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AEC Research and
Development Report
UC-81, Reactors - Power
[Special Distribution]

**quarterly progress report
PL-3 project
January 1 – March 31, 1962**

Contract No. AT[30-1]-2900
with U. S. Atomic Energy Commission
New York Operations Office

ALCO PRODUCTS, INC.
NUCLEAR POWER ENGINEERING DEPARTMENT

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Development Report
UC-81, Reactors, Power
(Special Distribution)

QUARTERLY PROGRESS REPORT

PL-3 PROJECT

JANUARY 1, 1962 - MARCH 31, 1962

By:

G. E. Humphries
Project Manager

Issued: April 10, 1962

Contract No. AT(30-1)-2900
with United States Atomic Energy Commission
New York Operations Office

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ABSTRACT

This document reports the progress made on the PL-3 reactor project during the period from January 1, 1962, to March 31, 1962. Progress is detailed on Phase II work; Phase I work is summarized.

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NUMERICAL IDENTIFICATION SYSTEM

The numbering system used to identify the tasks and subtasks in this report was established to agree with the Program Plan for PL-3. Each subtask is identified by three numbers, the first number identifies the task, the second number identifies the functional group within the PL-3 project staff responsible for the subtask, and the third number identifies the sequence of the subtask of a task within the functional group. The functional groups were assigned the following numbers:

<u>Group</u>	
Nuclear Engineering - - - - -	1
Mechanical and Materials - - - - -	2
Plant Systems - - - - -	3
Construction and Operations - - - - -	4
Health Physics - - - - -	5
Project Engineering - - - - -	6

SUMMARY

PHASE I - CONCEPT EVALUATION AND PRELIMINARY DESIGN

The work scheduled during Phase I was terminated on February 28, 1962.

Task 1 - Concept Evaluation

The data collection, systems evaluations, engineering analyses and technical decisions evolved during the performance of the conceptual design and evaluation of PL-2, PM-1 and PM-2A are reported in AP Note 400, "PL-3 Conceptual Design Evaluation, Task 1 Phase I Report". Of the five nuclear power plant concepts designed for service at Byrd Station, Antarctica, two were selected which best promised to satisfy the technical requirements delineated in the attachment to the PL-3 contract. They were the PL-2, a direct cycle BWR plant, and a PWR generically derived from PM-2A.

Task 2 - Preliminary Design

The work pursued during Task 2 was directed toward the development of preliminary designs of each of the two nuclear plants selected by the Task 1 evaluation procedures. Deliberate efforts were made to incorporate the design features of existing plants with demonstrated advantages for service in a remote location.

The ultimate objective of Task 2 centered about the selection of the nuclear plant design which was best suited for service in the Antarctic environment. The more advanced technology of PWR systems for remote inaccessible service competed with the simplicity, lower weight and lower cost of the BWR. The necessity for utmost reliability for the Byrd Station plant, the design, installation and operating experience with PWR plants for Arctic environments and the short schedule for completion of PL-3 decided the issue in favor of the PWR design. The principal arguments affecting the selection and the various ramifications of the arguments are discussed in AP Note-408, "PL-3 Concept Selection".

The designs of the BWR and PWR plants are presented in APAE 115, Vol. I and II, respectively. The BWR design is a modification of PL-2, incorporating design improvements to enhance its suitability for service in an adverse climate. The PWR design reflected the technical status of the project at the time the design report was issued, February 28, 1962. The vertical arrangement of the principal components in the primary loop has resulted in a compact horizontal

layout. Two vertical vapor containers house the entire primary system, rod drives and auxiliary heat exchangers; this is the minimal number of vapor containers attainable for a portable plant restricted by the cross-sectional dimensions of its components to 8 ft by 8 ft.

The reactor pressure vessel material will be 304 SS. This material was preferred for PL-3 because its NDT (nil ductility transition) temperature is considered to be well below the minimum temperatures of the Antarctic environment throughout the anticipated design life of the vessel.

The operating pressure of the primary system was reduced to 1000 psia. This reduction in pressure, while decreasing the safety margin between anticipated heat fluxes and the burnout heat flux, reduces the primary system weight without measurably affecting the conservatism of the design. This situation was engendered by the selection of the SM-1 core for the PL-3 where the power level of the SM-1 is greater than the PL-3; consequently, the PL-3 core design is too conservative. Adopting accepted safety margins for the PL-3 allowed this reduction in primary pressure without any deleterious effects on other primary system parameters.

A single turbine-generator set converts the heat energy produced by the reactor to electricity. The single system, shipped in two packages, offers cost, system simplification and installation advantages over dual turbine-generator units. APAE-306, "Evaluation of Single and Dual Turbine-Generator Units for PL-3", discusses the various aspects of this problem.

The secondary system design utilizes a glycol-coupled condensate heat removal system. This system was compared with the direct air condenser design used in other portable nuclear power plants. The possibility of freeze-up with direct air condensers in the Antarctic environment affects the continuity of operation of the plant. The absence of this problem with glycol coupling increases the system complexity but does not appreciably affect system cost or weight; the decision to employ it for PL-3 was based on the greater reliability of operation for the condensate heat rejection system. This is discussed further in APAE Memo-308, "Evaluation of Heat Rejection Systems for PL-3".

Cost estimates and schedules were prepared for the final design, development, procurement, fabrication, testing, packaging, shipping, installation, and start-up of the PL-3. This information was presented in AP Note-405, "PL-3 Phase II & III Cost Estimate". The project estimates were reviewed by the AEC and an approved course of action was negotiated in meetings between the Alco's PL-3 project staff and cognizant AEC personnel.

Task 3 - Research and Development

Work on this task was directed toward improving the design characteristics of present portable nuclear power plants. In particular, these efforts were directed towards the superior solution to the environmental, scheduler and logistical requirements of the PL-3 plant at Byrd Station, Antarctica. The following research and development problems were examined and completed.

1. Skid structure study
2. Waste heat rejection system
3. Packaging studies
4. Nuclear instrumentation simplification
5. Housing and footings
6. Antifreeze coolant study
7. Gaseous waste processing
8. Refueling system development
9. Shield optimization
10. Shielding effectiveness
11. Critical experiments on a 5 x 5 array of Type III fuel elements

Summaries and results of these studies are reported in APAE-115, Vol. III, "PL-3 Phase I Task 3 R & D Report".

PHASE II - FINAL DESIGN, PROCUREMENT, FABRICATION, TESTING, PACKAGING AND CREW TRAINING

The efforts associated with the design of the buildings and support facilities (Task 5) were initiated February 1, 1962. Task 6, scheduled to follow the termination of Phase I, was begun March 1, 1962.

Task 4 - Development Program

Work was initiated on the proposed full scale flow test for PL-3.

Task 5 - Support Facilities

The work on the building and support facilities design is on schedule. Efforts were directed toward minimizing the depth of the primary system tunnel. Snow tunnel orientations were changed to an east-west direction to facilitate snow excavations. The primary building crane capacity has been increased to 15 tons to satisfy refueling requirements. Designs and specifications for the fire extinguishing system, primary building jacks, air well casings and motor control centers were completed and forwarded to the customer for approval. The decision to use incandescent lighting rather than fluorescent lighting has been incorporated and substantially increases the 120 volt auxiliary power requirement. The designs of the operations and waste processing buildings have been completed and await approval by the AEC. Work in other areas is progressing as covered herein.

Building and foundation design drawings and specifications have been reviewed by the Constructions and Operations Group.

Task 6 - Final Design

The principal efforts of the PL-3 project were concentrated on the detailed scheduling of Phase II and the preparation of specifications for the procurement of long lead time components of the plant. These include the turbine-generator set, steam generator, reactor pressure vessel, primary pump and reactor core. The turbine-generator specifications have been sent to the customer for approval. The remaining specifications for long leadtime components will be presented to the customer for approval early in the next quarter. Preliminary reactor pressure vessel and primary coolant pump specifications were sent to the customer for information purposes.

