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HISTORY OF THE PM-3A NUCLEAR POWER PLANT MCMURDO STATION, ANTARCTICA

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HISTORY OF THE PM-3A NUCLEAR POWER PLANT

MCMURDO STATION, ANTARCTICA

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SUMMARY

Authorized and funded by Congress in 1960, the PM-3A Nuclear Power Plant located at McMurdo Station, Antarctica, first achieved criticality in March 1962 and was operated by Navy crews under the direction of the Martin Company and the Atomic Energy Commission (AEC) until May 1964. At that time, the Navy assumed full responsibility for its operation and continued to do so until the plant was shutdown in September 1972 and decommissioning actions completed.

The decision to terminate plant operations was based largely on economics. A shield water seepage into insulation around the reactor pressure vessel and primary coolant piping made chloride stress corrosion cracking of the surfaces of the pressure vessel a possibility. The high cost of performing a full inspection resulted in the decision to permanently terminate PM-3A operations.

During its ten years of operation, the PM-3A produced approximately 78 million kilowatt hours of electricity with an availability of 72 percent. In 1971, the plant set a record for the longest continuous power run of a military nuclear power plant--4400 hours. This excellent history of operation vividly demonstrated the ability to operate a nuclear power plant safely and reliably in a remote, hostile environment. The plant also represented the first use of nuclear energy ashore to distill fresh water, producing over 13 million gallons of potable water at its seawater distillation plant. These operational achievements are a credit to the many dedicated and highly talented officers and enlisted men of the Navy, Army, and Air Force, who served at or in support of the PM-3A during its operational lifetime.

The PM-3A eased the tremendous and costly (both in dollars and human lives) logistics problem of hauling millions of gallons of fuel oil to the Antarctic continent each year. At the same time, the habitability of McMurdo was upgraded by the provision of clean, safe electrical heat. The scientific research effort also benefited in that electrical equipment was not severely limited by the small electrical capacity of the fossil fueled plant, and the increased electrical capacity provided by the PM-3A was of a higher quality, regulated output.

In order to comply with the Antarctic Treaty, which prohibits the disposal of radioactive wastes on the continent, the plant was decommissioned by completely removing all contaminated components and disposing of them in the United States. In addition, 14,400 metric tons of crushed rock containing extremely small quantities of radionuclides were also removed from the site and shipped to the United States. The total removal effort was completed in February 1979.

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LIST OF ABBREVIATIONS

AEC - Atomic Energy Commission

AOIC - Assistant Officer in Charge

ASME - American Society of Mechanical Engineers

BST - Bistable Trip

BUDOCKS - Navy Bureau of Yards and Docks
(Now the Naval Facilities Engineering Command--NAVFACENGCOM)

CBC - Construction Battalion Center

CBU - Construction Battalion Unit

CFR - Code of Federal Regulations

Ci - Curie

CONUS - Continental United States

CRDM - Control Rod Drive Mechanism

CRUD - Chalk River Unidentified Deposits

CT - Current Transformer

EFPH - Effective Full Power Hours

ERSP - Environmental Radiation Surveillance Program

HPSC - Health Physics, Personnel Safety and Chemistry

HUT - Hold-up Tank

IAEA - International Atomic Energy Agency

M&S - Maintenance and Supply

MPC - Maximum Permissible Concentration

mRem - milli-Rem (Roengten Equivalent Man)

NAVFACENGCOM - Naval Facilities Engineering Command
(Formerly the Navy Bureau of Yards and Docks--BUDOCKS)

NI - Nuclear Instrumentation

NAVNUPWRU - Naval Nuclear Power Unit

LIST OF ABBREVIATIONS (continued)

NAVNUPWRU DET PM-3A	Naval Nuclear Power Unit Detachment PM-3A
NSFA	Naval Support Force Antarctica
OIC	Officer in Charge
PC	Primary Coolant
PPB	Parts per Billion
PPM	Parts per Million
PT	Potential Transformer
RTG	Radioisotope Thermoelectric Generator
RWDS	Radioactive Waste Disposal System
SECNAV	Secretary of the Navy
SS	Stainless Steel
USPHS	United States Public Health Service

CHAPTER I

PLANNING AND CONSTRUCTION

1. Project Initiation

Extensive Navy involvement in Antarctica actually began in 1955 in preparation for the International Geophysical Year. The Department of Defense delegated responsibility for logistic support of Antarctic operaions, and maintenance of stations located in Antarctica to the Department of the Navy.

In August 1960, Congress authorized and funded the design and construction of a nuclear power plant to be installed at McMurdo Station, Antarctica. A little over 18 months later, in early March 1962. the plant reached initial criticality and became the only nuclear power plant to date to operate in Antarctica.

Eighteen months is a phenomenally short time in which to design and construct a nuclear plant anywhere, much less in the distant and harsh environment of the Antarctic. However, the idea of utilizing nuclear power to support operation DEEP FREEZE in Antarctica was actually conceived as early as 1955 when a study concluded that utilization of nuclear power there was not only feasible but highly desirable.

Nuclear power on the remote continent was particularly promising in that money and manpower expended in logistic support far outweighed that spent directly on scientific research, and over half of this logistic effort was consumed in transporting fuel oil. Even in 1960 fuel oil delivered to McMurdo cost $1 to $3 per gallon. The fuel oil storage capacity at McMurdo was limited, thus the PM-3A promoted the conservation of fuel oil in storage. This conservation of fuel oil permitted the resupply of inland stations early in the season vice the late season resupply necessitated by the wait for the annual resupply tanker. Further, transportation operations in the Antarctic were hazardous, and a reduction in logistics requirements could be expected to result in fewer loses of lives and equipment. Also not to be overlooked was the nuclear potential for increasing the habitability of the station and the capacity for research by providing larger quantities of superior quality electrical power than could be afforded by a fossil fueled plant. This increased electrical capacity would also allow for more electrical heating and less use of oil heaters, which are dangerous fire hazards. Finally, in the political arena, the installation of a nuclear power plant in the Antarctic was seen as an outstanding example of the United States' "Atoms for Peace" program.

All in all, the case for nuclear power in the Antarctic looked good in the late 1950's, but there were other factors which hampered its initiation by the Navy. Since the construction cost of a nuclear plant is significantly higher than a conventional plant, and since such a project was in direct competition for funding with operational requirements, the promises of nuclear power never survived the Navy's budget cycle. Another contributing factor which hindered any substantial outlay of capital funds in the DEEP FREEZE program was the fact that the Antarctic Treaty had not yet been signed, making the permanency of U.S. operations on the continent questionable.

By 1960, however, the time was right for approval of the concept of nuclear power in the Antarctic. The Antarctic Treaty had been signed in December 1959, and the indication was that the U.S. would be in the Antarctic for the foreseeable future. Accordingly, it became necessary to plan for supporting Antarctic Operations on a basis consistent with long term occupancy rather than the adequate-for-survival, and minimal operational basis followed heretofore. The Naval Facilities Engineering Command (NAVFACENGCOM) had also completed economic studies in April 1959 and February 1960 which supported the development of nuclear power in Antarctica. Equally important was the fact that trips to the Antarctic by Senators and Representatives had spurred congressional interest in the intrinsic logistics problem. As a result of this interest, a study commissioned by the Atomic Energy Commission (AEC) was made by Kaiser Engineers for nuclear power in the Antarctic and other remote military installations. This study was presented in Congressional Hearings before the Joint Committee on Atomic Energy in April 1960, and in May 1960 Public Law 86-475 (AEC authorization for Fiscal Year 1961) authorized $13 million for power reactor plants for the Antarctic. The authorization was to cover plants at McMurdo, Byrd, and South Pole stations. However, the appropriations bill which followed only provided funds in the amount of $3.5 million. These funds, plus $1.5 million which the Navy had advanced to the AEC intending to be reimbursed after passage of the AEC's appropriation bill, were sufficient for design and fabrication of only the McMurdo plant. Even then, the Navy would be responsible for funding site preparation and on-site construction. Nevertheless, the chain of events had finally been initiated which would lead to the reality of nuclear power in the Antarctic.

2. Plant Construction

In anticipation of passage of the appropriations bill, the AEC on 20 June 1960 invited ten reactor manufacturers to bid on the McMurdo Station nuclear plant, and bids were received from three firms--Alco Products, Inc., The Martin Company, and Combustion Engineering, Inc. The Martin Company was selected, and the contract was entered into on 15 August 1960 for $4,086,148. The initial obligation of the AEC was limited to the $1.5 million advance from the Navy, however, since the AEC funds had not yet been appropriated.

The nuclear plant to be constructed was designated the PM-3A (a portable, medium-output reactor that was the third of its general type and the first of that type designed for field use). Portability was central to the PM-3A concept. McMurdo Station is accessible in summer by ship, but the Navy envisioned future use of nuclear power at inland stations and so developed the PM-3A as the prototype of a plant which could be delivered in modules by LC-130 aircraft to such places as Byrd and Pole stations. The ability to construct the plant during the short Antarctic summer season was also a required feature of the design. The final design of the plant resulted in 18 basic portable units, each with a maximum weight of 30,000 pounds and maximum dimensions of 30 feet long by 8 feet 8 inches square. A summary of the more important characteristics of the PM-3A are shown in Table I-1, and a diagram of the plant is shown in Figure I-1.

After signature of the contract in August 1960, component procurement was initiated immediately. In April 1961, the first Navy operating crew arrived to witness the early fabrication of the plant as it was assembled in the Environmental Testing Building of Martin-Marrietta, Baltimore, Maryland. In July the crew began participating in the testing program, during the next three months the complete plant was assembled and tested in all phases short of actual operation of the reactor itself. The reactor core was tested separately at zero power in the contractor's "critical" facility. Dismantling of the plant's secondary system began in September, and the primary system checkout began. Members of Naval Mobile Construction Battalion ONE were also present to observe the disassembly so that reassembly in the short construction season at McMurdo would go as quickly and smoothly as possible. Site preparation had begun the previous austral summer season and would be completed early during DEEP FREEZE 62 before the plant components arrived.

On 3 November 1961, all the plant modules had been loaded aboard the USS ARNEB (AKA-56), and the resupply ship sailed from Davisville, Rhode Island for its voyage to McMurdo Sound. On 13 December the ARNEB was secured to the annual ice a few miles from McMurdo, and by 29 December the last major package of the plant had been pulled by sled to the PM-3A site. Initial criticality of the core was attained 4 March 1962, and the last ship of the summer season departed. Left behind to test and operate the plant were 20 men of the Navy crew (including Army and Air Force personnel), three Martin engineers and two AEC representatives. A picture of the completed plant, located 300 feet up the side of Observation Hill and overlooking McMurdo Station proper, is shown in Figure I-2 and the site plat plan is shown in Figure I-3. The general plant arrangement is shown in Figure I-4, while the primary plant arrangement is shown on Figure I-5. Figure I-6 is a diagram of the PM-3A pressure vessel and core.

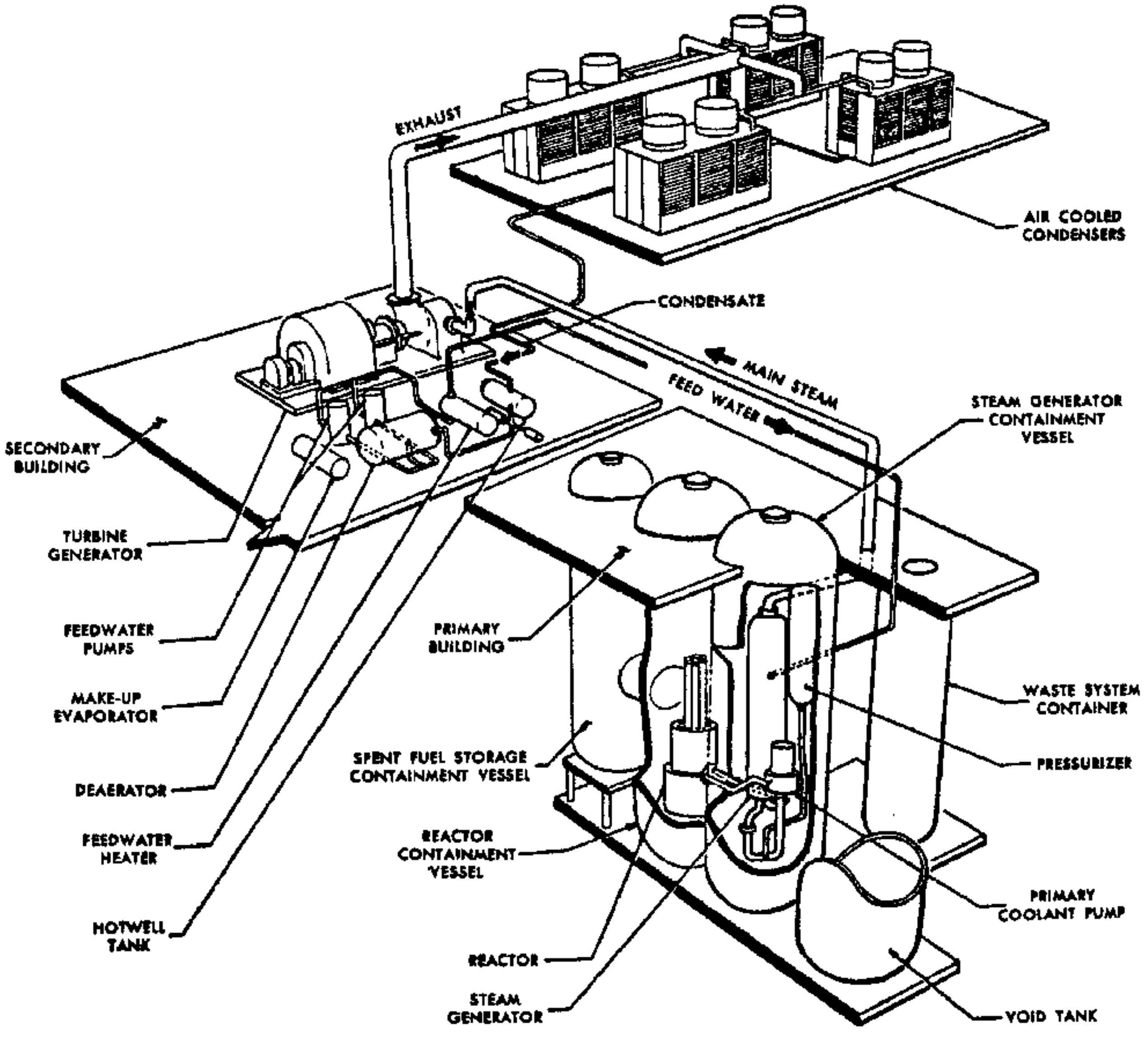
TABLE I-1

PM-3A PLANT DESCRIPTION

	INITIAL	FINAL
REACTOR TYPE	Pressurized Water	Pressurized Water
POWER (THERMAL)	9.36 Megawatts	11.27 Megawatts
NET OUTPUT (ELECTRICAL)	1500 Kilowatts	1800 Kilowatts
FUEL	Uranium 93.2% enriched in U-235	Uranium 9.6% enriched in U-235
FUEL ELEMENT CONSTRUCTION	Tubular Cermet	Pellet in rod
FUEL CLADDING	Modified type 347 SS	Type 348 SS
MODERATOR, REFLECTOR AND COOLANT	Water	Water
CONTROL ROD ABSORBER	Europium	Europium
BURNABLE POISON	Boron	Boron
PRIMARY LOOP OPERATING PRESSURE	1300 psia	1300 psia
CORE INLET TEMPERATURE	447°F	447°F
CORE OUTLET TEMPERATURE	479°F	479°F
PRIMARY COOLANT FLOW RATE	2200 gpm	2200 gpm
STEAM FLOW RATE	36,131 lbs/hr	42,900 lbs/hr
STEAM PRESSURE FULL LOAD	300 psig	290 psig
CONDENSERS	Steam-to-Air	Steam-to-Air

FIGURE I-1

PM-3A SCHEMATIC



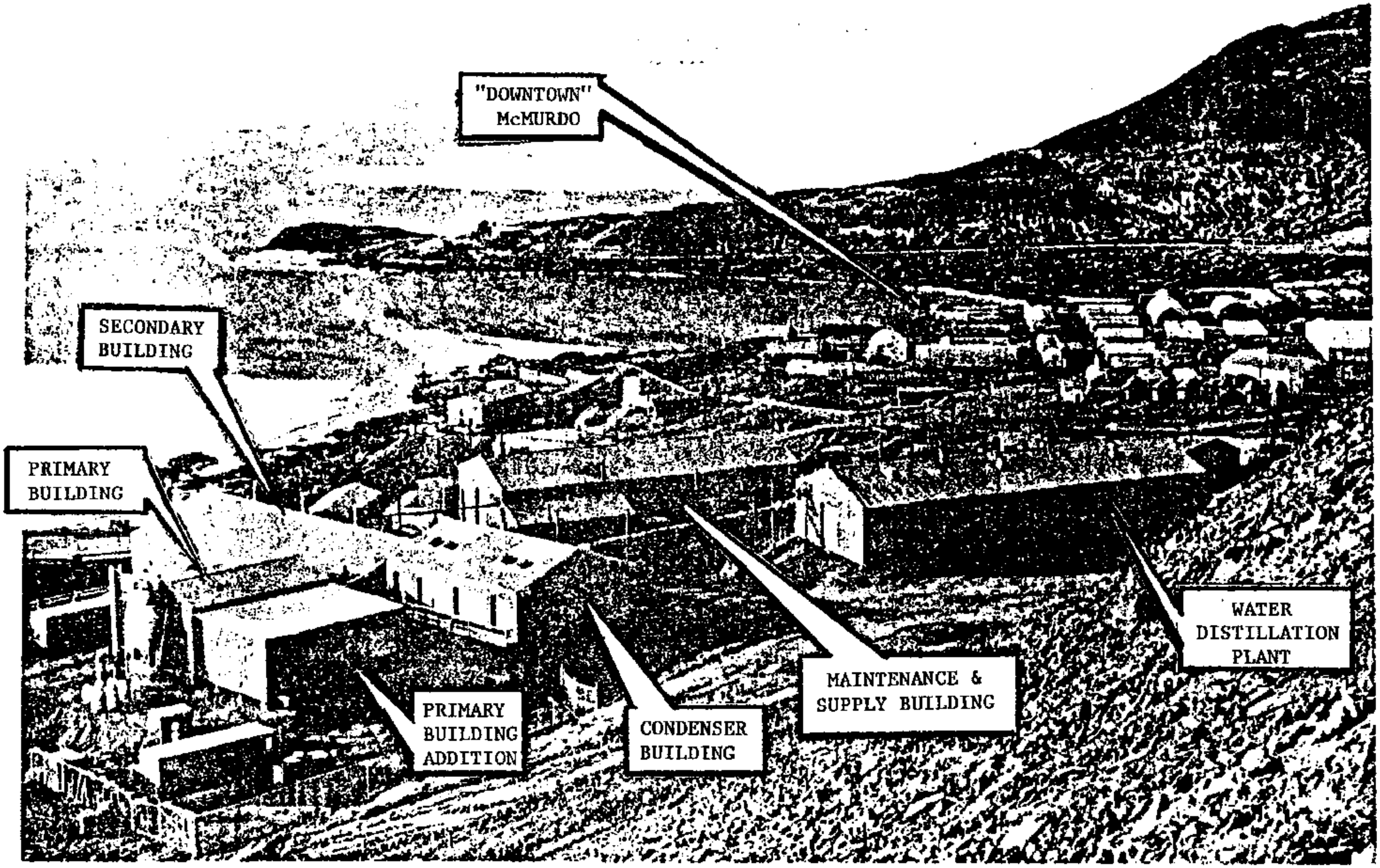
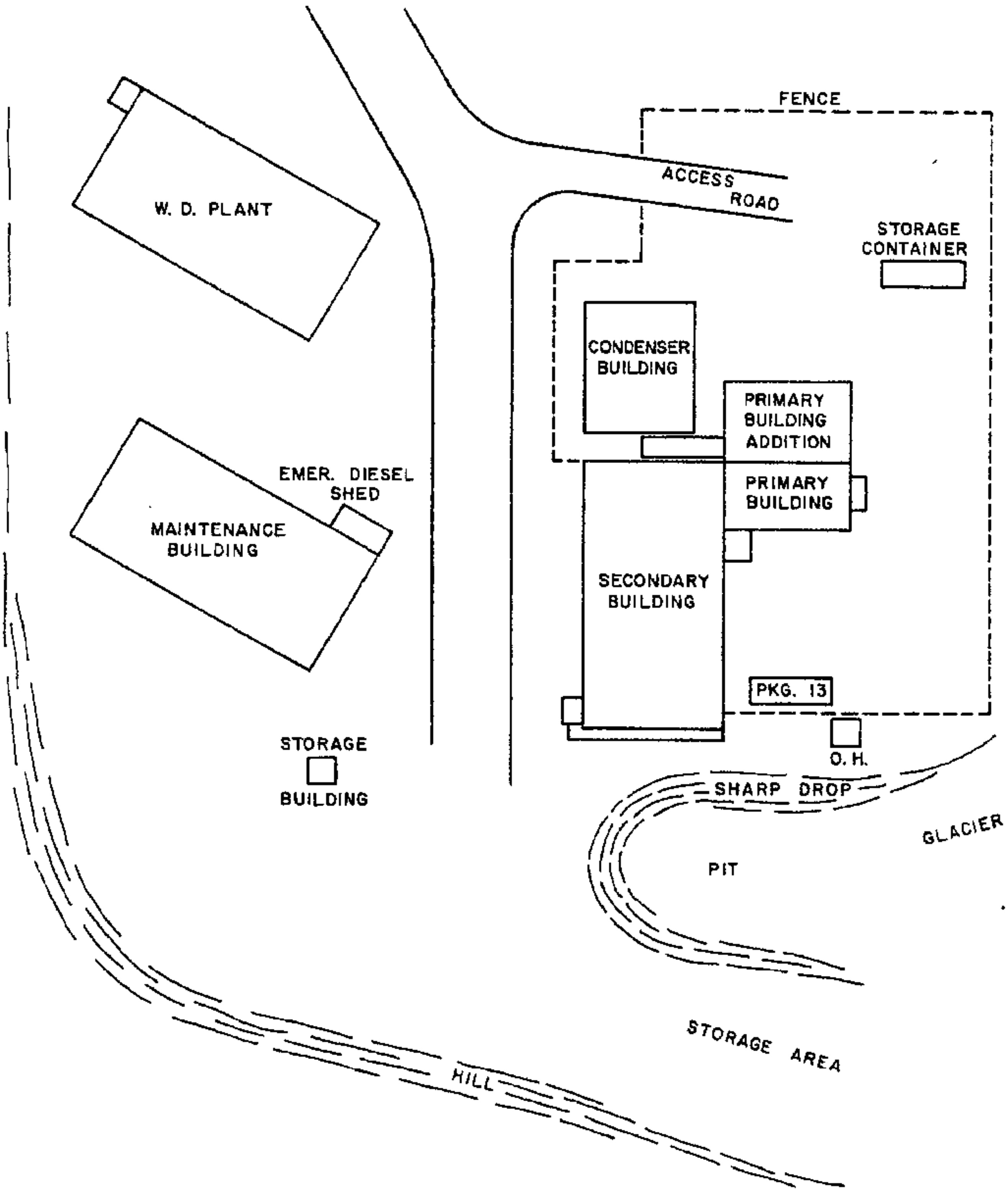
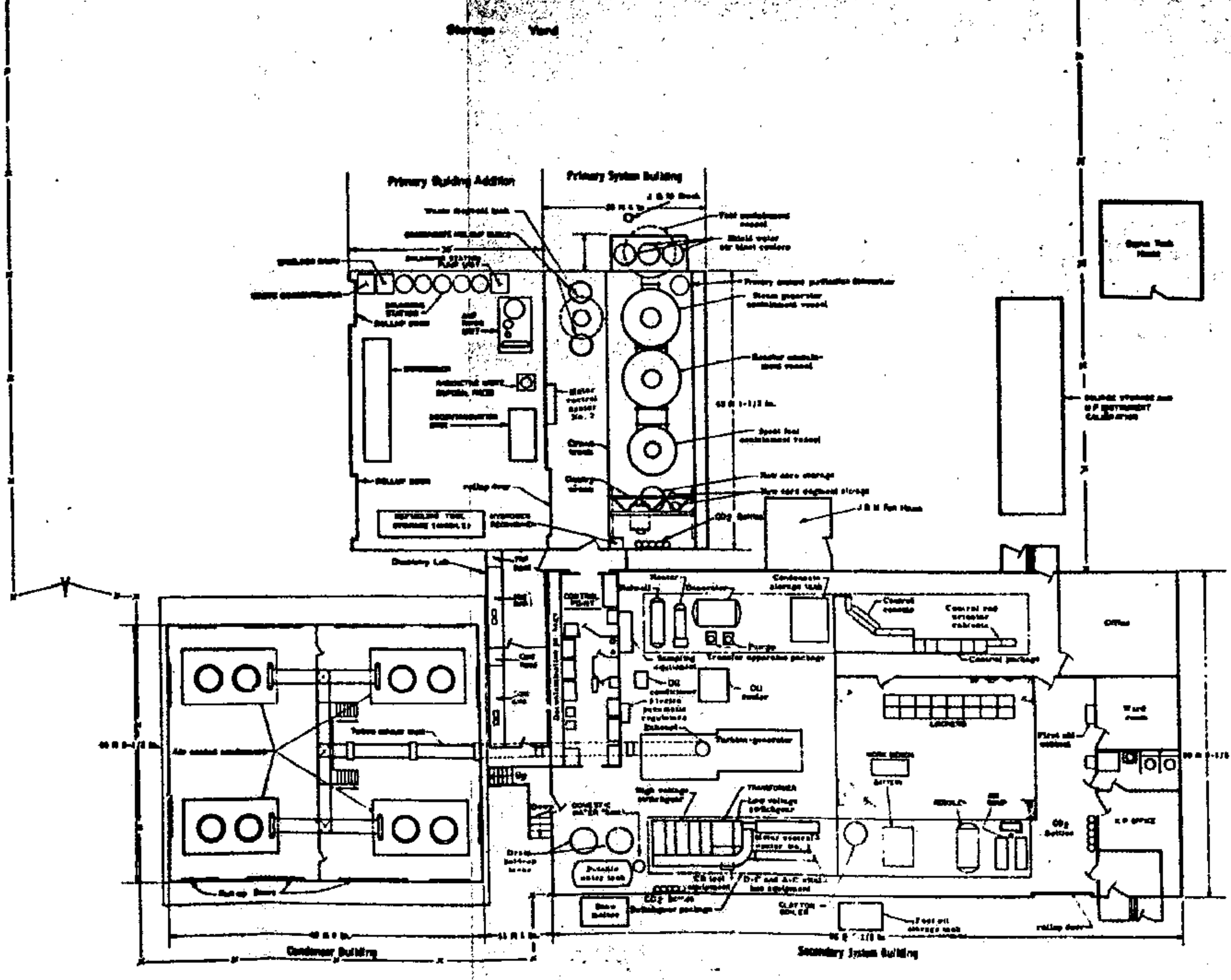


FIGURE I-2

Pict[illegible] of [illegible]-3A Site

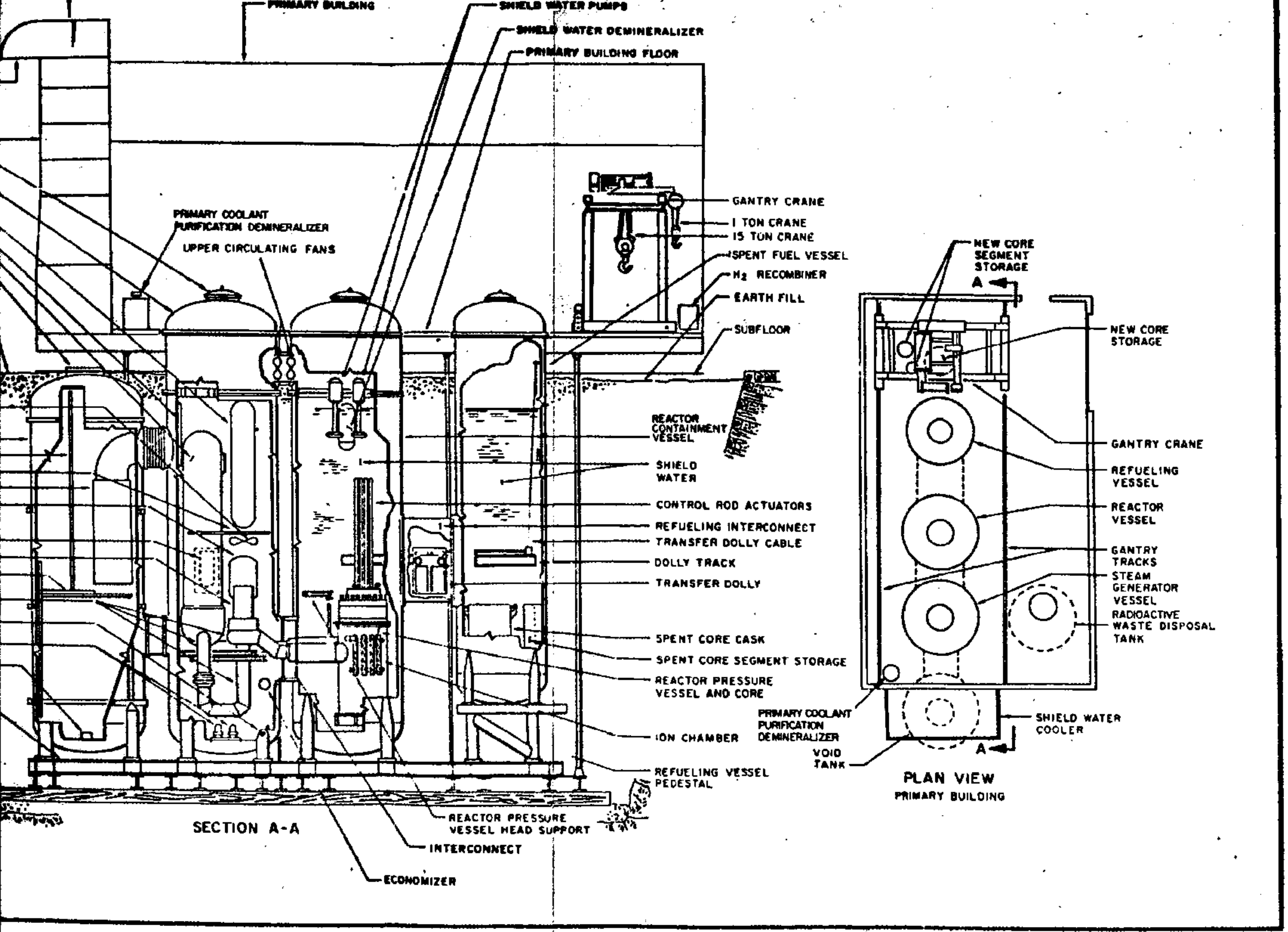
FIGURE I-3
SITE PLAT PLAN





GENERAL PLANT ARRANGEMENT

FIGURE I-4


SECTION A-A

PLAN VIEW

PRIMARY BUILDING

FIGURE 1.5

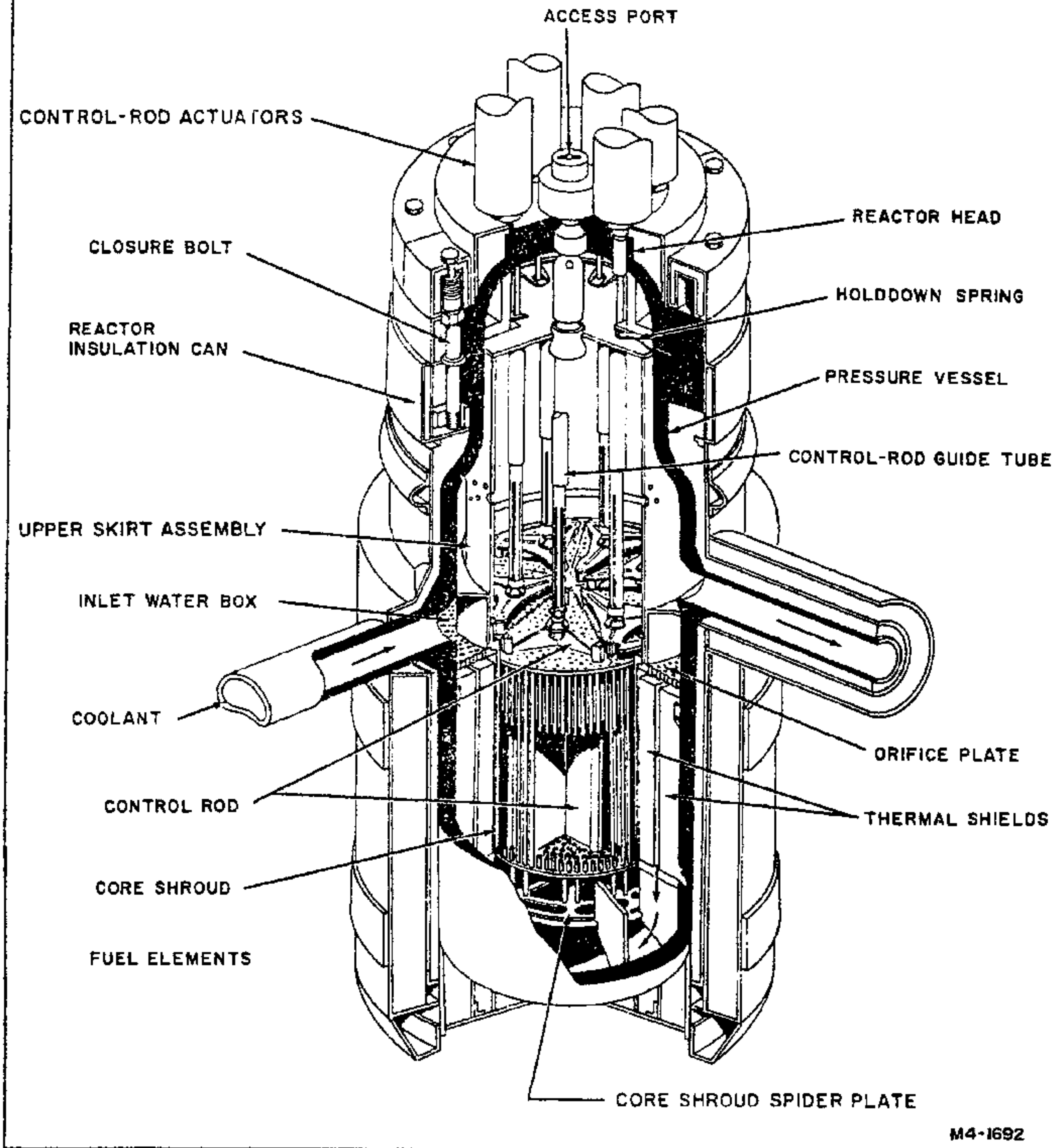


FIGURE I-6 PM-3A PRESSURE VESSEL AND CORE

CHAPTER II

INITIAL TESTING AND OPERATION

1. The First Year

Even though initial criticality had been attained in a very short time, months of testing, evaluation and debugging remained to be accomplished before PM-3A could start to perform its prime mission of supplying power to the McMurdo complex. Plans called for the demonstration of the plant's performance and reliability during the Antarctic winter with subsequent turnover to the Navy during the following austral summer season (October 1962-February 1963).

Numerous problems were encountered in preparing the plant for operation during the initial testing phase. The most persistent problem encountered during this period was the inability to successfully complete the containment air leak test which limited leakage to not more than 1.5 percent per day at 30 psig. This test was important in that it was an indication of how safely the plant could handle a postulated "maximum credible accident" by containing any released radioactive material from a core meltdown. Air leakage around nuclear instrumentation and electrical cable penetrations caused the greatest problems, but after repeated attempts and after making repairs to a seal weld in one of the containment tanks, the test was successfully completed in June.

In April, when performing the containment leak test for the fourth time, it was discovered that the Control Rod Drive Mechanism (CRDM) actuator cans, which housed the equipment controlling rod movement and reactor power, had been inadvertently crushed by air pressure. This situation did not cause an inability to operate control rods, and the condition was remedied by applying air pressure inside the cans, causing them to pop out to their original configuration. (Appendix A describes the PM-3A reactor rod control system). After inspection and adjustment of the internals, the cans were returned to satisfactory service.

Another problem which jeopardized early operation of the plant was the core's failure to meet the "one-rod stuck" criterion at room temperature. Preshipment criticality tests conducted at the Martin facility in Baltimore had not indicated a failure to meet the criterion, but at the site the reactor was critical with one of its control rods withdrawn 28.55 inches (30.75 inches is completely withdrawn) and the coolant at 50°F. It was determined that procedural controls, i.e., not allowing any withdrawal of control rods until the system temperature was such that the "one-rod stuck" criterion could be met, would be an adequate temporary measure until such time as reduced core reactivity would enable the core to meet the specification at room temperature. All later cores met the criterion.

Finally, after four frustrating months of testing and correcting discrepancies, on 10 July 1962, PM-3A exported power to the McMurdo Station electric heaters, and on 21 July, all station electrical loads were assumed by the plant for the first time. This was just the beginning, however, of the shakedown period of the plant.

Between 21 July and 7 October, PM-3A experienced four outages. The first occurred 14 August when momentarily low voltage gave a false signal of low primary coolant pump power, automatically shutting-down (scramming) the plant. The set point was checked, recalibrated and the plant put back in operation within 19 hours. The second outage occurred 25 August and lasted 154 hours. This shutdown was caused by moisture in the nuclear instrumentation due partially to radiation damage to instrumentation cables inside containment. The equipment was dried, resealed, and cables replaced and rerouted to help prevent recurrence of the damage. This incident was immediately followed by a 48-hour outage caused by failure of the boiler feed pump. The plant then operated continuously until 26 September when one control rod fell into the core due to a transient failure in the control rod power supply. This time PM-3A reassumed the load in less than four hours, operating on a five-rod bank until the control power supply was repaired a few hours later.

Then on 7 October the plant suffered a fire in the containment tanks which resulted in an extended outage. It was subsequently determined that the fire was caused by the combustion of hydrogen gas which was generated by radiolytic decomposition of shield and coolant water under high gamma flux. The damage from the fire was largely superficial. The short duration, high temperature flash fire caused scorching of cables and paint, and the resultant overpressure in the containment tanks damaged junction box covers, sheet metal work and some thermal insulation. The only major equipment items damaged were the control rod actuator coil cans, which were partially collapsed around the hold coils and position indicating mechanism. No injuries or unusual radioactivity resulted from the incident. The fact that a flash fire had occurred in the containment tanks was not known until repeated attempts to restart the plant after a scram were unsuccessful, and the containment was opened for investigation.

Investigation of the accident resulted in several equipment modifications and procedural changes being implemented to prevent the reoccurrence of an explosive mixture of hydrogen in the containment. It was also determined that data on hydrogen generation in the containment should be collected, and if necessary, based on this information, a hydrogen recombiner be designed and installed. This data was taken during November when the plant was run in 40 hour intervals due to the limit placed on hydrogen buildup. The plant was then shutdown on 28 November and remained down in order to work on the many items that would have to be completed prior to acceptance of the plant by the government. In addition to the installation of a catalytic recombiner for hydrogen in the containment tanks, this work included such items as nuclear instrumentation noise reduction, modification to the control rod actuator cans, repair of Condenser Number Four which suffered heavy freeze damage in September, modifications to the Radioactive Waste Disposal System (RWDS), and many minor plant operation items.

An inspection of PM-3A by NAVFACENGCOM in December 1962, however, revealed such a large number of deficiencies remaining that it was apparent the contractor could not complete them all before the end of the austral summer. What was to have been a final turnover inspection in February 1963, became instead an inspection to determine if the plant could be safely operated during the coming winter and to identify any additional areas which required attention before the plant could be accepted from the contractor.

The inspection team concluded that the condition of the plant was adequate to permit operation under the responsibility of the contractor during the winter, but specific problems were identified in twelve broad areas which the team felt should be corrected prior to any acceptance by the Navy. These broad areas were as follows:

a. Nuclear Instrumentation Reliability and Accuracy
b. Control Rod Actuator Performance
c. Hydrogen Generation in Containment
d. Vapor Containment Integrity
e. Refueling Procedures and Equipment
f. Inadequate Emergency Power
g. Plant Chemistry Data and Procedures
h. RWDS Capacity
i. Primary System Relief Valve Integrity
j. Lack of Detailed Design Information
k. Tritium Generation
l. Inadequate Core Physics Data and Testing Procedures

In reviewing the first year's operation of the PM-3A, it should be kept in mind that the plant was essentially a prototype, conceived after only ten years of nuclear power plant experience was available and was operated in the harshest environment in the world. Actually the period from initial power operation until the fire was impressive for a "shakedown" run, with the plant operating 79 out of 89 days.

2. Second Year Operation and Turnover to the Navy

After preoperational plant testing, PM-3A began a 400-hour test run on 27 February 1963. The plant scrammed three times during this run but was off the line for only brief intervals totaling eleven hours before termination of the run on 17 March. Between 17 March and 4 April, the plant remained down to allow completion of various corrective actions. This was followed by a period of plant testing, including rod drop and transient testing, during which the plant was cycled up and down numerous times. A second 400-hour demonstration run was then conducted from 14 April through 5 May when the plant was shutdown for demineralizer resin change. The total operating time for this demonstration run was actually 502 hours with one 4-hour down period on 18 April. After replacement of resins, PM-3A remained down for repairs to the emergency diesel generator as well as other miscellaneous minor repairs. On 15 May power operations resumed and continued with only minor outages (20 hours total) until

3 August when the plant was secured for scheduled maintenance. The plant returned to producing power 14 August and was only brought down twice for minor repair (6 hours total) before 30 August 1963, when the AEC representative ordered the plant secured due to pitting corrosion on the control rod actuator thimbles. Following this shutdown, the plant was only briefly operated twice--11 to 29 November 1963 for training and minor testing of components and 29 February to 3 March 1964 for a performance test--before the AEC accepted the plant from the contractor and the Navy assumed custody.

During the extensive down time which followed 30 August, the contractor not only replaced and modified the corroded thimbles, but also worked on an extensive list of discrepancies identified by the Navy and the AEC in order to turn the plant over before the next winter season. It became apparent, however, that all items requiring attention could not be accomplished in the time remaining. It was also the position of the contractor, with concurrence of the AEC, that not all the problem areas remaining were within the scope of the contract to correct. Recognition was being made of the fact that further continuing research and development and modification would be required in order for PM-3A to perform in accordance with the Navy's original expectations at a suitable reliability level.

In light of the above, the AEC proposed the following division of responsibilities for resolving plant deficiencies and accepting the plant from the contractor. First, Martin-Marietta would be required to complete certain items determined to be within the scope of the original contract and previous modifications. Additionally, a final modification to the contract, Modification 16, would be negotiated and accomplished as soon as possible, but acceptance of the plant would coincide with signing of the contract modification. Modification 16 included the following items of work:

a. Control rod actuator repair.

b. Preparation of a revised containment air leak test procedure and provision of a complete set of electrical penetrations.

c. Supervision of the first plant refueling.

d. Analysis of tritium generation.

e. Provision of primary and shield water demineralizers.

f. Modification of equipment/procedures to maintain shield water pH and steam generator blowdown chlorides within operating limits.

g. Analysis/verification of the life of the nuclear instrumentation cables.

h. Drawings and analyses of the modifications to date on the reactor safety system.

i. Replacement of defective batteries.

j. Provision of detailed as-built electrical drawings.

k. Preparation of set point analysis.

l. Provision of manuals, drawings and procedures reflecting latest revisions.

m. Preparation of core and plant monitoring procedures.

n. Preparation of a plant heat balance.

o. Modifications to the RWDS.

p. Establishment of criteria for air activity and gaseous release.

q. Preparation of a casualty procedure in the event of a fuel element cladding failure.

r. Preparation of steam generator level calibration and control procedures.

s. Preparation of an extended shutdown procedure.

t. Modification of the hydrogen recombiner system.

The AEC agreed to extend its Portable Medium (PM) Power Reactor Development Program to include further work in the following areas relating to the PM-3A deficiencies:

a. Improvement to the control rod actuator system.

b. Improvement in the nuclear instrumentation and reactor safety systems.

c. Investigation into the problem of hydrogen generation.

d. Improvements in the RWDS.

e. Development of an improved, low cost core (Type IV).

