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STUDY OF REMOTE MILITARY POWER APPLICATIONS
BYRD STATION
ANTARCTICA

FOR

UNITED STATES ATOMIC ENERGY COMMISSION
NEW YORK OPERATIONS OFFICE

NEW YORK, NEW YORK

MAY, 1960

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KAISER ENGINEERS

DIVISION OF HENRY J. KAISER COMPANY
OAKLAND • CALIFORNIA

KAISER ENGINEERS DIVISION OF HENRY J. KAISER COMPANY

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Contract No. AT (30-1)-2441

May, 1960

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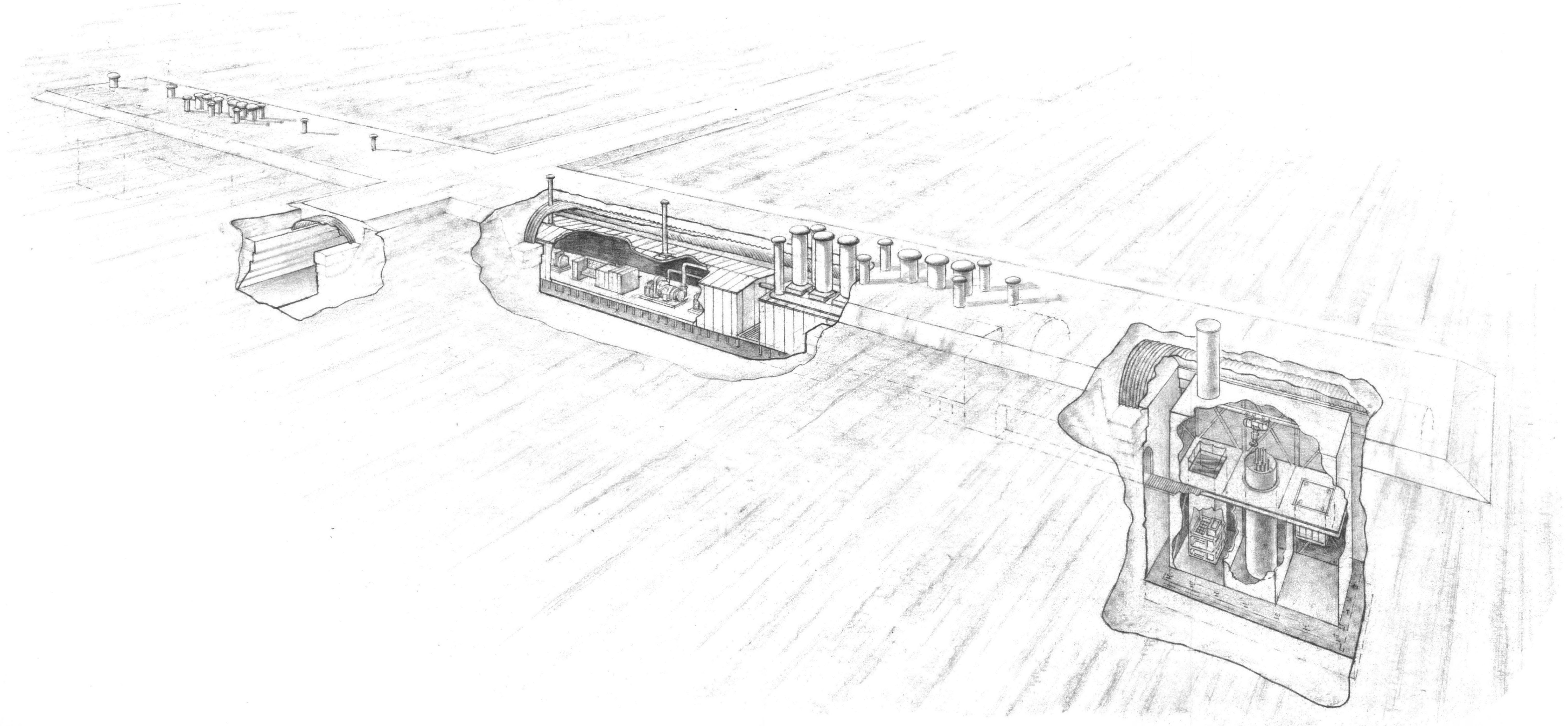

PROPOSED 800 KW NUCLEAR POWER PLANT
BYRD STATION, ANTARCTICA

KAISER ENGINEERS
DIVISION OF HENRY J. KAISER COMPANY

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SECTION I

INTRODUCTION

On August 17, 1959 the United States Atomic Energy Commission, through the New York Operations Office, issued Contract No. AT (30-1)-2441 to Kaiser Engineers for the "Study of Remote Military Power Applications." The study is essentially an evaluation of the economic considerations of constructing nuclear power plants at Atomic Energy Commission designated military installations, where increased power generating capabilities are contemplated by the Government for the period 1963 through 1970. On February 18, 1960 the scope of the contract was modified to include the study of the economic feasibility of installing nuclear power plants at Byrd and Pole Stations, Antarctica.

This report is an evaluation of the economics involved in constructing and operating a nuclear power plant at Byrd Station, Antarctica versus that for a conventional type power plant. Power requirements for Byrd Station have been established at 800 kw, of which 350 kw is electric power and 450 kw is heat. Completion of the nuclear power plant is desired by February 1963.

In the report will be found a description of a proposed 800 kw nuclear power plant together with concept drawings, construction cost estimate, design and construction schedule, and operating, maintenance and fuel costs. For purposes of comparison, a comparable 800 kw diesel power plant was selected, and concepts and costs included.

SECTION II

SUMMARY AND CONCLUSIONS

Byrd Station, originally established as one of the United States' scientific stations during the International Geophysical Year in 1956-1957, has been continuously occupied since that time by Navy and scientific personnel. To convert the present temporary facilities into a permanent camp, a reliable and economical power source is required to furnish electric power and heat.

Power requirements for the permanent Byrd Station have been established by the Navy at 800 kw, of which 350 kw is the electrical load and 450 kw is the heating load. Space heating will be by unit electric heaters. Operation of the power plant is desired by early 1963 (Section III A).

An analysis of the available reactor designs indicates that the PL-2 reactor as designed by Combustion Engineering, Inc. for the Atomic Energy Commission would provide a suitable nuclear power source meeting the requirements for the station. Studies further indicate that a satisfactory nuclear power plant would consist of two PL-2 power plants. Sufficient fuel oil will be stored at the station to operate the oil fired unit heaters for a 12-month period.

For comparison purposes, a conventional power plant consisting of four 400 kw diesel engine generators was selected. Sufficient fuel oil would be stored at the station to provide 14 months' operation at full load of 800 kw (Section III B).

The PL-2 nuclear power plant is a "portable packaged" power plant in the sense that the systems are preassembled and packaged at the point of manufacture to minimize the amount of construction work necessary at the site. The maximum weight of any single package is limited to 15 tons, the load that can be transported by a C-130-B cargo aircraft equipped with skis. The power plant is planned for installation at Byrd Station in two seasons, November 1961 to January 1962, and November 1962 to January 1963. The construction season is limited each year to the period that aircraft can land and take off at the station (Sections III C and D).

General arrangement and outline drawings have been prepared for both nuclear and conventional power plants to permit the preparation of reasonable and comparable estimates of construction cost. Table 1, page 4, summarizes the project cost estimates and unit power costs for the nuclear and conventional power plants. A summary of the nuclear and conventional power plant data is shown in Table 2, page 5.

The project schedule for the 800 kw nuclear power plant covers a 26-month period from initiation of the project to final completion in early February 1963. The project schedule for the comparable 800 kw conventional power plant covers a 26-month period from initiation of the project to final completion in early February 1963.

Sections IV and V present facility descriptions, cost estimates, construction schedules, and drawings for the nuclear and conventional power plants.

TABLE 1

ESTIMATED CONSTRUCTION AND OPERATING COSTS

800 KW (FIRM) NUCLEAR AND CONVENTIONAL POWER PLANTS

Estimated Construction Costs

	Nuclear Power Plant	Conventional Power Plant
Total Construction Cost	$6,847,000	$2,228,000
Escalation	413,000	132,000
Total Including Escalation	$7,260,000	$2,360,000
Design Engineering	400,000	100,000
Total Excluding Contingency	$7,660,000	$2,460,000
Contingency	1,540,000	340,000
Total	$9,200,000	$2,800,000
Fuel Oil in Storage	400,000	300,000
Total Project Cost	$9,600,000	$3,100.000

Estimated Annual and Unit Power Costs

	Nuclear Power Plant		Conventional Power Plant	
	Average Annual Cost	Unit Cost in mills per kwhr (4)	Average Annual Cost	Unit Cost in mills per kwhr (4)
Fixed Charges (1)	$480,000	68.6	$ 155,000	22.2
Operating and Maintenance Cost (2)	270,000	38.5	221,000	31.6
Nuclear Fuel Cost (3)	132,000	18.9		
Fuel Oil Cost (5)			2,101,000	300.1
Total Cost	$882,000	126.0	$2,477,000	353.9

NOTE: (1) Based on 20-year plant life equivalent to 5% of the total project cost. No interest on investment has been included.

