at 2000 MW power without exceeding 20,000 p.s.i. stress. This 18-1/2-foot diameter joint was welded and formed by Zallea Brothers, Inc., and represents one of the largest joints of this type ever fabricated in stainless steel.

2. Pipes were added within the bottom shield to distribute cooling water for more effective cooling of the top plate of this shield. A cooler top plate decreases bowing of the bottom shield and helps reduce stress in the tank wall near the perimeter of this plate. Subsequent plant operation showed the heating effect to be much smaller than calculated.

3. Baffles were added within the bottom shield to create an annular channel around the wall of the shield near the top plate. The introduction of water, which is relatively warm compared with the shield coolant, into this channel minimizes metal stresses by producing a balance in temperature between the shield wall, tank wall, and shield top plate. The installation of external facilities for supplying water to the channel was deferred until other plant changes are made to permit operation of the C Area reactor at levels approaching 2000 MW.

4. A second deflector or poison plate was added below the top shield. By capturing radiation this plate reduces capture and consequent heat generation in the bottom plate of the shield and thus reduces bowing of the shield and misalignment of plenum and shield tubes.

Another design change corollary to the increase in tank diameter from 16 feet 2-3/4 inches to 18 feet 6-3/4 inches was the replacement of the "tee" joint between the tank wall and the bottom shield by a curved knuckle. While this change improved the temperature-stress relationship in the region by only a modest amount, it produced an arrangement wherein all the moderator-retaining welds could be inspected by X-ray. This had not been possible with the "tee" joint in the R,P,L and K Area reactors. Use of the curved knuckle made it

necessary to raise the outlet nozzles 13 inches above the bottom of the reactor and connections had to be added to permit moderator drainage through several bottom shield tubes into the upflow cooling system.

Fabrication of the C Area reactor got underway at NYS in April, 1953, and the completed weldments were shipped to the Savannah River Plant in May, 1954.

INSPECTION

Reactor fabrication drawings released to New York Shipbuilding Corporation included varied and detailed specifications. Dimensions were given with plus or minus tolerances where required, the class of welding was specified, permissible shrinkage of the pattern was indicated and special Freon and hydrostatic tests were outlined. The Du Pont engineering staff in Wilmington followed the work closely and supplied by letter or telephone many detailed instructions to NYS personnel and the du Pont inspectors.

An enormous amount of inspection work was required during fabrication. Tube bores, for examples, were required to be vertical to the plane of the bearing plates within .020-inch from end to end. This meant that 673 large holes and 165 small holes had to be inspected in one weldment to make certain that this requirement had been satisfied. Numerous inspection procedures were programmed and a force assembled to conduct these inspections on a 24-hour, seven-day-a-week schedule. All results were recorded in the field inspectors' reports.

As part of the inspection task, the actual pattern of holes in the plenum, and top and bottom shields had to be determined as well as their deviation from the theoretical 7-inch triangular pitch lattice. This was carefully recorded since the information is vital in the operation of the charging and discharging machines and as reference dimensions in the event the reactor becomes deformed in service. The data has been issued to key operating personnel and is contained in project files.

New York Ship's fabrication and machining efforts and the inspections that followed indicated in a few cases an inability to meet design tolerances. Only after every possible method of adhering to these tolerances had been exhaustively tried were any adjustments made. Special talent at New York Ship and du Pont collaborated closely in solving the difficult machining problems.

ERECTION

Erection of the reactors at the plant was guided by de-

tailed specifications. These listed the principal items of work in the erection of the unit, specified the precision with which the various parts of the unit had to be positioned, and listed the various dimensions to be recorded in the permanent file. They also covered the foundation of the reactor, the main parts of the reactor, the annular tank or side shield, the casing, the principal process piping connected to the reactor, and the concrete immediately surrounding the reactor. These were supplemented by field procedures for executing the work.

In addition to the dimensional and "fit-up" field checks, certain hydraulic tests were specified in the "Functional Test Requirements". This manual covered the functional testing of all important equipment in the reactor buildings. The tests demonstrated that the reactor was mechanically and thermally stable and would allow unobstructed charging and discharging of the components, smooth operation of the control rods and leak-free containment of the moderator. They also demonstrated that the reactor could be maintained within a moderate temperature range by circulating moderator through the closed and leak-free system with cooling in external heat exchangers. In these tests a dummy load was used and the total D₂O flow was 76,200 g.p.m. including the 5200 g.p.m. upflow through the septifoils.

THERMAL SHIELD

In addition to shields designed to capture radiation emanating from the top and bottom of the reactor and remove resultant heat, a shield serving the same purpose was also provided around the wall of the reactor. The plan first proposed during the initial period when vertical heat exchangers were being considered included the use of four to six inches of lead around the tank followed by six feet of concrete. A four-foot wide gallery would contain the exchangers and this would be enclosed by a four-foot thick concrete biological shield. In this plan the outer shield extended 25 feet from the center of the reactor. Later the lead was eliminated and, with the adoption of horizontal exchangers, the double concentric shield was discarded. In their place a single concrete shield was to be used with a cast iron thermal shield between the reactor and the concrete to prevent overheating the concrete.

Calculations of shield requirements began in January 1951, on the basis that for each megawatt there would be about 5000 B.t.u./hr./sq.ft. heat flux to the shield. This had been Hanford's experience. In two months, however, when plans pointed toward an eventual operation at 700 megawatts, the heat flux to the shield was estimated at 15,000 B.t.u./hr./sq.ft.

By October additional changes in calculations had been introduced. Replacement of the blanket producer tubes by fuel tubes and the eventuality of operation at 1400 MW had the obvious effect of increasing the radiation and the heat load on the shield. At that time the thermal shield was to consist of 10-inch thick cast iron blocks arranged in rows, each row to be cooled by two 1-inch O.D. stainless steel tubes carrying deionized water. The cooling tubes were fed from a common influent header at one side of the tank and pumped in both directions around the tank to an effluent header on the opposite side of the tank. The tubes were bonded to the cast iron by casting molten lead around the pipes in their slots. The lead was later to be peened to achieve adequate heat transfer rates.

An analysis made in October, 1951, proved that the design was adequate for a 700 MW operation with blanket producer tubes, but questionable for a similar power level without these tubes and entirely inadequate for a 1400 MW level. Since the shield could not be redesigned to meet the higher requirements, the design was discarded. In its place a design resembling that of the top and bottom shields was proposed in which the shield would be an annular tank filled with either Raschig rings or iron grid blocks. The latter were favored because they could be better packed to give the cooling water distribution desired and were lower in cost. This shield type was tentatively accepted in November, 1951, and work was started on calculating the thickness required under the most adverse operating conditions that might be encountered.

A shield thickness of 18 inches was first specified but this was increased to 20 inches so that a man could enter the stainless steel tank and install the packing material. Selection of a filler type shield would depend on the use of either inhibited cooling water or uninhibited deionized water. The use of carbon dioxide gas between the reactor wall and the thermal shield to exclude air and prevent the formation of acidulous compounds of nitrogen was accepted.

These agreements resulted in the design used in the R, P, L and K Areas. The annular tank consists of three vertical sections filled with duriron grid blocks. Deionized water is recirculated through the three sections in parallel by a 1000 g.p.m. pump. This cooling water is then passed through a stainless steel heat exchanger and cooled with river water pumped from Building #190. The shields are adequate for a 1400 MW operation (calculated) during which approximately 44,200 B.t.u./hr./sq.ft. enters the inner wall of the shield.

Slag aggregate was used in pouring the concrete shield to obtain maximum density. Reports then available on the

resistance of concrete to higher temperatures indicated that only a slight disintegration might result from concrete exposure to temperatures up to 300°F. Temperatures much in excess of this were not anticipated and disintegration was not considered a problem. There did exist, however, some concern over the temperature gradients which might run as high as 70 to 80°F. per foot in the inner surfaces of the shield. Approximately 2000 feet of 1-inch steel cooling coils were therefore set in the shield but not connected at start-up, their use being reserved for a time when high reactor levels might raise the shield temperature.

Two factors compelled a change in shield design for the C Area. It was decided to limit the filler material to stainless steel to minimize the nuisance of radioactive corrosion products, caused by reaction of deionized water and Duriron. To use this in its cheapest commercial form it was decided to fill the shield with curved plates concentric with the tank walls. Also, a redesign of the reactor giving it a larger diameter and higher outlet nozzles led to the conclusion that the shield should be built in twelve vertical sections in order to fit it around the reactor and under the nozzles. The reduced size of each section made it possible to load the tanks with filler plates in the fabricating shop and transport them to the site as fabricated and tested units. The cooling system for the "C" Area reactor shield is essentially the same as that for the other reactors except for revisions in the piping connecting the twelve sections.

In November, 1954, after the concrete shield was poured and much of the construction work outside the concrete had been completed in Building #105-C, serious leaks were detected in the thermal shield. These appeared to originate at a level coinciding with the staybolts in two adjacent sections of the shield tanks. To examine these, a tunnel about 12 feet high and more than four feet wide was chipped out of the concrete surrounding the reactor. No defects were evident on the outer wall of the annular tanks but, by inserting thin strips of wood and metal through the narrow space between tanks, it could be determined that the inner wall joint at one staybolt was leaking in each of the two tanks. Ordinary methods of removing the defective joints could not be used since these would damage the parts, obscure the cause of failure, and might leave the tank in a condition difficult to repair. Instead, a trepanning procedure was used, by which a circular portion of the outer wall, filler plates, and inner wall around a staybolt would be successively removed. Tools were designed and an existing machine was converted in ten days to meet the space and job requirements. By this method the staybolts were removed within a week.

Examination of the faulty specimens revealed that welds joining the staybolts to the tank wall had appreciably less

depth than specified on drawings. In addition, threads in the weld zone of the staybolts had contributed to the joint weakness. A review of the fabricator's shop history indicated that the defective tanks had been the first two completed and this encouraged the belief that succeeding tanks had been welded to specifications. To confirm this improved workmanship, the concrete tunnel was enlarged and two staybolts were trepanned from a third tank. When the workmanship in this case was found to be satisfactory, it was agreed that no check on the quality of the nine remaining tanks was necessary. Each of the staybolts in the defective tanks was removed and poor workmanship found in most cases. These were then replaced and the tanks repaired in place.

Repair operations began in January, 1955, were completed by the end of that month and successfully tested, and the outer concrete shield was repoured on February 8.

EXTERIOR D₂O SYSTEM

From a third to a half of the heavy water in the reactor system is contained in equipment and piping outside the reactor. Most of this is in the pumps, heat exchangers and piping in the reactor cooling circuit, but a small amount is held in the auxiliary systems necessary for satisfactory control, operation and maintenance of the reactor and cooling system.

For the purpose of this discussion the term "Exterior D₂O System" includes all heavy water handling facilities exterior to the reactor and excluding the purification process. Under the title "Reactor Cooling System", the six parallel cooling circuits containing the pumps, heat exchangers and piping are described. Although the main pumps and heat exchangers are elements in this system, their importance merits separate treatment in the design history. The various auxiliary systems are described individually. Helium handling facilities are included in this category although they do not contain D₂O in the normal sense. A simplified diagram of the exterior D₂O system and the principal H₂O circuits is shown on page 153.

Pages 155 and 157 are perspective cut-away views of the Process Area between Elevations -40' and 0'-0". They show the equipment and piping arrangement.

REACTOR COOLING SYSTEM

The reactor cooling system removes heat generated by the fission reaction and releases it to the Savannah River. In development of the basic system there was general agreement on three principles that would govern the design. These were a minimum D₂O holdup, the use of only stainless steel or aluminum in contact with the moderator, and the inclusion of leak

BUILDING # 105-PROCESS AREA-SECTION AT ELEV. -40'-0"

DRAWING №7 OF 10

BUILDING #105-PROCESS AREA-SECTION

VODRODIN'S WATER TREATMENT & SMITH

detectors and collectors at all joints or potential points of leakage.

To provide the 76,200 g.p.m. moderator flow, a two-stage pumping scheme was first studied. An 18-inch line connected the reactor nozzle to the first stage pump, a 14-inch line connected the pump to the exchanger and a 14-inch line carried the D₂O from the second stage pump to the plenum. Continued study of the system's hydraulics and volume finally led to the selection of 20-inch piping to a single moderator pump and 12-inch lines from the pump to the exchanger and to the plenum. The velocity in the 12-inch line would be 36 feet per second and, although this would be about three times the values used in normal engineering practice, it appeared feasible. Adequate test work was planned to confirm the expected low erosion rates. This testing was done at NYX and the results are reported in DPXN-201, "Reactor Hydraulics".

To secure a reasonably uniform moderator flow, six parallel closed circuits were selected. Each circuit would consist of pumping equipment, two exchangers, the necessary valves and connecting piping. This plan was retained throughout design and its efficiency was demonstrated at NYX.

It will be recalled from the discussion of the reactor building design that the pumps and heat exchangers were first arranged peripherally around the reactor and that this pattern was abandoned because the provisions necessary for equipment handling and maintenance were difficult, costly, and occupied too much building volume. In its place three pumps and the exchangers were set in line on two sides of the reactor and parallel to the "X" axis of the building. This brought some variation in piping lengths but the effect on flow distribution was not considered significant.

As is normal engineering practice in parallel piping systems discharging to a common plenum or manifold, check valves were included in design to prevent backflow in the event of pressure losses in one or more of the piping circuits. In April of 1952, elimination of the valves was proposed. Under certain conditions when the valves were closing there could be a pressure surge up to 1000 p.s.i. A severe strain on the piping system could result if a valve were to stick and then close suddenly after reverse flow had been established. No practical method could be found for regulating the closing rate of the valve to reduce shock to a reasonable value. Flutter of the check valve and cavitation were also considered as undesirable factors.

Elimination of the check valves would, however, produce other problems incident to flow reversal. Were this flow reversal to occur, the core rods in the heat exchangers might move, the pumps and d.c. motors could be reversed and reactor

cooling could be affected. Also, a loss of power to any of the a.c. motors which were the pump main drives would cause back-flow in which case the d.c. motor would be reversed and the generator and diesel engine might be driven at an excessive and probably destructive speed. Remedies might lie in cutting off power to the remaining a.c. motors, disconnecting the d.c. generator from its motor automatically, mechanically disconnecting the pump from the d.c. motor, or automatically shutting the cone valve in the circulating system.

Before any final decisions were made the experience of a hydraulic consultant was solicited on this and other design problems. In his opinion, because of the high velocities in the process lines, special care should be taken to eliminate irregular surfaces that would cause excessive turbulence and possible cavitation. He agreed that the tilting disc check valves could be a serious hazard under the planned operating conditions and should, if possible, be eliminated. He pointed out that although surge arresters could protect against check valve slamming, these were not available in the sizes required. From the du Pont standpoint such arresters, had they been available, were undesirable because of their moderator hold-up.

After considerable study, it was decided that the check valves would be deleted. This necessitated the development of an alternative method for protecting the cooling system.

In most of the protection methods considered there were inherent compromises with the "on-line" power characteristics which had been established as a design criterion. In time, however, a suitable non-reversing clutch was procured and mounted on the pump drive to prevent reverse rotation. This is further discussed in a later history section under the subject "Formsprag Clutches".

As installed, each of the external reactor cooling systems has its origin at one of six nozzles at the side of the reactor and, except in C Area, flush with the tank bottom. Each nozzle has a six square foot opening, roughly rectangular, which is shaped as it leaves the reactor to join a 20-inch O.D. pipe section five feet from the reactor. The nozzle openings are fitted with parallel plate grids which, as 50 per cent iron and 50 per cent water, form a radiation shield and a coarse screen to prevent slugs or component parts from being carried to the pump. The 20-inch pipe section between the reactor and the pump contains two 90-degree ells buried in concrete to prevent radiation leakage through the outlet piping. Piping runs vary in length from 31 to 42 feet to accommodate the "in-line" arrangement of the pumps and exchangers. Ahead of each pump, the line carries a 20-inch motor operated stainless steel gate valve for shut-off purposes and a reinforced bellows-type expansion joint.

PROCESS PUMPS

Heavy water is circulated through the reactor and heat exchangers at a rate of approximately 70,000 g.p.m. by six pumps operating in parallel. A high degree of continuity in operation, very low leakage, low volume, and minimum down time were the most important considerations in equipment selection. To prevent D₂O circulation from ceasing too quickly after a power failure, flywheels were incorporated in the pump drives; and to maintain a minimum flow of about 10 per cent, both a supplementary and an emergency power supply system were connected to the main pump drives. Because of the high cost and limited availability of the coolant, control of leakage at the pump shaft was recognized immediately as one of the most critical design problems.

In surveying the advantages in various pump designs a "canned motor" pump, in which the shaft seal is eliminated by enclosing the pump and motor in a common casing, was studied as early as December, 1950. Aware of development work on such a pump for nuclear powered submarines, du Pont contacted the Naval Reactors Branch of the U.S. Navy's Bureau of Ships. Information secured there led to elimination of any further consideration of the design for use at SRP. It was found that the pump had unsatisfactory endurance records, that there was a complete lack of test or operating experience at that time with pumps of the capacity required, and that unfavorable efficiency characteristics would increase power demands for the Savannah River Plant.

In a relatively short time agreement had been reached on several of the important design features of the pump to be procured. It would include mechanical seals in place of packed glands since, in du Pont experience and that of many other pump users, such seals if properly designed would have a longer life and maintain a lower leakage rate. Sleeve bearings were selected over several anti-friction types for their traditional reliability. Also, any failure would be a simple "scoring" which would offer no threat to the integrity of the pump. Ball or roller bearings were eliminated because these on occasion had been known to fail and fracture a pump casing.

By the time specifications were prepared for pump vendors the system's capacity requirements had been increased to 12,000 g.p.m. per pump. Quotation requests issued to six vendors specified pumps of that capacity, 650 feet total dynamic head, 1800 r.p.m., single mechanical seals, minimum volume and leakage, low bearing loads, sound castings and complete performance tests in the vendor's plants. Numerous technical discussions with prospective vendors in the ensuing months led to changes in some design features, and new specifications were issued in April. A total of 32 pumps, six for each area

and two spares, was indicated, each to deliver 11,500 g.p.m. at a 700-foot total dynamic head.

In calculating the necessary pump head, designs of the heat exchangers, fuel elements and the reactor were analyzed for friction loss, and to this was added protection against boiling disease as provided at Hanford. It was realized that abnormal pressure reductions in the coolant channel of a fuel assembly or local flux surges could cause boiling. To suppress this boiling and re-establish normal flow, pressures substantially higher than normal had to be instantly available. Hanford had successfully used restrictive orifices for this purpose and these were included at the head of the SRP fuel assemblies. The 670 foot total dynamic head requirement for the process pump was, therefore, based on the following friction losses: heat exchangers, 235 feet; boiling disease orifices, 185 feet; fuel column, 190 feet; piping and valves, 60 feet.

An order was placed with the Byron-Jackson Company in June, 1951 and a period of intensive development of design details followed with both Byron-Jackson and du Pont engineers cooperating closely. It was decided that double mechanical seals should be used with fluid injection between the seals, and that the seal fluid would be circulated past the seal faces and through an external cooler by a pump integral with the seal. The vendor was required to build a tester to prove the seal design and evaluate the construction materials forming the mating surfaces of the seal.

Some difficulty was encountered in obtaining quality castings for the large and intricate pump casings. After several changes in foundry patterns to minimize shrinkage effects, castings meeting Class 3 U.S. Navy radiographic standards were produced. The objective had been Class 2 Navy quality but, with only a small amount of weld repair, the Class 3 castings proved satisfactory.

To assist the vendor in performance testing, du Pont temporarily supplied a 3000 hp. motor from SRP, reconnected to operate at 2200 volts. A limited electrical supply in the vendor's plant made it necessary to start the pump at low voltage and bring it up to speed before water was admitted to the suction. This resulted in rough and noisy operation until air was expelled from the system, but no damage occurred. The procedure was used for all pump tests.

The first six pumps manufactured were shipped to NYX, connected to the reactor mock-up and tested from July to November, 1952, through the full range of conditions anticipated at SRP. On the whole, performance was very satisfactory, but erratic seal behavior emphasized the importance

of maintaining the fluid between seals at an adequate and steady pressure and the careful preparation and handling of seal faces. Under a supplemental seal testing program at NYX, improved techniques were developed. Minor changes were made in thrust bearing designs, and cooling fins were added on the bearing housing to enable the pump to operate for several hours after an interruption in the oil supply without overheating. During the NYX tests all pumps were operated at 12,700 g.p.m. which, with the NPSH available at the Savannah River Plant, would permit moderator temperatures of about 100 deg. C. (Results of the NYX test work are reported in DPXN 222.)

In their final form the pumps are horizontal, single-stage, double suction, double volute units having 20-inch suction and 12-inch discharge connections. They are equipped with double mechanical seals on each side of the shaft, the seal faces being graphite vs. stellite. Radial bearings are a sleeve type with oil rings and the thrust bearing is a Kingsbury type with reduced face area to minimize sensitivity to oil supply. Casing and impeller are cast Type 304 stainless steel, with the shaft being high-impact 17-4 stainless. Bearings and seal units are designed for rapid replacement. The impeller design is oriented about the minimum NPSH requirement.

Pump performance in the plant has been quite satisfactory. Seal life has been greater than expected; the leakage has been nominal although higher than the design objective. Continuity of operation has been high and maintenance almost negligible.

PUMP SEAL SUPPLY SYSTEM

To guard against excessive heavy water loss, two mechanical seal assemblies are installed on each of the process pumps. An assembly consists of two rotating seals with an intervening chamber filled with D₂O under a pressure greater than the suction pressure of the pump. This heavy water is constantly circulated, an impeller in the seal assembly forcing it through an external cooler and back to the pump chamber. Any leakage through the inside seal enters the pumps and water escaping through the outside seal is caught by the leak collection system described later. Any D₂O lost from the seal chamber is replaced by the seal supply system.

Design of the supply system was based originally on the premise that only virgin D₂O drawn from the operating circuit should be fed to the seals. This was to avoid the accumulation of radioactive particles in the seal assembly that would prevent efficient maintenance and replacement. The system could also be adapted to measure the leakage rate on each of the four seals on a pump. Each pump would have two pots pressurized by helium to feed the D₂O, plus a collection pot. A

level drop in the supply pot would indicate a leak through either the inside or outside seals. A rise in the level of the collection pot would indicate the amount of leakage through the outside seal. The difference between the two level changes would indicate the amount lost through the inner seal. The leakage rate expected, combined with the supply pot size, would make recharging necessary at 11-day intervals. Although entirely workable, such a system would be practicable only if leakage rates were low.

Under testing at NYX the seal assemblies leaked at rates four to twenty times greater than the 50 gallons per year which had been set as the objective rate. Despite the fact that the many irregular procedures to which the pumps had been exposed at NYX were not conducive to good seal performance, it became obvious that the planned supply system would not be adequate for the plant. Not only would frequent recharging become an operating burden, but the amount leaking was greater than could be replaced with virgin D_2O . Also, a supply pressure would be necessary higher and steadier than could be reasonably maintained through frequent pot rechargings.

In redesigning the system it was decided to feed the seals with D_2O returning from the purification area. It was felt that the filters and deionizers in the purification train would remove radioactive particles and leave only the possible hazard of tritium contamination in the pump seals. AED, in turn, agreed to prepare maintenance procedures that would protect personnel from these tritium hazards.

To improve the performance of the supply system and reduce charging requirements, the pressure was increased from 35 to 50 lbs./sq. in. A 200-gallon supply tank was mounted at the 66-foot level in each of the reactor buildings and filled by a continuous sidestream from the purified D_2O line. Excess heavy water overflows from this tank and is piped back to the reactor system.

In the R and P Areas this redesigned system was included after the supply and leak collection pots of the original system had been installed. These, however, were retained as aids in the precise evaluation of seal leakage rates. In subsequent areas the supply pots were replaced by rotometers and the leak collection pots by sight glasses. These do not provide exact measurement but do reveal any unusual leakage rates which could indicate impending seal failure or the need for replacement. The capacity of the central tank system is sufficient to care for leaks ranging from 3 to 5 g.p.m. per pump but it is improbable that the leakage will ever reach that volume in more than one or two pumps at a time.

FORMSPRAG CLUTCHES

Since the six main pumps operate in parallel, it is necessary to provide protection against damage to the diesel engine generators driving the 120 hp. pump auxiliary drive motors in the event one of the main 3000 hp. motors loses power and permits reversal of the pump set. Check valves in each circulating system were considered but rejected due to water hammer which would result from their sudden closing.

Elimination of the check valves was made possible by the installation of a non-reversing clutch on each of the process pump drives. This Formsprag clutch rotates freely in only one direction while any effort at counter-rotation causes multiple shoes to grip the shaft, the reverse torque created being transferred to the floor by a torque arm. The assembly is provided with shear pins to prevent damage should the clutch seize during normal operation.

The first clutches were obtained in time for testing at NYX and, with minor exceptions, their performance was completely satisfactory. In May, 1954, however, after 16 months of service, a clutch failed in the R Area and, while this was being investigated, a second clutch failed. Each followed the same pattern of noisy operation, temperature build-up and seizure. Immediately clutches were removed from all operating units and precautions taken to insure prompt shutdown and prevent counter-rotation when an a.c. motor failed. In the meantime, a study of the failures indicated that with very low running clearances, the clutches had built up friction because of foreign particles in the oil supply until mounting temperatures caused seizure.

Alternative methods of preventing counter-rotation were again studied and several original designs were drafted. Detailed evaluation also was made of numerous schemes for automatically interrupting a.c. power to other motors upon failure of any one motor or of disconnecting the d.c. motor from its generator. Since all the electrical methods, to some degree, compromised the integrity of the power distribution systems by interposing "gadgets" in the circuitry, it was again concluded that a mechanical "back-stop" device was most desirable. Despite the plant failures, the Formsprag clutch appeared best suited.

Plant clutches were disassembled, examined, and their dimensional tolerances checked. Although the workmanship was good, it was possible to form combinations of parts that left insufficient clearances for thermal expansion. The clutch was, therefore, modified to provide greater internal clearances, bearing lubrication was improved, and the torque

arm was revised to minimize hazards in event of a clutch failure. Two clutches then were tested at the plant's Construction Division shops and operated satisfactorily in spite of artificially induced high temperatures, oil supply interruptions and the introduction of dirt in the oil. All clutches were then reworked in a similar manner and re-installed.

HEAT EXCHANGERS

As the means by which heat resulting from reaction is transferred from the moderator to river water, the heat exchangers perform a vital function in reactor operation. In the design and fabrication of the SRP units a combination of operating and maintenance requirements prevented the direct application of normal commercial practices. The exchangers had to offer sustained reliability and maximum efficiency, and to add as little as possible to the heavy water inventory. The prevention of leaks was a primary consideration and much of the development work centered about this element in design. Also, it became obvious that the exchangers would be large units, and that a practical method must be evolved for their installation and removal. Realizing that leakage of costly heavy water might not be entirely eliminated, early design data stipulated that river water on the shell side of the exchangers should be maintained at a higher pressure than the heavy water in the tubes so that leakage would be from the light water into the D₂O. Its removal was much simpler than the recovery of heavy water from larger volumes of river water.

Heat transfer calculations progressed through the fall of 1950 and were used in site evaluations and tentative sizing of the exchangers. By mid-December design, fabrication and procurement began to crystallize and by the end of the month Design personnel could outline to the Engineering Department and Purchasing Department the problems involved. At that time it was estimated that 450,000 sq. ft. of exchanger surface would be required for each reactor, this capacity to be contained either in six three-pass exchangers or 18 one-pass units. The tubes were to be 24 ft. long, and either a 1/4-inch or a 1/8-inch O.D. All materials in contact with the primary coolant were to be Type 304 stainless steel. General reviews were held on the subject of moderator hold-up, the importance of baffle and support spacing, staybolt construction of the tube sheets, and the possibility of using clusters of 1/4-inch tubes brazed into a ring with the ring welded into the tube sheet. Double tube sheets were considered seriously from the very beginning of design. As a result of these meetings, a development program was planned, and later a committee formed to study the feasibility of fabricating the required designs. The committee made detailed in-

vestigations and issued a report which contained the following highlights.

1. In addition to providing adequate heat removal, the exchangers had to hold a minimum of process liquid and could lose thru leakage no more than a gallon a day.

2. Since the exchangers would be about 15 times as large as conventional large units, the elimination of leakage by standard designs would be problematical. As an alternative, double tube sheets with a rolled tube design could be used with a drain to collect leakage. Triple tube sheets could be used for positive segregation of leaks.

3. Two tube sizes finally were considered: 1/4-inch O.D., 20 gage stainless steel, and 1/2-inch O.D., 18 gage stainless steel. The 1/2-inch tubes could be filled with a core bar to provide a 1/16-inch annulus but this combination would impose a greater pressure drop penalty.

4. Operating requirements limited materials to stainless steel, principally the 18-8 type, thus eliminating fabricating procedures successful with copper, cupro-nickel and admiralty metal.

In its studies the committee endeavored to develop a fabricating method that would insure practically no leakage at start-up or during the life of the exchanger. This included improvements to conventional fabrication methods and consideration of somewhat unconventional designs. Of several experimental exchangers the only unit that successfully passed severe pressure and cycling tests was of unconventional construction in that the tubes were welded by the inert gas, shielded arc method and then rolled. In this method, welding provides the primary seal and rolling gives additional strength and a secondary seal.

Before the Engineering Department and AED made a final selection, the heat exchanger committee investigated several widely differing designs, some of which had been proposed by manufacturers. A number of these were subjected to process conditions on a small scale basis and critically examined in a testing station in Bldg. #679-G-CMX, at the Savannah River Plant.

Before and during fabrication, much thought had to be given to the selection of leak detecting equipment. Two systems were in general use at the time. Helium was used with a mass spectrometer but the vacuum technique required was not adaptable to the test procedures necessary on the exchangers. Maximum sensitivity reported for the method was one part in a million since atmospheric air contains that amount of helium. The second system combined the use of a halogen gas and the

General Electric Leak Detector. It had a reported accuracy of one part in ten million, plus the advantages of low cost and equipment portability. This method, using Freon 12 as the gas, was selected for the exchanger tests.

1/4-INCH O.D. TUBE EXCHANGERS

All studies indicated that exchangers with 1/4-inch tubes would offer a slightly higher efficiency than the core tube design. In addition, pressure drops would be lower and smaller quantities of stainless steel would be required. Accordingly, two experimental 1/4-inch tube exchangers were built and mechanically tested.

The unit fabricated by the Alco Products Division of the American Locomotive Company had some desirable features. Each bundle of 120 tubes was fabricated separately as a complete assembly of tubes, baffles and transition end pieces. These were unique in that the tubes were brazed into a ring and this in turn was welded into a large hole in the tube sheet. Between the end rings of the tube bundle, the tubes were fanned out to achieve proper spacing for cooling water flow. The bundle was assembled by inert gas, shielded arc welding and by silver brazing the tube ends into the stainless steel ring. First tests with soap suds and Freon were generally satisfactory but subsequent pressure and temperature cycling tests uncovered joint failures.

In a second 1/4-inch unit, fabricated by the Babcock & Wilcox Company, the tubes were "drifted" into the tube sheet. When subjected to tests, leaks were discovered and all efforts in the vendor's shops could not make the unit completely tight.

1/2-INCH O.D. CORE TUBE EXCHANGER

Exchangers using 1/2-inch tubes and double tube sheet construction had been built commercially prior to design studies for the SRP units and the fabrication problems were fairly well understood. The generally accepted technique was to roll the tubes into the tube sheet under controlled conditions by using a Dudley controlled torque expander or the Airetool expander. In its studies of fabricating methods aimed at maximum tightness of tube and tube sheet joints, du Pont thoroughly investigated methods of welding the tubes to the tube sheets. A 61-tube experimental unit was made at ERL in which the tubes were rolled with a Dudley controlled torque expander after the tube ends were welded. It was subjected to several test cycles:

1. The shell side was pressurized with Freon 12 at 55 lbs/sq. in. and a kerosene and Freon mixture at 1000 lbs/sq. in. and examined with a G.E. Leak Detector. No leaks were

found.

2. The tube side was pressurized 15 times at 1000 lbs/sq. in. and then permitted to remain under pressure over night. No leaks were detected with the Freon detector test at 55 lbs/sq. in.

3. The tube side was tested hydrostatically to 5200 lbs/sq. in., about 1000 lbs/sq. in. beyond the calculated yield strength of the tube sheet. No deformation could be detected and no leaks were found with the Freon detector test.

4. While the tube side was held at a pressure of 400 lbs/sq. in., steam was applied to the shell side until the temperature reached 250°F. at the tube sheet. The steam was replaced with water and the unit was cooled as quickly as possible. The cycle was repeated three times. This rough treatment produced no leaks detectable by the Freon test.

Altogether the performance of the experimental exchanger was so satisfactory that the welded and rolled double tube sheet construction was recommended by the Heat Exchanger Fabrication Committee for the full-scale units.

TRANE ALUMINUM DESIGN

Two sample heat exchangers of an unconventional design manufactured by the Trane Company also were investigated and tested. The units consisted of a series of flat aluminum sheets separated by spacer strips to form a sandwich. The various elements of the sandwich were fastened together by a silicon-aluminum brazing alloy rolled onto the sheets when these were fabricated by the Aluminum Company of America.

Since, at best, considerable development would have been required to apply this construction to stainless steel, the design was rejected. A model was purchased, however, for plant study.

FALLING FILM HEAT EXCHANGER

Some interest was shown in the possibility of using falling film heat exchangers, and the E.G. Budd Company expressed a willingness to fabricate such units. As time passed, however, other work prevented the company from completing its plans. Since this type had never been built commercially and its development would involve more time than a design using tested methods, it was eliminated from consideration.

CONCENTRIC TUBE DESIGN

The Griscom-Russel Company proposed a heat exchanger which was essentially a cored design, the core functioning as

a cooling bayonet. The design's effectiveness depended, to a large extent, on the concentric spacing of the tubes. In this case, also, the lack of development and performance experience caused its elimination as a candidate design.

PROCUREMENT

Although design details had yet to be completed, the Purchasing Department began soliciting bids in January 1951 for 18 exchangers from 13 prospective vendors. The units were described as 24,000 sq. ft. shell and tube heat exchangers with double tube sheets, tubing to be 1/4-inch O.D. One major alternative offered was the use of either stayed or unstayed tube sheets. Calculations indicated that with the latter the 6-foot diameter tube sheets would have to be 6.5 inches thick which meant that the drilling of accurate, parallel holes was considered almost impossible. Staybolt construction, on the other hand, would permit much thinner tube sheets. Another alternative, the use of 1/2-inch cored tubes, was offered to the same vendors the following month.

Foster-Wheeler was selected as low bidder meeting specifications and, by May 1, 1951, the formal order had been issued.

During the quotation period, development work had been proceeding and specification discussions were being held with prospective vendors who were aware of all changes being made. The final order, therefore, varied somewhat from the equipment originally specified.

Foster-Wheeler was asked to fabricate 12 shell and tube heat exchangers for Bldg. #105-R. Each was to have 31,200 sq. ft. of surface, the tubes to be 27 feet 2-3/4 in. long, 1/2 inch O.D. Core rods of .294-inch O.D. were to be inserted in the tubes. There were to be 8800 tubes and stayed, double tube sheets were to be installed at each end of the exchanger. All stainless steel materials except the welding rods were to be furnished by du Pont. Objectives of the design and fabrication were (1) minimum tube-side volume, (2) maximum provision against leakage, (3) maximum heat transfer efficiency.

Reference has been made previously to CMX, Bldg. #679-G, as the location for extensive test work on small-scale exchangers representing designs being considered for plant use. It's extended use helped to solve a number of important process problems.

Early in January, 1951, it had been decided to provide permanent facilities for compiling basic data on the characteristics of the Savannah River water to be used in the design

and operation of #100 Area process equipment. For this purpose operating conditions would be simulated by treating, heating and passing river water through the shell-side of test exchangers. Shortly thereafter it was proposed that unclarified river water should be used in the heat transfer equipment. ERL, following a brief study, recommended a three-point program. First, plants along the Savannah River should be visited to learn of their experience with raw river water. Second, a small shell-and-tube exchanger should be installed at the plant as soon as possible to take cooling water directly from the river. Third, as soon as a final heat exchanger design was selected for the first reactor, a model or section should be procured and tested in parallel with the exchanger used in water fouling tests. Also to be included in the facility was a closed process water system consisting of a heater, a test converter containing reactor Q-tubes, high pressure pumps, test heat exchanger, and a heat recovery unit. CMX, constructed to contain these test facilities and placed in operation in July 1951, thus came to supply much information of value in the design and improvement of water treatment and heat exchange equipment, and verified the performance of reactor components. Test results were summarized as follows.

"The fouling of heat exchangers by raw Savannah River water was satisfactorily controlled by intermittent chlorination, to protect against biological growths. Only 2 per cent loss in heat transfer capacity occurred when intermittently chlorinated raw river water was employed in experimental heat exchangers (1/100th of full size) for ten months at temperature levels corresponding to reactor design power. This method of water treatment is satisfactory for power levels up to at least 1200 MW.

"Continuous chlorinated raw river water is also a satisfactory coolant if heat exchangers are cleaned once or twice a month to remove accumulated deposits. Plant prototype exchangers averaged 97 per cent of their original heat transfer capacity in a three-month test with continuously chlorinated water; the exchangers were cleaned every three weeks with oxalic acid. When the cleaning treatments were omitted, the exchangers lost 30 to 50 per cent of their efficiency over a three-month interval.

"Heat exchangers fouled by raw river water that was either intermittently or continuously chlorinated were cleaned while in service by maintaining oxalic acid at a concentration of 100 p.p.m. in the raw water for several hours. The cost of cleaning a plant heat exchanger with oxalic acid is estimated at less than \$1,000.

"The fouling characteristics of river water was not

altered greatly by conventional clarification and filtration of the water for removal of suspended matter. In an exploratory experiment, continuously chlorinated river water that was clarified with alum and filtered, fouled a small 9 sq. ft. exchanger less rapidly than did continuously chlorinated raw water, but more rapidly than did intermittently chlorinated raw water.

"Silt deposition is not expected in the plant heat exchangers when operated at design velocity of 2.4 ft./sec. No silt deposits were formed in plant prototype exchangers in nine weeks of operation at a velocity of 1 ft./sec. with raw water that had been settled for four hours to simulate the retention in plant reservoirs."

It will be recalled from the discussion of building arrangement designs in an early section of this history that originally the exchangers were to be mounted vertically. A horizontal arrangement was adopted for the R Area. As late as October 1951, however, the opinion persisted in some quarters that a vertical mounting could reduce building volume. The general building arrangement was reviewed again and it was agreed that although a two-shell vertical arrangement would be more attractive from a moderator hold-up basis, the shells would project into the reactor room and, since this was an intolerable condition, further study was considered unjustified.

In the meantime, progress in design and plant construction made it possible for the Purchasing Department, in October 1951, to issue requests for quotation on 50 additional exchangers. This, with the original order, would provide 12 for each area and two spares. Prospective vendors were given the opportunity of quoting on either 12 exchangers or the entire group.

After reviewing quotations du Pont, in December 1951, recommended to AEC that Alco be awarded an order for 12 units and Foster-Wheeler an order for 38 units. The Alco exchangers were to be fabricated at a small premium "to maintain construction schedules and provide a second or alternative source of supply to protect tight schedules established on the initial #100 Areas." This plan was approved by the AEC.

In the time intervening between issuance of the first order to Foster-Wheeler for 12 units and the second order for 38 units, design development had produced several significant changes. Tube ends were to be welded as well as rolled into the outer tube sheet to prevent leakage. O-ring seals were placed on the staybolts. To ease the handling problem the exchangers were mounted on railroad car trucks. The number of tubes was increased from 8800 to 8981 and the length of

each tube from 27 ft. 5-3/4 inches to 29 ft. 2-1/2 inches. This increased the transfer surface to 33,500 sq. ft. which became necessary when experiments proved that assumed heat transfer rates had been too high. In place of two 7/8-inch thick tube sheets, one sheet 1-1/2 inches thick and one 1-inch thick were used. Finally, an inverse dished head with diffuser vanes replaced the flat head to minimize the D₂O hold-up.

As Foster-Wheeler proceeded on the fabrication of the exchangers, continuing development work clarified numerous construction details, outlined testing specifications and cleaning procedures.

The cost of each heat exchanger was approximately \$420,000 including stainless steel plate and tubes furnished the fabricators by other du Pont vendors.

By early 1952 small-scale exchangers of various designs under consideration had been placed on the test line at CMX, but no full-scale units had been subjected to process conditions. The first unit fabricated by Foster-Wheeler, therefore, was shipped to NYX and installed in January 1953, in one of the six main circulating systems. During this test it was subjected to 12,500 g.p.m. flows for an extended period and to flows as great as 16,000 g.p.m. for short periods. Repeated thermal shocks were induced by simulating conditions of emergency scram, sudden cessations of cooling water and process water flows, and operating conditions representing 300 and 700 MW. Heat transfer coefficients were carefully checked.

Results were completely satisfactory, the thermal shocks producing no process liquid leakage and very little secondary coolant leakage. Heat transfer coefficients met specifications. Some minor items were noted and corrected, with details on these being included in the report.

Tubing

Anticipating a major procurement problem in supplying heat exchanger vendors with the stainless steel tubing required - eventually about 3000 miles of 1/2-inch tubing were purchased - the Purchasing Department initiated contracts with vendors in February 1951. Fourteen companies were advised of the program by telephone and in March representatives of six redraw mills attended a meeting in Wilmington to discuss capacities, testing procedures, sizes, delivery schedules, priority assistance, material analyses and the qualities of welded and seamless tubing.

Simultaneously the possible use of aluminum tubing was

being investigated. Its service under exposure to D₂O was satisfactory, but data gathered on aluminum in Savannah River water service indicated a life of only three to five years and all procurement was consequently limited to stainless steel.

By late March agreement had been reached on the use of 1/2-inch tubing and plans were formulated for procuring 550,000 lineal feet per month for 30 months or a total of 16,500,000 lineal feet. Four redraw companies, Agaloy, Ellwood-Ivins, Superior, and Bishop contracted to supply a total of 400,000 feet per month, leaving a deficit in requirements of 150,000 feet. After an intensive review of industry capacity, Republic Steel was given an order for this monthly quantity of welded, swaged tubing.

Discussions of tube materials naturally covered the relative merits of welded and seamless tubing. Although seamless was generally preferred, experience seemed to indicate that such tubing was not superior to welded when both were produced by redraw tubing manufacturers following aircraft hydraulic tubing standards. To confirm this experience, further test work was planned by ERL, and by June 1951 the laboratory could report that samples of seamless, welded drawn, and welded swaged tubes were consistently and equally good. These had been subjected first to 60 to 70 p.s.i. Freon pressures, second to 5000 p.s.i. hydraulic pressure, and finally to a bursting pressure.

Thorough testing of each piece of tubing in the vendors' plants had been urged by ERL and such arrangements were made, du Pont to supply the testing machine and test specifications. All tubing was to be tested hydrostatically at 5000 p.s.i. and held at this pressure for at least 30 seconds. Any tube showing evidence of bulging, leaking or weeping would be rejected. At the last minute, however, the redraw mills declined the testing responsibility and the du Pont M&E Section was assigned the task. Foster-Wheeler cooperated by providing space and labor to conduct the tests and, by late December 1951, these had been completed on the first production runs. Of 7915 pieces of seamless, five were rejected and only 20 of 11,380 pieces of welded tubing were rejected. No welded swaged tubing had been received. Two months later more extensive testing demonstrated leaks in .06 per cent of the seamless tubing, .14 per cent of the welded and drawn tubing, and .41 per cent of the welded and swaged tubing.

During these tests it had been felt that any tubes passing the 5000 p.s.i. hydraulic test were equally good regardless of type. For more definitive information it was suggested that Probolog testing might be valuable. During the fabrication schedule reviews held in February, the monthly

requirements were reduced and a decision had to be made on the type to be cut back. For that reason a program was initiated to obtain more evidence of tube soundness. Under this plan, 1000 successfully tested tubes of each type were to be selected and retested at 5000 p.s.i. for 10 minutes with Probolog examination to follow. Samples of Probolog detected defects were to be cut out for microscopic and macroscopic examination at ERL. These defective samples were to be subjected also to bursting and pull tests.

Evidence accumulated under the new program indicated the Probolog tests were inconclusive, no correlation having developed with microscopic and bursting tests. Welded drawn tubes from one source were, however, consistently defective. In May new tubing specifications were prepared, increasing the severity of the hydraulic tests. As a result, specifications for the SRP tubing were much more rigid than any standard commercial requirements.

As fabrication of the exchangers proceeded it was decided that as much seamless tubing as possible would be used and in this the Purchasing Department received very active assistance from the NPA. By January 1953, it was estimated that 65 per cent of the tubing in the exchangers was seamless, 15 per cent was welded drawn, and 20 per cent was welded swaged. Only one type was installed in any exchanger.

Total tubing shipped by the various vendors at the completion of the order was as follows:

		(Million Lineal Ft.)	
	<u>Welded</u>	<u>Welded & Swaged</u>	<u>Seamless</u>
Agaloy	.844		1.960
J. Bishop	.232		2.708
Ellwood-Ivins	.042		1.103
Superior	1.291		1.843
Allegheny-Ludlum			.230
Pacific			2.718
Republic		<u>3.515</u>	
Total	2.409	3.515	10.562

All tubes were cleaned by the vendor before shipment. They were first immersed in a hot tri-sodiumphosphate solution in which positive, high velocity flow was directed to each tube by a circulating pump and weirs. In the second tank, a hot water rinse, high velocity flow was provided as well as an air purge. Cleaning was completed with a second hot water rinse. All cleaned tubes were packed in paper-lined boxes which were sealed with water-proof paper.

In assembling the heat exchangers the two vendors found it impractical to maintain the required close tolerance on the 9000 matching holes in each of the four tube sheets of an exchanger. By the time the tube sheets had been formed and drilled, however, they represented a sizable investment and two alternatives for the use of sheets not within tolerances were approved. At the same time limitations were placed on the number of deviations from standards permitted in any tube sheet. Two categories of oversize drawn tubes were established, the largest being only .012 inch beyond the standard set by the specification. When tubes in the largest oversize category were used, the tube sheets and the 13 baffle plates could be remachined. In the case of the smaller oversize tubes only the tube sheets had to be adapted. In some cases it was possible to use standard size tubes where a hole was larger than a matching hole in sheets at the other end of the exchanger. In such cases the one tube end was pre-expanded.

To eliminate the human element as much as possible, the specifications for exchanger fabrication stipulated controlled torque expanding. By maintaining the clearance range between the tube sheet hole and the tube within close limits and expanding at a set torque, the joints were kept uniform and over-expanding of the tube was minimized.

Heat Exchanger Schedules

To arrange the timing of heat exchanger deliveries to the field a meeting was held in February, 1952, and a schedule was agreed upon for the five #100 Areas. This included only six exchangers for four areas, 12 for the C Area and one for NYX, since neither the supply of D₂O nor the completion of the cooling units would allow the initial installation of the 12 planned for each area without delaying the start-up of the several areas. At this meeting fabrication was released on 38 units and it was agreed that after fabrication of the 35th unit a further review would be made of the schedule.

This review, held in January 1953, revealed that only 23 units would be completed by the end of 1953 although many more would be partially fabricated. It was estimated that approximately 10 additional months would be required to obtain materials for the remaining 24 units not released for fabrication. Fabrication on all remaining units was released in March. This facilitated the flow of material to the vendor's shops and insured the lowest possible cost per unit.

The R,P,L and K Areas were designed for six pairs of exchangers, the D₂O to flow in series through each pair, but only six exchangers were installed in each area at start-up.

In the C Area, where 12 were initially installed, both coolants flow in parallel through each pair of exchangers.

HEAT EXCHANGER CLEANING BEFORE USE

In line with precautions taken on all equipment that would come in contact with the moderator, a "white cloth" test was specified as a check on heat exchanger cleanliness. A specialist in the cleaning field, Dowell, Inc., was employed to develop cleaning procedures which basically began with the belief that both an acid and a detergent wash would be necessary. It quickly developed, however, that physical problems in handling the acids and washes in quantities required for the large exchangers made the method impractical. It was also concluded, after considerable deliberation, that since both the tubes and core rods had been acid cleaned by the vendor this stage could be eliminated from the final cleaning specification. In December 1952, detergent cleaning and rinsing by using swabs or cloths, was adopted.

Five exchangers had by this time been fabricated and, for lack of floor space or facilities at the Foster-Wheeler plant, these were shipped to the Savannah River Plant where final cleaning methods were worked out. Authorization was received, however, to erect a Government-owned building at the vendor's plant and to equip it for exchanger cleaning. The estimated expenditure was \$100,000.

All efforts by the field to clean by the patch-draw or swab method proved laborious and time consuming and experiments were started with a felt pellet-drive method. This proved just as effective and consumed fewer manhours. This became the accepted method and Foster-Wheeler was instructed to use it on the remaining units. In the meantime six additional exchangers had been completed and cleaned by the swab method. Although attempts were made later to clean by forcing a nylon brush through the tubes by hydraulic pressure and by a turbannular flow using a De Vilbiss air gun, these did not improve cleaning or cut costs and all subsequent units were cleaned by the pellet-drive method.

To overcome its cleaning problems Alco proposed the erection of a building similar to that at Foster-Wheeler, but the expense could not be justified and all of Alco's exchangers were shipped to Foster-Wheeler's Cartaret, N.J. plant for cleaning.

HEAT EXCHANGER CLEANING AFTER USE

Since the production capacity of a reactor depends directly on the efficiency of heat transfer apparatus, extensive fouling of heat exchanger surfaces cannot be tolerated.

As experimental data accumulated on the effect of Savannah River water on cooling equipment, the tentative assumption that treated, clarified water only could serve as a coolant was discarded and preparations were made to circulate unclarified but settled raw river water. Attention was then directed toward the removal of the film deposits that might cause the fouling coefficient to exceed $f=1000$ used in the exchanger designs.

In May 1952, a tentative cleaning process was proposed in which inhibited 10 per cent sulphuric acid would be circulated through heat exchanger shells during reactor shutdowns. By the following month, however, experience at CMX resulted in adopting as a cleaning process the periodic addition of small amounts of oxalic acid to the river water during operation. At that time facilities were planned for the preparation of a 10 per cent oxalic acid solution and suitable pumps and piping to permit the addition of this solution to the inlet of any heat exchanger and to the two 42-inch supply headers. By continuous addition of the acid for periods up to one hour, the acid content of the cooling water would be increased to 100 p.p.m., a concentration sufficient to clean the equipment without damaging materials.

The cleaning equipment installed in each reactor building includes an 800-gallon dissolving tank equipped with a charging hopper for flake oxalic acid. Acid dissolution is hastened by an agitator and steam heating of the water. The acid solution is delivered by a 15 g.p.m. pump through pipe lines connected to each exchanger and the supply headers. All facilities handling the 10 per cent acid solution are constructed of Type 316 stainless steel.

UPFLOW COOLING SYSTEM

As was pointed out in the section entitled "Equipment Development, Assembly Area", the control clusters are unique among the reactor components in that cooling water flows up through the tubes and is discharged into the tank just below the top shield and above the poison plate. Plans for downflow from the plenum chamber, the method adopted for all other components, posed a singular and serious problem in the control clusters. To prevent cooling water under plenum pressure from rising into the extension rods leading to the actuators, a tight sealing gland had to be included in the design. This imposed a serious load on the control rod drives and adversely affected sensitive control of the actuator position. Up flow cooling consequently was adopted with the following distinct advantages:

1. It avoided the provision of a pressure-tight seal around the extension rods.

2. It offered an excellent method for introducing cool moderator into the tank in a distributed pattern without resorting to special distributors or spargers.

3. It improved heat removal from the bottom plate of the top shield and the poison plate by presenting a positive flow of cool water in that region.

Total flow requirements through the upflow cooling system were dictated by the sheath temperature of the rods and the prevention of stagnation and excessive temperature rise in the moderator in the reactor. To maintain this "fresh, cool" condition it was estimated that approximately 10 per cent of the total heavy water circulation had to be added at the top of the tank level. As this volume flowed down through the tank its increase in temperature would approximate the temperature increase in the coolant passing down through the quatrefoils. The flow for each control cluster was set at 85 g.p.m., the total for the 61 clusters reaching 5200 g.p.m. This effectively cools the control rods and gives an adequate moderator turnover.

A supply of heavy water for upflow cooling originates in a branch line downstream from the heat exchanger in each of the six pump circuits. These lines are joined to a circular header mounted under the bottom shield of the reactor and from this individual lines run to each control position. Cooling water enters the cluster through the upflow cooling water pin, actually a spiral, shielded insert which, at its upper end, engages a special fitting attached to the bottom end of the septifoil. This fitting incorporates seven restrictive orifices which impose a large pressure drop and thus maintain a flow balanced among all channels of the septifoil regardless of the individual rod position. The upstream pressure at the orifice is about 85 p.s.i. and this, contrasted to the supply pressure of about 190 p.s.i., permitted the use of high friction loss, small piping and the desired small moderator hold-up in the system.

SCRAM AND STORAGE SYSTEM

In each area the following quantities are required to fill the reactor and the various parts of the cooling system.

	<u>RPLK</u>	<u>C</u>
Reactor tank	94 tons	126 tons
Fuel and producer elements	10	10
Plenum chamber	7	7
12 Heat exchangers	53	53
6 Pumps	3	3
Pump suction piping	19	30
Pump discharge piping	14	23

	<u>RPLK</u>	<u>C</u>
Purification system	8 tons	8 tons
Overflow and drain systems	5	5
Monitoring and miscellaneous	<u>1</u>	<u>1</u>
Total per area	214 tons	266 tons

With 222 gallons of D₂O per ton, this represents a total of about 48,000 gallons for each area.

If an emergency condition arises, it is possible in this type of reactor to remove the moderator quickly and prevent sustained reaction. An early scope of work proposed such a method of "scramming" the pile but indicated it would be primarily intended to reduce reactivity when, under shutdown conditions, some of the control rods might be removed for maintenance purposes, leaving a reduced control surface. In this scope it was suggested that an evacuation rate of two feet per 10 minutes would be acceptable. After such a scram, however, three feet of moderator would be retained in the reactor to avoid loss of suction on the pumps and an interruption of coolant flow to the components. The vessel receiving the heavy water was to be large enough to hold the contents of the entire system.

Before design had progressed very far consideration was given to the practicability of scramming the liquid contents of the pile in three seconds, a rate comparable with the simultaneous release of all safety rods into the reactor. Design studies indicated that to approach this rate the entire tank bottom would have to be used as a rapid-action dump valve or a pumping capacity four times that required for normal operation would have to be installed. Discussions led to the adoption of a compromise rate of two to three minutes. At the same time it was agreed that the depth of the moderator remaining in the tank could be four feet above the bottom of the fuel column.

Plans for the scramming system changed from a single tank in a pit directly under the reactor to two tanks in a pit and finally to two tanks in a separate room at the minus 40-ft. level. Gravity flow, preferred for several reasons, was retained. It offered the simplest control and afforded a positive method for limiting the amount of moderator withdrawn. The scram tank was sized at 12,760 gallons and so located that when the desired quantity of moderator has been withdrawn the liquid level in the tank has reached that of the moderator remaining in the reactor. This scram tank is supplemented by a storage tank with a capacity of 38,000 gallons into which all heavy water still contained in the system can be pumped. When this is done a normally removed spool-piece is replaced in the line between the scram and

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storage tanks and the moderator is pumped from the scram tank to storage. As this is carried out, the water level in the reactor lowers by gravity flow into the scram tank.

To initiate liquid scrambling, the operator at the D20 panel in the central control room pushes several buttons which are properly protected against accidental operation. Valves in the six 6-inch lines branching from each of the 20-inch pump suction lines are thus opened and the heavy water is dropped through these lines into a 14-inch header, through which it flows to the scram tank. Total time required is approximately 2-1/2 minutes. Pumps connected to the scram and storage tanks return the moderator to the reactor system.

OVERFLOW SYSTEM

Precise pile control requires a constant moderator level during operation. To offset the volume changes accompanying rapid temperature fluctuations at start-up and shutdown and the more gradual changes during operation, a level control and constant moderator input and overflow are included in reactor design.

The liquid level is maintained by continuously adding from an overflow tank a stream of about 15 g.p.m. and allowing the excess to flow over a fixed weir which is 1/2-inch above the upper plate of the top shield. All effluent from the weir returns to the overflow tank.

When design began, the overflow system pump was to deliver 45 g.p.m. of which 30 g.p.m. was to be metered to the purification system and 15 g.p.m. to the reactor cooling system. In considering the problems involved in decontaminating a system in which a slug rupture has occurred, it was concluded that the feed stream to purification should be drawn from a flow location in which liquid turbulence favored suspension of the contaminating particles. For this reason the piping design was revised to obtain this feed from the discharge side of one of the main circulating pumps. Connections were, nevertheless, retained for a purification feed from the overflow system when the main pumps are at low speed and pressure is too low to feed the purification area.

The overflow tanks originally installed had a 600 to 800-gallon capacity or enough to accommodate volume changes resulting from temperature fluctuations in the reactor. Late in 1953 these tanks were replaced in all areas by 2300-gallon tanks large enough to accept the overflow originally considered plus the contents of the plenum chamber when this is drained prior to a reactor discharge.

The overflow system operates continuously while the reactor is in production. To eliminate the necessity of a re-

actor shutdown when the overflow pump fails, the overflow lines are connected to the drain-tank. This with its submerged pump can then operate as the overflow tank and pump while repairs to the inoperative pump are completed.

BLANKET GAS SYSTEM AND VENTING

To exclude N₂ and to pick up D₂O decomposition products and transport them to the purification area, an early scope of work specified the inclusion of a helium blanket above the moderator in the reactor. By using a high ratio of helium to decomposition gases and by continuously removing these gases in the recombination reaction, the accumulation of explosive concentrations is prevented.

This section deals only with those parts of the reactor and auxiliaries that handle blanket gas. Design development of the recovery process is treated in the history section on the purification area.

With the moderator held at a constant level 1/2-inch above the top shield there remains a 12-inch space between the water level and the bottom of the water plenum chamber. This space is the gas plenum. Helium, at low pressure, flows from the purification area into the gas plenum at about 1000 c.f.m. As it emerges from the plenum it is passed through a cyclone separator to remove any entrained D₂O. Residual pressure is sufficient to return the gas to the purification area, pressure in the plenum being maintained at about 10 inches H₂O above atmospheric. To prevent the possibility of damaging overpressure or vacuum in the reactor, a D₂O-sealed relief pot is installed in the 6-inch helium line entering the gas plenum and a second on the exit line.

Among the reactor auxiliaries there are a number of tanks that normally or occasionally contain D₂O, and all of these were vented originally to the blanket gas system. This excluded moisture-bearing atmosphere, minimized D₂O losses by evaporation, and conserved helium. When any part of the liquid in the reactor system was drained to an auxiliary tank, the helium was displaced and moved back into the reactor. The interconnection of the tank vents also served to assure a uniform gas phase pressure throughout the system and this, in turn, enhanced the reliability of gravity flow which in some cases depends upon a relatively small hydraulic gradient.

After the plant was placed in operation, it became clear that the interconnection of vents presented some disadvantages. Heavy water, inadvertently drained from the reactor circuits into the auxiliary circuits, could fill the drain tank and if undetected would enter the other auxiliary systems through their vent lines. If this continued, the pressure vacuum breakers would flood, D₂O would spill and the

safety protection afforded by the breakers would be lost.

The extension of all vent lines to a level higher than the water level in the reactor, and the connection of these to direct excess water to the reactor was recognized as the ideal solution. In some cases this was impractical for the extensions would have had to pass through the 6-foot thick zero elevation floor and would have interfered with the operation of the charge and discharge machines. Most advantages of the solution were obtained by the following changes which only partially altered the design of the venting system.

1. The pressure vacuum breakers were moved to the zero elevation floor and were designed more compactly to avoid interference with the charge and discharge machines.

2. Vents of the scram, storage, and leak collection tanks were removed from the blanket gas system. These tanks now vent to atmosphere.

3. An automatic valve was added to the 6-inch line leading to the purification area. If severe flooding occurs this valve can be closed to restrain D₂O from entering the gas system.

4. Instruments were added to give more reliable indication of normal and abnormal liquid levels in the auxiliary tanks.

LEAK COLLECTION AND DRAINAGE

Because D₂O is expensive, reasonable operating costs can be achieved only if all equipment through which the heavy water passes is leak-free or provisions are carefully made to collect the quantity lost through leaks. Similarly, handling losses during maintenance must be avoided.

In surveying the variety and size of the equipment necessary in the reactor system it was concluded that the ideal of a completely leak-free system would be impractical. Instead, over-all economy could best be served by tolerating a slight leakage at some points with care taken at such places to install equipment to recover the liquid and return it to the D₂O system.

Throughout design and construction every practical measure was taken to avoid loss of heavy water through defective equipment or piping. The number of pipe joints was kept to a minimum consistent with construction and operating needs. Flanged joints incorporated gasket materials proven by experience to be the most reliable for each type of service.

Threaded joints were excluded except in a few cases where alternate designs were not feasible. Where they had to be used, the threaded joints were sealed by welding or by a pipe dope, "Heldtite", which had been proven by prior use at the Chalk River plant. Equipment and piping welds were executed under exacting specifications and their soundness proven by extensive use of radiography, chemical penetrants, and pressure testing. Freedom from porosity in welds, castings and wrought shapes was insured by Freon or helium mass spectrograph tests, both of which are much more sensitive than the traditional air and soapsuds test.

The loss of fluid by valve stem leakage was prevented by selection of diaphragm-sealed valves of the Saunders patent or by the use of bellows seals. The few large-size valves and plug type valves not susceptible to this design were fitted with stuffing boxes containing two flights of packing. Any leaks through the first flight are trapped and piped to a collection pot. The second flight of packing prevents loss of D₂O to the atmosphere.

As was expected the restriction of losses at the process pump seals to a tolerable amount became an important design problem and it is in connection with these seals that widest application of collection equipment has been made. Mechanical seals were selected for their reliability and long service, but even with this type some leakage was anticipated. In fact, a small amount was deliberately permitted to serve as a lubricant and coolant for the rotating seal faces.

In the design and fabrication of the heat exchangers, painstaking care was used to insure perfectly tight joints. Although all the tube-to-tube sheet joints were proven leak-free before installation, it was not unreasonable to expect the operation stresses to produce leakage at some of the half-million joints present in the complement of exchangers installed in each reactor building. Provision therefore, was made to collect this leakage.

To serve the valves, pumps and heat exchangers and other potential leakage points, collection is made at approximately 60 separate locations. From each location a 1/2-inch stainless steel pipe extends into an area accessible during operation and there connects to a primary receiver. Each receiver is equipped with level indication and/or a high level alarm. Contents of these receivers fall into two categories. From some sources the leakage is suitable for re-introduction to the reactor system after processing through the purification area. These collections are piped to a drain tank and from there pumped to purification. In other cases, notably the pump seals and heat exchangers, contamination by light water or oil can be suspected and in these locations the collections are placed in portable containers or drums for more complete re-processing.

DRAINAGE SYSTEM

As described in the section on scrambling and storage, the scram and storage tanks are located at the minus 40-foot level. Moderator can be drained by gravity to the scram tank and from there pumped to the storage tank. Some heavy water inevitably remains in the system, however, and to permit complete drainage a 1000-gallon tank is installed in a pit in the pump room floor. Piping connections tie this tank to the lowest point in each of the six main pump circuits and several "pockets" in the D₂O circuits, such as the Rotovalve casings, from which complete drainage is not afforded by the slope provided in all process lines. Contents of this drain tank can be pumped directly to the storage tank. This tank, E.P. 208, which contains a submerged pump, is also connected to the overflow system to serve as a standby when maintenance is required on the overflow system. A second drain tank, E.P. 208.1, also installed with a submerged pump in a pit in the pump room floor is the collection center for possibly contaminated leakage.

As originally designed the two drain tanks received heavy water from both the leak collection and drainage systems. When it was discovered that some leakage might be contaminated, piping revisions were made to give each a separate function.

EMERGENCY COOLING AND MAJOR SPILL COLLECTION

A provision for cooling the reactor in the event of a major or total loss of the D₂O coolant was considered necessary although every reasonable measure was taken to minimize chances of a major pipe line break, pump casing rupture, or other serious breach. As an additional guarantee, therefore, it was decided to install a connection between the light water cooling system and a point in the D₂O circuit at or near the plenum chamber to assure a supply of at least 2000 g.p.m. of river water.

An 8-inch jumper was installed on each side of the X axis of the reactor to connect the river water header on each side of the building to the center or short 12-inch plenum feed line downstream from the Rotovalve. Double valving with intermediate bleed was provided to insure no cross-leakage. To prevent accidental operation of these valves, the controls are located behind glass panels in the central control room.

Aside from its effect on operation of the reactor, a major spill would result in a large monetary loss. Also, if light water cooling were employed over a long period, flooding and contamination of the building could follow. In the event of a spill the pump room can serve as a large basin. A 3-foot high dam is permanently installed at each doorway leading into the room. A 2000 g.p.m. sump pump is installed

in each of the drain tank pits and these can discharge the collected D₂O to an underground concrete storage tank, Building #106, which has a capacity of 60,000 gallons. This is about one and one-quarter times the moderator content of the reactor system. Piping to the concrete tank was so arranged that after the tank is filled the water from the sump overflows to the sewer.

SUPPLEMENTARY SAFETY FACILITIES

If at any time the control rods cannot hold the reaction within safe limits the safety rods can be lowered into the pile or the moderator can be quickly removed by a liquid scram. A third safety measure, completely independent of the other shutdown facilities, was proposed first in August 1951. As then conceived the system would, within one minute of initiation, inject 100 gallons of a borate solution into the moderator through the control septifoils. This scheme was abandoned some weeks later. However, when "LM" or enriched fuel loading of the reactors became an accepted reality in 1953, work was reinstated on a supplementary system.

The design requirements included consideration of solid neutron absorbers of various types as well as fluid "poisons". Any system selected was to be effective within three to ten seconds and was to remain operable through any mechanical disturbance (an earthquake, for example) that might misalign the plenum chamber and top shield. Were this type of an accident to happen, the movement of the control and safety rods could either be impaired or entirely prevented.

Attention was focused first on a safety rod consisting of nested cadmium tubes. Normally each rod would be suspended within a rod tube sleeve of the top shield. In any emergency the rod would be expanded telescopically into the reactor by air pressure either manually or automatically admitted. About 60 rods were planned for each reactor. Some effort was also given to a similar design in which rams would be propelled upward from the bottom shield. Both were rejected as too vulnerable to severe mechanical disturbances in which the disarranged fuel load would block entry of any type of rod.

Upon re-examining the merits of a liquid poison injected into the moderator, the system became more attractive since it was inconceivable that any mechanical disarrangement of the reactor could prevent its use. Several methods of getting the poison into the reactor were possible. Septifoils with upflow cooling provided ready channels for distributing the liquid through the top of the reactor after which it could follow the normal downward moderator flow of

about five feet per minute. Use of this method made it unnecessary to remove any fuel tubes. In a second method, specially designed spargers could be inserted through the bottom shield at several fuel tube positions. These could be so arranged that the poison effect would be almost instantaneous. Other important advantages existed in the system. The quantity of poison solution and the size of the injecting equipment could be kept small because of the relatively small hold-up. This permitted the efficient use of highly effective but expensive compounds of gadolinium and samarium as the poison. It was also felt that the spargers were more adaptable to possible future use with an automatic triggering device such as a "neutron fuse". Authorization was consequently given in March, 1954, to complete design for a sparger-type safety system.

In the final conception, two parallel injecting systems were installed in each reactor. Each consists of a 20-gallon storage tank, three spargers, piping and valves. Any one of the systems can stop reaction completely.

The storage tank contains 10 gallons of solution under 300 p.s.i. helium pressure which forces the solution into the reactor when a weight-loaded disk cutter punctures a rupture disk in the line. The weight is released through pneumatic relay by a manual switch in the central control room. Both poison systems operate from the one switch.

The sparger consists of two concentric aluminum tubes in which the poison flows upward through the annular space and into the reactor through holes in the outer tube. The lower end of the sparger passing through the bottom shield is made of stainless steel and is heavy enough to prevent the escape of radiation. A locking fixture anchors the sparger in place, seals against moderator leakage, and houses pressure connections for monitoring coolant flow to a target rod. This rod, which is identical to a control rod, is positioned inside the sparger to help preserve normal heat effects in surrounding fuel tubes. A small flow of water from the plenum chamber cools the rod.

A complete mock-up of the safety system was made and successfully tested at CMX prior to installation in the reactors.

EQUIPMENT CLEANING

In preceding reviews of equipment development the effect of heavy water cost and chemical properties on design has frequently been mentioned. Before the moderator could be introduced into the completed reactor system, final precautions had to be taken to free the system of any ionic impurities

that would increase decomposition rates, any dirt that could foul the heat exchangers or form radioactive matter that might settle on external equipment and make maintenance difficult, and any elements that would corrode aluminum components.

Theoretically a clean facility can be obtained at least cost by ignoring cleanliness until all units are assembled and connected at which time they can be pickled, washed and rinsed. In this case such a procedure could not be adopted. First, the strong reagents required to remove rust, scale and other contaminants would damage some of the components. Second, the complex geometry of the system prevented fluid velocities needed for thorough washing, sluicing and rinsing. Instead, it was decided that a satisfactory degree of cleanliness could be obtained only by employing suitable measures at each stage of equipment and piping fabrication. To establish uniform standards of performance for all vendors and the Construction Division, the Engineering Department prepared and issued two principal specifications. One, Du Pont Spec. No. 3056, covered the cleaning of austenitic stainless steel material, parts and subassemblies and fabricated products. The other, No. 3067 covered the cleaning of aluminum and aluminum alloys. These established inspection standards including careful visual inspection, a white cloth test, and a ferroxyl test to reveal any free iron on stainless steel surfaces. Beyond this the specifications described certain cleaning operations to be performed on different classes of factory, shop and foundry products, and listed several acceptable and unacceptable reagents. Recommended methods for sealing or packing materials for shipment also were included.

Procedural specifications were prepared for the final cleaning of certain large and complex items of equipment, such as heat exchangers and reactor tube sheets, and other items which were handled in sufficient quantity to justify a standardized procedure. The original intent was to have the construction forces at SRP do very little cleaning of parts and sub-assemblies, but a considerable amount was found necessary. In some cases cleaning by the vendor was waived by du Pont to avoid excessive charges or delays; in others the vendor's efforts had not been completely effective. Site cleaning was also required at times to remove dirt picked up in shipment and handling.

During erection, special measures were adopted to minimize contamination. Temporary enclosures were built in which air was kept at a positive pressure to exclude atmospheric dirt. For some jobs the workmen were required to wear clean coveralls and, occasionally, shoe covers. Demineralized water was used in hydrostatic tests of piping and equipment. Before separate pieces of equipment were closed and runs

of piping were connected, they were visually inspected and checked with the white cloth and ferroxyl tests.

Procedures were formulated for the final flush of the assembled reactor and hydraulic circuits. Demineralized water was circulated through the system by the main process pumps, screens in the 12-inch and 20-inch lines catching particles of any significant size. Filters in a by-pass stream removed finer particles. The final cleaning step was performed by operating personnel concurrent with functional testing. During this period a sidestream was fed through the Purification Area deionizers until the resistivity of the entire H₂O charge reached 1×10^6 ohms per cubic centimeter. After functional testing with a dummy reactor load was completed, the light water charge was drained. Residual H₂O was removed by application of vacuum and heat to some parts of the system and by the circulation of heated and dried helium through the remainder of the system. The plant was then ready for D₂O charging.

REACTOR CONTROL SYSTEM

Aside from the reactor itself, the development of a reliable reactor control system received a more prolonged and critical examination than any other problem associated with Building #105. The reactor's high specific power, large excess reactivity, large reactivity transients, and the regulation of neutron density distribution required a flexible and varied system of controls. For efficient and safe operation, a large number of several types of rods had to be subject by remote means to fine adjustments and swift, complete insertion into the reactor.

FUNCTION

Functionally the control system may be divided into two independent systems, the AH or safety system and the AG or control system. The safety system is a pushbutton control system with special provision for the release of the safety rods to "free-fall" in case of an emergency. The control system is a servo system for positioning the control rods in accordance with handset position commands. The control system incorporates a second or automatic control, closed loop, velocity servo system without the main, position demand servo loop which permits the reactor power to position a group of control rods so that a pre-set power level is maintained. The velocity servo also may be operated open-looped from the reactor and is used as an electrical means of setting the manual command.

The safety rods are normally operated as a group by a pushbutton control located in the control room. Limit lights

indicate rod position at the extremes of travel. The safety rods are raised and lowered by a cable wound on a grooved drum and coupled to a gear-motor by means of a dry powder magnetic clutch. Each motor and associated mechanical assembly is a motor package "B", containing a mechanical computing device. Under emergency conditions the magnetic clutch is de-energized, a d.c. voltage of opposite polarity is applied to the clutch for 1/10 of a second to assure fast break-up of the magnetic powder alignment and the rotary solenoid of a computer is de-energized. This locks one input to the computer differential. The differential then is driven at twice its drive-up speed to close a switch and re-energize the clutch when the rod has dropped approximately one-half the distance it had been raised. The drum is gradually snubbed and free-fall stopped, preventing the rod from striking the bottom of the tank. The package then lowers the rod to its lower limit position.