The Navy reluctantly agreed to this proposed turnover scheme, realizing that a continuing effort on its part would also be required to improve plant safety and reliability. Thus, on 12 March 1964 the Martin Company and the AEC executed Modification 16 to the contract, and the Navy took custody of the plant but did not assume operational responsibility. The plant remained shutdown during subsequent months while certain safety and operational matters were resolved between the Navy and the AEC. Major areas of concern were as follows:

a. Verification of the integrity of the containment vessels. (Failures had occurred in other structures made of stress relieved T-1 steel, of which PM-3A containment tanks were manufactured.)

b. Reevaluation of the consequences of a postulated breach of containment accident. (Certain assumptions had been made in calculating dose rates which required verification.)

c. Development of an Emergency Plan, should the need to evacuate McMurdo arise. (Concern for items (a) and (b) above and the difficulty in performing an evacuation during Antarctic storms caused particular attention to this area.)

d. The ability of CONUS organizations to adequately control the isolated plant.

e. Ability to monitor the status of the automatic safety shutdown system. (Here the correction of one problem had caused another. Originally the scram logic was devised such that two out of two signals were required to initiate a scram. In the event that one of the channels "failed to danger" between routine tests of the system, a scram could be prevented from occurring. The system was changed to one out of two logic which solved the "prevention of scram" problem but made it impossible to test the system on the line without causing a scram. This problem was initially solved by scheduling down times at satisfactory intervals to test the system. Shortly thereafter, the system was modified to allow on-line testing. This led to yet another problem--spurious false scrams during testing.)

f. Development of operating limits, since the technical specifications provided by the contractor would not suffice. (Technical specifications were eventually developed, but the operating limit procedure was utilized for several years.)

g. Problem with a previous modification to the Control Rod Actuators. (During original assembly of modified control rod actuators prior to the February test run, the buffer piston on the rod actuator of Port #6 was reduced .020 inches in diameter. It was determined that no further operation should occur with the reduced size buffer piston, and the actuator dimensions had to be brought to acceptable tolerances.)

The above problem areas were resolved to the satisfaction of the AEC and the Navy, and on 28 May 1964 the plant personnel received authorization to proceed with startup testing and commence operation. The next chapter of this report covers the operation of the PM-3A under Navy responsibility up until the decision to decommission the plant.

CHAPTER III
NAVY OPERATION (1964-1972)

1. Command Relationships/Responsibilities

a. AEC and Department of Defense. Under the Atomic Energy Act of 1954 and by Presidential Directive of 23 September 1961, the AEC was assigned continuing responsibility for the health and safety aspects relating to the operation of nuclear power plants by the Department of Defense. The Department of Defense was required to obtain comment or concurrence of the Commission on the safety aspects of the design, location, and operation and on the safety standards, procedures and instructions for utilization facilities and the special nuclear material for use therein. An agreement between the AEC and the Department of Defense was required to more closely define the division of responsibilities stated in the Presidential Directive.

A Memorandum of Understanding between the AEC and the Department of Defense concerning the PM-3A and PL-3 (PL-3 was planned for installation at Byrd Station but was never funded) nuclear power plants was finalized on 28 March 1962. This Memorandum of Understanding (Appendix B) delineated the responsibilities for both the Commission and the U.S. Navy that were to be applied to the operation of a nuclear power plant in Antarctica. A unique situation existed due to the fact that nuclear power plants in the Antarctica were not placed under the provisions of Section 91b (Chapter 9, Military Application of Atomic Energy) of the Atomic Energy Act of 1954, because Article I of the Antarctic Treaty (Appendix C) prohibits "any measures of a military nature" in Antarctica. The Chief of Naval Operations assigned the Department of Defense responsibilities within the Navy to the Naval Facilities Engineering Command (NAVFACENGCOM).

b. Naval Facilities Engineering Command. The special nature of the equipment, supplies and engineering involved in the safe, reliable and efficient operation of nuclear shore power plants resulted in assignment of overall program management and technical direction to NAVFACENGCOM. Within NAVFACENGCOM, the responsibility was assigned to the Director of the Nuclear Power Division, with tasking to provide technical direction and program management and to assume reactor safety responsibility for the development and operation of nuclear shore power plants for Naval applications. The Division was further responsible for selecting, training and providing qualified crews for the safe and reliable operation, maintenance, and modification of the power plants.

The Secretary of the Navy directed NAVFACENGCOM to issue and promulgate regulations and instructions as required in carrying out assigned responsibilities. The publication, known as NAVDOCKS P-311 "Nuclear Shore Power Plant", defined NAVFACENGCOM policies and organizational responsibilities and contained the instructions that governed the operation and safety of naval nuclear shore power plants. The material contained in NAVDOCKS P-311 was submitted to the AEC for review on 13 January 1964, and the

AEC concurred in the adequacy of the policies and instructions on 24 April 1964. Accordingly, P-311 was the equivalent of an AEC license for the operation of nuclear shore power plants by NAVFACENGCOM. Compliance with NAVDOCKS P-311 was mandatory for all personnel concerned with the operation of naval nuclear shore power plants. Therefore, from the time the Navy took over operation on 12 March 1964 until final criticality on 26 October 1972, the PM-3A operated under the parameters set forth by NAVDOCKS P-311.

c. Naval Nuclear Power Unit. As a matter of policy, the responsibility for technical support of the operation and maintenance of shore nuclear power plants was assigned outside of NAVFACENGCOM. Prime responsibility for the technical support and maintenance of the PM-3A was delegated to the Naval Nuclear Power Unit (NAVNUPWRU), an activity under the command of NAVFACENGCOM. The reasons for this delegation were twofold:

(1) By assigning the responsibility outside of NAVFACENGCOM, the Command was in a position to exercise independent reviews and avoid the undesirable situation of having personnel reviewing their own work.

(2) NAVNUPWRU was closely associated with the Army Nuclear Power Field Office and would have the benefit of experience and services of personnel used for similar work by the Army.

The stated mission of NAVNUPWRU was to provide field services for NAVFACENGCOM in acquisition, operation and support of nuclear shore systems and to perform related training and personnel management functions and other assigned tasks. Major support functions consisted of engineering and logistics support and review and analysis of PM-3A operating data. A few examples of the engineering support provided were (1) an engineering study to finalize the scope of a work project to upgrade CRDM's, (2) analysis of high steam generator blowdown activity during startup and after load transients, (3) evaluation of amendments to 10 CFR 50 proposed in 1971 to ascertain whether or not any modifications to the PM-3A or its operating instructions would be required to ensure compliance with the proposed regulations, (4) analysis to determine the thermal and hydraulic transients which would be experienced at the PM-3A in the event of a loss of coolant accident and to establish criteria for design of an emergency core cooling system, and (5) evaluation of operating parameters for all cores used in or proposed for the PM-3A.

Logistics support of the PM-3A was doubly unique. First, supplies, replacement parts etc., for a full years operations were deliverable only once each year during the short summer season. This required advance planning beyond the norm experienced by the majority of Naval bases, and the potential existed for a lengthy shut down of the plant due to an overlooked spare replacement part or repair item. Secondly, the majority of items utilized in the PM-3A were not available within the federal supply system. This situation frequently produced lengthy lead times when ordering replacement parts of major plant components, necessitating the maintenance of approximately 15,000 line items peculiar to nuclear power plants at the PM-3A. All supply requests, with the exception of office supplies etc., available locally, were processed through a supply coordinator at the Naval Nuclear Power Unit.

d. Naval Nuclear Power Unit Detachment PM-3A McMurdo. PM-3A Detachment, McMurdo Station, Antarctica was an operating unit of the U.S. Atlantic Fleet, Task Force 43, and participated year round in Operation DEEP FREEZE. The detachment operated the PM-3A nuclear power plant from March 1964 until final defueling in July 1973 for the Commander, U.S. Naval Support Force, Antarctica, in support of the National Science Foundation's U.S. Antarctic Research Program.

The unique acquisition of the plant and the requirements for nuclear, radiological and reactor safety warranted an exceptional position with respect to command. The Detachment Officer in Charge (OIC) reported to NAVFACENGCOM for command and to Commander, Naval Support Force, Antarctica for additional duty for support. The OIC further acted as advisor to Commander, Naval Support Force, Antarctica with respect to nuclear and radiological safety and safe operation of the PM-3A. The OIC was also designated the AEC Representative, Antarctica. In this capacity he assumed custody of special nuclear material (reactor fuel), complied with accountability reporting requirements of the AEC, and assured that the material was handled in accordance with approved procedures.

The mission of the Detachment was to provide the primary source of electrical power from the PM-3A nuclear power plant; to safely operate, maintain, and modify the PM-3A; to test and evaluate the concept of portable nuclear power plants in an isolated, hostile environment; and to provide a base of trained and experienced personnel for the Navy Nuclear Shore Power Program. The mission was expanded at the later dates to include operation, maintenance and modification of the seawater distillation plant and provision of technical assistance in support of Radioisotope Power Devices. This program operated closely with similar programs of the U.S. Army and Air Force.

e. Army, Navy and Air Force Interface. NAVFACENGCOM was required by the Chief of Naval Operations to cooperate with the Army and the Air Force in the development, design, and construction of nuclear shore power plants and to utilize established training facilities. In the early days of nuclear shore power in the Department of Defense, the U.S. Army Corps of Engineers was given primary responsibility for program development, a tri-service effort with the Army having the lead role. The Army had contracted with civilian engineering firms to provide technical support on the operation and maintenance of nuclear power plants, and agreements between NAVFACENGCOM and the Army Corps of Engineers made these services and facilities available to the NAVNUPWRU.

f. NAVFACENGCOM Inspection and NAVNUPWRU Engineering Support Teams. During the years of operating the PM-3A, NAVFACENGCOM and NAVNUPWRU sponsored an annual inspection team and two annual engineering support teams which deployed to the PM-3A site.

The NAVFAC inspection team's mission was to ensure that the new crew was qualified to operate the reactor and that the reactor operation during the previous winter had been in compliance with instructions. This team was headed by a military officer from NAVFAC or the Army Nuclear Power Program with the remainder of the team comprised of specialists, in and out of government, in such fields as health physics, reactor licensing and compliance, environmental health, and reactor systems. This team normally spent five to seven days making in-depth probes of all aspects of the PM-3A operation. Recommendations were made for improvements, specific items of non-compliance were noted, and the plant and crew were certified for the coming year's operation.

The Engineering Support Teams (EST) were comprised of nuclear qualified officer(s) and engineer(s) from NAVNUPWRU. EST I deployed during crew turnover and was headed by either the OIC or AOIC of NAVNUPWRU. This team reviewed all winter-over operations, observed crew turnover training and qualification boards, and authorized the relief of the outgoing PM-3A OIC. This team also reviewed any outstanding engineering problems or plant modification requirements which had surfaced during the winter-over period.

EST II deployed in January, toward the end of the summer season, and was normally headed by a prospective PM-3A OIC. This team assisted the plant personnel in the start-up testing required after the annual maintenance, ensured supply inventories were adequate, and provided health physics support for environmental sampling. Any team members who were new to the program stood indoctrination watches at the plant. This team also reviewed progress of the work projects scheduled for completion during the summer period.

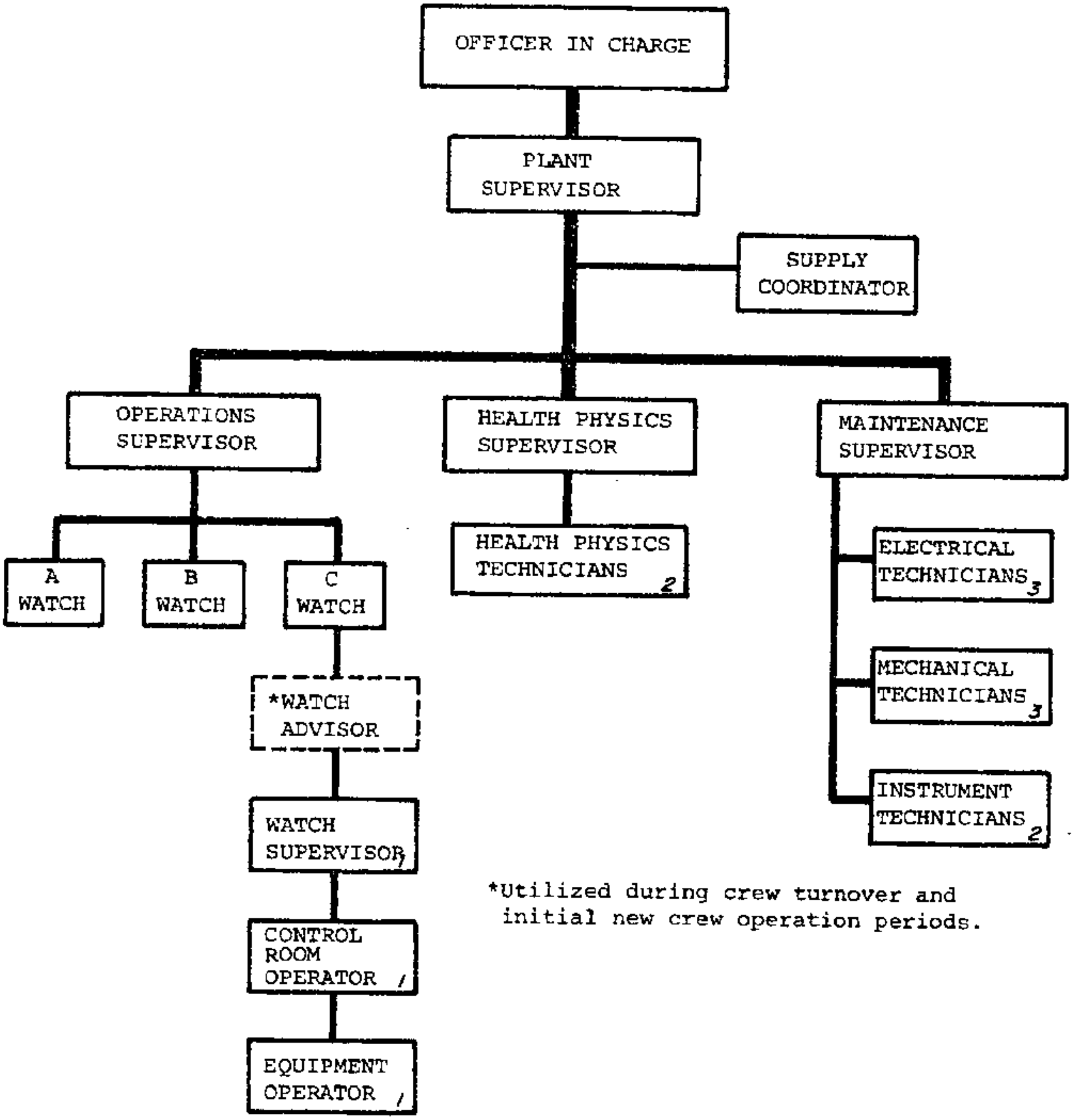
2. Personnel Training

a. Unique Location of PM-3A. The hostile environment, remote location and psychologically strenuous period of the long winter darkness made duty in Antarctica extremely arduous. In light of this isolated duty, a complete PM-3A crew turnover was required each year. (Typical crew structure is illustrated in Figure III-1.) This complete change over occurred each austral summer, with a one to two month overlap between the arrival of the new crew and the departure of the old. The short period for an operating staff turnover required that the new crew be trained, thoroughly familiar with plant layout and systems, and well versed in operating procedures and limits prior to arrival at the plant. This unique situation of the PM-3A resulted in a training cycle of 24 to 30 months.

b. Selection Program. Volunteers who met stringent intelligence, physical and personality requirements were selected from Navy Group VIII Construction Ratings (Seabees) and Group X Hospital Corpsman rating for Naval Nuclear Shore Power Program training. Individuals selected were encouraged to take appropriate correspondence courses and were given

FIGURE III-1

TYPICAL PM-3A CREW STRUCTURE



guided study as required to bring them to a minimum academic training level prior to their entering formal training.

c. Training Program. Individuals selected were transferred to the Nuclear Power Plant Operators Course which was nominally one year in length and administered within the Army Nuclear Power Program. The course consisted of three major phases -- academic, operations, and specialty. Specialty training was divided into mechanical, instrument, electrical, and health physics/process control courses. These four specialty courses were taught concurrently, and three of them were continued beyond the basic course graduation for periods of from four to fourteen weeks. Course graduate data by class and rating are contained in Table III-1.

The Navy also enhanced the operating and maintenance experience of its personnel by assigning them to nuclear power plants operated by the Army and Air Force. In return, Army and Air Force personnel were invited to participate as members of PM-3A operating crews. This training was available at the following nuclear power plants during their respective periods of operation:

(1) SL-1, National Reactor Testing Station, ID, Army, August 1958 - January 1961.
(2) SM-1A, Fort Greely, AK, Army, March 1962 - March 1972.
(3) PM-2A, Camp Century, Greenland, Army, October 1960 - July 1963.
(4) PM-1, Sundance, WY, Air Force, February 1962 - April 1968.
(5) MH-1A, Panama, Army, January 1967 - July 1976.

PM-3A crew members were identified one year prior to their deployment to Antarctica. During this year, specific training and qualifications were programmed to assure balanced operational and maintenance capability for each crew. Qualifications considered were operations supervisor, maintenance supervisor, watch supervisor, control room operator, equipment operator, health physics and process control, maintenance specialties, welding qualifications, and supply. One member of each specialty was selected for PM-3A nucleus training in advance of the crew's deployment. These four men were trained with the previous crew and received approximately six weeks of experience with that crew at the PM-3A. This nucleus group, along with several crew men who had previously completed tours of duty at the plant, contributed to PM-3A operational and maintenance continuity. A listing of personnel who made up each crew is contained in Appendix D.

Further training prior to deployment was obtained from manufacturers' training courses on specific equipment which would be operated or maintained at the PM-3A, and through PM-3A Replacement Crew Training. During Replacement Crew Training, members were given a comprehensive seven week course specifically prepared to teach PM-3A plant information, engineering fundamentals, plant operations and procedures, core physics, testing, maintenance, refueling, safety and related subjects.

Replacement crew operators all had qualifications in one or more similar type nuclear power plant for the operator position in which they

TABLE III-1

NUCLEAR POWER PLANT OPERATORS COURSE GRADUATES
by
CLASS AND RATING

Class	Navy Rating						Total
	CE	UT	EO	SW	CM	HM	
56	3	3	0	0	0	0	6
58	2	1	0	0	0	0	3
59/1	3	0	0	0	0	0	3
59/2	0	5	0	0	0	0	5
60/1	8	0	0	0	0	0	8
60/2	4	4	1	1	0	2	12
61/1	7	2	2	1	2	3	17
61/2	8	1	0	0	1	6	16
62/1	7	0	1	0	3	6	17
62/2	9	1	3	1	0	4	18
63/1	4	0	1	0	0	1	6
63/2	8	1	0	0	1	2	12
64/1	1	0	0	0	0	2	3
64/2	2	1	1	0	1	4	9
65/1	4	1	0	0	1	1	7
66/1	3	4	1	0	4	6	18
67/1	6	0	0	1	0	5	12
68/1	4	0	1	0	0	2	7
68/2	3	2	0	0	0	1	6

TABLE III-1 (continued)

NUCLEAR POWER PLANT OPERATORS COURSE GRADUATES
by
CLASS AND RATING

Class	Navy Rating						Total
	CE	UT	EO	SW	CM	HM	
69/1	1	1	1	1	0	1	5
69/2	2	4	1	0	0	1	8
70/1	5	0	2	2	3	0	12
71/1	6	1	0	0	3	3	13
71/2	4	2	0	0	0	2	8
72/1	4	2	1	3	3	6	20*
74/2	2	0	1	0	4	4	11
75/2	2	0	0	0	1	2	5
77/1	2	0	2	1	0	0	5
77/2	3	1	0	1	0	0	5
TOTAL	117	37	19	12	27	64	278

*Class 72/1 also had one Engineering Aide (EA) as a member.

NOTE: 38 of these graduates have advanced to officer status.

would be initially qualified at the PM-3A. Minimum training requirements for PM-3A were specified by NAVFACENGCOM with additional requirements established by the PM-3A OIC. The OIC conducted a stringent relief training program for qualifying new crew members, as well as upgrade and refresher training programs. Qualifications for nuclear shore power plant OICs and Plant Superintendents were also specified by NAVFACENGCOM.

3. Environmental Radiation Surveillance Program (ERSP)

a. Backgound. The U.S. National Science Foundation, being responsible for the coordination and management of the U.S. scientific programs in the Antarctic, reviewed any possible effects of nuclear power on these programs. Using the Foundation's desires as a guide, the following criteria were determined for the PM-3A nuclear power plant:

(1) The incidence of neutrons from the reactor would not exceed one neutron per square meter per minute at a distance of one mile from the reactor.

(2) Liquid waste having an activity greater than $1x10^{-7}$ microcuries per cc would not be released to the environment.

(3) Gaseous waste, exclusive of Argon-41, having an activity greater than $4x10^{-14}$ microcuries per cc would not be released to the environment.

(4) Activated air containing Argon-41 in concentrations greater than $1x10^{-8}$ microcuries per cc would not be released to the environment.

NOTE: Criterion (4) above was rather unusual and was due to the use of air cooling for the PM-3A secondary shielding. The primary system of the PM-3A was enclosed in four containment tanks within a hillside excavation. The excavation was backfilled with crushed basalt material to act as secondary shielding. The use of air for cooling the backfill (to maintain the frost line within pre-selected bounds that might have been exceeded by gamma and neutron heating of the backfill) introduced activation problems. The major radioactive constituent in the cooling air was postulated to be Argon-41, produced through the activation of Argon-40 by the neutron flux within the backfill.

To assure the peaceful use of the Antarctic, the 12 nations engaged in various scientific activity operations in Antarctica during the International Geophysical Year signed the Antarctic Treaty in December 1959. This treaty states, in part, that radioactive waste shall not be disposed of in the Antarctic. To meet the treaty obligations, the criteria set forth by the National Science Foundation, and the requirements of Title 10 of the U.S. Code of Federal Regulations, the PM-3A was designed for containmnent of radioactivity and temporary storage of radioactive wastes.

To provide conclusive data that the plant would not release activity greater than established limits after the scheduled initial criticality in March 1962, the Navy requested the Division of Radiological Health of the USPHS to maintain a radiological monitoring program at McMurdo Station. The ERSP at McMurdo Station was initiated by the USPHS in December 1960 and involved measurement of the background radiation of the lithosphere, the biosphere, and the hydrosphere.

Various environmental media were collected to determine if activity was increasing in the McMurdo area. Air was the most closely monitored media since it was the principal medium for transport of radioactivity. Other samples were collected routinely from the station drinking water and available snow. During the summer melted snow accumulated in low areas forming open water ponds, and these shallow ponds contained a form of blue-green algae which was sampled intermittently as available. The ponds are open for only a few short months during the summer and just a few samples could be collected each year.

The USPHS conducted the ERSP from its inception through October 1963 when the Navy assumed the responsibility. Collection and counting of samples was then assigned to the Health Physics and Process Control Section Supervisor, PM-3A. Analysis of all environmental data following Navy assumption of the program was performed by the Nuclear Branch, Engineering Division, U.S. Army Engineer Power Group, Fort Belvoir, VA.

b. ERSP Sampling Schedule. The following was the environmental sampling schedule at McMurdo Station. Sample locations are shown in Figure III-2.

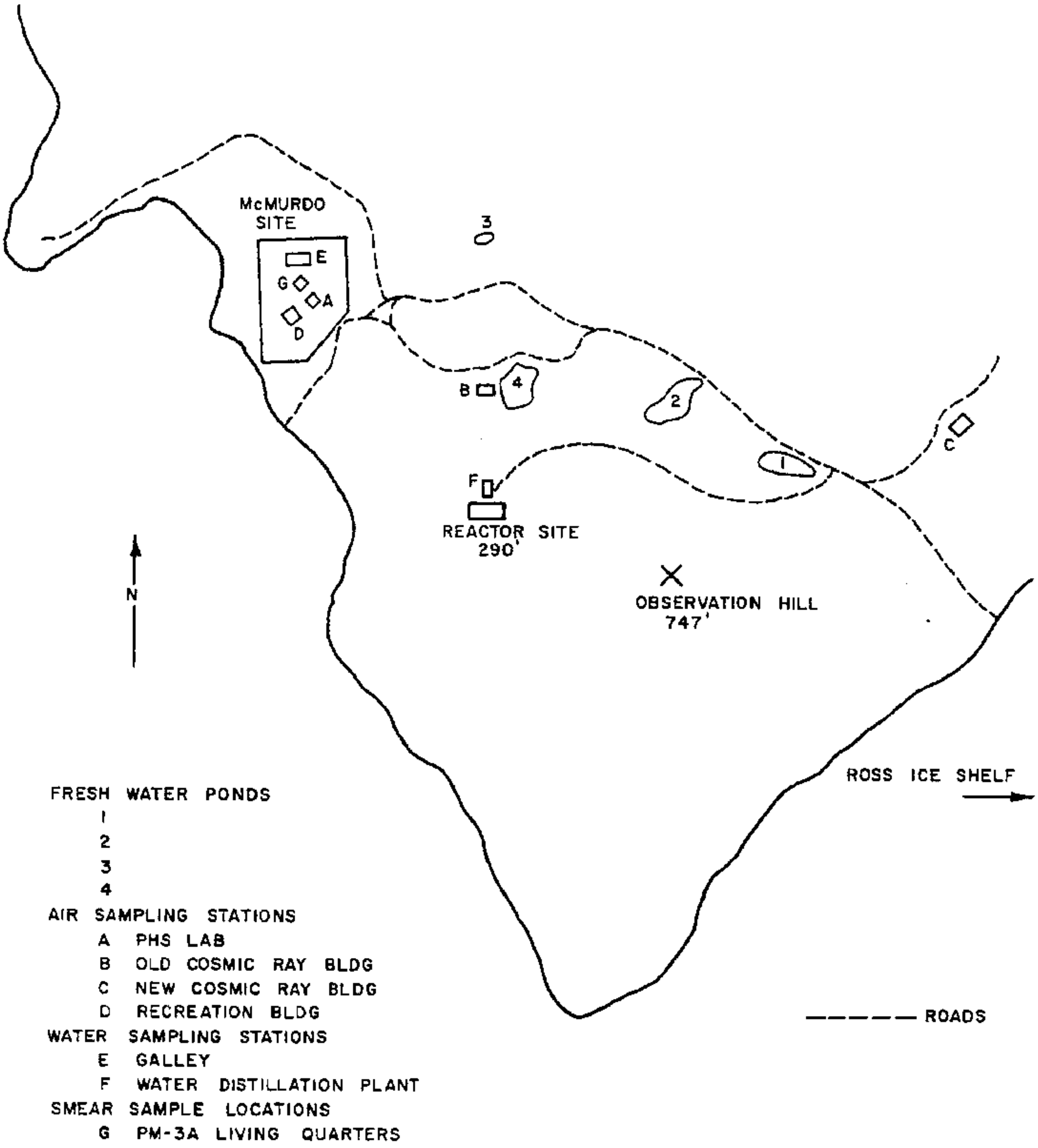
(1) Air Samples - long lived beta activity
  (a) Station 0101
    Location: New Building 63 (Recreation Bldg)
    Frequency: Continuous 24-hour sample
  (b) Station 0401
    Location: Cosmic Ray Laboratory
    Frequency: One 24-hour sample per week

(2) Water and snow sample - long lived beta activity
  (a) Galley water samples
    Frequency: One sample per month
  (b) Seawater distillation plant distillate sample
    Frequency: One sample per week

(3) Smear test for gross contaminations - gross beta activity
  Location: Various smears in McMurdo Station galley and PM-3A personnel living quarters
  Frequency: Survey once each week

(4) Water samples - Tritium activity (started in 1967)
  (a) Seawater samples
    Frequency: One sample per week
  (b) Seawater Distillation Plant distillate samples

FIGURE III - 2
McMURDO STATION ENVIRONMENTAL MONITORING SAMPLE LOCATIONS



Frequency: One sample per week

(c) Galley water samples

Frequency: One sample per week

c. Results and Conclusions. Fission products from fallout were determined to have the greatest effect on the activity found in air samples at McMurdo. Due to the large uncertainty in the air activity data, a comparison was made with findings by other investigators to explain trends in the McMurdo findings. In making the comparison, the following conclusions from references in the literature were helpful. (The numbers in parentheses are keyed to references listed at the end of this section.)

(1) Fallout is subject to seasonal fluctuations with a maximum between November and March (1, 2, 3) and is attributed to seasonal mixing of stratospheric and troposheric air in the polar regions (2).

(2) Low yield fission nuclear bombs produce almost only troposheric fallout while high yield thermonuclear bombs inject a large portion of fission products into the stratosphere (3).

(3) The residence time for fission products in the troposphere is on the order of months while residence time in the stratosphere is on the order of several years (3).

The first feature of McMurdo Station air activity was an increase of gross beta activity in early 1963 (see Table III-2 and Figure III-3). USPHS analyzed samples taken in late 1962 and early 1963 and found Cs-137, Ru-106, Zr-95, and Ce-144. The latter three isotopes are short-lived fission products. The USPHS also found Ru-106 and Zr-95 in Byrd Station samples (800 nautical miles southeast of McMurdo) which indicated the fission products resulted from fallout of U.S. and U.S.S.R. thermonuclear tests in 1961 and 1962. Similar increases in short-lived beta activity for late 1962 were also noted in New Zealand.

In early 1965, another increase in air activity at McMurdo was noted. Similar increases of long-lived fission products were found in air activity at the South Pole (700 nautical miles from McMurdo), rainfall concentration in New Zealand, and snow samples taken near Adelie Land (1500 miles southeast of McMurdo). Since no bomb tests were run in 1964 and no short-lived fission products were found in air activity in New Zealand, the increase was attributed to seasonal mixing of the stratosphere and troposphere.

Thereafter, the air activity decreased throughout the remainder of 1965 and 1966. With the resumption of atmospheric testing by the French between May and October 1966, short-lived fission products in the air were measured in New Zealand with large increases in late 1966 and again in August of 1967. These peaks matched the increase at McMurdo Station. A sharp increase in air activity at McMurdo was once more noted during early 1969 following renewed atmospheric bomb tests conducted by the French between June and October 1968.

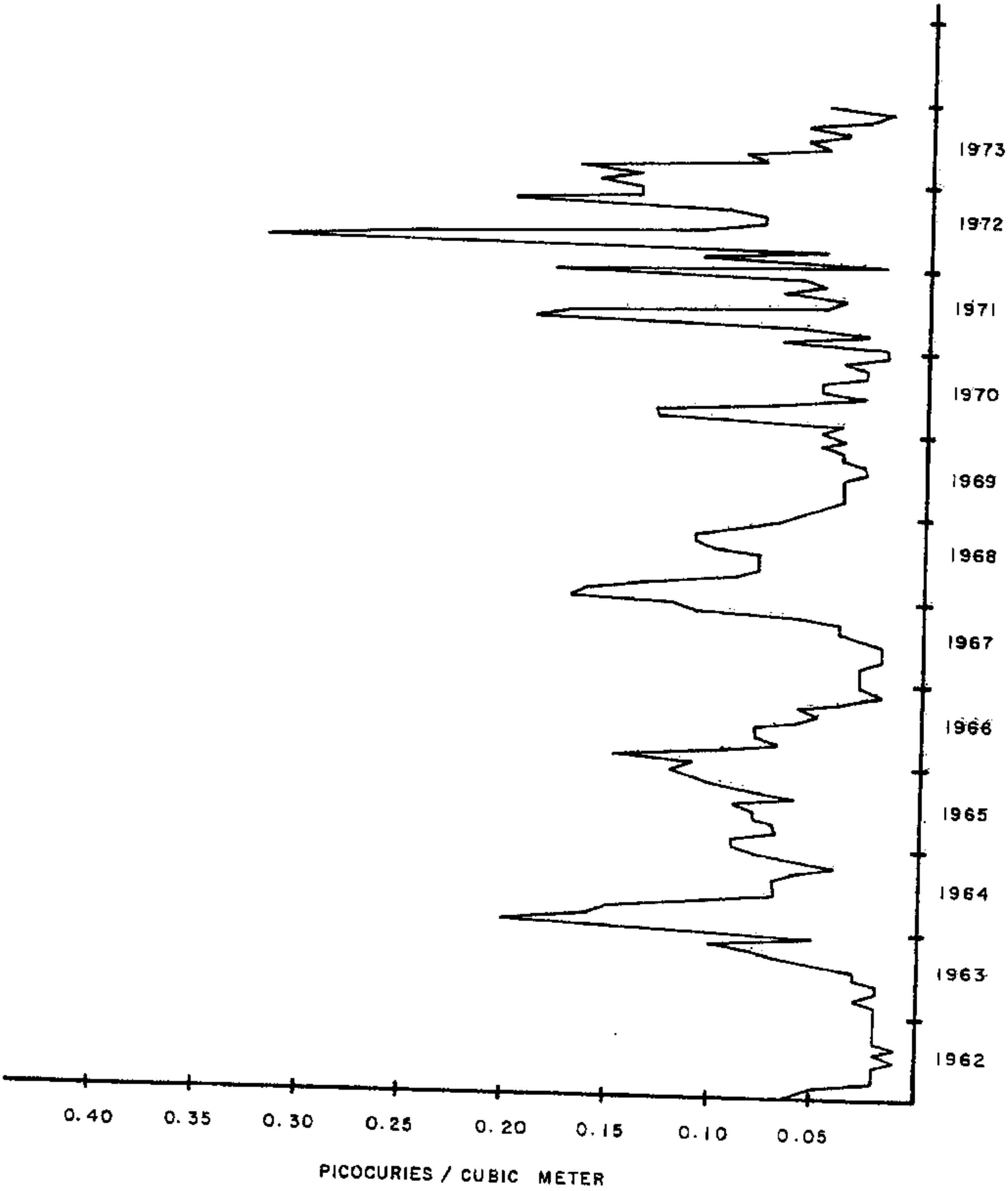
TABLE III-2

McMURDO STATION ENVIRONMENTAL DATA

MONTHLY AVERAGES OF LONG LIVED BETA ACTIVITY IN AIR SAMPLES AT
McMURDO STATION IN PICOCURIES PER CUBIC METER (pCi/m^3)

MONTH	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
JAN	0.06	0.02	0.13	0.09	0.11	0.03	0.17	0.06	0.05	0.02	0.02	0.16
FEB	0.05	0.02	0.20	0.09	0.15	0.03	0.16	0.05	0.04	0.07	0.11	0.14
MAR	0.02	0.03	0.16	0.07	0.10	0.03	0.13	0.04	0.13	0.03	0.05	0.17
APR	0.02	0.02	0.15	0.07	0.07	0.02	0.09	0.04	0.13	0.06	0.32	0.08
MAY	0.02	0.02	0.11	0.08	0.08	0.02	0.08	0.04	0.07	0.19	0.24	0.09
JUN	0.01	0.03	0.07	0.08	0.08	0.02	0.08	0.04	0.03	0.17	0.11	0.05
JUL	0.02	0.03	0.07	0.09	0.06	0.03	0.08	0.03	0.05	0.05	0.08	0.06
AUG	0.01	0.05	0.07	0.06	0.05	0.04	0.10	0.03	0.05	0.04	0.08	0.04
SEP	0.02	0.07	0.06	0.06	0.06	0.04	0.11	0.04	0.03	0.07	0.10	0.06
OCT	0.02	0.08	0.04	0.10	0.04	0.06	0.11	0.04	0.03	0.05	0.20	0.03
NOV	0.02	0.10	0.06	0.11	0.02	0.11	0.09	0.05	0.04	0.06	0.14	0.02
DEC	0.02	0.05	0.08	0.12	0.03	0.12	0.07	0.04	0.02	0.18	0.14	0.05
YEARLY AVERAGE	0.02	0.04	0.10	0.09	0.07	0.05	0.11	0.04	0.06	0.08	0.13	0.08

FIGURE III - 3
MONTHLY AVERAGES OF LONG LIVED BETA ACTIVITY
IN AIR SAMPLES AT McMURDO STATION



No bomb tests were made in the southern atmosphere in 1969. A corresponding smaller activity increase occurred in early 1970 due to seasonal mixing as described above. Ratios of Sr-89 to Sr-90 measured in New Zealand indicated that there was a stratospheric interchange of fission products across the equator (4). Continued French and Chinese bomb tests were made in 1970 and coupled with seasonal mixing contributed to air activity increases through 1973.

During the period of USPHS surveillance at McMurdo, the radioactivity in water samples collected from the galley averaged less than 10 picocuries per liter. During 1963, the average of the galley samples (Table III-3) rose somewhat above that of 1962. This could also have been due to an increase of fallout from the nuclear tests. The pond water and snow activity lagged in the trends shown by air but eventually did follow.

It was also observed that the activity in the galley water was an order of magnitude below the levels in the snow. This difference would be expected because the galley water was furnished by filtered, melted snow prior to operation of the seawater distillation unit. It was felt that the higher snow activity was attributable to the increased solids content of melted snow. The increased solids were assumed to be due to high winds in the station area causing dirt to be mixed with blowing snow. The Navy period of operations of the ERSP showed the same general trends observed during PHS operations.

The long-lived beta activity in galley water in 1969 (Table III-3) was found to be significantly higher than previous years. However, the levels of activity reported were extremely low and did not pose a threat to either personnel or the McMurdo environment. Action was taken by NAVNUPWRU to determine the cause of the increase and to correct the conditions if possible. It was concluded from a statistical analysis that the reported increase during the period January 1969 through January 1970 was attributable to improper measurement technique. One-liter samples had not been used and several of the samples had been counted on a Geiger-Muller system which was not capable of detecting activities in the one to ten picocuries per liter range using a reasonable (60 minute) count time. The unverified June 1969 value cannot be explained. It should be noted, however, that a one-liter volume was used for the February 1970 galley water sample and that the activity reported was within acceptable limits.

Algae and pond water samples were submitted when available, but the quantity of data submitted was insufficient to produce a true statistical analysis. It can only be concluded that there was no indication of a trend developing in these areas.

The results of tritium sampling, begun in 1967, are shown in Tables III-4 and III-5. As is seen from the tables, other than the higher concentrations occurring in the first year data was collected, no significant trend in tritium concentrations was noted.

TABLE III-3

McMURDO STATION ENVIRONMENTAL DATA

MONTHLY AVERAGES OF LONG LIVED BETA ACTIVITY IN GALLEY WATER AT McMURDO STATION IN PICOCURIES PER LITER (pCi/L)

MONTH	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
JAN	12	.5	25.0	19.3	18.3	11.5	0	9.8	11.6	52.9	6.4	9.6
FEB	12	35	4.0	18.0	29.5	5.6	0	2.1	42.8	7.7	4.6	3.8
MAR	4	6	12.0	12.1	21.8	11.4	8.2	1.3	32.4	4.1	4.0	3.9
APR	--	5	25.8	12.8	27.9	10.8	7.5	1.3	32.5	4.3	5.1	7.8
MAY	4	6	7.0	8.7	31.0	7.6	7.6	1.3	35.8	8.4	5.4	5.9
JUN	4	7	16.0	8.2	6.9	5.6	6.3	1.3	113.0	2.6	5.9	5.0
JUL	3	--	10.0	12.1	18.5	11.4	6.3	1.3	12.0	4.6	6.3	39.1
AUG	7	13	9.0	21.6	17.3	6.4	4.7	2.0	41.8	7.9	6.3	10.4
SEP	--	7	6.0	14.9	9.0	7.0	59.0	1.2	12.8	2.8	6.3	40.0
OCT	3	13	2.3	18.8	12.2	1.5	5.1	11.0	12.3	17.3	5.9	7.4
NOV	6	8	8.4	17.8	17.6	0	17.0	7.4	12.4	4.3	5.8	5.7
DEC	1	7	4.6	17.2	18.1	0	5.1	3.8	19.0	4.1	5.1	8.5
YEARLY AVERAGE	5.6	9.8	10.8	15.1	19.0	6.6	10.6	3.6	31.5	10.1	5.6	12.3

TABLE III-4

McMURDO STATION ENVIRONMENTAL DATA

Monthly Averages of Tritium Activity in Seawater at McMurdo Station in Microcuries per liter (U Ci/L)

MONTH	1967	1968	1969	1970	1971	1972
JAN	*	0.0080	0.0215	0.00656	0.00267	0.00187
FEB	*	.0082	.0011	.00648	.0022625	.00160
MAR	0.1700	.0080	.0050	.1396	.002127	.00351
APR	*	.0082	.0045	**	.004072	.00426
MAY	.0061	.0065	.0049	.00801	.00102	.00318
JUN	.0061	.0076	.0088	**	.000978	.003045
JUL	.0490	.0055	.0424	.0065	.00102	.00520
AUG	.0300	.0045	.0051	.00575	.00102	.005015
SEP	.0059	.0042	.0061	.0072	.00102	.003432
OCT	.0059	.0044	.0061	.0092	.00106	.004225
NOV	.0263	0.0510	.0124	.0056	.003027	.00330
DEC	0.0083	*	*	0.0027	0.001455	*
YEARLY AVERAGE	0.0342	0.0106	0.0107	0.0198	0.00180	0.003513

*None Taken

**Inst. Malfunction

TABLE III-5

McMURDO STATION ENVIRONMENTAL DATA

Monthly Averages of Tritium Activity in Distillation Plant Distillate in Microcuries per liter (UCi/L)

Month	1967	1968	1969	1970	1971	1972
JAN	*	0.0400	0.0049	0.00656	0.00228	0.00187
FEB	*	.0091	.0042	.0118	.00244	.00257
MAR	.4400	.0480	.0047	.0271	.002127	.00351
APR	*	.0160	.0197	**	.004072	.00378
MAY	.0084	.0080	.0043	.00801	.00102	.00399
JUN	.0061	.0076	.0049	**	.000978	.00264
JUL	.0650	.0055	.0049	.00692	.00102	.00413
AUG	.0055	.0045	*	.00591	.00102	.00574
SEP	.0031	.0046	.0061	.00703	.00102	.00318
OCT	.00200	.0051	.0060	.00557	.00106	.00315
NOV	.0130	.0820	.0135	.00996	.00409	.00372
DEC	0.076	*	0.0174	0.0027	0.001455	*
YEARLY AVERAGE	0.0707	0.0209	0.0082	0.00916	0.00188	0.00348

*No Data Collected
**Inst. Malfunction

The conclusion drawn from analysis of the ERSP is that the contribution of activity to the radiation background of the McMurdo environs by the PM-3A nuclear power plant was inconsequential.

4. Radioactive Waste Disposal

a. Background. Radionuclides produced in a nuclear reactor are of two kinds: Fission products and activation products. Fission products can occur in the reactor coolant water due to leaks from fuel elements. Unless major cladding failures occur, these products are effectively contained within the reactor core. Activation products result from neutron activation of impurities such as particles and minerals in the coolant water and of materials used in construction of the nuclear power plant. Radioactive wastes may be evolved in any physical state--solid, liquid, or gaseous.

b. Solid Waste. Solid wastes at PM-3A consisted of spent demineralizer resins, air filter cartridges, damaged components from the primary system, clothing, rags, paper, and contaminated laboratory apparatus or tools which could not be made fit for reuse by simple decontamination methods. These wastes were prepared for shipment and subsequent disposal by packaging in shipping containers approved by the U.S. Department of Transportation and the International Atomic Energy Agency (IAEA). High level wastes were packaged in modified specification 17H metal drums and placed in a concrete shielded Type B shipping container for shipment. Each shipping cask was capable of holding only one modified drum, and three of these shipping casks were available for PM-3A use.

Low level wastes were packaged in standard 17H metal drums (approved Type A shipping containers), and 24 of these drums were placed in a military conex box for ease in handling and storage during shipment. During the austral summer of 1966-67, a waste compactor was installed in order to reduce the number of low level waste drums being generated. The compactor was designed to compress selected types of material directly in a 17H drum.