ASME code calculations and weight and volume calculations were performed to determine vessel outline, shell and flange requirements, vessel weight and primary plant weight, respectively. Core support structure and vessel internals were investigated and preliminary layouts were prepared. Reactor vessel insulation and jacketing is under investigation, as is the design of the dry cap.

Primary piping layouts were initiated to provide supplementary data for the steam generator specifications. Preliminary primary piping stress analyses were started. The primary loop pressure drop was calculated to be 46.8 ft of 470° F water flowing at 2250 gpm.

Design studies and layouts were made of the control rod drives to optimize the location of the drives with respect to accessibility for servicing.

Fuel handling tools, shipping casks and fuel chute plugs designs were developed preliminarily. These design efforts will be continued during the next quarter.

Flow diagrams of the primary water processing and auxiliary systems were prepared. Description and design analyses of these systems were initiated during the quarter and will be completed, with equipment specifications, during the next quarter.

Preliminary investigations for the design of the chemistry laboratory were pursued.

Over-all plant layout drawings have been revised to include modifications and improvements of the systems and component designs as they develop.

Vapor container sketches and prints were submitted to the model makers to implement development of a full scale model of the primary system.

The peak hydrostatic pressure in the steam generator vapor container has been increased to 176 psig as a result of modifications in the primary system design.

The estimated core loading for PL-3 is 23.5 kg U-235 with 18.5 g B-10 for a conservative core life of 2 yrs at 7.4 Mwt.

Gamma heating in the primary shield is approximately 80,000 Btu/hr at a power level of 8.0 Mwt. A dose rate of 100 mrem/hr was established as the maximum dose to personnel handling spent fuel during fuel transfer. Gamma heating in the pressure vessel wall at reactor core mid-plane was found to be 2.0×10^5 Btu/hr-ft³ with no thermal shield. This is reduced to 7.0×10^4 Btu/hr-ft³ with a 3 in. thick thermal shield located 0.5 in. from the vessel ID.

An outline and schedule for completion of the report describing the preliminary hazards analysis was prepared.

Work performed under Task 6 has resulted in submittal of a final plant layout drawing and specifications for the turbine-generator set to the customer for approval. A power conversion system flow diagram and specifications for the main surface condenser, power conversion system pumps, auxiliary cooling heat exchangers and nuclear and process instrumentation systems are being prepared for submittal during the next period.

During this period, engineering analyses of the nuclear instrumentation system, process instrumentation systems, and fluid systems including main and auxiliary glycol system, auxiliary cooling system and feedwater and condensate systems have been carried out. The information gained from these analyses will become a part of equipment specifications in process and to be initiated during the coming period.

The design of the radiation monitoring system has been completed and preparation of specifications for its procurement are in progress.

The ventilation system design for control of radioactive contamination was begun during this quarter.

TASK 4
DEVELOPMENT PROGRAM

OBJECTIVE

The development program is directed toward advancing the design and improving the performance of the PL-3 nuclear power plant. Eight subtasks were established to implement this objective:

- 4.1.1 Critical Mockup Experiments and Analysis
- 4.1.2 Zero Power Experiments and Analysis
- 4.1.3 Full Scale Flow Test
- 4.2.1 Fuel Handling Tool Development
- 4.2.2 Gaseous Waste Disposal
- 4.2.3 Liquid Waste Treatment
- 4.2.4 Decontamination Methods
- 4.3.1 Packaging

SUBTASK 4.1.3 FULL SCALE FLOW TEST

OBJECTIVES

The objectives of this subtask are to determine experimentally the correct configuration of the core orifice plate and of any required flow baffle in the vessel, the velocities affecting vessel and shield cooling, and the pressure drops through the core and vessel.

SUMMARY OF RESULTS

The experimental equipment built for the SM-2 program was examined to determine the components which could be used for the flow test program for the PL-3. A program plan and cost estimate were prepared which were tailored to a minimum test producing only essential information.

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TASK 5

SUPPORT FACILITIES

OBJECTIVE

The objectives of Task 5 are to prepare engineering drawings of the snow tunnel layout, arches and bulkheads; to design, procure, fabricate, test, assemble and package the foundations, buildings and support facilities for the PL-3 plant; to provide supervision during transportation and site erection.

SUBTASK 5.3.1. - SUPPORT FACILITIES ENGINEERING

OBJECTIVE

Under this subtask, the layout of the snow tunnels will be established and the foundations, buildings and support facilities for the PL-3 facilities complex will be designed, procured, fabricated, tested, assembled, packaged for transportation and installed.

SUMMARY OF RESULTS

Snow Tunnels

On the recommendation of Navy personnel experienced in construction at the site, the main tunnels have been changed to an east-west orientation to facilitate snow excavation. Three of the main tunnels are to be 27 ft 6 in. deep; the fourth (primary tunnel) will be approximately 60 ft deep.

Corrugated Wonder Arches have been selected as the roof support for the main tunnels, and arch dimensions and gage of material have been selected by the Navy Bureau of Docks for the three shallow tunnels. Arch details and material thickness are still under consideration for the deeper primary building tunnel. The Wonder Arch Corp. is presently designing an adapter that will be provided for all arch penetrations of less than 41 in. diameter. Penetration requirements for building facilities and power plant are now being determined.

Several materials are being considered for use as the structural form for the personnel tunnels and a recommendation will be made as soon as the tunnel intersection details and the structural properties of the ma-

materials can be evaluated. At the present time, studies are underway on piping and cable tray routing, tunnel lighting, and ventilation requirements to determine the size of tunnel required and the expected piping loads.

Since plant layout and various details are reasonably firm, drafting effort will now be applied to the snow tunnels, with the emphasis on the details first. All drawings will be issued for approval during May.

Buildings and Foundations

The building shell layout and detail drawings are being completed as scheduled, and as building layouts become reasonably firm. Panel thicknesses and materials described in the reference design have been retained; however, panel connections have been changed from bolted to wedge to facilitate field erection. Panel details and the operations building and waste processing building drawings have been submitted for approval. Secondary building drawings and additional panel detail drawings are now in progress. The panel drawings and specification will all be completed by mid-April to permit placing an order by the first of June.

Anticipated relative settlements of the foundations and tunnel arches have been derived from the snow depth-density profile for Bryd Station.

Computation is in progress for:

1. Aluminum floor framing and foundation trusses for the operations, waste processing and secondary buildings.
2. Steel framing and foundation trusses for the primary building.
3. Wood-framed, stressed-skin plywood foundation panels.

The corresponding design drawings for the operations and waste processing buildings have been issued for approval. The design drawings covering the framing and foundations for the secondary and primary buildings are in preparation.

The foundations for the diesel-generators and the turbine-generator have been isolated from the building foundations. A dynamic analysis to insure that resonance will be avoided has yet to be made.

Final design of the support framing and foundations for the air-blast coolers has not yet been started, pending the selection between the proposed snow tunnel or above-the-surface location for this equipment.

Jacking and Level Indicating Systems

The major effort in this area has been directed to the jack assembly drawing and the specifications for the jacks, jack assembly and bearings. The drawing and the jack specification were issued early in March. Investigations of fabricating techniques and welding procedures have been pursued. It is expected that the assembly and bearing specifications will be issued early in April.

Design of the manometers and refinements of the design of the tilt indicators have been pursued and both are virtually complete. A drawing of these items is in preparation and it is expected that the drawing and specifications will be issued on schedule during April.

Additional investigation and design work is in progress on the controls for the jacks and remote level indicators and on pumps and controls for level indicating fluid handling.

