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SAVANNAH RIVER PLANT

FABRICATION AND TESTING HISTORY
PROTOTYPE AND PRODUCTION UNITS

NEW YORK SHIPBUILDING CORPORATION
Camden, New Jersey

Subcontractor
For

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 NO. 8980
SUBCONTRACT NO. AXC-167-1/2

September, 1954

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MASTER

SAVANNAH RIVER PLANT

FABRICATION AND TESTING HISTORY

PROTOTYPE AND PRODUCTION UNITS

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SAVANNAH RIVER PLANT

FABRICATION AND TESTING HISTORY

PROTOTYPE AND PRODUCTION UNITS

I - INTRODUCTION

From April, 1951 to August, 1954, New York Shipbuilding Corporation carried out a subcontract with E. I. du Pont de Nemours & Company that was without parallel in the shipyard's history.

The work, designated the "NYX Project" for reasons of security, was vital to the operations of the Savannah River Plant, Aiken, S.C., which was then being designed and constructed by du Pont for the Atomic Energy Commission. It consisted of three broad parts:

1. Developmental and Experimental Work.
2. Fabrication and Testing of a Prototype Unit.
3. Fabrication of Production Units.

Five production units were ultimately built, one of them converted from the prototype. All were fabricated from stainless steel, and involved welding techniques, control of thermal distortion and tolerances never previously attempted on assemblies of comparable size.

Du Pont's technical experience and the background of New York Ship in heavy construction, particularly in the fabrication of naval gun turrets, were combined from the outset to resolve the difficult fabrication problems that occurred almost daily. Representatives of both companies worked together as a team in the shops and at supervisory levels to an unprecedented extent.

The report that follows is intended primarily to summarize New York Ship's part in the project, but also includes some of du Pont's activities since the work of the two organizations was so interrelated. Because of the scope of the program, it will not always be possible to provide detailed information, but rather to record what happened in general terms. Where the reader desires more specific data, he should refer to original plans and records, including various reports compiled during the course of the project.

II - SUBCONTRACT WITH E.I. DU PONT DE NEMOURS & COMPANY (INC.)

INITIAL CONTACT BETWEEN DU PONT AND NEW YORK SHIP

The original contact between the two companies concerning the NYX Project took place during the first week of April, 1951. Du Pont was then making a survey of plant facilities on the East Coast, and in a telephone call to the Assistant to the President of New York Ship inquired about the shipyard's ability to handle the vertical boring of nests of tube sheets approximately five feet thick.

New York Ship expressed interest in further discussions of the proposed work and a meeting was held at the shipyard shortly afterward. The outstanding facilities at New York Ship and the availability of large machine tools and handling equipment caused du Pont to make an immediate and intensive study of the shipyard as the site for the project. A decision to award the work to New York Ship followed in a few days.

NEW YORK SHIP'S ORGANIZATION, ACTIVITIES AND FACILITIES

New York Shipbuilding Corporation with main office and works at Camden, New Jersey is incorporated under the laws of the State of New York. The company was founded in 1899, and the shipyard was constructed shortly thereafter on the Delaware River in the southern part of Camden. The yard was later enlarged to occupy nearly a mile of waterfront including the mouth of Newton Creek and river frontage in Gloucester City. The plant covers an area of about 250 acres on which are located the various shipways, docks and shops. Many machine tools of large size and capacity are available, along with handling equipment for assemblies up to 300 tons in weight.

At the beginning of 1951, New York Ship had built some 247 naval and 357 merchant vessels, including battleships and aircraft carriers, with a total tonnage of more than 2.1 million, as well as many items of heavy industrial equipment and machinery.

A particularly desirable feature of the shipyard from the standpoint of the NYX Project was the availability of the southern section of the plant known as the South Yard, which was separated from the main shipyard by Newton Creek. Substantial use of this area, with facilities having a replacement value in excess of \$12,500,000, had been discontinued due to the decline in shipbuilding following World War II.

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Two adjoining structures, Buildings 3 and 10, located in the South Yard had been used for wartime naval gun turret fabrication and were almost ideally suited for the test and fabrication programs contemplated by du Pont. The buildings were large, had excellent facilities and were convenient to dock areas where units could be loaded on barges for transportation to the Savannah River Plant.

At the time of initial contract discussions, New York Ship had four shipbuilding contracts in progress and fewer than 6000 employees--both considerably below the yard's capacity. The company was therefore in a position to accept additional work, and to carry out the NYX Project without an extensive building program.

LETTER OF INTENT, FORMAL CONTRACT AND SCOPE OF WORK

LETTER OF INTENT AND SUPPLEMENTS

On April 25, 1951, du Pont authorized New York Shipbuilding Corporation by a letter of intent to proceed with the fabrication and assembling of certain equipment for the Savannah River Plant, du Pont Project No. 8980. The work was to be performed under du Pont's prime contract AT(07-2)-1 with the United States Atomic Energy Commission, effective August 1, 1950. The Letter of Intent provided for the execution of a subcontract identified as AXC-167-1/2 within 120 days, or any mutually agreed extension. It was also provided that the subcontract would be on a cost-plus-a-fixed-fee basis.

The basic Letter of Intent was amended by fourteen separate supplements, numbered 1 to 14, which successively extended its termination date to December 31, 1952. The formal subcontract was approved by the Atomic Energy Commission on December 2, 1952, making any further extension of the Letter of Intent unnecessary.

FORMAL SUBCONTRACT AND MODIFICATIONS

The formal subcontract AXC-167-1/2 between New York Ship and du Pont, although effective as of April 25, 1951, was the subject of extended negotiations concerned largely with: (1) percentage of plant burden or overhead applicable to the work, (2) amount of the fixed fee, and (3) compensation for the use of the South Yard during the test phase of the project.

In the subcontract, du Pont and New York Ship agreed that overhead was to be reimbursed on the basis of 59 per cent of the salaries and wages paid between April 1 and September 30, 1951.

NEW YORK SHIPBUILDING CORPORATION. The South Yard lies below Newton Creek (center of photograph). Buildings 3 and 10 are the large white-sided structures which form an "L" adjacent to the creek. Building 3 is parallel to the creek and Building 10 parallels the Delaware River. Building ways are at upper left.

For the period October 1, 1951, to March 31, 1952, an overhead rate of 58-1/2 per cent was agreed upon. Succeeding overhead rates were to be established by negotiation. The subcontract further established New York Ship's fixed fee at \$975,000, and the payment for the use of South Yard facilities at \$10,700 per month during the test phase of the project.

The formal subcontract was signed by New York Ship on January 3, 1952, and transmitted to the Atomic Energy Commission for approval. It was approved by the Atomic Energy Commission on December 2, 1952, and returned to New York Ship December 15, 1952.

The subcontract listed the estimated cost of the NYX Project as \$15,200,000, exclusive of fee, based on the scope of work set forth in du Pont's letter of December 13, 1951.

Seven modifications were made to the basic subcontract. Three of these extended the scope of work and resulted in an increase in the estimated cost of the project and in the fixed fee.

Modification Number 1 of February 1, 1952, deleted the requirement for the contracting officer to approve payment of installments of the fixed fee.

Modification Number 2 of June 3, 1952, was a major revision of the subcontract. It provided a new basis for the reimbursement for overhead expenses, tentatively setting the rate at 53 per cent of salaries and wages, but providing for an annual audit as of April 30th each year to determine the actual overhead costs. The audit, to be performed by independent public accountants, would be used to adjust tentative payments made during the year to agree with the actual overhead expenses. The method to be followed in determining overhead costs was made a part of the subcontract and designated Appendix B.

The modification also provided for a reduction in the amount of payment by du Pont for the use of the South Yard in the event that New York Ship made use of parts of it.

Modification Number 3, dated January 11, 1952, covered the fabrication of a stainless steel tank known as the "Physics Laboratory Tank and Grid Beam Assembly" at a fixed fee of \$7500 and an estimated cost of \$75,000. The total fee and estimated cost figures for the project then became \$982,500 and \$15,275,000 respectively.

Modification Number 4, dated December 19, 1952, provided that applicable overtime, premium and shift differential pay would be included as salaries and wages in computing the 53 per cent overhead reimbursement to New York Ship.

Modification Number 5, dated March 24, 1953, covered the fabrication of three "deck plates" for the 105-R actuator guide system and five sets of "forest structures and deck framing." The fee for this work was set at \$33,400 and the cost was estimated as \$417,500. The total fee and cost figures for the project then became \$1,015,900 and \$15,692,500 respectively. The same modification also provided for a reduction in the monthly compensation for the use of the South Yard to \$7,300 per month for period April 1 to June 30, 1952; to \$6,700 per month from July 1 to July 31, 1952; and thereafter to \$4,800 per month during the period that the South Yard facilities were used in connection with the test work. (Use of the South Yard for test work ended on August 31, 1953.)

Modification Number 6, dated August 6, 1953, covered three principal items. First, it provided for the conversion of the "NYX" Unit to the "K" Production Unit at a fee of \$72,000 and an estimated cost of \$812,000. Secondly, it provided for the fabrication of two "holding racks" and purchase of materials to fabricate a total of five racks. The fee for this work was \$8,300 and the estimated cost \$104,000. The third provision covered the fabrication of three holding racks at a fee of \$6000 and cost of \$75,000. The modification resulted in bringing the total fee to \$1,102,200 and estimated cost to \$16,683,500.

Modification Number 7 revised Sections IIA, IIB and III of Appendix B to the subcontract for the purpose of establishing negotiated fixed percentage allowances to be paid for indirect costs and overhead expenses subsequent to the date April 30, 1954. The contractual provisions prior to Modification No. 7 would have required paying a temporary percentage allowance for such costs which would later be adjusted to conform to actual costs, as determined by audit. In consideration of the fact that the expenses of making such an audit would be borne by the Government, and the nominal amount of such costs involved, it was determined to be advantageous to all parties concerned to modify the subcontract as in Modification No. 7.

SCOPE OF WORK AND ADDITIONS

The basic letter dated December 13, 1951, defining the scope of work to be performed under New York Ship's subcontract AXC-167-1/2 was written by the du Pont Engineering Department. It listed the work under six headings, the first five of which were used as the basis for cost estimating by New York Ship. The scope of work at that time was as follows:

1. Developmental Work

- a. Prepare and test reduced size section.
- b. Perform developmental work in connection with fabrication, including machining and specialized welding experiments.
- c. Train and qualify welders in specialized techniques required for "NYX" development and production work.

2. Fabrication and Erection of Prototype (First) Unit

- a. Provide necessary materials, jigs and fixtures (except such as are provided by du Pont or the Atomic Energy Commission) and fabricate the following parts: Plenum Chamber, Top Tube Sheet Assembly, Main Tank, Bottom Tube Sheet Assembly, and Process Piping.
- b. Erect Prototype Unit.

3. Test Facilities and Services

- a. Provide materials, facilities, and services (except such as are provided by du Pont or the Atomic Energy Commission) as required for testing the Prototype Unit and its auxiliaries.
- b. Construct and erect all required alterations and additions to New York Ship's facilities including barricades, foundations, platforms, crane runways, pumping station, pipe lines, and sub-station to handle 18,000 kv.-a. for testing purposes.
- c. Obtain revisions to the Public Service Electric and Gas Company distribution system to provide 18,000 kv.-a. for testing purposes.
- d. Provide all labor, supplies and equipment to comply with Atomic Energy Commission security requirements.
- e. Subsequent to completion of testing, dismantle, remove and prepare for shipment as directed, all testing facilities, including Prototype Unit. Restore New York Ship's facilities to original condition.

4. Test Operations

- a. Handle, store, and service all Atomic Energy Commission and du Pont furnished equipment, and prepare and install it for test purposes.
- b. Perform required services during testing.

5. Fabricate Four Production Units

- a. Provide necessary materials (except as are provided by du Pont or the Atomic Energy Commission) and fabricate four Production Units generally similar to the final design of the Prototype Unit; said Production Units to be prepared for shipment to the Savannah River Plant without erection or testing.

6. Machine Tools

- a. Provide necessary machine tools and gages (except as are provided by du Pont or the Atomic Energy Commission) for the work outlined above.

The estimated cost of the project, based on information available on August 27, 1951, was listed in the December 13, 1951, scope-of-work letter as \$8,487,595 for labor and \$6,696,615 for materials, or a total of \$15,184,210, not including New York Ship's fixed fee. For contract purposes, this figure was rounded to \$15,200,000.

Various modifications and additions were made to the scope of work from time to time, and were reflected later in the subcontract either by reference or modification of the contract. The principal additions to the scope of work authorized by letter prior to modification of the basic subcontract are listed below:

On May 20, 1952, a supplementary letter was written by du Pont explaining that in Item 2(a) above, Process Piping was to provide only for the Prototype Unit. In Item 5(a), New York Ship was to be responsible for loading the units on a carrier to be provided by du Pont for shipment to the Savannah River Plant. These items were considered to have been covered by the original scope of work and the letter was treated as a clarification of existing scope.

A subsequent letter from du Pont, dated June 6, 1952, authorized New York Ship to proceed with the fabrication of a stainless steel "Physics Laboratory" tank as a change in the scope of work of the subcontract.

The scope of work was again increased on August 5, 1952, when du Pont authorized New York Ship to proceed with the fabrication of three "deck plates" and four "forest structures and deck framing." A fifth "forest structure," converted from an existing obsolete structure was added to the scope of work by a du Pont letter dated January 21, 1953.

On March 23, 1953, New York Ship was authorized to add to the scope of work the fabrication of two "holding racks" and the procurement of material for the fabrication of five "holding racks." On July 16, 1953, du Pont authorized New York Ship to proceed with the fabrication of three additional "holding racks."

Other additions to the scope of work were made by direct modification of the subcontract.

FINAL COMPLETION OF CONTRACT

All equipment fabrication was completed in May, 1954, but additional time was required to dismantle temporary facilities, restore buildings to their original condition, dispose of equipment and records, and complete other miscellaneous work. Some of the du Pont Engineering Department representatives, stationed at New York Ship, remained until August 13, 1954, to assist in the closeout work. The subcontract was not formally closed until a later date.

The final cost of the subcontract was approximately \$16,940,000, including New York Ship's fee.

III - ORGANIZATIONS - FUNCTIONS AND RESPONSIBILITIES

DU PONT ORGANIZATION FOR THE NYX PROJECT

As the prime contractor with the Atomic Energy Commission, E. I. du Pont de Nemours & Company had basic responsibility for the entire Savannah River Plant program of which the NYX Project was a relatively small, though critical part. Within the du Pont organization, the Engineering and Explosives Departments were most closely associated with the project.

Du Pont provided New York Ship with essentially all design requirements during the course of the project. Much of the procurement of materials was handled by du Pont also, particularly in the areas where serious shortages existed or where government directives were needed to obtain controlled items. The various pumps, motors and other auxiliaries used in the test operations of the prototype unit were also supplied by du Pont.

ENGINEERING DEPARTMENT

Over-all execution and control of the NYX Project during the first two months of New York Ship participation was the responsibility of the 100 Area Design Project Manager. The Design Project Manager continued to have design responsibility for the duration of the project.

Beginning in July, 1951, responsibility for the construction progress of the NYX subcontract was assumed by the Construction Division of the Engineering Department, which was represented by a Field Project Manager assigned to New York Ship.

The Material and Equipment Section of the Construction Division was active at New York Ship from the beginning of the project. This section provided expediting and priority services for both du Pont and New York Ship purchase orders. In addition, in its supervision of quality control, the Material and Equipment Section provided a complete inspection service throughout the project. A great number of special gages and instruments were designed specifically for application to the NYX Project, and inspections were carried out around-the-clock by the Material and Equipment Section.

The Control Division of the Engineering Department provided services in establishing and maintaining accounting and payroll procedures at New York Ship which were acceptable to the Atomic Energy Commission. A Control Division representative was resident at the site for performing the

control function at New York Ship until the completion of the subcontract.

The local du Pont construction organization is indicated by the organization chart, included as Exhibit "A-1" in the appendix.

EXPLOSIVES DEPARTMENT

- The test operations of the "NYX" Unit in the South Yard were carried out under the direction of the "NYX Organization" of the Atomic Energy Division of du Pont's Explosives Department.

NEW YORK SHIPBUILDING CORPORATION

In its role of subcontractor to du Pont, New York Ship was responsible for accomplishing the scope of work described in Part II of this report. Relatively little design work was needed since nearly all drawings were furnished by du Pont, although some of the temporary facilities used in the test of the prototype "NYX" Unit in Building 10 in the South Yard were provided by the New York Ship plant engineer.

New York Ship's principal responsibility was in the fabrication of the various units. The development of welding and line boring techniques, the furnishing of security protection, and the procurement of a large proportion of the materials and services for the project were additional responsibilities of considerable magnitude. In performing the fabrication work the various departments of New York Ship made a number of shop drawings. These covered various jigs and fixtures, and details of parts of du Pont drawings. Some four hundred such shop drawings produced during the NYX Project were listed in catalog form and copies of the list were transmitted to du Pont for the Project files.

Nearly all of New York Ship's twenty yard departments contributed to the NYX Project in some degree. The three departments principally engaged in the work were the Welding Engineer Department, the Boiler Shop and the Machine Shop. Organization charts, Exhibits "A-2 to 4," in the appendix to this report show the shipyard organization at the beginning and at the end of the NYX Project.

Within the New York Ship organization, a special "NYX Project Mannager" office was established on June 1, 1951. The NYX Project Manager reported to the shipyard's Works Manager, and had a staff which, at its peak, consisted of eleven persons. The organization of this office is described in detail in Part VII.

OTHER ORGANIZATIONS

Aside from regular services such as utilities, cleaning, sandblasting, etc., which New York Ship regularly obtained from outside organizations in its normal course of business, three firms were awarded special sub-subcontracts in connection with the test facilities provided in Building 10.

Public Service Electric and Gas Company of New Jersey received a sub-subcontract for the installation of temporary power facilities to Building 10 at a cost of \$204,907.86. Of this amount, \$200,249.50 was subsequently refunded because most of the installed facilities could be utilized by the company.

Ralph Cornell, contractor, Woodbury, New Jersey, received contracts totaling \$583,000 for furnishing labor and materials to construct nearly all of the test facilities in Building 10.

Upon the completion of test operations in Building 10, the Pantano House Wrecking Company, Philadelphia, was awarded a contract totaling \$39,060 to demolish and remove the major part of the facilities erected by Cornell.

FORCE CHARTS

The number of persons assigned to the work at New York Ship is indicated by force charts in the appendix. Exhibit "B-1" shows the number of New York Ship personnel, and Exhibit "B-2" indicates the total force, including all groups.

IV - ORGANIZING OF JOB

INITIAL ORGANIZATIONS FOR THE PROJECT

The formal Letter of Intent from du Pont of April 25, 1951, covered in very broad terms the work to be done at New York Ship, i.e., "Fabricating and assembling certain equipment, as requested in writing by du Pont, for the 100 Area at Savannah River Plant, Aiken, S.C."

Details of the job, as permitted by the clearance status of New York Ship personnel, were covered by du Pont in an initial design and fabrication conference at New York Ship on April 24 and in a series of subsequent meetings attended by New York Ship's Welding Engineer and the superintendents of a few departments such as the Machine Shop and Boiler Shop. A study of the procurement and fabrication problems involved in the project was thus begun simultaneously with the Letter of Intent. On May 16, all superintendents and department heads were notified that the shipyard had undertaken work, (New York Ship Contract 8000) for the Atomic Energy Commission, as a subcontractor to du Pont. A broad series of New York Ship charge numbers was assigned as follows: 8001, covering work relating to the reduced scale section; 8002, covering special security work (later to include general office work); 8100 to 8590 were reserved for actual production work; and 8600 and above were to cover all material and labor charges involved in the provision of facilities for production or test.

The shipyard was able to proceed with the work through its normal departmental organization, but a growing need to coordinate the over-all project, and almost continuous developments in design, made desirable the assignment of a project manager. On June 1, 1951, an NYX Project Manager was appointed. Although not a full-time position at first, it quickly became so and supervision by an NYX Project Manager continued until the end of the subcontract.

On May 1, New York Ship instituted a limited security program for the NYX Project through its Office Services Department. Questionnaires for initial clearances were processed through this office, but in view of the extent of security work and the proposed test operations of the "NYX" Unit a separate security office was necessary. On July 18, 1951, an NYX Security Officer was appointed as discussed in Part V of this report.

The first du Pont representative assigned to the project was from the Control Division. He arrived in mid-May, 1951, and was joined within a few days by an expeditor and an

inspector from the Material and Equipment Section of the Construction Division. The du Pont representatives were given office space in the upper floors of the employment office building and the adjacent yard office building.

On July 9, a du Pont Field Project Manager was assigned, and engineers for the Building 10 test area arrived in late July and August.

Du Pont's peak construction force consisted of eleven engineers, while the Material and Equipment Section grew to twenty-three inspectors and two expeditors.

Early in 1952, the du Pont representatives moved to offices in Building 3, in the South Yard to be nearer to the construction and fabrication work.

During the operations of the "NYX" Unit in Building 10, approximately seventy-five persons from the du Pont Explosives Department were assigned to New York Ship. The operations organization was provided with office space in Building 10, and later with additional offices in Building 3.

DEVELOPMENT OF CONSTRUCTION SCHEDULES

During the first weeks of the NYX Project at New York Ship both du Pont and New York Ship directed their efforts primarily toward obtaining materials and organizing the work. While fabrication and the development of welding and machining procedures were being pushed on a priority basis, operations were performed without formal scheduling.

The need for scheduling was recognized, and as soon as preliminary fabrication steps had been developed a series of meetings was held between du Pont and New York Ship representatives in which time estimates for each fabrication step were made. Limiting items were then selected from the various estimates and the remaining work scheduled in proper sequence in the program. The first master construction schedule was issued in September, 1951, by the du Pont Field Project Manager. Subsequent construction schedules were issued from time to time as required by design changes, difficulties in procurement of materials, and fabrication difficulties that had not been anticipated in previous scheduling.

As of the end of 1951, the du Pont construction schedule was based on the following optimum dates:

<u>Unit</u>	<u>Start of Fabrication</u>	<u>Completion of Fabrication</u>
NYX	September 1, 1951	March, 1952
R	November 1, 1951	May 1, 1952
P	February 15, 1952	July 15, 1952
L	May 1, 1952	January 1, 1953
K	November 1, 1952	July 1, 1953
C	May 1, 1953	January 1, 1954

Soon after the issuance of the original schedule, regular weekly meetings began between representatives of the New York Ship departments directly concerned with fabrication, du Pont Design Division, Construction Division and occasionally representatives of the Atomic Energy Division (Explosives Department), the Engineering Research Laboratory, Engineering Service Division and the Mechanical Development Laboratory. The New York Ship NYX Project Manager began the preparation of detailed weekly fabrication schedules in December, 1951, which continued for the duration of the project. The meetings continued until April 15, 1952, when they were discontinued and replaced by a weekly scheduling meeting attended by the New York Ship fabricating departments, the du Pont Field Project Manager's staff and Material and Equipment Section representatives. The scheduling meetings continued throughout the project.

DEVELOPMENT OF CONSTRUCTION REPORTS

The du Pont Field Project Manager at New York Ship initiated a Weekly Force Report in August, 1951, which was continued until the end of the project. The report showed the number of du Pont personnel of the Construction Division, along with New York Ship and lump-sum sub-subcontractors' employees, who were engaged in the project.

Du Pont also submitted: A Weekly Activities Report, summarizing important activities and problems encountered in the preceding week; a Bi-Weekly Progress Report showing percentage of completion of the various items of the subcontract, and listing the number of visitors and the number of persons working on the project; Organization Charts showing New York Ship and du Pont staffs; Monthly Atomic Energy Commission Furniture and Fixture Tag Report; a monthly Government Vehicle Report; Monthly Safety Report; a monthly Payroll, Overtime and

Premium Time Report; and a monthly Material Premium Report, showing premium payments necessary to obtain materials that were urgently needed to complete the project.

Monthly Cost Report, showing all reimbursable costs incurred were prepared by New York Ship, and submitted by du Pont to the Atomic Energy Commission. Quarterly Wage and Salary Reports, prepared by New York Ship, were also submitted by du Pont to the Atomic Energy Commission.

DESIGN STATUS WHEN WORK WAS STARTED AT NEW YORK SHIP

The design of the prototype "NYX" Unit and the subsequent production units was still fluid at the time New York Ship undertook the project. The concept at that time called for a unit similar to the final production units except that it had no Bottom Tube Sheet Assembly and the rod tubes were positioned horizontally rather than vertically.

However, by the time actual work was begun at New York Ship, the design of the "NYX" Unit had been frozen (as of May 30, 1951). Fabrication of the tube sheets from sections of plate commenced early in July, and the center-to-center spacing of the tubes was determined later in the month from shrinkage experiments on a reduced scale mock-up (Eight-Foot Mock-Up). Design and drafting work was expedited through June, and on July 12, 1951, drawings relating to the "NYX" Unit Plenum Chamber and Top Tube Sheet Assembly were issued so that New York Ship could proceed.

PROCUREMENT STATUS WHEN WORK WAS STARTED AT NEW YORK SHIP

The major procurement requirements for the NYX Project were stainless steel plate, stainless tubing, and special fabrication tools.

Prior to selecting New York Ship as a subcontractor, du Pont had anticipated the need for stainless steel plates and obtained allotments under the Controlled Materials Program. These were applied to general mill orders placed through G. O. Carlson.

Shortly after New York Ship started work on the project, a bill of materials was provided for the "NYX" Unit so that orders could be placed at once.

Du Pont had also initiated procurement efforts for welding wire and the stainless tubing required for the Plenum and tube sheet assemblies, but the delivery situation was not satisfactory at the time work was started at New York Ship. This situation was improved in time for fabrication by directive assistance.

The procurement of fabrication tools had been initiated by du Pont prior to the start of work at New York Ship in anticipation of critical requirements for such equipment. Du Pont was engaged in development work with the Air Reduction Company to perfect the special tube welding equipment later used on all units, and with Consolidated Machine Tool Corporation in connection with special boring equipment of a capacity to handle large tube sheets; but the rest of the welding machine and machine tool procurement program was carried out jointly by du Pont and New York Ship after the beginning of the NYX Project.

V - SECURITY

POLICIES AND PROCEDURES

Security was a vital consideration during the entire NYX Project. From the very beginning of the program, the safeguarding of information and materiel was a primary objective comparable to construction of the equipment.

The security measures taken by New York Ship in connection with the NYX Project were under the general supervision of the Atomic Energy Commission. Representatives of the Commission made frequent inspections of the shipyard and the procedures of the NYX Security Office.

Access to plans and restricted data was limited to those with an actual "need to know" who had been cleared for security by the Atomic Energy Commission. The shipyard was protected by a watch force and fences, while areas in which classified NYX work was done were further screened by barriers and patrolled night and day by special armed guards. All who entered classified areas were required to present passes and be identified by guards.

During preliminary negotiations with du Pont, New York Ship could not be informed of the classified details of the NYX Project. The equipment to be built was designated simply as tube sheets and the test operation outlined only briefly. When a Letter of Intent was issued by du Pont on April 25, 1951, it became necessary to advise New York Ship personnel of classified details of the job. Personnel Security Questionnaires were made out by key personnel of New York Ship who would be the first to have access to restricted data. On May 21, 1951, the first eight individuals to be cleared met in Wilmington, Delaware, for the purpose of orientation concerning the NYX Project.

In the meantime, on May 8, 1951, representatives of the Security Division of the Atomic Energy Commission visited New York Ship and surveyed the plant. They recommended that the company establish a separate security office for the NYX Project. On June 18, 1951, New York Ship engaged Henry W. Rodney, a former U. S. Secret Service Special Agent-in-Charge, as security officer of the NYX Project.

PERSONNEL SECURITY

The first work of the NYX Security Office was the processing of Personnel Security Questionnaires for the large number of New York Ship employees who would soon require

knowledge of restricted data in order to carry out their duties. The Security Officer interviewed each one, briefed him as to security requirements, and determined whether the employee desired to be assigned to the NYX Project. Those who volunteered were then photographed, fingerprinted and processed in accordance with directives of the Atomic Energy Commission. Normally "Q" Clearances were requested. These clearances required about two and one half months for completion. When it was not possible to anticipate the need for cleared personnel and the delay would slow the NYX Project, requests were made for "QE" (Emergency) Clearance.

Clearance of du Pont representatives was administered through the du Pont organization. The Atomic Energy Commission notified the Security Office of du Pont employees cleared to work on the project, and passes were issued to them by the NYX Security Office.

An "exchange" system of passes was used for identification of cleared personnel. Such personnel were issued identification cards by the NYX Security Office. Each card contained a description of the individual, his NYX number, photograph and signature. Matching badges were kept by guards at the entrance to the restricted area and classified either as "active" or "inactive". Upon presentation of his identification card, a person whose badge was in the "active" group would be issued his badge which he was required to wear at all times in the restricted area. On his departure he would return the badge and receive his card. Special permission was required from the Security Office to admit persons who, though cleared, were not actively engaged on work in the restricted area, and whose badges were, therefore, filed in the "inactive" category.

A number of visitors representing various agencies and vendors found it necessary to visit the project. They were required to obtain advance permission from the Area Security Officer of the Atomic Energy Commission.

During the period of operations of the NYX Security Office, approximately 2850 separate visits were approved by the Atomic Energy Commission. Since numerous visits were made by the same persons, the number of individuals visiting the project was considerably smaller. Each visitor was processed by the NYX Security Office and escorted while in the restricted area. (The above does not apply to individuals who, because of frequent visits, were issued regular photographic identification passes under the "exchange" system.) Both chronological and alphabetical records were maintained of all visitors and were held by the New York Ship Security Office until disposal was authorized by the Atomic Energy Commission.

Upon the closing of the NYX Security Office with Building 10 no longer a restricted area, the exchange system was abolished and visits were handled in accordance with regular shipyard routine. Admission was controlled by the watch force at plant gates, and granted when authorized by du Pont or the NYX Project Manager.

When employment of a cleared individual was terminated or he no longer required access to classified material, his clearance was also terminated. He was interviewed by the NYX Security Officer to make certain that he turned in all papers and other classified material and was warned not to discuss any classified information he might possess. He was also required to sign a Security Termination Statement which was forwarded to the Atomic Energy Commission.

As work of a classified nature drew to a close in the spring of 1953, the number of clearances to be terminated increased sharply. With the closing of the security phase of the project in Building 10 on May 13, 1953, the NYX Security Office made personal contact with all cleared personnel, except a few whose duties would require continued access to either classified material or restricted data. NYX identification cards were recovered from employees and destroyed, as were all exchange badges used in the restricted area of Building 10. Each employee whose "Q" clearance was terminated was briefed and required to sign a Security Termination Statement.

When the NYX Security Office was closed on June 19, 1953, clearances were outstanding for 50 employees of New York Shipbuilding Corporation. During the two-year period of operations of the NYX Security Office, a total of 487 "Q" clearances were processed to completion and approval by the Atomic Energy Commission. When the NYX Security Office was closed, cognizance of outstanding clearances was transferred to the New York Ship Security Office for termination at appropriate times.

MATERIEL SECURITY

During the early stages of the NYX Project, materiel security measures were concerned chiefly with blueprints and documents. Safes and combination lock cabinets were provided for storage of such materials. Outside of regular working hours, guards made hourly checks of all such safes and cabinets.

As fabrication of the process units proceeded, it became necessary to store uranium at the shipyard for use in tests of the "NYX" Unit which was to be assembled in Building

10 in the South Yard. Accordingly, a wire cage approximately 48 ft. long was built in the southwest corner of the building and, after inspection and approval by Atomic Energy Commission representatives, was established as a restricted area on October 10, 1951. When the first shipment of uranium arrived shortly thereafter from Oak Ridge, Tennessee, it was stored in the cage and a continuous armed watch was posted.

The restricted area was enlarged on December 15, 1951, to include the uranium cage and an additional 8200 sq. ft. to be used in uranium loading operations. This area was surrounded by a cinder block wall, topped with composition panels. The restricted area was further enlarged on June 6, 1952, to include all of Building 10. Since one end of the original building opened directly into Building 3 and one side was open to Building 5, extensive barricades were required. A personnel entrance was provided in the north barricade and designated Main Personnel Door No. 2. All other entrances to Building 10 were secured with padlocks. The restricted area, in which the "NYX" Unit was assembled and tested, was covered at all times by five guards so stationed that the entire area of the building was under constant surveillance.

Much of the work on the process units was carried out in the different shops of the shipyard simultaneously with the company's other activities. The normal yard security restrictions were considered adequate at this stage of the work, except that additional anti-sabotage precautions were taken.

Accountability for the uranium used in test operations at New York Ship was, in the case of the NYX Project, assigned to the Security Officer. He was designated Accountability Representative of the Atomic Energy Commission and in that capacity received, stored, issued and kept records of all uranium used in the NYX Project. He was assisted by an employee stationed at the cage in which uranium was stored.

The accountability representative issued uranium to certain other organizations such as Arma Corporation and American Machine and Foundry Company which required the material in constructing components for the process units. Such transfers were made only at the direction of the Atomic Energy Commission.

At the end of each month, the accountability officer took an inventory and submitted a report to the Atomic Energy Commission showing all transactions in uranium.

Uranium for the NYX Project was received in twelve separate shipments by truck from Oak Ridge, Tennessee, with the first shipment arriving on October 10, 1951.

Return of the uranium to Atomic Energy Commission custody began on February 24, 1953, and continued until April 29, 1953. A total of eleven shipments was made to the Savannah River Plant by truck.

By letter dated June 3, 1953, the New York Ship Accountability Representative was notified by J. H. Rubin, Accountability Representative, Atomic Energy Commission, Savannah River Operations Office, that all uranium materials received by New York Ship had been accounted for by other authorized accountability stations. The accountability station at New York Ship was thereupon placed on the inactive list as of May 13, 1953.

NYX SECURITY OFFICE AND STAFF

The NYX security office consisted of two rooms on the second floor of the Employment Building. Personnel were as follows:

Security Officer	Henry W. Rodney	6/18/51 to 6/19/53
Senior Clerk and Assistant to		
Security Officer	Warren S. Jones	6/25/51 to 6/19/53
Secretary	Mrs. Dorothy M. Marshall*	4/25/51 to 5/15/53

Note: *Employed in processing security questionnaires prior to formal establishment of NYX Security Office.

During the summer and fall of 1951, additional typists were used to prepare Personnel Security Questionnaires. A maximum of four was required and all were released by November, 1951.

During the period of activity of the NYX Security Office at New York Ship from June 18, 1951, to June 19, 1953, no known incidents involving compromise of classified material took place. There were no known cases of sabotage or loss of classified material.

VI - FABRICATION AND TESTING FACILITIES

FACILITIES CONSTRUCTED OR PROVIDED

Existing Buildings 3, 5 and 10 in the South Yard were well equipped for fabrication of the NYX Project. Known as the Machine Shop and Blacksmith Shop, Buildings 3 and 5 had been modernized and Building 10 constructed in 1940-1942 under Navy contract to fabricate and assemble large gun turrets for cruisers and battleships.

Equipment consisted of horizontal and vertical boring and facing mills, planers, lathes, turning and general purpose machine, welding positioner, radial drills, layout platens and two turret erecting pits. Excellent integrated overhead traveling crane facilities existed with capacities ranging from 5 tons to 250 tons lift. Also there were railroad trackage and equipment for transporting materials between the shops and the North Yard, including a specially designed barge and landing platform adjacent to Building 3 at the south side of Newton Creek, for transporting turret assemblies by water.

At the time surveys were begun in April, 1951, to determine the changes necessary to undertake the highly classified and specialized experimental NYX Project, these buildings were in occasional use for heavy machine work and generally for storage of large items of marine equipment. Following discussions with shipyard officials regarding the necessity for continued access to, and occasional use of, heavy machine tool facilities for the normal shipyard program, du Pont engineers continued their surveys to determine acceptable architectural changes that would assure adequate security control, and additional temporary electric power and water facilities required in connection with the proposed test and partial operation of the prototype unit.

Upon completion and approval of the preliminary studies in June, du Pont issued drawings for bidding purposes. The required work included a concrete foundation mat and twelve-sided foundation tower, temporary motor and pump foundations, inner and outer security barricades, control room and construction offices, instrument shop and dark room, precision crane runway and supports, stairways and platforms, and relocation of a 20-ft. boring mill. Temporary electric power and water facilities were also required.

Completion of inner barricades and assembly components was originally called for by September 1, with balance of work to be finished by October 1, 1951.

The shipyard maintenance departments were staffed for normal repair work only, and were not in a position to undertake this additional work; nor was there reasonable assurance that temporary help could be obtained quickly in the necessary trades of carpenters, plumbers, welders, steel erectors, electricians, laborers, etc. from the commercial labor market at a time of high industrial activity in the area. This situation was reviewed with du Pont and Atomic Energy Commission representatives, and the proposal to subcontract the work was approved. Competitive bids were solicited from Ralph Cornell, Inc., Goldner Construction Company and Kauffman Construction Company.

Cornell's low bid of \$511,979 was selected and approved by du Pont and Atomic Energy Commission and confirmed by New York Shipbuilding Corporation Purchase Order 8643-1 dated August 24, 1951. Cornell, a contractor primarily for structural steel erection, with offices in Woodbury, New Jersey, undertook the structural steel work himself and subcontracted the balance of the work as follows:

All pipe work for Cornell was done by Benjamin Lessner Company, Inc. of Philadelphia; all electrical work by Electro Construction Company of Philadelphia; all carpentry and general work, including forming and pouring of concrete, by Consolidated Construction Company, Inc. of Woodbury, New Jersey.

Subsequent design changes and additions to scope of Cornell's sub-subcontract amounted to \$72,325 increased cost. These included forty-five items such as increased size and thickness of foundation mat, 340 ft. of steel fencing for security purposes, additional pump and motor foundations, six heat exchanger supports, 145 tons of trap rock to fill in substation area, six permanent pump and motor foundations, cooling water supply and drains from six substation transformers, additional stiffening and concrete fill for twelve temporary pump and motor foundations, realignment of temporary pumps and motors, additional foundation and timber structures for heat exchanger, additional concrete work, floor topping, hand rail, etc.

The additional items resulted from design changes, unforeseen construction difficulties and work that was not anticipated when bids were requested on a lump sum basis. The urgent need for the facilities had made it necessary to extend invitations to bid prior to the completion of firm design drawings so that certain changes were to be expected. The additional work was covered by Purchase Order 8643-1A dated November 18, 1952.

There was also a reduction of \$1300 for work specified under the original contract but not performed, consisting of labor to connect six temporary heat exchangers to the cooling water system, and labor and material to provide and install a winch for lifting the screen of the Newman foot valve. These changes were summarized in Ralph Cornell's letter dated April 23, 1952, and were included under Purchase Order 8643-1A.

To accomplish as far as possible the large volume of work required within the time limit specified, Ralph Cornell arranged to work on a one shift basis, ten hours per day, six days per week, with such additional overtime as conditions warranted. The use of uncleared personnel for this phase of the construction was approved in the interest of building up a large working force in the shortest possible time.

Cornell arrived at the site August 2, 1951. Arrangements were made for him to have office space at the south side of Building 3 at the point where Building 10 adjoins. Building 10 was cleared, with the exception of certain heavy equipment which would not be in the way. The west end of Building 5 where it adjoined Building 10 was also cleared. The vertical boring mill in the south end of Building 10 was moved to Building 3, and later set on a revised turret mill foundation. Revision of this foundation was part of Cornell's sub-sub-contract.

The first reinforcing steel arrived August 2 and unloading was begun on that date. On August 3, a construction schedule was submitted and accepted and the following day layout was begun for the tank foundation and for the barricades.

Representatives of Electro Construction Company examined the site August 6. Benjamin Lessner Company, Inc. moved on the site August 11.

The build-up to a full working force was rapid, with occasional delays due to lack of materials and necessity of developing labor policies. By mid-October, the original scope of work was substantially completed.

By the middle of December, additional work was generally complete, and it was deemed advisable to bring the subcontractor's work to a conclusion in order to proceed with classified projects using only cleared New York Ship personnel.

A more detailed discussion of major facilities provided for the NYX Project follows.

ELECTRIC POWER FACILITIES

The shipyard's existing 26,400 v. power supply to its North Yard Substation, with feeders to an existing 2300 v. Substation in the South Yard, was required for current and estimated future demands of its shipbuilding business, but had sufficient reserve power available for fabrication of the NYX Project and for operation of auxiliaries, including a 300 hp. river pump motor, during tests.

Existing power supply in Building 10 consisted of 440 v. a.c., 240 v. a.c., 110 v. a.c., and 230 v. d.c.

An additional temporary power supply estimated at 18,000 kv.-a. maximum was required for 12 - 1500 hp. circulating pump motors. Accordingly, arrangements were made with Public Service Electric and Gas Company of New Jersey for a new 26,400 v. supply to feed into a new transformer substation located in the South Yard, outside Building 10.

A letter contract dated August 16, 1951, between New York Ship and Public Service Electric and Gas Company, approved by du Pont and the Atomic Energy Commission, authorized the design of facilities, procurement of material, and the performance of all work necessary to furnish a temporary power supply up to a total capacity of approximately 18,000 kv.-a. by November 1, 1951. The required date for full power was subsequently changed to March 1, 1952.

The estimated cost for these facilities was \$291,800. The letter contract provided further that the facilities constructed by Public Service Electric remained their property, and that upon determination by New York Ship that there was no further use for the temporary power supply, Public Service Electric agreed to remove those portions of the facilities located on New York Ship property which were no longer required, and to refund to New York Ship the value, as determined in accordance with standard practice and accounting procedure, of the new facilities which Public Service Electric utilized. Actual cost of removing those facilities Public Service Electric did not desire to retain were chargeable to New York Ship less net salvage value. New York Ship, du Pont and the Atomic Energy Commission reserved the right to audit such of Public Service Electric accounts as related to the cost of this project.

Public Service Electric agreed to supply electric service on a non-firm, when available basis and estimated minimum salvage value of the facilities after discontinuance of service at \$40,000.

Public Service Electric's work consisted generally of the following:

2-26 KV. Switch Positions - Camden Switching Station

2-34.5 kv. oil circuit breakers

Disconnecting switches

Steel structure

Bus work

Panels, relays, control cable

Main 26-kv. conduit and cable

Miscellaneous materials

Labor

1-26 KV. Switch Position - Gloucester Substation

1-34.5 kv. used oil circuit breaker

Disconnecting switches

Bus work

Panel, relays, control cable

Main 26-kv. conduit and cable

Labor

Outside Plant Work

76 Wood poles

Crossarms and hardware

66,250 ft. wire, 250 million cir. mil. bars

1,650 ft. aerial cable, 350 million cir. mil.

Telephone cable re-route

Manholes (Contract)

785 ft. ducts (Contract)

3,160 ft. underground cable, 500 million cir. mil.

Miscellaneous rearrangements

Labor

Installation of underground cable on shipyard property, and of the new South Yard transformer substation, switchgear and other electrical equipment between the terminal pothead and the motor terminals was included in the subcontract with Ralph Cornell as a part of his work of altering existing facilities. Also included was an item of repairs to one of two feeder lines between the shipyard's North and South Yard substations to provide emergency service in case of breakdown.

Public Service Electric was responsible for design of facilities outside of the plant area, and du Pont prepared the design for facilities within the plant area.

To provide the new substation with adequate transformer capacity, stepping down the 26,400 v. supply to 2300 v. required service, the following used transformers were located, inspected by du Pont engineers, and purchased by New York Ship:

<u>Quantity</u>	<u>Capacity</u>	<u>Type</u>	<u>From</u>
3	3750 kv.-a.	1 PH.OIWC	Brew-Woltman Company
1	4500 kv.-a.	3 PH.OISC	Brew-Woltman Company
3	4250 kv.-a.	1 PH.OIWC	Indiana-Michigan Electric Company

Sub-subcontracts were let to General Electric Company for untanking, cleaning, inspecting and reconditioning the seven transformers to place them in satisfactory operating condition.

A 34.5 kv. 400 amp. oil circuit breaker, sixty-cell battery and control equipment, manually operated switches, lightning arresters, grounding rods, wire, cable, insulators, terminals, etc. were purchased by New York Ship and installed by Ralph Cornell. Public Service Electric furnished the metering transformers.

Six low voltage Allis Chalmers switchgear units were supplied to New York Ship by du Pont. These units were obtained from the Atomic Energy Commission facility at Oak Ridge, Tennessee. A sub-subcontract was placed with General Electric Company for reconditioning and modifying these units to make them suitable for the designed power supply to the 1500 hp. circulating pump motors.

The transformers were all mounted on a common concrete pad, the oil circuit breaker and metering transformers were mounted on another concrete pad and structural steel support and the various buses, lightning arrestors, and disconnect switches were supported from a structural steel super-structure which rested on fourteen separate concrete piers.

Layout for the substation was started August 9. Removal of sod and excavation for pads and footings started August 10. Form work for concrete started August 14 and the first concrete was poured August 15. There was some delay waiting on delivery of structural steel, erection of which was completed September 11. Installation of equipment started September 15 when three 3750 kv.-a. transformers were moved from Building 10 to the substation slab. On September 18, three switchgear units were moved into place in Building 10. On October 6, the opening in east wall of Building 10 was closed up since all major pieces of substation equipment were in place. Substation, metering room, and switchgear installations were completed November 1 with exception of some equipment needed for oil circuit breaker control panel. Because of late delivery of this equipment the electrical contractor, Electro Construction Company, asked to be relieved of this work.

Additions to scope of contract for substation included: (a) covering entire area with 6 in. of trap-rock at insistence of insurance underwriters, (b) cooling water to and drain lines from three 3750 kv.-a. and three 4250 kv.-a. transformers, (c) brackets for supporting secondary cables, (d) relocating conduit in electrical manhole, (e) reinstalling 4 in. electrical conduit and rebuilding electrical manhole, (f) constructing doorway to substation in east wall of Building 10, (g) making alterations to switchgear, (h) relocating substation high voltage bus because of revised design for transformer bushing, (i) furnishing and erecting cyclone fence around metering room in Building 5, and (j) constructing cyclone fence east of substation between Buildings 5 and 6.

Public Service Electric completed the initial program October 3, 1951, making 2000 kv.-a. available on that date. Installation of transformers and metering equipment, switchgear, tie-in and motor leads were completed November 1, 1951, and service was energized January 27, 1952, on a no-load basis at \$1 per kilowatt hour for testing transformers and certain motor equipment. On March 6, 1952, Public Service Electric completed their construction and full capacity service of 18,000 kv.-a. was available. On March 16, 1952, substation and circulating pump motor tests were completed and the substation was ready for full capacity operation.

On January 30, 1952, Public Service Electric notified New York Ship that expansion plans for 1952 would permit them to allow maximum salvage value for the temporary service facilities if by no later than December 1, 1952, New York Ship had no further need for this service and it became available. The offer was subsequently extended to May, 1953.

The completion of the major part of the "NYX" Unit test program by April, 1953, made possible the discontinuance of special electric service within the extended time limit. Electric power facilities were dismantled and, with the exception of the transformers, removed by June 15.

WATER SUPPLY FACILITIES

While the water supply in the South Yard of New York Ship was adequate for fabrication work, the test program planned for the "NYX" Unit required large quantities of cooling water and certain special facilities in Building 10 which were not available. Most of the water supply system was installed by Ralph Cornell as a part of his subcontract, with the remainder being accomplished by New York Ship. Major items of equipment were supplied by du Pont, on a temporary basis wherever possible.

Cooling Water System

This system consisted of a 6000 gal./min. supply of river water to heat exchangers and auxiliary equipment in Building 10 and a return line to the river. The basic plan for the cooling water system was prepared by du Pont. Following award of the subcontract, detail design as required was prepared by New York Ship or Ralph Cornell, and submitted to du Pont for approval before proceeding with the work.

As originally designed, the scope of the river water cooling system included: a pump house at Pier 7, north of Building 10, containing the 6000 gal./min. pump and motor, Brassart filter, chlorinator system and 16-in. steel pipe projecting into the river, with foot valve and screen about 12 ft. below mean low water; about 400 ft. of 20-in. lock-joint concrete pipe below grade from the pump house south to Building 10; reducing to 18-in. carbon steel pipe above ground into the building, and about 400 ft. in successively reducing size from 18 in. to 10 in. diameter, with necessary reducing sections, valves, ells, tees, etc., connecting to six heat exchangers for cooling test unit circulating water; another 400 ft. of carbon steel pipe increasing from 10 in. to 18 in. diameter, carrying the cooling water discharge from the heat exchangers outside of Building 10 and then underground about 700 ft. westerly through 20-in. concrete pipe to a bulkhead, with open discharge into the river. Completion of the installation was scheduled for October 1, 1951.

Du Pont purchased the estimated quantities of pipe, valves and fittings for the river water cooling system based

on the original scope of work. Arrangements were also made by du Pont for delivery of the following equipment to the test site on a temporary basis:

1. 6000 gal./min. Goulds pump and 300 hp., 2300 v. motor from Oak Ridge.
2. 24-in. Brassart self-cleaning filter purchased originally for permanent installation in Savannah River 400 Area.
3. 16-in. Newman foot valve and screen.
4. 700 lb. per day chlorinator rented by du Pont and subsequently purchased when paid rental, which was credited to purchase price, equalled original cost.

Work on the pumping station to house the circulating pump, Brassart strainer and chlorine dispensing equipment for the cooling water system was started August 8 when a diver began taking mud measurements at the proposed location. The final design worked up by New York Ship differed principally in arrangement from du Pont's preliminary design.

The specifications called for a frame structure or equal. The contractor found it economical to use cinder block construction. The ground for some considerable distance back from the edge of Newton Creek rests on a timber platform supported on piles. The foundation mat for the pumping station was poured on this timber platform.

The original design called for the Newman foot valve intake to be out in Newton Creek, but the New York Ship plant engineer, considering the possibility that the shipyard might want to berth ships on both sides of the creek, asked that the intake be placed inside the wharfage in an opening cut in the timber platform or deck. To minimize clogging of the foot valve with silt and debris, the mud line was lowered several feet for a wide area adjacent to the intake.

Exact locations of underground services and facilities were not known and it resulted that approximately 114 ft. of 18-in. terra-cotta sewer line had to be relocated around the pumping station. This also necessitated relocation of the manhole where this 18-in. sewer tied into the main 24-in. sewer. This additional work was covered by Item 7 as listed in alteration to the sub-subcontract. Design for the pumping station included hatches in the roof of the chlorine dispenser room to facilitate handling of chlorine in 1-ton containers. It developed that this size container was not procurable in the local market. Twelve 150-lb. cylinders

were manifolded instead of three 1-ton containers and the removal hatch was sealed at a later date. Excavation for the foundation mat and walls was started August 17, the mat was poured August 23, and wall forms were stripped August 31. Walls for chlorinator room were formed September 19. Cinder block walls of pump room were started September 20 and both pump room and chlorinator room walls were completed September 26. The roof was completed October 8.

From the pumping station, an underground 20-in. lock-joint, reinforced concrete pipe for river cooling water was laid to the west side of Building 10. The line then surfaced and became an overhead steel pipe which connected inside the building to six temporary heat exchangers, then returned to the side of the building where it joined an effluent line leading to the Delaware River.

The underground lines were laid out on August 14, and the influent line was completed September 29. A hydrostatic test of 187.5 lbs./sq.in. was put on the influent line. Work on the effluent line began on August 22 and was completed September 28. The grade of the effluent line was lowered to avoid a tile electrical conduit and a 12-in. fire line. Several concrete pile caps from demolished World War I shipways were blasted out to allow laying the line.

The overhead lines in Building 10 consisted of some 1200 ft. of steel pipe in 8-in., 10-in., 12-in., and 18-in. sizes. Benjamin Lessner Company, Inc. submitted to Wilmington for approval plans for the various supports and hangers used on these lines. The du Pont Design Division requested certain changes in Lessner's design, mainly the elimination of rollers and substitution of free-swinging hangers.

The bulk of pipe and fittings for the overhead pipe lines was on order from McArdle Cooney of Philadelphia and though quoted out of stock, it soon became apparent delivery on much of both pipe and fittings would be too late to allow meeting the construction schedule. Lessner managed to buy most of the pipe and many of the fittings elsewhere, and in several cases, fabricated fittings, particularly reducers, to keep the job going. The six temporary heat exchangers fabricated by the du Pont Wilmington Shops were not available for Lessner to pipe the 8-in. lines to them, but he pre-fabricated as much of the pipe as practicable and altered his contract accordingly. A revision to the inlet detail of the overhead pipelines required the use of additional 90 degree ells. This work was taken care of by alteration to the scope of work. Fabrication of pipe for these lines started August 22 and was completed October 31.

Upon the arrival of the temporary heat exchangers from the Wilmington Shops in January, 1952, New York Ship personnel connected them to the river cooling system. The location of one of the main cooling water lines had been changed at the time of installation and this required offset of three of the connections in order to complete the installation. This phase of the work was completed in February, 1952.

On November 11, 1952, a permanent type heat exchanger constructed for the Savannah River Plant was delivered to New York Ship for testing with the "NYX" Unit. Its installation required removal of the No. 3 temporary heat exchanger and alteration of the river cooling supply and return lines. Piping of 18 in. diameter was used, and as much as possible was prefabricated to cut down installation time. The heat exchanger was ready for operation January 2, 1953.

The temporary heat exchanger replaced by the Savannah River Plant exchanger was utilized for special tests of the "NYX" Unit and was mounted on the concrete pad adjacent to the unit. River water cooling connections to the heat exchanger were made by New York Ship in January, 1953. Less extensive additions to the river water cooling system made by New York Ship personnel included:

1. One 3-in. take-off and return with necessary fittings for deionizer heat exchanger.
2. Six sets of 3-in. take-offs and return with flanges, ells, valves, etc. for cooling lubricating oil to bearings of permanent circulating water pumps for test unit.
3. About eighteen instrument taps with associated piping, valves, etc. for recording temperatures, pressure and rate of flow at various points in the system.
4. One 2-in. take-off and return with necessary fittings for cooling water to two 190 hp. diesel engines, driving generators providing reserve power to permanent circulating water pumps for test unit.
5. Twelve 1/2-in. take-offs and returns with fittings for cooling lubricating oil to bearings of temporary circulating water pumps for test unit.
6. Twenty yokes tying together long parallel runs of cooling water supply and return, as additional bracing against vibration in the vicinity of circulating water piping (added May 1, 1952).

Piping for the deionizer heat exchanger cooling water, lubricating oil coolers and instrument taps was completed in April, 1952. Piping for cooling water to the two diesel engines, and additional bracing of the main cooling water lines was completed in May, 1952.

PARTITIONS, ENCLOSURES AND STORAGE FACILITIES

Main Barricade

The main temporary barricade, which formed the north wall of the special security area, extended some 186 ft. across both the high (east) and low (west) bays of Building 10. The high bay barricade was approximately 92 ft. wide by 63 ft. high with an opening at the top central section, covered by a drop canvas curtain to allow transport of material by the 150-ton building crane. The drop curtain was operated by an electric-powered winch. In the west, or low bay, which was approximately 94 ft. wide, the barricade was built to a height of 31 ft. and from this elevation the opening to the bottom of the roof truss was covered by a canvas curtain. The roof truss, averaging about 8 ft. in depth was faced with asbestos board. At the top center of this wall, a canvas drop curtain operated by a power winch covered an opening 13 ft. 6 in. high and 16 ft. 10 in. wide. Both this drop curtain and the one in the high bay facilitated movement via crane of material to and from the security area.

The low bay of this barricade duplicated the construction used for the north wall of the inner barricade which is described later in this section. The high bay was similar except that the four bents were 61 ft. 6 in. high. A fifth bent 41 ft. high was added, as a field change, at center of the drop curtain. Payment for construction of this bent and for bracing it was covered by additions to the scope of the contract. This barricade, approximating 11,000 sq. ft. of face surface, was comprised of 1500 sq. ft. of cinder blocks, 7100 sq. ft. of asbestos board and 2400 sq. ft. of canvas curtain. The canvas curtains in this barricade and also in the loading area barricade were treated to make them fire resistant. All wood in the secured area, including all timber in the barricades, was hand brushed with a solution of sodium silicate as a fire retardant.

Two platforms were constructed to support the winches which were of 3/4-ton capacity, 3 hp. a.c. motor operated, furnished by Cornell. As a field change a "T" support was placed under the center (long way) of one platform. Payment for this support was made by an addition to the scope of work. Layout started August 6 and the barricade was essentially completed August 31.

Building 5 Barricade

The barricade in Building 5 was smaller and of simpler construction than the north barricade. It covered approximately 3400 sq. ft. of opening. Framing for this barricade consisted of wood posts set 12 ft. on centers with wood girts on 4 ft. centers. Aside from the framing, this barricade was similar to the north barricade described immediately above. However, there was no opening with drop curtains and no curtain above since the barricade extended from the floor to the roof. Width of barricade was 120 ft. and average height 26 ft. except for two dormer window sections each 21 ft. wide and approximately 7 ft. high. Work was started on August 17 with laying cinder blocks. The barricade was completed September 5.

Assembly Room, Platforms, Storage Racks, Inner Barricade and "Slug" Locker

The assembly room, referred to generally as the "loading area" was in the southwest corner of Building 10 and was approximately 90 ft. square. It was closed off from the rest of the building by a fixed barricade and curtain on the north side approximately 47 ft. high, and on the east side by a barricade extending from the floor some 60 ft. to the roof. The canvas curtain at the top of the north barricade provided access for two 30-ton cranes by means of a hand-operated canvas drop curtain. This was the first area to go under security and provided facilities for storing inactive slugs, storing "Q" foils and "C" rods, loading and unloading "Q" foils, boiling slugs to test for leakage of containers and for pressing and shearing of "Q" foils to be scrapped.