(2) Excludes interest on cost of fuel oil in storage, interest on spare parts, nuclear indemnity insurance, other insurance and taxes.

(3) Excludes nuclear fuel use charge except during fabrication period.

(4) Unit power cost is based on 100% of firm power requirement equivalent to 7,000,000 net kilowatt hours per year.

(5) Based on 1960 commercial rates plus shipping costs and average escalation over the life of the plant.

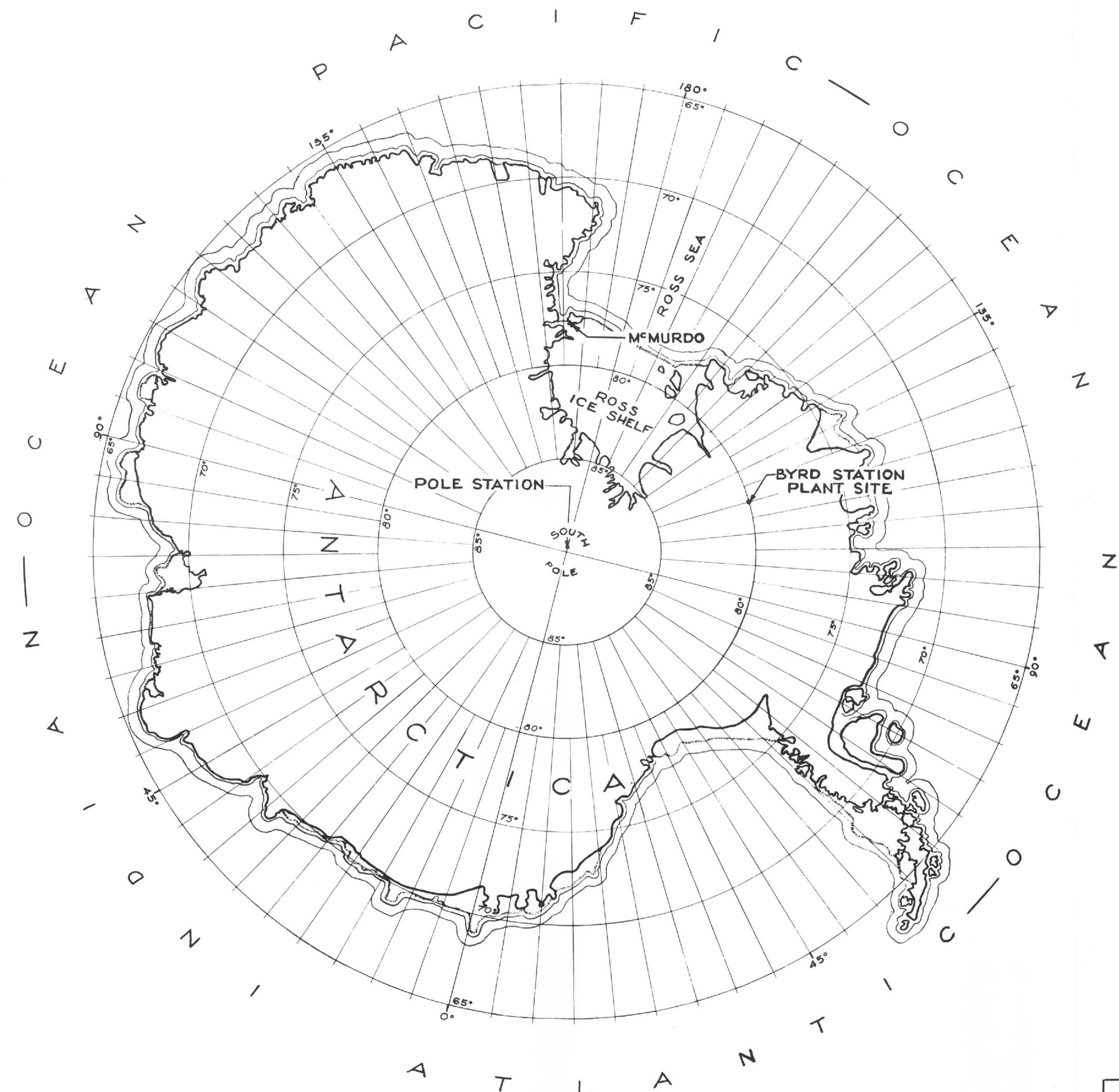
TABLE 2

SUMMARY OF POWER PLANT DATA

	Nuclear Plant	Conventional Plant
1. Over-all Performance		
Type of reactor/conventional power source	Boiling water reactor, PL-2	Diesel engine driven generators
No. of reactors	2	
No. of turbine-generators/ diesel engine generators	2	4
Electrical Capability		
Gross	975 kw/reactor	1,600
Net	800 kw (firm)	800 kw (firm)
Turbine Steam		
Flow (each reactor)	16,570 lb/hr	
Pressure	600 psia	
Temperature	486° F	
Feed-water return temperature	255° F	
2. Reactor Characteristics (per reactor)		
Fuel Assembly		
Fuel material	UO_2	
Initial enrichment	4.5%	
Weight of fuel in core	69.5 kg (U-235)	
Fuel burnup at discharge	12.4 kg (U-235)	
Cladding material	Stainless steel	
No. of fuel elements	24/reactor	
Control Rods		
No. of control rods	9/reactor	
Control material	Ag-In-Cd Alloy	
Reactor Vessel		
Outside diameter	58 in.	
Over-all height	18 ft	
Material	Carbon steel, Stainless steel clad	
3. Containment	None	

TABLE 2 (Cont'd)

	Nuclear Plant	Conventional Plant
4. Turbine-Generator		
Characteristics		
Number	2	
Type	Marine type, single barrel, split case, direct connected to generator	
Gross capability (6 in. Hg abs)	975 kw	
Generator coolant	air	
Generator voltage	480 v, 60 cycle, 3 phase	
5. Condensers		
Number	4	
Type	Air cooled	
6. Diesel Engine Generators		
Number		4
Type		Low speed, heavy duty
Rating (each)		400 kw
Generator voltage		480 v, 60 cycle, 3 phase
7. Fuel Oil in Storage		
No. of gallons	121,500 (Heating only)	634,000
Months of operation at full load	12	14



LOCATION MAP

GRAPHIC SCALE

0 200 400 600 MILES

APPROVAL	DATE
PROJECT ENGINEER D A Daly	5/5/60
CHIEF ENGINEER	

STUDY OF REMOTE MILITARY POWER APPLICATIONS FOR U. S. ATOMIC ENERGY COMMISSION

DIVISION OF HENRY J. KAISER COMPANY **KAISER ENGINEERS** OAKLAND CALIFORNIA

		DATE
SCALE		
DRAWN BY	J. MICHEAL	4-1-60
CHECKED BY	A.H. WINKLER	5-2-60
APPROVED BY	A.H. Winkler D. Mauser	5-4-60
CHIEF DESIGN ENGINEER	M Tobias	5-5-60

BYRD STATION, ANTARCTICA

800 KW POWER PLANT
SITE PLAN

JOB No. 5929 DWG. No. 1401-C

SECTION III

GENERAL CONSIDERATIONS

A. Power Requirements

Power requirements for Byrd Station include power required for lighting, communications, scientific equipment, small tools, cooking and heating. At the present time the station is heated by oil fired unit heaters located in each building. Cooking is done on oil stoves. Power for lighting, communications, and scientific equipment is supplied by three 30 kw diesel engine generators (Ref. 1).

Now that the decision has been reached to man Byrd Station permanently, facilities at the station must be constructed for a permanent crew capable of operating independently for extended periods. Since the station will be completely isolated from the outside world for periods of up to 10 months, except for radio contact, reliability of the power and heating plants is of prime importance since major repairs to the equipment cannot be made except during the three months' period the base is open to the outside. Also the ever present danger of fire dictates the use of a heating plant that will minimize this hazard.

Either a nuclear or diesel engine power plant will satisfy the requirements for a reliable, safe and reasonably trouble-free source of energy for electric power and heat. However, because of the extreme logistic difficulties in supplying the station, the use of nuclear power does have a definite advantage over any other source of power.

The installation of nuclear power generating facilities at Byrd Station would permit conversion of the station heating and cooking facilities from oil to electricity. Based on all electric heating, the power requirements have been established by the Navy Department at a total of 800 kw, of which 350 kw is for electric power and 450 kw is for heating and cooking. A further requirement is for operation of the power plant by early 1963 (Ref. 2).

B. Proposed Generating Facilities

The selection of components for both the nuclear and conventional power plants is based on the requirement for a reliable source of power. Each of the plants is therefore designed as a multiple unit installation with excess generating capacity and automatic controls and instrumentation.

All power plant schemes contemplate the maximum use of preassembled and prefabricated components to permit the rapid construction of the power plant. The sizes and weights of individual loads will be limited to the capacity of a C-130-B cargo aircraft equipped with skis (Ref. 2). Also see Appendix D.