Crane Arrangement

Refueling requirements dictate a 15-ton crane for the primary building instead of the 10-ton crane originally proposed. This change also caused a change from an underslung crane to a standard above-rail crane, because an underslung crane of over 10-ton capacity would be a special item. The crane will be made of steel to minimize height requirements and to speed fabrication and delivery. An aluminum crane would require longer delivery time. The specification covering the primary building crane and miscellaneous chain hoists will be issued for approval about the first of April. It is expected that a purchase order will be issued for the cranes by the middle of May.

Tunnel Cooling and Ventilating

At the end of March, the air well specification was forwarded to the customer for approval. The details of the air well ducts, casing, fans and installation, plus details and assembly of the tunnel ventilating fans will all be shown on a drawing to be issued during April.

The design of the air well is such that the air well assembly is to be installed in the tunnel wall close to the floor, with the well casing extending down into the snow at a 45° angle. Air from these wells will be discharged close to and parallel with the tunnel floor. This was done at the request of the Navy Bureau of Docks so that the air well assemblies could be totally removed from the tunnel space.

A system for tunnel ventilation was developed, using vent fans mounted in the tunnel arch and exhausting to the atmosphere. This ventilating system will provide more than 1/2 air change per hour, since they are sized to exhaust the amount of air discharged from two air wells. One fan will be installed in each of the four main tunnels, with each fan having a capacity of 7000 CFM. The ventilating fan assembly specification will be issued for approval early in April.

Building Heating and Ventilation

Design drawings have been started which will call for electrical heating units to warm air which is circulated through a cabinet containing filters and humidifier elements. Ventilation air will be drawn either through the floor or outside walls, heated to approximate return air temperature and mixed with return air. The return air will be drawn from the floor level, which will be at the lowest temperature. Mixed air will then pass through filters, through heaters controlled by a duct type thermostat to bring it up to near supply air temperatures and through a humidifying unit. Fans will distribute the warm supply air through ducts and discharge it through strip diffusers to blanket the floor with warm air. Final heaters mounted in the distribution ductwork and controlled by room thermostats will dictate the required temperature of leaving air. The specification for this work is in process. Submittal of drawings and specifications is expected during April.

Heating and ventilating work is also underway on the primary building. Studies of location and size of primary building fans and absolute filters are underway.

Electrical System

The motor control center specification and electrical one-line drawing have been issued for approval and will be followed shortly by the annunciator specification. Drafting is in process on the main grounding system layout and details, and on one 120 volt power drawing. Studies are being made of the 440 volt power and control runs, with final drafting to begin the first of April. As soon as the cable runs have been plotted, cable lengths will be determined and the cable specification will be issued for approval, in accordance with the procurement schedule.

In addition to work on electrical construction drawings and specifications, the electrical requirements have been written for the following specifications, some of which have been issued for approval:

1. Motor operation for jacking devices
2. Motor requirements for air well fans
3. Electrical requirements for plumbing skid
4. Electrical requirements for the fire extinguishing system

Various specification drawings have been made, such as front elevations of motor control centers and the annunciator, in addition to study drawings of typical electrical building penetrations, equipment layouts and the like.

Before the end of the next quarter, all of the specifications and drawings will have been issued and procurement will be underway for all items.

Lighting

A large percentage of the plant lighting proposed during Phase I was based on the use of fluorescent lamps. Due to a AEC directive against this type of lighting, a complete reappraisal was made of 120 volt power requirements with incandescent lighting. As a result of the change from fluorescent to incandescent and increases in the plant buildings and tunnels, auxiliary 120 volt power requirements increased to approximately 300 percent of that anticipated at the conclusion of Phase I, and additional lighting panels were added.

Drafting work is underway on the operations and secondary building lighting drawing, which will be followed by the primary and waste process building drawing.

Fire Extinguishing System

The fire extinguishing system drawings and specification, covering a low pressure centralized storage CO₂ system, were issued for customer approval early in March. Some preliminary comments were forwarded; however, formal approval of the system has not yet been received. Approval is required by the end of the quarter, and the order must be placed early in April to get promise of delivery by September 1st.

The initial charge and any subsequent replacement of CO₂ for the system can be purchased at Christchurch, New Zealand.

Plumbing

The drawing of the operations building plumbing skid, which consists of counting room, dark room, chem lab and toilet facilities has been prepared. The drawing showing the hot and cold water lines in the tunnel and the specification will be ready to issue for approval during April. Present plans are to have the plumbing skid fabricated of aluminum with aluminum angle and "T" shapes for framing. Enclosing walls will be plywood. All electrical fixtures, piping, furniture, fixtures and the like will be installed and ready for use with connection of service lines to the unit.

The purchase order for the complete plumbing system is scheduled to be issued early in May.

SUBTASK 5.4.1 - SITE ERECTION SUPERVISION

OBJECTIVE

This subtask encompasses the technical assistance to be provided by the plant construction and operations group to the organizations responsible for the erection of the buildings and support facilities. Over-all supervision of the buildings and support facilities will be provided under this subtask.

SUMMARY OF RESULTS

The primary building structure and foundation was reviewed and various ways of reducing over-all height were suggested. The primary building jacking system was reviewed and recommendations for a simplified design were made. The heating and ventilating drawings were reviewed and approved. The fire protection system design was reviewed and approved. The foundation drawings were reviewed and approved.

All specifications accompanying designs were reviewed and approved from the construction standpoint; e.g., installation and maintenance manuals and spare parts were requested in the specification.

Maintenance shop layouts were made and submitted to Project Engineering and J&M, who incorporated it in their arrangement drawing.

Erection schedules, manpower requirements and plane load requirements were prepared and checked with the support facilities subcontractor.

Logistics requirements and an airlift schedule were prepared.

TASK 6

FINAL DESIGN

OBJECTIVE

Task 6 encompasses the final design and the preparation of engineering drawings and procurement specifications for the entire primary and secondary plant system, including auxiliaries.

SUBTASK 6.1.1 - CORE PHYSICS ANALYSIS

OBJECTIVE

This subtask will include the analyses of neutron flux and fission power distributions in and around the reactor core, the rate of burnup of fission material, the rate of production of fission products, reactivity effects from changes in the operating environment of the reactor core, the effects of control rod location, positioning and motion, the activation of materials in and around the reactor core caused by neutron capture and the calculation and evaluation of nuclear and physical parameters associated with the self-sustaining fission process.

SUMMARY OF RESULTS

Core Burnup Analysis

The core selected for the PL-3 is based on SM-1 Core I. The latter core, operating at 440°F, released about 16.2 MWYR, excluding the effects of spiking and rearrangement when fresh elements were inserted in the core at 2/3 life. At 470°F, the energy release is about 15.2 MWYR, resulting in a core life of about 2.1 years at 7.4 Mwt. The accuracy of the measured SM-1 Core I lifetime is quoted at 10%*; therefore, the core loadings for the SM-1 Core I could conceivably not meet PL-3 contract lifetime requirements (2 years), especially since further design changes are possible. In this case, there would be no margin for error.

A series of burnup calculations by the CANDLE IBM-704 code were performed, varying the U-235 and B-10 content of the fuel plates. It was found that

*Weiss, S. H., "Summary Report of Physics Measurements On SM-1 Core I," APAE-96, February 6, 1962.

the addition of one kg of U-235 to the SM-1 core would be adequate to meet PL-3 lifetime requirements. To compensate for the added increase of reactivity due to fuel addition, 2.75 gm of B-10 were added. The results of this analysis compared with the original SM-1 Core I are given in Table 6.1. It is seen that with these loadings, the PL-3 requirement will be satisfied. Due to improved fabrication techniques and better control of fuel matrix densification and nominal dimensions, the weight percent of UO_2 in the fuel matrix is less than in the SM-1 Core I, the values being 25.4 w/o and 26 w/o for the PL-3 and SM-1 cores respectively.