Many medium level 17H drums (radiation levels exceeded Type A shipping container limits) were generated from compactor operations and the initial phase of PM-3A dismantling. These medium level drums as well as ones generated during the latter years of PM-3A operation, were packaged and shipped in a heavily shielded cask capable of holding 14 drums per load. Spent reactor cores, irradiated control rods and other large quantity shipments were made utilizing specially designed and approved spent fuel shipping casks.

c. Liquid Waste. Liquid wastes from the PM-3A were collected in a 1600 gallon sump tank and processed by a tank mounted evaporator (Figure III-4). The vapor from the evaporator was passed through an agglomerator to remove any carryover of particulates and then to a condenser. The collected condensate was pumped to a holding tank where the activity was measured to determine if the condensate required recycling to the sump tank for

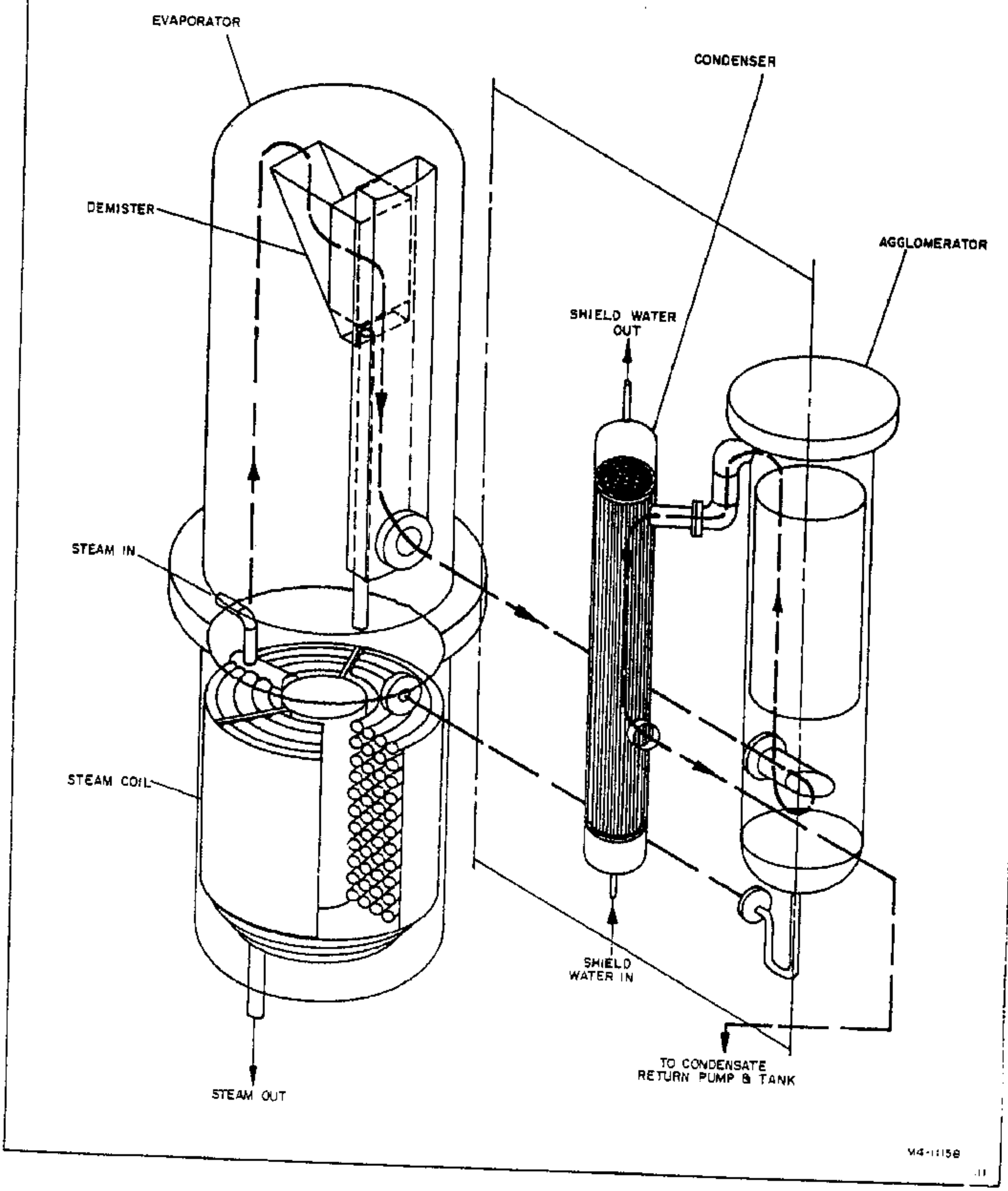


FIGURE III-4 TANK MOUNTED RWDS EVAPORATOR DETAILS further processing or was within limits for discharge.

The evaporator blowdown was drained to a shielded 500 gallon waste storage tank. A heating coil in this tank permitted liquification of the concentrated waste for removal and drumming. Continuous operational problems with the unit resulted in the installation of a second liquid waste disposal system and a new waste drumming station during the 1966-67 austral summer. The new skid mounted system (Figure III-5) operated at a low pressure (vacuum) and temperature (180°F) whereas the tank mounted system operated at atmospheric pressure and 212°F.

In 1963 it was found that tritium, a radioactive isotope of hydrogen, presented a disposal problem. Since tritium combines chemically with oxygen to form water, the solidification process for its removal was inadequate. A study on tritium control and discharge conducted by NAVNUPWRU is included in Appendix E.

d. Gaseous Waste. The following sources contributed to the release of radioactive gases or airborne particulates to the environment: (1) The containment purging system, (2) the radioactive waste disposal system, (3) the primary sampling system, (4) the chemistry lab, (5) the decontamination pad, and (6) the Primary Building work area. The activity from these sources was discharged to the Primary Building ventilation system which was ducted to the discharge stack for release to the atmosphere. The discharge piping or ducting from these sources contained absolute filters to remove particulates, and in the areas of the first four of these sources charcoal filters were installed to remove iodine. The discharge from the Primary Building ventilation system was continuously monitored and recorded for both gaseous and particulate activity.

The release of activity to the environment from the PM-3A was governed by NAVFACENGCOM Instruction which specified that the limits contained in Title 10, Code of Federal Regulations, Part 20 (10 CFR 20), Appendix B, Table II, Column I would be used for release of airborne activity in all cases where release was continuous or could not be controlled. A controlled release of activity exeeding these limits was allowed under certain meteorological conditions where adequate natural dilution could be assured. In such cases, the released activity was averaged over a period of one week and the average could not exceed the limits.

e. Handling and Shipment. Under the provisions of NAVDOCKS P-311, the PM-3A OIC was responsible for safe handling, packaging, and monitoring of all radioactive materials associated with the plant. NAVDOCKS P-311 further required that no radioactive materials, in concentrations greater than the limits established by 10 CFR 20 for continuous exposure in unrestricted areas, were to be released to areas external to the PM-3A nuclear power plant. All radioactive waste materials which could not be released within these limits were appropriately packaged, returned to the United States and disposed of through organizations licensed by the Nuclear Regulatory Commission. Table III-6 is a tablulation of all reactor core shipments between PM-3A and the United States.

FIGURE III - 5

SKID MOUNTED RWDS

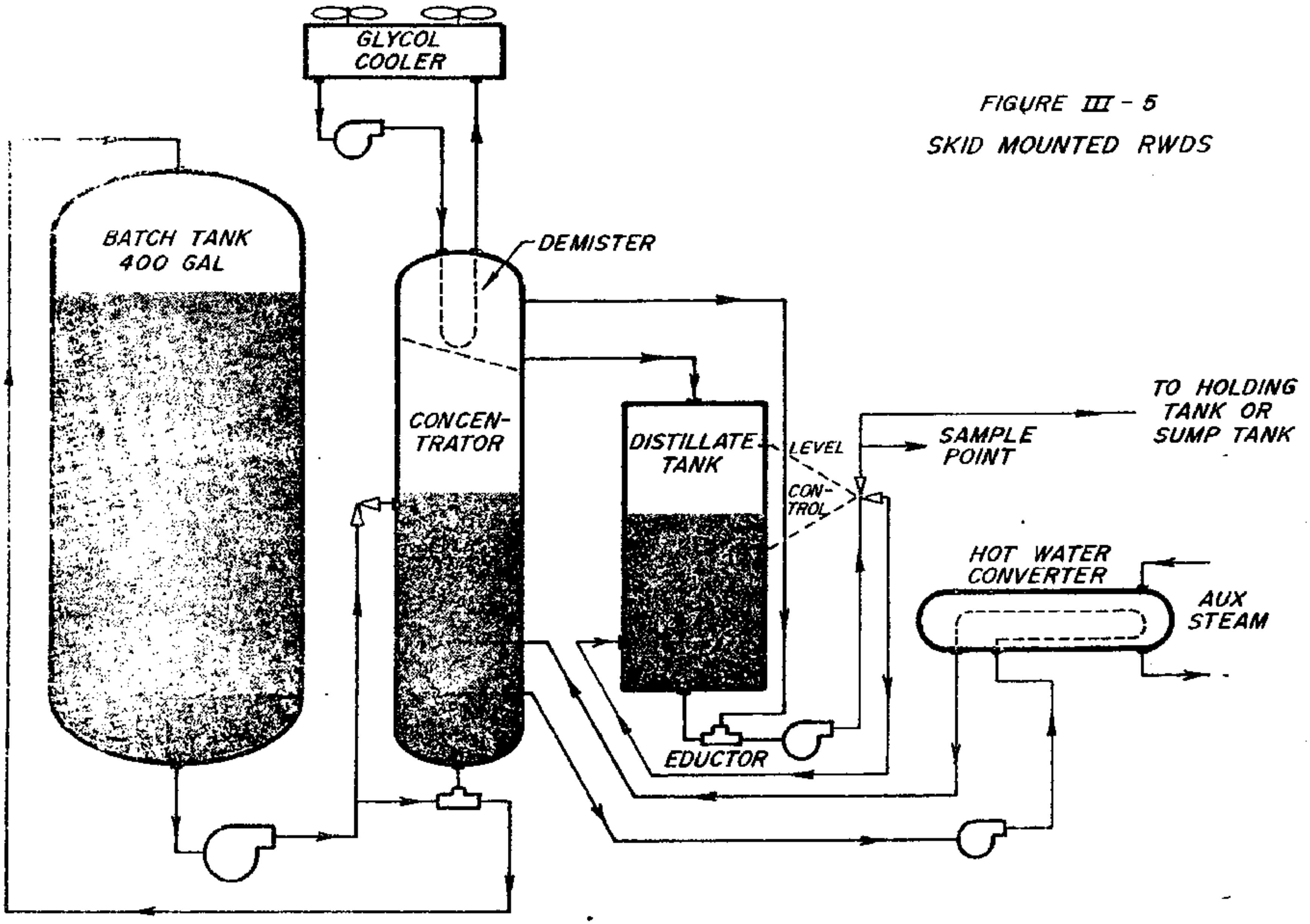


TABLE III-6

REACTOR CORE SHIPMENTS BETWEEN McMURDO STATION, ANTARCTICA AND CONUS

Designation	Ship to McMurdo (all USNS)	Date rcvd PM-3A	Condition of core	Period in Reactor	Date Shipped From McMurdo	Condition at Shipment	Ship to Davisville (all USNS)	Ultimate Destination
PM-3A, Type I Ser 2	ARNEB	Dec 61	New	Feb 62 10 Dec 64	Feb 66	Used	WYNDOTT	AEC Savannah River Plant
PM-3A, Type I Ser 1	ARNEB	Dec 61	New	17 Dec 64 16 Oct 67	Feb 69	Used	TOWLE	AEC Savannah River Plant
PM-3A, Type II Ser 1	WYNDOTT	Dec 65	New	18 Oct 67 21 Jun 70	Feb 72	Used	WYNDOTT	AEC Savannah River Plant
PM-1, Type II	TOWLE	Jan 69	Used	NOT USED	Feb 73	Used	TOWLE	AEC Savannah River Plant
PM-3A, Type IV Ser 1	WYNDOTT	Jan 59	New	NOT USED	Feb 70	New	WYNDOTT	NUMEC, Appollo, PA
PM-3A, Type IV Ser 1	WYNDOTT or TOWLE	Jan 72	New	NOT USED	Feb 74	New	TOWLE	National Lead Co., OH
PM-3A, Type IV Ser 2	TOWLE	Jan 70	New	30 Jun 70 1 Jul 73	Feb 74	Used	TOWLE	AEC Savannah River Plant

Since PM-3A shipments passed through foreign countries, the IAEA Safety Series Number Six was utilized in conjunction with other regulatory documents for preparation of PM-3A radioactive waste shipments. Continental United States waters as well as the Panama Canal Zone are under the cognizance of the United States Coast Guard, and 46 CFR 146 was the applicable shipping regulation in these areas (all shipping regulations now come under 49 CFR). United States highway shipments were normally accomplished by commercial carriers which are regulated by the U.S. Department of Transportation in 49 CFR 170 through 190. IAEA, Coast Guard, and Department of Transportation regulations were adhered to for all PM-3A shipments.

f. Incidents and Violations. There were no major incidents or violations of federal and international regulations concerning radioactive waste shipments during the years of Navy operation of the PM-3A. Incidents and violations which occurred but were of a minor nature are discussed below.

A personnel exposure of 3.596 Rem in one calendar quarter occurred in February 1967 when a worker removed the lid of a spent fuel shipping cask that presumably contained a non-radioactive cadmium control rod. A single exposure of 3.3 Rem took place when the worker climbed on the cask to see how the control rod was situated prior to removal attempts. The control rod was not in the cask. However, inspection revealed an irradiated core shroud. A radiation level of 200 R/hr was found at a point above the cask where a person would likely stand to inspect the cask contents. The overexposed worker was restricted from all radiation areas for the remainder of the calendar quarter. Following this incident all shipping containers were closely monitored to ensure no hazard existed.

In March 1968, the trailer bed of a commercial carrier became contaminated while transporting a PM-3A radioactive waste shipment from CBC Davisville to a burial site in Moorhead, Kentucky. The contamination could not be removed by high pressure water and steam, and replacement of the wooden trailer bed was required. Immediate investigation revealed that when the sealed truck was opened an overturned shipping cask was found lying at the end of the trailer near the door. The pallet was behind the cask and a single steel band was lying on the floor. The cask had not been banded to the pallet, but the steel band had been used to tie the cask and two conex boxes to one side of the trailer. There was no radiation exposure to personnel, no injuries, and no reportable release of radioactive materials. The cask was examined, and the lid was found to be welded completely around the cask. The lid was not bolted on, however, in any of the four bolt flanges. The weld apparently contained flaws, because approximately 1/3 of the circumference of the cask around the weld was grossly contaminated. The only actions taken were decontamination efforts and finally replacement of the trailer bed. Recommendations were that care be exercised to ensure solidification of all liquid wastes, that welding of lid to cask be certified, that the bolt flanges be used to further secure the lid to the cask, and that truck shipments be inspected to ensure adequate securing of cargo.

During the February-March 1969 radioactive waste shipment damage occurred when a portion of the load broke loose from the ship's hold. Investigation revealed that upon departure from McMurdo Station, the entire shipment consisting of three waste shipping casks, two spare unirradiated core bundles, one 1000-pound waste shipping cask, one SNAP-7C RTG in a specification 17H drum, and a radiography source had all been stowed in the tween-decks space of Hold Number 5 and had been well secured. When the ship encountered heavy seas between McMurdo and Port Lyttleton, New Zealand, the best information available indicates that an empty connex box broke loose striking the RTG container, the large waste shipping container (serial 0003), and the cable securing the 1000-pound shipping cask. Upon arrival at Port Lyttleton, the cargo was restowed and secured in the hold, and the large waste shipping casks were moved to the lower deck and secured. The large waste shipping cask suffered a triangular puncture near its base and the RTG container was extensively damaged. There were no injuries, no loss of shielding, and no release of radioactive material occurred. Damage to the waste shipping container did not preclude normal handling and trans-shipment to the disposal site. In order to prevent future occurrences of this nature, consignors were to reemphasize the necessity of adequate tie-down of radioactive consignments.

A radioactive waste shipment exceeded the allowable grouped transport indices for a single load in April of 1966. The waste barrels within three conex boxes were rearranged to make up two loads that met the limits. It was emphasized that all personnel initiating a waste shipment must insure that all shipping requirements were met.

In October 1966, a shipment identified as miscellaneous liquid samples was received by NAVNUPWRU. After routine handling and unpacking part of the samples, the radioactive contents were discovered. Radiation readings of 50 and 60 mR/hr at the surfaces of the polyethylene bottles, as noted on labels affixed to the samples, were verified. The container was not marked as a radioactive shipment. At the time of discovery, unpacking was immediately stopped until proper health physics procedures for receipt of a radioactive shipment could be conducted. Corrective actions, were initiated to assure that future shipments would meet established requirements.

During the 1970 shipment, explosive gases (oxygen and acetylene) were stowed in the same compartment onboard ship with the radioactive material, and in 1972 containers with a corrosive liquid label were located in the compartment with the radioactive shipment. Both items are specifically prohibited from being stowed in the same hold with radioactive material. Recommendations arising from these violations were that the OIC, PM-3A inspect the load and advise the ship's master of any discrepancies.

A conex box did not meet the criteria for maximum radiation levels at six feet from the container surface during the January 1971 radioactive waste shipment. The barrels of waste within the conex box were rearranged to meet the shipping criteria. It was recommended that to prevent future violations of this nature the NAVNUPWRU instruction be rewritten to reflect the current shipping regulations and that attention of PM-3A personnel to the shipping requirements be emphasized.

5. Health Physics Personnel Safety and Chemistry (HPSC) Reports

a. HPSC Type Definitions.

Type I: Occurrence of an injury to plant personnel or visitors requiring outside medical assistance.

Type II: Occurrences resulting in the exposure of personnel in excess of 350 mRem per seven consecutive days. Occurrences resulting in the radiation exposure of personnel in excess of the quarterly limits as specified in NAMVED P-5055 or 10 CFR 20 shall be reported by message within 24 hours.

Type III: Any release of radioactivity to the environment in excess of the limits of 10 CFR 20.

Type IV: Increase of radiation and/or activity levels within the plant by more than a factor of three above those normally experienced.

Type V: Water chemistry or radiochemistry analysis outside of a limiting condition for operation as indicated in the Operating Limits.

Type VI: Any inability to perform a required chemistry or radiochemistry analysis not otherwise reported as a malfunction report.

Type VII: Occurrences resulting in airborne particulate exposure to personnel greater than $3x10^{-10}$ uCi/cc gross beta for any 40 hour period in seven consecutive days.

Type VIII: Detection of airborne alpha activity greater than $2x10^{-12}$ uCi/cc.

b. Summary of the 223 HPSC Reports in the Operating History of the PM-3A.

Fourteen reports were Type I--outside medical assistance required. In 11 cases, the injured personnel were treated at the McMurdo Station Dispensary and returned to duty with minimal time absent from duty. In three cases, the injured individuals were admitted to the McMurdo Station Dispensary for observation. One case resulted in 14 days lost time from duty and another case in one day lost time from duty. In the third case, the injured individual was admitted to the McMurdo Station Dispensary for observation and further evacuated to CONUS.

One hundred twenty-three reports were Type II--radiation exposure in excess of 350 mRem in seven consecutive days. In every case but one excess exposure was authorized by the OIC, PM-3A for required maintenance. The unauthorized overexposure incident was discussed in the Radioactive Waste Shipment Section.

Four reports were Type III--release of radioactivity to the environment in excess of the limits in 10 CFR 20. Case one occurred in 1964 and resulted from the containment purge. The isotopes present were identified as Xe-133 and Xe-135. Although the release broke the plant operating limits set forth, it did not exceed 10 CFR 20 limits. Case two occurred in 1966 and resulted from the operator erroneously dumping Hold Up Tank (HUT) #4 overboard. Corrective action was taken by dumping HUT #1 overboard through the same line to dilute the water released from HUT #4. Case three occurred in 1972 and resulted when 200 gallons of water at 4.6×10^{-2} uCi/ml were released to the area adjacent to the Primary Building south wall. Total estimated release was .035 Ci. There was no evidence of release beyond the PM-3A restricted area. The frozen material was recovered and processed for disposal. There was no increase in background radiation levels. Case four occurred in 1973 and resulted when approximately two gallons of 3.0×10^{-2} uCi/ml water leaked under the Primary Building loading dock due to a malfunction of the skid mounted radioactive waste disposal system. The surface area was disposed of and the area was surveyed with results consistent with background.

Eleven reports were Type IV--increase in activity levels in the plant by more than a factor of three above those normally experienced. These increases in activity levels were due to various causes, and as the causes were rectified, the activity levels returned to normal.

Sixty-one reports were Type V--water chemistry or radiochemistry analysis outside of a limiting condition for operation. In each case, corrective action was taken until the activity returned to the normal operating limits.

Five reports were Type VI--inability to perform a required chemisty or radiochemistry analysis. Each case was due to equipment being inoperative.

Five reports were Type VII--airborne particulate radioactivity exposure to personnel greater than 3×10^{-10} uCi/cc gross beta. Appropriate action was taken in these cases to reduce personnel exposure.

There were no Type VIII reports.

6. Water Distillation

a. Background. The first U.S. land based desalinization plant using steam produced by a nuclear power plant produced fresh water from the sea at McMurdo Station, Antarctica, on 19 February 1966. This fresh water was obtained during a test in which steam obtained from the PM-3A secondary system was used as the heat source for the evaporation.

The 4,000 gallons of fresh water produced during this test was a welcome sight to scientists and Navy men at the station. Fresh water had previously been obtained by melting snow. Although snow is plentiful at

McMurdo, it was frequently difficult to obtain enough clean snow to satisfy water needs, as dirty snow is blown off the volcanic rock around McMurdo Station.

b. Operating History. During the austral summer of Operation DEEP FREEZE 64, November 1963 through February 1964, the major installation of equipment was completed. A saltwater intake and pumping system was installed with pipelines to take seawater to the distillation plant and to return concentrated brine to the sea. Steam, condensate, and fresh water lines between the nuclear power plant and the water distillation plant were partially installed and a major portion of the work on the fresh water distribution system within McMurdo Station was completed.

In February 1964, initial operational tests were conducted using a temporary oil-fired boiler as the steam source. Difficulties were encountered with freezing of the saltwater intake system and with adjustment and operations of the distillation unit. As a result of these factors, it was not possible to obtain rated performance of the unit during the tests, and as the equipment neccessary to correct those difficulties could not be received prior to the next austral summer, it was decided that no further attempt would be made to operate the system during the 1964 austal winter. The unit was drained and the equipment placed in storage.

Early in DEEP FREEZE 1965, a new oil-fired boiler which had been shipped to McMurdo in 1964 replaced the temporary boiler that had been used for the initial testing. The distillation unit was operated on a test basis throughout the 1964-1965 austral summer and some water was produced for the use by McMurdo Station personnel. Problems with the distribution system again required that the unit be deactivated for the austral winter.

The water distillation plant started producing potable water during tests in early 1966 using the oil-fired steam source and in February 1966 potable water was produced using steam from the nuclear power plant as the heat source. Testing was terminated and the plant shut down when freezing of the seawater intake and fresh water distribution systems recurred.

The plant remained shut down throughout the 1966 austral winter during which a major modification was made. This modification consisted of installing a reboiler in the PM-3A Secondary Building to allow continuous operations of the distillation unit with nuclear power. Nuclear steam was supplied to the tube side of the reboiler thereby converting distilled water on the shell side into steam required for water distillation. The modification completely separated the nuclear power plant's steam system from the steam supplied to the distillation units. The PM-3A crew completed the modification prior to the start of DEEP FREEZE 67. A major overhaul of the water distillation plant itself was completed during this winter period, including cleaning and reconditioning the fresh water and seawater storage tanks.

Responsibility for the operation and maintenance of the water distillation plant (exclusive of the seawater and fresh water distribution systems) was transferred to PM-3A personnel in December 1966 by agreement with the Commander, Antarctic Support Activities. On 29 December 1966, the plant began supplying potable water to McMurdo Station using the oil fired auxiliary boiler, and on 16 January 1967 regular production was begun with nuclear generated steam obtained via the reboiler. The plant produced its millionth gallon of fresh water 9 May 1967, and on 3 July 1967 the millionth gallon from nuclear energy. Table III-7 contains a yearly comparison of water produced by oil-fired and nuclear steam.

c. Plant Upgrade. A second flash evaporator unit was installed and placed in operation in January 1968, raising the production capacity of the distillation plant to 28,800 gallons of potable water per day. Decreasing water production rates and excessive maintenance problems with the two flash evaporator units during calendar years 1969 and 1970 necessitated a study of the seawater distillation plant. This study basically determined that the five year expected lifetime of the existing carbon steel units was much less than had been originally anticipated and that the major factor in decreasing water production was excessive corrosion of internal components with an accompanying blockage of flow paths. The study resulted in procurement of a new (third) copper-nickel provided reserve production capacity for peak demand during the austral summer months and served as a backup when one of the other units was out of service for maintenance.

7. Program Funding

A summary of the costs associated with the operation and support of the PM-3A from construction through its last year of operation is given in Table III-8. Prior to 1 July 1972, the Navy was totally responsible for all budgeting, funding, and programming for operation DEEP FREEZE including PM-3A. In 1970, however, the President reaffirmed long-term U.S. objectives in Antarctica and consolidated management and funding of the entire Antarctic program with the National Science Foundation (NSF). Thus, beginning 1 July 1972, NSF became responsible for funding and managing the majority of the Navy's logistic support effort in Antarctica.

As a result of the transfer in budget management and at the request of the Office of Management and Budget, NSF sponsored a study of logistic support in the Antarctic. This included a substudy examining the advisability of future utilization of the PM-3A with three alternatives considered: (1) Deactivation in 1974; (2) continued operation until 1981, the end of design life; and (3) continued operation until 1991, the last out year covered by the study. The findings indicated that based solely on cost effectiveness, the PM-3A should be decommissioned as soon as possible. However, with the idea that factors other than economical ones might also play a part in the PM-3A decision, NSF asked the Navy if continued operation of the plant were desired. If so, it was envisioned the Navy would subsidize the PM-3A operation by an amount equal to the estimated difference between nuclear and conventional power costs at McMurdo.

TABLE III-7

PM-3A WATER DISTILLATION PLANT PRODUCTION

YEAR	NUCLEAR	DIESEL	TOTAL	CUMULATIVE
1967	1,943,432	516,349	2,459,781	2,459,781
1968	2,167,768	1,343,123	3,510,891	5,970,672
1969	2,647,268	2,590,403	5,237,671	11,208,343
1970	1,924,261	5,535,294	5,459,555	16,667,898
1971	2,838,496	2,399,039	5,237,535	21,905,433
1972	1,857,171	4,110,727	5,967,898	27,873,331

TABLE III-8

PM-3A COSTS BY YEAR
(Thousands of Dollars)

	61-64	65-68	69-72	TOTAL
Military Personnel				
PM-3A Crew	975	1,047	1,272	3,294
PM-3A Support	329	533	407	1,269
Crew Trainees	496	533	648	1,677
Civilian Personnel				
NAVNUPWRU	23	300	310	63
NAVFACENGCOM	557	900	423	1,880
Support				
Admin	150	230	224	604
Technical	1,029	371	112	1,512
Construction	6,267	148	0	6,415
Ops. & Maintenance				
Supply	1,252	512	448	2,212
Work Projects	590	738	309	1,637
Nuclear Fuel	1,030	2,108	200	3,338
Fuel Oil	133	69	33	235
Research & Development	0	1,149	364	1,513
Travel	209	336	348	893
TOTAL	13,040	8,974	5,098	27,112

After careful consideration, the Navy took the position that it was in its best interest to continue operation of the plant, at least until the nuclear fuel on hand was consumed (around 1980). A further decision as to whether to operate beyond 1980 was planned. The Navy did agree that the yearly cost of operating the PM-3A was approximately $200,000 per year greater than a comparable diesel plant if the cost for diesel fuel was estimated at the Navy-wide bulk fuel cost of $.22 per gallon. They also recognized that changing AEC safety criteria would require modifications to the plant as regulations become more stringent. However, potential future fossil fuel shortages and cost increases combined with a need to maintain a nuclear capability within the Navy shore establishment favored continued PM-3A operation. What was otherwise a difficult decision by the Navy was reinforced by the desire of the Congressional Joint Committee on Atomic Energy that the plant should be continued in operation.

Final negotiations on the exact amount of subsidy to be provided by the Navy were underway when a totally independent problem resulted in the decision to cease plant operations. The reasons for this decision are covered in Section 9 of this chapter.

8. Operating History.

A chronology of the operating history of the PM-3A while under the responsibility of the Navy is presented in Appendix F. The chronology covers the period from 12 March 1964 when the Navy assumed custody of the plant to 10 October 1973 when the removal plan was initiated. Additionally, at roughly yearly intervals, a summary of the previous year's operation is presented. An overall summary of operating data for this period is presented in Table III-9, and Table III-10 provides a history of burn up and power produced by each core.

9. Investigation of Abnormal Water Drainage at the Interconnect between the Reactor (01) Tank and the Steam Generator (02) Tank

a. Background. On 18 September 1972, after 2900 hours of continuous power operations, the PM-3A Nuclear Power Plant was shutdown for routine maintenance. On 19 September 1972, during a general inspection of the steam generator tank, water was discovered draining through a normally water-tight interconnect between the steam generator tank and the reactor tank. Close examination of plant operating data indicated the leak developed in March - April 1972.

Extensive testing was conducted to determine the source of the water. Radiochemical analysis revealed it to be from the shield water surrounding the reactor pressure vessel. By pressurizing the 02 Tank, a minute crack was discovered at a weld on the insulation canning in the 01 Tank on the reactor outlet leg of the primary piping. The initial seepage rate was about 2.5 gallons per hour; however, subsequent partial repair reduced the rate to about 2.5 gallons per day. Following the repair, further pressurization tests revealed additional paths at both the reactor inlet and outlet shrouds.

TABLE III-9

OPERATING DATA TABULATION

13 March 1964--30 September 1973

CUMULATIVE OR MAX REPORTED

Operating Data	1964	1965	1966	1967	1968	1969
Time available for power operations (hr)	3,145 hrs 47 min	5,356 hrs 57 min	6,758 hrs 19 min	7,530 hrs 52 min	7,490 hrs 35min	6,984 hrs 09 min
Unscheduled Scrams	33	44	16	22	17	13
Downtime Maintenance and Repair (hr)	3,560 hrs 45 min	3,427 hrs 03 min	1,978 hrs 41 min	1,169 hrs 39 min	1,313 hrs 32min	1,871 hrs 51 min
Peak Reactor Power (%)	NR	NR	NR	NR	NR	116
Peak Power Produced (KW)	1500	1780	1810	1850	1800	1954
Peak Power Supplied (KW)	1155	1435	1430	1600	1550	1540
Total Electrical Energy produced (KWH)	3.24×10^6	6.94×10^6	8.69×10^6	9.52×10^6	1.00×10^7	9.7728×10^6
Total Electrical Energy exported (KWH)	2.41×10^6	5.37×10^6	6.78×10^6	7.38×10^6	7.86×10^6	7.6884×10^6
PM-3A Water Consumption (Gals)	137,372	245,893	317,190	361,944	484,811	623,134
PM-3A Diesel Fuel Consumption (Gals)						
(a) PM-3A	40,310	46,444	18,134	24,614	51,118	47,624
(b) WD Plant	NA	NA	NA	NA	57,065	94,959

TABLE III-9 (Continued)

OPERATING DATA TABULATION
13 March 1964--30 September 1973

CUMULATIVE OR MAX REPORTED

Operating Data	1970	1971	1972	1973	TOTAL
Time available for power operations (hr)	5,986 hrs 14 min	6,243 hrs 41 min	4,706 hrs 15 min	Cold Iron	54,182 hrs 49 min
Unscheduled Scrams	10	7	6	0	168
Downtime Maintenance and Repair (hr)	2,893 hrs 46 hrs	2,588 hrs 19 min	4,029 hrs 45 min	0	22,833 hrs 21 min
Peak Reactor Power (%)	117	110	98	0	117
Peak Power Produced (KW)	2049	2314	NR	0	2314
Peak Power Supplied (KW)	1560	1800	NR	0	1800
Total Electrical Energy produced (KWH)	8.714×10^6	8.45×10^6	6.4816×10^6	0	7.1808×10^7
Total Electrical Energy exported (KWH)	6.736×10^6	6.864×10^6	4.938×10^6	0	5.60264×10^7
PM-3A Water Consumption (Gals)	599,126	545,603	571,388	162,587	4,049,048
PM-3A Diesel Fuel Consumption (Gals)					
(a) PM-3A	37,804	30,779	45,898	40,050	382,775
(b) WD Plant	118,874	89,376	128,671	130,099	619,044

TABLE III-10

PM-3A REACTOR CORE DATA

Type	Serial	Installed	Removed	EFPH at Removal	Percent of Minimum Anticipated EFPH	KWHRExported (gross)x10^6	KWHR Exported (net)x10^6
I	2	Feb 62	10 Dec 64	7,165	52.8*	3.24	2.41
I	1	17 Dec 64	16 Oct 67	14,434	106	30.02	23.23
II	1	18 Oct 67	21 Jun 70	16,836	80.2*	25.62	19.95
IV	2	30 Jun 70	01 Jul 73	10,956	31.3**	19.47	14.81
					TOTAL	78.35	60.40

*Removal necessitated by increasing fission product accumulation in the primary coolant system resulting from a fuel leak of undetermined origin.

**Last critical on 26 October 1972

By testing, it was established that the remaining paths were at points which were essentially inaccessible. NAVNUPWRU then contracted an independent corporation to investigate the stress levels which would be produced in the vessel and piping legs if the vessel exterior were brought into direct contact with the shield water due to leakage through the insulation canning. The results of this analysis indicated that a credible mechanism for such flooding existed and that the allowable stresses under ASME Code, Section 8, Division 2, would be exceeded. It was also determined that a potential chloride contamination problem existed due to leaching of chlorides from the insulation surrounding the primary coolant piping when the piping became wet.

The contractor was then tasked with performing a detailed fatigue analysis of the vessel and appurtenances in order to determine what potential tradeoffs between fatigue stress levels would be necessary to permit future operations and what technical approach might be taken to inspect the piping. The initial evaluation indicated that tradeoffs could be made which would give the vessel adequate cycles for eight to ten years of operation, and work was begun on the more complete analytical model which was expected to confirm the initial evaluation. It was also determined that there was no easy way to perform the inspection, which would require specialized organizations. Accordingly, it was decided that the contractor would supply these services by qualified subcontractors.

b. Preparation for Inspection. The initial steps undertaken by NAVNUPWRU and the contractor, after the possibility of chloride stress corrosion cracking of the austenitic stainless steel primary system piping was raised, were those necessary to confirm that all the conditions essential to chloride stress corrosion cracking were, in fact, present. Since the conditions of tensile stress, high temperature, moisture and oxygen were known to be present, the only additional condition needed was the presence of chlorides. Confirmation of the presence of chlorides was obtained by an analysis of a sample of the water and by analysis of samples of insulation which were the same as that installed in the suspected area.

As soon as the possibility of chloride stress corrosion cracking was confirmed, arrangements for inspection of the indicated sections of piping were initiated. These sections of piping were covered with two inches of insulation and 3/16-inch thick 304 stainless cladding and were located under approximately 18 feet of shield water in a 300 to 400 Rem per hour radiation field.

Due to the high radiation fields, two immediate requirements were for shielding to reduce the radiation levels and remote tooling to remove the existing canning. A full scale mock-up was constructed of the reactor pressure vessel and primary system piping in order to develop procedures for installation of the shielding and welding of the replacement insulation canning. PM-3A personnel began construction of the shielding and the required rigging and support structures.

A complete set of inspection and repair procedures, including safety and quality control aspects, was formulated. The inspection was to include chloride smear tests, visual inspection, and dye-penetrant examination of the primary piping. All defects were reported to CONUS for concurrence of the repair procedure to be utilized.

c. PM-3A Inspection. Upon arrival at the plant on 8 January 1973, the inspection team, with major assistance from the PM-3A operating crew, began an exhaustive examination of the reactor piping. A temporary lead shield was constructed and installed in the reactor tank by the operating crew. Two sections of the insulation canning were cut open allowing a portion of the reactor pipe to be examined. It was discovered that the environment in the exposed sections contained ingredients conducive for initiating chloride stress corrosion cracking; however, no indication of the cracking was discovered on the small section of the reactor piping inspected. The pipe insulation was wet, and water was found standing in one section which indicated that the insulation around the reactor pressure vessel was also wet. This had been suspected in October 1972 from analysis of plant operating data. After analyzing the conditions found on site and conducting consultations in CONUS, the contractor recommended that the reactor not be operated until the reactor pressure vessel could be thoroughly inspected to determine if there was any evidence of chloride stress corrosion cracking.

The high cost of performing a full inspection, which would be required before any operations could be resumed, and the unknown probability of success of such an inspection resulted in the decision to terminate operation of the PM-3A and remove the plant from the Antarctic.

d. Alternative Courses of Action. In arriving at the decision to permanently shutdown the PM-3A, the following five alternative courses of action were considered:

Action	Description	Cost (millions)	Time (years)
Return to Power	No direct evidence of damage; Plant is operable; check out and go to power; operate with wet insulation.	Nominal	Few months
Detailed Inspection and Repair	Remove insulation canning; inspect for damage; repair if damaged; reinstall canning, new insulation; return to power.	$1.5	2-3

Redesign and Replace Pressure Vessel and Portions of Primary Piping	Design new pressure vessel and insulation system; remove existing pressure vessel; install new pressure vessel, return to power.	>$2.0	3
Entire New Plant	Design and build new 5MW plant; incorporate modern criteria, consider ice-strengthened barge for mobility; remove PM-3A	$35	6
Shutdown and Dismantle	Remove radioactive components; leave desalination plant; restore site.	<$1.0	3

e. NAVNUPWRU Recommendation. NAVNUPWRU recommended to NAVFACENGCOM that the PM-3A be permanently shutdown, dismantled, and removed from the Antarctic. This decision was based on the contractor's recommendations and comparisons of alternatives in relation to costs and time to implement. Additionally, significant radiation exposures were involved in completing any modifications or repair, and an alternate diesel power plant was already in existence.

The following chapter covers the decommissioning/removal effort from 1973 through 1979.

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CHAPTER IV

DECOMMISSIONING

1. Planning

Once the decision to decommission the PM-3A had been made, planning of the evolution began in earnest. The first crucial decision to be made was whether to completely dismantle the plant and remove it from Antarctica or to "entomb" the plant insitu. The latter, less costly approach was considered inadequate to comply with the intent and letter of the Antarctic Treaty; thus removal was deemed necessary. In September 1973, the Removal Plan for the Pm-3A Nuclear Power Plant, McMurdo Station, Antarctica was approved by NAVFACENGCOM and published. For background and a more detailed description of the decommissioning as planned, this document has been included as Appendix G.

Covered in the Removal Plan was the approach to be taken in collecting and segregating crushed rock on the site containing small quantities of radionuclides. During the operation of the PM-3A liquid effluent discharged below MPC as specified in 10 CFR 20 had flowed over the surface of the ground in its course to the sea. Small quantities of radionuclides from the effluents were reconcentrated by the rock. Additionally, there were three instances during plant operations when cracks in the containment were discovered and repaired, allowing some shield water to enter the crushed rock backfill surrounding the containment tanks.

Since the United States regulations contain MPCs for various radionuclides in air and water but not soils, it was decided to review international guidelines and the regulations of the nations signatory to the Antarctic Treaty to establish site decontamination guidelines. Based on a U.S.S.R. regulation, a de minimus quantity of radioactivity (levels below which matter would not be considered radioactive) for the principal contaminant, cesium-137, was established as 10 picocuries per gram of rock. The rationale for this approach, including other radionuclide contaminants, is discussed further in pages 26 through 28 of Appendix G. It was further determined that after all removal efforts had been accomplished a private contracter would perform an independent radiological survey of the site.

In addition to the basic Removal Plan, detailed Activity Specifications and Procedures were developed covering all aspects of the decommissioning effort. The final planning documents consisted of over 2,000 pages of detailed procedures with 225 engineering drawings. This detailed planning, begun in March 1973, continued in CONUS each austral winter (March-September) with the site work occurring during the austral summers (October-February).

The original plan envisioned the work to be completed over a three-year period as follows:

DF-74	Remove non-essential primary and secondary systems. Ship required materials and equipment to the site, and prepare vessel for shipment.
DF-75	Complete the pressure vessel shipping container, dismantle the primary building, and remove the containment tanks.
DF-76	Final site cleanup.

2. Execution

a. DEEP FREEZE 1974. Despite the severe Antarctic climate, the limited operating season, and the logistics problems associated with the remote location, the first year's effort in DF-74 went smoothly. During the summer season, a large part of the plant's secondary system was removed including the turbine generator, heat transfer apparatus package, reboiler, air-cooled condenser, snow melter, and the associated piping and wiring. All the nuclear fuel and approximately 70 metric tons of radioactive waste were packaged and shipped to CONUS. The reactor pressure vessel was also prepared for shipment. This included removal of approximately 30 radioactive components from the reactor pressure vessel and the placing of a concrete base in the bottom of the containment tank for support of additional depleted uranium shielding. A steel mock shield was temporarily installed to verify the design and to test the procedures for the installation of a depleted uranium shield that would be placed during the coming summer. Finally, a two inch hole was also cut in the bottom of the pressure vessel to allow placing of lead shot and grout in an inaccessible 40 inch diameter by 17 inch high void space beneath the vessel to provide shielding at the bottom of the tank. The DF-74 dismantling effort was completed 31 January 1974, 12 days ahead of schedule.

b. DEEP FREEZE 1975. During DF-75 austral summer, work was completed on preparing the pressure vessel for shipment. This included installing a depleted uranium shield and pouring concrete between the pressure vessel and its containment tank to provide additional shielding. All containment vessels were removed and shipped with the exception of the steam generator tank. This effort had also required the removal of 2300 cubic meters of crushed rock backfill from around the containment tanks. In all, over 365 metric tons of radioactive waste or radioactively contaminated components were removed from the PM-3A site. Work was completed 24 January 1975 when the last of the waste was loaded aboard the resupply ship for disposition at a licensed disposal site in CONUS.

c. DEEP FREEZE 1976. The third year of dismantling operations (DF-76 austral summer) began in October 1975. Early season projects, which were completed by the end of December, included removing the floor and foundation of the condenser building, removing the remaining systems in the secondary building, and dismantling the chemistry laboratory building. Removal of the primary system foundation and backfill cooling system proved more difficult. These elements were frozen in the surrounding crushed rock backfill and were extracted only after expending almost 270 kilograms of dynamite to loosen them.

Work was also begun in collecting and segregating additional backfill. Detailed field surveys of the 8.6 acre site were begun, and additional crushed rock was collected. The contaminated crushed rock was segregated into three categories based on concentrations of cesium-137, the major contaminant. Crushed rock in which cesium-137 was present greater than 2000 picocuries per gram, the level above which material is considered radioactive for transportation purposes according to United States and International Atomic Energy Agency standards, was boxed for shipment as Low Specific Activity waste. Rock which contained no more than 2000 picocuries per gram but greater than 10 picocuries per gram was staged for bulk loading on the resupply ship. Rock containing no more than the de minimus limit of 10 picocuries of cesium-137 per gram was classified as not radioactive and could remain on site. Field radiological surveys of the site were accomplished with a sodium iodide detector, and these measurements were verified by analyzing samples shipped to the United States.

Due to the late arrival of the resupply ship and the deteriorated condition of the ice wharf, it was not possible that year to ship bulk loaded rock as previously planned. However, 370 metric tons of radioactive waste, including the steam generator containment vessel and the boxed LSA crushed rock, were shipped to the United States for disposal.

d. DEEP FREEZE 1977. Radiological surveys were completed in the buildings remaining on site (Secondary, Water Distillation, and Maintenance and Supply Buildings) and field surveys of the site continued with further collection of crushed rock. Five thousand cubic meters of crushed rock were bulk loaded and shipped to the United States aboard the resupply ship. All available space allocated to bulk rock shipment was utilized, leaving an estimated 2700 cubic meters of rock to be shipped the following year.

e. DEEP FREEZE 1978. This fifth season of decommissioning efforts, begun in October 1977, was to consist of shipment of the remaining crushed rock and completion of final site survey by NUS Corporation. Problems with this plan developed early in the season when it was found that the majority of the remaining crushed rock, which was staged in the primary pit, had frozen in solid during the winter. Extensive explosive operations were required before the remaining rock could be dislodged from the sides and bottom of the pit. In addition, after the majority of the rock had been removed, survey results indicated that some areas contiguous to the storage site were contaminated above the action guideline.

The action level of 10 picocuries of cesium-137 per gram of rock was very near or below the concentrations of naturally occurring radioactivity on the site. The close proximity of staged contaminated rock had made it difficult to accurately determine what adjacent rock was above the de minimus limit. Additionally, it was thought that fly rock from explosive operations may have recontaminated some of the areas. Cleaning efforts were begun in these areas with the hope of finishing before the imminent arrival of personnel from NUS Corporation, who were to perform the independent site survey. The extensiveness and inaccessibility of the areas to be cleaned, however, resulted in cleaning efforts and the NUS survey occurring simultaneously. Moreover, the detailed NUS survey revealed a number of locations where their field survey techniques indicated contamination above the established limit. As many as possible of these areas were cleaned during the limited time remaining, and a total of 3500 cubic meters (4600 cubic yards) of crushed rock was loaded aboard the resupply ship.

It was decided that planning for the following season's effort would have to be delayed until NUS had completed its report of the survey results. These results would include correlation between the field survey data and the detailed laboratory analysis of 121 samples collected on the site.

f. DEEP FREEZE 1979. After thorough review and analysis of the NUS results, as well as the Navy's survey and sample data taken incident to late season removal efforts, it became clear that the goal to remove all rock containing cesium-137 in excess of 10 picocuries per gram was not reasonably achievable. Estimates of achieving the guideline were uncertain, but it was clear that many more years of surveying, jackhammering and removal of unknown but probably very large quantities of rock would be required.

A change in approach from the arbitrary application of a *de minimus* limit was necessary. It was determined that the following season's efforts would concentrate on removing the rock from those areas with the highest levels of activity indicated in the NUS report. This would be followed by a hazard analysis based on concentrations of contaminants remaining and evaluation of potential exposure pathways to man. Depending on the success of the cleaning efforts and the results of the hazard analysis, the site could be considered decontaminated to levels as low as reasonably achievable (ALARA) and cleared for unrestricted use.