The first work done in the loading area was construction of the barricade, the east wall of which was started August 9. The original plans for the north wall of the barricade called for five timber bents 31 ft. high averaging 17 ft. 6 in. apart between which were supported 5-in. channels supported by sag rods. Nailers were to be bolted to the channel girts and wallboard nailed to them except for bottom 8 ft. which was to have been sheet metal, either plain or corrugated. Late delivery of channel steel forced substitution of wood girts and studs. As a field change, asbestos board facing was used except for bottom 8 ft. where cinder blocks were used in place of sheet metal. The east wall of the barricade was built of wood framing with asbestos board facing and cinder blocks for lower 8 ft. Fastening this wall to the building steel eliminated the need for timber bents. The last work done on the barricade walls of the loading area was the covering of the roof truss directly over the north barricade with asbestos board. This was completed August 29.

Two flights of wood stairs in the southeast corner of the loading area led to a 20-ft. high wood platform some 30 ft. by 40 ft. in size. This main platform was supported on wood posts from the floor as was a 2-ft. wide wood walkway running north from the main platform. A 3-ft. wide wood walkway ran west from the southwest corner of the main platform and was supported on brackets fastened to the south wall columns. This walkway gave access to wood walkways 2 ft. wide at elevation 22 ft. along the top of two storage racks, each of which extended west some 56 ft.

The storage racks were constructed of structural steel and were 56 ft. long, 2 ft. wide and 22 ft. high with pairs of 4-in. channels at the top. "Q" foils and "C" rods were stored vertically in these racks, being supported at the top by wood blocks clamped around them.

A separate wood platform for the tipping table, approximately 7 ft. by 27 ft. at elevation 9 ft., with a stairway, was located under the northwest corner of the main platform. Another wood platform 4 ft. 4 in. by 14 ft. at elevation 4 ft. with stairs at center of east side, was located under west end of two openings in the main platform.

Two structural steel transfer fixtures bolted to the side of the main platform were used to transfer "Q" foils from the monorail hoist to a specially equipped hoist truck. This truck was used to move "Q" foils from the loading platform to the storage racks and later from the storage racks to a transfer fixture near the "NYX" Unit.

Also in the loading area was an overhead monorail system supported by approximately 380 ft. of 12-in. wide flange structural steel beam. This supporting steel was hung from the roof trusses with bottom of monorail steel being 2 ft. above the bottom of the roof trusses. All steel work was prefabricated and, in the loading area, either bolted or welded in place. In the southwest corner of the loading area, a woven wire locker 10 ft. by 45 ft. and 11 ft. high was provided for storage of slugs.

Cornell's sub-subcontract provided for erection of all the platforms and walkways described above and for the erection of the two storage racks, the monorail supporting steel (but not the monorail itself), fabrication and erection of the slug locker and placing of 2500 sq. ft., more or less, of "Crete-fix" (a special concrete grout) to provide a smooth floor surface in the operating area of the hoist truck.

Construction of the walkways and platforms was started August 16 and completed August 24 except for walkways on top of the storage racks, and sliding doors in east and north walls.

Later minor revisions to the platforms, started October 1 and completed October 6, were covered by an addition to the scope of work.

"Slug" locker erection was started August 18 and completed August 21. Wire panels were prefabricated for this locker but some obstructions not noted in original plan required reworking of some of the panels. On September 7 metal screen was placed over windows in "slug" locker. Though not in the sub-subcontract no addition to scope of work was made for this extra.

Erection of sliding doors in east and north walls was started August 28 and completed October 2.

Late delivery of the structural steel for the storage racks delayed their erection which was started December 5 and completed December 7.

The supporting steel for the monorail was erected September 29 and while erection of the monorail itself was not a part of Cornell's sub-subcontract because it was originally intended that New York Ship personnel would erect it, labor policy dictated that Cornell's men should do this work and also that they should install the electric power to it. Both of these items were covered by additions to the scope of the contract.

The amount of "Crete-fix" floor topping in the loading area was increased because of revised design. This was covered by an addition to the scope of the contract.

Subsequent to the completion of Cornell's sub-subcontract, New York Ship personnel added to and revised some of the structures in the loading area and also installed various equipment and facilities.

Control Room, Dark Room, Instrument Storage and Repair Rooms and Operating Department Office

Other than the "slug" locker previously described, the rooms and office listed above were the only separate enclosures constructed by Cornell.

The control room, 20 ft. by 27 ft. by 12 ft. high was of wood frame construction with exposed studs on the outside, plywood-lined walls inside, and "Celotex" lined ceiling. Roof was covered with tongue and groove boards.

The dark room, built against the east wall of the control room, was 8 ft. by 15 ft. 6 in. in size, including a labyrinth

entrance and was lined completely with "Celotex". It was painted black with all openings sealed to make the room light proof. Cornell furnished a 50-gal. capacity electric water heater, a sink, piped hot and cold water, and drain to a sewer. He, also, provided an exhaust fan for the dark room.

The instrument storage and repair rooms, each 20 ft. by 23 ft. in size, were located in the south end of Building 5 where it adjoined Building 10. During the early months of the job, the Control Room was used as an office by the Instrument Engineering personnel. Both the storage and repair rooms were constructed of woven wire panels. The storage room had a woven wire ceiling but there was no ceiling over the repair room. Woven wire design was used to make use of a roof-mounted unit heater in this part of Building 5. Since these rooms were located against the south wall of Building 5 and against the Building 5 barricade, woven wire panels were required only for the north wall of both rooms, the partition between them, and the ceiling of the storage room.

Framing of the control room, dark room and office was started September 5. Erection of woven wire panels for instrument storage and repair rooms was started September 25. Work on all these items was completed October 17. Field changes called for:

1. Partitioning the north end of the Operating Department office to make three small offices out of a single room.
2. Revising the lighting system accordingly.
3. Providing the additional doors required.
4. Providing five metal louvered ventilators.
5. Providing work benches for the dark room and the instrument repair room.
6. Applying "Crete-fix" to office floor.

FOUNDATIONS

NYX Unit Foundation

The "NYX" Unit foundation was a twelve-sided hollow tower approximately 33 ft. 6 in. high with sides 6 ft. 10 in. long and walls about 5 ft. 3 in. thick. The tower sat on a concrete mat 46 ft. by 76 ft. in size and 3 ft. 1-1/2 in. in height. The mat in turn rested on a 12-in. structural concrete slab to which were anchored 6-in. I-beams 4 ft. on centers.

A non-reinforced concrete filler had been poured between the I-beams. The structural slab in turn was supported by pile clusters under each building column. Only the mat and tower were new construction.

Platforms surrounded the tower at elevation of 18 ft. and 34 ft. above the original floor. Four flights of stairs, at the east side of the mat, gave access to the two tower platforms mentioned above.

Work on the mat began August 7, and it was poured August 13, requiring approximately 400 cu. yd. of concrete.

A misunderstanding regarding the size of the foundation mat, 46 ft. square versus 46 ft. by 76 ft. required an addition to the scope of the contract. A revision increasing thickness of the mat from 2 ft. 6 in. to 3 ft. 1-1/2 in. required another addition to the scope of the contract.

Erection of forms for the foundation tower and tying of reinforcing steel began August 16. Cornell rented reusable steel panel forms for this construction. The first lift, up to elevation 17 ft. 10-3/4 in. was poured August 24, the second lift to elevation 27 ft. September 7, and the third and final lift September 14. The four small piers at top of the foundation which supported the "C" rod actuator frame were poured September 20.

Structural steel at the top of the foundation was set in place November 2 and bolted loosely, since it would have to be removed temporarily when the "NYX" Unit was placed.

The two platforms around the unit foundation were supported by wood brackets fastened to the concrete with steel clips and bolts with lead cinch anchors. Drilling for these anchors started October 1 and was completed October 2. Erection of the two walkways was completed October 9. They were later strengthened considerably by the addition of supporting brackets with knee braces to corner posts in the handrails. This was done because of a change in the estimate of the number of people likely to be on the platforms at one time.

Because the stairs, to give access to the two platforms around the unit foundation, were supported from the precision craneway structural steel, construction was delayed pending erection of this steel. Work was started on the stairway December 8 and was completed December 14.

Pump and Motor Foundations

Temporary Pump and Motor Foundations

Twelve temporary pump and motor foundations were originally designed as grillage beams welded to the 6-in. I-beams anchored in the structural floor slab of Building 10. There was no structural floor slab under the six temporary pumps on the Building 5 side of the unit, and design called for the grillage beams to be anchored to an 18-in. thick reinforced concrete pad approximately 11 ft. 6 in. wide by 16 ft. 9 in. long. The pump base was bolted to 8-in. beams and the motors were bolted to 12-in. beams which were welded to the 8-in. beams. During operation of aligning pumps and motors, it developed that flexibility of grillage beam foundation prevented alignments to tolerance desired. As a first corrective measure, stiffeners were welded to both 8-in. and 14-in. beams. This was covered by an addition to the scope of the contract. While this reinforcement of the grillage beams permitted satisfactory alignment, it was found upon start-up of motors that excessive vibration occurred. To further reinforce the grillage beams and provide additional mass, they were encased in concrete grout. Addition of this grout very appreciably dampened motor vibration. Placing of this grout was covered by an addition to the scope of the contract.

The 18-in. thick concrete pads for the six temporary pumps and motors east of the unit were constructed first. It developed there was a misunderstanding regarding design for these six foundations. The additional work over and above that contemplated by Cornell, at the time he made his bid, was covered by an addition to the scope of the contract. Construction of the concrete pads was started August 21 and finished September 17. Placing of grillage beams, including grouting, for these six pumps was completed October 1. Work of aligning the east pumps and motors was started October 4 and was nearly completed October 10 when it was decided reinforcement of all grillage beams was required. In the meantime, grillage beams for the pumps west of the unit had been installed. These were welded to the 6-in. I-beams in the floor. Reinforcement of the grillage beams was completed October 19. Realignment of the six motors east of the unit was completed October 16 and was covered by an addition to the scope of the contract. Alignment of the six pumps west of the unit was started October 17 and completed October 24. Grouting of the temporary pumps and motors was started October 22 and was completed October 29. Another addition to the scope of contract was required to reimburse Cornell for work done in removing burned-off studs in pump bases. This was done by redrilling and retapping the stud bolt holes.

Permanent Pump and Motor Foundations

Construction of foundations for the six permanent pumps and motors was not a part of Cornell's subcontract. It was realized that the pouring of any sizable amounts of concrete after the area went under security would be difficult, and since design for these foundations was firmed up at time Cornell was doing his work in Building 10, this additional work was given to him and covered by an addition to the scope of the contract.

These foundations, 5 ft. 6 in. by 7 ft. for the pumps and 21 ft. by 7 ft. for the motors, were reinforced concrete 7-1/4 in. thick poured on paper laid on existing floor. Anchor bolts were 1-1/2 in. diameter and averaged 2 ft. 4 in. in length, six for each pump and sixteen for each motor.

The anchor bolts in the foundations were anchored to the structural slab of the building with lead cinch anchors. Drilling of the holes was slow work due to obstruction of reinforcing steel and 6-in. I-beams. Where possible, anchor bolts were welded to the I-beams or the reinforcing steel. Drilling for anchor bolts was started October 3 and completed October 10. Pouring of foundations was started October 17 and was completed October 26. For some eight or nine feet on the east end of the center motor foundation east of unit, the existing 8-in. thick floor slab (poured over and between railroad ties) was removed and replaced with an 18-in. reinforced concrete slab. This was poured level with the existing floor and the foundation poured on top of it. Anchor bolts in this portion were grouted into the 18-in. slab using plate washers.

PRECISION CRANE SUPPORTS

Cornell furnished and erected approximately 70 tons of structural steel for supporting the Precision Crane runway rails which were located in the high bay of Building 10. Span of the crane was 39 ft. and the top of crane rail beams was 68 ft. 10 in. above the floor. Supporting columns were spaced 30 ft. apart to conform to existing building steel and were tied to this building steel. Four of the columns rested on the "NYX" Unit foundation mat and the remaining twelve columns rested on grillage beams which in turn rested on the 6-in. I-beams imbedded in the floor.

Over the unit, where a minimum of deflection could be tolerated, the main rail beams consisted of plate girders 6 ft. deep made up of 1/2 in. plate with angle flanges and stiffeners. These two girders were 90 ft. long and the top of each beam was machined. The balance of the rail beams

were 24 in. wide flange 100 lb. section. Specifications called for use of "Dardelet" bolts for field erection, which started December 7.

All the steel was up December 9, but 2900 "Dardelet" bolts were lacking. Work was suspended until after the Christmas holiday when use of hot rivets was approved. Driving of these rivets was completed December 31, and the short delay had no applicable effect on the overall schedule.

PROCESS PUMPS AND MOTORS

Six specially designed stainless steel pumps, with drive motors, on order for the Savannah River Plant were to be used to circulate process water in the test program of the "NYX" Unit at New York Ship. The scheduled completion date of the pumps would have set the entire program back several months. A search by du Pont for substitute pumps that could be used immediately resulted in a rental agreement with Texas Eastern Transmission Corporation by which twelve pumps and motors of the same total capacity as the six stainless pumps were leased on a yearly basis. As the Savannah River type pumps were delivered, they were installed in place of the temporary pumps during test operations in Building 10.

Temporary Pumps and Motors

The temporary pumps, twelve in number, had been used to pump oil in the pipelines of Texas Eastern. They were Ingersoll-Rand centrifugal type, rated at 6000 gal./min., and driven by General Electric 1500 hp. a.c. motors. The pumps were installed on special foundations by Ralph Cornell during September and October, 1951, as part of his subcontract.

Because the pumps were made of cast iron, they required special treatment to prevent contamination of the process water. They were overhauled by the manufacturer and lined with neoprene by Synco Company, Emmaus, Pennsylvania, before delivery to New York Ship. The neoprene lining did not stand up during operations and was finally removed by New York Ship personnel.

As the Savannah River type pumps arrived, beginning in July, 1952, the temporary pumps were replaced, cleaned, painted and prepared for return shipment to Texas Eastern. All were returned during the fall of 1952.

Permanent Pumps and Motors

The six permanent pumps were Byron-Jackson stainless steel centrifugal type, each rated at 11,500 gal./min. The primary drives for the pumps were Allis-Chalmers 3000 hp. a.c. motors. These motors were designed for operation and across-the-line starting at the Savannah River Plant at 13,000 volts. Because the power supply at New York Ship was at a nominal voltage of 2300 volts, the windings of these motors were connected by Allis-Chalmers for operation at 1900 volts. To minimize the amount of overvoltage apparent in the above figures, the taps on the substation transformers were changed when the permanent motors were installed to lower the secondary voltage below 2300 volts. The characteristics of the power supply system were such that when the big motors were started across-the-line a large drop in voltage resulted, producing a long accelerating period. This combination of voltage drop and sustained starting inrush presented problems in protective relay settings and breaker coordination.

Direct current standby motors were mounted on the same shafts, and are described below under Emergency Power Equipment.

The pumps were designed with special seals, using fluid injection of deionized water between seals. An auxiliary pump was built in as an integral part of the seal to circulate seal water through an external cooler in a closed system. Two De Laval lubricating systems were installed, each serving three of the process pumps and their drive motors.

A torque arm was attached to the shaft of No. 3 process pump by means of which it was possible to measure torque due to back pressure.

Installation of the permanent pumps and motors was done by New York Ship personnel beginning in July, 1952. The Byron-Jackson Company, vendor of the pumps, had representatives on the job site during this installation. One of their representatives spent considerable time explaining the intricacies of the mechanical seals which were of a special design.

Through a misunderstanding regarding cleared personnel, Allis-Chalmers had no representative at New York Ship during original installation of their motors. A careful job was done in aligning the pump to the process pipe and the motor to the pump. Advantage was not taken of the wide tolerance for misalignment offered by use of the Thomas-Flexible couplings. Instead of 7/32 in. maximum tolerance permitted

by use of the flexible coupling, the misalignment was held to a maximum of 0.030 in., and in most cases, were considerably better than that. After the pumps had been run for several hundred hours, excessive vibration became noticeable and on one motor considerable noise developed. An Allis-Chalmers representative found a fan housing plate loose, two bolts having vibrated enough to drop out. Both bolts were found, one of them in the stator coils, and no damage resulted. Locking clips were designed for the bolts, and the Allis-Chalmers representative personally supervised installation of them on all the Allis-Chalmers motors. About this time, readings with a vibrometer showed vibration on the order of .001 to .004 in. on bearings of all three motors installed at that time. An extensive investigation by representatives of du Pont Design, Operations and Construction, and also Allis-Chalmers resulted in the conclusion that holddown bolts holding the motor to the flexible welded steel base had stretched and elongated in shipment with the result that the factory alignment of the motor and the flywheel no longer existed or was soon lost when the motors were put into operation.

As a result of this investigation, the three pumps and motors installed at that time were realigned holding the alignment of the coupling between the motor and flywheel to within .001 in. runout, angularly and axially. Tolerances for the jack-shaft between the pump and the motor were set at .003 to .005 in. runout angularly, and 1/64 in. axially. All holddown bolts and foundation bolts were tightened before realignment was started. A jig was developed to enable use of dial indicators for checking the alignment between the pump and the motor. The 12-in. and 20-in. process pipe to the pumps had to be cut and field fitted and pumps, also, had to be moved on their bases in some cases. As a result of this experience, it was decided that future shipments of the 3000 hp. motors would be in three pieces: (1) base with pedestals attached, (2) motor, and (3) the flywheel.

The coolers or heat exchangers, for the a.c. and d.c. motors were furnished by the Harrison Radiator Division of General Motors from their factory at Lockport, New York. Tests of these coolers prior to installation indicated leaks. Temporary repairs were made at New York Ship to a few coolers, and others were returned to Harrison's Lockport plant for repairs.

The Regan space heaters furnished as original equipment with the 3000 hp. a.c. motors proved unsatisfactory. They were energized to dry out the motors before their installation and burned out in a matter of hours. They were replaced with stripheaters for this installation.

Installation of the first permanent pump and motor, No. 6 system, was started in mid-July of 1952 and took approximately two weeks. Installation of the second pump and motor in No. 3 system was started August 11, 1952, and completed August 15, 1952. Initial installation of the third pump and motor, in No. 1 system, was started September 22, 1952 and was completed October 3, 1952. The first d.c. motor was installed in this system.

Installation of the fourth pump and motor, in No. 4 system, was started October 6, 1952. An erection engineer for the Allis-Chalmers Company arrived October 8, 1952, to investigate loud chatter in the No. 6 motor, caused, he found, by a loose fan housing plate. As mentioned above, this investigation led into a realignment program for the Nos. 6, 3 and 1 systems. Instead of continuing operations, a complete shutdown was made and all effort was put into realignment of these systems while the No. 4, No. 5, and No. 2 pumps and motors were being installed. Because of the closer tolerances decided upon for alignment, this work progressed slowly. Dial indicators were used to check alignment of couplings and were also used on the pump casings at the time the 12-in. and 20-in. process pipes were connected to the pumps. The d.c. motors were installed in the No. 4 and No. 3 systems while these two pumps and motors were being realigned.

The No. 1 system was started up, after realignment, November 6, 1952. The No. 5 system was started up initially and the No. 6 system was started up for the second time November 12, 1952. The No. 3 system, including the d.c. motor, was put into operation for the second time November 13, 1952. On the same day, the No. 4 system, including the d.c. motor, was started up. The No. 2 system was completed and put into operation November 15, 1952. It should be noted here that the du Pont Operating Department personnel assisted greatly in the pump and motor realignment program described briefly above.

HEAT EXCHANGERS

Heat exchangers were required for cooling process water to meet test conditions for the "NYX" Unit in Building 10. Du Pont, therefore, designed suitable temporary heat exchangers and, in order to expedite delivery to the greatest degree possible, fabricated them in the du Pont Wilmington Shops.

Temporary Heat Exchangers

Six temporary heat exchangers were built. Each was approximately 20 ft. long and 3 ft. in diameter, with single pass shell and tubes. The heat exchangers were fabricated from carbon steel, with neoprene coating applied to the faces of the tube sheets and inner side of head where process water would be in contact with the surfaces. The tubes were plated.

One heat exchanger was installed in each of the six process water circulating systems. The river water cooling system described previously supplied the cooling medium, with supports and much of the river water piping erected by Ralph Cornell.

The heat exchangers were mounted on the east and west sides of the "NYX" Unit foundation, those on the west side being horizontal and those on the east vertical because of limited space on the latter side. Mounting the temporary heat exchangers and connecting them to cooling water lines was included in the subcontract with Ralph Cornell, but because of delay in delivery of the heat exchangers, the work was done by New York Ship personnel.

Permanent Heat Exchanger

The Savannah River Plant type heat exchanger used in the NYX test program was delivered November 11, 1952. It had been built from du Pont designs by Foster Wheeler Corporation of stainless steel, with fixed double tube sheets, and was approximately 29 ft. long and 7-1/2 ft. in diameter. The empty weight of the heat exchanger was 93 tons, and required additional construction work to move it into position near the "NYX" Unit because of limited crane capacity in that area.

After studies of the lifting problem, du Pont designed a temporary trestle leading to the operating support of the heat exchanger, so that the heat exchanger could be placed on the trestle by a 150-ton crane and then moved to its operating location. A load study for the trestle suggested rolling the heat exchanger into position, using track and the trucks with which the heat exchanger was equipped. Because the trucks raised the centerline of the heat exchanger, their use required modification of the support erected by the subcontractor. New York Ship personnel performed the work, lowering the top of the support about 3 ft. 8 in., adding a third bent and six vertical members to take the dead load, and erecting the temporary trestle consisting of five timber bents. On top of the bents and support, two rail beams were laid and on these were placed 60-lb. rails which had been used previously for a temporary installation of the 2-ton crane used in the NYX test.

After setting the heat exchanger on trucks, and before lifting it into place, it was dried using warm circulating air and a portable "Stokes" vacuum drying unit. The heat exchanger was then Freon tested for leaks, with only one very small leak on the tube side being found.

The heat exchanger was lifted to the trestle, tested once more, and rolled to its operating position. As mentioned in the section on cooling water facilities, installation of the unit required alteration of the cooling water supply and return lines. In addition, a semi-permanent steam sparging system was installed to dry the heat exchanger prior to leak tests scheduled for various times during the test program. The heat exchanger was ready for operation January 2, 1953.

PROCESS WATER LINES

The process water lines consisted of six separate piping systems. Each connected one of the "NYX" Unit outlet nozzles in the tank bottom with a strainer, circulating pump or pumps, a heat exchanger and the corresponding inlet nozzle of the Plenum Chamber.

Because of the use of two sets of pumps in the NYX test operations, both temporary and permanent piping was required. Stainless pipe was required in 12, 16 and 20-in. sizes and, since none was available from suppliers, all process piping had to be specially fabricated from plate. Nearly all of the requirement for 12-in. piping was supplied by Joseph Oat & Sons, Philadelphia, Pennsylvania. This pipe was supplied in straight runs. The same company also made some stainless vanned elbows of both 12 and 20-in sizes. The remainder of the piping was fabricated and installed by New York Ship's Copper Shop, using fittings supplied by the Whitehead Metal Company. Straight pipe and fittings were, in general, fabricated to commercial standards. Assembly of these components into hydraulic circuits meeting the stringent dimensional specifications applicable to the process water lines required extreme care in aligning and bending, extensive hand grinding and repair of some defects found in the components.

Temporary Process Lines

In order to convert the process water system from the twelve temporary pumps to the six permanent Byron-Jackson pumps with the least dislocation of test operations, du Pont designed a piping layout using targets to represent the suction and discharge flanges of the permanent pumps.

Permanent piping was led to these targets; from there temporary piping carried the process water to and from the temporary pumps.

The suction side of the temporary piping consisted of a section of 20-in. piping with a "Y", and reducing sections to 16 in. in diameter which led to the suction sides of the two pumps.

The temporary pumps discharged into 12-in. lines which converged near the target into a single 12-in. line.

Permanent Process Lines

The permanent piping system included several special test sections in which various elbow designs could be inserted. Different types of elbows--plain, vanned, mitered, etc.--were fabricated for these sections so that a comparison of their operating characteristics could be made. In general, the process pipe was 12 in. in diameter on the discharge side of the pumps and 20 in. in diameter on the suction side.

Originally, all permanent piping was to have been fabricated and erected in accordance with Savannah River plans and specifications. However, it soon became apparent that adherence to the specifications in their entirety would cause considerable delay in the delivery of pipe subcontracted by New York Ship. Due to various modifications for testing purposes there were increasing doubts as to whether the pipe could be re-used at Savannah River without extensive reworking. For these reasons, full radiographing of butt welds and inert gas welding on all butt joints was not required and a substantial reduction in both fabrication and erection time resulted.

The 12-in. pipe butt joints were welded using a single "vee". The 20-in. pipe was welded in similar fashion except that backing strips were used and removed on completion of welding. Joints were ground internally to insure a smooth inside surface for liquid flow.

All lap joint stub ends for the 12-in. and 20-in. pipe were fabricated at New York Ship. They were made by welding annular rings to the pipe sections in accordance with standard pipe specifications. The back-up flanges for the stub ends were purchased from various pipe suppliers.

Field erection of the process piping was started in February, 1952, and except for the Plenum, heat exchanger connections were completed by mid-April. Following erection of the Plenum in May, installation of process piping was completed by New York Ship personnel.

During fabrication, the stainless pipe was hydrostatically tested. The field welds and untested joints were tested in place at 600 lb./sq.in. in the 12-in. pipe, and 225 lb. in the 20-in. pipe.

All pipe was pickled in a nitric-hydrofluoric acid solution to remove any free iron. Field welds which could not be so treated were ground wherever possible.

DEIONIZER

In order to supply water suitable for the process system during the testing of the "NYX" Unit, du Pont selected a mixed bed deionizer designed by the Illinois Water Treatment Company, Rockford, Illinois. The unit consisted of an ion-exchange tank, caustic and acid tanks and connecting piping and valves. Piping was largely of "Saran" plastic. The unit had been set up at the factory and partly disassembled for shipment.

Additional equipment such as the following was required to make the deionizer operable in the system: micro-filters, "Alsop" filters, pressure regulated control valves, "Saunders" type diaphragm valves, relief valve, air regulators, a control panel, a heat exchanger and a 40 gal./min. pump with a 10 hp. motor.

Construction of the foundation and structural support of the heat exchanger, pump and motor was carried out by Ralph Cornell. The rest of the piping and construction work was done by New York Ship.

The deionizer tanks were delivered in November, 1951. Gloucester City water supply connections and a safety shower were provided, and because of the acid nature of some of the drainage from the unit, a sump was constructed of acid-proof brick with a special 4-in. terra cotta drain leading from the deionizer along the side of Building 10 to a vitrified-clay sewer north of Building 6.

The circulating pump was purchased from excess stock at Oak Ridge. Its mechanical seal did not withstand the 75 lb. pressure originally recommended for the installation and maintained by a booster pump installed in the Gloucester City water supply main. A replacement pump was purchased but never installed since the original pump performed satisfactorily at lower pressure after a stuffing box gland seal was installed.

Resins were placed in the ion-exchange tank March 14, 1952, but the regeneration system did not function properly

because of fluctuating water pressure. A supply of pressure-regulated and filtered water was made available by alterations to the deionizer system in April, and the unit was ready for service by the middle of that month.

The micro-filter clogged quickly with resins, reducing the pressure in the system, and was replaced by an "Alsop" filter. Later, a regulating valve was installed to permit bleeding in water to the process lines to make up for losses in the seals of the twelve temporary pumps. Two stainless steel check valves were also installed to prevent back flow into the Gloucester water line and the return line from the monitor discharge header to the deionizer pump suction.

The deionizer later was used as a source of water for cleaning operations during the fabrication stages of the production units. At the conclusion of testing work on the "NYX" Unit in April, 1953, the deionizer was dismantled and moved to the west end of Building 3 where it was reassembled and put in operation in conjunction with a stainless steel storage tank which was being used as a container for distilled water brought in by tank truck.

INSTRUMENTATION AND CONTROL EQUIPMENT

The complex instrumentation and much of the control equipment required for the test of the "NYX" Unit was installed by New York Ship personnel under the supervision of du Pont instrumentation engineers and representatives of the various subcontractors.

A summary of the instrumentation and control equipment used in the test is given below to provide an indication of the scope of the work.

Work began in September, 1951, with the installation of an air dryer and filter which made possible the use of plant compressed air for instruments and saved the cost of compressors and storage facilities.

Instruments for the precision crane test station were then installed. One automatic and two manual control systems, flow measuring and static pressure instruments for the Q-tubes were included in this installation.

Twelve manometer panels were made, manifolds fabricated, tested and mounted for differential pressure measurements on the process water piping. Instruments in the permanent process pumps included six thermocouples and three flow and pressure switches in each of the six pumps. The process pump motors each required twelve thermocouples, six resistance

thermometers and six low pressure alarm switches. Pump and motor temperatures were led to a common terminal box where desired readings were selected by means of rotary switches.

Similar test and protective instruments were installed in the diesel generator sets, the two lubricating oil systems and the deionizer.

Thirty-five full size dummy tubes of various types were fitted with some 280 strain gages and gage cables for measurements within the "NYX" Units.

Approximately 5000 ft. of aluminum tubing was used in connecting monitor pins in the Bottom Tube Sheet Assembly to a rotary valve machine, and 480 separate leakage tests were made before the rotary valve system was perfected. The necessary test sets were fabricated by New York Ship.

Nearly 400 jacketed thermocouples were installed for tube temperature monitoring in the reactor. Temperature and flow monitoring machines were installed and tested.

Some 136 external and internal tank thermocouples were installed; tested and routed to two terminal boards and connected to rotary selector switches.

A hydrophone and thirteen accelerometers were located inside the unit and connected with gages in the control room.

Flow measurement of supply and return coolant to the Top and Bottom Tube Sheet Assemblies was recorded by instruments while temperature readings were taken by 32 thermocouples at various locations.

The Savannah River Plant type heat exchanger was fitted with thirteen temperature measuring stations, both external and internal, and temperature controls for vacuum drying and recording of absolute pressure. In addition, instruments were installed to measure the flow of river cooling water to the heat exchanger.

From September, 1951, until the disassembly of the NYX test equipment in Building 10 in the spring of 1953, a small force of New York Ship personnel was assigned permanently to instrumentation work. Mechanics from the Maintenance Department were used for actual installation and repair work, while the New York Ship Test Engineer's Department supervised and checked the installations. Two or three full-time technicians from the Test Engineer Group were in charge of the work, most of the time on a three-shift basis, under the supervision of du Pont instrumentation engineers.

EMERGENCY POWER EQUIPMENT

Diesel Motors and Direct Current Generators

Part of the NYX Program included testing an emergency power system designed to operate the process water system pumps at limited flow in case of failure of the 3000 hp. pump motors or the normal alternating current power supply.

Power for the emergency system was supplied by two diesel-generator sets. Each was driven by a Caterpillar diesel with a rating of 169 horsepower. The actual loads were 120 hp. under normal operating conditions, 160 hp. during emergency periods of long duration and 180 hp. peak during starting of the d.c. equipment.

The generator in each of the sets was designed and constructed by Reliance Electric Company and was wound to respond automatically to varying load demands. A minimum of electrical control was required, there being only a manually operated switch and circuit breaker for each generator. A single set of five storage batteries, provided with a trickle charger and an automatic charge control, was used to start each of the diesel engines in turn. Each engine was equipped with dual electric starters.

Cooling water was supplied to the diesels through a common 2-1/2 in. line from the river water supply system. A small heat exchanger mounted on each engine cooled lubricating oil and a larger exchanger mounted adjacent to each engine cooled the jacket water.

The diesel exhaust was led to the south wall of Building 10 through a Maxim silencer and 6-in. pipeline.

A fuel storage area with two 1200-gal. tanks was established inside the wire fence protecting the west side of Building 10. Two "Andale" strainers and a 20 gal./min. pump were mounted on the foundation pad poured for the storage tanks and were enclosed by a low cinder block dike. A 1-1/2 in. black iron pipe connected the storage tanks with two 100-gal. "day" tanks mounted near the diesel engines.

Work on the standby power supply began in March, 1952, but due to slow delivery of the generators, installation of the first unit was not completed until the following September. The second generator set was installed in November.

Direct Current Standby Drive Motors for Permanent Pumps

Each of the six Savannah River Plant process pumps and motors was fitted for a standby drive motor. The six 120 hp. standby

drive motors, mounted on the outboard end of the 3000 hp. a.c. motors were designed to carry the Byron-Jackson pumps and the a.c. motors at 600 r.p.m., one-third of their normal operating speed, to avoid a shutdown in event of an a.c. power failure. They were furnished by the Reliance Electric Company of Cleveland, Ohio, which also furnished two 110 kw., 350 v. d.c. generators. Cables were run from one generator to serve the three d.c. motors east of the reactor and from the other generator to the three d.c. motors west of the reactor. To prevent unintentional starting of a motor, no switching arrangements were provided for these cables from generator to motors. The cables had to be physically connected each time a different motor was run. Each generator provided power for only one 120 hp. d.c. motor at a time. A "Formsprag" back-stop clutch was mounted on the end of each d.c. motor shaft to prevent reverse rotation. The first three d.c. motors were received August 4, 1952, but were not tested until November 13, 1952. The other three d.c. motors, though delivered here, were never set in place.

A flexible coupling was used to connect these motors to the outboard end of the shaft of the 3000 hp. main drive motors. The Allis-Chalmers Manufacturing Company, vendor of the 3000 hp. motors, obtained these couplings from the vendor, the Thomas Flexible Coupling Company of Warren, Pennsylvania, and fitted one half-coupling on the shaft of each of their motors. They sent the other half-coupling for each d.c. motor to the Reliance Electric Company.

The emergency power equipment was tested in November, 1953, and at subsequent times and was found to perform in a satisfactory manner.

EQUIPMENT FURNISHED BY AMERICAN MACHINE AND FOUNDRY COMPANY

A number of the components used in the test of the "NYX" Unit were fabricated by American Machine and Foundry Company. These parts were primarily connected with the Precision Crane and the loading and unloading of foils and rods. Materials were furnished under a direct contract with du Pont. Installation and numerous later modifications to the equipment were made by New York Ship personnel, in consultation with American Machine and Foundry and du Pont engineers.

Material furnished by American Machine and Foundry included:

1. One-inch magazines used to load fuel slugs into the "Q" foil tubes. Difficulty was experienced in operating the magazines, and several modifications were made to give better control in positioning.

2. Vertical loading machines which served to guide the magazine, as a holder for the "Q" foil being loaded and also as a counterbalance to take the weight of a column of slugs as it was loaded into the "Q" foil. The two loading machines first used for the "NYX" Unit were hand-operated, but a motor drive was developed during the tests.
3. Lag racks, four in number, which were stands for holding "Q" foils. They were designed with an adjusting feature to place them on the centerline of the monorail hoist which carried the foils. During the test period this feature was found unnecessary.
4. Test Station: This installation was designed to duplicate hydraulic conditions in a loaded "Q" foil in the "NYX" Unit. Its component parts included pressurized tanks at top and bottom of the tube, a pump developing pressures somewhat over 300 lb./sq. in., a 500-gal. reservoir tank, a monitor pin at the bottom of the lower tank connected to four manometers for measuring flow through sections of the foil, a steam drying system, control panel and several air-operated control valves. Installation of the test station began in November, 1951, and was completed December 10. Subsequent work on the test station included addition of a stainless steel "Alsop" filter in the water supply line and repairs and design revisions to the tank seals.
5. The disassembly machine, also known as the "pushout" machine, unloaded "Q" foils by pushing out the slugs, a column at a time, with the tube vertical. The machine was about 40 ft. high with a pump, water reservoir tank and hydraulic cylinder at the lower level, indexing head at the intermediate level and the unloading and control platforms at the upper levels.

When the machine was first installed, the control panel was able to provide manual or fully automatic control. Later, use of the automatic controls was discontinued and the control panel removed. The existing platform at the 20 ft. elevation was revised and the balance of the structure supported by "Tube-Lox" scaffold. An extension of the monorail system was made to serve the machine.

The disassembly machine was set up between January 26 and February 5, 1952, on a 24 hour-a-day work schedule.

6. Tipping Table: This device was used in the transfer of the "C" rods from horizontal to vertical without bending them. The original design incorporated a friction clutch in the drive mechanism. The clutch proved inadequate and was replaced by a solid coupling. There was also considerable adjusting to be done to the latch mechanisms which held the tipping table in position. The tipping table was installed between November 23, 1951, and the following January.
7. A Foil Press and Shear machine, which pressed scrap "Q" foils flat and cut them into 8 to 10-in. lengths. Erection of the machine began in February, 1952, and continued in the form of development work for several months. The original hydraulic and control systems were replaced by entirely new systems of different design, though no major changes were made in the press, shear or feed mechanisms.
8. "C" rod Actuator: This was a complicated electronic and mechanical device for lowering and raising "C" rods and "S" rods. The model used for the "NYX" Unit test was designed primarily to check operating and wear characteristics of specific pieces of equipment.
9. Three masts for the Precision Crane. These are described under the heading "Installation of Precision Crane," Part IX.
10. Heads for the masts, above: Two types of heads were furnished for each mast, the second head in each case being an improved design.
11. Precision Crane Test Station: This test facility was partly assembled at the American Machine and Foundry Plant. It was installed by New York Ship personnel on the south side of the "NYX" Unit foundation in Building 10. The test station had three tube holes which in relative position and elevation simulated tubes in the unit. They were used to check accuracy of the Precision Crane settings without interrupting work in progress on the "NYX" Unit itself. Installation work on the test station began in December, 1952, and was completed in February, 1953.

MAJOR FABRICATION AND CONTRUCTION EQUIPMENT

Although New York Ship had a large variety of machine tools and fabrication equipment, many of the requirements of the NYX Project were almost unique. To meet them, special tools were designed and various additional equipment purchased or obtained through loan or rental. In general, because of the need for developing non-standard tooling, it was necessary to purchase rather than rent. In other cases the amount of rental over the period of fabrication would have exceeded the original purchase cost, so purchase was chosen as the most economical means of acquisition.

The urgency of the project also created a need for additional equipment. For example, the job could have been completed with fewer radial drills but only at the cost of many months in fabrication time.

Most of the special fabrication and construction equipment was obtained by New York Ship through regular procurement channels and charged directly to the project, although a limited amount was supplied directly by du Pont. A summary of the major equipment purchased by New York Ship is included on the following pages.

BUILDING 10 TEST OPERATIONS. A view of the "NYX" Unit foundation, looking north. Walkways, Precision Crane support steel and some of the process piping are shown. Unit is not in foundation.

SUMMARY OF MAJOR FABRICATION AND CONSTRUCTION EQUIPMENT PURCHASED BY NEW YORK SHIP

<u>Description</u>	<u>Source</u>	<u>Date Acquired</u>	<u>Reason for Procurement</u>
12' Master Super-Service Cincinnati Bickford Plain Radial Drill (26" Col.) Constant Speed Motor on Arm Drive, 3' Round Pedestal Base, Lifting Bail, Power Rapid Traverse to head Hydraulic Column and Arm Clamping, Adjustable Electric Light at Spindle, Cutting Lubricant Outfit, Spindle Speeds 6/650 RPM, and Special Feed Range and Incorporated Tap Leads of 4, 4-1/2, 6, 8, 9 and 12 Threads/inch. Serial No. 2C-135.	W.E. Shipley	8/21/51	New York Ship had only one 10 ft. radial and two 8 ft. radial drills. Additional radial drills were needed to meet schedule for line-boring plenums of units and for tube sheet drilling and trepanning.
12' Cincinnati Bickford Master Super-Service Plain Radial Drill (26" Col.) Constant Speed Motor on Arm Drive. Base (12' Length) Having Finishing Strips on Bottom, Machined for Mounting on Floor Plate. There is a lifting Bail, Hydraulic Column and Arm Clamping, Adjustable Electric Light at Spindle, Cutting Lubricant Outfit, Spindle Speeds of 6/650 RPM, and Standard Feeds and Tap Leads. Serial No. 2C-136.	W.E. Shipley	5/5/52	Same as above

SUMMARY OF MAJOR FABRICATION AND CONSTRUCTION EQUIPMENT PURCHASED BY NEW YORK SHIP

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(Continued)

<u>Description</u>	<u>Source</u>	<u>Date Acquired</u>	<u>Reason for Procurement</u>
10' Cincinnati Bickford Radial Drill, 24" Dia. Column, Overall Height 17', No. 6 Morse Taper in Spindle, Ten Feed Changes and Five Speed Changes in the Head, 25' of Track on 59" Centers, Carriage about 11' long Center to Center of Axle, Main Drive Motor 230 v. d.c., 500 to 1000 RPM with Controller, 1 - Separate Motor, 5 hp. 230 v. d.c., 1150 RPM for Propelling Base, Radial Drill, Serial No. 2C-47.	Miles Mach. Co.	7/5/51	Same as given on previous page.
Six Versa-Mills for Precision Milling, Boring and Grinding, each equipped with 440 v., 3 phase, 60 cycle a.c. Motor. Also, included (6) 90 degree Heads and 6 Feed Tables.	Calco Mach. Co.	12/7/51	Special milling operations such as slotting the Plenum Chamber tubes required portable equipment not available in Shipyard. The Versa-Mills were standard stock items and were used as a stop-gap measure. As soon as possible they were replaced with special design equipment.

SUMMARY OF MAJOR FABRICATION AND CONSTRUCTION EQUIPMENT PURCHASED BY NEW YORK SHIP

(Continued)

<u>Description</u>	<u>Source</u>	<u>Date Acquired</u>	<u>Reason for Procurement</u>
GC-300 Batteries, Total Capacity 600 lb. Dry Ice, Each Battery Consisting of 2 A.S.M.E. Code Pressure Vessels, Carbon Dioxide Process for Line Boring Equipment.	CO ₂ Development Company	7/11/52	For use in special cooling development in connection with line boring the "NYX" and production units.
20" Standard Cincinnati Rapid Transverse Shaper, V Belt Motor Drive 13" Single Screw Vise, with Standard Equipment, with 5 hp., 220/440 Volt, 3 Phase, 60 Cycle Motor, Serial No. 2202293.	Machinery Associates, Inc.	9/4/52	When fabrication operations were concentrated in Building 3, tool maintenance and development needs rose to a greater level than the shipyard tool room could process rapidly. To insure better control of tool work a small tool room was set up in Building 3 with necessary equipment.
No. 3-B Abrasive Surface Grinder Complete with 3 hp., 1750 RPM, 440 Volt, 3 Phase, 60 Cycle Motor with Attachments.	Abrasive Machine Tool Company, Inc.	8/25/52	Same as above.
No. 2 Cincinnati Plain Cutter and Tool Grinder, Complete with 3/4 hp., 440 Volt, 2 Phase, 60 Cycle Motor with Attachments.	Cincinnati Milling Machine Company	9/12/52	Same as above.

SUMMARY OF MAJOR FABRICATION AND CONSTRUCTION EQUIPMENT PURCHASED BY NEW YORK SHIP

(Continued)

<u>Description</u>	<u>Source</u>	<u>Date Acquired</u>	<u>Reason for Procurement</u>
5700 Gallon Capacity, Horizontal, Stainless Steel Tank, 14 Gauge, 18-8 Type 304 Stainless Steel, #2B Finish, Welded Construction, Inside Welds Heliarc Welded, Dimensions 6'4" Dia. by 24'2" Long on Straight Side with Shallow Conical Heads 8" Deep, Shell Reinforced with Angle Iron Rings, Tank equipped with 18" Dia. Manhole in Shell, one 2" Inlet, one 2" Outlet and two 1/2" Gauge Glass Connections in One Head. Serial No. 3180-3.	Perry Equipment Corporation	6/24/52	Cleaning requirements for the production units included use of deionized water in large quantities. A special storage tank was needed to avoid contamination.
Two 1000-Gallon Stainless Steel Storage Tanks 5'5" x 6'2" High Flat Welded Top, Conical Bottom, Mounted on Four Angle Iron Legs to Give 3' Clearance.	Perry Products Corporation	7/7/52	Originally obtained for the test of the "NYX" Unit, the tank was need to store deionized water used in cleaning production units.
Aircomatic Automatic Tube Welder, Complete with Reels, Tubes, Nozzles, Head and Reel Supports and Rotating Attachment.	Air Reduction Sales Company		Specially-developed equipment for welding large tubes and "R-tubes" in tube sheet assemblies. Ten complete tube welding sets were acquired.

SUMMARY OF MAJOR FABRICATION AND CONSTRUCTION EQUIPMENT PURCHASED BY NEW YORK SHIP

(Continued)

<u>Description</u>	<u>Source</u>	<u>Date Acquired</u>	<u>Reason for Procurement</u>
Aircomatic Automatic Track-Welding Machines complete with Heads, Reels, Track Panel, Mounting Arms, Radiographs and Contactors.	Air Reduction Sales Company	6/30/51	Needed for stainless track welding. Two complete sets were purchased.
No. 1389-3660 - #3S Aircomatic Gun Assemblies for Use of 1/16" Dia. S/S Wire Equipped with Heavy Duty Contact Tubes.	Air Reduction Sales Company	6/30/51	To Meet requirements for special shielded-arc manual welding on all "NYX" and production unit fabrication. Twelve complete units were purchased.
Lincoln Shield-Arc Motor Generator Type Welders; Model SAE-400, Type S-7046; 1800 RPM; NEMA Rated; Power Supply: A.C. 220 Volts, Reconnectable to 440 V., 3 Phase, 60 Cycle; Bulletin No. 1302, Stationary Model.	Lincoln Electric Company	8/20/51	Required to supply power to the Aircomatic welders listed above. A total of 9 motor-generators was purchased.
Lincoln Shield-Arc Motor Generator Type Welders; Model SAE-600, Type S-7059; 1800 RPM; NEMA Rated; Power Supply: A.C. 220 V., Reconnectable to 440 V., 3 Phase, 60 Cycle; Bulletin No. 1302; Stationary Model.	Lincoln Electric Company	12/5/51	Required to supply power to the Aircomatic welders listed above. A total of 12 motor-generators was purchased.

SUMMARY OF MAJOR FABRICATION AND CONSTRUCTION EQUIPMENT PURCHASED BY NEW YORK SHIP

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(Continued)

<u>Description</u>	<u>Source</u>	<u>Date Acquired</u>	<u>Reason for Procurement</u>
G.E. Model 6WD44A, 440 Amp. D.C. Motor Generator-Arc Welders, 220/440 V., 3 Phase, 60 Cycle Primary Current, Stationary Model.	Arcway Equipment Company	8/16/51	Required to supply power to the Aircomatic welders listed above. A Total of 4 motor-generators was purchased.
G.E. Model 6WD44 Motor Generator Type Welder; Model SAE-400, Type S-7046; 1800 RPM, NEMA Rated; Power Supply: A.C. 220 V. Reconnectable to 440 V., 3 Phase, 60 Cycle, Stationary Model.	Arcway Equipment Company	9/25/51	Required to supply power to the Aircomatic welders listed above. One Unit purchased.
Leblond 16 in. by 102 in. lathe with Attachments.	Swind Machinery Company	11/14/52	Required for Tool Room set up to maintain and develop tools for the project.
Cincinnati Notch Milling Machine, Including Rail Ram and Spindle Carrier. With Hand and Power Vertical Feed to Cutter and Manual Mechanical Movement of Ram along Rail. Wired for Operation on 440 V., 3 Phase, 60 Cycle Current.	Cincinnati Milling & Grinding Machines, Inc.	11/26/52	The slot milling machine, with an indexing head, replaced the Versa-Mills for tube slotting operations on the production units. It saved many hours of time and produced more accurate work than the old equipment.

SUMMARY OF MAJOR FABRICATION AND CONSTRUCTION EQUIPMENT PURCHASED BY NEW YORK SHIP

(Continued)

<u>Description</u>	<u>Source</u>	<u>Date Acquired</u>	<u>Reason for Procurement</u>
No. 2 Universal Milling Machine		11/52	Used in Machine Shop for keeping special tools sharp and expe- diting the fabrication work.

SUMMARY OF MAJOR FABRICATION AND CONSTRUCTION EQUIPMENT
RENTED OR LOANED TO
NEW YORK SHIPBUILDING CORPORATION

<u>Description</u>	<u>Source</u>	<u>Terms and Disposition</u>
10' Cincinnati Bickford Radial Drill. Serial No. 2C92	U.S. Navy	Leased at 1% per month of acquisition cost pursuant to Contract Nobs-4011. Delivery date April 21, 1952. Contract terminated July 18, 1953. Returned August 6, 1953.
10' Carlton Radial Drill. Serial No. 1407	U.S. Navy	Leased at 1% per month of acquisition cost pursuant to Contract Nobs-4011. Delivery date April 21, 1952. Contract terminated July 18, 1953. Returned August 6, 1953.
10' Carlton Radial Drill. Tag 5088	U.S. Navy	Loan. Received July 20, 1951. Returned June 15, 1954.
10' Carlton Radial Drill. Tag 5086	U.S. Navy	Loan. Received July 23, 1951. Returned June 15, 1954.
10' Cincinnati Bickford	U.S. Navy	Loan. Received July 27, 1951. Returned June 18, 1954.

Note: All drills were returned to the U.S. Naval Industrial Reserve Gear Plant, Lynn, Massachusetts, by rail shipment.

VII - FABRICATION OF "NYX" UNIT

DESCRIPTION OF MAIN UNIT

The "NYX" Unit, fabricated, assembled and tested at New York Shipbuilding Corporation was designed as a full-scale mock-up of production units to be used in the Savannah River Plant. Besides its function as a unit for test operation, the "NYX" Unit was to aid in developing welding and machining techniques and in evaluating design features.

As shown in the accompanying diagrammatic sketch, the "NYX" Unit is a cylindrical tank-like structure about 25 ft. high and 19 ft. in diameter at top and bottom (25 ft. in diameter face to face of flanges) and 16 ft. in diameter along the middle section. The unit has four principal assemblies: Plenum Chamber, Top Tube Sheet Assembly, Main Tank, and Bottom Tube Sheet Assembly. The Plenum Chamber and the two tube sheet assemblies contain tubes in matching patterns through which various sized rods and tubes can be lowered into the unit.

PLENUM CHAMBER

The Plenum is a Type 304 stainless steel weldment 17 ft. 5-3/8 in. outside diameter (25 ft. 1-1/4 in. face to face of flanges) by 10-3/4 in. deep (between outer faces of the tube sheets). Tube sheets are of 1-in. plate and contain a total of 673 large tubes (5-1/4 in. outside diameter) and 162 rod tubes (1-7/8 in. outside diameter). There are six 12-in. flanged nozzles spaced evenly around the "bulged" wrapper and a skirt of 5/16 in. plate which forms a seal with the Main Tank. The Plenum rests on the Top Tube Sheet Assembly.

TOP TUBE SHEET ASSEMBLY

The Top Tube Sheet Assembly is also a stainless weldment with a tube pattern which matches the Plenum except that the outside diameters of large tubes are 5 in. for non-bearing and 5-1/8 in. for bearing tubes. The Top Tube Sheet Assembly is 18 ft. 8-1/4 in. in outside diameter, 3 ft. 4 in. deep and has a flat wrapper of 1/2 in. plate except when lifting lugs are attached, plate is 7/8 in. The shield is strengthened by twelve internal gussets and contains eighteen inlet and eighteen outlet water distribution pipes between the wrapper and the tube pattern. A baffle plate 1 in. thick is located an inch above the lower tube sheet, while a similar deflector plate is suspended below the lower tube sheet. The Top Tube Sheet Assembly is fitted with twelve bearing pads and rests on the bearing ring in the Main Tank.

MAIN TANK

The Main Tank consists of two cylinders of 1/2 in. stainless steel and a bearing-expansion ring. The upper cylinder, known as the Top Tube Sheet Assembly Enclosure is 18 ft. 9-3/4 in. in diameter and 4 ft. deep. The lower cylinder is 16 ft. 3-3/4 in. in diameter and 12 ft. 4-1/4 in. from expansion ring to lower nozzles. The cylinders are joined by a bearing-expansion ring. The Plenum Chamber skirt seats on a rubber gasket in a groove, at the top of the Main Tank. The lower end of the Tank is welded to the nozzle assembly of the Bottom Tube Sheet Assembly.

BOTTOM TUBE SHEET ASSEMBLY

The Bottom Tube Sheet Assembly is similar to the Top Tube Sheet Assembly in shape, except that it is half an inch smaller in outside diameter and has a tank nozzle assembly welded to its upper tube plate. The assembly consists of six nozzles 20 in. in diameter spaced around a cylinder 16 ft. 3-3/4 in. outside diameter and 22-1/4 in. deep. The Bottom Tube Sheet Assembly is also similar to the Top Tube Sheet Assembly in its internal construction, containing gussets, water distribution system and a baffle plate. The tube pattern, differing from that of the other two tube sheet assemblies, contains only large tubes. The non-bearing are 3-15/16 in. and the bearing tubes are 4-1/8 in. in outside diameter. Flared-mouth cups are welded to the upper sheet of the Bottom Tube Sheet Assembly to position rods lowered through the small tubes in Plenum and Top Tube Sheet Assembly. The Bottom Tube Sheet Assembly is fitted with bearing pads and rests on the unit foundation.

DEVELOPMENT OF FABRICATION TECHNIQUES AND METHODS

MEETINGS FOR DISCUSSION OF FABRICATION TECHNIQUES

A number of preliminary discussions between du Pont and New York Ship representatives took place in March and early April of 1951. In these talks the general fabrication problems and the scope of the NYX Project were covered. On April 24 the first of six conferences at New York Ship was held to review and develop fabrication techniques. Subsequent meetings were held on May 1, June 1, June 8, June 22 and July 31. While almost daily conferences took place between various New York Ship and du Pont groups, the six fabrication meetings led to the major decisions reached in the planning stages, and provided the basis for the formal scope of work contained in the NYX contract.

15'-4 1/2" O.D. Tube Sheet Enclosure

18'-0" O.D. TOP TUBE SHEET

17'-5 1/2" O.D. PLENUM CHAMBER

15'-0" O.D. TUBE SHEET ENCLOSURE

PLENUM CHAMBER

TOP SHIELD
(TOP TUBE SHEET)

TOP SHIELD
ENCLOSURE

EXPANSION
JOINT

MAIN TANK

PLENUM
CHAMBER
W-130409
N-130539

TOP TUBE SHEET-W-130409
N-130539

TUBE SHEET ENCLOSURE
W-130516

15'-4" FACE

18
TA
W-13

PAGE THREE SMETS.

108

TANK BOTTOM TUBE SHEET
W-130463

Production Unit design was still fluid when the meetings began, and the addition of a tube-sheet assembly (Bottom) and modification of the rod tube arrangement from horizontal to vertical during May and June required additional fabrication plans. Both companies had a considerable amount of experience in fabrication work, but the size, material and close tolerances of the units presented certain unusual, if not unique, construction problems. Most of these problems were anticipated during the conferences, and solutions were developed through consultation or, when necessary, experimental work. Among the difficulties that were foreseen at the time were: welding of the stainless steel materials; the effect of welding shrinkage on tolerances; drilling tube sheets to required accuracy; alignment of tubes in Plenum Chamber with those of Top Tube Sheet Assembly; facing the ends of tubes; inspection procedures; procurement of materials and machine tools; and meeting the proposed schedules.

In the fabrication discussions, it was determined that the "NYX" Unit, if constructed of stainless steel, would give more useful results than a full scale mock-up of carbon steel, and would provide required cleanliness of testing equipment. Carbon steel would have to be stress relieved, thereby changing its dimensions to a degree that might make it useless for operational tests. Also, if the "NYX" Unit were built of stainless steel there was a possibility that it might later be converted to a production unit. The conversion actually took place, with a resulting saving of several hundred thousand dollars in government funds. The fact that the "NYX" Unit could be converted to a production unit despite material shortages, no precedent to work from, development of final design and inspection tools concurrent with fabrication, and the over-riding need for rapid completion existent during its fabrication is an indication of the quality of workmanship and planning that went into its construction.

The sequence of fabrication was established during the meetings as follows:

First an 8-ft. diameter stainless steel mock-up of the Plenum Chamber would be made. The mock-up would provide shrinkage data which could be projected to the full diameter tube sheets of the "NYX" Unit.

Next the "NYX" Unit would be constructed. The steps to be followed in fabrication were as listed below:

1. Machining and welding of plate into tube sheets.
2. Machining of tube holes in sheets.

3. Pre-machining of Plenum rod tubes; and Top Tube Sheet large and rod tubes.
4. Assembly and welding of tubes and tube sheets, etc.
5. Boring Plenum Chamber large tubes in alignment with Top Tube Sheet Assembly.
6. Facing tube ends.
7. Assembly of "NYX" Unit for test program.

Along with the establishment of a fabrication sequence, decisions made during the conferences determined fabrication methods and equipment as well as materials. Some of the more important of these decisions were:

Line Boring of Plenum and Top Tube Sheet Assembly

The required accuracies were so extreme that special precautions would have to be taken throughout construction. In the required finish of the tubes, in the matching of diameters and verticality, tolerances were comparable to those of a watch when overall size is taken into consideration. The basic decision made in this area was the use of radial drills and vertical boring bars rather than designing and building a special vertical boring mill.

Tubing

Early plans for New York Ship to machine tubing for the tube sheet assemblies were abandoned when the Connor Tube & Cutter Company was closed by a strike. The company had been awarded a subcontract to supply special tube boring tools, and in order to expedite work on the "NYX" Unit, du Pont decided to cancel the contract and pay settlement costs. The work was then placed with several subcontractors, who machined the tubing to the required tolerances and delivered it to New York Ship ready for installation.

While there was a preference for seamless tubing, the unfavorable delivery promises on this material dictated placing duplicating orders for centrifugally cast tubing and welded tubing so that diversified sources might be utilized to avoid serious delay. It happened that seamless tubing was the type first delivered in large quantity, hence the "NYX" Unit was built with seamless tubes except for some thirty-five cast tubes. Most of the tubing delivered on the duplicating orders was later used in production units.

Welding

It was decided to adopt the patented "Aircomatic" welding process (see below) for use wherever possible in production unit fabrication.

The development of certain specific fabrication processes - welding, drilling, boring and facing - is discussed in the following paragraphs of this section.