The safety system is interlocked with the control system to make certain that the safety rods are all withdrawn before any of the control rods are withdrawn. A mechanical weighing device on each safety latch determines that each latch has picked up its associated rod.

The AG control system is normally operated by manual command from the control room. A servo system control is cascaded to permit (1) sequential operation of all full rods in all clusters, (2) sequential operation of three separate gangs of full rods, (3) sequential operation of each cluster of full rods, and (4) group operation of half rods. Individual cluster trim operation is provided and may be used independently of the cascaded controls.

Master synchro generators are positioned manually to feed an over-all position command for the servo loop. These master synchro-generators feed through synchro differential generators so that the position command for any individual cluster of rods is the sum of the synchro generator and synchro differential generator commands. The position of the rod with respect to the commanded position is continuously checked by the synchro control transformers located in the control rod motor package "A" drive. Any deviation of the control rod position from the commanded position is transmitted as an error signal from the synchro control transformer to the servo amplifier associated with that control rod. The amplifier samples the error signal and, when it is beyond that allowed, a motor starting relay is closed that will drive the rod toward the commanded position until the error is insignificant.

A two-speed synchro system is employed with the servo amplifier taking the signal from a coarse control (transformer)

when the error signal is large and from a fine control (transformer) when the signal is small.—Sequencing of rods is accomplished through a sequencing transformer. Originally, stepping switches were considered for sequencing; but to eliminate a potential source of trouble, a transformer employing six outputs rotated 30 degrees electrically from each other was designed. The coarse command signal was put through the sequencing transformer and, by means of a switching circuit in the servo amplifier, the information for sequential driving is relayed to the rod drives.

It was considered unnecessary to provide "repeat-back" information. However, to be sure that the servo would never malfunction and that rods would not run away from the commanded position, a fault detecting circuit was included. This removed all but emergency shutdown control from a single rod drive if the rod it controlled was 7/10 of an inch or more from its commanded position.

There is a similar and separate series of synchro generators and associated equipment for half control rods. These have no velocity servo control and no provision is made for emergency shutdown.

Many special interlocks within the servo system and with reactor instrumentation were required. An interval regulator was provided for forced on-off withdrawal of the control rods until a process operating power level was reached. This interval regulator operated through the automatic control velocity servo when actuating a manual position command. Early installation difficulties with the velocity servo control required a close review of this system which resulted in replacement of reverse scram relays and redesign of the timer circuitry.

There are three classifications of emergency shutdown by the control system:

1. Scram I - All safety rods drop in and all full control rods drive in concurrently at maximum speed.
2. Scram II - All full control rods drive in concurrently at maximum speed.
3. Reverse - One gang of full control rods drives in sequentially at servo speed until the cause of the originating signal is corrected.

Provision also was made for remote operation of a single control rod and for remote reposition of any rod that is not at its commanded position.

DEVELOPMENT

It was decided at an early stage of design to incorporate producer elements in the control rods so that the neutrons necessarily absorbed to control the pile would not be wasted. Requirements could be met by 30 horizontal rods arranged in six vertical rows 60 degrees apart. Each row would contain five rods which would be adjustable to within 1/8-inch. Target material in the rods would have to be discharged and charged periodically.

This basic requirement was supplemented by a request for "striped" controls and "lightning rods". Striped controls consisted of a cluster of cylindrical rods and were so named because they contained alternating sections of neutron-absorbing and non-absorbing material in a regular pattern. These were to effect a uniformly distributed variation in the excess "k" of the central reactor zone. If, for example, a long neutron-absorbing cylinder is placed in a pile it reduces the pile's reactivity by an amount "dk" and lowers the neutron flux in its immediate neighborhood by a related amount. If a second cylinder, identical to the first, is placed in the pile some distance from the first the reactivity is reduced by "2 dk", there being little inter-action between the cylinders. If the second cylinder is moved into the neighborhood of the first, it approaches a region where the neutron flux has already been depressed. As it is thus "shadowed" by the first cylinder, its influence on reactivity is proportionately decreased until the two are side by side when total reduction is little more than that produced by one rod. By moving two such rods with respect to each other it is possible to control the reactivity of the pile rather precisely and to achieve a fairly uniform control of excess reactivity by distributing through the central zone of the reactor a number of rods whose length is small in comparison with the dimensions of the pile.

As visualized by AED, each striped control cluster would consist of two pairs of striped rods. Absorbing sections would be from 6 to 10 inches long; non-absorbing sections would be approximately three times as long.

As these rods moved up and down in a quatrefoil tube similar to those considered for fuel assemblies, the relationship of the absorbing sections could be varied through a wide range to open and close neutron paths. From 40 to 60 of these rods were to be spaced in a uniform pattern through the central zone of the reactor. "Lightning" rod controls were so called because their manner of functioning suggested the way in which an array of grounding points will draw an electrical charge from a passing cloud. Approximately 60 of these non-producing rods, made of boron or cadmium, would be held

normally within the top shield but could be lowered about one foot into the reactor zone. They could control the pile by shortening its length during short-term reactivity transients and could serve as a supplementary, fast-acting, emergency shutdown control.

The concepts of "striped" and "lightning" controls were abandoned later in favor of long vertical rods which offered a greater range of reactivity control.

The horizontal rods would provide safety control during shutdown and would give additional means of balancing the neutron density distribution, particularly in the top-to-bottom direction. They would enter the pile from the side in sleeves extending outward through the surrounding concrete shield.

When the American Machine & Foundry Company was awarded the subcontract for designing and developing the various rods and their control mechanisms, the three types of rods were included in the scope of work. Also included were emergency drives to function when normal drives became inoperable. Slow rod speeds were specified as 0.1 to 1.0 feet per minute, high speeds as 10 to 100 feet per minute and the emergency drive as 300 feet per minute.

The first study drawings were produced by AM&F in February, 1951, and became the basis for detailed discussions of rod designs. In May of that year doubt arose that horizontal rods could be operated reliably at the emergency speeds necessary for them to function as safety rods, and an investigation of the feasibility of vertical safety rods was started. There were to be 55 holes in the shields to accommodate 1-inch diameter safety rods; the safety rod drives were to be independent of the control rod drives; and safety rod thimbles were to be perforated for cooling purposes.

This approach tended to ease a difficult design problem but did not eliminate all requirements for horizontal rod and drive designs since some of these remained to perform a control function. It became apparent, however, that these rods, containing target material in aluminum jackets, would be susceptible to deflections that could interfere with accurate, reliable movements. Also, the internal supports necessary inside the reactor would absorb neutrons and seriously affect the nuclear efficiency of the pile. In addition, the huge building volume required for the operation, servicing and maintenance of the rods and their drives increased the volume of the moderator piping system. The additional building volume represented a substantial investment.

The design problems incident to any horizontal control method prompted a decision in May to adopt vertical movement

for all rods. From a pile operation standpoint, the new system offered the additional advantage of parallel rod and reactor axes which made control of the flux symmetry easier.

Following this decision many types of control rod operating mechanisms were evaluated by all available du Pont and AM&F talent. Proceeding actively for a year, this study reviewed 25 combinations of drives and drive locations in an effort to secure a rod actuating system that would be operable and reliable and meet at least five major design considerations: (1) any acceptable system had to include a suitable drive type, arrangement and location for the control and safety rods, (2) provide positive drive-down of the rods, (3) include facilities for delatching the rod at any position, (4) offer adequate shielding and, (5) contain a practical structure to support the actuators with means for raising and lowering the structure to permit tank loading and unloading and maintenance of the actuators.

By August 1951, five systems had been proposed. Two, designated "D" and "E", were significant developments.

Plan "D" featured a cylindrical "room" 20 feet in diameter by 34 feet high, gas pressurized to avoid contamination, in which control actuators of pinion and rack design, safety actuators of winch and cable design, and guide tubes were located. During operation the entire room, mounted on rollers, would be positioned over the reactor by moving it on telescoping rails. Three hydraulic rams located on the reactor room floor could precisely position the room over the reactor. When the reactor was to be charged or discharged, the room would be raised 36 feet through an opening in the process room ceiling which could then be closed by a horizontal sliding steel door. Maintenance on the room could proceed when this steel door was closed, when the steel door was open if the reactor was not being charged or discharged, or in the down position when the reactor was not operating. Flexible electrical cables, capable of following the descent of the room, would supply power to the actuators.

In plan "E" a movable, aluminum structure called a "forest" would carry vertical tubes with inner concentric members which would serve as guides for the rods. The actuators were to be located in the building area above the reactor room. During operation the "forest" would be placed over the reactor and would be moved into and out of the room by the 120-ton crane. A latch at the lower end of the concentric members of the guide tubes would engage the reactor rod and a latch at the top would engage the actuator racks by means of a large latching plate. This latching plate could be separated from the forest and raised above the crane

level by a hoist. Small openings in the ceiling of the reactor room would permit the passage of racks and cables of the actuators. Because the actuators were to be located in the building area above the process room, the electrical conductor cables did not have to move down through a ceiling opening as in plan "D".

Plan "D" appeared the more promising but there were distinct disadvantages and the search for an improved system continued. In September 1951, it was decided that the gastight enclosure for the "room" or actuator structure was unnecessary and continuing development led to the plan generally known as the "elevator" scheme.

This was a structural steel cage on which were mounted the safety and control rod actuators. The cage rested on top of the plenum during operation of the reactor, positioning of the vertical rods being effected by impulses sent from trailing overhead electrical cables. Prior to a reactor discharge, the rods were disconnected automatically from the actuators and left in the reactor. The cage assembly could, with the aid of vertical telescoping guides, be raised by cables and sheaves driven by a hydraulically operated cylinder into a cavity above the reactor room ceiling. A horizontal steel shield door closed the ceiling opening and maintenance work could then proceed on the cage while charging and discharging operations continued in the room below.

Actually this became only a stage in actuator development, since a closer scrutiny of its features during the preliminary design period indicated that its cost would be high, cable handling would be difficult, maintenance during operation would be almost impossible, and a serious situation could develop from a combination of a stuck rod and an inoperable motor. In October, it was decided to develop an alternative that would overcome the shortcomings of the elevator scheme.

To appreciate the complexity of the design problem, a summary of 17 specifications, set up in November 1951, is helpful.

1. All rods were to operate through the same vertical travel but would be operated in sequence.
2. A cluster of seven control rods would include full and half rods, independent of each other in operation.
3. The 61 control rod clusters would be divided into three gangs, one to contain 19 clusters, one 18 and the other 24. Provisions were later made for additional units.

4. Control sensitivity was to be adequate for a rod positioning accuracy and repeatability of 0.1-inch.
5. Maximum rod speed was to be 7.5 feet per minute.
6. Power applied to each rod should be sufficient to move a jammed rod.
7. Run-in of all rods on a "scram" should be accomplished in two minutes.
8. The design should allow changes in rod sequences.
9. Automatic control was to be provided for a cluster of seven rods or for the gangs in Specification 3.
10. Trim control was to be provided.
11. Design was to permit testing of individual rods in a septifoil.
12. Maintenance work on the actuator mechanisms was to be possible during charging and discharging operations.
13. A stuck rod was to be delatched in any position.
14. The top of the reactor was to be cleared for the charging and discharging of fuel elements.
15. Sixty-six safety rods were to be included in design.
16. Shielding was required to permit maintenance work.
17. Opportunities for equipment contamination were to be held to a minimum.

In weighing these requirements against a number of possible mechanical arrangements, attention was concentrated on three methods. In the first, the control and safety rod actuators would be permanently installed in a room over the reactor and holes through the reactor room ceiling would permit the rack extensions and safety rod cables to extend down to the "forest" on top of the reactor. The forest would be a structural frame supporting guide tubes to maintain vertical alignment of the rods. The second was the elevator scheme previously considered and in the third design, the cage would be horizontally removable. This would eliminate the expense of the elevator and the horizontal shield door.

The third alternative was accepted since time did not permit use of the first or second in the R or P Areas. It was stipulated that the reactor buildings in the R and P Areas

were to be so designed that the first alternative, which required a "top hat" structure for long racks, could be used at a later date if this proved desirable. It was also decided to proceed immediately on the development of the first alternative for Bldg. #105-L. Operating problems inherent in this method were recognized, however.

1. Because of the elusive nature of tritium contamination, such contamination of equipment on the movable cage would be a serious problem.

2. Because the control rod latch depended on a delatching plate with close tolerance holes for proper functioning and because delatching could occur only when the rack and rod were all the way down, such a design might result in jammed rods and a consequent major problem because of inability to delatch when the rods were not all the way down.

3. The large electrical connectors with their spring-loaded contacts did not offer maximum reliability, and contamination might keep personnel from manually engaging the large connectors.

4. Should a crane operating error occur, the cage could be damaged.

Maximum efforts during the next few months were devoted to the design and procurement of the equipment required for the R and P Areas and as time and personnel permitted, studies proceeded on the actuator scheme to be used in the L Area. In this simultaneous effort the disadvantages of having the actuators in the reactor room became increasingly apparent. First, if a breakdown of an actuator were to occur while a rod was performing a control function, the motor package on that rod would have to stay out of operation until shutdown. Second, it would not be possible to delatch a jammed rod. The L system would permit this. Third, the location of the motor packages and connectors on the movable cage could result in serious contamination problems because it was not considered possible to water wash the exposed electrical connections and motor packages without seriously affecting their operability and reliability. Fourth, serious electrical "check-out" problems were posed by the number of contacts on the large connectors that had to be re-engaged each time the cage was returned to the process room. Fixed electrical connections in a location accessible to maintenance personnel at all times were considered highly desirable. Fifth, the location on the cage of emergency power equipment for the safety rod drives was not an attractive arrangement.

At this time the control rod actuators consisted of an assembly of seven motor-driven gear reducers each driving a

15-foot long, vertically mounted rack. A latch at the bottom of the rack gripped a control rod and moved it through a vertical travel of 14 feet. The assembly, or motor package, contained synchros for reporting the position of the rods.

Individual drives planned for the L Area actuator system departed from this design in that the racks were 43 feet long and the actuators were mounted above the reactor room ceiling. Some doubt was felt that under this system a rod could be delatched in any position and, also, that a rod could be "driven down". This was a debatable point, some designers believing that the weight of the long rack would in itself push the jammed rod down. Others felt the rack was too heavy for the actuator motor. As an additional feature, guide plates were planned between the forest and reactor room ceiling and in the upper part of the building to prevent serious "bowing" in the long racks.

The latching and delatching device, considered a part of the forest, used on most of the schemes consisted of four jaws surrounded by a sleeve. As this sleeve was raised the jaws were cammed open. The sleeves were made a part of the rack with the sleeve extended up through the reactor room ceiling so that any differential motion between jaws and sleeve could be initiated from that point rather than the top of the reactor. In mounting the actuators above the reactor room ceiling with the seven rods in a small circle, it was impossible to meet the "push-down" specification established earlier and this was relaxed.

The promise of improved and more reliable operation contained in preliminary designs of the long rack and extended sleeve or "long latch" made it desirable to test their performance as soon as possible and AM&F was instructed to arrange the necessary facilities. Lack of building height in the tower of AM&F's Brooklyn Laboratory, where other tests had been conducted, led to the use of a stairwell in the new Chemical Building at the Argonne National Laboratory. Prototype actuator packages were installed there in February, 1952, and tested with prototype long latches. In addition, guide and match plates, delatching mechanisms, a dummy reactor lattice point and a simulated S-foil were installed. All tests were successful.

To review the status of design and procurement a meeting was held in February, 1952, at which it was proposed that development be directed toward general arrangement features rather than specific operating requirements. Specifically, all equipment was to be outside the reactor room; the forest would be vertically and horizontally removable; the actuators would be in a room above the reactor room; the latch would be operable from outside the reactor room; fixed electrical con-

nections were to be used; a simple lifting device or the 120-ton crane would be used to move the forest; all contaminated parts would be retained in the reactor room, and finally, there would be a minimum number of "prime movers". These were defined as any equipment for applying motive power to the rods through individual motor operators or ganged cable drives.

As a result of this meeting, continued development of the long-latch was approved and the following procurement plans were adopted.

1. Work on the R and P Areas was to continue on the basis agreed upon earlier.
2. Long-latch equipment was to be designed, procured and delivered to the R and P Areas by May 1, 1953 to replace equipment installed there.
3. Procurement was also to proceed on long-latch equipment for the L Area.

By March, three alternative long-latch schemes had been worked out. All met major requirements and the second of the three plans was adopted. This was approved for installation in Building #105-P, L and K with the movable cage design to be installed initially in the R Area if the long-latch equipment could not be obtained in time. Since two types of actuator systems were, under this plan, to be procured for the first two areas, the original scheme with actuators in the reactor room was labeled R1 and the newly approved long-latch scheme was labeled R2.

In the R1 method the structural unit or forest was to be carried into the process room and placed over the tank by the 120-ton crane. Twenty-eight feet high by 16 feet square, the cage contained three decks. On the center deck were mounted the 61 control rod actuators, each of which contained seven motor-driven units and the sensing portion of the servo system. Each drive unit was to operate a pinion and vertical rack through a gear train. At the bottom of the rack was a spring-type latch which was to engage the control rod tip. Each unit was to provide positive drive down of the rack and rod by containing the racks in guides which extended from the bottom deck through the top deck. The lower guides also provided a housing for the control rods during actuation.

From the control actuators on the center deck, electrical cables ran through the plug and socket type connectors to the 120 large connectors on each side of the cage above the top deck. The 240 large connectors were each to have 44 electrical contacts and were to be manually engaged and remotely

disengaged when the cage was moved into or out of the reactor room. The top deck of the cage carried the 65 safety actuators which raised and lowered the safety rods by means of wire rope cables and latches which engaged the rod tips. Each cable was wound over a grooved drum driven by a gear-motor unit through a dry powder magnetic clutch, the drum being rotated by the gear motor drive when the clutch was energized. The design requirement of a three-second scram on the safety rods was met by de-energizing the clutch leaving the drum free to rotate and unwind the cable supporting the safety rod.

The bottom deck of the cage carried storage batteries and charging equipment necessary to supply emergency power to the safety actuators. Collapsible platforms were located on opposite sides of the cage near the top and were to be used by personnel during manual engagement of the large connectors. Ladders gave access to the decks and platforms.

All drive packages had to be served through long flexible electrical cables with remote release connectors. These cables in turn were conducted through large openings in the floor of the amplifier room which was located above the reactor. When the cables were disengaged from the drive package connections on the cage, they were raised by small power hoists in the amplifier room. Fourteen such hoists were required for each building. The 427 servo amplifiers - one was necessary to control each control rod - were located in the amplifier room. The control room contained the full and half-rod control synchro units, and control panels for the safety actuators. Elsewhere in the building were motor generator units and storage batteries for normal and additional emergency power supply to the safety actuator drives.

No shield plate above the reactor room was necessary with the R1 design. The ceiling of the process room was to contain only the S-shaped slot openings required for the conductor cables to the actuators on the movable cage and the openings for the wire rope cables from the disconnecting hoists in the amplifier room to the large connectors located above the top deck of the cage. This plan, of course, had to be changed when the R2 scheme was adopted and holes had to be provided in the reactor room ceiling to match the S-foil lattice points of the reactor. Some extra holes were provided in the event control clusters were added for higher power level operation of the reactor.

In the R2 design the forest is about 15 feet high by 16 feet square and contains only the guide tubes for the control and safety rods. A match plate, containing the holes identical to those in the upper deck of the forest, is attached to a carrier lift deck by four rigid corner guide posts. The carrier deck is above the reactor room ceiling. The match

plate is attached to the forest by remotely operated latches so that the 60-ton hoisting equipment at the 130-foot level in lifting the carrier deck also lifts the forest. If necessary the forest can be left in place and the remainder of the assembly lifted out of the way. The 120-ton crane can then remove the forest from the reactor room.

The actuators for the control rods are identical to those in the R1 scheme but are permanently mounted at the 120-foot level. The safety rod actuators are located at the 130-foot level. Electrical cables are also permanently mounted. There is no change in the control system. Holes in the ceiling of the reactor room matching the S-foil lattice points permit the passage of rack extensions from the actuators to the top of the reactor.

The long-latch assemblies consist of concentric tubes which are supported during actuation by the racks of the control rod actuators and by the cables of the safety rod actuators. They can be telescoped 43 feet so that when the forest is raised that distance to clear the charging crane, the latch assemblies telescope and no rack movement is required. The actuator has the same rack drive of 14 feet as in the R1 scheme. Elevation drawings on pages 207 and 209 show the R2 actuator system in down and partially elevated positions.

In perfecting the actuator control system serious consideration was given to individual control and indication but this was dropped when space requirements were developed.

None of the several assemblies of the control system were available as ready-made units although all utilized commercial components to a major extent. A moderate amount of development was required to arrive at a satisfactory, trouble-free system. In the amplifier systems considerable time and effort was directed to improvements to the motor contactors, transient damping, signal detector temperature stabilizing, motor power fuse sizing and group fault re-set circuiting. The magnetic iron powder type, electromagnetic clutch, first selected, caused some trouble with "caking" but this was corrected by substituting a corrosion resistant powder.

The control rod actuators and the latch assemblies for the safety rod actuators were manufactured by the Ford Motor Company which had been selected as the vendor in January, 1952. When the R2 system of long-latches was adopted the R2 parts not common to the R1 scheme were added to the Ford order.

ACTUATOR TESTING

At various stages of design and development, full scale testing of the actuators and related equipment was required to make certain that requirements were being met with the re-

sult that installation and operating problems at the Savannah River Plant were forestalled. A convenient location suitable for some trials was found in a "tower" structure at the Brooklyn Laboratory of AM&F. There the motor packages of the control and safety rod drives with their related cable, rack and latch mechanisms were initially installed and the first mechanical and electrical tests were run on the actuators for the R1 scheme.

The erection of a reactor at NYX for hydraulic performance testing presented an excellent opportunity for actuator testing with a full-scale production unit. Three control and safety actuators were installed on a small, triangular-shaped movable cage over the reactor. Despite the care taken in reactor fabrication there remained the possibility of serious deflection between the plenum and tube sheet, therefore the effect of any such deflection on rod movements had to be determined. Incidental to this main objective were operator training programs and additional tests on actuator packages and control equipment.

At least one unsuspected difficulty of major importance was encountered. For the protection of the reactor it was absolutely essential that the actuators scram the rods from a "full-out" to a "full-in" position in three seconds. NYX experience proved that the solid-walled thimble as then designed for the safety rods would, if partially filled with water, prevent scram within the time limit. As a result, a thimble with perforated walls was adopted. Significant design improvements were also made in other parts of the control system, particularly in the electrical equipment.

Slow drop-out of the computer rotary solenoid caused the package to snub low. The clutch would de-energize and the rod free fall before the computer would set. The relaying is now wired to de-energize the rotary solenoid except when the package is being driven as the computer sees new information.

Lack of building height at NYX and AM&F's building in Brooklyn made it necessary, following the adoption of the telescoping long-latch system, to move the test site. The stairwell at Argonne was temporarily used but for more thorough testing a location usable for a longer period was required. The height necessary was equivalent to a thirteen story building. When a freight elevator shaft in the Veterans Administration Building in New York City was finally made available, the actuator test program was located there.

Essential parts of the R2 system were installed on platforms simulating Building #105 elevations and many problems in installation and erection were solved in time to enable the Construction Division to complete its work on the actuator structures and system with a minimum delay. Tests in the

VA Building also demonstrated repeatedly the ability of the long-latch assemblies to latch and delatch rods, to be moved through normal rod travel by actuator motor packages and to be raised and lowered through the 43 feet of movement required.

In the meantime, acceptance testing of motor packages for the safety actuators had disclosed inconsistencies in performance and a series of "scram" tests were added to the program at the VA Building. Production units with long-latch assemblies were subjected to extensive electrical tests to insure completely acceptable safety actuators at SRP.

Uncovering, as they did, a number of design and operating difficulties, the various tests proved the advantages of simulating field installations when possible. Had it not been for these tests it is probable that serious and expensive delays would have resulted at SRP because of unresolved design and operating problems.

Following the agreement of February 1952, design and procurement proceeded simultaneously on the R1 and R2 systems, the former to be initially installed in Building #105-R. When a status review was held in June 1952, progress on the R2 system encouraged the belief that it could immediately replace R1. This was confirmed by September and the R2 system was installed in the R Area without affecting the construction schedule of the building. All of the remaining #100 Areas were also equipped with the R2 actuator system.

Upon completion of construction, functional testing was carried out at great length to assure adequate performance of the equipment. The cascaded type of control system required the repetitive use of many plug-in type assemblies. To assure a high degree of sensitivity, rigid tolerances were specified. Special test equipment was provided to assure uniform testing of all components at the high standard required; and special test units were provided to assist in localizing troubles within an operating system. This special equipment used in conjunction with a group of Engineering Specifications for actuator checkout helped greatly in overcoming the numerous installation difficulties that were encountered. Operations accepted the Building #105-R equipment in October 1953.

During this test period many of the motor packages of the control actuators became inoperative when drive motors were stopped by thermal overload switches. In order to supply enough cool air to the blowers, a duct was installed under the control actuator deck at the 120-foot level and air ports were cut in the deck plate under each of the motors. In the R Area an auxiliary air conditioning unit was provided for evaluation purposes; but in subsequent areas unconditioned air was found to be adequate.

AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

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3 of 7

Design specifications for the #100-C Area were changed by the addition of 25 actuators.—Twelve control actuators and 13 safety actuators were added and additional instrumentation holes in the latch lifting carrier and all the actuator structures below the carrier were specified. These changes required modification of the related actuator structures and the large perforated metal units installed between Elevation 61 feet and 66 feet. By these changes the weight of the structure was increased approximately 20 per cent in Building #105-C. This, plus the likelihood that a number of long-latch assemblies would be added in the future, made it necessary to reinforce the carrier structure. Of the above changes introduced for C Area the provision of additional instrumentation holes in the various decks of the actuators was also made in Buildings #105-L and K.

SIMPLIFIED ACTUATORS

As the actuator development progressed, it became increasingly evident that the multifarious requirements imposed on the equipment as time went on were resulting in a complicated design, both of the mechanical parts and of the control system. Numerous reviews of requirements were made and some relaxations were effected. In spite of these efforts the design necessarily remained rather complex.

Several attempts were made to simplify the design, including the use of ganged drives, winches in place of the special gear-motor packages, and simple, semi-commercial gear units. None of these proposals met all of what were considered the basic, essential requirements so far as the control rods were concerned. Some time later, in 1954, the Savannah River Plant Laboratory developed an excellent inertia-braked safety rod hoist. This can be used as a replacement for motor package B if the non-fail safe magnetic clutch arrangement should ever prove troublesome.

ACTUATOR HOIST SYSTEM SAFETY STUDY

Knowing that the efficiency and reliability of the actuator system and its structure were critical to the operation of the reactor building, every feature was engineered with extreme care. It was felt, however, that a study of its structural aspects should be made to determine whether any additional safeguards were desirable especially in connection with the 60-ton hoist system. Such additional safeguards would further minimize the possibility of mechanical damage and prevent radioactive contamination that might result were a failure to occur. Such a study was undertaken in September 1953.

Before the study was completed, industrial accident statistics for hoisting apparatus published by the National

Safety Council, and the accident statistics for freight and passenger elevators published by the Otis Elevator Company, were examined. The margins of safety built into the hoist design at the plant were re-calculated and compared with standard practices. Information thus compiled indicated one failure per hoist in every 100 years of operation but, in view of the possible consequences of hoist failure, extraordinary precautions were considered justifiable.

An exhaustive analysis of 14 alternative safeguards was made with consultation by du Pont specialists, original vendors of the hoist equipment, and some 25 vendors of similar or related equipment. An adaptation of the "wedge and roller" device, widely used as a freight elevator emergency brake, appeared to offer the additional protection desired. Installation of the brake plus an auxiliary pinion tie-shaft between the hoist drums was decided upon.

To profit by the Otis Elevator Company's long experience in elevator design, du Pont asked Otis to furnish design details of the "wedge and roller" and to serve as a consultant on the final design of the braking system. In addition, Otis fabricated the first assemblies. The necessary laminated brake suspension bars, nominally 5 inches square and 60 feet long, were fabricated by the New York Shipbuilding Corporation and final assembly was performed at Wilmington Shops.

Load-distance characteristics of the design up to 120,000 pounds were obtained at Swarthmore College on a test wedge-roller and brake bar assembly. Load deflection characteristics were also determined on both ring spring assemblies of the shock absorber type that were being considered. Results conformed to Design specifications.

Du Pont designed, built and successfully tested the mechanical overspeed sensing and brake-tripping mechanism which is an important part of the braking system. It was found that the tripping device would activate the braking system within the first $3/8$ -inch of free fall.

Further assurance of the system's performance was obtained at the Savannah River Plant's Central Shops in November 1954. A full-scale mock-up of the hoist system was erected and in the test drop the 60-ton load in free fall was brought to rest within four inches and with a maximum deceleration force of 120 tons. No material failures were observed. To initiate this test a unique explosive rupture coupling, developed by du Pont, was used in the cable suspension system.

Installation and final testing of the braking system in Building #105-C was completed by the end of December 1954.

BUILDING # 105-SECTION THROUGH ACTUATOR
DOWN POSITION

PROJECT 8980
SAVANNAH RIVER PLANT

E. I. DU PONT DE NEMOURS & CO
ENGINEERING DEPARTMENT

R2 - SECTION LOOKING WEST

BUILDING #105-SECTION THROUGH ACTUATOR PARTIALLY ELEVATED

CHARGE AND DISCHARGE MACHINES

Perfection of a method for charging and discharging fuel and producer elements rapidly and safely was a major key to the successful development of the Savannah River reactors.

This material handling is accomplished by two cranes, one for charging and the other for discharging, which are remotely operated, precision mechanisms for lifting and carrying a variety of reactor elements. Their reliable, high speed, repetitive operations are semi-automatic. An entire program for loading and unloading a reactor can be pre-punched on a tape which, when fed into the crane control system, establishes all necessary data for the required operations.

FUNCTION

General

Page 213 illustrates the arrangement of the cranes and control console in Buildings #105-R and P. The physical arrangement is somewhat different in Buildings #105-L, K and C but the following general description of the equipment and its operation will suffice for all areas. Page 215 gives an exploded view of the crane, an examination of which precludes the necessity of a detailed description of mechanical drives.

The console and its related power and amplifier panels are located in the crane control room. Auxiliary equipment such as motor control centers and M-G sets are located in the crane equipment room directly below the control room. Control and power cables from this equipment to the crane are installed in cable trays up to the crane haunch or runway, and subsequently to the crane by means of a powered conveyor which follows the crane bridge movement and is known as the "cable slave".

The bridge motion is designated as "X", trolley as "Y", and hoist as "Z". The entire operating area of the cranes is divided into an imaginary X-Y coordinate system. The zero X and Y coordinates are outside the operating area so that all motion takes place within one quadrant. This coordinate network is used to identify motion of the X and Y drives. Z motion is indicated by elevation, in feet above absolute zero, absolute zero being below the normal operating range.

Console - General

The control of each crane is completely independent of the control of the other crane with the exception of protective interlocks. However, both are controlled from one console so that the operation of the two machines may be properly

coordinated. Either machine is capable of performing functions of charging and discharging the reactor. However, in normal operation, one machine performs charging operations and the other, discharging operations.

X-Y Drives

The controls of X and Y drives are similar and will be described as one. There are 4 "modes" of operation available to the operator.

1. Automatic - Automatically positions crane to the X-Y coordinates selected.
2. Manual - Variable speed manual control.
3. Emergency #1 - Fixed high speed drive using the main drive motor.
4. Emergency #2 - Fixed low speed drive using an auxiliary motor.

Automatic drive mode is used for normal operation at nominal maximum speeds of 180 ft./min. in X and 120 ft./min. in Y. The drives are closed loop positional and velocity servo type. Therefore, speeds vary from area to area because of variations in friction, backlash, and other factors affecting servo performance. Positional accuracy is $\pm 1/32$ -inch ($\pm 1/64$ -inch maximum electrical error and $\pm 1/64$ -inch mechanical error.) Positional accuracy is assured by use of a positive drive consisting of a rack and pinion on precision rails.

The X and Y positions are constantly indicated, in terms of coordinate location, on a "repeat back" dial. The X-Y position is also indicated by a miniature of the crane placed on a plotting board replica of the process area. This instrument is called the "tracker", and indicates to the operator at a glance the general location of both charge and discharge cranes. These repeat back systems are standard instrument servo systems employing two speed synchros for positional signal input.

For the automatic drive there are two "order input" systems, (1) "manual" and (2) "tape" (automatic). Both systems, insert a synchro signal input equivalent to the X or Y coordinate desired, the only difference being the method of insertion. Manual, as the name implies, requires the operator to insert an input order for each operation; tape is a programmed input, automatically inserted for each operation of a complete charge-discharge cycle.

GENERAL ARRANGEMENT
OF PRECISION CRANES AND
PRELIMINARY ARRANGEMENT OF
CONTROL CONSOLE

The X and Y drive systems include a complex interlock system to completely protect the crane in these motions against operator errors and physical obstructions.

The X cable slave conveyor is controlled by a closed loop power servo system using as its input a signal proportional to the difference in position of the crane bridge and the cable slave pick-up arm ("positional error" signal).

Z Drive

Installed on each of the three masts are chucks for gripping the various elements of the reactor. A functional description of these chucks will be made later. Each mast has its own mechanical drive system, and the one to be operated is selected at the console. This selection may be made by the operator with a manual selector switch or automatically by the tape input system.

There are three "modes" of operation available to the operator for Z drive.

1. Manual - Variable speed manual control
2. Emergency #1 - Fixed high speed drive using main drive motor.
3. Emergency #2 - Fixed low speed drive using auxiliary motor.

Manual drive mode is used for normal operation at a nominal maximum speed of 2 ft./sec. A speed selector switch provides four maximum speed ranges, 2, 1.3, 0.7, and 0.1 ft./sec., which can be selected by the operator to suit the operating conditions.

In addition, there are several functions which are auxiliary to the Z drive and must be operated in conjunction with the Z drive in a definite sequence.

1. Water pan - To catch moderator fluid draining off elements removed from the reactor.
2. Clamshell - To secure lower end of the element after removal and to guide element being inserted.
3. Chucks - To grip or release the element at proper time.

There are three Z drive sequences available for control of these functions and selection is made manually by the operator at the console.

1. Manual Sequence - Gives the operator considerable latitude in selecting manually a sequence of operation, however, through a complex system of interlocks the equipment is protected against damage due to operator error.

2. Semi-Automatic Sequence - Selects a definite sequence for the operator to follow, with each function manually controlled by the operator.

3. Automatic Sequence - Selects a definite sequence for the operation and performs each function automatically. The Z drive is manually controlled by the operator.

The position of the mast being operated is constantly indicated, in feet above absolute zero, on a functional representation of the mast called the "Z Tracker". This is an instrument servo system similar to those employed in X and Y repeat back data systems.

In case of mechanical or electrical failure of a crane during the performance of an operation, an emergency removal system is provided whereby several basic functions of the inoperable machine can be operated through the control system of the operable machine so that the machine can be removed from the process area.

For a detailed description of the control system and components see Volume I, Arma Corporation Instruction Manual, 2620-10,100.

DEVELOPMENT

When design of the cranes began it was decided that since the extent of contamination in the reactor room could not be precisely predicted they should be so designed that all their operations could be remotely controlled. At first, "gang" charging and discharging was proposed in which entire sections of the top shield and tubes would be removed and replaced as units. This plan was later discarded in favor of single tube handling. As a result the cranes were conceived as high speed, highly reliable, remotely operated units with precise positioning facilities and provisions for handling numerous emergency conditions.

To meet these general specifications, the cranes were first visualized as the cross rail, rams and ways of an extension-type vertical boring mill equipped with a working head on the end of the ram which could be used for connecting and disconnecting fluid lines or could be attached to tubes or shield sections. The crane would be able to lift a six-ton load, the equivalent of one top shield section, through a vertical travel of 24 feet and to move the load in any of

three directions at a speed of 10 feet per minute. These operations had to be performed with an accuracy of plus or minus 1/64-inch to prevent damage to components. The boring mill approach, which crystallized in August 1950, offered the ruggedness, precision, reproducibility of setting and motion scope apparently required by the reactor room crane.

Three major machine tool companies were contacted, the problem broadly described, and their interest evaluated. Only one, the Consolidated Machine Tool Company, expressed an interest in helping to solve the problem. As a result, Purchase Order AXC-1-1/2 was placed December 4, 1950 with this company for preliminary design and engineering assistance.

In mid-January 1951, Consolidated reported the result of its study. Its scheme for position location was to set an Invar bar in the X direction along the travel way of the crane with field-set stops at each reactor hole centerline and stops on the "crane" bridge for Y axis positioning. By using General Electric magnetic sensing devices these control stops could be used to send the machine remotely to any position on the X-Y grid so set up. Rack and pinion drives for rail and heads were favored because of probable mechanical difficulties with lead screws which are normal indexing drives on vertical boring machines. A weight sensing device was also developed.

About this time it was decided to abandon the gang charging and discharging concept (see Reactor Section) which eliminated a key specification of the boring mill, namely, the handling of a six-ton load. It developed too, that the speed capability of this 325,000-pound machine was definitely limited. Since the weight to be handled was sharply reduced and a higher speed was desired, a bridge and trolley crane appeared feasible as a carriage. The Consolidated study had clarified some design details which were immediately translated to a crane. These included the ram for vertical travel, the rack and pinion drive principle, and the closed-loop servo approach to precision positioning of the crane and ram. These rams are now commonly known as masts.

Because it did not manufacture this type of equipment, the Consolidated Machine Tool Company was eliminated by the new design approach. Consequently, bids were requested from major manufacturers in March and resulted in a purchase order issued to the Whiting Corporation (AXC-224-1/2) in late May 1951. The order covered 10 overhead cranes, each with a capacity of 3 tons, a span of 39 feet, a lift of 21 feet 6 inches, sets of runways rails, but no cab. Du Pont was to furnish all control equipment.

Having devoted some time to study of crane positioning, several representatives of the Argonne National Laboratory visited Wilmington in mid-January 1951. At an engineering review attended by du Pont and ANL personnel, the vertical boring mill concept of the charging and discharging cranes was discussed. ANL personnel agreed in principle with the approach and advised that they had some positioning schemes which could be of value. In early March, du Pont representatives visited ANL to witness highly successful demonstrations, on a small scale mock-up, of their servo-mechanism control system for positioning a crane within plus or minus 1/4-inch of the lattice position; and with a probing device placed the crane within plus or minus 1/64-inch over the centerline of a reactor lattice position.

The coarse positioning was accomplished by conventional use of servo-mechanisms using synchros for input signal. A small diameter pin with conical top, permanently positioned on top of the reactor at an exact distance and orientation with respect to the lattice position, served as a reference. The crane mast was equipped with a small pendulum mounted on the carriage with a retractable female probe mounted at the lower end.

After the crane was positioned coarsely, the hollow cone probe was lowered until it rested on the conical top of the pin. If the hollow cone center did not coincide with the pin center, the pendulum was deflected and contacted limit switches which energized motors moving the crane to permit the pendulum to hang plumb. This positioned the mast precisely over the lattice point without oscillation.

Evincing considerable interest in the arrangement, du Pont received an ANL agreement to write a tentative specification covering requirements of the control system. This was received in April 1951.

"Tentative Specifications for CP-6 (loader) Controls" described control aspects of the successfully demonstrated model extrapolated for use with plant-size equipment. It covered two similar cranes, traveling on the same set of rails, one for loading and the other for unloading, and individual controls so both could operate at the same time. The cranes would have specific features such as precision rails, precision gearing and a rigid vertical boom. The X and Y drives were to be directed by a closed-loop positional servo well damped and with little or no overshoot. Multiple speed synchros would be required to obtain a static accuracy of plus or minus 1/16-inch and the necessary range of operation. The contemplated maximum velocity in the X direction was 360 feet per minute and in the Y direction 60 to 120 feet per minute. The variable speed range in both directions was to be at

least 10 to 1. In Z or vertical motions, maximum speed was indicated at 60 feet per minute and the minimum at 6. A probe system was suggested.

The crane controls and the "repeat back" telemetering of all the functions had to be complete and so reliable that the cranes could be controlled through their entire function without observation of the reactor room by the operator. A plotting board or tracker indicating the position of both cranes might be required and the control arrangement would help to minimize any errors by the inclusion of suitable interlocks preventing initiation of a new crane movement before a current movement was completed.

While crane purchase negotiations were proceeding, bids were requested on the control systems in May 1951. Positioning accuracy was specified as plus or minus $1/32$ -inch, the mechanical tolerance as plus or minus $1/64$ -inch, and the control system tolerance as plus or minus $1/64$ -inch. Automatic control was specified but manual operation was to be included. The over-all cycle was indicated as 4- $1/4$ minutes for fuel tube unloading. Position input signal systems with "repeat back" confirmation were specified together with a complete console facility in the crane control room.

Both hydraulic and electrical control systems were considered. A survey of possible vendors was made with assistance from ANL. As a result, an order (AXC-251-1/2) was awarded to the Arma Corporation in late June 1951. It detailed specifications and summarized the important design considerations of reliability, as little material on the crane as possible, speed, and absolute safety in any machine failure.

To assure maximum reliability, the specifications included a provision that no vacuum tubes were to be used in the drive control systems. This was later rescinded as the time required to develop magnetic amplifiers, or other suitable substitutes for vacuum tubes, was too great. Instead, a complete set of spare amplifiers was to be included with necessary transfer switches.

At this point Specification 3035 covering the control requirements and Specification 3071 covering the mechanical requirements of the cranes and masts were prepared and circulated to Whiting, supplying the cranes, to Arma, supplying the controls, and to Wean Engineering Company, supplying the masts. The latter were to be prototyped by AM&F, a subcontractor of du Pont Development Engineering Division.

During the development stage, probe devices were not included in the specifications because the total mechanical and electrical tolerance of plus or minus $1/32$ -inch did not

require them. However, their use was kept as a reserve possibility in the event desired tolerances could not be realized. When it developed that the weld shrinkage encountered at New York Shipbuilding Corporation could not be completely overcome by the expanded tube pattern and a few lattice positions were found to have deviated appreciably from their theoretical position, probes were added to the Arma scope of work. They are used to correct for fabrication tolerances of the reactor plenum rather than for mechanical and electrical tolerances of the crane and its control system.

From the beginning of the project until May 1951, the design of the masts and fuel tube grippers was handled by du Pont alone with ANL continuing to make available the results of its original development work. By May the program was well formulated and the mechanical design of the mast assemblies was assigned to the American Machine & Foundry Company as subcontractor.

The original scope of work described four types of components to be handled by the masts and their grippers: fuel tubes (quatrefoils); control tubes (septifoils); control rods; and blanket tubes and blanket rods, both later deleted. Included were provisions for cooling the quatrefoils while they were held in the air by a crane; a spare mast; an ability to push a fouled Q-foil back into the reactor; and uniform pick-up ends on all component tubes.

By June 1951, preliminary studies by AM&F had resulted in the selection of three masts and grippers to accomplish the desired functions. Mast and Gripper No. 1 would load and unload control rods, No. 2 would load fuel, control and blanket tubes into the reactor, and No. 3 would unload fuel, control and blanket tubes from the reactor. Preliminary design of this three-mast arrangement included a chain drive to raise and lower the components gripped by the mechanism on the mast. The unloading mast differed in that it carried a tightly sealed cover at its lower end to collect D₂O draining from the withdrawn components. Also, the loading mast had a clamshell type guide at its lower end to support the tubes against horizontal motion while they were being lowered into the reactor.

In succeeding months significant changes took place in design requirements and the AM&F scope. By the first of July a fourth mast and gripper were added to handle insertion and withdrawal of the one-inch diameter safety, instrument or 35W5 rods at positions between the basic 7-inch lattice points. Du Pont requested that the masts be mounted "in-line" instead of in a diamond pattern. A few weeks later attention turned to a new Q-foil design in which the extension sleeve

was separate from the fuel tube assembly, a step in development discussed in the section "Assembly Area - Equipment Development". Despite this change, AM&F was requested to limit the number of masts to four. By August, however, the number of masts and grippers had reached a total of five and in September it was decided to purchase material for a five-mast prototype crane.

Each of the two cranes was to be capable of charging or discharging the reactor, the five masts, designated by letter, having the following functions.

A. Load or unload semi-permanent sleeves alone or with any components they might normally carry such as Q-tubes, S-foils, or plugs.

B. Load or unload S-foils with seven control rods or seven blanket rods and the control rod plug or muff.

C. Load or unload a quatrefoil and plugs for the quatrefoils or blanket rods.

D. Load or unload from one to seven control or blanket rods at a time.

E. Load or unload "B" or 35W5 rods, safety and instrument rods.

Aside from its effect on the magnitude of control equipment the number of masts critically affected building design. The masts were "in line" on 21-inch centers and parallel to the long axis of the reactor room. They determined the distance between the bridge beams of the crane and this largely determined the length of the reactor room, the distance between the shielding doors, and the length of the maintenance area beyond the doors.

An intensive study of functions was made in an effort to reduce the number of masts with the result that by December, with some design changes, the number was reduced from five to three. It was decided to eliminate detenting of the "A" outer chuck, to combine an inner chuck in "B" chuck for handling liners, and to alter the safety and instrument rod tips for pick-up by the center "C" chuck.

Through the latter part of 1951 and early 1952, a number of miscellaneous detail and testing problems were cleared up. In October, Arma was instructed to develop controls for the gripper units also. Originally AM&F was to supply a prototype set of masts and grippers for NYX with procurement for the SRP units being handled in the normal competitive manner. However, the construction schedule in the field and the status of gripper development were not compatible and it

was decided in December to have AM&F furnish prototype units for production use in Building #105-R. Testing of the crane and grippers at NYX with complete prototypes was still planned and for this Arma was in December requested to supply a control set-up.

The first formal write-up of the expected operational sequence was prepared by late December, 1951, to serve as basic data for Arma.

In considering materials that could be used in the construction of the various mast parts, it was believed essential to minimize the leakage of lubricants or corrosion products into the reactor. By January 1952, decisions had been made to use stainless steel construction, all bearing surfaces to be within this broad material classification and capable of operating without lubrication.

A Design Division liaison engineer was stationed at Arma to coordinate Arma's work with Whiting and AM&F, and he sponsored regular meetings between personnel of the vendors at which numerous detail decisions were made. Later, information for the Wean Engineering Company was furnished by this group.

In February 1952, mast and gripper drawings were exhaustively reviewed by du Pont before proceeding with procurement of the prototype and completion of the final design.

Two significant changes in mast design were initiated in April. One specified that the "C" mast should be so designed that it could remove blanket elements from a reactor without changing heads and with blanket rods designed to bring them to the same elevation as control rods. By this change the short chuck would handle both types and the long chuck could be eliminated. Heretofore, it had been expected that the short and long chucks would have to be interchanged manually, an undesirable feature from a contamination angle. The second change proposed a weight sensing feature on the cranes that would help to detect jammed Q-foils by indicating excessive weight when an attempt was made to pull them out of the reactor. This had the object of avoiding the hazard of breaking a swollen Q-foil element and had been a feature of the original Consolidated design. The weight indicator system, with exception of the primary elements on the masts, was made part of the Arma scope of work.

Weights to be handled by the crane in normal operation varied from 24 pounds for a single control rod to 376 pounds for Q-tube assembly. The heaviest combination, a Q-tube stuck in a semi-permanent sleeve, weighs 431 pounds. These are component weights and do not represent the force required

to break loose the O-ring seals. During abnormal operations the cranes would also have to handle the reactor tank robot, periscope and tool.

In April 1952, individual A, B and C masts without a crane were set up in Brooklyn to test thoroughly the operation of the grippers. Two hundred repetitive operations were performed to establish data from which improvements could be made. At this time concern was expressed over the use of carbon steel masts on the basis that invisible corrosion products on the inside of the masts might drop off and fall into the reactor. Stainless steel masts were later adopted.

Test work performed at the Brooklyn laboratory of AM&F on the Z, or vertical, operation of the mast disclosed the need for numerous design changes, each essential but relatively minor, to give the desired performance. A summary issued at the end of June, 1952, indicated that 17 design changes were required in the A mast, 17 in B and 11 in C. These changes were primarily directed toward increased rigidity and smoother operation.

In the final design the A mast carries out 12 sequential operations including the insertion in and the removal from the reactor of a Q-tube, plug and semi-permanent sleeve, the pick-up of these components from the presentation hanger, and their deposit in the exit conveyor. The B mast performs similar operations with the septifoil, muff, liner and thimble, and the C mast carries out these movements with the C, B and single rods. (In the final design, 'C' & 'B' rods are at different elevations in the reactor, however, they are handled by the same chucks.)

In mid-August 1952, a scheme for supplying both process and filtered water to the cranes to cool Q-tubes was reviewed. The process water system contained an air pressure tank in the purification area, piping to the crane haunch and a hose on the cable slave paralleling the electrical cables. This presumed the lower end of the Q-tube to be in the reactor. Filtered water could be supplied by a similar means but return flow, from the water pan under the Q-tube, was a gutter-type trough along the crane haunch. Filtered water can be used when the Q-tube is freely suspended and not immediately over the reactor. The control system was made a part of Arma's scope of work.

To dispose of the normal Q-tube drainage of process water collected in the water pan under the bottom fitting, it was originally intended to drain the pan into a tank adjacent to the deposit and exit conveyor. On each cycle the crane would deposit a Q-tube and then drain the water pan

before picking up another Q-tube. The tank used for collecting the water pan discharge would in turn be removed under the supervision of an operator from the reactor room after the entire unit had been discharged. Two objections were raised. First, the operator had to enter the room, an undesirable feature if contamination of the area had occurred during Q-tube discharging; second, the tank location interfered with the flexibility of robot operation. It was decided, instead, that the holding rack would be used as a receiver for the water pan drainage.

In the following months several significant additions were made to the crane design. In late August, splash covers were added to the grippers to protect the solenoids, limit switches, wiring, weighing and over-travel devices from radioactive contamination that would be difficult to remove.

Analysis of the hydraulic conditions in the reactor indicated that if a Q-tube or S-foil should break near its top, the plenum pressure could push the semi-permanent sleeve part way out of the reactor. To avoid this and the resulting spillage of D₂O, it was decided to provide hold-down latches which would be opened by the crane chuck.

As there are several basic mechanisms involved in an over-all discharge and charge cycle, consideration was given to the possibility of mechanical damage due to improper coordination of various machines. As a result, electrical interlocks were provided, with the following important functions.

1. Prevent charge and discharge machines from colliding with closed shield doors, shield door abutments, inlet conveyor, "dog-house", actuator forest and long latches.

2. Prevent shield doors from lowering on cranes.

3. Prevent cranes from over-traveling the ends of the rails.

4. Prevent cranes from entering the "supply point" (inlet conveyor) until following conditions are satisfied:

- a - Crane is ready to receive an element;
- b - Conveyor is in position to load the crane; and
- c - Conveyor controls are locked out.

5. Prevent cranes from entering the "discharge point" until the following conditions are satisfied:

- a - Crane is loaded with an element, ready to discharge:

b - Conveyor is empty and in position to receive an element; and

c - Conveyor controls are locked out.

6. Prevent operation of Z drive when operating in X and Y drives and vice-versa.

Part of this interlocking system was provided by Arma, the remainder by du Pont Design.

In mid-April 1953, many minor design revisions were in progress totalling a substantial amount of work and scrapping many chuck details already fabricated. At that date 78 design revisions were recognized with 36 still unfinished. These changes resulted from test work proceeding concurrently at AM&F locations and NYX, from physical interferences discovered as modified parts were assembled on the prototypes for the R Area, and from some material of construction substitutions.

By the end of June, active design or redesign items fell into the following main categories.

1. Functional testing.
2. Rack inspection at re-worked joints.
3. Probe box setting.
4. Alignment of cranes.
5. Elimination of copper bearing parts.
6. Staking of fastenings.
7. Rack and rail preservative oil.
8. Hydraulic buffer adjustment by Arma.
9. Additional work on the mast weight indicator system to give Arma information for the B and C heads.
10. Revisions to control system as dictated by NYX test results (See NYX tests).

By the time testing at NYX was completed the crane control system design included provisions for accepting instructions fed to the consoles by perforated tape. For a time procurement of the auxiliary tape equipment was deferred but in April, 1953, it was decided to procure all the remaining

equipment consisting of a tape puncher, verifier and readers to provide a fully automatic input order system for the cranes and essentially eliminate all possibility of human error.

To check the Z motions of the precision cranes, a 10-inch test hole was provided in the crane maintenance area which simulates a top hole in the plenum chamber of the reactor.

One type of emergency crane operation requires special operating precautions. The ceiling height of the reactor room had been established at plus 43 feet whereas the maximum normal crane operating height was plus 39 feet. If the lower two feet of a Q-tube becomes jammed in a semi-permanent sleeve the full ceiling height is needed because of the combined length of the two components. Ceiling lighting in the R and P Areas prevents random operation of the crane but clearance lanes were made available by re-arranging the light fixtures. This operation is, by necessity, executed by manual control of the crane functions.

NYX TESTS

A single crane was assembled at NYX for evaluation, testing and operator training. It was modified slightly to fit the building. The more significant differences from the SRP design were a special, simplified control console; crane rails were mounted on steel instead of heavy concrete; the masts were three feet shorter, due to a lack of building height, making it impossible to test fully the long "C" chucks on control or safety rods; carbon steel masts and aluminum carriages of the original crane design were used; the Q-foil cooling system was not available; the revised buffer system was not available; exact duplicates of the X and Y drive motors as designed for SRP were not used; and a festoon cable system was used instead of the conveyor-type system designed for SRP.

Specifically, the test program was designed to permit evaluation of the following:

1. Preliminary check-out to determine if the crane would perform its basic function;
2. Strength and deflection tests;
3. Positional accuracy tests;
4. Life tests and cycle time studies; and
5. Drive servo systems development.

By late May, 1953, the NYX testing was completed. The results are summarized in DPXN-231, "Precision Crane", which states that the crane is capable of charging and discharging any of the reactor elements. The positional controls for the crane proved to be both accurate and stable. However, certain mechanical features of the masts and grippers did not perform as smoothly as expected and further design and test work was recommended. Since the test site was being shut down, the additional test work was scheduled for SRP on the final crane installation and prior to actual use in building operation.

The main mechanical shortcomings were found in the buffer system, solenoid power level, mechanical binding of the chuck mechanisms, localized galling, difficult insertion of components with dry O-rings, and general alignment.

A summary prepared at the conclusion of the NYX crane tests indicates the reservations that had to be applied to the test results.

1. They were performed on jury rig equipment.
2. They were to establish that, mechanically and electrically, the equipment would work in the field and that the design in principle was sound. They added data necessary to refine equipment and to eliminate much field testing.
3. They field tested Whiting, Arma, AM&F and du Pont designed equipment as a functional unit.
4. Final acceptance testing of any equipment still had to be made at the site to the Operating Department's satisfaction.
5. The mechanical system at NYX was influenced by a lack of building stability and this permitted only limited checks on torsional rigidity, cross deflection, backlash, inertia and mechanical resonance. Repetitive probing was not demonstrable at NYX.
6. Accelerations, decelerations and velocities were established during development of the design and modified by NYX experience. The mechanical system by AM&F was not operated at the required Z speed.
7. The weight indicator system was not tested.
8. Chuck solenoid control from the console proved feasible but requires more power.
9. The masts and A frame were not full length.

10. The latest design changes were not incorporated in the masts and carriages.
11. Cooling water system was not tested.
12. The crane protective interlock system was not tested.
13. The X cable slave was not tested.
14. Tape input system was not tested.
15. Crane emergency removal system was not tested.

Because of the many design changes after the NYX unit was built, very little of the test crane was usable at SRP. The gripper heads were reconditioned and shipped to SRP as spare equipment, however. A majority of the Arma control and drive equipment was shipped to Arma, reconditioned and used on site equipment or as spares.

As a result of the NYX test program and a general re-examination of the design of the crane control system, Arma was requested to make a substantial number of design changes. Many had to be made at SRP as field modifications since equipment had been shipped prior to completion of design changes. The more important changes included Z cable handler modifications, synchro branch circuit fusing, drive and repeat back servo modifications, and provisions for emergency removal of a disabled crane by means of the other crane.

PROCUREMENT

As previously reported, the crane itself was supplied by Whiting, the crane controls by Arma, the prototype masts by AM&F, and the masts for the production units by Wean. This was changed because of schedules so that AM&F prototype units were shipped to the plant for installation in the R Area. Also for schedule reasons, it was decided to equip the R Area initially with carbon steel masts to be replaced by stainless steel masts when available. The chuck heads were to be furnished without weighing devices or the latest design of spring suspension. No cooling system was to be provided.

Shipment of the masts on September 15, 1952, as planned, was deferred since the crane rails and crane had not been received. It became possible, therefore, for AM&F to complete a number of design revisions and additions. It also became possible to provide stainless steel masts initially, eliminating extra work in the field and offering the chance for replacement under more favorable working conditions in the AM&F shops.

Procurement was proceeding satisfactorily until July, 1953, when a work stoppage occurred at Arma forcing the Engineering Department to formulate plans for continuing the work. Actually, construction could proceed so long as equipment remained available for installation and wiring. However, check-out operations required personnel specially trained in servo-mechanisms and for this reason a survey was made of Engineering Department personnel in all divisions who were qualified for this work.

At the time of the work stoppage, Arma had shipped all of the equipment for the R and P Areas and half the equipment for the L Area. Since construction of the L Area was being delayed, several solutions were considered. Another vendor could be sought to complete the Arma work, another vendor could be engaged to furnish a "Manual-Visual" system that could later be converted to automatic operation, or a slight delay could be accepted if it appeared that an early resumption of work was possible. Settlement seemed imminent. No alternative action was taken, and the stoppage was terminated by the end of September.

To keep the work moving during this period a team was organized under Design Division supervision to check out and trim the control systems. When Arma men returned they were informed that du Pont would continue to be responsible for servo adjustment and functional testing of the cranes and that Arma men would be expected to prepare the test procedures and assist in the work. Prior to the stoppage Arma had been charged with supervision of the work. The team continued to function for the balance of the work through the C Area.

FINAL DESIGN IMPROVEMENT

This team proceeded through the static and dynamic tests in October and November, 1953, and by early December had completed the check-out, run-in, and the handling of dummy components by the cranes in Building #105-R. The need for additional crane improvements developed during the test work. Some were needed immediately in Building #105-R and #105-P, others later.

Of those requiring immediate attention, the major items were:

1. Galling of some stainless steel parts on sliding surfaces between the inner and outer chucks, on the guide rods and bearings and the pan bearings and slides;
2. Improvement of the water pan and clam-shell drives, and the seal sleeve operating mechanism;

3. Fail-safe latching of the A mast pawls;
4. Prevention of "cork-screwing" and "knotting" of slave cables of the X cable; and
5. Study of X-Z type generator failures.

In most cases the equipment could be used for a time, but the following corrections were necessary for satisfactory long term service.

1. Electrical and mechanical improvements to X cable slave conveyor and drive.
2. Improved solenoid operation.
3. Elimination of erratic operation of signal, control and interlock relays.
4. Improved maintenance room testing facilities.
5. Provision for emergency removal of X cable slave.
6. Alignment of gripper heads.
7. Improved reliability and positioning accuracy of the inlet conveyor from the assembly area.

As a result of these observations, a committee was set-up to execute a cleanup program on all known items needing correction and any others that might develop. It was recognized that continued use of the cranes would develop other weaknesses not apparent in the preliminary testing which, for reasons previously described, could not be comprehensive. The committee divided the program into two parts. The first included relatively minor changes and refinements that could be made in the field and the second, those revisions requiring appreciable redesign.

By mid-January 1954, the problems were defined and corrective action agreed upon. The corrective action list at that time included thirty to forty items and since AM&F's services as a subcontractor were terminating, action was split, depending on the nature of the work, between the Field Design Group, DED at the Mechanical Development Laboratory and the Wilmington Design group. Schedules were prepared and design work initiated. The committee met regularly to review designs and current problems. Item by item, corrections were made in all five areas as the equipment became available.

By September 1954, the problems were reduced to four major items.

1. Positioning accuracy of the inlet conveyor.
2. Sub-standard operation of the water pan mechanisms.
3. X-Z type generator failures.
4. Evaluation of X cable slave cables.

During this period, the reactor in the R and P Areas was loaded and unloaded twice on production runs and the L reactor was loaded once. By this time the principal object of the program was to obtain optimum mechanical and electrical performance.

The corrections made to improve the inlet conveyor are described in the "Equipment Development - Assembly Area" section under "Gripper Pick-Up Station".

Operation of the water pan mechanism was improved by installation of larger solenoids and redesign of critical parts by the field group.

A thorough investigation was made of the generator windings and connected electrical circuitry. A new winding specification was developed and improved field surge protection provided. The improved field protection reduced the rate of failure and machines were re-wound on an "as-failed" basis. By June, 1955, a total of 15 X-Z generators were re-wound per the new specification (#3520), all of which proved satisfactory after extended operation.

At an early stage in the development program new cable, especially designed for the service, was purchased from the General Electric Company and installed in all five areas on the X cable slave and Z cable handler. Early operating experience with these cables proved their superiority to the original cable (Navy type MHFF-44), however, the investigation with various manufacturers leading up to the purchase of the G.E. cable indicated that the manufacturers had little or no experience with cables in this service - i.e. slack cable take-up where cables are moved under tension over a rotating drum. Therefore, accelerated life tests were made on a special cable test stand, simulating operating conditions. Samples of cables recommended by various manufacturers were purchased and tested along with the original Navy MHFF-44 cable and the G.E. cable. The tests indicated that the G. E. cable finally installed on the X cable slaves was the best commercially available cable for the application and its life was expected to exceed five years.

On several occasions during the development of the cranes and control systems, analyses were made in the hope of effecting simplification of both the mechanical equipment

and the control system, which are admittedly complex. Although possible alternative methods were proposed, none offered any reduction in complexity unless requirements were appreciably relaxed. It was concluded that any worthwhile relaxation would either jeopardize production or compromise safety.

REACTOR ROOM MATERIAL HANDLING

Material handling in the reactor room is normally concerned with the reactor components but on occasion the robots must be brought into the room and very infrequently it becomes advisable to remove reactor sections for cleaning and servicing.

As described in the "Equipment Development" section of the assembly area history, the reactor components are moved through a slot in the reactor room wall by the gripper pick-up station to a pick-up point where the charging machine can grasp the component, transport it to the reactor, and deposit it in the appropriate lattice location. During this operation, the discharging machine removes irradiated components from the reactor and places them in the deposit and exit conveyor which transports them into the transfer canal of the disassembly area. The flow of material is illustrated on page 235 .

Components placed in the deposit and exit conveyor rest in a carrier which pivots at the end of a long conveyor arm. The lower end of the carrier travels on a track which with the retractable conveyor arm accurately positions the carrier at both the deposit and exit points. All controls are located in the canal area. Power is supplied from a 10 hp. motor through a 660:1 gear reduction unit. A solenoid operated brake is mounted on the motor shaft to provide instantaneous stops. Double limit switches and a number of other safety features are included in the design to make certain that the conveyor will not carry the discharged components to a point where the water shielding is reduced and thus endanger the operators transferring the component from the conveyor to a storage hanger.

The design of the installed equipment was selected over a proposed two-track, curved trolley conveyor system because of its simplicity and its elimination of underwater mechanisms and machine parts that, with corrosion, could cause undesirable maintenance problems.

HOLDING RACK

When the charge and discharge crane program was firmly established, it became obvious that some intermediate facility

in the reactor room was necessary to store elements and component parts temporarily. Also storage was necessary for D₂O from the pans on the charge and discharge cranes which collected heavy water draining from discharged elements.

Requirements for an intermediate storage facility were based on the following probabilities.

1. Elements or component parts brought into the reactor room, and exposed to or partially inserted in the reactor before their nonacceptability was discovered, would not be returned to the assembly area.
2. Plugs and muffs sticking when removed from the reactor would require minute inspection before replacement. Since the lower part of the plug and all of the muff would be radioactive, they would have to be stored temporarily until they could be removed to shielded facilities.
3. This storage facility would occasionally serve as an O-ring replacement station for all elements.
4. Robot periscopes, light fixtures and tools with special sleeves required temporary storage near the reactor so that the charge and discharge cranes could easily pick them up and insert them in the reactor.

The initial idea of using racks on the walls of the reactor room became highly unattractive due to the large number required and the varying heights to which the cranes must lift the components. Each rack basically represented a gripper pick-up station to assure safe pick-up and deposit.

Since some space was available in the canal in which the deposit and exit conveyor is located, it was more practical to install a tank complete with the necessary holes and sleeves in this location and at the same level as the reactor.

The holding rack is approximately 8 feet by 3 feet with one-half of the tank 18 feet deep to hold major elements and one-half 5 feet deep to accept minor components such as plugs, muffs, and sleeves. Constructed of stainless steel, it has a 4-foot layer of concrete and lead shielding across the top and in this is set 41 machined tubes each five feet long. These are welded to the top and bottom plates of the top box section and are placed on lattice coordinates similar to the reactor. The elevation of the sleeves and probe pins corresponds to that of the reactor so that the cranes can function over the holding rack, when removing or inserting components, with the same ease and accuracy as over the reactor.

One of the 41 tubes is used as a receiver for the D₂O

which has drained into water pans on the cranes. This is collected in the bottom of the holding rack and pumped to main storage tanks after completion of reactor discharge and charge. Of the remaining holes, 9 can be used for shield and plug assemblies, 2 for Q-tube assemblies, 2 for S-foil weldments, 2 for C-rod clusters, 2 for C-rod shield muffs, 2 for 35W5 rods, 2 for S-rods, 9 for semi-permanent sleeves, 8 for internal robot fittings and 2 for shield plug pin casks.

Approximately 2550 elements and components are handled during a normal discharge and charge operation. Any doubtful incoming element or component is immediately placed in the holding rack while normal charging operations continue. These elements are later inspected and appropriate disposition made at the end of the charging operation.

The holding rack can also be used by the charge and discharge cranes as a check-out station for all components and elements.

EMERGENCY HANDLING EQUIPMENT

During operation of a reactor building it is expected that emergencies will occur in high intensity radiation areas which cannot be corrected by equipment normally used in the room. These fall into two general classifications; (1) those occurring within the reactor room but external to the tank, and (2) those occurring inside the reactor tank. Two broad titles, general purpose robot and reactor tank robot, were established for the special emergency equipment to be provided.

GENERAL PURPOSE ROBOT

This GP robot was originally conceived as a remotely operated machine capable of handling any irradiated component not removed from the reactor by routine methods. The presence of any such components in the pile, of course, would make it impossible for anyone to enter the room.

A study of similar emergency equipment at other sites, particularly Hanford, proved that previous designs were inadequate because they had been directed toward meeting specific emergencies. These seldom occurred exactly as anticipated. As a result, the primary aim at SRP was to incorporate greater flexibility by providing a mobile manipulator, equivalent to a human hand, remotely operated and capable of a hand's intricate motions.

Able to grip reactor elements as well as tools, the robot would be equipped to pick up elements from the floor and deposit them in a water basin, pull a jammed control rod out of its septifoil, cut any rod it could not pull from a septi-

foil, and remove an element from the cranes. Any parts operating over the tank could not jeopardize reactor operation through oil leaks or the release of corrosion products. It was hoped that a means of viewing from the robot position could be provided. Only one robot set would be included in plant equipment and would be transported from area to area as the need arose.

For motive power it was proposed that a battery-powered lift truck be used with a boom to hold the manipulator. To demonstrate the maneuverability of such a unit, a standard lift truck was jury-rigged at Yale & Towne, Philadelphia. Results were satisfactory.

Some thought was given to the use of mechanical arms developed by General Mills but their capacity was below that required for this application and design was begun on a set of manipulators that could meet the heavy load requirements including a pulling force of 1500 pounds. Direct current motors were selected for all manipulator drives because of their inherent torque characteristics. Various configurations of drive designs were laid out to obtain a multitude of movements and a selection was made that offered the least complexity and weight. Several parts of the design were jury-rigged before final fabrication.

To perform the functions for which it was intended the robot boom had to be long enough to reach any hole in the tank pattern when the truck was maneuvered as close to the edge of the tank as possible. For some time instrumentation plans included the installation of "fireboxes" at the side of the tank which would have required three feet of boom length to be added to bridge them. When the fireboxes were eventually eliminated the boom was shortened from 18 feet to 15 feet but it still remained too long for easy maneuvering within the building. Maneuverability was improved by including a three-foot retractable section.

Plans to rely on closed-circuit television for viewing had to be greatly simplified. In the beginning it was thought that three cameras could be installed to give side, forward and vertical viewing on three monitors. Efforts at Argonne National Laboratory to obtain three-dimension TV on one monitor were studied but these were in such an early stage of development and the cost was expected to be so high that no application of this form of television could be economically made. In the continuing studies of TV use, a demonstration was held at Arco, Idaho, with several models of cameras and equipment to determine lighting requirements and the best placement of cameras.

It became apparent that at least three cameras were necessary, one mounted on the manipulator for close-up view-

ing and two mounted in the reactor room for broad range vision. Studies of radiation effects on television equipment led to the conclusion that damage would result if the equipment were left in the room. Consequently the scope was changed to include room television mounted either on portable dollies or some similar arrangement.

To supply power to the robot, self-contained batteries were at first planned but this was changed to an external supply fed to the robot through a cable reel mounted on the 120-ton crane which would, through remote control, follow the robot into the room. Any power supply scheme was complicated by the fact that at least one of the large shield doors must be closed at all times to prevent any straight through opening into the room. Also, the cable could at no time be allowed to entangle the robot or other equipment. In the final design, a portable cable reel is placed at the 66-foot elevation over the reactor. The robot is carried by the 120-ton crane and deposited on the reactor room floor below a hole in the 66-foot floor. A cable latch is lowered through the hole, engages a latch and cable assembly on the robot and the combined latch is then raised above the 66-foot level where the power cable is manually connected. This eliminated separate reels and equipment for each building and the need for a remote power connection.

A wooden mock-up of part of the tank pattern and building walls was constructed in the maintenance area of Building IO5-P to conduct the final acceptance test of the robot. Dummy slugs, laid in various positions, were successfully removed by the robot but time limitations and the unavailability of other equipment made it impossible to test all functions.

REACTOR TANK ROBOT

The RT robot was conceived as a set of special tools including an optical device and lights with which emergencies inside the reactor could be handled. One set of tools was to be provided and would be moved from area to area as needed. Each item in the set would be shielded, and would be remotely inserted and removed by the precision cranes through empty fuel holes in the reactor. Anything inserted in the reactor would have to be extremely clean and materials would have to be selected to withstand a high level of radiation. For design and procurement purposes stainless steel, copper-free aluminum and non-browning glass were accepted as suitable materials.

To gather information on the effect of radiation on other materials, particularly for gaskets, a program was started at the Argonne National Laboratory. Eventually, Argonne reported that special rubber compounds under test

did not deteriorate too rapidly when exposed to high radiation and these were accepted as a gasket material. A minimum life of 50 hours was expected.

In addition, Westinghouse was contacted to determine if a light bulb of short life duration could be made of aluminum and stainless steel. A list of all elements, trace and otherwise, found in commercial light bulbs was obtained and reviewed for possible changes in the list of acceptable materials in the light bulb scope. The fabrication of a stainless-aluminum, non-browning glass bulb filled with argon was considered but the cost and delivery dates were too indefinite. In the meantime, it was decided to accept trace amounts of various elements found in standard bulbs and a 1000 watt aircraft type bulb, screened to prevent broken glass from falling into the tank, was selected. This is used in three assemblies to illuminate different tank levels.

For interior viewing, du Pont prepared the layout of a periscope showing shielding and dimensional requirements from which the Kollmorgen Optical Company completed a detailed optical and mechanical design. A periscope jury-rig was made, consisting of an outer shell and optics of standard glass, and was shipped to the field for functional testing. It performed satisfactorily. Since shielding requirements limited the maximum amount of vertical movement by any piece inserted in the tank to 27-1/2 inches, three periscopes of different lengths were supplied to permit scanning from the underside of the poison plate to the bottom of the tank.

To retrieve and handle various elements in the tank, five types of grapples were initially planned. These included grapple "SP" for small pieces, grapple "S" for septifoils, grapple "Q" for foils, grapple "M" for muffs and grapple "LS" for long segments. Eventually, the "S" and "Q" grapples were combined into one basic tool with the jaws interchangeable from type "S" to "Q". Grapple "LS" presented so many problems due to the short vertical stroke available that it was finally deleted.