A summary of the fuel matrix geometry and loadings for the PL-3 core is given in Table 6.2.

Core Nuclear Parameters

Nuclear constants for the core are calculated by the methods described in APAE Memo-289†. The atomic concentrations and nuclear parameters for the stationary fuel elements, pure water and pure steel, at 470°F, are presented in Table 6.3. Parameters at other temperatures are presently being calculated.

TABLE 6.1

CORE LOADINGS AND TOTAL ENERGY RELEASE

	<u>SM-1 Core I*</u>	<u>PL-3 **</u>
Total Core Loading		
U-235, kg	22.5	23.5
B-10, gm	15.75	18.5
Total Energy Release, MWYR		
Expected	16.2	16.5
Pessimistic value	14.6	14.9
Optimistic value	17.8	18.2
Core Lifetime, yrs. (100% load factor)		
Expected	1.6	2.2
Pessimistic value	1.5	2.0
Optimistic value	1.8	2.5

* Core operating at 440°F at 10 Mwt

** Core operating at 470°F at 7.4 Mwt

† Bobe, P. E., and Caton, R. L., "BOBCAT (Program #56) Code Preparation Analysis on the IBM-650", APAE Memo-289, August 9, 1961

TABLE 6.2

PL-3 FUEL PLATE LOADING

	<u>Stationary Fuel Plate</u>	<u>Movable Fuel Plate</u>
Fuel matrix thickness, in.	0.020	0.020
Fuel matrix width, in.	2.500 min.	2.281 min.
Fuel matrix length, in.	22.000	21.125
Fuel matrix volume, in. ³	1.1000	0.9637
No. of plates in core	684	112
U-235/plate, gm	30.046	26.324
UO ₂ /plate, gm	36.841	32.277
B-10/plate, gm	0.02365	0.02072
ZrB ₂ /plate, gm	0.6659	0.5834

Gross Radial and Axial Neutron Flux Distributions

To provide information for shielding and instrumentation analyses, the gross radial and axial flux distributions were calculated by use of the VALPROD IBM-650 code. The gross radial fast flux and thermal flux distributions at 470°F as a function of distance from the core centerline are shown in Figure 6.1. The gross axial fast and thermal flux distributions as a function of distance above and below the core centerline are shown in Figure 6.2. These calculations were normalized to a peak power of 9.3 Mwt.

Power distributions as calculated by VALPROD will be combined with the results of PDQ(x, y) calculations to obtain the over-all power distribution in the core. The latter calculations are presently being prepared. The gross radial power distribution in the core at 470°F, at 9.3 Mwt, is shown in Figure 6.3; the axial distribution is shown in Figure 6.4. The peak-to-average power ratio is 1.44 and 1.89 for the gross radial and axial distributions, respectively; the local power peaking, calculated by PDQ(x, y), is presently being determined.

Nvt Calculations

Nvt calculations are performed by use of the P1MG, IBM code, combined with the PDQ(r, z), IBM-7090 code. The results obtained from the P1MG code are presented in Figure 6.5; the graph shown does not include the axial factor (presently being calculated) or any normalization or uncertainty factors. In-

TABLE 6.3

NUCLEAR CONSTANTS FOR THE PL-3 REFERENCE CORE AT 470°F

Parameter	Units	PL-3 Reference Stationary Fuel Element	Water (1000 psia)	Stainless Steel (Type 347)
	cm ²	42.302430	42.159717	183.606982
D _f	cm	1.427893	1.601096	1.490530
a	cm ⁻¹	0.009639	0.000487	0.008118
sl	cm ⁻¹	0.024115	0.037490	0.000001
K _f		1.286855	-----	-----
P		0.714427	0.987174	0.000123
D _T	cm	0.253185	0.274743	0.365078
at	cm ⁻¹	0.209281	0.010551	0.153603
K _T		1.545000	-----	-----
g [†]		0.938356	-----	-----
N _H x10 ⁻²⁴	atoms/cc	0.043155	0.054428	-----
N _O x10 ⁻²⁴	atoms/cc	0.023266	0.027214	-----
N _{B-10} x10 ⁻²⁰	atoms/cc	0.082288	-----	-----
N _{SS} x10 ⁻²⁴	atoms/cc	0.015160	-----	0.084651
N _{U-235} x10 ⁻²⁴	atoms/cc	0.00044534	-----	-----

g[†] = thermal self shielding factor for the fuel element.

clusion of these factors is expected to produce an nvt greater than 1 Mev on the vessel centerline of about 1.4×10^{20} neutrons/cm² for 20 years operation at 7.4 Mwt, as compared to the PLMG value of 0.8×10^{20} neutrons/cm². These calculations were performed at 470°F with a 3 in. thermal shield and a 40 in. ID pressure vessel (see Figure 6.5).

Temperature Coefficient and Defect

Measured temperature coefficient data of the SM-1 Core I is available from 68°F to 440°F. For the PL-3, data is needed down to 40°F and up to 470°F. It is planned to secure more data during the PL-3 critical mockup

experiments; before this data becomes available, preliminary estimates are needed for hazards analysis, determination of shutdown margin, excess reactivity under various core conditions and the like. The measured data for the SM-1 Core I were fitted to a quadratic polynomial, integrated, and extrapolated from 40°F to 480°F. The curves from 40°F to 80°F and from 68°F to 400°F are shown in Figures 6.6 and 6.7, respectively. These curves indicate that the temperature coefficient remains negative for the entire range of interest. However, further analysis and measurements are needed to justify this statement.

SUBTASK 6.1.2 - THERMAL AND HYDRAULICS ANALYSIS

OBJECTIVE

This subtask is concerned with the calculation of conditions leading to the onset of nucleate boiling of the coolant, hot channel factors, burnout heat flux, the evaluation of thermodynamic parameters for design and off-design operating conditions, temperature distributions in the core, core structure, vessel internals and the pressure vessel, the kinetics of energy storage and release within the vapor containers, the transfer and removal of fission and fission product heat and primary system pumping requirements.

SUMMARY OF RESULTS

Reduction of Primary System Pressure

A study was made to determine the thermal performance of the reference core at pressures below 1200 psia. Reduced pressure operation is expected to save primary system weight and reduce thermal stress in the pressure vessel.

The hottest element in the reference core, element 45 was analyzed over a pressure range of 800 - 1200 psia. All other input to this analysis was identical to the preliminary thermal analysis done during Task 2.

The results of the steady state analysis using the STDY-3 IBM code are given in Table 6.4.

At the design core power of 9.3 Mwt, the hot channel of this element has some nucleate boiling for system pressures below 1200 psia. At 800 psia pressure, bulk boiling is present in the hot channel and some nucleate boiling in the nominal channel. The effect of nucleate boiling can be seen as a readjustment of hot channel mass flow rate which accompanies the higher two phase pressure drop.

The minimum DNB ratio remains constant over the pressure range. The "New Bettis" DNB correlations used in this analysis are not pressure sensitive.

A pressure of 1000 psia was selected as the new reference design pressure. At this pressure, the hot channel in element 45 will have some nucleate boiling for the design core power. No nucleate boiling is indicated at the yearly average core power.

Referring to the preliminary radial power distribution, it is estimated that 11 elements may have some nucleate boiling in their hypothetical hot channels with a maximum length of channel of 5 in. in nucleate boiling.

No adverse mechanical, thermal or nuclear conditions will occur by operating the PL-3 core with nucleate boiling.

A transient loss-of-flow analysis was made on element 45 at 125 percent of design power. The minimum DNB ratio during the transient was 6.3. A maximum of 4 percent exit quality was generated in the hot channel during the latter part of the transient.