In October 1978, the sixth season of removal efforts began. As had been the case the previous season, the majority of the cleaning effort was tedious and at times dangerous hand work with picks, shovels, and jackhammers. Many areas to be cleaned were on steep slopes where heavy equipment could not be used, and even in areas accessible to such equipment the permafrost resisted removal by anything but the slow progress of a jackhammer.

By the end of the season 540 cubic meters of rock had been shipped. The highest single point of cesium-137 concentrations in the rock remaining on site was 29 picocuries per gram, and the average over the site was 6.1 picocuries per gram.

3. Conclusion

In February 1979, NAVNUPWRU completed a detailed hazard analysis of the remaining man-made radiation a the PM-3A site, including all significant pathways to man. It was shown that the radiation dose received by an individual from man-made radioactivity at the site would not exceed 15 millirems per year as an upper limit or 6 millirems per year as a most probable value. The site was declared decontaminated to levels as low as reasonably achievable and cleared for unrestricted use.

APPENDIX A

EXCERPT FROM CHAPTER 3, PM-3A OPERATING MANUAL, REACTOR ROD CONTROL SYSTEM

APPENDIX A

Excerpt from

CHAPTER 3, PM-3A OPERATING MANUAL, REACTOR ROD CONTROL SYSTEM

Section 1 - System Description

A. FUNCTION. The function of the reactor rod control system is to provide the operator with the capability of positioning the control rods through manually operated switches and to provide automatic control for hold, fast insert and scram functions from safety system input signals. The system also provides rod position indications for all control rods.

B. GENERAL DESCRIPTION. Six magnetic jack-type actuators (Figure 3-1) move the rods in response to signals received from a signal generator. To move the rods, the output of the signal generator consists of voltage pulses of precise duration and sequence. These pulses alternately energize the hold, grip, and lift (or pulldown) coils on the actuator which results in a jacking action being imparted to the control rods. During normal plant operation, the signal generator delivers a constant voltage to the hold coils. A ROD SELECTOR switch is provided on the control console to determine which control rods will respond to manual signals. A ROD SPEED SELECTOR switch on the control console is used to select the speed of movement of the selected rod or rod(s). Individually, the rods may be moved at speeds of 2 inches per minute (slow) or 6 inches per minute (fast) according to the position of the ROD SPEED SELECTOR switch. All rods may be inserted simultaneously at 6 inches per minute by use of the FAST insert switch. This switch overrides the ROD SPEED SELECTOR and ROD MOTION CONTROL switches. The rods may also be moved in increments of approximately 0.06 inch by use of a ROD JOG switch on the control console. Adjustable limit switches on the position indicators prevent the rods from being pulled out more than 30.75 + 0.25 inches, unless set at some lower limit.

There are three automatic rod control signals which originate in the reactor safety system (Chapter 4): hold, fast insert, and scram. In general, automatic hold overrides all manual motion except insertion, fast insertion, and scram; automatic fast insert overrides automatic hold and all manual motion except scram; and scram overrides all other signals. All modes of 2-inch-per-minute insertion and single rod 6-inch-per-minute insertion override automatic hold.

Upward motion of the bundle-rod assembly compresses the scram spring located in the upper section of the scram spring housing. A scram signal will de-energize the actuator coils, and the spring force combined with gravity force will drive the rods into the core. A scram signal may be initiated manually by the operator or automatically by an instrumentation system signal.

The rod position is sensed by a three-winding transformer. One winding is the power or primary winding. The other two are connected in series (out-of-phase) and form the secondary of the transformer. They are physically located on either side of the primary winding. A magnetic slug which forms the core of the transformer and thus determines the coupling between the primary and secondary, is a part of the bundle rod assembly. When the magnetic slug moves in either direction, it causes the primary to be more closely coupled to one-half of the secondary than the other. This will generate an error voltage, in the secondary transformer, proportional to the slug travel. This unbalance is detected and used to drive a servo motor which, through a lead screw, moves the transformer windings in the direction to restore a null condition. A servo transmitter, which is attached to the position indicator lead screw, transmits a position indictor signal to the indicator mounted on the control console. Under a scram condition the core slug drops away from the transformer windings. Due to a slight difference in the number of turns on the two secondary windings connected in series, a signal is generated which causes the servo motor to automatically drive the transformer down to again reposition it with the core slug.

During the process of latching the control rod, the effective length of the bundle-rod assembly is shortened by 3/8 inch. This results in the control rod being supported by the actuator, rather than by the reactor core, when in the fully inserted position. Therefore, the impact of rod insertion during scram is not transferred to the core nor to the core support structure. Impact effects on the actuator itself are reduced to acceptable levels by the buffer piston portion of the bundle-rod assembly. The buffer piston, and therefore the bundle-rod assembly, are decelerated in a cylindrical dashpot which is incorporated into the bottom portion of the scram spring housing.

C. MAJOR COMPONENTS.

1. Magnetic Jack Actuator. The magnetic jack-type actuator consists of three major subassemblies: The rod actuator assembly, the drive coil assembly, and the position indication transmitter assembly.

a. Rod Actuator Assembly. The principal parts making up the rod actuator assembly are the bundle-rod assembly; the hold and grip armatures, the lift, grip, hold, and pulldown magnets; the scram spring; the pressure housing (consisting of the scram spring housing, the armature housing and the pressure vessel - armature housing spool piece) and the vent valve and mechanical stop.

The bundle rod, a portion of the bundle-rod assembly, consists of a cylinder of high permeability steel vertically divided into four segments. During normal reactor operation, the segments are deflected in the region of the hold armature, and are attracted to the hold coil pole faces with a horizontal force of about 1000 pounds. This force is sufficient to clamp the bundle-rod assembly to the hold armature against the vertical forces of the scram spring and component weights.

When the rods are being raised or lowered, the segments are alternately attracted in the regions of the hold and grip armatures. The segments are attracted to the grip coil pole faces with a force of about 2000 pounds.

The hold and grip armatures are similar to each other. The main difference is that the hold armature is attached to the armature housing while the grip armature is free to move 0.06 inch vertically.

The armatures have a function of providing well defined paths for the flow of magnetic flux. The paths are defined by building the armatures up from alternate rings of magnetic and nonmagnetic steel.

A typical flux path would extend from a coil (external to the pressure shell) through the pressure shell, through one ring of magnetic material in the armature, through a region of the rod bundle, back through an adjacent ring of armature magnetic material, and through the pressure shell to the coil.

The two elongated rings of magnetic material at the adjacent ends of the two armatures comprise the internal pole faces of the lift coil. When the lift coil is energized, the grip armature is lifted 0.06 inch as the magnetic circuit attempts to eliminate the gap between the pole faces.

The two elongated rings of magnetic material at the adjacent ends of the grip armature and the armature housing comprise the internal pole faces of the pulldown coil. The upper ring is attached to the grip armature and the lower ring is attached to the armature housing. When the pulldown coil is energized, the grip armature is pulled down 0.06 inch as the magnetic circuit attempts to eliminate the gap between the pole faces.

During scram, all of the actuator coils are de-energized. The bundle rod segments, therefore, are not deflected and do not touch the inner walls of either the hold or the grip armatures. The scram spring force and gravity will then drive the bundle-rod assembly downward and insert the control rod.

The actuator pressure shell consists of three regions: The region about the drive coils; a region above and magnetically remote from the drive coils, in which the scram spring is housed; and a region below and magnetically remote from the drive coils, which separates the armature housing from the pressure vessel head. This lower spool piece region is flanged to permit assembly and disassembly from the pressure vessel head.

The metal shell in the drive coil region is constructed of a semi-magnetic stainless steel in order not to impede the passage of the magnetic flux. Wall thickness is 0.1 inch. The upper shell is of nonmagnetic material and the wall thickness is slightly over 0.25 inch.

The lower end of the bundle-rod assembly extends beyond the actuator pressure shell and is equipped with spring-loaded "fingers" which grasp the control rod. Ball check valves are provided at the top of the scram spring housing. These valves are provided to bleed entrapped gas from the armature housing.

b. Drive Coil Assembly. The drive coils are housed in the coil assembly can which is seal-welded to the actuator pressure shell. Four groups of coils are provided for each actuator. They are: (1) four hold coils, (2) one lift coil, (3) ten grip coils, and (4) one pulldown coil.

The hold coils are the uppermost group of coils. They are electrically connected in series. Each coil contains 190 turns, is activated approximately 3.5 amperes, and develops an MMF (Magnet-Motive Force) of approximately 665 ampere-turns.

The lift coil is located in the middle of the drive coil housing. It consists of 730 turns, is activated by approximately 5 amperes, and produces an MMF of 3650 ampere-turns.

The grip coils are electrically connected as two parallel groups of five coils in series, and are physically located below the lift coil but above the pulldown coil. Each coil consists of 190 turns, is activated by approximately 4.5 amperes, and develops an MMF of about 855 ampere-turns.

The pulldown coil is the bottom coil of the group. It consists of 560 turns, is activated by 4.5 amperes, and produces an MMF of about 2520 ampere-turns.

c. Position Indication Assembly. The position indicator transmitter is contained in a separate assembly can which is placed over the scram spring housing and rests of the drive coil assembly can. The device is essentially a null seeking differential transformer made up of: (1) a three-coil transformer, (2) a servo motor, (3) a lead screw for moving the transformer, and (4) a synchro transmitter.

The transformer core is a slug of magnetic material which rides on the bundle-rod assembly inside of the pressure shell. When the slug moves, the transformer output is unbalanced and an error signal is produced. The error signal is amplified by a servo amplifier located in the control console. This amplified signal drives the servo motor and the lead screw to reduce the error signal to zero by repositioning the transformer windings relative to the core slug. The synchro-transmitter, which is mechanically attached to the lead screw, transmits a position signal to the position indicator at the console.

2. <u>Signal Generator</u>. The signal generator system is made up of eight sub-systems (see Figure 3-2). They are: (1) reference oscillator, (2) lift-lower monostable multivibrator, (3) hold monostable multivibrator, (4) grip bistable multivibrator, (5) lift-lower AND logic circuit, (6) hold AND logic circuit, (7) two-phase inverters, and (8) jog bistable multivibrator.

The reference oscillator sets the jacking cycle of the actuators and synchronizes the multivibrators. It is, essentially, a transistorized pulse generator whose pulse rate is determined by a resistor-capacitor network. The pulse rate (time between pulses) can be selected to give either a 0.333-second pulse rate for a 6-inch-per-minute rod travel or a 1.0-second pulse rate for a 2-inch-per-minute rod travel.

The monostable multivibrators are actuated by the reference oscillator pulses (or triggers). A characteristic of a monostable multivibrator is that for each pulse received by its input, it will deliver a full square wave output. Therefore, the output frequency of these monostable multivibrators is the same as the reference oscillator. The width of the square wave output, however, is determined by a resistor-capacitor network which is a part of the multivibrator circuit. The hold monostable multivibrator is used to determine the time at which the hold magnets are initially energized. The lift-lower monostable multivibrator determines the time at which the lift or pulldown magnets are initially energized.

The grip bistable multivibrator is also actuated by the reference oscillator. A characteristic of a bistable multivibrator is that for each pulse received by its input, its output state will reverse. Thus, for each two pulses received, a complete square wave will be generated. The grip bistable multivibrator, therefore, generates a square wave whose output frequency is one half of the reference oscillator frequency.

The AND logic circuits have two inputs each. These logic circuits have the characteristic that their outputs are maximum unless both inputs are energized (negative). The lift-lower logic circuit receives its inputs from the lift-lower monostable multivibrator and from the grip bistable multivibrator. Its output energizes the lift and the pulldown magnets through power amplifiers. The lift and pulldown magnets are energized only when both multivibrators are "ON". A control switch is used to select whether the insert or extract cycle will be followed. The hold logic circuit receives its input from the hold monostable multivibrator and from the output of the phase inverter circuit. The hold logic circuit output is "OFF" when both inputs are -28V. The hold magnets are energized for a greater time than the lift (or lower) magnets are de-energized.

The phase inverters serve as reversing circuits. One can be switched into or out of the lift-lower circuit. It is switched into the circuit during the lifting sequence to produce a correctly phased pulse for the lift sequence. The other inverter is in the lower circuit and produces a correctly phased pulse for the lower sequence.

The jog bistable is triggered by the lift-lower logic circuit when the ROD JOG switch is closed and the ROD MOTION CONTROL switch is turned to the IN or OUT position. The jog bistable operates to disable the lift and the pulldown magnets as soon as one pulse has energized the jacking magnets. This limits the rod travel to one jacking action and the rods to 0.06 inch travel each time the ROD MOTION CONTROL switch is operated.

The synchronizing of the multivibrators by the reference oscillator results in the magnets being energized and de-energized in a definite sequence. The grip magnets are energized before the hold magnets are de-energized, and do not release until after the hold magnets are re-energized. Thus, the bundle-rods are held continuously during a jacking operation. The lift (and pulldown) magnets are energized at the same time that the hold magnets are de-energized. Thus, as soon as the hold magnet releases, movement of the bundle-rod assembly will start. The lift (or lower) magnets are de-energized after the hold magnets are energized. Thus, the rods are clamped in the new position before the grip armature is released.

The sequence of a rod lift operation is as follows: The hold magnet is energized. The grip, lift, and pulldown magnets are de-energized. The grip magnet energizes and holds the bundle-rod. The lift magnet energizes and the hold magnet de-energizes simultaneously. The lift magnet raises the grip armature (and bundle-rod) 0.06 inch. The hold magnet energizes and the hold armature clamps the bundle-rod in position. The grip and lift magnets are de-energized and the pulldown magnet is energized to return the armature to the down position. The sequence is repeated until the ROD MOTION CONTROL switch is released or until the bundle-rod assembly reaches the limit of its travel.

APPENDIX B

MEMORANDUM OF UNDERSTANDING BETWEEN THE U.S. ATOMIC ENERGY COMMISSION AND THE DEPARTMENT OF DEFENSE CONCERNING THE PM-3A and PL-3 NUCLEAR POWER PLANTS IN ANTARCTICA

APPENDIX B

MEMORANDUM OF UNDERSTANDING BETWEEN THE U. S. ATOMIC ENERGY COMMISSION AND THE DEPARTMENT OF DEFENSE CONCERNING THE PM-3A AND PL-3 NUCLEAR POWER PLANTS IN ANTARCTICA

The Atomic Energy Commission and the Navy, acting as agent for the DOD, having undertaken to cooperate in providing nuclear power plants for United States facilities in Antarctica in accordance with the intent of the Congress, and in full recognition of the impact of environmental and logistic difficulties on the paramount criteria of safety and reliability, agree to the following division of responsibilities consistent with legal requirements.

1. The Atomic Energy Commission is responsible for:

    (a) Determining the appropriate design aspects of the PM-3A and PL-3 in consultation with the Navy.

    (b) Arranging for the fabrication and pre-shipment testing of the plants; scheduling and installation effort, and effecting the actual installation and successful test operation of the plants utilizing military personnel as appropriate.

    (c) Determining, in consultation with the Navy and prior to the transfer to the Navy, when each plant is suitable for the operational use intended.

    (d) Furnishing to the Navy, when each nuclear plant is transferred to the Navy's custody, detailed engineering data and operating and maintenance procedures and standards governing the plant's safe and efficient operation and maintenance.

    (e) After the transfer to the Navy's custody of each nuclear power plant:

        (1) Fulfilling its responsibilities in accordance with the understanding expressed in paragraph 3 below.

        (2) Furnishing such other technical advice and assistance as the Navy may request, and in accordance with such funding arrangements as are agreed to.

        (3) Reprocessing, at Navy expense, the cores turned over to Navy custody by the Atomic Energy Commission with each nuclear plant.

2. The Navy is responsible for:

    (a) Collaborating in selection of plant concept.

(b) Advising the Atomic Energy Commission, during all phases of the two projects, of the limits of Navy logistic capability in order to assure that such limits are accommodated in the design of the plants and in the shipment and installation schedules.

(c) Shipping the nuclear plants to Antarctica and delivering them to the plant sites.

(d) Providing support facilities, materials, personnel, and equipment for installation and test operation activities.

(e) Furnishing available transportation to and from Antarctica, and living accommodations there, for Atomic Energy Commission representatives (including Atomic Energy Commission-designated employees of the contractor) engaged in the supervision of installation or test-operation activities.

(f) Accepting custody of the plants when the transfer is made in accordance with paragraph 1. above.

(g) Thereafter, operating and maintaining the plants, and bearing all operating and maintenance costs, including among other things, the cost of fuel fabrication and burn-up of special nuclear materials, and fulfilling the Navy's responsibilities, in accordance with the understanding expressed in paragraph 3. below.

(h) Upon request, furnishing the Atomic Energy Commission with technical and economic data respecting the Navy's operation and maintenance of the plants, and such information respecting the Navy's possession or use of special nuclear material as the Atomic Energy Commission may request from time to time.

3. Upon acceptance of custody of each plant pursuant to 2. (f) above, responsibility will rest with the Department of the Navy for identifying and resolving health and safety problems relating to the operation of these plants, or to special nuclear material for use therein. In view of the Atomic Energy Act of 1954, the AEC will participate in the identification and resolution of these problems as a matter of responsibility. In this connection the Department of the Navy will prepare, issue and enforce safety standards, procedures or instructions applicable to the location and operation of these plants and to special nuclear material for use therein. Advice and assistance will be obtained from the AEC on the safety aspects of the design of these plants and in the preparation or amendment of safety standards, procedures or instructions relating to location and operation of these plants and the special nuclear materials for use therein, and comment or concurrence shall be obtained from the AEC as to their adequacy. Any disagreement as to safety aspects, arising as a result of comment by the AEC, which cannot be directly resolved by the two agencies will be referred to the President for decision.

SIGNED FRED KORTH	SIGNED GLENN T. SEABORG
February 19, 1962	March 28, 1962

APPENDIX C

ANTARCTIC TREATY

APPENDIX C

ANTARCTIC TREATY

"The Governments of Argentina, Australia, Belgium, Chile, the French Republic, Japan, New Zealand, Norway, the Union of South Africa, the Union of Soviet Socialist Republics, the United Kingdom of Great Britain and Northern Ireland, and the United States of America.

Recognizing that it is in the interest of all mankind that Antarctica shall continue forever to be used exclusively for peaceful purposes and shall not become the scene or object of international discord;

Acknowledging the substantial contributions to scientific knowledge resulting from international cooperation in scientific investigation in Antarctica;

Convinced that the establishment of a firm foundation for the continuation and development of such cooperation on the basis of freedom of scientific investigation in Antarctica as applied during the International Geophysical Year accords with the interests of science and the progress of all mankind;

Convinced also that a treaty ensuring the use of Antarctica for peaceful purposes only and the continuance of international harmony in Antarctica will further the purposes and principles embodied in the Charter of the United Nations;

Have agreed as follows:

Article I

1. Antarctica shall be used for peaceful purposes only. There shall be prohibited, inter alia, any measures of a military nature, such as the establishment of military bases and fortifications, the carrying out of military maneuvers, as well as the testing of any type of weapons.

2. The present Treaty shall not prevent the use of military personnel or equipment for scientific research or for any other peaceful purposes.

Article II

Freedom of scientific investigation in Antarctica and cooperation toward that end, as applied during the International Geophysical Year, shall continue, subject to the provisions of the present Treaty.

Article III

1. In order to promote international cooperation in scientific investigation in Antarctica, as provided for in Article II of the present Treaty, the Contracting Parties agree that, to the greatest extent feasible and practicable:

(a) information regarding plans for scientific programs in Antarctica shall be exchanged to permit maximum economy and efficiency of operations;

(b) scientific personnel shall be exchanged in Antarctica between expeditions and stations;

(c) scientific observations and results from Antarctica shall be exchanged and made freely available.

2. In implementing this Article, every encouragement shall be given to the establishment of cooperative working relations with those Specialized Agencies of the United Nations and other international organizations having a scientific or technical interest in Antarctica.

Article IV

1. Nothing contained in the present Treaty shall be interpreted as:

(a) a renunciation by any Contracting Party of previously asserted rights of or claims to territorial sovereignty in Antarctica;

(b) a renunciation or diminution by any Contracting Party of any basis of claim to territorial sovereignity in Antarctica which it may have whether as a result of its activities or those of its nationals in Antarctica, or otherwise;

(c) prejudicing the position of any Contracting Party as regards its recognition or non-recognition of any other State's right of or claim or basis of claim to territorial sovereignty in Antarctica.

2. No acts or activities taking place while the present Treaty is in force shall constitute a basis for asserting, supporting or denying a claim to territorial sovereignty in Antarctica or create any rights of sovereignty in Antarctica. No new claim, or enlargement of an existing claim, to territorial sovereignty shall be asserted while the present Treaty is in force.

Article V

1. Any nuclear explosions in Antarctica and the disposal there of radioactive waste material shall be prohibited.

2. In the event of the conclusion of international agreements concerning the use of nuclear energy, including nuclear explosions and the disposal of radioactive waste material, to which all of the Contracting Parties whose representatives are entitled to participate in the meetings provided for under Article IX are parties, the rules established under such agreements shall apply in Antarctica.

Article VI

The provisions of the present Treaty shall apply to the area south of 60° South Latitude, including all ice shelves, but nothing in the present Treaty shall prejudice or in any way affect the rights or the exercise of the rights, of any State under international law with regard to the high seas within that area.

Article VII

1. In order to promote the objectives and ensure the observance of the provisions of the present Treaty, each Contracting Party whose representatives are entitled to participate in the meetings referred to in Article IX of the Treaty shall have the right to designate observers to carry out any inspection provided for by the present Article. Observers shall be nationals of the Contracting Parties which designate them. The names of the observers shall be communicated to every other Contract Party having the right to designate observers, and like notice shall be given of the termination of their appointment.

2. Each observer designated in accordance with the provisions of paragraph I of this Article shall have complete freedom of access at any time to any or all areas of Antarctica.

3. All areas of Antarctica, including all stations, installations and equipment within those areas, and all ships and aircraft at points of discharging or embarking cargoes or personnel in Antarctica, shall be open at all times to inspection by any observers designated in accordance with paragraph 1 of this Article.

4. Aerial observation may be carried out at any time over any or all areas of Antarctica by any of the Contracting Parties having the right to designate observers.

5. Each Contracting Party shall, at the time when the present Treaty enters into force for it, inform the other Contracting Parties, and thereafter shall give them notice in advance, of

(a) all expeditions to and within Antarctica, on the part of its ships or nationals, and all expeditions to Antarctica organized in or proceeding from its territory;

(b) all stations in Antarctica occupied by its nationals; and

(c) any military personnel or equipment intended to be introduced by it into Antarctica subject to the conditions prescribed in paragraph 2 of Article I of the present Treaty.

Article VIII

1. In order to facilitate the exercise of their functions, under the present Treaty, and without prejudice to the respective positions of the Contracting Parties relating to jurisdiction over all other persons in Antarctica, observers designated under paragraph I of Article VII and scientific personnel exchanged under subparagraph 1(b) of Article III of the Treaty, and members of the staffs accompanying any such persons, shall be subject only to the jurisdiction of the Contracting Party of which they are nationals in respect to all acts or omissions occurring while they are in Antarctica for the purpose of exercising their functions.

2. Without prejudice to the provisions of paragraph 1 of this Article, and pending the adoption of measures in pursuance of subparagraph 1(e) of Article IX, the Contracting Parties concerned in any case of dispute with regard to the exercise of jurisdiction in Antarctica shall immediately consult together with a view to reaching a mutually acceptable solution.

Article IX

1. Representatives of the Contracting Parties named in the preamble to the present Treaty shall meet at the City of Canberra within two months after date of entry into force of the Treaty, and thereafter at suitable intervals and places, for the purpose of exchanging information, consulting together on matters of common interest pertaining to Antarctica, and formulating and considering, and recommending to their Governments, measures in furtherance of the principles and objectives of the Treaty including measures regarding:

(a) use of Antarctica for peaceful purposes only;
(b) facilitation of scientific research in Antarctica;
(c) facilitation of international scientific cooperation in Antarctica;
(d) facilitation of the exercise of the rights of inspection provided for in Article VII of the Treaty;
(e) questions relating to the exercise of jurisdiction in Antarctica;
(f) preservation and conservation of living resources in Antarctica.

2. Each Contracting Party which has become a party to the present Treaty by accession under Article XIII shall be entitled to appoint representatives to participate in the meetings referred to in paragraph 1 of the present Article, during such time as that Contracting Party demonstrates its interest in Antarctica by conducting substantial scientific research activity there, such as the establishment of a scientific station or the dispatch of a scientific expedition.

3. Reports from the observers referred to in Article VII of the present Treaty shall be transmitted to the representatives of the Contracting Parties participating in the meetings referred to in paragraph 1 of the present Article.

4. The measures referred to in paragraph 1 of this Article shall become effective when approved by all the Contracting Parties whose representatives were entitled to participate in the meetings held to consider those measures.

5. Any of all of the rights established in the present Treaty may be exercised as from the date of entry into force of the Treaty whether or not any measures facilitating the exercise of such rights have been proposed, considered or approved as provided in this Article.

Article X

Each of the Contracting Parties undertakes to exert appropriate efforts, consistent with the Charter of the United Nations, to the end that no one engages in any activity in Antarctica contrary to the principles or purposes of the present Treaty.

Article XI

1. If any dispute arises between two or more of the Contracting Parties concerning the interpretation or application of the present Treaty, those Contracting Parties shall consult among themselves with a view to having the dispute resolved by negotiation, inquiry, mediation, conciliation, arbitration, judicial settlement or other peaceful means of their own choice.

2. Any dispute of this character not so resolved shall, with the consent, in each case, of all parties to the dispute, be referred to the International Court of Justice for settlement; but failure to reach agreement on reference to the International Court shall not absolve parties to the dispute from the responsibility of continuing to seek to resolve it by any of the various peaceful means referred to in paragraph 1 of this Article.

Article XII

1. (a) The present Treaty may be notified or amended at any time by unanimous agreement of the Contracting Parties whose representatives are entitled to participate in the meetings provided for under Article IX. Any such modification or amendment shall enter into force when the depositary Government has received notice from all such Contracting Parties that they have ratified it.

(b) Such modification or amendment shall thereafter enter into force as to any other Contracting Party when notice of ratification by it has been received by the depositary Government. Any such Contracting Party from which no notice of ratification is received within a period of two years from the date of entry into force of the modification or amendment in accordance with the provisions of subparagraph 1(a) of this Article shall be deemed to have withdrawn from the present Treaty on the date of the expiration of such period.

2. (a) If after the expiration of thirty years from the date of entry into force of the present Treaty, any of the Contracting Parties whose representatives are entitled to participate in the meetings provided for under Article IX so requests by a communication addressed to the depositary Government, a Conference of all the Contracting Parties shall be held as soon as practicable to review the operation of the Treaty.

(b) Any modification or amendment to the present Treaty which is approved at such a Conference by a majority of the Contracting Parties there represented, including a majority of those whose representatives are entitled to participate in the meetings provided for under Article IX shall be communicated by the depositary Government to all the Contracting Parties immediately after the termination of the Conference and shall enter into force in accord- ance with the provisions of paragraph 1 of the present Article.

(c) If any such modification or amendment has not entered into force in accordance with the provisions of subparagraph 1(a) of this Article within a period of two years after the date of its communication to all the Contracting Parties, any Contracting Party may at any time after the expiration of that period give notice to the depositary Government of its withdrawal from its present Treaty; and such withdrawal shall take effect two years after the receipt of the notice by the depositary Government.

Article XIII

1. The present Treaty shall be subject to ratification by the signatory States. It shall be open for accession by any State which is a Member of the United Nations, or by any other State which may be invited to accede to the Treaty with the consent of all the Contracting Parties whose representatives are entitled to participate in the meetings provided for under Article IX of the Treaty.

2. Ratification of or accession to the present Treaty shall be effected by each State in accordance with its constitutional process.

3. Instruments of ratification and instruments of accession shall be deposited with the Government of the United States of America, hereby designated as the depositary Government.

4. The depositary Government shall inform all signatory and acceding States of the date of each deposit of an instrument of ratification or accession, and the date of entry into force of the Treaty and of any modification or amendment thereto.

5. Upon the deposit of instruments of ratification by all the signatory States, the present Treaty shall enter into force for those States and for States which have deposited instruments of accession. Thereafter the Treaty shall enter into force for any acceding State upon the deposit of its instrument of accession.

6. The present Treaty shall be registered by the depositary Government pursuant to Article 102 of the Charter of the United Nations.

Article XIV

The present Treaty, done in the English, French, Russian, and Spanish languages, each version being equally authentic, shall be deposited in the archives of the Government of the United States of America, which shall transmit duly certified copies thereof to the Governments of the signatory and acceding States

In witness whereof, the undersigned Plenipotentiaries, duly authorized, have signed the present Treaty.

Done at Washington this first day of December, one thousand nine hundred and fifty-nine.

For Argentina:
Adolfo Scilingo
F. Bello

For Autralia:
Howard Beale

For New Zealand:
G. D. L. White

For Norway:
Paul Koht

For Belgium:
Obert de Thieusies

For Chile:
Marcial Mora M
E. Gajardo V
Julio Escudero

For the French Republic:
Pierre Charpentier

For Japan:
Koichiro Asakai
T. Shimoda

For the Union of South Africa:
Wentzel C. du Plessis

For the Union of Soviet Socialist Republics:
V. Kuznetsov (Romanization)

For the United Kingdom of Great Britain and Northern Ireland:
Harold Caccia

For the United States of America:
Herman Phleger
Paul C. Daniels

APPENDIX D

PERSONNEL LISTING

APPENDIX D

PERSONNEL LISTING

*	Denotes second winter-over tour
**	Denotes third winter-over tour
@	Denotes second summer support tour
@@	Denotes third summer support tour
@@@	Denotes fourth summer support tour
@@@@	Denotes fifth summer support tour

1. Crew I Personnel, DEEP FREEZE 62

WINTER-OVER

MITCHELL, T. J.	LT, CEC, USN Officer in Charge
MATHERS, W. C.	LT, CEC, USN Plant Superintendent
BLACK, A. K.	CE1
BROOKS, W. B.	SP5
BRUCE, D. R.	SKCA
DUBAY, R. M.	UT1
FERGUSON, D. L.	SP5
FLEMING, J. P.	CECA
GABBERT, R. B.	UTCA
GABERLEIN, W. E.	CE1
KOZIKOWSKI, S. F.	HM2
LOWE, D. H.	SFC
MASCHKA, P. R.	A1C
McCANN, J. M.	UT1
MILLER, H. J.	UTCS
MILLER H. W.	CE1
POLLOCK, H. W.	CE1
SPENCER, S. T.	CECS
STIERER, B. A.	A1C
WILLIAMS, D. O.	SP5

CREW I SUMMER SUPPORT

REDMAN, B. D.	UTCA

2. CREW II Personnel, DEEP FREEZE 63

WINTER-OVER

COPE, R. P.	LT, CEC, USN Officer in Charge
MATHEWSON, M.	LT, CEC, USN Plant Superintendent
ANDREW, R. E.	SP6
CARRIGAN, C. E.	SK1
CARSON, G. A.	CE1
CROWE, E. J.	SP5
FADDEN, D. E.	UTCA
GOFF, T. W.	CES2
GOZA, J. N.	HM1
HILSABECK, W. G.	CMCS
HOGG, R. T.	CECA
ISENHOFF, G. P.	SFC
JOHNSON, D. L.	HM2
KNIGHT, D. W.	CECA
LAW, G. L.	CE1
LINN, P. E.	UT1
MILLER, G. J.	EOCA
SMITH, H. G.	EO1
SOURDIFF, L. J.	SSGT
SWINFORD, H. D.	UTCA
WAGES, J. C.	CECA

SUMMER SUPPORT

FEDDERSON, B. C.	CEC
GABERLEIN, W. E.	CE1
McCANN, J. M.	UT1
McKEE, C. R.	SWF2
SINGLETON, W. T.	CECA
TOLIN, D.	HMCA

3. CREW III Personnel, DEEP FREEZE 64

WINTER-OVER

FEGLEY, C. E., III	LT, CEC, USN Officer in Charge	
BATES, R. G.	LTJG, CEC, USN Plant Superintendent	
BELL, F. H.	HMC	
BENDER, N. E.	SFC	
BERNARDO, G. S.	UTCM	
CLARK, W. P.	CE1	
COLBY, S. C.	UTP2	
CUSTEAD, E. B.	HMC	
DEWEES, B. V.	CE1	
FORT, R. E.	CECS	
GABERLEIN, W. E.	CEC	*
GARLAND, R. A.	CE1	
KUMAGAI, T.	SFC	
LODGE, D. B.	HM1	
MOORE, E. H.	CEC	
QUICK, J. C.	SP5	
RANDALL, J. A.	CM1	
REDMAN, B. D.	UTCM	
RISING, H. A.	HM1	
SCHLOREDT, J. L.	CE1	
SCHULZ, G. K.	CEC	
SINGLETON, W. T.	CEC	
TOLIN, D. S.	HMC	
WOODS, J. R.	SK1	
YOUNG, T., Jr.	SGT	

SUMMER SUPPORT

ELDRED, D. T.	EON2	
GOLIGHTLY, E. J.	HM1	
HOLMES, W. A.	CMC	
KING, J. W.	CECA	
McCANN, J. M.	UT1	@
McGREGOR, L. G.	CE1	
McKEE, C. R.	SWF2	@
MELTON, J. L., Jr.	HMCA	
MOOREHEAD, J. R.	SW1	
POLLOCK, H. W.	CEC	
ROMINGER, G. R.	CET2	

4. CREW IV Personnel, DEEP FREEZE 65

WINTER-OVER

SHAFER, W. G.	LCDR, CEC, USN, Officer in Charge
STEPHENSON, W. S.	LTJG, CEC, USN Plant Superintendent
BELCHER, E. E.	CECM
BINGHAM, R. E.	HM2
CLARK, R. A.	CECS
DORCHUCK, R. E.	CM1
ELDRED, D. T.	EON2
EVANS, R. L.	CEC
FELTER, P. D.	HM1
FERGUSON, C. E.	CEC
GARDNER, K. A.	UTP2
HELMS, H. J.	SSG
HINOJOSA, R. A.	SP5
MELTON, J. L.	HMC
MILLER, F. P.	HM2
MOOREHEAD, J. R.	SW1
MUCHOW, M. J.	UTC
NELSON, D. L.	SK2
NOONAN, J. H.	CM1
PHILLIPS, R. C.	MSGT
ROMINGER, G. R.	CE1
SAUNDERS, R. S.	CE1
SPENCER, R. F.	HMC
THOMPSON, F. S., Jr.	CE1
VIOLETTE, R. E.	SP5
YONKER, C. P., Jr.	CEP2

SUMMER SUPPORT

BERKOWITZ, R. J.	UTB2	
BROWN, S.	HMC	
FLEMING, J. P.	CEC	
GANNON, J. W.	EO1	
HEEDER, C. A.	YN1	
HOFFMANN, E. H.	CE1	
HOLMES, W. A.	CMC	@
HOOVER, R. A.	CE1	
McCANN, J. M.	UT1	@@
McCARTHY, J.	CEC	
McGREGOR, L. G.	CE1	@
McKEE, C. R.	SWF2	@@
MONOHAN, M. L.	CEW2	
PLICHTA, R. T.	HM1	
POLLOCK, H. W.	CEC	@
REED, C. E.	CEC	
SCHNABEL, J. G.	CE1	

5. CREW V Personnel, DEEP FREEZE 66

WINTER-OVER

BOENNIGHAUSEN, T. L.	LT, CEC, USN Officer in Charge	
KING, J. W.	ENS, CEC, USN Plant Superintendent	
ADAMS, M. E.	SP5	
ANDERSON, R. F.	HM2	
BELL, M. H.	EOC	
BROWN, S.	HMC	
FUNKHOUSER, E. F.	SP5	
FLEMING, J. P.	CECS	*
GANNON, J. W.	EOC	
HAIR, R. B., Jr.	SK2	
HOFFMANN, E. H.	CE1	
HOOVER, R. A.	CE1	
MOFFAT, R. J.	CEC	
O'CONNOR, G. V., Jr.	CEC	
PERROTTI, D. J.	SP6	
PERSELL, H. L.	HM1	
PLICHTA, R. T.	HM1	
RAMSEY, M. E.	CMC	
RAY, J. E.	CEC	
REED, C. E.	CEC	
ROBERTSON, J. E.	CECS	
ROBSON, R. J.	CEW2	
WHITEMAN, R. J.	UTCS	

SUMMER SUPPORT

ASHENDEN, M. C., Jr.	CEC	
BENEFIEL, A. D.	SK1	
BLAKE, J. A., Jr.	CEC	
GABERLEIN, W. E.	CEC	@
GARLAND, R. A.	CE1	
GROOVER, E. D.	EO1	
HAMBY, E. C., Jr.	SWCS	
HATFIELD, L. D.	YN2	
McGREGOR, L. G.	CE1	@@
ORR, J. J.	HM1	
PAGE, L. D.	SFC	
RICCIO, T. J.	CET2	
SCHLOREDT, J. L.	CE1	
STANFIELD, W. D., Jr.	CEC	

6. CREW VI Personnel, DEEP FREEZE 67

WINTER-OVER

DONOVAN, L. K.	LCDR, CEC, USN	Officer in Charge	
MILLER, H. W.	LTJG, CEC, USN	Plant Superintendent	*
ALLARA, V. C.	SP6		
BARTLEY, J. D.	CECS		
BERKOWITZ, R. J.	UT1		
BLACK, A. K.	CEC	*	*
BLESS, J. W.	HM2		
BONTEMPO, J. E.	SP5		
CARSON, G. A.	CEC	*	*
COBB, R. O.	CE1		
CROWSON, F. R.	SFC		
DOOLEY, J. E.	HM1		
ERICKSON, D. L.	HM1		
HEINRICHS, R. J.	EQCM		
HOLMES, W. A.	CMCS		
JAKULEWICZ, C. S.	CM1		
JOHNSON, J. E.	CEC		
KRUPA, J. E.	SFC		
LINN, P. E.	WO1, CEC, USN	*	*
MONOHAN, M. L.	CE1		
NELSON, D. E.	SKC		
ORR, J. J.	HMC		
POLLOCK, H. W.	CECS	*	*
RICCIO, T. J.	CET2		
TWITTY, D. L.	HMCS		

SUMMER SUPPORT

ASHENDEN, M. C., Jr.	CEC	@	@
BENEFIEL, A. D.	SKC	@	@
BROBERG, J. G.	HMCS		
CAVANAUGH, R. F.	CM1		
ESLICK, R. W.	CE1		
EVANS, T. R.	UTCS		
FINE, M. L.	UTB3		
FORT, R. E.	WO1, CEC, USN		
JENNINGS, M. L.	YN2		
McGREGOR, L. G.	CEC	@@@	@@@
MILLER, G. J.	CWO2, CEC, USN		
SCHLOREDT, J. L.	CEC	@	@
WOOD, R. A.	CE1		
WYLIE, J. D.	UT1		

7. CREW VII Personnel, DEEP FREEZE 68

WINTER-OVER

KOHLER, A. D., Jr.	LCDR, CEC, USN Officer in Charge	
SWINFORD, H. D.	LTJG, CEC, USN Plant Superintendent	*
ALEXANDER, R. F.	CEC	
BROBERG, J. G.	HMCS	
CLARK, W. P.	CEC	*
DAVISON, T. R.	CE1	
DEWEES, B. V.	CEC	*
ESLICK, R. W.	CE1	
FORNEL, P. E., Jr.	SP6	
GABERLEIN, W. E.	CEC	**
GLOSS, D. R.	SP6	
GROOVER, E. D.	EOC	
HAUGH, J. R.	HMC	
MAGEE, H. J.	HM1	
MARKES, J. A.	CEC	
McDUFFEE, J. W.	HM1	
McNEISH, R. I.	SK1	
METCALF, C. B.	CE1	
RANDALL, J. A.	CMCS	*
SCHILE, G. D.	HM1	
SCHNABEL, J. G.	CEC	
SMITH, H. G.	EOCS	*
WOOD, R. A.	CE1	
YELLE, L. G.	SP6	

SUMMER SUPPORT

ASHENDEN, M. C., Jr.	CEC	@@
BROOKS, W. M.	CE1	
GARDNER, K. A.	UT1	
HILSABECK, W. G.	CWO2, CEC, USN	
HOUSEL, M. D.	CMC	
MARTIN, D. K.	SSGT	
McCANN, J. M.	UTC	@@@
McGREGOR, L. G.	CEC	@@@@
MERCIEZ, W. R.	EO1	
SINGLETERRY, D. G.	CETCN	
SMITH, D. L.	UT1	
SWARTZ, R. D.	SK1	
WRIGLEY, R. K.	PN3	
ZIMMERMAN, J. L.	CM1	

8. CREW VIII Personnel, DEEP FREEZE 69

WINTER-OVER

KURTZ, J. P.	LCDR, CEC, USN	Officer in Charge
MILLER, G. J.	CWO2, CEC, USN	Plant Superintendent
ASHER, B. F.	CECS	
BARCUS, C. K.	SP6	
BUCHANAN, R. J.	SP5	
CAVANAUGH, R. F.	CM1	
CHEEK, L. V.	CE1	
DORCHUCK, R. E.	CMCS	*
ELDRED, D. T.	EOC	*
GARLAND, R. A.	CECS	*
HALES, H. L.	SFC	
IRVINE, A. L.	CEC	
LAW, G. L.	WO1, CEC, USN	*
MILLER, F. P.	HMC	*
PACE, H. C.	UT1	
PUTMAN, D. W.	CEC	
SCHLOREDT, J. L.	CEC	*
SWARTZ, K.	SK1	
SIMMONS, J. A.	SW1	
SMITH, R. M.	HMC	
TATE, A. C.	HMC	
VIOLETTE, R. E.	SFC	*
WARD, C. A.	CEC	
WERNER, M. R.	UTC	
YOUNG, D. L.	HMC	

SUMMER SUPPORT

BUNCH, D. C.	CE3	
DUHN, E. D.	SFC	
FLEMING, J. P.	CEC	
HARRIS, R. W.	PN3	
HILSABECK, W. G.	CWO2, CEC, USN	@
HOUSEL, M. D.	UTC	
MELEE, T. R.	CECS	
REUTTER, R. E.	CECS	
ROETTGER, G. G.	HM1	

9. CREW IX Personnel, DEEP FREEZE 70

WINTER-OVER

REYNOLDS, R. R.	LCDR, CEC, USN Officer in Charge	
FORT, R. E.	CWO2, CEC, USN Plant Superintendent	*
BINGHAM, R. E.	HM1	*
BRANDON, J. L.	HM1	
BROOKS, W. M.	CEC	
CAISON, L. H.	SFC	
COX, R.	CECS	
GARDNER, K. A.	UTC	*
GUESS, T.	SK1	
MALCOM, D. E.	SFC	
MELEE, T. R.	CECS	
MERCIEZ, W. R.	EOC	
PRICE, G. L.	CE2	
REED, C. E.	CECS	*
ROBERTSON, J. E.	CECS	*
ROBSON, R. J.	CEC	*
ROETTGER, G. G.	HM1	
ROGERS, B. W.	HMC	
SINGLETERRY, D. G.	CE2	
SMITH, D. L.	UTC	
STRICKLIN, H. L.	SFC	
WHITEMAN, R. J.	UTCS	*
WILLIAMS, J. L.	CM1	
WINKLEY, D. A.	UT1	
ZIMMERMAN, J. L.	CM1	

SUMMER SUPPORT

BARRETT, B. F.	SW3	
DUSEK, L. G.	YN2	
FINLAW, D. F.	CE2	
GROOVER, J. A.	EO1	
HOUSEL, M. D.	CMC	@
KUKI, C. H.	SP6	
LOEBS, C. A.	UT2	
McCORMICK, T. D.	SFC	
SELMONT, R. M.	SFC	

10. CREW X Personnel, DEEP FREEZE 71

WINTER-OVER

ARCUNI, A. A.	LCDR, CEC, USN Officer in Charge	
LINN, P. E.	CWO2, CEC, USN Plant Superintendent	**
ANDERSON, R. F.	HM1	*
ANDREWS, D. L.	HMC	
ASHENDEN, M. C.	CECS	
BOST, R. R., Jr.	EO2	
CLOPTON, R. L.	SK1	
CLOVER, W. B., Jr.	UT2	
COBB, R. O.	CEC	*
DOZIER, R. E., Jr.	SW2	
DULANEY, J. D.	HMC	
GOODFIELD, M. C.	SFC	
GROOVER, J. A.	EO1	
HARVEY, P. A.	TSGT	
HINOJOSA, R. A.	SFC	*
JAKULEWICZ, C. S.	CMC	*
KLETT, T. F.	TSGT	
MILLER, F. P.	HMC	*
NEWMAN, E. W.	CE1	
OBEY, R. H.	CEC	
O'CONNOR, A. C.	CE2	
POLLOCK, H. W.	UTCM	**
SCHWEIBINZ, E. R.	CE1	
SISK, W. A., Jr.	CE1	
STRAWBRIDGE, L. R.	EO2	

SUMMER SUPPORT

BRANDT, B. K.	UTC	
BURT, C. R.	CMC	
BUSHALL, W.	CE2	
CARSON, G. A.	CEC	
FLETCHER, D. L.	CE2	
GROOVER, E. D.	EOC	@
KERSHNER, M. J.	CE3	
LOEBS, C. A.	UT2	
NEFF, D. B.	PN3	
REEVES, B. G.	UT3	
SYKES, T. P.	UT1	
WOOD, R. A.	CE1	@

11. CREW XI Personnel, DEEP FREEZE 72

WINTER-OVER

BOHNING, L. R.	LT, CEC, USN	Officer in Charge	
DORCHUCK, R. E.	EQCM	Plant Superintendent	**
BARRETT, B. F.	SW2		
BLAKELY, C. R.	CE2		
BRANDT, B. K.	UTC		
BUTLER, R. N.	SK1		
CODY, D. J.	HM1		
CONWAY, R. H.	UT1		
ERICKSON, D. L.	HMC		*
FINLAW, D. F.	CE2		
GROOVER, E. D.	EOCS		*
JONES, E. T., Jr.	HMC		
JONES, G. M.	HM1		
MACWATTERS, R. H.	CE2		
MAINES, R. E.	MSGT		
McGREGOR, L. G.	CEC		
PARCEL, J. E.	UT2		
REEVES, B. G.	UT2		
REUTTER, R. E.	CECS		
SAPHORE, V. C.	SFC		
SYKES, T. P.	UT1		
TALBERT, R. N.	SW1		
WAHLMAN, K. M.	SP6		
WESTERFIELD W. M.	CM2		
WOOLDRIDGE, J. D.	CE1		

SUMMER SUPPORT

EAST, L. G.	SW1	
FLETCHER, D. L.	CE2	@
GALLAGHER, W. C.	CM2	
GARLAND, R. A.	CECS	@
HARDING, J. N.	EO1	
HORNA, D. A.	SP6	
LOEBS, C. A.	UT2	@
McCARTY, D. A.	SFC	
MONK, L. B.	SFC	
NEFF, D. B.	PN2	@
SCHNABEL, John G.	CECS	@
SHADDIX, E. K.	CE1	
TAYLOR, R.	SFC	
WENTZ E. D.	SP6	
YUNA, W. R.	SFC	

12. CREW XII Personnel, DEEP FREEZE 73

WINTER-OVER

SCHLOREDT, J. L.	CECS	Officer in Charge (Acting)	**
BAKER, B.	CE2		
BUSHALL, W.	CE2		
CAVANAUGH, R. F.	CM1		*
DELONG, D. L.	EOC		
EAST, L.	SW1		
MARQUEZ, J. J.	CE1		
MERCER, H. M.	HM1		
MILLER, F. P.	HMC		**
ORR, J. J.	HMC		*
STRAWBRIDGE, L. R.	EO1		*
WELLS, D. H.	SP5		

PERSONNEL SCHEDULED TO WINTER-OVER WHO RETURNED TO THE UNITED STATES AT THE END OF THE AUSTRAL SUMMER DUE TO PLANT CONDITIONS.