WELDING DEVELOPMENT

When discussions between du Pont and New York Ship began, welding had already been selected as the means of fabricating the "NYX" and subsequent production units. There were, however, two basic problems which had to be overcome in order to employ welding successfully on the project: (1) impurities in the welds would cause operational difficulties when the units were placed in service and (2) the shrinkage resulting from welding would have to be predicted and allowed for in order to meet the very close tolerances required by the specifications.

Development of Welding Techniques

In the series of fabrication meetings which took place at New York Ship, all available welding methods were reviewed. A process was required that would hold distortion to a minimum, reduce welding time as much as possible, eliminate contamination and produce deep, penetrating welds of uniform strength. The units had many restricted areas, particularly the closely spaced tubes in the Plenum Chamber and Tube Sheet Assemblies, which could not be welded by some methods. The method offering the best possibilities appeared to be an inert gas shielded arc system patented by Air Reduction Company. Known as "Aircomatic", it differed from the tungsten arc method principally in the replacement of the tungsten electrode by a small diameter stainless steel filler wire fed continuously to the arc, and in the use of welding currents up to 350 amperes. A special mixture of gases, principally argon, was used for shielding.

Both du Pont and New York Ship were in agreement that "Aircomatic" welding was the only feasible method and it was formally adopted for the NYX Project at the fabrication conference of April 24.

At the time, automatic "Aircomatic" track welding machines were available but there were no automatic tube welders. Tube welding could be accomplished by semi-automatic

manually-operated units, though with less uniform results than in automatic welding--an undesirable feature particularly in areas where X-ray inspection would be impossible.

Air Reduction Company at du Pont's request had already begun the development of an automatic tube welding unit in its laboratory. New York Ship cooperated in the completion of this unit and accepted it for use following a laboratory demonstration. The first automatic tube welder was delivered to New York Ship on June 6, 1951.

The "Aircomatic" tube welder contained a centering spear which positioned it in the tube to be welded. When started, the head rotated around the centering spear, laying down a weld as wire was fed by an electric drive regulated by arc voltage. Welding was automatic and stopped at the completion of a pass.

Welding Mock-Ups

In order to obtain information necessary to fabrication plans, du Pont designed a welding mock-up 8 ft. in diameter with tubes and tube pattern similar to those of a plenum chamber. Construction was authorized at the fabrication meeting of April 24, 1951, with completion originally scheduled for May 15.

Delays in delivery of stainless steel tubes and sheets and the necessity for design changes, notably the addition of rod tubes, required a postponement of the completion date. By June 12 all materials had arrived. Tube welding commenced on June 18 and fabrication was completed on July 23.

The mock-up, designated as the "Eight-Foot Mock-Up" consisted of top and bottom tube sheets 1 in. thick spaced approximately 9 in. apart and surrounded by a wrapper sheet. Tube sheets were trepanned for 154 tubes of 5 in. outside diameter and thirty-six tubes of 1.9 in. diameter. The tubes, all of Type 304 stainless, were procured from several sources and included both welded and centrifugally cast types. The larger tubes were welded in the tube sheets by means of the new "Aircomatic" equipment developed especially for this project while the small tubes were hand welded with semi-automatic equipment.

While the Eight-Foot Mock-Up was used almost constantly in experimental work during the first few months of the project, its principal value at this stage of fabrication development was: (1) in confirming welding procedures selected for the full-scale units; (2) developing shrinkage standards and verifying means of distortion control; and (3) insuring that the physical properties of the welds and materials were adequate.

Procedure specifications for welds were prepared by New York Ship in cooperation with du Pont. These specifications showed the design of joints and gave operating data for each pass, including size of wire, wire feed, travel speed, current and gas flow. The procedure specifications were modified from time to time as the result of experience and were issued in final form on June 16, 1952, as "General Specification for Inert Gas Shielded Metal Arc Welding with Consumable Electrode on Stainless Steel." (See Appendix, Exhibit "C-1", for copy.)

The most important procedure to be qualified was the automatic welding of the 5-in. diameter tubes, using fillet welds, into the tube sheets of the eight-foot mock-up. Examinations were made of the initial welds and of macroetched specimens cut from test weldments of 5-in. tubes into 1-1/4 in. plate. The latter test was made in accordance with du Pont Specification 3034 "Welding Process and Operator Qualification and Control." (See Appendix, Exhibit "C-2", for copy.)

The initial welds on the Eight-Foot Mock-Up and specimens showed no porosity or under-bead cracks. Bend tests on the macroetched test welds indicated excellent weld toughness and ductility. There were, however, certain undesirable characteristics in the early welds, such as:

1. Incomplete wetting action between the weld bead and the plate where the ends of the weld bead overlapped. This was overcome by thorough cleaning of the plate immediately before welding, using carbon tetrachloride and soft brushes.
2. Cracks and craters occurred in some of the test welds. They were eliminated by installing an automatic timer on the welding machine to continue the flow of inert gas for a short period after the breaking of the arc.
3. For high currents in deep-groove butts, weld quality was improved by attaching a hood to the automatic head through which an additional supply of inert gas could be directed at the arc.
4. Some difficulty was experienced with the weld contour and penetration of the "Aircomatic" tube welder. This was corrected by adjustment of the contact tube radius and the angle used to direct the filler wire into the weld. Once these settings had been established, a bending jig was made to keep all tube welders in proper adjustment.

Proper setting of the automatic tube welders and increasing operator experience resulted in satisfactory welds on the Eight-Foot Mock-Up and indicated that "Aircomatic" welding was suitable for the full-scale production units.

Although it was known that shrinkage would occur in the tube sheets of the Eight-Foot Mock-Up during welding operations, there was no experience on which a prediction of the actual amounts could be based. Holes for the tubes were, therefore, laid out to the desired final spacings of 7 in. between centers.

In order to produce as symmetrical a shrinkage pattern as possible, the mock-up was held in a fixture and the entire assembly placed in a large lathe so that welding could be alternated readily between top and bottom tube sheets. Selected tubes were welded on one side, the mock-up turned and corresponding welds made on the other side.

Measurements of tube spacing were taken by du Pont inspectors before welding, after welding the thirty-six small tubes and nineteen of the 5-in. tubes, after welding seventy-two of the 154 large tubes, and after all tube welding was completed.

An analysis of the measurements led to the conclusion that welding shrinkage amounted to .003 in. per inch of tube sheet diameter and would be the same for sheets of larger diameter. When tubes were welded in proper sequence, it appeared that shrinkage would be very nearly uniform.

Two curved sections of plate, simulating nozzles, were welded on the Eight-Foot Mock-Up to determine whether the welding of plenum nozzles would cause appreciable shrinkage or distortion. Some distortion occurred but no definite shrinkage pattern was established. It was concluded that nozzle welding after machining of tubes was hazardous except under the strictest control.

Plans for the production units called for projecting pins to be welded to the upper tube sheet of the plenum chamber near each of the tubes. To determine the effect of welding these pins, seventy sample studs 1 in. long and 1/2 in. in diameter were attached to the mock-up by a Nelson Stud Welder. Before-and-after measurements of tube spacing by means of a ligament gage indicated no change. When the design of pins for the production units had been completed, actual pins were welded to the mock-up to confirm the previous test. As before, no distortion of the tube pattern occurred.

Confirmation of the physical properties of the proposed process units was obtained from the Eight-Foot Mock-Up and from four pressure and fatigue test vessels.

The test vessels were designed and fabricated while work on the Eight-Foot Mock-Up was in progress. There were three identical vessels, cylindrical in shape, each approximately 2 ft. in diameter and 1 ft. deep with a 5-in. diameter tube welded through the centers of the end plates. These vessels were delivered to the du Pont Engineering Research Laboratory where they were tested at pressures ranging from zero to 1000 lb./sq.in. and at cycles from 80 to 270 per minute. The weld joining the head to the shell on one vessel failed after testing at 1000 lbs. pressure, while the other two vessels tested to a maximum of 500 lbs. withstood from 30,000 to 50,000 additional cycles and then failed through the wall of the 5-in. tube. No change in tube welding procedures was made as a result of this test, but a stronger joint between tube sheets and wrapper plate was used in the full-scale units.

The Eight-Foot Mock-Up was then hydrostatically tested. Pressure was brought to 150 lb./sq.in. by hand pump and held at this level for two hours. Eight leaks were found and repaired and the unit was then tested to 250 lbs. There were three additional leaks at this pressure. All leaks were in the tube welds and of a minor nature. No welding procedure changes were indicated by the pressure tests.

Welding experiments carried out with the mock-up led to the following conclusions:

1. The proposed "Aircomatic" welding system and procedures would be successful in fabricating the "NYX" Unit.
2. Shrinkage due to tube welding could be predicted within allowable tolerances and would be uniform if proper controls were used.
3. Shrinkage from welding other parts of the various assemblies would have a negligible effect on the tube pattern.
4. Strength of welds and materials was adequate.

Welding Jig

The "skip" welding technique employed on the Eight-Foot Mock-Up to minimize distortion was adopted for the production units. To carry out the welding sequence on full-scale tube sheets with the greatest efficiency, a welding jig was designed to hold three "Aircomatic" tube welders. The welding units were attached to small electric chain hoists which operated on trolleys on a three-arm spider. The spider was

free to move on a jib crane which also supported the cables from the welding equipment and kept them clear of the working area. It was possible to position the tube welders over any three tubes provided an approximate angle of 120 degrees was kept between tubes, this angle being a basic part of the tube welding sequence.

In fabricating the units, the welding jig was used with sequence charts. Drawn to one-sixth scale, the charts represented the various tube sheets and by means of a pivoted indicator with 120-degree spacing between arms could be used to plan the entire tube welding operation. Sequence books were made from the charts and were kept by a junior engineer responsible for tube welding. During fabrication, the engineer selected the next tubes to be welded and placed special covers over them. The covers were removed by the welders when they positioned the "Aircomatic" machines just prior to lowering the center spears into the tubes. Welding was done on alternate sides, with a maximum of forty-eight tubes being welded on one side before turning. On the "NYX" Unit only the large tubes could be welded by the automatic "Aircomatic" process, but on subsequent units, automatic equipment was available for the smaller rod tubes. In both cases, the small tubes were made a part of the welding sequence.

Additional Shrink Welding

The welding experiments carried out on the Eight-Foot Mock-Up had indicated that uniform shrinkage of approximately .003 in. per inch diameter would occur in the tube sheets of a full-scale unit. Accordingly, a stainless steel drill jig for the "NYX" Unit was fabricated to an expanded tube-to-tube spacing of 7.021 in. All tube sheets, except baffle and deflector plates not having welded tubes, were pilot-drilled and trepanned to this pattern.

In November 1951, as welding progressed on "NYX" tube sheet assemblies, inspection checks showed that the shrinkage was not uniform for Plenum Chamber, Top and Bottom Tube Sheet Assemblies. The average tube-to-tube distances after tube welding were:

Plenum tubes	6.994 in.
Top Tube Sheet Assembly	7.004 in.
Bottom Tube Sheet Assembly	7.010 in.

TUBE WELDING. A Plenum Chamber is being welded with tube sheets held in special handling jig. Photo shows three-arm spider which supports the Aircomatic Tube Welders. One machine is in position, other two held by 1/4 ton electric hoists for positioning.

DETAIL OF TUBE WELDING. Three welding machines supported by spider shown in preceding photo are in various stages of readiness. Machine at left is ready to apply a weld; one in center is raised to show centering spear; one at right is in position to make a test weld. Technician in foreground is using sequence charts. Dark plugs on top sheet of assembly are compression caps which clamp sheets against shoulder tubes. Men in upper center are cleaning weld areas with air

These differences were in excess of allowed tolerances so it was necessary to induce further shrinkage in the Top and Bottom Tube Sheet Assemblies to match the pattern of the Plenum Chamber.

The Eight-Foot Mock-Up was used to determine the effect of additional welding passes around the tubes. An additional welding bead was laid around all tubes, following a "skip welding" sequence to avoid distortion. The average additional shrinkage between tubes resulting from the welding was found to be .015 in. or about three-fourths of the initial shrinkage.

Using data from the mock-up as a basis, an additional or shrink welding pass was made around approximately half of the tubes of the Top Tube Sheet Assembly. Further shrinkage was required, and the remaining tubes were shrink welded. The top plate of the Top Tube Sheet Assembly was then in satisfactory alignment with the Plenum; the bottom plate, however, still had too large a pattern and 600 of 673 large tubes were given an additional shrink weld pass. The entire Top Tube Sheet Assembly then matched the Plenum within allowed tolerances.

The Bottom Tube Sheet Assembly, which had contracted less than the Top Tube Sheet Assembly was brought into alignment by giving all of its tubes, in both tube sheets, a shrink weld at slower speed than was used on the other and adding a second shrink weld on approximately half of the tubes, top and bottom.

Shrinkage data on the "NYX" Unit, as recorded by du Pont were as follows:

	<u>Plenum</u>	<u>Top Tube Sheet Assembly</u>	<u>Bottom Tube Sheet Assembly</u>
Calculated Shrinkage from Eight-Foot Mock-Up (all figures are inches) on diameter of 182 inches.	.546	.546	.546
Average Shrinkage at completion of initial weld pass.	.696	.443	.276
Additional Shrinkage Required to mate "NYX" assemblies.	---	.253	.420

The varying degrees of shrinkage between the components of the "NYX" Unit paralleled the variation in outside diameters of the tubes in each assembly. Plenum tubes were 5-1/4 in. in outside diameter, Top Tube Sheet Assembly tubes 5 in. and Bottom Tube Sheet Assembly tubes 3-15/16 in. Although this factor had not been considered a significant element in fabrication planning for the "NYX" Unit, later analysis indicated that the cumulative effect of slight differences in tube diameter, and therefore in amount of weld metal deposited, was responsible for most of the shrinkage difference.

As a result of experience on the "NYX" Unit, the layout pattern for achieving 7.000 in. tube spacing in future units was calculated as: Plenum, 7.027 in.; Top Tube Sheet Assembly, 7.017 in.; Bottom Tube Sheet Assembly, 7.010 in. These figures were modified slightly in order to use an existing 7.021 in. center jig instead of fabricating a new 7.017 in. jig and became 7.031 in., 7.021 in. and 7.014 in. All subsequent production units were made to these spacings.

Leveling Plate Distortion

Plate profiles of the Eight-Foot Mock-Up taken when fabrication was complete had shown that some warping of the tube sheets resulted from welding. Heavy fixtures were constructed to hold the tube sheets of the "NYX" Unit (described under NYX assemblies) and it was hoped that they would keep the plates flat within allowable tolerances.

When the "NYX" Plenum was removed from the fixture after tube welding, the tube sheets proved to be sufficiently flat. Tube sheets of the Top and Bottom Tube Sheet Assemblies, however, had warped on the edges to an appreciable degree during the tube welding and subsequent shrink welding.

The outer edges of the warped sheets did not have tube holes and had apparently failed to shrink with the centers of the plates, so when these circumferential strips were pulled in to smaller diameters, they were forced into a scalloped pattern.

An attempt was made to remove the waviness by inserting stainless steel bars between low points and pressing the high spots of the tube sheets together, but this method and other applications of pressure proved unsuccessful.

Radial shrink welds were applied to the outer strips of the warped plates with satisfactory results. The welds were applied on both sides of the sheets of the "NYX" Top Tube Sheet Assembly. No advantage was found in welding the inside

tube sheet surfaces and subsequent assemblies were given radial shrink welds on the outsides only. This procedure was made standard for all subsequent tube sheet assemblies and was carried out before the sheets were removed from their fixtures. Radial welds were ground down flush after leveling had been accomplished.

Personnel Training and Qualification Tests

Prior to assignment to the NYX Project each welding operator was given special instruction at New York Ship's welding school for three or four days. During this period he received training in the use of "Aircomatic" welding equipment and became familiar with the procedures he would be required to follow. Approximately fifty welders were trained at the beginning of the program and thereafter instruction was given as necessary on an individual basis.

All welders were required to qualify in accordance with:

1. The ASME Boiler Code, Section U68 (Unfired Pressure Vessels 1949 edition).
2. The ASME Boiler Code Standard Qualifications for Welding Procedure and Welding Operator (1949 edition).
3. Du Pont Specification No. 3034 (See Appendix, Exhibit "C-2", for copy).

During all tube welding operations each welding machine was checked before every shift by means of a test weld of a tube section in a plate. The test plates were about 6-1/2 in. square and 1 in. thick with a hole similar to those in the tube sheet. Short sections of stainless tubing were welded into the plate using regular procedure. Sections were immediately cut from the plates and a cross section of the weld was polished, etched and inspected for quality and penetration. The practice of checking each machine once a shift was adopted as a standard procedure.

DRILLING

Development of Drill Jigs

The expanded center-to-center spacing of "NYX" Unit tubes and the development of jigs for the tube sheets had to await the completion of welding on the Eight-Foot Mock-Up in July, 1951, and an analysis of measurements taken of shrinkage.

Tube sheets of the mock-up had been pilot drilled using an 8-ft. long carbon-steel strip jig with two rows of holes. Tube sheet holes were then trepanned to full size. Similar procedure was chosen for the "NYX" Unit.

The mock-up shrinkage indicated that an expanded center spacing of 7.021 in. would result in the desired 7.000 in. tube pattern after welding. Du Pont authorized the drilling of "NYX" tube sheets to this dimension. In August, New York Ship fabricated a two-piece stainless steel strip jig to the 7.021 in. centers.

The jig was made of stainless steel to prevent errors that would result if carbon steel, with a different coefficient of expansion, were used under the wide range of temperatures in the shops. The jig was 18 ft. 7-3/4 in. long, 18.124 in. wide and 1-1/4 in. thick. Holes were lined with hardened steel bushings into which drill and reamer slip bushings were inserted. Drill bushings were 1.218 in. inside diameter and reamer bushings 1.250 in.

The jig was used in conjunction with a layout of the tube pattern to drill the Plenum sheets of the "NYX" Unit. Plenum sheets were then used as jigs in drilling the tube sheets of the Top and Bottom Tube Sheet Assemblies.

After trepanning operations on the tube sheets had been completed, variations in tube center spacing in the "NYX" Unit were discovered and traced in part to the drill jig. Measurements by du Pont inspectors using vernier calipers put the cumulative error of the jig at .080 in. in an overall length of 16 ft.

The resulting error in tube sheet pattern was not considered serious enough to warrant scrapping the sheets, and fabrication of the "NYX" Unit was not interrupted, but a new 7.021 in. jig was bored with bushings more accurately centered.

Tube welding on the "NYX" Unit made additional jigs necessary because of the varying shrinkage in the assemblies. Analysis of the results gave new expanded center distances as follows:

Plenum	7.027 in.
Top Tube Sheet Assembly	7.017 in.
Bottom Tube Sheet Assembly	7.010 in.

The new stainless steel strip jig with 7.021 centers represented a considerable investment. In order to use this

jig, approval of the du Pont Engineering Department was obtained to increase the expanded center spacing of the Top Tube Sheet Assembly by .004 in. Basic tube spacing of Plenum and Bottom Tube Sheet Assembly was increased by the same amount.

Jig spacings were therefore established as 7.031 in. for Plenum, 7.021 in. for Top Tube Sheet Assembly and 7.014 in. for the Bottom Tube Sheet Assembly.

Fabrication of the new jigs caused a delay of approximately thirty days in the schedule of the first production unit ("R" Unit). In order to prevent an even longer delay because of slow delivery of stainless plate, the existing 7.000 in. jig was converted to 7.031 in. centers so that work could proceed on the Plenum. The original (out-of-tolerance 7.021 in.) jig was utilized to make the 7.014 in. jig for Bottom Tube Sheet Assembly tube sheets. Jig drilling was done on a special Swiss jig borer at the du Pont Wilmington Shops.

In December, 1951, after the drilling of Top Tube Sheet Assembly sheets for the "R" Unit, the 7.021 in. jig was sent to the Wilmington Shops for checking on the Swiss jig borer. Seven holes at the end of one of the jig sections were found to be beyond average dimension variance of the other jigs. These holes were re-bushed and bored by du Pont. When the stainless plate on order was delivered, a new set of 7.000 in. center jigs was bored at the Wilmington Shops.

The four sets of jigs were then used without further modification on subsequent production units.

Pilot Holes and Trepanning

The relatively large number and diameter of the holes in the tube sheets led to a proposal by New York Ship that pilot holes be drilled and then enlarged by a trepanning process. Du Pont agreed to this method at the first formal design and procurement conference.

New York Ship investigated various trepanning procedures in use in other industries and developed a three-bladed cutter after some experimentation in the machine shop with two and four-bladed types. All trepanning tools were fabricated in the shipyard tool rooms.

A typical trepanning cutter consisted of a solid body tool head approximately 5 in. in diameter and 14 in. long with a No. 6 Morse taper shank and 1-1/4 in. diameter replaceable pilot. The diameter of the pilot was chosen to

provide sufficient strength while requiring the removal of a minimum amount of metal. Tool steel cutter blades were bolted into slots in the head.

Approximately fifty-five trepanning cutters were fabricated in sizes from 3-3/8 in. to 6-1/4 in. for tube sheet cutting.

Later work on Actuator Deck Plates for the Forest Assemblies required additional trepanning tools. Some thirty-eight of these were made, ranging from 2-3/4 in. to 6 in. in diameter. They were similar to the other cutters except that they were designed for working carbon steel and had a 1 in. diameter pilot.

Selection of Radial Drills

Fabrication plans called for more than 7000 holes, many of them five inches or more in diameter, to be drilled to extremely close tolerances in the tube sheets of a typical production unit. New York Ship's drilling equipment was inadequate to meet the production schedules established for the program and a search was begun at once to locate additional large radial drills. Tentative adoption of a radial drill method of line boring Plenum and Top Tube Sheet Assembly tubes added further urgency to the drill procurement program.

Machine tools were in critically short supply in the spring of 1951. Despite the best efforts of tool suppliers, and du Pont and New York Ship representatives who toured the East and Midwest, no suitable equipment could be located.

Du Pont unearthed a 10-ft. Cincinnati-Bickford drill through a supplier in Michigan. The drill had manual controls and was approaching obsolescence, but was purchased as a stop-gap measure since it could be obtained at once. It arrived at the shipyard on July 5 and was set up in the machine shop and used with New York Ship's 10-ft. Cincinnati-Bickford and 8-ft. portable radial drills. This arrangement was used in drilling and trepanning the first tube sheets and in conducting early line boring experiments.

The Atomic Energy Commission meanwhile arranged with the Navy Department to borrow three radial drills from the Navy's Industrial Reserve Gear Plant in Lynn, Massachusetts. Two 10-ft. Carlton drills and one 10-ft. Cincinnati-Bickford arrived at New York Ship between July 20 and 27. The two Carlton drills were used in special boring set-up in the Machine Shop. The Cincinnati-Bickford drill, the hand-operated 10-ft. radial, and the shipyard's portable 8-ft. drills were used to establish two additional drilling stations in the Machine Shop.

Additional drills were needed, particularly one or more with 12-ft. arms because the 10-ft. drills could not reach the centers of the tube sheets. Du Pont was able to obtain a National Production Authority directive diverting a new 12-ft. Cincinnati-Bickford drill to New York Ship. The drill arrived on August 21 and was added to one of the drilling stations in the Machine Shop.

A second 12-ft. Cincinnati-Bickford drill, then under construction, was requisitioned by NPA order but was not completed until the following spring, arriving at New York Ship on May 5, 1952.

Early in 1952 all newly acquired drilling equipment was moved to Building 3 and two stations were established: (1) one 12-ft. and two 10-ft. drills on line boring, and (2) two 10-ft. drills (one of them the hand-operated model) on tube sheet drilling, "neck" reaming, welded tubes, etc.

Drilling equipment was still not adequate to meet production schedules. In the spring of 1952, New York Ship drew on the Navy Industrial Reserve Gear Plant once more, obtaining a 10-ft. Cincinnati-Bickford drill and a 10-ft. Carlton which were delivered on April 21. These drills were leased at a monthly charge of one per cent of acquisition cost. With the arrival of the requisitioned new 12-ft. Cincinnati-Bickford drill early in May the manually-operated drill was removed from regular service and two tube sheet drilling stations of two drills each were established in the east end of Building 3.

A summary of the radial drill procurement program follows:

<u>Type and Size</u>	<u>Date Received</u>	<u>Disposition</u>
10 Ft. Cin.-Bick. (Manual Control)	July 5, 1951	Sold July 10, 1954 at public sale High Bid: \$2,185
*10 Ft. Carlton	July 20, 1951	Returned June 15, 1954
*10 Ft. Carlton	July 23, 1951	Returned June 15, 1954
*10 Ft. Cin.-Bick.	July 27, 1951	Returned June 18, 1954
12 Ft. Cin.-Bick.	August 21, 1951	Transferred to U. S. Navy June, 1954

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<u>Type and Size</u>	<u>Date Received</u>	<u>Disposition</u>
*10 Ft. Cin.-Bick.	April 21, 1952	Returned August 6, 1953
*10 Ft. Carlton	April 21, 1952	Returned August 6, 1953
12 Ft. Cin.-Bick.	May 5, 1952	Transferred to U. S. Navy June, 1954

Note: *indicates loan or rental from U. S. Navy.

BORING

Development and Choice of Boring Method

Conditions under which the production units would operate required that the tubes of the Plenum Chamber and Top Tube Sheet Assembly, and to a lesser degree, the Bottom Tube Sheet Assembly, be held in alignment within very small tolerance for an assembly of such size. The tolerances were established as follows:

Alignment of top bore of Plenum tube with mid-point bore of Top Tube Sheet Assembly tube to be	.015 in.
Verticality	.005 in./ft.
Plenum bore size	+ .005 in. - .000 in.
Plenum top bore finish	63 RMS
Plenum bottom bore finish	125 RMS

Various boring methods were considered during the fabrication conferences in the spring of 1951. A standard horizontal boring mill, even with a precision spindle and indexing mechanism, would have been of doubtful value. Plenum and Top Tube Sheet Assembly would have been machined on their sides, not subject to the deflecting forces encountered in the normal operating position, and there would have been critical problems in removing chips, overcoming gravity effects on the boring bar - which would have to extend some five feet into the bores - and in lubrication.

Du Pont developed an outline design of a large machine tool to overcome some of the disadvantages of a horizontal boring mill. The machine would have bored the Plenum and Top Tube Sheet Assembly in the horizontal position but would have been very costly - estimates ranged up to \$250,000 -

and the time required to build it would have put the production units many months behind schedule.

New York Ship suggested an alternate boring method that, if successful, would result in considerable saving in time and expense. Discussions and studies up to this point had assumed that the Plenum and Top Tube Sheet Assembly tubes would be line bored together for their full length. New York Ship proposed that finish-machined tubes be installed in the Top Tube Sheet Assembly and that rough-finished Plenum tubes be bored to alignment with those of the Top Tube Sheet Assembly. The verticality and tube pattern spacing of the Top Tube Sheet Assembly were to be held within tolerances by careful control of distortion during welding and by the use of expanded center dimensions to compensate for shrinkage.

Independently both du Pont and New York Ship came to the same conclusion regarding the line boring procedure. The New York Ship proposal confirmed the du Pont proposals made considerably earlier but withheld to gain the benefits of an independent evaluation by New York Ship of this critical problem.

The proposed method would permit the use of radial drills instead of boring mills. After thorough investigation, du Pont agreed to the development of the system. Meanwhile, studies of the special boring mill were to be continued in the event that the simplified system failed to meet specifications.

Development of radial drill boring methods by means of mock-ups began in the summer of 1951. Single Plenum tubes were clamped in a heavy base under New York Ship's only 10-ft. radial drill. Various cutters were used and experiments were carried out with drill speeds and rates of feed in cooperation with du Pont engineers.

While it was necessary to interrupt the boring development project frequently because New York Ship's drill was needed for tube sheet drilling and trepanning, and ship-building work, sufficient progress was made to prove that special jigs and fixtures would be needed. Simple boring bars with single edge cutters could not produce the necessary alignment within tolerances.

The arrival of additional radial drills in late July and August made possible a more concentrated effort to solve line boring problems. The new 12-ft. Cincinnati-Bickford drill, set up in the south end of the machine shop with a Navy-loaned 10-ft. drill, was used for boring development.

A mock-up of a seven-tube section of the Plenum and Top Tube Sheet Assembly was fabricated with mild steel plates to simulate the tube sheet sections.

The mock-up was set up so that the 12-ft. drill could be swung over it or back to a platen on which tube sheets were drilled. The mock-up was leveled and securely bolted in place with Plenum Chamber tubes approximately $3/32$ in. out of line with those of the Top Tube Sheet Assembly.

Three upper sections of the mock-up were fabricated during development work. The first two had six rod tubes in addition to the large tubes, the third had large tubes only. The first Plenum mock-up served chiefly to eliminate unsuitable boring procedures; actual production methods were proved on the second and third mock-ups.

The two principal areas of development in the boring mock-up program were: setting or "centralizing" the boring tool and the subsequent attainment of specified verticality, bore size and finish. Separate experimental work and tooling were required for the large tubes and the rod tubes.

Large Tube Line Boring

Centralizing tool: In establishing the initial position of the boring tool, consideration was given principally to three methods. (1) Use of Top Tube Sheet Assembly, after welding, as a jig to spot-machine the ends of plenum tubes with piloted tools. The Top Tube Sheet Assembly would then be removed and the Plenum bores finish-machined with an overhung boring bar. (2) Procedure similar to that above, but the Plenum tubes would be bored in line with the Top Tube Sheet Assembly tubes rather than to the true vertical in order to stay within the tolerance of .015 inches in tube bore alignment. (3) Boring the Plenum tubes in approximate alignment with Top Tube Sheet Assembly tubes by establishing the center of each Top Tube Sheet Assembly tube at its longitudinal mid-point and boring vertically toward that point.

The last method was adopted as the most promising, based on the assumption that the dimensions and verticality of the Top Tube Sheet Assembly tubes could be controlled during welding.

A centralizing bar was fabricated with four retractable fingers which could be expanded by means of a screw extending to the top of the bar. The fingers centered the lower end of the bar at the mid-point of a Top Tube Sheet Assembly tube. The bar was then leveled with a precision level and

the upper end positioned by means of an adjustable base plate which was bolted through adjacent tubes. The base plate served as part of the boring fixture and remained in place after the centralizing bar was removed.

Boring Fixture: The fixture consisted of the base plate mentioned above, bearing and bearing housing, boring bar and floating clutch. In the first fixtures, the bar turned in a splined bronze bushing which was pushed downward into the tube behind the cutting tool to prevent play as the bar extended into the Plenum. In practice, it was found that the bushing frequently jammed in the bore of the tube, scoring the surface and causing a removal problem. The bushing was re-designed to remain fixed in the housing and proved satisfactory except for rather rapid wear.

In the experimental work, chips from the reamers worked upwards along oil grooves in the boring bar, entered the bushings and damaged them. The problem was eventually eliminated by finding the ideal cutting angle for the shell reamer blades and using a gravity oil feed with an air blast to carry the chips downward.

Bushing wear continued to cause difficulty, particularly in the final cutting stages when nearing finished tube diameters. Bushings were replaced after thirty to fifty tubes had been bored.

In order to maintain the closest possible tolerances, New York Ship designed a tapered bushing of "Mechanite" cast iron for use in the final boring step. The boring bar was chrome plated for added wear resistance. These harder bushings proved satisfactory when placed in service on the "L" Unit and were used on subsequent units.

Three sizes of shell reamers were used in line boring the large tubes of the Plenum. The first, or rough bore, opened the tube from 4 in. to 4.250 in. Next was a semi-finish cut to 4.340 in. and the final cut to 4.378 in. Reamer sizes were developed over a long period, and at various times different values were used. In the boring work on the mock-ups and on the "NYX" Unit, an effort was made to make the final boring cut meet the bore size and finish specifications. The desired finish could not be achieved consistently, however, and in all later units the final .007 in. (approximately) were removed by honing with "Sunden" finish hones and oil.

Rod Tube Line Boring

In the "NYX" Unit, pre-machined rod tubes were used in both Plenum and Top Tube Sheet Assembly in order to complete the unit as rapidly as possible. Development work on line boring the Plenum rod tubes proceeded concurrently with "NYX" fabrication, and was completed in time to be used on the "R" Unit.

Centralizing Tool: The top of the rod tube in the Top Tube Sheet Assembly was used to establish the location of the boring tool. A special bushing with a concave spherical top was inserted in the rod tube and used to center the lower end of a centralizing bar. The upper end of the bar was aligned vertically above the bushing by means of a precision level and base plate, in a manner similar to that used on the large tubes. The bar was then removed and the base plate used to guide the boring tool. Boring was accomplished by four-fluted core drills, specially designed with sub-lands, which turned inside bushings in the base plates. The first drill used was 1-1/4 in. in diameter. It was followed, in the "R" and "P" Units by a special drill which created a neck in the lower end of the rod tube. The drill had a 1-9/16 in. tip and a 1-15/32 in. body. The final boring step was the use of a 1-1/2 in. reamer in the upper bore and a 1-5/16 in. reamer in the neck, followed by honing to produce the required finish. Rod tube necks were omitted in the "L", "K" and "C" Units.

Boring Development on Eight-Foot Mock-Up

Shrinkage in the tube sheets of the Plenum was expected as a result of thinning the tube walls during line boring. In order to determine the allowance, if any, to be made in laying out the tube pattern, tubes of the Eight-Foot Mock-Up were rough reamed. Approximately 1/8 in. was removed from the walls of all tubes except a few which were used as reference points for measurements. The calculated shrinkage amounted to .0015 in. per inch and was considered small enough to require no special allowance.

Production Line Boring Arrangement

Procurement of line boring tools began in the summer of 1951. When radial drills to be used for line boring arrived, New York Ship made templates of their bases and constructed patterns of pedestals to position the drills over the Plenum and Top Tube Sheet Assembly. The base castings were ordered from Birdsboro Steel Foundry and Machine Company in mid-September and delivery completed by

October 23. New York Ship machined the pedestals and installed the stud bolts.

In order to support the Top Tube Sheet Assemblies and allow access beneath them during line boring, twelve cast steel supports were designed and patterns made by New York Ship. Casting was done at Birdsboro and all supports were delivered by November 26 for machining.

By January 29, 1952, boring development work in the Machine Shop had reached a stage where it was sufficiently accurate to be approved by du Pont for use on the "NYX" Unit.

A large platen approximately 30 ft. on a side was assembled and three radial drills placed on pedestals and bolted in position. Two 10-ft. Carlton drills loaned by the Navy were located on one side of the platen, near the corners, while the 12-ft. Cincinnati-Bickford drill was placed at the mid-point of the opposite side. It was possible to reach every tube in the Plenum with this arrangement of drills. The seven-tube mock-up was installed adjacent to one of the 10-ft. drills so that boring development could be continued as necessary.

The line boring installation was ready for use on February 13, 1952, when the Plenum and Top Tube Sheet Assembly of the "NYX" Unit were set up on the cast steel supports.

Line boring procedures remained basically the same throughout the project, although improvements were made in lubrication, cutting speeds and rates of feed as operators gained experience. The radial drill method of line boring proved so reliable that it was considered superior to any other method, even if special machine tools had been available.

Estimates were made of the savings that resulted from the use of boring bars and radial drills rather than special tooling. They are summarized below:

Cost of special boring machine	\$250,000	Cost of radial drill and pedestals	\$60,000
Disposal value	<u>50,000</u>		<u>40,000</u>
Net cost of set-up	\$200,000		\$20,000
Labor and tube cost to line bore Plenum and Top Shield all units	<u>1,250,000</u>		<u>657,165</u>
Total	\$1,450,000		\$677,165

As estimated by New York Ship, savings using the radial drill procedure amounted to \$772,835.

FACING DEVELOPMENT

Requirement for Large Boring Mill

Plans for the tube sheet assemblies called for the projecting tube ends in each assembly, with the exception of the underside of the Top Tube Sheet Assembly, to be faced to the horizontal plane within close tolerances. The most critical area lay between the Plenum Chamber and Top Tube Sheet Assembly where the maximum allowed deviation of ends of all tubes from the established plane was .015 in.

After an investigation of methods such as grinding the tube faces, a vertical boring mill was selected in the fabrication planning meetings as the best machine tool to achieve the necessary degree of accuracy. In August, 1951, experiments were carried out on the Eight-Foot Mock-Up to determine whether tool pressure during intermittent cutting action would cause tube distortion and whether the tool would "dig in". A single point cutting tool was employed with reasonably satisfactory results, maintaining the plane of tube ends within .010 in. and leaving the tube bores round.

In the development of facing operations for the full-scale units two general problems arose: (1) The method by which the plane of tube ends would be selected and (2) how to face the Plenum, which exceeded the capacity of New York Ship's largest boring mill.

Establishment of the plane for tube-end facing was carried out in a similar manner for each assembly, although details varied somewhat. About twenty-five tubes, spaced throughout the pattern, were used to establish an "average" verticality. Four or five tubes near the periphery of the pattern and equally spaced were then selected as reference points. The assembly was leveled to the average verticality, and level differential readings were taken of the reference tubes by du Pont inspectors using a Wild NIII level. By reproducing the differential readings, the assembly could be set up on another platen or the rotating table of a boring mill in the proper plane.

The largest vertical boring equipment at New York Ship was a 20-ft. mill consisting of a turntable and two planer heads which had been used during World War II on gun turret production.

The mill would handle all components except the Plenum Chamber which, with nozzles and flanges, was about 25 ft. in diameter. Consideration was given, therefore, in the development of facing procedures to (1) enlargement of the 20-ft. mill, (2) procurement of a larger mill and, (3) changing the fabrication plan of the Plenum to permit tube facing without the nozzles in place.

The least desirable solution from the standpoint of maintaining tolerances was facing the Plenum before welding the nozzle sections. From June to September, 1951, the primary effort was directed toward finding a suitable mill that could be purchased or leased, or a subcontractor to handle the facing work in his own plant.

Du Pont located a 35-ft. mill in Brooklyn and a 40-ft. mill in Pittsburgh, but both would have needed extensive repairs and could not have been put in production in time for the first two units. A 40-ft. mill was installed at the Baldwin-Lima-Hamilton plant in Chester, Pennsylvania, but efforts to subcontract the work there were unsuccessful because the mill was scheduled for some three years on hydroturbine contracts.

New York Ship's 20-ft. mill was considered from the standpoint of retaining the turntable and procuring larger uprights, crossbar and traverse mechanism. No parts of proper size could be found, however. Since this mill was adequate to face all assemblies except the Plenum, it was moved from its location in Building 10 and set up in Building 3. The site had formerly been the location of a smaller mill, and new foundations were required. These were constructed by Ralph Cornell in October, 1951, and the mill was erected by New York Ship and placed in service in November.

In order to speed completion of the "NYX" Unit, plans were made to modify Plenum fabrication procedure. Nozzle sections were to be fitted and tacked in place, then chipped off so that facing could be done on the 20-ft. mill.

Test of Eight-Foot Mock-Up

In order to determine whether shrinkage or surface distortion in appreciable amounts would occur, the Eight-Foot Mock-Up, which had previously been faced, was used to simulate the nozzle welding procedure. Measurements of the mock-up before and after welding showed a shrinkage of .005 to .010 in. in the tube sheet diameter, with no definite distortion trend in the plane of the tube faces. The "NYX" Unit was basically a full-scale mock-up, and the need for rapid completion was urgent. These factors, coupled with the

satisfactory results obtained from the Eight-Foot Mock-Up led to a decision to use New York Ship's 20-ft. mill to face the "NYX" Plenum.

Work at Philadelphia Naval Shipyard

Meanwhile, a search continued for facilities which could be used to face subsequent production units. In December, a subcontract was negotiated with the U.S. Naval Shipyard, Philadelphia, to face "R" Unit and other Plenum Chambers. The Plenum assemblies were to be delivered to the Shipyard by barge and would be machined with nozzles in place on the 40-ft. vertical boring mill there.

A considerable saving in tooling investment resulted from the subcontract with the Naval Shipyard. The saving was estimated at \$100,000, based on the cost of a large boring mill compared with the charge of \$8,000 per unit for facing operations. A considerable portion of the boring mill investment presumably would have been recovered at the conclusion of the project, so the figure does not represent an absolute saving.

The development of facing operations with New York Ship's 20-ft. mill continued as the "NYX" Plenum was machined in December, 1951 and January 1952. A number of early difficulties resulted from the interrupted cutting and the toughness of the tubes. Regular carballoy cutting tools proved too brittle, but a combination of cutting angle and an alloy designated "Circle C" finally gave satisfactory results. The New York Ship mill did not have continuous cross feeds, another factor making for tool difficulties. However, by the time facing operations had been completed on the "NYX" Plenum, sufficient experience had been gained to machine the tube ends of subsequent tube sheet assemblies on "NYX" and other units without serious difficulty.

INSPECTION GAGES

The operational requirements of the production units were such that the precise location of nearly every part of each unit had to be known in relation to the other parts. In addition, the tolerances to which the units were fabricated provided for a greater degree of precision than had been attempted in any known weldment of comparable size and materials.

The result of such stringent specifications was a considerable increase in the number and complexity of inspection gages over those that would normally have been

required. Inspection work was carried out by personnel of du Pont's Material and Equipment Section, while design of special gages was generally a joint function of two or more du Pont groups with assistance from New York Ship and commercial gage makers. A large number of standard commercial gages were used separately or incorporated in the gages designed specially for the project. This section will cover only the major special gages, since the others were a part of normal machine shop practice.

Pattern Gage

Pattern gages were required to determine the coordinates of each tube in the three tube sheet assemblies. The X and Y axes of the assemblies were used as reference lines.

The original pattern gages used on the Eight-Foot Mock-Up and in the early fabrication stages of the "NYX" Unit were simple wood beams with a dial indicator at one end and a hook at the other. Designed by du Pont inspectors, the gage measured from the row of tubes lying on the X and Y axes to the tube being checked. The gage could span the half-diameter of any of the assemblies.

In use, the gage was set to a basic dimension by means of a pin gage calibrated to .001 in.

Before completion of the "NYX" Unit, du Pont designed and procured four ligament gages to replace the earlier wood gages. These were 48 in. long, each fitted with seven dials mounted on adjustable arms, and were fabricated by Newton Tool Company, Wenonah, New Jersey. Calibrating stands were fabricated for setting the ligament gages. A total of six stands was used, all fabricated by Thau Manufacturing Company, Baltimore, Maryland.

The pattern gage measurements were used in conjunction with tube bore measurements and final center line locations to calculate coordinate deviations from theoretical pattern. The ligament measurements were combined with the bore measurements of the tubes to provide the required data.

Verticality Gage

The close tolerances covering the verticality of tubes in all tube sheet assemblies required the use of special gages. The first attempts at verticality inspection were made on the Eight-Foot Mock-Up. A machined mandrel was fitted with a spring at the bottom end and a shoulder at the top on which precision level was placed. The mandrel

was inserted in a tube bore and held against the side of the bore by the spring and the inspector while shims were placed under the level to bring it to a zero reading. This method was too cumbersome for the larger units, and du Pont groups developed an improved model of the gage.

In the improved verticality gage, a larger mandrel with two sets of spring-tensioned shoes aligned itself in the tube bore. A fixed bar was attached to the top of the mandrel and perpendicular to it, while an adjustable hinged bar was positioned above the fixed bar. A level and dial indicator on the hinged bar measured the amount of adjustment necessary to bring the hinged bar to a level position, and the parts were designed to give a direct reading of the inches-per-foot the tube was out of vertical.

Centrality Gages

Centrality gages, sometimes referred to as eccentricity gages, underwent considerable development during the course of the NYX Project. The gages were required to determine the offset between the large tubes of the Plenum Chamber and the corresponding tubes of the Top Tube Sheet Assembly to the nearest thousandth of an inch. The reference points for measuring were established as the mid-point of the Top Tube Sheet Assembly tubes, and the lands of the Plenum tubes.

The first gage was a hollow sleeve with a dial indicator suspended in the lower part so that it would contact the mid-point of the Top Tube Sheet Assembly tube into which it was inserted. The gage was fabricated by the Newton Tool and Manufacturing Company, Wenonah, New Jersey.

It was found that the plunger of the dial indicator was easily damaged in use, and a modification was made to keep the plunger retracted during insertion and removal. However, the gage was still not completely satisfactory.

A new gage designed by du Pont and fabricated by Newton Tool incorporated several improvements. The gage had a longer body with a removable collar so that it could be used to take measurements during line boring, when base plates for the boring bar housing were in position. The dial indicator plunger was automatically retracted by a spring loaded fork and plunger. When a reading was taken the inspector had to depress the plunger. The new gage proved to be difficult to keep in adjustment and a special ring gage was fabricated as a standard for setting and checking the centrality gage.

The new gage was an improvement on the previous model, but was found to give a variation of several thousandths of an inch when used to measure the same tubes at different times. Since the purpose of the gage was to measure to the nearest thousandth of an inch, it was considered to be unsatisfactory.

While the developmental work on the mechanical centrality gages was taking place, du Pont was working on an electronic approach to the problem. The fabrication of a successful electronic gage at this stage made the further development of mechanical gages unnecessary, and all were considered obsolete.

Electronic Gage

Difficulties experienced with the mechanical centrality gages during line boring led to a proposal by du Pont's Mechanical Development Laboratory that an electro-magnetic gage be used. Du Pont's Design Division did the developmental work which resulted in the first electronic gage.

The first gage was fabricated by the Thau Manufacturing Company, Baltimore, Maryland and then shipped to Automatic Temperature Control Company, Philadelphia, for assembly and wiring. Somewhat similar in appearance to the mechanical gages, it consisted of three stages so that when in position they would be at the top, mid-point and bottom of the Top Tube Sheet Assembly tube bores. Each stage consisted of four plungers and differential transformers. The transformers were connected through electrical circuits to a control panel where the position of the plungers was read directly from indicator dials to the nearest thousandth of an inch.

A setting stand to calibrate the electronic gage was also fabricated by the Thau Company.

Difficulties encountered during the use of the first gage on the "NYX" and "R" Units led to the fabrication of two improved electronic gages with the following major changes:

1. Addition of a plunger stage at the level of bottom land of Plenum Chamber tube.
2. Addition of brass strips for plunger tip protection.
3. Addition of thrust bearing for universal leveling in one operation. (Previously, the gage had to be re-leveled each time it was rotated in the bore for readings at different positions.)

4. Addition of safety cam lock to prevent removal of gage from bore without first retracting the plungers.
5. Two indicating fixtures were fabricated to permit leveling the gage after removal of line boring base plates.

The setting bars of the original setting stand were replaced by a precision-honed tube supported in a rigid box frame. The honed tube was later replaced with two master cylinders made of high tensile bronze, chrome plated on the inside. Additional adjustment screws were added to the stand to control the position of the master cylinders more accurately.

The two improved electronic gages were fabricated by the same companies that produced the first gage. The procedure for using the electronic gages was developed on the "P" Unit and used on the subsequent units.

Functional Gages

Operational requirements of the production units for close tolerances in the Plenum-Top Tube Sheet Assembly tube bores resulted in the use of functional gages. The gages were designed and procured by du Pont and consisted of rods or cylinders which could be inserted into the appropriate tubes. If bore alignment was not within tolerance, the gages would not seat freely.

Three sizes of gages were called for: (1) a rod tube gage with a lower diameter of 1.271 in. and upper shoulder diameter of 1.484 in.; (2) a large tube gage with lower diameter of 4.330 in. and upper shoulder of 4.365 in.; and (3) a second large tube gage with the same lower diameter as the preceding one but a 4.375 in. shoulder diameter. The latter gage was used after final honing of the tubes.

Though not required by specifications, du Pont inspectors used a gage with a 4.378 in. shoulder in their final inspection, shifting to the 4.375 in. gage when binding was encountered.

The rod tube gage was first fabricated of carbon steel tubing but was found to be somewhat flexible. Solid carbon steel gages were then used, and later an improved model was made from "Flastus" alloy steel bar and chrome plated. The large tube gages were fabricated from carbon steel tubing. The gages were procured from the Chaumont Manufacturing Company, Glendora, New Jersey and the du Pont Wilmington Shops.

Precision Level

In order to obtain a high degree of precision in leveling the various tube sheet assemblies and other components of the units, du Pont purchased a used Wild NIII Precision Level. The instrument, a tripod-mounted telescopic type with optical micrometer, also proved valuable in the fabrication of the Forest Assemblies for the Telescope Actuator Systems.

The Wild level was obtained in the spring of 1952 and its early use showed the need for precision leveling rods and base plates which were ordered in April, 1952. In addition, four special level targets were designed by du Pont and fabricated by the Newton Tool Company, Wenonah, New Jersey. Experience with the above targets resulted in the fabrication of four improved models of the targets with revised housing structures. Two of the new targets were sent to the Savannah River Plant.

Theodolite

Requirements for erecting the "NYX" and production units called for the transfer of the X and Y axes from the Plenum Chambers to the Top Tube Sheet Assemblies. In view of the large size of the assemblies and the degree of accuracy specified, some method of plumbing optically was desired. A Wild TI Double Center Theodolite was selected by du Pont as the best instrument for the work.

In practice it was found that the adjustment of the line of sight of the theodolite between widely separated bench marks was a tedious and time-consuming operation. In order to avoid this delay, a special cross slide base for the instrument was designed and procured by the du Pont Design Division. The cross slide had a slow motion drive screw which enabled the operator to make very fine adjustments in positioning the instrument at right angles to the line of sight.

The theodolite was used in lofting-in the Bottom Tube Sheet Assembly and Main Tank, including Top Tube Sheet Assembly enclosure.

Further use was made of the instrument in the testing of the "NYX" Unit in order to detect movement of the Plenum Chamber.

FABRICATION OF PRINCIPAL ASSEMBLIES OF THE MAIN UNIT

The principal assemblies of the "NYX" Unit, described previously in this section are: Plenum Chamber, Top Tube Sheet Assembly, Main Tank and Bottom Tube Sheet Assembly.

Fabrication of the assemblies of the "NYX" Unit proceeded simultaneously as far as possible. Work on the Plenum Chamber and Top Tube Sheet Assembly took precedence in the early stages of the work because of the additional man-hours estimated for their construction.

Some of the problems anticipated in fabricating the "NYX" assemblies have already been discussed in the preceding paragraphs of this Section. In the case of the "NYX" Unit, procurement and fabrication steps had to be started in advance of firm plans. This was a calculated risk that saved many weeks in completing the unit and providing test data need for subsequent production units, but it resulted in changes that might have been avoided had time not been so critical a factor.

As fabrication progressed there were unexpected delays due to procurement and machining difficulties. They were held to a minimum by the use of substitute materials and tools wherever possible, but completion of the "NYX" Unit extended approximately five months beyond the initially established goal date, which was set before sufficient information was available for an accurate estimate.

PLENUM CHAMBER

The principal steps in the fabrication of the Plenum Chamber assembly were:

1. Fabrication of tube sheets from stainless plate.
2. Drilling and trepanning tube holes in sheets.
3. Fabrication of tubes.
4. Fabrication of components such as nozzles, bulges and skirt.
5. Assembly of tubes and sheets.
6. Welding tubes and components.

TYPICAL PLENUM CHAMBER. This picture of the "NYX" Plenum during conversion to "K" shows nozzle and skirt arrangement, as well as handling method used in turning assembly over. A third cable sling is attached to nozzle out of picture at upper left.

7. Facing
8. Line Boring
9. Milling tube-end slots and attaching component parts.
10. Cleaning and inspecting.

Fabrication of Tube Sheets

The 1-in. Type 304 plate for the Plenum was received at New York Ship on June 21, 1951. Magnetic and Ferroxy tests were made by du Pont inspectors and all traces of free iron were removed by grinding.

Three plates were required to form each of the two tube sheets. The center plate was made about 3/16 in. wider than specifications so that shrinkage resulting from welding of the side plates would bring the location of the weld to drawing dimensions.

Welding of the plates into tube sheets was carried out in the Boiler Shop, using semi-automatic Aircomatic welding equipment. The plates were first tack welded, then clamped to level building slab and weighted to prevent buckle. Three continuous passes were made on one side, the plates turned and a similar weld made on the opposite side. The welds were then completed, leaving a slight crown which was chipped and ground flush with the plate surface.

The entire length of the weld was X-rayed and repaired whenever defects were found. The early tube sheets needed a relatively large amount of weld repair, but defects dropped off rapidly in subsequent tube sheets as the welders gained experience and their techniques improved.

The tube sheets were laid out and burned to a rough diameter, allowing approximately 4 in. excess (decreased to 3 in. in later units) for the burning operation and dressing edges.

The edges of the tube sheet were straightened in a 350-ton press and waviness in the sheets was removed with a 70-ton deep-throat press.

The pair of rough-sized tube sheets was then turned over to the Machine Shop, which laid out the tube pattern on one sheet. The spacing of the tube holes was established at 7.021 in. based on shrinkage data from the Eight-Foot Mock-Up. After tube welding the spacing was expected to be 7.000 in.

Right-angle axis lines only were laid out on the second sheet and the two were bolted together. The sheets were rough turned in the South Yard on a 12-ft. open mill with portable heads welded to floor foundation beams. The two sheets were turned together to a diameter 2 in. larger than finished size. The edges were dressed and the two sheets set up under radial drills in the Machine Shop for drilling the tube holes.

A strip jig with spacing of 7.021 in. between centers was set to the layout of the sheet and clamped in position. Pilot holes of 1-1/4 in. diameter were drilled from the jig. Two of the holes, used as locating holes, were reamed and the jig was moved to a new location, positioned by a pair of hardened steel pins in the jig. When the number of drilled pilot holes increased sufficiently, a second strip jig was added.

All holes were finish-reamed with a piloted reamer, a procedure later changed to reaming directly from the jig by changing bushings in the jig.

The tube sheets were separated, and the tube holes trepanned by means of a specially-designed cutter. The edges of the holes on the outer surfaces of the tube sheets were chamfered for welding by means of a fly cutter having a lignum vitae pilot.

The trepanning and chamfering were checked by du Pont inspectors using plug gages with a "go" and "no go" difference of .002 in. and a bevel to fit the chamfer. In addition, ligament gages, a long straight edge, and multiple-mounted dial indicator gages were used to check the tube sheets.

When inspection was completed, the tube sheets were released to the Boiler Shop for assembly of tubes.

Procurement of the tubes for the "NYX" and subsequent units was the most difficult material problem encountered during the project. Several tube sizes were required for the Plenum, Top and Bottom Tube Sheet Assemblies, and a considerable amount of pre-machining was needed before assembly. Additional tubing and bar stock of smaller size had to be obtained for rod tubes in the Plenum and Top Tube Sheet Assembly.

Du Pont undertook procurement of materials for the large size tubes in the spring of 1951. The approximate quantity and sizes of tubing ordered for the "NYX" Unit based on seamless drawn tubes were as follows:

Plenum: 1370 ft. 5-3/8 in. outside diam. 4 in. inside diam.

Top Tube Sheet Assembly: 1655 ft. 5-1/8 in. outside diam.
3-3/4 in. inside diam.
1535 ft. 5-1/8 in. outside diam.
4-3/16 in. inside diam.

Bottom Tube Sheet Assembly: 3100 ft. 4-5/16 in. outside diam. 3 in. inside diam.

First efforts to procure the tubing indicated that delivery could not be obtained until December, 1951. Since completion of the unit was then scheduled for November, every possible means of expediting delivery was used.

Among the steps taken by du Pont were: A purchase order followed by a request for government directive, on Babcock & Wilcox Tube Company for stainless steel seamless tubes to cover the "NYX" Unit requirements for large tubes. An additional order for cast steel billets to be used in tube extrusion experiments was placed with Electric Steel Foundry Company and with U.S. Pipe and Foundry Company. A complete set of large tubes for the "NYX" Unit was also ordered from Pypon Company (welded tubing) and from U.S. Pipe and Foundry Company (centrifugally cast tubing). Cancellation of the latter orders was planned of necessity if the seamless tubing, which was the preferred type, could be obtained in time.

Directive action plus du Pont expediting resulted in obtaining delivery of the Plenum and Top Tube Sheet Assembly tubes from Babcock & Wilcox by September 1, but the company could not supply the Bottom Tube Sheet Assembly tubes until 1952. However, du Pont was able to obtain enough tubes from the Timken Roller Bearing Company to meet revised production schedules.

The cast and welded tubing orders were not cancelled because "R" and "P" Unit procurement problems required the use of substitute tubing in those units.

The tube extrusion program was completed but it was not applied for production use. Sixteen cast and machined billets were shipped to the U.S. Air Force Experimental Laboratory in Adrian, Michigan, for tests but delays in obtaining extrusion-die steel prevented receipt of information in time to be of value for tube procurement.

While procurement of tubes was proceeding, a problem arose in the pre-machining of the tubing for assembly in the units. The work was originally to have been done in

New York Ship's Machine Shop, but delays in delivery and design changes that increased the scope of the machining operations made the use of outside shops necessary to meet schedules. Some 150 firms were surveyed, but only ten were found that could offer reasonable delivery schedules. New York Ship placed orders with the ten vendors for approximately 2100 large tubes and 170 rod tubes. An additional 170 rod tubes were machined from bar stock by the du Pont Wilmington Shops for the "NYX" Plenum Chamber.

Drawings and partial material shipments were issued to the tubing subcontractors in August, and the "NYX" Plenum tubes were completed by mid-October. Top and Bottom Tube Sheet Assembly tubes followed in late October and November. A considerable number of tubes, not finished within the necessary tolerances, required re-machining at New York Ship and delayed the availability of the tubing for installation in "NYX" assemblies.

Assembly of the Plenum tubes and tube sheets began during the last week of September. A handling jig, known as a pot chuck, had been fabricated to simplify the Plenum assembly. It consisted of a heavy shell built in four sections, which firmly gripped the two tube sheets. The tube sheets were clamped in position by flat bar rings bolted to the inside of the shell. Openings in the side of the shell provided access to the space between the sheets, and a lifting rig made it possible to turn the handling jig over by means of an overhead crane and a pair of standard lifting beams.