Selection of the Nuclear Reactor

Three types of reactors were considered for use at Byrd Station (Ref. 2). These were:

PM-1, designed by The Martin Company, Baltimore, Maryland
PM-2A, designed by Alco Products, Inc., Schenectady, New York
PL-2, designed by Combustion Engineering, Inc., Windsor, Connecticut

The first two are pressurized water reactors and the third is a boiling water reactor. The PM-1, PM-2A and PL-2 are portable power plants in the sense that most of the systems are preassembled into air transportable packages at the point of manufacture to permit erection at a remote site in a short period of time. Table 3, page 13, includes a summary of the characteristics of these plants.

The PM-2A plant is the most developed at the present time. The first unit is scheduled to be shipped from the factory in May 1960 for erection at an arctic location shortly thereafter. The net electrical output of the PM-2A power plant is approximately 1,600 kw, and in addition the plant is capable of producing 1,000 lb/hr of steam for space heating. Hence the capacity of this plant is approximately twice that required for Byrd Station.

The manufacturer estimates that the cost of a PM-2A as described in Table 3 would be $2,800,000. By eliminating vapor containment, approximately $50,000 could be saved from this cost. In addition, estimates on similar plants indicate that the cost saving in scaling down a plant of the PM-2A type to meet the 800 kw requirement of the Byrd Station is approximately $100,000. Thus the cost of a PM-2A type plant with no containment and sized to meet only the power requirements for Byrd Station might be expected to cost approximately $2,600,000 f o b factory including preassembly and testing (Ref. 3).

Although the PM-1 plant is not presently developed to the same extent as the PM-2A, its design is substantially complete, and since this plant is scheduled for installation at Sundance Air Force Base in Wyoming during the summer of 1961, the cost estimate for the PM-1 is on a comparatively firm basis. The designer of this plant has estimated that the selling price of a PM-1 type plant, **f o b** factory, designed specifically for the Byrd Station conditions, excluding buildings, containment, and factory preassembly and testing, would be approximately **$1,900,000** (Ref. 4).

The PL-2 project is somewhat less developed than the PM-1 and PM-2A reactors since only a reference design has been completed at the present time and there are no specific plans for construction of a unit of this type. However, the design of this concept is based upon the experience of the 300 kw SL-1 now operating at the National Reactor Testing Station in Idaho. The PL-2 design differs from the SL-1 in the following respects:

1. The PL-2 is a portable plant whereas the SL-1 is a stationary power plant.

2. The power output of the reference design PL-2 is approximately three times that of the SL-1.

3. The SL-1 fuel elements use highly enriched uranium and aluminum cladding, whereas the PL-2 fuel elements use partly enriched UO_2 fuel clad with stainless steel.

4. The air cooled condensers used in the two plants are of somewhat different design.

It is presently planned that during the summer of 1961 a PL-2 type condenser will be installed at the SL-1 plant in Idaho and the reactor thermal output increased to a level comparable with the reference design PL-2. During the summer of 1961 a partly enriched stainless steel clad core will be installed in the SL-1. Thus by the summer of 1961 the only undemonstrated feature of the PL-2 will be the packaging. The designer of the PL-2 estimates that the cost of a plant of this type **f o b** factory with no containment, excluding buildings and factory preassembly and testing, is approximately $1,700,000 (Ref. 5).

Any one of these three reactors is suitable for use at Byrd Station and can be erected in time to meet the required operation date of early 1963. The cost of shipping, housing and erecting the PM-1 and PL-2 plants is nearly equivalent and the PM-2A only slightly more expensive as a result of its greater number of packages.

The estimated annual nuclear fuel cost for the PL-2 is the lowest of the three reactors, with the cost for the PM-1 and PM-2A following in that order.

Table 4, page 14, compares total construction costs, annual nuclear fuel costs and annual operation costs for each of these plants. From Table 4 it can be seen that the total construction costs of PM-1 and PL-2 plants are very close, with the construction cost of the PM-2A being in excess of $1,000,000 higher. The use of the PM-2A reactor would thus result in a higher annual cost than either the PM-1 or PL-2.

Since costs for the PM-1 and the PL-2 are within 10%, within the accuracy of these preliminary estimates they might be considered equal. However, since a selection must be made to arrive at a basis for the report, the PL-2 plant was selected as having an apparent saving in annual cost over the PM-1.

In addition to the PM-1, PM-2A and PL-2 plants, the direct cycle, gas cooled ML-1 plant, designed by Aerojet-General Nucleonics of San Ramon, California, was also considered for use at Byrd Station. This plant, although having the advantage of being fully transportable in only three packages, was not selected for the following reasons (Ref. 6):

1. Maximum capacity of only 500 kw.
2. Estimated plant life of 6 years.
3. Installed cost approximately equal to that for the PL-2 plant.
4. Higher fuel cost.

Selection of the Nuclear Power Plant

To meet the requirements established by the Navy of 350 kw of electric power and an equivalent of 450 kw of heat, four nuclear power plant schemes were analyzed to determine the most suitable scheme for use at Byrd Station, as follows:

1. One 800 kw (net) nuclear power plant and three 400 kw diesel engine generators. Sufficient diesel oil would be stored to operate two of the three diesel engines for 12 months at full load.

2. One 800 kw (net) nuclear power plant and two 350 kw diesel engine generators. Sufficient diesel oil would be stored to operate one of the diesel engines at full load for 12 months and the oil fired unit heaters for 12 months.

3. Two 800 kw (net) nuclear power plants. Sufficient diesel oil would be stored to operate the oil fired unit heaters for 12 months.

4. One 800 kw (net) nuclear power plant and three 400 kw diesel engine generators. Sufficient diesel oil would be stored to operate two of the three diesel engines for approximately 7 months at full load. This amount of diesel oil would also be sufficient to operate one of the diesel engine generators at 350 kw load and provide oil fired heat for a 12-month period.

Schemes 1 and 4 differ only in the amount of fuel oil storage provided.

Table 5, page 15, shows preliminary capital and average annual costs for the four schemes based on estimates received from Combustion Engineering, Inc. for the PL-2 reactor. Scheme 2 has the lowest average annual cost of any of the schemes.

Scheme 2 was not selected because of the need to use the oil fired heaters during emergencies and when the reactor is shut down for maintenance and refueling. Besides the fire hazard inherent in using the oil fired heaters, the heaters would have to be left in place at all times and maintained in a ready to operate condition.

Scheme 3, using two 800 kw (net) reactors and having the next lowest average annual cost, was selected as being the most suitable scheme for use at the Pole.

Selection of Conventional Power Plant

Selection of the conventional power plant was based on the same power requirements and criteria used in selecting the nuclear power plant.

The conventional power plant must have the same degree of reliability and ability to deliver power under all operating conditions. For these reasons, the design of the plant must include provisions for excess capacity, quick starting, load sharing, automatic synchronization, and complete instrumentation.

Unit capital costs and production costs for power plants of the size required for the Byrd Station are considerably higher for gas turbine and conventional steam plants than for diesel engine plants (Ref. 7). Therefore, the conventionally fueled power station selected for this comparison is of the multiple unit diesel engine generator plant design.

The requirement of reliability (continuity) of power service indicates the use of multiple and completely independent generating units, with excess capacity provided in the form of spare units. System simplicity, which is a measure of system reliability, is maximum when the smallest number of machines is used to meet the requirements. Since one unit will be down at planned intervals for maintenance and overhaul, two spare units are provided in addition to those required to meet normal load requirements.

For comparison purposes two conventional power plant schemes were analyzed to determine the scheme with the lowest over-all cost, as follows:

1. Four 400 kw diesel engine generators. Sufficient diesel oil would be stored to operate two of the four diesel engines at full load for 14 months.

2. Six 200 kw diesel engine generators. Sufficient diesel oil would be stored to operate four of the six diesel engines at full load for 14 months.

Table 6, page 16, shows preliminary capital and annual costs for the two conventional power plant schemes. Scheme 1 with the lowest capital and annual cost was selected as the most suitable type conventional power plant for installation at Byrd Station. Of the initial 14-month supply of diesel oil, only the cost of two months' supply is included in the capital cost. This quantity represents an emergency reserve of diesel oil which would always be on hand. For either scheme, heavy duty, turbo-charged diesel engines, 720 rpm or less with low BMEP, were selected to reduce maintenance and provide a reliable source of power with minimum fuel consumption.

TABLE 3

SUMMARY OF CHARACTERISTICS

PORTABLE AND MOBILE NUCLEAR POWER PLANTS

Concept	ML-1	PL-2	PM-1	PM-2A
Type of Reactor	gas-cooled	boiling water	press. water	press. water
Design Contractor	Aerojet-General Nucleonics	Combustion Eng.	The Martin Co.	Alco Products
Nominal Capacity	330 kw (net)	1,000 kw (net) +0.4 mwt steam	1,000 kw (net) +2.0 mwt steam	1,560 kw (net) +0.3 mwt steam
Auxiliary Power, kw	70	237	250	315
Reactor Thermal Rating, mwt	3.4	8.8	9.37	10
Core Lifetime, mwt-yrs.	3.9	30.0	18.7	8.0
Heat Dissipation	gas-to-air	steam-to-air	steam-to-air	steam-to-glycol
Design Ambient Air Temp., °F	100	60	70	arctic conditions
Design Altitude, ft above sea level	0	6,000	6,500	arctic conditions
Plant Lifetime, years	6	20	20	20
No. of Operating Personnel per reactor	6	7	8	8
No. of Shipping Packages per reactor (excluding foundations and turbine building)	4	17	17	26
Shipping Weight, lb, per reactor (excluding foundations and turbine building)	120,000	480,000	510,000	710,000
Delivery Time (f o b Plant)	15 mos.	15-18 mos.	14 mos.	15-18 mos.
Status of Project	Prototype operation scheduled in 1961. Component tests, GCRE and GTTF are now operating.	Ref. Design of PL-2 complete. Stationary 300 kw prototype (SL-1) now operating. PL-2 type core to be tested at 8-10 mwt starting July 1961.	Design complete. Operation scheduled for summer 1961 at Sundance, Wyoming.	Being installed at Camp Century, Greenland for operation by September 1, 1960.