CRANE, T. C.	LCDR, CEC, USN Officer in Charge	
DUBAY, R. M.	CWO3, CEC, USN Plant Superintendent	
ASHER, B. F.	CECS	
CARR, R. A.	SP6	
ELDRED, D. T.	EOCS	@
FLYNN, D. F.	CMC	
GALLAGHER, W. C.	CM2	@
GOUGH, D. T.	SP6	
HARDING, J. F.	EO1	@
JOZSA, J. J.	HM2	
ROBSON, R. J.	CEC	
RUMBAUGH, R. M.	SK1	
TURNIDGE, R. D.	SP5	

SUMMER SUPPORT

ALEXANDER, R. F.	CECS	
DUHN, E. D.	SFC	@
GRAFF, T. L.	SP5	
HALE, R. C.	CM1	
McCARTER, I. D.	EO2	
OWINGS, C. M.	SP6	
RODGERS, D. B.	UT3	
SMITH, D. L.	UTC	@
SNYDER, T. P.	SP6	
WORKMAN, M. W.	PN3	
YEAZLE, C. E.	CE1	
ZIMMERMAN, J. L.	CMC	@

13. Crew XIII Personnel DEEP FREEZE 74

COX, R.	UTCM	Officer in Charge (Acting)	*
CONLEY, D. B.	CE2		
DUPALO, R. J.	EO1		
McCARTER, I. D.	EO2		@
PFARR, G. K.	CM2		
SMITH, R. M.	HMC		
YEAZLE, C. E.	CE1		@
ZIMMERMAN, J. L.	CMC		@

14. Decommissioning Crew I 1973-74

CRANE, T. C.	LCDR, CEC, USN	Officer in Charge	@
RENZETTI, J. L.	LCDR, CEC, USN		
ASHER, B. F.	CECS		@
BROWN, C. L.	CE1		
CHYZ, D. H.	CE2		
CRAWFORD, H. W.	SK1		
ELDRED, D. T.	EOCS		@@
ELLIS, D. F.	CE2		
GALLAGHER, W. C.	CM2		@@
GARDNER, K. A.	UTC		
GREEN, W. D.	CM1		
HARDING, J. N.	EOC		@@
JAKULEWICZ, C. S.	CMC		
JODWAY, L. W.	CE2		
JONES, E. N.	EO2		
JOZSA, J. J.	HM2		@
LASSO, R. E.	CE1		
MACY, G. J.	SW1		
PRICE, G. L.	CE1		
ROBERTS, R.	HM1		
ROBSON, R. J.	CEC		@
RODGERS, D. B.	UT2		@
ROETTGER, G. G.	HM1		@
RUSSELL, J. W.	UT1		
SIMS, J. R.	HM2		
TATE, A. C.	HMCS		
TURNIDGE, R. D.	SP5		
WYLIE, J. D.	CW03, CEC, USN		@

15. Decommissioning Crew II 1974-75

FILSON, John V.	LT, CEC, USN	Officer in Charge	
BROWN, C. L.	CE1		@
BUTLER, R. N.	SKC		
DIETRICH, J. G.	HMC		
DUPALO, R. J.	UT1		

15. Decommissioning Crew II 1974-75 (Continued)

ELLIS, D. F.	CE1	@
GARDNER, K. A.	UTCS	@
GREEN W. D.	CMC	@
HALE, R. C.	CM1	
JODWAY, L. W.	CE1	@
JOHNSON, J. S.	BU2	
JONES, E. T., Jr.	HMCS	
LYONS, W. T.	CM1	
MACY, G. J.	SW1	@
PILAR, M. B.	EA2	
ROBERTS, J. R.	CM2	
ROETTGER, G. G.	HMC	@@
ROGERS, B. C.	HMC	
ROGERS, D. B.	UT2	@@
RUSSELL, J. W.	UT1	@
SIMS, J. R.	HM1	@
WYLIE, J. D.	CWO3, CEC, USN	@@

16. Decommissioning Crew III 1975-76

FILSON, J. V.	LT, CEC, USN Officer in Charge	@
CARL, R. G.	HM1	
DIETRICH, J. G.	HMC	@
DOIG, S. W.	CM1	
DUPALO, R. J.	UT1	@
GARRETT, J. P.	CE1	
JOHNSON, J. S.	BU1	@
McDANIEL, J. R.	HMCS	
MORRIS, G. A.	EO2	
MORRIS, W. J.	CIV	
PEREZ, J. F.	CE1	
PILAR, M. B.	EA2	@
POSTON, R. W.	CMC	
ROBERTS, M. G.	CM2	
ROETTGER, G. G.	HMC	@@@
ROGERS, B. W.	HMC	@
TREVINO, LA. Q.	CM2	
WISE, R.	HM1	

17. Decommissioning Crew IV 1976-77

McDANIEL, J. R.	HMCS (Acting OIC Oct-Dec 76)	@
JOHANNESMEYER, C. A.	LCDR, CEC, USN Officer in Charge (Jan-Feb 77)	
BEECHER, D. L.	HM2	
CARL, R. G.	HM1 (Oct 76)(Jan-Feb 77)	@
FARLEY, G. W.	PNSN	
JONES, G. M.	HMC (Jan-Feb 77)	
MORRIS, G. A.	EO1	@
ROBERTS, J. R.	CM1	@

17. Decommissioning Crew IV 1976-77 (Continued)

ROBERTS, M. G.	CM1 (Jan-Feb 77)	@
STANDIFER, M. S.	CE2 (Jan-Feb 77)	

18. Decommissioning Crew V 1977-78

JOHANNESMEYER, C. A.	LCDR, CEC, USN (OIC Oct-Nov 77)	@
JONES, G. M.	HMC (Acting OIC Nov-Dec 77)	@
FOSTER, M. E.	LT, CEC, USN (OIC Jan-Feb 78)	
++ BRISTER, D. D.	EO3 (Jan-Feb 78)	
BEECHER, D. L.	HM2	@
CAVANAUGH, R. F.	CMC (Oct-NOV 77)	
DERLEY, D. E.	CMC (Jan-Feb 78)	
+ FRICK, S. D.	EOCN (Oct-Nov 77)	
++ IMHOFF, J. M.	EO3 (Jan-Feb 78)	
KLUENDER, R. L.	CE1 (Jan-Feb 78)	
++ SHILTS, J. R.	EO3 (JAN-Feb 78)	
TALBERT, R. N.	SW1 (Oct-Nov 78)	
+ TORO, G. W.	EO3 (Oct-Nov 78)	
++ ZORN, K. R.	EO3 (Jan-Feb 78)	

+ Volunteer from NMCB-5
++ Volunteer from NMCB-40

19. Decommissioning Crew VI 1978-79

FOSTER, M. E.	LT, CEC, USN (OIC Oct-Dec 78)	@
MORRISON, W. A.	LTJG, CEC, USN (OIC Feb 79)	
+ BALZ, J. E.	SW3 (Oct-Dec 78)	
+ BUTLER, L. A.	SW3 (Oct-Dec 78)	
CARL, R. G.	HMC (Jan-Feb 79)	@@
+ DUTILE, G. A.	CM3 (Oct-Dec 78)	
FRANK, R. J.	HM1 (Oct-Dec 78)	
+ GARY, T. L.	SWCN (OCT-Dec 78)	
+ JANES, F. B.	BUCN (Oct-Dec 78)	
JONES, G. M.	HMC (Oct-Nov 78)	@@
LARSON, L. C.	HM1 (Oct-Dec 78)	
+ MAGNUSON, B. R.	BU3 (Oct-Dec 78)	
+ ROSEN, A. J.	EO2 (Oct-Dec 78)	
+ WEIMAN, R. D.	EO3 (Oct-Dec 78)	

+ Volunteer from MCB-5

APPENDIX E

PM-3A NUCLEAR POWER PLANT
TRITIUM CONTROL, MONITORING AND RELEASE
(SPECIAL OPERATING REPORT)

SPECIAL OPERATING REPORT
FOR
PM-3A NUCLEAR POWER PLANT
MCMURDO STATION ANTARCTICA

PM-3A NUCLEAR POWER PLANT TRITIUM CONTROL, MONITORING AND RELEASE

Prepared by:

U. S. NAVAL NUCLEAR POWER UNIT
P. O. BOX 96
FORT BELVOIR, VIRGINIA 22060

8 SEPTEMBER 1967

PM-3A NUCLEAR POWER PLANT TRITIUM CONTROL, MONITORING AND RELEASE

I. INTRODUCTION

The phenomena of tritium generation in some nuclear power plants has been recognized for many years. Studies performed at heavy water (deuterium) moderated and boiling water reactors established tritium generation rates for these type plants as early as 1956.(1) In contrast, very little tritium work was done on light water moderated pressurized water reactors. Plant designs for this type of reactor with the exception of the PM plants invariably included an adequate supply of uncontaminated water for the dilution of plant effluents contaminated with radioisotopes.(2) Tritium concentrations in these effluents are normally discharged in the same manner without exceeding the Maximum Permissible Concentrations in Water (MPCw) specified in controlling regulations.(3)

The detection and measurement of the tritium concentrations found in the effluents of nuclear reactors is difficult. The higher energy beta particles from the decay of fission and corrosion products mask the extremely low energy (.018 MEV) beta decay of tritium.(4) With the advent of more sophisticated equipment in the early 1960's, tritium counting became feasible.(5) Some unknown problems were discovered.

One of the first problems to be recognized was the presence of tritium activities, well above the occupational exposure MPC, in the plant systems at the PM-3A Nuclear Power Plant, McMurdo Station, Antarctica. This report summarizes the history of the tritium problem at the PM-3A, the action taken to resolve that problem and the progress towards a final solution to the control, monitoring, and release of tritium at the PM-3A.

II. PM TYPE PLANT TRITIUM PROBLEMS

A. In the late 1950's a compact, air transportable nuclear power plant design for military use was completed under the joint auspices of the United States Atomic Energy Commission and the United States Army Nuclear Power Program. The prototype plant (PM-1) was installed at the U. S. Air Force, 731st Radar Squadron (ADC), Sundance, Wyoming in 1961-62, to supply site heat and electricity. The first field plant of this type (PM-2A) was installed on the Greenland icecap in snow tunnels to power the Army's Camp Century. It has since been dismantled due to curtailment of the Camp Century mission. The second field plant (PM-3A) was installed at McMurdo Station, Antarctica to supply the base electrical load.(6) Both PM-1 and PM-3A design deficiencies delayed reliable power production until 1965.

B. The PM-1 and PM-3A were designed to operate with a minimum requirement for system make-up-water as a result of treatment and reuse of decontaminated plant water.(8) Routine analysis of water samples returned to the United States from the PM-3A in late 1963 revealed that tritium activities in the primary coolant and shield water were well above the MPC's for occupational exposure.(9) Additional samples were obtained from both PM type plants and analyses of the samples confirmed the presence of tritium in both plant systems.(10) (11)

C. The Atomic Energy Commission recognized the existence of a tritium problem and at the request of the Navy, the New York Operations Office of the AEC acted to procure modern tritium detection equipment for use at the PM-3A(12) (13) (14) and funded an investigation of tritium generation and release in the PM type nuclear power plants.(15) The contract for this investigation was awarded to the Battelle Memorial Institute, Columbus, Ohio with the PM-3A designated as the pilot plant for the program.

D. A review of the tritium levels in the primary coolant of other industrial and Army Nuclear Power Program pressurized water reactors disclosed that tritium generation was occurring in all reactors of this type, and that the tritium generation rate was a function of uranium fissions.(16) Release of tritium was not presenting a problem for these other reactors, since they all were designed with sufficient supplies of untritiated water for dilution of other contaminated effluents to below MPC_w.

E. The Battelle Memorial Institute completed the investigation on tritium generation and release in PM type Nuclear Power Plants in 1966.(17) Their study revealed that the major source of tritium generation was ternary fission in the fuel and subsequent diffusion through the cladding into the primary coolant. The tritium then migrated into all plant systems by leakage to the shield water or by the reuse of decontaminated plant water as makeup. The evaporation and demineralization processes used to decontaminate water in the PM type plants do not remove the tritium because the tritium atom, is an isotope of hydrogen in water. Therefore, continual reuse of this water concentrates the tritium in certain plant systems. Potential radiological health hazards were calculated for various methods of handling plant wastes and Battelle Memorial Institute made the following recommendations as the most practical and economical solutions for each plant.

PM-1 - Periodically remove tritiated water from the plant site by AEC licensed contractor at a cost of approximately $1.40 per gallon.

PM-3A - Discharge the tritiated water to a restricted area where it can freeze and sublime to the atmosphere at a concentration safe for release to unrestricted areas.

III. TRITIUM CONTROL AT THE PM-3A

A. Operation of a Nuclear Power Plant in Antarctica requires compliance with the provisions of the Antarctica Treaty which governs the purposes and principles by which Antarctic research and development is carried out by the signatory nations.(18) This Treaty specified that the Antarctic will not be used as a dumping ground for radioactive waste. The requirements for operation of a Nuclear Power Plant in the Antarctic were amplified by the National Science Foundation (19) to preclude the release of materials that would increase the background radioactivity in the lithosphere, hydrosphere or biosphere by more than 10 percent. During the first two years of reactor operations, plant effluent was discharged without monitoring for tritium concentrations. At this stage of pressurized water reactor development, tritium generation had not been recognized as a signficant problem and no such precautions were included in the radiochemical monitoring program. All plant effluents were monitored and discharged by the AEC contractor in accordance with activity level restrictions incorporated in the AEC approved PM-3A Health Physics Manual.(20) Upon assuming operational control of the PM-3A for the Navy in 1964, the Naval Facilities Engineering Command, in the absence of a definition of "radioactive wastes" adopted the limitations specified in Title 10, Code of Federal Regulations, Part 20 for release to an unrestricted area.(21)

B. After confirmation of high tritium concentrations in the plant systems in late 1964, several changes were made in the PM-3A operating procedures and a thorough investigation of the tritium levels present in each plant system was initiated. At the same time, the U. S. Naval Nuclear Power Unit, Fort Belvoir, Virginia, initiated an independent study of the PM-3A tritium problem in cooperation with the Engineering Department of the Army Nuclear Power Field Office.(22) Based upon the findings of this study (23) and PM-3A plant experience, an interim program of tritiated water control was formulated by the Naval Nuclear Power Unit (24) and approved by the Naval Facilities Engineering Command.(25) The principle operations of this interim program were:

1. The PM-3A secondary system was drained and refilled with untritiated water.

2. Makeup to the secondary system using treated effluent from the Radioactive Waste Disposal System was discontinued.

3. All pertinent plant systems were routinely monitored for tritium activity.

4. The glacier area was declared a restricted area and approaches to this area were posted with appropriate signs.

5. The total volume of water and the total microcuries of tritium that the plant released were monitored on a weekly basis to insure the concentration of tritium in the glacier did not exceed the MPC_w for a restricted area.

C. These changes in plant operation were based on the best available information on plant water usage. During the latter part of 1965 and 1966 the PM-3A was at power over 70% of the time allowing the tritium levels of various plant systems and the plant effluent rate to become stablized. It became apparent that some changes might be required to the control program caused by the volumetric increases in plant liquid release and longer sustained power runs at increased power levels.(26)

D. Prior to the 1966-1967 austral summer, the glacier formed by the liquid releases from the PM-3A had been observed to disappear during the austral summers without observable runoff of the melted ice. It was concluded that the glacier was being reduced by a combination of sublimation and surface evaporation. Calculations for this mode of release demonstrated that the tritium concentration released by this mechanism would be less than the MPC for airborne tritium (MPCa) in an unrestricted area at a glacier tritium concentration equal to the restricted area MPCw.(27) PM-3A records verified that the tritium concentration in the water dumped to the glacier had increased at sustained high power level operations and then leveled out at a maximum activity less than the restricted area MPCw when averaged on an annual basis. Based on the above data and observations, plus the results of the Battele Memorial Institute investigation, continued release of plant water to the glacier with annual averaging of the tritium content was authorized by the Naval Facilities Engineering Command provided a downhill sampling program was initiated to support the BMI study.(28)

IV. TRITIUM RUNOFF

A. Early in the 1966-67 summer season an intensive tritium monitoring program of the glacier and its possible runoff route was initiated. The primary purpose of this program was to prove or disprove the total tritium glacier sublimation theory. The results of this program, (29) determined that the PM-3A glacier sublimates at temperatures near and below 32°F, but melts and runs off down the natural drainage through and into the sea when melting occurs during extended warm periods of the summer when ambient temperature gets above 32°F. This runoff is partially channeled underground, above the permafrost among the loose volcanic rocks on the side of Observation Hill, it is not visible except during prolonged periods above freezing temperatures. Gross beta and gamma spectral analysis of samples taken below the glacier certified that fission and corrosion product activities were below unrestricted area isotopic MPCw's during periods of maximum runoff. This tritiated water runoff is eventually infinitely diluted in the Ross Sea.

B. The following calculations are presented in support of current operations.

1. The tritium concentration of water released to the glacier is less than or equal to 0.04 uci/cc based on a survey of 1966 plant statistics. Numerous samples taken from the glacier have verified this upper limit. The specific volume of water in changing from a solid or liquid to a saturated vapor is increased by a factor of 2 x 10^5. Thus the maximum concentration of tritium in water vapor just above the glacier surface or above any liquid runoff is 2 x 10^7 uci/cc which is the MPCa for tritium in an unrestricted area. Air movement across ice and water surfaces greatly dilutes this concentration at the head level of a standing person. Thus no airborne health hazard due to tritium exists for continuous personnel occupancy of the glacier region or its runoff path.

2. The MPCw for tritium in unrestricted areas is 0.003 uci/cc. This limit may be relaxed according to 10 CFR 20.106 when a licensee demonstrates that: (a) a reasonable effort has been made to minimize the radioactivity contained in effluents to unrestricted areas: and (b) that it is not likely that radioactive material discharged in the effluent would result in the exposure of an individual to concentrations exceeding the MPC of 0.003 uci/cc. The basis for MPC's in water for unrestricted areas is a continuing daily water intake of 1100 ml during the 8-hour work day plus 1100 ml off the job over a 50 year period.(30) The glacier runoff path is through an

unoccupied region on the opposite side of the PM-3A complex from McMurdo Station and is rarely, if ever, traversed by Navy or scientific personnel. The maximum occupancy of the region has been by PM-3A health physics personnel taking water and ice samples and is conservatively estimated to be less than 50 hours in one year for any one individual. It can be positively stated that there has been no liquid intake of gully water by PM-3A health physics personnel. The possibility that any other personnel at McMurdo Station have or will drink any water directly from this gully is extremely unlikely due to its location, the fact that the majority of the flow is among loose rocks, and the limitations placed on personnel movement outside the confines of the station. Averaged over one year, an individual would have to consume 30 liters of water directly from the point of highest tritium concentration in the gully to approach the maximum permissible intake. The probability of this occurring can be considered so low as to be not credible. Upon reaching the base of Observation Hill, the glacial runoff enters McMurdo Sound where it is infinitely diluted by the Ross Sea water.

3. The only physical problem actually created by the above background tritium concentrations in the gully would arise if a scientific sample were taken from the area and the increased tritium activity levels were not anticipated by the scientist. This would mean that this small region should not be used as a sampling area for background determinations.

V. CONCLUSIONS

Operation of the PM-3A has added to a small, unoccupied gully, water containing tritium concentrations slightly above MPCw for unrestricted areas. This condition has probably existed for several years. No corrosion or fission products have been detected in the gully above MPC for unrestricted areas. There is no radiological health problem now or is one anticipated in the future. Strict control over water released from the PM-3A is maintained to insure tritium concentrations are within the bounds discussed in this report and future year's should be very similar to 1966 operations. The runoff path from the glacier is contained between the PM-3A complex and its point of infinite dilution in the Ross Sea. No influence on the ecology or environment of the Antarctic continent or scientific endeavors is apparent or anticipated. No violation of the Antarctic Treaty has occurred in the past or will occur during continued operations when interpreted within the established regulations of 10 CFR 20.

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(5) Bray, G. A., "A Simple Efficient Liquid Scintillator for Counting Aqueous Solutions in a Liquid Scintillation Counter", Anal Biochem, 1960

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(7) "Nucleonics" Volume 20, NO4 April 1962

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(12) Bureau of Yards and Docks letter 41.300, ser H-101, to AEC New York Operations Office dated 14 April 1964

(13) Martin Nuclear Division letter PM-3A 1035 to AEC New York Operations Office dated 25 August 1964

(14) Message to Martin Nuclear Division, Baltimore, Md. from Atomic Energy Commission, New York Operations Office, R151858Z - Oct 1964

(15) Bureau of Yards and Docks letter 41.300, ser 136 to AEC New York Operations Office of 13 Sept 1964

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(17) "Investigation of Tritium Generation and Release in PM Type Nuclear Power Plants", Battelle Memorial Institute 31 Oct 1966

(18) Message to the United States Senate, 86th Congress, 2nd Session from the President of the United States dated 15 Feb 1960, forwarding the Antarctic Treaty

(19) National Science Foundation letter of 29 July 1960

(20) Technical Manual for PM-3A Navy Nuclear Power Plants, Volume I of I, "Health Physics and Water Chemistry Manual", dated 6 Dec 1961

(21) NAVFACINST 11310.22 dated 11 May 1964

(22) U. S. Naval Nuclear Power Unit letter, ser 390 to NPFO Engineering Department with enclosures dated 22 May 1964

(23) "Problem 'C', PM-3A Chemistry-Tritium", USAERG Contract DA-44-009-AMC-547

(24) U. S. Naval Nuclear Power Unit letter, ser 350, to Chief, Bureau of Yards and Docks, Code 41,300, dated 29 April 1965

(25) Bureau of Yards and Docks - Code 41.300 letter, ser 719, to OIC Naval Nuclear Power Unit, dated 6 April 1966

(26) U. S. Naval Nuclear Power Unit Detachment McMurdo message 020310Z to U. S. Naval Nuclear Power Unit of 2 May 1966

(27) U. S. Naval Nuclear Power Unit letter, ser 414 to Naval Facilities Engineering Command dated 7 June 1966

(28) Naval Facilities Engineering Command Code 42, letter ser 934, to U. S. Naval Nuclear Power Unit dated 16 August 1966

(29) U. S. Naval Nuclear Power Unit Detachment McMurdo letter, ser 94, to U. S. Naval Nuclear Power Unit, dated 28 Dec 1966

(30) National Bureau of Standards Handbook 69, Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure.

APPENDIX F

OPERATING HISTORY

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OPERATING HISTORY

12 Mar 64	Plant was placed in custody of the U.S. Navy in a shutdown maintenance status pending the resolution of safety problems.
27 May 64	Navy operation authorized for test and evaluation.
01 Jun 64	Precritical tests completed and reactor brought critical for core physics tests.
06 Jun 64	Transient noise problems encountered in scram circuitry causing spurious plant scrams, PM-3A Operating Report #1; Malfunctions 64-27, 64-28, 64-29 and 64-30.
07 Jun 64	Completed core physics tests and proceeded to power operations.
10-18 Jun 64	Plant initially picked up McMurdo Station heater load; however, plant operations were eventually limited to carrying plant load. Transients in reactor outlet temperature scram circuitry prevented assumption of McMurdo Station load. PM-3A Operating Report Number 1; Malfunctions 64-32, 64-33, 64-34, 64-35, 64-36, 64-37, 64-38 and 64-39.
18 Jun 64	Transient problems temporarily relieved by installation of capacitors and switches on output of high reactor outlet temperature scram bistables.
18-27 Jun 64	Plant carried McMurdo Station load for 205 hours of 240 hours total. Three unscheduled scrams occurred during this time frame. In order of occurrence they were caused by (a) Transients due to switching ops and testing ops at control console (Malfunction Report #63-29), (b) Condenser freezing due to leaking steam valve (Malfunction Report #64-42), (c) Primary coolant pump low delta pressure when feedwater pump was turned on with the plant on Cat Diesel (Malfunction Report #64-43).
28 Jun - 01 Jul 64	Plant carried McMurdo Station load.
01 Jul 64	Reactor scrammed during bistable drift tests. Plant returned to power nine hours after scram. PM-3A Operating Report Number 2; Malfunction 64-44.
01-11 Jul 64	Plant carried McMurdo Station load.
11 Jul 64	Reactor scrammed during scram logic tests. Plant returned to power nine hours after scram. PM-3A Operating Report Number 2; Malfunction 64-45.

11-15 Jul 64	Plant carried McMurdo Station load.
15 Jul 64	Reactor scrammed during scram logic tests and was returned to a reactor critical status in one hour. A second reactor scram occurred due to transient low primary coolant pump power while placing condenser fan in operation. Plant returned to power within eight hours of initial scram. PM-3A Operating Report Number 2; Malfunctions 64-46 and 64-47.
15-20 Jul 64	Plant carried McMurdo Station load.
20-21 Jul 64	Scheduled plant shutdown for maintenance and modification to the condensate system, nuclear instrumentation circuits, containment cooler fans, pressurizer heaters and many minor items.
22-29 Jul 64	Plant carried McMurdo Station load.
29 Jul - 04 Aug 64	Plant shutdown by manual scram due to pressurizer heater failure. PM-3A Operating Report Number 2, Malfunction 64-48.
04-08 Aug 64	Plant carried McMurdo Station load.
08 Aug 64	Reactor scrammed due to faulty containment pressure switch. Plant returned to power 12 hours after scram. PM-3A Operating Report Number 3; Malfunction 64-49.
09-17 Aug 64	Plant carried McMurdo Station load.
18 Aug 64	A transient induced by switching channel 3 into test position caused the reactor to scram while preparing for a planned shutdown to change resins in the primary demineralizer. PM-3A Operating Report Number 3; Malfunction 64-51.
19-20 Aug 64	Plant shutdown for primary demineralizer resin change since chemistry data indicated a continued upward trend in the iodine activity level of the primary coolant. This anomaly was caused by a small fuel cladding defect resulting in the release of fission products to the coolant. BUDOCKS granted permission to temporarily increase the operating limit from 0.1 to 1 uCi/cc iodine. PM-3A Operating Report Number 3; Malfunction 64-50.
20-22 Aug 64	Plant carried McMurdo Station load.
22 Aug 64	Reactor scrammed when containment pressure switch was disturbed. A second scram occurred during startup in the intermediate range when the condenser fan was energized in the reverse direction and a low electrical power frequency resulted. Plant returned to power in 13 hours, 20 minutes after initial

	scram. PM-3A Operating Report Number 3; Malfunctions 64-52 and 64-53.
23 Aug 64	Reactor scrammed due to transients in instrumentation. Probable cause was broken lead in PC pump power converter. Plant was at power for 6.5 hours preceeding the scram and returned to power 8.5 hours after the scram occurred. PM-3A Operating Report Number 3; Malfunction 64-54.
23 Aug - 04 Sep 64	Plant carried McMurdo Station load.
04 Sep 64	Plant shutdown for partial flush of the primary system, demineralizer resin change and circulation to cleanup the primary waters due to high primary system iodine. In addition, the reactor scrammed while transferring plant electrical load to the auxiliary diesel generator during the planned shutdown. Scram was due to low power to primary coolant pump caused by frequency and voltage transients during load transfer to the auxiliary diesel generator. PM-3A Operating Report Number 4; Malfunctions 64-55 and 64-56.
04-07 Sep 64	Plant down for replacement of source range detectors. Moisture penetration through faulty cable coverings on channel numbers 1 and 2 source range detectors caused them to fail. The plant was in shutdown condition when failure was detected. During this same time frame plant was manually scrammed due to the failure of control rod number 3 hold current power stage caused by a loose ground connection. PM-3A Operating Report Number 4; Malfunctions 64-57 and 64-58.
08-11 Sep 64	Plant carried McMurdo Station load.
11 Sep 64	Reactor manually scrammed due to the loss of control rod number 3 while at power. Failure was caused by the burnout of a wrong size resistor in the initial replacement of the power stage module.
11-13 Sep 64	Failure of source range detector numbers 1 and 2 discovered while plant was in down status. Cause was attributed to ageing on the shelf during storage.
14 Sep - 09 Oct 64	Plant carried McMurdo Station load.
09 Oct 64	Plant dropped load for less than two hours for Crew IV training.
09-26 Oct 64	Plant carried McMurdo Station load.
26-31 Oct 64	Plant shutdown for source range detector replacement, nuclear

	instrumentation testing, primary and shield water demineralizer resin changes and Crew IV training. The changing of the source range detector was due to a poor voltage plateau being produced by the previous BF^3 detector. PM-3A Operating Report Number 5, Malfunctions 64-69, 64-70 and 64-71.
31 Oct 64	Reactor brought critical and plant load carried.
01 Nov 64	Reactor scrammed during planned shutdown for training due to a switching transient. A second reactor scram occurred due to a test transient during a bistable trip test. PM-3A Operating Report Number 6; Malfunctions 64-73 and 64-75.
01-04 Nov 64	Plant shutdown for crew training and engineering support team work effort. Reactor brought critical and scrammed for training. Plant load picked up and dropped for training. Engineering support team test in progress.
04-07 Nov 64	Plant up for crew training and engineering team work effort. Plant carried McMurdo Station load and maintained full power with bypass steam for 10-hour xenon transient test. Steam generator chemistry and radiochemistry out of specifications due to system cycling during training on 5 November. Source range channel number 2 malfunctioned on 6 November due to a loose connector on the drawer. High air activity was encountered in the Primary Building on 7 November due to the excessive number of iodine samples. PM-3A Operating Report Number 6; Malfunctions 64-76, 64-77 and 64-78.
08 Nov 64	Reactor scrammed manually from 100% load for operator training. Hot rod drop tests and temperature coefficient runs performed at this time.
08-11 Nov 64	Plant down for testing and scheduled routine maintenance.
11-13 Nov 64	Reactor brought critical for engineering support team work effort. Continued scram response tests and performed cold rod drop tests.
13 Nov 64	Reactor shutdown and placed in cold iron status for scheduled summer maintenance and modification.
14-19 Nov 64	Purging containment for maintenance and modification. High air activity in containment forced delay in purging. PM-3A Operating Report Number 6, Malfunction 64-80.
20 Nov 64	Containment purge completed, containment opened. Plant modifications and maintenance program initiated. The major modifications and maintenance performed included the removal of the turbine casing and inspection of the turbine generator, the erection of the temporary shield water storage facility,

fuel transfer mechanism replacement, removal of the CRDMs in preparation for reactor refueling, installation of a new wiring system in the Maintenance and Supply Building and the installation of a new subfloor lighting system under the Primary Building.

21 Nov 64	Removal of shield water to temporary storage tanks under Condenser Building initiated.
23 Nov 64	CDRM and position indicator can removed.
26 Nov 64	Transfer of shield water complete; sluce gate, dolly and old fuel transfer equipment removed.
30 Nov 64	Installation of new fuel transfer equipment completed.
01-05 Dec 64	Hairline cracks rewelded in stainless steel liners of reactor and spent fuel tanks and refueling interconnect. Instrumentation logic test drawer switches replaced and new core installation monitoring system checked and tested. PM-3A Operating Report Number 7; Annex 1.
06-07 Dec 64	Returned shield water to containment tank from temporary storage area. Installed temporary shield water filtering system. Rebuilt spent fuel cask to proper dimensions for spent core tank storage.
08-09 Dec 64	Placed spent fuel cask in spent fuel tank. Cleaned up Primary Building and made final tool check in preparation for refueling.
10 Dec 64	Completed defueling spent core. Placed spent core in spent fuel cask.
11-13 Dec 64	Installed spare two-cubic-foot demineralizer in additional shield water recirculation system to aid cleanup of shield water activity from storage of spent core. PM-3A Operating Report Number 7, Malfunction 64-83.
14-16 Dec 64	Removed dummy source tube from the new core and installed a Po-Be start-up source. Replaced spent fuel tank recirculating pump, and calibrated nuclear instrumentation for new core loading.
17 Dec 64	Installed new core Type I, Serial 1, in reactor pressure vessel. Completed installation and testing of McMurdo Station evacuation alert alarm.
18-19 Dec 64	Completed final phase of core loading. Finished construction of condenser under-floor storage area. Tested all plant safety valves.

20-26 Dec 64	Repaired CRDM collets to meet diameter specifications and reassembled in reactor after refueling. Prepared and shipped old collet assemblies to CONUS for evaluation. Performed CRDM latching and 3/8 inch pickup procedures.
27 Dec 64 - 02 Jan 65	Packaged solid radioactive wastes for shipment. Welded cracks in steam generator tank sump liner. Completed control rod actuator dimension checks and marked actuator wiring. Replaced steam generator and tested and certified unit.

1964 SUMMARY

During the first year of operation under Navy responsibility the PM-3A underwent major modifications to instrumentation circuitry, the CRDMs, chemical and radiochemical limits in the primary coolant water, and radiation monitoring within the containment vessel. A number of additional components were required to alleviate problems with transient scrams in the scram logic system. In addition, a modification to the scram logic circuit enabled technicians to inject one or more combinations of simulated scram conditions without actually scramming the plant. Tests involving these modifications continued throughout the entire year, but transient noise problems in the system continued through December 1964.

The increase of I^{131} in the primary coolant was first recorded in June 1964. After many special tests had been completed, it was confirmed in August that a small fuel cladding defect did indeed exist, resulting in the release of fission products into the primary coolant. This problem was reaffirmed subsequent to the primary demineralizer resin change in early September. The I^{131} activity dropped sharply from 10^{-1} uCi/cc to 10^{-3} uCi/cc and then resumed a steady increase to about 0.25 uCi/cc in October.

On 11 September 1964, after an extensive investigation into the problem, BUDOCKS granted the temporary operating limit of 1.0 uCi/cc (gross Iodine) to permit further operation to obtain information to better define the problem. The temporary limit remained in effect until the core change in December 1964.

During the months of September and October 1964, the source range detectors, channel numbers 1 and 2, were replaced three times. The first incident was due to moisture penetration through faulty cable covering. This was corrected by a modification to the cable covering. A subsequent failure occurred one week after the initial malfunction. The reason for this second failure was attributed to ageing on the shelf during storage. As a result, resupply procedures were improved to assure freshest possible detectors were sent to the PM-3A. The third occurrence took place approximately two weeks after the second failure. Defects in the manufacturing of the detector were cited as the cause for this final detector malfunction.

The CRDMs began malfunctioning in September 1964. The first two malfunctions, electrical in nature, merely involved changing a resistor or transistor, but when the CRDMs were removed in preparation for the core change in December 1964, it was noticed that damage had occurred to the CRDM latching collets. Dimensional checks determined that they were deformed and did not meet designed dimensional specifications. The collets were generally flared at the bottom. The operating crew mechanics hand ground and polished the latch collets to meet specifications and measured all mechanisms to insure they were within tolerance. Control rod latch assemblies were then replaced on the CRDM bundles. The Navy began action to manufacture a new replacement set of collets, and in addition a program was initiated to investigate the cause of collet deformation. The next yearly summary will contain the results of the CRDM investigation.

03-07 Jan 65	Completed installation of electrical penetrations and painting of containment. Completed cold hydrostatic test of primary system. Pressurized containment to 30 psig to aid in locating containment tank leaks.
08-15 Jan 65	Completed annual containment leak rate test in accordance with Special Test Number T-53 with satisfactory results. Initiated instrumentation calibration and tests. Completed primary sample system modification.
16-21 Jan 65	Completed instrumentation calibration of the steam generator and pressurizer level control. Conducted five control rod drops. Control rod Number 1 cable found to be grounded.
22-25 Jan 65	Control rods failed to drive in "bank" or "three rod" modes of operation due to high current flow. Containment opened, CRDMs inspected and found to have sustained water damage as a result of containment leak tests. Removed CRDM units and began drying five coil can cables and three coil cans to remove moisture. PM-3A Operating Report Number 8, Malfunction 65-7.
26-28 Jan 65	Completed drying and venting of two coil cans to satisfactory condition. Two coil cans (serial Numbers 202 and 203) could not be satisfactorily repaired and were prepared for shipment to CONUS for emergency repair.
29-30 Jan 65	Coil cans Serial 202 and 203 backloaded to CONUS. BUDOCKS Inspection Team arrived for annual PM-3A safety and administration inspection.

31 Jan- 01 Feb 65	In process of backloading radioactive waste and other material to CONUS.
02-04 Feb 65	Completed filling one high level waste cask with resin; second cask partially filled. PM-3A Operating Report Number 9, Annex I.
05-08 Feb 65	Completed backloading six CONEX boxes each containing twenty-three drums of radioactive solid waste and two high level casks containing resins. In the process of completing new caterpillar diesel-generating building.
09-20 Feb 65	Plant in cold iron status awaiting arrival of repaired CRDMs and new cables.
21 Feb 65	Received CONUS repaired coil cans 202 and 203 with associated cables. PM-3A Operating Report Number 9, Annex II.
22 Feb 65	Installed can housings and coil can cables on the reactor pressure head. Installing position indicator cans and new cables. Completed caterpillar diesel generator building.
23-25 Feb 65	Completed installation of CRDMs, latched and performed required control rod pick-up tests. Completed cold control rod drop tests and primary system cold hydro test. Steam generator drained and flushed. Instrumentation and electrical precritical checks completed. Initiated radiochemistry sampling. In the process of cleaning up CRUD and reducing primary coolant system activity level with demineralizer.
26 Feb 65	Plant reached initial criticality on the new core. Plant shutdown to adjust limit switch. Plant critical. Plant shutdown due to insufficient lift current on control rod Number 1. Increased lift current and plant once again critical. PM-3A Operating Report Number 9; Malfunction 65-16.
27 Feb 65	Plant shutdown attributed to the loss of shield water flow due to the failure of shield water pump Number 1. Manually started shield water pump Number 2. A blown fuse was found to be the cause of the malfunction to shield water pump Number 1. Plant critical. Conducting shutdown margin tests. PM-3A Operating Report Number 9, Malfunction 65-17.
28 Feb 65	Reactor scrammed during temperature coefficient testing when control rod Number 5 dropped. Reactor scrammed twice on fast period during temperature coefficient testing. PM-3A Operating Report Number 10, Malfunctions 65-18, 65-19, and 65-20.

01 Mar 65	Reactor critical for core physics testing.
02 Mar 65	Reactor scrammed on fast period during temperature coefficient testing. PM-3A Operating Report Number 10; Malfunction 65-21.
03 Mar 65	Reactor scrammed on low primary coolant pump power following completion of temperature coefficient tests, temperature coefficient and six rod bank worth tests. Six rod bank position versus temperature data, reactivity insertion rate and radiochemical sampling performed. Plant shutdown due to loss of main steam pressure and steam generator level indication. PM-3A Operating Report Number 10; Malfunction 65-23.
04-05 Mar 65	Plant shutdown. Cleaned steam generator level reference column. Replaced feedwater check valve internals. Nuclear instrumentation channel Number 3 failed due to a burnt capacitor. PM-3A Operating Report Number 10; Malfunction 65-24.
06 Mar 65	Repaired nuclear instrumentation intermediate range channel Number 3 drawer and cables. Reactor scrammed during startup on fast period. PM-3A Operating Report Number 10, Malfunction 65-25.
07 Mar 65	Plant placed in cold iron status awaiting CONUS evaluation of steam generator malfunction.
08-17 Mar 65	Plant in cold iron status. Completed primary system cold hydrostatic test. Completed wiring for scram circuits self test and display system modification. Disassembled and inspected steam generator level system datum column and calibrated steam generator level system.
18 Mar 65	Calibrated feedwater flow control valve. Plant shutdown. Self test display drawer modifications failed to test out satisfactorily. Drawer wiring returned to original configuration at CONUS direction. Replaced detectors on nuclear instrumentation (intermediate range channel Number 3 and power range channel Number 7).
19 Mar 65	Control rod Number 5 would not drive properly during pre-startup tests. After repair the reactor was brought critical for continuation of core physics and primary system testing. PM-3A Operating Report Number 10; Malfunction 65-26.
20 Mar 65	Reactor scrammed on fast period during zero power operation. PM-3A Operating Report Number 10, Malfunction 65-27.

21-22 Mar 65	Reactor critical. Following tests completed: 1. Temperature coefficient and six rod bank position versus temperature. 2. Pressurizer level calibration. 3. Steam generator level calibration. 4. Primary system instrument tests. 5. Pressurizer spray valve response.
23 Mar 65	Reactor scrammed on instrumentation transient prior to warming main steam line. Control rod Number 5 would not drive during pre-startup tests. After repair the reactor was brought critical for secondary system shakedown tests. Reactor scrammed on loss of power from McMurdo Station diesel plant with main turbine generator at synchronous speed and no load. PM-3A Operating Report Number 10, Malfunctions 65-28, 65-29, and 65-30.
24 Mar 65	Reactor brought critical for secondary system shakedown tests. Reactor scrammed by instrumentation switching transient. PM-3A Operating Report Number 10; Malfunction 65-31.
25 Mar 65	Reactor brought critical for secondary system shakedown. Plant load picked up on main turbine generator. Turbine generator set vibration tests completed.
26 Mar 65	Reactor critical, turbine generator on the line carrying plant load. Reactor scrammed on a transient while preparing to shut down plant. PM-3A Operating Report Number 10; Malfunction 65-32.
27 Mar 65	Reactor shutdown. Automatic mode of feedwater control system malfunction.
28 Mar 65	Reactor brought critical for nuclear instrumentation power range channel testing. Reactor shutdown to replace decay heat system check valve. Reactor brought critical and plant load picked up on main turbine generator.
29 Mar 65	Reactor critical with plant load being carried on the main turbine generator. Assumed McMurdo Station electrical load. Continued secondary system shakedown tests.
30 Mar 65	Plant on the line carrying McMurdo Station load. Reactor scrammed on high power. PM-3A Operating Report Number 10 Malfunction 65-33.
31 Mar 65	Assumed plant and McMurdo Station load for continuous power operations. Steam generator blowdown cooler partially blocked.