When these RT robots are to be used the 120-ton crane, fitted with a hoist assembly, carries them from the maintenance area to the holding rack in the reactor room. From that point they are carried by the precision cranes to the reactor and deposited in the preselected holes. A movable aluminum platform is placed over the reactor and the operator then enters the reactor room, attaches handles to the robots and proceeds, with the aid of the periscope and lights, to restore the tank interior to its normal condition. All equipment inserted in the tank is decontaminated before storage in special boxes. The robots can also be carried into or removed from the reactor room by the precision cranes; and for this purpose piping at the ceiling of the crane maintenance

area was rearranged to create a two-foot wide aisle on the centerline of the building.

Prototypes of all equipment were tested at NYX and at SRP.

120-TON CRANE

When design of the reactor building began, a 150-ton crane was planned for various service handling operations in the reactor room including the erection and dismantling of the reactor and possible gang loading and unloading of fuel elements. The crane capacity was reduced to 120 tons after the weights of the shield and plenum were determined and individual tube loading had been adopted.

In requests for quotation the crane was described as a general purpose, twin-trolley, four-hook crane arranged for remote control from a console. The first crane was ordered in September, 1951, but subsequently was altered in December to accommodate handling of the actuator forest, a 17-foot square by 28-foot high assembly located atop the reactor. When performing this function the crane would be positioned over the forest and would lift it up between the crane girders high enough to clear stuck control rods and then carry the forest out of the room for decontamination and maintenance. The crane girders were spaced wider for this purpose, and were equipped with special drive and drive gear designs since the total crane width was limited by the shield door spacing in the crane wash area.

A simple, remote control system was designed with three multi-conductor cables mounted on reels in the maintenance area and with a positioning system in which switches on the haunches are tripped by the crane. Lights on the control console indicate the location of the crane. Precision leveling of the forest was obtained by telemetering from a special pendulum type level designed by Argonne National Laboratory and adapted to this use. Normal lifting speeds of 8 inches per minute and 2 feet per minute are provided with micro-inching for precise control. When remote control is not required, the crane can be operated from the bridge or from a drop pendant.

The crane can handle the G.P. Robot and can remove the holding rack. It is equipped with a monorail hoist to lift small elements and robots for special work and in emergencies it can push the charge and discharge machines to a position over the discharge canal in the reactor room.

VERTICAL STEEL DOORS

Early in the design effort it was recognized that provisions for moving the charge and discharge machines out of the reactor room would be necessary to provide for maintenance. To meet this requirement a large opening in the reactor room wall was required and special shielding doors were designed to minimize the escape of radiation. A labyrinthine passage was first proposed as an alternative but was found to require excessive building space. Water-filled, lead, and concrete doors were also considered but solid steel was finally selected, primarily on the basis of cost.

Procurement of the steel doors to be located between the reactor room and the maintenance area was initiated in May of 1951 when du Pont issued requests for quotations giving general specifications and stipulating that the successful vendor would be required to design and fabricate the doors. These were to be constructed of 8-inch thick carbon steel, approximately 63 feet wide at the top, 27 feet wide at the bottom and 43 feet 7 inches high. At the crane runway ledge, Elevation 30 feet, 11 inches, where the door would extend to its full width, its lower edge was slotted to clear the rails of both the precision and 120-ton cranes and the various crane cables.

Of two possible vendors experienced in this special field, Westinghouse Electric Company and the Dravo Corporation, the latter was selected for its capacity to do all design and fabrication with the exception of certain hoisting equipment. A letter of intent was issued to Dravo in August of 1951 covering the two identical doors required for the R Area.

To construct the doors Dravo proposed welding steel slabs into one unit to give the required beam strength and the resistance to a 1000 p.s.i. windloading when in the down position. This method was approved by du Pont.

Since a minimum door thickness of 8 inches was required for shielding, the steel mills receiving orders for the slabs were requested to reduce the standard mill tolerance for out-of-flatness of 8-inch plate from one inch in 12 feet to one-half inch in 12 feet. As it developed, the mills had difficulty in meeting these conditions and after matching the slabs as carefully as possible, the fabricators leveled out variations by using filler pieces and welding additional reinforcing to secure uniform shielding qualities.

The gantry mounted on the building roof at Elevation 48 feet is approximately 67 feet wide and 56 feet 4 inches high and so designed that the doors pull up between the gantry legs. Lifting power is supplied by a 125 hp. motor operating a sheave system with cable attachments through hinges welded

to the top of the door. An identical system including the motor is installed for each of the two doors.

Numerous safety precautions were taken in design of the hoisting equipment including electric braking, separate shoe brakes controlled by a torque motor, and the installation of double limit switches and mechanical circuit breakers in nearly all controls. Each door weighs 292 tons, has a lifting speed of 5 feet per minute and a lowering speed of 9 feet per minute. All control is from the crane control room.

The location of the steel doors can be seen on pages 63 and 65.

COMPONENT SERVICING MACHINE

The semi-permanent sleeves are hydraulically sealed in the plenum by O-rings; but since the lower end of the sleeve becomes radioactive, it was desirable to provide facilities for removing and replacing O-rings without hazard to maintenance personnel.

It was decided to change the O-rings "in place" and to accomplish this a traveling bridge was designed, prototyped and shipped to SRP by AM&F to serve as a working platform over the reactor. The device, moved by the 120-ton crane, consists of a square frame which is positioned on and anchored to the forest floor. Mounted on the machine is a hand-propelled bridge with sufficient travel to traverse the top of the reactor. The bridge in turn carries 10 chucks with the same spacing as the lattice to permit 10 men to work simultaneously. The semi-permanent sleeve is engaged by a chuck and raised a few inches to expose the O-rings. These are removed, the grooves cleaned, and new rings installed. The sleeve is then lowered into position. Radioactive shield plugs are replaced in the same manner.

Only one machine is provided for five areas.

DISASSEMBLY AREA

The subcontract with the American Machine and Foundry Company, AXC 8-1/2, under the general supervision of the Development Engineering Division, included the design, prototyping, and preparation of specifications for most of the equipment in the disassembly area. The Design Division executed the design of the material handling system as well as the over-all arrangement of the equipment in the building.

Some of the prototypes fabricated by AM&F were installed in the R Area as production machines.

UNDERWATER DESIGN CONSIDERATIONS

All design of underwater disassembly equipment was required to satisfy two major considerations. First, the equipment had to be as simple and reliable as possible, and second, the materials of fabrication had to be capable of giving efficient service for as much as two years without extensive repair or maintenance. With adequate time and study, designers could produce equipment meeting the first requirement. Meeting the second was more difficult because, in the selection of bearing and gear materials, designers could find very little industrial experience on which to draw. As a result no precise prediction could be made of the performance expected from some metal parts required to operate without the aid of standard lubricants.

Although it would have been possible to incorporate automatic operation in a number of underwater equipment pieces, the opposite approach was emphasized. The Development Engineering Division was requested to keep the machines simple by using as few moving parts as possible. By thus holding the number of machine parts to a minimum the opportunities for malfunctioning were decreased and the probable demands for parts repair or replacement were reduced. In a few cases, where no detriment to reliability resulted, some automatic features were built into machine operation.

From the outset any type of oil or grease was prohibited in underwater equipment since this would produce an oil slick on the surface of the basin water and impair visibility. The metals used for the moving parts and the tolerance specifications were, therefore, based on the use of water as a lubricant.

Of almost equal importance to wear in material selection was the factor of corrosion which would affect service and water cleanliness. At first it was believed that operating conditions and requirements left no alternative but the use of stainless steel for all equipment. When it became necessary to conserve stainless, the specifications were changed to zinc sprayed, or galvanized, carbon steel for the removable framework of the machines. Permanently mounted frame sections were to be stainless as were moving parts unless some other materials proved equal or superior. In December of 1951 a further modification permitted the use of zinc sprayed carbon steel for the foundation plates and stands grouted to the basin floors. Contacts with numerous industrial and governmental groups versed in the underwater operation of equipment early established the fact that there was no successful experience

with ball bearings. It then became a question of determining what type of sleeve bearing would give the best service. A du Pont Engineering Service Division consultant group coordinated a survey and testing program with the Atomic Energy and Design Divisions of du Pont and with AM&F during which all available information was accumulated on the wearing and corrosion qualities of various materials exposed to conditions similar to the disassembly area basin. Early in 1951 the list of materials considered for various applications was extensive. It included: stainless steels of the 300 and 400 series, molybdenum alloys, meehanite, bronzed phosphur, bronzed aluminum, bronzed manganese, naval brass, Teflon, Kel-f, Koro-seal, Neoprene, lignum vitae, hard and soft rubber, Inconel, Monel, chromium and cadmium plated materials, galvanized metals, paint types, Micarta, other phenolic impregnated materials, and graphite. By the end of June, however, this list was greatly reduced when discussions and studies had eliminated the non-metallic materials as too short-lived.

In the meantime the ESD materials survey had included contacts with the U. S. Naval Experimental Station, Argonne National Laboratory, the Babcock and Wilcox Research and Development Laboratory and many manufacturers experienced in underwater equipment. Argonne at the time, was engaged in an underwater ball bearing testing project for the AEC and Babcock and Wilcox Laboratory was studying liquid metals and water lubricated bearings for the U. S. Bureau of Ships.

By mid-year it appeared that the most likely materials for sleeve bearings would be found in carbon, barium metal, Waukesha metals and the leaded bronzes. In August AM&F proposed that sleeve bearing materials and stainless steel shafting be given wear tests in Savannah River water. This was approved and specifications and testing procedures were given to the New York Testing Laboratories, Inc., under a purchase order issued by AM&F. The following were to be tried on a lapped Type 304 stainless steel shafting: SAE 64, Ampco 18, Waukesha 7, SAE 660, Bearium B4 and carbon. At the same time the corrosion resistance of various metals was to be tested at du Pont's Experimental Station.

Before full advantage could be taken of these tests it became necessary for the sake of simplifying and expediting design, procurement and fabrication, to establish specifications for the disassembly equipment in the R Area. Agreement was reached on the use of bronze bearings and hard, corrosion resistant journals of either Armco 17-7PH, Stellite 6 or chrome plated steel. At that time, January 1952, there was no assurance that the bronze bearings would operate for two years without maintenance. The critical factors in wear rate would be the surface finishes and the minimum practical clearances of the bearings and journals. In addition, the propensity for

crevice corrosion of bronze bearing alloys in Savannah River water introduced an unpredictable accelerating factor in wear rates. What this factor might be could only be established by plant experience.

Believing that current material tests would uncover superior bearing types, designers of the R Area equipment built in a measure of adaptability. Since it was likely that the newer types would have different load carrying capacities and different space requirements from the installed bearings, an assessment was made of the probable substitutes and an allowance made for their use. It was generally believed that test results and new bearings would be available in time to replace any premature failures of the bronze bearings.

The selection of a gear material also presented a problem. Tests of several combinations of gears were made by the New York Testing Laboratories including SAE 64 against Ampco 46; SAE 64 against SAE 64; S Monel against S Monel; and SAE 64 against Type 304 stainless. Again, before tests could be completed, a gear metal, Bronze ASTM, specification B143-49, Alloy 2A, was selected for the R Area. Operating experience and further testing would determine any material substitutions in other areas or replacements in the R Area.

FOIL PRESS AND SHEAR

Once the aluminum extrusions have been exposed in the reactor and their irradiated contents removed in the disassembly area, no further use can be made of them. The foil press and shear was designed to compress and shear the foils into flat lengths suitable for storage in buckets and eventual disposal by burial. Other waste aluminum material to be stored and buried is also processed by this machine.

Before development of the present machine several alternatives were considered. Baling was discarded when it developed that the cost and difficulty of adapting commercial presses to underwater use would be excessive and that tight bales could not be made. Some AM&F design time was also spent on flattening and coiling equipment but this idea was dropped as impractical and too expensive.

The first press and shear was conceived as a machine capable of pressing and shearing the foils and shearing the stainless steel rods and rod extensions. Preliminary designs of this equipment led to the conviction that the great force required to shear the steel, when combined with a flattening die, would create severe off-center loading and lead to operational difficulties and high machine costs. Therefore the operations were separated. The press and shear was designed to handle the foils only and design was started on another

machine, the rod shear, to handle the other items.

The major components of the foil press and shear are the feed table with hydraulically operated chain conveyor, the hydraulic press and shearing blade, the electrical controls and the pump. Empty foils, or rods and thimbles, are carried by tongs, placed horizontally on the feed table, and positioned under the press by pushers attached to an endless chain. As a section is pressed flat the previous section, already pressed, is sheared off by the blade and chuted to a bucket. Foils may be fed manually by turning a handwheel, or automatically through a hydraulic cylinder. The press, with a 25-ton capacity, is mounted on four vertical steel columns and is operated by a 1000 p.s.i. hydraulic system.

The first unit built for installation in the R Area employed a combination of electric power, air pressure and hydraulic pressure. Tests revealed that a number of operating problems resulted from this arrangement and simpler controls using a combination of electric and hydraulic power were designed.

When the rod extensions were changed from stainless steel to aluminum, the shearing problem was simplified and a single equipment piece could be designed for both the foils and rods. At the same time it was decided that in view of the infrequent discharge of safety, cadmium and some instrument rods, these could be indefinitely stored at random on the floor of the basin.

The foil press and shear installed in the P, L, K and C Areas is a redesign of the model originally intended for the R Area but is modified by the installation of a low pressure hydraulic system for foil cutting and a booster cylinder for rod shearing, and has features for improved feeding.

ROD SHEAR

The shear in the R Area is designed to cut the safety rods, the rod plugs of the 5Y3 and instrument rods, instrument rods of the thermocouple type, the 5Y3, safety and instrument rod thimbles, solid control rods and rod extensions of the control and 5Y3 rods.

In perfecting the operation of the rod shear no major changes were required in the first design submitted to tests at AM&F's Brooklyn location. The shear consists of an inclined feed trough with its support, the alligator-type shear with its frame and support, a hydraulic cylinder for operating the shears, and hydraulic and electric controls. The hydraulic power is supplied by the Triplex 1000 p.s.i. pump used in common with the foil press and shear. Actual tests at the

New York Testing Laboratories indicated that a force of 30 tons would shear the 1-inch diameter steel rods. In designing the machine the capacity was set at 40 tons to meet any unforeseeable conditions. The shear blades are AISI type 440C hardened to Rockwell C56.

In operation, the rods are placed manually by tongs on the feeding trough from which they move by gravity against a stop, are sheared, and then slide down a chute into a storage bucket.

VERTICAL FUEL TUBE DISASSEMBLY MACHINE

As an approach to the vertical disassembly of quater-foils, attention was given to the use of either a fixed or a free hydraulic piston or gravity fall. The piston operation would be performed with the tube in its usual upright position. For gravity fall the tube would be up-ended to allow the contents to fall out of the top of the tube. The gravity method was first tested in May of 1951 using spacers and plain tubes but it appeared that the slug sheaths could be damaged very easily in falling and that cocked spacers would prevent the slugs from dropping out of the foil. Continuing difficulties with this method led to a test of the free hydraulic piston method which also produced erratic results. During these tests a plan was tentatively entertained to expand the tubes hydraulically to aid in releasing the tube contents. When these methods proved unsatisfactory, attention turned to pushing the slugs out of the top of the tube. To accomplish this, flexible rods, screws and several types of pistons were tried. Finally, after tests with a solid piston, a hydraulically loaded hollow piston, and a spring loaded hollow piston, it was decided to use the hydraulic double-acting cylinder with a solid piston and an attached 17-foot ram. It appeared that this method would offer the greatest dependability and the greatest resistance to buckling. AM&F fabricated a prototype for testing and use at NYX and a commercial manufacturer built the five production units for the plant. One is installed in each area. The NYX machine was made shorter than the SRP machines since it was not necessary to allow for a water shield of 11 feet between the operator and the top of the foil.

The hydraulic cylinder and ram are mounted in a pit extending to the -51'-3" level. At the top of the cylinder is an indexing device and a clamp which receives and locks the bottom end fitting of the quaterfoil in place. The top of the foil is suspended from a bracket. After the foil has been set in place and the orifice assembly removed, a chute with diverters is swung into position. From the control panel, mounted at Elevation 0'-0", the operator can adjust the clamp, swing the chute into position, start the pump, activate

the ram, and rotate the ram to remove the contents of each section of the foil. Safety features are included to prevent operation of the machine if the ram or chute are not in their proper positions.

The orifice assembly remover, which is considered a part of this machine, is actually a portable mechanism which can be used with the push-out machine or with the plow in machine area No. 2. Normally the remover is suspended in a bracket near the machine. After the foil has been clamped in position, the remover is placed manually over the foil. By remote control the screw heads are engaged and turned and the orifice assembly is lifted by the remover, carried to a bucket and released.

FOIL ROD EXTRACTOR

It was planned originally to transfer loaded septifoils into the dry cave where a seven-head gripper on the rod disassembly machine could withdraw the blanket rods one at a time and deposit them on the arms of the rod disassembly machines. When, for process improvement, it was decided to eliminate the introduction of the foils into the cave, it became necessary to design equipment which would remove the rods from the foils before their movement into the cave. The simplest design appeared to be a vertical arrangement in which the foil would be dropped from a stationary rod or the rod pulled out of the stationary foil. The pit provided for a future fuel rod disassembly machine would give adequate space for this vertical operation.

The extractor is designed to lower the foil as single rods, retained by a hanger, are withdrawn. It consists of a weighted tube in which the foil is placed and clamped. The "B" rod gripper, suspended from the overhead monorail system, is then attached to one of the rods and the foil is lowered until the rod clears the foil. This is repeated until the foil is empty. The seven rods, then attached to one hanger, are moved to the transfer carriage of the rod disassembly machine. During operation the extractor moves between Elevations -7' and -30', its position being controlled by cables attached to two drum hoists. The moving foil method was adopted to eliminate the need for very long hangers used with a stationary foil.

HORIZONTAL DISASSEMBLY MACHINE

Whether many of the fuel tubes and slugs would suffer such dimensional changes during reaction that their disassembly in the vertical machine would not be possible remained an unknown until after start-up. Only operating experience could give this information; but it was felt that

an alternate method of disassembly would have to be provided. For this purpose, a special plow was designed from specifications which permitted no resulting damage to the fuel slugs. No restrictions were placed on damage to the foils.

Several emergency methods of releasing the slugs from the quatrefoil were proposed and tested. These included the can opening, the wire opening, the hydraulic expansion and the plowing methods. In the first, two parallel lines one-half inch apart would be scored the length of the tube. The strip between the lines would be unrolled and a tool inserted that would spread the opening large enough for the slugs to fall out. This idea, however, was discarded since it involved an excessive number of operations and components; also, it was difficult to secure a tool that would raise a lip, and the thin strip of tubing would break easily. After such a break it proved extremely difficult to re-insert a tool that would continue to unroll the narrow metal strip. The second method, that of wire opening, was discarded primarily because of technical considerations. The wire was to be incorporated in the tube structure and would, therefore, be present in the reactor during operation. When additional calculations indicated probable adverse effects on the neutron flux, further investigation of the method was abandoned. A few early attempts at wire opening had, in the meantime, proved unsatisfactory.

Similarly, the third method, that of expanding the tube to the point where it would release slugs, did not test successfully. Lack of uniformity in the strength of tube walls made it impossible to expand the tube evenly before weak spots gave way to internal pressure. During this period jury rig tests with various plow shapes had shown promises of satisfactory operation and this method was adopted for final design. It appeared that the plow would open the tubes with few chips and would spread the tube wide enough in one operation to allow the contents to fall out. Re-entry, should the plow pull out of the foil, also seemed feasible.

The machine consists of two welded carbon steel frames approximately 22 feet long. On the frames are supports for the two plow carriages so mounted that two sections of the quatrefoil can be opened simultaneously. The carriages are driven by long screws. Between the two frames is a trunnioned clamping fixture which chucks the quatrefoil and in which it is rotated as successive channels are opened. Although two sections can be opened at one time it is planned, generally, to open only one at a time. The left and right carriage drives are controlled through gear-motors and variable speed units, the main power being supplied by an electric motor. Two separate control mechanisms are installed for rotating and indexing the holding fixture. Hydraulic power is used for the holding fixture and piercing tools.

By original specifications the plow was to travel .015 in. outside the tube, making it in effect a ripping tool rather than a cutting tool. This, it was believed, would prevent any damage to the fuel slugs. To make the plow effective it was necessary to design a piercing tool that would enter the foil at one end and raise a piece of the foil high enough to obstruct the passage of the blunt-nosed plow. Then, as the plow moved along, it would engage the raised piece and rip out a channel in the foil. Before a demonstration of the machine could be made at the Brooklyn Experimental Laboratory of AM&F, fourteen different plow shapes and four types of piercing tools were tried. By August, 1952, the machine was ready and personnel of du Pont AED, DED and Design and AM&F witnessed its effectiveness on a number of foils. These August tests proved to be unsatisfactory. Because of the fixed tolerance between the plow and the tube exterior, any appreciable variation in the tube surface caused the plow to pull out. Also, re-entry proved to be less efficient than expected.

The frequency of these pull-outs compelled a complete review of the machine specifications and design. At first it seemed that the simplest solution would be the addition of a hydraulic tracer, also referred to as a follower, which could be used to maintain a constant relationship between the plow and the tube surface. AED and Design concurred and AM&F was requested to study available tracer designs. Several suppliers of hydraulic tracing equipment were located and a system quickly devised that could give control of the plow to within .001 inch. It was the opinion of the DED group and of AM&F, however, that the plow would function satisfactorily without the tracer if a more efficient re-entry tool could be designed and if the plow could ride 1/16-inch below the outside diameter of the tube wall. This, in effect, would make the plow a cutting tool rather than a ripping tool.

Discussions of alterations to the plow design were resolved in January, 1953, when AED issued a revised specification for the equipment. This permitted the plow to operate inside the foil but no closer than 1/16-inch from the normal outside diameter of the canned slugs and stipulated that a positive stop be provided to prevent the bottom of the plow under normal operating conditions from gouging the cans any deeper than .001 inch. It was also requested that an improved re-entry tool be designed which could be either portable or attached to the plow carriage. It was on this basis that the final machine design was completed.

TIPPING DEVICE

This equipment rotates the quatrefoil from a vertical to a horizontal position and places the foil in the plow machine. It was designed by an independent engineering firm under a purchase order issued by AM&F.

The device consists of a hoisting framework attached to trolley carriers which run on the overhead monorail. After the foil has been removed from its hanger and placed on the tipping device, the orifice assembly and perforated can are removed. The foil is then rotated to a horizontal position, raised to Elevation 11 ft. 3 in., carried over the plow and lowered to a point where the foil can be clamped in the disassembly machine. Clamps are then released and the tipping device is removed.

EMERGENCY SLEEVE REMOVER

Normally the sleeve remains in the reactor when the foil is removed. However, it is expected that in some cases the foil will be so distorted by swollen slugs that it will not pass up through the sleeve. In such cases the sleeve and foil are removed together and transported to this machine which may also be used to cut up damaged sleeves discharged from the reactor.

The installed machine is substantially the same as that originally specified. Mounted on vertical guide rails, it can be lowered to Elevation -30 ft. or raised above the level of the basin water. It consists of a set of clamps, an open throat pipe cutter and a vertical slitting saw. Hydraulic pressure operates the clamps, opens and closes the cutter half, and raises or lowers the table on which the vertical saw is mounted. Sealed gear motors operate the slitting saw and the machine itself is raised or lowered by an electric hoist. The various vertical elements are controlled by hand winches.

In the disassembly operation, the sleeve and foil are placed in the machine and two 10-inch long vertical cuts, 180 degrees apart, are made along the lower end of the sleeve. The sleeve and foil are released and the machine is lowered to a point where the pipe cutter can make a circumferential cut near the top of the vertical slits. The lower part of the sleeve, forming the shoulder supporting the foil, drops away and the foil can be drawn through the sleeve.

In developing the sleeve remover design it was hoped that commercially available equipment could be largely utilized. This was not the case, however, and nearly all assemblies are specially designed. Several changes were necessary after

testing of the prototype. Feed table cocking was eliminated by adding gears and racks; and a positive displacement pump was installed to supply hydraulic pressure, originally supplied by the plow pump, to the table feed. This eliminated an objectionably slow table movement.

One machine is provided for use in the plant's five #100 Areas.

DRY CAVE ROD DISASSEMBLY MACHINE

Radioactive material other than uranium is mounted in a different type of reactor component and requires a machine unlike the quatrefoil disassembly equipment. In this case the slugs are tightly jacketed by an aluminum tube, have a stainless steel extension at one end, and are received in the disassembly area either in a septifoil or as a single rod. The rods first must be removed from the foil and then each rod separated into slugs.

Originally it was thought that the process could be conducted under water with either a horizontal or vertical machine. Partial designs of both were completed and some preliminary tests were run to determine design effectiveness. When, in May 1951, the control rod design was changed to make the slugs fit tightly in their aluminum sheath, a complete re-design of the disassembly machine became necessary.

For these altered conditions two methods were considered. Either the sheaths could be expanded hydraulically or the rod could be cut transversely, on a line between two canned slugs. The second method appeared more feasible and was adopted. This raised the question of possible basin contamination and radiation hazards should a can be damaged accidentally in the cutting operation. To remove this danger it was decided to operate the machine in air, the equipment to be located in a "cave" separated from the remainder of the disassembly area by concrete shielding walls. The presence of radioactive material in the cave compelled remote operation of the disassembly machine. Major components of the machine as then planned were the elevator mechanism and transfer arm previously designed for the underwater vertical machine, a tilting device to bring the foils or rods into the cave, and cut-off machine. It was thought that commercially designed equipment could be used for the latter, but the late delivery dates and extensive alterations required made it advisable to design a completely new machine. Subsequent changes eliminated the elevator and the transfer arm.

The transfer mechanism by which components would be brought into the cave was originally designed to handle both individual rods and septifoils. An extractor in the cave,

equipped with a seven gripper head, could select any one of the rods in the foil for deposit on the rod disassembly machines. To simplify the process, a foil rod extractor was designed and only individual rods are now brought into the cave, thus eliminating the need for the multiple gripper head. Later changes included the addition of blowers to supply 300 c.f.m. of air along the length of a type of hot rod which has since been dropped from production plans, the addition of a piece counter to give the operator a record of the number of pieces cut from a rod, and the installation of a bracket on which an alpha counter could be mounted to monitor the 5Y3 cutting operation.

To place the rods on the cutting machine, two pieces of transfer equipment, the transfer carriage and the extractor are provided. The transfer carriage itself is a tubular frame structure mounted on a track located just below the operating floor level. This track extends from a point outside the cave, passes under the shielding wall at the end of the cave and terminates in a curved section in the cave. When the carriage has received a rod, it is pulled along the track by steel cables on an electric winch. The curved section causes the carriage to rotate from a vertical to a horizontal position bringing the rod up to about 5 feet above the cave floor. There the carriage is held in place while the extractor, traveling on tracks suspended from the cave ceiling, moves over the arms of the cutting machine, grips the rod and reverses its movement to deposit the rod on the arms of one of the machines. After the rod is removed, the transfer carriage is released from the fixed position in the cave and returned to its loading station outside the cave by a counterweight riding vertically in a steel frame.

When the rod has been deposited on the cutting machine arms, these are raised and the rod slides down to a conveyor. Pinch rollers on the conveyor move the rod into a position where feed rollers can push it through the cutting head and against an index stop. The two-bladed rotating cutter severs the .024-inch thick sheath at the juncture between two slugs, and the slug falls to a chute and then into the cask. If the cut is not made at the juncture and the slug does not separate from the rod, a knock-off device is used. When all the slugs have been cut off, the rod extensions are fed back through the rollers to the conveyor which is tilted approximately 40 degrees and the extensions are chuted to an underwater collection tray for disposal.

HOT LAB TABLE

A Type 304 stainless steel tray top, approximately 7 feet 2 inches by 3 feet 9 inches, is mounted on a steel-framed support placing its surface just below the bottom of

the adjacent observation window. Glass enclosed to a height of 20 inches, the table has a 10-inch turntable at one end. A glass door, swinging down, permits access of materials to the turntable.

HOT LAB SCALES

Of the even balance type, the scales give automatic indication on a special 1/2-gram increment chart to a maximum of 30 grams. The scale will take weights up to 15 kg.

HOT LAB GAUGE STATION

This equipment enables an operator to measure a slug's diameter, length and warp. Located on the lab table, the gauge station consists of a rack assembly, shoes, and the dials which give measurements to .001 inch. The canned slug is placed on the rack and pushed to a point between the shoes. As the slug is rotated, the shoes indicate dimensions on the various dials. A master pin, accurate to within .0005 inch, is provided for gauge calibrations.

No suitable commercial equipment to perform this operation could be located and AM&F designed and built the unit for the R Area.

HOT LAB PROFILOMETER

Designed to give a recorded measurement of the longitudinal contour of a fuel slug, this instrument has a chuck to grip the slug and support rollers on which the piece rests. A selector switch can translate probe deviations into three gains, 2.5, 5 or 10. Chucking is done manually with the manipulator but rotation and recording are done remotely on a console outside the cave.

HOT LAB PERISCOPE

A precision optical instrument, the monocular periscope permits close examination of the canned slug exterior. The eyepiece is located near the viewing window and manipulator controls so that an operator can study and manipulate the slug at the same time. The objective is near the normal

position of the slug as it is placed on the profilometer.

Some thought was given to the design of a periscope with interchangeable one power and ten power magnifications and 90-degree scanning around a vertical axis. When the development and fabrication costs appeared to be unwarranted, the plans were changed to a simplified design having only 10-power magnification, no scanning, and focusing only with the eyepiece. Lenses are of non-browning glass and the metal housing is non-corrosive. A 10-inch thick lead shield is installed over the end of the periscope on the outside of the cave to eliminate radiation hazards. The instrument was designed and fabricated by the Kollmorgen Optical Corporation with the assistance of a consultant from the Engineering Research Laboratory of du Pont.

HOT LAB MANIPULATORS

Similar to the manipulators developed at the Argonne National Laboratory, this equipment was manufactured by Central Research Laboratory. To facilitate handling of slugs, du Pont substituted curved grips of its own design for the flat grips used on the Argonne model. All areas of the laboratory table can be reached and all laboratory instruments operated by the manipulators.

HOT LAB WINDOWS

The four windows in the dry cave are of similar construction but differ in size depending on the thickness of the shielding wall and the observation area required. Basically they are metal tanks filled with optical grade zinc bromide. Non-browning lime glass is used on the cave side of the windows, water white lime glass on the side facing away from the cave. Development details and a more complete description of the windows is contained in the section of this history entitled "Special Developments - Windows".

DRYER

A carbon steel tank with 6-inch lead-filled walls, the dryer is approximately 24-inches wide, 4 feet long and 22 inches high. Rails at each end support the 2000 pound lead-

filled lid which is fitted with wheels so that it can be moved back and forth to clear the opening through which the slug baskets are moved into and out of the dryer.

A basket containing fuel slugs is brought up from the basin through a hole in the floor by a monorail hoist. The monorail track guides the hoist, operated by a pulley system, over the water and acid wash tanks, the dryer and the turntable on the laboratory table. Baskets containing slugs are dipped in the acid wash tank, the water wash tank and then placed in the dryer where moisture is removed by the inherent heat of the slugs and an air flow drawn from the room and exhausted to the ventilating system. When dry, the basket is placed on the turntable and rotated to give the manipulators access to any of the slugs.

Only the R and P Areas are equipped with the above hot lab equipment items.

FORK TRUCK

A standard fork truck has been adapted to engage the trunnions of the slug casks used with the rod disassembly machine.

MONITOR BASIN TURNTABLE

For the underwater microscopic examination of canned fuel slugs, the turntable is designed as a mount on which the individual slugs can be placed and so rotated that all surfaces can be examined.

The request for the turntable, issued in April 1952, stipulated that motion in four directions should be provided: (1) rotation about the long axis of the slug in either direction, (2) rotation in a horizontal plane with the short axis the center of the slug, (3) movement to and away from the viewer, and (4) movement across the field of the viewer in either direction. Equipment serving the same purpose had been installed at Hanford but difficulty had developed with the flexible controls. At Savannah, manual controls operate the turntable through connecting rods, gears and splines.

Two rollers at the top of the turntable support the canned slug. These rollers are placed on a revolving mount and with supporting tables give the required movement.

Rotation of the four knobs at the desk approximately 19 feet above the turntable give a 1/2-inch table movement to right or left, 1/4-inch movement forward or backward, a 72 degree table rotation and a 360 degree rotation of the slug.

The prototype designed and fabricated by AM&F was installed in the R Area. Subsequent testing and the completion of a binocular microscope to be used with the turntable brought several changes. Originally, the underwater moving parts were made of aluminum to reduce the effect of inertia. Fear that these parts might form a corrosive coupling with the bronze bushings used, led to bronze specifications for these moving parts. Also, when it became apparent that the microscope would be too large to allow direct vertical control between the turntable and the desk, the desk was placed on the opposite side of the turntable and horizontal connecting rods were installed between the desk and the vertical rods.

BINOCULAR MICROSCOPE

In the design of a microscope which would enable an operator at a desk on the rim of the monitor basin to study slugs at the -15 foot level, the du Pont Design Division availed itself of the technical assistance of optical specialists at its Engineering Research Laboratory. The latter specified the materials to be used, generally outlined the desired design, and periodically reviewed design details submitted by the vendor. It was requested that the instrument provide interchangeable magnifications of 1 power and 15 power, with lenses to be made of non-browning glass and the entire unit to be removable for possible use in other areas.

Although several manufacturers were engaged at the time in developing non-browning glass, no commercial supply of satisfactory quality could be located. Enough glass for the lenses was supplied eventually by the Argonne National Laboratory. Because of the inherent differences in the glass it was necessary to work out a completely new lens computation for this non-browning type. This computation, with the design of the complete optical system, became the subject of a purchase order issued to the Kollmorgen Optical Company. In addition, the company was to fabricate one set of binocular optics, demonstrate the quality of the optical image, and prepare drawings showing the optical arrangement, the various controls and over-all

dimensions of the instrument.

Upon the successful completion of the lens work and general design of the microscope, Kollmorgen was also issued a purchase order for its fabrication. Special lighting used in connection with the microscope was designed by du Pont.

TONGS

To manipulate foils, rods and component parts in the disassembly operations ten long handled tools or tongs were designed. The original design for the can tongs was based on drawings obtained from Hanford. To some extent the design of all tongs was influenced by this earlier design but, because of the greater length necessary at SRP, some changes were made.

Although the tongs are generally similar, each was fabricated to perform a specific type of operation. Each pair of tongs consists of a gripping handle, a long tube containing an actuator rod, and the jaws or grapple mechanism. As a rule, pressure on the gripping handle opens the jaws and a spring in the tube forces the jaws together when pressure is removed from the handle. Removable ballast tanks are placed on the upper portion of the tongs to equalize weights.

Can end tongs are used to pick up cans from the sorting trays and place them in buckets. An alternate type of can tong is provided to pick up cans and, at the same time, remove adhering spacers.

Spacer tongs are 19 feet long, enabling the operators to scoop up a number of spacers at one time from the sorting trays of the two types of disassembly machines.

Vertical foil tongs can be used manually to lift empty foils from the vertical disassembly machine or, mechanically, to lift loaded foils by means of monorail hoists.

Foil transfer tongs are used to lift empty septifoils from a monorail hanger, after which they can be grasped by the vertical foil tongs for transfer to the foil press and shear.

Horizontal foil tongs are used to pick up a plowed foil from the sorting tray of the horizontal disassembly machine. On this set of tongs the gripping jaws swivel so that foils

can be changed from a horizontal to a vertical position.

Rod end tongs are used to transfer the rods from the deposit and exit conveyor to the rod hanger, and from the rod hanger to a machine.

Utility tongs are used to pick up miscellaneous items weighing less than 50 pounds. These tongs are fitted with an extension making them usable to a depth of 30 feet. Forked tongs are used to manipulate cans and rods into a position where they can be grasped by other tongs designed for a specific use.

STORAGE HANGERS

Used to transport and store the loaded foils and rods, these hangers were constructed of 3/4-inch diameter steel rod with a vertical welded plate at the top and a horizontal plate at the bottom. The top plate is bolted to the clevis swivel on a monorail trolley and the bottom plate is slotted to suit a component. Hangers designed for rod handling have seven slots in the bottom plate, and septi-foil hangers have an internal expanding gripper instead of a slotted plate. Lengths of the hangers vary from 14 to 19 feet. Aside from some jury rig testing, little development work was necessary.

In the C Area, agreement had been reached on the use of double hangers so designed that in place of the single plate carrying a foil, a larger bottom plate swivelled in the center with each end slotted to support the foils under the top fitting. Because of the economy offered in the number of hangers and the space necessary for storage, and because of its flexibility with respect to possible new fuel elements it was decided to install the double hanger in the L Area. Production of the single hangers had by that time been stopped but the supply on hand was enough to equip the K Area.

CRANES

The repair shop crane is standard. The 30-ton crane in the transfer area, a duplicate of the Hanford crane, has special twin-hooks with narrow blocks to facilitate movement into and out of the transfer pits. Alignment and spacing of the hooks is constant throughout travel.

CASKS

The slug bucket casks are a Hanford design. For scrap transfer, a cask with a 19 cubic foot capacity was designed in conjunction with Dempster-Dumpster, vendors of the cask handling equipment.

TRANSFER CAR TANK

When it was decided to re-design the railroad cask car used at Hanford from a two to a three-compartment car, it was necessary to re-design the transfer tanks. A discussion of the cars and tanks is found in the Section on "Transportation" in Volume IV.

BUCKETS

Fuel and scrap buckets are a duplicate of those at Hanford.

MONORAIL SYSTEM

Except for minor alterations to adapt American Monorail equipment to the disassembly area, the system is standard.

PURIFICATION AREA

In the section describing building design development it was pointed out that the Blaw-Knox Company had available a manpower force experienced in canyon design work. To expedite the construction of the purification area, building and equipment development was turned over to that company in the fall of 1951 under the guidance of resident du Pont Design Division personnel.

MODERATOR PURIFICATION

For process continuity three parallel moderator purification units are installed providing a standby of two units with one unit operating at a flow of 30 g.p.m. If contamination should exceed normal conditions, two or all three cells can be operated simultaneously. Full operation is expected only on rare occasions when slug failure might occur.

Generally speaking, the design of the cell equipment, composed of a pre-filter, deionizer, and after-filter, follows standard principles. Departures lie chiefly in the precautions taken to prevent, detect or collect leakages, and in the use of trunnions, outriggers and guide pins for remote handling and accurate placement within the cells. The latter were patterned after #200 Area experience at Hanford where this method of positioning and handling had proven successful.

Necessarily, design tolerances on all equipment pieces and pipe connections were close and meticulously maintained in fabrication. Without such strict adherence to specifications the difficulties in remote installation would have been greatly increased. Briefly, the wall nozzles, positioning guides and finished floor for each cell were set from an established field work point to a tolerance of plus or minus 1/32-inch from the true dimension. The maximum variation of the finished cell floor from its true sloping plane was plus or minus .005 inch. The various vessels and supporting frames were built to close dimensions and tolerances as shown on drawings.

Before any equipment was installed in a cell, its dimensional accuracy was checked in Building #717-F in the #200 Area by actual installation on a mock-up basis. The facilities in Building #717-F were originally designed for #200 Area equipment mock-up but the similarity in installation problems led to utilization of the building and its equipment for both #100 and #200 Areas. When successfully mocked-up, the equipment was transported in its individual frame to the #100 Area and installed, the outriggers on the frame and permanently mounted guide pins in the cell structure

assuring precise placement. As an additional demonstration of accuracy in equipment fabrication and the problems encountered in remote installation, the initial placement of the equipment in the cells was made remotely by the cell crane.

In addition to the above considerations, three primary objectives were emphasized in design. First, the several units were designed as compactly as possible to fit into the limited space within a cell. Second, maximum efficiency had to be achieved with minimum hold-up of the valuable heavy water. Third, the cost of each equipment piece had to be kept to a minimum since disposal of the equipment when fouled appeared to be the only practical solution. Brief consideration was given at one stage to replacement of filters or the resin beds. To do so, it would have been necessary to install underground storage tanks into which the contaminated wastes from the filters and the contaminated, exhausted resins could be flushed. Also involved were a much more complicated vessel design and a flushing system. Both the cost and operating difficulties of such a scheme made it impractical.

All equipment piping in the cells is fabricated from Type 304 stainless steel to prevent contamination of the moderator. Special gasket materials are used to prevent leaks.

FILTERS

Four requirements governed the design of the filters. These were (1) low first cost, (2) maximum surface to volume ratio to minimize moderator hold-up, (3) fine filtration, (4) release of no organic contaminants. In the selection of a filter all organic materials were eliminated and attention given to fiberglass, sintered stainless steel and asbestos. It was determined that Johns-Mannville had developed, largely for U. S. Navy use, a special asbestos, WI-4809, Grade AAA, 95 per cent asbestos cloth, which, under du Pont tests, demonstrated the desired qualities. This is used with Alsop "Disc-Pak" discs.

The filter vessels are approximately 17 inches high, 13 inches in diameter and contain 20 sections of perforated metal discs covered with asbestos cloth. The moderator enters at the bottom, passes up through the filters and is withdrawn through perforations in a cylindrical tube mounted vertically in the center of the vessel. Connector flanges of the same design as used in the #200 Areas are provided for liquid inlet and outlet lines and are located at the top of the tank to simplify remote installation and maintenance. The pre-filters and after-filters are identical.

DEIONIZER

As was the case in most of the equipment installed in the area, the development of the deionizer was concentrated on maximum efficiency in a small, compact unit. In the search for the best possible exchange medium a number of resins were evaluated but eliminated in favor of Rohm & Haas Amberlite IRA-400 and IR-120. In du Pont laboratory tests one part of cationic and two parts of anionic resins were used in beds one inch in diameter and 40 inches deep. Test flow rates ranged from 5 to 100 g.p.m. per square foot. From these tests it was concluded that the selected resins could easily maintain the desired exchange rate at the planned flow rates. They also indicated that higher flow rates could be used if desirable. The exchange capacity of the resins could not be divorced, however, from their performance under drying. This quality was equally important because the maximum recovery of heavy water from the spent resins by hot gas drying was contemplated and any degradation to the point of moderator contamination could not be tolerated. The IRA-400 and IR-120 resins, under testing, demonstrated the necessary stability and this, coupled with their exchange efficiency, was the basis of their selection for use in the deionizers. These resins also qualified because they retain relatively small amounts of chemically bound light water, a contributor to isotopic contamination of the moderator.

In the beginning, some thought was given to resin regeneration but at that time the isotopically pure regenerants required were not available and their special preparation would be so costly as to be unwarranted. Subsequently, tests at the Engineering Research Laboratory on drying and regeneration demonstrated a loss of ion exchange capacity after drying, a danger of excessive isotopic contamination if the resins were re-used, and finally, a severe degradation of the resins when re-wetted with heavy water. These reasons together with the cost of underground storage tanks and a flushing system led to adoption of vessel disposal plans with no effort made to regenerate the resins.

The deionizer vessel is approximately 4-1/2 feet high and 3 feet in diameter with reinforced top and bottom heads. A 30-g.p.m. distributor is mounted at the top and bottom of the tank with an additional 1-1/2 g.p.m. distributor at the bottom to introduce heavy water during the deuterization process. The resin bed is approximately 45 inches high. The connections for inlet and outlet moderator flows are also used for gas flow during the drying stage. A special inlet line is connected to the 1-1/2 g.p.m. distributor during deuterization.

CONTAMINATED MODERATOR

Aside from the types of materials used and the tolerances specified, the equipment in Cell D is patterned after standard industrial designs. This includes the temporary storage tank, surge tank, evaporator, evaporator return condenser and four vertical, centrifugal pumps.

CRANE

The remotely operated bridge crane, which has access to each of the four cells and to the trailer loading space, is similar to the Building #221 cranes at Hanford and the Savannah River Plant. By means of a complex control panel and twin periscopes, the operator in a shielded cab can remotely install or replace process and electrical jumpers, pumps or vessels and perform general maintenance work on cell equipment when human access is not permissible.

The crane is equipped with six hooks. A 30-ton main hoist is used to move the cell covers and the lead cask cover. A 5-ton auxiliary hoist is provided for cask equipment and jumper handling. Two one-ton and two one-half ton monorail hoists are used for the lighter work including the manipulation of jumpers, impact wrenches and pipe grabbers. The cab console includes a wide range of speed controls for the bridge and trolley travel and the vertical motion of the several hooks. Included in the special design features of the crane are hydraulic cable cutters for emergency use, an auxiliary set of hydraulically operated bridge wheels, a provision for manual movement of the bridge in case of a power failure and extensive braking devices on the hoists. The cab is air conditioned with air intake through CWS filters and is equipped with a special cooler.

Throughout design much attention was given to dimensions of the various crane components to assure maximum movement, strength, reliability and flexibility.

BLANKET GAS SYSTEM

The final design of the blanket gas system follows closely the original data submitted to the Design Division by the Atomic Energy Division of du Pont. The principal problems grew out of the selection of a blower with adequate seals, the perfection of the recombiner design and the design of the coolers.

BLOWERS

The emphasis in blower selection was placed on reliability, a steady gas flow, and a seal that would prevent the introduc-

tion of air, oil, or water into, or helium losses from the blanket gas system. Selection of a blower was complicated by the low density of helium, low specific heat and high slip relative to air. Among the blower types considered were those using a spiral lobe rotor, straight lobe rotor, centrifugal types and the Nash positive displacement type. During the preliminary stages of design a Nash Hytor model was believed most suitable but a Read-Standard spiral lobe type was finally selected because of its freedom from pulsation, low cost, lower power requirements and the fact that no auxiliaries were required.

The various kinds of seals studied for possible use were a dry seal; a mechanical type with a stationary, oil-impregnated, bronze face and a rotating stellite face; and an oil lubricated, single mechanical seal with an internal oil slinger. At no time was a seal employing oil studied without very critical analysis of possible oil leaks into the gas stream. The seal finally selected is a non-lubricated mechanical type that can be operated dry or with water coolant. The seal has a rotating stellite and a stationary carbon face.

RECOMBINER

The selection of a catalyst and the general specifications for the recombiner vessel were made by the Atomic Energy Division of du Pont and submitted as original data to the Design Division. Candidate catalyst materials were; first, platinum deposited on activated carbon; second, platinum on alumina pellets; and finally, 0.2 per cent palladium supported on 1/8-inch alumina pellets. Selection of the latter was based primarily on experimental work conducted at the Argonne National Laboratory and data developed by the du Pont Engineering Research Laboratory and Chemical Department.

The recombiner vessel is approximately 3-1/2 feet in diameter and 4 feet high with an impingement plate enclosed in an open conical hood at the top of the vessel to improve distribution of the incoming gas. The 10 cubic feet of catalyst, approximately 1-1/2 feet deep, are supported on a grid above which is a screen to retain the catalyst pellets. Connections include gas inlet and outlet lines and eight thermowells with 16 measuring points to check bed temperatures. A lateral 10-inch opening is provided for catalyst charging and a similar opening for catalyst removal.

When it becomes necessary to remove catalyst fines, the gas stream is transferred to the idle gas purification room. The system is then purged by blowing room air through all equipment in the cell. When the cell is safe for personnel entry the catalyst is manually removed from the recombiner,

sifted through a portable screening unit and manually re-charged to the recombiner. Before the unit is again placed in operation a strong air current is passed through the bed to carry to the stack any fines generated by the charging operation.

The system is then evacuated by a special vacuum pump to remove oxygen from the catalyst and to avoid introducing air into the blanket gas circulating system.

The gas pre-heater which is operated when the catalyst bed is not at operating temperature is a vertical, double tube sheet exchanger 12 inches in diameter with tube lengths of 12 feet. It contains 68 three-quarter inch tubes. Gas is on the tube side, steam on the shell side.

Double tube sheet coolers used in the gas system typify the construction found necessary in a number of locations in the purification area to minimize the possibility of moderator or helium contamination by light water or ammonia refrigerant. These coolers presented severe problems in stress since the incoming gas from the recombiner was cooled from approximately 600 deg. F. to approximately 100 to 105 deg. F. To offset the danger of tube warpage, the double tube sheets at each end of the coolers were separated by more than the normal distance to reduce stress on each tube at any given point. Extra tubes were also incorporated to compensate for the loss of heat exchange area caused by the tube sheet spacing.

Two such coolers are installed and operate in series. Each is a vertical unit 16 inches in diameter with a 10-foot tube length. Approximately 121 3/4-inch diameter tubes, are incorporated in each exchanger with gas in the tubes and water on the shell side. Connections include gas inlet and outlet, water inlet and outlet, two drains, two plugged weep holes and a vent.

The gas separator is a cyclone type, 18 inches in diameter and 3 feet high, with a long conical bottom head and a dished top head. Gas enters through a tangential inlet connection and is expelled through the top. Collected moderator drains continuously through a bottom inlet. As in the moderator purification lines and equipment, the metal parts exposed to the blanket gas are Type 304 stainless steel.

DISTILLATION SYSTEM

The capacity of the distillation system was determined by two factors: first, the volume of light water expected to accumulate in the moderator system and, second, the volume of distillation column overhead that could be re-processed

in the #400 Area. On the basis of an anticipated 2000 pounds per year pick-up of H_2O , the continuous input of the moderator to the system was set at 7 g.p.m. The maximum amount of overhead to be re-processed per #100 Area is approximately 5 tons per year with a concentration of about 80 mole per cent D_2O . On this overhead a very low limit of radioactivity was set as a design criterion since the #400 Area is in no way prepared to handle a contaminated product.

Distillation specialists from the du Pont Engineering Research Laboratory established the design for the facilities after completing numerous and complicated calculations on the Card Program Calculator at the Oak Ridge National Laboratory. The specifications for the distillation towers prepared by ERL reflected low liquid hold-up and high reflux ratio on the order of 3000 to 1. Absolute column tightness was imperative because of operation at high vacuum. The use of sieve plates, which were included in the column design because of their very low hold-up characteristics, also represented a lower fabrication cost. Major economies in construction resulted from the use of carbon steel instead of stainless steel, as originally planned. In this respect designers profited from the successful experience with carbon steel at the Wabash River Ordnance Works. As in the #400 Area, the distillation columns are operated under vacuum to secure the advantages of a more favorable volatility relationship between D_2O and H_2O .

For a short time, in the early stages of design, a distillation system completely enclosed by a Class I structure was believed essential for personnel protection from residual activity. Further investigation led to the conclusion that the activity was of a sufficiently low level that shielding would not be required. Therefore, columns were located outdoors in a conventional manner.

As designed, the columns are approximately 83 feet high and contain 90 horizontal sieve plates. The lower part of the column, which includes 44 plates, is 41 inches in diameter and the upper part containing the remaining plates is 47 inches in diameter. With the use of sieve plates, the columns had to be increased in diameter at the top to maintain a constant gas velocity throughout. The 1/4-inch thick plates have a splash baffle, inlet and outlet weirs and three overflow pipes. The overflow pipes, which are flush with the top of the plate, extend to within one-half inch of the plate below. The very small fluid accumulation on each plate is controlled by the outlet weir.

The usual provisions were made in the column for personnel access at various levels. Connections include: vapor outlet, six feed nozzles, reflux inlet, three thermowells, vapor inlet, condensate drain, pressure recorder and level controller.

Much attention was given to structural stability and accurate installation to assure the levelness of the plates, which for maximum efficiency could not vary more than one-eighth inch from the true horizontal.

The column reboiler is a vertical calandria, 20 inches in diameter, 4 feet high with 120 one-inch tubes. Double tube sheets are used to minimize contamination of the moderator. The column condenser is also a double tube sheet exchanger, 30 inches in diameter, 8 feet in length, with 376 one-inch tubes.

RESIN PREPARATION FACILITIES

One of the more important development problems in the purification area centered about the mixing and wetting of the resins to be used in the deionizer. To provide data upon which a satisfactory method could be based, the Engineering Research Laboratory was requested to study the mixing and wetting problem. The following conditions were believed essential for efficient operation of the deionizer: (1) a uniform bed of resins, (2) uniform distribution of the entering D₂O and uniform collection of the effluent D₂O, (3) minimum dilution of the heavy water, and (4) a distributor that would not cause excessive pressure drop during operation.

The charging, agitation and deuterization methods proposed by the Engineering Research Laboratory were adopted with subsequent but minor revisions. To secure a uniform bed the deionizer is partly filled with light water and then as the cationic and anionic resins are added the revolving agitator paddle is slowly raised until the desired resin depth has been secured. The paddle is 10 inches high, 18 inches long and revolves at 86 r.p.m. The laboratory also determined the maximum rates at which D₂O could be fed to the resins in replacing the light water, that rate being a vertical linear displacement of 1 cm./min. The information on the number of pounds of liquid that should be diverted to each of the three cut tanks to minimize the blending of light and heavy water during the deuterization process was largely developed by the Argonne National Laboratory and submitted to the Design Division by the Atomic Energy Division of du Pont.

Almost as important as the mixing and wetting method was the D₂O recovery method to be used in drying the resins. The laboratory's objective in the test program was to secure, by varying gas temperatures, velocities and the drying times, the maximum recovery of heavy water with minimum decomposition of the resins. The experiments indicated that the resins could be dried at room temperature to a moisture content of 8 to 10 per cent without causing excessive decomposition. It also appeared that the cationic resins were much more stable under the drying process than were the anionic resins which

decomposed rapidly as the drying gas temperature increased. Among the resins tested, IRA-400 and IR-120 consistently performed better than other candidate resins.

Recovery of the heavy water from the spent resins is, therefore, carried out at room temperature with approximately three days required to bring the moisture content of the bed down to about 8 to 10 per cent. Approximately 21 such drying operations are anticipated each year.

When the deionizers have been charged, they are subjected to hydrostatic tests to assure vessel and connection soundness and freedom from leaks, and then deuterized.

REFRIGERATION SYSTEM

The complex refrigeration system required for condensing heavy water from the vents of the various systems in the purification area was designed by Blaw-Knox engineers in consultation with engineers of the Carrier Corporation. Since Freon does not ionize in water and would, therefore, be much less susceptible to removal from the moderator should it enter the heavy water stream, ammonia was selected as the refrigerant. This can be removed from the moderator by the deionizer.

The 8-ton capacity system consists of two compressor stages, both of which are spared, a condenser, a receiver, liquid and gas cooler and desuperheater. Three temperature levels are supplied by the system, 40 deg. F., minus 15 deg. F., and minus 40 deg. F. For a time thought was given to incorporating a lower temperature in the system but this was eliminated so that early delivery carbon steel could be used in equipment fabrication. At lower temperatures scarcer nickel steels would have been required. Oil traps which separate oil from the compressor discharge gas return this oil to the compressor crankcase. An intercooler is provided between stages and a desuperheater is placed on the booster stage suction line.

Two general suction pressure levels are used. The booster stage operates at 9.4 p.s.i.a. and serves the process coolers which are maintained at 19.8 p.s.i.a. and 10.4 p.s.i.a. The high stage operates at 44.7 p.s.i.a. and serves coolers operating at 71.8 p.s.i.a. All coolers except the drying gas freezers are equipped with back pressure regulators to control evaporator temperatures at the desired level. The drying gas freezers at 10.4 p.s.i.a. operate at about the same pressure as the booster compressor and thus require no further regulation.

Liquid refrigerant is supplied from the receiver to the

various process coolers. A solenoid valve in the liquid line leaving the receiver closes when the high stage compressor stops and another solenoid valve in the liquid branch line to the subcooling coil closes when the booster compressor stops. This gives positive protection against any process cooler flooding back to the compressor due to a leaky control valve allowing high pressure liquid to enter the cooler during shut-down periods.

An equalizing line and a liquid drain line connect the receiver and all process coolers which must be thawed periodically. When a cooler is to be thawed, its normal liquid and suction connections are closed and the two lines to the receiver are opened. After the receiver pressure and cooler pressure are equalized, the liquid in the cooler drains to the receiver by gravity. At this time the defrosting line is opened and hot discharge gas at 221 deg. F. from the high stage compressor enters the cooler. As hot gas is condensed in the cooler it drains to the receiver. This continues until thawing is completed. All switching for defrosting is done manually and both the booster and high stage compressors operate automatically after start-up. They are interlocked so that the booster compressor cannot start without starting the high stage compressor but the high stage machines can be operated alone when necessary.

MISCELLANEOUS

PIPING

Because of the successful operating experience with several types of connectors and impact wrenches and the system of prefabricating piping and jumpers in the #200 Area at Hanford, the specifications and methods employed there were widely used in the purification area.

All stainless steel piping imbedded in the concrete floor and walls was 100 per cent X-rayed before installation. At least 10 per cent of the welds on the various stainless steel vessels were X-ray inspected as were 5 per cent of the prefabricated piping welds. Welding was by the "heliarc" method to insure a U-68 quality as established by the 1949 ASME Unfired Pressure Vessel Code. In addition all prefabricated piping was submitted to a mass spectrometer test at 5×10^{-5} C.C./Sec. All jumpers were fabricated in the Building #717-F pipe shops and tested before pre-assembly in a mock-up frame.

VALVES

Much attention was given to the design of valves that would perform well under remote operating conditions and retain minimum leak characteristics. All valves in the moderator and gas lines are fabricated of Type 304 stainless steel.

and the bellows on the special sealed valves are made of Type 316 stainless steel.

GASKETS

After analyzing a number of materials suggested for use in gaskets, designers selected for cell use a new type of material developed primarily for the #200 Area. This is a blue African asbestos fabric, 45 to 50 per cent by weight, with a dry Teflon from aqueous dispersion, 50 to 55 per cent by weight. No fillers or binders are used other than Teflon. The principal advantage of this material, aside from its performance characteristics, is the fact that with the use of Teflon the gaskets will not stick to the flanges. These gaskets are used on all connectors in the cell rooms. In other locations, depending on temperatures, pressures and type of material circulating, the gaskets are either rubber, Teflon, or Buna S bonded, compressed asbestos.

INSTRUMENTATION

The central panel in the control room contains all controlling, recording and indicating instruments by which operations in the purification area are maintained. The three-section panel, mounted with miniature type panel instruments, carries all the instruments for the two gas purification systems on one section. These include controllers for the gas flow to and from the area, temperature controllers for the recombiner, preheater, gas cooler, the oxygen and helium make-up controllers and the gas analyzers.

The center section of the panel carries the health monitoring units which record the degree of radiation present at any location as measured by ion chambers. The presence of radioactive gases or air and any induced radioactivity in the gas purification and gas drying lines is detected by Kanne-type ion chambers which transmit signals to the control panel.

The third section of the control panel contains instruments for the cells, gas drying equipment room, distillation, refrigeration, leak detection and the utilities. Cell instrumentation consists of liquid flow controllers, drying gas flow controllers and a differential pressure indicator for each deionizer and filter. For leak detection, approximately 30 transmitters are installed under various wall jumper connections, vessel connections, valves and other points where leakage might occur. Temperature indicators and recorders, dew point recorders and flow controllers are installed in the gas drying equipment rooms. In the distillation system are differential pressure indicators to measure changes across the columns, and steam flow controllers and level recorders for the reboiler.

The problem of developing an efficient and reliable gas analysis method was solved by a joint effort of the du Pont Engineering Research Laboratory and the Beckman Instrument Company. It was recognized that with a high neutron flux density and the presence of some moderator contaminants, the moderator would decompose to give a stoichiometric ratio of deuterium and oxygen. The extent of this dissociation would be related to the amount of contamination in the moderator. Also, a portion of the freed oxygen would be lost through its combination with corrosion products or peroxides thus creating a possible excess concentration of deuterium in the blanket gas system. With pure moderator this would be an advantage. With increasing contamination in the moderator the deuterium would cause excessive dissociation.

To provide for the operation of the gas system under either an oxygen or a deuterium excess, an efficient recombiner was designed and facilities installed for adding both oxygen and deuterium.

The result of the instrument development work is a unit that continuously measures the quantities of oxygen in the recombiner effluent and by this measurement guides operators in adding either oxygen or deuterium to give any desired ratio between the two. The gases are added directly from cylinders, the deuterium originating in the #400 Area, the oxygen being supplied by commercial vendors. Two taps in the gas line, one before and one after the recombiner, feed to the oxygen analyzer. Either tap can be used independently. The analyzer activates a strip recorder which gives the quantity of oxygen in the gas stream. Operators reading the recorder then add the required quantity of either gas.

The analyzer consists of a recorder, catalyst cell, cycle timer and an oxygen injector. Samples are fed through the cell and a measurement made of the oxygen excess in the gas system. If an excess of deuterium exists in the system, oxygen is injected into the sample line and a measurement made of the amount injected to record the relationship between the two gases. At first an electrolytic cell was installed to supply the oxygen needed for sample measurements but it was found that slight pressure variations in the sample line caused fluctuations in the output of the cell and led to faulty measurements. It was also evident from early operation of the instrument that mixing of the gases was not adequate and good control was hard to maintain. To eliminate these difficulties instrument oxygen is now admitted under pressure through a capillary tube. Actually a hypodermic needle is used for this purpose.

As a general rule the use of mercury in instruments was not permitted because of the danger of moderator or gas

contamination should an instrument break. It was impossible, however, to eliminate mercury entirely, for analytical precision and reliability demanded its use in two rectifier tubes and a thermometer in the mass spectrometer, and in the standard cells of the potentiometers. The cells are protected from injury by special housings which can also retain the cell contents should one break.

DEVELOPMENT OF BUILDING #105 INSTRUMENTATION

Virtually all the instrumentation in Building #105 is associated with the reactor and the nuclear processes which take place within it. To integrate a system that would give the type of reactor control desired and the operating information necessary, a broad development program was required to produce either new techniques of industrial instrumentation or modifications of specialized equipment designed for the Hanford piles or various other AEC reactors. If Building #105 instrumentation is compared with that of a conventional industrial process, nearly all the equipment is special.

When viewed from a cost standpoint, the large dollar investment in the building's process equipment justified a proportionately large investment in nuclear instrumentation. It also justified a somewhat larger ratio of instrumentation to process than would normally be encountered were the process investments more dispersed.

Reactor instrumentation can be divided generally into three categories: (1) nuclear instruments required for reactor control; (2) instruments which permit utilization of the reactor up to its maximum capacity; (3) instruments associated with the reactor auxiliaries such as pumps, piping and heat exchangers. A fourth category not directly associated with reactor operation but related to the nuclear process, includes health monitor instruments intended to assure personnel safety.

REACTOR CONTROL

The focal point for reactor operation is the console, the medium through which only that information essential to the operation of the pile is collected from a variety of instruments and presented in a coordinated form to a single operator. In its final form the SRP console is a much streamlined version of that originally contemplated. An early AED scope, presented to Design in 1951, included a great many instruments and controls that were to be grouped at eye level

and within reaching distance of the operator. Through all arrangement studies the dominant factor influencing design was the positioning of six large master synchro units for the actuators. The final design has these enclosed within the console framework on self-contained carts on wheels, one set of three on each side of the operator.

To check the various features of the projected design, a wooden mock-up was constructed by the Panellit Company, vendors of all the control room panels, and this was carefully reviewed by AED and also used at NYX for operator training.

Details of the construction and arrangement of the console appear in the "Description of Facilities" in the latter part of this Building #105 history.

The August 1950 concept of the reactor included ion chambers to follow rapid changes in power level. Neutron instruments for control of the reactor were mentioned in the scope of October, 1950, in connection with start-up and low level operation only. Between six and eight ports were to be provided in the foreshield for location of the required chambers. These ports continued as an integral part of the design as the concept of the thermal shield and the biological shield developed and crystallized, although their number and location varied. The final design employs 12 ports, four equally spaced around the reactor at each of three levels. The instrument scope of work prepared in December of 1950 mentioned the use of such chambers with electrometers for shutdown in case an excessively high neutron flux develops during normal operation. Presumably, such chambers would also be located in the ports provided in the shield.

During the early part of 1951, ion chambers which would be suitable for the high neutron levels encountered in the shield were designed jointly by ERL and Design. These were to be used with a battery operated galvanometer at full level operation to provide an indication of the neutron level within the reactor independent of the a.c. power supply. The galvanometers were located on the console. In the early days of reactor operation at other locations, it had been customary during changes in reactor power level to determine the period of the reactor, or rate of power changes, by counting the seconds required for the galvanometer to travel between two predetermined points on its scale.

In August 1951, AED requested an electronic system for determining reactor period similar to that which had been developed at Oak Ridge. A joint survey by Design and AED indicated that the only commercial source was the Westinghouse Electric Company which had designed and manufactured

such equipment for use on a submarine with a 400-cycle power supply. Negotiations with Westinghouse to rework their design for 60 cycles at first broke down because the difference in sizes of 60-cycle and 400-cycle components would have required complete redesign of nearly every element. Therefore, late in 1951, AED requested the installation of the Westinghouse system complete with Westinghouse chambers and the necessary 400-cycle motor-generator sets. This included indicators for the logarithm of the neutron intensity and the derivative or inverse pile period, the latter two being driven by Westinghouse compensated ion chambers, and a count-rate meter section driven by either conventional BF₃ gas counters or the Westinghouse version of the fission counter.

Early operating experience with the Westinghouse system showed that it did not act quickly enough to provide the operating safety desired with this type of reactor. The nature of the Westinghouse circuits was such that simple changes which would speed up the response also resulted in noisy and erratic operation and, further, the unitized nature of the Westinghouse design, which was customary for shipboard or military service, made changes extremely difficult and expensive. Consideration was given, therefore, to two other systems which had been developed in the period after Westinghouse was first selected as a vendor. One was the Oak Ridge system which, by that time, was being manufactured commercially by several vendors; the other was an adaptation made at ERL of the logarithmic Beckman electronic electrometer. After being subjected to non-nuclear laboratory tests at ERL, the Beckman electrometer had been selected for use on both health monitoring and reactor safety circuits. It had also been successfully tested on the experimental pile in Building #777-M. The Oak Ridge system was installed in the R Area, the Beckman-ERL system in the P Area. Performance of both was better than the Westinghouse system and the Beckman-ERL system appeared to be superior to the other two. Economic evaluation showed that the cost of adding Beckman-ERL systems to all buildings would be less than the cost of the Oak Ridge system or the cost of converting the Westinghouse system to give the desired operating characteristics. Accordingly, in September 1953, it was decided to install the Beckman-ERL system in all five areas.

As operating experience developed and reactor design power levels increased it became apparent that the power instruments were still noisy and showed erratic variations not attributable to changes in neutron flux. A task force was organized to investigate these difficulties as well as the noise problems encountered in some of the monitoring systems. As a result all low-level signal circuits were completely isolated from high-level power circuits. The inherently noisy instrument systems containing relays connected to the

same a.c. power circuits that supplied the more sensitive neutron instruments, were separated and corrected.

Failure of one of the du Pont-designed gamma compensated ion chambers after about a year of exposure to neutron flux was traced to deterioration of the Teflon tetrafluorethylene resin insulation. Some time after these had been designed, Westinghouse chambers had become available, were installed, and were giving satisfactory service. In March 1954, AED requested Westinghouse chambers as drives for the safety and galvanometer circuits.

TEMPERATURE MONITORS

Most of the development problems connected with temperature monitoring grew out of its use in detecting incipient slug failure and are discussed in a later section on reactor capacity. Temperature monitoring is, however, associated with reactor control, specifically actuator system operation, in that the hi-lo lights of the individual quaterfoils appear on the full-rod trim panel where they can act as a guide to the operator in trimming out local regions of high temperature.

For the more than 1200 alarm lights on the trim panel, normal circuitry would have required the use of at least one relay with each of the lights. To avoid the extreme complexity and bulk of this arrangement, ERL developed a system utilizing the unusual properties of the neon glow lamp to keep the lights on once they had been lit. In original plans a lamp of a different color was to be used for the low bulb but production problems in producing this lamp with sufficient brightness and with the required uniformity in firing proved very complex. The relative advantages of the two-color feature did not warrant continued efforts and the plant installations have two lamps of the same color.

The problem of selecting and maintaining the 6000 lamps required for the reactor building proved more serious than tests involving 100 lamps at NYX had indicated and, for a time, relay circuits were considered. These were never installed since the problem, although annoying, never became really serious. Later, the plant and a lamp manufacturer launched a program to obtain neon lamps of more uniform characteristics through the use of standard techniques employed in radio tube manufacture.

NEUTRON COUNTERS

The problem of measuring neutron flux distribution within the reactor received much attention throughout design. Only by such measurement could control rods be positioned to

maintain the required uniformity in neutron flux through the major portion of the reacting mass. Although no mention was made of measurement in the scope of August 1950, possible alternatives for this relatively difficult problem were discussed in the scope of October 1950. By January 1951, an experimental project was authorized for the development of a boron-coated thermocouple at ERL. A form of this device was in use at other experimental sites and, at the time, appeared most promising.

As the ERL development program progressed, attention shifted to a fission chamber containing within a small capsule a natural uranium cylinder. The cylinder would hold an insulated collecting electrode maintained at high voltage with respect to the uranium cylinder. A three-element triaxial cable, composed of a signal lead, a guard lead and a ground, would be carried outside the reactor to a point where connections could be made in an area free of neutron flux. Fission within the cylinder, similar in nature to that occurring in the reactor fuel, would cause ejection of ionized particles which would be collected by the electrode and produce a current measured by instrumentation at the other end of the cable.

Several major development problems were presented by the fission chamber because, in addition to its complex construction, it had to be waterproof, maintain a high electrical resistance, utilize only materials which were impervious to neutron flux, and contain no materials which would contaminate the neutron reaction. The chamber was assigned the code work "firebox" since it developed fluxes corresponding to full reactor heat, generally equivalent to 100 watts.

The expanding scope of instrument work in 1951 brought two refinements in the use of the fission chambers. In August, Design was requested to include the recording of information emanating from the chambers. By November, the concept of flux measurement had increased to the point where three chambers were to be spaced vertically at each of 39 horizontal locations of the reactor. The ratio of the current from the top and bottom chambers in any single location was to be measured and displayed on or near the half-rod trim panel. The current from the center chambers was to be averaged in groups to give information on the reactivity in any control zone to guide the operator in positioning the gang controls. The integrated flux values were also to be displayed on the console. By the end of November 1951, ERL development on these elements was sufficient to permit negotiations for their manufacture and a contract was awarded to Radiation Counter Laboratories.

For the desired flexibility in connecting various groups of chambers, cables were brought from junction boxes around the reactor through conduits in the concrete to a common distribution box located in a room directly below the control room. Special waterproof connectors were developed with the Amphenol Corporation for use at the junction boxes near the reactor.

To satisfy metering requirements, a special modification of a ratio meter manufactured by Sensitive Research Instrument Company was developed by ERL. Originally it was planned to display the ratio of the relatively low currents in the top and bottom fission chambers at a point in the reactor pattern on the trim panel corresponding to the actual location of the chambers. Because space was limited it was decided, instead, to provide only three meters and a selector switch near the distribution box on the floor below by which the signal from any desired pair of chambers could be selected and fed to the meter on the panel. This saved much high-impedance cable but necessitated the development of a high-impedance stepping switch and an ingenious control mechanism. The latter was so arranged that the operator could press a button at a location on the graphic array on the trim panel corresponding to that of the flux measurement desired. When the button was held until the light above it became illuminated, the ratio meter indicated the flux ratio at the point selected.

As the system was then designed, the signal from the fireboxes was sufficient, so long as the reactor operated at full power level, to drive the ratio meter directly. To extend the range a special amplifier was designed which could be switched in for low signals. The receiving element for the several groups of chambers giving integrated flux values was an ordinary microammeter since the integrated signal was relatively large. The three fission chambers were mounted in a vertical element called an instrument rod.

Originally a complete set of instrument rods was to be ordered for each 100 Area but in March, 1952, AED reduced the scope to a set for the R and P Areas only. It was believed that when the later areas achieved complete flux uniformity leading to maximum pile production, new and better types of flux monitoring instruments would probably be available. At this writing, 1955, the Operating Department is testing a traveling-wire monitor in the L Area. The fireboxes have not been installed in the R and P Areas.

AUTOMATIC PILE CONTROLS

From the beginning of design, the advantages of automatic pile control were recognized and through 1951 several possible systems were investigated by AED. Actual develop-

ment naturally awaited the perfection of manual control methods. In all the areas, however, provision was made on the console for the later inclusion of the necessary control knobs and transfer switches.

Active work on a system was initiated in September 1952, when ERL was authorized to investigate the dynamics of the control problem and to construct an electronic device that would simulate the behavior of the pile from a control standpoint. With this a prototype of the control device was built and tested and additional development work was carried out at the plant by the Operating Department. In response to an AED request of August 1954, the necessary conduit, wiring and connections were included in all #100 Areas to permit installation of automatic control at a future date. By November of that year development had progressed to the point where AED requested its addition to Building #105-C and it was subsequently installed.

REACTOR CAPACITY

A nuclear reactor is a complex assembly to which it is not possible in design to assign a specific maximum capacity. The pile's power rating results from a number of variable factors as well as judgment and operating experience. It is chiefly by instrumentation that its capacity is actually determined and the development of the SRP instrumentation was an important and difficult problem. Most of the instrumentation associated with reactor capacity in addition to measuring the actual power level at any given time, assists in determining structural limitations on reactor capacity and detects slug failure, or more importantly, incipient slug failure. For safe and efficient operation of the pile an accurate picture of slug conditions is a prime requirement.