TABLE 4

COMPARISON OF COSTS

NUCLEAR POWER COSTS MODIFIED FOR BYRD STATION
(STAND-BY REACTOR NOT INCLUDED)

	PL-2	PM-1	PM-2A
Plant Net Capacity, kwe	800	800	800
Reactor Thermal Power, mwt	5.5	5.5	5.5
Electric Energy per Core, kwhr	33.9×10^6	28×10^6	11.3×10^6
Electric Energy per Year, kwhr (1.0 plant operating factor)	6.97×10^6	6.97×10^6	6.97×10^6
Core Lifetime, yrs	4.64	3.69	1.62
Core Fabrication Cost	$ 330,000	$ 250,000	$ 240,000
ESTIMATE OF PROJECT COST			
Structures and Improvements	$ 315,000	$ 286,000	$ 350,000
Nuclear Power Plant Equipment	1,853,000	2,081,000	2,750,000
Total Direct Construction Cost	$2,168,000	$2,367,000	$3,100,000
Indirect Cost	1,612,000	1,753,000	2,290,000
Total Direct and Indirect Construction Cost	$3,780,000	$4,120,000	$5,390,000
Escalation	220,000	250,000	320,000
Total Including Escalation	$4,000,000	$4,370,000	$5,710,000
Design Engineering	400,000	400,000	400,000
Total Excluding Contingency	$4,400,000	$4,770,000	$6,110,000
Contingency	880,000	950,000	1,220,000
TOTAL PROJECT COST	$5,280,000	$5,720,000	$7,330,000
ANNUAL COSTS			
Nuclear Fuel			
Fabrication	$ 71,000	$ 68,000	$ 148,000
Burnup	30,000	44,000	50,000
Reprocessing	19,000	52,000	91,000
Transportation	12,000	7,000	16,000
Sub-Total, Nuclear Fuel	$ 132,000	$ 171,000	$ 305,000
Operating and Maintenance			
Labor w/escalation	$ 233,000	$ 272,000	$ 272,000
Supplies	37,000	32,000	42,000
Sub-Total, Operating and Maintenance	$ 270,000	$ 304,000	$ 314,000
Fixed Charges	264,000	286,000	366,000
TOTAL ANNUAL COST	$ 666,000	$ 761,000	$ 985,000

TABLE 5

COST COMPARISON

NUCLEAR POWER PLANT SCHEMES

	Description	Scheme 1 1-800 kw PL-2 3-400 kw Diesel Generators	Scheme 2 1-800 kw PL-2 2-350 kw Diesel Generators	Scheme 3 2-800 kw PL-2	Scheme 4 1-800 kw PL-2 3-400 kw Diesel Generators
1.0	Land and Land Rights	$ - -	$ - -	$ - -	$ - -
2.0	Structures and Improvements	478,000	458,000	548,000	478,000
3.0	Reactor Plant	1,130,000	1,130,000	2,116,000	1,130,000
4.0	Turbine-Generator Plant	352,000	352,000	686,000	352,000
5.0	Accessory Electrical Equipment	281,000	281,000	486,000	281,000
6.0	Miscellaneous Power Plant Equipment	61,000	61,000	93,000	61,000
7.0	Transmission Plant	7,000	7,000	7,000	7,000
8.0	Communication System	6,000	6,000	6,000	6,000
9.0	Stand-by Diesel Plant	200,000	130,000	- -	200,000
10.0	Fuel Oil Storage and Distribution System	250,000	145,000	- -	145,000
	Total Direct Construction Cost	$2,765,000	$2,570,000	$3,942,000	$2,660,000
11.0	Indirect Cost	2,460,000	2,430,000	2,905,000	2,440,000
	Total Construction Cost	$5,225,000	$5,000,000	$6,847,000	$5,100,000
12.0	Escalation 6%	315,000	300,000	413,000	306,000
	Total Including Escalation	$5,540,000	$5,300,000	$7,260,000	$5,406,000
13.0	Design Engineering	400,000	400,000	400,000	400,000
	Total Excluding Contingency	$5,940,000	$5,700,000	$7,660,000	$5,806,000
14.0	Contingency 20%	1,190,000	1,140,000	1,540,000	1,164,000
	Total Including Contingency	$7,130,000	$6,840,000	$9,200,000	$6,970,000
	Fuel Oil in Storage *	1,570,000	910,000	400,000	1,015,000
	TOTAL PROJECT COST	$8,700,000	$7,750,000	$9,600,000	$7,985,000
	ANNUAL COSTS				
	Nuclear Fuel	$ 118,000	$ 118,000	$ 132,000	$ 118,000
	Diesel Fuel	210,000	136,000	- -	210,000
	Operating and Maintenance	237,000	237,000	270,000	237,000
	Sub-Total	$ 565,000	$ 491,000	$ 402,000	$ 565,000
	Annual Depreciation	435,000	388,000	480,000	399,000
	TOTAL ANNUAL COST	$1,000,000	$ 879,000	$ 882,000	$ 964,000
	Quantity Fuel Oil in Storage, Gal	543,000	315,000	122,000	315,000

* The only difference between Schemes 1 and 4 is the quantity of fuel oil in storage. The value shown for fuel oil in storage is equivalent to the total value of fuel oil in storage less the value of the fuel used annually by the stand-by plant for scheduled shut downs and refueling (estimated to be 10% of the time).

TABLE 6

COST COMPARISON

CONVENTIONAL POWER PLANT SCHEMES

	Description	Scheme 1 4-400 kw Diesel Engine Generators	Scheme 2 6-200 kw Diesel Engine Generators
1.0	Land and Land Rights	$ - -	$ - -
2.0	Structures and Improvements	205,000	216,000
3.0	Fuel Oil Storage and Distribution System	209,000	209,000
4.0	Diesel Generator Plant	327,000	400,000
5.0	Accessory Electrical Equipment	96,000	116,000
6.0	Miscellaneous Power Plant Equipment	20,000	24,000
7.0	Transmission Plant	4,000	5,000
8.0	Communication System	4,000	4,000
	Total Direct Construction Cost	$ 865,000	$ 974,000
9.0	Indirect Cost	1,363,000	1,530,000
	Total Construction Cost	$2,228,000	$2,504,000
10.0	Escalation	132,000	146,000
	Total Including Escalation	$2,360,000	$2,650,000
11.0	Design Engineering	100,000	100,000
	Total Excluding Contingency	$2,460,000	$2,750,000
12.0	Contingency	340,000	400,000
	Total Including Contingency	$2,800,000	$3,150,000
13.0	Fuel Oil in Storage	300,000	300,000
	TOTAL PROJECT COST	$3,100,000	$3,450,000
	Annual Costs		
	Diesel Fuel	$2,101,000	$2,101,000
	Operating and Maintenance	221,000	235,000
	Sub-Total	$2,322,000	$2,336,000
	Fixed Charges	155,000	172,000
	TOTAL ANNUAL COST	$2,477,000	$2,508,000

C. Description of Station

Byrd Station was established in the winter of 1956-1957 as one of the United States' scientific observation stations for the International Geophysical Year. The station, located at 80° south latitude and 120° west longitude, is approximately 850 miles from NAF McMurdo and 700 miles from the South Pole (Ref. 8).

The station consists of some sixteen small buildings housing the galley and mess hall, recreation facilities, powerhouse, quarters, shops, garage, storage facilities, and communications and scientific equipment. Most buildings are of the temporary Clemens or Jamesway type and include some built at the site from dunnage and other scrap materials. These buildings, constructed on wooden sills laid on top of the snow, are in poor condition and will have to be reconstructed or replaced in the near future (Ref. 1). At the present time the Navy has plans to rebuild the station in snow tunnels to provide a more permanent type installation.

Power for the station is provided by three 30 kw, high speed diesel electric generators, 110/220 v, single-phase. Two additional 30 kw units are at the site but were damaged in transit and must be repaired before they are usable (Ref. 1).

Space heating is provided by oil fired unit heaters installed in the buildings. Cooking is done primarily on oil fired stoves (Ref. 1).

Diesel oil storage is provided by three 800 gal steel tanks and one 10,000 gal neoprene tank plus caches of 50 gal drums at each building (Ref. 1).