It is concluded that the PL-3 core will operate thermally safe at 1000 psia system pressure.

Reactor Vessel Thermal Stress

Preliminary evaluations of the thermal stress in the reactor vessel wall at the core centerline elevation were made using the PREV 1 IBM 650 code. Stress values were calculated both with and without 3 in. thick gamma shield. Preliminary gamma heating values were obtained from the ROC IBM-650 code. The following table shows the results of the thermal stress analysis.

TABLE 6.5

REACTOR VESSEL THERMAL STRESS AT CORE CENTERLINE ELEVATION

<u>Configuration</u>	<u>No Thermal Shield</u>	<u>With Thermal Shield</u>
Coolant temperature, °F	454	454
Coolant velocity at wall ID, ft/sec	.85	8.0
Wall ID gamma heat, Btu/hr ft ³	200,000	59,000
Effective attenuation coefficient, ft ⁻¹	11.1	13.5
Wall ID stress (tensile), psi	27740	6450
Wall OD stress (compressive), psi	4045	1025

TABLE 6.4

PRIMARY SYSTEM PRESSURE SURVEY ELEMENT 45

CORE MEAN TEMPERATURE 470°F

CORE POWER 7.4 Mwt

System Pressure psia	Nominal Channel Flow Lb/hr-ft ² x10 ⁶	Hot Channel Flow Lb/hr-ft x 10 ⁶	Outlet Temp. Nominal Channel °F	Outlet Temp. Hot Channel °F	Max Plate Surface Temp.	Meat Temp.	Min DNBR	Nucl. Boiling Hot Channel	Bulk Boiling Hot Channel	Nucl. Boiling Nominal Channel
1100	.675	.594	482	496	566	583	7.91	-	-	-
1000	.675	.594	482	496	556	572	7.91	-	-	-
900	.675	.594	482	496	544	561	7.91	Yes	-	-
800	.675	.520	482	501	532	549	7.91	Yes	-	-

Core Power 9.3 Tmw (Full Load)

1100	.675	.594	489	506	567	588	6.29	Yes	-	-
1000	.675	.557	489	509	556	577	6.29	Yes	-	-
900	.675	.520	489	513	545	566	6.29	Yes	-	-
800	.675	.446	489	515	533	554	6.28	Yes	Yes	Yes

The results show that the present shield configuration will reduce the vessel gamma stresses to an acceptable level. Stresses in the shield itself will be investigated.

Vapor Containment

The change in volume and operating pressure of the primary system requires a reevaluation of the pressure loadings on the vapor container walls. The pressure-volume relationship for the steam-generator container based on an adiabatic, constant energy blowdown was recalculated to include the latest primary system changes. Table 6.6 lists the changes made since the preliminary analysis was performed (AP Note 411).

TABLE 6.6

INITIAL CONDITIONS FOR VAPOR CONTAINER ANALYSIS

	<u>Preliminary (AP Note 411)</u>	<u>Design- Task 6</u>
System pressure, psia	1200	1000
System temperature, °F	470	470
Primary system water volume, ft ³	66.6	73.4
Pressurizer steam volume, ft ³	8.6	8.6
Vapor container pressure, psia	12.2	12.2
Vapor container temperature, °F	100	120
Container net volume, ft ³	1478	1505

Figure 6.8 shows the pressure-volume relationship for the new design conditions. The peak hydrostatic pressure in this container will be 176 psig compared to 165 psig for the preliminary analysis.

Further evaluation of local loadings due to air shock and jet impingement will be made.

Decay Heat Removal System

The decay heat removal requirements have been calculated for two conditions.

1. Holding the primary system temperature at 470°F:

The following heat balance may be written

$$P = Q_L + Q_B + Q_G$$

Decay power generation	System heat leakage	Blowdown heat loss	Heat to Steam Generator
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Values of decay power generation, P/P_0 , at any time after shutdown were obtained from the Clancy-Stehn curve; P_0 was taken as 7.4 Mwt (25.3 x 10⁶ Btu/hr). Q_L , by recent calculations, is 2 x 10⁴ Btu/hr. In calculating Q_B , the average blowdown was assumed to be 250 lb/hr and average temperature difference between blowdown and make-up to be 100°F. Calculated results were plotted in Fig. 6.9 for irradiation times of one month and one year.

2. A 25°F per hour temperature cooldown rate in the primary system:
For this condition, the heat balance is:

$$P + Q_M + Q_H = Q_L + Q_B + Q_G$$

where, Q_M = sensible heat of metal

Q_H = sensible heat of water

Metals for vessels, pipes, valves etc., are estimated to weigh 41,800 lbs. with a specific heat of 0.25 Btu/lb °F. Q_M is estimated to be 26.1 x 10⁴ Btu/hr in cooling down 25°F. Water in the system is approximately 3,400 lb and Q_H is 8.5 x 10⁴ Btu/hr. Q_L is assumed to vary according to the following relationships (assuming an ambient temperature of 70°F).

$$Q_L = \frac{T_0 - 70}{470 - 70} (2 \times 10^4)$$

$$T_0 = 470 - 25 t \text{ (t in hours)}$$

Q_B is assumed to be the same as in Case 1. Calculated results are plotted in Fig. 6.10 for irradiation times of one month and one year.

Decay Heat Removal by Natural Convection Cooling of the Spent Fuel Shipping Cask

The casks are sized to ship half a core. Initial heat output of 1/2 core is 66,900 Btu/hr based on 2 years' irradiation at the yearly average core power of 7.4 Mwt. The maximum water temperature in the shielding tank and the maximum water temperature coming out of the top of the core were 100°F and 190°F, respectively. The thermal driving head for natural circulation is, therefore, 90°F.

With an inside cask height of 44-1/8 in. and 90°F temperature differential, the head available for effecting natural circulation is 1.44×10^{-3} ft H₂O.

With the above available head there are two ways to effect natural circulation:

- (A) Using six straight tubes of 1 in. OD x 0.05 in. maximum wall thickness to connect the shielding tank and the inside of the cask, the required pumping head was calculated to be 7.09×10^{-4} ft H₂O.
- (B) Using four straight tubes of 1.25 in. OD x 0.05 in. maximum wall thickness, a required pumping head of 6.1×10^{-4} ft H₂O was calculated for this configuration.

Method A is preferable because it provides better distribution of coolant to the spent fuel elements. The calculated available head is conservative in view of the fact that available head is calculated on the basis of core height only. The available head from the outlet to the inlet piping is 2.1×10^{-3} ft H₂O. Figure 6.11 shows a schematic of the recommended cooling pipe arrangement for the spent fuel shipping cask.

Primary Loop Pump Requirements

The design pressure drop through each component of the primary loop has been established, based on the latest information on design configurations. The pressure drops were derived by standard methods of calculation for the piping and for the reactor nozzles. Reactor core and plenum chamber losses were derived from SM-2 test experience. The pressure drop for the steam generator was based on the upper limit to be allowed in that specification, which has been acknowledged as sufficient by a qualified designer and manufacturer.

The calculated loop pressure drop at the design flow rate of 2250 gpm, and 470° mean temperature, is 46.8 ft of (hot) water, including contingency factors. This represents a 15 percent reduction from the pumping head requirement

predicted during Phase I, due to replacing approximate conservative methods with a more detailed calculation. Table 6.7 gives the component parts of this pressure drop.