01-03 Apr 65	Plant carried McMurdo Station load. Checked calibration of steam and feedwater flow systems. Automatic mode of feedwater control system still malfunctioning. Main Condenser Fan 2B out of service.
04-27 Apr 65	Plant carried McMurdo Station load. During this period, the steam generator blowdown chemistry analysis was outside specified limits three times. Automatic mode of feedwater control system inoperative. PM-3A Operating Report Number 11; Malfunctions 65-34, 65-35 and 65-36.
28 Apr 65	Unplanned reactor scram due to insufficient grip current on control rod Number 6 causing it to slip when the operator drove rods "in" resulting in the inability to maintain primary pressure. Corrected by replacing a burnt resistor on the grip current board. Fire broke out on top of the diesel engine when electrical load was being removed from the unit due to high temperature engine. Damage was mainly superficial with some wiring damage. PM-3A Operating Manual Number 11; Malfunctions 65-37 and 65-38.
29-30 Apr 65	Attempted to start up but had to shutdown due to inability to maintain primary system operating pressure. Replaced pressurizer heater element Number 13. Added high voltage monitors to nuclear instrumentation power range channels. Installed rod drop test modification to signal generator and log drawer in CRDM cabinet. PM-3A Operating Report Number 11; Malfunction 65-39.
01 May 65	Reactor was brought critical and assumed plant load. Plant load was alternately dropped and picked up twice for operator training.
02-05 May 65	Plant carried McMurdo Station load.
06 May 65	Secondary system secured for maintenance on feedwater flow control valve bypass line (leak). Plant scrammed on fast period. A second reactor scram occurred during synchronization with McMurdo Station Diesel Plant. A blown fuse in the synchronizing circuit produced false synchronizing information. PM-3A Operating Report Number 12; Malfunctions 65-40 and 65-41.
07-21 May 65	Plant carried McMurdo Station load.
22 May 65	Plant up for power operations. Steam generator blowdown chemistry out of specified limits. PM-3A Operating Report Number 12; Malfunction 65-42.

23 May 65	Plant up for power operations. Main condenser Number 1 was frozen while attempting to phase it into operation. PM-3A Operating Report Number 12; Malfunction 65-43.
24 May- 9 June 65	Plant carried McMurdo Station load.
10 Jun 65	Steam generator blowdown chemistry out of specified limits. PO_4 and SO_3 concentrations were above limits. Corrected by increasing steam generator blowdown thereby reducing concentration.
11-16 Jun 65	Plant carried McMurdo Station load.
17 Jun 65	Plant scrammed due to low primary pressure. Primary system hydrogen concentration out of specified limits. PM-3A Operating Report Number 13; Malfunctions 65-45 and 65-46.
18-22 Jun 65	Plant shutdown for scheduled and unscheduled maintenance. Containment opened. Made cold hydrostatic test of primary system, steam generator and expansion tank. Inspected all containment instrumentation. Checked pressurizer heaters. Inspected steam generator level system. Completed containment electrical equipment megger tests. The unscheduled maintenance included the replacement of the pressurizer relief valve due to excessive leakage in the primary system.
23-28 Jun 65	Plant carried McMurdo Station load.
29 Jun 65	Plant up for power operations. Main condenser Number 1 frozen while attempting to place it into service. PM-3A Operating Report Number 13; Malfunction 65-47.
30 Jun- 09 Jul 65	Plant carried McMurdo Station load.
10 Jul 65	Plant up for power operations. Nuclear instrumentation channel Number 6 failed. PM-3A Operating Report Number 14; Malfunction 65-48.
11 Jul 65	Plant up for power operations. Nuclear instrumentation channel Number 6 failed. PM-3A Operating Report Number 14; Malfunction 65-49.
12 Jul 65	Plant up for power operations. Containment cooler fan No. 1 tripped. Power to motor control center No. 2 was lost while attempting to restart containment cooler fan No. 1. PM-3A Operating Report Number 14; Malfunction 65-50.

13-24 Jul 65	Plant carried McMurdo Station load.
25 Jul 65	Plant up for power operations. Feedwater system oxygen concentration out of specified limits. PM-3A Operating Report Number 14; Malfunction 65-51.
26-27 Jul 65	Plant carried McMurdo Station load.
28 Jul 65	Plant up for power operations. Two fuses blew in control rod actuator 12 volt power supply and the lift and pull down power supply. PM-3A Operating Report Number 15; Malfunction 65-52.
09-11 Aug 65	Plant shutdown for scheduled and unscheduled maintenance to the primary system, nuclear instrumentation and auxilliary diesel generators.
12 Aug 65	Reactor control rod No. 1 was sluggish while attempting to achieve criticality. Reactor critical for primary system hot leak rate and shutdown margin tests. PM-3A Operating Report Number 15; Malfunction 65-54.
13 Aug 65	Reactor shutdown to reset control rod limit switch and further evaluate reactor control rod No. 1 withdrawal response while in a hot shutdown condition. Reactor brought critical.
14-16 Aug 65	Plant carried McMurdo Station load.
17 Aug 65	Plant up for power operations. Nuclear instrumentation power channel No. 6 failed. PM-3A Operating Report Number 15; Malfunction 65-55.
18 Aug 65	Plant up for power operations. McMurdo Station load was dropped for approximately four hours to allow Public Works personnel to perform maintenance on the power distribution system.
19-20 Aug 65	Plant carried McMurdo Station load.
21 Aug 65	Plant scrammed due to switching transient in turbine generator speed governor switch. Reactor brought critical. Shutdown secondary system due to inability to obtain over ten inches of vacuum in the condensate system. PM-3A Operating Report Number 15; Malfunctions 65-56 and 65-57.
22 Aug 65	Plant up for power opeations. CRDM malfunctioned. Plant manually scrammed due to loss of main condenser vacuum. Reactor brought critical. PM-3A Operating Report Number 15; Malfunction 65-58 and 65-59.

23-26 Aug 65	Plant carried McMurdo Station load.
27 Aug 65	Plant scrammed due to a momentary short circuit of the 24-volt DC power supply in the control console. Reactor brought critical. PM-3A Operating Report Number 15; Malfunction 65-60.
28 Aug- 02 Sep 65	Plant carried McMurdo Station load.
03 Sep 65	Plant up for power operations. Steam generator blowdown activity was out of specified limits. This was caused by a temporary change in the dissolution rate of steam generator CRUD. PM-3A Operating Report Number 15; Malfunction 65-61.
04-05 Sep 65	Plant carried McMurdo Station load.
06 Sep 65	Plant scrammed due to an apparent electrical transient. Reactor brought critical and plant assumed McMurdo Station load. PM-3A Operating Report Number 16; Malfunction 65-62.
07 Sep 65	Plant scrammed on 120% power. Reactor brought critical. Preparing to place secondary system in operation, when plant scrammed due to fast reactor period. PM-3A Operating Report Number 16; Malfunctions 65-63 and 65-64.
08 Sep 65	Plant scrammed while withdrawing control rods to achieve criticality. Control rod No. 3 dropped from 15 inches to 9.5 inches while driving up. Insufficient coil current was cited as the cause. Increased coil current brought reactor critical and assumed McMurdo Station load. PM-3A Operating Report Number 16; Malfunction 65-65.
09 Sep 65	Plant up for power operations. Lost time accident occurred when the equipment operator stepped off the turbine generator bed plate and sprained his left ankle. PM-3A Operating Report Number 16; Malfunction 65-66.
10-11 Sep 65	Plant carried McMurdo Station load.
12 Sep 65	Plant scrammed due to apparent electrical transient. Brought reactor critical. PM-3A Operating Report Number 16; Malfunction 65-67.
13-21 Sep 65	Plant carried McMurdo Station load.
22 Sep 65	Plant scrammed due to a short circuit in the primary system leak detector. Steam gnerator blowdown chemisty analysis out of normal specified limits. PO_4 fluctuated above and below limits and pH followed accordingly.

	Reason: The addition of M and S Building heating load to the plant system immediately after plant startup before the secondary system attained chemistry equilibrium. PM-3A Operating Report Number 16, Malfunction 65-68 and 65-69.
23-24 Sep 65	Plant shutdown. Containment opened. Performed numerous maintenance items and completed required 2500 hours tests.
25 Sep 65	Closed containment, reactor brought critical, and assumed McMurdo Station load.
26 Sep 65	Plant up for power operations. Nuclear instrumentation power range Channel 6 failed. PM-3A Operating Report Number 16; Malfunction 65-70.
27 Sep 65	Reactor scrammed due to accidental main steam stop valve closure. Reactor brought critical and plant assumed McMurdo Station load. PM-3A Operating Report Number 16; Malfunction 65-71.
28-29 Sep 65	Plant carried McMurdo Station load.
30 Sep 65	Plant up for power operations. Nuclear instrumentation power range Channel 6 failed. PM-3A Operating Report Number 16; Malfunction 65-72.
01-07 Oct 65	Plant carried McMurdo Station load.
08-09 Oct 65	Plant scrammed due to an unknown cause followed by three scrams attributed to switching transients and one training scram. PM-3A Operating Report Number 17; Malfunction 65-73.
10-15 Oct 65	Reactor brought critical and plant assumed McMurdo Station load.
16 Oct 65	Plant scrammed manually when control rod No. 2 dropped. Reactor brought critical and assumed plant load. Began cycling of plant for Crew V training. PM-3A Operating Report Number 17, Malfunction 65-74.
17 Oct 65	Plant scrammed for training. Reactor brought critical and assumed plant load. Continued plant cycling for training.
18 Oct 65	Plant cycling for training with one scheduled scram. Reactor brought critical and assumed McMurdo Station load.
19-22 Oct 65	Plant carried McMurdo Station load.

23 Oct 65	Commenced cycling plant for training, scheduled scram and shutdown for maintenance. Commenced containment purge.
24-30 Oct 65	Plant down for scheduled routine maintenance.
31 Oct 65	Reactor critical for core physics testing. Reactor scrammed on an indicated 30 second period. Reactor brought critical and scrammed on a short period. Reactor brought critical. PM-3A Operating Report Number 18; Malfunctions 65-76, 65-77 and 65-78.
01 Nov 65	Reactor critical for core physics testing. Reactor scrammed due to electrical transient. Reactor brought critical and then scrammed for scheduled maintenance. PM-3A Operating Report Number 18; Malfunction 65-79.
02-15 Nov 65	PM-3A down for scheduled maintenance.
16 Nov 65	Reactor critical in preparation for power operations. Reactor scrammed due to electrical transient. Reactor brought critical and again scrammed due to short period on nuclear instrumentation channels Nos. 3 and 4. PM-3A Operating Report Number 18; Malfunctions 65-81 and 65-82.
17 Nov 65	Reactor brought critical. Scrammed by an electrical transient in 4160V distribution system from McMurdo Station diesel plant. Reactor brought critical assumed McMurdo Station load. PM-3A Operating REport Number 18, Malfunction 65-83.
18 Nov 65	Plant carried McMurdo Station load.
19 Nov 65	Dropped McMurdo Station and PM-3A load. Repaired leak in feedwater system line. Assumed PM-3A and McMurdo Station heater bank load.
21-30 Nov 65	Plant carried McMurdo Station load.
01 Dec 65	Plant up for power operations. Secondary system chemistry out of normal specifications. The cause was due to operator inexperience with coordinated phosphate control system used at the PM-3A. PM-3A Operating Report Number 19; Malfunction 65-85.
02 Dec 65	Plant carried McMurdo Station load.
03 Dec 65	Plant up for power operations. Released approximately 180 gallons of $1.32\text{x}10^{-7}$ uCi/ml liquid waste. The prescribed limit is $1\text{x}10^{-7}$ uCi/ml. This was due to misalignment of valves on the piping servicing holdup tanks 3 and 4. PM-3A Operating Report Number 19; Malfunction 65-86.

04-05 Dec 65	Plant carried McMurdo Station load.
06-10 Dec 65	During the period 6-10 December 1965, the PM-3A was shutdown for routine and unscheduled maintenance. Many modifications were performed in the primary and secondary system and in the water distillation plant. Tests were completed to obtain information on the excessive leak rate in the primary system. In addition, while working on a CRDM modification three men exceeded their 300 mRem/wk limit. However, this exposure was approved by the Officer in Charge in order to complete the job.
11 Dec 65	Reactor brought critical.
12-26 Dec 65	Plant carried McMurdo Station load.
27 Dec 65	Plant up for power operations. Received and stored PM-3A Core III and 55 curie Po-Be startup source.
28 Dec 65 - 07 Jan 66	Plant carried McMurdo Station load.

1965 SUMMARY

During the second year of operation, extensive changes to the PM-3A Health Physics and Water Chemistry Manual were implemented. Incorporated in these changes was the once temporary operating limit of 1.0 uCi/cc (gross Iodine) for primary coolant standards.

Modifications to the CRDMs continued throughout the entire year. The latching collet problem was solved early in the year by fabricating replacements made from 17-4 PH SS. (This type of stainless steel had a yield strength about 3 times greater than the stainless steel, Type 304, that was initially used.) This action was decided after tests performed by the manufacturer had been completed. They proved that collets made from 304SS would deform due to high scram decelerations and lower yield strength, while collets made from 17-4 PH SS could sustain higher scram deceleration without deforming significantly.

Another problem involving the CRDMs was encountered in late January during final checks just prior to the initial approach to criticality on the new core. It was found that neither the six rod bank nor either of the three rod banks would drive due to excessive current flow. The cause was eventually found to be water and abrasion damage to the interiors of three actuator coil can assemblies and their associated cables. Two of these cans and all of the cables were sent back to CONUS for modification and repair. The third was "baked dry" and put in satisfactory condition on site. Upon the return of the two coil cans and new cables in late February and their reinstallation, criticality was achieved for the first time utilizing the new Type I Serial I core.

Electrical transients continued to create problems at the PM-3A during 1965, but the majority of these situations were corrected by merely changing the configuration of the electrical components involved or changing a resistor or capacitor in a particular piece of equipment.

08 Jan 66 Primary coolant chemistry was out of limits. Possible causes for this malfunction were:

- a. Excessive addition of ammonium hydroxide.
- b. Possible holdup of previous additions of ammonium hydroxide.
- c. Leaks of hot primary coolant through check valve, raising temperature of water to primary demineralizer resins.

Supplemental information:

- a. Primary purification micrometallic filter was changed approximately six hours prior to malfunction. Temperature scan point 58 (purification demineralizer inlet) showed increase in temperature to 200°F, apparently caused by leakage of decay heat check valve.
- b. New procedures were approved for changing the micrometallic filter with isolation valve closed or with isolation valve open. PM-3A Operating Report Number 20; Malfunction 66-1.

09-10 Jan 66 Plant carried McMurdo Station load.

11-23 Jan 66 PM-3A shutdown to remove spent core and place in storage.

24 Jan 66 Reactor critical. Plant carried McMurdo Station load.

25-29 Jan 66 Due to leak of hot primary coolant through check valve, water temperature to the primary demineralizer resins rose causing a PH of 10.3, an ammonia concentration of 36 ppm and a conductivity of 31.6 umho/cm. Corrective action included the standard bleed, feed and vent procedure and isolating the primary demineralizer with increased sampling frequency. These procedures had little or no effect in balancing primary coolant chemistry.
The PM-3A was shutdown in order to change primary demineralizer resins on 26 January 1966. This project was completed on 30 January 1966. PM-3A Operating Report Number 20, Malfunction 66-3.

30 Jan-
05 Feb 66 During purging prior to opening of containment and while the RWDS was in operation, it was discovered that the RWDS sump level was decreasing rapidly. It was determined that the

	malfunction was caused by a dirty RWDS evaporator level control system. The system was cleaned and an operating manual change notice on procedures and criteria for blowing down the evaporator was prepared. PM-3A Operating Report Number 21; Malfunction 66-5.
06 Feb 66	While restarting, rod six would not drive up. It was determined that the cause was the failure of the 28 volt power supply. PM-3A Operating Report Number 21; Malfunction 66-8.
07 Feb 66	While the reactor was critical and driving control rods for heatup, control rod six stopped driving. All other rods would not drive much further than eleven inches. The cause was determined to be CRUD deposits on the control rod bundles, and a piece of metal filing lodged in the movable armature gap of CRDM 207. PM-3A Report No. 21; Malfunction 66-9.
08-11 Feb 66	PM-3A shutdown for CRDM repairs. All of the control rod bundles were removed, cleaned and reinstalled. CRDM #207 was replaced with CRDM #206 in port six.
12-13 Feb 66	Plant carried McMurdo Station load.
14 Feb 66	While carrying McMurdo Station load and during adjustment of power range, the placing of Channel #5 test switch into test gave several scram annunciate alarms. Returning to operate gave scram as well. High power scram not annunciated. The malfunction was apparently caused by a noise transient when the test/operate switch on Channel #5 was returned to operate position. Investigation as to the cause was initiated. PM-3A Operating Report Number 21; Malfunction 66-6.
15-18 Feb 66	Plant carried McMurdo Station load.
19-20 Feb 66	The PM-3A supplied 20,000 lbs. of nuclear power produced steam to the McMurdo Station water distillation plant for the initial distillation of fresh water from seawater. Approximately 4000 gallons of fresh water were produced.
21 Feb - 10 Apr 66	Plant carried McMurdo Station load.
11 Apr 66	Plant up for power operations. Bistable Number 12 (High power scram set point, normally set at 122%) tripped at approximately 98% power. PM-3A Operating Report Number 23; Malfunction 66-11.
12-20 Apr 66	Plant carried McMurdo Station load.

21 Apr 66	Plant up for power operations. Reactor coolant pump lower bearing temperature indicator became erratic. PM-3A Operating Report Number 23; Malfunction 66-12.
22-28 Apr 66	Plant carried McMurdo Station load.
29 Apr 66	Plant up for power operations. Loss of vacuum and control of main condenser number three necessitated paralleling the PM-3A with McMurdo Station Diesel Plant for a short period of time. PM-3A Operating Report Number 23, Malfunction 66-13.
30 Apr- 08 May 66	Plant carried McMurdo Station load.
09 May 66	PM-3A scrammed due to a channel discrepancy alarm. The period discrepancy light for channels one and two went on, off and then on again, at which time the plant scrammed. The cause was determined as being: a. A shorted coaxial connector on signal cable at preamp caused noise transient to be injected into NI system. b. Cable inside containment had apparent water leak and detector had a low resistance. c. Noise transient caused bistables 17 and 19 (high reactor coolant outlet temperature) to trip. These faults were corrected in conjunction with scheduled and unscheduled maintenance.
10-15 May 66	PM-3A remained shutdown for scheduled and unscheduled maintenance to the main condensers, feedwater heater, nuclear instrumentation, CRDM's, reactor coolant pump and the pressurizer heaters. The primary resins were also changed.
16 May 66	With reactor critical and driving control rod No. 2 to attain a period for start of temperature coefficient test, NI channel No. 4 indicated a 40 to 50 second reactor period. NI channel No. 3 came on scale rapidly and reactor period on channel No. 3 indicated approximately 20 seconds. Reactor scrammed on short period. The cause was determined to be overcompensation (high voltage) of channel No. 3 during prestartup test. The voltage to channel No. 3 was adjusted and the problem was corrected. PM-3A Operating Report Number 24; Malfunction 66-15.
17 May 66	Criticality achieved. The plant scrammed while performing temperature coefficient runs. The control room received scram alarms from short period channel No. 1, No. 2, No. 3 and No. 4. Rod driving was not in progress as the opeator was waiting for temperature equalization. It was determined that the cause of the malfunction was due to maintenance personnel working in the rear of the control console. They

had vibrated some terminal strips which resulted in a transient short period scram.

Reducing sensitivity to transients and increasing reliability by decreasing or eliminating period scrams and using reduced high power scram set point for zero power accident protection was recommended. These recommendations were evaluated, along with other possible improvements, in developing new instrumentation under the PM Development Program. PM-3A Operating Report Number 24; Malfunction 66-16.

18 May 66	Reactor critical. PM-3A assumed McMurdo Station load.
19 May 66	Plant carried McMurdo Station load.
20 May 66	During power operations and while maintenance personnel were calibrating console electrical meters for the main generator, the main generator breaker tripped causing the reactor to scram. Overcurrent relay 50V-51V appeared to have caused the trip of the main generator breaker. The malfunction was caused by maintenance personnel when they shorted CTs in the relay meter circuit in order to calibrate the KVAR meter. When the KVAR standard was connected, the current and voltage were not polarized to standard, causing the main generator breaker to trip. Relays were thought to be out of circuit with CT's shorted, but current was fed back to the relay through a misconnection in the test circuit. In order to alleviate the problem it was decided that all trip circuit contacts were to be pulled at relays prior to any future testing and calibration while at power. Subsequent to the previous malfunction on the 20th in the morning, another scram occured later that afternoon. Criticality had been achieved and the reactor was at operating temperature and pressure. The operator was exercising the load limiter and received the scram annunciation of low primary coolant flow. A noise transient was determined to be the cause of the scram. PM-3A Report Number 24, Malfunctions 66-17 and 66-18.
21 May 66	Plant carried McMurdo Station load.
22 May 66	Plant up for power operations. Failure of main condenser fan 1B. PM-3A Operating Report Number 24 Malfunction 66-19.
23 May - 16 Aug 66	Plant carried McMurdo Station load.
17 Aug 66	Plant up for power operations. PM-3A switched from coordinated phosphate control to morpholine control for maintaining steam generator pH. PM-3A Operating Report

	Number 27; Section VI, Item 4.
18 Aug - 07 Oct 66	Plant carried McMurdo Station load.
08 Oct 66	Plant up for power operations. At 0101 the PM-3A surpassed the record for the longest continuous power run for nuclear power plants operated by military personnel with a power run of 3390:25 hours.
09 Oct 66	Plant up for power operations. Reactor manually scrammed at 1155 because of a sharply increasing steam generator level and indication of a high feedwater flow. The cause was determined to be a blown fuse in the steam generator level controller. PM-3A Operating Report Number 29; Malfunction 66-20.
10-14 Oct 66	Plant carried McMurdo Station load.
15 Oct 66	Plant up for power operations. Reactor scrammed due to a rapid increase in both steam and feedwater flow and an increase in power level. The cause was found to be improper alignment of valving which resulted in the loss of air to plant systems. The bypass steam valve was partially opened on loss of air resulting in increased steam flow and high power scram. Reactor manually scrammed several times for training of new crew. PM-3A Operating Report Number 29; Malfunction 66-21.
16-21 Oct 66	Plant carried McMurdo Station load.
22 Oct 66	PM-3A dropped McMurdo Station load. Cycling of plant for crew training.
23 Oct 66	Plant being cycled for crew training. Reactor scrammed. The apparent cause of the scram was a noise transient from relay contact chatter in the Pyr-A-larm system when its drawer was opened by maintenance personnel. The relays in the system were out of adjustment. PM-3A Operating Report Number 29; Malfunction 66-22.
24 Oct - 06 Nov 66	PM-3A shutdown for annual maintenance.
07 Nov 66	Reactor brought critical and then scrammed. Instrument personnel were taking Channel Number 1 out of service and the reactor scrammed on short period indications from Channels 3 and 4. Noise transients seen by those two channels were determined to be the cause of the malfunction. PM-3A Operating Report Number 30, Malfunction 66-23.

08 Nov 66	Reactor scrammed. Control rod number 6 would not drive up and it would drive down at slow speed only. Apparent misalignment of the CRDM caused binding of the rod bundle assembly. PM-3A Operating Report Number 30; Malfunction 66-24.
09-10 Nov 66	PM-3A shutdown to correct misalignment of CRDM.
11 Nov 66	Reactor brought critical for core physics testing.
12 Nov 66	PM-3A continued core physics testing. A fire was discovered and extinguished under the condenser storage area in the core handling tool storage room. The oil fired space heater in that room leaked oil out of the fire box into a drip pan. The leaking oil was set afire by the hot fire box. No damage resulted. PM-3A Operating Report Number 30; Malfunction 66-25.
13 Nov 66	Reactor scrammed on noise transient. Reactor brought critical and scrammed on noise transient. PM-3A Operating Report Number 30; Malfunctions 66-26 and 66-27.
14 Nov 66	Performing test procedure RC-3, control rod drop time. Power lost to Channel Number 5. Rod Number 1 appeared unlatched. PM-3A Operating Report Number 30; Malfunctions 66-28 and 66-29.
15-27 Nov 66	Plant shutdown, containment opened in preparation for replacement of Control Rod Number 1. PM-3A Special Operating Report for broken control rod replacement prepared 28 February 1967.
28 Nov 66	Reactor brought critical. Reactor scrammed due to low primary pump power. Apparent increase in span of power converter after modification caused gross changes in indicated KW for slight change in frequency. PM-3A Operating Report Number 31; Malfunction 66-30.
29 Nov 66	Reactor brought critical; reactor scrammed. McMurdo Station requested PM-3A to go on local generator to avoid placing another engine on the line. When this was attempted, the auxiliary generator tried to pick up excess load and opened the site tieline breaker. Auxiliary generator frequency and voltage varied causing the reactor to scram on low primary pump power. Reactor brought critical, assumed plant load, then dropped plant load. The equipment operator noticed water gushing from air ejector vent. An ejector trap appeared to be blocking condensate flow to hotwell. The cause for this malfunction was unknown. It was theorized that the trap float had stuck in the closed position and was freed by maintenance personnel when they dismantled it

	for cleaning. PM-3A Operating Report Number 31; Malfunctions 66-31 and 66-32. 30
Nov 66	PM-3A assumed, dropped, and reassumed McMurdo Station load.
01 Dec 66	Reactor scrammed. Primary pump power indication was erratic and drifting down scale. Low pump power scram. Diesel generator started but failed to relay in. Primary and secondary transformer breakers failed to trip because of a blown PT fuse, thus causing the emergency diesel-generator breaker not to close. PM-3A Operating Report Number 31; Malfunction 66-33.
02 Dec 66 - 01 Feb 67	Plant carried McMurdo Station load.

1966 SUMMARY

During 1966 the PM-3A set a new record for the continuous power operation of a nuclear power plant by military personnel: 3390:25 hours of uninterrupted power operations.

Despite the fact that in total numbers most of the scrams were caused by malfunctions of a miscellaneous nature, almost 95% of the down time during the year was attributed to problems connected with the control rod drive system. The longest single period of down time occurred in November when the plant was shutdown for 354 hours after it appeared that one of the control rods had become unlatched. Upon inspection it was found that a break existed in the control rod just below the pickup ball. The cause was investigated and a special report was issued during 1967. The findings of this report will be covered in the next yearly summary.

02 Feb 67	Reactor scrammed. Single phase of feeder line #2 broke at the knife switch on the first pole and grounded on switching station #1. Short circuit opened site tieline and turbine generator breakers. The cause was due to constant flexing of the cable in the wind and the age of the distribution lines. PM-3A Operating Report Number 33; Malfunction 67-2.
03-08 Feb 67	PM-3A shutdown for unscheduled maintenance to the pressure vessel head, nuclear instrumentation, and many portions of the secondary system. The Primary Building addition was completed, and the new RWDS was moved into it.
09 Feb 67	Reactor scrammed while being brought critical. Instrument personnel were running rod actuator power requirements test. The cable connected to lift and pull down power supply rubbed on the current adjustment for CRDM No. 6 introducing a transient in the system which caused a scram. Reactor

	brought critical. PM-3A Operating Report Number 33; Malfunction 67-4.
10 Feb 67	Reactor scrammed. Nuclear instrumentation channel number 5 read 30% power, Channels 6 and 7 read zero. The apparent cause was open detector leads. It was later found that the cables and connectors on Channels 6 and 7 were damaged during or after installation in containment. PM-3A Operating Report Number 33; Malfunction 67-5.
11 Feb 67	Reactor brought critical.
12 Feb 67	PM-3A assumed McMurdo Station load. Reactor scrammed. Nuclear instrumentation Channel 6 was reading near zero while Channels 5 and 7 were operating properly. The cause was a faulty number 6 detector and cable assembly. Reactor brought critical and assumed electrical load. PM-3A Operating Report Number 33; Malfunction 67-7.
13 Feb - 08 Apr 67	Plant carried McMurdo Station load.
09 Apr 67	Reactor scrammed for no apparent cause with no scram alarms except low flow. Investigation revealed Phase A of the lower feeder had parted at the same location as Malfunction 67-2 (knife switch at the first pole by Switching Station Number 1), shorted against the Switching Station, and caused the tieline and main generator breakers to trip. [Following normal scram recovery procedures, plant operators had no success in starting either emergency diesel generator. The generators would not start due to low temperature in the PM-3A Emergency Diesel Generator Building caused by heat loss through new louvers installed the previous summer. Operators started emergency cooldown of the Primary System using the Steam Generator and dumping steam overboard. After three hours one diesel generator was started by heating with Herman-Nelson heaters from the McMurdo Public Works Department and with a torch. The gasoline air compressor had to be thawed for starting air. Some water was added to the Steam Generator before the diesel generator tripped off the line, due to a ruptured fuel line, after six minutes of operation. The second generator was started but its breaker tripped each time it was closed although no fault was apparent. The fuel line of the first generator was repaired, and it was started and assumed the plant load. After power was restored, the Steam Generator was slowly filled and water was added to the Pressurizer. Both the Pressurizer and Steam Generator level were off scale. Approximately sixty gallons of water were added to the primary system to bring the pressurizer level to above normal. The Shield Water System and Reactor Coolant Pump

	were placed in operation and the temperature of the primary loop was reduced by dumping steam until the Decay Heat Pump could be placed in operation. The Reactor operated to the right of the operating curve from a pressure of 425 PSIG and temperature of 340 degrees F at 11:55 am until power was restored at 1:18 pm. At no time did the primary temperature exceed saturation temperature for that primary pressure. PM-3A Operating Report Number 35; Malfunction 67-9. This was a serious situation. With no power and no coolant flow, there was considerable concern about potential core damage. Analysis of primary system parameters following return to power revealed no evidence of core damage.
10-14 Apr 67	PM-3A shutdown for scheduled and unscheduled maintenance to the M & S Building and water distillation plant heating system, the hot and cold water systems in the chemistry labs, and items damaged by freezing and electrical single phasing when the PM-3A scrammed on 09 April 1967.
15 Apr 67	Reactor brought critical. Reactor scrammed on a fast positive period. Channel Number 3 signal cable was found to have a bad connection at the penetration inside of containment. It had apparently been stepped on or bumped during reactor tank maintenance. Reactor scrammed during planned shutdown. Bistable trip number 5 was tripped, but Channel Number 3 was in the test position for Malfunction 67-10 evaluation. When nuclear instrumentation Channel Number 4 turned on the source range high voltage, the reactor scrammed on a short period from Channels 1 and 2 due to the voltage surge. PM-3A Operating Report Number 35; Malfunctions 67-11, and 67-12.
16 Apr - 14 Sept 67	Plant on the line for a 3643:15 hour power run, surpassing the old record of 3390:25 hours established in October 1966.
15 Sep 67	Reactor scrammed. NI channel number 1 failed. PM-3A Operating Number 40; Malfunctions 67-18 and 67-19.
16-20 Sep 67	PM-3A shutdown for routine testing and maintenance. In addition a new decay heat pump was installed and the pump and purification system was pressure tested with satisfactory results.
21 Sep 67	Reactor brought critical.
22 Sep 67	Two reactor scrams occurred due to faulty main steam stop valve actuator. PM-3A Operating Report Number 40; Malfunctions 67-20 and 67-21.
23-25 Sep 67	Plant carried McMurdo Station load.

26 Sep 67	Reactor scrammed on high primary pressure system due to pressurizer heater bank number 3 being left in the manual mode too long following the charging of water to the primary system. Reactor brought critical shortly thereafter. PM-3A Operating Report Number 40; Malfunction 67-22.
27 Sep 67	Reactor scrammed while preparing to parallel the PM-3A with the McMurdo Diesel Plant. An apparent drop in frequency due to an unknown cause by the McMurdo Diesel Plant caused the reactor coolant pump to slow down and scrammed the reactor on low primary coolant flow. Reactor brought critical. PM-3A assumed McMurdo Station load. PM-3A Operating Report Number 40; Malfunction 67-23.
20 Sep - 08 Oct 67	Plant carried McMurdo Station load.
09 Oct 67	Began cycling plant for relief crew training.
12 Oct 67	Plant shutdown for core change. PM-3A Operating Report Number 41; Annex III.
13 Oct 67	Containment opened. CRDM removal started.
14 Oct 67	Completed CRDM removal.
16 Oct 67	Pressure vessel head removal completed. The old core was placed in the spent core tank.
18 Oct 67	New core installed in pressure vessel.
20 Oct 67	Completed replacement of pressure vessel head.
21 Oct 67	Completed installation of CRDM.
22 Oct 67	All control rod latching completed.
23 Oct 67	Initial criticality achieved with new Type II Core, and initial startup testing began. Reactor scrammed on short period. Control Rod Number 5 dropped from critical position. Reactor brought critical. PM-3A Operating Report Number 41; Malfunctions 67-24 and 67-25.
24 Oct 67	Reactor scrammed on short period. Reactor brought critical. PM-3A Operating Report Number 21; Malfunction 67-26.
25 Oct 67	Reactor scrammed when the McMurdo Diesel Plant opened the PM-3A tieline breaker. Reactor brought critical. Reactor scrammed when the McMurdo Diesel Plant's Number 2 Generator tripped off the line. PM-3A Operating Report Number 41; Malfunctions 67-27 and 67-28.

26 Oct 67	Reactor brought critical. Reactor scrammed when the auxiliary diesel generator tripped off the line. PM-3A Operating Report Number 41; Malfunction 67-29.
27 Oct 67	Reactor critical for testing.
28 Oct 67	Pressurizer level system out of calibration. Reactor scrammed on high primary system pressure. Sluggishness in control rod drive system. PM-3A Operating Report Number 41; Malfunctions 67-30, 67-31 and 67-32.
29 Oct - 01 Nov 67	Plant shutdown for maintenance.
02 Nov 67	Reactor brought critical, shutdown and brought critical again while undergoing rod drop tests.
03 Nov 67	Reactor twice shutdown and brought critical. The reactor scrammed due to a vital AC-DC system transient caused by an instrument technician momentarily shorting the 65V DC lines while connecting leads to the RWDS sump level indicator. PM-3A Operating Report Number 42; Malfunction 67-33.
04-29 Nov 67	Plant carried McMurdo Station load.
30 Nov 67	PM-3A assumed McMurdo Station load. PM-3A Operating Report Number 40; Malfunction 67-23.
30 Nov 67	PM-3A operated isolated while Public Works Department inspected the switching station breakers.
30 Nov - 01 Dec 67	Plant carried McMurdo Station load.
02 Dec 67	Reactor scrammed twice. The first scram was due to operator error when the reactor coolant pump was inadvertantly secured instead of the coolant charging pump. During scram recovery a second scram occurred when the nuclear instrumentation Channel Number 2 would not indicate properly in test position C due to low pulse amplifier gain. PM-3A Operating Report Number 43; Malfunctions 67-34 and 67-35.
03-27 Dec 67	Plant carried McMurdo Station load.
28 Dec 67	Reactor scrammed when an instrument technician accidently shorted out the Vital AC system with a screwdriver while he was replacing the cord on the control room operating net handset. Reactor critical and picked up McMurdo Station load. PM-3A Operating Report Number 43; Malfunction 67-36.
29 Dec 67 - 01 Jan 68	Plant carried McMurdo Station load.

1967 Summary

In January of this year the Primary Building addition was completed, and the new RWDS was installed within it.

A new record was established for continuous power operation of the PM-3A with a run of 3643:15 hours between 16 April and 15 September.

The Water Distillation Plant operated throughout the austral winter for the first time since its installation and produced a yearly total of 2,459,781 gallons of fresh water.

The PM-3A underwent its second core change in mid-October when the Type I Serial 1 Core was removed after 14,746 EFPH and replaced with the Type II Serial 1 Core with an expected life of 21,000 EFPH. In conjunction with the refueling, the ammonia based primary resins were replaced with neutral based resins. This reduced the primary system pH which resulted in less CRUD deposited throughout the system and less crevice corrosion.

During 1967 the majority of malfunctions and the longest down time periods could not be attributed to any one system. Many diverse incidents, such as a broken distribution line and a loose connection in an overspeed trip assembly, caused most of this year's problems.

02-17 Jan 68	PM-3A shutdown for scheduled turbine inspection and scheduled maintenance.
18 Jan 68	Reactor brought critical and shutdown due to the inability to maintain Primary System pressure above 950 psig. Defective pressurizer relief valves were found to be the cause. PM-3A Operating Report Number 44; Malfunction 68-1.
19-29 Jan 68	Plant carried McMurdo Station load.
30 Jan 68	Reactor scrammed due to operator error. An electrical technician was repairing the indicating light for the purification demineralizer isolation valve and accidently grounded the Vital AC/DC System. PM-3A Operating Report Number 45; Malfunction 68-2.
31 Jan - 10 Feb 68	Plant carried McMurdo Station load.
11-14 Feb 68	PM-3A shutdown to perform scheduled maintenance to the condensers and CRDMs.
15 Feb - 25 Mar 68	Plant carried McMurdo Station load.
26-30 Mar 68	PM-3A shutdown to perform unscheduled maintenance on the

	primary and secondary systems.
31 Mar 68	Plant carried McMurdo Station load.
01 Apr 68	Secondary system shutdown to perform unscheduled maintenance due to a steam leak. The cause of the malfunction was attributed to the failure of an isolation valve's packing due to age and infrequent operation of the valve. Reactor brought critical. PM-3A assumed McMurdo Station load. PM-3A Operating Report Number 47; Malfunction 68-8.
02 Apr - 20 Jun 68	Plant carried McMurdo Station load.
21 Jun 68	Reactor scrammed for no apparent reason. Suspected an electrical noise transient. PM-3A Operating Report Number 49; Malfunction 68-10.
22 Jun - 19 Jul 68	Plant carried McMurdo Station load.
19 Jul 68	Reactor in the process of shutdown. Plant scrammed because of the failure of the Gem Switches on the Steam Generator tank sump pumps and level alarm. Also an electrical test transient was introduced during the performance of test RS-6. PM-3A Operating Report Number 50; Malfunctions 68-12 and 68-13.
20-23 Jul 68	Plant shutdown.
24-26 Jul 68	Plant carried McMurdo Station load.
26 Jul 68	Reactor scrammed due to momentary distribution line arcing caused by high winds (gusting to 50 knots) which resulted in an electrical transient being felt by the PM-3A safety system. A second scram occurred during start-up due to an indicated short period on nuclear instrumentation channel number 3 as channel 3 came on scale. Improper adjustment of compensating voltage was found to be the cause. PM-3A Operating Report Number 50; Malfunctions 68-14 and 68-15.
26 Jul - 12 Sep 68	Plant carried McMurdo Station load.
13 Sep 68	Reactor scrammed. The cause was found to be a failure of the insulation in the electrical containment penetration supplying power to the reactor coolant pump. The failure caused an electrical short and ground faults in the penetration. As a result of the short, the reactor coolant pump breaker tripped and the scram occurred due to loss of pump power and low pump differential pressure. No spare

	penetration assemblies were available on site, and the problem was resolved by reconditioning the original assembly. The plant was returned to power on 23 September. PM-3A Operating Report Number 50; Malfunction 68-19.
14-22 Sep 68	Plant shutdown.
23-25 Sep 68	Plant carried McMurdo Station load.
26 Sep 68	Reactor shutdown. Feedwater pump number 1 tripped off the line because of a blown fuse. PM-3A Operating Report Number 50; Malfunction 68-22.
27 Sep - 15 Oct 68	Plant carried McMurdo Station load.
15 Oct 68	The site tieline breaker was manually opened to reduce KVAR load when the McMurdo Station Diesel Plant paralleled with voltage too low to assume any reactive electrical load.
15-18 Oct 68	Plant carried McMurdo Station load.
18-19 Oct 68	The secondary system was cycled eight times for replacement crew training by transferring the electrical load between the PM-3A and the McMurdo Station Diesel Plant.
19-21 Oct 68	PM-3A shutdown for maintenance work in the secondary system and the water distillation plant.
21-23 Oct 68	The primary system was cycled six times for replacement crew training.
23-24 Oct 68	Reactor critical. Performing core physics tests.
24 Oct - 20 Nov 68	Plant carried McMurdo Station load.
20 Nov 68	Reactor scrammed due to a transient period signal induced in nuclear instrumentation Channel Number 3. The instrument technician placed the drawer test switch in the test position while performing test RS-6. The test procedure RS-6 did not reflect the existence of the scram logic test toggle switch which would have prevented switching transients during the test. PM-3A Operating Report Number 51; Malfunctions 68-27 and 68-28.
21 Nov 68	Reactor critical. Nuclear instrumentation channel 4 became erratic, and an indicated transient period scram resulted. During startup nuclear instrumentation channel 6 failed to come on scale when steam was bypassed to raise power level into power range. PM-3A Operating Report Number 51; Malfunctions

	68-29 and 68-30.
21-24 Nov 68	Primary system cycled for replacement crew training. Core physics tests being performed.
24 Nov - 06 Dec 68	Plant carried McMurdo Station load.
06 Dec 68	Reactor scrammed. The reactor was critical and a planned secondary system shutdown was nearing completion. The McMurdo Station Diesel Plant was supplying McMurdo Station and PM-3A electrical loads. A low reactor coolant pump power scram occurred due to low frequency. One McMurdo Station diesel generator had tripped off the line. PM-3A Operating Report Number 51; Malfunction 68-32.
06-10 Dec 68	Plant carried McMurdo Station load.
10 Dec 68	Secondary system shutdown to repair steam leaks on two turbine steam lines. PM-3A assumed McMurdo Station load.
10 Dec 68 - 01 Jan 69	Plant carried McMurdo Station load.

1968 Summary

Electrical problems of many types such as blown fuses, electrical transients, shorts and line voltage swings were responsible for the majority of this year's malfunctions and down time periods. Each malfunction of an electrical nature was corrected to a satisfactory condition and every effort employed was directed towards non-recurrence of each situation.

A second flash evaporator unit was placed in service in the water distillation plant this year which enabled the yearly total to exceed 1967's by slightly over one million gallons. The yearly total of fresh water produced was 3,510,891 gallons.

Many changes to the PM-3A Technical Manuals were initiated during 1968. New welding procedures, developed by NAVNUPWRU, were approved by NAVFACENGCOM and incorporated into the PM-3A Maintenance Manual. Also, a new Health Physics Manual was drafted to replace the older edition.

01-02 Jan 69	Reactor scrammed. Failure of the pin connection of the K-11 relay in the signal generator and logic drawer resulted in loss of power to control rod number one grip coils, causing the rod to drop. Reactor brought critical. PM-3A assumed McMurdo Station load. PM-3A Operating Report Number 51; Malfunctions 69-1 and 69-2.

02-15 Jan 69	Plant carried McMurdo Station load.
15 Jan - 21 Feb 69	PM-3A shutdown for annual maintenance. The containment air leak rate test was performed during this shutdown. (An unexplained displacement of shield water occurred during this procedure. Investigation of the loss is detailed in the 1969 summary.)
22 Feb 69	Plant carried McMurdo Station load.
23 Feb 69	PM-3A on the line supplying PM-3A (plant), Maintenance and Supply building, and the water distillation plant with electrical power while maintenance was being performed on the McMurdo Station electrical distribution system.
23 Feb - 07 Mar 69	Plant carried McMurdo Station load.
07-08 Mar 69	PM-3A shutdown because of a leak that developed in the feedwater line at the flow nozzle caused by erosion. PM-3A Operating Report Number 52, Malfunction 69-9.
08 Mar 69	Reactor brought critical.
09-13 Mar 69	Plant carried McMurdo Station load.
13 Mar 69	PM-3A Secondary Systems shutdown. A union in the gland seal piping for the low pressure end of the turbine began leaking due to normal wear and steam erosion of the union. PM-3A assumed McMurdo Station load. PM-3A Operating Report Number 52, Malfunction 69-12.
13-23 Mar 69	Plant carried McMurdo Station load.
23 Mar 69	Reactor scrammed due to a transient noise signal tripping two of the three high reactor outlet temperature bistables. PM-3A Operating Report Number 52, Malfunction 69-15.
23 Mar - 02 Jun 69	Plant carried McMurdo Station load.
02-04 Jun 69	PM-3A shutdown due to an excessive primary system leak rate. The problem was traced to the lower flange on the pressurizer level datum column. The cause was attributed to improper torquing and misalignment of the flange gasket. PM-3A Operating Report Number 53; Malfunction 69-16.
05 Jun 69	Reactor brought critical.
06-14 Jun 69	Plant carried McMurdo Station load.