Uranium reacts with water to form a sludge of finely divided uranium oxide particles. If this occurs after the uranium has undergone nuclear reaction, fission byproducts are intermixed with the uranium sludge. Rupture of a fuel element would result in products being distributed through the reactor system by the circulating pumps. Highly radioactive, these fission products with sufficient build-up in the circulating water can make it difficult or impossible to perform necessary maintenance.

Normally, the uranium slugs are encased in aluminum to prevent their contact with water; but minor imperfections in this casing or in the welds on the end caps can release small amounts of radioactive material into the tank. Slugs with abnormal metallurgical or nuclear properties or with small pin

holes may gradually swell until the aluminum jacket is ruptured by the internal pressure.

Consequently an elaborate system was installed at SRP to determine when slug swelling occurs, when the first pin hole appears in the aluminum jacket and to identify the slug or fuel column in which the trouble originates. This takes the form of flow and temperature measuring instruments and activity monitoring units.

FLOW MEASUREMENT

The August 1950 scope mentioned activity monitoring for slug failure and temperature monitoring to detect incipient slug failure. To this the October scope added flow monitoring, presumably for each tube or column of slugs, but this was not definite at the time. The desirability of measuring the surface temperature of every slug was mentioned but the difficulty of such an approach was also recognized. In this connection, experimental work was undertaken at ERL and preliminary models of a coaxial thermocouple using a constantan center wire and an aluminum outer sheet were constructed. Surface measurement at individual slugs was later abandoned.

A great deal of thought was given to the choice between measuring flow at the inlet or the outlet of the fuel tube. When the Pi-Pile concept was abandoned in favor of single tube handling, the inlet connection problem at each fuel change loomed so large that the design quickly evolved into a system for measuring all flows and temperatures at the bottom of the reactor. This made it necessary for the monitors to determine, from a distance of 10 feet or more, what was happening within a fuel column. This included the detection of actual or incipient slug failure, excessively high slug temperatures, or subnormal flow rates. The present instrument tubing and monitor pin arrangement primarily serves the flow and temperature measuring systems but incidentally provides a point of attachment for an ion chamber which identifies the tube containing a ruptured slug.

Originally guide pins were located on the bottom of the reactor tank to hold the fuel tubes in position. As the fuel tube developed into a quatrefoil, flow measurement at its bottom required an end fitting having orifices through which the flow could be discharged. The pin design was modified to act as a guide for thermocouples set under each fuel tube and as a point for measuring the pressure upstream from the orifice.

Several alternatives on instrument connections to the tank were reviewed. Consideration was first given to a basket

arrangement which brought the leads from a false bottom plate to the top of the reactor.— In another study the leads came in a funnel-like arrangement from the monitor plate or false bottom and passed through the tank bottom by means of a special seal. These plans had obvious disadvantages. The problem of handling 5000 instrument connections is difficult enough without running them under water and having them exposed to neutron flux. Complications anticipated with the use of a false bottom for instrument locations soon led to the adoption of a bottom tube sheet as a replacement for the solid tank bottom and this paved the way for the monitor pin concept. In many ways this was an important decision for it committed the Engineering Department to the design of a system where valuable heavy water might leak from 5000 points. The best available fitting, based on prior du Pont experience, was selected and leakage has not been a problem.

Before arriving at a final pin design, two measuring methods were analyzed. In one there was a pin for each fuel column to give four flow measurements and four temperature measurements. In the second there was only one pin for each quatrefoil, giving four temperature measurements and a combined flow measurement. Extensive testing carried out at ERL demonstrated that the hydraulic noise introduced in the individual pin design was approximately four times greater, percentage-wise, than that in the pin measuring combined flow. As a result, no gain in sensitivity to flow rate changes in individual fuel columns was obtained. Accordingly, the simpler scheme employing one flow measurement per quatrefoil was adopted in July 1951.

The monitor pin as installed is an integral cylindrical unit which passes through the bottom tube sheet and engages the bottom end fitting of the quatrefoil. Instruments can be placed in the pins from a movable platform in the pin room below the reactor. Special and semi-automatic equipment for removing monitor pins and thermocouples was designed by AM&F. Thermocouple removal can be effected without draining or losing any heavy water.

At first conceived, flow measurement was intimately associated with activity measurement but these became relatively independent and their history is traced separately.

The flow monitor provides a record of flows, gives a visual and audible alarm in the event of reduced flows and with a very low flow gives both a visual and audible alarm and initiates automatic reactor shutdown. In 1951, ERL undertook a survey to find the most suitable type of commercial differential pressure measuring device for the Savannah River Plant service. This evaluation was based on electrical output, low hold-up, corrosion resistance, range, and the ease

with which the unit could be calibrated while connected to the process. Emphasis was directed, particularly, to the electrical output characteristic. Because of the large number of lows to be recorded, it was believed that an electrical output would be much more adaptable to some type of multi-point recording than pneumatic output. Also, signal transmission to the control room would be much simplified. When no satisfactory commercial equipment was found, modifications of existing instruments and instruments under development were considered. The Brown electric differential converter was finally selected from approximately 20 contenders because it met the requirements reasonably well and was the only instrument available for evaluation on a prototype basis.

Very early in development the concept of a rotary valve machine was introduced. Its purpose was to connect successively the flow signal from any one of a group of quatrefoils to a single instrument, reducing the number of instruments required and thereby simplifying the switches and connections in the control room. The rotary valve machine could also provide a means for purging air from the signal lines to the instruments. Some importance was attached to this since it was impossible to slope and vent the lines as in normal instrument practice because of building and equipment interferences. A prototype of the valve machine was tested at NYX but three considerations led to its abandonment. First, NYX experience proved that satisfactory performance could be obtained only after further development of the valve seat facing material. Second, with radioactive heavy water flowing through the machine, leaks could occur and endanger personnel attempting to maintain or adjust the machine. Third, the arrangement did not give continuous surveillance of the flow conditions in every tube.

After studying a number of alternative approaches, a low flow contact was added to each flow instrument to give continuous surveillance. The contact would be set to give a shut down signal when a flow was reduced by 40 per cent. Intermittent recording, a feature of the rotary valve machine, was retained. A single recorder and printing mechanism cyclically records the flow in up to 144 quatrefoils on a "roller towel" type of chart composed of two-inch by six-inch segments, one segment for each quatrefoil. Five recorders are installed to care for the total of 606 quatrefoils. On each recorder a 24-hour record is provided in the six-inch length of each segment and an expanded scale is given in the two-inch width above the operating point. The chart advances intermittently and the flow value is printed in each segment in turn, the complete circuit being made in approximately five minutes. A secondary drive mechanism advances the point within the segment as printing proceeds. The necessary stepping switch and control circuits were

developed at ERL and prototype-tested at NYX. Final design and fabrication were executed by the Panascan Division of Panellit.

The flow signal is also connected to an alarm circuit which audibly and visually notifies the operator when a low flow condition, defined as a single value, occurs. In calibrating 600 flow instruments and maintaining reproducibility, accuracy and reliability are critically important since any malfunction or miscalibration trips the safety system and shuts down the reactor. Every effort was made in design to keep the flows, pressure drops and orifice sizes the same. Time and cost required to obtain this desirable situation were prohibitive and compromises had to be made. Further compromises were made in early elements in reactor loadings to receive component shipments in time. As a result the actual pressure drops and flows vary from point to point and each instrument must be individually calibrated. To combat this situation, a continuing program of gradual refinement and improvement has been carried on. Early in 1954, when LM fuel was being considered for immediate use, AED set forth very stringent accuracy requirements as the ultimate goal of flow monitoring. This led to the consideration of various radical changes such as measurement of flow in each channel with four times as many instruments. The cost and complexity of such changes were not justified in view of the provisional nature of plans for different types of fuel. The LM program, however, gave impetus to the program for obtaining maximum sensitivity from the monitors.

Part of the activities of the noise task force mentioned earlier involved the location and correction of internal sources of noise in the monitors resulting from interactions which had not been foreseen when the smaller size monitor prototype was built at NYX.

A program for the development of a more reliable and precise low flow switch was carried out in 1954. The goal was a switch which could be dependably set within 3 to 5 per cent of the operating point. When shutdowns offered the opportunity, improved versions of the switch were installed in all areas. Range change to compensate for variations in the actual flow arising out of tolerances or process variations has been simplified by providing electrical adjustment in the control room rather than mechanical adjustment of range at the instrument.

TEMPERATURE MONITORING

Thermocouples are provided under the exit stream from each fuel column to measure the water temperature. The accuracy required was specified in the original October 1950 scope as 0.2 deg. C., a precision greater than the best

industrial practice and one normally achieved only in laboratories by scientifically trained personnel. The thermocouple primarily indicates incipient slug failure. Since swelling of a slug will reduce the flow through the channel, the constant heat generation in the channel will cause the temperature to rise. A secondary purpose of the temperature measurement is to provide a guide for full-rod trim as described in the section on reactor control. The monitoring of temperatures, as well as the monitoring of flows, provide not only a warning of departures from normal reactor performance but also aid in reactor operation.

Conventional temperature measuring techniques employed in industry were not applicable since the standard elements are bulky, contain materials which are not resistant to neutrons, and have slow response. Special thermocouples were developed by ERL in cooperation with tubing manufacturers and are an outgrowth of the original study for a coaxial thermocouple to be attached to each slug. The final design is a fiber glass insulated I.C. thermocouple with both wires jacketed together in a 1/8-inch diameter stainless steel tube. It is removable and uses a standard industrial type of high temperature insulation rather than special neutron-resistant insulation since the portion of the thermocouple exposed to high neutron flux is relatively small.

Whether the thermocouple should be placed in a well or exposed to the moderator with the attendant hazard of leakage was carefully studied. The general desire to avoid a well because of its inherent slow response finally crystallized into the present design when it was demonstrated that the Crawford fitting would operate satisfactorily with the tube projecting through the fitting for some distance rather than ending at the fitting as is the case when normally installed. Special fittings were designed for the thermocouples in cooperation with Crawford and the Wilmington Shops. With these fittings and a special fixture the thermocouples can be removed without draining moderator from the tank.

Special precautions were taken to obtain the maximum possible accuracy at all stages in the thermocouple installation. Nearly three-quarters of a million feet of thermocouple wire were purchased to the tightest possible specifications for uniformity. All spools were then tested to insure conformity with the specifications. Prior to installation, the finished thermocouples were calibrated and grouped with similar thermocouples in the same quatrefoil. To avoid the errors common to terminal boxes and extension leads, the thermocouples were made long enough to be carried directly to a common junction box which was carefully insulated so that its entire area would be isothermal. Copper wires lead from soldered terminals within this box to the monitoring systems

in the control room where gold-plated contacts are used throughout to minimize stray voltages. The electrical portions of the temperature monitor, involving stepping switches and segmental recorders similar to those used in the flow monitor, were developed at ERL. A small-size prototype was built and installed at NYX which served as a basis for the final design and fabrication by Panellit's Panascan Division.

The end fitting of a quatrefoil does not provide the ideal location for measurement of temperature. Because a space must be provided to allow for expansion of the quatrefoil and the entire expansion and tolerance accumulation of the reactor and its components is taken up in the location where temperature must be measured, a certain amount of stream intermixture takes place. Measurements of efficiency of the proposed arrangement, made by ERL, resulted in changes in the monitor pin and quatrefoil design to obtain maximum possible performance. The results, although not perfect, indicated adequate performance would be obtained with small changes in flow and the resulting small increments in temperature. Initial results with the final temperature monitor were disappointing. Such factors as the precise routing of each lead to obtain proper cancellation of spurious signals in the face of the millivolt signal being handled had been taken into account; and yet the noise resulting from the interaction between stepping switches and other parts of the circuit was ten times higher than anticipated. The noise task force eliminated some of the major causes. A compromise in the maximum possible speed of the monitor, not in use at that time, permitted additional electrical filtering and an improvement to the point where the process temperature variations due to control rod changes and neutron flux variations became commensurate with the internal noise in the monitors.

Experimental work carried out at ERL during the latter half of 1953 in connection with the LM program included the extension of the temperature monitor effectiveness curves, earlier obtained, to much lower values of flow in one channel. It was observed that for the original quatrefoil-monitor pin configuration these curves dropped off very rapidly. In other words, when the flow in one channel only decreased, the temperature signal appearing at the thermocouple was a very small fraction of the actual temperature rise in that channel. Comparison of these curves with the practical limitations imposed by monitor noise and process variations showed that the alarm function of the temperature monitor was completely masked, and that the available temperature signal would never increase sufficiently to be distinguishable from normal variations. This situation, of course, only applied when a temperature change took place in a single channel. Changes in the entire quatrefoil, which might be the result of variations in control rod adjustments, appeared exactly duplicated in magnitude on the temperature monitor.

The quatrefoil design had been changed, in the meantime, to the ribbed quatrefoil extrusion. With this design it is much more difficult for a swollen slug to completely block a channel. This, combined with the increased sensitivity desired for LM loadings, made it imperative that the temperature monitor be made as sensitive as possible to serve as a back-up and if possible as an advance warning to the flow monitor. An extensive program of investigation was undertaken involving flow splitters, jets, vanes, and inverted end fittings.

Each of the many suggested devices was plagued by the expansion allowance that had to be provided at the point of temperature measurement. In most cases any improvement in temperature monitoring was offset by impaired flow measurement. Two alternative designs were finally chosen. The original, adopted for Buildings #105-R, P and L, is a form of free piston flow splitter installed within the bottom Q-foil fitting. It rides on the nose of the existing pin and diverts to each of the thermocouples a part of the flow of each of the respective channels. Orifice holes in the bottom quatrefoil fitting meter the flow. A second design, the meter monitor pin, was adopted for # Buildings 105-K and C. In these Buildings the pins were more easily modified because the areas had not yet been placed in operation. The nose of the monitor pin is slightly longer and has four ports, each passing the main flow from its respective channel. The companion quatrefoil end fitting to this design has no holes. The two arrangements are shown on Page 289.

SLUG FAILURE DETECTION

The need for slug failure detection equipment was discussed in all the scopes of work issued in 1950. The exact type of instrument was not specified but it was presumed to be some sort of radiation detection device. A sample was to be fed to this device by a tube coming from the base of each quatrefoil or fuel column to permit easy identification and subsequent removal of the offending element.

The first detailed conception of a slug failure monitoring device arose in connection with the rotary valve machine. This was proposed by ERL and involved additions to the machine which permitted a sample to flow through the machine into a holding chamber. The rate of decay was measured over a short period by the use of an ion chamber. With the aid of a capacitor memory circuit the amount of current passed by the chamber during two predetermined brief periods was measured. If the charges generated were approximately equal, the presence of long-period fission products was indicated. If the charge during the second period fell off, decay rates characteristics of the oxygen and nitrogen normally present in the heavy water were indicated.

ORIGINAL MONITOR PIN

METER MONITOR PIN

In September 1951, consideration was given to an alternative system in which detection of the first sign of failure would be made in the six main circulating streams by a scintillation type of counter rather than an ion chamber. The sample side stream would flow past one scintillation counter, through a long pipe line, and past a second scintillation counter 15 to 30 seconds later. After shutdown had been initiated by the detectors in the main stream, a survey of the monitor pin "filters" with a portable detector would permit location of the ruptured slugs. The scintillation counter would measure the activity by detecting gamma rays while the ion chamber would detect beta rays. The same general principle of decay time comparison is used in the gamma system although the circuitry is considerably different.

In January 1952, AED requested a gamma monitor system. Since the scintillation type of detector was still undergoing development while the ion chamber-beta system was well along in its development, both systems were carried forward as alternatives to measurement of the activity in the circulating process streams. By March 1952, sufficient data was obtained from Argonne and Hanford to demonstrate the superiority of the gamma scintillation counter system and AED requested that it be installed.

As originally conceived, the discharge from the activity sampling system was led to a sump and then pumped back into the reactor or into the purification system. The monitor pin was to include two valves; one to drain the annulus between the monitor pin and the tube sheet, the other to shut off the sample line. Two physical connections were provided downstream from the valves, one to drain the monitor pin channel and the other leading to flow measurement apparatus. The valves were provided solely as shut-offs in case of leakage in the instrumentation and to facilitate complete drainage of the pin prior to its removal. The possibility of heavy water boiling in the channels of the monitor pin brought the recommendation that positive means be provided to get water as a coolant into the space between the monitor pin and the tube sheet. At first this water was to be added during shutdown periods through the drain connection or by draining from the annulus until no more air was withdrawn. With the simplification of the individual monitor systems inherent in the gamma monitor, it was possible to return the output from the monitor pin filter directly through the annulus drain connection at the bottom of the pin, thereby providing a continuous flush of the annulus.

After the decision to abandon the rotary valve machines, the dual valve with integral filter was developed for the monitor pins in cooperation with Hoke, Inc. The filter is composed of two cylindrical stainless steel screens, one

fitting inside the other. For a portion of the filter's length, an asbestos filtering cloth separates the two screens. A greater part of the heavy water flowing into the center of the filter passes through the portion unobstructed by the asbestos. The latter, however, serves to catch an appreciable quantity of contaminating particles. In this adopted form the continuous full flow, requested by AED in July 1952, has been achieved. However, experience by 1955 had shown that the filters plugged due to the presence of more particulate matter in the moderator than originally anticipated. The filters have been removed and alternative schemes such as modified filters or sediment chambers are being evaluated.

The original proposal for the gamma monitor involved two systems separated by a length of pipe which served as a time delay. Each system measured the intensity of radiation at two energy levels characteristic of the two principle radiating elements present in the process stream. Outputs of these four elements were balanced in a computing circuit to give a zero reading. When any fission fragments having a decay time different from those normally present appeared in the process stream, the circuit would be unbalanced to give a positive reading. Tests at ANL showed that there was a very high signal-to-background ratio for the fission fragments. This made possible a simplified system having only two measurements instead of four.

The first detector was provided with a filter to catch fission particles. The second detector in the sample stream followed immediately after and had no filter. Presence of active particles on the filter, resulting from a slug rupture, would unbalance the circuit connecting the two detectors and give a positive reading.

Provision was made for the full computing system at Savannah River because complete information on the signal-to-background ratio at the plant was not available. However, early in May 1952, AED requested that actual installation be limited to the filter system. Efforts to keep the electronic circuitry of the system operating efficiently proved rather difficult. By March 1954, it appeared that improved reliability would result from using a single probe system although its sensitivity would be somewhat lower. In this system the sample stream passes through a single filter which is monitored by a scintillation counter. The count rate in one band of energy levels, characteristic of slug rupture products, is continuously compared with the count rate in another band, characteristic of the materials in the water which cause the normal background activity. If the ratio becomes excessive, a ruptured slug is indicated and an alarm is actuated.

POWER LEVEL

Provision for measurement of the total B.t.u generated in the reactor for power level determination was always an essential part of the scope. It was recognized from the beginning that the requirement for the shortest possible heat exchanger piping on the process or heavy water side would preclude an accurate measurement of flow since such measurement requires a pipe length containing representative flows with a minimum of turbulence. An accurate measurement of power can be made on the cooling water side with the disadvantage, however, of being relatively slow in response. These neutron instruments located in ports in the shield were relied upon to measure rapid changes on a qualitative basis. An electric B.t.u. computing system was installed on each of the six circulating systems in the R, P, L and K buildings. This system uses resistance thermometers and the Brown electric differential converter in a bridge circuit patterned after the circuits used at Hanford and developed at ERL. The outputs of the six bridges are added electrically to give total B.t.u. for the reactor, this output being recorded on a panel and displayed on a counter on the console.

The power computer for the C Area presented a problem because the heat exchangers are installed in parallel and power measurements required the addition of the computed power in each of the 12 exchangers. The situation was further complicated by the piping arrangement that was too close-coupled to give accurate cooling water flow measurements. The method adopted measures the B.t.u. generated between the inlet and outlet headers on each side of the building and totals the values. On the basis of estimates or computations, corrections are made electrically for side streams which add or subtract heat not generated in the reactor.

REACTOR STRESS AND TEMPERATURE MEASUREMENTS

Since structural limitations also affect reactor operating level, instrumentation was included to measure reactor stresses and temperatures at critical points. A meeting between AED and Design in July 1951 reviewed the important temperature and motion measurements but the subject was not actively investigated until 1952. In mid-March, AED and Design met to discuss the advisability of measuring reactor and shield movements mainly from the viewpoint of determining the cause of any mechanical movement reaching the point where semi-permanent components would bind or fail to enter the tubes. The main measurements discussed were:

1. Relative horizontal motion of top shield and plenum chamber. Angular displacement to be measured.

2. Horizontal motion of the top plate of the top shield versus the bottom plate. Borescope to be used if and when motion takes place.
3. Vertical deflection of the top plate of the top shield and plenum chamber. Deflection of plenum to be measured only as it bears on top shield.
4. Lateral deflection of the bottom shield top plate relative to the bottom plate. No measurement necessary since vertical deflection data suffices.
5. Vertical deflection of the bottom plate.
6. Movement in the expansion seal at the top of the tank.
7. Deflection of side walls.

The last two measurements were desired as an indication of stress in the weld where the tank wall joins the top plate of the bottom shield and of movement resulting from stress in the expansion joint.

In May 1952, the complete scope of work for five areas was agreed upon. The temperature measurements were to be obtained from thermocouples located in the R reactor as follows: 21 in concrete surrounding the reactor's annular tank; 24 in the annular tank; 84 on the outside reactor tank wall; 3 on the bearing ring; 60 in various locations in the moderator; 10 in dry wells just under the top plate of the bottom shield; 31 between the upper poison plate and the bottom plate of the top shield; 12 on the bottom plate of the top shield; 9 on the expansion joint; 12 in the top shield; and 3 on the inner end of steel beams supporting the reactor bearing ring. Minor changes in location were made in later reactors on the basis of structural differences and refined calculations.

The motions to be measured are listed in the following table.

<u>Motion</u>	<u>Direction</u>	<u>Maximum Range</u>	<u>Antici- pated Range</u>	<u>No. of pts. of Measurement</u>
Center of plenum	Vertical	0.111"	0.052"	1
Bottom of plenum tube relative to top of tube sheet tube at edge of reactor.	Radial	0.080"	0.021"	3
Top bearing ring	Radial	0.140"	0.074"	3

<u>Motion</u>	<u>Direction</u>	<u>Maximum Range</u>	<u>Anticipated Range</u>	<u>No. of pts. of Measurement</u>
Top of tank wall	Radial	3/8"	1/4"	3
Top of tank wall	Vertical	3/8"	1/4"	3
Top of bottom tube Sheet.	Radial	0.137"*	0.066"*	3
Bottom of bottom tube sheet.	Radial	0.043"*	0.014"*	3
Center of bottom tube sheet.	Vertical	-0.053") +0.141")	-0.053") +0.059")	1

*Note: These distances do not allow for bodily shift of the tube sheet as a whole. Because of differences fourteen instead of 22 measurements are required in C reactor where the general pattern is the same but greater motions are anticipated.

To measure metal and water temperatures within the reactor at inaccessible places exposed to high neutron flux and where there is no possibility of replacement or repair, stainless steel jacketed thermocouples similar to those in the monitor pins are installed. The units in the R reactor are insulated with pure asbestos, selected for its resistance to damage by neutrons. Later, it was found that a commercial wire insulated with fiberglass wound over asbestos and impregnated with silicone had equivalent neutron resistance and that the silicone better protected the iron wire against rusting. Thermocouples with this type of insulation are used in the P, L, K and C reactors.

Where possible, strains or deflections are measured by optical means. Plenum vertical deflection in all reactors and the bottom sheet deflection in the L, K and C reactors is measured by a Swiss-made Wild precision level. The remaining strains are measured electrically by a soft iron core moving in a balanced coil winding. The electrical signal resulting from an unbalanced position of the core is read on a centrally located indicator. When the point of measurement is in a high neutron flux, push rods are connected to the core and/or coil to transmit the motion through shielding to a point where the flux intensity is low enough to prevent damage to coil insulation. Each reactor contains from 14 to 22 electrical instruments of this general type. Among these are three to seven sub-types differing in mechanical detail in each reactor.

In design of the instruments, the materials of construction presented a major problem, particularly in the case of those operating in contact with the moderator and exposed to neutron flux. The design problem was made still more difficult by the small access holes through which the push rods and their bearings were to be installed. The most troublesome problem was the measurement of a 1/4-inch motion in the reactor about 10 inches below the top tube sheet and at right angles to the access hole which is 1-5/16-inches in diameter and six feet long.

In addition to the instruments in the reactor, strain gages are installed in the P,L and C Area thermal shields. Both AED and Design realized that these would not survive very long under the normal operating neutron flux but it was believed that they would survive long enough to provide some additional information during start-up, on the stresses at critical points.

REACTOR AUXILIARIES

Rather extensive instrumentation, largely associated with the piping carrying various gas and liquid streams to and from the reactors, was also required. Most of this is of conventional design and is described in the "Description of Facilities" section. Several measurements did present development problems.

CONTROL ROOM

The physical arrangement of the control room is discussed in the building arrangement section. Although its design started with the console operator in a position facing the window and viewing the reactor directly, the final arrangement locates the operator facing the trim panels. He can observe the reaction of the high-low lights on the full-rod trim panel and is thus guided in his operation of the rod gang controls. Other monitoring equipment is grouped nearby with the recorders on the right and the power level and neutron measuring equipment on the left. The other end of the room is devoted to the gas and water system instrumentation and includes the graphic panel.

Agreement to use graphic panels for the various gas and water temperatures, pressures and flows required considerable joint planning on the arrangement of various symbols to provide maximum legibility and clarity. In the R,P,L and K Areas provision was made on the panels for 12 heat exchangers connected in series. In the C Area, where the exchangers are connected in parallel, the panels had to be redesigned to confine the panels to the same space as in the previous areas.

This was largely achieved, without sacrifice of clarity, by designing a miniature version of the three pushbutton control stations for motorized valves which occupied a large portion of the panel space in the earlier areas.

UP-FLOW COOLING

In mid-1951, after up-flow cooling of the control rods had been selected, AED requested measurement of the flow to each septifoil. For this purpose plans were made for an orifice in each of the 61 lines leading from the ring header around the pin room to the septifoils. As design progressed it became apparent that because of the limited space under the tube sheet it would be necessary to use minimum size tubing for these lines. It was later demonstrated that because of the pressure drop through these lines the required precision could be obtained by a simple pressure switch at the inlet to each septifoil and the orifices were omitted.

The possibility of using thorium control rods rather than lithium-aluminum arose at about the same time that drop tests at NYX proved that the end fitting could be knocked out of the septifoil through improper operation of the control rods. The suggested substitution presented several additional problems. Since heat generation would be higher, the cooling requirements for thorium rods were more critical. Furthermore, a failure such as a missing or leaky bottom end fitting would, without alarm, cause increased flow and a decreased pressure signal at the pressure switch. Therefore, in mid-1952, AED requested instrumentation that would insure a flow of cooling water past the control rods at all times. With the design of the reactor essentially frozen at that time and the fabrication of many parts underway, alterations which would have provided easy access to suitable points of measurement were almost impossible.

Plans to deduce flow resistance from measurements under the reactor were made difficult by the water's flow through a common chamber and by a distribution plate within the septifoil. Fluctuations in flow because of stoppage or because of rupture in the septifoil were masked by normal changes in flow resulting from position changes in the individual control rods and by redistribution of the flow by the distributor plate at the bottom of the septifoil. Extremely precise flow measurements would have been required. Flow or temperature measurement at the discharge of the septifoil was complicated by the fact that the discharge occurred within the reactor and that the discharge from the center channel of the septifoil was through the other six channels.

The gravity head of the moderator, rising in the extension wells of the control rod actuators in the "forest",

is the force which causes water to discharge through the orifices in the septifoil near the top of the reactor. Computations made by ERL showed that discharge flow rates could be measured if instrument settings were carefully set to compensate for individual septifoil variations caused by slight differences in piping configurations. The studies had also shown that changes in flow resulting from the majority of predictable failures within a septifoil led to slight changes in the water level in the extension tubes of the actuator forest that were barely distinguishable from normal variations in level caused by control rod movements.

Early in December 1952, these data were reviewed with AED and it was decided to install pressure switches to detect level changes in the discharge end of the septifoils rather than precise instrumentation at the input end. Completion of this design required the development of a special "multi-connector" permitting remote, simultaneous disconnection of 61 pressure connections leading from the actuator "forest" through the floor of the process room at the zero level.

PUMPING CIRCUITS

Measurement of the main process water flows presented an instrument development problem because the piping was short-coupled to minimize heavy water hold-up. At no point was there a straight run long enough to give the uniform flow on which a primary measurement could be based. Velocities in the 12-inch inlet lines to the plenum were so far above those encountered in normal metering practice that no data were available. Also, the flows were large enough to preclude an experimental determination of calibration coefficients. Although velocities in the 16-inch discharge lines were more conventional, the lines were extremely short-coupled, there being only one or two diameters between each elbow and valve. This problem first received consideration at NYX where a Taylor pitot-venturi, which multiplies the normal impact head obtained with a pitot tube, was installed. This was selected because it could give a signal comparable to that obtained from a normal pitot tube in the 12-inch line and could also be installed in 16-inch, low velocity lines where erosion and impact forces were much less of a problem. Orifices were never considered because of the prohibitive drain on horsepower entailed in the permanent head loss. It should be noted here that all instrument calculations grew out of an original conception that flow measurements should cover a range of nearly 100 to 1. The pitot-venturi offered some possibility of giving a measurable signal at the lowest flow ranges required.

At NYX, operation of the pitot-venturi was not entirely satisfactory because of noise inherent in the particular piping arrangement in which it had been installed. An additional

difficulty was the unexpectedly large calibration coefficient obtained because linear extrapolation of existing data to the velocities encountered in the 16-inch piping proved to be invalid. This was corrected by boring out the venturi. In view of these difficulties, a heavy-duty pitot tube built by Foxboro was selected for process measurement at the Savannah River Plant. Performance of this unit, although adequate, is not entirely satisfactory because of the short-coupled piping and the resulting turbulence at the point of measurement. Unexplained shifts in calibration have accompanied temperature changes and these may result from shifts in the velocity pattern.

Instrument rods were provided also which measure temperature of the moderator at various points throughout the reactor. The scope, as finally agreed upon in late January 1952, included 12 rods, each with five equally spaced thermocouples, and patterned after the instrument rods containing "fireboxes" described in previous paragraphs. Originally the thermocouple was to have been made from 30-gage, iron-constantan wire insulated with pure asbestos, a design selected to minimize the quantity of neutron-absorbing material introduced into the reactor. An experimental program for the manufacture of this wire was set up by du Pont, General Electric, and Radiation Counter Laboratories, fabricators of the finished rod. In this work the problem of rusting and the fineness of the wire precluded any rapid progress. Early in November 1952, comparative tests on commercial fiberglass-silicone insulated thermocouple wire became available from the AEC's Materials Testing Reactor. Computation showed that the amount of boron present in the fiberglass insulation of the 60 thermocouples did not significantly affect the k of the pile. The final design, therefore, was very similar to that described in connection with reactor temperature measurements, except that the sheath was made of aluminum. The junction was also insulated from the sheath since the iron and constantan wires would not make a satisfactory weld with aluminum. In mid-1953, AED requested that only 36 instrument rods with thermocouples be provided for the plant in the belief that the behavior of the moderator temperature could be determined in the first three reactors and rods could then be shifted to later reactors if a few points of measurement were required there.

LEAK DETECTION

To minimize heavy water leakage, the Design Division had been requested to include double tube sheets in the heat exchanger design. Design was also requested to include instrumentation to detect leakage of heavy water into the light water. This was to be a simplified version of the Y-scintillation, counter-type detector used to monitor for broken

slugs in the process water. These instruments determine activity by measuring the small amount of oxygen converted by neutron action into radioactive oxygen and nitrogen in the heavy water.

In Buildings #105-R and P these instruments were first installed in the pipe alley at the -40-foot level where it was believed the levels would be low enough to permit occasional maintenance and reliable measurement with negligible interference from the background. The building redesign for the L, K and C Areas eliminated these pipe alleys and the chambers were installed in the safe side of the corridor wall at the -20-foot elevation. Performance of the monitors in the latter areas was so much better, largely because of the high background level in the R and P Areas, that AED requested removal of the chambers in the first two areas to the inner wall of the motor room.

PERSONNEL SAFETY

The chief development in connection with personnel safety, sometimes referred to as health monitoring, was the evaluation of various types of "electrometers" by ERL. The word "electrometer" is a misnomer since the instrument is actually a micro-microammeter. However, it serves the function an electrometer originally served and the term has been adopted by both manufacturer and user.

It was realized at an early date that a large quantity of these instruments would be required for health monitoring purposes and probably for reactor control. The instrument finally selected is used for reactor control but its widest application is in health monitoring and is for that reason discussed under this heading.

Specifications for an electrometer, based on Hanford experience, were included as part of the 100 Area instrumentation scope of work prepared in December 1950. A project for the purchase and evaluation of candidate instruments was authorized in January 1951. Formal results available in August 1951 showed that the Beckman model VCE was superior although it required slight modification. Five hundred were ordered and stocked for allocation to the various plant areas.

SUPPLEMENTARY SAFETY SYSTEM

This is designed primarily to protect reactor equipment rather than personnel but is discussed here because it counteracts the effects of a catastrophe, earthquake or an unforeseen combination of equipment failures which are extraneous to the reactor.

Should the control rod or safety rod system fail to function properly or some natural-cause upset the performance of the reactor, the supplementary safety system is the last resort. With it, chain reaction can be interrupted almost instantly.

A review of several devices for stopping the reaction led to the adoption of a sparger system for introducing a liquid poison into the tank. Instrumentation entered the picture when it was decided to release this poison by remotely tripping, from the control room, a mechanism located at the -40-foot level. A pneumatic transmission system, a hydraulic system, and a rope and pulley system were considered. AED requested the pneumatic system mainly because it could be so constructed that accidental rupture of signal lines would automatically release the system, thereby making it in this sense "fail safe". The system thus became a closed signal line storing air under pressure and having no connection to an external source of supply. To keep the system leak-proof for long periods, fabrication techniques similar to those used on the SRP process lines, but unusual in normal instrument practice, were followed to insure maximum ruggedness and tightness. Modifications of a standard diaphragm operator were perfected for maximum dependability.

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IV - SPECIAL DEVELOPMENTS IN DESIGN OF BUILDING #105

A number of special items were developed which are either for use in one or more areas of the building or are not susceptible to classification by area. They are, therefore, discussed in this section.

"ON-LINE" POWER AND WATER SUPPLY

Such a close relationship exists between the continuity of the electric power supply and the flow of moderator and river water that, as design progressed, these were considered more and more in their broad aspects as a unified design problem.

Two principal operating conditions were anticipated for the Savannah River reactors: (1) normal operation at a controlled reaction level and, (2) shutdown of the reactor. The transition from the first to the second can be planned as in the case of a reactor discharge, or it can be precipitated suddenly by one of the control devices. Under any circumstance, the primary requirement is an absolute assurance that the reaction can be safely controlled and its heat removed. Continuity of production reaction is considered secondary to the maintenance of a safe condition at all times.

To assure this safe condition primary attention was directed to the quality and number of alternate power sources for the control system, the main process pumps, and the H₂O cooling system under a variety of emergency conditions.

The highest possible reliability in power normally supplying the main process pumps is critically important. Within an extremely short time after failure of circulation the temperature in the reactor rises to the maximum permissible limit and the reactor must be automatically shut down. If the duration of a power outage is long enough to reduce pump speeds appreciably or to stop the pumps entirely, two hours of production time might be lost because of the time required to bring the process pumps up to full speed again. Of more serious consequence is the possibility of damage to the reactor and its auxiliaries through sudden unplanned shutdowns. The possibility of temporary boiling in the reactor, with its undesirable effect, could be increased by flow cessations following a power failure. Also, dependence is placed on electrical and mechanical devices that, in spite of careful design and maintenance, might at one time be subject to coincident failure with

disastrous results. In addition, although the heat exchangers have been designed to minimize the effect of thermal shock, stresses can be imposed at points where leakage of moderator into the cooling water would result.

Coolant flows were, of course, calculated to maintain the desired temperature levels within the fuel elements. The principal objective was to keep the surface temperature of the uranium slugs below the point at which the core temperature becomes excessive. The quantity and distribution of coolant flow was required to protect the reactor against localized or widespread boiling to prevent localized overheating of slugs. Loss of power to only one of the coolant pumps would cause temperatures in some zones of the reactor to rise and in turn lower the margin of protection against boiling.

A failure of the power supply to any coolant pump must, therefore, automatically shut down the reaction by inserting the control rods into the reactor, a process that consumes several seconds. When a failure occurs the pumps which have lost power must therefore be transferred automatically to a secondary power source that will drive them at a rate sufficient to remove heat liberated by the reactor in its shutdown condition. During the first minute of this shutdown period, the major source of heat is the fission of uranium by delayed neutrons. For some time after that, heat release continues from the decay of fission products. In the brief interval during which the control rods are inserted, a fly-wheel effect added to the pump action provides a smooth transition from the normal coolant flow to the reduced flow rate. A third, or emergency diesel, power source is installed for use when the normal and secondary sources fail.

In the Savannah design, it was expected that the normal power would be so reliable that an automatic shutdown will occur only a few times a year. It is hoped that the emergency diesel generators will never need to be used.

The above summary, of course, contains some conclusions reached only after detailed analysis of operating conditions and problems. Design development is traced in the following pages. However, in highlighting critically important process considerations, the summary can aid the reader to appreciate the need for a closely integrated and dependable power and water supply system.

WATER REQUIREMENTS

A preceding section of this history, "Basic Process Data", reviewed the changing estimates of moderator and river water requirements as the reactor design was developed and outlined the basis on which final flows were calculated. Briefly, the basic site requirements included a total cooling water flow of 70,000 g.p.m. per reactor. Actually, from a process standpoint, flows of about 60,000 g.p.m. were planned for both the D₂O and H₂O for a reactor operation at 300 megawatts.

Continued progress in process development by late 1950 had made it necessary to agree upon a set of design features that would economically give the desired results and it was decided to use flow rates of 69,000 g.p.m. of D₂O and 60,000 g.p.m. of H₂O. Subsequently, the number of fuel columns was increased to 2424 and the D₂O circulation rate stepped up to 76,200 g.p.m. without an accompanying increase in the H₂O rate. By January 1951 the initial preliminary compilation of utility requirements for a reactor building indicated a cooling water requirement of nearly 100,000 g.p.m. At final design the cooling water flow through the exchangers was set at 60,000 g.p.m. with a possible future flow of 75,600 g.p.m. The D₂O circulation was set at 76,200 g.p.m. In the C Area provisions were made for an ultimate moderator flow of 120,000 g.p.m. and an ultimate cooling water flow of 130,000 g.p.m.

POWER AND WATER SYSTEM DEVELOPMENT

In the course of planning the flow requirements, the Design Division was asked to consider the following emergency situations and to design facilities which could maintain continuity of flow at what was considered a safe minimum level.

1. Electric power failure;
2. Steam supply failure;
3. Failure or imminent failure of both electric and steam power associated with an enemy attack after a five to ten minute warning period; and
4. Failure without warning.

In a very fundamental decision, it was concluded that no attempt would be made to continue operations under any of these emergency situations and that the reactors would be shut down. However, approximately 10 to 15 per cent of

the cooling water flow had to be maintained during a shut-down period even if the emergency extended for several weeks.

Discussion of these problems brought agreement on a set of proposed facilities that were to be further discussed and investigated. These included:

1. Two D₂O motor-driven pumps, with flywheels, on each of the six sets of exchangers;
2. Power tie-in with a second source of electricity;
3. Sufficient emergency generating capacity in Building #105 to operate the above pumps at the reduced flow;
4. An emergency water pump in Building #105 to draw from the reservoir, inter-100 Area connection, or a storage basin and return the effluent to the reservoir, to the basin, or the retention basin;
5. A diesel generator at each river pump house to supply the water plant or reservoir directly in case of a power loss at the river; and
6. Auxiliary power for reduced operation of the clarification plant.

During the next six months many schemes were advanced for meeting the criteria established.

An early arrangement patterned after Hanford's Building #190 visualized the water treatment plant ending in a clearwell from which the Building #190 pumps would take their suction. In Building #190 there were to be a number of sets of two pumps in series, the first-stage pump to be steam-driven, the second, electric-driven. Indoor elevated storage tanks were to supply water for short term emergencies. In addition, an inter-area water line, the retention basin, and the metal storage basin were to be tied into the suction of a separate electric-driven emergency pump in Building #105 supplied by diesel-driven generators.

In early March, criteria were set up which reiterated the emergency situations previously listed and translated the conditions into actual requirements.

1. Failure of normal power facilities should result in a gradual transition to the shutdown condition over a period of approximately 60 seconds by means of a "flywheel" effect.

2. As the flywheel ceases to be effective, a secondary means of cooling water supply and process circulation should be available. These secondary means should already be "on the line", that is, both should be under power and functioning at the time they are called upon for use at reduced power levels. It should be possible to operate these secondary means for an extended time, e.g., several months. The normal and secondary power supplies should emanate from reasonably well separated points.
3. For emergency shutdown operation, a special means should be provided for circulating process water and for pumping cooling water by using power generating facilities installed in Building #105. The reactor building would then be self-sustaining. As indicated previously, the metal storage basin could in this circumstance be used for circulation through the heat exchangers.

During the first quarter of 1951, two basic drive and power supply schemes were developed in attempts to accomplish the desired objectives, a hydraulic scheme and an electrical scheme. During the evaluation of these schemes basic concepts were developed which defined three types of power supply required for the pumping facilities. These became known as "production power", "on-line power" and "emergency power". Production power was defined as that which is normally available for full production operation of the process facilities. On-line power was to be available in reduced quantity and applied during normal operation so that power would be supplied to the drives during the transition period following the loss of production power. Energy so supplied by the on-line power source would be in addition to energy applied by a flywheel on the drive system. Emergency power was to be made available quickly following the loss of production power to provide sufficient power for extended periods of emergency, shutdown operations.

The possible use of hydraulic turbine drives for the process pumps was carefully studied. The proposed scheme involved the use of six 2150 horsepower, 1800 r.p.m., 800 feet head, hydraulic turbines each powered by 10,900 g.p.m. of cooling water. The water discharged from the turbines was in turn passed through the shell side of the D₂O reactor heat exchangers and then discharged to the retention basin. The 800 feet head was to be imparted to the cooling water by the pumps in Building #190. During this study the possibility of gravity flow from the reservoir behind Building #190 through the hydraulic turbine and heat exchanger series and out of Building #105 at the -40 foot elevation through

a tunnel was advanced. At the conclusion of the hydraulic study, the Engineering Department weighed the other factors involved and decided not to recommend the use of this type of drive. The decision was based primarily on the lack of available operating information, preventing du Pont from assuring the AEC that it was the most reliable drive that could be installed for this extremely critical service.

The initial phase of development of a suitable electric drive and power supply scheme for the process and cooling water pumps actually began in mid-February 1951, when an inquiry was issued covering drive motors for the main process pumps. Discussions were held with the leading electrical manufacturers and all motor design features affecting reliability were examined. To provide back-up for the main drivers, smaller auxiliary motors would be connected to the pump shafts and these would receive power either from on-line diesel generators or emergency diesel generators. In March 1951, several electrical schemes were diagramed and discussed with leading experts from the major manufacturing concerns. After a month of study and evaluation a drive and supply arrangement was developed having the following basic features.

1. A 13.8-kv. primary supply bus was established in the area power house to which the local generators and the transmission transformer were connected. The bus was arranged in a ring with several sectionalizing circuit breakers to isolate and localize system disturbances.
2. Six independent sets of radial feeders would be supplied by a like number of feeder circuit breakers. One feeder in each set would supply a step-down transformer serving one of the main process pump drive motors while the other feeder in the set would supply a similar independent transformer at the cooling water pump drive motor. Each process pump drive would have a d.c. auxiliary motor which would perform the following functions: provide some driving power during normal operation; drive the pump set at half-speed following the loss of production power; and provide sufficient power for starting the pump from rest and accelerating it to half speed.
3. The six d.c. auxiliary drive motors would be supplied from six associated d.c. generators which in turn would be driven by three diesel generators.
4. Emergency cooling water pumping would be accomplished by three independent sets of a.c. motor-driven pumps each supplied by a diesel-driven alternator.

Before proceeding further with the design of the electrical system, a consultation was held with Philip Sporn, President of the American Gas and Electric Company and a recognized authority on power systems, who endorsed the salient features of the transmission system and the #100 Area power supply and pump drive systems. An account of the development of a final design for the #100 Area electrical distribution system can be found in the electrical section of Volume VI of this history.

Although the concepts of primary and secondary power and on-line and emergency power had been discussed in general when the selection of the basic type of drive and supply system was being made, it was necessary, before proceeding with final design development, to have a set of basic data to be used as design criteria for the drive system. This was summarized as follows.

1. On-line power must operate six small D₂O drivers. A minimum of two operating pumps is required for minimum safety. On-line power must operate an equivalent number of H₂O pump drivers.
2. Six small D₂O and equivalent H₂O pump drivers will be supplied only from on-line power.
3. Small D₂O and equivalent H₂O drivers must be capable of starting their loads.
4. Small D₂O and equivalent H₂O drivers must be fully loaded during normal operation to the same amount of power required of them for 600 r.p.m. operation.
5. A spare is required for on-line power source.
6. Emergency power source has a maximum time of one minute to start.
7. There will be two emergency motor-driven H₂O pumps in Building #105 which need not operate during normal conditions.

It should be noted that 600 r.p.m. had been selected as an adequate process pump speed to meet the reduced flow, shutdown operating conditions. When these data were discussed the only change having significant effect upon the final design was the change in Item 4 which reduced the on-line power requirements from "fully loaded" to "loaded to at least 50 per cent of the 600 r.p.m. load".

The development of an over-all project power supply plan and the #100 Area pump drive and supply arrangement

were closely related problems. It was necessary to decide, based upon such factors as the availability and reliability of power from outside sources, whether to generate sufficient power within the #100 Area to meet full production requirements or to import production power and generate only sufficient power for on-line and/or emergency requirements. These alternates became known as Case 1 and Case 2 respectively. Case 1 incorporated the generation within the area of 23,000 kw. of production power with a transmission substation serving as an alternate source of production power. Diesel-driven generating equipment would provide emergency power. In Case 2, production power would be imported through the substation and two 3000 kw. turbine generators would provide on-line power. Diesel generator sets would again be used as emergency power sources. Neither of these two schemes was considered entirely satisfactory. In Case 1, production power and on-line power were electrically parallel. In Case 2, on-line power and emergency power were electrically parallel.

After discussing these schemes with the AED, the Design Division proposed a modified version of Case 1. In this on-line power and emergency power were provided by separate diesel generator sets. These two sources were paralleled only in a mechanical way on the shaft of a double MG set, the generators of which would supply the auxiliary motors on the pump drives.

This on-line and emergency power scheme was reviewed on May 8, 1951. A general acceptance of the arrangement was indicated. However, approval was withheld pending a further study of the use of steam turbine drivers in place of the diesel engines shown in Building #190 and confirmation of the rating of the emergency H₂O pump units.

While awaiting final approval of the scheme, preparations were made for initiating procurement of the electrical equipment involved. Leading motor manufacturers were consulted in an effort to determine the best voltage rating for the 3000 hp. main process pump motors, the type of motor most suitable for starting the flywheel and pump load and offering the best reliability. By selecting a water-cooled motor to operate on 13,200 volts, appreciable building space was released which would otherwise have been required to house step-down transformers and ventilation equipment for the motor rooms. Before selecting the high voltage, water-cooled motors as the main drivers for the process pumps, the electrical design group first satisfied itself that these features would not have adverse effects on the over-all motor reliability. The requirements of the d.c. on-line and emergency equipment were also discussed with experts from leading manufacturing concerns. These requirements demanded

essentially a constant horsepower output from the d.c. auxiliary motor over a 3 to 1 speed range between 600 r.p.m. and 1800 r.p.m., plus sufficient torque output to accelerate the main motor, flywheel and main pump between zero and 600 r.p.m. However, because of the reliability requirements, it was felt desirable to avoid the use of exciters, rheostats and other auxiliary equipment which are usually required for variable speed applications. The manufacturers were therefore urged to incorporate du Pont concepts into combinations of motors and generators which, by inherent machine characteristics, would meet the variable speed applications.

By the end of May 1951, a decision was made to proceed with the on-line and emergency drive arrangement as outlined. Diesel engines had been selected as the auxiliary power source in Building #190. About a month later, however, the concept of on-line power was modified and a considerably simpler arrangement of equipment was evolved.

Gravity flow as an "on-line" water supply and normally operating, diesel-driven, direct current generators in Building #105 as an on-line power for the D₂O pumps were chosen. This arrangement did not require diesels in Building #190. The plan was thoroughly reviewed, was approved, and conditions necessary to the plan's operation were established.

1. The normal reservoir water level to be at Elevation 295.75 feet in the R Area.
2. Normal water flow level over the crest of the weir at the retention basin to be at Elevation 277 feet.
3. Gravity flow, based on conditions in Items 1 and 2, would be sufficient under emergency conditions to supply the required amount of water to all heat exchangers until the reservoir level dropped to Elevation 285.75 feet. This assumed that no water entered the reservoir during this period.
4. Gravity flow would be adequate for the shield coolers.
5. By-passes would be installed around the pumps in Building #190 to open under conditions requiring gravity flow.
6. Diesel-driven d.c. generators would be provided to energize 6 d.c. motors continuously at full load in Building #105.

7. D.c. motors would be especially designed for 1800/600 r.p.m. operation to reduce diesel fuel consumption.
8. D.c. motors would require 120 horsepower from the diesel-driven generators.
9. Building #190 diesels with their motor-generator sets in Building #105 would be deleted.
10. No provision would be made to recirculate the retention basin water to Building #105 or to the reservoir.
11. Key emergency service water supplies would be protected.
12. Miscellaneous a.c. emergency power demand in Building #105 and #108 would be 2000 kw.
13. This demand would be supplied by two 1000 kw., 10-second starting diesel-driven a.c. generators.

The installation of the by-passes represented a modification of the requirements previously stated although a substantial quantity of cooling water was expected to continue to flow through the pump after the impeller had stopped.

Under this arrangement the on-line and emergency power characteristics for the D₂O pump drives would be combined into one set, consisting of a d.c. generator and motor, which would not require any switching or control operations when changing from the on-line to the emergency functions. The on-line and emergency power requirements for D₂O pumping could be met by the same equipment.

For a demonstration of the feasibility of the plan for using a.c. motors and d.c. motors as tandem drivers for the process pumps, representatives of du Pont visited the wind tunnel installation of the Cornell Aeronautical Research Laboratory where the basic functions of on-line and emergency power were demonstrated.

The SRP auxiliary drive installation is unique in the complete absence of operating control equipment, either manual or automatic. There is neither the generator field rheostat nor the "field forcing" control circuit usually required to provide sufficient torque output for starting and accelerating a high inertia load. Even the dependence on an auxiliary exciter or an external d.c. power source for generator field excitation has been eliminated. By providing permanent magnet pole pieces, in addition to the

usual shunt and series fields, the designers of this equipment eliminated all external auxiliaries, making each combination of motor and generator completely independent and highly reliable. The only piece of operator-controlled equipment is a manual disconnect switch between the generator and the motor. By means of a motor bus-and-jumper arrangement, any one of the three motors can be connected to any one of four generators; thus providing a means by which each diesel generator can be taken out of service on a regularly scheduled basis for routine maintenance.

As finally developed then, the drive for each of the main process pumps consists of a flywheel, a 3000 hp. a.c. motor and a 75/120 hp. d.c. auxiliary motor. Power for the main drivers comes directly from the 13.8-kv. ring bus system via independent underground cables. Power for the d.c. auxiliary motor comes from a matched generator driven by a diesel engine located in one of the Engine Houses, Buildings #108-1 and 2. By providing d.c. equipment having inherent characteristics which match the special requirements for the auxiliary drive without external switching or auxiliary control equipment, the on-line and emergency power functions are performed by one set of equipment for each pump drive.

The decision first made to locate diesel-driven a.c. and d.c. generators plus emergency cooling water pumps in Building #105 posed a problem since the foundation drawings for the building were already being issued to Construction. To serve the two sides of the reactor building and to comply with security plans in which all key services are sectionalized, the added space required for the generators and pumps was placed in two separate areas. The addition adjacent to the assembly and purification areas was designated Building #108-1 and that adjacent to the disassembly area, Building #108-2. The two latter wings house the emergency pumps in a section walled off from the diesel room itself.

RETENTION BASIN

Design and construction of the retention basin, Building #107, was stopped in August 1951. Since process improvements made contamination of the cooling water at SRP highly improbable, the safety and convenience provided by the retention basin was being restudied. At Hanford, where cooling water contacted the fuel slugs, contamination had been a definite possibility. The retention basin was finally deleted at SRP but the forebay portion containing the weir was retained since it was an integral part of the gravity on-line cooling water system. Later it was decided to install an 11,000 g.p.m. pump in Building #107 so that

effluent water could be returned to the reservoir. This would permit water conservation in the event that no water could be brought into the area for an extended period of time. The pump motor can be supplied from the diesel-driven a.c. generator bus.

Page 315 presents a cooling water diagram for Building #105-C and illustrates requirements typical of each of the #100 Areas.

SPECIAL FINISHES

In June 1951, a memorandum was issued outlining the requirements for interior finishes on walls, floors, ceilings and equipment casings within Building #105 in order to make them:

1. Resistant to contamination;
2. Generally decontaminable by simple, hose flushing techniques using water or detergent solutions; and
3. Locally decontaminable by a dust-free peel-off of surface finish.

By July a committee had been appointed to investigate the problem, study possible surface finishes and prepare specifications. The committee met weekly and in September issued the first interim report which indicated that a flexible vinyl base coating appeared to be the best candidate. It also recommended that concrete forms be made of plywood to secure relatively smooth surfaces on which to apply a coating.

In October the committee submitted its second interim report which included three main recommendations:

1. No grease or oil should be used on concrete forms;
2. Waterproofing should be used on all exterior walls below grade; and
3. Adherence to a wall and floor finish schedule for the entire building which detailed room by room the type of pour, concrete finish, concrete surface preparation, type of floor covering, and wall and ceiling treatment.

Service conditions which formed the basis for the selected finish schedule were also given in the report.

After extensive review and revision, a final report was prepared by the committee and issued in early November 1952. It repeated the interim recommendations and recommended either the Cocoon or Liquid Envelope system for the basin and canal of the disassembly area. The regular vinyl system was recommended for the floors, walls and ceilings where specified on the finish schedule.

Analyses of candidate waterproofing materials, especially for the disassembly area, were based on ease of application, impermeability to water, resistance to abrasion, curing qualities, resistance to salt solutions leached from the concrete or present in ground water, strength through changes in basin structure, elongation characteristics and appearance.

The evaluation of waterproofing materials was made the subject of a consultant's agreement with the John B. Pierce Foundation under order number AXC 345-1/2 on August 15, 1951. The Foundation conducted studies on eleven suggested materials including Elvacet 1A and 1B, Amercoat 88, Pen-Kote, Amercoat 33, Cocoon, Cocoon and Amercoat, Lucanol, Neoprene, Liquid Envelope and Liquid Envelope with Amercoat. All were submitted to tests duplicating as closely as possible the conditions that would exist in the basins. A system of numerical values was assigned to the ten tests used and a performance record was established for the materials. Four of the methods proved reasonably satisfactory. These were Cocoon, Cocoon with Amercoat, Liquid Envelope and Liquid Envelope with Amercoat.

The results of the Pierce Foundation tests indicated that G.E. Cocoon White or Liquid Envelope would be satisfactory for the basin service. Since actual field experience was meager, it was decided that these coatings should be applied to a concrete tank and exposed to conditions simulating those to be expected in basin service. Accordingly arrangements were made to have a concrete tank immersed in a marsh at the du Pont Chambers Works with the top about one foot above ground. The tank was 4 ft. x 4 ft. x 6 ft. deep with 8-inch walls. After a five-month drying period the interior surfaces were acid etched. The surfaces were then coated by a licensed applicator of Cocoon and Liquid Envelope.

Periodic observations and strip tests were made to determine adhesion properties. These indicated that adhesion of both was satisfactory, that Plioband primer was superior to Gates primer for Cocoon, that unlike the Liquid Envelope strips, G.E. Cocoon strips showed some evidence of aging, and that the Liquid Envelope surface was easily cleaned by water turbulence methods. Specifications for the

application of these materials were incorporated in Section BR-6, of Specification 3019, "Building Materials and Plumbing". Cocoon was eventually selected for use in the disassembly area basin.

The fire hazard encountered in applying these finishes made it advisable to review the extent to which special finishes were to be used throughout the building. The need for Cocooning was reaffirmed for the basin and canal, but substantial amounts of vinyl painting were deleted in other areas. This included the crane wash area ceiling, the storage tank area above the 10-foot level, the entrance labyrinth to the overflow tank room, the heat exchanger area above the 10-foot level, and the instrument room.

In late June 1953, some time after the disassembly area basin and canal had been filled with water and emptied, it was discovered that blisters or bubbles were forming under the Cocoon coating of Building #105-R basin floor. The liquid in the blisters was found to be high in alkaline and iron salts. By mid-July the cause of the blister formation had not been clearly established although it was believed that ground water had seeped through the bottom mat. The ground water level surrounding the building was about 18 feet higher than the deep portion of the basin where the bulk of the blisters was found.

The Design Division suggested several alternative remedies: continuous operation of the well point system to reduce ground water level; application of a cement waterproofing coat over the bottom of the basin; or a membrane waterproofing topped with 4 to 6 inches of concrete plus Cocooning. Because of the high cost of repairs, the need for Cocooning was reconsidered and it was decided to accept Building #105-R with the blisters and to fill the P Area basin immediately to balance ground water action. Cocooning was eliminated in the L, K and C Areas and in its place Amercoat 33 was used on the floor and walls of the repair shop, transfer area, pit #2, monitor basin, the minus 19 and minus 30-foot levels of the emergency disassembly area, the machine area and the dry cave. This vinyl paint was applied also to the floor of pit #1 and the bucket storage area, to the walls of the canal below the dry cave and the discharge canal, and to the ceiling of the dry cave.

SHIELDING WINDOWS

GENERAL

One of the basic design requirements for Building #105 was the provision of some means of observing process room operations. It was felt that shielding windows would be most satisfactory, offering as they do a large field of view which can be scanned rapidly, and good general observation of transient operations such as loading and unloading the reactor. Eventually, similar windows were used elsewhere in the building.

It was known that Argonne National Laboratory, starting in 1948, had assumed a leading role in the development of all types of shielding windows. Accordingly, arrangements were made to secure assistance from Argonne.

Shielding windows are of three general types:

1. Glass-filled, in which a tank with glass face plates is filled with one-inch thick glass sheets with a liquid laminate between the sheets to reduce surface reflection;
2. Liquid-filled, in which a tank with glass face plates is filled with a transparent liquid of the approximate density of the glass itself; and
3. Lead glass, in which the window is a single piece of solid high-density glass set in a suitable frame.

Usually it is most convenient to use a window of approximately the same thickness as the wall in which it is placed. Since concrete, lime glass, and the zinc bromide solution ordinarily used in liquid-filled windows are of about equal density and shielding value it is customary to use glass-filled or liquid-filled windows in concrete shielding walls. For the same reason, lead glass windows are usually used in steel walls, although the density of the glass at 6.2 does not approach that of steel. Where dense aggregate concrete walls are used, a newly developed lime glass of 3.2 density is most suitable for a glass-filled window. For special conditions, a combination of glasses of different densities is sometimes used to form a single window. Normally in any type of window, some portion of the glass on the "hot" side is non-browning.

In Building #105 with ordinary concrete shielding walls, the choice lay between glass-filled and liquid-filled windows. In the process area, where operating

continuity is essential, the glass-filled type was chosen. It was felt that the possibility, however remote, of a sudden loss of shield through rupture of a face plate of a liquid-filled window ruled out the use of that type.

In the disassembly and purification areas, where the possibility of an operating interruption is not intolerable, it was decided to take advantage of the lower cost of liquid-filled windows.

PROCESS AREA WINDOWS

In Buildings #105-R and P three windows were furnished for observation of the reactor room. Windows on either side of the reactor, one in the main control room and the other in the crane control room give a good view of operations around the reactor itself as well as a general view of the reactor room. A second window in the crane control room wall gives a view of the discharge point of the unloading crane. These windows are supplemented by two magnifying periscopes located to give detail viewing of pick-up and discharge points of the reactor loading and unloading cranes.

In Buildings #105-L, K and C, the reduced size of the reactor room and the change in layout made it possible to view the entire room from one window in the crane control room.

The pump room in Buildings #105-R, P, L, K and C may be observed through four windows, two on either side of the reactor, which are located in the walls of the instrument and observation rooms at Elevation -40.

No windows were provided for general viewing of the heat exchangers, but three periscope locations in the Elevation -20 corridor wall on each side of the building make detail observation possible.

DISASSEMBLY AREA WINDOWS

In this area, the only above-water operations are carried on in the dry cave, where control, blanket and 5Y3 rods are disassembled. In Buildings #105-R and P, a hot lab for examination of slugs was provided at one end of the cave.

Four windows are installed in the cave, one in each wall. The side windows are for close observation of the machines and the end windows for general viewing. In Buildings #105-R and P, one of the end windows serves the hot lab

only. In all buildings, the other small end window is placed in a corner so that the entire cave can be observed.

PURIFICATION AREA WINDOWS

In Buildings #105-R and P, the crane serving the cells is operated from a shielded crane cab. In Buildings #105-L, K and C, the crane is operated from the passageway, with the operator viewing movements through two windows in the wall.

DEVELOPMENT OF DESIGN

GENERAL

At the time the design of Building #105 windows was initiated, ANL had built windows only for comparatively small caves with shielding walls about 30 inches thick. Due to the larger areas to be viewed and the heavier shielding walls at SRP, ANL designs could not be used. The design of Building #105 windows, while based on principles developed at ANL and accomplished with considerable advice from that source, followed ANL designs in a general way only.

GLASS-FILLED WINDOWS

In establishing the size of these windows by calculation and layout, it was found that they could be reduced in size on the observer's side without reduction of the field of view. Further, the size required and the nature of the service was such that it did not seem practical to design these windows as tanks to be permanently cast in the wall as they were at ANL. Design then proceeded on the basis of casting a steel frame in the wall, with the window consisting of two removable sashes, one in front of the other, mounted on rollers. The stepping inherent in making the observer's side smaller provided some of the shielding required to protect the void around the rollers, but very careful layout was necessary to determine necessary shielding at all points. Most of this shielding was provided by the addition of steel plates to the sash and frame.

In all windows of this type, some stepping of the tank or sash is necessary to compensate for the clearance between the glass and the inside of the sash. This space is filled with oil of little shielding value and is usually considered as a void space in shielding calculations. In a straight single sash window such as those in use at ANL at the time, this void was usually shielded by the addition of steel

plates around the inside of the tank. Since the glass sheets in the SRP windows had to be of several different sizes, the shielding problem became more complex.

No serious difficulties were encountered in developing the design of the windows and reasonable solutions were found for the problems encountered. ANL prepared specifications to cover the glass and oil, and procurement proceeded without complications.

Since the assembly and installation of glass-filled windows is a complex job, arrangements were made for one construction engineer to receive training in this work at ANL.

LIQUID-FILLED WINDOWS

At the time design of these windows was undertaken, ANL tests had indicated that a water solution of zinc bromide was the best of the shielding materials considered. Windows containing such a solution had been in use at ANL for about two years and had been generally satisfactory. The small amount of haze encountered had settled out and there was no indication that further haze would develop. Some coloring had occurred due to the oxidation of iron in the solution, but the addition of a very small amount of reducing agent, hydroxylamine hydrochloride, prevented this effect in later windows.

Other tests had shown that a seven-coat application of a vinyl paint, Amercoat 31, was the only completely satisfactory tank lining. Most other materials were found to cause coloration or haze through the dissolving of the liner itself. While the effect on the liner was usually almost imperceptible, the minute amounts of material dissolved were sufficient to affect the solution. Also, when organic liners were used, it was necessary to step the inside of the tank to compensate for the lack of shielding value of the liner.

After thorough examination of the windows at ANL and consideration of the data offered, it was decided that the disassembly area windows should be plain, straight steel tanks grouted in the cave walls, lined with Amercoat 31, fitted with 2-in. laminated glass face plates and filled with zinc bromide solution. Design was started on this basis in June of 1951.

While, due to the materials chosen, it was not necessary to provide internal steps in the tank, a wide, shallow slot was cut in the top plate. This, with the liquid filler tube entering it, was found to be an adequate expansion

chamber for the liquid. With the glass plates about flush with the wall faces, it was necessary to cut back the concrete in the way of the face plate spacers and clamp bars. To compensate for this loss of shielding, a steel bar was added around the outside of the tank. Also, to compensate for possible poor grouting under the tank, a plate was added at that point.

To avoid damage to the tank lining in handling, it was decided that the Amercoat 31 should be applied with the tank in place. Complete instructions covering the installation, Amercoating, and filling of the tank were written and transmitted to the field.

When, in 1953, it was decided to use windows in the purification area, the disassembly area designs were used as a basis. Since the windows were to be placed considerably above the field to be observed, they were mounted at an angle to give a better view, and some changes were made in the tank design to suit these conditions.

PERISCOPES

All periscopes installed in the process area of Building #105 are generally similar in design, the principal differences lying in the length required. The unit in the pin room projects through a 10-foot wall, those in the process room are in 7-foot walls and those in the heat exchanger transfer tunnels are used in 4-foot walls. All are removable, hoists being provided for their installation. Sleeves and shields as well as spare optics were supplied with the periscopes. The sleeves are cast in the concrete wall and act as a case for the periscope as well as a mount for the shield on the observer's side. With the periscope removed, the shield is swung into place as a plug for the empty sleeve. When the periscope is installed, the shield, first swung out of the way, is returned to a position in back of the periscope where it blocks the path of radiation through the sleeve and periscope.

The vertical leg of the periscope, on the observer's side, is about three feet long and carries the power shift lever and focusing knob. A short horizontal section, terminating in the eyepiece, is at the bottom of the vertical leg.

The unit installed in the pin room has angular magnifications of 1 and 10 power, 30 deg. and 3 deg. field, and a viewing range of 6 to 25 feet. Those in the process room have angular magnifications of 2 and 10 power, 15 deg. and 3 deg. field, and a viewing range of 6 to 50 feet. Those in

<u>Bldg.</u> <u>#105</u>	<u>Area</u>	<u>Room</u> <u>Observed</u>	<u>Windows</u> <u>Per</u> <u>Room</u>	<u>Tanks</u> <u>Per</u> <u>Window</u>	<u>Type</u>	<u>Wall</u> <u>Thick-</u> <u>ness</u>	<u>Approx. Size (HxW)</u> <u>Object</u> <u>Observers</u> <u>Side</u> <u>Side</u>	
RP	Process	Process	3	2	Glass-Filled	7'-0"	5'-1"x5'-0½"	3'-11"x4'-5½"
LKC	Process	Process	1	2	Glass-Filled	7'-0"	5'-1"x5'-0½"	3'-11"x4'-5½"
RPLKC	Process	Pump	4	2	Glass-Filled	4'-0"	2'-8"x3'-2"	1'-9"x2'-7"
RP	Disass.	Dry Cave	1	1	Liquid-Filled	2'-6"	1'-9"x2'-0"	1'-9"x2'-7"
	Disass.	Dry Cave	2	1	Liquid-Filled	2'-6"	2'-0"x3'-0"	1'-9"x2'-7"
	Disass.	Dry Cave	1	1	Liquid-Filled	3'-6"	2'-0"x4'-0"	1'-9"x2'-7"
LKC	Disass.	Dry Cave	1	1	Liquid-Filled	2'-6"	1'-9"x2'-0"	1'-9"x2'-7"
	Disass.	Dry Cave	2	1	Liquid-Filled	3'-6"	2'-0"x3'-0"	1'-9"x2'-7"
	Disass.	Dry Cave	1	1	Liquid-Filled	3'-6"	1'-9"x2'-0"	1'-9"x2'-7"
RP	Purif.	-	-	-	-	-	-	-
LKC	Purif.	Cells	2	1	Liquid-Filled	2'-0"	3'-0"x6'-0"	3'-0"x6'-0"

the transfer tunnels have magnifications of 2 and 10 power, 15 deg. and 3 deg. field, and a viewing range of 6 to 50 feet.

With the periscope and sleeve going through the wall at the 7-foot level, the eyepiece is normally about 4 feet above the floor. However, the entire periscope can be rotated about the horizontal barrel to bring the eyepiece arm to a convenient height. Counterbalancing is provided for ease of operation.

Any target within a 180 deg. arc from the inside wall on the object side can be located through rotation of the eyepiece assembly and swinging of the eyepiece on its hinges. In rotation, or tangential motion, the line of sight describes a cone in the object space. The angle of the cone is determined by the tilt of the eyepiece. With the direction of the eyepiece axis always parallel to the line of sight, the operator has a sense of complete orientation.

On the basis of low bid and early delivery the Kollmorgen Optical Corporation was selected as the supplier for the one 10-foot periscope, the two 7-foot periscopes and the two 4-foot periscopes in Building #105-R and the similar periscopes installed in the other reactor buildings.

MODELS

To aid in the studies of arrangements and in judging the feasibility of the many methods that would be proposed for accomplishing certain objectives or segments of work, the preliminary scope of work included the construction of a model of the reactor building, the reactor and principal auxiliaries. Many changes in the first model were encountered before a final design and final model were completed.

The Design Division initiated procurement of a reactor building model in January 1951 and signed a contract with Industrial Models, Inc. (AXC 39-1/2) in February. Since the work would be classified and the vendor had no facilities that could be isolated by security barricades, a security area was set up at the Wilmington Shops of du Pont. There the vendor's trained model makers, assisted by du Pont pattern makers, constructed the Building #105 model. Clearances were arranged for the personnel involved.

Representing the February 1951 design of the reactor building, the model was delivered in late March and set up in a room on the second floor of the Nemours Building in

Wilmington. At that design stage the heat exchangers were to be handled by a bridge crane, the reactor was mounted on a solid concrete foundation and horizontal control rods were to be used. Subsequent abandonment of the horizontal control rods and other design changes soon made the model obsolete and it was photographed and destroyed.

In June, 1951, two new models were ordered, Industrial Models and Wilmington Shops continuing the work. One of the models was for du Pont use and the other for AEC use, but the latter was shipped in September, 1951, to the Construction Division at SRP for training purposes. A third model was ordered for the AEC.

In addition to the three Building #105 models, two purification area models, two purification cell piping models and two reactor piping models were built as well as sections of #200 Area work. As was expected, many changes in details were made to the models as the design developed. The model used by du Pont greatly aided the designers in their work on the piping and contributed to a general understanding of the design by others. The building is very large and complex and in many areas is inaccessible during operation. This had to be kept in mind as designers performed their detailed work. Study of the models aided materially in coordinating this design work.

The Atomic Energy Division of du Pont used the model to acquaint newly assigned or employed personnel with the work and in normal operating problem reviews requiring physical interpretation. No photographs were made of these later models.

INSTRUMENTATION

LEAK COLLECTION AND DETECTION

Because of the high value of heavy water unusual precautions, including a leak collection and detection system, were taken to account for the liquid and to guard against its loss. Need for such a system was recognized early and was mentioned in the scope received from AED in October, 1950, but until piping and building arrangements became reasonably firm, little could be done on the actual design. Initially it was thought that the system would contain collection pots, float alarms, and a panel for alarms and controls. As such it was primarily an instrument problem. Later, when the system was simplified, the primary responsibility shifted to the process design group.

A detailed scope for a leak collection system was received from AED in November 1951, and indicated the points at which collection was to be made. For this purpose about 60 pots, some with remotely operated valves, were to be provided. Annunciators indicating full pots were to be mounted on a panel together with the controls for remotely operated dump valves. It was felt that such auxiliary functions and those of temperature measurement, mainly on the process pumps, were not directly related to the activities of the control room, so the leak collection and miscellaneous temperature panels were to be located in the pump observation room. This system was installed in the R and P Areas.

Late in January 1952, representatives of the process and instrument design groups met with AED and selected approximately 370 points in the heavy water circulating system to which leak detection equipment was to be applied. The detection device was visualized as a pair of wires with a wick-like insulation which became an electrical conductor, when wet. Provision was made on the panel for 150 signal lights, each indicating leakage in a group of flanges or points of leakage close together. To prevent spurious alarms from condensation on the pipes, polythene enclosures were provided around each flange.

By the early part of 1953, enough experience had been accumulated in the operation of NYX, the Dana Plant, and the #400 Area at SRP to cause AED to re-assess leak detection plans. Leakage had not been as serious as expected and a larger supply of heavy water was available. Late in January, Design was requested to withhold procurement on all leak detection equipment and the alarm-type pots and annunciator system used for leak collection. Instead, design of a simplified leak collection system without detection was to be prepared to consist chiefly of piping to pots in which the level was to be visually monitored. In May, AED decided to install the simplified system in the L Area, but requested that provision be made in the form of conduits buried in concrete for the future installation of the complete leak collection and detection system as originally designed. Several months later, the simplified system was installed in the K and C Areas as well. Procurement on the original system was not canceled, but held in the event that operating experience proved the more elaborate equipment to be necessary. By April of 1954, AED was satisfied that the modified system would meet requirements and the original equipment orders were canceled.