TABLE 6.7
PRESSURE DROP, FT H₂O

<u>Component</u>	<u>Calculated</u>	<u>Contingency Percent Used</u>	<u>Allowed</u>
Reactor vessel (minus core, but incl. distrib. baffles)	7.3	10%	8.03
Reactor core	0.8	10%	0.88
Steam generator	22.7	5%	23.84
Piping (incl. pump inlet elbow)	12.33	5%	12.95
Flow tube	<u>1.00</u>	<u>10%</u>	<u>1.00</u>
Total hydraulic horsepower	44.13		46.7

Figure 6.12 shows the pressure drops as a function flow rate at 470°F mean water temperature. At 60°F, because of the higher friction factors experienced with low water temperatures, the over-all head loss would be approximately 53 ft at 2250 gpm. From this, it is estimated that the cold flow rate will be 3 to 4 percent below the flow at operating temperature.

SUBTASK 6.1.3 - SHIELDING ANALYSIS

OBJECTIVE

The objective of this subtask is the analysis and evaluation of shield materials and configurations to develop a shield design which satisfies the requirements of personnel safety during all operating and maintenance conditions of the PL-3 plant. This work includes the analysis of biological dose rates, the optimization of the requisite shielding to minimize weight and the heating effects of gamma rays in materials.

SUMMARY OF RESULTS

Gamma Heating in Primary Shield

The ROC shielding codes were run to determine the gamma heating in the primary shield. With no thermal shield and an 8.0 Mwt reactor power level, the gamma heating in the primary shield is approximately 80,000 Btu/hr. This value is presently being revised to determine the effect of shielding changes, the thermal shield, and reactor operation at the peak power of 9.3 Mwt.

Primary Shield Optimization

The data generated under Task 3 of Phase I were interpreted and plotted. APAE Memo-115, Vol. III, gives the details of the work performed and the conclusions which have been drawn. Results of the optimization study indicate that lead has a shipping weight advantage over steel for gamma shielding. The study also indicated that the preponderance of the lead shielding might be eliminated by increasing the shield radius to about 10 ft.

Fuel Transfer Shielding

To insure that the dose to personnel during handling of spent fuel elements is not excessive, a dose rate of 100 mrem/hr has been established as the design point for fuel transfer operations. Calculations were performed to determine the required depth of water, covering a spent fuel element, to reduce the dose rate to 100 mrem/hr. Figure 6.13 shows that the required depths above the meat portion of an average and the hottest spent PL-3 fuel element are 6 ft 7 in. and 7 ft. of water respectively.

The design should be based on the 7 ft of water shielding required for the hottest element.

Gamma Heating in Pressure Vessel

IBM-650 ROC shielding codes were used to determine the gamma heating in the pressure vessel wall at the reactor centerline. The peak heating value in the pressure vessel wall at 9.3 Mwt was found to be 2×10^5 Btu/hr-ft³ with no thermal shield. Stress analysis indicated a thermal shield would be required to reduce the vessel heating. The ROC codes were rerun with a three inch thick thermal shield spaced a half inch from the pressure vessel. The thermal shield reduced the peak heating to 7×10^4 Btu/hr-ft³.

SUBTASK 6.1.4 - SAFETY AND HAZARDS

OBJECTIVES

The objectives of this subtask will be to evaluate the safety with which the plant can be installed, operated and maintained and to assist in the determination of plant characteristics and design features which require modification to enhance its safe utilization.

SUMMARY OF RESULTS

An outline and a schedule for completion of the preliminary hazards report for the PL-3 was prepared. Agreement was reached with the various technical personnel as to areas of responsibility for writing the various sections of the report.

Information was received from the U. S. Army Cold Regions and Engineering Laboratory on the environmental conditions in the Antarctic. Information was also received from the Weather Bureau on a related study of the climatology at McMurdo Sound. A request is being prepared to obtain similar data for Byrd Station from the Weather Bureau. Microfilms of Byrd Station wind data are also being ordered from the Weather Bureau.

Present schedules are based upon publication of the preliminary hazards report in early June.

SUBTASK 6.2.1 - REACTOR VESSEL AND CORE MECHANICAL DESIGN

OBJECTIVE

The objective of this subtask is to develop, design, prepare engineering specifications and initiate procurement of the reactor pressure vessel, core, core support structure and the shipping skid that will be required for the PL-3 nuclear power plant.

SUMMARY OF RESULTS

Work performed prior to March 1 and reported in APAE-115 resulted in selection of a 7 x 7 SM-1 type core with a 7 rod open array as the reference core. The reactor pressure vessel will be fabricated of type 304 stainless steel and bottom control rod drive mechanisms are to be used. The reactor

vessel less its internals is to be shipped as an individual package having weight less than 20,000 lb and within the maximum dimensional limits of 8 ft x 8 ft x 30 ft. All components including skid and packaging will permit shipment to and storage at the environmental conditions of Byrd Station at the Antarctic.

ASME Code calculations have been made to establish reactor vessel shell dimensions. Preliminary weight and volume calculations were made. Reactor vessel specifications and outline drawings are being prepared to permit the fabrication of the reactor vessel shell, insulation and jacketing, thermal shield, control rod drive mounting pad and penetrations, and the core support structure and vessel mounting pads. Thermal stress analysis was continued to determine whether the proposed vessel outline presents any apparent critical or highly stressed areas.

Mechanical design of the core components including the fuel elements, absorbers and control rod assemblies is in process.

SUBTASK 6.2.2 - CONTROL ROD DRIVE MECHANISM DESIGN

OBJECTIVE

The objective of this subtask is to develop, design, prepare engineering specifications and initiate the procurement of the control rod drive mechanisms, including seal housing, spool pieces, the clutch assembly and gear motors structural support, and the electrical circuitry and auxiliary cooling water piping to the vapor container penetrations.

SUMMARY OF RESULTS

The control rod drive mechanisms which were mounted vertically on the steam generator container wall, have been relocated horizontally with the drives mounted on a pedestal support in the vapor container. This new arrangement is shown on Dwg. AES-619. The removal of the shielding surrounding the portion of the rod drives in the steam generator vapor container permitted this change. A layout of the control rod drive extensions has been completed and is shown on Dwg. AEL-784.

Final design calculations, detail drawings and a component specification have been initiated and are in process.

Figure 6.1. Thermal and Fast Radial Flux Distributions for PL-3 Reference Core Operated at 470°F and a Power of 9.3 Mw

Figure 6.2. Axial Fast and Thermal Flux Distributions For PL-3 Core at 470°F-Clean Power Level of 9.3 Mw

Figure 6.3. Power Distribution for PL-3 Reference Core Operated at a Power of 9.3 Mw (470°F)

Figure 6.4. Axial Power Distribution
PL-3 Reference Core-470° F - Clean

Figure 6.5. Integrated Fast Neutron Flux for the Reference PL-3 as a Function of Distance in the Radial Direction

Figure 6.6. Integrated Temperature Coefficient Vs. Temperature, SM-1 Core I

Figure 6.7. Integrated Temperature Coefficient Vs. Temperature, SM-1 Core I

Figure 6.8. PL-3 Vapor Container Pressure - Volume Requirement

Figure 6.9. Heat to be Extracted by Steam Generator to Maintain the Primary System at 470°F Vs. Time After Shutdown

Figure 6. 10. Heat to be Extracted by Steam Generator to Effect 25°F per Hour Temperature Decrease in the Primary System Vs. Time After Shutdown

Figure 6.11. Decay Heat Removal in Spent Fuel Tank (Cask)
Suggested Piping Arrangement

Figure 6.12. Pressure Drop In PL-3 Primary Loop

Figure 6.13. Dose Rate From One PL-3 Fuel Element

SUBTASK 6.2.3 - VAPOR CONTAINER DESIGN

OBJECTIVE

The objective of this subtask is to develop, prepare engineering specifications, design and initiate procurement of the primary system vapor containers, their internals, and the shipping skids and packaging that will be required for their shipment with the PL-3 nuclear power plant.