The bottom tube sheet was placed in the jig and ninety-one special tubes with 1/16 in. shoulders were installed to act as internal spacers for the tube sheets. The top sheet was then lowered in position and clamped in the handling jig. Adjustments were made to the jig to obtain the best condition of verticality between corresponding tube holes, and the jig was secured rigidly with fitted bolts.

Rod tubes were inserted and tack welded at the inside of the bottom tube sheet, by means of a manual Aircomatic gun extended through an adjacent large tube hole. A shortage of rod tubing during this stage of the "NYX" Plenum assembly caused a delay in fabrication. With available rod tubes installed, the large shoulder tubes were oriented by means of a splined straight edge which fitted slots cut in the tops of the tubes. The tube sheets were then bolted against the shoulder tubes by means of tie rods and caps which fitted over the projecting ends of the shoulder tubes and bore on the tube sheets.

The rod tubes were welded in place with Aircomatic manual equipment in accordance with a sequence set up by

New York Ship's welding engineer. Approximately fifteen tubes were welded, the assembly turned over and thirty welds made on the bottom, then the Plenum was turned and thirty tubes welded on the top. This procedure continued until all rod tubes in the Plenum had been welded.

The remaining rod tubes were received and installed in the Plenum Chamber on September 29 and 30.

All rod tube welding was inspected visually for defects. Repairs were made in a few places where cracks and porosity were evident.

Inspection of the tube sheets following rod tube welding disclosed that the large 5.250 in. tube holes adjacent to the rod tubes had been shrunk out of round. Attempts were made to insert tubes (outside diameter 5.246 in.) in the holes by shrinking the tubes in alcohol cooled by dry ice. When this did not succeed, the tube holes were enlarged by grinding. The latter method resulted in uneven holes and proved to be very slow. Portable drill presses were set up and the holes reamed to their original size in both top and bottom sheets. Tube holes corrected by reaming were found to be approximately .010 in. oversize, which was acceptable. Plans were made to ream all subsequent tube sheets in the same way.

The assembly of the Plenum continued with the insertion of the large non-shoulder tubes. Of this group, seventeen tubes were of the cast type and the rest seamless. The tubes were assembled in groups from the center out, with the Plenum resting on a large slab. When each tube was seated on the slab and properly oriented by means of slots in its top, it was tack welded to the inner surface of the lower tube sheet. A special 5-ft. Aircomatic welding gun was used for this operation, and was inserted through an adjoining tube hole to make the weld. After a number of tubes had been tack welded, checks of the upper ends revealed that tubes were dropping progressively further through the Plenum. It was found that the tack weld pulled each tube down a few thousandths of an inch and that the cumulative effect would result in serious errors.

The Plenum Chamber was then raised on pedestals about 4 ft. high so that tubes could be installed independently. A heavy steel rail was jacked in position so that its upper ends bore against two shoulder tubes. The straight tubes between the two shoulder tubes were then inserted and tacked in position, with shims used as necessary. (Later, the straight tubes were set independently of their lower ends in order to line up their internal weir slots with the plane of the lower tube sheet. The same general

procedure was followed, however, with shims being used on the rail to adjust individual tubes.)

The assembly of the Plenum tubes progressed from the "X" axis line in both directions toward the ends of the "Y" axis. After all tube alignment from a shoulder tube had been completed, the tube was tack welded. A few tubes that could not be reached for tack welding inside the Plenum were tacked in the weld bevel of the top tube sheet.

Permanent welding of the large tubes began on October 5. The specially-designed "Aircomatic" tube welding equipment was used, and a skip welding technique developed on the Eight-Foot Mock-Up was followed.

The Plenum was placed under the welding jig with the spider hub above the center tube. The three rotating spider beams which carried the "Aircomatic" tube welding machines were rotated and the machines run in and out to follow the prescribed welding sequence.

Each welder turned out a test coupon with his machine at the beginning of each shift. The coupons, made of scrap 1-in. plate and tubes, were cut, etched and inspected. Inspection of the samples took place from 4 to 8 hours after they were made.

Tube welding machines were started simultaneously to prevent electrical interference, and set to weld a complete bead with 1 in. to 1-1/2 in. overlap at the joints.

The "Aircomatic" equipment was just beyond the experimental stage at this time. There were several breakdowns which made changes in welding sequence necessary. Porosity was found in some welds, usually adjacent to rod tubes.

Upon completion of tube welding on October 10, a thorough inspection of the Plenum was made. Approximately forty-eight crater cracks were found, all of them appearing where the weld overlaps occurred. The crater spots were ground out, and in a few cases repair welds were made.

The Plenum was moved to the Machine Shop where it was set up under two radial drills in order to face and neck-ream the rod tubes.

The determination of the correct plane for both rod and large tube faces was complicated by a "dishing" of the Plenum tube sheets. The vertical distance from high to low points was found to be 3/16 in. with the centers of the sheets low.

It had been intended originally to maintain the level of the lower end of internal weir slots in the large tubes $1/8$ in. above the bottom plate. Since dishing made this impractical, decision was made to mill the internal tube slots flush with the bottom tube sheet. The tops of the tubes would be faced to the best average verticality of the tubes.

The Plenum was moved to a level platen where individual slot heights were measured. In order to expedite the preparation of the unit for testing, fifteen high slots were selected to be milled down to the average plane of the lower tube sheet. No cut into the sheet of more than $1/32$ in. was permitted. If the "NYX" Unit became a production unit at a later date, the remaining slots were to be milled down to the plate level.

Rod tubes were faced to height using the bottoms of correct weir slots as the basis for measurement by theodolite and staff. The tubes were spot machined with fly cutters.

The rod tubes were then neck-reamed, to open the areas which had shrunk during welding. The Plenum was turned over and the operation repeated on the bottom sides.

The shrinkage pattern of the Plenum lead to a decision to bore the rod tubes of subsequent units at the time the large tubes were line bored, rather than accepting the chance of pre-bored tubes shifting out of verticality due to uneven welding shrinkage. Orders to subcontractors were changed so that rod tubes then being fabricated for future units would have $7/8$ in. diameter bores. Development work was started on rod tube line boring equipment similar to that being made ready for the large tubes.

The Plenum was leveled to give the best average verticality of the large tubes, and readings were taken on five reference tubes with the Wild NIII level. The Plenum was cleaned and sent by rail to the South Yard where it was set up on the 20-ft. boring mill, and reference tube settings matched. The tube sheets were finish turned and beveled for the nozzle bulge.

The six Plenum Chamber nozzles and bulges had been under construction in the Boiler Shop simultaneously with the fabrication of the tube sheets. Materials for the nozzle bulge assembly were received in June and October of 1951 and January, 1952.

Large forming dies had been designed to shape the bulges and nozzle sides and were ordered on a priority basis from Birdsboro Steel Foundry and Machine Company. The throat pieces were to be cut from the inside neck section of a 10-in. 45-degree heavy-wall long radius elbow. New York Ship's regular shop equipment was capable of handling the remaining shaping operations.

Top and bottom plates for each of the six nozzles were laid out and burned to shape with a $1/4$ in. allowance for finishing edges, edges planed, and sent to the Machine Shop for drilling and countersinking for staybolt welds. The plates required slight shaping on hydraulic presses.

Staybolts and shroud plates for the nozzle vanes were fabricated and assembled on special jigs. One assembly of five staybolts and shroud covering and two assemblies of three staybolts and covering were required for each nozzle.

The vanes and top and bottom nozzle plates were assembled and welded. Special precautions were taken during this operation to hold distortion to a minimum and to dress and clean welds thoroughly between each pass as X-ray inspection of these assemblies was not possible.

The male and female dies for the nozzle sides and Plenum bulges were received in September, 1951, and were machined, ground and fitted to New York Ship's hydraulic press.

The plates for the nozzle bulges were laid out to developed templates and formed. After machining and chipping, each set of nozzle bulges was placed in a specially prepared jig with the corresponding vane section. Backing strips were tack welded in position and the bulges were tacked to the top and bottom plates. The assembly was then removed from the jig and welding was completed.

The nozzle throat pieces, which had been ordered in the form of 45 degree elbows from a steel supplier had not been delivered. The Boiler Shop fabricated the necessary dies and shaped these sections from plate.

The assembly jig was used to fit the throat pieces and a short neck section which had been fabricated from 12-in. pipe. The sections were tack welded, removed from the jig and placed on a vertical positioner which was rotated to provide as much downhand welding as possible.

Certain design modifications to the shroud plates of the nozzle vanes were made at a later date including the welding of the plates to the inside of the nozzle at the leading edges and provision for relief holes.

A large jig had been constructed to hold the six nozzle assemblies and the bulge sections that joined the nozzles to form a periphery of the Plenum Chamber. The jig had a center hub and six targets to position the corresponding nozzle assemblies. All lines needed in fabrication were laid out and marked on the jig.

The nozzles were positioned and the bulges fitted by means of templates with adjustable end plates, and tacked into the assembly which then became a hollow ring.

The assembly was moved to the South Yard and placed on a former turret boring mill which had been reconditioned for the NYX Project. The inner edges of the nozzle assembly were bored to the proper diameter and beveled for welding to the Plenum tube sheets.

During the first week of December, 1951, the Plenum nozzle assembly was tack welded to the tube sheet assembly. As discussed in a preceding section, the capacity of the 20-ft. mill on which the Plenum was to be faced was insufficient to handle the assembly with the nozzles in place. Therefore, only the bulge sections between the nozzles were welded at this time and the six nozzles were chipped loose for later assembly to the Plenum.

In the subsequent production units, which were faced on a larger mill at the Philadelphia Naval Shipyard, the nozzles were welded in position at this stage of fabrication.

The Plenum was placed on the special 20-ft. boring mill set-up and leveled to the reference tubes. Erection buttons to mark the horizontal plane was turned to the proper height and thereafter used as reference points. After several inspections and checks, the upper tube faces were semi-finished. The original handling jig, or "pot chuck" would no longer hold the Plenum because of the side bulges, so a lifting and turning jig had been constructed to handle the Plenum as it neared completion. The jig consisted of four beams joined in pairs which formed a "sandwich" and held the Plenum clamped between them. Bolts with wood collars were passed through tubes of the Plenum to prevent the assembly from shifting while being turned.

The Plenum was turned over, using the new handling jig, and the large tubes finish faced on the bottom side. The Plenum was turned back and the final facing cut made on the top side of the tubes.

The fifteen tubes in which weir slots were to be machined flush to the bottom plate were milled at this time by means of special tool consisting of an angle head air motor and 5/16 in. end mill with guides.

The six nozzles and nozzle flanges were fitted and tacked in position and a special positioning jig was assembled and bolted to the Plenum. The jig supported the Plenum in a vertical plane while permitting it to be turned on trunnions supported by pedestal bearings. By turning the assembly, welders were able to use downhand welding on nearly every joint as nozzle welding progressed. However, the turning jig proved to be so awkward in operation that numerous weld repairs were required. The jig was not used on subsequent production units.

Upon completion of the nozzle welding, X-rays and repairs were made. The skirt plate, which had been largely prefabricated in the Boiler Shop using standard dies for forming, was then fitted to the Plenum in sections and welded.

The Plenum Chamber was ready for the line boring operations by February 11, 1952, somewhat behind the original schedule. Progress on the Top Tube Sheet Assembly had been slowed by the difference in pattern spacings between the two assemblies which resulted from tube welding. Shrink welding, as described in the previous section, was required on the Top Tube Sheet Assembly to bring its pattern into sufficient alignment with the Plenum to permit line boring. The Top Tube Sheet Assembly was ready for line boring on February 13.

The line boring station was set up in Building 3, South Yard, as described previously. The Plenum was placed on the Top Tube Sheet Assembly, which in turn was supported on cast pedestals.

A functional gage seated properly in all rod tubes, though approximately thirty per cent of the tubes exceeded the .005 in./ft. out of verticality allowed in the tolerances. A check with the Wild NIII level showed that the Plenum was level with a maximum differential of .015 in.

Bearing surfaces between the bottoms of the Plenum large tubes and the tops of those of the Top Tube Sheet Assembly were checked with feeler gages and found to be satisfactory.

Following the various alignment checks, three index devices were tack-welded in position, and final measurements were taken to determine whether the welding had caused any motion. Wooden chip stoppers were pressed into the Plenum tube weir slots, and the unit was released for line boring.

Line boring began on February 17 and continued until April 5. It was the most difficult and time consuming operation in the fabrication of the "NYX" Unit. The line boring

PLENUM AND TOP TUBE SHEET ASSEMBLY. Photo shows functional gaging of the large tubes. The positioning of the assemblies and location of lifting eyes are clearly shown. One of the centering devices can be seen just below the nozzle in center foreground.

procedures and some of the problems have been discussed in the section on development of fabrication techniques. Improvements in the methods of establishing initial boring settings and in inspecting the accuracy of the bored tubes were made as the work progressed. The procurement of boring bar housings with "Meehanite" bushings and the use of hard-chrome plated bars improved the performance of boring considerably.

The rough boring of the large tubes - in the case of the "NYX" Plenum the rod tubes had been pre-machined to final inside diameters - proceeded relatively fast, with approximately fifty tubes a day being completed. When the finished boring stages were reached, however, various difficulties caused the rate to fall to fifteen or fewer a day, compared to an original estimate of forty-five in the schedule.

A method study by du Pont tooling engineers recommended more detailed and organized preparations of tools and equipment. When placed in effect, the suggested procedures speeded up production considerably.

After all the Plenum tubes had been bored to a rough diameter of 4.250 in., measurements indicated that boring had caused a .036 in. shrinkage in diameter of the tube sheets.

To insure minimum shrinkage in the subsequent finishing steps, the original "random" boring method was changed. The center tubes were to be finished first, with the boring moved progressively outward. Constant checks as boring progressed showed very little shrinkage. A return to random boring, with each radial drill working in specified sectors was then permitted, with a resulting increase in the rate of completion of tubes.

Measurement of the finished large tubes indicated that approximately forty per cent exceeded the verticality tolerance of .005 in./ft. and that about ten per cent had out-of-round bores in the bottom land. The functional gage (4.365 in. in diameter) would not seat in eight tubes. Several of these tubes were removed from the Plenum, using a special boring tool developed for such a contingency, replaced and bored. The other tubes were repaired by grinding with abrasive discs.

After all repairs had been made, the large tubes were again functional gaged. Five tubes still did not pass the gage but were so close to meeting the requirement that they were accepted by du Pont Design group.

All rod tubes accepted the functional gage test without repair work.

The Plenum was removed from the line boring station on April 10. The large tubes were beveled and the edges dressed. The assembly was set up on the open mill and the skirt plate finished to proper height.

The Plenum was then hydrostatically pressure tested. All tubes and the nozzles were blanked off. The nozzle flanges did not maintain a watertight seal and had to be removed and machined to give a better joint. While repairs were being made, the Plenum was temporarily sealed, sand-blasted and passivated.

The repaired flanges were installed and the assembly filled with regular city water and tested at a pressure of 375 lbs./sq. in. for two hours. Two leaks around rod tubes were discovered. They were chipped out, ground and re-welded and the Plenum again tested. One more leak was found and repaired. The Plenum then passed the test for water-tightness.

The flanges were removed and lines scribed on the tube tops as a guide for milling "V" slots. On the "NYX" Unit, these slots were cut with portable "Versa-Mills" which were procured specifically for the slotting operation. The "Versa-Mills" had been tested on the Eight-Foot Mock-Up and special bases had been made for them. Four mills were used at a time, but work progress was slow due to vibration and frequent failures of the gears and other parts of the mills.

As a result of the experiences with the light-weight "Versa-Mills", Cincinnati Milling and Grinding Machines, Inc. was consulted on the design of a notch cutting machine engineered for the job. The company constructed a special track milling unit with an indexing head and delivered it to New York Ship in November 1952, in time for use on "P" and subsequent production units.

Approximately ten per cent of the slots in the "NYX" Plenum failed to pass inspection and were re-finished with the "Versa-Mills".

At this time, progress of construction work on the "NYX" test facilities required a trial installation of the Plenum Chamber in the concrete foundation erected in Building 10. The Plenum was mounted on the foundation and templates were lifted for the 12-in. diameter process piping. Other needed measurements were checked and the Plenum was returned to the turret-building pits at the west end of Building 3. These pits, stripped and water-proofed to serve as cleaning basins, had been provided with water, steam and air systems.

One cleaning pit was filled with city water and steam heated to approximately 160 degrees. "Oakite 31", a caustic compound with a wetting agent additive, was added in powder form under the direction of an Oakite Company representative. The Plenum was submerged in the solution for approximately 72 hours. It was then rinsed in the second pit, which was filled with city water at approximately 150 degrees. The Plenum was raised and lowered in the rinse water several times and drained. Despite the rinse, the interior of the Plenum did not meet cleanliness specifications because of "Oakite" deposits.

A more thorough cleaning method was devised employing a closed circulation system. Wood plugs were placed in the tube ends and the nozzles were blanked-off. The assembly was thoroughly rinsed with water sprays. Dowell, Inc., a company specializing in industrial cleaning work, was employed under a subcontract to wash the Plenum with special equipment. Using "Oakite 17", a phosphoric acid and wetting agent compound, Dowell pressure-cleaned the Plenum and rinsed it with city water. The unit again did not meet the rigid specification required for cleanliness. However, due to the urgency of beginning operations in Building 10 the Plenum was accepted for test work.

The cleaning of assemblies to the degree set forth in the specifications proved to be a major problem in their fabrication. Following the difficulties with the "NYX" Plenum, more intensive precautions were taken during assembly and more detailed cleaning processes were developed with Dowell, Inc. Dowell was retained for cleaning work during the remainder of the NYX fabrication program.

Upon completion of the cleaning baths, the Plenum was given finishing touches. There were forty-seven V-slots which required re-machining. The large tube bores were acid washed for passivation, rinsed, and dressed with abrasive discs.

Tubes whose bores did not meet the specified 63 R.M.S. finish were honed with a portable "Sunnen" stone rig driven by an air motor. Frequent checks were made to prevent enlarging tubes beyond the maximum limit of 4.380 in.

Approximately 24 tubes were not finished to the required smoothness by May 20, 1952, when the Plenum was acid washed and moved to the test site in Building 10. These were accepted at the time to evaluate their leakage behavior under test.

At this stage of the "NYX" Plenum fabrication, the next Plenum assembly--designated as "R" had been line bored and was almost fully assembled. The third or "P" Unit Plenum tube sheets were being assembled, and the fourth or "L" Unit Plenum tube sheets were being drilled and trepanned. Many of the fabrication problems encountered in the "NYX" Plenum were avoided in subsequent units, but a considerable amount of work on the first three units was concurrent or nearly so, making the use of improved methods or machines impracticable on these units.

TOP TUBE SHEET ASSEMBLY

The principal steps in the fabrication of the Top Tube Sheet Assembly were:

1. Fabrication of tube sheets, baffle and deflector from stainless plate.
2. Drilling and trepanning tube holes in sheets.
3. Fabrication of tubes.
4. Fabrication of components such as gussets, distribution pipes, spiral inserts, and tube collars.
5. Assembly and welding of tubes and sheets.
6. Shrink welding of tube sheets to match Plenum tube pattern.
7. Assembly and welding of components.
8. Facing tops of tubes.
9. Line boring of Plenum with Top Tube Sheet Assembly as guide.
10. Cleaning, filling with raschig rings and inspecting.

Preparation of the tube sheets and the drilling and trepanning operations were similar to those used in fabricating the Plenum Chamber. The center-to-center spacing of 7.021 in. between tubes used for the Plenum was adopted for the Top Tube Sheet Assembly after welding experiments with the Eight-Foot Mock-Up.

On October 10, assembly began in the Boiler Shop. The bottom tube sheet was set up on a building slab and the gusset plates were tacked in position. A baffle sheet was to be held 1 in. above the bottom sheet by small collars around each tube.

To aid in assembly, the collars were tack welded in position except for those used on the shoulder tubes, which were held in place by the tube shoulders. Production was interrupted at this point because of late delivery of collar pieces being supplied by G.O. Carlson Company, Thorndale, Pennsylvania. A handling jig, or pot chuck, similar to the one used in assembling the Plenum Chamber had been made for the Top Tube Sheet Assembly. The tube sheets were assembled in the jig, then dismantled as a result of a decision to countersink more deeply to strengthen the welds where tubes would be faced off flush with the tube sheet.

On October 23, the tube sheets were re-assembled in the handling jig with shoulder tubes in place, following the method used on the Plenum except that a baffle plate was installed before the top plate. Verticality checks were made and the handling jig adjusted. A shortage of rod tubes slowed work, but all available rod tubes were installed and hand welded, using the "Aircomatic" process. The gusset plates were welded to the top sheet, and sealing bars, which closed space between gussets and baffle, and held the baffle plate against the collars were fitted and welded. The remaining rod tubes were received and welded. It was found, as in the Plenum, that the welding had distorted adjacent large tube holes. Grinding was used to fit the non-shoulder tubes but as in the case of the Plenum was not entirely satisfactory. On subsequent assemblies, distorted large tube holes were reamed after welding. Large tube welding was done with automatic "Aircomatic" equipment as described in the Plenum Chamber fabrication. The outside diameter of the Top Tube Sheet Assembly tubes was $1/4$ in. less than that of the Plenum tubes, while the inside diameter was approximately $3/8$ in. larger. Possibly as a result of this difference, the shrinkage resulting from tube welding was found to be considerably less in the Top Tube Sheet Assembly than in the Plenum.

Corrective action required a period of about a month. Many inspection measurements were made of the tube pattern at various temperatures. Following a series of meetings between du Pont and New York Ship engineering personnel, additional tube welds for the purpose of shrinking the Top Tube Sheet Assembly pattern were authorized. Approximately thirty per cent of the large tubes on both sides of the assembly were given a second welding pass. At the same time, fourteen defective welds found during inspection were ground out and rewelded.

Upon removal of the handling jig, waviness, or scalloping of the plate edges was found. An unsuccessful attempt was made to straighten the plates by compressing

them against bars, as mentioned under "Leveling Plate Distortion". Radial shrink welds were then selected as a possible solution and proved satisfactory.

In installing the handling jig, preparatory to shrink welding, two tubes were damaged. A special tube removal tool had been developed and was first put in service at this time. The tool was a sleeve with a cutting edge which slipped over a tube and, driven by one of the radial drills, cut away the welding bead. Tubes with flush ends were bored through the tube sheet.

Due to a difference in pattern size between the top and bottom tube sheets of the assembly, an additional shrink weld was applied to selected tubes of the bottom sheet. The two new tubes were welded in place and the radial shrink welds were made in accordance with instructions from the New York Ship Welding Engineer.

On December 13, the tube patterns of the Top Tube Sheet Assembly were accepted by du Pont inspectors, and the assembly was sent to the South Yard. The tube sheet edges were beveled for wrapper sheets on the 12-ft. open mill and the gussets were milled using a portable horizontal mill. (The lower 8 in. of the gussets was turned rather than milled because the horizontal mill could not be lowered sufficiently to reach this area).

Thirty-six dummy circulation tubes, with stainless cast spiral inserts fabricated by Allegheny Ludlum Corporation, were assembled and welded. While the interior of the tube sheet assembly was protected by wood strips, gusset stiffeners and remaining sealing bars were welded and dressed. The wrapper plates of 1/2 in. and 7/8 in. stainless plate were fitted and tack-welded.

A welding positioner, already available in Building 3, was modified to handle additional weight and used to rotate the tube sheet assembly during welding of the wrapper plates. The positioner proved more satisfactory than the lifting and turning jig in which skirt and nozzle welding of the Plenum had been done, and was employed in the fabrication of all subsequent tube sheet assemblies.

The Top Tube Sheet Assembly was placed under a set-up of three radial drills subsequently used for line boring. Gas tubes were faced off as required on the bottom side, the inner surfaces of the tube ends beveled, and a selected "spider web" pattern of nineteen tubes reamed to original inside dimensions. The latter operation was required because tube welding had caused shrinkage in the tubes, and a verticality gage could not enter the bores.

The assembly was leveled to the best average verticality of the selected tube pattern, with individual tube variations ranging from .005 to .015 in./ft. Bench marks were established by du Pont inspectors using the Wild NIII level, and the assembly was moved to the 20-ft. boring mill. It was re-set to the bench marks, and the tubes faced and reference buttons finished for future orientation. The assembly was turned over and the bearing pads faced to the same plane. Since the lower ends of the tubes did not bear on any other surface, precision facing was not carried out on the lower side of the assembly.

The Top Tube Sheet Assembly was returned to the radial drill set-up and leveled. All tubes both large and rod, except those previously machined as part of the reference pattern (above), were reamed at top and bottom weld lines to remove "hour-glass" shrinkage. Revised center lines were established, based on the centers of tubes along the X and Y axes.

The deflector plate, though drilled to the nominal 7-in. centers, proved usable despite the excess shrinkage of the Top Tube Sheet Assembly. The relatively large clearance of deflector plate holes proved ample to pass the foils and rods.

On February 10, 1952, the Top Tube Sheet Assembly was placed on the specially-designed cast steel pedestals in the line boring set-up. It was leveled using an 18-ft. straight edge and checked. The three radial drills were carefully aligned with the assembly and the entire set-up rechecked for levelness and verticality with precision instruments.

The Plenum Chamber was lowered into place on the Top Tube Sheet Assembly guided by a centering mandrel through the center tube of each assembly. Center lines were used to orient the two sections. Further checks of level were made, and the alignment of each Plenum tube with the corresponding one in the Top Tube Sheet Assembly was inspected.

Following other preparatory steps and the actual line boring, described in the preceding Plenum Chamber section, which required nearly two months, the Plenum was removed. Several large tubes in the Top Tube Sheet Assembly which would not pass the functional gage were enlarged slightly.

The Top Tube Sheet Assembly was given a hydrostatic test with city water brought up to 52-1/2 lbs./sq. in. by hand pump and held for two hours. Fifteen rod tube and two large tube welds on the top side, and fourteen rod tube and two large tube welds on the bottom side were found to have leaks. All defects were chipped out and repaired, and rod tubes which were re-welded were faced.

Both the Top and Bottom Tube Sheet Assemblies were to be filled with small stainless cylindrical tubes, or raschig rings, approximately $1/4$ in. in. diameter and $1/4$ in. in length, formed from .050 in. strip. The raschig rings were difficult to procure because of the large quantity needed (approximately 120 tons total for both assemblies) and the fact that they had to be free of contamination. Du Pont was able to obtain the necessary quantity of raschig rings only after surveying fabricators in several nearby states and doing considerable expediting work.

The method by which the tube sheet assemblies were to be filled had been the subject of several conferences between New York Ship and du Pont representatives, and a special filling cradle designed to hold both assemblies had been fabricated. The cradle had two steel rims extending around somewhat more than half of the circumference. The rims were provided so that the cradle could be rolled back and forth in channel beams on a heavy bed plate to pack the raschig rings around the tubes and other internal projections of the tube sheets.

The two large main filling ports for the rings were chipped in the wrapper sheets of the Top Tube Sheet Assembly, and the filling cradle installed. Prior to actually filling with rings an extensive cleaning operation was carried out.

The assembly was jet washed with an "Oakite" solution and blanks were welded over open ports. In addition, wood blanks were bolted on the tube ends, and all openings were plugged. The assembly was then sandblasted and acid washed on both sides. The wood blanks were removed and filling port blanks chipped off. Inspection disclosed that contamination was still present. The loading cradle was installed and the assembly submerged in a washing pit filled with a heated solution of "Oakite 31" for approximately 24 hours. The assembly was raised and lowered in order to agitate the cleaning solution, then flushed and drained. The tubes were scoured with a steam gun, but the assembly still did not meet cleanliness specifications. It was also discovered that sandblasting sand had entered, having drifted into the cleaning pit when a nearby door of Building 3 was forced open by wind while sandblasting was in progress outside.

The loading cradle was already in place, and an effort was made to complete the cleaning by tumbling raschig rings in the assembly while jetting the interior with steam jets. The rings were emptied and the assembly flushed with city water, agitated and rolled. The Top Tube Sheet Assembly was accepted for use in the test program although it still did not completely meet the cleanliness requirements, for

RASCHIG RING LOADING. Rings are being poured into "R" Unit Bottom Tube Sheet Assembly from stainless hopper at top. Assembly is held in rolling cradle used to distribute rings during filling.

Savannah River. It met the requirements for the test program and could be cleaned later for Savannah River use.

Between April 28 and May 1, raschig rings were loaded, with precautions being taken to avoid introducing any dirt into the assembly. All equipment used in handling the rings was Type 304 stainless steel which had been passivated and ferroxyl tested. Loading operators wore clean white cotton overalls and gloves.

- Loading was carried out as follows: Raschig rings were received in heavy cardboard drums weighing approximately 400 lbs. each. Five drums were emptied into a pair of funnel shaped hoppers. The hoppers were lifted alternately by crane to a chute leading to a filling port in the tube sheet assembly. The rings were fed in approximately 10-ton increments, then the Top Tube Sheet Assembly was rolled back and forth on the track by means of crane fittings on the filling cradle. When the assembly was filled as completely as possible, ports were sealed and it was lifted from the tracks by the 150-ton crane in Building 10, and lowered to a horizontal position. Additional raschig rings were blown in by compressed air and poured in by funnel until all spaces had been filled. An estimated total of 49 tons of raschig rings was required to fill the tube sheet assembly.

Filling port covers were tack welded in position. The Top Tube Sheet Assembly was moved temporarily to the test foundation in Building 10 and lowered into the Main Tank to check the various clearances, then returned to Building 3. The filling ports were welded and the assembly given an air pressure test with filtered air, which it successfully passed. After passivating and grinding of contaminated spots on the exterior, the Tube Sheet Assembly was fitted with its deflector plate and turned over to the du Pont Operations Department for the NYX test program.

BOTTOM TUBE SHEET ASSEMBLY

The principal steps in the fabrication of the Bottom Tube Sheet Assembly were:

1. Fabrication of tube sheets and baffle plate.
2. Drilling and trepanning tube holes in sheets.
3. Fabrication of large tubes.
4. Fabrication of components such as gussets, nozzle sub-assembly, split retaining rings and flanges.

5. Assembly and welding of tubes and sheets.
6. Shrink welding of tube sheets to match Plenum and Top Tube Sheet Assembly.
7. Assembly and welding of components.
8. Facing tops and bottoms of tubes.
9. Neck-reaming tubes.
10. Cleaning, filling with raschig rings and inspecting.

The Bottom Tube Sheet Assembly was essentially similar to the Top Tube Sheet Assembly, and was added to the "NYX" Unit during preliminary design stages. The Bottom Tube Sheet Assembly had no rod tubes, nor did it contain "dummy" tubes as in the Top assembly. It had, instead, a system of inlet and outlet pipes. The raschig rings with which it was filled were retained by inlet distribution chambers and outlet cups which covered the ends of the respective piping systems inside the assembly.

Plate for the tube sheets and baffle was received on June 21, 1951. The sheets were welded, X-rayed and repaired in the Boiler Shop and laid out in the Machine Shop for the tube holes. The top tube sheet was marked with a complete layout, while the bottom sheet had center lines only. The two sheets were bolted together and rough turned in the South Yard to about 2 in. over the finished size of 18 ft. 7-3/4 in.

The center-to-center spacing in the layout was 7.021 in. based on the work with the Eight-Foot Mock-Up.

In the Machine Shop the two sheets were set up and drilled from the 7.021 in. strip jigs and reamed. The sheets were then individually trepanned and countersunk, with subsequent processing and assembly of tubes proceeding as in the Top Tube Sheet Assembly, except that there were no rod tubes.

By November 27, large tube welding had been completed, using "Aircomatic" automatic tube welders. Preliminary measurements by du Pont inspectors indicated that the shrinkage of .276 in. on the diameter resulting from tube welding was somewhat less than that of the Top Tube Sheet Assembly and considerably less than the Plenum, which had shrunk .696 in.

Necessary weld repairs were made to the Bottom Tube Sheet Assembly, and two tubes found to be defective were replaced. Additional welding around the tubes was selected as the means of shrinking the pattern, as in the case of the Top Tube Sheet Assembly.

By means of the "Aircomatic" tube welding equipment, a second bead was laid around all tubes on both sides of the Assembly. Pattern measurements showed that the tube spacing was still oversize, so a third weld was made around approximately half of the tubes on both sides. Shrinkage was then sufficient to meet requirements, and the pattern spacing was accepted by du Pont inspectors.

The considerable amount of shrink welding needed in the cases of the Top and Bottom Tube Sheet Assemblies led to further study of the welding problem and resulted in new layout patterns. These are discussed under "Welding Development".

The Bottom Tube Sheet Assembly was moved to the South Yard early in December. The tube sheets were turned for wrapper plates on the 12-ft. open mill, and the mill was used to position the assembly while the gusset plate edges were milled with two portable machines. Wrapper sheets, inlet distribution chambers and outlet cups were fitted and tack-welded in position.

The Bottom Tube Sheet Assembly was installed on the welding positioner by means of a special handling jig, since the original jig or "pot chuck" could be used only when the plate edges of the tube sheets were oversize before turning and free. Wrappers were welded in the downhand position by the "Aircomatic" method, as was done with the Top Tube Sheet Assembly.

The assembly was then set up under drill presses at the station established at the east end of Building 3. As with the Top Tube Sheet, a pattern of eighteen tubes was reamed to original dimensions so that these tubes could be used to establish an average verticality. The assembly was then moved to the 20-ft. boring mill where it was leveled to the established plane, and the tube faces, orientation buttons, and bearing pads were turned to planes parallel with the common plane.

The Bottom Tube Sheet Assembly was returned to the drill presses to complete the reaming of remaining tubes. The tubes had three inside diameters, becoming progressively larger in steps from the top down. Reaming from the bottom side of the assembly was found more effective because the tools could be guided by bushings seated in the larger sections of the tube bores. It was found later the time consumed could be decreased by power controlled drills with wider speed ranges and greater spindle rigidity.

No allowance had been provided in the pre-machined 3.250 in. diameters of the upper lands of the tubes for

reaming, and it was found that multiple welding passes and the short projection of the upper tube ends above the tube sheet caused expansion or "belling" in excess of the .007 in. allowed tolerance. Du Pont approval was obtained to increase the upper land diameter to 3.270-3.277 in.

As a result of excessive distortion of the tube ends, subcontractors were immediately instructed to decrease the upper land diameter of future pre-machined tubing for Bottom Tube Sheet Assemblies by .040 in. of metal in excess of finished inside diameter. This modification together with the larger finished diameter produced satisfactory results in subsequent production units. The reaming tools were also improved by using heavier, stiffer boring bars.

Tube ends were chamfered internally to a slight angle and a small semicircular groove was drilled vertically in the bore of about a third of the tubes to locate monitor pins which would be inserted through the tube bottoms during the test program. Special jigs were required for this slotting work.

On February 26, 1952, the Bottom Tube Sheet Assembly was moved from the radial drill station and set up for cleaning and testing. The assembly was filled with city water, the pressure brought to 52-1/2 lbs./sq.in. and maintained for two hours. One tube leaked at the top weld bead and was repaired. The assembly was re-tested and accepted by du Pont inspectors.

Sandblasting and acid washing on the top side followed. The assembly was, also, submerged repeatedly in a hot solution of "Oakite 31" for interior cleaning. It was then flushed with city water, inspected and rejected. The raschig ring filling cradle was attached and used to submerge the assembly in the "Oakite" bath and then drain it in a vertical position to give a stronger flushing action. While this method was an improvement, it did not bring about the cleanliness later achieved for plant units. Although the Bottom Tube Sheet Assembly did not meet Savannah River cleanliness specifications, it was accepted since these standards of cleanliness were not required in the NYX test program for the interior of this particular assembly.

The assembly was moved to the raschig ring loading station on March 3, and loading began as described in the preceding section about the Top Tube Sheet Assembly. It was halted, however, when inspectors discovered dirt particles mixed with the raschig rings. Inspection of the shipping containers disclosed that many of them were contaminated. The introduction of dirt into the assembly was considered unacceptable by du Pont, necessitating emptying approximately thirty tons of rings already loaded, and recleaning the unit.

The Bottom Tube Sheet Assembly was flushed with steam and water, loaded with about ten-tons of cleaned raschig rings, rolled and steamed. The rings were removed and the assembly washed out again. In the meantime, some 100 tons of raschig rings had been sent from the shipyard to a Philadelphia plant for cleaning. When these were returned, a total of approximately sixty tons was used in filling the Bottom Tube Sheet Assembly.

The Bottom Tube Sheet Assembly was now ready for attachment to the sub-assembled nozzle section to which the lower section of the Main Tank shell had already been welded. The nozzle section contained six outlet nozzles to which transition pieces ending in 20-in. diameter 90-degree elbows would be attached. Fabrication of the nozzles and components had been progressing simultaneously with work on other parts of the "NYX" Unit.

The nozzle assembly, including the 90-degree elbows or "special ells", was a major fabrication problem because of the numerous compound curves, the large amount of welding, and the close tolerances involved. Numerous dies and jigs were required.

Following procurement of material, the first step in fabrication of the nozzle assembly was the construction of a mock-up of one nozzle by the Boiler Shop. From this mock-up the Pattern Shop developed patterns for casting three dies required to form the upper section of the nozzle. The dies were cast on a priority basis by Birdsboro Steel Foundry and Machine Company, and returned early in November for machining and finishing at New York Ship. Du Pont considered this mock-up an outstanding contribution by New York Ship during initial stages. Also, the mock-up assisted in firming final design for Savannah River.

The individual nozzle pieces were formed, including a main section piece for each nozzle which was shaped on existing equipment, and assembled on special jigs. The six nozzles were then welded into the tank bottom assembly by means of additional jigs. Each step required precise fitting as well as allowances for shrinkage during welding.

The transition pieces and special elbows were also fabricated as sub-assemblies to be attached to the nozzle section after the latter was welded to the Bottom Tube Sheet Assembly.

The transition pieces consisted of four parts each and were fabricated by the Boiler Shop using a hydraulic press and standard dies for forming, and a special jig for assembly and welding.

The special elbows contained four pieces each. Two half-round sections, which made up the sides of each nozzle, when received from an outside vendor in January, 1952, did not conform to pattern. After the vendor made an unsuccessful attempt to correct them, additional forming was done by New York Ship in order to save time. The elbows were fitted and welded on jigs with the transition pieces in place, then the assemblies were sandblasted and acid washed.

The nozzle assembly with forming jig installed was set to a layout on a large building slab in the Boiler Shop, leveled and clamped. The lower Main Tank section, also with forming jig in place, was set to the best verticality, the joint between it and nozzle assembly fitted and held in position with clips. The joint was completely welded on one side, back chipped on the opposite side and welded. X-ray inspection and necessary repairs were completed and the nozzle-tank assembly was measured for roundness within the 1/4 in. diametrical tolerance and accepted.

The assembly was moved to the South Yard and fitted to the Bottom Tube Sheet Assembly after the latter had been loaded with raschig rings. Excess material was chipped off, the small lip sections which formed part of the nozzle bottom extending beyond the Bottom Tube Sheet Assembly were fitted and welded, and the nozzle assembly clamped in position. The butt was dressed so that the joint was "iron bound" within 1/32 in. Initial welding was done by the manual "Aircomatic" method with two welders working simultaneously on opposite sides of the vertical plate between the nozzle outlet sections. Great care was taken to start and stop the welding arcs at the same time until the assembly was fully welded with one bead. The remainder of the welding was done in a similar manner, though with less extreme coordination of the two arcs, and the joint was inspected for visual defects. Shrinkage measurements taken by du Pont inspectors indicated that the overall tube pattern of the Bottom Tube Sheet Assembly had expanded .008 in. during welding of the nozzle assembly.

The special 20-in. 90-degree elbows were fitted to the nozzles by means of an extensive jig system. At each nozzle, a welded steel target was bolted to the bearing pad at that location, and also welded to an iron strap bolted around the Bottom Tube Sheet Assembly. The location of the center of the outlet end of the elbow was accurately established by measurements extended from the tube pattern. The transition section was fitted to the nozzle, and both pieces chipped and welded over back-up strips. X-ray inspection was made of all welding and repairs made as necessary.

The design for the NYX Bottom Tube Sheet Assembly called for semi-circular wrappers-around the two rows of ports for the inlet distribution chambers and outlet cups. For testing the unit these wrappers were omitted and a substitute piping system was designed with 90 degree street elbows 2 in. in diameter being welded to twenty-four of the openings and connected to short pipe extensions reaching above the top sheet of the Bottom Tube Sheet Assembly.

The complete assembly was installed in the concrete foundation, as described more fully in Part VIII, and while other work was in progress, rod cups were welded in position on the top side of the Bottom Tube Sheet Assembly. The assembly was then vacuum cleaned and turned over to the du Pont Operations Group for the test program.

In developing plans for the subsequent production units, the du Pont Design Division had provided a system of grid plates (muffs) in the outlet nozzles above the Bottom Tube Sheet Assembly. In order to test the operation of one of these muff assemblies on the "NYX" Unit, the process piping of the No. 4 system was disconnected at the outlet nozzle in November, 1952, and a nozzle muff was fitted and installed.

The muff consisted of nine horizontal leaves with faired edges which closely fitted the contour of the nozzle section. The inner parts of the leaves were bent to form a funnel-like entry for process water leaving the Main Tank. Top and bottom keys were welded to the nozzle. Leaves were held rigidly in position by pins, keys, and spacers.

MAIN TANK

The principal steps in the fabrication of the Main Tank Assembly were:

1. Fabrication of the tank shell sections from stainless plate - including rolling, fitting and welding.
2. Fabrication of enclosure section.
3. Fabrication of expansion ring.
4. Fabrication of Bearing Ring.
5. Fabrication of components such as seal ring, lifting eye pockets and nozzles.
6. Joining of bearing and expansion rings and final machining.

7. Assembly of enclosure, bearing and expansion rings.
8. Fitting and welding lower tank shell to nozzle assembly.
9. Lofting and welding above assembly to Bottom Tube Sheet Assembly.
10. Installation in foundation and welding lower tank shell to the enclosure-bearing ring-expansion ring assembly.

Due to a shortage of large size stainless plate, the lower section of the tank was made up of six pieces (two courses of three plates each, joined by a circumferential weld) rather than the three or four plates used on later units. The upper section, or Top Tube Sheet Assembly enclosure, consisted of three pieces.

Stainless plate for the tank shell was received in June, 1951. The plates were laid out in the Boiler Shop and welded flat to a plan designed to provide two half-shells for the lower part of the tank with sufficient extra material for weld shrinkage. Automatic "Aircomatic" track welding was used, and the plates were clamped to building slabs with heavy weights placed near the butts to minimize warping. The welds were X-rayed and repaired as necessary. Flat half tank sections were rolled to proper diameter in a 15-ft. horizontal roll and finished to tolerance of 1/4 in. on the diameter by hammering with wooden mallets.

The halves of the lower section of the tank were fitted to a mild steel form with three rings, or spiders, held rigidly in place by internal stringers. The steel shell was clamped in place by cables and the vertical butts tacked. The tank was placed on a pair of rollers so that it could be turned to permit downhand welding, and the butt welds were completed with "Aircomatic" manually operated equipment. Welds were X-rayed and repaired as necessary. A manhole 2 ft. in diameter, used on the "NYX" Unit only, was installed in the tank side and various additional test fittings, such as six 1/2 in. pipe tap pads and vibration pick-up mountings were attached.

On the "NYX" Unit it had been decided that the lower tank shell and the nozzle assembly would be welded to form a single assembly, leaving the joint between the tank shell and expansion ring to be welded after the unit was installed in its foundation for the NYX test.

The nozzle assembly, fabrication of which was discussed under the Bottom Tube Sheet Assembly, was fitted to the tank, welded on one side, back chipped, and welded on the other side. X-rays and necessary repairs of the joint were completed and the assembly was moved to the South Yard where it was cleaned and fitted to the Bottom Tube Sheet Assembly.

Many minor attachments and modifications were made to the Main Tank during the test program of the "NYX" Unit in Building 10. These alterations along with change in design of expansion joint and bearing ring, made the tank unsuitable for later conversion to production use, and it was scrapped and sold as a cylinder when the "NYX" Unit was rebuilt as the "K" Unit.

Material for the Top Tube Sheet Assembly Enclosure, bearing ring and expansion ring was received between June and late September. Fabrication plans called for rough machining the entire bearing ring and finish machining surfaces that would fit the expansion ring and the 2-3/4 in. wide shell section which was a part of the tank enclosure wall.

The bearing ring, on which the Plenum and Top Tube Sheet Assembly rested, was fabricated from 3-in. stainless plate. Six segments were laid out with excess for machining and welding shrinkage. The pieces were burned to rough shape, machined and welded together on a large building slab in the Boiler Shop. All butts were X-rayed and repaired where necessary and the bearing ring was moved to Building 3 for turning on the 20-ft. mill.

The narrow shell section formed from four pieces of 1/2 in. plate was fitted and welded in position for joining to the enclosure section. Welding was required on the upper and outside faces of the bearing ring, and the resulting shrinkage distorted the assembly beyond allowable tolerances. The 2-3/4 in. enclosure section was straightened by hand bending, and the bearing ring was brought into acceptable shape by shrink welds on its upper face.

The expansion ring was fabricated from 3/16 in. stainless plate which was formed in 60-degree segments. A bending form was constructed and the segments were bent to shape by cold working in the bending form with hammers and flatters. The pieces were then fitted together, butt welded and X-rayed. The expansion ring was fitted to the lower face of the bearing ring and welded. Following X-ray checking of all new welds, the bearing ring-expansion ring assembly was finish turned. Index slots for aligning the Top Tube Sheet Assembly were milled with portable "Versa-Mill" equipment.

The Top Tube Sheet Assembly Enclosure which had two long and two short nozzles and to which a seal ring with gasket slot had been assembled, was then fitted to the 2-3/4 in. shell piece of the bearing ring assembly and oriented to center lines and the best verticality. The joint was welded from both inside and outside the tank, X-rayed and repaired where necessary.

The assembly was set up on the 20-ft. mill in Building 3 for machining the slot in the seal ring. The two long nozzles in the enclosure would not clear the mill housings. The long nozzles were cut off for the machining operation and re-welded and joints X-rayed. The inside of the enclosure was sandblasted and passivated before fitting to the lower section of the tank shell.

The fitting of the Top Tube Sheet Assembly Enclosure to the Lower Main Tank section was accomplished in the "NYX" Unit foundation in April and May, 1952. The bearing ring was raised 1/2 in. above its seat on the foundation beams and a line was scribed from the top of the lower tank section on the extension of the expansion ring. The expansion ring was chipped to size, allowing for weld shrinkage, lined up in the foundation with precision instruments, and the bearing ring marked for bolt holes. The upper tank assembly was then removed and the holes drilled and tapped for bolting to the support beams. The upper section of the tank was again placed in the foundation, the bearing ring bolted to the support beams and the forming jig removed. After final fairing of the expansion ring, a backing strip was fitted and tacked in position. The expansion ring was then welded to the lower tank section. The weld was X-rayed and repaired as necessary. After welding, the upper face of the bearing ring was checked by du Pont inspectors using a Wild NIII level and found to be acceptable.

Fabrication of the Main Tank concluded with the weld joining the upper and the lower sections. The interior of the tank was pickled in spots showing free iron, and was cleaned with vacuum cleaners before being released for operational testing.

GENERAL FABRICATION PROBLEMS

INCREASE OF PERSONNEL

In the early stages of the NYX Project, engineering, administration and fabrication work was handled by New York Ship's existing organization in the same way that individual ship construction contracts were performed. However, the specialized nature, scope and security restrictions of the project soon required that a staff be assigned to the work on a full time basis.

Supervisory Personnel

In June, 1951, an NYX Project Manager was appointed. His position was at first similar to that of a Ship Manager, but developed to more independent status as the separation of the NYX work from the rest of the shipyard became more pronounced. During the fall of 1951 the Project Manager acquired a staff consisting of two schedulers.

Increased fabrication and scheduling problems, coupled with the fact that work was going forward seven days a week, twenty-four hours a day, made additional supervisory personnel necessary. A survey was made of engineering schools in the area, and advertisements and employment agencies were used to obtain applicants for the position of Project Foremen. From these sources, two men were obtained while others were transferred from their current New York Ship jobs.

The "NYX" Project supervisory personnel group by the summer of 1952 was enlarged to the following organization:

- Project Manager
- Assistant Project Managers (3)
- Project Foremen (3)
- Staff Assistant
- Chief Scheduler
- Scheduler

Note: Organization chart of NYX Project Manager and staff is shown in the appendix, Exhibit A-2.

In addition to the general supervisory group, the Boiler Shop and the Machine Shop both built up supervisory groups in the South Yard.

In June, 1951, the Machine Shop assigned a Foreman and a Chief Estimator to the NYX Project on a full-time basis. The work was handled under their direct supervision with the Estimator also doing scheduling until the activating of Building 3. In January, 1952, a Shop Foreman and a Draftsman were added to the full-time NYX Group, and shortly thereafter the staff was moved to Building 3 in the South Yard. Two Sub-Foremen were added at this time to supervise the second and third shifts. In April, 1952, a Junior Clerk was assigned to the office.

Following the establishment of a separate NYX office in Building 3, the full-time Foreman was withdrawn in June, 1952, and the work placed under the supervision of the Machine Shop's Assistant General Foreman. A third Foreman was added at this time for the first shift. The estimating and scheduling work ceased to be a full-time job,

since a separate scheduling group was operating under the NYX Project Manager, and the full time Estimator's position was terminated.

All supervisory personnel were obtained from the existing Machine Shop staff so that no employment problem was involved.

The Boiler Shop assigned a sub-foreman to each of three shifts at work in Building 3, and during the peak of test work in early 1952 designated an additional sub-foreman for Building 10 test operations.

A welding sub-foreman was also assigned to each shift in Building 3. The assistant general foreman and the two shop foremen in the Boiler Shop office spent a major part of their time on the project. In the Boiler Shop, a layout man and a sub-foreman were assigned to the project on practically a full-time basis.

Supervision from the other departments engaged in work for the project was drawn from regular department organization as needed. The other shipyard departments did not find it necessary to assign full-time staffs to the NYX Project.

Labor Force

The administration of the NYX Project was similar to that of any other major contract at the shipyard in that employees were not recruited specifically for the project. The yard hired employees at the request of the various shipyard department heads as their workload increased beyond the capacity of their existing force. The NYX Project was given priority in the assignment of labor; that is, requests for labor on NYX work were filled even though other work in the department concerned had to be stopped.

In the spring and summer of 1951, the project began requiring sizable amounts of labor. Approximately 2000 hours were spent on it in May, 4000 in June, 5000 in July, 20,000 in August, and nearly 50,000 in September. The shipyard was not operating at a high production level when the project was started and was able to absorb some of the work load. As each department found it necessary to add employees to maintain its schedules, requests for additional personnel were made. During the summer of 1951 about 200 employees per month were hired and the net increase in the shipyard payroll between May and September amounted to about 650.

Labor was obtained through the normal operations of the company Employment Office. At the time, because of the heavy demand for skilled labor, it was not possible to fill the need for skilled mechanics promptly in many cases. Within the shipyard departments a training program was carried on to up-grade helpers and mechanics ratings for work on the project. Men were also trained for specific operations on the NYX Project, particularly for the line boring work and for welding stainless steel.

During 1951 and the early part of 1952, obtaining sufficient personnel for the project was a major problem. During 1952 the working force of the yard had been built up sufficiently so that from the standpoint of quantity, at least, the NYX Project had few subsequent personnel problems.

ACQUIREMENT OF TOOLING ENGINEER

The fabrication of assemblies of the size and complexity of the "NYX" and production units in stainless steel was unique in the experience of New York Ship. Moreover, in certain operations such as line boring the Plenum Chamber and establishing the tube pattern within extremely close tolerances, no record of similar construction could be found to provide a basis for tooling and layout.

Fabrication problems were approached with the close cooperation of du Pont and New York Ship engineers, to which was added the practical experience of the shipyard supervisors in such departments as the Machine and Boiler Shops and the Welding Department. Du Pont provided information on stainless steel fabrication based on its consultations with outside engineering firms and its own experience in chemical process equipment.

Du Pont also procured the services of a tooling engineer from its Engineering Service Division. His suggestions and guidance proved valuable in assembling the most efficient equipment and in employing the best production methods. During the early part of 1952 the tooling engineer worked full time at New York Ship, but as procedures became established he acted as a consultant on occasional problems.

PERFECTION OF IMPROVED TOOLING

One of the many purposes of the prototype "NYX" Unit during the fabrication phase was the testing and improvement of tooling and procedures, so that production units could be fabricated with the least chance of costly delays

or mistakes. Tooling development had been in progress from the beginning of the project as discussed in the preceding part of this section under "Development of Fabrication Techniques."

Coupled with the fabrication development aspects of the "NYX" Unit, however, was the urgent need for operational test data by du Pont designers then at work on the subsequent production units. It was not possible to hold up production to work out improved tooling methods, though a certain amount of tooling improvement had to be done to build the unit within tolerances.

The major tooling contribution made by the "NYX" Unit was the virtual perfection of the radial-drill method of line boring the Plenum Chamber. This work established that a large, specially-built boring machine would not have to be procured. However, until the second of the production units had been completed line boring equipment underwent various modifications.

Boring of the tubes in the Bottom Tube Sheet Assembly was perfected on the "NYX" Unit, with cutter angles, boring bar arrangement, and procedures remaining the same for subsequent units. It was found that boring the land in the upper ends of the tubes was best accomplished by working with the assembly turned over. After boring the bottom of the tube, a long boring bar with a "Teflon" plastic bushing which seated in the newly bored end, was run into the tube and used to bore the top land. Distortion of the tubes due to welding was greater than anticipated, and the original finished land diameter was increased .020 in. to allow a smooth finish.

The upper tube ends of all assemblies were beveled at angles ranging from 10 to 45 degrees. Tooling for these bevels was perfected to a large degree on the "NYX" Unit.

The weir slots in the Plenum Chamber tubes had to be lowered to the level of the bottom tube sheet. An air-operated portable right-angle milling attachment was developed for cutting these slots. While subsequent production units were modified, the tubes being pre-machined with longer slots, errors occurred in positioning the slots which required the use of the milling tool in other units.

The fabrication of the "NYX" Unit, despite the urgency of completion, provided day-by-day experience in the perfection of tooling that contributed greatly to the progress of the subsequent production units. Also, it confirmed that the design was feasible to fabricate, and the fabrication methods and procedures selected were substantially suitable.

IMPROVEMENT OF MACHINE TIME

The principal improvement in machine time during the fabrication of the "NYX" Unit took place during line boring of the Plenum Chamber and Top Tube Sheet Assembly. The manner in which this was brought about is discussed in the sections "Development and Choice of Boring Method."

While the experience gained in setting up for and performing each machining operation improved the quality and speed of repetitive operations, it is difficult to select individual examples. Moreover, the "NYX" Unit was a pioneering effort, and the differences between it and succeeding production units were great enough that there were few cases where direct comparisons of machining time could be made.

VIII - ERECTION OF "NYX" UNIT

The "NYX" Unit was installed in its concrete foundation in Building 10 under the direction of the du Pont Construction Division with inspectors of the Material and Equipment Section providing much of the instrument work. Extremely close tolerances were established for a structure of such size.

Erection of the unit was carried out by New York Ship personnel drawn from a "pool" of cleared personnel established in anticipation of security restrictions to be placed in effect in Building 10. Responsibility for the erection of the unit was assigned largely to the Boiler Shop, with the Plant Engineer Department and the Machine Shop making important contributions. An outside contractor was used for some of the instrument work.

ESTABLISHMENT OF HORIZONTAL AND VERTICAL CONTROLS FOR ERECTION

HORIZONTAL CONTROL

Horizontal control for the erection of the "NYX" Unit was transferred from the frame of Building 10 to bench marks on X and Y axes inside the foundation. Tolerances were such that precision instruments, not yet available at New York Ship, had to be used. Aero Service Corporation of Philadelphia was engaged to transfer reference lines for the building axis. The reference line was a line between the centers of two supporting columns for the precision crane. This was transferred, with the assistance of a New York Ship engineer, by means of a Wild T-II theodolite, and brass plates inside the foundation were scribed to mark the location of the X axis. The Y axis was established at right angles to the X axis, with both lines passing through the center of the foundation. A detailed report on the procedure followed is contained in du Pont's "Summary of Erection Procedures for the 'NYX' Unit".

Du Pont's Material and Equipment Section inspectors at New York Ship checked the orientation of the axes after their Wild T-I theodolite had been received. The locations were found to be parallel to the building within the required .015 in. in 8 ft. The inspectors then transferred the axis to four angle-iron A-frames set in the upper part of the foundation, slightly higher than the tank enclosure.

VERTICAL CONTROLS

Vertical controls were established by New York Ship personnel, assisted by du Pont inspectors, using a surveyor's dumpy level. The level of the floor of Building 10 was

designated on the plans as zero elevation. A metal bench mark was set in the floor at the southeast corner of the support pad to afford an accurate basis for measurements, and from this mark the elevation of one of the bearing plates (Number 7) for the Bottom Tube Sheet Assembly was determined by means of a surveyor's dumpy level and a machinists scale graduated to sixty-fourths of an inch. Subsequent control was established with a Wild NIII precision level and pin gages.

The bearing pad to which control had been transferred was used as a back sight in checking the other eleven pads. A point on pad No. 8 was selected as the median level of the support pads.

Control was subsequently moved upward to the support beams for the bearing ring, using a pre-set pin gage and measuring from No. 8 lower pad. Since these beams had to be removed during the installation of the "NYX" Unit, a reference was established on two temporary bench marks located on nearby actuator supports. The du Pont Material and Equipment Section made checks of the controls with the Wild NIII level and determined the amount that individual bearing surfaces at both levels were out of plane.

After the Main Tank and the Bottom Tube Sheet Assembly were set in the foundation, a third permanent bench mark was established on the actuator support on the northeast side of the unit, using the upper support beam control point as a reference. This latter bench mark was used to check elevations of assemblies of the "NYX" Unit, such as the bearing ring, faces of the Plenum tubes and Top Tube Sheet Assembly.