Fresh water is supplied by a snow melter at the power plant. Sanitary wastes are disposed of in holes dug in the snow (Ref. 1).

During Operation Deep Freeze IV a wintering-over party of 10 Navy personnel and 13 scientists occupied the station (Ref. 1).

The area at Byrd Station is a plateau averaging about 5,000 ft above sea level. Soundings in the area indicate that the ice cap is some 10,000 ft thick, extending some 5,000 ft below sea level. Weather conditions are severe, with mean temperatures ranging from a low of -32.0° F in the winter to a high of -5.7° F in the summer. Lowest recorded temperature was -82.0° F. The average wind velocity in the winter is 17.2 mph and in the summer 15.7 mph. Gusts of up to 68.0 mph have been recorded. An average summer day is one with the temperature at 0° F and winds of 12 mph (Ref. 1).

The average snowfall at Byrd Station is approximately 15 inches per year. Drifting is a problem due to the almost constant wind, and excavations in the snow are quickly filled and supplies and equipment covered unless special precautions are taken (Ref. 1).

During the Antarctic summer the sun is visible 24 hours per day, allowing outside construction activities to continue around the clock.

When the original station was constructed, men, materials, supplies and equipment were transported 646 miles from Little America V by tractor train to the site (Ref. 8). With the advent of the C-130-B aircraft, it is planned that all cargo and personnel will be transported from NAF McMurdo to the site by air (Ref. 2). Due to weather conditions the flying season is limited to about four months per year, from about October 15 to February 10. Ski equipped planes land at the site on a runway prepared by leveling the snow ridges by means of a drag.

C-130-B aircraft flying between NAF McMurdo and Byrd Station can carry a payload of 30,200 lb. Approximately this same load can be carried on the return trip providing additional jet fuel is carried by the plane, and with a resulting smaller payload into the station (Appendix D).

The normal method of transportation from the United States will be by cargo vessel to McMurdo Sound and then by C-130-B aircraft to Byrd Station. Ships assisted by icebreakers can enter McMurdo Sound starting the latter part of December. Cargo is off-loaded onto the ice and hauled by tractor drawn sleds to NAF McMurdo four to ten miles distant where it is stored for transportation by air to the site. In the past the last ship has left the area about the middle of March (Ref. 1).

Cargo planes flying from New Zealand 2,300 miles distant can operate into NAF McMurdo, starting in October and continuing until the middle of February (Ref. 1).

The proposed power plants can be located above the snow or in cut-and-cover tunnels under the snow, as is being done at Camp Century in Greenland. Buildings located above the snow are soon covered to the roofs by drifting snow, requiring increased maintenance. In addition, the extreme temperature range and constant wind impose difficult environmental conditions, which increase the cost of constructing and heating the buildings. For these reasons the proposed power plants are designed for installation under the snow in cut-and-cover tunnels (Ref. 9).

D. Construction Considerations

Construction at Byrd Station imposes many new and unusual problems in logistics and working conditions. Unless personnel are prepared to winter over, the construction season is limited to approximately 90 days from mid-November to mid-February, during which time the sun is visible 24 hours per day and weather conditions are the most favorable.

Living accommodations at Byrd Station are limited, as are messing and other facilities. Since construction work will be done on a two-shift per day basis, personnel can be doubled-up in existing quarters so that only a limited amount of temporary quarters will be required. However, additional messing facilities will have to be provided. A wintering-over construction force could not be accommodated without extensive new construction and the importation of large amounts of fuel oil and other supplies.

By careful planning it is anticipated that the nuclear or conventional power plant can be completed in two seasons, and therefore a wintering-over party will not be required.

Adequate quarters and other facilities are available at NAF McMurdo for construction personnel required to construct the permanent fuel oil tanks and to support the construction work at the site.

Construction Labor

All construction work will be performed by Navy Construction Battalion personnel with the assistance of contractor supervisory personnel. In the past work has been performed on a 12-hour per day shift, seven days a week. For purposes of this study a six day work week has been adopted with two 10-hour shifts per day. Construction labor costs have been based on an average rate of $20,350 per man year, of which $7,500 is pay and allowances and the balance transportation, services and supplies (Ref. 10).

Approximately 110 Construction Battalion personnel would be required the first season to complete the snow tunnels, foundations and buildings for the nuclear power plant. The following season approximately 113 Construction Battalion and contractor personnel would unload and erect the power plant equipment.

The second season the nuclear power plant operators will assist the construction personnel in the final assembly and test of the plant. Also, a representative of the nuclear reactor manufacturer will be on hand to lend further assistance, and if necessary winter over the first year of operation. It is hoped that by proper selection and training of the nuclear power plant operators, it will not be necessary for the manufacturer's representative to winter over.

Construction Materials

Due to the limited construction season it is imperative that the bulk of the construction materials be prefabricated into units of a size that can be easily handled at the site. Foundation timbers should be precut, predrilled and match marked. Buildings should be constructed of prefabricated panels, using special fasteners similar to the standard T-5 type building. Tunnel arches should be fabricated to size. Fuel oil storage tanks will be made of neoprene coated fabric. Large size piping should be prefabricated with flange connections, etc.

The cost of construction materials has been based on U. S. prices, f a s Davisville, Rhode Island, the supply point for Task Force 43.

Construction Equipment

At the present time two D-8 and two D-4 tractors are on the site, plus two Tucker Sno-Cats and two Weasels. This equipment has all been used for several years and due to a lack of maintenance facilities at Byrd Station is in poor condition (Ref. 1). This equipment should be rehabilitated so that at least one D-8 and one D-4 tractor will be available at the time construction begins in late 1961. The D-8 tractor will be equipped with a side boom.

In addition it is planned to fly in two D-6 tractors, one equipped with a front loader and one equipped with a side boom.

One Peter Snow Miller will be required for excavating the tunnels and backfilling over the tunnel arches.

Other equipment required will include cargo sleds, welding machines, and miscellaneous small tools.

At the end of each construction season the D-6 tractors and Snow Miller will be returned to McMurdo Sound for maintenance and storage.

Permanent Equipment

All permanent power plant equipment will be purchased in the United States. The nuclear power plants will be designed so all major items will be preassembled at the factory into packages that can be easily installed in the field.

Shipping and Warehousing

The key to the successful construction of a power plant at Byrd Station is the planning and coordination of the shipment of men, materials and equipment. This must of necessity be done in two steps. First, materials and equipment must be assembled at Davisville, Rhode Island, or other selected ports, and shipped by cargo vessel to McMurdo Sound, arriving as early as possible in December. There the materials and equipment are off-loaded over the ice and stored on shore. A minimum of two C-130-B cargo aircraft will then be used to transport the cargo to Byrd Station, each plane making an average of one trip per day.

The first year it will be advisable to ship the Snow Miller and two tractors to New Zealand by cargo vessel in November for transshipment in the two C-130-B aircraft that will be used for the Byrd Station flights. This will allow work on the tunnels to begin prior to the arrival of the first cargo vessel at McMurdo Sound.

Personnel and small tools will also be flown into McMurdo Sound before the arrival of the first vessel.

The second year essential equipment needed to start construction will be flown to NAF McMurdo prior to the start of the construction season and then to Byrd Station. The balance of the materials and equipment will be transported on cargo vessels to McMurdo Sound and then by plane to the site. See Table 7 for logistic data for the nuclear power plant and Table 8 for the conventional power plant.

For shipping purposes, all bulk materials will be palletized, with the size and weight of any package limited by the cargo-carrying capacity of the C-130-B.

Contractor Facilities

Personnel furnished by the nuclear manufacturer or other contractor will be limited to a maximum of three at Byrd Station. Cost of transporting and messing these men is included in the cost estimate.