14-15 Jun 69	PM-3A shutdown because the reactor coolant pump differential pressure indicator drifted downscale due to a faulty D/P cell and loose linkage in the transducer unit of the pressure transmitter. PM-3A Operating Report Number 53; Malfunction 69-20.
16 Jun - 21 Jul 69	Plant carried McMurdo Station load.
21 Jul 69	Reactor scrammed due to a transient that was induced when an instrument technician moved a loose wire while performing PM-3A Test Procedure RS-6. Reactor brought critical. PM-3A assumed McMurdo Station load. PM-3A Operating Report Number 54; Malfunction 69-23.
21 Jul - 02 Aug 69	Plant carried McMurdo Station load.
02-05 Aug 69	PM-3A shutdown. The feedwater line developed a leak at the southeast corner of the primary building and was blowing steam and water. PM-3A Operating Report Number 54; Malfunction 69-25.
06 Aug 69	Reactor critical.
07-09 Aug 69	Plant carried McMurdo Station load.
09-10 Aug 69	PM-3A shutdown due to excessive primary system leakage across the gasket seat surface of the CRDM in Port One. PM-3A Operating Report Number 54; Malfunction 69-30.
11 Aug 69	Reactor Critical.
12 Aug - 22 Oct 69	Plant carried McMurdo Station load.
22 Oct 69	While preparing for a planned overlap training shutdown, the reactor scrammed due to coincident occurrences of transient pulses and test pulses during the performance of PM-3A Test Procedure RS-6. PM-3A Operating Report Number 55; Malfunction 69-33.
22-26 Oct 69	PM-3A shutdown.
26-27 Oct 69	The primary system was cycled for replacement crew training.
27-28 Oct 69	The secondary system was cycled for replacement crew training.
28 Oct 69	Reactor manually scrammed due to the dropping of control rod number one. It is believed that high temperature in

	the CRDM drawer for control rod number one caused the loss of power to this rod. Reactor brought critical. PM-3A Operating Report Number 55; Malfunction 69-37.
29 Oct - 05 Nov 69	Plant carried McMurdo Station load.
05-06 Nov 69	Secondary system shutdown due to a leak in the feedwater line in the Primary Building. The leak was attributed to a faulty weld joint which was made as a result of malfunction 69-25. PM-3A assumed McMurdo Station load. PM-3A Operating Report Number 55; Malfunction 69-39.
06-26 Nov 69	Plant carried McMurdo Station load.
26 Nov 69	The site tieline breaker was opened for CBU 201 to facilitate relocation of Switching Station Number One (Work Project M-50).
27 Nov - 05 Dec 69	Plant carried McMurdo Station load.
05 Dec 69	Reactor shutdown for NAVFACENGCOM inspection. Reactor brought critical.
06 Dec 69	Plant carried McMurdo Station load.
07-08 Dec 69	The site tieline breaker was opened in order that CBU 201 could continue Work Project M-50.
08-17 Dec 69	Plant carried McMurdo Station load.
17 Dec 69 - 27 Jan 70	Reactor scrammed on a low reactor coolant flow due to a low voltage condition. The Control Room Operator had inadvertently over adjusted the main generator voltage regulator. While attempting to assume plant load subsequent to the scram, the plant had to be shutdown due to loss of governor speed control on the main turbine generator. The loss of control was caused by erosion of the steam chest casing around the valve seats which permitted steam flow in excess of the amount required to maintain the turbine at low speed stop. This resulted in an overspeed trip of the turbine. It was decided to begin the annual maintenance shutdown. PM-3A Operating Report Number 55; Malfunctions 69-44 and 69-46.

1969 Summary

During 1969, mechanically oriented problems far surpassed any other type of malfunction in contributing to down time at the PM-3A. Repeated problems were encountered with feedwater line breaks and steam erosion in the turbine. Work Project 69-5, however, provided for the procurement of materials and replacement of eroded components in the feedwater system piping, and Work Project 69-7 called for the procurement of materials for a complete overhaul of the turbine-generator unit.

During the January 1969 containment air leak test, a displacement of approximately 510 gallons of shield water occurred. This corresponded to a loss at the rate of 0.15 gpm during the 60 hour test. Shield water leakage of 275 gallons was also observed during the leak test of November 1965. An exhaustive investigation of all water leakage paths failed to account for the 510 gallons.

A review of the test data showed that the leak rate was essentially constant indicating the water leakage path was below shield water level. PM-3A Monthly Operating Report Number 7 describes cracks and holes which were discovered and repaired in December 1964 in the stainless steel liner of the interconnect between the reactor and spent fuel tanks. The possibility existed that additional imperfections had occurred since 1964 or were present at the time and were not detected. After an analysis of possible leak paths from containment, it was concluded that the most likely location was the interconnect region and that the displaced shield water had leaked from containment directly into the backfill.

It was determined that under the PM-3A postulated maximum credible accident conditions, the opening that was responsible for a loss of 510 gallons during containment air leak testing would pass approximately 850 gallons in the 72 hour containment cooldown period. To conservatively avoid exposing the leak opening to containment gas during a postulated maximum credible accident, the shield water low level alarm was set at a value which was 850 gallons above the lower level experienced during containment air leak testing. The top of the interconnect was about 60 inches below the shield water level, amounting to a reservoir of some 4000 gallons above the places considered to be the most likely location of the leak.

A more detailed containment inspection completed in January 1970 revealed the source of the problem, as suspected, to be cracks and pits in the welds and on the surfaces of the interconnect. Welding repairs were implemented during DEEP FREEZE 70 austral summer with satisfactory results, and it was decided to perform periscope inspections of the interconnect area on a continuing basis.

On the first of March 1969, hydrogen addition to the primary system was terminated. As of December 1969, the oxygen concentration had been maintained between zero and 15 PPB. The hydrogen concentration gradually decreased to approximately 5-15 cc/kg, where it leveled off. Changes to the hydrogen and oxygen concentration operating limits were made in January 1970.

A total of 5,237,671 gallons of fresh water was produced by the Water Distillation Plant during 1969. This represented an increase of 1.7

million gallons over the previous year's output.

27 Jan 70	Reactor critical for startup testing.
28 Jan 70	PM-3A assumed plant load.
29-31 Jan 70	Plant carried McMurdo Station load.
31 Jan 70	Reactor scrammed on low primary pressure due to an improper set point on the low pressure scram bistable. PM-3A Operating Report Number 56; Malfunction 70-11.
31 Jan - 09 Feb 70	PM-3A shutdown to facilitate the installation of 22-turn potentiometers on all type "A" and "M" bistables. This action was a direct result of Malfunction 70-11. Also during this period, the shield water was found to be clouded with suspended solids.
10 Feb - 04 Apr 70	Plant carried McMurdo Station load.
04 Apr 70	Reactor scrammed. The turbine governor failed causing a scram from full power operations. Preliminary investigation revealed failure of the governor upper pilot valve. PM-3A Operating Report Number 56; Malfunction 70-23.
05-08 Apr 70	PM-3A shutdown so that further investigation and work could be accomplished on the turbine governor.
09 Apr 70	Reactor brought critical.
10 Apr - 07 May 70	Plant carried McMurdo Station load.
07 May 70	Main turbine generator shutdown. A steam leak had developed across the turbine throttle valve drain line flange. The flexatallic gasket in the flange, which had failed, was replaced. PM-3A assumed McMurdo Station load. PM-3A Operating Report Number 57; Malfunction 70-27.
07 May - 20 Jun 70	Plant carried McMurdo Station load.
21 Jun - 08 Jul 70	PM-3A shutdown for refueling with Type IV Core. PM-3A Operating Report Number 58; Appendix D.
08-15 Jul 70	Pre-startup testing and core physics testing of Type IV Core.
15-18 Jul 70	Plant carried McMurdo Station load.

18 Jul 70	Secondary system shutdown for core physics testing.
18 Jul - 17 Sep 70	Plant carried McMurdo Station load.
17 Sep 70	Reactor scrammed. An instrument technician inadvertently caused a transient in the vital AC/DC system while making an adjustment to the reactor temperature resistence/current converter. Reactor brought critical. PM-3A assumed McMurdo Station load. PM-3A Operating Report Number 58; Malfunction 70-42.
17 Sep - 02 Oct 70	Plant carried McMurdo Station load.
02 Oct 70	PM-3A shutdown for scheduled maintenance. There was a high primary system leak rate through the pressurizer vent and drain valves. PM-3A Operating Report Number 58; Malfunction 70-47.
03 Oct 70	Reactor brought critical.
04 Oct 70	PM-3A assumed McMurdo Station load. Reactor scrammed on low primary coolant flow. A plugged sensor element leg at the D/P cell caused oscillations in the steam generator level when the control system was in the automatic mode. The operator failed to take corrective action when the sensing element indicated system failure. Reactor critical. PM-3A Operating Report Number 59; Malfunction 70-48.
04-05 Oct 70	Plant carried McMurdo Station load.
05-06 Oct 70	Plant secondary system shutdown due to a leak around three studs at the high pressure end of the turbine directly under the steam chest. The leak was temporarily repaired and PM-3A assumed McMurdo Station load. PM-3A Operating Report Number 59; Malfunction 70-49.
06-19 Oct 70	Plant carried McMurdo Station load.
19 Oct 70	Reactor scrammed on low flow due to decreased frequency. Adjustment of the turbine governor servo motor oil pressure was inadvertently increased rather than decreased. Reactor critical. PM-3A assumed McMurdo Station load. PM-3A Operating Report Number 59; Malfunction 70-50.
19-22 Oct 70	Plant carried McMurdo Station load.
22-26 Oct 70	Primary system being cycled for replacement crew training.
26-28 Oct 70	An unscheduled delay in startup was caused by a steam

	generator blowdown activity level higher than the acceptable upper limit. Reactor critical. PM-3A Operating Report Number 59; Malfunction 70-51.
28-29 Oct 70	PM-3A on the line for power operation and load transfer training.
29 Oct 70	Reactor scrammed due to a blown fuse in the control rod actuator cabinet. Reactor critical. PM-3A Operating Report Number 59; Malfunction 70-52.
29-30 Oct 70	Secondary system cycled for training.
30 Oct - 01 Nov 70	Plant carried McMurdo Station load.
01-03 Nov 70	Reactor shutdown. During test PS-5 (Pressurizer level calibration), level elements "A" and "B" showed a 4 inch difference. Due to the inability to ascertain actual level, a planned shutdown was initiated and the level system repaired. Reactor critical. PM-3A Operating Report Number 59; Malfunction 70-53.
03 Nov 70	Secondary system cycled for training.
03-10 Nov 70	Plant carried McMurdo Station load.
10 Nov 70	Reactor scrammed. While making voltage checks, the instrument technician shorted out the 24 volt power supplies. The short caused a transient in the vital AC/DC system which resulted in the scram. PM-3A Operating Report Number 59; Malfunction 70-56.
11-25 Nov 70	Plant carried McMurdo Station load.
25 Nov 70	Reactor scrammed. While removing a D/P cell for cleaning, an instrument technician shorted out the 65 volt power supplies. The short caused a low voltage transient in the vital AC/DC system which resulted in the scram. Reactor critical. PM-3A assumed McMurdo Station load. PM-3A Operating Report Number 59; Malfunction 70-58.
25-28 Nov 70	Plant carried McMurdo Station load.
28-29 Nov 70	Site tie breaker opened. The site tie breaker tripped after replacement of a phase over-current relay. Incorrect wiring was found to be the cause. PM-3A Operating Report Number 59; Malfunction 70-60.
29 Nov 70	Plant carried McMurdo Station load. Reactor scrammed. While replacing the RWDS sump tank level D/P cell, an

	instrument technician shorted out the 65 volt power supplied. The short caused a transient in the Vital AC/DC system which resulted in the scram. PM-3A Operating Report Number 59; Malfunction 70-61.
29 Nov - 04 Dec 70	Reactor critical. A delay in startup was caused by an increase in the steam generator blowdown activity level above the operating limit. PM-3A Operating Report Number 59; Malfunction 70-62.
04-05 Dec 70	Reactor shutdown. An instrument technician was performing the scram logic circuitry test and a logic gate associated with the test failed. The failure allowed the test pulses to pass through the low pressure scram logic gate into the safety system. PM-3A Operating Report Number 59; Malfunction 70-63.
05 Dec 70- 02 Jan 71	Reactor shutdown. A leak in the RWDS evaporator tubes was discovered on 27 Nov while the system was shutdown for cleaning. A backlog of radioactive waste water, caused by the above occurrence, filled waste water storage facilities leaving no storage space. It was decided to remain shutdown for annual maintenance, repair, and overhaul. PM-3A Operating Report Number 59; Malfunctions 70-59 and 70-65.

1970 Summary

During 1970, the PM-3A experienced several mechanical malfunctions. The turbine generator, which was scheduled for complete overhaul in February 1971, caused many problems throughout the year. The biggest mechanical problem during the year dealt with the RWDS evaporator tube leak. It caused early initiation of the annual maintenance shutdown and created severe problems with elevated steam generator blowdown activity, delaying several startups during the year.

A revision of the PM-3A Operating Limits Manual was approved by NAVFACENGCOM during December 1970. The purpose of the revision was to provide a much clearer meaning as to what the operating limits were and what action was to be taken when a limit was violated.

This period also marked the fourth calendar year of water distillation plant operation under PM-3A management. A total of 5,459,555 gallons of fresh water was produced during 1970, an increase of 221,864 gallons over the previous year's production.

03-19 Jan 71	PM-3A shutdown for annual maintenance.
19-21 Jan 71	Reactor critical for startup testing.

21-22 Jan 71	Reactor shutdown. Deposits from the steam generator acid cleaning plugged the steam generator level sensing line causing the level indication to increase while the actual level decreased. The D/P cells were cleaned and the sensor lines replaced. PM-3A Operating Report Number 60; Malfunction 71-2.
22-23 Jan 71	Reactor critical for startup testing.
23 Jan 71	Reactor scrammed. Incorrect settings of the protective relay caused the transformer secondary breaker to trip and scram the reactor. The relays were recalibrated. PM-3A Operating Report Number 60; Malfunction 71-3.
23-24 Jan 71	Reactor critical for startup testing.
24 Jan - 15 Feb 71	Reactor manually scrammed. Control Rod Number 3 could not be withdrawn above 14.40 inches. Subsequent to this malfunction and during attempts to restart, problems with pressurizer level elements, broken wires and a plugged steam generator level sensing system caused a substantial delay. PM-3A Operating Report Number 60; Malfunction 71-4, 71-5, 71-6, 71-7, and 71-8.
15 Feb 71	Reactor critical for startup testing.
15-19 Feb 71	Reactor manually shutdown. The pressurizer level elements, "A" and "B" indicated a discrepancy in level. Inability to determine calibration points dictated a manual shutdown of the plant. During recovery from this malfunction, a leak caused by erosion was discovered in the feedwater line. The damaged pipe was replaced and the system hydrostatically tested and returned to service. PM-3A Operating Report Number 60; Malfunctions 71-9 and 71-10.
19-21 Feb 71	Reactor critical. Condenser Number 2 would not maintain the proper temperature and differential pressure. Investigations indicated that a previously plugged tube had blown out. The plug was replaced and the condenser returned to service. While work was being completed on the blown plug, it was discovered that the turbine speed could not be increased to the overspeed trip point, with either the local control at the turbine or with the remote control on the control room console. The governor was replaced. PM-3A Operating Report Number 60; Malfunctions 71-11 and 71-12.
21 Feb - 02 Mar 71	Plant carried McMurdo Station load. On 21 February the single speed fan for Number 2 Condenser tripped causing a vacuum loss in the turbine exhaust trunk. The motor leads were reterminated and the condenser was returned to service. Six days later the exact same malfunction shutdown Condenser

	Number 3. PM-3A Operating Report Number 60; Malfunctions 71-13 and 71-14.
02-03 Mar 71	Reactor manually scrammed. The scram logic test indicated a failure of the rod interlock amplifier. A failed diode in the test circuit was replaced. Less than an hour after the scram and while electrical power for the PM-3A complex was being provided by the auxiliary 250 KW diesel, the automatic transfer coil in Switching Station Number 1 overheated and caught on fire. PM-3A Operating Report Number 60; Malfunctions 71-15 and 71-16.
03-07 Mar 71	Plant carried McMurdo Station load.
07-08 Mar 71	Secondary system shutdown. A steam leak developed at the upstream blockvalve for the turbine bypass valve. The valve bonnet was removed and a blank flange was installed in its place. PM-3A Operating Report Number 60; Malfunction 71-18.
08-18 Mar 71	Plant carried McMurdo Station load.
18-21 Mar 71	PM-3A shutdown because of excessive deviation between pressurizer elements "A" and "B". During startup on the 21st, rod position indicator for control rod number six failed to follow the movement of the control rod. The servo amplifier was changed and the position indicator returned to normal. In addition a reactor coolant leak occurred at the solenoid operated pressurizer drain/vent valve. A new crush-ring was installed with satisfactory results. PM-3A Operating Report Number 60; Malfunctions 71-21, 71-22 and 71-23.
21-23 Mar 71	Plant carried McMurdo Station load.
23-25 Mar 71	Reactor shutdown. Rod position indicator for Control Rod Number 6 failed to follow the movement of the control rod. Attempts to correct the problem from outside containment were unsuccessful, and the reactor had to be shutdown. Reactor critical. PM-3A assumed McMurdo Station load. PM-3A Operating Report Number 60; Malfunction 71-24.
25 Mar - 24 Sept 71	PM-3A on the line for power operations producing a record run of 4400 hours 20 minutes.
24 Sep - 01 Oct 71	PM-3A shutdown for scheduled and unscheduled maintenance to both the primary and secondary systems.
01-14 Oct 71	Plant carried McMurdo Station load.
14-23 Oct 71	PM-3A shutdown for crew training.
23-28 Oct 71	Plant carried McMurdo Station load.

28-31 Oct 71	Reactor scrammed. While removing the face plate on the pressurizer level indicator an instrument technician inadvertently shorted out the 65 volt power supply on the indicator. This caused a transient voltage drop on the 65 volt system and a reactor scram. Reactor critical. PM-3A assumed McMurdo Station load. PM-3A Operating Report Number 63; Malfunction 71-48.
31 Oct - 02 Nov 71	Plant carried McMurdo Station load.
02-06 Nov 71	Reactor manually scrammed. A fire was discovered in the exciter end of the main generator. After the fire was extinguished by the fixed pipe CO 2 system it was found that a 4160 volt lead had burned in two at a connector at the top of the main generator and had destroyed approximately ten feet of cable. A loose connection was determined to be the cause of the fire. PM-3A Operating Report Number 63; Malfunction 71-50.
06 Nov 71	Reactor critical. Reactor manually scrammed. While conducting a test of the pressurizer level D/P cells, the control room operator noticed smoke coming from the servo amplifier 20 volt power supply. Further investigation disclosed that two electrolytic capacitors in the servo amplifier for Control Rod Number 1 had been installed with reversed polarity and consequently caused the failure of the other components. The component failures caused excessive current to be drawn by the amplifier power supply, thus resulting in overheating and smoking. PM-3A Operating Report Number 63; Malfunction 71-51.
07-10 Nov 71	Reactor critical.
10 Nov - 12 Dec 71	Plant carried McMurdo Station load.
12 Dec 71	Reactor shutdown for NAVFACENGCOM inspection.
13 Dec 71	Reactor brought critical. PM-3A assumed McMurdo Station load.
14 Dec 71	Reactor manually scrammed. While performing the rod drop time test (RC-1) on Control Rod Number 1 the source range count rate unexpectedly dropped downscale, and the position indicator stopped moving. Investigation of the CRDM drawer for Control Rod Number 1 revealed several failed electronic components in the servo amplifier power supply. PM-3A Operating Report Number 63; Malfunction 71-54.
14 Dec 71 - 24 Jan 72	PM-3A shutdown for annual maintenance.

1971 Summary

In the first quarter of 1971, several problems were encountered with the pressurizer and steam generator level elements. The problems associated with the pressurizer level elements were attributed to misinterpretation of an alignment procedure. This was corrected and the procedures performed as written.

The majority of the down time at the PM-3A during 1971 was attributed to problems associated with CRDM electronics.

The tank RWDS evaporator coil replacement work project was scheduled for the DEEP FREEZE 74 austral summer season due to the long lead time for coil procurement. New temporary operating limits for steam generator blowdown activity were approved by NAVFACENGCOM, and a conceptual design for a PM-3A Emergency Core Cooling System was formulated as the basis for final design, installation, and operation specifications. A work project was established during the last quarter of 1971 to provide materials for the system.

A new power run record for a military operated shore based nuclear power plant was established by the PM-3A between 25 March 1971 and 24 September 1971. The record run was 4400.3 hours of continuous operation. In addition, 5,096,417 gallons of fresh water were produced by the Water Distillation Plant during the year.

24 Jan 72	Reactor critical. Reactor shutdown. While performing test procedure PS-5 (Pressurizer Level Calibration) it was noted that no increase in upper calibration heater temperature was seen as the indicated upper quench point was uncovered. The pressurizer level indication meter was found to be defective and was replaced. Reactor critical. PM-3A Operating Report Number 64; Malfunction 72-1.
25-28 Jan 72	Reactor shutdown. The operating watch was performing test procedure PS-5. Charging Pump Number 2 was started to regain pressurizer level, but no level increase was noted. Charging Pump Number 1 was started with the same results. It was discovered that improper gaskets had been installed in two valves of the charging system. PM-3A Operating Report Number 64; Malfunction 72-2.
29 Jan 72	Reactor Critical.
30 Jan 72	PM-3A assumed plant load.
31 Jan 72	PM-3A assumed McMurdo Station load. Reactor scrammed. While removing a thermocouple extension wire from behind the control console an instrument technician inadvertently shorted out the 65 volt power supply, thus causing a transient

	voltage drop and a reactor scram. Reactor critical. PM-3A Operating Report Number 64; Malfunction 72-4.
01 Feb - 03 Mar 72	Plant carried McMurdo Station load.
03 Mar 72	Reactor scrammed. During a severe storm several electrical faults occurred in the McMurdo Station electrical system. These faults caused erroneous transient signals in the reactor safety system which in turn scrammed the reactor. PM-3A Operating Report Number 64; Malfunction 72-7.
04 Mar 72	Reactor critical.
05-19 Mar 72	Plant carried McMurdo Station load.
19 Mar 72	Reactor shutdown. An increase was noted in the frequency of operation of the containment sump pumps along with an increase in secondary water usage. Further investigation inside containment revealed a leak at a weld on the feedwater line. The weld was repaired and the system returned to service. PM-3A Operating Report Number 64; Malfunction 72-8.
19-24 Mar 72	PM-3A shutdown. [Containment was closed and a bubble had been formed in the pressurizer. The McMurdo Public Works electrical shop was in the process of relocating some of the 4160 volt power lines, thus requiring the PM-3A Auxiliary diesel generator to provide power to the M & S building, water distillation plant, fresh water line heat tapes, salt water pump house heaters, and the PM-3A. Total load on the auxiliary generator was 375 amperes. The load on the generator had been trimmed as much as possible, and in order to proceed with a startup it would have required securing power to the M & S and Water Distillation Buildings. Also, the heat tapes on all water lines to McMurdo would have to have been secured and the lines drained. Since the power line relocation was due to be completed within 12 hours, the reactor startup was delayed.] Upon completion of the relocation project the PM-3A proceeded with a normal startup. PM-3A Operating Report Number 64; Malfunction 72-9.
24-31 Mar 72	Plant carried McMurdo Station load.
31 Mar - 01 Apr 72	PM-3A shutdown. The position indicator for Control Rod Number 1 became erratic, and a new position indicator can was installed. PM-3A Operating Report Number 64; Malfunction 72-12.
02-05 Apr 72	PM-3A shutdown. A leak developed in the pressurizer vent drain system due to badly galled threads on a component of the reactor drain valve. PM-3A Operating Report Number 65; Malfunction 72-14.

05-09 Apr 72	Plant carried McMurdo Station load.
09 Apr 72	Reactor scrammed. Following the operation of the emergency diesel generator for training, the control room operator erroneously opened the transformer secondary breaker resulting in a reactor scram. PM-3A Operating Report Number 65; Malfunction 72-15.
09-19 Apr 72	Plant carried McMurdo Station load.
19-25 Apr 72	Reactor scrammed. Deterioration of the power cable to the coil can for Control Rod Number 1 caused the control rod to drop and required a reactor scram. PM-3A Operating Report Number 65; Malfunction 72-16.
25-28 Apr 72	Reactor critical. Reactor shutdown. Moisture in the coil can cable connectors for Control Rod Number 4 caused the control rod to respond improperly. PM-3A Operating Report Number 65; Malfunction 72-17.
28-30 Apr 72	Plant carried McMurdo Station load.
30 Apr - 03 May 72	Reactor scrammed. An instrument technician inadvertently shorted out the 24 volt power supply while performing maintenance. During reactor startup following the scram it was noticed that Control Rod Number 6 responded improperly. Moisture and corrosion in the coil can cable connectors was found to be the cause. PM-3A Operating Report Number 65; Malfunctions 72-18 and 72-19.
04-10 May 72	Plant carried McMurdo Station load.
10-19 May 72	PM-3A shutdown. A failure in the control rod drive grip circuitry of control rods one and three dictated a controlled shutdown for necessary repairs. A delay in startup occurred when burned insulation on several wires inside coil can serial 207 was discovered. PM-3A Operating Report Number 65; Malfunctions 72-20 and 72-21.
19-20 May 72	Plant carried McMurdo Station load.
20 May 72	Reactor manually scrammed. Extreme secondary system cycling, apparently caused by excessive steam flow to the deaerator tank, resulted in a low steam generator level and a manual reactor scram. PM-3A Operating Report Number 65; Malfunction 72-22.
20 May - 18 Sep 72	Plant carried McMurdo Station load.

18 Sep – 16 Oct 72	PM-3A shutdown for scheduled maintenance in the primary and secondary systems. During a routine inspection of the steam generator tank, water seepage was discovered at the lower interconnect between the reactor and steam generator tanks. Upon investigation, the seepage was located at the collar of the reactor outlet nozzle insulation shell assembly. PM-3A Operating Report Number 66; Malfunction 72-26.
16 Oct 72	Reactor critical for crew overlap training.
17-22 Oct 72	PM-3A shutdown for further investigation of interconnect water seepage.
22-26 Oct 72	Reactor critical for crew overlap training.
26 Oct 72 – 30 Jun 73	Reactor shutdown pending results of independent laboratory analysis of the probability of chloride stress corrosion cracking to the stainless steel primary system piping. PM-3A Operating Report Number 67, Appendix I.

1972 Summary

During the first quarter of the year, many problems were encountered with the CRDMs. These problems were primarily attributed to deterioration of the cables and their associated connectors.

Due to the existence of a confirmed leak in the tank mounted RWDS evaporator steam coil that could not be repaired until DEEP FREEZE 73 summer season, the total primary system decontamination planned for the summer of DEEP FREEZE 72 was postponed until such time as the evaporator would be fully operable. In the interim, a supplementary decontamination procedure was carried out which made possible an on-site evaluation of the major decontamination procedure and materials while providing a subtantially smaller amount of contaminated water for processing. This supplementary procedure was to result in decontamination of the economizer shell, the purification cooler tubes and the delay tank. Overall, the limited decontamination project had only marginal results and involved total personnel exposure of 10.209 REM. Accordingly, decontamination of the entire primary loop was not considered feasible or justifiable and planned additional work was cancelled.

A controlled shutdown for scheduled maintenance was initiated on 18 September during which period a failure within the reactor outlet insulation canning was discovered. It was determined that the possibility of chloride stress corrosion cracking existed, and a civilian firm was contracted to perform extensive on site investigations prior to PM-3A returning to power.

A total of 5,967,898 gallons of fresh water was produced by the Water Distillation Plant.

01 Jul 73	Defueling procedure initiated.
05 Jul 73	Defueling procedure successfully completed.
06 Jul - 09 Oct 73	PM-3A in Cold Iron Status.
10 Oct 73	Initiated PM-3A Removal Plan.

APPENDIX G

REMOVAL PLAN

REMOVAL PLAN
FOR THE
PM-3A NUCLEAR POWER PLANT McMURDO STATION ANTARCTICA

Prepared by:

NAVAL NUCLEAR POWER UNIT
P. O. BOX 96
FORT BELVOIR VIRGINIA—22060

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

SEPTEMBER 1973

REMOVAL PLAN
FOR THE
PM-3A NUCLEAR POWER PLANT
McMURDO STATION, ANTARCTICA

SEPTEMBER 1973

Prepared By:

Naval Nuclear Power Unit
Fort Belvoir, VA 22060

Approved By:

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CDR, CEC, USN
Director, Nuclear Power Division
Naval Facilities Engineering Command

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PREFACE

The removal of the PM-3A Nuclear Power Plant from McMurdo Station, Antarctica will be an extremely complex task extending over a period of several years. The severe Antarctic climate, limited operating season and logistics problems all add to the inherent problems of dismantling and shipping radioactive reactor components.

The purpose of the Removal Plan is to provide an outline of the scope of this project with a general description of the work to be performed and the proposed methods to be employed in dismantling and removing the PM-3A Nuclear Power Plant from Antarctica. Only major tasks and items of significance are discussed.

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I. BACKGROUND

A. Plant Description

The PM-3A Nuclear Power Plant is located at McMurdo Station, Antarctica (Figure 1). As shown in Figure 2, the site is on a plateau 300 feet above sea level overlooking the Ross Sea and McMurdo Station.

The plant is divided into two major areas, primary and secondary, to provide maximum control of radioactive contamination. Physical plant arrangement is shown in Figure 3.

The majority of the primary system components are located in four steel containment vessels as shown in Figure 4. These vessels are interconnected and sealed to form a vapor retaining area having a void volume of approximately 3,300 cubic feet.

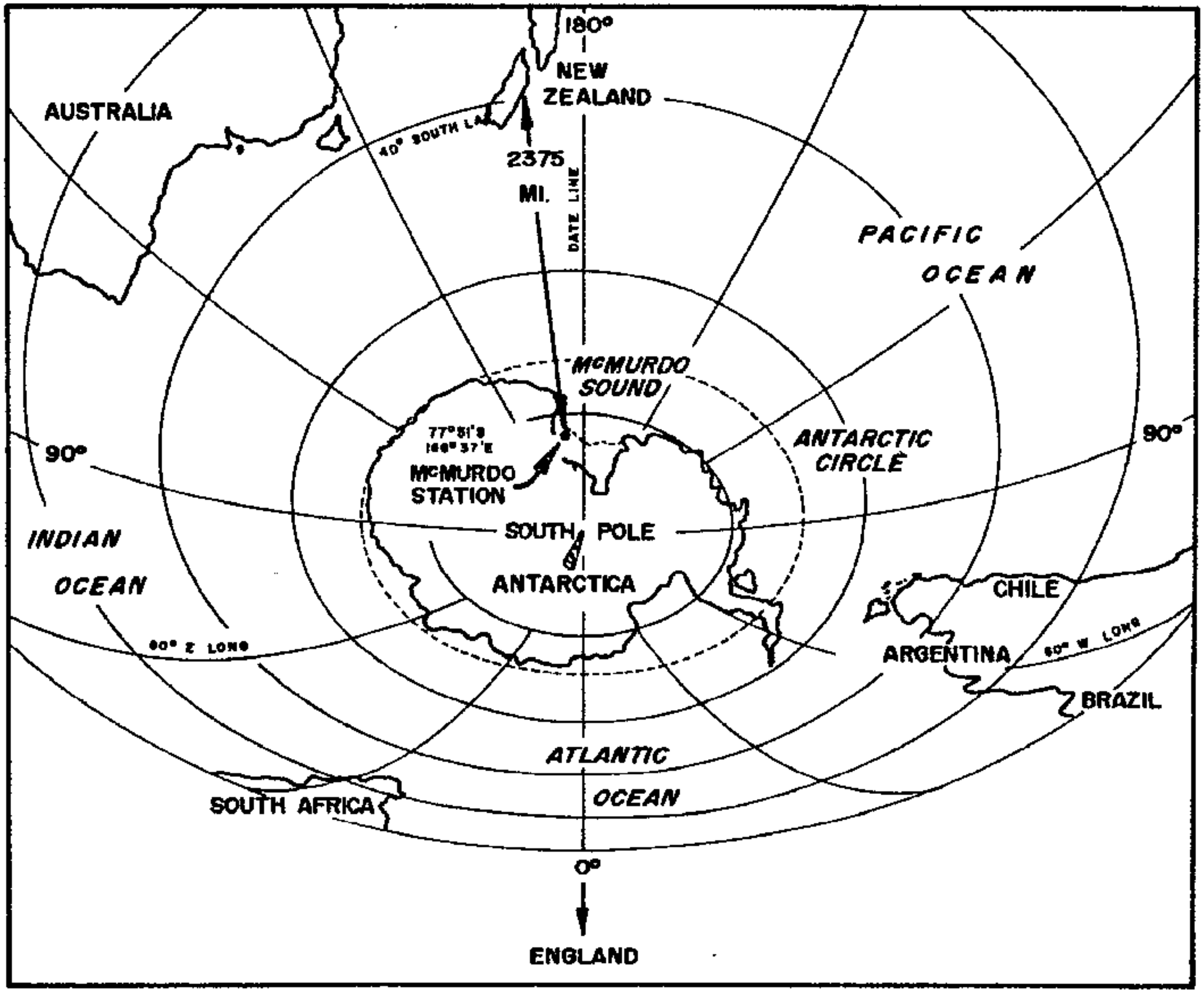
Secondary system components and four air cooled condensers are located in two buildings adjacent to the primary building. The two buildings contain the majority of the non-nuclear supporting equipment required for power plant operations.

The plant's pressurized water reactor has a thermal output of 11.27 Mw. The plant is rated for an electrical output of 1800 KW at a 0.8 power factor. In addition to producing electrical power, steam from the plant is used in the operation of the water distillation plant.

The PM-3A was designed as a portable nuclear power plant capable of being air transported in C-130 aircraft. Plant systems were designed under the concept that disassembly, packing and transportation would be accomplished with minimum difficulty. The plant was transported to McMurdo by ship in 20 basic modular packages of 15 tons maximum and several crates containing approximately 45 tons of miscellaneous equipment.

B. Operating History

The PM-3A was designed and constructed by the Martin Nuclear Company. The plant was transported to McMurdo Station by ship and arrived on site 12 December 1961. First criticality was achieved on 3 March 1962, 81 days after arrival. On 10 July 1962, the first electric power was provided by the PM-3A. The plant was operated by Navy crews under the direction of the Martin Company and AEC until



MAP of the SOUTH LATTITUDES

FIGURE 1

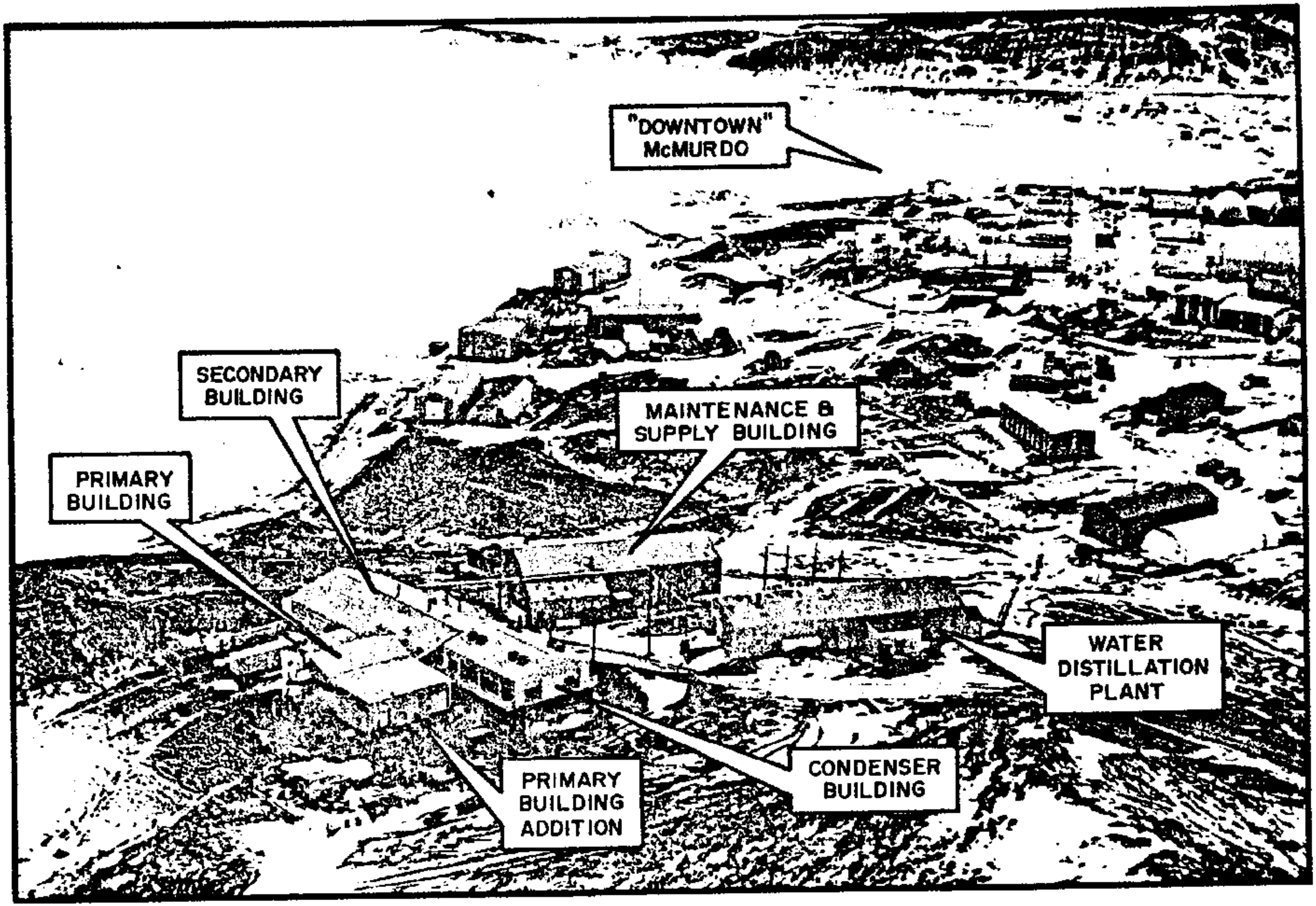


FIGURE 2

Site Of The PM-3A Nuclear Power Plant
McMurdo Station, Antarctica

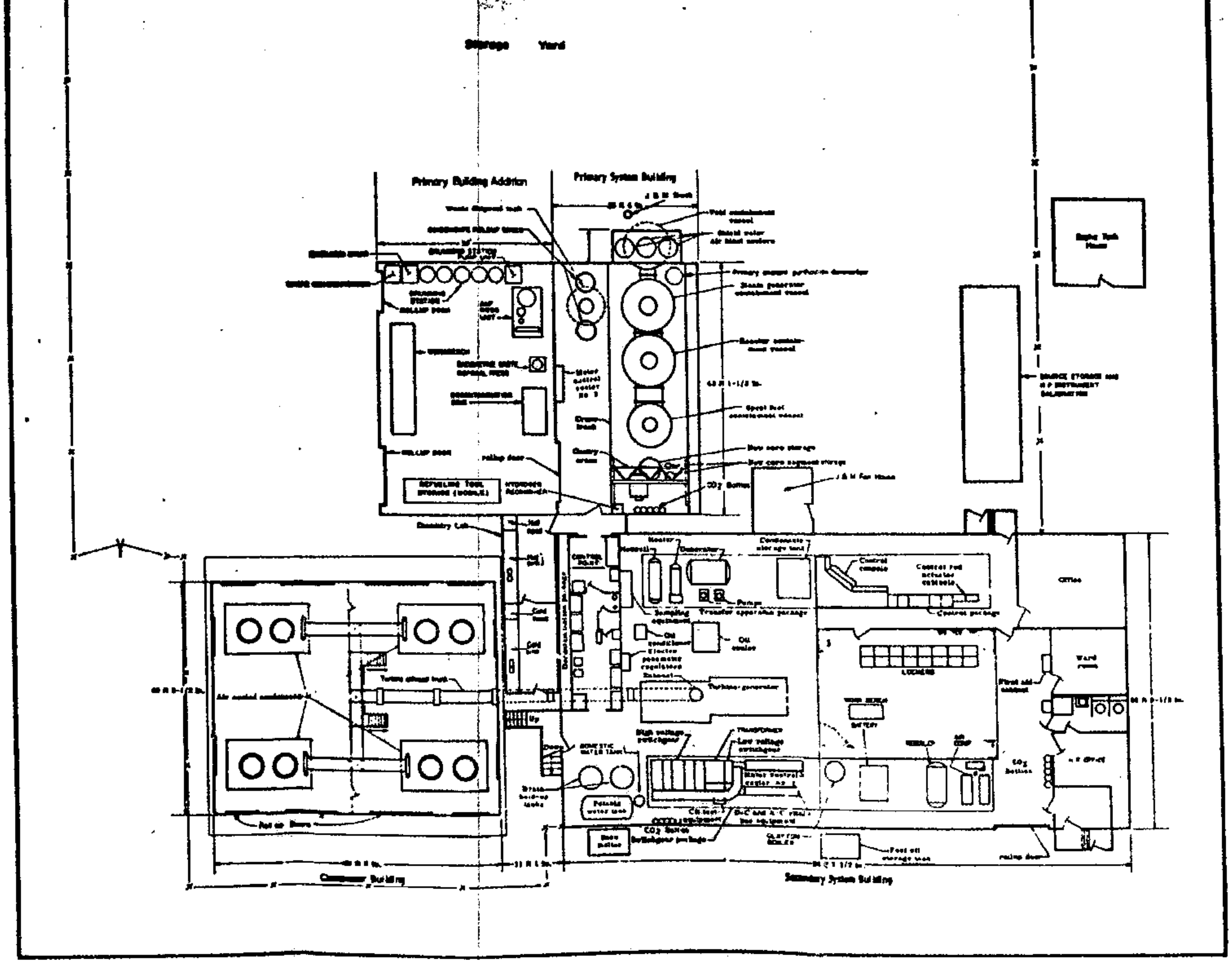


Figure 3 GENERAL PLANT ARRANGEMENT

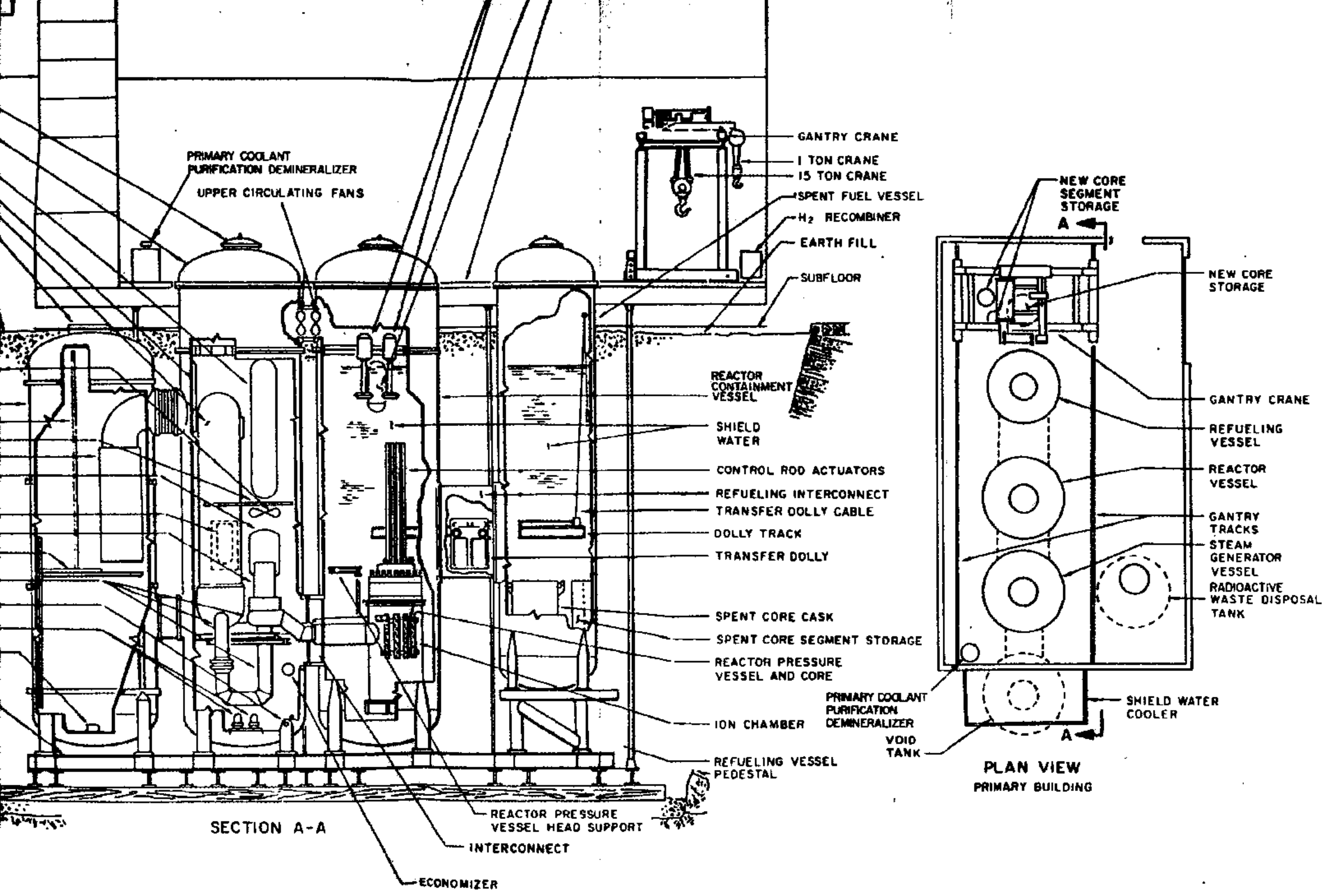
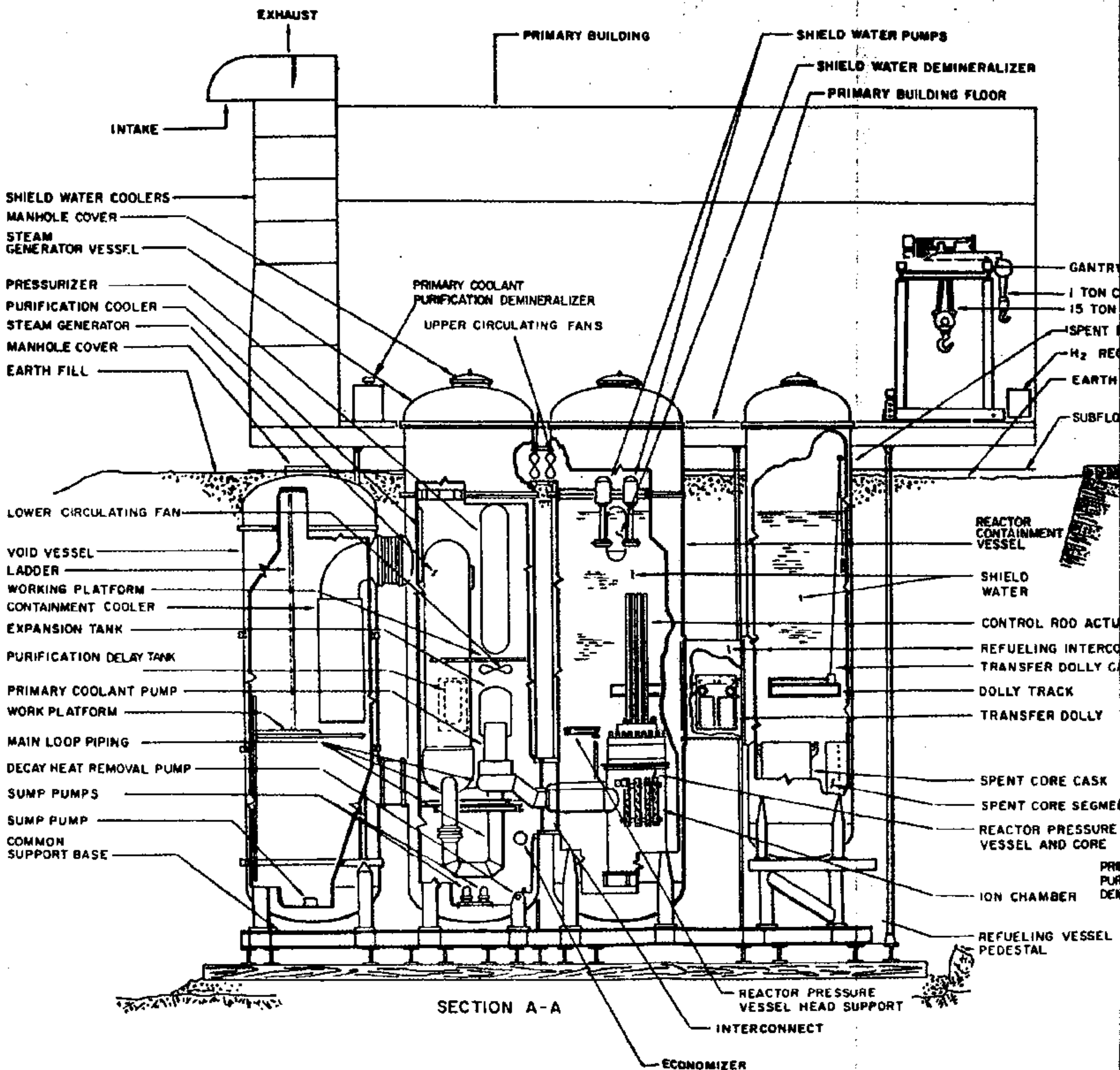


FIGURE 4 PRIMARY PLANT ARRANGEMENT



SECTION A-A

EXHAUST
INTAKE
PRIMARY BUILDING
SHIELD WATER PUMPS
SHIELD WATER DEMINERALIZER
PRIMARY BUILDING FLOOR
SHIELD WATER COOLERS
MANHOLE COVER
STEAM GENERATOR VESSEL
PRESSURIZER
PURIFICATION COOLER
STEAM GENERATOR
MANHOLE COVER
EARTH FILL
PRIMARY COOLANT PURIFICATION DEMINERALIZER
UPPER CIRCULATING FANS
GANTR
I TON C
15 TON
SPENT
H2 RE
EARTH
SUBFLO
LOWER CIRCULATING FAN
VOID VESSEL
LADDER
WORKING PLATFORM
CONTAINMENT COOLER
EXPANSION TANK
PURIFICATION DELAY TANK
PRIMARY COOLANT PUMP
WORK PLATFORM
MAIN LOOP PIPING
DECAY HEAT REMOVAL PUMP
SUMP PUMPS
SUMP PUMP
COMMON SUPPORT BASE
REACTOR CONTAINMENT VESSEL
SHIELD WATER
CONTROL ROD ACTU
REFUELING INTERC
TRANSFER DOLLY C
DOLLY TRACK
TRANSFER DOLLY
SPENT CORE CASK
SPENT CORE SEGME
REACTOR PRESSURE VESSEL AND CORE
PR
PU
DE
ION CHAMBER
REFUELING VESSEL PEDESTAL
REACTOR PRESSURE VESSEL HEAD SUPPORT
INTERCONNECT
ECONOMIZER

27 May 1964, at which time the Navy assumed custody and full responsibility for its operation.

The plant operated until September 1972. Since commencement of operations in 1962, the PM-3A has produced approximately 78 million kilowatt hours of electric energy with an availability of 72%.