A review of other phases of the leak collection system is included in the section--"Process Area - Equipment Development".

LM PROGRAM

In April of 1953 preliminary design was initiated on facilities required for reactor loadings using enriched fuel, the program being identified as "LM" by early association with the start-up loading in the L Area. By late 1954 the installation of facilities for LM storage and security had been made in all assembly areas, and in 1955 shipping casks were provided in the R Area for moving two partial loads.

The original scope for the Savannah River Plant indicated that the Operating Department was giving some thought to a type of reactor loading that would require modification of component design, alterations to the charge and discharge machines and the temperature monitoring system, and significant equipment additions in the assembly and disassembly areas. Of special significance were exacting requirements for the security of stock-pile quantities of strategic material and the hazard of attaining a critical mass of the new fuel.

COMPONENTS

Two schemes for reactor loading were under early consideration. The first employed canned slugs of both fuel and producer material loaded sequentially in a quatrefoil of conventional design. Only minor adjustment in the length of spacers and in the size of piston orifices was indicated. The second scheme envisioned the assembly of fuel and target material in separate rods, one producer and three fuel rods being loaded in a quatrefoil. The Q-foil assembly would be modified in such a way that the producer rod might be removed from the reactor without pulling the whole Q-foil. Component design in the #100 Areas was directed toward modification of the Q-foil adapter to permit removal of the producer rod, and toward suitable flow restriction in the producer channel where less heat would have to be removed.

The latter scheme offered the advantages of fuel economy by recharging fresh target material to fuel only partially exhausted. On the other hand, a new hazard was presented. If a column of fuel slugs without target material was dropped on the floor of the reactor a critical mass might be formed. Safety considerations, as well as relative simplicity in execution, dictated for the time being the choice of striped, individual slug loading.

ASSEMBLY AREA

Associated with any scheme of LM loading were the more stringent security regulations governing the storage of enriched fuel. Initial consideration was given to converting the storage rooms in the assembly area into mercantile vaults. The expense of providing very large vault doors and the fact that the rooms are in the heart of the security area, led the AEC at SRP to relax the requirement and specify general reinforcement of the existing doors, the addition of combination locks, and a special guard station at the storage rooms.

Aisle spacers were installed in the slug storage room to restrict the mass of metal to a specified concentration. A crane was added to facilitate the stacking of slug boxes. Segregated inspection enclosures were provided in the working area. The choice of slug loading made no equipment alterations necessary.

PROCESS AREA

If rod type loading had been adopted, modifications in the temperature monitor system to remove the target position from the alarm circuits would have been required as well as a new chuck for the "B" mast of the charge and discharge machines to pick up an individual producer rod from the quatrefoil. These requirements were eliminated with the adoption of slug type loading.

The development of a supplemental safety device to control the increased hazard of enriched fuel operation is reported elsewhere.

DISASSEMBLY AREA

Design effort in the disassembly area was expended mainly on slug containers and shipping casks. With separations facilities located in the #200 Area at SRP, Oak Ridge, and subsequently at Arco, the shielded shipping container had to be designed precisely to minimize the weight and subsequent cost of rail shipments. Special consideration was given to the maximum number of slugs that might be shipped in a container without approaching a critical mass. Extensive design study was given to an air-cooled cask for transcontinental shipment in preference to the conventional submerged design. In this du Pont collaborated with the Chemical Plants Division of Blaw-Knox Company, engineers for the Arco processing facilities.

Design of an underwater cutting machine for fuel rods was briefly studied and initiated prior to abandonment of the program. Only minor alterations and additions in the disassembly area equipment are involved in the current program.

Because of the economy in numbers and because of their adaptability to the early concept of the LM fuel element, double hangers were installed in the L and C Areas. This required the use of whip hoists at the pick-up point and disassembly machine in place of monorail lift sections.

REFRIGERATION

All other conditions remaining constant, reactor capacity is increased by the availability of low temperature cooling water. During the site evaluation studies in the early fall of 1950, the use of refrigerated cooling water was considered but preliminary calculations made at the time indicated the scheme was neither economically justified nor practical. It was demonstrated that exchangers could not effectively utilize the refrigeration applied due to the respective temperature levels indicated in the hypothetical reactor calculations used for site evaluation purposes. Calculations did indicate that refrigeration applied directly to the D₂O coolant, i.e., by a refrigerated cooler following a river water cooler, was effective. Again, such an arrangement could not be economically justified and the additional heavy water volume required was not available.

Subsequently, during the L reactor studies, refrigeration was again reviewed and the following schemes evaluated.

1. Helium refrigeration cycle wherein helium at atmospheric pressure served as a moderator as well as a refrigerant. The power requirements of such a system made it impractical.
2. Flash cooling of the D₂O cycle by which the coolant was partially flashed in the shell of a condenser and the vapor condensed by river cooling water. This scheme was considered impractical because the equipment sizes required were much larger than the liquid to liquid exchangers, and the coolant circulating pumps would have to be lowered to a -60 or -80 foot elevation.

The Power Design Section also examined the investment costs, operating costs and benefits resulting from year-round application of refrigeration to cooling water ahead of the heat exchangers. Three types were considered: steam jet,

centrifugal refrigeration with condensing steam turbine drives, and ammonia absorption utilizing heat exchanger effluent as the source of heat.

The results indicated that the cost of obtaining additional production by refrigeration would be two and one-half times that of the designed facilities and would never be attractive under normal economic or production conditions.

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V - DESCRIPTION OF FACILITIES - BUILDING #105

ASSEMBLY AREA

Essentially all operations in this area are conducted under normal plant conditions because there are no irradiated materials present. Care is taken that fuel stored in the area remains adequately dispersed so that a critical mass will not be created. Extreme cleanliness of all components is essential.

Material handling is by crane, fork truck and an extensive monorail system.

PRINCIPAL COMPONENTS

RECEIVING AREA

This area, enclosed and separated from the remainder of the building, is the entry point for all shipments. These are made by trucks which are washed immediately before entry to minimize the introduction of dirt into the building.

WORKING AND STORAGE AREA

For storage, the large boxes are stacked on the floor, fuel slug tray pallets are stacked on the floor in a locked room, and small parts boxes are stored on shelves adjacent to the slug storage room. Boxes containing sleeves, plugs, piston assemblies and rod extensions are stored on pallets on the floor.

The working area contains space for inspecting and cleaning components, the assembly and testing of equipment, and facilities for transferring the assembled units to storage hangers for movement into final storage.

The area, except that used for small parts storage and inspection, is served by a monorail and interlocking crane system by which materials can be raised, lowered, or transported throughout the assembly area. The 2-ton, twin-hook crane covers the entire tube and rod storage area and interlocks with the rails of the degreaser hoist.

The monorail system serves the tipping table, loading lines and test stations and extends into the final storage room. Two lift towers are provided for the placement of components on fixed elevation storage hangers.

FINAL STORAGE ROOM

All components sent to the process area, except control septifoils, are stored in this room on hangers. The S-foils are transferred to a rack for storage.

GRIPPER PICK-UP STATION

Physically not a part of the assembly area, this station is an integral part in the assembly area operations. Components are moved on the monorail system into this room for delivery through a slot in the reactor room wall to the charging crane pick-up point.

FAN ROOM

The assembly area in Buildings #105-R and P contains a fan room housing refrigeration units with pumps which supply chilled water throughout the entire building. There is also a fan supplying conditioned outside air to the assembly area. Three additional fans are installed; one, with a spare, supplies conditioned outside air to the crane control room in the process area, and the remaining fan exhausts air from the assembly area and discharges into the final storage room.

CONSTRUCTION DETAILS

Since there are appreciable differences in the physical size, orientation and layout of the five assembly areas the Building #105-R assembly area will be described and differences noted for the other areas.

This area is of Class I construction, has a single story with basement and is approximately square. Dimensions are 186' by 191' (including wall at Cols. BL). Roof height for a portion, 186' by 135', is 43' -11" above ground floor, the remainder, 34'. Approximately 54' by 70' of the high portion extends to 20' below ground level.

The floor plan of the P Area, shown on Page 67, is somewhat similar to R but appreciably smaller. Dimensions are 186' by 132' (incl. wall at Cols. BL). Roof height for a portion, 186' by 74' is 42' -9" above ground floor, the remainder, 34'. Approximately 63' by 75' of the high portion extends to 20' below ground floor.

The floor plans of L, K and C are identical and are composed of part Class I and part Class III construction. They are also single story with basement but irregular in shape. Roof height in Final Storage is 34', the remainder 40'. Approximately 57' by 66' of the high portion extends to 20' below ground floor.

Housing the reactor, the process room at this level is about 150 feet long by 42 feet wide at the floor and has a nominal ceiling height of 43 feet except the portion immediately over the reactor which is 61 feet high. The east and west walls, opposite the reactor, are set back 8 feet for improved viewing from the windows at the 15-foot level. In the northwest corner of the room, a concrete "doghouse" encloses the drive and discharge station of the deposit and exit conveyor. The south end of the room is closed by one of two vertical steel doors which are described in the "Special Developments" section.

The concrete walls are generally 7 feet thick except for the side walls above the plus 34-foot elevation to the ceiling, which are 5 feet thick. The ceiling, also, is 5 feet thick, and the floor 6 feet thick. The reactor plenum extends above the floor approximately 20 inches. Directly above the reactor guide plates are mounted in the ceiling, bored to the precise lattice pattern to accommodate the safety and control rods. Actuator forest supporting members and the telescopic guide supports provide continuous alignment of the rods throughout their travel.

At the plus 31-foot level, concrete haunches support the rails of the 120-ton crane, the rails of the charging and discharging cranes (both operate on the same rails) and the cable conveyors of the C and D cranes.

The presentation point of the inlet conveyor is located on the east side of the room.

Immediately south of the process room is the crane wash area which is normally enclosed both on the north and south by 8-inch thick steel shield doors. Further to the south is the crane maintenance area where the C and D machines, and 120-ton cranes are stored when not in use. Still further south is the shield basin which is a circular pit in the floor provided for the storage of the top shield and plenum chamber when these are removed from the reactor. Their storage in a pit is necessary to protect personnel from radiation. Oxalic acid preparation equipment for cleaning the cooling water system is also located in this portion of the building.

Adjacent to the crane maintenance area on the south is a deepwell which extends from the 0'-0" level down to the minus 40-foot level. It serves as an air intake for the fans at the minus 40-foot level and as a hatchway for removal of equipment from the lower portion of the building. The crane maintenance area is closed at the south by a rolling steel door which both protects the area from the weather and serves as a ventilation control.

The main entrance for personnel is located at the south end of corridor No. 1 on the west side of the reactor room. This portion of the center section houses personnel facilities and is so arranged that personnel entering or leaving areas which may be contaminated do so through the checking stations and locker rooms. Access to the disassembly area is through doors in the west wall, and to the assembly and purification area through doors in the crane maintenance area.

In addition, a number of rooms at this level are devoted to housing service facilities such as control room equipment, transformers, telephone switching equipment, ventilation and air conditioning system facilities, and power supplies for crane and actuator systems.

Of the four remaining #100 Areas, only Building #105-P is identical in layout to the R Area. The entirely different arrangement in the L, K and C Areas has been described previously under "Building Development - General." In those areas the process room is generally wider, being 58 feet, and about the same length. The ceiling height remains the same as do the wall, floor and ceiling thicknesses. The inlet conveyor is on the opposite side of the room but the deposit and exit conveyor location with its "doghouse" is in essentially the same location as are the crane wash area, crane maintenance area, shield basin and the oxalic acid facilities. The deepwell has been eliminated with relocation of the minus 40-foot fan rooms. The hatch for removal of equipment from the minus 40-foot level is outside the building and west of the shield basin section.

The remainder of the 0.0-foot level contains the same equipment extensively rearranged and generally housed in Class III construction. The accomplishments of this redesign have been listed in the "Building Design Development" section.

The comparison of floor areas at this level follows:

Elevation 0'-0" Process Area Comparison
(Sq.Ft.)

<u>Room</u>	<u>R</u>	<u>P</u>	<u>L</u>	<u>K</u>	<u>C</u>
Process Room	7360	7360	10,656	10,656	10,656
Crane Wash.	1624	1624	2304	2304	2304
Crane Maintenance	7992	7992	8856	8856	8856
Personnel (Inc.Fan)	11,400	11,400	8640	8640	8640
Canal (Transfer)	8142	8142	-	-	-
Power Transf.Rms.(1-4)	4126	4126	4258	4258	4258
Motor Gen. & Rod Equip.	2000	2000	1938	1938	1938
Stack & R.R.	5625	5625	5625	5625	5625
Corridors & Misc.	24,152	24,152	29,229	29,229	29,229
Fan Room	-	-	10,128	10,128	10,128
Total	72.421	72.421	81.634	81.634	81.634

DRAWINGS - ELEVATION 48 FT. AND ELEVATION 66 FT.

	R	P	L	K	C
Plan at El. 48'	W-130486		W-132335	W-133993	W-134374
Plan at El. 48'			W-132336	W-133991	W-134375
Plan at El. 66'	W-130471	W-131619	W-133171	W-133982	W-134376
Cross-section	W-130556	W-131567	W-132056	W-133954	W-134377
Long. Section	W-130557	W-131618	W-132054	W-133955	W-134378

DISASSEMBLY AREA

PRINCIPAL COMPONENTS

GENERAL

Essentially all operations in this area are conducted under water to shield operating personnel from the irradiated materials. The extent of shielding required to permit an operator to work an eight-hour day in the room without exceeding his permissible daily safe dosage depends on the type of material emitting radiation, the amount of time that has elapsed after the material's removal from the reactor, and the concentration of the material. The maximum shielding required is about 13 feet of water, and this value has been used throughout the design to insure safe operating conditions.

The temporary tube storage and machine area portions of the basin are generally 30 feet deep, while the balance of the area is 17 feet deep. Concrete walls, to permit isolation of a portion of the basin in the event machine maintenance requires drainage of the surrounding water, divide the entire basin into seven areas including the canal. These walls have narrow vertical openings at strategic points to permit transfer of material from one area to another. The openings can be closed by portable stop-logs when necessary.

In order to dissipate the heat generated by the radioactive materials, a continuous flow of 1500 g.p.m. of filtered water is maintained throughout the basin. The flow enters at three points and is discharged at five points on the opposite side of the building. Water depth in all or a portion of the basin is controlled by stationary weirs over which all water is discharged.

In the section devoted to "On-line Power and Water Supply", reference is made to a "last-ditch" supply of reactor heat exchanger cooling water represented by the basin contents. In the upper left hand corner of the drawing on page 69 will be seen three 24-inch suction lines connecting this basin to the emergency pump room. At the lower right hand corner is shown a 36-inch return line. The basin ca-

capacity and amount of emergency cooling water available in each area is tabulated below:

<u>Area</u>	<u>Capacity</u>	<u>Available Emergency Water</u>
R- gallons	7,500,000	1,500,000
P- "	4,500,000	1,000,000
L- "	3,490,000	822,000
K- "	3,490,000	822,000
C- "	2,570,000	640,700

MONORAIL SYSTEM

This system, with most of the rails at elevation 7 feet, spans the entire basin. General movement through the R Area is from east to west and all fixed rails run in that direction.

Movement between rails is, generally, by hand-pushed monorail transfer cranes running north and south with the exception of the electrified transfer crane provided at the entrance to the temporary storage area.

All underwater movement or storage in the canal and disassembly area proper is accomplished with this monorail system. Assembled items are carried vertically on storage hangers and the disassembled items are stored in buckets hung from yokes. Both the hangers and yokes are suspended from monorail trolleys and pass through slots in the floor commonly known as lanes.

CANAL

The canal extends from the temporary tube storage basin to the transfer point outside of the reactor room, a distance of approximately 148 feet. Discharged components are placed on hangers at the transfer point and pushed by hand to the storage basin. Of the four lanes in the canal, one is for the movement of loaded hangers, one is for the return of empty storage hangers, and two are for storage. The building redesign in L, K & C eliminated this canal.

TEMPORARY TUBE STORAGE

This area contains 40 storage lanes each approximately 46 feet long. In Buildings #105-L and K, there are 48 lanes for tube storage, two of which are for movement of empty and loaded hangers between pick-up points in the canal and the transfer crane. In Building #105-C there are 25 lanes where all components are retained for their entire storage period before disassembly. The operating floor at Elevation 0.0 is

made up of concrete platforms, each giving access to two storage lanes. At the entrance to the basin the electrified transfer crane, which accommodates four components and has a deck at Elevation 0.0 to carry an operator, is used to distribute the hangers to the storage lanes. A hand-pushed crane at the west side of the area is used to move empty hangers back to the canal and to move loaded hangers from any of the 40 lanes to the lanes entering the machinery areas.

Except for the control and blanket rods, material is stored in the basin only until it can be accommodated by the disassembly machines. Provisions have been made in the disassembly area for the possible use of producer material other than lithium-aluminum. If such material is used, a very much longer storage period will be required and storage then will be after disassembly.

MACHINE AREA NO. 1

This area contains machinery for reducing scrap to a size suitable for underwater bucket storage. Safety rods, thimbles, cadmium rods and rod extensions are cut into short lengths in the rod shear and chuted into buckets. The foil press and shear flattens the foils, cuts them into short lengths and chutes them into buckets. All items are placed on machine feed tables with tongs, some being carried to the tables on hangers.

One rod shear and one foil press have been provided with space allotted for a second foil press. For processing simplicity, aluminum was substituted for stainless steel in the rod extensions in Buildings #105-PLK and C; and with this change, one combination foil press and shear was installed with space provided for a second. With this change it became necessary to store the safety rods, cadmium rods, and the instrument rods at random on the floor of the basin, the depth of which in this area ranges from 17 to 30 feet.

MACHINE AREA NO. 2

Two vertical fuel tube disassembly machines are installed in this area. Provisions originally were made for a third but this space has been used for the foil rod extractor. Provisions also have been made for two emergency disassembly machines, should these prove necessary. In the P, L, K and C Areas, one vertical fuel tube disassembly machine is installed with provisions for a second. As in the R and P Areas, two locations are provided for future plow machines, while in the L, K and C Areas only one location has been provided for a future plow.

Basin depth in this area ranges from 17 to 30 feet, except for the pits containing the ram cylinder of the fuel tube dis-

assembly machines which extend down to elevation -51'3".

The two machine areas in Buildings #105-R and P were combined in the L, K and C Areas into one area which contains the foil press and shear, space for a second, the vertical fuel tube disassembly machine with space for a second, provision for an emergency disassembly machine, and the foil rod extractor. All installed equipment is similar to that in the R Area. If, at any time, new fuel shapes are introduced in the C Area, the vertical fuel tube disassembly machine will be replaced.

In the L and C Areas, a whip hoist and a gripper are used to seat the foil in the vertical disassembly machine.

EMERGENCY DISASSEMBLY

One horizontal fuel tube disassembly machine, commonly referred to as a plow, and a tipping device are installed here with provisions for a second disassembly machine. Quatrefoils which cannot be disassembled in the vertical machine are processed by the plow.

The emergency sleeve disassembly machine, which is portable, can be installed and used on the tracks and rails provided in this area. The machine, designed to remove sleeves from foils, can also be transported to other #100 Areas.

It is expected that unforeseen disassembly operations for which no machines have been provided will be performed in this area with tools designed and fabricated to suit the particular need.

The emergency disassembly area is located close to the canal so that water from other basin areas flows toward it to assure that contamination here will not spread but be carried out of the building. Basin depth ranges from 17 feet 9 inches to 30 feet. No equipment is installed in the emergency disassembly area of L, K & C.

DRY CAVE

The cave houses two rod disassembly machines, associated handling equipment and, in a separate enclosed room, the facilities of the hot laboratory.

The cave is approximately 16 feet by 76 feet, inside dimensions, with 30-inch thick concrete shielding walls extending to the roof. Four liquid-filled shielding windows permit observation of remote operations in the cave. A doorway, equipped with 7-inch thick steel doors, is used for personnel

and equipment entry to the cave, and an open channel in the floor permits material entry from the basin below.

In a corner of the cave the hot laboratory contains equipment necessary for remotely measuring, weighing and examining dry fuel slugs with a pair of master slave manipulators. The controls of the manipulators are located outside the cave at a shielding window which gives full view of the laboratory interior. Walls of this portion of the cave are 42 inches thick.

All cave air is exhausted to the atmosphere through filters. In the smaller dry cave of the L, K and C Areas there is no hot laboratory. Instead, space for the future construction of such a laboratory has been provided near the wall of the transfer station.

BUCKET STORAGE

Twenty-two lanes, each approximately 143 feet long, are provided for the storage of buckets of fuel slugs and scrap metal. The north 15 lanes of this area can be isolated from the remainder of the basin, and access to the transfer station is from this portion of the area. Transfer cranes are located at both ends of the area so that buckets can be shifted in storage as required. The basin depth is, generally, 17 feet.

Because of provisions made in the C Area for the future use of extended fuels, the bucket storage area is replaced by the final storage area, approximately 18 feet x 185 feet. This is an open pool in which baskets of strips can be stored on the bottom. Access openings to the transfer station, machine area and monitor basin have been provided.

TRANSFER STATION

Two pairs of tracks end at car stops in front of the two transfer pits. Platforms are provided between the tracks and against the west wall as an aid in car loading. A third pair of tracks serves the outside loading platform. Slug buckets are brought in from the basin and lowered into a cask in one of the pits by means of a monorail hoist. The cask in turn is raised by the 30-ton twin-hook crane and placed in a special railroad tank car. Scrap buckets from the basin are dumped into a scrap cask in the other pit, raised by the crane and placed on the floor of the transfer area. A Dempster-Dumpster truck transports the scrap cask to the burial ground. Producer slug casks are transported by trailer which loads and unloads in the transfer area. The 5Y3 casks are shipped and received in express cars and are handled at the outside platform.

In C Area provision has been made for shipping long elements.

MONITOR BASIN

A binocular microscope, a semi-portable instrument which serves all the plant disassembly areas, has been installed for detailed slug examination.

In Buildings #105-L, K and C the monitor basin contains no equipment. Installation of any equipment will depend upon future requirements.

STORAGE, WASH AREA AND OFFICE

A platform at elevation 4 ft. 4 in., connecting with the loading platform outside, is used for the storage of 5Y3 slug casks. One office, with facilities for one man, has been provided.

The area adjacent to the office serves as a general storage area with adjacent floor drains and hose connections available so that a portion of this space also can be used as a wash pad.

ELECTRICAL ROOM

Electrical power and lighting distribution panels are housed in this room.

REPAIR SHOP

This shop is equipped for the repair of disassembly area equipment.

FAN ROOM

Buildings #105-L and K contain a room of Class III construction which houses a fan supplying 5000 c.f.m. of outside air to the fan room, 9200 c.f.m. to transformer room No. 4 and 74,990 c.f.m. to the disassembly area. Of the latter amount, 14,000 c.f.m. is sent first to the rod control room, 4000 c.f.m. to the MG Room and 9500 c.f.m. to transformer room No.1.

The fan room of Building #105-C houses a fan to supply 4000 c.f.m. of outside air to the fan room, 11,200 c.f.m. to transformer room No. 4, and 73,800 c.f.m. to the disassembly area. Of the latter, 13,000 c.f.m. is sent first to the rod control room, 4000 c.f.m. to the MG Room, 11,300 c.f.m. to transformer room No. 1 and 1500 c.f.m. to several smaller rooms.

The transfer station in Buildings #105-L, K and C is supplied 7400 c.f.m. of air by a separate fan located between the station and the fan room. Discharge is to atmosphere.

CONSTRUCTION DETAILS

There are appreciable differences in the physical size, orientation and layout of the five disassembly areas, hence the R Area building is described and differences between it and the other areas noted.

This area is of Class I construction, roughly rectangular, single story, and houses a water basin beneath most of the area. The building length from Column Line RF to the end is 326 feet with a maximum width of 187 ft. Width from Columns NR to the end is approximately 131 ft. Roof height from ground floor to top of roof slab is 15 ft. except for the southwest corner where the height is 40 ft. The basin, varying from 30 to 17 ft. in depth below Elevation 0.0 underlies the entire building except for the west end portion and the repair shop.

The P Area, shown on Page 69 , is smaller than R but similar in layout and construction. The building length from Column FR to the end is 235 ft. while the maximum width remains 187 ft. The width from Column LR to the end is 131 feet. Roof heights remain the same.

The floor plans of the L and K Areas are identical but differ radically from R. The layout for L Area is shown on Page 71. These areas are of construction similar to R but roughly square. The length of the area is 219 feet and the width is 159 feet. There is no change in roof heights from R and P.

In C Area the arrangement is entirely different from L and K and the building is somewhat smaller, the length being 193 ft. and the basic width, 135 feet. The roof heights are unchanged. The area is illustrated on Page 73 .

A comparison of the areas, volume and floor space, simulated in many cases due to the water basin beneath, is presented on the following page.

The construction details of the areas are briefly summarized as follows:

Foundations - Reinforced concrete on 8 and 5-foot thick mats.

Superstructure - Reinforced concrete walls and roof except corrugated asbestos walls in L, K & C fan room.

Interior Partitions - Concrete, except flat cement asbestos board on steel studs in office and electrical room.

Ceiling - Exposed concrete, except flat cement asbestos board on wood joists in office.

Doors - Hollow metal and rolling steel.

Roofing - Built-up.

Floors - Concrete and removable wood panels on steel and concrete substructure. Concrete is painted and wood treated with linseed oil.

Special Finishes - See "Special Development - Finishes" elsewhere in this history.

Heating - Forced air through coils in conjunction with ventilation.

Air Conditioning - None

Ventilation - 84,500 c.f.m. from fan in process area, of which 6,400 c.f.m. is exhausted from cave by adjacent fan and 7,400 c.f.m. is redirected through transfer station by fan. Remainder passes through louvered and protected openings to atmosphere.

Lighting - Incandescent, except fluorescent in cave and sodium vapor in hot lab.

DISASSEMBLY AREA - AREA COMPARISON
(Sq.Ft)

<u>Room</u>	<u>R</u>	<u>P</u>	<u>L</u>	<u>K</u>	<u>C</u>
Temporary Tube Storage	11,900	7960	5809	5809	4480
Machinery Area	10,044	7750	6955	6955	4096
Repair Shop	2139	1755	1170	1170	1768
Bucket Storage	14,784	8036	7777	7777	4416
Dry Cave & Cask Floor	5202	5005	4862	4862	7144
Monitor Basin & Storage	2600	2600	1848	1848	1280
Transfer Area	3564	3483	4012	4012	4816
Corridors & Misc.	1299	400	873	873	400
Fan Room	-	704	2236	2236	1512
Dry Cave Fan Room	640	640	640	640	640
Total Area 0'	52,072	38,313	36,182	36,182	31,720
Total Area at (-17 & -30)	42,712	29,531	25,590	25,590	26,482

PURIFICATION AREA

PRINCIPAL COMPONENTS

MODERATOR PURIFICATION

In the R and P Areas this system consists of four remotely operated and maintained cells designated Cells A,B,C and D. Cell D contains equipment for receiving and pumping contaminated moderator to one or more of three parallel purification circuits located in Cells A,B and C, each consisting of a prefilter, deionizer and after-filter connected in series. Cell D also contains facilities for the collection, storage and batchwise decontamination of moderator too impure, isotopically, to be introduced directly into the main moderator system. A filter is included in Cell B, only, for removal of any radioactive particulate matter present in gas used for drying the equipment in Cells A,B and C.

Maintenance and transfer of movable equipment and piping components in the cell area, where human access is not permissible, is effected by a 30-ton bridge crane equipped with a shielded cab and dual optical systems for remote viewing. Special connector assemblies have been provided on piping and equipment so that pipe and electrical connections can be made remotely by the crane. Positioning guides and supports also have been provided for piping and equipment similar to those in the canyons of Bldg. #221-F.

The crane operator is stationed in a shielded cab separated from the cell area by a concrete parapet. By sighting through the optical system he can view the interior of the hot cell areas and, by means of a console in the cab, he can manipulate six hooks hanging from the crane. In the L,K and C Areas, the crane has no cab or optical system, and observation of cell interiors is through shielding windows in the cell walls. Crane movements are controlled from consoles located near the viewing windows. In this modified design, only three hooks are installed.

At one end of the cell area there is space for the receipt, removal and temporary storage of movable equipment, lifting yokes and tools, and for crane maintenance. Vessels containing radioactive waste materials are removed from the building for disposal through this space by means of a trailer-mounted lead cask. The trailer enters the area through a motor-operated steel shielding door.

Aside from changes in the crane, the principal difference in the moderator purification system provided in the

L, K and C Areas is the use of only two cells, designated E and F. Each contains parallel moderator purification circuits consisting of a deionizer and after-filter connected in series. Cell F contains the evaporator for decontaminating impure moderator.

BLANKET GAS SYSTEM

Helium blanket gas is passed in a closed circuit through the reactor gas plenum to remove and recombine deuterium and oxygen gases evolved from the reactor moderator system.

Two identical, remotely-operated systems, one a standby, connected in parallel and housed in separate, shielded rooms are provided. Each contains a blower, catalytic recombiner and spray separator plus heat exchangers to maintain proper temperature of the gas stream. Provisions are included for venting gas to avoid high pressure and radioactivity levels and for introducing fresh helium and oxygen to replace losses.

DISTILLATION AREA

This system removes light water from the moderator in two distillation columns mounted outdoors but adjacent to the purification area. A steel framework and poured concrete base provide access to and support for column auxiliaries such as reboilers, run-down tanks, condensers, vacuum system, pumps, and non-condensable gas disposal. Overhead product is placed in drums for further processing in the #400 Area and bottoms are returned to the moderator circulation system.

In the L, K and C Areas this equipment is similar except that the vacuum pumps, bottoms pumps, reflux pumps, and the twin desiccant beds for non-condensable gas dehumidification are located inside the building.

GAS DRYING SYSTEM

A closed circuit for circulating helium gas through any filter or deionizer in Cells A, B and C of the moderator purification system removes moderator prior to vessel disposal. A portion of the reactor circulation system can be dried with these facilities. Equipment consists of coolers for condensation of moderator vapor, a blower and a preheater.

Except for the use of twin desiccant beds instead of coolers for the dehumidification of the circulating helium, the system in the L, K and C Areas is similar to that in the R and P Areas.

REFRIGERATION SYSTEM (R and P Areas Only)

A two-stage ammonia refrigeration system of conventional design, and equipped with spare compressors, provides direct cooling of various gas streams. Auxiliary piping is provided for thawing several process exchangers which act as freezing units by piping hot ammonia gas directly from the compressor discharge.

RESIN PREPARATION AREA (R and P Areas Only)

This includes facilities for deuterization of mixed ion exchange resins which contain by weight about 50 per cent light water as received from the manufacturer. Equipment consists principally of storage tanks, a hydraulically-actuated movable agitator assembly and moderator pumps. This area also serves as a general purpose area, containing drum spots for unloading moderator and collecting distillation column overhead product, scales for accounting and inventory purposes, sink for collection of samples from various process streams, oxygen cylinders and unloading manifold, vacuum pump and purge blower auxiliaries for the gas system, certain health monitoring apparatus, and miscellaneous storage.

STORAGE AND MAKE-UP AREA (L,K and C Areas Only)

A general purpose area, it contains some of the auxiliary equipment located in the resin preparation area of the R and P buildings. Included are drum spots for unloading moderator and collecting distillation column overhead product, scales for accounting and inventory purposes, a sink for the collection of samples from various process streams, oxygen cylinders and unloading manifold, and miscellaneous storage.

INSTRUMENT CONTROL

This room contains fifteen instrument panels for the remote control and operation of gas and moderator systems.

ELECTRICAL CONTROL

All electrical control and emergency power apparatus is housed here.

LABORATORY AREA

A conventional chemical laboratory room, a room for mass spectrometers, and a counting room are included in this area for analysis of process samples. In Building #105-P there is a chemical laboratory room, a room for mass spectrometers, and a counting room, but no equipment is installed. No laboratory facilities are included in Buildings #105-L,K and C.

OFFICE AREA

This contains a two-man office, a small change room, and a toilet.

BASEMENT AREA

Much of the space in the basement is used for inter-connecting process pipe lines, service headers and conduits. Piping carrying radioactive materials is isolated by a shielding wall. Some components such as control valves, which are subject to routine maintenance, are isolated in five shielded cubicles which are independently accessible. A steam condensate removal system and floor sump are included.

The basement area in Buildings #105-L, K and C differs in that it contains six shielded cubicles instead of five. Additional equipment installed in the basement includes the vacuum pump and purge blower auxiliaries for the gas system, the distillation system pumps and certain health monitoring apparatus. In addition to the six shielded cubicles, there is an accessible cubicle containing equipment for introducing fresh and recovered moderator to the main circulating system.

CONSTRUCTION DETAILS

The differences in the layout of the R and P Areas and the L, K and C Areas have been described in the building development section of this history. In all areas the building proper is of Class I construction, but the distillation and gas storage equipment is unprotected.

Of irregular shape, the building in the R and P Areas is single story with pipe space beneath the floor slab. The roof elevation is at 22 feet except in the cell area where it is at 49 feet 11 inches over the cells and 53 feet 1 inch over the trailer space. The elevation of the finished floor slab varies from 3 feet 7 inches to 14 feet. In the L, K and C areas the single story building is also of irregular shape but the roof elevation is at 18 feet 6 inches except over the cell area where it is at 47 feet 6 inches. The elevation of the finished floor varies from zero to 14 feet.

The foundations, exterior walls and roof slab in all areas are of reinforced concrete. Generally, the interior partitions are poured concrete except in the spectrometer room and chemical laboratory in the R and P Areas, the instrument control room in the L, K and C Areas, and the change room and office in all areas which are cement asbestos board on metal studs.

LABORATORY AREA - R ONLY

Various standard items of laboratory and office furniture, fume hoods, gas rack, vacuum pump, water chiller, water still, Pyrofax gas manifold and exhaust blower, 100 c.f.m. at 33" H₂O vac. suction.

The P Area contains a laboratory area but no equipment was purchased or installed.

OFFICE AREA

Conventional office furniture, toilet and change room facilities.

BASEMENT AREA

E.P. 242X7 - Steam condensate pumps, 40 g.p.m. at 30' head.

E.P. 242X7-2 - Steam condensate receiver, 100-gal.

E.P. 242X6 - Vertical sump pump, 15 g.p.m. at 30' head.

Miscellaneous stainless steel piping and fittings.

With redesign in the L, K and C Areas much more of the equipment used for various process operations was located in the basement. Items placed in the basement are so marked in the equipment list on the preceding pages.

TRAILER SPACE

E.P. 241X4 - Trailer space door.

CRANE OPERATING GALLERY - L, K & C ONLY

Crane control equipment.

E.P. 252X1 - Liquid-filled window

INSTRUMENTATION

Instrumentation consists primarily of standard instruments for indicating, recording and controlling process variables in the continuous moderator and gas systems and for health monitoring. An instrument control room provides a central location for process control.

A modified Beckman oxygen analyzer, employed to continuously analyze and record blanket gas oxygen or hydrogen content, consists of two primary elements, a catalytic chamber for combining oxygen and hydrogen and a paramagnetic-type oxygen analyzer.

DRAWINGS

<u>Title</u>	<u>R</u>	<u>P</u>	<u>L</u>	<u>K</u>	<u>C</u>
Basement Plan, Equip. Arrgt.	W-143081	W-143300	W-144128	W-144128	W-143756
1st Floor Plan, Equip. Arrgt.	W-143082	W-143301	W-144129	W-144129	W-143757
Section, Equip. Arrgt.	W-143085	W-143302	-	-	-
1st Floor Plan, Equip. Arrgt. Part I	W-143093	W-143303	-	-	-
1st Floor Plan, Equip. Arrgt. Part II	W-143092	W-143304	-	-	-
Floor Plan, Equip. Arrgt. Part III	-	W-143305	-	-	-
Elevations, Arch. Sheet 1	-	-	W-144070	W-144070	W-144442
Elevations, Arch. Sheet 2	-	-	W-144071	W-144071	W-144443

INSTRUMENTATION

GENERAL

The facilities described here apply almost exclusively to the Process Area of the building.

POWER LEVEL BY NEUTRON FLUX MEASUREMENT

These systems consist of neutron counters, ion chambers, amplifiers, indicators and/or recorders. Twelve special holes through the ion shield and concrete shield leading to the reactor wall accept variable insert designs to accomodate different types of neutron counters and ion chambers. Co-axial cables join these detectors to a connector box, permitting any detector to be connected into several alternative receiving instruments located in the central control room. The following systems are provided.

1. Neutron Counters

- a. One system, utilizing one of two different neutron counters 180° apart, provides for start-up indication and a record of power levels on a count rate basis.

- b. One system, utilizing the remaining neutron counter, provides indication on a scaler for start-up.
- c. Several portable counting rate meters and scalars are also provided for low power level measurements during loading. Signals can be obtained from counters used in systems listed under Items "a" and "b" or from special counters inserted temporarily inside the tank.

2. Ion Chamber

- a. Three gamma-compensated ion chamber systems indicate and record power level and automatically shut down the unit at preset levels.
- b. One system indicates power level on a galvanometer system consisting of absolute meter and differential meter.
- c. Two systems indicate and record the logarithmic power level and pile period. They automatically shut down the reactor if the period is less than a predetermined value.
- d. One system indicates and records small deviations from an essentially steady power level.

MISCELLANEOUS REACTOR TEMPERATURES

The temperature of various points of secondary importance in and around the reactor are recorded on a panel, E.P. 480.6, located in the control room. Multipoint recorder capacity for about half the total number of thermocouples is provided for monitoring any particular points of interest. A jack panel is provided to afford flexibility in the selection of points to be recorded.

Instrument tubes containing five thermocouples along their length are provided for insertion into the reactor through special holes in the top tube sheet. The leads from these thermocouple tubes are brought to the same junction boxes as the thermocouples listed below.

Location and quantities of miscellaneous thermocouples are:

<u>Location</u>	<u>RPLK</u>	<u>C</u>
Tank Wall	84	
Tank Wall		38
Top Bearing Ring	3	
Top Bearing Ring		6

	<u>RPLK</u>	<u>C</u>
Support Beams	6	
Top deflector plate		6
Septifoil Discharge Water	31	
Septifoil Discharge Water		25
Chimes Inside Tank		6
Bottom Plate of Tube Sheet (Top Tube Sheet)	12	
Bottom Plate of Tube Sheet		18
Bottom Deflector Plate		6
Top Plate of Tube Sheet (Bottom Tube Sheet)	10	
Top Plate of Tube Sheet		13
Top Tube Sheet Packing (Bldg.#105-R&P)	12	
Top Tube Sheet Packing (Bldg.#105-L&K)	3	
Annular Cooler	24	(8 per section)
Annular Cooler (Bldg.#105-K)	34	(8 per section 10 on walls in one section)
Annular Cooler		35 (2 per section plus 13 in one section)
Concrete Shield	21	
Concrete Shield		27
Instrument Rods	60	
Chimes Outside Tank		4
Isothermal Box	15	
Neutron Counter and Ion Chambers	24	
Cast Iron Blocks on Top of Annular Cooler	9	(Bldg.#105-K)

FLOW MONITOR AND GAMMA MONITOR

The flow monitor provides scanning, automatic low flow alarm signals and recording of flow through each quatrefoil. The gamma monitor provides slug failure detection by recording and automatically alarming when the activity of water samples taken from the six circulating systems of the reactor increases abnormally. Location of the quatrefoil containing a bad slug is determined by monitoring a by-pass filter-separator at the bottom of each quatrefoil pin with a portable activity detector.

Facilities for flow monitoring consist of a 3/16-in. O.D. stainless steel tube connected from each quatrefoil pin directly to the high pressure sides of 606 (594 in C Area) transmitters located in the shielded transmitter room. Tubing terminal points are connected with Crawford Swagelok fittings. Intermediate connections are welded. Transmitter output signals are recorded on a monitoring unit panel, E.P. 480.11, and alarmed on panel E.P. 480.4, both located in the central control room. Each transmitter contains a mechanically actuated switch which also alarms on panel E.P. 480.4 and shuts down the reactor at extra low flow.

Facilities for the gamma monitor consist of six sampling systems which take samples from each pump discharge past two scintillation counters and back to pump suction. Auxiliaries include remote operated valves for drains, by-pass lines and interlocks. Counters are located in sleeves running through the wall of the transmitter room near the reactor. Electronic equipment, consisting of power supplies, amplifiers and computers, is located on the balcony of the transmitter room. Readings are transmitted electrically to six recorders, Panel 480.12, in the central control room.

TEMPERATURE MONITOR

This unit provides scanning, manual selection, and recording of signals from four thermocouples in each of the fuel tube instrument pins. The couples consist of iron and constantan 20 gage TC wire with fiberglass insulation over which a stainless steel jacket is drawn. Since continuous operation is of the utmost importance and the replacement of assemblies would be difficult, approximately 7 to 10 per cent spare assemblies are installed with the result that approximately 2600 separate couples are required. All thermocouples are connected to terminals within a thermally insulated junction box located in the pin room. Copper lead wire is used between this junction box and the monitor cubicle in the central control room.

The monitor provides the following:

1. Graphic record of all fuel-tube coolant temperature rises;
2. Indication, on a graphic panel, of the existence and location of any deviation from normal temperature rise;
3. A graphic jack panel to permit continuous monitoring of particular temperatures by means of auxiliary recorders;
4. Means for monitoring three groups of 24 temperatures so that their deviations from normal are indicated on the control console; and
5. Various alarms and annunciator signals.

A thermocouple extraction tool and cask are provided for changing thermocouples without draining the reactor.

LEAK DETECTION

The cooling water leaving the heat exchanger section is

sampled to detect whether process water has leaked into the cooling water through internal defects in the heat exchanger. This is accomplished by continuously checking 12 sample streams for radioactivity by using scintillation probes installed in the sample chambers located in the motor rooms in R and P, and in a corridor at the -20-foot elevation in L, K, and C. Pulses from the probes are detected by 12 counting rate meters installed in the transmitter room and recorded by two 8-point recorders, connected to the C.R.M.'s and located in the control room on panel 480.8.

Various pump and valve packing glands, which are potential sources of process water leakage, are monitored continuously in Buildings #105-R and P. Fifty-eight prefabricated units which collect the leakage and measure and transmit its level are installed at each system. A monitor unit located in the observation room continuously scans these units and sounds an alarm in case of high level.

In Buildings #105-R and P, approximately 200 pipe and valve flanged joints which are potential sources of process water leakage are equipped with special "wet wire" means for leak detection. In the event of a leak at any of these points a visible signal is given on an instrument panel located in the pump observation room.

AREA MONITORING

GENERAL HEALTH MONITORING

Eighty-one gamma ion chambers (76 in C Area) are installed at various locations throughout the entire building for the purpose of monitoring radiation level in inaccessible and accessible areas. These chambers are connected to Beckman amplifiers which in turn are connected to Brown 4-point recorders. Where possible, the chambers are grouped so that up to four chambers are connected to a Beckman 4-point selector switch and then connected to one amplifier. The majority of the Brown recorders are located on panels in the zero level health monitoring panel room with an alarm system to notify the operator of a high level at any location. Certain recorders were mounted elsewhere to provide a readily accessible record at locations in more active use.

VENTILATING DUCT MONITORING

A gas sample is taken from the ventilating ducts which exhaust air from the reactor area, the -40-foot level and the purification area. In addition, a sample of the combined gases is taken from the stack at a point 52 feet from the top. Gas sampling equipment is located at the +48-foot level in two rooms, one on either side of the reactor area exhaust fan room. Sampling equipment consists of filter, ion chamber, pumps and a Beckman amplifier which transmits a signal to the

Brown recorder on the panel in the 0-0 level monitoring room. This panel contains an alarm system for high level, and this alarm is connected also to the annunciator panel in the central control room.

THERMAL SHIELD COOLING WATER

Activity of the cooling water in this system is checked by mounting two gamma ion chambers on the discharge pipe from the heat exchanger for the top and bottom shield system and the side shield system. One chamber on each system is a standby. The two chambers are connected to two Beckman amplifiers in the transmitter room which in turn are connected to a Brown recorder on a panel in the Elevation 0-0 level monitoring room.

GAS AND WATER SYSTEM

Provision is made for the measurement and indication or recording of process variables including temperature, pressure, flow, liquid level and electrical conductivity, exclusive of measurements made in the reactor itself.

Provision is made for the remote manual operation of numerous valves and pumps from the central control room.

A 40-foot long panel, located in the central control room, graphically presents the gas and water system by means of the instruments and controls mentioned above which are arranged to correspond to relative process locations.

A power calculating system panel permits the continuous and automatic calculation and recording of the megawatt production of the reactor based on heat absorbed by the cooling water in the heat exchangers. Total power is also indicated by a specially developed digital type indicator located on the control console.

A main pump system temperature monitor panel for 130 points (150 points in C Area) of temperature measurement at six pumps and motor systems is located in the pump observation room in R and P and in the transmitter room in L, K and C. Segmental recorders are used to reduce the quantity of instruments required.

Two alternate systems, each consisting of 61 (73 in C) pressure switches, monitor the process cooling water flow to control septifoils. Each point of measurement is equipped with low-flow alarms.

CENTRAL CONTROL ROOM

AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

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VI - DESCRIPTION OF PROCESS - BUILDING #105

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VI - DESCRIPTION OF PROCESS - BUILDING #105

ASSEMBLY AREA

The assembly area receives, cleans, assembles and tests the fuel, target and semi-permanent elements to be charged into the reactor, accumulating in final storage 120 per cent of the quantity required for each reactor charge. Operation is on the basis of five shifts per week.

Tractor-trailer and truck deliveries are made at the receiving area and rail shipments are unloaded at a spot a short distance from Building #105. Since the maintenance of a high degree of cleanliness is an important consideration, the receiving area is enclosed from the rest of the assembly area to contain the dirt from incoming shipments and to serve as an air lock for the air conditioned working and storage areas. Hose connections are installed on the outside truck apron for washing the vehicles prior to entry.

Trailers used for component shipments between buildings on the plant are equipped with rigid but detachable roofs; other shipments are received from canvas covered trucks. During unloading operations in R and P the detachable covers are placed on a platform at the side of the receiving area at Elevation 15. In L, K and C the covers are placed on carpenter's horses.

In the R Area a two-ton monorail bridge crane is used to remove the truck covers, unload the large boxes, and place them on a tube box dolly which is mounted on rails and shuttles the containers between the receiving area and the storage area. In the P, L, K and C Areas, the crane transports the boxes directly to storage.

Boxes containing small parts and the pallets carrying fuel slugs are unloaded and transported to storage by fork lift truck. For security control, the slug pallets are stacked on the floor of a locked room and are removed to the loading machine only as required. Accountability records are constantly maintained on the slug inventory.

The various intermediate steps in the assembly process in which parts are cleaned and inspected and the manner in which they are transported are illustrated in the flow diagram, page 403.

Beyond the inspection and cleaning stages the basic material handling system within the main operating portion of the area is by an overhead monorail system which includes lift towers for changes in track elevations as well as monorail hoists for placing components in and removing them from the several pieces of equipment.

After the fuel slugs, 1-inch in diameter by 8 inches long, have been inspected for surface finish and dimensional tolerance, they are placed on trays and transported by dolly to the loading machines. Small Q-foil parts such as orifice piston assemblies, piston sleeves, adapters, adapter bolts, and boat-tails are degreased in a basket and in-process quantities made available to operators at the loading station.

Individual foils are laid on a long inspection table, are gaged for critical tolerances, placed in a long basket, degreased, and arranged on a horizontal storage rack which is pushed to the loading station.

The stations for loading and assembling the quatre-foils and other components are along parallel slots in the operating floor. In the R Area, four lines are provided, each serviced by the monorail system. The first line, comprising the tipping table, rotating rod holding rack, functional gage No. 3 and lift tower No. 1, is for the assembly of long rod elements and thimbles. The second line is the major assembly line where the Q-foils are loaded and tested. It is equipped with the Q-foil hydraulic loading machine, the individual channel and gross flow test stations, and functional gage No. 2. Line three contains functional gages Nos. 1 and 4 for the testing of semi-permanent components and septifoils. In line four is the monitor pin test station for hydraulic calibration of the metering type monitor pins employed in the #100-K and C Areas. At the end of line four is also the original Q-foil final test station which now is used for steam heating and air drying the Q-foils passed from line two. Accessory tanks, pumps, piping, valves and metering runs for the hydraulic loading machine and the test stations are located in the basement.

The loading of quatrefoils constitutes the greater part of the assembly work since approximately 670 such tubes are necessary for each reactor charge. Actual assembly commences at the loading station where the light Q-foil weldment is raised to a vertical position and lowered gently into the hydraulic loading machine tank. Piston sleeves are inserted in the top of each of the four channels, a top fitting is set in place to seal three of the channels, and against the cushion of an up-flow of water, the fuel slugs are inserted by hand in the open column one at a time.

time each component is pushed out of the room on its hanger to the gripper pickup station which moves the hanger through a slot in the reactor room wall to a point where the charging crane engages the component and deposits it in a pre-arranged position in the reactor. The empty hanger is withdrawn from the reactor room and returned to final storage, and from there moved into the assembly area to repeat the process cycle.

A small percentage of loaded Q-tubes may be sent to Building #305-M where nuclear properties can be checked in the test pile after which the tubes are returned to Building #105 for use in production.

PROCESS AREA

This area of Building #105 houses the reactor, the reactor coolant system, the control system, and the charging and discharging facilities as well as many auxiliary systems and facilities. Reference to preceding exhibits will help to illustrate material movement and liquid flows in the process area. A flow diagram, reactor cooling and blanket gas system, is given on page 153 and a flow of production material through the reactor room is given on page 235.

GENERAL

In previous sections of the history, mention has been made of the care with which the reactor, its auxiliaries, and the coolant piping were fabricated and the extreme cleanliness required of all this equipment.

To be certain that the equipment and systems operated at design capacity, were properly run in, and all adjustments made, AED Operations made a test run. A dummy charge of Q-foils, which were exact prototypes hydraulically, but contained no uranium, was inserted in the reactor and the coolant system completely filled with deionized light water. The reactor and its associated equipment was then operated hydraulically for a number of days while the performance of all equipment was carefully checked.

At the conclusion of the run the dummy load was discharged and forwarded to the next area for similar checks. The system then was drained completely of light water, dried out thoroughly (with equipment provided) and filled with heavy water. A complete charge of components was inserted in the reactor by the charge crane starting with the safety and control rods and finishing with the uranium filled Q-foils.

After all channels are loaded the foil is removed with a monorail hoist and placed in the adjacent single channel flow test station where measurements are made to determine whether or not the resistance to flow of each of the channels lies within the prescribed value. While the foil is still in the channel tester, the top adapter with the piston orifices is bolted to the Q-foil top fitting. This completed, the loaded and assembled foil is hoisted again, then lowered into functional gage No. 2, a step which simulates insertion in the reactor.

When an assembled fuel tube has been checked completely in the flow test station, it is positioned in a final station to be steam heated and air dried. This removes any residual light water which would, in the reactor, become an isotopic impurity. From the drying station the loaded foil is conveyed by monorail hoist to lift tower No. 2 for transfer to a monorail hanger, on which it is pushed to the final storage room.

Producer and control rod elements received from the #300 Area, nominally 15 feet long by 1 inch in diameter, are fitted with suitable rod extensions at the tipping table, are raised to the vertical and transferred to the revolving rack for temporary storage. From the rack the rods are lowered into functional gage No. 3 for simulated insertion in the reactor, and then moved to lift tower No. 1 for transfer to monorail storage hangers.

Thimbles and septifoils are essentially long sleeves in which the rod elements are housed in the reactor. After inspection and cleaning, the thimbles are routed to the tipping table, brought to a vertical position and loaded on hangers at lift tower No. 1. The septifoils, in turn, are routed to functional gage No. 4 and then to lift tower No. 2 for transfer to one of two types of storage hangers on which they can be conveyed to rack storage in the final storage room.

From time to time the semi-permanent sleeves, spiral shields, and plugs used in the reactor must be replaced and a supply of these is kept in the assembly area pending demand. When required, the pieces are hoisted to functional gage No. 1 which simulates some reactor sections and verifies the ease with which the parts can be placed in the reactor. After the proper O-rings have been slipped into grooves in the pieces, they are mounted on hangers and transported to the final storage room.

As a result of assembly operations, a full complement of reactor components is accumulated in the final storage room by the time the reactor is to be recharged. At that

COOLANT RECIRCULATION

In the "Process Area - Equipment Development" portion of this history a complete description of the pumps, heat exchangers, valves and piping is given. The pump drive description is given in the "Special Developments" section. The six 3000 hp. a.c. motor-driven coolant pumps normally operate at 1800 r.p.m. recirculating a total of 76,200 g.p.m. through the reactor-heat exchanger circuit to remove the nuclear heat of fission during the entire irradiation cycle which may last for several months.

AUXILIARY SYSTEMS

During the irradiation cycle the only other systems normally operating are the instruments for monitoring the operation, the control system regulating the power level at the desired point while maintaining nuclear trim, the blanket gas system sweeping gaseous dissociation products out of the reactor and the shield cooling systems.

Cooling water is supplied to the heat exchangers from the light water pumps in Building #190. In the engine house the six small diesel-driven d.c. generators operate continuously to energize the d.c. motors operating as an integral part of the coolant pump drives. These motors are designed to maintain 600 r.p.m. operation of the coolant pumps in event of complete a.c. power failure. When the reactor has been shut down coincident with the loss of a.c. power, flywheels, included in the drive, prevent the pumps from decelerating from 1800 to 600 r.p.m. faster than the rate at which fission heat emitted by the fuel subsides.

COOLING WATER SYSTEM

Cooling water enters Building #105 through two 42-inch headers, one on each side of the building, passes through the shell side of the heat exchangers and discharges to Building #107, Cooling Water Effluent Sump, and in turn to the area outfall. A small amount of the cooling water entering the building is diverted from the 42-inch headers for the thermal shield heat exchangers, 3000 hp. motor coolers, the diesel engine jackets in Building #108, and other miscellaneous uses.

In the event of a.c. power failure to the Building #190 pumps, the "on-line" gravity flow feature of the cooling water system becomes effective and an appreciable flow continues for several hours. Alternate supplies of cooling water are described under "Special Developments -On-Line Power and Water Supply".

REACTOR

The reactor was planned to operate on natural uranium, but flexibility in the SRP design permits operation with other fuels including depleted uranium. An important concern in reactor operation is the possibility of fuel slug rupture which would release fission products into the moderator circulating system.

Operations are concerned also with the continuity of heat removal from the reactor, with the radiation that escapes through the shields, the build-up of impurities in the heavy water, and the control rod adjustments required to maintain safe and efficient reactor operation.

As previously described, heat is removed from the reactor by the circulating D₂O and transferred to the cooling water in the exchangers. Continuity of heat removal is all-important to maintain the integrity of the fuel sheaths and prevent the escape of fission products into the moderator. Failure of coolant flow would undoubtedly cause melting of the fuel elements with serious results.

Constantly escaping radiation causes considerable concern for the safety of operating personnel. The thermal shield, surrounding the sides of the reactor, and the top and bottom shields are designed to contain 50 per cent light water and 50 per cent iron to absorb neutron and gamma radiation as well as alpha and beta rays. The thermal shield in turn is surrounded by a concrete shield. During reactor operation the area surrounding the unit below the 0.0-foot level is uninhabitable because of the radiation through the concrete shield and high intensity but short-lived gamma radiation from the oxygen and nitrogen isotopes in the circulating D₂O. When the reactor is shut down this area normally can be entered after routine checks and precautions have been taken.

Within a few hours after shutdown, the reactor room can, if necessary, be entered provided no fission products or other active impurities have escaped into the moderator and settled out in the plenum.

All operations are so planned, however, that personnel normally do not need to enter the room. If emergencies arise requiring entry, this is permitted only after radiation measurements prove it to be safe.

During the course of the production cycle a 30 g.p.m. side stream of heavy water is passed continuously through the filters and ion exchangers in the purification area to remove solid contaminants such as small particles of dirt

or dissolved corrosion products. A portion of this stream is put through the isotopic stills in the same area to remove light water picked up hygroscopically by the moderator during charging periods. The blanket gas system constantly removes evolved gases from the top of the reactor and recombines the deuterium and oxygen for return to the reactor.

The control rods must be adjusted constantly to maintain the proper nuclear trim of the reactor, to avoid formation of hot spots, and to offset the accumulation of poisons in the fuel as the cycle proceeds. Cooling water temperature variations also require rod resetting although these variations as a rule are not very abrupt.

CHARGE AND DISCHARGE OPERATION

At the completion of an irradiation cycle the reactor is shut down gradually by inserting all control and safety rods into the reactor. The 60-ton actuator hoist is energized and the carrier lift deck and attendant structure, including the forest, raised a few inches. This movement causes all control and safety rod latches to open and delatch the rods so that subsequent lifting of the structure will raise the latch in the reactor.

At this point the Operating group has a choice of two methods of clearing the top of the reactor. After being delatched, the rod extensions can be raised a few inches by their own drives while the 60-ton hoist lowers the forest. The actuator structure can then be disengaged from the forest proper and lifted to the top of its travel leaving the forest over the reactor. The forest can then be removed horizontally from the reactor room by the 120-ton crane.

The other method is to raise the actuator structure, with forest attached, to the upper limit of its travel. This permits the cranes to operate under the forest. The actuator structure is then locked in its upper position. Page 209 shows the forest in its retracted position.

If the latter method has been selected, the vertical steel doors are raised and the charge and discharge cranes are brought into the room. The steel doors are closed to protect personnel in the crane maintenance area from radiation emitted from the components being removed from the reactor.

Discharging and charging operations are performed simultaneously. To start the sequence a shield plug is removed from a plenum tube semi-permanent sleeve and placed in the holding rack by the discharge crane. The following sequence is then repeated for each of the 606 Q-foils.

1. The discharge crane removes the irradiated Q-foil from the plugless hole and places it in the deposit and exit conveyor which in turn swings the component out of the reactor room and into the canal where an operator transfers the foil to a monorail hanger. The empty conveyor arm is swung back into the reactor room to receive the next Q-foil.
2. The charging crane meanwhile has been directed to the pick-up point to receive a fresh Q-foil. It deposits the foil in the lattice position just emptied by the discharge crane which is then at the deposit and exit conveyor. The C crane then returns to the pick-up point for the next fresh Q-foil.
3. The discharge crane returns from the conveyor to the second lattice point, removes the shield plug and places it over the fresh Q-foil. It then removes the hot Q-foil from the second position and transports it to the conveyor.

All other components can be removed and replaced in a similar fashion although they normally are not replaced after every cycle. (The reader is also referred to the "Process Area Equipment Development - Charge and Discharge Cranes" portion of this volume.)

In the event a Q-foil cannot be removed from the reactor because of swelling or sticking in the semi-permanent sleeve, the operator can remove the sleeve and the Q-tube as a unit. After depositing the assembly in the conveyor, a new sleeve is placed in the reactor by the charge machine and normal operations are resumed. If at any time a hot Q-foil must be held out of water for a period of time, cooling water can be fed to the Q-tube by the crane. Either D₂O or filtered water may be used.

At the completion of the discharging and charging cycle the vertical steel doors are raised, the cranes withdrawn from the room, and the doors closed. If the cranes are contaminated they may be spray-washed in the area between the doors.

The actuator structure is then lowered into position which relatches the rod extensions to the rods and operations can be resumed.

LEGEND

- (3) ROD ENDS
- (4) 5Y3 SLUGS (35W5 IN ASSEMBLY AREA)
- (5) PRODUCER SLUGS
- (9) Q-FOILS
- (10) ROD EXTENSION
- (11) Q-FOIL SMALL PARTS
- (15) FUEL SLUGS
- OTHERS AS SHOWN

NOTE :

ALL ITEMS ARE RECEIVED FROM THE REACTOR ROOM VIA THE EXIT CONVEYOR, E.P. 176, TRANSFERRED TO HANGERS AND PLACED IN TEMPORARY STORAGE.

CONTROL RODS AND BLANKET ASSEMBLIES ARE STORED ONE MONTH BEFORE DISASSEMBLY AND REQUIRE NO FURTHER STORAGE. STORAGE PERIODS GIVEN FOR FUEL SLUGS AND SCRAP INCLUDE TIME IN TEMPORARY STORAGE.

FLOW DIAGRAM
DISASSEMBLY AREA
BLDG. 105-R

CASK
 (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12) (13) (14) (15)

SPR. TRUCK

DISASSEMBLY AREA

GENERAL

All materials irradiated in the reactor are processed through this area before shipment to other areas, to off-plant destinations, or before burial. This includes the instrument rods, safety rods, non-target type control rods, thimbles, 5Y3 rods, full and empty S-foils, target control rods and Q-foils. Emergency handling of sleeves, plugs, spiral shields and muffs can also be accommodated.

The diagram, page 415, shows the flow of materials through the area from the deposit and exit conveyor to outgoing trucks or railroad cars.

Elements removed from the reactor are swung out of the reactor room and into the canal by the deposit and exit conveyor where they are transferred manually to storage hangers. The hangers are hand-pushed to the electrified transfer crane from which distribution is made to various portions of the temporary tube storage space.

DISASSEMBLY

The Q-foils, which contain irradiated fuel slugs, represent the largest volume of material processed in the disassembly area. They are held in the temporary tube storage area to age and then fed gradually in the R Area to machine area No. 2 for disassembly in the vertical machines.

A lift section is provided in the monorail track above the vertical disassembly machine so that track, hanger and foil can be raised, centered over the machine and the foil lowered onto a seat. The Q-foil is clamped in place and the hanger disengaged and moved away. The orifice remover is brought over, set in place over the Q-foil and is used to grip and unbolt the orifice assembly which is carried over and dropped into a bucket by the remover.

A hydraulic ram, operating in a cylinder below the foil, enters through the bottom end fitting and pushes up the slug column which strikes a diverter as it emerges from the top of the foil. The slugs and other parts slide down a chute and into a sorting tray. From the tray, slugs are tonged into one bucket and other parts into another. The slug bucket at this point is on a track scale and the slugs are weighed and counted with the accumulative total printed on a tape.

The empty foil is grasped by tongs, unclamped and carried to the foil press and shear in machine area No. 1. The orifice assembly, boat tails and other metal parts removed from the foils are stored in buckets in the scrap storage area prior to removal through the transfer station to the burial ground.

At this writing, development of a simplified disassembly machine is well advanced. This device simply inverts the foil and dumps out the slugs. This method was considered originally but discarded because of the hazard of damaging slugs.

If at any time it is impossible or unwise to remove the slugs from the Q-foils in the vertical disassembly machine, the foils are moved on their hangers into the emergency disassembly area where the horizontal fuel tube disassembly machine and tipping device are located. Any foils with ruptured slugs, or foils damaged and corroded to the extent that rupture of slugs in normal disassembly is possible, are brought into the emergency disassembly area. The emergency disassembly area is "downstream" so that contamination released there is carried out of the building in the basin overflow rather than spread to other portions of the basin. This special area can be isolated to protect the remainder of the basin.

The Q-foil is clamped in the tipping device, brought to a horizontal position, carried over the horizontal disassembly machine, lowered into the holding fixture and clamped. A hole is pierced in each upper channel of the foil, the plow tools are engaged in these holes and the channels are plowed open. As the holding fixture is revolved to bring the other channels into plowing position, the contents of the plowed channels fall out and slide down to the sorting tray. From here slugs and parts are tonged to the proper buckets. The empty foil is grasped with tongs, unclamped, and carried to the foil press in machine area No. 1.

If the orifice assembly has not been removed elsewhere, it is removed immediately after the foil is placed in the tipping device by the same tool used in conjunction with the vertical disassembly machine. The orifice remover can be moved from area to area in the basin through the floor slots.

The sleeve cutter, which removes sleeves from foils in cases where the foil cannot be drawn through the sleeves during discharge, can be installed and used on tracks and rails provided in the emergency disassembly area. One machine has been provided and can be moved from building to building

as required. The sleeve is cut vertically by a slitting saw and radially by a pipe cutter and the jammed portion falls away from the foil. In the infrequent cases where sleeves are replaced in the reactor room, they can be reduced in this machine to a size that can be handled in the same manner as other scrap metal.

It is expected that disassembly operations of types not foreseen and for which no machines have been provided will be performed in this area with tools designed and fabricated to suit the particular need.

Basin depth ranges from 17 feet to 30 feet except for the pits accommodating the ram cylinder which extend down to a depth of -51 feet 3 inches.

Located in the space originally provided for a future vertical disassembly machine is the foil rod extractor which is used to remove control and blanket rods when these are received in septifoils.

Extracted rods are placed on hangers and handpushed to the transfer carriage of the rod disassembly machine.

At this station the rods are removed with tongs from the storage hangers, placed on the transfer carriage outside the cave, and brought up horizontally through a slot in the floor between the two units of the rod disassembly machine. An extractor, running on overhead rails, engages and draws the rod from the carrier and lays it on the arms of one of the units. These, in turn, are raised and the rod rolls down onto the machine conveyor and is fed past the cutting head and against a stop. Cuts can be made through the rod sheath at the juncture between the slugs by selecting one of the several stops located in different positions. In that way the rod end is first cut off and chuted through the floor slot into the basin. Then the slugs, as they are cut off, are deposited in a cask by remote adjustment of the chute. If producer or target metal requiring much longer storage is used, the slugs are not loaded directly into the dry cask. Instead, the chute is used to divert the slugs to an underwater tray from which they are tonged into buckets and stored. After storage they are handled in the same way as fuel slugs.

The feed tables of this machine are so pivoted that after the slugs have been cut off, the remaining rod extension can be made to slide backwards to a chute and down to a tray to Elevation -12'. From this point it is carried with tongs to the rod shear.

The entire operation of these machines is necessarily remote because of the presence inside the cave of unshielded radioactive material. Observation windows in the cave walls are placed opposite the cutting ends of the machines and control panels are mounted on either side of these windows.

Casks are carried in and out of the cave by a fork truck. Both cask types are so sized that their capacities are a multiple of the number of slugs in a rod. That is, when the cask is full, the machine is empty. The cave may be entered under these conditions and therefore the fork truck is not remotely operated. Operating procedure for handling casks is as follows.

1. Open cave doors and drive in truck to position in front of machine.
2. Engage cask lid with hoist fixed above and raise.
3. Leave cave on foot and close doors.
4. Disassemble rods until cask is full.
5. Lower cask lid into place using outside hoist control.
6. Open doors, enter cave and drive out truck.
7. Place cask on floor and pick up empty cask.
8. Repeat cycle.

Air is exhausted from the cave through filters to atmosphere by a fan located nearby.

MISCELLANEOUS

Loaded producer slug casks are carried by the fork truck to the transfer area, placed on a flat bed trailer by the 30-ton crane, and transported to their destination. If necessary, these casks can be stored on the floor adjacent to the dry cave until they can be loaded on the trailer. Casks containing 5Y3 slugs are deposited by the cave's fork truck on the floor under a stub monorail carrying a hoist. The cask is moved by monorail to a second monorail hoist and then to the platform from which the fork truck can transfer the casks into a railway express car at the outside platform. For empty fuel slug casks and empty producer slug casks returned from other areas and empty 5Y3 casks returned by rail, the above procedures are simply reversed.

Safety rods, solid control rods, thermocouple-type instrument rods, rod plugs, rod extensions and the thimbles of the safety rods, instrument rods and 5Y3 rods are cut into 10-inch lengths by the foil press and shear in machine area No. 1, chuted into buckets which, after storage, are placed in casks and shipped to the burial ground. Instrument rods of the firebox type and foil plugs and shields which cannot be put up in the rod shear are permanently stored at random on the bottom of the basin.

All empty quatrefoil and septifoil extrusions are reduced to scrap size by the foil press and shear in machine area No. 1. A combination press and guillotine-type shear, it presses and cuts off sections of the tubes into 8-1/2-inch lengths suitable for storage in buckets.

Two operations in the disassembly area are not a part of the physical disassembly process. Since the entire process is conducted either under water or remotely, it is not possible to observe the slugs closely as they are removed from their components. Facilities for such study are provided in the monitor basin and the hot laboratory of the dry cave. In the monitor basin, canned fuel slugs are removed from a bucket and placed on an underwater turntable where dimensional and surface characteristics can be examined by an operator at a binocular microscope mounted on a desk at the basin rim. Controls at the desk enable the operator to rotate the slug as he wishes.

In the hot laboratory, dry fuel slugs can be weighed, measured and examined by the use of the master slave manipulator and profilometer, pin gauging station, scales and monocular periscope. Only small percentages of the slugs are examined either in the monitor basin or the hot laboratory.

At the completion of a storage period the buckets containing irradiated fuel slugs and those containing producer or target slugs are hand-pushed to pit No. 1 of the transfer station. Casks used for the shipment of slug buckets come into the transfer station on railroad cars and are lowered into the pit by the 30-ton twin-hook bridge crane. As the cask nears the pit floor, the cask lid comes to rest on projections from the wall of the pit. After the cask has been moved to the rear of the pit, the slug bucket can be lowered into the cask by a monorail hoist. As the cask with its bucket is being raised, the lid is replaced.

Buckets containing scrap are taken to pit No. 2 where the scrap is dumped into a cask with a hinged lid. In this case the lid is lifted and lowered by a hoist mounted on the pit rim. The filled cask is raised and placed on the

floor of the transfer station and from there a Dempster-Dumpster truck can remove the cask to the burial ground where the scrap is dumped and the cask is then returned.

In Building #105-C it was decided to design one transfer pit to handle both jobs of slug and scrap transfer. This included the design of a new scrap cask of larger capacity with a lid that can be automatically removed as in the case of the slug transfer cask of the previous areas. C Area also includes some provisions for handling long fuel elements.

PURIFICATION AREA

The purpose of the purification area is: (1) to maintain the initial quality of the heavy water moderator circulating through the reactor and (2) to provide a circulating blanket gas for purging the reactor gas plenum. Related to these functions is the recovery of moderator from the area equipment and from the helium gas recycled between the reactor and the purification area. The diagram on page 423 shows the process fluid flows within the area.

In circulation through the primary reactor cooling system, the heavy water becomes contaminated from aluminum corrosion products, an increase in light water content, a pick-up of foreign particles, the formation of gases from D₂O dissociation and, in extreme cases, from fission products after a slug rupture. To remove these impurities a small amount of the moderator is continuously pumped from the reactor system to the purification area. The normal flow of 30 g.p.m. is sufficient in a 24-hour period to process a volume equivalent to the entire moderator inventory.

A 2-inch line from one of the process pump discharge lines conveys the moderator to a surge tank in Cell D. From there a 2-inch line from one of the three submerged 30 g.p.m. pumps conveys the moderator to one of the three identical and independent purification cells, A, B, and C. The nominal capacity of each is 30 g.p.m. and all can be operated simultaneously to give a maximum capacity of 90 g.p.m., an operating level required only in the event of excessively heavy contamination.

When pumped from the surge tank the moderator is first filtered through 4000 square inches of asbestos cloth capable of removing all particles larger than 10 microns. The filtered moderator then passes through a mixed bed deionizer with a 26 cubic foot resin capacity. This removes any ionized materials carried by the liquid stream. An afterfilter, similar to the prefilter, further screens the moderator.

Flow from the afterfilter is monitored to check its conductivity level. When this becomes too high the flow is diverted to a fresh resin bed in another cell. To remove the light water accumulating in the moderator a small side-stream is normally diverted from the purification cell flows to the distillation columns. All moderator not so diverted returns to the suction side of a pump in the reactor circulating system.

During the operation of the reactor and the circulation of the moderator there are inevitable heavy water losses due to leaks, evaporation, and adherence to components withdrawn from the reactor. To maintain the required moderator level, make-up is periodically added by unloading 55-gallon drums into the surge tank in Cell D.

CONTAMINATED MODERATOR

All of the points at which heavy water might leak from equipment or pipelines are equipped with either leak detection devices or drip pans. If not locally collected, heavy water leakage is collected in sumps. All such collection is carried by a header to a temporary storage tank in Cell D. Here, as is the case in the surge tank, influent lines are dipped below the level of the liquid in the tank to prevent any air intake or loss of the helium blanket maintained above the liquid level.

To salvage this moderator a flow is directed from the temporary storage tank to an evaporator in Cell D where the liquid is heated to vaporization. The vapor is filtered through 16 inches of fiberglass in the evaporator and piped to a water-cooled condenser. The condensate flows to the evaporator condensate tank where it is held for sampling and the noncondensibles are vented through a refrigerated condenser. This condensate flows to the temporary storage tank. If the heavy water in the receiving tank passes sampling tests, it is pumped to the surge tank in Cell D. If it contains an excess of light water, it is sent to the distillation columns where it can be admitted to any of several plates depending on its composition. The evaporator effluent is constantly checked by a radiation recorder-controller. If the activity in the line rises above a predetermined maximum, the vapor flow to the evaporator condenser is stopped, steam to the evaporator is cut off and cooling water is admitted. A portion of the pressurizing helium in the temporary storage tank is vented to the stack and the vapor in the lines is passed through an air-cooled evaporator return condenser, the condensate draining to the temporary storage tank. The evaporator, which then contains residual radioactivity, is discarded.