SUMMARY OF RESULTS

In APAE-115, a vertical vapor container arrangement was reported for the preliminary design. One vapor container will house the reactor vessel and necessary shield water, while a second vertical tank will house the steam generator, pressurizer, primary pump and auxiliary equipment. Flexible interconnects will be used between the two vapor container tanks to provide passageways for the primary piping, control rod drives, etc.

The steam generator vapor container operates normally dry. Its design conditions have been established at 176 psig and 400°F. The reactor vapor container (normally filled with shield water) will be designed for 176 psig and 200°F. ASME Code calculations are being made in order to determine the vapor container shell and flange dimensions. Preliminary weight and volume calculations are being made.

Investigation of construction materials for the vapor containers is in process and will continue, as will the spent fuel transfer system design.

SUBTASK 6.2.4 - PRIMARY EQUIPMENT DESIGN

OBJECTIVE

The objective of this subtask is to develop, design, prepare engineering specifications, and initiate procurement of the steam generator, pressurizer, primary coolant pump and primary piping for the PL-3 nuclear power plant.

SUMMARY OF RESULTS

APAE-115 reports the performance requirements established for the steam generator and selection of a vertical design. Preliminary design calculations established the feasibility of meeting the performance requirements without exceeding size limitations.

Preliminary sizing of the pressurizer was started and liaison with a heating element fabricator was initiated to determine dimensional data for 1000-watt capacity heaters.

The draft of the specification for the steam generator was reviewed prior to submittal to the customer for approval, as was the draft of the primary pump specification. A layout of the primary piping loop was nearly completed (Dwg. AEL-783) and a preliminary piping stress analysis was initiated.

The final specification for the primary pump is in process and this effort is continuing.

SUBTASK 6.2.5 - PRIMARY SHIELD DESIGN

OBJECTIVE

The objective of this subtask is to design the primary shielding, consisting of shield rings, shield tanks and auxiliary shielding and to initiate its procurement.

SUMMARY OF RESULTS

The primary shielding concept was established and reported in APAE-115. This included auxiliary shielding requirements during periods of fuel handling. Work is continuing on the shielding arrangement.

SUBTASK 6.2.6 - FUEL HANDLING TOOLS & SHIPPING CASKS

OBJECTIVE

The objective of this subtask is to design, prepare material specifications and initiate procurement of all components of a fuel transfer, storage and shipping system and the tools necessary to perform all of the required refueling operations.

SUMMARY OF RESULTS

A drawing of a fuel element, absorber and retrieving tool was made. Conceptual drawings of a shipping cask, various fuel chute plugs and a detachable hopper have been prepared for comparative design studies.

Radiation shielding requirements have been investigated and initial standards set. Vendor contacts have been made preparatory to obtaining bolt-tensioners and a tool for underwater removal of a seized reactor cover nut.

Studies and drawings of shipping casks, capable of storing one-half core directly from the reactor, are continuing.

SUBJECT 6.2.8 - PRIMARY SYSTEM ARRANGEMENT

OBJECTIVE

The objective of this subtask is to develop a primary system plant arrangement.

SUMMARY OF RESULTS

The preliminary primary plant arrangement, Dwg. AEL-762, was presented in APAE-115. It features vertical vapor containers with peripheral water shield and refueling tanks around the reactor vapor container. Dwg. AES-617 shows the proposed floor arrangement in the primary building. This layout was made to facilitate the development of operational and maintenance procedures with allowance for working space requirements. Installation of original and replacement primary system components were also considered in the arrangement of this layout.

SUBTASK 6.2.9 - MATERIALS TECHNOLOGY SUPPORT IN PRIMARY AND SECONDARY SYSTEMS DESIGN

OBJECTIVE

The subtask objective is to furnish materials support in all areas of PL-3 primary and secondary systems design.

SUMMARY OF RESULTS

Materials for primary and secondary components were tentatively established for major items. Materials, material testing and quality control requirements for all primary and secondary components were studied.

Principal efforts were extended to the preparation of materials requirements, fabrication procedures and quality control for the specifications for the reactor pressure vessel, steam generator, primary pump, main surface condenser, turbine-generator, building jacks, building and fire control system.

A survey of bearing materials was conducted to determine the feasibility of a replacement material for Stellite bearings which does not exhibit high neutron-induced activity after shutdown.

SUBTASK 6.2.10 - PRIMARY WATER PROCESSING AND AUXILIARY SYSTEMS

OBJECTIVE

The objective of this subtask is to produce a design of the primary water processing system and the necessary primary auxiliary systems.

SUMMARY OF RESULTS

System functions were developed and basic methods of performing these functions were evaluated. A preliminary flow schematic was completed. Complete and detailed system flow diagrams are in process and continuing.

SUBTASK 6.2.11 - WASTE DISPOSAL

OBJECTIVE

The object of this subtask is to identify the waste disposal requirements and to develop a system design to meet these requirements.

SUMMARY OF RESULTS

As reported in APAE-115, preliminary waste disposal requirements were identified and various processing and disposal methods considered. A preliminary waste disposal system schematic was completed. Since March 1, work has consisted solely of planning in the area of gaseous waste disposal.

SUBTASK 6.2.12 - PLANT CHEMISTRY AND CHEMICAL CONTROL

OBJECTIVE

The objectives of this subtask are to conduct a chemical engineering design study and investigation in the areas of chemical control and instrumentation, to determine and recommend to the plant systems group methods for adequate control of plant chemical systems and to identify laboratory requirements.

SUMMARY OF RESULTS

Preliminary chemical control procedures and parameters were established during Phase I. Design of the chemical injection system is in process and effort continues; this includes its location and method of injection. Sampling points in both systems are being determined and appropriate in-line instrumentation will be recommended. A list of control parameters is being prepared. Chemical engineering assistance in the final design of the chemistry laboratory is being provided and will continue until the design is complete. This includes recommendations for equipment and materials for the lab.

SUBTASK 6.2.13 - CHEMICAL TECHNOLOGY SUPPORT

OBJECTIVE

The objective of this subtask is to provide chemical engineering support to the project and to provide for supervision and coordination of chemical engineering activities.

SUMMARY OF RESULTS

Engineering in the area of chemical technology to assist the over-all project has been provided. Chemical technical assistance will continue to be provided for activities such as hazards analysis, progress reports, primary system activity analysis, specification review, and materials applications.

SUBTASK 6.2.15 - CORE DESIGN & SPECIFICATION

OBJECTIVE

The objective of this subtask is to prepare core specifications and to evaluate and select a fabricator by competitive bid.

SUMMARY OF RESULTS

Studies were initiated to determine the allowable cobalt and tantalum impurity levels in Type 347 SS. Preliminary specifications were prepared for Type 347 SS cladding and matrix powder, spherical uranium dioxide, zirconium diboride poison, europium oxide flux suppressors and absorber material and for elemental SS powder for absorber and flux suppressor cores.

Core procurement specifications are in process and will be a continuing effort. Requests for quotations were sent to vendors of special low impurity Type 347 SS.

SUBTASK 6.3.1 DESIGN ANALYSIS OF PLANT SYSTEM

OBJECTIVE

The objectives of this subtask are to establish all parameters for the secondary system and to assist in formulation of the primary system parameters which directly affect power conversion components.