TABLE 7

BYRD NUCLEAR PLANT

LOGISTIC DATA

1961	ITEM	EXPORT WEIGHT ESTIMATED SHORT TONS	NUMBER OF SHIPPING PACKAGES	STAGING AREA	DEPARTURE DATE	METHOD OF SHIPPING	TRANSSHIPPING AREA	NO. OF AIRCRAFT TRIPS	REMARKS
	2.0 Structures and Improvements								
	2.1.2 Tunnel Roof - "Wonder" Arch	72	24 - 3 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	5	Two C-130-B aircraft required during 1961
	2.1.3 Water Supply	10	4	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	1	
	2.1.4 Sanitary Sewage Disposal			Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.1.5 Tunnel Lighting			Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.1.6 Fire Extinguishing Equipment			Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Sub-Total	82 Tons	28 Packages					6 Trips	
	2.2 Turbine-Generator Buildings (2)								
	2.2.1 Substructure (Timber 20'-0" Lengths)	75	15 - 5 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.2.2 Superstructure T-5 Building	100	20 - 5 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.2.3 Heating and Ventilation	12	3	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.2.4 Plumbing	8	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.2.5 Building Electrical	6	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.2.6 Painting	2	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.2.7 Cranes and Hoists	3	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Sub-Total	200 Tons	42 Packages					14 Trips	
	2.3 Reactor Buildings (2)								
	2.3.1 Substructure	100	20 - 5 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.3.2 Superstructure	90	18 - 5 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.3.3 Miscellaneous	15	3 - 5 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Sub-Total	205 Tons	41 Packages					14 Trips	
	Construction Equipment and Supplies								
	Snow Miller	15	1	Davisville, Rhode Island	September	AKA to New Zealand	New Zealand Via aircraft from New Zealand to McMurdo		5 Trips from New Zealand to McMurdo 5 Trips from McMurdo to Byrd 3 Trips return from Byrd (Snow miller and tractors returned for overhaul to McMurdo at end of construction season)
	Tractors	17	2	Davisville, Rhode Island	September	AKA to New Zealand			
	Welding Machines	8	2	Davisville, Rhode Island	September	AKA to New Zealand			
	Miscellaneous	50	10 - 5 Ton Packages	Davisville, Rhode Island	September	AKA to New Zealand			
	Sub-Total	90 Tons	15 Packages					13 Trips	
	TOTAL 1961	577 Tons	126 Packages					47 Trips	
	Personnel - Navy McMurdo 25 Byrd 85 Total 110								Naval Construction Personnel will be flown to Antartica in planes from CONUS required for cargo airlift. Personnel will be required @ McMurdo for equipment off-loading, warehousing, and loading aircraft.
1962									
	3.0 Reactor Plant (PL-2)								
	3.1 Reactor Package (2)	120	8 - 15 Ton Packages	Davisville, Rhode Island	September	AKA cargo vessel to New Zealand	McMurdo	8	Two C-130-B aircraft required during 1962
	3.2 Feed and Condensate Package (2)	30	2 - 15 Ton Packages	Davisville, Rhode Island	September	One complete plant to be air-lifted to McMurdo.	McMurdo	2	
	3.3 Waste and Spent Fuel Storage (2)	30	2 - 15 Ton Packages	Davisville, Rhode Island	September		McMurdo	2	
	3.4 Purification Package (2)	30	2 - 15 Ton Packages	Davisville, Rhode Island	September	One complete plant to remain on the AKA and transshipped at McMurdo.	McMurdo	2	
	3.5 Miscellaneous Equipment (2)	20	2 - 10 Ton Packages	Davisville, Rhode Island	September		McMurdo	2	
	3.6 Piping and Insulation (2)	30	2 - 15 Ton Packages	Davisville, Rhode Island	September		McMurdo	2	
	Sub-Total	260 Tons	18 Packages					18 Trips	
	4.0 Turbine-Generator Plant								
	4.1 Turbine-Generator Package (2)	30	2 - 15 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	2	
	4.2 Condenser Package	105	7 - 15 Ton Packages	Davisville, Rhode Island	September		McMurdo	7	
	4.3 Piping	30	2 - 15 Ton Packages	Davisville, Rhode Island	September		McMurdo	2	
	Sub-Total	165 Tons	11 Packages					11 Trips	
	5.0 Accessory Electrical								
	5.1 Electrical Package (PL-2) (2)	30	2 - 15 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	2	
	5.2 Switchgear and Miscellaneous	10	1 - 10 Ton Package	Davisville, Rhode Island	September		McMurdo	1	
	Sub-Total	40 Tons	3 Packages					3 Trips	
	6.0 Miscellaneous Power Plant Equipment								
	6.1 Fire Extinguishing Equipment	3	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	6.2 Fire Alarm System	1	1	Davisville, Rhode Island	September		McMurdo		
	6.3 Shop Equipment	3	1	Davisville, Rhode Island	September		McMurdo		
	6.4 Office Furniture and Equipment	2	1	Davisville, Rhode Island	September		McMurdo		
	6.5 Start-up and Emergency Heating System	15	1	Davisville, Rhode Island	September		McMurdo		
	6.6 Laboratory Equipment	5	1	Davisville, Rhode Island	September		McMurdo		
	Sub-Total	29 Tons	6 Packages					2 Trips	
	Construction Equipment and Supplies								
	Snow Miller	15	1	McMurdo	September	C-130-B		} 3	
	Tractors	17	2	McMurdo	September				
	Welding Machines			McMurdo	September				
	Miscellaneous	55	11 - 5 Ton Packages	Davisville, Rhode Island	September	AKA to New Zealand. Airlift to McMurdo.	New Zealand and McMurdo	3	
	Sub-Total	87 Tons	14 Packages					6 Trips	
	Sub-Total Less Oil	501 Tons	52 Packages					40 Trips	
	Initial complement of fuel oil 121,500 gallons in 50-gallon drums	432 Tons	2,430 - 50 gallon drums	Norfolk, Virginia	September	AKA to McMurdo	McMurdo	36 Trips	68 bbl/trip
	TOTAL 1962	1,013 Tons	52 Packages					76 Trips	
	Personnel Navy (McMurdo) 25 Navy (Byrd) 85 Civilian (Byrd) 3 Total 113								Naval Construction Personnel will be flown to Antartica in planes from CONUS required for cargo airlift. Personnel will be required @ McMurdo for equipment off-loading, warehousing, and loading aircraft.

TABLE 8

BYRD CONVENTIONAL PLANT

LOGISTIC DATA

1961	ITEM	EXPORT WEIGHT ESTIMATED SHORT TONS	NUMBER OF SHIPPING PACKAGES	STAGING AREA	DEPARTURE DATE	METHOD OF SHIPPING	TRANSSHIPPING AREA	NO. OF AIRCRAFT TRIPS	REMARKS
	2.1 General Improvements								
	2.1.2 Tunnel Roof	90	18 - 5 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	6	During 1962 one C-130-B aircraft will be required to transport men and materials from CONUS to Byrd Station. See Appendix A for particulars of the C-130-B.
	"Wonder" Arches								
	2.1.3 Water Supply System	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.1.4 Sanitary Sewage Disposal	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.1.5 Tunnel Lighting	2	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	1	
	2.1.6 Fire Extinguishing System	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Sub-Total	95 Tons	22 Packages					7 Trips	
	2.2 Diesel Generator Building								
	2.2.1 Substructure	63	13 - 5 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	20'-0" Lengths - Cut and Marked								
	2.2.2 Superstructure	50	1 - 3 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Roof Panels, Trusses, Wall and Floor Panels (T-5 Building)								
	Sub-Total	113 Tons	14 Packages					8 Trips	
	3.0 Oil Storage								
	Tankage at Pole	12	12	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	1	
	12 Neoprene Tanks at 50,000 Gallons Each								
	Lube Oil	7	32	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	1	
	32 - 55 Gallon Drums								
	Piping and Pumps	7	2	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Tankage at McMurdo	115	23	Davisville, Rhode Island	September	AKA to McMurdo	Off-load at McMurdo		Install at McMurdo
	Tote Tanks and Transfer Equipment	5	3	Davisville, Rhode Island	September	AKA to McMurdo	Off-load at McMurdo		Install at McMurdo
	Sub-Total	146 Tons	72 Packages					2 Trips	
	Construction Equipment								
	Snow Miller	15	1	Davisville, Rhode Island	September	AKA to New Zealand, via Aircraft from New Zealand to McMurdo	New Zealand and McMurdo		Snow Miller and Tractors to be returned to McMurdo for overhaul and repair and reshipped by air the following year to Byrd Station.
	Tractors	17	2 - 8.5 Ton Package	Davisville, Rhode Island	September				
	Cargo Sleds	3	1	Davisville, Rhode Island	September				
	Welding Equipment	8	2 - 4 Ton Packages	Davisville, Rhode Island	September				
	Miscellaneous	15	1	Davisville, Rhode Island	September				
	Sub-Total	58 Tons	7 Packages					13 Trips	
	TOTAL 1961	412 Tons	115 Packages					30 Trips	
	Personnel - Navy: Byrd 25; McMurdo 10; Total 35								Naval Construction Personnel will be flown from CONUS to Antarctica on the plane required for cargo airlift. Personnel will be required at McMurdo for tank erection, equipment off-loading, loading an aircraft and warehousing.
1962									
	Construction Equipment and Supplies	58	3	McMurdo (Stored)	November	C-130-B	McMurdo	4	1. During 1962 one C-130-B aircraft will be required to transport men and materials from CONUS to Byrd Station for power plant construction. 2. During 1962 three additional aircraft will be required to transport the initial complement of fuel oil to the Station. 3. The 234 tons of material and equipment required for the plant will become a portion of a consolidated shipment on an AKA (6,000 ton) and costs have been prorated in the report on the assumption that the balance of the cargo will be required for the existing stations.
	2.2 Diesel Generator Building								
	2.2.3 Heating and Ventilating Equipment and Ductwork	5	4	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.2.4 Plumbing	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.2.5 Building Electrical	2	2	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	1 (2.2.3–2.2.7)	
	2.2.6 Miscellaneous Cranes and Hoists	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.2.7 Paint	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Sub-Total	68 Tons	12 Packages					5 Trips	
	4.0 Diesel Generator Plant								
	4.1 Diesel Generators and Accessories	90	12	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	6	
	3 Packages each Engine - Engine, Generator, and Accessories								
	4.2 Combustion Air	4	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	4.3 Cooling System	4	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	4.4 Diesel Generator Foundations	10	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	4.5 Diesel Engine Lubricating System	4	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	2 (4.2–4.9)	
	4.6 Instruments	2	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	4.7 Plant Piping	12	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	4.8 Starting Air	2	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	4.9 Auxiliary Foundations	4	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Sub-Total	132	20 Packages					8 Trips	
	5.0 Accessory Electrical Equipment								
	Switchgear, Panels, Cables, Breakers	22	3	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	6.0 Miscellaneous Power Plant Equipment	10	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Sub-Total	32 Tons	4 Packages					2 Trips	
	7.0 Transmission Plant	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	Consolidated with Item 5 and 6	
	8.0 Communication Plant	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Sub-Total	2 Tons	2 Packages						
	Sub-Total Less Oil	234 Tons	38 Packages					15 Trips	
	Initial Complement of Oil 634,000 Gallons	2,250 Tons	Bulk	Norfolk, Virginia	September	AOG Tanker to McMurdo	McMurdo	157 Trips	14 months' supply of fuel pumped into storage tanks at McMurdo and transshipped in 4,000 gallon tote tanks aboard C-130-B aircraft.
	TOTAL 1962	2,484 Tons	38 Packages					172 Trips	
	Personnel - Navy: Pole 30; McMurdo 12; Total 42								Naval Construction Personnel will be flown from CONUS to Antarctica on planes required for cargo airlift.