The establishment of bench marks and controls was handicapped by the initial roughness of the bearing pads and beams which supported the unit. Before satisfactory measurement control points could be established, the supports had to be faced and straightened.

SEQUENCE OF ERECTION OF "NYX" ASSEMBLIES

The erection of the "NYX" Unit in its foundation in Building 10 began with the preparation of the lower bearing plates. Mechanics from the Boiler Shop spent considerable time grinding and scraping the bearing plates to provide a suitable foundation surface.

The plane of the bearing ring was to be level within .007 in. An effort to establish liner plate heights by means of a precision level and a long straight edge, reaching partly across the foundation was unsuccessful when it was

NYX UNIT MOVES TO BUILDING 10. The Bottom Tube Sheet Assembly and lower part of the Main Tank are carried through the security barricade in a special fixture to be lowered into the foundation.

NYX UNIT IN FOUNDATION. Photo shows "NYX" Unit in place with some of process piping connected. Plenum Chamber is visible at top, with special elbows of Bottom Tube Sheet Assembly showing through openings about halfway up the foundation.

proved that errors greater than the tolerance could be introduced without detection. A tram method of checking was then used with satisfactory results, which were made more accurate by a Wild NIII level and precision target operated by du Pont inspectors.

As a result of experience with the rough-finished bottom bearing plates, steps were taken to improve the surface of the upper plates before extending control to them. The radial beams were removed and sent to the Machine Shop where they were straightened and bearing surfaces machined. Additional time was needed to finish the bearing surfaces of the cross beams on which alternate radial beams were supported.

The approximate thickness of each upper liner plate was determined by measuring from the corresponding lower plate with a steel tape. The plates were pre-machined to the high side of the tolerance, to allow for final fitting. During preliminary leveling of the upper plates, it was found that the weight of a man on the support beams caused a deflection approximating the allowed tolerance of .007 in. Loose fitting bolts were removed, the bolt holes reamed and body-bound-bolts driven in place. Through this modification a relatively firm base for measurement was established.

A platform for the Wild level was erected across the top of the foundation, and a separate platform for an observer was constructed around it. Level measurements to determine precise liner thickness were then made at each bearing plate.

The upper support beams were then removed in order to allow the passage of the Bottom Tube Sheet Assembly.

Upon the completion of the foundation bearing pads, the "NYX" Unit was installed. The Bottom Tube Sheet Assembly nozzle assembly and lower section of the Main Tank up to the expansion ring were lowered into the foundation as a unit. A special lifting fixture had been fabricated for this purpose, and assembled so that it could be knocked down and removed through the door of the space in the foundation beneath the Bottom Tube Sheet Assembly.

The "NYX" assembly was supported by the 150-ton crane in Building 10 so that there was just enough friction between the Bottom Tube Sheet Assembly and the lower bearing plates to keep the assembly from swinging. The Wild T-I theodolite was set up at the top of the foundation and used by du Pont inspectors to orient the Bottom Tube Sheet Assembly with the building axes. Axial alignment of the unit was accomplished by inserting wedges between the tank nozzles and adjacent foundation walls, while sighting on the orientation buttons along the axes of the upper face of the Bottom Tube Sheet Assembly.

The upper bearing plates and support beams were replaced and checked. The Top Tube Sheet Assembly enclosure with expansion joint and bearing ring attached, was positioned on 1/2 in. thick spacer blocks and fitted to the tank. The bearing ring assembly was removed, chipped and returned to the foundation for welding. Some difficulty was encountered in this operation because of non-uniform shrinkage and the tacked joint had to be broken and re-welded, after bracing with heavy bars.

The Top Tube Sheet Assembly was placed in position to check its clearance in the enclosure. It had not yet been loaded with raschig rings, and though some sixty tons light, caused deflection in the support beams. Further checks made after the Top Tube Sheet Assembly had been filled showed that a deflection averaging about 1/32 in. was caused.

The du Pont Design Division requested that the bearing ring be raised 1/8 in. to compensate for this additional deflection. Shims were inserted by Boiler Shop personnel without removing the Main Tank from the foundations. Portions of the bearing ring were unbolted and shims of an average thickness of .157 in. inserted between the ring and the bearing pads while the ring was raised slightly by an overhead crane. No more than three bearing pads were free at one time.

Three index keys which determined the location of the Top Tube Sheet Assembly in the bearing ring were fitted. The assembly was positioned within .006 in. of the axis lines, well within the tolerance.

The final step in the erection of the "NYX" Unit was the installation of the Plenum Chamber. Matching centering lugs had already been installed on Plenum and Top Tube Sheet Assembly during the line boring operation. The Plenum was lifted with two nozzles suspended from separate hooks, and two other nozzles connected by chainfalls to one of the hooks. After positioning by the crane and chainfalls, the Plenum was lowered and checked for orientation. It was found to be within the tolerance established during line boring work. Some difficulties were encountered, however, in functional gaging the tubes due to an apparent slight shifting between the Plenum and Top Tube Sheet Assembly.

It should be pointed out that the NYX erection was an unusual accomplishment in that a support was provided which would not require destruction of the reactor to remove it from the support. The unusual design necessarily reflected this requirement but resulted in considerable saving in dismantling cost later.

GENERAL

Erection measurements taken during the positioning of the "NYX" Unit were compiled in a du Pont Construction Division report "Summary of Erection Procedures for the 'NYX' Unit" dated June 16, 1952. The report covered the various steps in more detail than attempted in this section and should be referred to for further data.

Experience gained in setting up the "NYX" Unit proved extremely valuable in erecting subsequent production units in the field. A foreman from the Boiler Shop who had supervised erection work on the "NYX" Unit traveled to the Savannah River Plant and assisted in the erection of the production units there, making his Building 10 experience available on a first-hand basis. In addition, the various tolerances established by du Pont's Design Division were confirmed and recommendations made concerning an increase in required accuracy of the lower foundation support plates and Bottom Tube Sheet Assembly bearing pads for a better fit between the two bearing surfaces.

IX - PRECISION CRANE

A specially-designed crane of the bridge and trolley type was procured by du Pont for functional testing in connection with the operations of the "NYX" Unit in Building 10. Components of the Precision Crane, as it was generally known at New York Ship, were fabricated by three principal subcontractors: Whiting Corporation, Arma Corporation, and American Machine and Foundry Company. New York Ship's part in the Precision Crane test program consisted of furnishing labor and materials as directed by the du Pont Construction Division. From June, 1952, until April, 1953, three New York Ship crane specialists from the Maintenance Department and two electricians worked on the Precision Crane under du Pont supervision on practically a full-time basis. Three machinists from the Maintenance Department on duty in Building 10 and additional labor were provided from time to time upon du Pont request.

LOW LEVEL INSTALLATION OF PRECISION CRANE

The Precision Crane was designed to operate at an elevation of approximately 69 ft. above the floor, using precision rails laid on the craneway erected by Ralph Cornell. In order to simplify assembly and testing, as well as for safety reasons, a temporary low-level craneway was installed by New York Ship during the summer of 1952 on steel previously erected by Cornell. The crane operated on a single length of precision rail which was supported, aligned and leveled to simulate high-level conditions. The rail was set within a horizontal plane tolerance of .025 in., while alignment was within .010 in.

Bridge and trolley were assembled and placed on the rails, and control room equipment installed by New York Ship labor. Arma Corporation conducted low-level tests between October 10 and November 25, 1952. Assistance from New York Ship during these tests included the fabrication of additional steel stiffening for the runway girders, the installation of the "Y" hydraulic buffer system and numerous alterations and repairs.

HIGH LEVEL INSTALLATION OF PRECISION CRANE

Control points for aligning the crane at high level were transferred by du Pont inspectors from the centerlines of the "NYX" Unit foundation by means of the Wild T-I theodolite. It was found that the structural steel crane girders were out of alignment, vertically and horizontally,

as much as 1-1/2 in. Modifications were made to the saddles in which the rail was mounted, and rail was laid and aligned with the control bench marks.

Difficulties were encountered in installing the rails because of dimensional variations due to temperature changes, effects of rising and falling tide on ground elevations, crane movements and windload on Building 10. Following setting of the rails, by Maintenance Department erectors, rack installation was completed by the crane electricians.

The bridge of the Precision Crane was raised to its high level runway on December 2, followed by the trolley assembly on December 16. The moves required extensive rigging preparation and were complicated by the small clearance between the craneway and the roof girders of the building. In lifting the crane bridge and trolley, blocks were attached to the overhead building structure and a cable was led from the 150-ton crane through the blocks to specially-designed lifting jigs.

A similar but lighter rig powered by a ship winch was used to hoist the Precision Crane components into position for installation on the trolley.

Installation of the various drive motors, control wiring and operating "masts", and the leveling of the craneway was completed about March 23, 1953. Progressive testing of crane components continued from September, 1952, through April, 1953, with testing of the complete crane assembly during the last month.

X - TESTING OF EQUIPMENT

A major part of the NYX Program, from the standpoint of both cost and personnel, was the testing of the "NYX" Unit under simulated operational conditions.

The test program was carried out almost entirely in a special security area established in Building 10. In this program, New York Ship provided labor for equipment installation, start-up and many of the test runs. Du Pont's Construction and Operations divisions supervised the work directly. They also set up schedules and made specific requests for the manpower required in Building 10. Shipyard personnel were then drawn from a "pool" of cleared men established in the various shops by the Security Office. The size of the "pool" was based on du Pont estimates of the force that would be needed at the peak of the test program.

The availability of a group of security-cleared mechanics resulted in considerable savings in labor costs. Men with a variety of skills could be obtained upon short notice, and, in general, upon equally short notice returned to their regular shipyard work. Without such a pool, manpower could not have been built up quickly because of the acute labor shortage existing at the time, and many men would have had to be retained through slack periods in order to keep them available for future needs.

The number of New York Ship personnel engaged in the test work in Building 10 varied from 80 to 150, with an average of about 120 men during the period May 1952, to May 1953, when full-scale test work was in progress.

In working out plans for the test program in the first half of 1951, du Pont had scheduled the start of the "NYX" Unit somewhat earlier than actually proved possible. Due to the urgency of the program, du Pont made arrangements for substitute equipment whenever auxiliaries such as pumps and heat exchangers of plant design could not be obtained in time for the scheduled start-up. In most cases, plans called for the substitute components to be replaced when permanent types of equipment become available.

The original goal was set back approximately six months from the initially desired November 1951, start-up date. Procurement affected accomplishing the goal date, as well as the time necessarily required to develop methods of fabrication and modify design as the work progressed. As a result, in the early stages of the "NYX" Unit testing many different phases of the work were in progress

simultaneously. Equipment installation, test runs, replacement of temporary with permanent machinery and alterations to installed equipment could all be included in a day's work. In the testing of the Precision Crane, for example, a schedule was set up that permitted testing on one or two shifts and additional construction work on the third shift.

The principal assistance given by New York Ship personnel in conducting the NYX test program was in providing operators for the pumps, motors and auxiliary equipment; personnel from the Test Engineer's department to aid in obtaining test results; and mechanics to modify, repair or interchange equipment. In addition to the above, New York Ship provided a security force to protect the restricted area.

A two weeks continuous test of the river water cooling system was started March 25 and completed April 9, 1952. The chlorinator system was operated for two hours each day. For the first three days the system was operated with valves to the heat exchangers closed off. These valves were opened and the system operated at full capacity on the fourth and fifth days. The heat exchanger valves were then closed and the reduced system operated for the remaining time to observe functioning of the motor and pump, the filter, the chlorinator system and the foot valve and screen. Upon completion of the test, a flange connection was broken and the 16-in. riser, including foot valve and screen, was lifted from the water for inspection. The screen and valve were in good condition with no evidence of mud or silt present. About one-eighth of the area of the screen was clogged with paper, sticks and similar foreign matter which was removed by scraping. Soundings of the river bottom indicated no apparent silting in way of the foot valve and generally satisfactory conditions for continued operation as required by the test unit. Arrangements were made to lift the screen monthly for scraping, to clear the obstructed areas. A 10-in. globe valve was removed for inspection about midway in the system. The interior of the valve and the adjacent piping walls were found to be free of foreign matter and in good condition, indicating the effectiveness of operating the chlorinator two hours each day.

Subsequently, the cooling water system was operated up to four hours a day prior to beginning full time operation of the test unit.

Installation of the "NYX" Unit in its foundation was sufficiently complete by May 22, 1952, to allow partial start-up of the process water circulating systems. As described in preceding sections of this report there were six circulating systems, each with pumps, heat exchangers

and control valves, supplying water to the unit. The river cooling system furnished the cooling water to the heat exchangers. At this time, twelve temporary pumps and six temporary heat exchangers were installed, pending arrival of permanent equipment.

The process water systems were tested during May 1952, and indicated need for certain modifications to correct noises and vibrations due to hydraulic conditions. These included installation of orifices, air relief valves and additional pipe bracing.

As operations continued in the early part of June, bits of neoprene began clogging the strainers. Spool pieces with cleanout handholes were placed in all six systems for ready access and inspection of the strainers. The temporary pumps, which were neoprene-lined, were disassembled and cleaned.

During the week of June 7 to 15, the "NYX" Unit was loaded with "Fuel Slugs" for the first time. Since the Precision Crane was still being assembled, the Wright 2-ton crane was used in loading the rods and foils. Operations continued with the unit in various conditions of loading, while New York Ship personnel operated auxiliary equipment and assisted in instrumentation work.

Early in July, neoprene particles in the systems caused a shut-down. Inspections disclosed that the lining on the inside of heat exchangers and valves was working loose. From July 10 to 26, New York Ship personnel dismantled, cleaned and reassembled the circulating systems. The heat exchangers were partially clogged with neoprene, requiring the cleaning of each tube with brushes and solvent.

The first two Savannah River Plant design pumps were received in Building 10 on July 16. Installation began at once, with the unit in partial operation until November 16, when all permanent pumps had been received and installed. All six systems were then started up for continuation of the test program. During the period of changeover from the twelve temporary pumps, individual systems were operated independently, with non-functioning lines blanked off.

Various difficulties were encountered in setting up and operating the permanent pumps. Alignment of motor and pump assemblies proved troublesome and time-consuming, with extreme accuracy required in setting the foundation.

The permanent pumps had been aligned with the motors by the use of a square and a piano wire stretched across the

couplings. Considerable vibration and seal trouble occurred in the pumps during operations in September and October of 1952, and New York Ship recommended that a tripod and indicator method of alignment be used to re-set the pumps. Two tripods and a pin gage were fabricated and the pumps were aligned to closer tolerances as described in Part VI under "Process Pumps and Motors".

Probably the most persistent trouble was leakage around the pump seals. The seals were of special design and required breaking in, and extensive maintenance. A "seal repair" room was set up in the southwest end of Building 10. Here were assembled a sensitive lapping machine, surface plates, seal parts and tools. A mock-up was fabricated to simulate running conditions of the seal assemblies, and various materials were used in operating tests. As a result of this work, it was possible to achieve substantially satisfactory seal performance in later plant operation. The seal repair room work continued until May, 1953, and was the last operation in the test program to be terminated.

General test and development work on the "NYX" Unit continued into 1953, with the No. 3 process system gradually being converted to plant-design fittings and equipment. In January the No. 3 system 12-in. supply line to the Plenum was fitted with an electrically-operated plug-valve. Shortly thereafter, a motor-operated gate-valve was installed in the 20-in. suction line. Installation and a considerable amount of subsequent maintenance and repair work were performed by New York Ship mechanics.

Work was rushed on the installation of the Savannah River Plant heat exchanger. It was rolled into position on a trestle, as described in a previous section of this report, and by February was tested and connected in the No. 3 system. On February 4, No. 3 system was operated for the first time with all plant-type equipment. A final series of tests was carried out with all systems in operation, and in mid-February the partial dismantling of the process system was directed by du Pont. Systems 5 and 6 were blanked off and work began on the removal of piping, pumps and fittings. In March dismantling of the No. 2 system commenced.

The Nos. 1 and 3 systems continued in operation, however, and were used in connection with the Precision Crane and in testing the Diesel-driven emergency power generator.

By April 2, the testing of the "NYX" Unit was essentially completed, though additional development work was scheduled for the Precision Crane.

Process piping was disconnected and salvageable materials were crated for shipment to the Savannah River site. The Plenum Chamber and Top Tube Sheet Assembly were removed from the foundation on April 8, and the enclosure section of the Main Tank was burned free from the lower tank section. The remaining assembly of tank and Bottom Tube Sheet was then lifted from the foundation with the handling fixture used during installation. In order to permit further tests of the Precision Crane, the Top Tube Sheet Assembly and Plenum Chamber were returned to the foundation, where they remained until May 4. At that time the assemblies were removed and dismantling work began on the Precision Crane.

The difficult rigging operations by which the Precision Crane and the Wright 2-ton crane were placed on the high runway rails were repeated to lower the two units to the floor of Building 10. The Precision Crane trolley and bridge components were shipped to the Whiting Corporation, the drive mechanisms to Arma Corporation and the masts and grippers to American Machine and Foundry Company. Precision racks and rail, cables and consoles were shipped to the Savannah River Plant.

Special security restrictions on Building 10 were lifted on May 13, 1953, bringing the test phase of the NYX Program to an end.

XI - FABRICATION OF PRODUCTION UNITS

GENERAL DISCUSSION

The NYX Project contemplated the fabrication of five production units based on the design of the prototype "NYX" Unit. The possibility of converting the prototype to a production unit had been a consideration in its fabrication, except that the test operations were not delayed for this reason.

Under normal circumstances, the "NYX" Unit would have been proven and design changes made as necessary before beginning fabrication of the succeeding units. Since the urgency of the NYX Project made the use of normal procedures impossible, both design and fabrication of the production units, designated "R", "P", "L", "K", and "C", were carried out almost simultaneously with the fabrication of the prototype.

To give an example of the parallel nature of the work, on May 20, 1952, when the "NYX" Unit was installed in its foundation in Building 10 and before any of the test phase of the project had commenced, the status of the other units was as follows:

"R" Unit	Plenum Chamber and Top Tube Sheet Assembly were completely assembled and being line bored. Bottom Tube Sheet Assembly was assembled, tubes faced and reamed.
"P" Unit	Plenum Chamber and Top Tube Sheet Assembly plates were in handling jigs and tubes were about to be welded. Bottom Tube Sheet Assembly plates had been fabricated and were ready to be placed in handling jig.
"L" Unit	Preliminary work was being done using "P" drawings. Material had arrived. (By late summer of 1952, all tubes had been installed in the assemblies.)
"K" and "C" Units	Had not been started.

As a result, changes in design found desirable during the tests were sometimes difficult to accomplish on the production units and the experience gained from work on one unit in many cases could not be utilized until fabrication for the "C" Unit began. However, as a result of the NYX

prototype unit it was possible to catch in time all necessary major modifications as well as make corrections to already built equipment at New York Ship rather than under costly and delaying field conditions.

In general, the fabrication of the production units followed the pattern established for the "NYX" Unit. Improvements in welding and line boring techniques and the addition of certain machine tools such as the special Cincinnati V-slot miller improved production time and resulted in fewer repairs. However, a corresponding improvement in inspection methods, improving the quality of the later units, also caused certain corrective work on the early units, to improve their quality.

The first three production units, "R", "P" and "L", were almost identical in design and in the methods used for fabrication. Upon the completion of test operations in Building 10, the "NYX" Unit was carefully studied to determine whether its conversion to a production unit was feasible. Cost studies were made of the alternatives, from fabricating an entire new unit, to converting each assembly of the "NYX" Unit to production status. Conferences were held between du Pont and New York Ship on the subject and the situation was resolved in favor of converting the "NYX" Plenum and Top Tube Sheet Assembly. Further studies on the fabrication of a new Main Tank and Bottom Tube Sheet Assembly versus conversion of these parts were made, and New York Ship prepared detailed estimates covering the work that would be required in each case. The final decision called for the fabrication of a new Main Tank and the conversion of the Bottom Tube Sheet Assembly. The unit when converted was designated "K" Unit. The fact that it was possible to convert resulted in a considerable saving to the government.

The "C" Unit, though similar in general concept to the other production units, contained major revisions from the standpoint of fabrication. Different size Plenum and Bottom Tube Sheet nozzles, Main Tank shell, etc., required new dies and fixtures.

In the sections that follow, summaries of the major design and fabrication differences between the units are arranged on the basis of the "NYX" Unit design. However, where a change occurs between the "NYX" and a production unit it is assumed to hold for all subsequent units unless specifically excepted. "C" Unit, for example, should be assumed identical to "L", and "L" identical to "P", and "P" to "R" except for changes listed below. The exception to this sequence is the "K" Unit, which as a conversion from "NYX" lists changes from that unit.

TYPICAL TANK AND BOTTOM TUBE SHEET ASSEMBLY. This photo of "L" Unit is typical of the first four production units. Parts, from top, are: Enclosure, bearing ring, expansion ring, tank shell, nozzle assembly (with special elbows installed), and Bottom Tube Sheet Assembly.

"C" UNIT AND BOTTOM TUBE SHEET ASSEMBLY. Showing how "C" Unit differed from first four production units. Photo illustrates, from top: Narrower enclosure section, heavy bearing ring, wide expansion ring (covered by protective shell), larger diameter tank and nozzle assembly, and Bottom Tube Sheet Assembly.

A summary of the dates on which the various units were started and completed appears below:

	<u>Start of Fabrication</u>	<u>Completion of Fabrication</u>
"NYX" Unit	Sept. 1, 1951	May 20, 1952
"R" Unit	Oct. 27, 1951	MT BTS Aug. 1, 1952
		P TTS Oct. 30, 1952
"P" Unit	March 7, 1952	BTS Oct. 28, 1952
		MT Jan. 15, 1953
		P TTS April 15, 1953
"L" Unit	June 5, 1952	BTS
		MT June 3, 1953
		P TTS Sept. 19, 1953
"K" Unit	April 9, 1953	Oct. 2, 1953
"C" Unit	April 20, 1953	May 20, 1954

Note: Symbols under "Completion of Fabrication" column indicate that unit was shipped to plant site by assemblies at different times. Completion date for each shipment group is shown. Symbols are abbreviated as follows:

P Plenum
MT Main Tank
TTS Top Tube Sheet Assembly
BTS Bottom Tube Sheet Assembly

"R" PRODUCTION UNIT

PLENUM CHAMBER

Design Differences

During the test on the "NYX" Unit, it was found through instruments that vibration and whistling noises were emanating from several nozzles. Upon inspection, it

was found that part of the shrouding that formed the nozzle vanes was tearing loose from the staybolts.

To remedy this condition the vanes were redesigned in the "R" Unit. On "NYX" Unit the three vanes of each nozzle were of similar design incorporating solid staybolts with a 1/4 in. thick shroud welded to the staybolts. The tip radii at each end of the vanes were formed of 1/8 in. plate.

The new design called for solid vanes with slightly different dimensions than those of the "NYX" Unit, and specially-designed staybolts incorporating varying diameters. The special staybolts were shrink fitted in the vanes.

The solid vanes involved considerable work due to their design. The material was burned to shape leaving excess on length and width for machining. There was a great deal of planer work involved in preparing these vanes for fitting and some of the work was subcontracted to outside shops to save valuable time.

At this stage of the project both "R" and "P" Plenum nozzles were completely fabricated, including vanes of the "NYX" type. Therefore, it was necessary to remove the vanes and install solid ones. The procedure used to remove these vanes was established from trials on "P" Plenum nozzles. ("P" was used because the tubes had not yet been line bored whereas "R" Unit tubes had been.) It was felt that the welding involved in the repair operations might cause enough shrinkage to affect tube alignment. First, the tops of staybolt welds were chipped out and centers of staybolts laid out from original drilling template for top and bottom nozzle plates, taking into consideration that welding of nozzles had probably caused a slight shrinkage of original layout. Care was taken to keep staybolts in a straight line with the distance between holes to best suit the as-welded condition. Holes for removal of staybolts were laid out to above procedure, with only the outer rows of staybolts on Nozzles Nos. 1, 3 and 5 being chipped and laid out at this time. The staybolts were then drilled out and chipped loose on top side. The Plenum was turned and the above procedure followed and the staybolts and shroud plates were removed.

The three inner staybolts were left in each nozzle. The tops of these staybolts were chipped flush, laid out, drilled and countersunk on both sides. Further trouble was encountered as each of three Plenum centering devices was very close to one staybolt and had a support bracket that would have to be removed. Countersinking the staybolt hole would also cut material away from center web of centering device. It was decided to remove the support bracket from

one side of each centering device and change the angle of countersinking and the size of the adjacent bored hole in bottom plate of nozzle. The ends of new staybolts that fitted these holes were redesigned, changing angles and providing for a "J" weld.

In order to install solid vanes it was necessary to cut out metal from the throat and flange of the nozzle to give a 3-in. wide section so that the vanes could fit into the nozzle. After the vanes had been inserted, these cutouts were filled in with weld metal and finished to the contour of the nozzle.

For the "R" Unit Plenum it was necessary to determine a new center-to-center tube dimension layout. The "NYX" Plenum tube sheets had been laid out on 7.021 in. tube centers and the final average dimension after welding was 6.994 in. tube centers. A dimension of 7.031 in. for layout was finally decided upon for "R" Unit Plenum. (For details of tube center dimensions, see Part VII "Welding Development".)

The weir slots in the tubes as originally designed for the "NYX" Unit were 8-1/2 in. high and 0.312 in. wide. Three slots were evenly spaced around each tube with the bottom of the slots located 1/8 in. above the top of the bottom tube sheet, providing a uniform 1/8 in. film of liquid. The slight dishing of the tube sheets eliminated this uniform layer, so on "NYX" Unit fifteen tubes had their slots extended to the plane of the bottom tube sheet. On "R" Unit the weir slot dimensions remained the same as the original design but all slots were lowered to the plane of the top of the Bottom Tube Sheet.

The 4.625 in. diameter bore of the tubes was 9.067 in. long for "NYX" with one end chamfer located above the bottom plane of the top sheet and the other below the top plane of the bottom sheet. On "R" Unit this length was reduced to 8.084 in. The bottom chamfer was located even with the top plane of the bottom tube sheet and the top chamfer below the bottom plane of the top tube sheet to increase tube strength.

The number of centering tongues was increased from three on the "NYX" Unit to six on "R" Unit.

The number of V-slots on top of the large tubes was increased from one per tube on "NYX" to three on the "R" Unit. The NYX design specified three V-slots but only one was cut to expedite the unit for the testing program.

There were 162 1-7/8 in. outside diameter rod tubes in "NYX" and 165 2 in. outside diameter rod tubes on "R" Unit.

The lifting eye hoods originally designed for "R" Unit bulged on the sides upon hydrostatic test of ten lb./sq.in. The hoods were scrapped and new hoods fabricated from 1/4 in. plate in lieu of the 0.0625 in. sheet formerly used.

A hydrostatic test was performed as on the "NYX" Unit. Starting with "P" top tube sheet and plenum prior to line boring, and "L" bottom tube sheet, a special drop hammer with a ten pound weight dropping a distance of two feet in the center of each triangle-shaped tube cluster was added to the hydrostatic test to test the tube welding on this unit for soundness.

The total number of large tubes remained at 673, being made up of approximately 421 cast compared to thirty-five in "NYX", sixty-three seamless compared to 638 in "NYX" and 189 welded tubes.

On the experimental "NYX" Unit a token quantity of forty-seven probe pin sockets were attached to the upper tube sheet grouped around one nozzle, whereas on "R" Unit the total complement of 842 was installed covering the entire tube sheet. Motion measurement brackets were added starting with "R" Unit to accommodate probe pin sockets located outside the diameter of the tube sheets.

The number of latch studs was increased from 324 to 330 due to the addition of three more rod tubes on the "R" Unit.

There were 838 number tags, one for each of the large and rod tubes made for this unit that were not installed on "NYX". The tags for the "R" Unit were attached at Savannah, whereas on all later units they were attached during fabrication.

Beginning with "R" Unit and continuing through the later units, a tangential slot of 5/16 in. maximum depth was cut 3/4 in. from the top of each large tube for the hold down latch. These slots were not cut on "NYX". They were cut in "R" Unit tubes in the field and on the remaining units during fabrication.

A water retainer 3/16 in. thick and 1 in. high with six drain connections was installed on the top of the Plenum Chamber, enclosing all tubes. This retainer first appeared on "R" Unit and was installed in the field. For all later units it was installed during fabrication. Each of the six sections of the Plenum skirt for the "NYX"

Unit was shaped and bent from one plate, whereas, on "R" and later units each section was formed from three separate pieces which were welded into an identical skirt with minor modifications.

Fabrication Changes and Difficulties

On the "NYX" Unit, when fabricating the various elements, plates were burned and simply dressed, but starting with "R" Unit, all burned edges were either chipped or machined back $1/4$ in. to eliminate carbon deposits.

The rod tubes were all hand welded using "Aircomatic" welding machines on the "NYX" Unit as the automatic tube welding method had not been fully developed at this time. On "R" Unit the rod tubes were welded by the automatic "Aircomatic" method.

On the "NYX" Unit, the rod tubes were machined to length and finish bored to an inside diameter of 1.500 in. with a bottom land of 1.3125 in. before assembly and lightly honed to remove any distortion due to welding after assembly. On "R" Unit the rod tubes were finish bored after assembly from .875 in. inside diameter to 1.505 in. and 1.3125 in. respectively. Also $1/8$ in. was left on the top to be machined off after assembly, and $1/4$ in. was left on the bottom. These operations required a complete new set of jigs and fixtures.

The "R" Unit Plenum was shipped to the Philadelphia Naval Shipyard for facing the tops and bottoms of the large tubes to proper length and in the same plane. The Naval Shipyard also finished the bottom edge of the skirt. These operations were necessary because the New York Ship 20-ft. vertical boring mill would not swing the Plenum Chamber with nozzles welded in position. On the "NYX" Unit, the tubes were faced prior to welding of nozzle assembly, but this was done out of necessity because a large boring mill could not be found (for further details see Part VII).

Upon completion of line boring large tubes, specifications called for honing to a size between 4.375 in. and 4.380 in. Five tubes had inside diameters exceeding the top limit, so they were cut out and replaced. In doing so, tube welding caused approximately forty-nine tubes to go out of round. After considerable discussion it was concluded that the only safe method of "reclaiming" the "R" Plenum involved honing all large tubes to a larger bore. The tubes were then honed to between 4.385 in. and 4.390 in. and were accepted as being within tolerance.

Twelve precision photographs on glass plates were taken of the Plenum after cleaning to obtain a permanent record of the pattern on the top side of the Plenum. These pictures were also a test to determine whether inspection costs and time might be reduced by use of precision photographs.

Ferroxyl tests were instituted for various components received from vendors to insure that materials were free of iron deposits.

On "R" and later units, miscellaneous supplied fittings were machined by New York Ship to suit the work and changes in design.

The cleaning of the "NYX" Plenum Assembly was performed by New York Ship personnel with materials and the services of a field consultant supplied by the Oakite Company. The Plenum was submerged in "Oakite No. 31" solution (a caustic compound with a wetting agent additive) for seventy-two hours in a converted Building 3 turret-building pit. The Plenum was then rinsed in another pit, filled with city water heated to 150 degrees F., by raising and lowering several times. It was then sealed and "Oakite No. 17" (comprised of phosphoric acid with a wetting agent additive) flushed through a closed circulating system for six hours. Although the Plenum did not meet the rigid cleanliness specifications required for units to be installed at Savannah River, it was acceptable for test purposes at New York Ship.

Dowell, Inc., Philadelphia, Pennsylvania, performed the cleaning operation for "R" and subsequent production units.

The "R" Unit cleaning procedure was established and given a preliminary trial upon completion of line boring and honing of the tubes. Hot detergent was pumped in through bottom connections and allowed to spill over at top of chamber while being air agitated. The solution was then flushed out as rapidly as possible. This procedure was continued until samples of detergent showed no traces of soluble oil. The Plenum was then filled with hot distilled water and drained as rapidly as possible. The cleaning procedure did not produce the required results so at the time of final cleaning, hot detergent was forced into the Plenum under pressure through one nozzle with the remaining nozzles sealed. Each of the nozzles in turn was opened. The Plenum was then washed and rinsed with the assembly slightly tilted in order to allow foreign material to be washed out. After two complete cleanings the assembly was accepted. A rubber lined tank and 300 g.p.m. rubber lined pump with bronze impeller was used to handle the detergent.

TOP TUBE SHEET ASSEMBLY

Design Differences

The expanded tube center dimension used for the Top Tube Sheet Assembly of "NYX" was 7.021 in. After welding, it was discovered that shrinkage was less than expected. The new expanded tube center dimension arrived at for the Top Tube Sheet Assembly was 7.017 in. In order to use the existing jig of 7.021 in. centers, it was decided to make the tube center distance for this assembly 7.021 in. and set the tube center dimensions for the Plenum and Bottom Tube Sheet Assembly from this figure. (For further explanation of tube center dimensions see Part VII.)

The lifting eyes were changed slightly from "NYX" to "R" and remained similar through "P", "L", "K" and "C" Units. The change involved reshaping the eye to better fit the crane hooks and a modification of the gusset plates stiffening the eyes. The thickness of the shell plate under the eyes was increased to 7/8 in. compared to 1/2 in. on the "NYX" Unit.

As on the Plenum Chamber, the number of centering grooves was increased from three on "NYX" to six on all later units, with small modification in design.

There were no instrument wells on the "NYX" Unit, whereas "R" and "P" Units had a total of twelve, six terminating 6 in. above the baffle plate, three terminating 12 in. above the baffle plate and three terminating 18 in. above the baffle plate. These wells were hydrostatically tested at 2000 lbs./sq.in. for ten minutes. "R" Unit contained a total of 165 rod tubes compared to 162. "NYX" rod tubes had ten degree angles on tops of tube bores compared to thirty degree for "R" and later units. "NYX" tubes were faced flush on top and protruded through the sheets 1/16 in. on bottom. "R" and later units had tubes protruding through sheets 1/4 in. both top and bottom. In addition, three additional 1-5/8 in. outside diameter tubes were added on "R" Unit as instrument lead and liquid level tubes, there being none on "NYX".

"R" Unit had seventy-three shoulder tubes and 600 non-bearing tubes compared to ninety-one shoulder tubes and 582 non-bearing tubes on "NYX". These 673 tubes included approximately 130 cast, 74 seamless and 469 welded tubes. The pre-machined "R" Unit tubes were 3/8 in. longer on the bottom end than "NYX". "NYX" Unit had a 1-in. hole in each shoulder tube wall above the top plate. These holes do not appear on "R" Unit.

All production units had closure bars for space between gussets or webs, and the baffle plates. Although similar in size, there were minor differences in shape from unit to unit. The web plates were again similar through all the units, but for "R" Unit the stiffeners on the web plates were increased in thickness from $3/8$ in. to $1/2$ in. for both types of web and extended another $3-3/4$ in. along the inside of the wrapper for the straight webs. This entailed a change in the machining the web cutouts of the baffle plate.

The baffle plate was similar to "NYX" in dimension and number of different sized holes except that "NYX" contained 162 $2-1/4$ in. holes, while "R" had 168 holes stepped in size from $2-1/4$ in. on outside of sheet to $1-7/8$ in. at center of sheet. "R", "P" and "L" were identical in baffle plate design.

The "NYX" Unit contained twenty-four equally spaced baffle support plates measuring $1-3/4$ in. by 4 in. by 1 in. whereas "R" Unit had forty-two plates measuring $1-3/4$ by 3 in. by 1 in.

A 24 gage stainless steel (spring temper) seal ring added on "R" and later units was spot welded to the baffle plate to seal the annular opening between baffle and wrapper sheets.

Chime rings were a major design change on "R" Unit and subsequent production units. This involved reducing the size of the deflector plate from 17 ft. 10 in. diameter down to 16 ft. $2-3/4$ in. diameter. The number and size of holes in the deflector plate remained the same except for the addition of 3 $1-5/8$ in. diameter holes to accommodate the additional rod tubes.

The chime rings consisted of four rings of 1 in. plate, $6-1/8$ in. wide with four segments to each ring, suspended from the lower tube sheet by welded brackets. The outer chime ring was 17 ft. $6-3/4$ in. outside diameter and each succeeding ring was 4 in. smaller in diameter. The rings were held together by twelve pins with spacing washers between rings. Other smaller items involved in this redesign were: "NYX" had shoulder bolts for holding deflector, "R" had studs, one $1-1/2$ in. pipe plug hole in bottom tube sheet in way of chime bracket had to be plugged, seal welded and dressed, and another similar hole drilled and tapped.

The length of the bearing plates on the "R" Top Tube Sheet Assembly was changed to 12 in. from 8 in. on "NYX".

Twelve thermocouple slots were added to the bottom tube sheet of the "R" assembly.

Fabrication Changes and Difficulties

On the "NYX" Unit the cutouts in the baffle plates were milled, whereas on "R" Unit the same result was accomplished by horizontal boring.

Originating with "R" Unit, it became necessary to allow extra material in laying out so that all burned edges could be machined or chipped back 1/4 in. to insure that the metal was carbon free.

A Zy-glo test was required for all tubes after welding, as was a 1000 lb./sq.in. hydrostatic test for each tube.

All material received from subcontractors was closely inspected upon arrival at New York Ship, and considerable time was spent reworking defective material, particularly poor machine work on a number of tubes.

Many of the containers of raschig rings received did not meet cleanliness specifications. This involved either returning them to vendor for further cleaning or cleaning them at New York Ship, requiring added time and expense.

Dowell, Inc. performed the internal cleaning for "R" and all subsequent future assemblies. The cleaning procedure established for this unit was formulated in a meeting as described under the Plenum Chamber. The primary purpose of this meeting was to outline a cleaning procedure for the "R" Plenum Chamber during "reclaiming operations". No definite cleaning procedure was set up for this assembly, so therefore the cleaning procedure outlined for "R" Plenum Chamber was used as a guide for the cleaning of this assembly. Essentially internal cleaning was the same as the Plenum Chamber except for the methods incorporated in the handling and getting the cleaning solution into and out of the unit.

With the unit in a vertical position, the unit was pumped full of hot detergent. The solution was air agitated and allowed to overflow out of the upper raschig ring inspection ports for one-half hour, then drained through the lower ports. The unit was then filled with hot distilled water and the above procedure repeated, with the additional step of rocking the assembly in the cradle bed during draining operations. Four washes were required and results were not acceptable. The unit was partially filled with raschig rings and by tumbling these rings and washing with Dowell detergent, then rinsing with distilled water and rolling the assembly, an acceptable degree of cleanliness was attained.

MAIN TANK

Design Differences

The diameter of the tank and the thickness of the plate were the same for this unit as "NYX", but the overall height was reduced from 12 ft. 11-1/2 in. to 11 ft. 10 in.

The "NYX" tank contained one manhole, which was eliminated on "R" and all later units.

"R" and later tank assemblies did not contain the twelve 2-in. diameter pads 1 in. thick with 1/2 in. pipe tap located around the circumference of the "NYX" tank or the "NYX" vibration pick up mounting pads. The "NYX" Unit had miscellaneous thermocouple pads on the inside and outside of the tank whereas "R" Unit contained a regular pattern on the outside of the tank.

The expansion ring design from "NYX" to "R" Unit was completely changed. The ring for the "NYX" Unit had an L-shaped cross section with a 9-3/16 in. horizontal leg and a 3-in. vertical leg. The horizontal leg was welded to the inner bottom of the bearing ring. The newly designed ring was similar for "R", "P", "L" and "K" Units, and contained two bends in cross section incorporating two vertical legs of 6-1/2 in. and 5-1/4 in. and one horizontal leg of 9 in. The 6-1/2 in. vertical ring was attached to the bearing ring inside diameter.

Due partially to the addition of the chime rings on the "R" Unit and partially to improvement in design, the bearing ring was modified between the "NYX" Unit and the "R" Unit. This new design followed through on "P", "L" and "K" Units also.

There were twelve bearing plates on the Top Tube Sheet Assembly for both "NYX" and "R", the difference being that on "NYX" the plate size was 8 in. by 1-3/4 in. by 3/4 in. while on "R" the size was increased to 12 in. by 1-3/4 in. by 3/4 in.

These bearing pads rested on the bearing ring in locations determined by index keys. The indexing devices were similar for "R", "P", "L" and "K" Units, the only difference being in the design of the indexing cutout on the bearing ring.

The narrow section of the Top Tube Sheet Assembly enclosure shell extension that was welded to the bearing ring was extended an additional 3/4 in. on the "R" Unit to give less chance of distorting the bearing ring when welded to the rest of the enclosure shell.

On the "NYX" Unit the twelve bottom bearing surfaces measured 16 in. by 4-1/4 in. and extended 1/4 in. from bottom of ring. They were attached with twenty-four (2 per surface) 1-1/8 in. bolts to other bearing plates on the permanent supports. On the "R" Unit the twelve bottom surfaces were formed by a cut 1/2 in. deep and 12 in. wide circumferentially across the bottom of the rings. These sections were designed to rest on bearing plates firmly attached to the unit foundation. Keys would then be fitted between bearing plates and edges of cutouts and retained with dowel pins.

The Top Tube Sheet Assembly enclosure was very similar for "NYX" and "R" Units. There were two connections on "NYX" consisting of two 8 in. long stub sections of 4 in. pipe, welded into the wrapper plate. These connections on "NYX" were replaced on "R" by an overflow pocket arrangement. The pockets were drained by two connections each, one at the top and the other at the bottom of the pocket. The pockets were 2 ft. wide, 3-5/16 in. deep and 15-3/4 in. high inside dimensions. The top connection was formed to a nozzle and the bottom was a 6-in. long stub of 3-in. pipe. The two connections were separated by a 1/4 in. plate in the pocket containing a 1/2 in. diameter hole. There was also one 3/4 in. hole in the wrapper plate tangent to the inside of the bottom plate forming the pocket.

The bearing ring on the "R" Unit contained thermocouple holes that entered the ring at an angle and a set screw hole at right angles to the thermocouple holes for holding thermocouple wire in place. These were not installed on the "NYX" Unit.

Fabrication Changes and Difficulties

On "NYX" the tank formers were all mild wrought steel turned to tank diameter. On the "R" Unit, after the final position of the field joint had been established, it was decided to ship the complete Main Tank as a unit. A building, handling and shipping form was fabricated from mild wrought plate. Three forming rings in tank and tank enclosure were clad with 3/4 in. stainless steel 2 in. wide. This eliminated any possibility of contamination of tank or enclosure from the forming rings.

Several mock-up sections of different type expansion joints that could be made without going into a die building program were developed before fabricating the "R" expansion joint. The outside bending form for "NYX" which had been fabricated in the Boiler Shop of New York Ship was augmented by the fabrication of an inside bending form to take care of the new inside radius on "R" Unit expansion joint.

It was known that welding had warped the "R" bearing ring to such a degree that the outer face of the bottom side was approximately .050 in. higher than the inner face. This same condition existed when the assembly was in position and resting on the twelve pedestals clamped to the 20-ft. boring mill table. As the result of a meeting between du Pont and New York Ship, it was decided to pull the bearing ring face flush (or as near as possible) to the top faces of the twelve cast iron pedestals using large staybolts to hold the bearing ring in a level plane. Since the bearing ring when in an operating position in the field would be subjected to the weight of the Top Tube Sheet Assembly and Plenum Chamber, it was believed that the ring face would straighten under operating conditions.

BOTTOM TUBE SHEET ASSEMBLY

Design Differences

The "NYX" Unit had 162 fabricated rod cups installed during fabrication at New York Ship, whereas "R" Unit had 165 cast rod cups of heavier material installed in the field. The "R" Unit rod cups were machined at New York Ship, and required considerably more time than "NYX" design.

The nozzles and nozzle muffs were identical to "NYX" Unit, the only difference being that the muffs were provided in only one nozzle on "NYX" (to obtain test data) and in all six nozzles on "R" and later units. The tank bottom nozzle section extended 22-1/2 in. above the Bottom Tube Sheet on "NYX" compared to 28-1/2 in. on "R" Unit.

The split retaining rings at the lower tube ends remained similar to "NYX" rings with the addition of two 1/16 in. flats. Rings that shrunk out-of-round were fitted to scrap tubes and were trued up by hammering.

The baffle plate was of same diameter and thickness as "NYX" but was modified somewhat in layout. The "NYX" Plate contained 588 4-9/16 in. diameter holes, seventy-nine 4-3/4 in. holes and six 4 in. holes, whereas "R" Unit plate contained 594 4-9/16 in. holes, seventy-three 4-3/4 in. holes and six 4 in. holes. The milled-out sections in the edge of the plate near the webs were increased due to heavier stiffeners. Additional milling was required because of the addition of twelve short webs and twelve additional half moons cut out of edge of plate to clear water inlet and outlet cups. "R" Unit baffle plate also contained ten additional 1-1/2 in. diameter holes for instrument wells.

There were ten instrument wells and collars incorporated in this assembly which did not appear in "NYX" assembly. These ten wells were all of one design.

The pre-machined shape of the "R" tubes was modified as a result of experience with the "NYX" Unit. The internal chamfer was changed from 45 to 10 degrees. The "belling" of the upper ends of "NYX" tubes required a decrease in pre-machined upper land diameters from 3.250 in. to 3.210 in. Approximately 100 of the "R" Unit tubes had been completed to the original dimensions but the additional metal was left in the rest and in the tubes of all subsequent units.

The larger finished diameter of 3.270-3.277 in. was also applied to "R" and subsequent units. A maximum of .067 in. was thus left in the top tube bores to be removed by line reaming and honing, making for a better finish and necessitating a modification to the reaming bars.

The final tube center layout spacing was 7.014 in. (See Part VII, "Welding Development", for details of this change.)

The end stiffeners for both straight and bent webs were increased from 3/8 in. to 3/4 in. plate and also increased in width. Between the bent webs the wrapper plate was increased from 1/2 in. to 1-1/4 in. in thickness. The side stiffeners on the bent webs located close to plate perimeter on "NYX" were omitted from "R" Unit. In addition, twelve 12-in. webs were added to "R" Unit evenly spaced around assembly.

The addition of these short webs made it necessary to increase the number of inlet and outlet connection from twelve each to twenty-four each. On "NYX" these connections were street elbows, whereas on "R" Unit they were 8-in. half pipe and tees. On "NYX" twelve of the twenty-four openings were plug welded closed.

The "NYX" Unit contained 582 straight tubes and ninety-one shoulder tubes as compared to 600 straight tubes and seventy-three shoulder tubes on "R". The number of each of the various types as follows: 106 seamless, eighty-five cast and 482 welded. "NYX" had one monitor pin locating hole drilled in the bottom of all but about sixty tubes, whereas "R" Unit tubes had three locating holes in each tube.

Three motion measurement pads were added to "R" Unit on the top edge of wrapper.

On the "NYX" Unit, the twelve bearing plates contained clearance holes for holding unit, whereas on "R" Unit there were elongated holes with taper for dowel pins. Following the original drilling of these holes they were inspected and found outside of layout, and no allowance had been made for taper. It was decided to drill holes to a larger diameter and counter bore holes (from top side) 1/8 in. deep for insertion of a shoulder head bushing. When bushings were pressed in line, they were drilled, tapped and doweled.

Fabrication Changes and Difficulties

As with the other assemblies of this unit, it was necessary to leave an additional 1/4 in. on all burned edges for machining to insure that there would be no carbon deposits. A 1000 lb./sq.in. test and Zy-glo test of all tubes after welding, and a ferroxy test and inspection of plates upon receipt were now required.

The raschig rings as sent in by vendors were not clean, which involved both returning some to vendor for recleaning and cleaning of some by New York Ship. Considerable repair work was performed on material received from vendors, particularly on tubes.

After facing and reaming of tubes it was discovered that approximately fifteen tubes had been distorted or "caved in" on the bottom end tube wall. This condition resulted from feeding the cutting tool too deep during facing of the bottom tube ends. Since tube bottom lands were to finished size, it was decided to repair the tubes rather than replace them. New York Ship attempted to swage the bottom lands to original dimensions and in doing so, seven of the tubes were swaged oversize. This method was discontinued because swaging resulted in bell-ing of the tube end. To bring the tube bores within tolerance, the seven tubes were shrunk by welding a series of beads around the bottom of the tubes. Heli-arc welding without filler metal was used to shrink all seven tubes. After shrink welding, the bottom land bores were honed to 3.377 in. Tubes were then inspected and found within tolerance. Inspection of the top land of all tubes showed one tube oversize and out of round. This tube was removed and replaced and other minor mechanical defects were repaired by either honing, cloverleafing or smoothing out defects with crocus cloth.

A preliminary hydrostatic test was performed on this assembly. A leak occurred in the weld seam on one of the welded tubes at 22 lbs./sq.in. This tube was cut out and replaced. The assembly was again tested and another

welded tube seam leaked. This tube was also cut out and replaced. Since there were 480 other welded type tubes in this unit, it was decided to discontinue the hydrostatic test and thoroughly evaluate the extent of the unsatisfactory quality of welded tubes in this assembly. Twenty-two tubes were known to be questionable after Zy-glo examination. Zy-glo was followed up by a freon test, then a hydrostatic test, followed by a second freon test and then a final Zy-glo inspection. The above steps were followed on all tubes for this assembly. Certain tubes were shipped to the du Pont Engineering Research Laboratory for cyclic pressure tests to determine extent of unsatisfactory condition.

A total of thirty tubes was found to have defects of varying nature. The majority of the defects appeared to be lack of fusion in the welded seam of the tube. Sixteen of the above tubes were removed and replaced, the remainder were satisfactorily repaired. All tube replacements were either cast or seamless, and no welded tubes were used in any subsequent assemblies. In order to make sure that the sixteen replaced tubes were sound, the unit was given a freon test, followed by a Zy-glo of the sixteen new tubes and adjacent tubes and finally a hydrostatic test. No leaks were found and all tubes were considered acceptable.

Preliminary internal cleaning prior to welding wrapper plate was performed on this assembly. Since no preliminary cleaning procedure was available, experience gained from cleaning the "NYX" assemblies was used by Dowell, Inc. in the cleaning operation. With the assembly slightly tilted, a wetting agent (F-29) was jetted into the unit using a high pressure car wash unit for several hours from all sides. The unit was similarly jetted with distilled water for further cleaning action and rinsing and accepted.

The final internal cleaning was very similar to the procedure used on "R" Unit Top Tube Sheet Assembly. No specific cleaning procedure had been developed, but the same steps were followed as in the top assembly cleaning.

"P" PRODUCTION UNIT

PLENUM CHAMBER

Design Differences

Nozzle vanes of "NYX" design had already been installed in "P" Unit nozzles when the redesign was decided upon. In order to determine the best removal method, it was decided to experiment on "P" Unit because it had not been finished

bored at this time. One nozzle was selected and the staybolts and shrouds removed, new vanes were fitted, staybolts were assembled and welded. Inspection checks were made at every step to determine what effect welding would have on the tube pattern. From knowledge gained on this experimental nozzle, the system for removal and replacement was devised that was used successfully on both "R" and "P" Units. (See "R" Unit for details.)

The pre-machined finish of the "P" Unit large tubes differed from "R" Unit tubes in that $1/4$ in. rather than $5/8$ in. excess was provided on the bottom of the tubes for removal during facing.

There were 358 seamless tubes in the "P" Unit Plenum, 314 cast tubes and one welded tube.

Fabrication Changes and Difficulties

The "R" Unit Plenum Chamber top plate was found to be dishd about $1/4$ in. When the tops of the tubes were faced to a reference tube in the center, (low area) the tubes on the outside of the pattern were approximately $1-3/4$ in. from the plate instead of 2 in. as specified on the drawing.

As a result, a new procedure was established. Tubes were faced top and bottom in planes parallel to the datum plane as defined by bench mark readings. The top faces of the tubes were faced off to a distance of 1.750 in. above the high point of the top plate. Tubes were then finished to the specified overall length. The bottom edge of the Plenum skirt was finished to size with reference to the bottom faces of the tubes.

It was ascertained through inspection that the lifting lug holes in the Plenum skirt would not allow the four lifting lugs of the Top Tube Sheet Assembly to pass through when the units were mated. It was therefore necessary to enlarge these holes and hoods were made oversize to fit.

To eliminate confusion in locating tubes, the tube coordinates were stamped on the top ends of all large tubes. Rod Tube numbers were stenciled near the tube on the top side of the top tube sheet.

Freon test conducted on "R" Unit in the field showed several tube weld leaks. It was believed that moisture trapped in small cracks or pin holes had prevented the escape of freon during New York Ship tests. As a result of a drying step just prior to freon testing was added on this and subsequent assemblies.

During the line boring on the "NYX" and "R" Unit Plenum Chambers, many tubes would not accept the functional gage after finish boring. This was due to the fact that the corresponding tube bores in the Top Tube Sheet Assembly were beyond drawing tolerance with respect to verticality, while the Plenum Chamber tubes were vertical within drawing tolerance. This condition was relieved by enlarging the bores of the Top Tube Sheet Assembly tubes by grinding and honing at the point where the functional gage and Top Tube Sheet bore interfered, but the procedure was time consuming and costly. A boring fixture base tilting procedure was established for the "P" Unit and some of the Plenum Chamber tubes were bored out of vertical up to a maximum of 0.010 in./ft. on "P", "L" and "C" Units. The number of tubes requiring grinding and honing was greatly reduced and no tubes had to be replaced. This tilting base procedure reduced the time and cost of these later units by a considerable amount.

All of the 673 large tube ends (top and bottom) were Zy-glo tested to determine if any lamination or cracks were present. This inspection came about as a result of finding a laminated cast tube in the "P" Bottom Tube Sheet Assembly.

Prior to assembling and welding the Plenum nozzle assembly to the tube sheets, a preliminary cleaning was performed with hot deionized water and a high-pressure car wash unit.

Field complaints about the cleanliness of "R" Plenum led to further study of this problem and the following procedure was adopted and used for "P" Plenum final cleaning.

A solution of 0.1 per cent detergent, 1.0 per cent caustic and 1.0 per cent trisodium phosphate mixed with hot deionized water was jetted through each nozzle as in the "R" Plenum. An extra step was added, with the use of a special tube plug to spray cleaning solution through the slots in each tube. After being rinsed with deionized water the Plenum was filled with cleaning solution and suspended vertically for one hour, air agitated and then drained. In this vertical position the assembly was final rinsed with deionized water.

All preliminary cleaning of pre-assembled parts was accomplished with F.O. 128 (a proprietary solvent) in lieu of carbon tetrachloride to eliminate any chloride deposits.

After "P" Plenum Chamber was removed from the circumferential handling jig, the jig was thoroughly cleaned and

painted with chromate to prevent iron oxide or rust from "flaking off" and contaminating future Plenum Chambers. This greatly reduced the amount of iron contamination on both "L" and "C" Plenums.

TOP TUBE SHEET ASSEMBLY

Design Differences

"P" Unit contained 594 non-bearing tubes and six gas tubes as against 591 non-bearing tubes and nine gas tubes on "NYX" and "R" Units. "L" and "C" Units were similar to "P". The "P" Top Tube Sheet Assembly had 438 cast and 235 seamless 5 in. outside diameter tubes.

Fabrication Changes and Difficulties

Dowell, Inc. again performed the cleaning operation on this assembly in a manner similar to that used for the "R" Unit. After cleaning several times, a residue resembling scale was found on the inside of the assembly. Samples of this residue were analyzed and it was desirable to have it removed. Internal cleaning was halted at this time. Field experience with cleanliness of the "R" Unit, and the cleaning difficulties experienced at time of its fabrication, led to a complete new study of the cleaning problem.

A formal cleaning procedure was adopted for the "P" Unit Top Tube Sheet Assembly. The solution used was 0.1 per cent detergent, 1 per cent caustic, 1 per cent trisodium phosphate with deionized or distilled water at 150-190 degrees F. With the assembly upside down all wrapper plate openings were jetted for five minutes each and drained. Next, with all wrapper openings closed, the assembly was completely filled. While filled, the assembly was flushed through one outlet tube at a time for ten minutes and drained through the mating inlet tube. The unit was then placed in a vertical position, filled completely and rolled 60 degrees. While draining the assembly, the level was maintained by more feed and also air agitated thirty minutes. While in vertical position the assembly was twice rinsed, first with hot distilled water and finally with deionized water. After following the above procedure the cleanliness of the unit was acceptable.

In order to eliminate tube weld leaks reported from the field, a new tube weld examination and closer control of welding were required.

Tube weld leakage occurred most frequently at (1) large tube weld overlay, (2) weld roll-over where rod tube and large tube weld joined and (3) roll-overs on large tube welds due to lack of fusion. In order to eliminate the above items, New York Ship was requested to grind and chip all large tube overlay, chip out all weld roll-over where rod tube and large tube weld joined and to chip out all roll-overs on large tube welding due to lack of fusion. The above procedure was followed on both sides of the "P" Top Tube Sheet Assembly.

A hydrostatic test was performed on this assembly similar to "R" Unit test, and a hammer drop test was incorporated for this and all later assemblies.

The internal drying was performed on this assembly as described under the Plenum Chamber.

MAIN TANK

Design Differences

The design of this assembly was similar to "R" Unit Main Tank Assembly.

Fabrication Changes and Difficulties

A report from the field stated that "R" Unit expansion joint had seven small cracks in parent metal perpendicular to the upper girth weld. During the field hydrostatic test two of these cracks leaked. The defects in the expansion joint were evident after re-examination of the radiographs, however they were originally interpreted by du Pont and New York Ship personnel as "lead marks". (X-ray pictures are made with the film enclosed in a cardboard outer pack with two thin sheets of lead on one side and one thin sheet on the other. While inserting the X-ray film or removing it from the pack, the lead shields can easily be damaged by gouges, scratches or punctures. X-ray pictures taken using damaged leads frequently show images of the lead defects as well as those of the metal or weld. The images of the lead defects are commonly known as "lead marks".) It was felt that these cracks were caused from forming dies used to fabricate the segments of the expansion joint. The original die (for "NYX" Unit) had been converted and utilized for forming the "R", "P", "L" and "K" expansion joint segments by removing a skirt plate. When the plate was cut off, depressions on the edges were not filled in, and the working segment areas on the dies were not smoothed in. When the expansion joint segments for "R" were formed, the rough edges in the skirt plate were believed to have caused the cracks.