DISTILLATION SYSTEM

Two identical units, consisting of a reboiler, distillation column and condenser, are installed. These operate in series under a maximum vacuum of 88 mm. Hg absolute.

The 7 g.p.m. flow diverted from the purification cell effluent enters the first stage reboiler, is heated to vaporization, then passes through the first distillation column. The bottoms product, which is high quality heavy water, is returned to the surge tank in Cell D after passing through a cooler and filter. All overhead from the first column is sent through a water-cooled condenser. The condensate goes to the second stage reboiler, the non-condensibles are compressed to atmospheric pressure, dehumidified and vented.

In the second column, as in the first, the liquid is passed through the reboiler and column with the vapors going to a condenser, the bottoms product to the top of the first column as reflux. The condensed overhead from the second column contains approximately 80 mole per cent heavy water and 20 mole per cent light water and is split into two streams. One enters the top of the second column as reflux and the other is directed to drums to be processed in the 400 Area.

All non-condensibles to be vented are compressed by vacuum pumps and then passed through one of two refrigerated condensers. These operate alternately to freeze and thaw a heavy water condensate out of the vented gases.

BLANKET GAS PURIFICATION

When exposed to intense radiation in the reactor, a small percentage of the moderator dissociates, releasing gaseous deuterium and oxygen. To dilute the deuterium gas below the explosive limit and to carry any gaseous impurities from the moderator, a constantly circulating blanket of helium is passed over the surface of the moderator in the reactor. This gas is recycled through 6-inch lines between the reactor and the purification area where it is processed to recombine the deuterium and oxygen and to dispose of the undesirable gases. Joining this major stream is a purge stream from the surge tank in Cell D. Normally, the quantity of impurities in the gas stream is very slight but a slug failure can release gases that must be removed from the helium blanket.

Each of the two gas purification rooms contains identical equipment consisting of a blower, gas pre-heater,

recombiner, first and second stage coolers, a spray separator, and two vent condensers. One room is a standby.

Gas is moved through the system by the 1100 s.c.f.m. blower to the recombiner where the catalyst (palladium supported on alumina pellets) reforms the deuterium and oxygen into heavy water vapor. If this catalyst bed has not reached operating temperature, the gas is first heated in the preheater. The exothermic recombination reaction further raises the temperature to about 600 degrees F. in the recombiner and the gas is sent through the two water-cooled heat exchangers operating in series. As the temperature of the gas is reduced to 100 to 105 degrees F., some of the heavy water is condensed and drains to the surge tank. The cyclone-type separator then removes any entrained moisture and catalyst dust and the gas is cycled back to the reactor gas plenum.

To keep the activity level and pressure of the gas at the required operating level approximately one per cent of the circulating flow is vented to the building stack and fresh helium is added. Before venting, the gas is passed through refrigerated vent condensers to recover most of the heavy water vapor it contains. The extent of venting, of course, depends entirely upon the activity level. Should abnormal conditions arise, emergency valves can be opened to vent any quantity of the blanket gas.

The addition of helium to the gas system is on a continuous schedule since some gas losses occur through leaks as well as through venting. Pressure instruments control valve openings in lines from Building #110, Gas Storage Building, to maintain the desired system pressure.

The gas stream is also analyzed for oxygen and deuterium content, the balance of these playing a large part in the moderator decomposition rates. Facilities are installed for adding either oxygen or deuterium to give any desired ratio between the two.

GAS DRYING SYSTEM

Before any filter or deionizer from Cells A, B or C and the evaporator from Cell D is removed or disposed of, the heavy water it contains is recovered by a closed circuit gas drying system. When an equipment piece is to be removed, the D₂O lines are disconnected, gas lines are connected, and helium under pressure is admitted to force as much of the D₂O as possible back into the surge tank. Because air is admitted to the system when pipe connections are broken, a portion of the first gas flow is vented to

the stack. When the gas system is essentially pure helium, the vent and purge valves are closed and the drying gas blower is started.

Gas leaving the filter or deionizer first passes through a chiller where all moisture that can be condensed without freezing is removed. The condensate flows by gravity to the surge tank and the gas-vapor mixture goes to a freezer. Two freezers are installed to operate alternately as do the condensers in the blanket gas system and distillation system.

Exposed to a temperature lower than in the water cooler, additional vapors condense and freeze. When a quantity of this frozen condensate has accumulated, the second freezer is placed in service and the condensate in the first is thawed and drained to the surge tank.

Gas from the freezers is piped to the pre-heater where the temperature is raised to a level necessary for drying the filters and deionizers. This varies between 85 degrees F. and 120 degrees F. and is achieved by using one or all sections of the three-section heater. The heated helium is forced by the blower through the equipment to be dried and the cycle is repeated. When the temperature of the gas entering and leaving the unit are equal, the vessel is considered dry. Since the drying gas room is normally accessible when equipment is not operating, the drying gas filter, which collects radioactive particles from the drying gas stream, was located in a shielded area, Cell B.

Provision is made to admit cooling water to the heater referred to above to limit the temperature to a maximum of 120 degrees F. in the event that the compressive action of the blower adds heat sufficient to raise the gas temperature above 120 degrees F. Too high a gas temperature would promote decomposition of the resins and cause the evolution of water-soluble gases which would partially exhaust the next deionizer to be used.

The gas drying system can also be connected to the gas plenum in the reactor to remove any light water prior to start-up.

RESIN PREPARATION

In the resin preparation room all new deionizers are prepared for service by mixing in them a slurry of resins and light water. This is followed by a process known as deuterization in which the light water is displaced by heavy water and the unit can then be installed in one of the purification cells.

Five tanks, - three cut tanks, a feed tank and a constant head tank - are used in resin preparation. First, a two-foot high freeboard is bolted to the top of the deionizer after which the deionizer is partly filled with light water from cut tank No. 1. An agitator is inserted and resin added in the proportion of two parts anionic to one part cationic resin. After partial agitation, the paddle, any excess water, and the freeboard are removed and the cover placed on the deionizer. By this charging method any entrapped air is disengaged and a uniform distribution of the resins is obtained. The unit's structural soundness is subsequently checked by hydrostatic tests.

Upon completion of the tests, and before the unit can be placed on the process line, deuterization is necessary to prevent isotopic dilution of the moderator in the circulating system. Heavy water from cut tank No. 3 is introduced to the deionizer by way of the feed and constant head tanks. The specific gravity of the effluent stream from the deionizer is checked and as soon as heavy water appears, the stream is diverted from its flow to cut tank No. 1 to cut tank No. 2. Finally, as nearly pure heavy water appears in the stream, the flow is directed to cut tank No. 3.

The deuterization procedure results in a transfer of liquids from one tank to another and in partial dilution of the heavy water, making it necessary to add make-up. Drums containing heavy water are pressurized with helium and the contents fed into the feed tank just before this tank's original content, transferred from tank No. 3, has been exhausted. This minimizes mixing of the tank No. 3 contents and the fresh heavy water. When a previously determined quantity of water has been returned to tank No. 3 from the deionizer, deuterization is considered complete and the unit is ready for installation in one of the cells.

The disposition of the contents of the several tanks varies. Liquid in tank No. 1 can be used either for further resin preparation or drummed for processing in the #400 Area. The water in tank No. 2 is sent to the #400 Area. The contents of tank No. 3 can be sent to the #400 Area or drained to the feed tank. The decision made in each case is based on sample analyses.

PROCESS DIFFERENCES IN THE L, K AND C AREAS

Certain unit operations within the same general process are modified to effect savings in construction cost, greater simplicity in operation and higher quality of product.

The following are the more significant differences.

1. Elimination of the surge tank and pumps by utilizing the head pressure of the main process to effect flow through purification area equipment.
2. Location of the small 12-inch diameter filters in the deionizer jumpers and the elimination of the prefilter by using the resin bed itself as a sand filter.
3. Elimination of the temporary storage tank and pump by directing hot and cold drains respectively to a hot sump and cold return tank located in separate S.W.P. (Special Work Permit) Areas.
4. Elimination of Cell D by moving the sump to a S.W.P. Area and the evaporator to another cell.
5. Because it involved special electrical jumpers, leak detection on the cell vessels was eliminated.
6. Its justification being uncertain, the drying gas filter was eliminated.
7. Following tests in which it was found that certain reaction products of a slug break passed the de-ionizers, alterations were made in the distillation equipment to permit a low-boiler purge designed to separate the products from the circulating system.
8. Desiccant beds were substituted for the freezing condensers to simplify operations and reduce congestion. The product is recovered from the beds by a closed regeneration cycle with moderator condensed from the recycle stream.

VII - FUNCTIONAL TESTING - BUILDING #105

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VII - FUNCTIONAL TESTING - BUILDING #105

In September, 1952, AED and Design realized the wisdom of recording formally the design intent of all equipment in the reactor buildings for the benefit of Construction and AED field personnel.

The Construction Division had already prepared a procedure for the completion, check-out, run-in, start-up and acceptance of equipment, facilities, buildings and areas. It was expected however, that the Functional Test material would supply additional data necessary to guide Construction personnel in making certain that the equipment would perform its intended function and would also become the basis of performance testing on which AED would accept the equipment or facility.

For uniformity in testing, the procedure prepared jointly by the AED Process Group and the Design Division was prepared under the following headings for each piece of equipment or facility:

1. Design Intent
2. Test Requirement
3. Timing of Test
4. Special Test Conditions
5. Special Precautions
6. General Remarks
7. Key Information
8. Special Equipment Required for Test

Reproduced below is a sample extracted from the functional test procedure, dealing in this case with the reactor primary cooling system.

- A. The reactor tank and shield structure is designed to accept, irradiate, and discharge fuel components and special materials. In so doing, the reactor must meet two primary mechanical requirements:

1. It must be mechanically and thermally stable to permit unobstructed charging and discharging of components, smooth operation of control rods, and leak-free containment of moderator.
 2. It must be maintained within a moderate range of temperature by removal of heat from the fuel components, control rods, and surrounding moderator by circulating the moderator through these parts and external heat exchangers in a closed and leak-free system.
- B. The pumps used for this purpose must be so driven that the reactor is in a safe condition at all times; when the primary source of power is lost, and the reaction is immediately shut down, flow of moderator must continue at a sufficient rate to prevent excessive temperature rise from decay heat. This continuation of flow must be accomplished without interruption and without having to actuate any mechanical or electrical devices, being done by use of flywheels and a continuously operating diesel - d.c. backup system.
- C. The required circulating flow rates are approximately as follows:
1. Normal operating flow - 76,200 g.p.m.
Upflow cooling (Incl.) 5,200 g.p.m.
 2. "On-line" flow - 30 sec.
after loss of primary power 24,000 g.p.m.
 3. "On-line" flow-minimum
over long duration - 11,000 g.p.m. (two d.c. motors operating).
 4. Charging and discharging flow rate - 4,000 g.p.m.
- D. The temperature of moderator leaving the reactor has been limited to 75°C. as the basis for reactor design.

TEST REQUIREMENTS

SCOPE OF TESTS

1. Two types of functional tests are required on the reactor, viz.,

- a. Dimensions and fit-up as erected.
- b. Hydraulic operation.

Since the first category has been covered in the Erection Procedure (August 12, letter Bunker-Brewer to Mason-Scherffius and Browne) it will be excluded from this discussion.

2. Hydraulic operation of the reactor of necessity involves all parts of the reactor primary cooling circuit, therefore, for purposes of functional testing, the entire circuit will be considered as a single system. All phases of the functional testing of this system will occur during the "Run with Dummies".
3. The reactor load during this functional testing will be as tabulated in the section on "Reference Material". A list of other items of equipment involved is also given under "Reference Material".
4. Prior to the "Run with Dummies" all parts of the circuit shall have been thoroughly flushed and all sediment removed from low points in the system. Screens (E.P. 165.6 and 165.7) shall be installed in the suction and discharge lines and the system shall be full of deionized water obtained from Building #180 through Line No. DM-1 (W-131334). At the start of the run all valves in the system shall be closed.
5. During the run accessory circuits such as the liquid scram system, water purification system and gas regeneration system shall be cut in and operated in conjunction with the reactor circuit. Functional testing requirements of these accessory systems are being described elsewhere. The upflow cooling system is considered a part of the reactor circuit.
6. Except where specified otherwise the tests shall be made with the water at ambient temperature.

PUMP START-UP WITH D.C. MOTORS

1. Open upflow cooling valve SV-130.
2. Take one pump up to 600 r.p.m. on d.c. motor with discharge valve SV-111 closed.

- a. Check approximate time to come to speed and measure terminal speed.
3. Open discharge valve SV-111 to full open position.
 - a. Check piping and pump for unusual noise and vibration.
 - b. Run for 30 minutes, then check motor and bearing temperatures.
4. Shut down pump and close discharge valve.
5. Repeat items 1, 2, 3 and 4 for other five pumps, in succession.
6. Start up one pump with discharge valve open.
 - a. Check time to come up to speed.
7. Shut down pump and then close discharge valve.

PUMP START-UP WITH A.C. MOTORS

1. Take one pump up to 1800 r.p.m. on a.c. motor with discharge valve open.
 - a. Determine approximate time to come up to speed and measure terminal speed.
 - b. Check pump for unusual vibration, shaft oscillation and cavitation noise.
 - c. Check pipelines for water hammer and noises or excessive pressure drop at screens. (E.P. 165.6 and 165.7)
 - d. Run pump for 30 minutes, then check motor and pump bearing temperatures. If any bearing temperature rises beyond 200°F. shut pump down and determine cause of overheating.
 - e. If any seal leaks at more than one quart in 30 minutes, replace before proceeding with tests.
2. Shut down pump and close discharge valve.
3. Repeat items A and B for other five pumps in succession.

FULL FLOW

1. Start up one pump with both a.c. and d.c. motors simultaneously and with discharge valve open.
 - a. Determine time to reach terminal speed and measure this speed.
2. Start up a second pump with both a.c. and d.c. motors and with discharge valve closed.
3. Open discharge valve when pump reaches full speed.
4. Repeat 2 and 3 for each of the other flow pumps in turn.

NOTE: Tests at NYX may develop a smoother start-up by bringing all pumps up to 600 r.p.m. and then energizing each a.c. motor in turn. If this can be done without stalling any of the d.c. motors, this test outline shall be modified. However, it is not anticipated that this change will make an appreciable difference in the overall test schedule.

- a. Using permanent pitot flow measuring instruments, determine flow in each of six systems. If any flow is more than ± 500 g.p.m. from the average of all six, check this flow against the pump delivery flow from pump curve. This check should indicate whether flow measuring device is functioning properly.
5. Any flow unbalance greater than ± 500 g.p.m. must be corrected by removing abnormal resistance (material on screens, improperly set valves, etc.) or, if all lines are clear, by adjusting the flow with the trimming orifice E.P. 221.1.
6. Examine all flanges, valves, and pipelines for any sign of leakage.
7. Examine "O"-rings on bottom pins (E.P. 169) and semi-permanent sleeves for leakage.
8. Up-flow cooling.
 - a. Open valves SV-127 on drain and pressure taps.
 - b. Check the pressure of up-flow cooling circuit with pressure measuring instrument connected to each of the return bends on Line No. 25. Any pressure reading which does not fall within the range 90-120 p.s.i.g. shall be reported to the Design representative.

9. Expansion joints and pipe supports.

- a. With the system operating at full flow, shut off the flow of cooling water to the heat exchangers (E.P. 201) and let temperature in the main recirculation system rise to 75°C. Maintain the water temperature at this point by the addition of cooling water to the heat exchangers. Check the pipe supports, guides and expansion joints for freedom from undue strains, binding, or other malfunctioning.
- b. Check the entire system for leaks. If this method of heating is too time consuming, hot water may be added to the heat exchangers on the shell side.
- c. Return the system to ambient temperature. Following tests may be started after temperature is below 60°C.

PUMP SHUT-DOWN TEST

1. Shut off all six a.c. motors simultaneously.
 - a. Measure the time required for speed to level off at approximately 600 r.p.m. (d.c. motor speed)
 - b. Measure flow at 30 seconds after primary power is shut off. It must be 24,000 g.p.m. or greater for total flow.

CHARGING AND DISCHARGING FLOW

1. Shut off four d.c. motors leaving two alternate pumps (1 and 4, 2 and 5, or 3 and 6) running.
2. Close valves SV-111, SV-110, and SV-130 on the systems which were shut down in paragraph A.
3. Measure flow at this point, minimum flow is 11,000 g.p.m.
4. Throttle valves SV-111 on the lines connected to the two operating pumps until the total flow is 4000 g.p.m.

NOTE: There are a number of combinations of pumps and valve settings which will give this flow without overflowing the reactor when some elements have been removed. If NYX test information develops a different combination for obtaining this flow it will be incorporated at a later issue of this test procedure.

a. Check this flow with pitot tube flow measuring instruments.

5. Shut down all pumps and close valves.

NON-REVERSING CLUTCH ASSEMBLY TEST

1. Bring all pumps up to full flow as outlined under "Full Flow" above.

2. Leaving valves open, shut off power to both a.c. and d.c. motors.

a. Let pump come to rest and observe the action of the non-reversing clutch. No reverse action should take place. Observe for five minutes.

b. If any reverse action occurs, close SV-111 immediately.

3. Close valve SV-111 on discharge of this pump.

4. Bring this same pump back to full flow with both a.c. and d.c. motors.

5. Open valve SV-111 immediately upon attainment of full pump speed.

6. Repeat 1 through 5 for the other five pumps in turn.

7. Shut all pumps down and close valves.

TIMING OF TEST

Listed below are various systems and pieces of equipment which are closely related with the hydraulic test of the reactor primary cooling system. Relative timing with respect to the subject system is indicated.

Pump lubricating oil system	- prior
Gas purification system	- concurrent

Moderator purification system	- concurrent
Drain and overflow tank systems	- concurrent and following
Valve operation - E.P. 222	- prior
Flow restrictor - E.P. 221	- concurrent
Liquid scram	- concurrent
Leak detection including "O" rings	- concurrent
Drying by helium-pressure drop tests	- following
Shield cooling system	- concurrent or following
CO ₂ system	- concurrent or following
Leak collection	- following
Hot water generating	- concurrent

SPECIAL TEST CONDITIONS

- A. Deionized water.
- B. Dummy reactor loading. See following tabulation under "Reference Material".

SPECIAL SAFETY AND/OR SECURITY PRECAUTIONS

Personnel should stand clear of piping, plenum chamber, heat exchangers and pump as these are being brought up to pressure for the first time. Similarly they should stay clear of flywheels, etc. as these are initially brought up to speed. Keep safety guards in place except where removal is actually necessary for performance of tests.

All work will be within the security area, hence only authorized personnel will be admitted.

GENERAL REMARKS

Due to the complexity of this system, remarks on the scope of these tests are included in the preceding "Scope of Tests" for clarity and continuity. No additional remarks are deemed necessary for thorough understanding of this functional test.

Developments" a description of the "on-line" power and water supply is included. Since the safety of the reactor was involved, detailed tests were executed and reports prepared.

The R and P Areas are essentially identical in cooling water design so detailed tests were run in the P Area to minimize the problems of start-up in the first area.

The report covers the results, basic criteria and description of the system, general test program, results of individual tests, and test data. The report states:

1. That the installed equipment and facilities, energized by either normal or emergency power, performed in accordance with the design intent.
2. That the Building #190 pumps supplied design flows and pressures.
3. That the limits of the reservoir under gravity flow were from a depth of 17.25 feet down to a depth of 4 feet.
4. That pressure surges encountered were not of sufficient intensity to damage the system.
5. That all tests were conducted in the cold condition, i.e., no heat was available for removal from the heat exchangers.
6. That the characteristics of the system under various gravity flow conditions were graphically plotted.

Similar tests were conducted in the L Area as representative of the L and K Area design but on a smaller scope, the material common to the P Area report being omitted. The C Area cooling system differs in some respects from L and K so the tests were repeated and a supplementary report prepared.

VIII - SIXTH REACTOR STUDY

VIII - SIXTH REACTOR STUDY

In April 1952, the AEC requested du Pont to proceed with engineering studies for a sixth reactor plant with supporting facilities. It authorized an expenditure of \$50,000 and the Engineering Department conducted the study under Work Order 25,680.

The study was treated on a basis completely independent of the design concept of the R, P, L, K and C reactors and fuel elements used in these reactors. Ideas on reactor design and fuel element shapes were solicited from a large number of technical people. In analyzing new and improved methods, the principal objective was an increased surface to volume ratio of the fuel elements without a significant increase in the amount of parasitic materials in the reactor, such as aluminum jackets and foils.

Many ideas were submitted and evaluated. A complete report, prepared in February 1953, described 55 ideas covering reactor concepts, material handling possibilities, and fuel element shape proposals. Represented among proposed reactor designs were types using horizontal and vertical lattices, designs for batch and continuous operation, units using clumped and unclumped fluidized beds and water slurry reactors. Material handling suggestions were largely confined to handling fuel elements into and out of the reactor and in many cases consisted of hooking short elements together in a chain-like manner for semi-continuous movement through the reactor. This would achieve a uniform exposure of all elements, a process advantage not obtained with the SRP or Hanford reactors.

Concepts of the fuel elements presented a great variety of shapes including long vertical strips, serpentine strips, wafers, cylindrical tubes, coiled wires, pellets, balls, helical finned slugs and split discs.

The report also discussed the use of heat exchangers as thermal shields, liquid gas coolants, and the "canning" of coolant channels instead of fuel channels. Rough sketches of nearly all the concepts were included.

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IX - #100 AREA SUPPORTING FACILITIES

PROCESS BUILDINGS

BUILDING #106-R - PROCESS WATER STORAGE TANK

FUNCTION

The storage tank receives and conserves moderator in the event of a major break in the process water system in Building #105-R.

PRINCIPAL COMPONENTS

Sump pumps located in Building #105-R, at Elevation -46'-6", discharge to the tank through a 16-inch line. A 20-inch branch leaves the top of this line near the tank and leads, as a tank by-pass, to the process sewer. However, water cannot enter the by-pass until 60,000 gallons have entered the tank and the tank level has reached the elevation of the by-pass. It is computed that most of the process water will be included in the water entering the tank and the water by-passed will be essentially all light water.

No equipment has been provided with the tank. It is planned that the tank will be emptied, if necessary, by pumping the contents into 55-gallon drums which will be transported to Building #105 purification area or to the #400 Area. No outlets are provided in the tank except a 4-inch vent and a plugged opening in the tank top through which a pump suction line can be lowered. The sloped bottom of the tank leads to a sump immediately under the plugged opening. During the emptying operation, 100 drums of process water may be stored on the top of the tank.

The tank top does not offer sufficient shielding against the effects of radiation. Therefore, if contaminated water is received in the tank, it will be necessary to erect barriers to prevent the access of personnel to the immediate area.

Such barricading would also be necessary when uncontaminated water at sufficiently high temperatures is received and personnel hazards from vented tritium-bearing vapors make the area untenable.

BUILDING DETAILS

The tank structure is Class I, measuring approximately 44 ft. x 25 ft. -6 in. x 18 ft. -6 in. over-all. The entire tank is underground with its top occurring at Elevation 0'-0".

The walls and top of the tank are 2 ft. thick reinforced concrete and the bottom is 3 ft. thick reinforced concrete.

The total area of the tank is 1120 square feet and the total volume, 20,760 cubic feet.

CONSTRUCTION DETAILS

There is no foundation for the tank other than the heavy reinforced concrete bottom and no superstructure except the underground tank walls and the grade-elevation top.

Waterproofing was applied to the tank in the form of a single-ply membrane with insulation type protective covering on all sides. The bottom of the tank was poured on a three-ply membrane laid on a 3-inch construction slab.

No lighting or instrumentation was provided.

DEVELOPMENT OF DESIGN

The requirement for a process water storage tank in each #100 Area was based upon the necessity of providing some means of salvaging and storing the process water charge of approximately 40,000 gallons from each Building #105. This was based on the remote, yet possible, chance that a major break might occur in the system. If this should take place, the loss of the scarce and costly process water could not be tolerated.

Specifications for the size and construction of the tank were developed from the consideration of several important factors. It was computed that the storage volume would permit the transfer of the 40,000-gallon charge plus a certain dilution volume of light water. A sudden large loss of process water from Building #105 would necessitate the immediate addition of light water to prevent a possibly disastrous over-heating of the reactor. This dilution would increase the amount of liquid to be diverted to the storage tank. It was determined that when 60,000 gallons had been pumped to the storage tank, all the process water would have been recovered together with some light water. After this

capacity had been reached, the discharge from the sump pump in Building #105 could be diverted to the process sewer.

It was decided also that the storage tank facilities would provide recovery only for a major break and that the recovery of minor spills or losses would be effected by equipment installed in each #105 Building.

DRAWING

W-131381 - Plans and Sections, Arrangement and Concrete.

BUILDING #106-P, L, K AND C

These buildings are identical to the Process Water Storage Tank constructed in the #100-R Area.

BUILDING #109-R - PURGE WATER STORAGE BASIN

FUNCTION

This basin serves to hold up deionized water discharged from the Building #105 reactor shield cooling system until radioactivity has dissipated and the water can be discharged safely to the sewer.

PRINCIPAL COMPONENTS

The basin is approximately 11 ft. by 17 ft. by 6 ft. deep, inside dimensions. A sump pit, from which the 6-in. outlet to the process sewer originates, is 18 in. by 24 in. and is separated from the basin by a 10-in. thick weir extending to within 22 in. of the top of the basin walls. The water from Building #105 enters through the wall opposite the weir, flows around three staggered concrete baffles, makes eight 90-degree turns and travels about 75 feet between inlet and outlet pipes. The removable basin cover is supported by two transverse concrete beams and the exterior walls. A handrail is provided on top of the walls with a removable handrail around the crib.

BUILDING DETAILS

This is a rectangular basin with outside dimensions of approximately 13 ft. by 19 ft. by 7 ft. deep over-all.

Concrete thicknesses are 10 in. for exterior walls and 12 in. for the floor. The total area is 255 sq. ft., the volume, 1740 cu. ft.

CONSTRUCTION DETAILS

The walls and floor of the basin are of reinforced concrete as are the baffles built into the basin. The roof is composed of precast roof tile, 2-3/4-inch thick, resting on concrete beams. There is no lighting.

No equipment is installed.

DEVELOPMENT OF DESIGN

Following the decision to bleed off a definite quantity of water continuously from the recirculating cooling system of the reactor thermal shield and the system serving both the top and bottom reactor shields, it became necessary to plan a temporary storage facility for this water. Direct discharge to the sewer was prohibited because of the level of radioactivity in the water. For this reason the concrete structure was designed to incorporate baffles delaying the flow of water through the basin long enough to effect the decay of harmful radiation.

Total flow from the two cooling systems is set at 6 g.p.m. Half of this quantity comes from the thermal shield and half from the top and bottom shields. The basin is so sized that all water entering is retained for approximately 12 hours during which the half-life of the radioactive material has vanished.

The top, constructed of three removable precast concrete tiles, makes it possible to clean the basin at any time the reactor is shut down and the flow of water has stopped. A lapse of about 12 to 15 hours will be required from the time flow to the basin is stopped until it is safe to commence cleaning operations.

DRAWING

W-133180 - Plan and Sections, Arrangement and Concrete.

BUILDINGS #109-P, L, K AND C

These buildings are identical to the Purge Water Storage Basin constructed in the #100-R Area.

BUILDING #110-R - GAS STORAGE —

FUNCTION

Fresh helium blanket gas is unloaded from special U.S. Government railroad cars and stored in this area for eventual use in Building #105-R.

PRINCIPAL COMPONENTS

Gas Unloading

A wooden unloading platform and compressor house are provided for transfer of helium from 2200 p.s.i. cylinders mounted on a railroad car to gas storage tanks.

Gas Storage

Thirty gas storage tanks mounted on concrete piers out-of-doors are provided to store 300,000 s.c.f. of helium at 700 p.s.i. pressure.

BUILDING DETAILS

The compressor house is a Class III, single story, rectangular structure, 12 ft. x 20 ft. x 12 ft. -10 in. high, with double-pitched roof. It has an area of 240 sq. ft. and a volume of 3270 cu. ft.

CONSTRUCTION DETAILS

Reinforced concrete foundations support a structural steel frame. Exterior walls are corrugated cement asbestos board with a poured concrete curb to a height of 6 in. above floor level. Interior walls are exposed outersheathing. There are no partitions. The doors are 1-3/4 in. thick, Standard B2B, type WB-3. There are no windows. The roofing is corrugated cement asbestos board, Standard B4Y. The floor is exposed concrete.

One unit heater operates on 20 p.s.i.g. steam. Lighting is fluorescent.

EQUIPMENT

Gas unloading compressor, 3-stage reciprocating, 118 s.c.f.m. at 750 p.s.i. discharge.

Gas storage tanks, (30), 2' dia. x 80' long at 700 p.s.i. max. pressure.

Oil filter, 55 gallons.

Oil separator, 8-1/2 gallons.

Instrumentation

Various pressure gages, pressure reducing stations, temperature indicators, and pressure safety relief valves are provided.

DEVELOPMENT OF DESIGN

In early design stages this facility did not exist as a building. Instead, it was anticipated that the gas would be supplied from rented trailer tanks. These would be parked near the building and would feed the gas to a manifold located in Building #105-R.

Further investigation proved that it would be cheaper to obtain the gas directly from the government. To do this, it was necessary to purchase the gas in railroad tank cars and the preliminary design utilizing trailer tanks was abandoned.

The design of the Hanford storage tank farm and compressor was chosen as a basis for design work on the new Savannah River Plant facility as Hanford had purchased gas which was delivered in railroad cars. The resulting Savannah design incorporated a Class I compressor house with Class III storage tanks. The blast-resistant compressor house was to have been built of reinforced concrete with walls and roof about one-foot thick. The unloading and storage system was planned to be essentially the same as the system now in use.

Still further along in the course of design studies, it was felt that a Class I compressor house could be eliminated for two reasons:

1. The tanks themselves, while they were not Class I, were low profile, cylindrical receptacles and could be expected to withstand much of the force of a blast without being put completely out of service; and
2. Since this was true, it was felt that gas flow to Building #105-R could be maintained by merely

relying on pressure from at least one cylinder. Toward this end, at least one of the tanks is kept with its pressure constantly at maximum.

By utilizing this present design the compressor building could be changed to a more economical Class III type of construction.

DRAWINGS

W-143035 - Plans, Sections and Details - Steel.

W-143028 - Plans, Sections and Details - Concrete.

W-143038 - Plans, Sections and Details - Arrangement and Architectural.

BUILDING #110-P - GAS STORAGE

This building is similar to Building #110-R except that storage is limited to 60,000 s.c.f. and no facilities are provided for reloading helium to railroad tank cars.

The same design considerations did not apply to both the R and P Areas. Once a reserve capacity had been built into the first area from which subsequent areas could be temporarily served and which could meet abnormal demands during initial equipment operation, it was necessary only to satisfy the demands of normal operation. If required, helium can be reloaded into tank cars in the R Area for delivery to the P Area.

BUILDING #110-L, K AND C - GAS STORAGE

These buildings duplicate the facilities in the P Area.

BUILDING #122-R - PROCESS STORAGE BUILDING

FUNCTION

This building serves as the storage vault for the heavy water required to supplement and replenish the original charges in the five reactors. Storage is made in approximately 1300 drums each holding 55 gallons. Four

drums are placed on a pallet and the pallets are stacked three high. Space is also provided for the storage of spare pallets.

The drums are handled on their pallets by a standard fork lift truck borrowed from the purification area of Building #105. Single drums can be handled by barrel trucks which are provided in the building.

BUILDING DETAILS

The Class I structure is 45 ft. x 105 ft. -9 in. x 14 ft. -10 in. high. It has an area of 4758 sq. ft. and a volume of 76,128 cu. ft.

CONSTRUCTION DETAILS

The foundations are concrete on spread footings, the walls are reinforced concrete, the roof is a flat concrete slab. There are two motor-driven rolling steel doors at openings 9 ft. x 12 ft. The floor is concrete sloped to a sump. There are no partitions and the ceiling is the exposed roof slab.

The four unit heaters are supplied with steam from the area power plant, lighting is incandescent, and air is exhausted from the building by a propeller fan in the roof.

EQUIPMENT

Wood pallets, (425), each sized to accommodate four 55-gallon drums.

Barrel trucks, (2), auto-load type.

Pit scale, 1000-lb. capacity.

Standard unit heaters, (4).

Fan - propeller exhaust fan mounted on roof in a concrete box louver.

Fire extinguishers, (3), twenty-pound Ansul dry powder type.

DEVELOPMENT OF DESIGN

Originally it was planned to make Building #122-R a part of the #400 Area. Had this been done its designation would have been Building #422-D. It was decided, however, that the building should be erected in the #100-R Area, given its present designation, and changed to Class I construction.

To meet AED requirements, the floor was designed to carry a load of 600 pounds per square foot. It was found that the Building #105-R excavation extended into the site of this building and that it would have been necessary to carry footings well below normal depth to reach undisturbed soil. As a result, a controlled compacted backfill was used over the entire building area with both the footings and the floor slab resting on this backfill. Actual floor strength is approximately 6000 pounds per square foot.

The building is not continually occupied and no provision for cooling the stored product had to be made.

DRAWINGS

W-155700 - Architectural - Plans and Elevations.

W-155702 - Concrete.

W-155705 - Heating and Ventilating.

PERSONNEL AND SERVICE FACILITIES

BUILDING #701-1R - AREA GATE HOUSE AND PATROL HEADQUARTERS

FUNCTION

This building houses the central headquarters for the area patrolmen together with both the normal and emergency control equipment including fire alarm recording, blackout and public address systems, and radio and telephone communications facilities. Facilities are also provided for processing and issuing personnel health meters. This is primarily the control point for personnel and vehicular traffic into and out of the area. During shift changes, Building #701-3 becomes the control point.

One section of the building is of Class I construction to provide protection against gamma rays and to furnish emergency shelter and assure the continued operation of vital communication facilities during disaster periods.

PRINCIPAL COMPONENTS

The location of this gate house provides security control over a two-lane vehicular entrance to the area. As a part of the structure there are two pedestrian entrance lanes, designed to handle 175 men per shift, with a badge issuing counter between them.

The area for testing health meters is composed of a Health Physics laboratory, a small office, a work bench and power supply for instrumentation. These, and the patrol facilities consisting of patrol offices, a mustering area, locker and toilet rooms for approximately 60 men, and storage space for uniforms, are in the Class III section of the building.

The emergency control and communications equipment are located in the Class I portion of the building. Here is situated a satellite telephone exchange which automatically handles calls both within the area and over the plant. The basic equipment for radio communications, blackout, public address system and controls also are housed in the Class I structure. A dual set of controls for normal use, together with the fire alarm recorder, are located in the Class III section.

BUILDING FLOOR SPACE

<u>Class I</u>	<u>Approx. Sq. Ft.</u>
Telephone exchange	350
Emergency control center	180
Utilities room	160
 <u>Class III</u>	
Badge alley	190
Two offices	450
Health meter laboratory	95
Two toilets	200
Utilities room	170
Lunch room and assembly area	295

Locker room	635
Clothes storage room	155
Unallocated space	360

BUILDING DETAILS

This is a single story building composed of a Class I wing, approximately 23 ft. wide by 51 ft. long by 11 ft. from the floor to the top of the flat roof slab. An adjoining Class I unit, approximately 8 ft. by 8 ft. by 8 ft. high, houses a generator. The Class III portion is approximately 48 ft. wide by 64 ft. long by 11 ft. high from floor to top of the roof slab. The total area is 4162 square feet and the total volume is 54,810 cubic feet.

CONSTRUCTION DETAILS

The building has reinforced concrete foundations with spread footings and concrete floor. The Class I section has reinforced concrete walls and roof, and interior partitions of concrete baffle construction. The ceiling is formed by the exposed underside of the roof structure. Doors in this area are of hollow metal and there are no exterior windows. Roofing is built-up.

The Class III section has a structural steel frame with web roof joists supporting a concrete roof slab on riblath. Exterior walls of this portion of the building are of corrugated asbestos board. Interior partitions, and the interior of exterior walls are of flat cement asbestos board on steel studs. Toilet room walls are concrete to a height of 4 ft. with flat cement asbestos board on walls and ceiling above this level. Doors are hollow metal and double-hung window sash is steel. Roofing is built-up.

Exterior walls and roof in the telephone section are sheathed with asbestos board over wall insulation. This same treatment is carried to a height of 6 ft. in other parts of the Class I section and on interior walls of the health meter laboratory. The concrete floor is covered with asphalt tile in all offices and corridors, in the health meter laboratory of the Class III section, and in the telephone exchange of the Class I section.

Heating in the Class I wing is supplied by forced air through ducts in conjunction with an air conditioning system. The same means of heating is provided in the health instruments laboratory. Unit heaters are installed in the

badge alley. All other areas in the Class III section are heated by forced air through ducts. The steam source for these heating services is the area power house. The Class I section and the health meter laboratory are air conditioned by self contained units. Fans on the roof maintain an air exhaust through ducts from the Class I area, the locker room, toilets and the Class III area corridor. Fluorescent lighting is installed in the offices, badge alley, health meter laboratory and the emergency control center. All remaining areas have incandescent lighting.

EQUIPMENT

Radio receiving and sending equipment, 30-watt capacity.

Fire alarm recorder, blackout and public address system controls.

Telephone exchange, 100-line capacity.

Diesel-driven electric power generator, 3.5 kw., 120 v.

Two self-contained air conditioning units.

Air supply and exhaust fans, air heating units, duct work.

Conventional office furniture.

Guns and cabinets.

61 Lockers with benches.

Lunch facilities.

Badge counter.

Minor equipment for processing health meters.

DEVELOPMENT OF DESIGN

A separate facility, designated Building #702, to house the area telephone exchange equipment and an emergency control center, was included in the preliminary scope of design for the Savannah River Plant. On August 31, 1951, it was decided to delete this building and to incorporate its facilities in a wing to be added to the Gate House and Patrol Headquarters. The combination was effected as a result of a study of the separate facilities provided for these operations at Hanford. It was decided that the emergency

control centers should be more readily accessible to the radio control operators, who normally are located in the patrol and security buildings, in the event disaster control operations should become necessary.

Design criteria required that the housing of the telephone exchange and emergency control center be of Class I construction since these facilities must be habitable during disaster control. Class III construction, however, was suitable for the normal security and patrol functions. The obvious solution was the specification of a Class I wing for the communications operations attached to a Class III structure for the operational security facilities. In addition to meeting these two basic requirements, Class I construction provided a bomb shelter and protection against gamma ray contamination for building personnel.

Some time after acceptance and occupancy of these buildings by the Operating Department, it was found advisable to make certain revisions and alterations in the locations of some of the building functions to provide facilities for storing the uniforms used by the patrol groups. This uniform control consists of checking, storing and issuing the uniforms before and after laundering and dry cleaning. Storage space was also provided for an adequate supply of boots and raincoats.

The readjustment of building floor space involved only a few structural changes. The long narrow badge alley was divided by a partition. Two windows in the outside wall were removed and the openings closed. A double doorway was installed in the smaller room to provide an exit to Building #701-3. The original Health Physics laboratory office was converted into a Health Physics laboratory. Two laboratory tables were installed and electric and air conditioning services were supplied. The former Health Physics laboratory was made into an office for area and patrol supervision. A door was installed from this area to the central corridor and electric and telephone facilities were supplied. The office adjacent to the assembly area was converted into a clothes storage room by the addition of clothes racks, storage cabinets and a clothes hamper.

DRAWINGS

W-156134 - Plans and Sections.

W-156136 - Elevations.

BUILDING #701-1P, L, K AND C

These buildings are identical to that constructed in the R Area. Structural changes incorporated in the R Area were also made in these areas.

BUILDING #701-2R & P - GATE HOUSE

FUNCTION

This building serves as a security check point for personnel and vehicular traffic at the entrance to the security zone of Building #105. It also provides weather protection for the guards assigned to this duty.

PRINCIPAL COMPONENTS

Located between two vehicular and personnel traffic lanes, the facility consists of a one room building with an interior personnel lane served by a badge counter and an exterior lane defined by a handrail served by a pass-through window.

BUILDING DETAILS

A single story, Class III structure, the over-all dimensions are approximately 10 ft. by 15 ft. by 9 ft. high. The roof extends to form a 2 ft. overhang on the long sides. Total area of the building is 150 square feet and the volume, 1375 cubic feet.

CONSTRUCTION DETAILS

The foundations are of reinforced concrete with the superstructure of wood frame treated for fire resistance. The wood roof joists also are treated for fire resistance, and the exterior walls are covered with corrugated cement asbestos board. The interior walls and the ceiling are sheathed with flat cement asbestos board.

Doors are wood and the windows are wood, double hung. Roofing is built-up and insulation is installed in the exterior walls and above the ceiling. The floor is concrete. Heating is provided by an electric heater and lighting by incandescent fixtures.

DEVELOPMENT OF DESIGN

Originally a smaller building, the gate house was designed to allow personnel to pass outside of rather than through the building. To achieve more effective control of traffic and to reduce the number of patrolmen required, the structure was redesigned to provide an interior counter and badge rack.

EQUIPMENT

- 1 - Electric heater, 7.5 kw.
- 1 - Transformer, 9 kv.-a.
- 1 - Electric water cooler.
- Conventional office furniture.

DRAWINGS

- W-157216 - Plans and Elevations, Sections and Details, R Area.
- W-157897 - Plans and Elevations, Sections and Details, P Area.

BUILDING #701-2L, K, AND C - GATE HOUSE

FUNCTION

This facility provides a security check point for personnel and vehicular traffic entering the security zone of Building #105. In addition, it furnishes weather protection for the guards on duty at this entrance.

PRINCIPAL COMPONENTS

Located just inside the security fence on the access road to Building #105, the facility consists of a one-room building divided by a badge counter running the length of the structure.

BUILDING DETAILS

A single story, Class III structure the over-all dimensions are approximately 13 ft. by 17 ft. by 9 ft. high.

The floor space is approximately 220 square feet and the volume, 1900 cubic feet.

CONSTRUCTION DETAILS

Building foundations are of reinforced concrete with wall footings. The frame is wood and the exterior walls are sheathed with corrugated asbestos siding. Interior walls and ceiling are covered with flat cement asbestos board. The flat, built-up roof extends 2 feet on all sides to form a protective overhang. The floor is a 4-inch concrete slab. Electric unit heaters are furnished and lighting is incandescent. Windows are double hung wood sash and the wood doors at each end of the badge alley have top panels of glass.

DEVELOPMENT OF DESIGN

This building was originally designed as a smaller gate house with two outside personnel control passages defined by hand rails and served by pass-through windows. Later the structure was redesigned, and the larger gate house with the interior badge alley was substituted to facilitate the positive identification of all personnel using the area. This system of individual checking provides a more direct and effective control over all persons entering these exclusion areas.

EQUIPMENT

- 1 - Transformer, 9 kv.-a.
- 1 - Electric heater, 7.5 kw.
- 1 - Lighting panel.
- 1 - Badge counter.
- Office furniture.

DRAWINGS

- W-160642 - Plans, Sections, Elevations and Details, L Area.
- W-160643 - Plans, Sections, Elevations and Details, K Area.

W-160644 - Plans, Sections, Elevations and Details,
C Area.

BUILDING #701-3R, P, L, K AND C - GATE HOUSE

FUNCTION

This auxiliary gate house provides a control point for security checking of personnel and vehicular traffic during shift changes at the entrance to the area. At times other than shift changes, security control is maintained at the #701-1 Gate House.

PRINCIPAL COMPONENTS

The installation consists of a sentry-box type gate house located in the center of a two-lane vehicle entrance. There is a single personnel control lane outside the building.

BUILDING DETAILS

A one-story, Class III structure, the dimensions are approximately 8 ft. by 8 ft. by 9 ft. high from the floor to the top of the flat roof. The area is 64 square feet and the volume approximately 590 cubic feet.

CONSTRUCTION DETAILS

The foundations are of reinforced concrete and have wall footings. The wood frame and the wood roof are treated for fire resistance. Exterior walls are corrugated cement asbestos board. The interior walls and the ceiling are finished with flat cement asbestos board. Doors and the double hung window sash are wood. The flat built-up roof has a 2-foot overhang on three sides and a 6-foot overhang on the remaining side. Exterior walls and the ceiling are insulated. There is no covering on the concrete floor. Heating is provided by an electric unit heater, lighting is incandescent.

EQUIPMENT

- 1 - Unit heater, fan type, 5 kw.
- 1 - Lighting panel.

DRAWING

W-161182 - Plan, Sections, Elevations and Details-
R, P, L, K and C Areas.

**BUILDING #704-R - OFFICE AND SHOPS BUILDING, CHANGE HOUSE
AND STORES**

FUNCTION

This is the area administrative headquarters with office facilities provided for operating and maintenance personnel. The area cafeteria, medical center, and maintenance shop, with a combination stores and tool room, also are housed in this building. The stores section is the area receiving and distribution point for maintenance material coming from Building #713-A, Central Stores. Gasoline and tire service is furnished for area vehicles at a service island near the shops section of the building.

PRINCIPAL COMPONENTS

Administrative facilities include twenty-two offices, a file room, a conference room for thirty persons, and the necessary toilet room facilities for male and female personnel. The medical suite consists of a waiting room, two treatment rooms, a rest room, a medical laboratory and a doctor's office, with separate toilet room facilities. This section is equipped to treat minor injuries, major cases being referred to at Medical and Employment Building #719-A. The cafeteria is designed only to serve food, although a griddle is provided for quick orders. The prepared food is delivered to the area from the main cafeteria. The principal eating area provides sixty seats, while an auxiliary dining area for janitors has eighteen seats. One set of serving facilities provides for both areas. A canteen is operated in conjunction with the cafeteria.

Area routine maintenance and inspection work involving shop facilities is performed in the Maintenance Shop. Facilities are provided here for machine, electric, millwright, sheet metal and pipe and welding shops. The tool room and stores area is part of the maintenance shop. Storage is provided adjacent to this shop for materials and equipment awaiting shop action.

BUILDING FLOOR SPACE

Approx. Sq. Ft.

Administrative

Twenty-two offices	3300
File room	300
Office toilet and rest rooms	450
Conference room	600
Medical area	960
Cafeteria	2350
Locker, toilet and shower rooms	1175

Shops

Two offices	330
Tool room and storage	1175
Shops area	5200
Roofed-over gas cylinder storage	30

BUILDING DETAILS

Of single story, Class III construction, the building is ell-shaped with one leg approximately 73 ft. by 170 ft. and the other 39 ft. by 161 ft. The first section is approximately 14 ft. and the latter 12 ft. high from the floor to the top of the flat roof slab. Total area is approximately 18,500 square feet and total volume, 256,825 cubic feet.

CONSTRUCTION DETAILS

The building, with foundations of reinforced concrete on spread footings, has a structural steel frame with web roof joists and a flat concrete slab roof on riblath. Exterior walls of the shop are cast-in-place concrete to a height of approximately 4 ft. 8 in. above the ground. Above this level they are covered with corrugated asbestos board as are all other exterior walls. Interior partitions and the interior of exterior walls are of flat cement asbestos

board on steel studs, except in the machine shop where fiber board is carried to a height of 4 ft. Toilet room walls are concrete to a height of 4 ft. and shower room walls are concrete faced with ceramic tile to a height of 7 ft. Ceilings are suspended, except in the machine shop, locker room and tool room. In the medical section, conference rooms, cafeteria and corridor they are finished with perforated flat cement asbestos board with sound absorbent insulation backing for acoustical treatment. Doors are hollow metal and sash is double-hung steel. Roofing is built-up and the roof, exterior walls, and walls of toilets and rest room are insulated. The concrete floor slab in the shops, shop offices, and the tool room and locker room has no covering. Floors in the cafeteria are finished with grease resistant tile. Quarry tile is laid over the concrete floor in the locker room, showers, and cafeteria kitchen. All other areas are finished with asphalt tile.

Heating is provided by unit heaters in the shop section and tool crib, and by fin-tube type radiators in the office area and toilets. Forced air through heaters, in conjunction with individual air conditioning units, is supplied to the conference room, medical section and cafeteria, and forced air through heaters and duct work is sent to the shop locker room, offices and toilets. The steam source for these services is the area power house. Air exhaust is maintained by fans through ducts from the cafeteria kitchen, locker and toilet rooms, corridor and welding shop.

Fluorescent lighting is installed in the offices, medical section, conference room, kitchen and shop. Incandescent fixtures are installed in all other areas.

EQUIPMENT

Offices

Conventional office furniture.

Package air conditioning unit, 5.5 tons, for conference room, including duct work.

Medical Section

Conventional office furniture.

Minor examination equipment facilities for treatment of minor injuries.

Resuscitator, aspirators.

Diathermy machine for heat treatments.

Package air conditioning unit, 7.4 tons, including duct work.

Cafeteria

Serving counter with auxiliary equipment.

Refrigerator.

Ice cube maker.

Dish washer.

Garbage disposal unit.

Package air conditioning unit, 15.5 tons, including duct work.

Tray trucks.

Griddle.

Fume exhaust system.

Tables with chairs attached.

Food container truck.

Dishes and tableware.

Maintenance Shop

1 - 16" x 102" Lathe.

1 - Pedestal grinder.

1 - Sensitive drill press.

1 - 16" Metal cutting saw.

1 - 1/4" to 2" Pipe machine.

3 - 400 amp. Arc welders.

1 - Squaring shear.

1 - Sheet metal roll.

1 - Sheet metal brake.

Cabinets, shelving.

Gas cutting and welding equipment.

Air compressor - 40 c.f.m.

1 - 1-ton capacity Monorail system.

Welding and layout tables.

Wood and steel benches.

Electrical and mechanical testing equipment.

Miscellaneous small equipment, hand tools, machine tools, etc.

1 - 500 gal. Underground gasoline storage tank and pump.

DEVELOPMENT OF DESIGN

A minimum of shop space and equipment was required for this facility since major overhauls, fabrication and rebuilding are done in the Maintenance Central Shop, Building #717-A. Similar considerations affected the size of the cafeteria facilities, since food is prepared in the main cafeteria, Building #708-A. In addition to these factors, the usual design aspects contingent upon Class III construction applied to this building.

It was decided, on April 28, 1953, to provide expanded metal partitions and cement asbestos partitions in the electrical and instrument shop areas. Electrical, compressed air and telephone services and additional equipment were also authorized. This change was effected to provide required equipment and protection for test equipment in the electrical shop and the instrument shop of this facility.

DRAWINGS

W-156572 - Floor Plan

W-156574 - Elevations

BUILDING #704-P, L AND K

These buildings are identical to that constructed in the #100-R Area.

BUILDING #704-C

This building differs from that in the other areas in that twelve additional offices are provided to house supervisory personnel engaged in work concerned with all the #100 Areas.

The smaller office wing of this building is extended approximately 61 feet to provide the required accommodations. All construction details are identical to the other buildings.

By April 1953, it was found that air conditioning was necessary in the office wings of these facilities and this revision was effected by the installation of window air conditioning units and 1000 c.f.m. fans; 10 each for Buildings #704-R, P and K, 11 for Building #704-L, and 14 for Building #704-C.

BUILDING #706-C - OFFICE BUILDING

This former T.C. building, #8300-C, was transferred to the capital account of Project 8980 to provide office space for the Technical Group.

Air conditioning equipment, consisting of one 15-ton package unit transferred from excess and individual window conditioning units, was procured and installed.

BUILDING #711-R, P, L, K AND C - STEEL AND PIPE STORAGEFUNCTION

This facility provides a sheltered storage space for pipe, large valves, steel bars, small shapes and sheet metal. It is located near the area maintenance shop, in Building #704.

PRINCIPAL COMPONENTS

The building consists of a roofed-over area, open on two sides for storage of steel stock and pipe, and two areas enclosed on three sides - one area for sheet metal and the other for large valves.

BUILDING FLOOR SPACE

	<u>Approx. Sq. Ft.</u>
Steel Stock and Pipe Storage	440
Sheet Metal Storage	50
Valve Storage	140

BUILDING DETAILS

Of single story, Class III construction, approximately 20 ft. by 34 ft. by 11 ft. high from the floor to the top of the flat roof which extends to form a 4 ft. overhang on two sides and one end. The total area is 680 square feet and the total volume is 8280 cubic feet.

CONSTRUCTION DETAILS

With foundation walls of reinforced concrete, the structure is of wood frame treated for fire resistance. Exterior walls and interior partitions are of corrugated cement asbestos board on wood studs which are exposed on the interior of exterior walls and on one side of the interior partitions. The ceiling is formed by the exposed under side of the roof sheathing. Roofing is built-up and the floor is a concrete slab. Lighting is incandescent. There are no doors or windows.

EQUIPMENT

Storage racks for steel stock, pipe and sheet metal.

DRAWINGS

W-155286 - Plan, Elevations and Sections, R Area.

W-157758 - Plan, Elevations and Sections, P Area.

W-157749 - Plan, Elevations and Sections, L Area.

W-157755 - Plan, Elevations and Sections, K Area.

W-157752 - Plan, Elevations and Sections, C Area.

ELECTRICAL FACILITIES

Steam electric generating plants are located in four of the five #100 Areas, namely #100-R, P, L and K. The plants in Areas R, P and L each consist of two 140,000 lb./hr. 625 p.s.i.g. 825°F. boilers and two 11,500 kw. preferred standard condensing turbine generators. Area #100-K is identical except that each of the turbine generators is rated at 12,500 kw.

These steam electric stations provide the required power not only for the #105 buildings but also for necessary process and service use in other parts of each area. Excess electric power generated in each area is fed into the 115 kv. plant power transmission system.

To provide emergency and standby power for critical requirements in the #105 buildings, two diesel plants are located in each #100 Area, each consisting of four 169 hp. Caterpillar diesel engines directly connected to d.c. generators. Three of these units are normally in continuous operation in each diesel plant. A 1000-kw. diesel electric unit also is installed to supply 440 v. 3-phase power for emergency use. These diesel facilities are located in Class I structures entirely below ground level.

The following electrical facilities are discussed in detail in Volume VI of this history.

Building #151-1RPLKC - Primary Substation

Building #151-2RPLKC - Primary Substation

Building #152-RPLKC - Secondary Substation

Building #501-RPLKC - Fence and Road Lighting

Building #503-RPLKC - Distribution Lines

Building #505-RPLKC - Fire Alarm Systems

Building #506-RPLKC - Telephone Cable and Instruments

Building #507-RPLKC - Safety Alarm System

STEAM FACILITIES

Steam generating plants are provided in each of the five #100 Areas. In Areas #100-R, P, L and K each of these consists of two 140,000 lb./hr. 625 p.s.i.g. 825°F. spreader stoker fired boilers. In Area #100-C, since there are no steam electric generating facilities and only process and heating steam is provided for the area, there are two 35,000 lb./hr. 325 p.s.i.g. saturated, spreader stoker fired boilers.

Each installation is provided with a railroad track siding with coal hopper, conveyor, silo, and coal storage yard. Each coal silo has a capacity of 750 tons, with the coal handling equipment capable of delivering 120 tons of coal per hour from the track hopper to the silo and 40 tons per hour from the silo to the boilers.

Ash disposal in Areas #100-R, P, L and K is handled by dumping boiler ash into hoppers from which it is sluiced into pits and pumped, by way of overhead pipelines, to ash disposal basins capable of holding a ten-year collection in each area. In Area #100-C, boiler ash is handled by a dry system which transfers the ash pneumatically from the boiler pits to a storage silo, from which the ash is periodically removed in trucks for disposal.

The following steam facilities are discussed in detail in Volume VI of this report.

- Building #184-RPLK - Power House
- Building #184-1C - Power House
- Building #184-2C - Service Building
- Building #188-RPLK - Ash Disposal Basin
- Building #801-RPLKC - Pipe Supports
- Building #802-RPLKC - Steam Lines
- Building #809-RPLK - Ash Sluicing Lines

WATER FACILITIES

Each of the Savannah River Plant production reactors requires large quantities of cooling water, the ultimate demand ranging from 76,000 g.p.m. in the first reactor to 130,000 g.p.m. in the final or C reactor. This is supplied from the Savannah River by two pump houses, Buildings #681-1G and #681-3G, having a combined design capacity in

excess of 500,000 g.p.m.--one-fourth of the total river flow. Distribution is by a system of underground piping extending over 80 miles, the lines varying in size from 36 inches to 80 inches in diameter. Individual #100 Areas contain reservoirs having a capacity of approximately 25,000,000 gallons to insure continuity of flow during normal and emergency conditions.

Each pump house is designed for ten pumps rated at 28,000 g.p.m. at a 350-foot dynamic head, but only eight were initially installed. In each #100 Area the water treatment facilities consist of a clarification plant and a filter and softener plant. To meet cooling water requirements anticipated in the R Area, the clarification plant for that area was designed with a capacity of 80,000 g.p.m. In the other areas, the 4000 g.p.m. clarification plant meets miscellaneous service requirements. In each area, 3100 g.p.m. of clarified water is piped to the filter and softener plant. Of this quantity, 120 g.p.m. is softened for boiler feed water and special use in Building #105.

The turbo-generator condensers in the #100-R, P, L and K Area power houses are supplied with cooling water from the 27,500 g.p.m. capacity cooling towers in each area. Ash sluicing water is also supplied to the power houses in these areas from the cooling tower basins.

The following water facilities are discussed in detail in Volume VI of this history.

- Building #107-RPLKC - Cooling Water Effluent Sump
- Building #108-1RPLKC - Engine House
- Building #108-2RPLKC - Engine House
- Building #108-3RPLKC - Fuel Unloading Facilities
- Building #183-1R - Clarification Plant (Cooling Water)
- Building #183-2RPLKC - Filter and Softener Plant
- Building #183-4PLKC - Clarification Plant (Miscellaneous Services)
- Building #185-RPLK - Cooling Tower
- Building #186-RPLKC - Cooling Water Reservoir
- Building #190-RPLKC - Cooling Water Pump House

Building #808-RPLKC - Chlorine Lines

Building #901-RPLKC - Water Lines

GENERAL FACILITIES

A discussion of the general facilities and services common to the entire plant, such as roads, walks, parking areas, fences, sewers and sewage treatment, is contained in Volume IV of this report. There, by a record of the over-all problems and specific solutions, it is possible to present a comprehensive review of their general characteristics.

Building #601-RPLKC - Standard Gauge Track

Building #603-RPLKC - Roads (Including Bridges and Culverts)

Building #604-RPLKC - Walks

Building #605-RPLKC - Fences

Building #607-RPLKC - Septic Tanks

Building #613-RPLKC - Parking Areas

Building #697-RPLKC - Site Work and General Grading

Building #698-RPLKC - Landscaping

Building #699-RPLKC - Extra Machinery

Building #732-RPLKC - Furniture and Fixtures

Building #903-RPLKC - Sanitary Sewers

Building #904-RPLKC - Process Sewers

Building #907-RPLCK - Storm Sewers

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X - NYX PROGRAM

INTRODUCTION

In providing the nuclear reactors for the Savannah River Plant #100 Areas under the Atomic Energy Commission contract No. AT(07-2)-1, du Pont conducted experimental work, designated as the NYX Program, to develop techniques for reactor fabrication and to confirm the expected mechanical and hydraulic performance of the reactor by fabricating, erecting and testing a full-scale prototype. The NYX Program also included performance testing of the more important reactor auxiliary equipment.

An extensive experimental program was carried out between April 1951 and May 1953 through the combined efforts of the Engineering Department and the Atomic Energy Division of the Explosives Department. The Engineering Department engaged the New York Shipbuilding Corporation to assist in developing the fabricating techniques required to construct the prototype reactor and the five Savannah River Plant production reactors. In addition, New York Ship was requested to prepare the testing area and to provide operating assistance to the AED operations group in charge of the prototype reactor testing.

During the development period and continuing to May 1954, New York Ship was fabricating the five Savannah River Plant production reactors, as part of the same subcontract, and building some additional equipment not covered in the original subcontract.

This review of the NYX Program is complemented by a separate volume, the New York Ship "Fabrication and Testing History - Prototype and Production Units", which describes details of the New York Ship subcontract work, especially the fabrication development, reactor fabrication, and the preparation of the reactor testing area. There are also 37 technical reports covering the NYX test work, written by du Pont, which are listed in the appendix as Exhibit M.

REASONS FOR THE NYX PROGRAM

In August 1950, the Engineering Department began the design development of the Savannah River Plant. The early process work in the #100 Areas involved coordinating the development work of the Development Engineering Division's Engineering Research and Mechanical Development Laboratories with the Design Division efforts.

The Design Division concentrated its initial effort on the reactor assembly and a design was gradually developed that consisted of a plenum, a top shield and a tank. These assemblies were large size weldments which were to be constructed of stainless steel and it was essential that fabrication be held to precise tolerances.

At the same time the Mechanical Development Laboratory (MDL) was developing the fuel element assemblies which were to be suspended in the reactor and, in addition, was developing the control and safety rod assemblies. The efforts of the Engineering Research Laboratory (ERL) were directed toward the hydraulic development concerned with the individual fuel assemblies and the over-all flow problems of the reactor and its six external circulating systems.

Each of the above Engineering Department divisions eventually determined that a few major problems were susceptible to calculation and conclusions based on a number of qualified assumptions. The ERL was particularly concerned with the vibration problems which they could foresee due to the hydraulic phenomena expected within the reactor and in the external circulating system. The MDL was concerned with the strength, stability and feasibility of assembly and the handling of the components to be inserted into the reactor. The Design Division was concerned about fabrication of the reactor itself since the feasibility of fabricating such large weldments to the accuracy desired was not certain. The most critical problem, involving the combined hydraulic-vibration effect of the reactor circulating system with all the components charged into the reactor, could not be satisfactorily determined by calculation, small scale testing, or by test of individual components or small groups of components. Therefore, it became mandatory that the equipment involved in the reactor design be mocked-up in full scale and tested to determine hydraulic and vibrational behavior and to confirm calculated performance for the reactor system.

The discussion of these major problems within the Engineering Department finally led to the recommendation by the Design Division to the Atomic Energy Division of the Explosives Department that a formal mock-up program be instituted. The purpose of the program was to:

1. Establish reactor fabrication methods;
2. Ascertain feasibility of fabrication and dimensional tolerances obtainable; and
3. Confirm expected hydraulic and mechanical performance.

This proposal met with favorable reception by the Explosives Department and in turn by the Atomic Energy Commission. Subsequent to the initiation of the program, prototype testing of essentially all major equipment associated with the reactor was included in the scope of work. This program also served as a training operation for a number of key operating personnel.

SELECTION OF THE REACTOR FABRICATOR AND TEST SITE

Design studies had progressed by February, 1951, to a point where it became obvious that the fabrication of the reactor assemblies, plenum chamber, top shield and tank, could be accomplished only by a limited number of fabricating firms in this country. This conclusion was dictated by the size of the weldments to be fabricated, the type and size of machine tools adaptable to the nature and size of the weldments, and the large shop and crane facilities required within the vendor's plant. Accordingly, an Engineering Department group, representing the Design Division and the Construction Division Materials & Equipment Section, was assigned to visit concerns which du Pont felt had equipment and shop capacity capable of performing the work. This survey group also determined the following information from the various companies:

1. Interest in performing the work;
2. Availability of existing shop space, or need for additional new shop space;
3. Shipping facilities;
4. Test site and electric power availability for mock-up tests;
5. Manpower availability; and
6. Security attainability.

Concurrently with this broad search for a fabricator, the Combustion Engineering Company was consulted regarding the feasibility of manufacturing these assemblies because of its experience in the heavy equipment fabrication field and because it had been helpful to du Pont during the design and construction of the Hanford Engineer Works. In March 1951, the Combustion Engineering Company engineers agreed that the fabrication of the reactor assemblies was feasible and that a mock-up was desirable to determine welding shrinkages.

Heavy industrial equipment manufacturers and large shipbuilders were canvassed during March and April of 1951 as possible fabricators of the reactor parts. The Savannah River Plant was also considered as the site for a new shop. The companies and locations considered were as follows:

Babcock & Wilcox Co., Barberton, Ohio
 Baldwin-Lima-Hamilton Corp., Eddystone, Pa.
 Combustion Engineering Co., Chattanooga, Tenn.
 General Electric Co., Schenectady, N. Y.
 M. W. Kellogg Co., Jersey City, N. J.
 Newport News Shipbuilding Co., Newport News, Va.
 New York Shipbuilding Corp., Camden, N. J.
 Pusey & Jones Co., Wilmington, Delaware
 A. O. Smith Co., Milwaukee, Wisconsin
 S. Morgan Smith Co., York, Pa.
 Sun Shipbuilding Co., Chester, Pa.
 Westinghouse Electric Mfg. Co., East Pittsburgh, Pa.
 Savannah River Plant, Aiken, South Carolina

As a result of the evaluation of the various fabricators, the New York Shipbuilding Corporation was selected by du Pont on April 26, 1951 to fabricate the reactor assemblies, and to provide and prepare a site for mechanical and hydraulic testing of a full size reactor.

SURVEY PROCEDURE

Initial contacts were made with management or regional representatives of the various companies to determine interest and, depending upon the individual interest, to arrange a more detailed discussion of the job. The discussion meetings were held at the prospective vendors' plants, when possible, with representatives of the du Pont Engineering and Purchasing Departments and representatives of the vendors in attendance. Inspection of the plant facilities, discussion of the job requirements with its specific machining problems, and determination of the vendor's experience, facilities, manpower, shop load, and other factors were covered in surveying the interested vendors.

EVALUATION

Approximately one month was required for the survey beginning about March 5, 1951. Six of the vendors were not interested in the job so that early in the survey the number of prospective fabricators was reduced to seven. General Electric Co. and Westinghouse Electric Manufacturing Co. declined in the telephone inquiry stage. Babcock & Wilcox Co., Newport News Shipbuilding Co., and S. Morgan Smith Co., following an inspection visit by M & E Section representatives, declined the job because of heavy shop schedules. A. O. Smith Co., after preliminary discussion on March 27, 1951 at Wilmington, also declined because it would have been necessary for them to build a new shop.

Combustion Engineering Co., the first fabricator contacted, was well qualified to perform the job and appeared to be a logical choice. However, lack of shop space in its Chattanooga Shop would have required the construction of a new shop, including procurement and installation of specific tools necessary for the job. The serious time delay to the project as well as the high investment cost in building a new shop made the selection of Combustion Engineering Co. less promising.

For the same reasons of time and cost the new shop proposed for the Savannah River Plant was also considered an unfavorable choice for reactor assembly fabrication.

The survey continued with a visit to Baldwin-Lima-Hamilton Co. which also proved to be a very good prospect. Three visits in all were made to this company's plant. It was not until the third visit, on April 5, 1951, that Baldwin-Lima-Hamilton indicated it was not interested because available qualified engineering personnel and the plant's suitable boring facilities were committed to long-term government contracts. In addition, Baldwin did not desire to carry out the test phase of the NYX Program in its shops.

Sun Shipbuilding Co., suggested by Baldwin, was surveyed on April 6, 1951, followed closely by New York Shipbuilding Corp. Both New York Ship and Sun Ship were considered capable of fabricating the SRP reactors. However, New York Ship was favored because its fabricating and machining facilities were better suited to the job requirements, it had an outstanding shop and available mock-up testing space, and it was currently operating with a light shop load.

With the investigation of New York Ship the survey was completed and an evaluation of the vendors was made. The Vendor Survey Evaluation Chart is reproduced in the appendix as Exhibit D.

Following the selection of New York Ship on April 26, 1951, the du Pont Company requested an approval by the Atomic Energy Commission to enter into a subcontract with New York Shipbuilding Corporation. Approval was granted verbally on April 27 and confirmed by letter of May 4, 1951.

BROAD DEVELOPMENT OF THE SCOPE OF WORK

A scope of work was developed in July, 1951, that defined the program required to achieve the goals originally outlined. This scope included:

1. Fabrication and erection of a full-size Savannah River Plant reactor;
2. Procurement and installation of SRP type reactor auxiliary equipment and necessary testing equipment;
3. Design and construction of temporary support structures for the reactor unit auxiliary equipment and test facilities;
4. Design and construction of a temporary "security area" including barricades and service buildings;
5. A test program; and
6. A report of test results.

In February 1952, the scope was amended to include operator training and the development of an operating procedure.

It was originally contemplated that the entire program would be supervised by the Design Division through its subcontractor, New York Shipbuilding Corporation. However, as the program began to crystallize it became evident that broader participation by du Pont was required for efficient prosecution of the work.

The organization set up was typical of du Pont practice. The Engineering Department assumed responsibility for design, procurement and construction of the reactor, its auxiliary equipment and all test facilities, while the Explosives Department assumed responsibility for operating the equipment, gathering test data and reporting test results. The scope of the test program was controlled by a steering committee composed of representatives of both departments.

The scope was handled as three basic elements: reactor fabrication, testing area preparation, and testing program and operator training. The first two elements proceeded simultaneously in preparation for the testing phase. A stepwise testing program was adopted so that the more important tests required for reactor design information could be performed early in the program. In general, reactor hydraulic and mechanical testing was performed first, auxiliary equipment performance second, and operator training and development of operating procedures third. A rapid exploration of the more critical reactor characteristics was made on the initial test start-up; detailed testing, coupled with changes indicated by test results, followed this exploratory testing. Special expedients were used to obtain preliminary hydraulic testing data as soon as possible. Temporary recirculation system pumps, rented from the Texas Eastern Co. "Big Inch" pipeline system, were installed for the initial reactor tests. These were later replaced by SRP type pumps to complete the tests. Preliminary testing was performed on a 1/6th loaded reactor under single pump unit flows. Finally, dummy components were used in lieu of SRP components to reduce procurement delay due to material scarcity and required machining time. The component substitutions were made for blanket, control, instrument, safety and 35W5 rods which were charged into the reactor. Approximately 5/6ths of the monitor pins were dummy pins not equipped with ports for flow and temperature monitoring. Dummy fuel slugs replaced about 1750 out of 47,200 fuel slugs on which the cans had become pimpled, ruptured or scratched.

The NYX Program test start-up was scheduled for November 1, 1951, on the basis of initial estimates of the earliest attainable date, if all materials required were made available immediately. The probable completion date for the testing period was scheduled for January or February, 1952. The Atomic Energy Division NYX Operations group was to continue operation of the test equipment until approximately September 1, 1952, for the purpose of developing operating procedures and training operators. Due to fabrication delays and to delays resulting from insufficient priorities assistance for material procurement, hydraulic testing of the reactor was not started until May 1952. The actual testing operations, performed under an extended program meeting both testing and training objectives, carried through May 1953.

The definition of the scope of work and the outline of the testing program were mutually developed by ERL and MDL of the Development Engineering Division, Design Division and the AED of the Explosives Department.

The initial testing program had the following objectives:

1. Assembled Quatrefoil	- Flow, vibration and physical behavior
2. Material Handling	- Q-crane performance
3& 4. Rod Assemblies and Drives	- Performance and physical characteristics
5. Slug Charging Equipment	- Performance
6. Assembly Bench	- Tube loading, handling, testing and shipping demonstration
7. Disassembly Facilities	- Normal and emergency techniques demonstration
8. Q-Foil Instruments	- Pressure and temperature monitoring performance
9. Shield and Plenum	- Determination of fabrication methods and tolerances
10. Reactor Tank	- Determination of fabrication methods and tolerances
11. Flow Test of Reactor Tank	- Determination of hydraulic characteristics of recirculating system including Q-foils
12. Recirculation Pumps	- Flywheel, driver and pump capacity and performance
13. Pump Seals	- Performance

Development of the final details of the testing phase was handled by AED with the assistance of the Design Division through surveys and preliminary test programs circulated for comment among the groups participating in the NYX Program. Final development of the test program was started in August, 1951, and was completed in February 1952. The testing program added two objectives to the initial NYX Program:

1. Training of supervisory and operating personnel;
2. Development of SRP operating and maintenance procedures, including
 - a. Normal operations,
 - b. Emergency operations, and
 - c. Evaluation of increased power level operation.

SUBCONTRACT WITH NEW YORK SHIPBUILDING CORPORATION

The du Pont Company subcontract with New York Shipbuilding Corporation, on a cost-plus-fixed-fee basis, covered the fabrication of a prototype reactor, the test work required for the NYX Program, and fabrication of five production reactors for the Savannah River Plant. The scope of the subcontract was subsequently increased by additional work of similar nature but not part of the NYX Program.

The agreement covering this work was Subcontract No. 24 under du Pont's Prime Contract No. AT(07-2)-1 with the AEC, and was assigned du Pont Subcontract No. CT-4143 (NYS Contract No. 8000). It was generally referred to as Subcontract AXC 167-1/2, the number of the du Pont purchase order for the job.

A Letter of Intent issued on April 25, 1951 was the initial agreement executed by du Pont and NYS. This letter authorized New York Ship to proceed with the performance of services requested by du Pont and specified that a formal subcontract, to be executed within 120 days (or by August 23, 1951) or any extension mutually agreeable, would include the full scope of work, and all terms and conditions required by statute, government regulations and AEC requirements. The Letter of Intent also fixed the subcontract on a cost-plus-fixed-fee basis and set up provisional monthly reimbursement for (1) direct wages, (2) allowable costs, and (3) indirect and overhead costs. Controls by audit and procedures for accounting and purchasing were specified by du Pont.