SECTION IV

PROPOSED NUCLEAR POWER PLANT

A. General Description

The power plant for the Byrd Station will consist of two PL-2 nuclear power plants. Each PL-2 reactor plant generator will be modified to produce 800 kw net electrical power at 480 volts. While one plant is operating to provide the required 800 kw, the other reactor will be maintained at temperature and pressure to provide 100% back-up for the operating plant.

The reactor plant is based on the PL-2 design being made by Combustion Engineering, Inc. under contract to the U. S. AEC. The plant is described in References 11, 12 and 13 and includes design changes made up to April 23, 1960. The estimate of cost is based on cost data furnished by Combustion Engineering, Inc. (Ref. 5).

The PL-2 reactor is a light water moderated and cooled, natural circulation boiling water reactor capable of producing 8.5 megawatts of thermal power in a stainless steel clad uranium dioxide pellet core, enriched to 4.5% U-235 content. The core will be contained in a stainless steel clad, carbon steel cylindrical pressure vessel, 52 in. diameter by 18 ft high. The top head will contain penetrations for nine rack-and-pinion control rod drives. The control rods will be cruciforms of silver-indium-cadmium alloy jacketed in stainless steel. The reactor pressure will be controlled automatically by the central control rod. Each reactor will produce 17,870 lb/hr of dry saturated steam at 615 psia with feed water at approximately 255° F. By-pass demineralizer purification systems will be used to maintain system purity, and storage tanks will be provided to collect and store radioactive waste from all of the plant drains and sumps. The reactor vessels will be contained in 11.5 ft cylindrical, water filled shield tanks located in the reactor tunnels. The waste storage tanks and spent fuel storage tanks will be located adjacent to the shield tanks.

Reactor produced steam will be supplied to the turbines through a 3-in. stainless steel pipe. About 1,000 lb/hr of steam from the reactor will be by-passed to a space heat exchanger, which will produce hot water for building heating. Each turbine exhausts through a 12 in. stainless steel pipe to two air cooled condensers operating at 6 in. Hg abs. The condensers drain to hotwells located on the feed and condensate skids. Make-up water (50 gal per day) will be admitted at the hotwells. The condensate is used to provide equipment cooling (including shield water cooling) before being returned to the reactors by the feed-water pumps.

All plant facilities will be constructed within snow tunnels excavated below the surface. Each plant will be located in separate tunnels 28 ft wide and approximately 350 ft long on opposite sides of the station's main access tunnel. The reactors, shield tanks, waste tanks and spent fuel tanks will be located in a portion of the tunnels 49 ft deep. The remainder of the equipment will be located in tunnels 24 ft deep. There will be 40 ft of snow fill between the reactor and the secondary plant to serve as shielding. A small connecting access and pipe tunnel will be provided through the shielding.

A Peter Snow Miller will be used to excavate a trench to the required size and to prepare a level bench for supporting the roof arches spanning the tunnel. After erecting the steel arches, the Miller will be used to place the snow shielding and about 3 ft of snow fill over the tunnels. Clearance between the buildings and the tunnel walls will be provided to permit air circulation and tunnel maintenance.

Buildings and equipment will be supported by timber posts and cribbing bearing on timber mats. These foundations will be placed 2 ft below the tunnel floor under the secondary plant buildings and 5 ft under the reactor building. Snow will be backfilled over the foundations.

The turbine-generator plant buildings, one 20 ft wide, 12 ft high and 148 ft long, and the other 20 ft wide, 12 ft high, and 140 ft long, will be heavily insulated prefabricated panel buildings and will house the secondary plant equipment, control console, shop and office equipment, decontamination facilities, and heating and ventilation equipment. A prefabricated building, 20 ft wide by 76 ft long, will be provided to enclose the condensers for each plant. The reactor building will be a steel structure, 20 ft wide, 36 ft long, supporting the reactor and shield tank, the spent fuel tank, and the waste retention tank. Above the reactor, an insulated hoist house will provide access to the reactor equipment for maintenance and refueling. Screw jacks will be incorporated into the structure and will make it possible to level and raise the hoist house and equipment simultaneously to correct for excess or differential settlement at the foundations. A shaft to the surface through the tunnel roof over the spent fuel tank will be provided for the placing and removal of the spent fuel cask.

There will be 2,430 drums (50 gal each) of diesel fuel oil located on the surface adjacent to the Station tunnels.

This will provide a 12-month supply of emergency fuel oil to unit heaters in the buildings in the event both reactor plants are down.

Heating and ventilation will be provided for the power plant building, heat being supplied by reactor steam. Cold outside air will be conveyed through the plant tunnel for the removal of heat loss from the buildings. This tunnel ventilation will be sufficient to maintain the snow temperature close to its yearly average and thereby minimize foundation settlements. A "cold well" will be provided to draw cold air from the snow during the summer should this additional cooling be required for the foundation under the reactor to remove excess heat due to conduction and gamma heating.

Potable water and make-up water to the plant will be supplied from existing station facilities.

Fire protection equipment will consist of portable dry type chemical extinguishers located in the buildings and plant tunnels.

B. Basis for Project Cost Estimate

1.0 Land and Land Rights

Land and property acquisition are not included in this estimate.

2.0 Structures and Improvements

2.1 General Improvements

2.1.1 Snow Tunnels

Snow excavation for the plant is based on the use of the Peter Snow Miller as manufactured by Konrad Peter, Ltd., Liestal, Switzerland. The Miller is capable of cutting a trench to a depth of at least 24 ft below the snow's surface, the depth being determined by the limitation in ejecting the snow to the surface. Tunnels deeper than 24 ft will require excavation in stages. Snow fill deposited by the Miller sets up in a firm mass, having a density equal to the natural density of snow at a depth of 30 ft or more. This fill provides a suitable foundation material. As indicated on the drawings, the sills supporting the roof arch bear on a pad of this redeposited snow fill.

The excavation of the tunnels and pits for the nuclear power plants will require approximately 34,500 cu yd of snow excavation and 12,000 cu yd of fill.

That portion of the main tunnel serving the power plants will be 125 ft long, 24 ft wide and 24 ft deep and will require 3,300 cu yd of excavation and 1,400 cu yd of fill.

Access ramps and connecting tunnel sections to and from the floor of the tunnels will require an additional 2,500 cu yd of excavation and 100 cu yd of fill.

2.1.2 Tunnel Roofs

Steel arches supported on timber sills on each side of the trench will span the tunnel and will be covered by 3 ft of snow fill. The arch will consist of double curved and corrugated, zinc coated, 18 gauge steel, (Series 3510), as manufactured by the Wonder Building Corporation of America, Chicago, Illinois. The main corrugations are 7-7/8 in. deep.

The arches over the reactor plant, turbine-generator and condenser buildings will span 27 ft with a rise of one-fourth the span. The top of the arch will be approximately at original snow line. This location permits a minimum clearance of 4 ft at any point between the arch and the building beneath it and places the foundation pad of the arch at 6 ft 6 in. below the original snow level.

The arches over the main access tunnel will span 19 ft with a rise of one-fourth the span. The top of the arch will be approximately at original snow level. This location places the foundation pad of the arch at 5 ft below the original snow level.

2.1.3 Water Supply

Power plant and domestic water requirements of approximately 100 gal per day will be supplied from existing station snow melting facilities and delivered in drums to the power plants. The water will be stored in two 250 gal storage tanks, one located in each building.

2.1.4 Sanitary Sewage Disposal

Sanitary waste will be collected in containers and disposed of by methods conforming to existing station procedures.

2.1.5 Tunnel Lighting

General tunnel lighting will be provided.

2.1.6 Fire Extinguishing Equipment

Fire extinguishing equipment for the tunnel area will consist of portable dry type chemical extinguishers.