In order to prevent the occurrence of this condition on later units, the following steps were taken: (1) the expansion joint forming dies were completely reworked by filling in all depressions in the skirt plate and grinding all sharp corners to a smooth contour, (2) fine grain X-ray film was substituted for coarse grain film, (3) adoption of a more efficient X-ray reading procedure and, (4) repair and new X-ray's of all doubtful welds.

The above procedure was followed in re-examining all sections of the "P" Main Tank Assembly. Defects found were of minor nature.

Due to the considerable amount of welding repairs necessary on the expansion joint and the fact that the main tank assembly had not been lofted into the "P" Bottom Tube Sheet Assembly because of the welding difficulties, it appeared that this assembly would not be ready on the shipping date. Therefore, in order to make shipment it was decided to make all remaining welding repairs at the site.

Also the decision was made to loft in the "P" Main Tank shell to the Bottom Tube Sheet at the plant site. A New York Ship representative accompanied a du Pont inspector to the Savannah River Plant to assist the field personnel in this operation.

BOTTOM TUBE SHEET ASSEMBLY

Design Differences

On "R" Unit during the assembling of the split flange and rings on the lower ends of the tubes, hexagon nuts were used to clamp the monitor pins and upflow cooling water pins in the bottom end of a large tube. When tightening up the split flange the threads were not long enough and the nut froze on the body of the stud. This condition was not noted in the field and as a result the studs were twisted off at the weld in an effort to tighten the flanges. Examination of welds showed satisfactory results so the threaded length was increased to 1-1/8 in. on each of the four retainer ring studs. This was accomplished on "P", "L", "K" and "C" Units.

There were ten instrument wells in this assembly, the same number as in "R". Three of the wells were of "R" Unit design and the remaining seven were of slightly modified design.

The pre-machined finish of both the bearing and the non-bearing tubes was similar to the modified plan for "R" Unit except that 1/4 in. less material was left on each end of "P" Unit tubes.

The wall thickness of the 8-in. split pipe welded to the periphery of the wrapper plate was changed from .109 in. to .148 in. because of: (1) difficulty in working and handling material due to thin walls, (2) weld burn-through frequently experienced in joining pipe segments together for making the transverse butt weld joint and, (3) difficulty in getting the quality of weld to pass code requirements.

Fabrication Changes and Difficulties

As a result of the problems encountered in the use of welded tubes in "R" bottom tube sheet, only cast and seamless tubes were assembled in this unit.

It was decided to Zy-glo the ends and bores of all large tubes in this assembly. The Zy-glo process showed all tubes satisfactory, however a crack 1-3/8 in. long was found in the top side of top plate 1/4 in. from fillet tube weld. This cracked area was chipped out, ground smooth, Zy-gloed and welded. After grinding and Zy-glo inspection it was accepted.

During the fabrication of this assembly, it was necessary to remove and replace a total of eight tubes due to laminations or weld burn-through.

After facing and reaming tubes, it was discovered that eight tubes had been distorted or "caved in" on the bottom end tube wall. All tubes were repaired satisfactorily using the same method described in "R" Unit.

As a result of welded tubes in the "R" assembly leaking, it was decided to hydrostatic test each tube in the "P" Assembly, in a manner identical to that performed on "R" Unit. Final results of this test indicated that no leaks were present in the tube walls.

Following leak repair shown by freon test on instrument wells, the wells were borescope inspected and showed poor penetration of butt welds on the inside making it necessary to replace seven wells. The design of the original instrument wells was altered slightly to fit the holes in the bottom of the tube plate which were enlarged while cutting out the defective wells. After welding in new wells, another freon test showed no leaks.

Preliminary internal cleaning was not performed on this assembly, but New York Ship personnel performed a thorough cleaning of all external surfaces.

The final cleaning of this assembly was similar to that performed on "R" Bottom Tube Sheet Assembly except that air agitation was continued for 2-1/2 hours and the assembly was rinsed three times.

"L" PRODUCTION UNIT

PLENUM CHAMBER

Design Differences

On "L" Unit the nozzle vane design differed from "NYX", "R", "P" and the "K" conversion. "L" Plenum vanes were considered the most desirable design but fabrication of the preceding units had progressed to a point where they could not be modified to the "L" vane design without excessive risk of distortion. The "L" vanes were 3/4 in. plate shaped top and bottom to fit the nozzle with 3-in. "fish-tails" on both ends. Three vanes were attached in each nozzle by continuous fillet welds all around, and "Zy-glo" inspected. The location of these vanes remained as in the other units.

The total number of large tubes, both bearing and non-bearing, remained the same as "P" Unit and consisted of 673 seamless drawn tubes.

Fabrication Changes and Difficulties

Due to the welding of tubes, tube shrink welding and radial shrink welding around the outer periphery on both sides of the unit, waviness resulted in the top and bottom tube sheets. This waviness was of such a degree that machining a minimum 1/8 in. thick back-up shoulder on the circumference of the tube sheet edges was impossible. This problem was overcome by building up the inside of the plates with weld metal so that the back-up shoulder was 1/8 in. minimum.

Plenum bulge depth was too small by 1/8 in. To remedy this, the inner edges of the bulge were undercut 1/16 in. and a minimum of 1/32 in. was removed from the back-up shoulder to receive the plenum bulge. The depth of the weld groove was carefully measured every 6 in. and recorded prior to welding. Where the depth was not at least .843 in., weld reinforcement was built up on the joint between the bulge and tube plate to equal this amount.

The bottom edges of the six gas tubes for the "NYX" Unit were chamfered on the inside diameter for 1/8 in. This dimension was revised by design for "L", "K" and "C" to 1/4 in.

Rod tube bores were finished bored straight through in lieu of incorporating the smaller bore or land in the bottom of the tubes as in previous units.

"L" Plenum assembly received two preliminary internal cleanings. The first cleaning procedure was similar to that used on "P" Unit, but rust and weld oxides were found after cleanings. The assembly was then soaked in a solution of five per cent phosphoric acid and flushed with deionized water. Upon inspection the assembly was found free of all rust and weld oxides, and the cleaning procedure that was followed for "P" Unit was adopted for "L" Unit with minor modifications. Instead of rinsing each of the 673 large tubes ("P" Unit) with deionized water using the special tube plug, rinsing was done by "jetting" with hot deionized water through each of the six nozzles using a long stainless steel pipe.

Instead of gradually draining the unit as in "P", the "L" Unit was rapidly drained to provide a better rinsing action.

TOP TUBE SHEET ASSEMBLY

Design Differences

The number and design of instrument wells differed from "R" and "P" Units in that "L" Unit had only three wells that terminated 6 in. above the baffle plate, compared to twelve on the previous units.

There were ninety-four thermocouple clamping studs on this and "C" Top Tube Sheet Assemblies that were not on the other units.

All 673 large tubes in this assembly were Type 304 seamless.

Fabrication Changes and Difficulties

Three large tube holes in the top tube sheet were trepanned to 5-1/4 in. instead of 5 in. diameter. The three straight tubes to be welded in these holes were built up with weld bead where they would fit the oversize hole and machined to 5-1/4 in. outside diameter. After turning to size and reaming the weld neck on the inside, the built-up

area on each tube was X-rayed. Each tube was given a second hydrostatic test at 1000 p.s.i. for ten minutes and dimensionally checked before welding into the Top Tube Sheet Assembly.

During the process of assembling and tack welding large tubes into the Top Tube Sheet Assembly, after 212 tubes had been inserted, inspectors discovered ten tubes having holes burned in the outside tube wall, a result of poor welding technique. As a result of the above discovery, a back check on all tubes was made and any tubes where tack welds could not be observed either visually or with the aid of a borescope were removed from the assembly as a precautionary measure. On completion of the back check, eighty-eight large tubes were removed. Of the eighty-eight removed, seventy-seven were found to be defective. The remaining eleven tubes (removed in order that all tack welds could be observed) were not defective and were re-assembled. The seventy-seven defective tubes were repaired in the following manner, accepted and re-assembled: (1) defects hand ground and tube cleaned before welding, (2) defects heli-arc welded, (3) excess weld removed by hand grinding, (4) X-rayed, (5) hydrostatically tested at 2000 p.s.i.g. with pressure held for ten minutes, and (6) tubes were put back in assembly with identification number on same end as other tubes, however, the tube was rotated so that the new tack did not fall in same position as original tack weld.

The internal cleaning of this assembly was performed following the latest cleaning procedure as described under "P" Unit. In order to remove all foreign material, a vacuum cleaner with attachments was used following the use of a drop hammer on the top plate to dislodge any particles. The vacuum operation was performed prior to the washing.

During the process of assembling the handling jig and the aluminum disc for tube end protection to the bottom side of the assembly prior to shipping, interference between the jig and the ninety-four thermocouple studs welded to the bottom tube sheet resulted. The handling jig and aluminum disc were removed. It was discovered that the thermocouple studs were protruding beyond the 1/2 in. extension of the tube ends. To correct the interference all ninety-four studs were ground off to 1/2 in.

MAIN TANK

Design Differences

The design of this assembly was similar to "R" Unit Main Tank Assembly.

Fabrication Changes and Difficulties

After bearing ring and expansion joint had been fabricated, welded together and rough machined, the use of fine grain film for weld X-ray and a new film reading procedure by du Pont inspectors disclosed that the "L" Unit expansion joint contained a considerable number of weld defects. It was felt that repair of these numerous defects would cause warping to such a degree that the expansion joint would not meet specifications. Therefore, it was decided to scrap this expansion joint and the bearing ring and fabricate a new assembly.

The expansion joint forming dies were reworked before joints were made for the "L" and "K" units. All indentations were filled in with weld metal, rough spots were ground smooth and all protrusions were made flush.

The expansion joint material ($3/16$ in. thick) was closely inspected for surface defects and ground to sound metal or discarded, depending on thickness. New concave and convex welding jigs were made to hold formed pieces and upper and lower skirt pieces. All vertical welds between the six segments were aligned, each segment being made up of three pieces of metal. The use of center punching in layout was eliminated.

The metallic arc welding process was authorized rather than heliarc or Aircomatic on all metal $1/4$ in. thick and thinner to minimize porosity, inclusions, heat input, and distortion.

Circumferential welds in segments were ground flush and surface imperfections were ground out, particularly those 2 in. on either side of weld and on radius portion of formed piece. A careful visual inspection was made of welds prior to X-ray, including a thickness check for $3/16$ in. minus 0.025 in. minimum. Prior to annealing, all welds were X-rayed, using fine grain film, and any defects detected were repaired.

Individual segments were annealed, two at a time, on a special jig at 1900 degree F. for 20 minutes followed by an air cool in three minutes to 800 degree F. After annealing the segments were pickled until the surface was bright and clean, and the welds were re-X-rayed, using fine grain film. The six segments were then placed in a circular welding jig and welded together. The vertical welded joints were inspected and X-rayed as before.

During fabrication of "L" Unit Main Tank, the shell was accidentally dropped in handling. This caused minor damage to the plates. "Caved-in" spots were removed by using a 450-ton cold press and a large wooden hammer. One scar was welded and then ground smooth. After all necessary repairs were made and the welding X-rayed, dimensions were checked, particularly circumferential measurements. The unit was accepted as satisfactory.

BOTTOM TUBE SHEET ASSEMBLY

Design Differences

The half pipe pieces were made a larger diameter than in preceding units for 8-1/2 in. both sides of centerline of each of the four connections.

The bearing plates on this assembly were also modified from preceding units in that they were shaped for fitting of key in lieu of elongated holes.

All large tubes in this assembly were of the seamless type.

The "L" nozzle muff assembly was modified from the design used on "NYX", "R" and "P" Units. The sleeves that appeared as part of the muff assembly on these earlier units were changed to rods, and the pins were changed in shape and size. These changes modified the welding slightly at the ends of the rods.

Fabrication Changes and Difficulties

Visual inspection of all large tube bores revealed that twelve tubes had weld melt-throughs. A meeting was held to discuss the disposition of these tubes and it was decided to inspect as follows: (1) grind out melt-through and ream out weld neck, (2) inspect with borescope, (3) hydrostatically test at 2000 lb./sq.in. for thirty minutes, and (4) re-inspect with borescope. After the above inspections were performed, all tubes but one were acceptable and this one was removed and replaced.

Preliminary internal cleaning of this unit was performed following the newly issued cleaning procedure. This involved setting the assembly in a vertical position for cleaning and rolling the assembly similar to procedure described in preceding section.

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During the honing operation of large tubes, one tube was honed 0.027 in. out-of-round. To correct this, it was necessary to heli-arc shrink the tube to provide sufficient metal in the bore for honing to size.

Due to field experience pertaining to the finished condition of large tube bottom land and monitor pin grooves on "R" and "P" Units, the 3/16 in. drills used to drill the monitor pin grooves were replaced by a 3/8 in. drill ground to 7/32 in. pilot for 1/2 in. in length. Bushings in the drill jig were replaced with proper sizes to receive the new type drill.

After this situation was corrected, it was found that twenty-five tubes were badly marked in the "O" ring seating area, and nine tubes badly marked but not in this area. These marks consisted of deep scratches, grind marks, gouges and tool marks. Plastic molds of the defects were taken and it was decided that the tolerance of 3.382 in. I.D. be increased to 3.385 in. This still left six tubes with defects impossible to clean up so it was decided to move the "O" ring seating area in the field on these six tubes. It was also found that monitor pin groove edges cut the "O" ring, so all groove edges were ground smooth. This operation left marks on the tube land near the "O" ring seating area. A protector, covering the land entirely, with the exception of the grooves, was devised and fabricated from gasket material so that the land would not be scratched by the grinding tool.

The assembly was internally dried prior to the Freon test. This was the first Bottom Tube Sheet Assembly to receive this drying step. All leaks discovered during Freon test were repaired and no tubes or wells required replacement.

The final internal cleaning of this assembly was similar to that used on "P" Bottom Tube Sheet Assembly.

The top and bottom circumferential split pipe sections were fabricated, assembled and welded to the "L" Bottom Tube Sheet Assembly using the welding procedure adopted for "P" Unit, however, an additional step was added to "L", "K" and "C" Units. This step consisted of introducing argon gas into the interior of the entire assembly, to displace all air, at a flow of 10 cu.ft./hour during the welding operation. This flow was maintained for one hour, then reduced to 5 cu.ft./hour and all welding completed. The gas provided an internal or secondary gas shield to prevent oxidation of weld metal on the inside of the piping, and provide a smoother weld contour. Also, the

split pipe itself was beveled on a 70 degree angle at the top and a 45 degree angle on the bottom, both with 1/32 in. land and no root gap for complete weld penetration.

"C" PRODUCTION UNIT

PLENUM CHAMBER

Design Differences

The nozzles for this unit were increased from 12-in. pipe size to 16-in. pipe size. The vanes for the nozzles were similar to "L" Unit design. They were constructed of 3/4 in. plate incorporating "fishtails" on both ends and welded into the nozzle at top and bottom.

The total number of large tubes was again 673, made up of 582 non-bearing tubes and 91 bearing tubes, all of seamless tubing.

The number of rod tubes was increased to 178, thirteen being added to previous designs. The number of probe pin sockets was increased to 855 following the increase in the number of rod tubes. Similarly the number of latch studs was increased from 330 to 356.

The water retainer had minor modifications. The height was reduced from 2 in. down to 1 in. and the pockets were increased in size relative to the "L" Unit.

All other major dimensions and design features remained similar to "L" Unit design.

Fabrication Changes and Difficulties

At the time of fabricating the "C" Unit Plenum, all major fabrication procedures had been established and there were no major changes in any procedures.

The male and female dies for nozzle bulges that were supplied by the Birdsboro Steel Company and used for previous units were altered to suit and used on this unit to press to shape the tapered rounded section at each side of the six plenum nozzles. The nozzle throat pieces were pressed also from dies used on previous units altered to suit.

The male and female die for the plenum bulges that were used on previous units was again used on this unit with no alterations required.

TOP TUBE SHEET ASSEMBLY

Design Differences

This unit contained 178 1-5/8 in. outside diameter rod tubes compared to 165 for the other units, and also contained three instrument tubes of same diameter. The "C" Top Tube Sheet was 2 in. smaller in outside diameter than "R", "P" and "L".

The webs for this unit differed from the previous units in that instead of having end stiffeners, the wrapper plate was increased to 7/8 in. thickness in vicinity of web. A 9-in. web was added near end of the six straight webs. The shape and location of these webs was generally the same as in previous units, with slight dimensional and location changes. The modifications to the webs involved a change in baffle sheet layout and machining in order to conform to design.

The twelve bearing brackets of the "C" Top Tube Sheet Assembly were mounted on the outside of the wrapper, (near the top plate) instead of being welded on the bottom plate. The Top Tube Sheet passed partially through the bearing ring before seating on the ring.

The baffle plate differed from preceding designs in that its diameter was decreased to 18 ft. 4-7/8 in. The rod tube hole sizes increased from the center of the sheet outward as follows: twenty-four 1-7/8 in. holes, eighty-four 2-1/8 in. holes, seventy-three 2-1/4 in. holes. The baffle plate contained cutouts for the short web plates. Other cutouts were added to the baffle plates to allow for the bearing pad wrapper plates. In fact, all cutouts in the baffle plate were modified to some extent to allow for the web plates.

The baffle plate for "C" Top Tube Sheet Assembly was originally fabricated in accordance with "L" Unit drawings, prior to the release of "C" Unit drawings and much modification took place. Additional slots for the web plates were added in addition to plugging and relocating existing slots. These slots were plugged with approximately 1 in. by 1 in. stainless strips. Plugs were then seal welded; however, during the machining of tube holes in the plate, there were some areas in which the holes passed through the seal strips, thereby exposing the remaining 1/2 in. area between seal welds. These cracks between welds became saturated with oil. After the baffle plate had been sand-blasted, passivated and ferroxyl tested, a seepage of oil from these cracks was observed. To correct this condition, the following steps were performed: (1) heated all 1/2 in.

exposed areas between welds with acetylene torch, (2) chipped and plug welded exposed area using manual Aircomatic welding machine, and (3) ground and dressed welds.

The number and size of baffle support plates also differed from preceding design, there being twenty-eight 1-3/4 in. by 3 in. by 1 in. and eight 1 in. by 2 in. by 1 in. plates.

The new design of the "C" assembly called for two deflector plates in lieu of the previous one. Each plate contained 673 4-3/4 in. diameter holes, with one having 178 2-1/8 in. diameter and eight 1-1/2 in. diameter holes and the other having 178 2-1/4 in. diameter and eight 1-5/8 in. diameter holes. One of these two plates was converted from the "NYX" deflector plate. This material salvage was typical of many cost reducing steps practiced throughout the program.

Alterations on this plate included turning the diameter down from 17 ft. 10 in. to 17 ft. 0-1/4 in., plugging two rod tube holes, removal of old instrument clips, drilling 296 7/16 in. thermocouple clip holes and adding eighteen additional rod tube holes.

The "C" chime ring had an outside shell diameter of 18 ft. 6-1/4 in. which was 2 in. smaller than in previous units.

Fabrication Changes and Difficulties

Additional work on the expansion ring required the outside diameter of the entire assembly to be machined for roundness. The lower 12-1/2 in. was turned to 18 ft. 6-1/8 in. and the remainder, up to the bearing pads, was turned to 18 ft. 6-1/4 in. Any step at the transition was ground smooth. The bottom edge of the bottom tube plate was also given a 1/4 in. radius. This work was necessary to assist in providing 1/4 in. radial clearance between the expansion ring inside diameter and the top tube sheet outside diameter; also to prevent any binding or damage while inserting the top tube sheet.

The two-pass tube weld caused more tube pattern shrinkage than occurred on any previous unit. Deflector plates were machined to 7-in. centers, and on fit-up of deflectors, interference was encountered between tube bores, deflector holding studs and deflector holes. This condition necessitated reworking both deflectors to enlarge stud holes, rod tube holes and the outer seven rows of large tube holes.

All tube holes were chamfered 1/4 in. by 45 degree for a two-pass tube weld to increase soundness.

MAIN TANK

Design Differences

The "C" Unit design called for a new type expansion ring and considerable modifications to previous design bearing rings and enclosures. The bearing pads located on the underside of previous units were attached to the wrapper sheet of the "C" Top Tube Sheet Assembly. Twelve bearing pad sections were fitted equally around the circumference of the assembly in sections cut out of the wrapper plate pieces. The bearing surfaces were located 2 ft. 9 in. above the bottom plate of this assembly, each having a bearing surface measuring $2\frac{3}{4}$ in. by 12 in.

There were three indexing devices with tongues welded to the wrapper plate of the Top Tube Sheet Assembly. The mating indexing blocks were attached to the Top Tube Sheet Assembly Enclosure. A 2 in. high by 1 in. by 12 in. long spacer bar was inserted during installation to give the 2 in. clearance between tongue and upper bearing surface of the bearing ring. The wrapper plate was increased from $\frac{1}{2}$ in. to $\frac{7}{8}$ in. thickness in way of indexing blocks.

The bearing ring was of completely new design. It incorporated twelve top bearing surfaces 13 in. long and twelve bottom bearing surfaces 12 in. long, measured along the circumference of the ring. The bottom surfaces were machined $\frac{1}{2}$ in. into the bottom of the bearing ring. The cross section of the "C" bearing plate was different from preceding units in that the lower bearing surface of the ring extended 3 in. beyond the outside diameter of the Tube Sheet Assembly Enclosure. The overall height of the ring was also increased to $4\frac{3}{4}$ in.

The expansion ring for "C" Unit differed entirely from either of the two previously used types of rings. It was a bellows type expansion joint of an inside diameter sufficient to receive the Top Tube Sheet Assembly. There were $\frac{1}{2}$ in. plate nipples at the top and bottom of the expansion ring, the upper nipple welded to the inside diameter of the bearing ring and the lower nipple welded to the main tank shell. These two nipples were connected by a .078 in. thick bellows section consisting of five convolutions $2\frac{13}{16}$ in. apart and having a $2\frac{13}{16}$ in. to 3 in. depth. The length of the expansion joint including bellows and nipples in a neutral position was 2 ft. $9\frac{1}{2}$ in. The bellows were held in a neutral position by a $\frac{1}{2}$ in. thick temporary sleeve tack welded to the inside of the upper and lower nipples. The bellows section was also protected outside by a temporary cover plate supported by temporary retaining bars.

The Top Tube Sheet Assembly Enclosure was similar to previous units with some dimensional modifications.

As mentioned previously, the indexing devices were attached to this enclosure section which was new design. This assembly had four nozzles attached, two gas inlet and two gas outlet nozzles, located at 90 degrees to each other and ending in 6-1/2 in. outside diameter section. It also had two water outlet connections, that were rectangular shaped pieces leading from a 3 in. by 2 in. opening in the shell plate, bending 90 degrees and then merging into a 3-in. pipe.

The lower shell of the main tank was made up of 1/2 in. plate. It was 18 ft. 6-3/4 in. inside diameter and 9 ft. 2-5/16 in. high.

Fabrication Changes and Difficulties

The expansion ring for the "C" Unit was fabricated by Zallea Brothers, Wilmington, Delaware, under separate contract with du Pont.

When the expansion ring was checked at New York Ship after delivery on January 5, 1954, it was discovered that the expansion ring was out of round and small on I.D. opposite bellows to nipple welds due to weld shrinkage and radial clearance between top tube sheet and expansion ring would be considerably less than the required 1/4 in. Numerous meetings were held between du Pont, New York Ship and Zallea Brothers to determine the procedure to be followed to work the ring to an acceptable condition.

The top and bottom nipples were rolled with the turret track turning mill to make them round and to increase their diameter. Permission was obtained from du Pont design to bore nipple inside diameter to required dimension and reduce wall thickness from 1/2 in. to 3/8 in. if necessary.

Zallea Brothers furnished a special roller to fit the expansion ring bellow and also supervised New York Ship personnel in its use in rounding up the bellows to size, following rolling of the nipples.

The ring was then set up on machined blocks and the Top Tube Sheet Assembly lowered into position and the clearance checked. After the ring was welded to the tank, a sweep device was used to check the inside radius at all points on the ring.

The expansion ring was finally worked into acceptable condition and approved by inspection for use on the unit.

BOTTOM TUBE SHEET ASSEMBLY

Design Differences

The rod cups of this assembly were identical with "R" Unit design, but the number was increased to 178.

The bottom tube sheet nozzles were similar to the preceding units, but were enlarged considerably in capacity. Details of the nozzles were of new design.

On previous units, the bottom of each nozzle was formed partially by the top tube plate and partially by a 1/2 in. extension plate. On "C" Unit the nozzles were incorporated in the tank shell which rests on the Bottom Tube Sheet Assembly. The top tube sheet of this assembly was a 1 in. plate, to the outer periphery of which was welded the outer portion only of a flanged head, varying in thickness from 1 in. at knuckle to 1/2 in. where the head joined the main tank. This head was formed by the Lukens Steel Company. The nozzle assembly was attached at this 6 in. level. On previous units the top tube sheet was a flat plate and the tank shell came down directly to the plate.

On previous units the section incorporating the nozzles was 22-1/2 in. in height, whereas on this unit it was 5 ft. 6 in. in height. The nozzle stubs and elbows were increased in size on "C" Unit, with the elbows terminating in a 24 in. diameter section compared to 20 in. on previous units. The elbows also differed in shape and number of make up plates from previous assemblies.

The nozzle muff assembly was similar in design to "K" Unit, with dimensions modified to suit the larger nozzles. The number of muff leafs was increased due to increase of height of nozzle. The inside rods were not offset in section view as for other units. In addition, the pin that was added on the bottom key on "K" Unit was omitted on this unit.

The split retaining rings were similar to those used on "R" Unit with the exception of 7/16 in. bolts used in lieu of studs.

The baffle plate for this assembly differed in many respects from the preceding units. The thickness of the plate remained at 1 in. but the diameter was reduced from 18 ft. 6-1/2 in. to 17 ft. 9-5/8 in. Holes in the plate were provided as follows: thirty 1-11/16 in. diameter for 1-1/4 in. pipe, 594 4-9/16 in. diameter, 73 4-3/4 in. diameter, 6 4 in. diameter, 30 4 in. diameter, 13 1-13/16 in. diameter and 16 1-5/8 in. diameter holes.

The 594 4-9/16 in. diameter holes and the 13 1-13/16 in. diameter holes were spot faced 1/16 in. allowing slight collar movement. On previous units these collars were all tack welded. The short webs and the half-moon cutouts on earlier units were omitted from this plate. There were no milled-out sections at the outer edge of the plate in way of stiffeners.

Three additional instrument wells, making a total of thirteen, were in this assembly. The design of these wells was modified from past units, but overall dimensions were practically the same.

The pre-machined finish of all bearing and non-bearing tubes was identical to that of "P" Unit.

The tube collars differed only in that no collars on "C" Unit contained the twenty-four 3/16 in. diameter holes that appeared on certain of the collars on all past units.

The number of suspension pins was increased to sixteen on this unit, with the pin slightly larger in way of top plate compared to a uniform diameter pin previously used.

Four hot water chamber instrument tubes were added on this unit. They were inserted through the bottom sheet, 8-1/2 in. in from periphery, and extended on an angle into the hot water chamber in the upper section of the assembly.

This unit incorporated a hot water chamber that extended around the circumference of the assembly in the upper section immediately under the top tube sheet. The decrease in baffle plate diameter was due to the addition of this chamber. A seal ring attached to the outside diameter of the baffle plate was used as in previous units, but pressed against a special plate that was added between the baffle plate and hot water chamber. A second seal ring was used between the special plate and the hot water chamber. The addition of this hot water chamber necessitated cutouts in the webs. These cutouts were sized to give adequate clearance for the inside assembly welds around this chamber, and remained open in final design. There were three 1-1/2 in. schedule 40 S nozzles spaced at 120 degree intervals, and three 2 in. schedule 40 S nozzles also spaced at 120 degree intervals around the chamber at the top section acting as the inlet and outlet connections to the hot water chamber only. There were five 1/8 in. diameter rods on 5/16 in. centers horizontally placed across the nozzle at the shell for the 1-1/2 in. nozzles and six 1/8 in. diameter rods also spaced at 5/16 in. centers across the nozzle at the shell for the 2 in. nozzles. In the bottom of the chamber three 2 in. drain holes were covered on the inside by slotted caps

used to prevent possible movement of raschig rings from the hot chamber to the main body of the unit.

On previous units there were inlet and outlet connections through the wrapper to vertical distribution chambers on the edge of the assembly with slots opening into the inside chamber of the assembly. These connections in turn were externally connected by half pipe sections running around the entire assembly, one for inlet and one for outlet. On the "C" Unit the inlets were horizontal 2-1/2 in. pipes entering through the wrapper and did not incorporate the half pipe wrapper piece. These inlet pipes were directly connected to 3 in. pipe sections attached to the bottom plate. From the 3 in. pipe 1-1/4 in. pipes led to the area between top plate and baffle in the center of the bundle. This area between the two plates had six 1-1/4 in. schedule 40 S nozzles equally spaced at 60 degrees around periphery of shell. The nozzles incorporated 1-5/16 in. diameter strainer plates.

There were also thirty outlet connections that differed from previous arrangements in that they received flow directly from the space between the top plate and baffle, and discharged the cooling water through 3-in. pipes with 2-1/2 in. horizontal outlets. Unlike the inlet connections, these outlet connections were in turn connected with the half pipe wrapper piece that extended around the unit, with two outlet tee connections on the half pipe section.

Fabrication Changes and Difficulties

The dished head that formed the top plate of this assembly was a topic of several conferences before the as-built design was decided upon. The dished head was formed by the Lukens Steel Company from flat 1 in. thick plate. A special fixture was made up for handling this plate using a condemned bearing ring from "L" Unit. The top edge of the dished head was faced prior to installing the special fixture.

A shoulder was built up by welding applied on the outside radius of the head, and was machined to shape and the skirt plate welded on. The outside of the dished head and skirt plate was milled to a common plane, but not to finished dimension. The center piece was then cut from the head, edges machined to shape and attached to the Bottom Tube Sheet Assembly. The dished head and skirt plate were then rolled to size on the 20 ft. milling machine. Due to its warped condition and size that would not lend itself to use in fabrication, the cut out center section of the dished head was scrapped.

Machining work on the "C" Unit baffle plate had been progressing following "L" Unit drawings. When "C" Unit drawings were received showing new design it was necessary to rework the baffle plate. The plate had to be turned down to a smaller diameter. In order to accomplish this, it was necessary to plug the ends of the web cutouts to prevent the tool from digging in. The short web cutouts had been milled in this plate and also had to be completely plugged, welded and machined to plate finish. Seven instrument tube holes that were not on new drawings had to be plugged, welded and dressed. The short webs, which had been fabricated for this unit prior to receipt of new drawings, were scrapped.

The holes for the hot water chamber instrument tubes in the bottom tube sheet were drilled by a special angle drill press brought to Building 3 from the Machine Shop.

The installation of the 1-1/4 in. internal piping in this assembly presented a new problem in fabrication. The numerous sections of this 1-1/4 in. piping were fabricated from templates made for each run of pipe. The various lengths that made up each individual section were inserted into the assembly prior to setting the top plate. Only the shoulder tubes had been installed at this time. After rebending some lengths to suit layout, the pipe was assembled and tacked. After fitting the top plate, these sections were removed, some in one piece, some in two or three pieces. The lengths that made up these pieces were welded together on a slab using a target to simulate the inlet and outlet pipe and keeping in mind that joints to be welded inside the assembly must be in an accessible position. The pieces as removed were then inserted in the unit and the connecting welds were made by a welder climbing inside the unit. The 1-1/4 in. pipe was welded to the 3-in. inlet pipe at this time.

The wrapper sheet for this assembly differed from previous units in that it was fabricated from multiple plates around the periphery and was made up of three separate courses in the vertical direction also. This added two extra weld beads around the periphery of the unit. The wrapper plate remained within verticality tolerances in way of webs, but tended to "cave in" between webs. The bearing pads were welded on later.

During the rinsing of the assembly after preliminary internal cleaning had been performed, a tar-like substance was found on the tube surfaces and plates. A complete investigation was made but the source of this foreign substance could not be located. After numerous conferences it was decided to wash the internal area of the assembly with nitric acid. Due to the fire hazards attending use of the

acid, its dangerous reaction with most metals and injury to the human body, it was decided to conduct this acid wash outdoors on an isolated riverfront pier. A special carrier held the unit in position. New York Ship exercised every safety precaution, some of which were: roping off the area to all but necessary personnel, providing all necessary protective clothing, deluge type safety showers, Fire Department standing by and capable supervisory personnel. Two tank trucks transported the acid to the site and acid was pumped into the unit until it overflowed. After standing full of acid four hours, the unit was emptied by blowing the acid back into the trucks with compressed air. The acid was returned to vendor for disposal. The unit was then rinsed, first with distilled water and finally with deionized water. The unit was not rinsed clean so it was brought inside to the washing pit and re-rinsed with deionized water and accepted as clean. Stainless steel pipe was used during this cleaning with teflon pipe dope on the pipe connections. The rubber vent hoses were discarded following this work.

The monitor pin slots used on previous units were eliminated and replaced by monitor guide strips spot-welded in four semi-circular sections to the lower end of each tube. The strips were formed by means of a die fabricated in the Machine Shop, and were grooved in a special milling set-up.

A jig was built to clamp each monitor pin guide strip in position for spot welding, and special inspection gages were prepared for checking the orientation and V-groove depth.

"NYX" UNIT CONVERSION TO "K" PRODUCTION UNIT

PLENUM CHAMBER

Changes from "NYX" Design

The "K" Unit Plenum Chamber was converted from the "NYX" Plenum with modifications as explained below.

The "NYX" nozzle vanes were converted to the design used on "R" and "P" Units. The description of the vanes and the removal and replacement system used is discussed under "R" and "P" Plenums.

The weir slots in the tubes of the "K" Plenum differed from "NYX" in that all the slots were extended down to the plane of the top of the Bottom Tube Plate, making them 8-5/8 in. long rather than 8-1/2 in. long as in the other assemblies.

The number of centering tongues was increased from three on "NYX" to six on "K" Plenum.

The "NYX" Plenum skirt was replaced by one of "R" Unit design.

The large tubes and rod tubes remained identical in number and material with "NYX". However, many were reworked.

The number of probe pin sockets was increased from forty-seven on "NYX" to 839 on "K" in order to cover the entire tube sheet.

There were 835 number tags added on the "K" Plenum to bring it into conformity with the other production units.

The number of V-slots was increased to three per large tube, as compared to one per tube on "NYX".

A water retainer around the top plate and a tangential slot near the top of each large tube, both as described under "R" Unit, were added to the "K" Plenum Assembly.

The Plenum nozzle flanges were cut off, rewelded and faced flat and square.

The chamfer on the bottom side of the six gas tubes was changed from 1/8 in. depth to 1/4 in.

Fabrication

An analysis of design, material procurement, time and cost determined that the conversion of "NYX" to "K" Plenum was economical and feasible.

After a general inspection it was concluded that welds were in good condition, dimensions were mostly within tolerances; sandblasting, passivation and ferroxyl test results were favorable with all surfaces free of serious contamination.

Based on the above, it was decided to convert "NYX" Plenum to "K" Unit Plenum.

There were 147 tubes that had undersize V-slots and all these were brought up to a width of 0.530-0.535 in. There were also ninety-eight tubes whose V-slots were oversize or whose angular deviation was too great; these slots were welded and then remachined. In addition, two

additional V-slots were machined in each tube. After completion of the above, 211 V-slots were found undersize in width and 113 V-slots were out of orientation. These slots were re-worked as necessary.

A "Thor" No. W14 angle-head air motor and a 5/16 in. end mill were used to mill the weir slots flush with the top side of the Plenum bottom plate. Some slots that had been milled into the top of the bottom plate were plug-welded and re-milled.

All nozzle flanges were chipped off and later replaced and faced. The nozzle vanes and staybolts were removed from the nozzles using the procedure followed on "R" Unit, and were replaced with solid vanes.

When the large tubes were originally inspected it was found that all tubes contained either scratches, steps, tool marks, weld splatter or burrs. These were cleaned up by honing or cloverleafing. One large tube was oversized and out of round and was removed from the assembly and replaced.

The thirty-five cast tubes incorporated in the "NYX" Plenum were Zy-glo inspected on bore and butt ends for laminations or cracks and were considered satisfactory.

After the Plenum and Top Tube Sheet Assembly were mated, a check of the large tubes and rod tubes with the functional gage indicated that the two assemblies were misaligned. In order to obtain optimum alignment of the assemblies, the three indexing devices were removed. The Plenum was rotated by hydraulic jacks around the center tube until all large tubes were in alignment. The indexing devices were then re-welded in correct position and three new indexing devices were added, all devices located 60 degrees apart.

Thirty-five rod tubes would not accept the functional gage. Five were condemned, removed and replaced. The remainder of the tubes were either (1) counter bored to a maximum of 1.513 in. diameter, (2) as much of the 1.3075 in. bottom land was removed as necessary up to 1.500 in. diameter, or (3) the diameter of Top Tube Sheet Assembly rod tubes was increased to a maximum of 0.020 in. over maximum bore size, or 1.3375 in. in diameter.

The above steps were carried out by reaming, honing and cloverleafing the rod tubes until all tubes accepted the full length of the rod tube functional gage.

The tangential slot on all large tubes was milled on this Plenum as it was not incorporated in the "NYX" design. The additional probe pin sockets, latch studs, tube number tags and motion measurement brackets were also added.

The final internal cleaning of the assembly was performed by Dowell with the cleaning solution and procedure used on both "P" and "L" Units.

As in previous units, this assembly was externally cleaned, acid washed and acid rinsed. It was also hydrostatically tested, photographed, internally dried and freon tested.

Finally the entire unit was vacuum cleaned to remove all dust particles or other foreign matter, and then all external surfaces were washed down with "F.O. 128" solvent.

TOP TUBE SHEET ASSEMBLY

Changes from "NYX" Design

"K" Unit Top Tube Sheet Assembly contained three instrument wells that terminated 6 in. above the baffle plate, whereas the "NYX" Unit did not incorporate any of these wells.

This assembly contained the same number of rod tubes as "NYX", with three instrument lead and liquid level tubes added. In addition, six rod tubes were converted to instrument tubes.

The baffle plate for this assembly contained three additional 1-3/4 in. holes for thermometer wells that did not appear in the "NYX" Unit.

The principal modification to "NYX" Top Tube Sheet Assembly was the addition of chime rings. These chime rings were similar in design to those previously described under "R" Unit. Due to the addition of the chime rings, a smaller deflector plate was required. The deflector plate of the "K" Unit was fabricated from new plate, and the former "NYX" deflector plate was later used in the "C" Unit Top Tube Sheet Assembly. The method of attaching the deflector plate was modified in that shoulder bolts were used on "NYX" while specially designed shoulder studs were used on this unit.

The "NYX" Unit used twelve bearing plates of 8 in. by 3/4 in. by 1-3/4 in. plate, whereas on this assembly the same number was used but changed to 12 in. by 3/4 in. by 1-3/4 in. plate.

The baffle plate of this assembly had to be modified in position. It required twelve patch pieces in the sheet edges at the offset gussets.

Fabrication Changes and Difficulties

Due to excessive amounts of residue concentrated in tube bores as a result of experimental operation, it was necessary to devise a method of cleaning before tube inspection could be performed. After trying several methods, it was decided to use "F.O. 128" cleaning solution with an air driven nylon brush and an extension rod of required length as a means of application. This method proved satisfactory.

One of the first operations performed in the process of converting "NYX" Top Tube Sheet Assembly to "K" was the removal of raschig rings. The lifting cradle was installed and the assembly set in the vertical position. The two loading port cover plates were chipped off and the rings were dumped into canvas lined open trucks, which were sent to the S. W. Evans Company, Philadelphia, for cleaning and acid washing. When the wrapper plate was machined and chipped off, a large percentage of remaining rings was removed. The assembly was again raised vertically and rolled, removing the remaining raschig rings.

The lifting eyes were cut off the assembly, and later "R" Unit design lifting eyes were incorporated.

Prior to installation of the wrapper plates, the assembly was cleaned with Dowell detergent and sodium metasilicate for the removal of oil and grease. This was accomplished by using a high pressure jet and rinsed with deionized water. This was followed by a submerged wash with 5 per cent phosphoric acid at 160 degree F. for 4 hours to remove rust and weld smoke deposits. Finally, after removal of the foreign material, the assembly was washed down with deionized water, vacuumed, tapped with a hammer and then air blasted.

Cleaning was performed by Dowell, Inc. using the new established cleaning procedure. Wrapper plate openings and the inlet and outlet tubes were cleaned by circulation of the solutions through these openings. The unit was then set vertical, and with valved connections closed, solution was pumped in thru the eighteen upper half inlet and outlet tubes and air agitated thru the lower tubes. The assembly was rolled varying degrees. This was repeated several times. The unit was rinsed in a manner similar to that described above, with a final fast drain to remove any foreign particles in fast flow of water. Upon inspection the internal cleanliness of the unit was found to be satisfactory.

Raschig rings were loaded in the assembly using the loading cradle and established procedure. After vertical loading was accomplished, additional raschig rings were added through the 2 in. auxiliary loading ports using an air gun to blow in the rings.

During the conversion work performed on this assembly, welds were continually inspected, chipped out where necessary, rewelded and ground smooth. Similarly, all tube bores were inspected for dimensions, gouges, scratches or other defects. Rod tubes and large tubes were honed and some of the large tubes were neck reamed.

The webs on "K" Unit required heavier end stiffeners, therefore it was necessary to mill out additional material on the edge of the baffle plate at all the bent webs. With this additional material milled out, the section involved was necked down so that little support was left. Therefore, a larger section was cut out, two at each web, patches formed and then these pieces were welded back in with two sides welded to the webs to give additional support.

MAIN TANK

Changes from "NYX" Design

An entirely new Main Tank was fabricated for the "K" Unit, following insofar as possible the design used for the "R", "P" and "L" Units. The enclosure section, bearing ring, expansion ring and lower tank shell used in the "NYX" Unit were scrapped because design changes and improvements in fabrication techniques made their re-use impracticable.

Fabrication Changes and Difficulties

After the bearing ring top and bottom surface had been machined to final size, the fillet weld joining the top tube sheet extension and bearing ring was found to be porous and of insufficient penetration. This condition was due to faulty welding and to machining too much metal off the top side, including the weld.

It was necessary to chip out and machine out the entire weld, make a new bevel of sufficient depth, reweld the joint, and remachine the top surface of the bearing ring to a flat plane. In order to salvage this assembly, the Design Division permitted the thickness of the bearing ring to be reduced $1/8$ in. less than the drawing dimension. With this modification, the assembly was reworked and accepted.

BOTTOM TUBE SHEET ASSEMBLY

Changes from "NYX" Design

The nozzle muffs for preceding units "NYX", "R" and "P" were identical, but for "L" and "K" Units the design was modified. The sleeves were changed to 1 in. diameter rods and the pins were changed in shape and size. This modified the welding slightly at each end of rods. On "NYX" only, one nozzle contained muffs; whereas muffs were inserted in all six nozzles for "K" Unit.

In lieu of plug welds in the top plate of the nozzles on previous units, "K" Unit had two blind $3/4$ in. holes $1/2$ in. deep in the top key in which pins were inserted that extended up into top nozzle plate. The pins were welded on the top on the nozzle plate. There also was one pin inserted in the bottom key. This pin was in a blind hole, but the hole was in the bottom tube sheet and the pin was welded from the top of the bottom key. In general the size and dimensions of nozzle muff elements remained the same, the major differences being the above mentioned method of attachment and modifications to some welds.

The 90 degree special elbows were not converted from the "NYX" Unit, but new ones were fabricated for "K" Unit. Although of similar design for both units, the elbows were not converted because the welds were doubtful; holes for special test fittings had been cut during "NYX" test, and it was felt that the chipping off and rewelding would make the nozzles undersize.

The baffle plate was converted from "NYX" and modified to suit this unit. Cutouts were revised for both the double and single webs, and twelve sections $11-1/2$ in. by $8-1/2$ in. of baffle plate were cut out and twelve small webs described under "R" Unit added and baffle plate pieces tacked in to suit shape. Again, as in "R" Unit, twelve additional half moon sections were milled out on edge of plate and the ten additional holes for instrument wells were added.

Ten instrument wells were added to the assembly upon conversion. All the wells were of one design similar to the seven of modified design that first appeared on "P" Unit.

"NYX" contained forty-two 2 in. by $1-1/2$ in. by 1 in. spacer blocks welded to the underside of the top plate, whereas "K" incorporated thirty 1 in. by 4 in. by $1-3/4$ in. spacer blocks.

One 4 in. diameter pad 1 in. thick with a 1-1/2 in. pipe tap was welded to the bottom plate 10 in. from perimeter. Covering this tapped hole was a 3-3/4 in. pipe 2-1/2 in. high containing eight small slots.

The half pipe pieces and tees replaced the street elbows of "NYX" Bottom Tube Sheet Assembly. These half pipe pieces were expanded to a larger diameter for 8-1/2 in. both sides of centerline of each of the four connections.

The tank bottom nozzle section was a new fabrication and extended 28-1/2 in. above the Bottom Tube Sheet Assembly, in lieu of the 22-1/2 in. extension on "NYX" Unit.

Conversion of "NYX" to "K" required the addition of six motion measurement pads. Three pads were located on the bottom plate and three others were located on the wrapper plates.

A Number 24 gage stainless steel (spring temper) seal ring plug was spot welded to the baffle plate and pressed against the wrapper to seal off the annular opening.

Sections cut from the baffle plate mentioned above were required due to the increase in number of inlet and outlet connections from eighteen to thirty of each type.

The end stiffeners on all webs were strengthened and lengthened during conversion, also the wrapper sheet between bent webs was increased from 1/2 in. to 1-1/4 in.

The number of rod cups remained unchanged at 162, but "K" Unit contained heavier cast cups compared to lighter fabricated cups on "NYX".

The design of the bearing plates differed from "NYX" in that they were of "L" Unit design, incorporating a key rather than clearance holes.

Design changes in the conversion of "NYX" to "K" Unit required the machining of two additional monitor pin slots making a total of three, at the bottom of each tube compared to one on "NYX" Unit. A great amount of time and labor was expended machining these slots. Sixty-nine tubes had slots drilled less than blue print length dimension. These slots were lengthened by redrilling. Two tubes contained slots having lengths greater than allowable dimensions. These slots were welded, ground smooth and cloverleafed until blended in with the tube wall. Twenty-eight tubes had grooves impressed in tube wall next to center slot, due to forcing the monitor pins into position during Building 10 operations. Repairs were made by welding as

above. One tube had slot drilled 180 degrees out of orientation. This slot was welded and another was drilled in the required location. A small air driven pencil point (artist) drill was used to remove the sharp edges of the pin grooves that were sharp enough to cut the "O" rings during insertion.

Conversion changes required the addition of seven instrument lead tubes, requiring the drilling of seven additional holes through top plate, baffle plate and bottom plate.

Fabrication

All surfaces, weld seams and tube welds of the "NYX" Bottom Tube Sheet Assembly were examined for any defects. No corrosion was found and the general weld condition was favorable. After removal of the Tank and Tube Sheet Assembly from Building 10, the tank nozzle section was burned off and burned edges chipped. The Bottom Tube Sheet Assembly was then subjected to a hydrostatic test of 52-1/2 lb/sq.in. in order to determine the condition of the Bottom Tube Sheet Tube welds. No leaks were found.

The raschig rings were then removed, following the same procedure used in emptying the Top Tube Sheet Assembly. During the procedure, the wrapper plate was chipped off, as were the end stiffeners and sealing band.

Upon re-establishing the location of the baffle plate, 1 in. below the top plate, "NYX" to "K" conversion changes called for thirty spacer blocks. After fitting the spacer blocks to layout and tacking, they were welded on three sides due to the inability of the welders to reach the back side. Also, due to inaccessability, metallic arc welding was used rather than the generally preferred Aircomatic welding process.

Inspection of bottom land finishes and bore sizes of the tubes showed the following discrepancies: Scratches in bore, ten oversize and one out of round tube, 125 tubes with bad chamfers, twenty-four undersize tubes, sixty-four tubes with bore size very close to maximum limit, sixty-eight tubes requiring heavy bore repair work. Cloverleafing removed all minor scratches, nicks, etc. and a small air driven pencil grinder was used for deep gouges or burrs. Cloverleafing was also used to bring all undersize tubes up to size. In spite of extreme care, twenty-three tubes after repair were oversize. Shrink welding, cloverleafing and grinding was used to save these tubes. After

shrink welding, cloverleafing and/or grinding 103 tubes had bore sizes slightly exceeding specifications, but not to an extent to make them unacceptable in this condition.

The top land finishes and bore sizes of the tubes were inspected and similar defects were found. However, honing in addition to grinding and cloverleafing was permissible in the case of top lands. At the completion of all necessary repair work, it was found that fourteen tubes had slightly oversize but acceptable bores.

Sixty-seven tubes required repair work on the bore between the top and bottom land. Grinding and cloverleafing were the methods used to eliminate the defects.

All overlays were ground off the tube welds to reveal weld faults which might allow leakage at this point. When necessary, deep crater cracks, areas of porosity, etc., were chipped, rewelded and ground smooth.

Prior to installing the wrapper plates, the assembly was Dowell washed. This was done by alternately raising and lowering the unit, in a horizontal position, every fifteen or twenty minutes for three hours. The solution used was 1.0 per cent trisodium phosphate, 1.0 per cent caustic, 0.1 per cent Dowell detergent in distilled water at 100-125 degrees F. The assembly was rinsed using high pressure jets of deionized water, with the assembly in a slightly inclined position, and final rinsed in a vertical position. Upon examination, rust, chips and grinding dust were found. The Bottom Tube Sheet Assembly was then acid washed and completely Dowell cleaned a second time. Although some oxidation was apparent on the gusset edges and a few rust spots remained, the assembly was accepted.

The removal of wrapper plates necessitated the removal of the twelve bearing pads and fabrication changes required the installation of twelve new pads. The bottom bearing surfaces of three pads were damaged just prior to shipping. Repair work consisted of scraping and stoning the rough spots from the bearing surface.

The final internal cleaning of this assembly was performed by Dowell in a manner similar to that described above for Top Tube Sheet Assembly.

After cleaning and rinsing, the assembly was internally dried. Then a drop hammer was used on the plates and any loose chips or dirt observed was removed with a vacuum cleaner.

The unit was loaded with raschig rings following the established procedure. After the final freon test and final hydrostatic test showed no indication of leaks, the unit was externally cleaned and made ready for shipment.

XII - FABRICATION OF TELESCOPE ACTUATOR SYSTEMS, PHYSICS BUILDING TANK-AND HOLDING RACKS

TELESCOPE ACTUATOR SYSTEM

Five Telescope Actuator Systems designated as "R", "np", "L", "K" and "C" were fabricated at New York Ship starting in August, 1952. All five assemblies were similar in design except for minor details.

Each Telescope Actuator System was approximately 120 ft. high and consisted of two sections. The lower section rested on a structural steel frame known as the Forest Assembly and extended from the zero to the 66 ft. level. There were two fixed deck plates in the Forest Assembly and one "make-up" plate immediately above it which was connected to the Forest Assembly by a latch. The "make-up" plate was raised and lowered by a cable and pipe system. As it moved up, it met and carried with it two other deck plates suspended by telescoping hanging guide tubes at the 31 ft. 8 in. and 46 ft. 4 in. levels.

The upper section of the Telescope Actuator System, above the 66 ft. level, was similar to the lower except that it had no Forest Assembly. The pipe system which raised the lower make-up plate lifted a framework in the upper section known as the lifting carrier, which in turn carried two telescoping deck plate assemblies with it to the 120-ft. level.

The nine deck plates were fabricated of mild carbon steel and were approximately 16 ft. 11 in. square and 1/4 in. thick. The deck plates of each Actuator System were similar in design except: (1) hole diameters varied on certain plates, (2) the lower seven deck plates on "K", "L" and "C" systems had fourteen more holes than "R" and "np".

Various jigs and special tools were required to fabricate the Actuator Systems. A full size steel template formed from six carbon steel plates approximately 17 ft. by 2-1/2 ft. by 13/16 in. was fabricated for drilling pilot holes for the deck plate pattern. The pilot holes were then trepanned in a manner similar to that used in fabricating the tube sheets of the production units. The same 7.000 in. center stainless strip jig used for drilling production unit baffle plates was utilized in making the Actuator template.

Inspection of the template disclosed some holes located outside the required tolerance. These were plugged, re-drilled, reamed and bushed.

Parts of these Actuator Assemblies required chrome plating. New York Ship had a very difficult time locating a suitable plating firm, and surveyed facilities from New England to the South. Finally, the Simmons Plating Company, Atlanta, Georgia was selected.

Metal spray work on machined and base metal areas was accomplished by the Metal Weld Company, Philadelphia, Pennsylvania. All metal spraying was accomplished prior to chrome plating. After chrome plating, the items were shipped directly to the field from the Simmons Company.

Some of the 8-1/2 in. tubing was out of round, out of parallel or oversize when received. This tubing required additional work by New York Ship to bring within acceptable tolerance.

"P" Unit hanging guides were substituted for "R" guides in the field. "R" guides were returned to the Simmons Company for plating and metal spray repairs. One lower inner and outer hanging guide had an excess in thickness of chrome of approximately 0.050 in. Upon inspection it was found that the field weld made on the lower inner hanging guide had shrunk the areas surrounding the weld, therefore this guide would not pass through the outer guide. The inner guide was ground at the affected area and the bore of the outer guide was cloverleafed until proper fit was attained. Any areas where chrome was removed were touched up with aluminum paint, with du Pont Design Division permission.

Numerous conferences were held between New York Ship and du Pont to discuss questions and difficulties that arose in the fabrication of the Actuator Systems. Some of the items covered in these conferences were: Shipping of components, minor machining problems, chrome plating difficulties encountered by Simmons Company, modifications to chrome, painting and metal spraying procedures and relaxing of certain tolerances.

An obsolete structure known as the "R-1 Cage" was shipped to New York Ship and was converted into the Forest Assembly of the "L" System.

Completion dates of the various Telescope Actuator Systems were as follows:

<u>System</u>	<u>Actuator Frames and Plates</u>	<u>Forest Assembly</u>
"R"	November 1, 1952	January 20, 1953
"P"	January 15, 1953	February 18, 1953
"L"	April 18, 1953	March 23, 1953
"K"	April 18, 1953	April 18, 1953
"C"	June 3, 1953	June 4, 1953

Shipments of the parts of the systems to be plated by Simmons were made by truck. Special thread gages had been fabricated at New York Ship and delivered to du Pont inspectors. The tube threads were checked following plating at the Simmons plant and delivered directly to the Savannah River Plant.

Whenever barge shipment dates were near at hand, the non-plated parts of the systems were sent by water; otherwise, shipment was made by truck to the site. Crates and boxes for system parts were re-used for the different shipments.

To facilitate alignment of the Telescope Actuator Systems in the field, New York Ship fabricated two Plenum templates and one box frame. The frame was kept at the Savannah River Plant and used as a support for the templates. As each Plenum Chamber tube pattern was established, a template was adjusted to it and sent to Savannah. Two templates were required to prevent delays in erection at the plant site.

HOLDING RACKS

Five Holding Racks designated as "R", "P", "L", "K" and "C" were designed by du Pont and the American Machine and Foundry Company. All assemblies were alike except for minor details.

Each holding rack contained thirty-seven large tubes, twenty-eight of which were 5 in. in diameter made up of twenty-four straight and four shoulder tubes and nine 4-1/2 in. in diameter made up of eight straight and one shoulder tube. In addition to the large tubes, four rod tubes were welded into the unit. For all tubes, both large and small, there was one probe pin socket.

The upper section or container, was 70 in. by 92 in. by 39 in. and the tank bottom had approximate dimensions of 15 ft. 7-1/2 in. by 56 in. by 39 in. The container had two 1/2 in. thick rack plates and the plates and tubes were assembled in a manner similar to that for the process units. A box type carbon steel jig was used to hold tubes during assembly and an additional jig plate at top end of tubes was used to help setting of tubes, to align V-slots, and to maintain required verticality during tacking and welding. Following welding, the tubes were neck reamed. The tube nest was then placed in the container and rack plates welded to container. The area between the two rack plates was filled with approximately 50 cu. ft. concrete and there was a 7-in. layer of lead on top of the top plate. The 5-in. tubes each contained a 9/16 in. deep V-slot on the top. Nineteen permanent sleeve weldments had three additional V-slots added to top on "C" Unit.

A flange plate was welded around the container 16-1/2 in. from the top of the container for supporting the assembly.

On March 23, 1953, New York Ship began fabrication of the "R" and "P" Holding Racks when the vendor previously awarded the job was unable to fabricate the units satisfactorily and meet field required delivery dates. On July 16, 1953, New York Ship was awarded "L", "K" and "C" racks.

New York Ship was in a position to fabricate these racks because part of the working force, including the Engineering Department, normally assigned to the production units could be used for fabrication of these racks.

In order to adapt the American Machine and Foundry and du Pont drawings to New York Ship fabricating technique, New York Ship made up their own drawings for the first two racks, but the last three units were fabricated from du Pont drawings.

All units were fabricated in accordance with du Pont cleanliness specification No. 3056.

New York Ship incorporated in "L", "K" and "C" racks with du Pont approval, 111 stainless steel tubes which did not meet minimum specifications for the production units. This was possible due to the fact that tolerances for finish and size for the holding racks were much more liberal than on the production units because these tubes did not require "O" ring seating areas.

One of the problems that arose in fabricating the holding racks was the type of lead used. Although the drawings called for Type ASTM B-29 chemical lead, New York Ship used Type ASTM B-29 Grade A common de-silverized lead "A" for "R", "P" and "L" racks. Du Pont accepted this substitution but requested the chemical lead in "K" and "C" units.