The formal subcontract was executed in January, 1952, and approval of the AEC was obtained December 2, 1952. Fourteen supplements to the Letter of Intent were issued to extend its termination date until execution and approval of the formal subcontract was obtained. There were seven modifications to the formal subcontract. These modifications covered changes in the scope of work, estimated contract

cost, contract conditions, and clarification of contract terms. For full details refer to Subcontract AXC 167-1/2 and modifications thereto. Exhibit E is a compilation of the entry date and cost status of the formal subcontract and its modifications, including an outline of the latter.

The estimated cost of all work outlined in the subcontract and the amount of the fixed-fee were as follows:

Estimated Cost	\$16,683,500
Fixed-Fee	<u>1,102,200</u>
Total	\$17,785,700

This total represented the authorized expenditure limit under the contract for NYS work on the NYX Program prototype reactor fabrication and testing, the fabrication of four production reactors, and the fabrication of the Process Development Pile, (referred to as the "Physics Laboratory Tank" in "History" prepared by NYS), five actuator structures and five holding racks. Exhibit F lists the basic scope of work, with modifications, and the related cost estimates.

All fabrication work was completed and the final shipment made by May 20, 1954, and close-out details were begun. When the subcontract was closed, with the final payment February 25, 1955, the total cost including the fixed-fee of the subcontractor amounted to \$16,941,188.

NYX REACTOR FABRICATION

The full-scale stainless steel reactor, a prototype of the SRP production units, was fabricated by NYS in accordance with the design prepared by the du Pont Engineering Department under a coordinated development and fabrication program whereby du Pont and NYS successfully accomplished the first and second goals of the NYX program: (1) to establish reactor fabrication methods, and (2) to ascertain feasibility of fabrication and dimensional tolerances obtainable.

The reactor design, by May 1951, consisted of four principal assemblies, basically cylindrical weldments about 18 feet in diameter, to be fabricated of Type 304 stainless steel. These included the plenum chamber, the top shield, the bottom shield, and the main tank, expansion joint and top shield enclosure.

The first three assemblies were tube and tube-sheet weldments in each of which approximately 800 tubes were welded and machined to close tolerances in matching patterns. The fourth assembly was a tank of unconventional design. The sketch on page 495 illustrates the NYX reactor, as erected.

The scope of work in fabricating the NYX reactor consisted of: (1) development of reactor fabrication techniques, (2) procurement of materials, special tools, etc., and (3) fabrication of reactor assemblies.

The Design Project Manager for the #100 Areas was responsible for the design and procurement work. The reactor concept was developed, and arrangement and detail drawings were made by du Pont to present the design of the four reactor assemblies. Actual purchases of all fabrication materials and tools, with minor exception, were made by NYS. Du Pont assisted by procuring the stainless steel required in bulk tonnage under CMP allotments, by obtaining priorities, expediting materials and tools, and by purchasing the tubes and raschig ring filler for the shield assemblies.

Fabrication development was performed as a joint effort of the du Pont Engineering Department and New York Ship, coordinated by the #100 Area Process Design Group in charge of the NYX Program. Specialists and engineering groups from Construction, Design, Development Engineering and Engineering Service Divisions of the du Pont Company, and from New York Ship participated in the work.

Reactor fabrication was carried out by NYS under the supervision of its NYX Project Manager who directed the work with an organization separate from the shipbuilding departments. The du Pont Construction Division NYX Field Project Manager was responsible for the fabrication, scheduling, production, quality, and other construction functions relative to the work. Inspection of work and materials was performed by the du Pont resident Materials and Equipment (M & E) Section inspection group.

Consulting services of a tooling engineer were supplied by the du Pont Engineering Service Division to assist the du Pont and New York Ship engineers. This consultant's first assignment was a full time study of the NYX plenum line-boring operation, in progress at the time, and his recommendations resulted in improved production efficiency. Extensive consultation was provided also for the first SRP production reactor; thereafter the services were occasional as required.

In the development phase, key NYS personnel were oriented in the design of the reactor by du Pont Design Division representatives during the period from April 26 through July 31, 1951. Through these reviews du Pont and NYS resolved the basic fabrication methods and acceptable tolerances, and adopted a fabrication procedure for the NYX unit.

The major fabrication steps established early in this development stage were:

1. Machining and welding of tube-sheet plates.
2. Layout and machining of tube-sheet holes.
3. Pre-machining of tubes.
4. Assembly of tube-sheets, tubes, etc.
5. Welding of tubes to tube-sheets.
6. Welding wrapper, or shell, on tube-sheet periphery.
7. Reaming weld distortion from tube bores of the shields.
8. Boring plenum tubes in alignment with top shield tubes.

In the same period, fabrication methods to carry out these steps were selected as follows:

- Tubes
- (a) Use seamless or centrifugally cast tubes.
 - (b) Pre-machine shield tubes to finish size to eliminate boring after welding; ream weld distortion from bore.
 - (c) Pre-machine plenum tubes to pre-welding size; bore to finish size in line with top shield tubes.
 - (d) Machine or weld shoulders on some tubes to aid in spacing tube-sheets during assembly.

Tube-Sheet Plate Welds - Perform welding by "Aircomatic" semi-automatic, consumable (filler) electrode, shielded-arc, track welding machines.

Tube-Sheet Hole Machining - Drill holes in tube-sheets from layout and drill-jig location; pilot drill all holes and then trepan to size.

MAIN TANK

JOINT

10'-0" BETWEEN TOP OF BRACING PLATES

24" O.D. MANHOLE
W-130463

STURDY W-130463

W-130912
STEEL BEAMS
FOR BRACING

STEEL BEAMS
FOR BRACING

STEEL BEAMS
FOR BRACING

BOTTOM SHIELD
(BOTTOM TUBE SHEET)

10'-0" BETWEEN TOP SHEET

THE NYX UNIT
ELEVATION VIEW SHOWING FOUR
ASSEMBLIES AS ERECTED

15'-4" FACE TO FACE TUBE SHEETS

18'-11"
TANK
W-130463

24'-10"

22'-0"

5'-0"

TANK BOTTOM TUBE SHEET
W-130463

Tube to Tube-Sheet Welds - Perform welding with "Aircomatic" automatic, consumable (filler) electrode, shielded-arc, rotating welding machines placing the full weld deposit in a single pass.

Assembly - Prepare segmental "pot-chuck" fixtures with trunnions for clamping and rotating assembled tube and tube-sheet weldments to permit down-hand "skip welding" in sequence for attainment of uniform shrinkage.

Plenum Tube Boring - Bore plenum tubes in line with the top shield tubes utilizing radial drills and a vertical boring bar technique. Specialized boring equipment was to be investigated as an improved method if required.

Proceeding from the development conferences, du Pont and NYS conducted experimental programs to confirm and further develop the fabrication methods selected for the NYX unit, and to gain fabricating experience.

The 8-foot mock-up weldment program was essentially a welding experiment, through fabrication of a tube and tube-sheet weldment similar to the plenum chamber (see Exhibit G in the Appendix), that aided in the development of shrinkage allowances and distortion controls and confirmed the reliability of the tube welding techniques and procedures. In addition, machining problems were worked out on the mock-up, and deflection and stress relieving tests were made that ascertained the structural stability of the design.

Tube boring experiments were started on single tubes using a radial drill and boring bar to study suitability of the plenum tube boring method, and selection of boring bars, cutters, machining feeds and speeds. A seven-tube mock-up section of the plenum-top shield adopted at a later date, served to establish the actual production methods.

Experimental shop work was carried out both prior to and during fabrication of the NYX unit to provide necessary fabrication data as required. Details of the developmental work, including the experimental shop work, and its relation to the methods by which the reactors were actually fabricated is presented in the "History" compiled by New York Ship.

In keeping with the development of the fabrication techniques, the du Pont M & E Inspection Group in conjunction with the Design Division established a fabrication inspection program to assure meeting the operational requirements of the reactor. The close tolerances and interrelation of parts

made it necessary to provide fabrication checks as production progressed as well as final inspection of the sub-assemblies to achieve the inspection goal.

A variety of gages, both of a proprietary and special nature, required for this purpose were developed under the direction of the M & E Technical Inspector or the Design Division Shop Practices Specialist. The du Pont Design Division and Development Engineering Division tool engineers provided the design for the special gages with the assistance of NYS. Development of the special gages and their use has been related in the activities reports of the du Pont M & E Section and in the "History" prepared by New York Ship.

Following completion of the welding shrinkage allowance experiments on the eight-foot mock-up, fabrication of the NYX reactor was started on July 16, 1951, with preparation of the bottom shield tube-sheet plates. Fabrication and development work then proceeded until the reactor was completed and erected in the testing foundation in Building 10 on May 20, 1952.

Elapsed time for fabrication was 310 days, an extension of 100 days beyond the estimated completion date of February 7, 1952, per the construction schedule approved by the du Pont Field Project Manager and the NYX Program Design Coordinator in September 1951. The extension was due to the need for additional fabrication development, late material deliveries and fabrication delays.

Fabrication of the plenum chamber, top shield, bottom shield and main tank for the NYX reactor, as well as assemblies of the R, P, L and C reactors, followed the techniques which resulted from the development program. The NYX reactor "Fabrication, Welding and Inspection Procedure" (see Exhibit H) records the original sequence and methods for welding, machining, cleaning, inspecting and miscellaneous fabricating operations used to accomplish the job. The principal operations performed in fabricating the assemblies are listed in Exhibit I, which also indicates the basic similarity in the fabrication operations of the plenum and shields. Of four special machining operations done on all three tube and tube-sheet weldments, three operations used the same basic machine tools; namely: line-boring, line-reaming, and welding-neck reaming. The main tank was fabricated in accordance with large tank practice except for cold-forming of the expansion ring from light plate, welding and machining of the heavy bearing rings and special measures employed to obtain close-tolerance dimensions. The "History" prepared by New York Ship describes the fabrication work for the NYX reactor assemblies in detail, covering procurement and shop problems, additional development work, and changes in procedure.

TEST AREA PREPARATION

New York Ship provided and prepared the reactor testing area for the NYX Program in accordance with du Pont design utilizing an outside contractor to do a part of the work.

The test site was an existing large building and adjacent outdoor space in the NYS South Yard situated on a pier along the Delaware River at the mouth of a tidal creek. The south end of the building, approximately 60,000 sq. ft., with its high-bay section and requisite large capacity cranes, was ample for housing the test equipment.

The site was prepared by clearing machinery and stored equipment from Building 10, the general name for the test area, constructing temporary foundations, structures and security barriers, providing electric and water services, and installing the reactor and associated auxiliaries. The Process, Electrical, Power, Instrument, and Architectural and Civil Sections of the du Pont Design Division provided the design for these preparations. New York Ship carried out the construction work and equipment installations in liaison with the du Pont Field Project Manager's staff representatives.

The work was carried out in two phases: (1) construction of foundations and structures, and installation of the reactor and auxiliaries, utilizing temporary facilities in place of plant design auxiliaries; (2) minor construction and changes after start-up, and installation upon delivery of the reactor auxiliaries diverted from the Savannah River Plant which replaced temporary equipment or were a part of the test scope. This approach was dictated by the urgency of obtaining reactor hydraulic and mechanical performance data and the late delivery of SRP auxiliaries, such as the process pumps and motors, and the reactor charge-discharge machine, thereby making it necessary to perform the initial reactor performance tests separately from a combined reactor-SRP major auxiliaries mock-up program.

The mock-up equipment assembled for the NYX Program tests under these two phases consisted, in general, of six major units.

REACTOR HYDRAULIC SYSTEM

A full-scale SRP design reactor, in which the matching tubes of the plenum and top shield were charged with Q-foils, S-foils, blanket foils, safety rods, instrument rods and 35W5 rods, was erected in a reinforced concrete foundation, and six process water circulation piping loops were connected to the reactor. In each loop there was a motor-driven

pumping unit, a heat exchanger and suitable valves. The water circulating in the reactor system was pumped to the plenum nozzles and distributed throughout the plenum chamber from which it flowed via slots in the plenum tubes down into the main tank through Q-foil passages. The water was then returned to pump suction through the main tank outlet nozzles. For the tests, non-enriched fuel and light water moderator were used and no danger of criticality existed; as a safety precaution a neutron indicating instrument was installed in the reactor.

Twelve carbon steel, rubber-lined, 6000 g.p.m. pumps and 1500 hp. motors, operated two per loop in parallel, were used temporarily until six SRP stainless steel 12,700 g.p.m. pumps and 3000 hp. motors were delivered. Also installed for testing were two emergency d.c. power systems, which consisted of a diesel motor and generator, and d.c. motors connected to the SRP pump-motor shafts for operation of pumps at one-third normal speed. The heat exchangers mentioned above were of carbon steel construction, much smaller than the SRP units, and designed only for temperature control of circulating water. One of the SRP stainless steel tube-and-shell heat exchangers was later installed at NYX for testing as soon as it became available, replacing one of the carbon steel exchangers.

Deionization equipment was installed for purification of the initial charge and to condition water continuously in the recirculation system.

The top and bottom shield cooling system and a special purpose cooling system for nine Q-tubes were installed after the initial hydraulic tests to obtain thermal differential effects for reactor testing. These systems consisted of separate piping headers and connectors, a pump and one of the temporary heat exchangers, as well as an interconnection with the SRP heat exchanger under test in the No. 3 circulation loop.

ASSEMBLY AREA

An enclosed area separate from the main testing area was equipped with special machines and handling equipment for assembly, test, storage and disassembly of reactor components required for reactor charging, testing of equipment, and training of operating personnel.

A fuel slug magazine, mechanical loading machine, and flow testing station were provided for Q-foils. Also, a tipping table was installed to raise slender rod tubes to a vertical position without bending them in order to load

control rods into the S-foils. Q and S-foils were stored on vertical racks to which they were transferred by means of a fork-lift truck with a special vertical carrying mast. The area also included a slug push-out machine for Q-foil unloading, a press and shear machine for reducing bulk of scrap Q and S-foils (a test installation), boiling vats to test slugs for canning defects before loading, and a monorail conveyor for handling foils to various machines and equipment in the area.

REACTOR COMPONENT CHARGING AND DISCHARGING

For the NYX tests seven different types of components were to be charged into or discharged from the top of the reactor through approximately 835 matching tubes in the plenum chamber and top shield. These consisted of multiple tube-cluster foils (Q, Blanket, and S-foils) and single rods (control, safety, instrument and irradiated rods).

An ordinary 2-ton service crane was installed for the initial reactor testing operations to handle the long foil and rod components for manually guided insertion into the reactor following manual insertion of semi-permanent sleeves in the plenum and top shield tubes. Other shielding components fitting on top of the foils were loaded manually also; namely, a spiral and a solid plug for Q and Blanket foils, and an S-foil muff, or cored cylinder, for S-foils in which the control rods were permitted to move.

An SRP type charging and discharging machine, or precision crane, was tested during the latter part of the NYX Program, replacing the 2-ton service crane. The NYX precision crane had been modified slightly to provide both charging and discharging service in one machine for test purposes (SRP used separate machines for each service) and to fit building space limitations at New York Ship. Automatic and remote control was provided by a special control console which could perform all basic functions of the crane but which did not include any of the automatic features of the SRP console for vertical motion. For charging and discharging tests a high-level transfer station was installed above the plenum chamber level in simulated plant design for handling the loaded foil and rod components between a transfer station rack and the reactor. The components were transported from the assembly area storage racks to a low-level transfer station (used with the 2-ton crane) via a fork lift truck with a special vertical mast, and then lifted to the high level transfer station by a service crane, from which the components were picked up by the precision crane and loaded or charged into the reactor.

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ACTUATOR SYSTEM

A mock-up of the C-rod and S-rod actuator system was installed to test operating and wear characteristics of the electro-mechanical devices and the reactor components which they raised and lowered. The mock-up consisted of a three-column structural steel support with operating platforms, 3 C-rod actuators, 3 S-rod actuators, and control equipment. The unit was installed on top of the reactor for functional tests and at floor level for simulated operations testing.

INSTRUMENTATION FOR TESTING

Instrumentation was installed or provided for the reactor testing program to record data and control operations during the test with special attention to hydraulic, vibration, and Q-tube flow and temperature monitoring studies. Miscellaneous instruments were also provided for equipment undergoing tests, as were special measuring and inspection tools, and specific health instrumentation such as low level neutron detectors, survey meters and film badges for personnel protection. About 3000 instrument items were used for the NYX Program.

A control room equipped with sufficient centralized recording devices, alarms, communication systems, and controls was located in the test area to coordinate the testing operations of the reactor unit. An instrument shop was also provided in the testing area for installation, storage and maintenance work.

For the hydraulic study, pressure gages, manometers, level indicators, pitot tubes, flow meters, thermocouples and associated recorders, indicating instruments and alarms were set up for readings in the process and cooling water systems.

Vibration measurements during operation required installations such as the following: 280 strain gages on all tube types; 13 accelerometers and a hydrophone installed inside the reactor; and special devices for measuring vibration at the bottom ends of foils and rods. Determination of the natural frequency of the plenum chamber was performed by means of a vibrator, furnished and serviced by the U. S. Navy, which was mounted on top of the reactor unit. Portable vibration measuring instruments were provided to indicate the readings.

Testing was also performed on prototype equipment for flow and temperature monitoring of water discharged from Q-tubes for 1/6 of the reactor. About 100 SRP type monitor

pins in the bottom shield were connected by tubing that supplied flow to the multiple-port rotary valve and multiple-flow transmitter mechanisms and recorders. The temperature monitoring system required installation of about 400 thermocouples in the monitor pins and their connection through an isothermal junction box to switching mechanisms and recorders.

SERVICE FACILITIES

A 26,400 v. substation was erected for transforming current to a 2300 v. supply for the process pump motors. An 18,000 kv.-a. supply was furnished by the public utility to feed the substation at maximum load.

A river water cooling system was built to supply 6000 g.p.m. of water to meet cooling loads on the heat exchangers, motor bearings, diesel motors, deionizer heat exchangers, and other cooling requirements.

The NYS power house distributed common electrical services of ordinary load ratings, steam, air and city water as required for area use.

Ralph Cornell, Inc., a construction contractor engaged by NYS under a lump-sum contract in the amount of \$511,980 (subsequently increased to \$583,000), did the major part of the pre-start-up construction since the shipyard's normal forces were not large enough to meet the schedule for the large volume of work required. Cornell started the work on August 2, 1951, using a large force of uncleared personnel and was practically finished by mid-October. With only a few minor items uncompleted, Cornell's contract was closed in December 1951, so that NYS cleared personnel could proceed with installation of classified equipment.

New York Ship forces continued the pre-start-up construction, finishing the residual work from Cornell's sub-contract and building other structures needed for the test start-up. NYS construction, and the work of Cornell included several foundations for SRP equipment on which delivery was scheduled for the post-start-up phase. In addition, du Pont and NYS negotiated a contract with Public Service Electric & Gas Co. of New Jersey to furnish an 18,000 kv.-a. temporary power supply, to install switching stations and distribution lines in its utility network at a cost of \$205,000 (\$200,000 refunded upon removal of equipment), and to supply 26,400 v. service to the Building 10 substation on a nonfirm, when available, basis.

Installation of the reactor,—auxiliaries and testing facilities was New York Ship's primary job and covered both the pre and the post-start-up test preparations. In November 1951, NYS forces began this task with the installation of the assembly area equipment as soon as security barricades, platforms, and handling facilities had been completed by Cornell. NYS completed the pre-start-up phase on May 21, 1952, with final assembly of the plenum chamber in the reactor foundations in readiness for the tests. After a short interim period during which initial test runs of the reactor hydraulic system were made, the post-start-up preparations commenced about June 20, 1952 when installation was started on two SRP type diesel engines for emergency d.c. power generation, and the precision crane was being installed on a temporary floor level crane-way for preliminary trials. Following that date the SRP pumps, the SRP heat exchanger and other equipment were installed, or changes made, to suit test operations. Final preparations were completed in March 1953, when the precision crane was assembled on the regular crane-way over the reactor for operating trials.

A summary of the over-all preparations made in equipping the testing area, showing the division of work between New York Ship and its subcontractor, is included as Exhibit J in the Appendix. Details of this installation work are covered in the New York Ship history.

During the construction of the testing area, and in both the pre-start-up and post-start-up phases, the du Pont Safety and Fire Protection Division was consulted and made recommendations upon safe design and equipment installations. Special cases which required attention during the job were the fire-proofing of the temporary wooden structures, equipment supports and walkways, and the strengthening of the inspection walkways about the reactor in expectation of loading by a larger number of personnel than originally contemplated.

ERECTION OF THE NYX REACTOR

The NYX reactor was erected on a reinforced concrete foundation, a hollow tower-like structure constructed in Building 10, in which the elevation differentials of the SRP reactor foundations were simulated. The unit was erected by lowering the four sections of the reactor into the tower in the following sequence: first, the bottom shield with the lower main tank section welded to the top periphery of the bottom shield nozzle assembly; second, top shield enclosure, bearing ring and expansion ring as a welded assembly; third, the top shield; and finally the plenum

chamber. Field positioning and welding of the lower main tank and the top shield enclosure section were required. All reactor assemblies were set with extreme precision in relation to other parts of the unit and also with respect to the precision crane installation in order to meet operability requirements for the NYX Program testing. The sketch on page 495 indicates the various elevations of the unit and the method by which the reactor was anchored and supported on the foundation.

Erection work was done by New York Ship forces to settings measured by du Pont M & E Section inspectors with a theodolite and level instruments. This accurate optical measuring technique was adopted to accomplish the exacting tolerances specified by the Design Division for elevations, levelness and orientation. A portion of the instrument work, and the determination and recording of the "building axes", was performed by a surveying contractor.

As the first step the X and Y Building axes, parallel to the precision crane-way axes and coincidental with the center of the foundation, were established through accurate optical measurements. Vertical lines were scribed on plates attached to inside walls of the reactor foundation as reference for horizontal dimensions, or axial orientation of the assemblies. These reference marks were transferred to four rigid A-frames located on top of the reactor foundation for facility in sighting the axes after the first section was installed. A vertical control point was established by a similar measuring technique.

In erecting the reactor in Building 10, the sections were transported by the 2-hook 150-ton crane and set into the foundation per design specifications. The work was done in the period from March 25 to May 20, 1952. The installation details, difficulties, and experiences together with recommendations have been reported in du Pont Construction Division's "Summary of Erection Procedures for the NYX Unit". This report also includes the Design Division discussion regarding reactor installation tolerances. The report information and advice given by the NYS rigging foreman, who visited Savannah River, proved extremely helpful in the proper installation of the first SRP production reactor.

NYX TRAINING SEMINAR

In March 1952, in preparation for start-up and testing of the NYX Program reactor and major reactor auxiliaries, the Engineering Research Laboratory conducted an orientation course on the NYX Program development and objectives.

The seminar was presented for personnel responsible under the NYX Program for: operating and maintaining test equipment; planning and executing equipment tests; analyzing test results and formulating conclusions for technical reports; the design, fabrication, and installation of the test equipment; and miscellaneous service functions. By means of the seminar the groups concerned were informed adequately so that they could proceed with the test work with a full understanding of the over-all program and its objectives.

A tentative seminar program, prepared January 22, 1952, included the presentation of papers on program background, technical phases of test work, and test facilities by speakers with intimate knowledge of the specific problems and capable of discussing questions arising from their papers. During the next few weeks, final plans were developed with the assistance of Atomic Energy Division of the Explosives Department, and the Construction, Engineering Service and Design Divisions of the Engineering Department.

The seminar was held at the Engineering Research Laboratory, du Pont Experimental Station, from March 3 to 7, inclusive, during which the program papers listed in Exhibit K were presented with daily round-table discussion of the papers. Representatives of the Atomic Energy Division of the Explosives Department and of the Construction, Design, Development Engineering, and Engineering Service Divisions of the Engineering Department attended the various sessions, all groups accounting for a total attendance of approximately 200 man-days. Since the papers covered classified information, only cleared personnel authorized by their supervision attended the sessions.

The NYX training seminar successfully accomplished its goal of indoctrinating the NYX Program personnel. Moreover, the benefits of the seminar did not cease with the close of the lecture-discussion meetings. Added training benefits were gained through the use of a wire recording transcript made as the speakers presented their papers. These recordings, together with approximately sixty charts used to illustrate the lectures, were presented to the NYX Operations Superintendent of the Atomic Energy Division after the seminar was closed, and were used for additional training, especially of personnel assigned to the Atomic Energy Division NYX Operations organization after the NYX training seminar had been completed.

THE NYX TESTING PROGRAM

The NYX testing program was the reactor testing phase and the concluding step of the NYX Program. By means of the tests the Engineering and Explosives Departments studied the performance of the full-scale NYX prototype reactor under simulated operating conditions and gained technical information and operating experience which led to the achievement of the remaining goals of the NYX Program: (1) to confirm design performance of the reactor system; (2) to provide operating procedures; and (3) to develop improvements for SRP reactor systems.

The Atomic Energy Division NYX Operations group, organized in a way similar to a plant organization consisting of operations, technical, maintenance, and service sections, operated the testing program on a 24-hour, 7-days-per-week basis and was assisted by New York Ship personnel in all direct operational and maintenance work. The group was staffed by AED personnel, and Engineering Department engineers loaned for the duration of the tests. An Engineering Department coordinator and his assistants worked closely with Operations to direct activity toward Engineering Department objectives. For additional information refer to the general section devoted to "Organizations" and to organization charts in the Appendix.

Testing operations were carried out in accordance with the previously discussed NYX testing program developed by AED and the Engineering Department. The tests, as planned, fell into five categories: (1) tests on the reactor; (2) tests on the auxiliaries; (3) development of standard operating procedures; (4) development of procedures for unusual operations; and (5) data for higher power level operation and for design of later reactors. To provide the technical data on reactor performance, 78 tests were planned for Groups 1, 2 and 5, and 36 tests were planned under Groups 3 and 4 for operating data.

The NYX Program tests commenced on May 21, 1952, with start-up trials and closed approximately one year later on May 2, 1953, upon completion of the precision crane tests. The start-up on May 21 was approximately two months later than originally planned due to NYX reactor fabrication delays. Early project schedules specified a 90 to 120-day test program followed by reactor operation over a six-month period for training purposes. Hydraulic-vibration testing of the reactor with temporary pumps and one SRP process pump was completed 120 days after start-up, but the program still required tests of the reactor with a full complement of six SRP pumps and auxiliaries as well as other SRP prototypes. To carry out the full scope, the program was

extended approximately 220 days to May 2, 1953, because of late delivery of test equipment and unscheduled interruptions. In actual performance, 76 technical data tests were conducted, investigating the reactor system in relation to mechanical performance; hydraulic, vibration and structural (load-deflection and thermal effects) characteristics; corrosion, erosion and wear; and leakage of process fluid. The tests associated with Groups 3 and 4 were not performed separately, but were integrated with the technical data tests, and the required information was developed through observations and experiences encountered therein.

Because the technical data tests were the key to the objectives of the NYX testing program, special attention was directed to planning, authorization, performance and reporting of each test. The method employed is illustrated in Exhibit L which shows how specific test work reported in DPXN-224, "Valve Performance", was carried out.

Results of the NYX testing program were reported in 37 formal technical reports. Report DPXN-200 summarizes the entire NYX testing program and the high-lights of the individual reports on related test items. Exhibit M lists the NYX final reports by document number and title.

The major conclusions drawn from the tests were that, within the limits of its scope, the NYX testing program proved the basic soundness of the design of the SRP reactors. Satisfactory reactor hydraulic, vibrational, and mechanical performance was obtained, and, in general, reactor auxiliary equipment functioned within design limits as expected. However, the test resulted in a number of changes in design and fabrication of the production units, as explained in the following section.

PRODUCTION REACTORS - DESIGN, FABRICATION & INSPECTION REVISIONS

A production reactor was built at New York Ship for each of the #100-R, P, L, K and C Areas, and each conformed with the basic reactor concept used for the NYX prototype.

The R, P and L reactors were very similar in design and employed the same general methods of fabrication.

The K unit was produced by converting the NYX prototype. After studying feasibility and cost of conversion, the NYX plenum, top shield and bottom shield were modified to include essentially all features of the R, P and L assemblies. A new main tank was fabricated in accordance with the improved design of the production reactor tanks.

The C reactor introduced several new developments and design changes that increased the potential reactor capacity, but still retained the original design concept. Fabrication methods for this unit were also planned for best utilization of the experience gained in building the NYX, R, P and L reactors.

Many improvements were made in design and fabrication of the production reactors as a result of the NYX Program. The effect of these changes was to reduce the Savannah River Plant construction costs, and prevent or reduce delays in plant start-up, or plant shutdowns which would have been required to make the corrections at the plant site.

1. When the recirculating system was being hydraulically tested, some shroud plates were torn from the diffuser vanes of an NYX unit plenum nozzle. A solid vane was designed to replace the shroud-type vanes in the R and P units, and in the conversion of the NYX unit into the K unit. Nozzles in the L and C units were fabricated with solid vanes.
2. The number of centering tongues and grooves for the plenum and top shield of all SRP reactors was increased from three to six to insure freedom from motion of the above assemblies under process operating conditions. The testing of the prototype indicated that relative movement of the plenum and top shield would occur if only three guides were used.
3. Because of process water leakage through O-ring seals of components in the NYX unit, a small strip of stainless steel fitted with drainage outlets was welded about the periphery of the plenum to collect leakage should it occur in the plant. The R unit was fitted in the field; the remaining units were equipped at NYS.
4. Horizontal latch slots were cut in all large plenum tubes for the component sleeve hold-down latch. Certain types of component breakage during operation would create an unbalanced hydraulic force which would expel the sleeve from the plenum tube. Hence, the latch was devised. Slots in the R tubes were milled at SRP; P, L, K and C tubes were milled at NYS.

Fabrication method improvements and progressing design created many more differences between the R, P, L and K units and the NYX prototype. The C unit design changes reflected some of the reactor design approaches explored by du Pont. The following are the major changes effected.

1. Tube pattern layout dimensions in plenum, top shield and bottom shield
2. Rod tube automatic welding
3. Plenum rod tube line-boring
4. Plenum facing at the Philadelphia Navy Yard
5. Photographic record of the plenum tube pattern
6. Improved tube-weld inspection
7. Improved cleaning procedures
8. Top shield "chimes"
9. Line-boring improvements - the adjustable base techniques
10. Modifications to the C unit including larger circulating system nozzles in the plenum and bottom shield, bottom shield cooling system, dished head for bottom of main tank, bellows type expansion ring, top shield enclosure, bearing pads, and main tank changes

These differences and modifications, along with many similar changes, are reported in the "History" prepared by New York Ship and the more interesting changes are summarized below.

TUBE PATTERN

Tube sheets of the NYX plenum, top shield, and bottom shield were all machined to a 7.021" expanded tube pattern. Welding shrinkage was expected to produce the desired 7.000" pattern. When the tubes were welded into the assemblies, the shrinkage produced patterns such that the plenum spacing (6.990") was less than that of the top shield (6.999") which in turn was less than the bottom shield spacing (7.006"). For the NYX unit this effect was corrected, after first checking this technique on the 8-ft. mock-up, by additional shrink welding applied to the shields. New expanded patterns were calculated for R and subsequent units, and new drill jigs individually sized for each assembly were made for laying out the tube sheets. The new expanded, or layout, patterns were as follows:

Plenum	7.031" —
Top Shield	7.021"
Bottom Shield	7.014"

PHOTOGRAPHIC RECORD OF PLENUM TUBE PATTERN

To obtain a record of the large tube pattern in the R, P, L, K and C plenums that would supplement the final pattern measurements made by the M & E Section inspectors, 12 photographs of the top side of each assembly were taken with a semi-fixed focus camera equipped with a special lens designed to eliminate rectilinear-distortion. Sharp-focus pictures were made under uniform lighting on Kodalithic plates in accordance with procedures developed by the Engineering Research Laboratory and evaluated experimentally on the NYX unit. Pattern measurements can be made from the developed plates under a toolmaker's microscope with the aid of 6 ft. scale photographed in each picture.

The major pattern measurements, recorded in M & E Section inspection reports, were made on the top and bottom shields as well as on the plenum chamber of each reactor, using a ligament gage to determine the location of the large tubes with respect to the X and Y axes of the weldment. Pattern measurements were made on both top and bottom side of the plenum and bottom shield assemblies but only the top side pattern was measured on the top shield assemblies.

IMPROVED TUBE-WELD INSPECTION

Weldment fabrication met required specifications by means of quality welding and vigilant inspection of tubes welded into the plenum and shield assemblies. The NYX and R units were visually inspected for such welding defects as cracks, porosity, and undercutting. Also, hydrostatic and Freon tests were made to check for leaks. After shipment of the R plenum to SRP, four leaks at welds were detected through further Freon tests. Consequently, the NYS inspection control for soundness of tube welds in the P, L, K and C units was augmented by drop-hammer tests made in accordance with the 1949 ASME Boiler Code for Unfired Pressure Vessels. In this test a 10-lb. weight was dropped from a height of two feet on the center of each tube sheet segment surrounded by a cluster of 3 large tubes while the unit was under hydrostatic pressure, and by drying the assemblies before Freon testing (as done at SRP) to remove moisture occlusions in weld faults that would prevent passage of Freon gas. In addition, visual inspection was

carried out after sandblasting of welds had cleaned the surface and enabled more accurate and easier inspection work.

C UNIT MODIFICATIONS

Design improvements were incorporated in the C reactor to allow higher power level operation and to meet thermal effects possible at that level.

The circulating system inlet and outlet nozzles were each enlarged in diameter to permit increased moderator flow. The plenum nozzles were modified by enlarging the pipe flange size from 12 in. to 16 in. and adapting the nozzle to the new pipe size; the flat flared shape and three solid diffuser vanes were retained. The bottom shield outlets were fabricated with 90° reducer ells that terminated in a 24-in. pipe size connecting with pump suction piping instead of the 20-in. diameter used for the other reactors.

To permit the use of a butt-welded joint that could be inspected fully by X-ray technique instead of a "T" joint which could not be X-ray inspected, the original design was changed to permit the C unit bottom shield to be fabricated with a flange-and-radius section of a flanged head welded to the top tube sheet of the bottom shield instead of welding the lower edge of the cylindrical bottom shield nozzle assembly directly to the top tube sheet. The revised fabrication method gave greater assurance that the weld quality would be sufficient to withstand the stresses expected at high power levels.

The C bottom shield cooling system was substantially different from the other SRP reactors. The original system distributed the cooling water in succession through the raschig ring filler, baffle openings, and the 1 inch space between the baffle and top tube sheet. Considerable by-passing of water around the 1 inch baffle space was possible through the clearances provided to permit free thermal expansion. The new system improved the top tube sheet cooling by piping about 80% of the cooling water directly into the baffle space.

In the C unit main tank and top shield enclosure a five convolution bellows-type expansion ring replaced the single step expansion joint used in the R, P, L and K units. By this modification of the main tank the bearing ring, bellows expansion joint and a shorter top shield enclosure surrounded the top shield. The expansion joint was welded in line with the lower tank section which was increased in diameter from 16-1/4 ft. in the original design to 18-1/2 ft. The revised

design also made it necessary to relocate the 12 top shield bearing pads from the bottom edge of the top shield to its periphery at a level about 6 inches below the top tube sheet.

ADDITIONS TO THE SCOPE OF WORK

Three types of equipment other than the #100 Area production reactors were made by New York Ship for the Savannah River Plant. These were the process development pile, E. P. 777M-770; five telescope actuator systems, E. P. 105-160 and 161, for use with the R, P, L, K and C reactors; and five holding racks, E. P. 105-179.1-R&P, 105-179.3-LK&C, for use with the R, P, L, K and C reactors. Fabrication of the units was performed as an addition to the original scope of work, which included only the fabrication of the reactors.

The process development pile was built in accordance with designs prepared by Voorhees, Walker, Foley and Smith under subcontract by du Pont. The unit consisted of a 16 ft. I.D. x 16 ft. deep stainless steel tank supported by a carbon steel I-beam framework, on which was mounted a stainless steel diaphragm plate with a 16-1/2 ft. diameter opening. Above the diaphragm 31 stainless steel grid beams of novel design were installed and fitted with cover plates to support and space components in the reactor. The grid beam system allowed reactor loading variations for experimental purposes.

Fabrication of the PDP was negotiated with NYS because it closely resembled the fabrication work for the #100 Area reactors, and advantage could be gained from that experience and the shop facilities provided for reactor fabrication. The work was begun in July 1952, following minor delays due to material deliveries, and was completed in January 1953.

The telescope actuator system in the SRP #100 Areas consisted of (1) the electronically controlled actuator mechanisms for lowering and raising the safety and control rods within the reactor to control the process, and (2) the telescoping tower guiding the vertical movement of the actuator equipment was designed for easy hoisting clear of the reactor room floor during precision crane discharging and charging of the reactor. The fabrication of the five telescoping towers for the R, P, L, K and C actuator systems was performed by New York Ship per the addition to Subcontract AXC 167-1/2.

The tower was a two-section carbon steel unit about 120 ft. high by 17 ft. square. The lower section (0' to 66'

level) consisted of the "forest" assembly or rigid two-deck framework fitted with safety and control rod guide tubes, a make-up deck with long vertical pipe masts at each of the four corners, and two rod-extension guide decks hung on telescoping tubes. The upper section (66' to 120' level) included a rigid two-deck framework and two telescoping rod-extension guide decks. The "forest" assembly was fitted for mounting over the plenum with the guide tubes positioned to the reactor pattern, and two latches in the make-up deck hooked onto the "forest" assembly. The tower was so designed that a hoist above the 120 ft. level could lift the lower section to the ceiling of the reactor room at the 66 ft. level by means of cables connected to the make-up plate through the four long masts. The pipe mast, by sliding through holes in the reactor room ceiling, engaged the upper section and raised it off the upper floor. The design also included means for withdrawing the rod-extensions and rods, operated by the actuator system, through holes provided in the concrete ceiling of the reactor room.

New York Ship received this work because of its general fabricating experience and its experience in fabricating to the reactor pattern tolerances which were closely related to the telescope actuator system pattern. The R unit telescoping tower was begun in August, 1952. All five towers were completed by June, 1953.

The holding rack fabrication for the R and P units was negotiated with and accepted by New York Ship when it was determined that the shop load on the original vendor's facilities would not permit him to meet delivery requirements. Fabrication was done in accordance with du Pont and American Machine & Foundry design plus approved shop changes by NYS. Much of the material for the first two units was available from du Pont on procurement done for the first vendor, and the R and P units were completed on an accelerated schedule from April through June, 1953. The remaining three units for the L, K and C Areas were fabricated in the period from July, 1953 through May, 1954.

The racks, fabricated mainly of stainless steel, consisted of a nest of 37 large and 4 rod tubes fitted into an enclosure 6 ft. deep by 7-1/2 ft. by 3-1/2 ft. that was welded to a tank 15-1/2 ft. deep by 4-1/2 ft. by 3-1/2 ft. The tube nest was filled with concrete over which molten lead was poured to form a 7-in. layer. Placed in the Building #105 reactor room floor, the rack served as a temporary storage for components handled by the precision crane during a discharging and charging cycle.

The job was well fitted to the experience New York Ship had gained in building the reactors. Fabrication of the

holding racks required the use of the tube to tube-sheet welding technique, welding-neck reaming, V-slot milling, and probe-pin stud welding as done on the reactors. In addition, the du Pont M & E Inspection group could meet most gaging requirements from equipment used on the reactors.

SECURITY

Security measures were necessary at the New York Shipbuilding Corporation plant in connection with Subcontract AXC 167-1/2 to safeguard security information and material kept at the NYX Program testing site, classified documents retained in the offices of New York Ship personnel and resident du Pont representatives, and assemblies under fabrication in the shipyard shops.

The NYX Security Office established on June 18, 1951, upon the recommendation of the Atomic Energy Commission, was responsible for the security task and performed the following duties:

1. Administered New York Shipbuilding Corporation personnel security clearances;
2. Maintained security control of the Building 10 testing area;
3. Accounted for uranium used in the NYX Program tests;
4. Maintained security watch of offices in which classified documents were used or stored; and
5. Maintained security watch of reactor assemblies and other SRP equipment under fabrication in the shops.

This office, which was discontinued on June 19, 1953, carried out these responsibilities under the general supervision of the Atomic Energy Commission, and representatives of the AEC made frequent inspections of the shipyard and the procedures in force.

The New York Ship Security Office, the shipyard's normal security organization, assumed the duties of the discontinued office in June 1953, since the Project 8980 work required only the ordinary security restrictions as practiced for regular NYS work after that date.

The security task was completed successfully with no known disclosure of security information.

PERSONNEL SECURITY CLEARANCES

The NYX Security Office during its two-year period of operation administered 487 "Q" and "QE" clearances for NYS personnel. The majority of the NYS personnel had been cleared for construction and operations work on the Building 10 testing area facilities. When the testing phase of the NYX Program had been completed and the security measures for the testing area were discontinued on May 12, 1953, many of the NYS personnel clearances were terminated. Administration of 50 outstanding clearances were transferred to the New York Shipbuilding Corporation Security Office when the NYX Security Office was closed.

Clearances of du Pont representatives or personnel of other organizations who worked at or visited New York Ship in connection with the NYX testing program were administered by the individual's own organization. The NYX Security Office was notified through the AEC of the status of these representatives, and NYX Security Office passes, identifying the holder as "cleared" for entry into the Building 10 testing area, were issued to them.

NYX PROGRAM TESTING AREA SECURITY

The Building 10 testing area was enclosed by security barricades erected in accordance with du Pont design, approved by the AEC, to provide controlled access and limited visibility of testing facilities and operations since observation of the equipment would reveal classified information. One barricade enclosed the assembly area loading operations in the southwest corner of Building 10 while construction in the Main Testing Area was being completed, and provided space for a uranium slug storage cage and accountability station. Other barricades were erected to enclose the entire testing area.

The testing area, classified as an "exclusion area" in security work, was guarded by a continuous building watch and entrance guards who permitted entry only to "cleared" personnel by means of an exchange pass system set up by the NYX Security Office.

The assembly area section was put under security control on December 15, 1951 when component loading operations began. On June 6, 1952, just prior to the initial reactor charging operation, the security control was extended to include the entire testing area. These security controls were continued until May 1953.

URANIUM ACCOUNTABILITY

Accountability for the uranium used in the NYX Program was also assigned to the NYX Security Office by the AEC. Receipt, storage, inventory and transaction records were kept and a monthly inventory report was submitted to the AEC.

Twelve shipments of uranium slugs were received at NYS, the first arriving on October 10, 1951. Storage was made in the cage in the assembly area and a continuous armed watch was maintained. The slugs were issued for reactor component loading in the assembly area, and at the direction of the AEC, a small number of slugs was supplied to the Arma Corporation and to the American Machine & Foundry Company, which were working as subcontractors to du Pont on Project 8980 work.

At the completion of the NYX Program reactor testing, disposition of the uranium slugs was made by returning the material at NYS to AEC custody. The slugs were shipped to the Savannah River Plant in eleven shipments via truck in the period from February 24 to April 29, 1953. All the uranium received by New York Ship was accounted for and the accountability station was closed.

SECURITY WATCH OF OFFICES AND SHOPS

Security watch and measures for work done outside the testing area were covered by the normal shipyard security restrictions. Plant fences, gate guards, special daytime area guards, and patrol guards at night afforded the required protection. Plant access control was carried out with the aid of a badge system. Visitors to the du Pont project work were admitted only upon approval of the du Pont project supervision. The guard force also performed daily inspections of offices outside regular hours to maintain security of classified documents stored in lock-files located in the offices.

ORGANIZATIONS

The du Pont Company and the New York Shipbuilding Corporation were the principal organizations concerned with the NYX Program and equipment fabrication on Subcontract AXC 167-1/2. Three other firms were awarded subcontracts for various phases of the work as indicated below.

Public Service Electric and Gas Company of New Jersey - Installation of temporary power facilities and furnishing of electric power.

Ralph Cornell, general contractor - Furnishing labor and material to construct most of the test facilities.

Pantano House Wrecking Company - Dismantlement and removal of the major part of the test facilities.

A number of vendors had representatives on the job at various times to supervise the installation of equipment they were furnishing.

THE DU PONT ORGANIZATION

The du Pont Engineering Department directly and through its subcontractor, New York Ship, had full responsibility for design, procurement and construction of the SRP equipment and installation of the NYX reactor with its auxiliaries and test facilities. All divisions of the Engineering Department participated in the program. The Atomic Energy Division of the Explosives Department had the responsibility for the NYX reactor test operations.

The Administration Section of the AED coordinated the engineering and contractual work for the NYX Program and the fabrication performed at New York Ship.

During the first two months of the subcontract period the Design Division carried the responsibility for all phases of the work. However, as the scope of fabrication and testing developed and the magnitude of the undertaking could be more accurately determined, responsibilities for the work were divided among the Design and Construction Division of the Engineering Department, and the Atomic Energy Division of the Explosives Department. Each division executed its normal functions.

The Design Division retained its responsibility for the design and procurement phase under the NYX Section Assistant to the Design Project Manager.

In July 1951, the Construction Division appointed a Field Project Manager as resident administrator of the fabrication work and NYX testing site construction. A Field Engineering group assisted the manager.

The Materials and Equipment Section of the Construction Division had started on the project with the Design Division and continued with coverage of inspection of work and

materials received as well as the expediting of du Pont and NYS purchase orders, the latter by NYS request. On November 2, 1953, the M & E Section Coordinator assumed responsibility for administration of fabrication work, the only subcontract work remaining after the NYX Program was completed.

The Wilmington Shops of the Engineering Department Construction Division assisted greatly in the procurement program. Fabrication of the prototype and dummy components used in the NYX reactor was handled expeditiously while these parts were undergoing necessary design developments. The Shops also made the NYX "temporary" heat exchangers and certain special tools when commercial fabricators could not meet delivery dates.

The Control Division, represented by a Control Superintendent at NYS from May 21, 1951 until completion of the subcontract, performed accounting and estimating functions with relation to Subcontract AXC 167-1/2. Procedures for purchasing, payroll accounting, and other contractual items were established by the Accounting Section. The NYS cost estimates for the original scope and additions to the subcontract were checked by the Estimating Section.

The Development Engineering Division and the Engineering Service Division participated in the design, fabrication and testing of the reactor and its auxiliaries. DED conducted special studies necessary for reactor design information and developed the reactor components together with their assembly and handling mechanisms. ESD rendered consulting services on reactor design, reactor fabrication techniques, utility contracts for the testing area, and various problems relating to the testing work.

On August 21, 1951, the Atomic Energy Division of the Explosives Department appointed a Superintendent of NYX Test Operations. Operation, technical, maintenance and service groups made up the Operating Department's organization. An Engineering Department Coordinator, assigned from the Design Division, who was aided by special assistants appointed by ERL and MDL, worked closely with the Operating Department organization to direct activity towards Engineering Department objectives. A steering committee composed of representatives of both departments determined the scope of the test program. The Operations personnel were transferred to SRP Operations upon completion of the NYX Program in May 1953.

The du Pont Company Purchasing and Traffic Departments performed in their normal capacity for the NYX Program. The Purchasing Department worked with the Design Division

Procurement group and the M & E Section in carrying out the procurement of material and equipment for the job. The Traffic Department handled the special water-borne shipment of the reactor sections to SRP.

THE NEW YORK SHIP ORGANIZATION

The New York Shipbuilding Corporation was responsible primarily for the fabrication of the reactor units and construction work in preparation of the NYX Program testing area. In conjunction with du Pont, NYS was also responsible for development of fabrication techniques which included shop design of tools, machines and fixtures. As part of the subcontract, NYS was responsible for procurement of fabrication materials and special services, furnishing security protection, and providing test operations assistance for the NYX Program.

NYS utilized practically all shipyard departments to perform its scope of contract. NYS management participated directly in the program and contributed substantially in managerial and technical assistance. The Plant Engineer directed the construction work for the Building 10 test area preparations and building restoration. A special organization under a NYX Project Manager was established in June, 1951, to administer the fabrication work and the assistance given to test operations.

Two major sub-subcontracts were awarded by NYS to expedite the construction work for Building 10. Ralph Cornell, Inc. did construction work as the major part of pre-test preparations at a cost of about \$583,000. The Pantano Wrecking Company dismantled and removed the walls, foundations, temporary buildings and craneway steel erected in Building 10. The total cost of the Pantano sub-subcontract was approximately \$39,000.

The du Pont and New York Ship organizations are outlined by organization charts, Exhibit N in the Appendix.

PROCUREMENT

Work under Subcontract AXC 167-1/2 required the procurement of a variety of materials, much of it stainless steel, as well as equipment, tools, and the sub-subcontract labor for construction, operation and restoration of the reactor testing area; fabrication of the NYX prototype and production reactors; and fabrication of actuator structures, holding racks and the process development pile. During the period

of the subcontract about 3300 purchase orders and sub-contracts valued at approximately \$7,640,000 were processed. This represented about 35 per cent of the total cost of the fabrication and testing work.

Responsibility for procurement was divided between the du Pont Engineering Department and New York Ship. Du Pont furnished equipment of both standard and special design for which installation only was required. New York Ship furnished basic materials for fabrication work, special machine tools and other tools, materials and labor for preparation and operation of the reactor testing area and services, and finally miscellaneous supplies and stores items.

Procurement procedures established by the du Pont Engineering Department governed both New York Ship and du Pont purchasing. New York Ship was guided by the "Labor and Material Accounting Procedure" prepared by the Control Division, and the du Pont Engineering Department used the "Design and Procurement Procedures".

The du Pont Engineering Department purchased materials, equipment and services on 330 orders, excluding equipment diverted from SRP purchase orders, valued at approximately \$2,660,000. New York Ship placed about 3000 separate orders with a total value of approximately \$4,980,000.

The du Pont Engineering Department and New York Ship employed their established procurement organizations to perform this function. The NYS Purchasing Department handled the shipyard purchases for Subcontract AXC 167-1/2 up to an authorization limit of \$2,000; orders above that amount and special labor contracts were processed after approval by du Pont. Du Pont procurement was done through the Design Division procurement section in conjunction with the du Pont Purchasing Department which contacted vendors and made purchases to design specifications, and with the Construction Division which handled labor contracts. The Atomic Energy Commission approved all orders in excess of \$10,000 and all orders placed for items made by NYS or du Pont.

The greatest stress during the procurement program was encountered during the early phase of the subcontract in 1951 and 1952 because completion and testing of the full-scale reactor was desired as soon as possible to derive test information necessary for the design of the production reactors. Large quantities of stainless steel for fabrication (about 240 tons per reactor), pre-machining of 2400 tubes for reactor assemblies, the special fabrication tools, and reactor testing equipment and prototypes had to be obtained

practically concurrently. Due to the extensive expediting program conducted by the du Pont Construction Division M & E Section as well as the use of the CMP priorities and allotments obtained by du Pont, reasonably good delivery was obtained on most material and equipment ordered. Relatively few items required NPA directive assistance through the Atomic Energy Commission.

The major problems centered on the (a) purchase and pre-machining of tubes for assembly into the reactor, (b) purchase or leasing of radial drills for tube-sheet hole cutting, tube boring and reaming operations, (c) development of the Airco-matic welding units and procuring welding wire, (d) fabrication by the du Pont Wilmington Shops of the reactor components and carbon steel heat exchangers used for the tests and (e) expediting the major prototypes being built on SRP purchase orders.

The first three problems have been covered by the "History" compiled by New York Ship. The Wilmington Shops was chosen to fabricate the monitor pins and reactor components because of its facilities for handling the many developmental problems and the many possible design changes. Orders for the heat exchangers for the tests were placed with the Shops because commercial fabricators could not meet the delivery required. Changes in design, modifications of fabrication methods, and the late receipt of materials delayed fabrication of these items. However, through great effort on the part of the Shops, the facilities were available for required test use. The SRP type equipment, such as the precision crane, actuator system components, one heat exchanger, and a full complement of pumps and motors, were made available for the NYX Program tests, as planned, by diverting the equipment purchased for the plant. The M & E Section and the Design Division groups interested in testing the prototype reactor auxiliaries, worked jointly in expediting the delivery of this equipment from the various vendors in time for the test operations. In spite of the great effort expended by du Pont in expediting the delivery and by NYS maintenance forces in making installations quickly after delivery, a program delay of a few months was encountered because of poor delivery.

SCHEDULES AND WORK PROGRESS

The original estimated completion date of Subcontract AXC 167-1/2, based on the Construction Division schedules for fabrication of the SRP reactors, was the fourth quarter of 1953. In August 1953, however, a revised date, the second quarter of 1954 was established to adjust for added scope items.

Reactor fabrication scheduling as of December, 1951, was as follows:

<u>Unit</u>	<u>Start of Fabrication</u>	<u>Completion</u>
NYX	*9/1/51	2/7/52
R	11/1/51	5/1/52
P	2/2/52	7/1/52
L	5/1/52	1/1/53
K	11/1/52	7/1/53
C	5/1/53	1/1/54

*Tube sheet plate preparation and layout were started July 16, 1951, and partially completed in August, 1951.

When fabrication of the actuator structures, process development pile, and the holding racks were added to the scope of work, these items were worked into a schedule to meet the requirements of the #100 Areas and the Physics Assembly Laboratory, Building #777-M.

Fabrication of the five reactors, including conversion of the NYX prototype, extended from July, 1951 through May, 1954. The actual fabrication period for each reactor and for the added scope items is listed in the following table and a chart of work progress is included in the Appendix as Exhibit O.

<u>Reactors</u>	<u>Fabrication Period</u>		<u>Elapsed Months</u>
	<u>Started</u>	<u>Completed</u>	
NYX	July 16, 1951	May 19, 1952	10
R	October 10, 1951	October 30, 1952	13
P	February 25, 1951	April 15, 1953	13-1/2
L	April 12, 1952	September 16, 1953	17
K	*November 7, 1952	October 2, 1953	11
C	**November 11, 1952	May 20, 1954	17
<u>Added Scope</u>			
E.P. 777M-770	July 1952	January 1953	7
Actuator Structures	August 1952	June 1953	11
Holding Racks			
R & P	April 1953	June 1953	3
L, K & C	July 1953	May 1954	11

*K unit tank and the tube sheets of the plenum and shields started; in April, 1953, modification of NYX plenum, top shield and bottom shield allowed transfer of this work to the C Unit.

**Work started on K was transferred to C.

The good performance was obtained even in the face of procurement delays, added development work, fabrication difficulties, labor stoppages, and extensive design changes in the C unit.

In connection with the NYX unit major delays were experienced in procurement of the pre-machined heavy wall tubes for the plenum and shield assemblies and fabrication time was lost due to the lack of large radial drills needed to meet schedules. The NYX unit fabrication schedule was also extended because development work was required in addition to establishing a fabrication procedure, namely: shrinkage welding to match tube patterns of the plenum and shields; line-reaming bottom shield tubes; and line-boring plenum tubes.

Further development was required for R unit line-boring, especially for rod tubes, and improvement of internal cleaning techniques for the tube-sheet assemblies. Inspection and repair of faulty welded-seam tubes in the bottom shield also caused a major delay.

The C unit design revised the tank expansion joint from an offset ring to a bellows arrangement. The bottom shield cooling system was re-designed also, and changes were made that increased the capacity of the process water recirculating system. These changes made it necessary to modify shop techniques and proceed carefully in performance of the work. Experience on the previous units helped New York Ship to overcome this handicap and achieve a good rate of progress permitting the C unit to be finished by May 1954.

ESTIMATES AND COSTS

ESTIMATES

Following normal practices, cost estimates of various types were prepared in connection with the subcontract with the New York Shipbuilding Corporation. They were used for negotiating the subcontract, forecasting expenditures, controlling costs and for other purposes.

The over-all estimates were prepared by the du Pont Engineering Department Estimating Section, with the assistance of New York Ship. The subcontractor furnished estimates covering his part of the work, and these were checked and incorporated in the over-all estimate by du Pont.

In March 1951, a study request was made for the reactor mock-up program on the basis of a "high-spot" estimate of \$8,000,000 prepared by the Design Division.

The Letter of Intent for entry into subcontract AXC 167-1/2, written in April 1951, contained a revised estimate of \$10,000,000 to cover the NYX Program plus fabrication of four production reactors.

After further development of the scope of work and more accurate determination of the requirements, an order-of-magnitude estimate was prepared by the du Pont Estimating Section. This estimate, dated November 7, 1951, was as follows:

	<u>Research and Development</u>	<u>Construction</u>	<u>Total</u>
Du Pont	\$2,500,000	\$ 2,400,000	\$ 4,900,000
New York Ship	<u>3,200,000</u>	<u>13,000,000</u>	<u>16,200,000</u>
	\$5,700,000	\$15,400,000	\$21,100,000

"Research and Development" covered equipment for the tests, preparation of the test area, test services and test operations by New York Ship, NYX Program development and operation by the Engineering Department and AED (Explosives Department), and related work. "Construction" included fabrication of the NYX reactor, four production reactors, and other equipment.

The "Research and Development" authorization was revised in the estimate of October, 1952, to \$6,850,000 in order to reflect costs chargeable to extended training work by AED and NYS and to include increased costs due to more detailed scope, late delivery of test equipment, and higher fabrication costs for NYX reactor components. The "Construction" estimate remained the same throughout the subcontract.

New York Ship prepared estimates covering the initial scope of work and added scope items. These estimates were accepted for the subcontract and are recapitulated as follows:

<u>Estimate Basis</u>	<u>Est. Costs</u>	<u>Fixed Fee</u>	<u>Total</u>
1. Initial Scope:			
NYX Program			
(Research and Development)	\$ 3,000,000	\$ 190,000	\$ 3,190,000
(NYX Reactor Fabrication)	3,000,000	190,000	3,190,000
Fabrication of four production reactors	<u>9,200,000</u>	<u>595,000</u>	<u>9,795,000</u>
	\$15,200,000	\$ 975,000	\$16,175,000

<u>Estimate Basis (Cont'd.)</u>	<u>Est. Costs</u>	<u>Fixed Fee</u>	<u>Total</u>
2. Physics Laboratory Reactor (E.P. 770 March 1952)	\$ 75,000	\$ 7,500	\$ 82,500
3. Actuator Structural Assemblies (November 1952)	417,500	33,400	450,900
4. Rework of "NYX" Reactor (March 1953)	812,000	72,000	884,000
5. Holding Racks - 2 units (May 1953)	104,000	8,300	112,300
6. Holding Racks - 3 units (June 1953)	<u>75,000</u>	<u>6,000</u>	<u>81,000</u>
	\$16,683,500	\$1,102,200	\$17,785,700

For each job a summary and itemized estimate detailing material, labor, overhead, and fixed-fee was presented by NYS to the du Pont Engineering Department Estimating Section for review. Estimates agreed upon by du Pont and NYS, as listed above, then were accepted by du Pont. For each job phase AEC approval was obtained for performance of the work represented by the estimate.

In the case of the actuator structural assemblies the work was begun on the basis of an estimate which was 100 per cent higher than the final estimate of \$450,900. The reduction was made when work progress after two months of fabrication allowed more complete data and indicated a revised estimate was necessary.

Estimates were made of alternative schemes for converting the NYX unit into a production reactor to determine the most economical over-all plan. The decision to convert the NYX plenum, top and bottom shields, and to fabricate a new main tank was made on the basis of these estimates.

The du Pont Estimating Section also checked the estimate of Ralph Cornell, Inc. before approval of his subcontract for preparation of the testing area. The du Pont estimate of \$490,500 was considered a reasonable verification of Cornell's \$511,979 lump-sum bid, and contract approval was granted.

The final estimate prepared by du Pont for the cost of subcontract AXC 167-1/2 and related du Pont expenditures was as follows:

	<u>Research and Development</u>	<u>Construction</u>	<u>Total</u>
Du Pont	\$2,468,000	\$ 2,509,000	\$ 4,977,000
New York Ship	<u>4,797,000</u>	<u>12,144,000</u>	<u>16,941,000</u>
	\$7,265,000	\$14,653,000	\$21,918,000

COSTS

The approximate actual cost of the NYX Program and the Savannah River Plant fabrication work as of July 31, 1954, when essentially complete, is shown below:

<u>Research and Development</u>	<u>Construction</u>	<u>Total</u>
\$7,250,000	\$14,680,000	\$21,930,000

The cost, which included both du Pont and New York Ship expenditures, exceeded the original order-of-magnitude estimate of \$21,100,000 by only 4 per cent.

Du Pont expenditures for this work amounted to approximately \$5,000,000 and NYX expenditures to \$16,930,000. These costs agreed very closely with the du Pont authorization for the project. Based on the estimates for their scope of work, New York Ship completed Subcontract AXC 167-1/2 at a cost 5% under the approved estimated total of \$17,785,700.

Factors which influenced the project cost were costly materials of construction, close tolerances for fabrication, the experimental nature of fabricating and testing the prototype reactor, the urgency for completing test operations and fabrication work, and design changes and fabrication problems.

Stainless steel and aluminum were required design materials for the reactor assemblies, the holding racks, and the process development pile in order to provide corrosion resistance and freedom from process contamination. Each of the five #100 Area reactors required approximately 240 tons of stainless steel at a total cost in excess of \$2,500,000.

The close design tolerances specified for the tube pattern, tube verticality and alignment, required welding and machining precision that was unusual in such large assemblies. Achieving this degree of precision increased

shop labor added heavily to the cost through training of personnel, detailed planning, and close supervision. Development of tube welding and tube boring methods, and meeting such special problems as shrinkage welding of the assemblies, line-reaming of bottom shield tubes, and facing of the NYX plenum (refer to the "History" prepared by New York Ship for detailed information), also influenced the cost.

Project costs were held to a minimum by cost reductions achieved throughout the fabricating and testing phases of the subcontract due to the efforts of du Pont and New York Ship. The cost reductions, in general, very nearly equaled the costs of the NYX Program and the SRP fabrication work. The savings pertained to the following project classifications:

1. Development of fabrication techniques;
2. Labor and material reductions in fabrication and construction work;
3. Testing program operation;
4. Plant maintenance reductions obtained through design changes that were corrected as a result of the test program findings; and
5. Elimination of a sixth reactor fabrication by converting the NYX prototype reactor to an SRP production unit as originally contemplated.

SHIPMENT OF REACTORS TO SRP

Barge shipment was the method chosen for transporting the reactors to the plant since clearance and weight limitations made it impractical to use rail or highway carrier. New York Ship, selected as the fabricator because it could provide access to water-borne facilities for shipping and met other criteria, had excellent dock and crane facilities on the Delaware River for handling the shipments.

Following solicitation of four shipping firms, the du Pont Construction Division, with the assistance of the Traffic Department, selected James Hughes, Inc. as the transporter. Hughes provided a 132 ft. by 50 ft. steel barge, a house trailer for the AEC couriers who accompanied each shipment, and ship-to-shore radio communications. Towing service, included in the barging contract, was supplied by McCallister Tug Company of Baltimore between Camden, N. J. and the mouth of the Savannah River; a shallow-draft tug,

used on the Savannah River, was provided by Merry Brothers. Cost per barge trip was approximately \$14,700.

Seven barge shipments were made, leaving NYS on the following dates:

<u>Shipment</u>	<u>Date</u>
1	August 2, 1952
2	November 1, 1952
3	January 15, 1953
4	April 18, 1953
5	June 3, 1953
6	October 2, 1953
7	May 20, 1954

Although the service was provided primarily for shipment of reactor assemblies, other SRP items fabricated at NYS, such as the actuator system, structural subassemblies and Bldg. #777 tank assemblies, were shipped via the barge. In addition, material used in the testing program was included in the January, April and June, 1953, loadings.

NYS was responsible for the barge loadings. Before the initial trip, NYS outfitted the barge with a heavy-timber breakwater in the bow, strengthened the underdeck framing, and welded cleats on the deck for securing the load. Loadings were planned in advance to obtain the draft and trim required for navigation in the Savannah River and during shipment the assemblies were protected against damage to machined surfaces and entry of dirt and water. Actual loadings were made in the North Yard because crane facilities were not available in the South Yard where the reactor fabrication shops were located.

Difficulty was experienced only in handling the 100-ton top and bottom shields. Rail and roadway bridges over a creek separating the North and South Yards could not support the load. The most economical solution was to recondition New York Ship's gun-turret barging system, which allowed sinking of the barge onto underwater piling adjacent to the South Yard pier, skidding the shields aboard, refloating, and towing the turret barge to the Hughes barge in the North Yard.

Barge movements were made via the Delaware River and the intracoastal waterway to provide the most protected shipping route. For security purposes, assemblies were concealed by tarpaulins during and after loading, and barge departures were kept secret. AEC carriers aboard the barge and the U.S. Coast Guard convoy and patrols maintained optimum security and safeguards against sea hazards during the 10-day trip.

DISMANTLING AND CLOSING

Closing of Subcontract AXC 167-1/2 covered the normal preparations in settling contractual commitments, reimbursement accounting, and disposal of Government-owned property and records prior to signing the contract release. Dismantling and disposition of the reactor testing and fabricating equipment and materials, restoration of the Building 10 testing area, and disposition of records required the major attention.

New York Ship dismantled and disposed of the equipment and materials in accordance with the du Pont Field Project Manager's dismantling and salvaging procedures. Disposition of items was recorded on lists maintained by the Construction Division. NYS carried out the Building 10 restoration and disposition of records per contract agreement.

Test equipment dismantling began in February, 1953, during the final stages of the NYX testing program and was accomplished by June 15, 1953. The work included unloading of the components and dismantling of the reactor, auxiliaries, instruments, and service facilities. The plenum and top shield, reinstalled in the reactor foundation for a short time to permit additional testing of the precision crane, and the SRP pump seal-testing facilities operated by the Design Division, were removed by May 14 and May 29, 1953, respectively.

Disposition of the testing equipment was made by transferring many of the items to Savannah River since they originally had been diverted from SRP purchase orders or were surplus equipment usable at the plant. The remainder was disposed of through AEC and other Governmental agencies or by outside sales.

After equipment had been removed from the testing area the Pantano Wrecking Company dismantled the temporary structures, the reactor foundation and other concrete bases, security barricades, and the precision crane steel erected by Ralph Cornell, Inc. in Building 10. The work was

performed under a lump sum subcontract in the amount of \$39,060, the lowest bid submitted. The job was started June 15 and completed on August 12, 1953.

Following the demolition work, NYS restored the buildings as per subcontract agreement by repairing the walls, floors and structural steel and relocating original building equipment. Because dismantling cost exceeded salvage value the following facilities were left in the "as is" condition upon agreement of AEC, New York Ship and du Pont: (1) the Bldg. 5 barricade, (2) the river water pump house, (3) offices and enclosures modified or built in existing buildings, (4) a re-routed sewer, and (5) underground river water concrete pipelines.

As the last unit, the C reactor, was being built, disposition was arranged for fabrication tools and equipment, and excess material. Leased tools were returned to the owners and NYS tools released for other use. The Government-owned equipment was offered for transfer to SRP Construction, SRP Operations, AEC or other Governmental agencies, and for outside sale, in that order. Disposition is recorded in the Project 8980 files.

Disposition of NYX Project records in the possession of New York Ship or in the du Pont offices at NYS was made under terms of the subcontract, covering:

1. AEC property, or technical records and classified documents, to be delivered to du Pont as AEC custodian, or destroyed as directed, and
2. NYS property, or all other records, to be preserved for five years after subcontract settlement or disposed per agreement of the AEC and New York Ship.

Early in 1954, New York Ship and the du Pont Construction offices inventoried records in their possession at du Pont's request. The Control Division reviewed the NYS list and resolved the proper disposition for all documents. A master file of Government-owned records was then transferred to the Savannah River Plant vault, Chief Supervisor of Records, and NYS-owned records were stored at their plant. The closeout of records by New York Ship under Subcontract AXC 167-1/2 was accepted as complete by the du Pont Control Division and Savannah River Plant on August 30, 1954.

CHRONOLOGY OF EVENTS

<u>Date</u>	<u>Event</u>
March 16, 1951	#100 Area Mock-up Tests programed
April 20	NYX Program accepted by AED
April 25	Du Pont entered into subcontract with New York Ship
June 18	Started fabrication of Eight Foot Mock-up
July 9	Scope of Work for NYX Program issued
July 11	Construction Division FPM assigned to NYS
July 16	NYX Unit fabrication began
August 2	Bldg. 10 testing area preparation began
August 21	AED accepted managership of NYX Program operations
October 10	R Unit fabrication started
February 25, 1952	NYX Program scope of test work issued
February 25	P Unit fabrication started
April 12	L Unit fabrication started
May 8	Bldg. 10 ready for initial test operations
May 20	NYX Unit fabrication completed
May 21	NYX Unit installed in Bldg. 10; reactor flush-out and start-up trials began
June 6	1/6 loading of NYX unit started in preparation for reactor tests
June 6	Bldg. 10 "exclusion area" security restrictions in force
June 20	Post start-up test preparations started with installation of precision crane for floor level trials

CHRONOLOGY OF EVENTS

<u>Date</u>	<u>Event</u>
August 2	Barge shipment No. 1: R Tank and Bottom Shield
November 1	Barge shipment No. 2: R Plenum and Top Shield
February 15, 1953	Dismantling of test equipment began
April 9	NYX Unit conversion to K unit began
April 15	P Unit fabrication completed
April 20	Fabrication of fifth reactor, C unit, began
May 2	NYX Program tests completed
May 12	Bldg. 10 security restrictions removed
August 12	Dismantling of test area facilities completed
September 16	L Unit fabrication completed
October 2	NYX Unit conversion to K unit completed
May 20, 1954	C Unit and all other fabrication completed
May 20	Final Barge Shipment
August 13	Du Pont personnel vacated NYS offices
August 30	Close-out of AEC records at NYS completed

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DRAWING SUMMARY

In designing the #100 Areas it was necessary to prepare thousands of drawings and specifications for equipment procurement and field construction. Since many buildings are essentially duplicates in the five areas it was possible to reproduce many original tracings and issue linen reproductions with minor revisions for construction use in other #100 Areas. The procedure was economical and yet permitted separate drawings to be prepared for each area. This was highly desirable since changes occurring in one area could be noted on those tracings, avoiding the confusion that might have resulted if revisions covering several areas had been recorded on a single set of tracings. Detail drawings for pieces of equipment common to all areas were not reproduced and issued separately for each area. Experience had shown that revisions after installation were relatively few and easily identified.

The following tabulation represents the number of drawings issued for the five areas by the Design Division or its subcontractors. Drawings made for NYX were, to a large extent, used for SRP where suitable and are included in the tabulation.

The bulk of the mechanical drawings listed were made initially by the American Machine & Foundry Company. They were, however, issued by the du Pont Design Division to Construction, and all equipment procurement other than prototype from the drawings was executed by the Du Pont Design Division.

#100 AREA DRAWINGS

TO 1/1/55

	<u>Process</u>	<u>Mech.</u>	<u>Power</u>	<u>H&V</u>	<u>Elec.</u>	<u>Inst.</u>	<u>A&C</u>	<u>Total</u>
R	823	4,128	400	60	560	340	409	6,720
P	843	4,039	391	58	554	349	418	6,652
L	716	3,295	368	66	585	331	565	5,926
K	734	3,242	351	65	577	330	570	5,869
C	792	3,236	288	66	527	305	759	5,973
NYX	130	99	-	-	4	54	23	310
Total	4,038	18,039	1,798	315	2,807	1,709	2,744	31,450

PROCUREMENT SUMMARY

The procurement of equipment by the Design Division and its subcontractors represented a major undertaking. Where possible, equipment was ordered for all five areas at one time, but in a number of cases this was not possible. The attached tabulation is, therefore, an "area-order" tabulation and the 9753 total does not mean that many separate orders. For example, the number of orders for the R process section is 663 and in P is 632, but as many as 500 might have been common to both.

The tabulation of the dollar value of equipment, however, accurately represents the distribution, since dollars were allocated to the proper areas whether or not the equipment was ordered for single or multiple areas. NYX is included since much of this equipment was eventually transferred to the Savannah River Plant.