In 1966, steam generated by the PM-3A was used to produce fresh water from seawater by evaporative distillation. Since that time, the water distillation plant has produced over 13 million gallons of fresh water using steam generated by nuclear energy.

C. Cause of Shutdown

In September 1972, shield water leakage into the steam generator tank was discovered during a routine inspection. It appeared that the cause of the leak was the failure of a weld on the primary coolant piping insulation canning.

It was postulated that failure of the insulation canning weld had allowed shield water to wet the insulation around the primary coolant piping. It was further postulated that the water could be in contact with the reactor pressure vessel. Since it was known that the insulation contained leachable chlorides, the possibility of chloride stress corrosion cracking of the reactor pressure vessel and coolant piping existed.

In January 1973, it was verified by inspection that the stainless steel reactor pressure vessel and primary coolant piping had become wetted due to the failure of the insulation canning. It was further verified that the thermal insulation around the piping contained chlorides; the water in which the reactor pressure vessel was immersed contained chlorides and oxygen; and the piping and nozzles had been contaminated with chlorides. All of the conditions necessary for chloride stress corrosion cracking failure in austenitic stainless steel were present, i.e., temperature, stress, chlorides and oxygen.

During the January inspection, approximately 60 in^2 of the reactor pressure vessel nozzle and primary coolant piping were accessible for visual examination. A dye penetrant inspection of the exposed areas of nozzle and piping revealed no indication of chloride stress corrosion cracking. However, the possibility of chloride stress corrosion cracking of the inaccessible surfaces of the pressure vessel still existed.

The high cost of performing a full inspection which would be required before any operations could be resumed, the unknown probability of success of such an inspection, and the lack of any other feasible course of action resulted in the decision to terminate permanently operation of the PM-3A and remove the plant from the Antarctic.

D. Alternative Courses of Action

In arriving at the decision to permanently shutdown the PM-3A, the following five alternative courses of action were considered:

Action	Description	Cost (Millions)	Time (Years)
Return to Power	No direct evidence of damage Plant is operable Check out and go to power Operate with wet insulation	Nominal	Few months
Detailed Inspection and Repair	Remove insulation canning Inspect for damage Repair if damaged Reinstall canning, new insulation Return to power	$1.5	2-3
Redesign and Replace Pressure Vessel & Portions of Primary Piping	Design new pressure vessel and insulation system Remove existing pressure vessel Install new pressure vessel Return to power	> $2.0	3
Entire new Plant	Design and building new 5MW plant Incorporate modern criteria Consider ice-strengthened barge for mobility Remove PM-3A	$35	6
Shutdown and Dismantle	Remove radioactive components Leave desalination plant Restore site	< $1.0	3

E. Comments on Alternatives

Return to Power. Since evidence of possible cracking of the primary system is circumstantial only, there is no leakage of primary water and the plant is operable, the Navy could take the position that the PM-3A should return to power promptly to provide power and fresh water to McMurdo Station from a nuclear source in order to reduce logistics problems associated with diesel-fueled energy sources. However, this option is not prudent from a nuclear safety point of view. While specific AEC approval is not required before returning to power, it is anticipated that the AEC regulatory staff would actively oppose such action. During the current austral winter season (March - October 1973), the disesl generators at McMurdo have operated satsifactorily and the two new units will increase reliability for the future. As a result, there exists no urgent operational consideration which might tend to modify a normal conservative nuclear safety course of action.

Detailed Inspection and Repair. This option involves the following execution elements:

Completion of detailed planning (a preliminary plan has already been prepared).

Development and procurement of remote cutting, inspection and welding equipment and a personnel shielding system.

Construction of mock-ups in CONUS to test feasibility of procedures and to permit training of personnel prior to deployment to McMurdo.

Deployment to site.

Cutting and removal of existing canning from around pressure vessel and piping legs.

Visual inspection of the entire surface of the pressure vessel and wetted piping using remote techniques (radiation level will be too high for direct methods, even with core removed).

Repair (grinding and welding) of cracks discovered during the inspection, if any, and if possible.

Installation of new insulation and reinstallation of old canning. (Installation and welding of a new canning system is much preferable but is considered to be unacceptably complex and costly using the remote methods made necessary by the ambient radiation field).

Test of integrity of canning system and repair if necessary and possible.

Completion of documentation for justification for return to power.

The major drawback to this option is the lack of assurance of success in returning to power. It is impossible to predict what the inspection will uncover, thus it is not possible to assess in advance the probability that a technical case can be made for return to power. In addition, there is no way to develop assurance that the reinstalled old canning system will not leak again in the future. The inspection and repair would involve a significant (but controlled within allowable limits) exposure of 30-40 military and civilian consultant personnel to ionizing radiation. This lends importance to the need to have reasonable assurance of success before proceeding and the need to weigh this radiation exposure against expected results.

Redesign and Replace Pressure Vessel. This course of action entails the complete redesign of the pressure vessel and its insulation system and portions of the primary system piping with three major objectives in mind: (1) measures to make highly unlikely the exposure of components of the primary system to serious potential corrosion problems like chloride stress corrosion cracking; (2) measures to permit detection of incipient conditions which might lead to corrosion problems and (3) measures to permit inspection and repair of affected surface if suspected exposure to corrosion conditions should occur. The estimate of $2 million is considered to be a minimum. The major concern with this option, which complicates the comparison of cost versus benefit, is the possibility that with such a major modification planned the Navy may conclude, or the AEC may insist, that the plant should be brought into substantially full compliance with the current General Design Criteria for Nuclear Power Plants, as contained in Appendix A, 10CFR50. NAVFAC has had plans underway for some time to install an Emergency Core Cooling System (ECCS) in the PM-3A. All of the options which contemplate return to power include the installation of such a system. However, no plans are being made to carry out wholesale backfitting to comply fully with the other provisions of Appendix A, 10CFR50, since it was concluded that no substantial additional protection of public health and safety would result from the large costs of such backfitting. Plans to perform a major modification to the PM-3A because of the current chloride stress corrosion cracking problem, however, could well lead to a decision to backfit completely to 10CFR standards despite the marginal increase in safety which will occur. This could result in the cost of this option being greatly above $2.0 million, making very dubious the conclusion that the expected benefit outweighs the cost. In considering this option, it has been noted that major plant components are over 10 years old, built with a technology which approaches 15 years of age.

Entire New Plant. For the sake of completeness this option has been included and a price and construction schedule estimated. However, the lack of a compelling operational requirement, the strong competition offered by other Navy programs for R & D, MILCON and other dollar resources, and the lack of any expected fund source outside of the Navy lead to the conclusion that this is not a logical alternative at this time. In truth, this option is not exclusive of the others. Its execution would involve carrying out the option below. Also, it is really an independent alternative which can be exercised at a later date if conditions should change to make it attractive.

Shutdown and Dismantle. Article V of the Antarctic Treaty states that there shall be no dumping of radioactive wastes (See page 15). NAVFAC has taken the position that this means all radioactive components of the plant will have to be removed from the continent when a decision has been reached to permanently terminate plant operations. The lack of any other reasonable and appropriate course of action leads to a conclusion that the PM-3A should be shutdown permanently, and, in order to comply with the intent and letter of the Antarctic Treaty, that it should be dismantled and removed from the Antarctic. It is planned that the only portion of the PM-3A to remain will be the Water Distillation Plant Building and the Maintenance and Supply Building, needed for support of the desalination mission.

II. CURRENT PLANT STATUS

A. General Plant Conditions

The PM-3A has been shutdown since September 1972. In February 1973, the plant was placed in an extended shutdown status and the heat transfer apparatus package, shield water air blast coolers, condensers and reboiler were drained and dried. The core was removed from the reactor in July 1973. The shield water was then lowered to the level of the reactor pressure vessel head.

The auxiliary steam, electrical distribution, instrumentation and radioactive waste disposal systems as well as the water distillation plant are fully operational.

B. Operating Crew

The "cold iron" operating crew (DEEPFREEZE 73 Winter, March - October 1973) consists of 12 men: an Officer in Charge (Acting), a Health Physics Supervisor, 3 maintenance technicians, 6 operators and 1 Environmental Monitor/Storekeeper.

The crew is responsible for the operation and maintenance of the water distillation plant and the operational systems previously discussed.

C. Fissile Material

The PM-3A was defueled in July 1973. The irradiated Type IV serial II core is stored in its shipping cask located in the primary yard.

An unirradiated Type IV Serial I core is stored in the new core storage vault within the primary building.

An unirradiated Core Type IV spare bundle assembly is stored in the vault within the primary building.

Four unirradiated core Type IV removable fuel elements are stored in the vault within the primary building.

All fissile material will be transported in approved containers by ship to CONUS in early 1974 for eventual reprocessing.

D. Radioactive Sources

A variety of low level radioactive sources are maintained at the PM-3A primarily for calibration and operational checks of health physics instrumentation. A complete list of these sources is shown in Table 1.

These sources will be retained at the site to maintain the health physics instrumentation in proper working order. When no longer required, the sources will be transported in radioactive waste shipping containers to CONUS for disposal or transferred to authorized agencies for further use.

E. Major Radioactive Inventory

All radioactive waste resulting from removal will be in solid form. The major source of radioactivity is the reactor pressure vessel which has been irradiated for approximately 10 years. Based on an activation analysis, the radioactivity present in February 1975, which is the earliest date that preparations could be completed for shipping, has been estimated to be on the order of 40,000 curies.[1] This includes the thermal shields, lead shield canning, and upper skirt as well as the reactor pressure vessel.

Primary system components and piping and the radioactive waste disposal system have become contaminated primarily with radioactive corrosion products. Total radioactivity of these components has been estimated to be approximately 7 curies.

The total project radioactive waste inventory is shown in Table 2.

TABLE 1

PM-3A SOURCE INVENTORY

1.	Sr 90	1.035	uCi	28.	Fe 59	5.84	uCi
2.	Sr 90	0.69	uCi	29.	Co 60	0.001	mCi
3.	Sr 90	1.0	uCi	30.	Cd 109	.1	uCi
4.	Sr 90	1.0	uCi	31.	Cs 137	9	uCi
5.	Sr 90	1.0	uCi	32.	Cs 137	9	uCi
6.	Sr 90	1.0	uCi	33.	Cs 137	0.7	mCi
7.	Sr 90	1.0	uCi	34.	Cs 137	30	mCi
8.	Sr 90	1.0	uCi	35.	Cs 137	9	uCi
9.	Sr 90	10.	uCi	36.	Cs 137	100	mCi
10.	Sr 90	1.0	uCi	37.	Cs 137	9	uCi
11.	Sr 90	1.0	uCi	38.	Cs 137	20	uCi
12.	Sr 90	1.0	uCi	39.	Tl 204	0.114	uCi
13.	Sr 90	1.0	uCi	40.	Pu 239	2.25	mCi
14.	Sr 90	1.0	uCi	41.	Pu 239	188	uCi
15.	Sr 90	1.0	uCi	42.	Pu 239	1.99	uCi
16.	Sr 90	1.0	uCi	43.	Pu 239	26.6	uCi
17.	Sr 90	1.0	uCi	44.	Pu 239	4.03	uCi
18.	Sr 90	1.0	uCi	45.	Nat'l U	.002	uCi
19.	Co 60	0.02	mCi	46.	Cs 137	75.9	uCi
20.	Co 60	1.34	mCi	47.	Pb 210	.179	uCi
21.	Co 60	1.02	mCi	48.	PuBe	2	Ci
22.	Mn 54	.82	mCi	49.	PuBe	5	Ci
23.	Na 22	.52	mCi	50.	Cs 137	126	Ci
24.	Ba 133	.21	mCi	51.	Cs 137	0.7	mCi
25.	Cs 137	.36	mCi	52.	Cl 36	83.2	uCi
26.	H 3	90.56	uCi	53.	C 14	.165	mCi
27.	H 3	1188.	uCi				
					TOTAL	153.14	Ci

TABLE 2

SOLID WASTE INVENTORY

Item	Weight (lb)	Estimated Activity (Curies)
Reactor Tank	40,000	40,000
Steam Generator Tank	40,000	1.0
Spent Core Tank	28,395	Negligible
Void Tank	22,467	Negligible
Radioactive Waste Disposal Tank	24,000	1.5
Primary Pipe and Components*	31,000	2.0
Primary Building	350,000	Negligible
Primary Building Addition	97,800	Negligible
Contaminated Backfill	40,000	Negligible
Contaminated Soil	Unknown	Unknown
2 RWDS Units	7,000	2.

*To be shipped in Void and Spent Core Tank

III. REMOVAL OPERATION

A. General

Article V of the Antarctic Treaty states:

> 1. Any nuclear explosions in Antarctica and the disposal there of radioactive waste material shall be prohibited.
>
> 2. In the event of the conclusion of international agreements concerning the use of nuclear energy, including nuclear explosions and the disposal of radioactive waste material, to which all of the Contracting Parties whose representatives are entitled to participate in the meetings provided for under Article IX are parties, the rules established under such agreements shall apply in Antarctica.

Thus the PM-3A must be dismantled and shipped to the Continental United States for disposal.

Due to the severe Antarctic climate during the winter months, the removal effort will be principally carried out during the austral summer, i.e., from October through February. It is anticipated that at least three summer seasons will be required to remove the PM-3A.

The project will be divided into two phases annually: planning and execution. The planning phase will extend from March through September of each year until the project is completed. This work will be performed at the Naval Nuclear Power Unit, Fort Belvoir, Virginia. During this time, Activity Specifications, Detailed Working Procedures* and drawings will be developed. Materials, tools and equipment required during the forthcoming austral summer will be procured and shipped to Antarctica. Training and plant familiarization courses will also be conducted during this time.

The execution phase will extend from October through February of each year until the project is completed. The work will be performed by personnel of the Naval Nuclear Power Unit at the PM-3A, McMurdo Station Antarctica, under the command of an Officer in Charge. The PM-3A Officer in Charge reports to the Office in Charge, Naval Nuclear Power Unit, Fort Belvoir, Virginia.

During the austral winter after the first removal season (March-October 1974) the PM-3A will be manned by a nine man crew. The crew

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*Defined on pp. 17 and 18

will consist of a Chief Petty Officer in Charge, Health Physicist and seven operating and maintenance personnel. The primary duties of this crew will be to operate and maintain the water distillation plant and continue the environmental monitoring program. Additionally, the crew will operate and maintain essential plant systems such as heat, electrical power and radiation monitoring. These systems will be required for the second execution season.

In addition to operating and maintaining essential systems, the crew will also provide plant security. No fissile material will be on site; however, large quantities of radioactive waste will remain. Since the site will be manned continuously, access control will be maintained to prevent inadvertent exposure to ionizing radiation by unauthorized personnel.

During subsequent winter seasons, it is anticipated that the water distillation plant will be operated by Naval Support Force Antarctica personnel, the reactor pressure vessel will have been encased in concrete and the radioactive waste will have been removed from the site. Thus, future winter crews should not be required. The site will be placed off limits to all personnel during winter-over by Commander, Naval Support Force, Antarctica.

Non-contaminated plant equipment which is compatible with existing McMurdo Station utility systems will be transferred to Commander, Naval Support Force, Antarctica for further utilization. The remaining non-contaminated equipment will be shipped to a Defense Property Disposal Agency in the Continental United States for salvage or disposal, as required. Contaminated equipment will be shipped to CONUS for disposal as radioactive waste.

No special tools or equipment will be required for the removal project. A mobile crane of 50 ton capacity or greater will be required for lifting the reactor tank and a backhoe will be required for backfill removal. These items will be shipped to the site in December 1973. Other construction and weight handling equipment presently on site, i.e, bulldozers, front-end loaders, etc., will be used as required.

B. Program Control

The Naval Facilities Engineering Command (NAVFAC) has final authority for actions concerning the decommissioning and removal of the PM-3A from Antarctica. The Command relationships and policies for operation of the plant as contained in the publication NAVFAC P-311 "Nuclear Shore Power Plants"[2] will continue to remain in force with minor modifications appropriate to reflect the change from an operational status to a shutdown and removal status. Such modifications to P-311 will be documented and approved by NAVFAC.

In addition to the publication NAVFAC P-311, the other key documents governing the dismantling and removal project are:

(1) PM-3A Removal Plan (this document)
(2) Activity Specifications
(3) Detailed Working Procedures
(4) Health Physics and Industrial Safety Manual
(5) Removal Schedule

The Naval Facilities Engineering Command will exercise review and approval authority over the PM-3A Removal Plan, the Removal Schedule, the Health Physics and Industrial Safety Manual, and over selected Activity Specifications and Detailed Working Procedures. All Activity Specifications and Detailed Working Procedures will be submitted to NAVFAC for review. Project execution will be the responsibility of the Officer in Charge, Naval Nuclear Power Unit and his subordinate, the Officer in Charge, PM-3A.

1. Activity Specifications

An activity specification defines the scope, proposed methods and sequence of accomplishing a major task. The activity specifications for the removal are:

a. Decontamination of the Primary Building and Primary Building Addition.
b. Primary Building and Primary Building Addition Systems Removal.
c. Secondary System Dismantling.
d. Preparation of Containment and Radioactive Waste Disposal Tanks for Shipment.
e. Primary Building, Primary Addition Building and Backfill Removal.
f. Containment and Radioactive Waste Disposal Tank Removal and Disposal.
g. Removal of Contaminated Soil.
h. Final Site Condition.

2. Detailed Working Procedures

Detailed working procedures will be written for each activity specification. The procedures will be a comprehensive, detailed outline of the work required to dismantle a specific system or to perform a specific task. They will be written in step-by-step, checklist form such that a mechanic could readily accomplish a specific task even though he were not familiar with the PM-3A. Detailed drawings will accompany each working procedure as required.

3. Health Physics and Industrial Safety Manual

The work to be performed in the removal of the PM-3A will be similar to that encountered in a normal construction or demolition project. However, the remote location of the site, the extremely cold climate and the presence of radioactive material are unique to the removal project.

Since the beginning of Operation DEEPFREEZE in 1955, considerable experience has been gained in working in the Antarctic environment. Similarly, considerable experience has been gained in the handling of radioactive material in the Antarctic since the beginning of PM-3A operations in 1964. The results of this experience have been incorporated into the intensive training program in radiological and industrial safety that each man receives prior to deploying to the PM-3A. In addition, over 50 percent of the PM-3A removal crew have previous Antarctic experience.

Radiological and industrial safety will receive the highest priority during the removal project. Safety standards are contained in the PM-3A Health Physics and Industrial Safety Manual which has been amended to include those items pertaining to the removal project. A chapter on industrial safety has been added and a new industrial safety instruction has been issued. The safety standards in the Manual are in conformance with Department of Labor Occupational Safety and Health Standards. Health Physics and Industrial Safety will be discussed further in Section IV.

4. Removal Schedule

Work scheduling and performance monitoring will be accomplished through the use of Program Evaluation Review Technique (PERT) programming, supervisor's daily progress reports and management meetings as required.

Scheduling of work for the execution phase of the project will be accomplished using a PERT program. Each task will be identified on the program by name, start and completion date. The schedule will be updated weekly and revisions made as required.

The Officer in Charge and the Plant Superintendent will be in close contact with supervisory and working personnel throughout the execution phase. Consequently, management and work review meetings will be conducted on an as required rather than a scheduled basis. Weekly Situation Reports will be made to the Naval Nuclear Power Unit with an information copy to NAVFACENGCOM as specified in NAVFAC P-311.

C. Description of Major Activities

1. Decontamination of the Primary Building and Primary Building Addition

Following the removal of the irradiated core from the primary building, cleanup of the primary and primary addition buildings will take place. Lagging will be removed from pipes. Wall surfaces will be cleaned. All radioactive material resulting from the cleanup, with the exception of liquid waste, will be placed in approved shipping containers for shipment to CONUS. Once cleanup has been accomplished, all contaminated surfaces in the buildings will be sealed with paint or another acceptable contamination fixing agent. Surface contamination fixing by the above method will prevent spread of radioactivity during dismantling procedures. Fixing to prevent the spread of contamination is an acceptable and established procedure for shipment of contaminated materials.

2. Primary Building and Primary Building Addition Systems Removal

All components and systems within the primary building and primary building addition will be removed. This operation includes all associated piping, instrumentation and wiring outside of the containment tanks. Major components include:

a. Shield water air blast coolers and shield water piping.
b. Main steam line.
c. Feedwater system.
d. Primary purification system.
e. Coolant charging and addition system.
f. High and low temperature radioactive waste disposal system.

Large components such as the shield water air blast coolers, pumps, etc. will be packaged in wooden industrial boxes for shipment.

Piping and small components will be placed in the void and spent core tanks.

Each system is virtually independent. Thus, a system may be dismantled completely with the removal sequence depending on accessibility. Maximum effort will be made to disconnect piping mechanically at bolted flanges and unions. Cutting, either pneumatic or gas, will be used if required.

Prior to commencing the dismantling operation, minor modifications to the primary building will be required to provide ready access to the void tank. The intake and exhaust ductwork assembly will be removed from the shield water air blast cooler. A plywood cover will be bolted and sealed to the remaining ductwork support frame to maintain primary building integrity. Two primary building wall panels located directly in front of the air blast cooler will be removed. The void tank will then be accessible.

During the first season of plant removal, it is anticipated that all systems outside containment with the exception of heating and ventilation, lighting, radiation monitoring, and radioactive waste processing will be removed. The radioactive waste processing system will be removed when it is no longer required while the remaining systems will be removed prior to primary building dismantling.

3. Secondary System Dismantling

During the first season of plant removal, it is anticipated that the following systems will be removed:

a. Condensers and condenser building.
b. Turbine generator package.
c. Heat transfer apparatus package A and B.
d. Reboiler.
e. Snow melter.
f. J & M fan house.

All piping, wiring and instrumentation associated with the above systems will also be removed.

The remaining systems will be removed during subsequent execution seasons:

a. Switchgear package.
b. Maintenance package.
c. Decontamination package.
d. Laboratory package.
e. Control package.
f. Potable water tank and hold up tanks 1 and 2.
g. Clayton boiler and heating system.
h. Offal house.
i. Package 12 (Tool storage)
j. Package 13 (Calibration facility)

All piping, wiring, and instrumentation associated with the above systems will also be removed. The Secondary Building will be removed and returned to CONUS for appropriate disposal when there is no need for control of access to a high radiation area or to monitor personnel and material. A temporary Health Physics laboratory will be set up in the Maintenance and Supply building as will offices for management personnel.

The turbine generator, heat transfer apparatus, switchgear, maintenance, decontamination, laboratory and control packages are self-contained, skid-mounted units. These packages will be disconnected, jacked up onto multi-ton rollers and moved to the secondary building retractable door using a fork lift and appropriate rigging. The package will be lifted onto a trailer using a mobile crane and transported to a staging area.

The condensers will be disconnected, lifted onto a trailer using a mobile crane and transported to a staging area. It is anticipated that the condenser building will be dismantled prior to removing the condensers.

Prior to removal, all components will be checked for spreadable radioactive contamination and decontaminated as required.

Piping will be cut to suitable lengths and packaged in wooden industrial boxes for shipment. Wiring will be packaged in the condensate storage tank and snow melter. The self-contained packages, condensers and other large components will be shipped in their existing condition. Miscellaneous equipment will be shipped in packages 12 and 13. The condenser and secondary building wall and roof panels will be stacked, banded and palletized for shipment. Steel structural members will be banded and palletized.

The packages and components will be backloaded and shipped to the Continental United States for disposal.

4. Preparation of Containment and Radioactive Waste Disposal Tanks for Shipment

a. Void and Spent Core Tanks

As previously noted, piping and small components removed from within the primary building will be placed in the void and spent core tanks for shipment.

Prior to loading material into the spent core tank, the fuel transfer dolly will be removed, the interconnect omega seals will be ground out and metal plates will be installed over the interconnect opening on the inside of the tank. Prior to loading material into the void tank, the upper and lower interconnect omega seals will be ground out and metal plates will be installed over the interconnect on the inside of the tank.

After the tanks have been loaded with material, the piping and components will be shored or encased in urethane foam to prevent movement during shipment. All openings will be sealed and the tanks will meet all requirements for LSA shipping containers.

b. Steam Generator Tank

There is an estimated 1.0 curie of activity associated with steam generator tank components. The installed components will be shipped to CONUS within the steam generator tank. All components will be placed in their original shipping position and shoring or polyurethane rigid foam will be provided as additional insurance against components breaking loose and causing damage to the tank during shipment. Analyzing each component in the tank separately and assuming a uniform distribution of the activity throughout each component, the specific activity qualifies each component to be shipped as low specific activity transport group III. The tank will therefore be shipped as low specific activity (LSA) since the radioactivity of each component does not exceed .3 millicurie per gram.

The omega seals will be ground out of the upper and lower interconnects and metal plates will be installed over the interconnects on the inside of the tank. All openings will be sealed and the tank will meet all requirements for LSA shipping containers.

c. Reactor Tank

It is planned to encase the reactor pressure vessel in concrete within its containment tank as shown in Figure 5 and ship the entire package to CONUS for disposal.

Initially, all extraneous components will be removed from the tank, e.g., shield water pumps, demineralizer, detector housings, etc. A concrete base will be placed on the bottom of the tank up to the 7 inch I beams which support the pressure vessel. Due to the high radiation field, the concrete will be placed underwater using a tremie pipe. A hole will be burned in the bottom of the pressure vessel to allow for the installation of lead shot and concrete in the installed 40 inch pipe directly under the pressure vessel. Depleted uranium or lead panels will be installed around the perimeter of the pressure vessel as required by the safety analysis to provide the required shielding. The panels will be placed on the concrete base and will be restrained by banding.

After the shielding has been installed, concrete will be placed in the remaining void area up to the pressure vessel head. The interior of the pressure vessel will also be filled with concrete.

Since weight limitations are governing, the top 6 foot extension to the containment tank will be removed and shipped separately.

All openings will be sealed and the tank will meet all requirements of Title 10, Code of Federal Regulations, Part 71 for a shipping container for large quantities of radioactive material.[1]

d. Radioactive Waste Disposal Tank

When all radioactive waste water has been processed, the interior of the tank will be cleaned, dried and decontaminated as practicable. The tank will be surveyed and lead shielding added if required to reduce the dose rate to within shipping limits. All openings will be sealed and the tank will meet all requirements for an LSA shipping container.

5. Primary Building, Primary Addition Building and Backfill Removal

Prior to dismantling, all building surfaces will be cleaned and decontaminated as previously discussed. Wall, floor and roof panels will be disassembled, stacked, banded and palletized. Steel structural members will be banded and palletized.

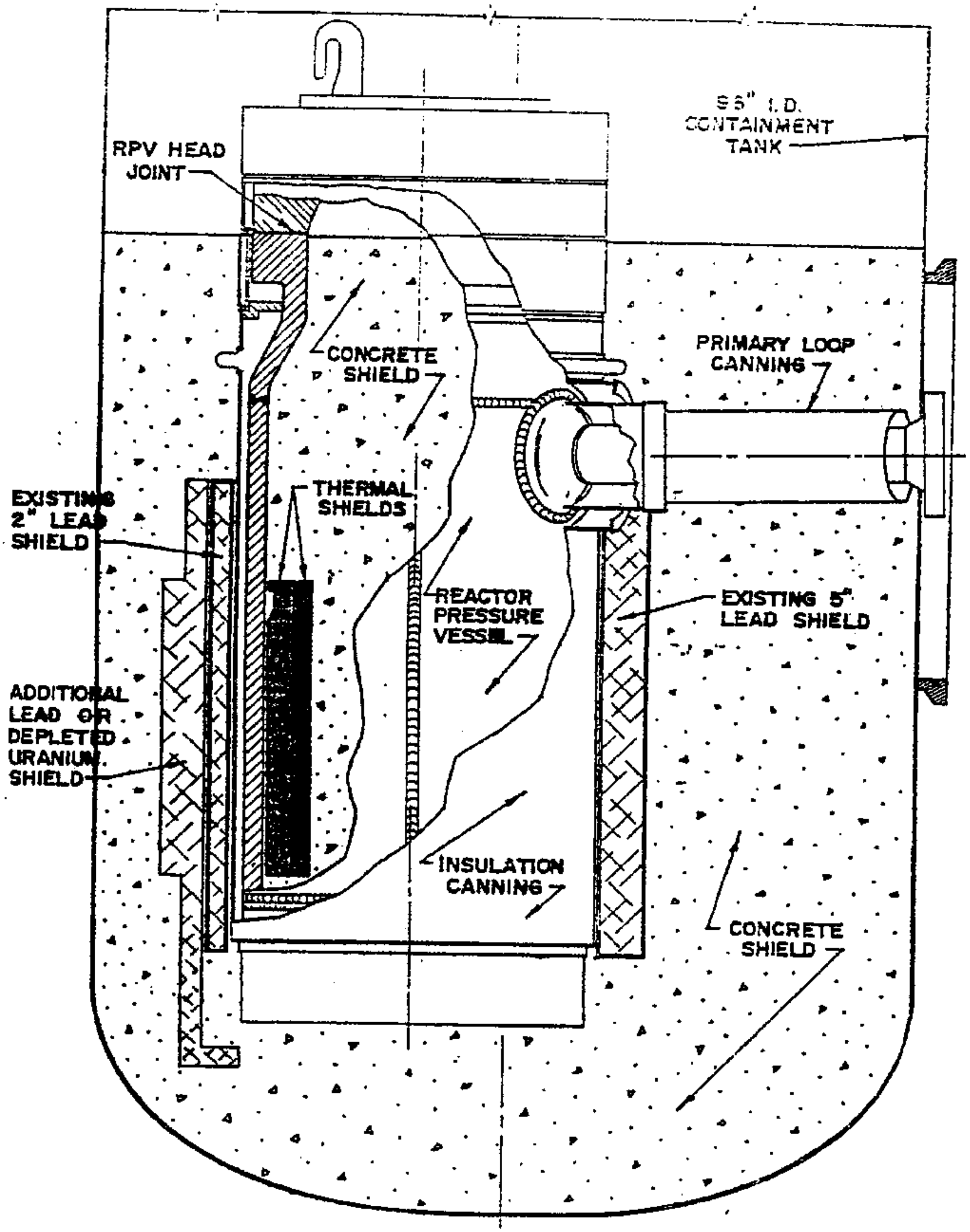

FIGURE 5

Placement Of Biological Shields And Concrete Shield

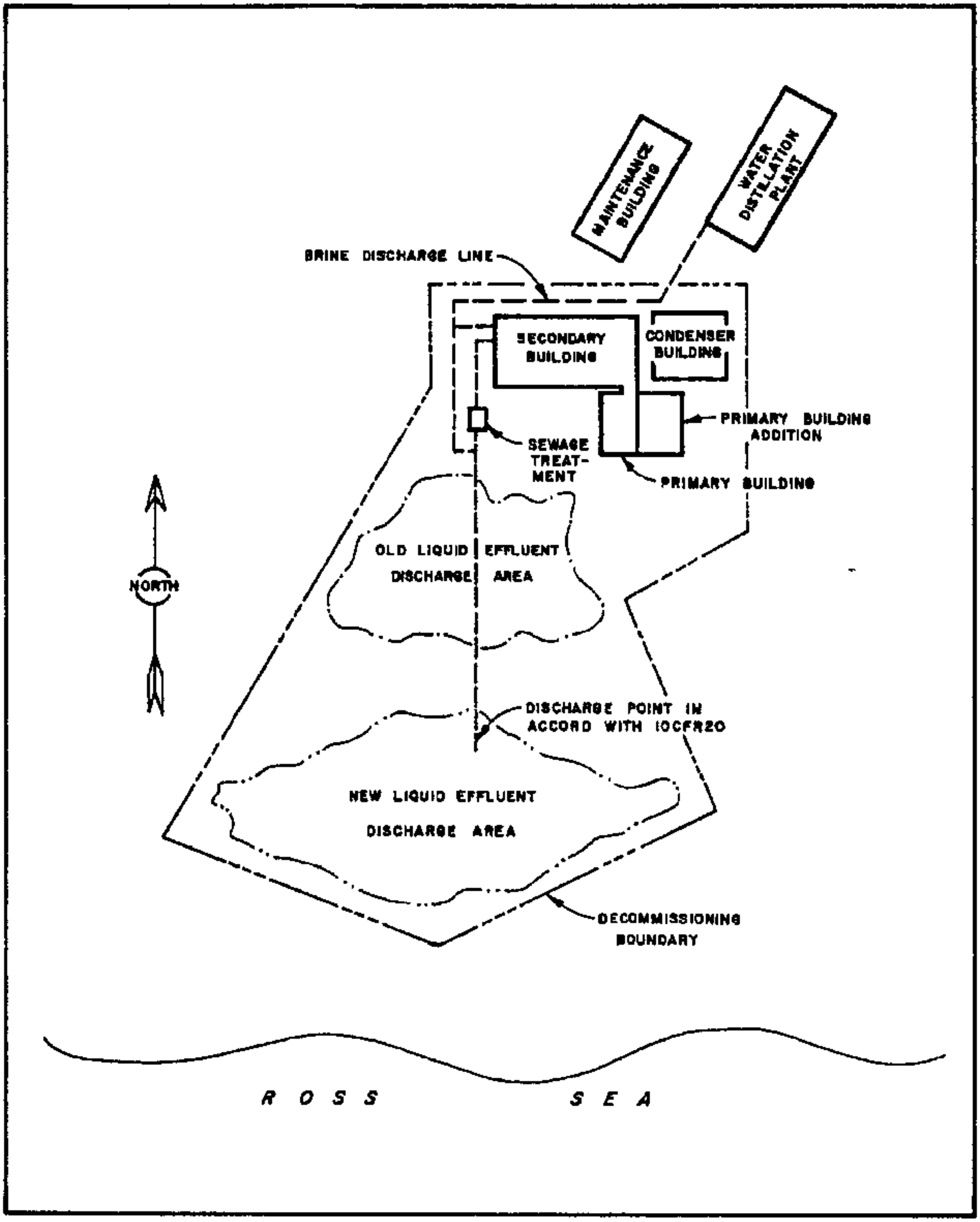

FIGURE 6

EFFLUENT DISCHARGE AREAS

Using the rationale that a gram of soil is equivalent to a milliliter of water, the MPC values for release to unrestricted areas as given in 10 CFR 20 Table II, Appendix B are equal to, or lower than, the USSR limits as calculated above, except for the isotopes Be-7, Fe-55, Ni-63, Cs-137, Nd-144, Sm-147, Po-210, Th-232, and Pu-239.

All the countries which are signatory to the Antarctic Treaty are members of the I.A.E.A. The USSR standard contains the only definition of radioactivity which relates to soil. The 10CFR20 MPC values are more conservative than the USSR standard's values. Therefore, soils which show radionuclide concentrations above background and which exceed the 10CFR20 MPC values (with 1 gram of soil equal to 1 milliliter of water), except for the isotopes in the paragraph above for which the USSR standard's values will apply, will be taken up and removed to the Continental United States for disposal.

8. Final Site Condition

An independent firm will be placed under contract to perform a radiological survey of the removal site to insure conditions specified under section 7 (Removal of Contaminated Soil) are met.

One objective of plant removal is that the site be environmentally and physically similar to its original condition. After contaminated soil and backfill have been removed, the site will be cleared of all debris and graded to conform to the surrounding topography as practicable.

IV. HEALTH PHYSICS AND INDUSTRIAL SAFETY

A. General

The health physics and industrial safety aspects of the removal project will be governed in detail by the PM-3A Health Physics and Industrial Safety Manual and the current Naval Nuclear Power Unit Detachment McMurdo Safety Instruction (NAVNUPWRUDETINST 5100.1D).

The Officer in Charge shall be responsible for the implementation of the health physics and industrial safety program. The Health Physics Supervisor shall directly supervise the program and report to the Officer in Charge or his designated representative on all aspects of safety.

B. Radiological Safety

Personnel working within the primary building will be subject to low level radiation from the accumulation of activated corrosion products in the piping. In order to reduce the radiation level in the work area, local "hot spots" such as the primary purification demineralizer, micro-metallic filter and shield water demineralizer will be removed as soon as possible after the dismantling work begins. The anticipated dose rate within the primary building work area will be on the order of 5 to 10 mRem/hr. Personnel exposure will be carefully controlled in accordance with the requirements of the Health Physics Manual.

Specific precautions will be taken to keep airborne activity to a minimum. It is anticipated that the primary building cleaning and painting operations, previously discussed in Section III C.1 will eliminate the major source of airborne contamination. However, additional air circulation and filtration equipment will be installed in the work area to remove airborne particulate matter and supplemental air monitoring in the primary building will be employed as appropriate. A fresh air breathing system, consisting of a Nash Model OC-5 Breathing Air Compressor, a 4 station quick disconnect air breathing manifold and appropriate air hoses and hoods will also be installed and utilized if the aforementioned precautions prove inadequate.

By far the largest source of radiation in the plant is the reactor pressure vessel. The shield water level in the reactor containment tank will be approximately at the pressure vessel head flange. The dose rate within the tank will range from 10 to 100 mRem/hr with the average on the order of 50 mRem/hr. Approximately 150 manhours of work will be required in the reactor tank for system component removal, shield installation and concrete placement. Personnel exposure will be carefully controlled in accordance with the requirements of the Health Physics and Industrial Safety Manual. After the concrete has been placed, the dose rate has been estimated to be less than 100 mRem/hr at 3 feet from the surface of the tank. Therefore, it is expected that the limits specified by 49CFR173 for sole use shipments can be easily met.

As previously discussed, large quantities of solid, radioactive waste will be handled and transported during the project. All radioactive waste will be packaged and shipped to the Continental United States for disposal in accordance with Department of Transportation, Atomic Energy Commission and IAEA Regulations.

C. Industrial Safety

Industrial Safety will receive special emphasis during the removal operation. Normal familiar conditions will be disrupted as components are removed. Cutting torches will be in general use. Heavy objects will be unbolted or cut loose and lifted by crane and hoist. Several heavy lifts, e.g., the reactor containment tank, steam generator tank and turbine-generator package will be required. These unusual circumstances demand special attention to insure adequate personnel safety. Such special attention will include but not be limited to (1) new chapter addition to the Health Physics Manual treating the subject of industrial safety; (2) specific appropriate training for the Safety Chief; (3) special training and assistance for the conduct of heavy lifts; (4) specific safety orientation and training of all personnel; (5) adequate supplies of safety equipment; (6) revised detachment safety instruction.

Standard industrial safety precautions augmented by Chapter 9 of the Health Physics and Industrial Safety Manual will be employed throughout the project. These include the wearing of proper face and eye protection during cutting, grinding or welding, use of ear protection in high noise areas, and the wearing of protective clothing, safety shoes, and hard hats. The provisions of the Occupational Safety and Health Act Standards, 29 CFR 1910, will be followed. Safety discussions and safety inspections will be conducted by the Safety Chief on a regular basis.

REFERENCES

1. Naval Nuclear Power Unit, Safety Analysis for the PM-3A Reactor Pressure Vessel Shipping Container, 1973.

2. Naval Nuclear Power Unit, Environmental Impact Assessment for the Removal of the PM-3A Nuclear Power Plant, October 1973.

3. Nuclear Shore Power Plants, NAVDOCKS P-311, Naval Facilities Engineering Command, August 1964.

4. Jackson and Moreland, PM-3A Nuclear Power Plant Report on Secondary Shielding System Operations, 1964.