The tank bottom section of each of the racks was given a hydrostatic test using deionized water; also both container and tank section were sandblasted, acid washed and ferroxyl tested.

The container and tank bottom were shipped separately with the field joint machined for welding in the field.

The shipping dates of the various Process Room Holding Racks were as follows:

<u>System</u>	<u>Racks</u>
"R"	May 26, 1953
"P"	June 15, 1953
"L"	October 29, 1953
"K"	December 28, 1953
"C"	May 20, 1954

All racks were shipped to field by truck except "C" Unit Rack which was shipped by barge with the final production unit shipment.

PHYSICS BUILDING TANK

The Physics Building Tank, more fully described as the 777M Physics Laboratory Tank and Grid Beam Assembly, was fabricated by New York Ship in the latter part of 1952.

The tank part of the assembly consisted of a stainless steel cylinder 16 ft. 1/2 in. high and 16 ft. 2-3/4 in. inside diameter fabricated from 1/2 in. plate. The tank bottom was a flanged only head fabricated by Lukens Steel Company. The upper part of the tank had four chambers equally spaced around the rim and extending 3 ft. 4 in. down the side with flanged connections. There was also one smaller chamber located at the top of tank with a 1-1/2 in. nozzle at the bottom.

A 1 in. nozzle was located at the center of the bottom head and four 4 in. nozzles spaced around the center, 4 ft. 4 in. from it. A wire mesh mat on 3 in. spacers covered the bottom of the tank.

A carbon steel I-beam framework supported the tank and was clad with stainless steel wherever it bore against the tank.

A diaphragm plate was supported above the tank. It was a square stainless plate 17 ft. 8-1/4 in. on a side and 1/4 in. thick with a circular opening 16 ft. 5-1/2 in. in diameter. The outer edges were attached to the supporting framework of the tank and the inner edges rested on a "Neoprene" hose wrapped around the top edge of the tank. The diaphragm had a uniform slope toward the center.

Above the diaphragm was the Grid Beam Assembly. The Grid Beam support assembly consisted of stainless steel angle sections in an I-beam framework attached to the tank framework. Thirty-one grid beams were installed inside the assembly.

Each of the grid beams contained two 3/8 in. thick support plates to which cover plates were attached.

There were twenty different sizes of cover plates, all of aluminum wrought alloy. The cover plates were all of one width but varied in length, number of holes and size of hole. Numerous machining operations were performed on the plates including: Drilling large holes, drilling 5/16 in. bolt holes, drilling 9/16 in. holes, chamfering large hole top edge, machining cover plate locating grooves and drilling semi-circular 11/16 in. radius cutouts on plate edge. The cover plates were attached to top and bottom of the support plates by 1/2 in. bolt stems that extended from top plate to bottom plate. The lower plates contained threaded holes and top plate had clearance holes with heads of fabricated bolts nesting on top of top plates.

The tank was fabricated in a manner similar to that used in the production units. No unusual fabrication problems were encountered.

A hydrostatic test was performed on the tank. The tank was filled with water containing 20 gal. of "Glim" detergent to an inside height of 15 ft. 3 in. and allowed to stand eight hours.

The completed physics laboratory tank and grid beam assemblies were shipped to the Savannah River Plant January 15, 1953, on the third barge shipment.

XIII - SHIPMENT OF PRODUCTION UNITS TO PLANT SITE

One of the considerations in the selection of New York Ship as the fabricator of the production units was the shipyard's location on navigable waters. The size and weight of the production unit assemblies made their transportation overland impractical, so du Pont planned to ship them by a barge to a point on the Savannah River near the site where they would be installed.

SELECTION OF CARRIER

The selection of the carrier was made by du Pont after solicitation of bids. James Hughes, Inc., of New York, offered the best type of equipment and the greatest amount of experience in similar shipping and was awarded the contract. Hughes provided a steel barge, "Hughes No. 100", 132 ft. long and 52 ft. in beam which had been converted from a Navy landing craft. The carrier furnished a house trailer as living quarters for the Atomic Energy Commission couriers who accompanied each shipment, and a ship-shore radio for their use, and also made arrangement with towing companies to move the barge from Camden, New Jersey to Savannah, Georgia and thence by shoal-draft tug up river to the plant site.

Seven barge shipments in all were made from Camden to the plant site by Hughes, and the same barge was utilized in each case:

Shipment No. 1	August 2, 1952
Shipment No. 2	November 1, 1952
Shipment No. 3	January 15, 1953
Shipment No. 4	April 18, 1953
Shipment No. 5	June 3, 1953
Shipment No. 6	October 2, 1953
Shipment No. 7	May 20, 1954

SECURING OF LOAD

Alterations were made to the Hughes barge to suit the special nature of the production units and auxiliaries. A breakwater of 3 in. by 10 in. timbers reinforced by steel

framing was constructed in the bow. Additional underdeck framing was installed in the barge by the Boiler Shop, and heavy timbers were fastened across the deck to distribute the load. Pads were welded to the deck at various locations to aid in securing the assemblies in position.

Several weeks prior to each shipping date, New York Ship naval architects were given details of the proposed load. From this data they developed a loading diagram for the barge deck. Barge dimensions were laid out on the floor of Building 10 or Building 3, and necessary shores and fittings were fabricated using the actual assemblies on the layout, whenever possible.

In loading the assemblies aboard the Hughes barge, a somewhat complicated procedure had to be followed for the Top and Bottom Tube Sheet Assemblies, which weighed about 100 tons each. Their fabrication was completed in the South Yard where there were no direct handling facilities for loading such weights on the barge. The railroad trestle connecting with the north part of the shipyard was not strong enough to permit moving the assemblies over it to the large overhead cranes of the building ways.

Several means of moving the tube sheet assemblies were studied. The most suitable and economical proved to be the renovation of a turret transporting system used during World War II.

The system consisted of a turret barge, known as the "Jim Stein", and a special platform of submerged piling on which the barge was sunk during loading. Heavy skids lead from Building 3 to the sea wall adjacent to the barge loading area, and similar skids were attached to the barge. A turret skid was altered to hold the tube sheet assemblies, and the piling on which the barge rested was examined by a diver before the completion of the first assembly.

In loading the assemblies aboard the "sunk" turret barge, the skid was moved aboard and the sea cocks in the barge were closed at low tide to keep the water to be pumped out to a minimum. Remaining water was pumped out and a local tug company moved the barge to the North Yard Wet Slip where a 150-ton crane placed it aboard the Hughes barge.

Lighter assemblies, including the Plenum Chambers, were moved by rail or truck to one of the North Yard piers where they were placed aboard the Hughes barge by 40-ton Clyde-Whirley cranes.

All parts and assemblies being shipped to Savannah by barge were carefully prepared for shipment. The tubes of

SHIPMENT TO SAVANNAH RIVER PLANT. Barge shipment No. 5 consisting principally of the "L" Unit Main Tank and Bottom Tube Sheet Assembly, "deck plates" and Forest Assemblies. The trailer for the Atomic Energy Commission courier is at the stern of the barge. All seven barge shipments were loaded in a similar manner.

the major assemblies were individually protected by plugs or caps, and sheets of soft aluminum plate covered the tube ends. Canvas covers were then used, with an inner cover of white untreated canvas and an outer cover of waterproofed gray canvas.

Small miscellaneous parts were packed in wood boxes with waterproof linings.

All assemblies and boxes were bolted or lashed to the deck of the barge by means of angle pads welded to the deck and slotted to receive 1-1/2 in. bolts.

SHIPMENT OF OTHER COMPONENTS

Actuator Deck Plates and Forest Assemblies, the Physics Building Tank, and Holding Racks, fabricated under modifications to the basic subcontract, were shipped to the Savannah River Plant in part by truck and partly by the Hughes barge, depending on size and whether a barge shipment was scheduled at the time one of these units was complete.

PROTECTION OF UNITS IN TRANSIT

The equipment used and routes chosen for the shipments were calculated to provide the best possible protection from damage by weather or other natural causes. Protection against intentional forms of damage was provided by the Atomic Energy Commission couriers who accompanied each barge shipment, and by U.S. Coast Guard. The couriers were able to maintain radio communication with government agencies along the route. Further protection was afforded by security restrictions covering the time of departure of the barge and its route and concealment of the load by canvas tarpaulins.

Truck shipments were also protected by special arrangements along the route made by the Atomic Energy Commission.

XIV - PROCUREMENT

SCOPE

Since the NYX Project was well into the planning stages when New York Ship was selected as the site for fabrication and testing, du Pont had already initiated procurement of certain long-delivery items. Du Pont continued procurement of various items during the project and, while no sharp line of demarcation existed between the two companies, New York Ship generally bought items pertaining to the fabrication of the production units while du Pont obtained materials and equipment for the test of the prototype "NYX" Unit in Building 10.

The equipment and facilities required for both the test program and production unit fabrication were generally of such unusual design or materials that little use could be made of existing stock equipment. Stainless steel was a serious procurement problem at the time the project's requirements were at a peak.

Procurement for the NYX Project included large machine tools, fabricating equipment, temporary and permanent test machinery, and electrical equipment. Nearly all of this material, and most of the long term delivery parts for the production units, were obtained by du Pont or in accordance with detailed du Pont instructions. In general, New York Ship's purchase orders covered:

1. Basic materials requiring further fabrication, such as stainless steel plate and pipe.
2. Special machine tools and other tools.
3. Materials necessary to supply services to the Building 10 test area.
4. Miscellaneous supplies and stores items.

During the project, a period of slightly more than three years, the Purchasing Department of New York Ship placed more than 3000 separate purchase orders, having a total dollar value of approximately \$5,000,000. A chart showing the number of purchase orders placed and the dollar amount by months appears in Part XV.

PROCUREMENT POLICIES

SOURCES OF SUPPLY AND SELECTION OF VENDORS

New York Ship followed its customary procurement practices in obtaining sources of supply for the NYX Project. Requisitions were received from the Material Control Department (formerly the Order Department) or, in some instances, directly from the NYX Project Manager.

Invitations to bid were then sent out in written form to three or more suppliers, and not infrequently fifteen or twenty were contacted. Telephone bids were frequently secured, depending on the value of the material. Orders were placed with the low bidder provided other requirements of service, quality, etc., were equal.

On orders for less than \$100, no Tabulation of Bid form was required. Orders from \$100 to \$2000 were not sent out until a Tabulation of Bid form was prepared and signed by the buyer and an authorized New York Ship executive. Orders from \$2000 to \$10,000 were not released until the Tabulation of Bid form had been signed by an authorized du Pont representative in addition to the New York Ship signatures. Orders over \$10,000 required the prior approval of the du Pont Wilmington office and the Atomic Energy Commission.

In some cases, it was necessary that orders be placed without competition due to the urgency of delivery or the restricted nature of the materials. Du Pont authorization was obtained prior to any such purchases, and the reason was recorded as: "Early Delivery", "Required Design", or other special requirement.

In addition, no commitments were made to purchase any of the following without du Pont approval in advance: non-expendable tools, office furniture and equipment, first aid or hospital equipment, automotive equipment, engineering services, utilities services, and equipment rental.

No direct purchases of automobiles or typewriters were made by New York Ship, such items being procured directly by the Atomic Energy Commission.

SUB-SUBCONTRACTS

Formal sub-subcontracts, approved by du Pont as to form, were required for the procurement of certain materials or services involving field labor on New York Ship premises, or cost-reimbursable materials or services provided by a supplier to New York Ship.

Formal contracts were not required, however, for erection supervision, mechanical repair services, telephone installation and repair services and similar special services performed on a standard or commercially recognized basis. Included in this category were: Sandblasting, special on-site cleaning of assemblies of "NYX" and production units, and use of a diver in preparing test facilities in Newton Creek.

A summary of New York Ship's formal sub-subcontracts appears in a subsequent section.

PROCUREMENT ORGANIZATIONS AND PROCEDURES

The responsibility for procurement of materials and equipment for the NYX Project was shared primarily by du Pont and New York Ship. The Atomic Energy Commission, by directives or other means, assisted in expediting delivery of certain critical items, and placed some orders direct when the supplier was another governmental agency.

New York Ship orders amounting to more than \$2,000 and those not awarded to the lowest bidder received prior approval by du Pont. All orders in excess of \$10,000 were approved by the Commission prior to placement.

Expediting of orders, and in general, procurement of materials and equipment not requiring further fabrication at New York Ship were du Pont responsibilities.

Remaining procurement was handled by New York Ship through the same departments and in a manner similar to regular shipyard material purchasing. Certain individuals of New York Ship such as the President, NYX Project Manager, Marine and Plant Engineers were authorized to approve purchases. Upon approval, orders were executed by the Purchasing Department, where there were approximately eleven individuals authorized to issue purchase orders. NYX Project orders were handled by the various buyers in the Purchasing Department in accordance with their specialties, and were given the highest priority.

When it appeared that delivery of a purchase order could not be made within the required time, despite the priority designation, du Pont representatives at New York Ship were consulted. They determined whether delivery could be expedited and, if necessary, obtained from the Atomic Energy Commission a directive to the company selected as a supplier.

PRIORITIES

The NYX Project was handled on a priority basis by New York Ship. Purchase orders were given special handling within the Purchasing Department and, during the period when the Controlled Materials Program was in effect, were classified as E-1 under CMP Regulation 6. When the Controlled Materials Program was superseded by the Defense Materials System in March, 1953, effective for the third quarter of the year, the same priority rating of E-1 was retained under DMS Regulation 2.

During the period that the Controlled Materials Program was in use, material that was not controlled was certified as priority DO-E1 under CMP Regulation 3.

Quarterly allotments of materials were assigned to New York Ship by du Pont, and the Purchasing Department kept accounts of orders against the allotments. In general, the assigned priority was sufficient to obtain materials in time to meet schedules.

In cases where delivery was unsatisfactory, the order with assigned priority was placed on a selected supplier and du Pont obtained directive action from the Atomic Energy Commission.

Although the Controlled Materials Program was still in effect at the end of the project, availability of materials had improved and orders tapered off in late 1953 and in 1954 so that deliveries were generally satisfactory without the need for special treatment.

EXPEDITING AND INSPECTION

Both inspection at source and expediting of materials for the NYX Project were handled by the du Pont Material and Equipment Section. Inspections at New York Ship were generally made by du Pont personnel with assistance as required from shipyard inspection groups.

The principal problems encountered by New York Ship were in the tubes received from fabricators for inclusion in the "NYX" and "R" Units. Many of these were late in delivery and when received did not meet specifications, requiring emergency measures by New York Ship's Machine Shop to salvage as many as possible.

Du Pont encountered almost daily problems in maintaining the flow of materials to the shipyard, but perhaps the most pressing was the procurement of large radial drills in

time to meet fabrication schedules. Special Atomic Energy Commission directives were needed to obtain these, as well as cooperation from the Navy Department in releasing drills in reserve storage.

PROCUREMENT OF SPECIAL MATERIALS AND EQUIPMENT

Procurement of such items of substantial cost or quantity by New York Ship, aside from stainless plate and materials used in the various units, was limited to radial drills, a specially-designed tube-end milling machine, and Aircomatic welding equipment. The reader is referred to Part VI for a listing of major equipment items and to Part VII for a description of development and procurement problems encountered in obtaining special fabrication materials and equipment.

PROCUREMENT PROBLEMS

Some of the principal procurement problems are discussed in other sections of this report. The chief difficulties encountered were in obtaining machine tools, fabricators for tubing, and certain critical materials. It should be noted that du Pont did most of the procurement and expedition work on critical items, and was able to achieve substantial advancements to keep the project going.

New York Ship was originally scheduled to machine the tubing required for the tube sheet assemblies of the units. Orders had been placed with the Connor Tool and Cutter Co., Detroit, Michigan, for the necessary tools when the plant was closed for an indefinite period by a strike. An intensive search was made by du Pont and New York Ship representatives to locate fabricators. More than 150 firms were approached before ten were found that could meet delivery schedules. The work was contracted to the ten vendors by du Pont, and the tool order with Connor was canceled.

A nearly completed new 12-ft. radial drill was located at the works of the Cincinnati-Bickford Company. Directive action was obtained through du Pont and the Atomic Energy Commission to divert the drill to New York Ship.

A procurement problem was also met in obtaining the Aircomatic Automatic Tube Welders which were under development at the beginning of the project. Assistance of New York Ship welding engineers helped to perfect and complete this equipment so that it could be placed in

service on the "NYX" Unit in the case of the large tube machines and the "R" Unit in the case of the rod tube welders.

Suitable welding wire was a critical procurement problem in the summer and fall of 1951. The project was operating on a hand-to-mouth basis in July, 1951, and in danger of being held up entirely for lack of wire. Specifications were relaxed to permit the use of somewhat less critical types of wire and government directive action was obtained which resulted in the delivery of 1500 lbs. of wire in August, and a regular supply thereafter.

The procurement of raschig rings, individually small but representing a considerable tonnage collectively, required a du Pont task force to seek out possible fabricators and to expedite deliveries.

The finding of substitute pumps for the 12,000 gal./min. process pumps to be used in the test of the "NYX" Unit, and the fabrication of temporary heat exchangers were other difficult problems of procurement among the many solved by du Pont.

SUB-SUBCONTRACTS

Few lump-sum sub-subcontractors were used by New York Ship during the NYX Project. The three significant lump-sum contracts were:

1. A Letter Contract with the Public Service Electric and Gas Company of New Jersey effective May 29, 1951, and dated August 16, 1951. The contract authorized the design, procurement of material and performance of all work necessary to supply temporary power up to 18,000 kv.-a. to New York Ship. The estimated cost was \$291,800 and the contract provided for an audit after completion of the work to determine the actual cost, for which the company could be reimbursed. The actual installation cost was \$204,907.86.

Provision was made for a refund at the conclusion of the NYX test program for any of the new facilities that could be utilized by Public Service Electric. On June 29, 1953, Public Service Electric transmitted a check to New York Ship for \$200,249.50, representing the value of the new facilities which could be utilized by the company.

2. Ralph Cornell, Contractor, Woodbury, New Jersey, was awarded a sub-subcontract 8643-1 on August 24, 1951, for furnishing certain materials and labor to construct facilities for the test of the "NYX" Unit in Building 10. The lump sum price for the specified work was \$511,979. To this was added an itemized modification to the scope of work 8643-1A dated November 18, 1952, which resulted in the addition of \$71,025 to the previous lump sum.

Before selecting Cornell as the successful bidder, various contractors in the area were informed of the proposed job and given an opportunity to bid. Formal bids were received from the following in addition to Cornell:

Goldner Construction Company, Inc.,
Philadelphia \$561,000

Kaufman Construction Company, Inc.
Philadelphia \$669,000

Since Cornell agreed to meet the required time schedule, he was awarded the sub-subcontract by reason of being low bidder. The itemized additional work was awarded without bids as a result of negotiation, because Cornell was then on the site with his labor force and equipment. His estimates for each item were studied and found to be reasonable.

3. The Pantano House Wrecking Company, Philadelphia, was awarded a lump sum sub-subcontract for the demolition and removal of most of the facilities installed by Ralph Cornell. The lump sum price for the specified work was \$39,061.

Various contractors in the area were advised of the impending demolition job. Among those notified but unable to quote were: Ralph Cornell, Cleveland Wrecking Company, and William M. Hanley. In addition to the bid from Pantano, bids were received from:

Robert Hawthorne, Inc., Philadelphia \$59,455

Edward H. Ellis & Sons, Inc.,
Merchantville, New Jersey \$99,798

Since Pantano was the low bidder and agreed to meet the specified completion date, he was awarded the sub-subcontract.

PURCHASE ORDER NUMBER SYMBOL AND SERIES

From the accounting standpoint, the division between overhead and direct costs in the NYX Project and the provision for approval of certain purchases by du Pont or both du Pont and the Atomic Energy Commission, made the use of a large number of separate accounts desirable.

The general symbol used to identify all purchase orders applicable to the NYX Project was No. 8000. Various series of numbers were used with the "8000" Group to identify specific charges. The general assignment of number series made at the start of the project was as follows:

- 8001 Series - All preliminary and test work relating to the experimental, reduced scale section.
- 8002 Series - Preparation and purchase of special forms, office labor in setting up security office, fingerprinting, etc.
- 8100 to 8500 - Reserved for actual production work.
- 8600 Series - All material and labor charges involved in the provision of facilities for fabrication or test.

The number of purchase order series within the "8000" framework increased as the project developed, reaching a total of 136 separate series of orders. The number of orders within each series varied from one to over 600.

On September 1, 1953, a re-organization within the Purchasing Department took place and subsequent purchase orders for the NYX Project were assigned a consecutive number within a larger group of orders classified as "Miscellaneous". Each NYX Project purchase order contained the appropriate charge number, however, and was written on paper of a distinctive green color so that it could be readily identified among the other miscellaneous purchase orders in the group.

A tabulation of the purchase orders used by New York Ship appears on the following pages. Purchase orders placed after the procedure change of September 1, 1953, bore consecutive numbers between 1 and 2000, but for clarity are shown under their respective charge numbers as though the former system had been continued throughout the project.

<u>NYX Charge No.</u>	<u>No. of Purchase Orders</u>	<u>Description</u>
8001	13	Experimental Work
8002	48	Security Processing and General Office
*8003	1	Telephone Services
8004		Retroactive Pay Adjustment
8005		Overtime Premium
8006		Supervisory Force
8007		Training Men
8008	1	Temporary Power
8009	10	Miscellaneous Office Supplies
8010		Extra Shift Premiums
8011	212	Miscellaneous Shop Supplies
8012		Operators Time Sub-Station S. Yard Only
8013		Sale of Scrap or Equipment
8014		Hand and Power Tools
8015	22	Pickling, Sandblasting - NYX Unit
8016	20	Pickling, Sandblasting - R, P, L & K Units
8017		Lighting, Building #3 and #10
8018	9	Safety Expenses Building #10
8019	2	Apply Siding and Tile
8020	5	Addl. Clean. Bldg. #3 & #10 (Over Std.Pract.)
8021	1	Cleaning of Work Clothing
8022		Rehabilitating South Yard Gate House
8023	2	Cleaning of Various Parts of NYX Unit
8024	6	Cleaning of Various Parts of "R" Unit
8025	9	Cleaning of Various Parts of "P" Unit
8026	8	Cleaning of Various Parts of "L" Unit
8027	6	Cleaning of Various Parts of "K" Unit
8028	23	Constructing One (1) Steel Tank
8029	1	Rehabilitate Room and Building #3
8030	7	Renovation of Women's Wash Room
8031	1	Repairing Entrance to South Yard Park. Lot
8032	114	Fabricate Forest Structures, Plates, etc.
8033	2	Construct Soundproof Room
8034		Reversing #4 Coupling Halves
8035	6	Construct Enclosure, Paint, etc.
8036		Machining Bearing Bushing
8037		Dismantling Equipment, etc., Bldg. #3
8038		Salvage of Items in Building #3
8039	10	Dismantling Equipment in Building #10
8040	2	Salvage Items in Building #10
8041		Overtime Premium "C" Unit Construction
8042		Shift Time for "C" Unit
8043	9	Drying Out Top and Bottom Tube Sheets
8044	1	Demolition of Facilities in Bldg. #10
8046		Production Bonus Plan
8101	286	Constructing One (1) Unit
8151	620	Testing Unit - NYX
8152		Operations Expense-Testing NYX Unit

<u>NYX Charge No.</u>	<u>No. of Purchase Orders</u>	<u>Description</u>
8153		Miscellaneous Repairs
8201	119	Constructing One (1) "R" Tank Unit
8202	90	Constructing One (1) "P" Tank Unit
8203	91	Constructing One (1) "L" Tank Unit
8204	69	Constructing One (1) "K" Tank Unit
8205	32	Construction of "C" Unit Plenum
8206	14	Construction of "C" Unit Top Tube Sheet
8207	52	Construction of "C" Unit Bottom Tube Sheet
8208	11	Construction of "C" Unit Tank
8209	8	Conversion of Top Tube Sheet
8210	11	Conversion of Plenum
8211	27	Conversion of Bottom Tube Sheet
8212	19	Fabricate Holding Rack "R" Unit
8213	8	Fabricate Holding Rack "P" Unit
8214	15	Fabricate Holding Rack "L" Unit
8215	10	Fabricate Holding Rack "K" Unit
8216	9	Fabricate Holding Rack "C" Unit
8217		L & M for Changes to NYX Tank Enclosure
8218		Six Lip Extensions and Three Form Slvs.
8219		Repairs to Expansion Ring - "C" Unit
8601	60	Automatic Aircomatic Units - Welders
8602	9	Maintenance Radial Drills
8603		Clearing Building #10 South Yard
8604	32	Aircomatic Gun Assemblies - Welders
8605	11	Radiographs - Welders
8606	3	Electrode Holders - Welders
8607	5	Motor Type Welders
8608	3	Cutting Equipment
8609	1	Steel for Pump and Motor Foundations
8610	2	Induction Motors - 1500 hp.
8611	69	Electric Power Supply Equipment
8612	13	Crane Runway
8613	1	Racks and Monorail Supports
8614	1	Handling Office Furniture, etc., Equip.
8615	1	Structural Steel for Tank Supports
8616	2	Structural Steel for Barricades
8617	1	Moving Welding Positioner
8618	1	Preparing Boring and Facing Mill
8619	11	Electric Service for Pump
8620	1	Repairing Cranes
8621	3	Check 350,000 C.M. Lead Cable
8622	78	Office Equipment
8623	1	Tube-Machinery Tools
8624	2	Monorail System with Hoists
8626		One (1) Gould Control Battery
8627		Re-inforcing Steel
8628	11	Top-Running 2-Ton Crane
8630		Rental of Model Utilitrac

<u>NYX Charge No.</u>	<u>No. of Purchase Orders</u>	<u>Description</u>
8631	3	Re-locating Boring Mill
8632	1	Structural Supports
8633	8	Excavation of River Mud
8634		Dismantling Pump
8635	1	Tables
8636		Planner Tools
8637	307	Small Tools
8638	10	Radial Drills and Motors
8639		Safety Relief Valves
8642	8	Yard Fac. for Subcontractor
8643	2	Structures and Fac. for Test Fac.
8645	1	Boring Heads
8647	2	Preparing Tool Heads
8648	4	One (1) Boroscope
8649	1	Tube-Machining Tools
8650	2	Safety Hats
8651		Making of Ident. Nos.
8652		Boroscope
8653	1	Platform Scales
8655		Four (4) Racks
8656	10	Head and Feed Tables
8657	49	Six (6) Pumps
8658	31	Bore Gages and Dial Indicators
8659	4	Twelve (12) Pumps
8660	6	Repair Heating Equipment
8661		One (1) Strain Gage Selector Unit
8667	3	Removing Machine
8669	7	Reconditioning Three (3) Offices
8670		Straightener for Steel Tubes
8671	8	Push Bottom Stations
8672	2	One (1) Pump
8673		Furn. Gas, Oils, etc.
8676		Reference Table
8677		Two (2) Track Turning Machines
8678		Cleaning 2 Sets of Platens
8679		Repairs and Maint. - Sellers Boring Mill
8680		One Kemp Dryer
8681		Shipping Three (3) Boxes
8682		Fire Protection
8683	1	Protection for Equipment in Sub-Station
8684	3	Security Entrance to Main Barricade
8685		L & M for Platforms and Walkways
8687	22	L & M to make Minor Alterations
8688	1	Repairs to Government Owned Sedan
8689	57	Repairs to Government Owned Cars
8690		Const. of Two (2) Steel Weldments
8691	1	Supplies - Building #10 Operations
8692		Revising Two (2) Vaned Elbows

<u>NYX Charge No.</u>	<u>No. of Purchase Orders</u>	<u>Description</u>
8693	1	Film
8694		Labor to Inspect all Bolts
8695		Additional Platform Supports
8696		Four Crates Steel Filing Cabinets
8697	3	One Dis-Assembly Machine and Motor
8698	16	One (1) Whiting 10-Ton Crane
8700	1	Talk-a-phone
8701	1	Renovate Office Building #3
8702		Engineering Ins. Yard Fac. Sub-Station
8704		Engineering Insp. "K" Unit
8706	16	Install and Service 2 Generator Sets
8707		Renovate Dispensary Building USNX 2782
8708	5	Maint. and Repairs to Mach. and Equip.
8709	1	Protection to Machinery and Equipment
8710		Engineering Insp., etc., Yard Fac.
8711	1	Pipe and Bolt Machine
8712		Moving Milling Machine
8713	1	Centrifugal Pump
8714	1	Two Diesel Engines
8716	3	Loan of Radial Drills - Maintenance
8721	1	Two (2) Ventura Fans
8722		Rod Washing Stations
8723		Two (2) Oil Systems
8729	1	Two (2) Air Conditioning Units
8730	1	Six (6) Motors
8731		For Alterations to Tool Crib
8732	1	Four (4) Fans
8733	3	Design and Develop One Milling Attach.
8734	1	One Grinding Fixture
8736		One (1) Metallic Rectifier
8737	1	Three (3) Aircomatic Gun Assembly-Weld.
8738	2	Equipment and Services - CO2
8739	4	Ventilating Units
8740	4	Eighteen (18) Fans, 3 Floor Fans
8741		L & M Recondition Winch
8743	1	Four (4) Portable Grinders
8745	1	One (1) Elect. Drinking Fountain
8746	1	Removing Boring Mill
8748	1	One (1) Boroscope
8749		Three (3) High Pressure Pump Units
8750	1	Additional Windows for Control Room
8751	1	Roof Ventilators - Building #10
8752	1	Install Insertion Tube Brackets
8753	1	Two (2) Platform Scales
8754		Monochromatic Light-Lapp Machine
8756		Two (2) Storage Tanks
8758		Seal Bench Tester, Jig, etc.
8760	4	Pump Maintenance Room

<u>NYX Charge No.</u>	<u>No. of Purchase Orders</u>	<u>Description</u>
8761	9	Permanent Heat Exchanger and Installation
8763	1	One (1) Racine Utility Saw and Motor
8764	2	X-Ray Supplies
8765		L & M Provide Facilities for Sandblasting
8766		One (1) Electro Lift Hoist and Trolley, etc.
8767		Eight Cabinets Made for Tool Crib
8768	2	Super Station Vacuum Cleaner
8770	1	Repair Parts for #3 Grinder
8771		Sixteen Foot Straight Edge
8772	1	Rotary Air Grinders

Note: Numbers marked * were open purchase orders for continuous services such as telephone charges.

XV - WORK PROGRESS

WORK SCHEDULES AND PERFORMANCE

The original program for the development of production units called for completion of the prototype "NYX" Unit by November, 1951, and completion of all units by the fourth quarter of 1953.

Due to the complexity of design, shortages of tools and personnel, the necessity for New York Ship to "make ready" for fabrication, and various other reasons, it was not possible to meet the desired schedule.

One of the first schedules for the overall project based on the existing procurement and labor situation was presented to New York Ship on January 26, 1952. It showed the following dates:

	<u>Start of Fabrication</u>	<u>Completion of Fabrication</u>
"NYX" Unit	September 1, 1951	March, 1952
"R" Unit	November 1, 1951	May 1, 1952
"P" Unit	February 15, 1952	July 15, 1952
"L" Unit	May 1, 1952	January 1, 1953
"K" Unit	November 1, 1952	July 1, 1953
"C" Unit	May 1, 1953	January 1, 1954

From this time, almost to the end of the project, the schedules for the production units and their sub-assemblies were changed at intervals in the light of work progress. As has been mentioned throughout this report, the work was of a different type than had been fabricated previously by the shipyard. There were many experimental developments that had to be completed before fabrication could begin. There were expected fabrication difficulties, such as tube sheet shrinkage, which proved more time consuming than anticipated. Other problems arose that could not be fully anticipated.

Again, in the case of the "NYX" Unit, difficulties in tube procurement and obtaining directives in connection therewith were accountable for a substantial part of the delay.

Despite the best efforts of du Pont and New York Ship personnel, the optimism goal schedules could not be met, which were initially set up based on full availability of material, equipment and manpower.

The actual dates on which the units were started and completed were as follows:

	<u>Start of Fabrication</u>	<u>Completion of Fabrication</u>
"NYX" Unit	September 1, 1951	May 20, 1952
"R" Unit	October 27, 1951	BTS August 1, 1952 MT August 1, 1952 P October 30, 1952 TTS October 30, 1952
"P" Unit	March 7, 1952	BTS October 28, 1952 MT January 15, 1953 P April 15, 1953 TTS April 15, 1953
"L" Unit	June 5, 1952	BTS June 3, 1953 MT June 3, 1953 P September 19, 1953 TTS September 19, 1953
"K" Unit	April 9, 1953	October 2, 1953
"C" Unit	April 20, 1953	May 20, 1954

Note: Symbols under "Completion of Fabrication" column indicate that unit was shipped to plant site by assemblies at different times. Completion date for each shipment group is shown. Symbols are abbreviated as follows:

P - Plenum
MT - Main Tank
TTS - Top Tube Sheet Assembly
BTS - Bottom Tube Sheet Assembly

USE OF OVERTIME AND MULTIPLE SHIFTS TO EXPEDITE WORK

When the urgency of the NYX Project became known, steps were taken to increase the force assigned to the work by the use of multiple shifts and overtime. An initial step was the continuation of work during the two-week period in July, 1951, when the shipyard was scheduled to close down for vacations. In August, the NYX Project manager was authorized by du Pont to use overtime, including Saturday and Sunday work as necessary, except for short periods when the work was at a stage where overtime would not produce appreciable savings in time, and periods of labor stoppage described more fully below. In general, multiple shifts and overtime were used for the duration of the project.

Paid holidays provided in the company's labor agreement were observed by those assigned to the NYX Project. When such holidays fell, or were celebrated on a Friday or Monday, the "long" week end was observed on several occasions.

On certain days when work was scheduled on the project, stoppages took place as a result of labor demonstrations or disagreements. The more important of these are listed below:

1951

November 9	No work after 3:45 p.m.
November 10	No work (Saturday)
November 11	No work (Sunday)
November 17	No work (Saturday)
November 18	No work (Sunday)

1952

May 3	No work (Saturday)
May 4	No work (Sunday)
November 15	Machine Shop personnel refused overtime

1953

February 18	4:00 a.m. to 8:00 a.m., jurisdictional dispute
November 7	Machine Shop personnel refused overtime
November 8	Machine Shop personnel refused overtime
December 19	No work (Saturday)
December 20	No work (Sunday)

1954

January 2	No work (Saturday)
January 3	No work (Sunday)
January 9	No work (Saturday)
January 10	No work (Sunday)
January 16	No work (Saturday)
January 17	No work (Sunday)
January 23	No work (Saturday)
January 24	No work (Sunday)
January 30	No work (Saturday)
January 31	No work (Sunday)
April 2	First and second shifts worked only half scheduled time

April 6	At 8:30 a.m. a yard-wide "sit-down" strike began
April 7	Sit-down strike
April 8	Sit-down strike
April 9	Sit-down strike. Work began at 12:01 a.m. April 10.

Additional steps taken to expedite the work included studies of fabrication problems by a tooling engineer (Part VII) and the appointment of one of New York Ship's most experienced superintendents as NYX Project Manager. Personnel were then assigned to the Project Manager to supervise Building 10 construction and unit fabrication work, as described in more detail in Part VII.

Procurement of materials was handled on a priority basis, with du Pont expediting orders and obtaining government directives when necessary. An indication of the rate of commitment of orders is shown in the chart on the next page.

NYX PROJECT WORK PROGRESS

XVI - SAFETY PROGRAM

Over a period of approximately three years in which 3.4 million man-hours were expended at New York Ship on the NYX Project, records show no fatal accidents and only five lost-time accidents to New York Ship employees engaged on the project.

Such pleasing results were obtained largely because of a safety program administered jointly by du Pont and New York Ship.

The du Pont Control Supervisor acted as Safety Coordinator. He made regular inspections of the working areas and received recommendations from the du Pont Material and Equipment Group concerning safety hazards.

A full-time New York Ship Safety Inspector was assigned to the NYX Project from the fall of 1951 to the closing of the test program in Building 10 in May, 1953, and was available seven days a week.

The Safety Inspector was provided with a copy of the du Pont safety instructions as well as New York Ship's instructions. Whenever feasible, du Pont safety instructions were followed in the Building 10, NYX Program.

Numerous safety suggestions were made by du Pont, with particular emphasis placed on the marking of passageways, roping off of areas beneath overhead construction work, installation of warning sirens for overhead cranes and similar precautions to prevent injury from falls and falling objects. New York Ship in turn reviewed du Pont construction drawings and suggested various revisions for eliminating potential hazards, such as modifying the lifting rig designed for raising the Precision Crane to the upper level rails.

Weekly safety meetings attended by du Pont inspectors and supervisors, and New York Ship Safety Inspectors provided an opportunity to discuss and correct potential hazards.

Upon the completion of test operations in Building 10, a full-time Safety Inspector was no longer considered necessary. However, regular inspections by du Pont and New York Ship supervisors continued, as did the weekly safety meetings. The South Yard area was made a part of the safety zone assigned to a shipyard Safety Inspector, who made periodic investigations of Buildings 3 and 10 and

took action to correct hazards. In addition the Safety Inspector was present whenever any particularly hazardous operation was scheduled.

Records show but seventy man-days lost due to accidents during the entire project. The most serious accidents were (1) fractured skull due to a fall from a ladder and (2) burns resulting from ignition of an alcohol solution used in painting metal for layout.

Regular safety reports were made by the du Pont Field Project Manager. New York Ship's safety records cover the entire shipyard, and detailed statistics for the NYX Project are not available. The following data are indicative of the safety record of the project compared to total shipyard experience which includes the NYX Project and the more hazardous shipboard work.

New York Shipbuilding Corporation Accident Record

July 1951 - June 1954

	<u>NYX Project</u>	<u>All Contracts</u>
Total Man-Hours	3,400,000	39,300,000
Number Lost-Time Accidents	5	558
Accidents Per Million Man-Hours	1.47	14.2

XVII - WAGES AND HOURS

EXISTING WAGE RATES

New York Ship divided its employees for pay purposes into two general groups: Hourly Paid and Salaried Paid.

Hourly Paid employees were members of the shipyard union, the Industrial Union of Marine and Shipbuilding Workers of America, Local No. 1, in Affiliation with the International Brotherhood of Boilermakers, Iron Ship Builders and Helpers of America, Lodge 801, A.F.L. This union later dropped the first part of its title and for brevity will be referred to as Lodge 801, A.F.L.

Salaried Paid employees were divided into four groups:

- Group 1: Salaried employees exempted from the provisions of the Fair Labor Standards Act of 1938, as Amended.
- Group 2: Unorganized salaried employees covered by the provisions of the Fair Labor Standards Act of 1938, as Amended.
- Group 3: Salaried employees covered by the Collective Bargaining Agreement between the Corporation and the Marine Draftsmen's Association.
- Group 4: Salaried employees covered by the Collective Bargaining Agreement between New York Ship and Lodge 801, A.F.L.

The rates of pay of the Hourly Paid employees on April 25, 1951, when the Letter of Intent for the NYX Project was issued, had been established by collective bargaining with Lodge 801, A.F.L. in June, 1950. The salary rates of Salaried Paid employees in Group 4 had been similarly established; while rates for Group 3 employees had been arrived at by collective bargaining with the Marine Draftsmen's Association. Salaries of Group 1 and Group 2 employees were in line with the general range of pay for the other groups.

The shipyard wage structure at the time was keyed to a first-class skilled manual classification rate of \$1.57 per hour. The hourly rates for various classifications and the salary rates and ranges are listed in detail in Appendix A and exhibits to the basic Subcontract AXC 167-1/2. Because of the large number of individual rates, they will not be itemized in this report.

CHANGES IN WAGE AND SALARY RATES

At the time work was commenced on the NYX Project, regulations of the Wage and Salary Stabilization Boards were in effect. In the early spring of 1951, wage and holiday adjustments were granted by other East Coast shipyards. Accordingly, New York Ship agreed to a similar adjustment in Lodge 801, A.F.L. rates subject to approval of the Wage Stabilization Board, that would increase the first-class skilled rate from \$1.57 to \$1.81 per hour, with a corresponding 15.5 per cent increase in other rates. Petitions were also submitted to cover Salaried Paid Groups 1, 2, and 3. Approval of the wage adjustment for Lodge 801, A.F.L. was granted on June 11, 1951, retroactive to February 26, 1951. A similar increase for Salaried Groups 1, 2, and 3 was made retroactive to March 5, 1951.

On January 19, 1953, the Wage Stabilization Board approved an agreement with Lodge 801, A.F.L., increasing the first-class skilled rate to \$1.95 per hour, with a corresponding 7.6 per cent increase in other rates. The increase was to be retroactive to June 23, 1952. A similar increase, with the same retroactive provisions covered Salaried Group 4, and was authorized for all Salaried Groups. It was granted by the company to Groups 2 and 3 and to certain individuals in Group 1.

On February 2, 1953, the Wage Stabilization Board approved an increase in the first-class skilled rate to \$2 per hour, with a corresponding 2.5 per cent increase in other rates. The increase was retroactive to January 27, 1953. This increase was applied to the Salaried Groups in the manner described in the preceding paragraph.

Upon the issuance of Executive Order No. 10434, an additional paid holiday (Good Friday) was granted to Lodge 801, A.F.L., and Group 4 salaried employees, the cost of which was deducted from the last wage increases, leaving a net increase of 7.6 per cent effective January 19, 1953, and retroactive to June 23, 1952.

Effective August 3, 1953, an agreement with Lodge 801, A.F.L., was reached providing an increase of 7 cents to 36 cents in existing hourly rates depending on the classification. Employees covered by the agreement were also granted retroactive pay adjustments of 15 cents per hour for each hour paid for between June 23, 1953, and August 3, 1953.

The last two increases, above, were applied generally to New York Ship employees in Salaried Group 2. Certain individual changes were made for employees in Salaried Group 1 and were applicable to the NYX Project, were incorporated in the Subcontract (AXC 167-1/2) as changes to Appendix A.

It should also be noted that, as a result of negotiations with Lodge 801, A.F.L., the collective bargaining agreement was amended, effective August 3, 1953, to eliminate all piecework and incentive premiums previously applicable to certain employees. The amendment also provided for a yard-wide incentive plan to become effective at the same time. The plan was generally referred to as the "Production Bonus Plan". Under this agreement, a distribution of 8 per cent of the amount of working pay in September, 1953, was made in October to all employees covered by the plan. Additional bonus payments of 3 per cent were made for the months of February, March and April, 1954.

OVERTIME AND SHIFT PREMIUM RATES

The rates of overtime pay for employees covered by the agreement with Lodge 801, A.F.L., and by the fair Labor Standards Act of 1938 as amended, provided that hours worked in excess of eight per day or forty per week (and in the case of Lodge 801, A.F.L., during hours other than an employee's regular shift) would be compensated at one and one-half times the established base rate. A similar rate applied to work on Saturdays.

Work on Sundays and holidays, or the days celebrated as holidays, was compensated for at double the established base rate.

Employees working on the second and third shifts received a premium of 7 per cent of their established base rates, such compensation being considered a part of the base rate for the purpose of calculating overtime.

WORKING HOURS, OVERTIME AND SHIFT WORK

The normal working day at New York Ship was eight hours, and the normal week was five days.

Because of the urgency of the NYX Project, New York Ship was authorized at an early stage of the work to use multiple shifts and overtime when such action would materially advance the completion date of the various assemblies. This authorization remained in effect until the end of the project.

In the spring and summer of 1951, when a relatively small working force was engaged, no formal policy on normal working periods for the project was in effect. During the yard-wide vacation period in July, 1951, approximately

twenty-three men were requested to work during the two-week shut-down of the plant to prepare tube sheets for the "NYX" Unit as well as helping to prepare jigs and fixtures, and facilities for the scheduled test operations in Building 10.

By September, fabrication of the "NYX" Unit was well underway. The normal work week was set as six days per week three shifts. Sunday work, which was considered as an emergency measure at this time, soon became routine in certain trades and for practical purposes became a part of the normal work week for the duration of the project. However, to avoid any unnecessary overtime charges, men were individually selected for Saturday and Sunday work, with a relatively small number called in on Sundays.

At the time the NYX Project was initiated, the shipyard had only two regular shifts, with hours as follows:

First Shift 7:30 a.m. to 11:30 a.m.
12 noon to 4:00 p.m.

Second Shift 4:00 p.m. to 8:00 p.m.
8:30 p.m. to 12:30 a.m.

When a third shift was instituted for the project, the hours were established as:

Third Shift 12 midnight to 4:00 a.m.
4:30 a.m. to 8:30 a.m.

The addition of the third shift resulted in a half-hour overlap between second and third shifts and an hour overlap between third and first shifts. While this arrangement was not satisfactory from the standpoint of continuous operations such as were in progress on the "NYX" and production units, the terms of the collective bargaining agreement with Lodge 801, A.F.L., required union consent to modify the periods or the meal intervals. An agreement was reached with the union in August, 1952, and the three-shift schedule for the NYX Project was revised to the following schedule which was maintained for the duration of the contract:

First Shift 8:00 a.m. to 4:00 p.m.

Second Shift 4:00 p.m. to 12 midnight

Third Shift 12 midnight to 8:00 a.m.

Authorization for the use of overtime work was given to New York Ship by du Pont, and the following excerpt is quoted from the du Pont Atomic Engineering Manager's letter

dated May 12, 1952: ". Specifically, the following are required to prevent delays affecting the role the Savannah River Plant is to play in the nation's overall defense effort Work three shifts per day, seven days per week, throughout the fabrication program and for some ten to twelve weeks to come on the Building 10 test program."

A tabulation indicating by months the overtime premium hours and total man hours spent on the NYX Project appears in the Appendix as Exhibit "D".

XVIII - ESTIMATING

PRELIMINARY ESTIMATES

The Letter of Intent dated April 25, 1951, covering the initial scope of the NYX Project provided that a definitive subcontract would be negotiated within 120 days or a mutually acceptable extension. In order to establish a basis for the subcontract, all departments of New York Ship concerned with the project were directed on August 27, 1951, to prepare estimates on which the calculation of the fixed fee was to be based. Actual costs of the work to and including the week of August 26 were to be incorporated in the estimates, to which would be added remaining work and purchases yet to be made so far as they were known at the time.

The first estimate was based on the following broad groupings:

1. Developmental Work
2. Fabrication and Erection of Prototype "NYX" Unit
3. Test Facilities and Services
4. Test Operations
5. Fabrication of Four Production Units

As the result of cost studies by the various departments, du Pont was given an itemized estimate on October 19, 1951, which is summarized below:

<u>Material</u>	<u>Labor</u>		<u>Total</u>
\$5,379,609	\$4,276,176		\$ 9,655,785
		Overhead 60%	2,565,706
			<u>\$12,221,491</u>
		Fee (10%)	1,222,149
			<u>\$13,443,640</u>
		Total	

As a result of modification to the scope of work subsequent to the August 27, 1951, "cut-off" date and after negotiations with du Pont, the basic Scope of Work letter issued by du Pont on December 13, 1951, included a summary estimate (Order of Magnitude) for the project which differed from the initial estimate. The grand total at this date, including machine tools and provision for advancing wages and material prices was:

<u>Material</u>	<u>Labor</u>	<u>Total</u>
\$6,696,615	\$8,487,585	\$15,184,200

The total above was rounded to \$15,200,000 for contract purposes.

In March, 1952, an estimate was prepared for the fabrication of a stainless steel assembly known as the "Physics Laboratory Tank and Grid Beam Assembly". As transmitted to du Pont on March 19, 1952, the estimated price, including a fee of 10 per cent, was \$81,990. In revising the subcontract to cover this work, the figures were rounded to \$75,000 estimated cost and fee of \$7,500.

In August, 1952, New York Ship prepared an estimate for the fabrication of "deck plates" and five Forest Assemblies and arrived at a cost figure of \$743,015 and fee of \$59,440. In November the estimate was reviewed in the light of work actually completed by the end of October. As a result of this review it was determined that the estimated cost could be reduced to \$417,500 and fixed fee to \$33,400. The latter figures were incorporated in subcontract.

Late in 1952, a series of du Pont-New York Ship meetings were held concerning the possible conversion of the "NYX" Unit to a production unit to be designated "K" Unit. In order to determine the best way to make the conversion, estimates were prepared to cover the various possibilities as follows:

	<u>Estimated Cost</u>	<u>Fixed Fee</u>
1. Conversion of "NYX" Plenum to "K"	\$226,530	\$18,122
2. "NYX" Top Tube Sheet Assembly to "K"	107,205	8,576
3. "NYX" Main Tank to "K" plus new enclosure	124,027	9,922
4. "NYX" Bottom Tube Sheet Assembly to "K"	370,827	29,666
5. Fabrication of new "K" Main Tank	152,486	12,199
6. Fabrication of new "K" Bottom Tube Sheet Assembly	565,162	45,213

Based on cost and the condition of the assemblies of the "NYX" Unit, Items 1, 2, 4 and 5 above were selected. The estimated cost and fixed fee were reviewed and agreed upon in a modification to the subcontract as \$812,000 and \$72,000 respectively.

In the spring of 1953, New York Ship was requested to proceed with the fabrication of two Holding Racks. Fabrication of three additional Holding Racks was contemplated, and du Pont requested that an estimate be prepared for contract purposes showing the costs involved. On May 26, 1953, New York Ship submitted the following figures:

	<u>Estimated Cost</u>	<u>Fixed Fee</u>
1. Engineering work in revising tracings	\$2,119	\$170
2. Material purchases for Holding Racks	15,257	1,221
3. Approximation of material value reclaimed from other work under the subcontract	23,876	
4. Fabrication of initial two Holding Racks	83,997	6,720
5. Fabrication of three more Holding Racks	117,079	9,366

A revised estimate was requested by du Pont, to be based on a five-day, forty-hour week, with no overtime employed. The following revised estimate of Item 5, above was submitted on June 29, 1953:

	<u>Estimated Cost</u>	<u>Fixed Fee</u>
5. Fabrication of three more Holding Racks	\$66,339	\$5,307

(Additional material to be purchased was estimated as \$8,811)

As a result of the two estimates, the subcontract was modified to cover the materials and fabrication of the first two Holding Racks at an estimated cost of \$104,000 and fee of \$8,300. The fabrication cost of the three additional Holding Racks was estimated as \$75,000 with fee of \$6,000.

In July, 1953, New York Ship prepared an estimate for the fabrication of eight special tanks in accordance with Lummus Company Req. R-3269-SQ301B dated May 15, 1953. The estimated cost was \$54,975 and the fixed fee \$4,400. This work was not awarded to New York Ship.

Summarizing, the total estimated cost of work performed on the NYX Project to and including Modification No. 6 to the basic subcontract was \$16,683,500 and the total fixed fee was \$1,102,200.

XIX - COSTS

GENERAL DISCUSSION

The over-all estimated cost of the NYX Project, as developed from the original scope of work in 1951 and modified to cover changes in scope, was \$16,683,500, exclusive of fixed fee. The actual cost of the project proved to be very close to the estimates.

The cost of the project was affected considerably by the following factors:

1. Novelty
2. Quality Requirements
3. Urgency
4. Security

Because of the novelty of the undertaking and the lack of precedent, many early phases of the project were experimental in nature. Techniques had to be developed for many of the fabricating operations, including welding, machining, and boring.

The operating requirements of the units were such that they had to be fabricated with extreme care and accuracy. As previously mentioned in this report, the tolerances of the center-to-center distances of the tubes and the verticality between the Plenum and Top Tube Sheet tubes were extremely exacting, requiring development work to determine fabrication methods suitable for obtaining the necessary accuracy.

It was essential that virtually all welds be practically flawless. This requirement necessitated considerably more precautionary measures in the welding operations and more extensive checking of the welds than are encountered in normal practice.

Another major requirement of the units, governed by rigid specifications, was cleanliness or freedom from contamination. The problem of contamination of assemblies either through oxide scale at the welds, free iron imbedded in the surface of the stainless steel plate, or grease and dirt clinging to inaccessible parts of the interiors was difficult to overcome. Stainless welded parts, such as piping and elbows, supplied by outside vendors in preparation for the test operations in Building 10 were unacceptable in

regard to dimensions and weld quality in some instances and were scrapped because repair would have been more costly than replacement.

To insure accuracy of dimensions, high quality of materials and cleanliness, an extensive inspection program was required throughout the whole project. In some instances it was necessary to delay parts of the work to provide time for inspection. Special gauges and measuring devices were developed for checking dimensions and alignments very accurately. All critical welds were checked by X-ray, and many machined surfaces required close inspection for smoothness.

The urgency of the project had a major effect upon the over-all cost of the project, and made it necessary to take many steps in the interest of national defense that might have been avoided in a normal commercial project. For example, materials were ordered from several suppliers when it appeared that delivery would be slow. Subsequent cancellation entailed settlement costs but was acceptable as a form of "insurance". Materials were ordered and parts fabricated as fast as individual groups of drawings could be released. Design changes sometimes required the modification of tube sheets and other parts that had been fabricated. In the test operations of the "NYX" Unit, temporary pumps were used to gain time in starting up. Also, temporary heat exchangers were designed and fabricated to expedite the tests.

Labor charges were higher than normal because of the urgency of the project. Shift differentials and overtime amounted to a considerable figure, and where a choice existed between a faster but costlier means of doing a job and a slower, less costly method, it was necessary at times to choose the faster way.

Security represented not only a considerable expense in itself but increased materially other expenses. Information could not be disseminated freely and delays resulted from the restrictions on individual access to the operating areas.

Developmental work and testing of the "NYX" Unit and other facilities accounted for approximately 28 per cent of the total cost of the subcontract.

Although the project required a great amount of experimental and developmental work, which is inherently expensive, it should not be inferred that costs were disregarded. Throughout the project every operation was analyzed and performed in what was considered the most economical manner except in those instances where such action would not be in the national interest.

One of the major cost reduction items, jointly developed, was a radial drill method of line boring the Plenum-Top Tube Sheet Assemblies. By perfecting this method and eliminating the need for a special boring mill, an estimated saving of \$1,060,300 in labor, materials and overhead was made. Many other means were employed by du Pont and New York Ship for reducing costs, which when considered collectively, resulted in a substantial reduction.

COST SUMMARY

New York Ship kept individual accounts of costs according to a series of charge numbers designed to separate the major parts of the NYX Project. A summary of these charge numbers, a brief description of the accounts, and the final costs accumulated by New York Ship are included in the Appendix as Exhibit "E".

XX - CLOSING OF JOB

DISMANTLEMENT OF MATERIALS AND EQUIPMENT

DISMANTLEMENT OF TEST EQUIPMENT AND RESTORATION OF BUILDINGS

The dismantling and restoration program for the test phase of the NYX Project was divided into two main parts: (1) The work performed by New York Ship and (2) the sub-subcontracted demolition work by the Pantano Wrecking Company.

The work performed by New York Ship consisted of three main categories: (1) Dismantling of equipment and related facilities, (2) disposition of equipment and material, and (3) final repair and clean up of Buildings 3 and 10. The sub-subcontracted demolition work by the Pantano Wrecking Company was as follows: (1) Removal of all concrete pads and supports; (2) removal of the assembly area barricade, and the north barricade of Building 10 and offices therein; and (3) removal of the precision crane runway structural steel.

In the early preplanning stages of the Restoration Program, it became evident that savings could be realized by leaving certain NYX facilities as they were because the labor cost for their removal would exceed the salvage value of the material and equipment in these facilities. Agreement was reached between the Atomic Energy Commission, New York Shipbuilding Corporation and du Pont to leave the following facilities in an "as is" condition: (1) The barricade in Building 5, (2) the river pump house, (3) the 20-in. influent and effluent cooling water lines, (4) the 18-in. vitrified clay sewer and manhole in vicinity of the river pump house, (5) the 20-ft. boring mill in its new location in Building 3, and (6) the various offices and enclosures in adjacent to Buildings 10 and 3. This agreement resulted in an estimated saving of \$24,900.

DISPOSITION OF FABRICATION EQUIPMENT

At the direction of the Savannah River Plant Operating Department or the Atomic Energy Commission, all fabrication equipment was disposed of generally as follows:

1. Equipment retained on lease or rental basis was returned to the owners.

2. Capital equipment requested by the du Pont Operating Department was shipped to the Savannah River Plant.
3. Other capital equipment was shipped to various Government installations as directed by the Atomic Energy Commission.
4. The remaining excess material and equipment were disposed of by public sale.

In general all jigs, fixtures and tools, particularly those of a special nature, that might be required to build additional units of the "C" Unit design, or replacement expansion ring assemblies for the "R", "P", "L" and "K" Units, were shipped to the Savannah River Plant for storage.

DISPOSITION OF RECORDS

Article IX of the basic subcontract with du Pont provided that sketches, drawings, plans, etc., developed at New York Ship would become the property of the Atomic Energy Commission and be turned over to du Pont or disposed of as directed by that company.

The subcontract also provided that all other records in New York Ship's possession should be preserved for a period of five years after final settlement of the subcontract, or otherwise disposed of as agreed upon by the Government or New York Ship.

On March 15, 1954, and May 25, 1954, conferences were held at New York Ship with du Pont representatives to develop a program for the disposition of project records in accordance with contractual requirements.

New York Ship agreed that records considered property of New York Ship, which were to be retained in their custody for a five year period, would be carefully reviewed and audited for completeness by New York Ship before placing in storage. This review was to include such records as Accounting, Purchasing, Personnel and Stores.

Following these conferences master inventory lists of project records were prepared by New York Ship. These lists were reviewed with du Pont to insure that all pertinent record matter was being retained and that retention of duplicate or non-record matter was minimized.

By letter of June 21, 1954, from du Pont, New York Ship was provided with complete instructions and procedures

necessary to close into storage those project records considered property of the AEC. Before shipment, these records were placed in standard record cartons and indexed in accordance with established procedures. All such shipments were forwarded to du Pont in care of the Chief Supervisor of Records at the Savannah River Plant.

Contained in such shipments to du Pont were all shop drawings prepared by New York Ship for the project. Prior to shipment each shop drawing was cataloged and assigned an appropriate du Pont drawing number. A list of these drawings was transmitted to du Pont.