SUMMARY OF RESULTS

Electrical

Analyses of nuclear instrumentation systems have been made to assure that the concepts under consideration conform to the best current practice. Environmental criteria and performance requirements have been established. Preliminary vendor contacts have been made to determine availability of nuclear instrumentation systems conforming to the above criteria and to Military Specification MIL-N-19900. A basic L-shaped layout for the control console has been developed. A concurrent design program is being carried out to define the various process instruments and controls necessary for the plant primary and secondary process systems. Analysis of auxiliary electrical loads is in progress. The loads given in Table 11.2 of APAE 115, Vol. II, are being checked and updated as required. Electrical loads for heating, ventilation and lighting were determined by Jackson & Moreland to be 246 kw; maximum load occurs during shutdown conditions. Diesel generator and switchgear manufacturers have been contacted to obtain performance data and experience that can be applied to PL-3 system designs. An electrical one-line diagram is undergoing engineering analysis to determine electrical ratings of cables, switchgear and electrical instrumentation. Consultations with the U. S. Army Signal Corps Research and Development Laboratory at Fort Monmouth, New Jersey, were held; the discussions concerned the rigid ma-

SECTION THRU
VAPOR CONTAINER
ONLY

TYPICAL
DRIVES

LAYOUT			
ALCO PRODUCTS INC. SCHENECTADY, NEW YORK ATOMIC ENERGY DEPT.			
MODEL PL-3	STARTED 8-26-53	DESIGNED BY R. S. Gentry	REVIEWED BY E. J. HANCOCK
REVISION AEL 754	DATE 8/26/53	APPROVED R. S. Gentry	DATE 8/26/53
AUTHORITY	DATE	APPROVED	DATE
TITLE CONTROL ROD DRIVE ARRANGEMENT #2			
LAYOUT NO. AES-619

<p>LAYOUT</p> <p>ALCO PRODUCTS INC. SCHAUMBURG, ILL. 60196 ATOMIC ENERGY DEPT.</p>	
<p>MODEL -</p> <p>P.L. 3</p>	<p>DRAWN BY</p> <p>W. J. 7754</p>
<p>REFERENCES -</p>	<p>REVIEWED BY</p> <p>R. D. Bandy</p>
<p>AUTHORITY -</p>	<p>APPROVED BY</p> <p>R. S. Schindler</p>
<p>DATE</p> <p>10/1/64</p>	<p>DATE</p> <p>10/1/64</p>
<p>TITLE</p> <p>CONTROL ROD DRIVE EXTENSIONS</p>	
<p>LAYOUT NO. -</p> <p>AEL-784</p>	

terial requirements imposed on plant electrical cabling by the Antarctic environment. Informative data were acquired and will be considered in designing the interconnecting cabling. Intra-plant communications systems are being reviewed for applicability to PL-3 and for concurrence with established environmental criteria.

Mechanical

Engineering effort during the period has been directed toward producing secondary system fluid flow diagrams. Analysis of fluid systems is being carried out and pipe sizes, pump sizes and heat loads are being established. Systems under consideration include the main and auxiliary steam system and the glycol heat rejection system. Design analyses of the condenser, the turbine-generator set and the air blast coolers have been carried out. Data resulting from these analyses will be included as part of the respective equipment specifications.

SUBTASK 6.3.2 - PLANT SYSTEM SPECIFICATIONS

OBJECTIVES

The object of this subtask is to prepare, issue, and obtain approval for engineering specifications covering mechanical, instrumentation and control equipment to be installed in the power conversion systems of the PL-3 nuclear power plant.

SUMMARY OF RESULTS

Electrical

Data obtained from design analyses being carried out under Subtask 6.3.1 are being incorporated in specifications for electrical equipment. Development of specifications for the nuclear instrumentation system is directed at obtaining equipment built to Military Specification MIL-N-19900. It is anticipated that exceptions to this specification will be made. The extent of the exceptions will be determined by the performance and environmental criteria established for the system. Specifications for the control console will also make use of data resulting from current design analyses. Process instrumentation specification will incorporate results of design analyses of secondary systems as well as the control console. Auxiliary electrical load analysis will provide data for engineering specifications of the auxiliary diesel generator units, the plant switchgear and the intra-plant wiring and cabling.

Mechanical

Design analyses completed during this period have resulted in the submittal of specifications for the turbine-generator set (PL-3/4003/P) for customer approval. Specifications for air blast, the main surface condenser and other secondary system components (pumps, valves, etc.) will be submitted during the next period.

SUBTASK 6.3.3 - EQUIPMENT LAYOUT

OBJECTIVE

The object of this subtask is to develop final layout drawings for the plant as a whole and for the individual modules making up the plant. Attention is given to integrating the plant complex and the general camp layout. Within the plant, attention is given to optimum construction practices, radiation safety and ease of operation.

SUMMARY OF RESULTS

Mechanical and Electrical

Alco Drawing No. AEL 771, Plant Plan Arrangement, has been submitted for customer approval. Within the plant, engineering sketches have been made of various modules, piping systems and electrical power and instrumentation systems. These sketches have been used as a basis for engineering design analyses performed under Subtask 6.3.1. Systems under development include steam systems, condensate and feedwater systems, auxiliary cooling water systems, glycol heat rejection systems, turbine auxiliary systems and secondary auxiliary systems. To develop piping layout for these systems, preliminary layouts of the condenser skid, the turbine-generator skid, the turbine auxiliaries skid and the secondary auxiliaries skid have been made. As specifications are completed and final data is obtained on various pieces of equipment, these sketches will become final design and construction drawings. Engineering evaluations are being made of several methods of interconnecting electrical and fluid systems on the various plant modules. An attempt is being made to develop a unitized rack to carry piping and wiring between skids. Several unitized racks could be shipped pre-assembled on a single skid base.

SUBTASK 6.5.1 - HEALTH PHYSICS

OBJECTIVE

This subtask provides for the necessary engineering effort to incorporate into the PL-3 nuclear power plant an adequate system for radiation control. This includes the reactor complex, the radiation monitoring system and its supplemental portable instruments and calibration facilities and the personnel monitoring system and its associated equipment.

SUMMARY OF RESULTS

Ventilation System

The ventilation system design incorporates methods of monitoring all plant exhausts for radioactivity and control of air flows from clear areas to areas of possible contamination, and provides for the use of the reactor tunnel as a means of secondary containment.

The exhausts from the areas of possible contamination are continuously monitored for airborne particulates and daily, 24 hour samples are taken for possible gaseous iodine activity. The exhausts from the operations and secondary buildings are monitored on a daily (24 hour sample) basis for particulates and gaseous iodine.

Radiation Monitoring System

The radiation monitoring system, in addition to the gaseous and particulate monitors mentioned above, consists of an area monitoring system with six channels and a process monitoring system of two channels. The area monitors are as follows:

<u>Location</u>	<u>Range</u>
Control console	0.1 to 100 mr/hr
Radio chem lab	0.1 to 100 mr/hr
Waste processing area	0.1 to 100 mr/hr

Spent fuel area	(a)	0.01 to 10 R/hr
Vapor container entrance	(b)	0.01 to 10 R/hr
Calibration room	(c)	variable

- (a) This detector is relocated to the barrier in the tunnel between the waste processing and reactor buildings during reactor operations.
- (b) This detector is relocated to the barrier in the tunnel between the secondary and reactor buildings during reactor operations.
- (c) This detector can be used as a spare for any of the other five detectors. The channel is used to calibrate any of the six detectors.

The process monitors consist of a gaseous monitor on the condenser air ejector and an on-line monitor on the primary system purification line. Also included in the radiation monitoring system is a gaseous monitor for continuously recording the gaseous activity in the steam generator vapor container.

SUBTASK 6.6.1 - PROJECT SCHEDULING BY CRITICAL PATH METHODS

OBJECTIVE

The objective of this subtask is to develop a detailed PL-3 project schedule that will meet the project time requirements and provide an effective means with which management can monitor the progress of the program.

SUMMARY OF RESULTS

A planning network of approximately nine hundred activities has been established, consisting primarily of the engineering, procurement and state-side testing activities up to shipment to P.O.E. The first trial run of the network was completed using the Critical Path Method program on the GE 225 digital computer. The results are being analyzed and modified by the project group.

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