#100 AREA PURCHASE ORDERS

TO 1/1/55

<u>Area</u>	<u>Process</u>	<u>Mech.</u>	<u>Power</u>	<u>H&V</u>	<u>Elec.</u>	<u>Inst.</u>	<u>A&C</u>	<u>Total</u>
R	663	95	176	71	417	245	57	1724
P	632	110	175	66	446	253	55	1737
L	611	112	171	71	496	266	58	1785
K	603	113	134	69	501	284	57	1761
C	619	123	167	70	542	292	57	1870
NYX	192	0	8	0	12	124	0	336
Spare Parts								540
Total	3,320	553	831	347	2414	1464	284	<u>9753</u>

EXHIBIT B-2

DOLLAR VALUE
 (Thousands)-
 TO 1/1/55

<u>Area</u>	<u>Process</u>	<u>Mech.</u>	<u>Power</u>	<u>H&V</u>	<u>Elec.</u>	<u>Inst.</u>	<u>A&C</u>	<u>Total</u>
R	16,279	3,524	3,649	214	5,830	1,633	136	31,265
P	15,686	4,146	3,325	207	7,381	1,433	136	32,314
L	14,743	3,749	3,290	207	8,837	1,221	211	32,258
K	15,692	3,760	3,272	207	8,838	1,389	210	33,369
C	16,810	3,781	1,634	207	8,935	1,416	180	32,963
NYX	<u>2,480</u>	<u>-</u>	<u>27</u>	<u>-</u>	<u>30</u>	<u>118</u>	<u>-</u>	<u>2,655</u>
	81,690	18,960	15,190	1,042	39,851	7,210	873	164,824
Spare Parts								<u>1,114</u>
						Sub Total		<u>165,938</u>
All Areas - Alterations after June 1, 1954, on all du Pont and subcontractor orders placed prior to that date.								<u>319</u>
						Total		166,257

BLDG. #105 AIR FLOW QUANTITIES, TEMP. LIMITATIONS AND RELATIVE AREA PRESSURES

ROOM OR AREA	CFM	AIR SOURCE & CFM	RATE OF CHANGE	TEMP. IN DEG. F.	TEMP. OUT DEG. F.	TEMP. LIMIT	AUXILIARY FANS	RELATIVE PRESSURE
<u>BLDG. #105-R&P</u> <u>PUMP RM. PATTERN</u>								
Motor Room	94,500	-40' Deepwell	1.1 Min.	96-1/2	101-1/2	5 Deg. F.	12 Vaneaxial	Positive
HX Room	107,700	-20' Level 5,000 BL-6 Corridor 1,700 BR-6 Corridor 3,400 Motor Room 82,000 Hor. Stg. Tank 13,000 Valve Pit 2,600	11.2 Min.	102	109-1/2			Negative
Pump Room	107,700	Pump Room	1.06 Min.	109-1/2	115-1/2			Negative
-20' Area	5,000	-40' Deepwell	6.6 Min.	96-1/2	101			Positive
-40' Sup. Fan Rm.	6,000	-40' Deepwell	26 Min.	96-1/2	103-1/2			Positive
-40' Exh. Fan Rms.	6,000	-40' Deepwell	12 Min.	96-1/2	110			Positive
-40' Seal Pump Rm.	2,000	-40' Deepwell	2.5 Min.	96-1/2	101-1/2			Positive
Transmitter Rm.	4,000	-40' Deepwell	4.8 Min.	60	82			Positive - Pump Rm. Negative - Fan Rm.
Corridor SE	1,700	-40' Deepwell	9 Min.	96-1/2	101-1/2			Positive
Corridor SW	3,400	-40' Deepwell	10.7 Min.	96-1/2	101-1/2			Positive
Corridor NE	5,000	-40' Deepwell	4.5 Min.	96-1/2	101-1/2			Positive
Corridor NW	8,000	-40' Deepwell	4.2 Min.	96-1/2	101-1/2			Positive

EXHIBIT C-1

ROOM OR AREA	CFM	AIR SOURCE & CFM	RATE OF CHANGE	TEMP. IN DEG. F.	TEMP. OUT DEG. F.	TEMP. LIMIT	AUXILIARY FANS	RELATIVE PRESSURE
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BLDG. #105-R&P (CONT'D)

Horiz. Tank	13,000	BL-2, BR-2 Corridors	9.6 Min.	101-1/2	105		Yes	Negative
Valve Pit	2,600	BR-2, & East Corridors	5 Min.	101-1/2	104			Negative
Circ. Pump Rm.	1,300	BR-2, & East Corridors	1.9 Min.	101-1/2	104			Negative

MAIN TANK ROOM PATTERN

Main Tank Rm. & Crane Wash Area	118,760	Supply Fan Rm. at +48' 97,000 Crane Repair 13,760 Final Storage 8,000	5.7 Min.	96-1/2			Not a Consid- eration	Negative
Main Tank Supply Fan Room	6,000	Main Tank Supply Fan	13.4 Min.	96-1/2	102-1/2			Positive
Main Tank Exhaust Fan Room	6,000	Main Tank Supply Fan Rm.	6.8 Min.	103	111			Negative
Actuator Room	20,000	Main Tank Supply Fan Rm.	3.9 Min.	96-1/2	105			Positive
Control Area- East		Air Conditioning Unit						Positive
Zero Level	4,400	"	3.7 Min.		(Summer Conditions 80 Deg. F., 50% R. H. Winter Conditions 70 Deg. F.			"
+15 Level	7,600	"	6.9 Min.					"

ROOM OR AREA	CFM	AIR SOURCE & CFM	RATE OF CHANGE	TEMP. IN DEG. F.	TEMP. OUT DEG. F.	TEMP. LIMIT	AUXILIARY FANS	RELATIVE PRESSURE
<u>BLDG. #105-R&P (CONT'D)</u>								
Control Area- West		Air Conditioning Unit		(Summer Conditions (80 Deg. F., 50% R. H.				Positive
Zero Level	17,000	"	5.3 Min.	(Winter Conditions (70 Deg. F.				"
+15 Level	18,550	"	4.2 Min.					"
Crane Maint.	66,200	Zero Level Fan Rm. 46,400 Transformer Rm. 16,800 +15 Fan Rm. 3,000	3.8 Min.	96-1/2	101-1/2	5 Deg. F. rise in summer		Slightly Positive
Transformer Rm.	16,800	Zero Level Fan Rm.	0.7 Min.	96-1/2	100-1/2	5 Deg. F. rise in summer		Positive
Purification Cell Area	8,000	-40 Supply Fan Rm.	3 Min.			Not a Consi- deration		
Purification Corridor & Storage Rm.	15,800	Zero Level Fan Rm.		96-1/2	105			
Purification Lab. Area	8,730	Air Cond. Unit		Summer Conditions 80 Deg. F., 50% R. H.				
Purif. Counting Room	1,100	Air Cond. Unit		Constant Conditions 75 Deg. F., 45% R. H.				

EXHIBIT C-3

ROOM OR AREA	CFM	AIR SOURCE & CFM	RATE OF CHANGE	TEMP. IN DEG. F.	TEMP. OUT DEG. F.	TEMP. LIMIT	AUXILIARY FAN	RELATIVE PRESSURE
<u>BLDG. #105-R</u>								
<u>Assembly Area</u>								
Unloading Area	5,000	Separate Fan	22.6 Min.	96-1/2	105		Yes	Positive
General Area	44,000	Air Cond. Unit	22.5 Min.	Summer Cond. 80 Deg. F., 50% R. H.				Positive
Test Pit	5,900	General Area	12.5 Min.	80	85		Yes	Positive
Degreaser Pit	7,000	General Area		80	85		Yes	Positive
Final Storage	8,200	General Area	20.8 Min.	80	82			Positive
<u>Disassembly Area</u>	84,600	Separate Fan Rm.	6.9 Min.	96-1/2	105	11 Deg. F. Rise		Positive
Transfer Area	7,400	General Area	16 Min.	106	110		Yes	Positive
Dry Cave	6,400	General Area	1.9 Min.	105	111		Yes	Negative

BLDG. #105-PAssembly Area

Unloading Area	5,000	General Area	17.4 Min.	96-1/2	105		Yes	Positive
General Area	29,800	Air Cond. Unit	17.8 Min.	Summer Cond. 80 Deg. F. 50% R. H.				Positive

ROOM OR AREA	CFM	AIR SOURCE & CFM	RATE OF CHANGE	TEMP. IN DEG. F.	TEMP. OUT DEG. F.	TEMP. LIMIT	AUXILIARY FANS	RELATIVE PRESSURE
<u>BLDG. #105-P (CONT'D)</u>								
Test Pit	5,900	General Area	12.5 Min.	80	85		Yes	Positive
Degrease Pit	7,000	General Area		80	85		Yes	Positive
Final Storage	8,200	General Area	20.8 Min.	80	82		Yes	Positive
<u>Disassembly Area</u>	58,400	Separate Fan Rm.	6.9 Min.	96-1/2	105	11 Deg. F. Rise		
Transfer Area	7,400	General Area	16 Min.	106	110		Yes	
Dry Cave	6,400	General Area	1.9 Min.	105	111		Yes	

BLDG. #105-L, K&C

Pump Room Pattern

Motor Room	101,300	Outside 71,400 -20 Level 29,900	1.1 Min.	96-1/2	101-1/2	5 Deg. Vaneaxial F.		Positive
HX Room	106,400	Motor Room 79,200 Pipe Tunnel 1,500 Pipe Tunnel 5,100 -40 Corridor 7,600 Scram Tank 6,500 Scram Tank 6,500	3.4 Min.	102	105			Negative
Pump Room	106,400	HX Room	0.72 Min.	105	111			Negative

EXHIBIT C-5

ROOM OR AREA	CFM	AIR SOURCE & CFM	RATE OF CHANGE	TEMP. IN DEG. F.	TEMP. OUT DEG. F.	TEMP. LIMIT	AUXILIARY FANS	RELATIVE PRESSURE
<u>LDG. #105-L, K&C (CONT'D)</u>								
40 Corridor	7,600	-20 Level 5,100 Outside 2,500	3.8 Min.	96-1/2				Positive
40 Corridor	15,300	Outside 9,200 -20 Level 3,500 -20 Corridor 2,600	2.3 Min.	96-1/2	101-1/2			Positive
20 Level	40,100	Outside 32,600 Tunnel-20 along Col. BR 4,500 Tunnel-20 along Col. BL 3,000	4 Min.	96-1/2	101-1/2			Positive
20 Tunnel along Col. BR	4,500	Outside	5 Min.	96-1/2	101-1/2			Positive
20 Tunnel along Col. BL	3,000	Outside	5 Min.	96-1/2	101-1/2			Positive
transmitter Rm.	5,300	Outside	5.7 Min.	60	82			Positive
Hot Tunnel	2,000	Outside		96-1/2				Positive
transformer Rm.	12,000	Outside	2 Min.	96-1/2	100-1/2			Positive

EXHIBIT C-6

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ROOM OR AREA	CFM	AIR SOURCE & CFM	RATE OF CHANGE	TEMP. IN DEG. F.	TEMP. OUT DEG. F.	TEMP. LIMIT	AUXILIARY FANS	RELATIVE PRESSURE
<u>BLDG. #105-L,K&C (CONT'D)</u>								
<u>Main Tank Room Pattern</u>								
Main Tank Rm. & Crane Wash Area	125,000	Outside 97,000 Crane Maint. 20,000 Final Storage 8,000	4.1 Min.	96-1/2			Not a Consi- deration	Negative
Main Tank Supply Fan Room	6,000	Outside	19.8 Min.	96-1/2	102-1/2			Positive
Main Tank Ex- haust Fan Room	6,000	Supply Fan Rm.	6.8 Min.	103	111			Negative
Actuator Room	20,000	Outside	4 Min.	96-1/2	105			Positive
Control Area	28,650	Outside 6,000 Air Cond. Unit Recirculated 22,650	5 Min.	Summer Cond. 80 Deg. F. 50% R. H.				Positive
			5 Min.	Winter Cond. 70 Deg. F.				"
Personnel Area HP Offices & Lab.	2,700	Outside 800 Air Cond. Unit (Summer) Recirculated 1900 (Summer)	3.8 Min.					Positive
								"
Other Personnel Area	Summer 31,700	Outside	2-1/2 Min.	96-1/2	101-1/2			Positive

ROOM OR AREA	CFM	AIR SOURCE & CFM	RATE OF CHANGE	TEMP. IN DEG. F.	TEMP. OUT DEG. F.	TEMP. LIMIT	AUXILIARY FAN	RELATIVE PRESSURE
<u>BLDG. #105-L, K&C (CONT'D)</u>								
All Personnel Areas	Winter 18,550	Outside	5 Min.	20	70			Positive
Crane Main- tenance	62,580	Zero Level Fan Rm. 48,400 Fan Room 2,000 Transformer Rm. 11,180 Starter Rm. 1,000	3.8 Min.	96-1/2	101-1/2	5 Deg. F. rise in summer		Slightly Positive
Transformer Rm.	11,180	Zero Level Fan Rm.	1.6 Min.	96-1/2	100-1/2	5 Deg. F. rise in summer		Positive
Purification Area								
Basement	4,000	Zero Level Fan Rm.		96-1/2		Not a		
Runway	5,000	" " " "		96-1/2		Consideration		
Corridor & Stairwell	5,920	" " " "		96-1/2				
Instr. Control Rm. & Office	3,550	Air Cond. Unit		Summer Cond. 80 Deg. F. 50% R. H.				

BLDG. #105-I&KAssembly Area

Unloading Area	5,000	Separate Fan	16.5 Min.	96-1/2	105		Yes	Positive
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ROOM OR AREA	CFM	AIR SOURCE & CFM	RATE OF CHANGE	TEMP. IN DEG. F.	TEMP. OUT DEG. F.	TEMP. LIMIT	AUXILIARY FAN	RELATIVE PRESSURE
<u>BLDG. #105-L&K (CONT'D)</u>								
General Area	30,000	Air Cond. Unit	23.2 Min.	Summer Cond. 80 Deg. F. 50% R. H.				Positive
Test Pit	5,900	General Area	20 Min.	80	85		Yes	Positive
Degrease Pit	7,000	General Area	0.98 Min.	80	85		Yes	Positive
Final Storage	8,200	General Area	13.7 Min.	80	82			Positive
<u>Disassembly Area</u>	74,790	Separate Fan 47,490	4.85 Min.	96-1/2	104	11 Deg. F. Rise		Positive
		Office 300						
		Elec. Control Rm. 500						
		Rod Control Rm. 13,000						
		Crane Control Eq. Rm. 4,000						
		Transformer Rm. 9,500						
Transfer Area	7,400	General Area	18 Min.	106	110		Yes	Positive
Dry Cave	6,400	General Area	1.9 Min.	105	111		Yes	Negative
Horiz. Tank	13,000	-40 Corridor	7.6 Min.	101-1/2	105		Yes	Negative
Circ. Pump	1,300	-40 Corridor	2.7 Min.	101-1/2	104			Negative

4 OR 1	CFM	AIR SOURCE & CFM	RATE OF CHANGE	TEMP. IN DEG. F.	TEMP. OUT DEG. F.	TEMP. LIMIT	AUXILIARY FAN	RELATIVE PRESSURE
<u>3. #105-C</u>								
<u>Assembly Area</u>								
loading Area	5,000	Separate Fan	17.3 Min.	96-1/2	105		Yes	Positive
eral Area	30,000	Air Cond. Unit	19.2 Min.	Summer Cond. 80 Deg. F. 50% R. H.				Positive
t Pit	5,900	General Area	12.7 Min.	80	85		Yes	Positive
rease Pit	7,000	General Area	1.2 Min.	80	85		Yes	Positive
ual Storage	8,200	General Area	13.7 Min.	80	82			Positive
<u>Assembly Area</u>	73,800	Separate Fan 44,270 Office 500 Elec. Control Rm. 500 Rod Control Rm. 13,000 Crane Control Eq. Rm. 4,000 Transformer Rm. 11,030 Check Station 500 Elec. Shop 750 Elec. Office 270	4.2 Min.	96-1/2	104-1/2	11 Deg. F. Rise		Positive
ansfer Area	7,400	General Area	21.7 Min.	106	110		Yes	Positive
y Cave	6,400	General Area	1.9 Min.	105	111		Yes	Negative

ROOM OR AREA	CFM	AIR SOURCE & CFM	RATE OF CHANGE	TEMP. IN DEG. F.	TEMP. OUT DEG. F.	TEMP. LIMIT	AUXILIARY FAN	RELATIVE PRESSURE
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BLDG. #105-C (CONT'D)

Horiz. Tank	13,000	-40 Corridor	7.6 Min.	101-1/2	105		Yes	Negative
Circ. Pump	1,300	-40 Corridor	2.7 Min.	101-1/2	104			Negative

VENDOR SURVEY EVALUATION

<u>SELECTION FACTORS</u>	<u>BABCOCK & WILCOX</u>	<u>BALDWIN- LIMA- HAMILTON</u>	<u>COMBUSTION ENGINEERING</u>	<u>GENERAL ELECTRIC</u>	<u>M. W. KELLOGG</u>	<u>NEWPORT NEWS SHIP</u>
Date Contacted	March 9	March 23 March 29 April 5	March 5 - March 13 March 14	Telephone only	March 28	March 8
Interested	No	No	Yes	No	Yes	No
Fabrication Facilities	Good	Good	Good	(1)	Inadequate	Good
Shop Space	(1)	Adequate	Inadequate (New shop req'd)	(1)	Adequate	(1)
Shop Load & Schedule	(1)	Heavy	Heavy	(1)	Open	Heavy
Experience	(1)	Good	Good	(1)	Good	Good
Man-Power - Shop Technical	(1)	Adequate Inadequate	Inadequate Inadequate	(1)	Adequate Adequate	(1)
Mock-up Space & Facilities	(1)	Adequate	New Shop	(1)	Inadequate	(1)
Security Attainability	(1)	Adequate	Adequate	(1)	Adequate	(1)
Water-borne Shipping Facilities	Inadequate	Good	Adequate (But long route)	(1)	Good	Good
Elec. Power (Mock-up)	(1)	No	No	(1)	No	(1)

Notes: (1) Vendor not evaluated in this selection factor

(2) The SRP shop would be designed for optimum service conditions for the sole purpose of fabricating reactor assemblies

CHART (1951)

<u>NEW YORK SHIP</u>	<u>PUSEY & JONES</u>	<u>A.O. SMITH</u>	<u>S. MORGAN SMITH</u>	<u>SUN SHIP</u>	<u>WESTING- HOUSE ELECTRIC</u>	<u>SAVANNAH RIVER PLANT</u>
April 9	March 29	March 27	March 13	April 6	Telephone only	-
Yes	Yes	No	No	Yes	No	-
Good	Inadequate	(1)	Adequate	Good	(1)	New Shop
Adequate	Adequate	(1)	(1)	Adequate	(1)	New Shop
Light	Open	(1)	Heavy	Heavy	(1)	Open (2)
Good	Good	(1)	(1)	Good	(1)	(2)
		(1)	(1)		(1)	(2)
Adequate Inadequate	Adequate Inadequate			Adequate Inadequate		
Good	Adequate	(1)	(1)	Adequate	(1)	New Shop
Adequate	Adequate	(1)	(1)	Adequate	(1)	New Shop (2)
Good	Good	(1)	(1)	Good	(1)	None Req'd.
No	No	(1)	(1)	No	(1)	No (New Shop)

SUBCONTRACT AXC 167-1/2 - CONTRACT ENTRY MODIFICATIONS AND COST STATUS

<u>Contract Item</u>	<u>Effective Date</u>	<u>Nature of Modifications</u>	<u>Cost Status</u>	
Letter of Intent	4/25/51			
Formal Contract	4/25/51	Merging and superseding the Letter of Intent with fully defined subcontract.	Est. Cost	\$15,200,000
			Fixed Fee	975,000
			(Est.) Total CPFF	\$16,175,000
Modification No. 1	2/1/52	Deleting necessity for (AEC) Contracting officer's approval to pay installments of Fixed Fee.	Est. Cost	\$15,200,000
			Fixed Fee	975,000
			(Est.) Total CPFF	\$16,175,000
Modification No. 2	4/25/51	Seven items:	Est. Cost	\$15,200,000
		a. Defining scope per du Pont letters dated 12/13/51 and 5/20/52.	Fixed Fee	975,000
			(Est.) Total CPFF	\$16,175,000
		b. Estimating contract completion as fourth quarter 1953.		
		c. Clarifying contract termination clauses.		
		d. Revising indirect costs reimbursement rates and determination; adding Appendix "B" as method of determination.		
		e. Defining fee and terms of rental for South Yard.		
		f. Addition of "unallowable costs" items.		
		g. Revision of liability and actions in regard to Patents and in contract disputes.		

<u>Contract Item</u>	<u>Effective Date</u>	<u>Nature of Modification</u>	<u>Cost Status</u>	
Modification No. 3	1/11/52	Amending scope of work to add fabrication of Eq. Pc. 770; revising estimated cost and fixed fee therefor.	Est. Cost Fixed Fee (Est.) Total CPFF	\$15,275,000 982,500 \$16,257,500
Modification No. 4	12/19/52	Addition of overtime premium and shift differential pay to salary amounts on which Indirect Costs reimbursement was determined.	Est. Cost Fixed Fee (Est.) Total CPFF	\$15,275,000 982,500 \$16,257,500
Modification No. 5	3/24/53	Amending scope of work to add fabrication of 3 deck plates for #105-R actuator guide system, 5 sets of "forest structures" and deck framing; revising Est. Cost & Fixed Fee therefor. Reduction of South Yard rental fee.	Est. Cost Fixed Fee (Est.) Total CPFF	\$15,692,500 1,015,900 \$16,708,400
Modification No. 6	8/6/53	Amending scope of work to add fabrication of NYX unit conversion to K unit and five holding racks; revising Est. Cost & Fixed Fee therefor. Revising Est. Completion to 2nd quarter, 1954.	Est. Cost Fixed Fee (Est.) Total CPFF	\$16,683,500 1,102,200 \$17,785,700
Modification No. 7	4/25/51	Revising Appendix B to establish negotiated fixed percentage allowances to be paid for indirect costs and overhead expenses subsequent to April 30, 1954, so that no adjustment to conform to actual costs, as determined by audit, would be necessary per the temporary allowances used prior to this change.	Est. Cost Fixed Fee (Est.) Total	\$16,683,500 1,102,200 \$17,785,700
Modification No. 8	12/15/54	Modification of paragraph 1 of article VII increasing the installment amount payable from 90% to 99%.	Est. Cost Fixed Fee (Est.) Total	\$16,683,500 1,102,200 \$17,785,700

SUBCONTRACT AXC 167-1/2 - SCOPE OF WORK AND RELATED COSTS

<u>Scope of Work</u>	<u>Cost - Plus - Fixed - Fee</u>		
	<u>Est. Cost (Auth. Limit)</u>	<u>Fixed-Fee</u>	<u>Est. CPFF</u>
1. <u>Basic Scope</u>	\$15,200,000	\$975,000	\$16,175,000
a. Perform developmental work to establish fabricating techniques			
b. Fabricate and erect the prototype reactor			
c. Provide space, facilities, services, security requirements for NYX Program testing; restore area after completion of testing.			
d. Perform test operation services			
e. Fabricate four (4) production reactors			
f. Provide machine tools & gages, etc. necessary for work			
(The above scope outline is defined in detail per the Scope of Work Letter to NYS dated 12/13/51 and modified in the supplemental letter dated 5/20/52.)			
2. <u>Addition (Mod. No. 3)</u>			
Fabrication of Eq. Pc. 770 by NYS (Stainless steel tank (16'-2-3/4" I.D. by approx. 16'-0" high), test beams, and cover).	\$75,000	\$7,500	\$82,500
Development of specialized manufacturing techniques for work by NYS.			
Design supplied by du Pont.			
Material supplied by du Pont.			

<u>Scope of Work</u>	<u>Cost - Plus - Fixed - Fee</u>		
	<u>Est. Cost</u> <u>(Auth. Limit)</u>	<u>Fixed Fee</u>	<u>Est.</u> <u>CPFF</u>
3. <u>Addition</u> (Mod. No. 5)	\$417,500	\$33,400	\$450,900
Fabrication by NYS of:			
3 Deck plates for 105-R actuator guide system (R-1)			
5 "Forest structures and deck framing" sets (R-2) for 105-P, L, K, C and R.			
Design by du Pont			
Major materials supplied by du Pont			
4. <u>Addition</u> (Mod. No. 6)			
A. Fabrication by NYS to convert NYX unit to a production reactor (K unit). The re-work of the plenum, top shield and bottom shield (the latter extensively). Fabricate a new main tank.	\$812,000	\$72,000	\$884,000
B. Fabrication by NYS of:	\$104,000	\$ 8,300	\$112,300
2 Holding racks (Eq.Pcs. 179.1R & 179.1P)			
Purchase material by NYS for:			
5 Holding racks (except for partial procurement available from du Pont)			
Design by du Pont.			

<u>Scope of Work</u>	<u>Cost - Plus - Fixed - Fee</u>		
	<u>Est. Cost</u> <u>(Auth. Limit)</u>	<u>Fixed Fee</u>	<u>Est.</u> <u>CPFF</u>
C. Fabrication by NYS of:			
3 Holding racks (Eq.Pcs. 179.3L, 179.3K)	\$75,000	\$ 6,000	\$81,000
Design by du Pont			
TOTALS	\$16,683,500	\$1,102,200	\$17,785,700

NYI - 8-FOOT MOCK-UP

PLENUM CHAMBER

(Sheet 1 of 6)

New York Shipbuilding Corporation
Camden, New Jersey

Project 8980 - N.Y.X.

Fabrication, Welding and Inspection Procedure

PLENUM CHAMBERI Preparation of MaterialsA. Tube Sheets

1. Plane edges of individual plates for sheets to give $1/8"$ - $5/32"$ root face and 35° bevel + $2-1/2^\circ$ on both sides. Allow $1/4"$ extra width in center plate.
2. Fit plates with tight root, tacking only where necessary to obtain alignment. Fit run off tabs where necessary.
3. Weld butts with Aircomatic head, using established and approved procedures.
4. Flush welds on both sides to aid in clamping and stacking during drilling and reaming and in layout.
5. X Ray welds 100% in accordance with A.S.M.E. U68 Code Requirements. Make necessary repairs.
6. Du Pont inspector to inspect radiographs and make visual inspection of the welds.
7. Rough cut O.D. of tube sheets with stainless steel cutting torch to a 16' 10" diameter. Straighten tube sheets after cutting.
8. Layout tube sheets with sufficient reference lines based on center to center distance of 7.021" for orienting, clamping and bolting plates together and for setting tube sheets in relation to one sheet of tank bottom tube sheet which will be used as a jig for drilling.
9. Drill preliminary holes for holding sheets together and bolt securely.

PLENUM CHAMBER

(Sheet 2 of 6)

10. Rough turn O.D. of sheets to a 16' 9" diameter.
11. Drill 673 pilot holes 1-7/32" dia. through both sheets together for the 5-1/4" dia. holes using one of the previously drilled sheets from tank bottom tube sheet as a jig.
12. Ream pilot holes to 1-1/4" diameter.
13. Separate sheets and trepan holes to 5-1/4" dia. +.005" -.000. Check holes for size.
14. Chamfer 5-1/4" holes for welding, 1/8" - 5/32" deep with 45° bevel.
15. Du Pont inspectors to check up to 25% of ligaments at random.
16. Put sheets together again carefully checking alignment of the two sheets.
17. Drill 162 holes for small tubes to a finished size of 1.875" dia. + .005" -.000. Use sheet from top special tube sheet to spot location on plenum sheets. Check layout pattern of these holes before drilling.
18. Separate sheets and chamfer small tube holes for welding, 1/4" deep by 5/16" wide.
19. Drill and tap 12 holes for 1/8" N.P.T. in top sheet.
20. Drill and tap 19 holes for 1/2" 13 T.P.I. in bottom sheet.
21. Clean surface of tube sheets in way of tube welds.
22. Thoroughly degrease tube sheets.

B. Tubes

1. Turn 91 shoulder tubes to 5-1/4" O.D. + .000 -.004 leaving shoulder for supporting tube sheets. Cut ends of tubes square leaving 1/2" excess both ends of tube for overall tube length of 20-1/8".

PLENUM CHAMBER

(Sheet 3 of 6)

2. Turn 582 tubes to 5-1/4" O.D. +.000 -.004. Cut ends square leaving 1/2" excess on both ends for overall tube length of 20-1/8".
3. Rough bore all 5-1/4" tubes to 4" I.D. $\pm$ 1/64" at ends.
4. Bore recess to finished size.
5. Cut slots in all 5-1/4" tubes, holding dimension from end of tube to end of slot to $\pm$.005".
6. Cut 1/4" wide x 1/4" deep slot in top end of tubes directly over one slot as an aid during assembly.
7. Clean up edges of slots as required.
8. Make 162 pieces small tubing 11" long by 1.875" O.D. + 0 -.004" with bore to suit drawing, from 2-5/8" dia. bar.
9. Du Pont inspectors to check tubes at vendors in accordance with approved inspection procedure.
10. Cut 1/2" wide by 1" deep slots in bottom ends of tubes.
11. All tubes or tubing material to have hydrostatic test prior to assembly.
12. Degrease all tubes prior to assembly.

C. Circumferential Pipe and Nozzles

1. Form half pipe section from plate leaving excess on until assembly and excess on I.D.
2. Make up nozzle sections complete with stay bolts and baffle plates. Leave excess on I.D. after assembly. During assembly rough cut edges with torch and trim clean, 1/8" back from flame cut surface, by chipping, grinding or machining. All pieces that were hot formed to be annealed prior to assembly.
3. X Ray all butt welds 100° and make necessary repairs.

EXHIBIT H-4

PLENUM CHAMBER

(Sheet 4 of 6)

4. Du Pont inspectors to inspect radiographs and make visual inspection of welds.
5. Trim I.D. of pipe sections and nozzles either by assembling and temporarily tacking pieces to form a complete ring and machining I.D. or by chipping and grinding individual pieces.

D. Skirt Plate

1. Make up skirt plate in individual sections by welding 3 plates together using corner joints.
2. Trim skirt plate sections neat except leave excess on one end of each section for assembly.

E. Centering Tongues

1. Make up 3 centering tongues complete.

II Assembly of Plenum Chamber

1. Assemble tube sheets with all 5-1/4" dia. shoulder tubes on level platen securely bolting unit together with bolt and clamp at each shoulder tube. Take care to set tubes on proper axis and to set slots of tubes at same height by making sure ends of tubes are all at same height from platen.
2. Check tubes for verticality by means of special mandrel. Tack tubes to sheets on inside of unit. Continue the check of verticality of tubes at intervals throughout assembly and welding of unit.
3. Securely clamp circumferential handling jig around O.D. of tube sheets. This jig to hold unit rigid and keep edges of tube sheets from spreading.
4. Assemble and weld small tubes using manual Aircomatic gun. Tubes to be carefully assembled and welded in accordance with the sequence to be set up for keeping distortion to a minimum. Unit to be turned over as required to balance welding.

PLENUM CHAMBER

(Sheet 5 of 6)

5. Assemble remaining 5-1/4" dia. tubes. Tack or clamp tubes securely in place. Use alcohol and dry ice to shrink tubes for expediting assembly. Take care to set tubes on proper axis and to set tubes at proper height so that slot height is same on all tubes.
6. Weld 5-1/4" dia. tubes, using special Aircomatic tube welders, with three welders working 120° apart. Tubes to be welded in accordance with the sequence to be set up for keeping distortion to a minimum. Unit to be turned over as required to balance welding. Unit to be carefully checked on level platen during course of welding to maintain unit as flat as possible.
7. Remove circumferential handling jig from unit.
8. Turn O.D. of the tube sheets to finish size.
9. Assemble and weld half pipe sections to periphery of the unit. Balance welding to keep distortion to a minimum. Use manual Aircomatic gun.
10. X Ray the circumferential welds and make necessary repairs.
11. Du Pont Inspectors to inspect radiographs and make visual inspection of welds.
12. Prestress the unit to relieve stresses.
13. Check the unit carefully for flatness and verticality and establish the necessary datum and guide lines for machining and lining up unit.
14. Machine top and bottom ends of tubes to correct length and plane.
15. Du Pont inspectors to check unit before removing from mill.
16. Assemble and weld nozzles to periphery of the unit. Taking special care to balance welding and keep distortion to a minimum. Use manual Aircomatic guns.

EXHIBIT H-6

PLENUM CHAMBER

(Sheet 6 of 6)

17. X Ray circumferential weld and welds to half pipe sections and make necessary repairs.
18. Du Pont inspectors to inspect radiographs and make visual inspection of the welds.
19. Weld skirt plates to the plenum chamber.
20. Pressure test completed plenum chamber.
21. Line up the plenum chamber on top of top special tube sheet which has previously been set and leveled on special foundations for the line boring set up. Check alignment of small tubes carefully, as these do not bore.
22. Du Pont inspectors to check alignment along with New York Ship.
23. Locate centering tongues to maintain alignment and insure future alignment of plenum chamber to top special tube sheet.
24. Bore and finish plenum chamber to correct size, using top special tube sheet tubes to set alignment fixtures for the line boring. Hone if required. A continual check is to be kept during the line boring to insure proper alignment at all times.
25. Chamfer both ends of all 5-1/4" dia. tubes.
26. Face and chamfer top ends of small tubes.
27. Cut wedge shaped slot in top of each 5-1/4" dia. tube.
28. Du Pont inspectors to make final inspection of plenum chamber and top special tube sheet.
29. Clean completed plenum chamber.
30. Attach all 1/4" O.D. stainless steel tubings and fittings for test connections.

TOP SPECIAL TUBE SHEET

(Sheet 1 of 8)

New York Shipbuilding Corporation
Camden, New Jersey

Project 8980 - N.Y.X.

Fabrication, Welding and Inspection Procedure

TOP SPECIAL TUBE SHEETI Preparation of Material

A. Tube Sheets and Baffles

1. Plane edges of individual plates to give $1/8"$ - $5/32"$ root face and 35° bevel + $2-1/2^\circ$ on both sides. On tube sheets allow $1/4"$ extra width on center plate. On baffle and deflector center plate to be neat.
2. Fit plates with tight root, tacking only where necessary to obtain alignment. Fit run off tabs where necessary.
3. Weld butts with Aircomatic head, using established and approved procedures.
4. Flush welds on both sides to aid in clamping and stacking during drilling and reaming and in layout.
5. X Ray welds in tube sheets 100% in accordance with A.S.M.E. U 68 Code Requirements. Make necessary repairs. Baffle and deflector welds do not X Ray.
6. Du Pont inspector to inspect radiographs and make visual inspection of the welds.
7. Rough cut O.D. of tube sheets, baffle and deflector with stainless steel cutting torch as follows:

Tube Sheets - $18' 11-1/4"$ Dia. ($18' 10-1/4"$
on N.Y.X. only)
Baffle - $18' 8"$
Deflector - $18' 1-3/4"$

Straighten after cutting.

TOP SPECIAL TUBE SHEET

(Sheet 2 of 8)

8. Layout baffle with tube pattern complete enough to act as guide for setting drill jig. This layout to be on center to center distance of 7". Layout clearance slots for gussets.
9. Layout deflector with sufficient reference lines based on 7" center to center distance to orient deflector for clamping and bolting to baffle.
10. Layout tube sheets with sufficient reference lines based on expanded center to center distance of 7.021" for orienting and clamping and bolting plates together and to set tube sheets in relation to one sheet of tank bottom tube sheet which will be used as a jig for drilling.
11. Drill preliminary holes for holding sheets together and holding baffle and deflector together. Bolt tube sheets securely together.
12. Finish turn O.D. of baffle to an 18' 7" diameter.
13. Finish turn O.D. of deflector to an 18' 0-3/4" diameter.
14. Rough turn O.D. of tube sheets to an 18' 10-1/4" diameter. (18' 10" on N.Y.X. only)
15. Machine slots in baffle. Check layout after slots are cut.
16. Bolt baffle and deflector together and drill 1-7/32" pilot holes for large clearance holes, using drill jig No. J8101 on layout on baffle.
17. Separate baffle and deflector.
18. Ream pilot holes in baffle to 1-1/4" diameter.
19. Trepan holes in baffle to 5-3/4" dia. for bearing tubes and to 5-5/8" dia. for other tubes except 6 tubes at center which trepan to 5-1/8" dia.
20. Drill clearance holes in baffle for small tubes from Jig No. J8101 to a finished size of 2-1/4" dia.

TOP SPECIAL TUBE SHEET

(Sheet 3 of 8)

21. Drill and ream 18 holes for 3" diameter pipe around periphery of baffle from layout, using 7" standard layout.
22. Weld locating blocks for bottom end of 3" pipe to baffle.
23. Drill 673 pilot holes 1-7/32" dia. for 5" dia. holes in both tube sheets together using one of the previously drilled sheets from tank bottom tube sheet as a jig.
24. Ream pilot holes in sheets to 1-1/4" diameter.
25. Separate tube sheets and trepan holes to 5" dia. +.005" -.000". Check holes for size.
26. Chamfer 5" holes in tube sheets for welding, 1/8" - 5/32" deep with 45° bevel for all protruding tubes and 1/2" deep with J groove having 1/4" radius and 30° bevel for flush tubes.
27. Du Pont inspectors to check up to 25% of ligaments at random.
28. Put sheets together again, carefully checking alignment of the two sheets.
29. Drill 162 holes in the sheets for small tubes from jig No's J8101-12 and J8101-14 to a finished size of 1.625" dia. Check layout pattern of these holes before drilling.
30. Drill and ream 36 holes for 3" dia. pipe around periphery of top sheet from layout, using 7.021" expanded layout.
31. Chamfer small tube holes in tube sheets for welding, 1/4" deep by 5/16" wide.
32. Clean surface of tube sheets in way of tube welds.
33. Thoroughly degrease tube sheets.
34. Use deflector as a jig for drilling baffle in tank bottom tube sheet.

TOP SPECIAL TUBE SHEET

(Sheet 4 of 8)

35. Ream pilot holes in deflector and baffle of tank bottom tube sheet to 1-1/4" diameter.
36. Separate deflector and baffle from tank bottom tube sheet.
37. Trepan holes in deflector to 4-3/4" diameter.
38. Drill clearance holes in deflector for small tubes from Jig No. J8101 to a finished size of 1-5/8" dia.
39. Drill 8 1-1/8" holes in deflector for suspension bolts from layout.

B. Tubes

1. Turn 73 shoulder or bearing tubes to 5" O.D. +.000 -.004", leaving shoulder for supporting tube sheets. If necessary, weld a bead around tube to provide sufficient material for such shoulder. Cut ends of tube square, leaving 1/2" excess on top and 1/8" excess on bottom of tubes for overall length of 3' 11".
2. Turn 600 tubes to 5" O.D. +.000 -.004". Cut ends square, leaving 1/2" excess on top end only for over-all tube length of 3' 11-3/8".
3. Finish bore all 5" diameter tubes to, 4.385" inside dia. .005.
4. Drill 1" dia. hole in bearing tubes.
5. Cut 162 pieces 1-5/8" O.D. tubing to an overall length of 3' 4-1/4".
6. Bore 1-5/8" O.D. tubing to 1-3/16" diameter.
7. Du Pont inspectors to check tubes at vendors in accordance with approved inspection procedures.
8. Make up 36 - 3" dia. pipe complete with dummy. Drill spiral holes.
9. All tubes or tubing material to have hydrostatic test prior to assembly.
10. Degrease all tubes prior to assembly.

TOP SPECIAL TUBE SHEET

(Sheet 5 of 8)

C. Gussets

1. Make up gussets complete except leave stiffeners at outer end loose. Trim to proper height but leave 1/2" excess on outer end.

D. Wrapper Plate, Lifting Pads, Centering Groove and Misc. Material

1. Trim edges of individual wrapper plates neat and roll to proper diameter. Leave excess on one end and bevel other for welding. Cut openings for final filling of unit.
2. Lifting pads to be made up with section of wrapper plate.
3. Make up 3 centering groove assemblies complete.
4. Misc. Material to be made up neat prior to assembly.

II Assembly of Top Special Tube Sheet

1. Place bottom sheet on blocks on platen and tack gussets to it.
2. Place collars for supporting baffle and clamp in position. Position and weld 24 baffle support plates around periphery of the sheet.
3. Assemble inside baffle, sliding it down over the gussets.
4. Place shoulder tubes in place in bottom sheet.
5. Assemble top sheet, securely bolting unit together with bolt and clamp at each shoulder tube.
6. Check tubes for verticality by means of special mandrel. Tack shoulder tubes and gussets to top sheet. Tack tubes on inside of unit. Continue the check of verticality of tubes at intervals through assembly and welding of unit.

TOP SPECIAL TUBE SHEET

(Sheet 6 of 8)

7. Securely clamp circumferential handling jig around O.D. of sheets. This jig to hold unit rigid and keep edges of sheets from spreading. Provisions to be made for access to inside for welding brackets. Provision also to be made for moving and holding baffle at both top and bottom to allow access for welding.
8. Assemble and weld small tubes using manual Aircomatic gun. Tubes to be carefully assembled and welded in accordance with the sequence to be set up for keeping distortion to a minimum. Unit to be turned over as required to balance welding.
9. Weld gussets to top and bottom tube sheets, taking care to balance welding. Unit to be turned over as required to give most downhand welding. Baffle to be moved and secured to give access for welding. Put baffle in final position and weld seal bars to gussets.
10. Assemble remaining 5" dia. tubes. Clamp tubes securely in place and/or tack to underside of top sheet. Use alcohol and dry ice to shrink tubes for expediting assembly. Maintain ends of tubes at same height to expedite checking during welding.
11. Weld all 5" dia. tubes using special Aircomatic tube welders, with three welders working 120° apart. Tubes to be welded in accordance with the sequence to be set up for keeping distortion to a minimum. Unit to be turned over as required to balance welding. Unit to be carefully checked on level platen during course of welding to maintain unit as flat as possible.
12. Remove circumferential handling jig from unit.
13. Fit 3" dia. outlet pipe and weld to baffle.
14. Fit 3" dia. inlet pipe over locating block on baffle and then weld both 3" dia. pipe to top sheet.
15. Turn O.D. of sheets to finish size with end recessed for rabbited joint for welding.
16. Mill excess off end of gussets.

TOP SPECIAL TUBE SHEET

(Sheet 7 of 8)

17. Fit and weld stiffeners to outer end of gussets.
18. Fit and tack wrapper plates, working sections containing lifting pads first so that any internal weld may be done. Make sure unit is relatively clean before closing up.
19. Weld butts in wrapper plates.
20. Make circumferential wrapper welds placing unit on positioner and rotating for welding. Balance welding on both sides to keep distortion at a minimum.
21. X Ray all butts unless waived by inspector due to inaccessibility, and make necessary repairs.
22. Du Pont inspectors to inspect radiographs and make visual inspection of welds.
23. Weld gusset plates to lifting pad and top sheet.
24. Fit and weld bearing plates.
25. Prestress unit to relieve stresses.
26. Ream tubes, if necessary, to remove local distortion in way of tube welds.
27. Face or grind bottom end of 73 bearing tubes flush with sheet.
28. Check unit carefully for flatness and verticality and establish necessary datum and guide lines for machining and lining up unit.
29. Machine top ends of tubes and bearing plates to correct plane and heights.
30. Du Pont inspector to check before removing from mill.
31. Chamfer top ends of tubes.
32. Drill and tap holes in bottom sheet for suspension bolts that hold deflector.
33. Pressure test completed top special tube sheet.

TOP SPECIAL TUBE SHEET

(Sheet 8 of 8)

34. Set up and level top special tube sheet on special foundations preparatory to landing plenum chamber on it for line boring.
35. Make necessary check measurements and inspection of the top special tube sheet.
36. Land plenum chamber on top of top special tube sheet.
37. When top special tube sheet and plenum chamber are properly aligned, locate centering groove to maintain and insure future alignment.
38. After completion of line boring, clean the completed top special tube sheet.
39. Fill unit through openings in wrapper. A lifting gear sufficient to lift and turn unit to fill and check loading at 18 points on the circumference must be used.
40. Weld up filling and checking openings using patch plate or plug as specified.
41. Hang deflector on bottom of top special tube sheet.
42. Du Pont inspectors to make final inspection of top special tube sheets.
43. Make all attachments for test connections.

TANK BOTTOM TUBE SHEET

(Sheet 2 of 7)

9. Layout bottom sheet with sufficient reference lines to orient bottom plate for clamping and bolting to top plate.
10. Layout baffle with sufficient reference lines based on 7" center to center distance for orienting baffle and for setting baffle in relation to deflector from top special tube sheet which will be used as a drill jig. Layout clearance slots for gussets.
11. Drill preliminary holes for holding sheets together and holding baffle and deflector together. Bolt tube sheets securely together.
12. Rough turn O.D. of tube sheets to a 18' 9-3/4" diameter.
13. Finish turn O.D. of baffle to a 18' 6-1/2" diameter.
14. Drill 1-7/32" pilot holes for 3.94" dia. holes in both tube sheets together using drill jig No. J8101-2 on layout on top sheet. Reams holes used for indexing purposes.
15. Machine slots in baffle to clear gussets. Check layout after slots are out.
16. Drill 1-7/32" dia. pilot holes for large clearance holes in baffle using deflector plate from top special tube sheet as a jig.
17. Ream pilot holes in sheets and baffle to 1-1/4" diameter.
18. Separate sheets and trepan holes to 3.94" dia. +.005 -.000". Check holes for size.
19. Trepan clearance holes in baffle to 4-3/4" dia. for bearing tubes and to 4-9/16" dia. for other tubes except for 6 tubes around center which trepan to 4-3/16" diameter.
20. Chamfer 3.94" holes in sheets for welding, 1/8" - 5/32" deep with 45° bevel.
21. Du Pont inspector to check up to 25% of ligaments at random.

EXHIBIT H-15

TANK BOTTOM TUBE SHEET

(Sheet 1 of 7)

New York Shipbuilding Corporation
Camden, New Jersey

Project 8980 - N.Y.X.

Fabrication, Welding, and Inspection Procedure

TANK BOTTOM TUBE SHEETI Preparation of Material

A. Tube Sheets and Baffles

1. Plane edges of individual plates to give $1/8"$ - $5/32"$ root face and 35° bevel $2-1/2^\circ$ on both sides. On tube sheets allow $1/4"$ extra width on center plate. On baffle, center plate to be neat.
2. Fit plates with tight root, tacking only where necessary to obtain alignment. Fit run off tabs where necessary.
3. Weld butts with Aircomatic head using established and approved procedures.
4. Flush welds on both sides to aid in clamping and stacking during drilling and reaming and in layout.
5. X Ray welds in tube sheets 100% in accordance with A.S.M.E. U 68 Code requirements. Make necessary repairs. Baffle welds do not X Ray.
6. Du Pont inspector to inspect radiographs and make visual inspection of welds.
7. Rough out O.D. of tube sheets and baffle with stainless steel cutting torch as follows:

Tube Sheets - $18' 10-3/4"$
Baffle - $18' 7-1/2"$

Straighten tube sheets and baffle after cutting.

8. Layout tube pattern on top sheet complete enough to act as a guide setting drill jig. This layout to be on the expanded center to center distance of 7.021".

TANK BOTTOM TUBE SHEET

(Sheet 4 of 7)

E. Nozzles & Misc. Material

1. Make up top half of nozzle into an assembly. During assembly rough cut edges with torch and trim 1/8" back from flame cut surface, by chipping, grinding or machining. Any pieces that were hot formed to be annealed prior to assembly.
2. X Ray all butt welds 100% and make necessary repairs.
3. Du Pont inspector to inspect radiographs and make visual inspection of welds.
4. Make up inlet distribution chambers and outlet cups.
5. Weld bolts to split retaining ring.
6. Other Misc. Material neat.

II Assembly of Tank Bottom Tube Sheet

1. Place top sheet on slab on level blocks, top side down for assembling unit in inverted position.
2. Tack gussets to it taking care to place gussets properly with unit in inverted position.
3. Place collars for spacing inside baffle and securely clamp in place.
4. Assemble inside baffle, sliding it down over the gussets.
5. Place shoulder tubes in place.
6. Assemble bottom sheet, securely bolting unit together with bolt and clamp at each shoulder tube.
7. Check tubes for verticality by means of special mandrel. Tack shoulder tubes and gussets to bottom sheet. Tack tubes on inside of unit. Continue the check of verticality of tubes at intervals throughout assembly and welding of unit.

EXHIBIT H-17

TANK BOTTOM TUBE SHEET

(Sheet 3 of 7)

22. Clean surface of tube sheets in way of tube welds.
23. Thoroughly degrease tube sheets.

B. Tubes

1. Turn 73 shoulder tubes to 3.938" O.D. + .000 -.004" leaving shoulder for supporting tube sheets. If necessary weld a bead around tube to provide sufficient material for such shoulder. Cut ends of tube square leaving 1/2" excess on both ends of tube for overall tube length of 4' 2-1/2".
2. Turn 600 tubes to 3.938" O.D. + .000 -.004". Cut ends square leaving 1/2" excess on both ends for over-all tube length of 4' 2-1/2".
3. Bore all tubes to finish size which is stepped giving 3.25" dia. at top, 3-5/16" dia. in middle and 3.376" dia. at bottom.
4. Du Pont inspectors to check tubes at vendors in accordance with approved inspection procedures.
5. All tubes or tubing material to have hydrostatic test prior to assembly.
6. Degrease all tubes prior to assembly.

C. Gussets

1. Make up gussets complete except leave stiffeners at outer end loose. Trim to proper height but leave 1/2" excess on outer end.

D. Wrapper Plates

1. Bevel edges of individual wrapper plates neat and roll to proper diameter. Leave excess on one end and bevel other for welding.
2. Fit and weld semi-circular inlet distribution chambers and outlet cups to sections of wrapper.

EXHIBIT H-20

TANK BOTTOM TUBE SHEET

(Sheet 6 of 7)

20. Du Pont inspectors to inspect radiographs and make visual inspection of welds.
21. Plug weld 22 or 24 ga. stainless steel sheet to O.D. of baffle.
22. Fit and tack wrapper plates, making sure unit is relatively clean before closing up.
23. Weld butts in wrapper plates.
24. Make circumferential welds, placing unit on positioner and rotating for welding. Balance welding on both sides to keep distortion at a minimum.
25. X Ray all butts unless waived by inspector due to inaccessibility.
26. Du Pont inspector to inspect radiographs and make visual inspection of welds.
27. Fit and weld bearing plates to bottom sheet and miscellaneous pads to top and bottom sheets.
28. Prestress unit to relieve stresses.
29. Pilot ream tubes, if necessary, to remove local deformation in way of tube welds.
30. Drill and tap holes through pads and top and bottom sheets.
31. Check unit carefully for flatness and verticality and establish necessary datum and guide lines for machining and lining up unit.
32. Machine top and bottom ends of tubes and bearing plates to correct plane and heights.
33. Du Pont inspector to check before removing from mill.
34. Chamfer bottom ends of tubes and cut 1/16" radius groove.
35. Fit nozzles and tank sections to top sheet.
36. Weld butts first, then weld to top sheet. Weld staybolts.

TANK BOTTOM TUBE SHEET

(Sheet 5 of 7)

8. Securely clamp circumferential handling jig around O.D. of sheets. This jig to hold unit rigid and keep edges of sheets from spreading. Provisions to be made for access to inside for welding gussets. Provision also to be made for moving and holding baffle at both top and bottom to allow access for welding.
9. Weld gussets to top and bottom tube sheets, taking care to balance welding. Unit to be turned over as required to give most downhand welding. Baffle to be moved and secured to give access for welding. Put baffle in final position and weld seal bars to gussets.
10. Attach baffle to top sheet.
11. Assemble remaining 3" dia. tubes. Clamp tubes securely in place and/or tack to inside of bottom sheet. Use alcohol and dry ice to shrink tubes for expediting assembly. Maintain ends of tubes at same height to expedite checking during welding.
12. Weld all 3.94" dia. tubes, using special Aircomatic tube welders with three welders working 120° apart. Tubes to be welded in accordance with the sequence to be set up for keeping distortion to a minimum. Unit to be turned over as required to balance welding. Unit to be carefully checked on level platen during course of welding to maintain unit as flat as possible.
13. Remove circumferential handling jig from unit.
14. Turn O.D. of sheets to finish size.
15. Mill excess off end of gussets.
16. Fit and weld stiffeners to outer end of gussets.
17. Fit and weld inlet distribution chambers and outlet caps that go between gussets.
18. Weld lip that forms part of nozzle to top sheet. Grind flush.
19. X Ray butts and make necessary repairs.

TANK BOTTOM TUBE SHEET

(Sheet 7 of 7)

37. X Ray all butts and make necessary repairs.
38. Du Pont inspectors to inspect radiographs and make visual inspection of welds.
39. Pressure test completed tank bottom tube sheet.
40. Weld rod cups to top sheet.
41. Fill unit through openings in wrapper. A lifting gear sufficient to lift and turn unit to fill and check loading at 18 points on the circumference must be used.
42. Weld up filling and checking openings, using patch plate or plug as specified.
43. Test and weld half pipes to outside of wrapper.
44. Du Pont inspectors to make final inspection of tank bottom tube sheet.
45. Attach split retaining ring and split flange to bottom of tubes.

FABRICATION OF NYX REACTOR ASSEMBLIES - SUB-ASSEMBLIES

<u>Sub-assemblies</u>	<u>Plenum</u>	<u>Top Shield</u>	<u>Bottom Shield</u>	<u>Tank</u>
1. Tube sheets	x	x	x	-
2. Baffle	-	x	x	-
3. Deflector	-	x	-	-
4. Tubes	x	x	x	-
5. Nozzles and half-pipes shell sections	x	-	-	-
6. Gusset Plates	-	x	x	-
7. Wrapper (Shell) plates	-	x	x	-
8. Tube collars	-	x	x	-
9. Circulation Tubes and Spiral Dummies	-	x	-	-
10. Centering Devices	x	x	-	-
11. Water Distribution Chambers	-	-	x	-
12. Skirt Plates	x	-	-	-
13. Bearing Pads and Index Plates	-	x	x	-
14. Bottom Shield Nozzle Assemblies & Elbows	-	-	x	-
15. Nozzle Muffs	-	-	x	-
16. Circumferential Half-pipe Water Distributors	-	-	x	-
17. Split Ring and Split Flange Pin Retainers	-	-	x	-
18. Main Tank Shell	-	-	-	x
19. Bearing Ring and Expansion Joint	-	-	-	x
20. Top Shield Enclosure, Seal Ring, and Nozzles	-	-	-	x

Key: x - indicates assembly for which sub-assembly was made.
 - - None required.

EXHIBIT I-2

FABRICATION OF NYX REACTOR ASSEMBLIES - FABRICATION OPERATIONS

<u>I. Weldment Assembly Operations</u>	<u>Plenum</u>	<u>Top Shield</u>	<u>Bottom Shield</u>	<u>Tank</u>
1. Assemble and Weld Tubes, Baffles, Collars, Gussets and Tube sheets	x	x	x	-
2. Fit and Weld Circulation Tubes	-	x	-	-
3. Fit and Weld Circulation Chambers	-	-	x	-
4. Fit and Weld Half-pipe shell Sections	x	-	-	-
5. Fit and Weld Wrapper Plates	-	x	x	-
6. Fit and Weld Bearing Pads and Index Plates	-	x	x	-
7. Weld Nozzle Assembly to Bottom Shield Weldment	-	-	x	-
8. Test & Repair Welds	x	x	x	-
9. Weld expansion Ring to Bearing Ring	-	-	-	x
10. Weld Top Shield Enclosure to Bearing Ring	-	-	-	x
*11. Weld Expansion Ring on Main Tank	-	-	-	x
12. X-ray, inspect & repair	-	-	-	x
*13. Weld Tank to Nozzle Assembly of Bottom Shield	-	-	x	x
<u>II. Weldment Machining Operations and Required Operations</u>				
1. Face tubes & Bearing Pads	x	x	x	-
2. Fit and Weld Nozzles & Skirt Plates	x	-	-	-
3. Face Skirt	x	-	-	-
4. Line-bore Large Tubes (set-up on Top Shield)	x	-	-	-
5. Ream Welding Neck in Tubes	-	x	x	-
6. Line-ream Top Land of Tube Bore	-	-	x	-
7. Mill V-slots	x	-	-	-

EXHIBIT I-3

III. <u>Miscellaneous Operations</u>	<u>Plenum</u>	<u>Top Shield</u>	<u>Bottom Shield</u>	<u>Tank</u>
1. Intermediate and Final Inspections	x	x	x	x
2. Cleaning of Units	x	x	x	x
3. Loading Raschig Ring Filler	-	x	x	-
4. Misc. Equipment Installation	x	x	x	x

Key: x Indicates assembly for which operation was performed.
- Not required.

Note: * Field weld operation performed at New York Ship for
NYX unit and at Savannah River Plant in erecting
R, P, L, K and C units.

SUMMARY OF REACTOR TESTING AREA PREPARATIONSPre-Start-up Test Site PreparationsA. Building 10 ConstructionMain Testing AreaRalph Cornell Co. Work

Reactor foundation, platforms, and stairway

Process pump and motor foundations - 12 temporary and
6 SRP type

Heat Exchanger foundations and supports - 6 temporary and
1 SRP type

Deionizer System foundations and supports - Pump, heat
exchanger and drainage sump.

Crane way steel erection - "Precision Crane"

Operating & Service Bldgs. - Control Room, Operations
office, Instrument repair & Storage Shop, Photo-
graphic dark-room

Security Enclosures - North Wall & Bldg. 5 barricades,
outdoor fences

NYS Work

Reactor platforms - Increased support

Temporary Process Motor foundations - Added concrete
grout for vibra-
tion dampening

Diesel Motor and D.C. Generator foundations

Low-level Component Transfer Tower

Temporary Crane Operation Walkways

Assembly AreaRalph Cornell Co. Work

Component Loading and Unloading facilities - Platforms,
stairways, storage racks, operating fixtures, monorail
mat'l handling system

EXHIBIT J-2

Assembly AreaRalph Cornell Co. Work (Cont'd.)

Slug storage cage

Concrete runway - foil transfer truck operation

Security Enclosures - East and North Wall barricades

NYS Work

Disassembly Equipment - platform change and monorail extension

B. Test Equipment InstallationMain Testing AreaRalph Cornell Co. Work

Process Pumps and Motors - 12 temporary units.

NYS Work

NYX Reactor

Temporary Heat Exchangers

Process Water Deionization System

Process Piping

Instrumentation

Temporary Loading and Unloading Crane

Assembly Area

AMF Loading and Unloading Equipment - Loading Machine, Tipping Table, Disassembly Machine, Foil Press and Shear Machine, Final Test Station

Fork-Lift Truck with Special Mast

Slug Testing Autoclaves

C. Service Facilities

Ralph Cornell Co. Work

26.4 KV Electric Sub-station - transformers, switchgear, etc.

River Water Cooling System - Pump House, pumps, strainers, and pipe lines, etc.

NYS Work

River Water Cooling System - chlorinator

Post-Start-up Test Site Preparations (NYS Work)

A. Building 10 Construction

Main Testing Area

Control Room Modification - Precision crane console and observation window

Precision Crane-way Walkways

Assembly Area

Pump Seal Lapping and Testing Rooms

B. Test Equipment Installation

Main Testing Area

SRP Type Process Pumps and Motors with D.C. Standby Motors

SRP Type Pump Bearing Lubricators - pump & motor lubrication

SRP Type Heat Exchanger

SRP Type Diesel Motors, D.C. Generators & D.C. Switchgear

SRP Type Precision Crane System - a) low level
b) high level

C-rod and Shield Cooling Water Systems

Reactor Surge Tank System

Control and Safety Rod Actuator System (Partial only)

NYX TRAINING SEMINAR PROGRAM
Speaker, Paper, and Recording Transcript

TRANSCRIPT
DOCUMENT NO.
DPEX-404

Monday Morning - March 3, 1952

H. C. Vernon	- "Welcome to Training Seminar"	B-1998-1
C. M. Cooper	- "Welcome to E.R.L."	
H. B. Gage	- "N. Y. Shipbuilding & du Pont Co."	
A. A. Johnson	- "A.E.D. Responsibilities and Objectives"	
D. F. Boucher	- "Significance of Hydraulic and Vibration Test Program"	B-1998-2
G. E. Alves	- "Hydraulic Studies"	B-1998-3 B-1998-4

Monday Afternoon - March 3, 1952

S. E. Isakoff	- "'S' Foil Hydraulics"	B-1998-5 B-1998-6
D. D. Friel	- "Hydraulic Test Instruments"	B-1998-7
ROUND TABLE DISCUSSION		B-1998-8

Tuesday Morning - March 4, 1952

H. Worthington	- "Nuclear Reactors"	B-1998-9 B-1998-10
S. W. Blom	- "Hydraulic Test Station"	B-1998-11
R. C. Holmes	- "Vibration Studies"	B-1998-12

Tuesday Afternoon - March 4, 1952

R. C. Holmes	- "Vibration Studies"	B-1998-13
D. D. Friel	- "Vibration Test Instruments"	B-1998-14
ROUND TABLE DISCUSSION		B-1998-15

EXHIBIT K-2

TRANSCRIPT
DOCUMENT NO.
DPEX-404

Wednesday Morning - March 5, 1952

V. F. Hanson	- "Reactor Instrumentation"	B-1998-16 B-1998-17 B-1998-18
M. T. Cichelli	- "Temperature Sensing Elements"	B-1998-19

Wednesday Afternoon - March 5, 1952

J. M. Morris	- "Temperature Monitoring System"	B-1998-20
M. T. Cichelli	- "Flow Sensing Elements"	B-1998-21
J. M. Morris	- "Flow Monitoring System"	B-1998-22

ROUND TABLE DISCUSSION

Thursday Morning - March 6, 1952

H. C. Vernon	- "Leak Detector"	B-1998-23
J. G. Brewer	- "Reactor Fabrication"	
J. G. Brewer	- "Mechanical Performance of Process Equipment"	B-1998-24
C. C. Lockhart	- "S.R.P. Heat Exchanger"	
M. S. Brinn	- "Heat Exchanger Temperature Shock Tests"	B-1998-25 B-1998-26

Thursday Afternoon - March 6, 1952

J. G. Brewer	- "Process Equipment"	B-1998-27
J. C. Lynch	- "Electrical Auxiliaries"	
A. R. Furbeck	- "Orientation for Special Mechanical Devices"	
E. K. Dockstader	- "Cranes and Crane Controls"	B-1998-28
E. J. Mc Bride	- "'Q' Crane Gripper"	B-1998-29
T. P. Evans	- "'S' Foil Actuators"	
C. J. Brous	- "Loading Machine"	
C. J. Brous	- "Disassembly Machine"	B-1998-30
C. J. Brous	- "Foil Press and Shear"	
H. Little	- "Tipping Table"	B-1998-31

EXHIBIT K-3

TRANSCRIPT
DOCUMENT NO.
DPEX-404

Friday Morning - March 7, 1952

N. A. Nielson	- "Corrosion Consideration I"	B-1998-32
J. A. Collins	- "Corrosion Consideration II"	B-1998-33
J. R. Caddell	- "The Ion Exchange System"	B-1998-34
W. P. G. Hall	- "NYX Test Information to Date"	

Friday Afternoon - March 7, 1952

J. T. Kephart	- "River Pump House"	B-1998-35
A. L. Bolton	- "Building 10 Orientation"	
G. M. Homewood	- "Safety at NYX"	B-1998-36
R. H. Mc New, Jr.	- "Comments from Construction"	
F. Bond	- "Comments from Construction"	B-1998-37

ROUND TABLE DISCUSSION

NYX TESTING PROGRAMExample of Test Planning, Authorization, Performance and Reporting - Report DPXN-224

1. The scope of the NYX Testing Program included performance and leakage studies of the SRP 12" control and 20" gate motor-operated valves, 12" check valves, and the rubber-lined carbon-steel 12" and 20" gate valves (start-up substitutes) in the reactor circulation system.
2. The AED Technical Group planned and wrote summaries of the tests, which indicated broadly the purpose, program, timing and magnitude of effort, in accordance with the Testing Program scope:
 - Summary 1.8.3 - Leakage of Valves
(SRP 12" & 20", other types and sizes)
 - Summary 2.2.1 - Performance of Check Valves
 - Summary 2.2.2 - Performance of SRP Motor-Operated Valves
 - Summary 2.2.3 - Performance of Temporary NYX Valves
3. Authorization approvals were then obtained from interested parties of the AED and the Engineering Department.
4. Upon approval of the summaries, the AED Technical Group detailed the test procedures and scheduled the tests.
5. The tests were performed by the AED Operating Group under the direction of and assisted by the Technical Group. Plant operating conditions in the reactor mock-up and special bench tests simulating pressure conditions were

EXHIBIT L-2

the test methods used. The SRP motor-operated valves were subjected to life, leakage, throttling and pressure drop tests per summaries 2.2.2 and 1.8.3. The NYX 12" carbon-steel valves were tested only for throttling characteristics and pressure drop. Summary 2.2.1 was not performed since check valves were eliminated from the SRP design.

6. DPXN-224, reporting those valve tests actually performed, was written by the AED Technical Group. The report was submitted for approval of the AED and the Engineering Department, and then issued in final form as a secret document.

NYX TESTING PROGRAMNYX FINAL REPORTS

<u>Document No.</u>	<u>Title</u>
DPXN-200	Summary of NYX Test Results
DPXN-201	Reactor Hydraulics
DPXN-202	Special Elbows and Tank Outlet
DPXN-203	Flow Distribution Among External Hydraulic Systems
DPXN-204	Distribution of Flow to Fuel Tubes
DPXN-205	Disengagement of Gases
DPXN-206	Mixing of Process Water in Reactor
DPXN-207	Vibration of Reactor and External Hydraulic Systems
DPXN-208	Noise Level of External Hydraulic Systems
DPXN-209	Process Water Clean-up
DPXN-210	Corrosion, Erosion, and Wear Studies
DPXN-211	Neoprene and Nickel Linings
DPXN-212	Preliminary Testing of Hydraulic Systems
DPXN-213	Cleaning of NYX Reactor
DPXN-214	Thermal Effects on Reactor Structure
DPXN-215	Assembly and Erection of Reactor
DPXN-216	Reactor Shield Deflections
DPXN-217	Reactor Component Replacement
DPXN-218	Performance of O-Rings
DPXN-219	Leakage in NYX Reactor System
DPXN-220	NYX Reactor Components

EXHIBIT M-2

DPXN-221	NYX Temporary Pumps
DPXN-222	Byron-Jackson Pumps
DPXN-223	Motors and Generators for Byron-Jackson Pumps
DPXN-224	Valve Performance
DPXN-225	Performance of Heat Exchangers at NYX
DPXN-226	Temperature and Flow Monitor Systems
DPXN-227	Instrument Rods
DPXN-228	Measurement of Flow in External Hydraulic Systems
DPXN-229	Control Rod Actuators
DPXN-230	Safety Rod Actuators
DPXN-231	Precision Crane
DPXN-232	Component Assembly Equipment
DPXN-233	Quatr il Test Station
DPXN-234	Compon. : Disassembly Equipment
DPXN-235	Vacuum Drying of External Hydraulic Systems
DPXN-242	Summary of High Flow Tests

ENGINEERING DEPARTMENT

EXHIBIT N-1

DESIGN DIVISION100 AREA PROCESS SECTION - BUILDING 105 AND NYXDesign Project Manager - H.L. BunkerSpec. Coordinator - F. McLellan 9/53-12/53

Ass't. DPM - A.D. Duff (to 10/52 & from 9/53)
 - F. McLellan 10/52-9/53

Process Section

Process Area - Bldg. 105 - F. McLellan (to 9/53)
 A.C. Flinn (from 9/53)

H.L. Luebs 8/52-9/53

Main Tank System & Piping - Bldg. 105 - J.G. Brewer
 (from 11/50)

J.D. Cambridge 9/51-10/52
 F.C. Gersen 9/51-9/53
 A.A. Arthur (from 12/51)
 C.G. Todderud (from 10/52)
 J.E. Cronin (from 1/53)
 Otto Frank (from 4/53)
 H.G. Hey (from 11/53)
 W.N. Jones 10/51-5/52
 C.C. Bailey 8/52-10/53
 H.C. Plummer 9/52-4/53

Assembly Area - Bldg. 105 - W.H. Piper (to 3/52)
 J.T. Fay (to 8/53)
 W.N. Jones (from 8/53)

T.F. Moschetto (from 2/53)
 W.N. Jones 5/53-8/53

Disassembly Area - Bldg 105 - H.L. Luebs (to 8/52)
 M.G. Stroud (from 8/52)

NYX - A.L. Bolton (to 10/53)
 W.P.G. Hall (from 10/53)

Assistant - W.P.G. Hall 2/51-10/53

J.D. Cambridge 5/51-9/51
 A.T. Strand 5/51-9/52
 J.M. Schlotterback (from 5/51)

EXHIBIT N-2

R.W. Nolan	6/51-3/52
R.D. Barry	3/52-7/53
I.K. Steele	9/51-12/51
D.G. Tynan	9/51-12/51
M.A. Pagano	8/51-5/53
V. Spliid	8/51-11/53
A.E. Geers	6/52-10/52
N.H. Whittle	9/52-6/53
C.G. Todderud	1/52-10/52
H.C. Plummer	6/52-9/52
P.K. Bacher	7/52-12/52

Mechanical Section - AMF & ARMA Design

Technical - W.R. McKenna 4/51 to 11/53
W.P.G. Hall (from 11/53)

E.K. Dockstader	11/51 to 9/53
H.G. Hey	11/51 to 11/53
W.J. Lord	11/51 to 11/53
J.B. Medlin	3/52 to 9/53
A.T. Strand	4/52-5/53
L.R. McGuire	2/52-10/53
M. Matsen	3/51-9/51
R.D. Barry	7/53 to 9/53

Design Specialist Groups

Arch. & Civil - G.W. Dutcher, T.J. Conroy, E. Pollitt
Electrical - H.E. Houck, W.N. Livermore, J.C. Lynch
Power - C.S. Robinson, R.T. Matthews, F.L. Hunt,
J.T. Kephart
Instruments - F.H. Trapnell, P.M. Fleming, R.J. Hunn
Mech. Engineering - J.R. Boyer, R.E. Dolman, D.B. Westrom,
W.R. Heald

Engineering Service Division Consultants

Engineering Materials - J.A. Collins
Materials Handling - W.H. Bogar, G.N. Brown
Mechanical Improvement- R.W. Nolan
Maintenance - J.E. Spellman, J. Jessen

Fabrication Consultant - W.R. Heald

* Assumed responsibility for work when H. W. Gosney was transferred 8/1/53.
 ** Also Technical Inspector after November, 1953.

NYX PROJECT ORGANIZATION CHART
 DU PONT CONSTRUCTION DIVISION - FIELD CONSTRUCTION

SUPERINTENDENT: L.G. Ahrens 9/51 to 10/52
K.W. French 10/52 to 3/53
W.E. Winters 3/53 to 4/53

OPERATIONS SUPERVISOR: K.W. French 9/51 to 10/52
W.E. Winters 10/52 to 3/53

<u>Shift A</u>		<u>Shift B</u>	
J.T. Brock	4/52-11/52	W.E. Craddock	4/52-1/53
A.M. Golabek	11/52-2/53	D.H. McKinney	1/53-2/53
D.H. McKinney	2/53-4/53	R.W. Keiser	2/53-3/53
		J. Juinnies	3/53-4/53

<u>Shift C</u>		<u>Shift D</u>	
J.E. Eggert	4/52-3/53	R.W. Keiser	4/52-2/53
R.N. Morrill	3/53-4/53		

Total Shift Personnel: 43 Peak - 23
Avg. - 16

SPECIAL ASSIGNMENT: D.A. Noyes 6/52-8/52
L. Galloway 6/52-8/52

SUPERVISOR - SPECIAL ASSIGNMENT: L. Galloway 8/52-2/53
L.H. Thacker 2/53-3/53

J.E. Martin	8/52-10/52	F.J. Digney	10/52-1/53
R.G. Rech	8/52-11/52	H.T. Williams	1/53-3/53
L.H. Thacker	8/52-2/53		

TECHNICAL SUPERVISOR: A.A. Johnson 4/52 to 3/53
R.C. Holmes 3/53 to 4/53

PLANNING SUPERVISOR: R.C. Holmes 4/52 to 3/53

J. Betts	W.J. Hartin	F.J. Poss
D.R. Becker	R.W. Hinterleiter	J.E. Thompson
D.L. Button	F.B. Longtin	L. Bernath
J.G. Goessling	R.W. Metter	E.C. Bertsche
C.K. Harshbarger	R.J. Mulvihill	N.L. Spidow

EXHIBIT N-6

MAINTENANCE SUPERVISOR: N.J. Bell 4/52 to 12/52
 J.A. Mann 12/52 to 3/53
 F.C. Locke 3/53 to 4/53

J.W. Adams	4/52-10/52	F.C. Locke	8/52-3/53
B.G. Kitchen	4/52-4/53	W.P. Stewart	8/52-2/53
J.A. Mann	4/52-12/52	F.D. Pagane	10/52-3/53
A.J. Bauerlin	6/52-3/53	T.R. Herold	12/52-4/53

SERVICE SUPERVISOR: L.M. Pope 4/52 to 3/53
 L.H. Thacker 3/53 to 5/53

R.I. Kirk 4/52-11/52
 F.E. Reed 4/52-4/53

ENGINEERING DEPARTMENT COORDINATOR: A.L. Bolton 12/51 to 5/53

ASSISTANT COORDINATOR AND DESIGN: W.P.G. Hall 1/53-5/53

R.D. Barry	J.B. Medlin
A.T. Strand	A.E. Geers
M.A. Pagano	H.C. Plummer
N.H. Whittle	J.M. Schlotterback
V. Spliid	

E.R.L. : L.M. Magnor 11/52 to 4/53

M.D.L. : A.R. Furbeck 11/51 to 8/52
 F.F. Glasgow 8/52 to 4/53

NYX PROJECT ORGANIZATION CHART
NEW YORK SHIPBUILDING CORPORATION

AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910

301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

7 of 7

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7/26/94

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