As New York Ship did not request retention of any records deemed property of the AEC, after completion of their work, no special provisions were required for post-contract retention or access.

XXI - CHRONOLOGY OF EVENTSYear 1951Date

April 25	Letter of Intent issued by du Pont
May 23	First stainless plate arrived at New York Ship
June 14	First overtime
June 18	Started fabrication "Eight-Foot Mock-Up"
July 31	"NYX" Unit tube center layout set at 7.021 in.
August 6	Cornell began construction of test facilities
September 1	"NYX" Unit fabrication began
September 7	First approved drawings "NYX" Unit received at New York Ship
October 27	"R" Unit fabrication began
November 15	"R" Unit Plenum tube center layout changed to 7.031 in.
November 29	"R" Unit Bottom Tube Sheet Assembly tube center layout changed to 7.014 in.
December 31	Cornell completed construction of test facilities in Building 10

Year 1952

February 17	Started "NYX" Unit line boring
March 3	"R" Plenum to Navy Yard
March 7	"P" Unit fabrication began
April 4	Completed "NYX" Unit line boring
April 23	Started "R" Unit line boring
May 20	"NYX" Unit fabrication completed
May 21	"NYX" Unit installed in Building 10 for test operations

Year 1952

June 5	"L" Unit fabrication began
June 6	Building 10 went under security restrictions
June 6	New York Ship authorized to fabricate "Physics Laboratory" Tank
July 23	Completed "R" Unit line boring
August 1	"R" Unit Tank and Bottom Tube Sheet Assemblies completed
August 2	Barge Shipment No. 1
October 28	"P" Unit Bottom Tube Sheet Assembly completed
October 30	"R" Unit Plenum and Top Tube Sheet Assemblies completed
November 1	Barge Shipment No. 2
November 7	"P" Plenum to Navy Yard
December 9	Du Pont - New York Ship meeting at Newark, Delaware to discuss "NYX" conversion to "K" and fabrication of "C" Unit

Year 1953

January 12	Started "P" Unit line boring
January 15	"P" Unit Main Tank completed
January 15	Barge Shipment No. 3
January 21	Fifth Telescope Actuator added to scope of work
February 26	Completed "P" Unit line boring
March 16	"L" Plenum to Navy Yard
March 23	New York Ship authorized to fabricate two Holding Racks
April 9	"K" Unit conversion began

Year 1953

April 15	"P" Unit Plenum and Top Tube Sheet Assemblies completed
April 18	Barge Shipment No. 4
April 20	"C" Unit fabrication began
April 29	Final Precision Crane demonstration
May 4	Building 10 testing terminated
May 9	Started "L" Unit line boring
May 12	Security restrictions removed from Building 10
June 3	"L" Unit Tank and Bottom Tube Sheet Assemblies completed
June 3	Barge Shipment No. 5
June 15	Pantano began demolition in Building 10
June 27	Completed "L" Unit line boring
July 16	New York Ship authorized to fabricate three additional Holding Racks
August 12	Pantano completed demolition of Building 10
September 19	"L" Unit Plenum and Top Tube Sheet Assemblies completed
October 2	"K" Unit conversion completed
October 2	Barge Shipment No. 6
November 24	"C" Plenum to Navy Yard

Year 1954

January 20	Started "C" Unit line boring
March 11	Completed "C" Unit line boring
March 25	Nitric Acid Wash "C" Unit
May 20	"C" Unit completed
May 20	Barge Shipment No. 7

APPENDIX

* 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

EXHIBIT A-1

NYX PROJECT ORGANIZATION CHART
NEW YORK SHIPBUILDING CORPORATION

EXHIBIT A-2

EXHIBIT A-3

NEW YORK SHIP

CAMDEN

CHAIRMAN
CHIEF EXECUTIVE

GENERAL COUNSEL

PRUITT COURSEN
OECHLER McLAUGHLINSECRETARY
TREASURER AND
CONTROLLER
J.E. ICENHOURASSISTANT TO
PRESIDENT
CH. DORE

SHIPBUILDING CORPORATION

CAMDEN, NEW JERSEY

NEW YORK SHIPBUILDING CORP.
CAMDEN, NEW JERSEY

APPROVED *H.W. Pierce* DATE 15TH MAR. 1954
PRESIDENT

EXHIBIT B-1

NYX PROJECTNEW YORK SHIPBUILDING CORPORATIONPERSONNEL ASSIGNED TO PROJECT

EXHIBIT B-2

NYX PROJECT

TOTAL FORCE CHART

ALL GROUPS

EXHIBIT C-1
(Pages 305 to 369)

GENERAL SPECIFICATION FOR INERT GAS SHIELDED METAL
ARC WELDING WITH CONSUMABLE ELECTRODE ON STAINLESS STEEL

SAVANNAH RIVER PLANT
PROJECT 8980

E. I. du Pont de Nemours & Company, Incorporated

Prepared by
New York Ship Building Corporation
Camden, New Jersey

Date June 16, 1952

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

6/17/52

General Specification For Inert Gas Shielded Metal
Arc Welding With Consumable Electrode On Stainless Steel

1.0 PROCESS:

1.1 Welding is to be done by aircomatic Welding Process (or equal) with the following types of equipment:

1.1-1 Manual Aircomatic Gun - semi-automatic manually operated unit, Airco Model #3, or equal.

1.1-2 Aircomatic Head - fully automatic unit for mounting on traveling carriage or other suitable fixture.

2.0 BASE METAL:

2.1 The base metal is to be Type 304 or Type 304L Stainless Steel unless otherwise noted, and must conform to Du Pont Specification SW 304M Grades 304 and 304L.

3.0 FILLER METAL:

3.1 The filler metal is to be type 308 or Type 308 with .05% maximum Carbon Stainless Steel. All wire for Aircomatic Welding must be cleaned and coiled particularly for this process.

4.0 POSITION:

4.1 Welding with the Manual Aircomatic Gun may be done in any position with flat position to be used where possible. Welding with the Automatic Aircomatic Head can be done in flat position only.

5.0 PREPARATION OF BASE MATERIAL:

5.1 The edges or surfaces to be welded shall be prepared by machining, chipping or grinding. Powder cutting may be used for rough cutting, provided final preparation is made as above with at least 3/16" of metal removed from the burnt edge. All joints and adjoining plate surfaces must be clean and free from scale, dirt, paint, grease, oil and moisture.

(Continued from Sheet No. 1)

General Specification for Inert Gas Shielded Metal
Arc Welding With Consumable Electrode on Stainless Steel

6.0 CURRENT:

6.1 All welding is to be done, using Direct Current Reverse Polarity.

7.0 ARGON:

7.1 A special mixture of Argon, Aircomatic Gas #2, as specified by the Air Reduction Laboratory to eliminate weld undercut, is to be used for shielding. Welding must be done in locations relatively free from drafts, so that the Argon shield will not be destroyed. For high currents in deep groove butts with the automatic head, it is desirable to use an auxiliary shielding gas behind the torch with the gas introduced under a hood or trailer attached to the torch.

8.0 WELDING TECHNIQUE:

8.1 The joint design and operating data for each pass, including size of wire, current voltage, wire feed, travel speed and Argon flow, shall be as specified for each type and position of joint to be used with each type of equipment. Back chipping, if required to insure complete penetration, shall be done where specified. Each individual bead shall be cleaned with a mechanically driven stainless steel wire brush or hand stainless steel wire brush and inspected for defects, such as cracks, pits, porosity, etc., which shall be removed and repaired prior to depositing subsequent beads.

9.0 FIT UP:

9.1 All fit-ups shall be as accurate and uniform as possible, to take full advantage of this automatic and semi-automatic welding process. Temporary fixtures and clamps shall be used where necessary to insure good fit and to prevent excessive distortion during welding. Welds may be cooled immediately with either air or water if necessary, to help minimize distortion.

10.0 DEFECTS:

10.1 Defects in the welds are to be removed by chipping, grinding or machining. Repair welds shall be made, with either the Manual Aircomatic Gun or Automatic Aircomatic Head.

(Continued from Sheet No. 2)

General Specification for Inert Gas Shielded Metal
Arc Welding With Consumable Electrode On Stainless Steel

11.0 QUALIFICATION:

11.1 Procedure Specifications shall be qualified in accordance with Section IX of the A. S. M. E. Boiler Construction Code, Standard Qualification for Welding Procedure and Welding Operator and Du Pont Specification No. 3034.

11.2 Welding operators shall be qualified for the operation of each type of equipment in any position in accordance with Section IX of the A. S. M. E. Boiler Code and Du Pont Specification No. 3034.

12.0 INSPECTION:

12.1 All finished welds shall present a suitable and uniform appearance and be of the proper size. All butt welds shall be X Rayed, unless waived by the inspector, due to the inaccessibility and have a quality equal to the requirements for U68 Unfired Pressure Vessels of the A. S. M. E. Boiler Code. Quality of the tube welds with the Special Tube Welders shall be controlled by the making of sample tube welds to be cross-sectioned and macro etched, in accordance with Du Pont Specification No. 3034.

New York Shipbuilding Corporation

/s/ R. D. Bradway
Welding Engineer

(Sheet 1 of 2)

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

3/13/52

Procedure Specification for Inert Gas Metal Arc
Welding With Consumable Electrode on Stainless Steel

Index of Detail Procedure Specifications

Automatic Aircomatic Head

<u>Spec. No.</u>	<u>Joint</u>
AH-1c	1" Double Vee
AH-2	3/8" Single Vee welded both sides
AH-3	1/2" Single Vee welded both sides
AH-4	1/2" Double Vee
AH-5	1/8" Butt welded from one side

Special Aircomatic Tube Welder

<u>Spec. No.</u>	<u>Joint</u>
T-1a	Large Tubes in 1" Plate
T-1-1	Large Tube in 1" Plate
T-2	Small Tubes in 1" Plate

Manual Aircomatic Gun

<u>Spec. No.</u>	<u>Joint</u>	<u>Position</u>
MG-101	Small Tubes in 1" Plate	Flat
MG-102	1" Double Vee	"
MG-103	1/2" Single Vee with Sealing Bead	"
MG-104	1/2" Double Vee	"
MG-105	1/2" Single Vee on Backing	"
MG-105-1	1/2" Single Vee on Backing	"
MG-106	3/8" Single Vee on Backing	"
MG-107	7/8" Single Vee on Backing	"
MG-108	3" Double Vee	"
MG-109	1/4" Fillet	"
MG-110	Staybolt in 7/8" Plate	"
MG-111	Flange to Pipe	"

(Continued on Sheet No. 2)

(Sheet 2 of 2)
(Continued from Sheet No. 1)

<u>Spec. No.</u>	<u>Joint</u>	<u>Position</u>
MG-201	1/2" Single Vee with Sealing Bead	Horizontal
MG-202	1/2" Double Vee	"
MG-202-1	1/2" Double Vee	"
MG-203	Tee Joint 5/8" Gusset to Tube Sheets	"
MG-204	7/8" Single Vee on Backing	"
MG-205	1/4" Fillet	"
MG-206	Tee Joint 1/2" Tank to Tube Sheet	"
MG-301	1/2" Single Vee with Sealing Bead	Vertical
MG-302	3/16" Single Vee	"
MG-303	1/4" Fillet	"
MG-401	1/4" Fillet	Overhead
MG-402	1/2" Single Vee	"

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 2-21-52

Procedure Specification No. T-2

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Special Aircomatic Tube Welder

Type of Joint: Small Tube in 1" Plate

Position: Flat

Preparation of Joint and Pass Sequence:

Operating Data

<u>Tube Size</u>	<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Volts</u>	<u>Weld Time</u>	<u>Argon (CFH)</u>
2" O.D.	1	1/16"	340	30	30 Sec's	70
1-5/8" O.D.	1 2	1/16"	340	24 30	2 Continuous passes at max. speed of welder	70

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 9-14-51

Procedure Specification No. AH-2

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Head

Type of Joint: 3/8" Single Vee with Sealing Bead

Position: Flat - Longitudinal Seam in Pipe

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Volts</u>	<u>Speed (ipm)</u>	<u>Argon (CFH)</u>
1	1/16"	220	25	18	35
2	1/16"	250	23	18	55
3	1/16"	240	24	13	30 Auxiliary
					55
					30 Auxiliary

Notes: - Pass No. 1 may be made with Hand Gun mounted on Radiograph.

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date _____

Procedure Specification No. AH-3

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Automatic Aircomatic Head

Type of Joint: 1/2" Single Vee welded both sides

Position: Flat

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Volts</u>	<u>Speed (ipm)</u>	<u>Argon (CFH)</u>
1, 3	.0625	350	23-25	27-1/2	55 Main 25 Aux.
2	"	"	"	31	"
4, 5, 6, 7	"	"	"	30	"

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 3-15-52

Procedure Specification No. AH-5

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Automatic Aircomatic Head

Type of Joint: 1/8" Butt welded from one side

Position: Flat

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1	.045	120	23	50

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 2-21-52

Procedure Specification No. T-1a
(Supersedes T-1)

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Special Aircomatic Tube Welder

Type of Joint: Large Tube in 1" Plate

Position: Flat

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Tube Size</u>	<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Volts</u>	<u>Weld Time</u>	<u>Argon (CFH)</u>
5" O.D.	1	1/16"	350	31	1 min-15 Sec's	70
5-1/4" "	1	"	"	"	1 " 26	"
4" "	1	"	"	"	1 " 03	"

Notes: Tube Weld time to give 1" to 1-1/2" overlap of weld.

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 6-19-51

Procedure Specification No. MG-101

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: Small Tube in 1" Plate

Position: Flat

Preparation of Joint and Pass Sequence:

Operating Data

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1	1/16"	300	200	30

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 2-27-52

Procedure Specification No. AH-1c
(Supersedes H-1b)

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Automatic Aircomatic Head

Type of Joint: 1" Double Vee

Position: Flat

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Volts</u>	<u>Speed (ipm)</u>	<u>Argon (CFH)</u>
1,3,4,6,9,12	.0625	350	23 to 25	27-1/2"	55 Main 25 Auxiliary
2,5	"	"	"	31"	"
7,8,10,11	"	"	"	30"	"

Notes: - 1. No back chipping required
2. Auxiliary Argon Coverage using hood trailer in rear.

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 8-31-51

Procedure Specification No. MG-102

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: 1" Double Vee

Position: Flat

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1	0.0625	300	200	35
2	0.0625	300	200	35
3	0.0625	300	200	35
4	0.0625	300	200	35
5	0.0625	300	200	35
6	0.0625	300	200	35

- Notes:
1. No back chipping required
 2. Pass sequence may be varied if necessary to maintain alignment.

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 8-31-51

Procedure Specification No. MG-103

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: 1/2" Single Vee with Sealing Bead

Position: Flat

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1	.045	170	224	30
2 to 4	.045	190	255	30

Notes: No Back Chipping Required.

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 3-3-52

Procedure Specification No. MG-104

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: 1/2" Double Vee

Position: Flat

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1	.045	170	220	30
2 to 4	.045	190	255	30

Notes: No Back Chipping required.

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

AIM

Association for Information and Image Management

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

Centimeter

Inches

MANUFACTURED TO AIIM STANDARDS
BY APPLIED IMAGE, INC.

4 of 4

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 3-3-52

Procedure Specification No. MG-105

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: 1/2" Single Vee on Backing

Position: Flat

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1 to 3	.0625	320	150	30
--- or ---				
1 to 3	.045	190	255	30

Notes: 1. Backing Strip to be chipped off after welding where so specified.

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date _____

Procedure Specification No. MG105-1

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: 1/2" Single Vee on Backing

Position: Flat

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1 to 3	.0625	330	150	30

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 3-3-52

Procedure Specification No. MG-106

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: 3/8" Single Vee on Backing

Position: Flat

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1 to 2	.045	190	255	30

Notes: 1. Backing Strip to be chipped off after welding where so specified.

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 3-3-52

Procedure Specification No. MG-107

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: 7/8" Single Vee on Backing

Position: Flat

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1	.045	190	220	30
2 to 10	.0625	330	150	30

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 3-3-52

Procedure Specification No. MG-108

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: 3" Double Vee

Position: Flat

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1 Side 1	.045	180	235	30
2 to 23	.0625	290	150	30

Other Side
All .0625 Wire

- Notes:
1. Work to be turned over and welding balanced as required to maintain alignment.
 2. Back Chip to solid metal before starting weld on second side.

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 3-3-52

Procedure Specification No. MG-109

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: 1/4" Fillet

Position: Flat

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1	1/16"	310	230	35
2	1/16"	310	230	35
		---- or ----		
1	.045	190	280	30
2	.045	190	280	30

Notes: 1/16" Wire recommended for deep penetration

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 9-10-51

Procedure Specification No. MG-110

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: Staybolt in 7/8" Plate

Position: Flat

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1	0.045	225	250	35
2	0.0625	250	150	"
3	0.0625	250	150	"
4	"	"	"	"
5	"	"	"	"
6	"	"	"	"

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date _____

Procedure Specification No. MG-111

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: Flange to Pipe

Position: Flat

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1 - 4	.045	190	255	30

Notes: 1. No back Chipping required for 100% penetration

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 3-3-52

Procedure Specification No. MG-201

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: 1/2" Single Vee with Sealing Bead

Position: Horizontal

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
All	.045	200	265	30

- Notes:
1. Back chip to solid metal prior to welding seal bead.
 2. Sequence of passes may be varied to maintain alignment.

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 3-15-52

Procedure Specification No. MG-202

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: 1/2" Double Vee

Position: Horizontal

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1 to 8	.045	180	200	30

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 3-3-52

Procedure Specification No. MG-202-1

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: 1/2" Double Vee

Position: Horizontal

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1	.045	170	224" P/M	30
2 to 4	.045	190	255" "	30
5	.045	170	224" "	30
6 to 7	.045	190	255" "	30
8	.045	170	224" "	30

- Notes:
1. Back chip to solid metal prior to starting weld on second side
 2. Pass sequence may be varied to maintain alignment

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 9-20-51

Procedure Specification No. MG-203

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: Tee Joint - 5/8" Gusset to Tube Sheets

Position: Horizontal

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1	0.0625	305	220	35
2	"	"	"	"

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N. Y. X.

Date 3-10-52

Procedure Specification No. MG-204

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: 7/8" Single Vee Backing

Position: Horizontal

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1 to 24	.045	190	255	30

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 3-15-52

Procedure Specification No. MG-205

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: 1/4" Fillet

Position: Horizontal

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1 - 2	.045	190	255	30

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 3-15-52

Procedure Specification No. MG-206

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: 1/2" Double Bevel Tee Joint

Position: Horizontal

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1 to 5	.0625	330	150	30

Notes: Twin Arc Root Beads.

New York Shipbuilding Corporation
Camden, New Jersey

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 3-15-52

Procedure Specification No. MG-206-1

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joint: 7/16" Fillet

Position: Horizontal

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1 - 6	.0625	330	150	30

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

New York Shipbuilding Corporation
Camden, New Jersey

Du Pont Project 8980 - N.Y.X.

Date 3-3-52

Procedure Specification No. MG-301

Aircomatic Welding Process on Type 304 ELC Stainless Steel

Equipment: Manual Aircomatic Gun

Type of Joing: 1/2" Single Vee with Sealing Bead

Position: Vertical

Preparation of Joint and Pass Sequence:

Operating Data:

<u>Pass No.</u>	<u>Wire Dia.</u>	<u>Amps</u>	<u>Wire Feed (ipm)</u>	<u>Argon (CFH)</u>
1 to 7	.045	180	235	30

- Notes:
1. All weld beads to be run down
 2. Back chip to solid metal prior to welding seal bead
 3. Sequence of passes may be varied to maintain alignment

New York Shipbuilding Corporation

/s/ R. D. Bradway,
Welding Engineer

EXHIBIT C-2
(Pages 371 to 376)

Specification 3034
Sheets 1 to 5

WELDING PROCESS AND OPERATOR QUALIFICATION
AND CONTROL
PROJECT 8980 - 100 AREA

Signed By James A. Collins

Date September 21, 1951

E. I. du Pont de Nemours & Co., Inc.
Wilmington, Delaware

WELDING PROCESS AND OPERATOR QUALIFICATION

AND CONTROL

PROJECT 8980 - 100 AREA

1.0 Scope

1.1 This specification sets forth minimum requirements for qualification of welding procedures and operators, and weld-quality control.

2.0 Qualification

2.1 All welding procedures and operators should be qualified in accordance with Section IX of the 1949 A. S. M. E. Boiler Construction Code, except as noted in paragraphs 2.2 to 2.6 inclusive. All welding must meet U68 code quality requirements.

2.2 The procedure for making the fillet welds between the 5.00" O.D. x 4.385" I.D. type 304 stainless steel tubes into the plenum chamber, and the upper and lower special tube sheets shall be qualified as follows:

2.2-1 Using the proposed production welding procedure, weld five type 304 stainless steel tubes 5" O.D. shall be welded into a 1" or 1-1/4" thick type 304 stainless steel plate on 7" centers.

2.2-2 Each of the tubes and test welds (2.2-1) including part of the plate shall be cut out and sectioned parallel to the bore of the tube (transverse to the weld) into quarters. The cut faces across the weld shall be ground flat and finished with a 120 grit abrasive-paper or belt and acid etched to develop the weld structure. (See paragraph 2.6)

2.2-3 All sections of all fillet welds shall show a minimum vertical leg along the tube of 1/2" with a minimum penetration below the surface of the plate of 1/4", and a horizontal leg from the tube O.D. surface out onto the plate of 1/4" minimum. The welds shall be sound with no evidence of porosity, cracks, slag, nor undercutting.

2.2-4 After completing the examinations of 2.2-3 the specimens shall be given a root bend test to expose the root of the weld. The root shall be clean, and sound with no evidence of porosity or cracks.

2.3 The procedure for making the fillet welds between the 1.875" O.D. x 1.500" I.D. or 1.625" x 1.313" I.D., type 304 stainless steel tubes and the plenum chamber and the upper special tube sheet shall be qualified as follows:

2.3-1 Using the proposed production welding procedure, weld five type 304 stainless steel tubes 1.875" O.D. or 1.625" O.D. into a 1" or 1-1/4" thick type 304 stainless steel plate.

2.3-2 Cut out the tubes and welds with part of the plate and prepare for examination per paragraph 2.2-2.

2.3-3 All sections of all the fillet welds (2.3-1) shall show a minimum vertical leg along the tube of 5/16", with a minimum penetration of 1/4" below the surface of the plate, and a horizontal leg from the tube O.D. out onto the plate of 1/4" minimum. The welds shall be sound with no evidence of porosity, cracks, slag, nor undercutting.

2.4 The procedure for welding the 1-3/4", 2", and 2-1/4" diameter type 304 stainless steel stay bolts into the plenum chamber shall be qualified as follows:

2.4-1 Using the proposed production welding procedure weld six stay bolt test specimens. The test specimen shall consist of a single stay bolt welded into the center of a 12" square or a 12" circle of type 304 stainless steel 7/8" thick. The stay bolt on all six specimens shall extend 1/8" above the top of the plate. On three specimens the stay bolt shall extend below the plate 2 to 4 inches and on the other three the stay bolt shall extend 15 inches below the bottom of the plate.

2.4-2 The three stay bolt specimens with the 3" - 4" extension below the plate shall be sectioned and prepared for examination in accordance with the procedure given in paragraph 2.2-2. For this soundness-penetration test, the minimum diameter of stay bolt which may be used is 1-1/2"

2.4-3 All sections of the stay-bolt weld shall show complete penetration through the $7/8$ " thick plate. The welds shall be sound with no evidence of porosity, cracks, slag, nor undercutting.

2.4-4 The three stay bolts specimens with the 15" extension below the bottom of the $7/8$ " plate shall be used for physical tests. The end of the bolt extending through the plate shall have a 2" diameter for a length of 4", and the balance of the stay bolt shall have a $2-1/4$ " diameter, exclusive of the transition section from the 2" diameter to the $2-1/4$ " diameter. The transition shall have a 4 to 1 taper and there shall be a smooth intersection between the tapered and cylindrical sections of the bolt. The bolt shall be tested in tension to determine the load and unit stress to pull the bolts down through the plate from the underside. These three stay bolt specimens shall be sent to the E. I. du Pont de Nemours & Co., Inc., Engineering Department, Engineering Research Laboratory, Experimental Station, Wilmington, Delaware, attention C. B. Cameron.

2.5 Special Hydrostatic and Hydrodynamic Test Units

2.5-1 A pressure test unit shall be made which shall consist of one type 304 stainless steel tube 5" O.D. welded into the center of two 1" or $1-1/4$ " thick type 304 stainless steel circles 25" O.D. spaces 8 to 12" apart, using the procedure qualified in paragraph 2.2. A $3/8$ " thick type 304 stainless steel wrapper sheet shall be welded around the unit to complete a closed tank. The 5" O.D. tube shall extend $1/2$ " beyond one plate and 6" beyond the other plate. Two standard $3/4$ " half couplings shall be welded to the wrapper sheet 180 degrees apart, and at opposite ends of the unit.

2.5-2 A pressure test unit shall be made which shall consist of five type 304 stainless steel $2-1/4$ " diameter stay bolts welded into two type 304 stainless steel circles $31-3/4$ " diameter by $7/8$ " thick spaces 8 to 12" apart using the welding procedure qualified in paragraph 2.4. One stay bolt shall be at the center with the other four distributed around it 90 degrees apart on a circle of $22-1/2$ " diameter. The stay bolts shall not extend beyond the plates more than $1/8$ ". A $3/8$ " thick type 304 stainless steel wrapper sheet shall

be welded around the unit to complete a closed tank. Two standard $3/4$ " half couplings shall be welded to the wrapper sheet 180 degrees apart and at opposite ends of the unit.

2.5-3 A pressure test unit shall be made which shall consist of seven 5" O.D. type 304 stainless steel tubes and six 1.875" or 1.625" O.D. type 304 stainless steel tubes welded into two type 304 stainless steel circles 30" diameter x 1" thick spaces 8 to 12" apart, using the welding procedures qualified in paragraphs 2.2 and 2.3. The 5" O.D. tubes shall be spaced on 7" centers on an hexagonal pattern with one tube at the center, and the six remaining distributed around the center one at 60 degree intervals. The six 1.875" O.D. or 1.625" O.D. tubes shall be distributed one next to each of the outer 5" O.D. tube so as to duplicate the tube pattern in the plenum chamber. The 5" O.D. tubes shall extend $1/2$ " beyond the one plate, and 6" beyond the other plate. The 1.875" or 1.625" O.D. tubes shall extend not more than $1/8$ " beyond both plates. A $3/8$ " thick type 304 stainless steel wrapper sheet shall be welded around the unit to complete a closed tank. Two standard $3/4$ " half couplings shall be welded to the wrapper sheet 180 degrees apart and at opposite ends of the unit.

2.5-4 The special test units made in 2.5-1, 2.5-2 and 2.5-3, shall be forwarded to the E. I. du Pont de Nemours & Co., Inc., Engineering Department, Engineering Research Laboratory, Experimental Station, Wilmington, Delaware, attention of C. B. Cameron. They will be tested as follows:

- a. Hydrostatic test at 500 lb./sq.in.
- b. Freon or helium leak test
- c. Hydrodynamic cycle test, 0-500 lb./sq.in. until failure or for a maximum of 1 million cycles
- d. Freon or helium leak test
- e. Section and examine welds

2.6 Etchants to develop weld structure

- 2.6-1 *28 parts by vol. of 65% nitric acid
 *12 parts by vol. of 31.5% hydrochloric acid
 * 2 parts by vol. of 48% by hydrofluoric acid

Specification No. 3034
 Sheet 4
 September 21, 1951

Immerse in etchant at 150 degrees F. (max.) for sufficient time to develop weld structure. Rinse thoroughly in water and dry. Note: This etchant is very active and can produce serious burns on contact with the skin. Body contact must be avoided.

2.6-2 *1 part by vol. of 65% nitric acid

*3 parts by vol. of 31.5% hydrochloric acid

Immerse in cold etchant for sufficient time to develop weld structure, and rinse thoroughly with water and dry. This etchant is not so active as 2.6-1 but can produce burns. Therefore, body contact must be avoided.

* denotes commercial acid concentrations.

3.0 Quality Control

3.1 Butt Welds

3.1-1 All welds shall be X-ray radiographed, and shall meet the requirements of the A. S. M. E. 1949 Boiler Code, Section VIII paragraph for U68 quality.

3.2 Fillet Welds 5-5 1/4" O.D. Tubes.

3.2-1 Each automatic Aircomatic fillet welder shall be checked at the beginning of each 8-hour shift or after each 50 welds, whichever is the greater, and/or after a major machine adjustment such as a change in current, voltage, gas flow, rate of rotation, etc. or the use of weld wire or gas from a different supplier.

3.2-2 The control test shall consist of welding a 5" O.D. stainless steel tube into a 1" thick 304 stainless steel plate. This test coupon shall be sectioned, examined, and meet requirements of paragraphs 2.2-2 and 2.2-3.

3.3 Fillet Welds 1-7/8" O.D. tubes.

3.3-1 A qualifying test shall consist of welding a 1-7/8" O.D. 304 stainless steel tube into a 1" thick 304 stainless steel plate. Joint geometry, bevel, fit-up shall be identical with those used in actual equipment welds. The test coupon shall be sectioned, examined, and meet requirements of paragraphs 2.3-2 and 2.3-4.

EXHIBIT D

NYX PROJECTNEW YORK SHIPBUILDING CORPORATIONTotal Hours and Overtime Hours

[REDACTED]

[REDACTED]

E. I. DU PONT DE NEMOURS & CO., INC.
WILMINGTON, DELAWARE

N Y S CHARGE NO	DESCRIPTION	DIRECT SALARY & WAGES	
		CURRENT MONTH	TO DATE
8001	Experimental Work	-	34,273.92
8002	Security Processing & Gen'l Office	542.51	265,950.26
8003	Telephone Services	-	-
8004	Retroactive Pay Adjustment	-	163,315.38
8005	Overtime Premium	CR 14.06	655,418.75
8006	Supervisory Force	1,056.00	205,858.50
8007	Training Men	-	11,003.07
8008	Temporary Power	-	-
8009	Misc. Office Supplies	-	-
8010	Extra Shift Premiums	-	143,817.12
8011	Misc. Shop Supplies	-	5,265.35
8012	Operators Time Sub-Sta. S.Yd. Only	-	31,826.14
8013	Sale of Scrap or Equipment	-	1,005.51
8014	Hand & Power Tools	-	-
(1) 8015	Pickling, Sandblasting - NYX Unit	-	4,870.31
(2) 8016	" " - R,P,L&K Units	-	28,898.80
8017	Lighting, Bldg. #3 & #10	-	446.98
8018	Safety Expense Bldg. #10	-	10,611.06
8019	Apply Siding & Tile	-	767.90
8020	Addl.Clean.Bldg.#3
 (OverStd.Pract.)	-	60,989.74
(2) 8021	Cleaning of Oil Skin Suits	-	11.97
8022	Rehabilitating So. Yard Gate House	-	332.16
(1) 8023	Cleaning of Various Parts of NYX Unit	-	245.04
(2) 8024	" " " " " "R" "	-	24.06
(2) 8025	" " " " " "P" "	-	47.96
(2) 8026	" " " " " "L" "	-	-
(2) 8027	" " " " " "K" "	-	-
(3) 8028	Constructing One (1) Steel Tank	-	79,173.15
8029	Rehabilitate Room & Bldg. #3	-	1,306.72
8030	Renovation of Women's Wash Room	-	2,687.48
8031	Repairing Entrance to So. Yd. Park. Lot	-	-
8032	Fabricate Forest Structures, Plates, Etc.	-	248,585.35

EXHIBIT E

ING CORPORATION
N. J.
ROGRAM

MONTH August 1954
INCL. PAYROLL - WEEK ENDING August 15, 1954
MONTH ENDING August 31, 1954

INDIRECT OVERHEAD		MATERIAL PURCHASES		TOTAL	
CURRENT MONTH	TO DATE	CURRENT MONTH	TO DATE	CURRENT MONTH	TO DATE
-	21,455.26	-	3,908.49	-	59,637.67
226.77	136,633.90	17.22	14,784.36	786.50	417,368.52
-	-	92.85	23,425.77	92.85	23,425.77
-	77,212.54	-	-	-	240,527.92
5.88	336,982.12	-	-	CR 19.94	992,400.87
441.41	103,094.95	-	-	1,497.41	308,953.45
-	5,368.92	-	-	-	16,371.99
-	-	-	335,707.02	-	335,707.02
-	-	.84	2,316.91	.84	2,316.91
-	72,368.12	-	-	-	216,185.54
-	2,800.80	-	59,865.23	-	67,931.38
-	15,987.38	-	-	-	47,813.52
-	508.18	-	CR 27,401.10	-	CR 25,887.41
-	-	-	561.75	-	561.75
-	2,165.24	-	18,374.24	-	25,409.79
-	14,629.27	-	15,490.20	-	59,018.27
-	122.58	-	528.52	-	1,098.08
-	4,572.57	-	1,683.15	-	16,866.78
-	406.26	-	928.81	-	2,102.97
-	29,217.34	-	4,714.77	-	94,921.85
-	6.58	-	524.95	-	543.50
-	154.88	-	111.91	-	598.95
-	122.57	-	1,428.00	-	1,795.61
-	13.24	-	4,171.00	-	4,208.30
-	22.95	-	8,060.00	-	8,130.91
-	-	-	10,372.00	-	10,372.00
-	-	-	12,913.25	-	12,913.25
-	38,444.09	-	6,423.94	-	124,041.18
-	712.41	-	334.21	-	2,353.34
-	1,478.03	-	1,059.16	-	5,224.67
-	-	-	200.00	-	200.00
-	122,479.09	-	148,796.75	-	519,861.19

NEW YORK SHIPBUILDING
CAMDEN
N. Y. X.

MONTHLY COST REPORT TO:

E. I. DU PONT DE NEMOURS & CO., INC
WILMINGTON, DELAWARE

N Y S CHARGE NO	DESCRIPTION	DIRECT SALARY & WAGES	
		CURRENT MONTH	TO DATE
8033	Construct Soundproof Room	-	105.24
8034	Reversing #4 Coupling Halves	-	90.13
8035	Construct Enclosure, Paint, Etc.	-	7,014.84
8036	Machining Bearing Bushing	-	13.17
8037	Dismantling Equipment, Etc., Bldg. #3	419.50	25,262.81
8038	Salvage of Items in Bldg. #3	3.87	812.98
8039	Dismantling Equipment in Bldg. #10	-	83,180.05
(4) 8040	Salvage Items in Bldg. #10	-	195.87
(4) 8041	Overtime Premium "C" Unit Construction	-	99,984.50
(4) 8042	Shift Time for "C" Unit	-	31,927.99
(4) 8043	Drying Out Top & Bottom Tube Sheets	-	3,719.61
8044	Demolition of Facilities in Bldg. #10	-	-
8046	Production Bonus Plan	-	24,900.60
(1) 8101	Constructing One (1) Unit	-	774,310.87
(5) 8151	Testing Unit - NYX	-	280,832.63
(5) 8152	Operations Expense-Testing NYX Unit	-	329,124.83
(5) 8153	Misc'l Repairs	-	34.00
(2) 8201	Constructing One (1) "R" Tank Unit	-	472,863.74
(2) 8202	" One (1) "P" " "	-	601,875.94
(2) 8203	" One (1) "L" " "	-	724,388.49
(2) 8204	" One (1) "K" " "	-	69,383.19
(4) 8205	Construction of "C" Unit Plenum	-	266,674.35
(4) 8206	" " "C" " Top Tube Sht.	-	214,225.18
(4) 8207	" " "C" " Bottom Tube Sht.	-	341,470.52
(4) 8208	" " "C" " Tank	-	105,707.94
(4) 8209	Conversion of Top Tube Sheet	-	64,602.22
(4) 8210	" " Plenum	-	98,659.79
(4) 8211	" " Bottom Tube Sheet	-	133,533.35
8212	Fabricate Holding Rack "R" Unit	-	22,343.02
8213	" " "P" " "	-	18,136.99
8214	" " "L" " "	-	10,545.17
8215	" " "K" " "	-	10,904.26
TOTALS			

INDING CORPORATION
N. N. J.
PROGRAM

MONTH August 1954
INCL PAYROLL - WEEK ENDING August 15, 1954
MONTH ENDING August 31, 1954

INDIRECT OVERHEAD		MATERIAL PURCHASES		TOTAL	
CURRENT MONTH	TO DATE	CURRENT MONTH	TO DATE	CURRENT MONTH	TO DATE
-	57.64	-	87.97	-	250.85
-	49.20	-	-	-	139.33
-	3,427.82	-	3,802.89	-	14,245.55
-	6.20	-	-	-	19.37
175.35	10,812.37	-	2,832.65	594.85	38,907.83
1.62	342.41	CR 4,043.08	CR 26,983.85	CR 4,037.59	CR 25,828.46
-	40,421.86	-	196.88	-	123,798.79
-	95.46	CR 52.50	CR 35,229.64	CR 52.50	CR 34,938.31
-	49,638.13	-	-	-	149,622.63
-	15,835.47	-	-	-	47,763.46
-	1,777.33	-	1,110.26	-	6,607.20
-	-	-	39,061.00	-	39,061.00
-	8,551.22	-	-	-	33,451.82
-	429,106.67	-	656,553.41	-	1,859,970.95
-	136,274.45	-	365,139.19	-	782,246.27
-	157,755.38	-	48.34	-	486,928.55
-	16.28	-	62.37	-	112.65
-	235,825.55	-	107,646.48	-	1,116,335.77
-	295,573.08	108.78	365,919.50	108.78	1,263,368.52
-	360,286.60	23.87	307,859.31	23.87	1,592,534.40
-	33,775.44	-	32,696.90	-	135,855.53
-	131,431.17	2.10	34,783.19	2.10	532,888.71
-	105,193.11	-	168,589.39	-	488,007.68
-	168,945.57	-	247,619.07	-	758,035.16
-	51,890.24	-	36,783.14	-	194,381.32
-	32,043.59	-	6,359.78	-	103,005.59
-	49,137.40	-	5,636.83	-	153,434.02
-	66,122.88	-	16,046.23	-	215,702.46
-	10,769.73	-	5,563.70	-	38,676.45
-	8,867.08	-	2,916.11	-	29,920.18
-	5,257.95	-	1,236.89	-	20,040.01
-	5,437.00	-	3,559.03	-	19,900.29

NEW YORK SHIPBUILDING
CAMDEN
N. Y. X.

MONTHLY COST REPORT TO:

E. I. DU PONT DE NEMOURS & CO., INC.
WILMINGTON, DELAWARE

N Y S CHARGE NO	DESCRIPTION	DIRECT SALARY & WAGES	
		CURRENT MONTH	TO DATE
	8216 Fabricate Holding Rack "C" Unit	-	11,284.34
(2)	8217 L&M for Changes to NYX Tank Encl.	-	6,962.93
(4)	8218 Six Lip Extensions & Three Form Slvs.	-	3,153.06
	8219 Repairs to Expansion Ring - "C" Unit	-	5,222.47
	8601 Automatic Airromatic Units - Welders	-	66,685.69
	8602 Maintenance Radial Drills	-	4,635.56
	8603 Clearing Bldg. #10 So. Yard	-	2,864.16
	8604 Airromatic Gun Assemblies - Welders	-	11,042.77
	8605 Radiographs - Welders	-	655.07
	8606 Electrode Holders - Welders	-	13.11
	8607 Motor Type Welders	-	3.29
	8608 Cutting Equipment	-	14.07
(5)	8609 Steel for Pump & Motor Foundations	-	14.20
(5)	8610 Induction Motors - 1500 H.P.	-	458.99
(5)	8611 Electric Power Supply Equipment	-	19,084.01
(5)	8612 Crane Runway	-	7,882.77
(5)	8613 Racks & Monorail Supports	-	155.87
	8614 Handling Office Furniture, Etc., Equip.	-	106.52
(5)	8615 Structural Steel for Tank Supports	-	540.16
(5)	8616 " " " Barricades	-	217.71
(2)	8617 Moving Welding Positioner	-	1,809.31
(2)	8618 Preparing Boring & Facing Mill	-	1,717.11
(5)	8619 Electric Service for Pump	-	1,264.01
	8620 Repairing Cranes	-	995.41
	8621 Check 350,000 C.M. Lead Cable	-	1,225.81
	8622 Office Equipment	-	585.91
(5)	8624 Monorail System with Hoists	-	550.21
	8625 Portable Platform Scale, Cap. 1000#	-	1.61
(5)	8626 One (1) Gould Control Battery	-	28.81
(5)	8627 Re-inforcing Steel	-	51.01
(5)	8628 Top-Running Ton Crane	-	4,018.81
	8629 Re-inforced Concrete Pipe & Fittings	-	-
(5)	8630 Rental of Model Utilitrac	-	75.11

INDING CORPORATION
N. N. J.
PROGRAM

MONTH August 1954

INCL. PAYROLL - WEEK ENDING August 15, 1954

MONTH ENDING August 31, 1954

INDIRECT OVERHEAD		MATERIAL PURCHASES		TOTAL	
CURRENT MONTH	TO DATE	CURRENT MONTH	TO DATE	CURRENT MONTH	TO DATE
-	5,622.48	-	3,435.27	-	20,342.09
-	3,471.86	-	326.19	-	10,760.98
-	1,572.18	-	204.63	-	4,929.87
-	2,604.03	-	39.32	-	7,865.82
-	35,497.23	-	96,280.46	-	198,463.38
-	2,823.57	-	112,859.56	-	120,318.69
-	1,796.14	-	173.60	-	4,833.90
-	5,914.16	-	32,405.17	-	49,362.10
-	388.85	-	9,579.30	-	10,623.22
-	8.17	-	2,035.92	-	2,057.20
-	2.02	-	17,440.62	-	17,445.89
-	8.77	-	2,579.39	-	2,602.23
-	8.92	-	2,153.81	-	2,176.93
-	286.95	-	12,593.81	-	13,339.75
-	11,303.88	-	93,329.19	-	123,717.08
-	4,327.91	-	16,574.25	-	28,784.87
-	95.70	-	2,003.54	-	2,254.97
-	65.52	-	26.06	-	198.10
-	267.81	-	351.65	-	1,159.56
-	117.42	-	657.16	-	992.32
-	1,104.29	-	454.35	-	3,367.95
-	1,073.91	-	419.00	-	3,210.02
-	787.76	-	3,232.76	-	5,284.55
-	621.73	-	76.48	-	1,693.70
-	769.92	-	3,277.38	-	5,273.18
-	307.42	CR 8.30	19,372.52	CR 8.30	20,265.86
-	25.77	-	74.16	-	650.16
-	.06	-	1.18	-	2.88
-	16.91	-	-	-	45.77
-	29.61	-	-	-	80.61
-	1,880.42	-	1,436.85	-	7,336.13
-	-	-	2.06	-	2.06
-	47.21	-	-	-	122.38

NEW YORK SHIPBUI
CAMD
N. Y. X.

MONTHLY COST REPORT TO:

E. I. DU PONT DE NEMOURS & CO., INC.
WILMINGTON, DELAWARE

N Y S CHARGE NO	DESCRIPTION	DIRECT SALARY & WAGES	
		CURRENT MONTH	TO DATE
(2)	8631 Re-Locating Boring Mill	-	1,567.
(5)	8632 Structural Supports	-	821.
(5)	8633 Excavation of River Mud	-	3,931.
(5)	8634 Dismantling Pump	-	145.
	8635 Tables	-	816.
	8636 Planner Tools	-	33.
	8637 Small Tools	-	6,782.
	8638 Radial Drills & Motors	-	5,981.
(5)	8639 Safety Relief Valves	-	17.
	8640 One (1) Hygrothermograph	-	-
	8641 Provide Foundations for Machining Units	-	-
	8642 Yard Fac. for Sub-Contractor	-	16,187.
(5)	8643 Structures & Fac. for Test Fac.	-	13.
(2)	8645 Boring Heads	-	3.
(2)	8647 Preparing Tool Heads	-	4,865.
	8648 One (1) Boroscope	-	1.
	8650 Safety Hats	-	-
(2)	8651 Making Ident. Nos.	-	159.
(5)	8652 Boroscope	-	35.
(5)	8653 Platform Scales	-	1.
	8655 Four (4) Racks	-	236.
(2)	8656 Head & Feed Tables	-	1,985.
(5)	8657 Six (6) Pumps	-	19,596.
(2)	8658 Bore Gages & Dial Indicators	-	173.
(5)	8659 Twelve (12) Pumps	-	3,635.
(5)	8660 Repair Heating Equipment	-	2,610.
(5)	8661 One (1) Strain Gage Selector Unit	-	-
(2)	8667 Removing Machine	-	3,233.
	8669 Recconditioning Three (3) Offices	-	1,908.
	8670 Straightener for Steel Tubes	-	92.
	8671 Push Button Stations	-	7,954.
(2)	8672 One (1) Pump	-	13.
	8673 Furn. Gas, Oils, Etc.	-	3.

LDING CORPORATION
N. N. J.
PROGRAM

MONTH
INCL. PAYROLL - WEEK ENDING
MONTH ENDING

August 1954

August 15, 1954

August 31, 1954

INDIRECT OVERHEAD		MATERIAL PURCHASES		TOTAL	
CURRENT MONTH	TO DATE	CURRENT MONTH	TO DATE	CURRENT MONTH	TO DATE
-	980.97	-	540.91	-	3,089.56
-	399.16	-	1,060.71	-	2,281.11
-	2,366.41	-	9,179.32	-	15,476.82
-	91.23	-	-	-	236.48
-	478.81	-	318.14	-	1,613.92
-	21.04	-	18.87	-	73.45
-	3,609.44	-	163,106.75	-	173,498.83
-	3,741.03	-	7,127.26	-	16,849.66
-	10.98	-	-	-	28.61
-	-	-	1.57	-	1.57
-	-	-	2.80	-	2.80
-	10,442.32	-	2,442.40	-	29,072.02
-	8.20	-	583,004.00	-	583,025.36
-	2.43	-	1,355.61	-	1,361.91
-	3,042.30	-	101.10	-	8,009.17
-	.85	-	1,245.90	-	1,248.56
-	-	-	316.05	-	316.05
-	87.35	-	24.31	-	270.96
-	19.51	-	-	-	54.96
-	1.10	-	85.68	-	88.54
-	36.74	-	-	-	272.90
-	964.00	-	8,163.32	-	11,112.63
-	10,359.70	-	30,648.73	-	60,605.15
-	86.62	-	2,978.81	-	3,239.14
-	1,561.03	-	1,321.36	-	6,517.74
-	1,565.55	-	939.15	-	5,115.03
-	-	-	47.44	-	47.44
-	2,012.45	-	818.77	-	6,064.41
-	1,101.32	-	1,326.26	-	4,335.90
-	55.52	-	42.82	-	191.30
-	3,489.37	-	1,170.31	-	12,614.29
-	7.21	-	92.93	-	113.24
-	1.81	-	9.65	-	14.75

NEW YORK SHIPBL
CAM
N. Y. X.

MONTHLY COST REPORT TO:

E. I. DU PONT DE NEMOURS & CO., INC.
WILMINGTON, DELAWARE

N Y S CHARGE NO	DESCRIPTION	DIRECT SALARY & WAGES	
		CURRENT MONTH	TO DATE
8676	Reference Table	-	52
8677	Two (2) Track Turning Machines	-	115
8678	Cleaning 2 Sets of Platens	-	452
8679	Repairs & Maint. - Sellers Boring Ml.	-	867
8680	One Kemp Dryer	-	-
(5) 8681	Shipping Three (3) Boxes	-	9
8682	Fire Protection	-	1,894
8683	Protection for Equip. in Sub-Station	-	362
8684	Security Entrance to Main Barricade	-	-
(5) 8685	L&M for Platforms & Walkways	-	3,897
8686	Fab. Equip. for Magazine Lod. Tables	-	-
(5) 8687	L&M to make Minor Alterations	-	39,063
8688	Repairs to Gov't Owned Sedan	-	-
8689	" " " " Cars	-	54
8690	Const. of Two (2) Steel Weldments	-	139
(5) 8691	Supplies-Bldg. #10 Operations	-	4
(2) 8692	Revising Two (2) Vaned Elbows	-	754
8693	Film	-	-
8694	Labor to Inspect all Bolts	-	206
(5) 8695	Add'l Platform Supports	-	1,692
8696	Four Crates Steel Filing Cabinets	-	29
(5) 8697	One Dis-Assembly Machine & Motor	-	3,973
(5) 8698	One (1) Whiting 10 Ton Crane	-	10,224
(5) 8700	Talk-a-phone	-	-
8701	Renovate Office Bldg. #3	-	145
(2) 8702	Engineering Ins. Yard Fac. Sub-Sta.	-	302
(2) 8704	Engineering Insp. "K" Unit	-	12
(5) 8706	Install & Service 2 Generator Sets	-	5,642
8707	Renovate Dispensary Bldg. USMX 2782	-	614
(5) 8708	Maint. & Repairs to Mach. & Equip.	-	1,687
(5) 8709	Protection to Machinery & Equipment	-	229
(1) 8710	Engineering Insp. Etc. Yard Fac.	-	1,145

BUILDING CORPORATION
DEN. N. J.
PROGRAM

MONTH August 1954
INCL. PAYROLL - WEEK ENDING August 15, 1954
MONTH ENDING August 31, 1954

	INDIRECT OVERHEAD		MATERIAL PURCHASES		TOTAL	
	CURRENT MONTH	TO DATE	CURRENT MONTH	TO DATE	CURRENT MONTH	TO DATE
39	-	32.64	-	1.21	-	86.24
43	-	71.92	-	-	-	187.35
22	-	279.61	-	-	-	731.83
29	-	540.38	-	47.40	-	1,455.07
	-	-	-	6.36	-	6.36
15	-	5.70	-	61.60	-	76.45
04	-	996.01	-	75.38	-	2,965.43
96	-	226.15	-	83.63	-	672.74
	-	-	-	125.50	-	125.50
68	-	1,778.06	-	510.34	-	6,186.08
59	-	.37	-	4.59	-	5.55
40	-	18,834.52	-	4,640.72	-	62,538.64
	-	-	-	9.00	-	9.00
19	-	25.49	-	2,484.74	-	2,564.42
64	-	87.01	-	20.85	-	247.50
64	-	2.89	-	62.63	-	70.16
62	-	468.25	-	-	-	1,222.87
	-	-	-	24.00	-	24.00
17	-	128.46	-	6.04	-	340.67
17	-	881.22	-	713.99	-	3,287.38
35	-	17.25	-	-	-	46.60
37	-	2,322.31	-	1,096.23	-	7,391.91
86	-	4,268.85	-	3,159.47	-	17,653.18
	-	-	-	33.54	-	33.54
81	-	90.85	-	123.70	-	360.36
64	-	141.24	-	-	-	443.88
80	-	6.02	-	-	-	18.82
89	-	2,607.51	-	2,156.05	-	10,406.45
03	-	382.58	-	168.83	-	1,165.44
66	-	836.61	-	1,010.79	-	3,535.06
07	-	111.96	-	76.63	-	417.66
75	-	690.30	-	71.85	-	1,948.90

NEW YORK SHIPBUI
CAMD
N. Y. X.

MONTHLY COST REPORT TO:

E. I. DU PONT DE NEMOURS & CO., INC.
WILMINGTON, DELAWARE

N Y S CHARGE NO	DESCRIPTION	DIRECT SALARY & WAGES	
		CURRENT MONTH	TO DATE
	8711 Pipe & Bolt Machine	-	-
	8712 Moving Milling Machine	-	380.5
(5)	8713 Centrifugal Pump	-	-
(5)	8714 Two (2) Diesel Engines	-	-
(2)	8716 Loan of Radial Drills - Maintenance	-	363.8
	8719 Two (2) Metallic Rectifier	-	-
	8721 Two (2) Ventura Fans	-	74.2
(5)	8722 Rod Washing Stations	-	204.6
(5)	8723 Two (2) Oil Systems	-	87.9
	8729 Two (2) Air Conditioning Units	-	220.8
(5)	8730 Six (6) Motors	-	42.0
(2)	8731 For Alterations to Tool Crib	-	568.2
(2)	8732 Four (4) Fans	-	-
(2)	8733 Design & Develop One Milling Attach.	-	-
	8734 One (1) Grinding Fixture	-	-
	8736 One (1) Metallic Rectifier	-	-
	8737 Three (3) Aircomatic Gun Assembl. Weld.	-	84.0
(2)	8738 Equipment & Services - CD 2	-	-
	8739 Ventilating Units	-	1,671.3
	8740 Eighteen (18) Fans 3 Floor Fans	-	-
	8741 LAM Recondition Winch	-	26.1
	8742 One (1) Dry Type Transformer	-	-
(2)	8743 Four Portable Grinders (4)	-	-
	8745 One (1) Elect. Drinking Fountain	-	3.2
(2)	8746 Removing Boring Mill	-	1,568.8
	8748 One (1) Boroscope	-	2.3
(3)	8749 Three (3) High Pressure Pump Units	-	8.1
	8750 Add'l Windows for Control Room	-	426.8
	8751 Roof Ventilators - Bldg. #10	-	957.0
	8752 Install Insertion Tube Brackets	-	1,096.5
	8753 Two (2) Platform Scales	-	23.4
	8754 Monochromatic Light-Lapp Machine	-	-
	8756 Two (2) Storage Tanks	-	16.3
TOTALS			

LDING CORPORATION
EN. N. J.
PROGRAM

MONTH August 1954
INCL. PAYROLL - WEEK ENDING August 15, 1954
MONTH ENDING August 31, 1954

INDIRECT OVERHEAD		MATERIAL PURCHASES		TOTAL	
CURRENT MONTH	TO DATE	CURRENT MONTH	TO DATE	CURRENT MONTH	TO DATE
-	-	-	596.79	-	596.79
-	226.34	-	2.32	-	609.16
-	-	-	6.15	-	6.15
-	-	-	844.63	-	844.63
-	13.85	-	10,973.71	-	11,351.40
-	-	-	2.58	-	2.58
-	40.88	-	168.02	-	283.18
-	7.79	-	112.41	-	324.82
-	48.42	-	177.16	-	313.57
-	121.52	-	675.21	-	1,017.55
-	23.14	-	233.49	-	298.69
-	312.72	-	229.43	-	1,110.44
-	-	-	48.40	-	48.40
-	-	-	30,321.43	-	30,321.43
-	-	-	444.37	-	444.37
-	-	-	6.32	-	6.32
-	46.24	-	4,904.89	-	5,035.16
-	-	-	3,595.73	-	3,595.73
-	919.68	-	1,065.38	-	3,656.37
-	-	-	888.47	-	888.47
-	14.37	-	-	-	40.49
-	-	-	2.27	-	2.27
-	-	-	218.05	-	218.05
-	1.80	-	157.63	-	162.70
-	863.29	-	124.31	-	2,556.44
-	1.27	-	299.48	-	303.05
-	4.51	-	2.82	-	15.52
-	234.45	-	126.70	-	787.21
-	524.90	-	997.27	-	2,479.23
-	529.74	-	106.30	-	1,732.54
-	12.69	-	49.21	-	85.33
-	-	-	63.11	-	63.11
-	9.00	-	-	-	25.35

NEW YORK SHIPBU
CAMI
N. Y. X.

MONTHLY COST REPORT TO:

E. I. DU PONT DE NEMOURS & CO., INC.
WILMINGTON, DELAWARE

N Y S CHARGE NO	DESCRIPTION	DIRECT SALARY & WAGES	
		CURRENT MONTH	TO DATE
8757	One (1) Pump	-	-
8758	Seal Bench Tester, Jig, Etc.	-	-
(5) 8760	Pump Maintenance Room	-	1,296
(5) 8761	Permanent Heat Exchgr. & Instl.	-	15,785
8763	One (1) Racine Utility Saw & Motor	-	-
8764	X-Ray Supplies	-	-
8765	L&M Provide Facilities for Sandblast	-	1,378
(5) 8766	One Electro Lift Hoist & Trolley, Etc.	-	-
8767	Eight Cabinets made for Tool Crib	-	874
8768	Super Station Vacuum Cleaner	-	-
8770	Repairs Parts for #3 Grinder	-	-
8771	Sixteen Foot Straight Edge	-	919
8772	Rotary Air Grinders	-	-
		2,007.82	7,111,382
			Subcont Project 6 AEC
	KEY		
	(1) Fabrication of NYX Unit		
	(2) Fabrication of 4 Units		
	(3) 77 M. Tank		
	(4) Fabrication of "C" Unit		
	(5) Erection and Testing of NYX Unit		

BUILDING CORPORATION
DEN. N. J.
PROGRAM.

MONTH August 1954
 INCL. PAYROLL - WEEK ENDING August 15, 1954
 MONTH ENDING August 31, 1954

INDIRECT OVERHEAD			MATERIAL PURCHASES		TOTAL	
	CURRENT MONTH	TO DATE	CURRENT MONTH	TO DATE	CURRENT MONTH	TO DATE
	-	-	-	2.52	-	2.52
	-	-	-	170.73	-	170.73
63	-	617.34	-	1,042.75	-	2,956.72
14	-	7,489.92	-	7,103.43	-	30,378.49
	-	-	-	862.68	-	862.68
	-	-	-	332.10	-	332.10
36	-	648.20	-	246.19	-	2,272.75
	-	-	-	5.98	-	5.98
91	-	411.45	-	25.59	-	1,311.95
	-	-	-	296.25	-	296.25
	-	-	-	431.94	-	431.94
57	-	432.45	-	72.19	-	1,424.21
	-	-	-	560.00	-	560.00
39	839.27	3,580,466.70	CR 3,898.22	4,938,438.67	CR 1,011.13	15,630,287.76
			Fixed Fee Payments (100%)			1,102,200.00
			South Yard Payments			208,700.00
						16,941,187.76
FINAL REPORT						
Contract AXC 167 1/2 - CTL143						
800 - Savannah River Plant						
Contract AT (07-2)-1						

DATE

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6/27/94

END