2.2 Turbine-Generator Buildings

2.2.1 Substructure

The substructure of the buildings will consist of timber floor joists at 4 ft centers spanning 14 ft with a 3 ft cantilever on each side. A continuous timber sill will run longitudinally at 3 ft from each edge of the building. A continuous timber header will run longitudinally at each edge of the building. Solid timber blocking between floor joists will be located at the center of the building and over each longitudinal sill.

The sills will be supported by timber columns at 4 ft centers. The columns will be supported by a short transverse beam spreading the load to a continuous timber plank mat running longitudinally the length of the building.

Footings for the buildings have been sized to minimize differential settlement. Snow bearing pressures under the footings will not exceed 500 psf from both dead load and live load.

Footings will be founded 2 ft below the tunnel floor. After installation of the footings, snow will be backfilled to the level of the tunnel floor.

The building substructure will be designed to facilitate jacking and shimming to level the building in the event of differential settlement.

2.2.2 Superstructure

The superstructure is based on an Army T-5 building as developed by the Engineering Research and Development Laboratory, U. S. Army, at Fort Belvoir, Virginia for Arctic use.

Each turbine-generator building will be 20 ft wide and 12 ft high. One building will be 140 ft in length and the other 148 ft in length. The condenser buildings will be 20 ft wide by 76 ft in length. These buildings will consist of heavily insulated, prefabricated 4 ft wide plywood panels for floor, roof and walls. The panels will have a heat transmission factor of not more than 0.10 Btu/hr/sq ft/^{o}F. Floor panels will be designed for 100 psf.

Equipment and personnel access doors will be provided at each end of the buildings.

Interior surfaces will be clad with aluminum to minimize fire hazard. Floors will be covered with a suitable abrasive and fire resistant, nonslip floor covering. Exterior surfaces will be treated with fire retardant paints at time of manufacture.

The prefabricated panels and trusses of the T-5 buildings are designed to minimize site erection labor. The buildings will be preassembled at the point of manufacture to ensure proper assembly and will be packaged for air transport. They will be erected in the completed snow tunnels with floor elevation 4 ft above the tunnel floor, allowing about 2 ft of clear space under the buildings. The condenser buildings will be separated from the turbine-generator buildings by 8 ft. They will be connected by timber platforms at floor level.

2.2.3 Heating and Ventilation

Building heating and ventilation for each plant and tunnel cooling will be a single combined system in each turbine-generator building.

A heating and ventilating unit in each building will draw 1,100 cfm of outside air through the tunnel, heat it, humidify it and deliver it via an air duct to the ceiling diffusers. Air will be exhausted through a vent stack. Approximately four air changes per hour will be provided both in the building and in the tunnel. Hot water for the heating unit will be supplied from a heat exchanger furnished with the reactor plant and utilizing reactor steam.

Water will be circulated through the heating and ventilating units by a circulating pump with a stand-by. A 60 gal surge tank will be provided to allow expansion and make-up.

2.2.4 Plumbing

A lavatory, shower, and chemical type toilet will be provided in the office and personnel area.

2.2.5 Building Electrical

Electrical facilities will consist of the building lighting, grounding and power for building services other than those provided with the package unit.

2.2.6 Painting

Interior wood surfaces (not factory treated) will be coated with a fire retardant paint. Interior carbon steel surfaces will be painted.

2.2.7 Cranes and Hoists

Heavy equipment will be lifted with a portable steel frame. A 3-ton manual hoist will be provided. A 1-ton light duty manual hoist will be provided for miscellaneous service.

2.3 Reactor Buildings

2.3.1 Substructure

The substructure will consist of longitudinal and transverse steel and timber beams bearing on a timber mat. The mat will be founded at 5 ft below the tunnel floor. After construction of the foundation, snow will be backfilled to the tunnel floor level. Foundation pressure beneath the mat due to the operating load of the reactor will be approximately 400 psf.

2.3.2 Superstructure

The superstructure will consist of field bolted steel framing. This framing will be enclosed with prefabricated insulated plywood panels similar to the panels used on the Army T-5 buildings. The hoist house at the operating floor level will be 20 ft by 36 ft in plan. The lower portion containing the reactor and shield tank, the spent fuel tank and the waste retention tank will be 16 ft by 34 ft.

The floor framing for the hoist house will support the reactor plant equipment. The entire upper building, including the operating floor and the reactor plant equipment, can be raised or lowered by eight screw jacks built into the structure. This may be accomplished from the operating floor level and is provided to correct for excess or differential settlement of the foundation.

A monorail beam at the center of the hoist house ceiling will accommodate the 3-ton hoist used to refuel the reactor.

A 6 ft diameter shaft through the roof of the hoist house and tunnel arch will permit the removal of the 25,000 lb spent fuel cask.

2.3.3 Cooling System

A pressure blower, located in the condenser building adjacent to the reactor, will draw 3,000 cfm air at approximately -28° F from a cold well. The cold well will consist of a 16 in. diameter slotted pipe extending 50 ft below the tunnel surface. This air will be pumped to a pair of buried 14 in. diameter perforated pipes at each reactor located just above the reactor footings. It will then pass through the snow covering the footings into the reactor tunnel space. A 14 in. diameter perforated duct above the reactor enclosure will collect the air in such a manner that the flow will be evenly distributed in the space between the building and the tunnel walls. An exhaust fan will discharge this air to the atmosphere.

2.3.4 Building Electrical

The hoist house facilities will consist of the building lighting, grounding and power for building services other than those provided with the package unit.

3.0 Reactor Plant

3.1 Reactor

Each reactor plant will include the stainless steel clad pressure vessel 52 in. ID and 18 ft high; the core structural supports and the steam drier contained in the pressure vessel; the rack-and-pinion control rod drives mounted on the top head of the pressure vessel; and the vertical sections of an 11.5 ft diameter carbon steel shield tank which will surround the pressure vessel. Also included will be a shipping container for spent fuel, a spent fuel transfer cask, lead shielding, the reactor vessel support tank (which also serves as the lower neutron shield) ducting, insulation and heaters.

The pressure vessel and head (including rod drives) for each reactor will be shipped on one air transportable skid. The vertical sections of the shield tanks will be packaged in eight sections on two skids. Each spent fuel cask will require a shipping skid and a separate airlift. It is expected that the remainder of the equipment can be shipped as two airlifts. The equipment price includes the cost of skids, assembly of equipment on the skids and export packing.

Required site work will include erection of the pressure vessels on the support tanks; welding of the shield tank vertical sections and welding of these assemblies to the support tanks; installation of shielding, ducting, heaters and the reactor cores; and control rod alignment. Interconnections are required to the purification skids, turbine-generator skids and the feed and condensate skids.

3.2 Feed and Condensate Skid

The following items are included in each feed and condensate skid:

30 cu ft stainless steel hotwell for operation at 6 in. Hg abs

10 gpm low pressure drain pump

150 gal stainless steel low pressure drain tank

Two 53 gpm condensate pumps at 122 ft TDH

Steam jet air removal equipment

1,700,000 Btu/hr shell and tube space heat exchanger

Two 192 gpm circulating pumps at 94 ft TDH (space heat system)

29,000 Btu/hr shell and tube rod drive seal water cooler

2,500 lb/hr cartridge type raw water demineralizer

5 gpm make-up water pump

25 cu ft stainless steel make-up water storage tank

1,535,000 Btu/hr closed feed-water heater

Two 70 gpm feed-water pumps at 1,660 ft TDH

Two 12.5 gpm lube oil cooling pumps

Stainless steel lube oil cooling system surge tank

150,000 Btu/hr shell and tube lube oil system cooler

Valves, filters, traps and strainers, pipe and insulation and local controls are also included. The skids are preassembled in single air transportable shipping packages at the factory. Site work includes locating the skids on the floor of the turbine buildings and making the required interconnections.

3.3 Waste and Spent Fuel Storage Tanks

Each waste tank will be a 500 cu ft stainless steel tank located adjacent to the reactor shield tank. The waste tanks will collect and store all radioactive waste from the plant and will be sized to store approximately three volumes of reactor coolant. Each stainless steel spent fuel storage tank will be also located adjacent to the shield tanks. Spent fuel elements and the spent fuel transfer cask can be stored in these tanks.

Each set of two tanks will be bolted together for shipment on single air transportable shipping skids. Site work will include bolting the tanks to their supports and making interconnections to the reactors, purification skids and, for the waste tanks, to the plant drains.

3.4 Purification Skid

Each purification skid will include two heat exchangers, two disposable cartridge ion-exchange demineralizers, a hold up tank, two 5 gpm purification system pumps, piping and local controls. Also located on these skids will be tanks for storage of reactor poison used for reactor shutdown.

The purification skids will be preassembled at the factory and shipped as single air transportable packages. Site work will include locating the skids on the floor of the turbine buildings and making the required interconnections.

3.5 Miscellaneous Equipment

Miscellaneous reactor plant equipment which requires field assembly includes the reactor drains, decontamination equipment (solvent storage tanks, drains, basin, etc.), 128,000 Btu/hr, submerged shield water coolers and 130,000 Btu/hr shell and tube fuel pit vent condensers. This equipment will be shipped as one airlift of miscellaneous equipment.

3.6 Piping

The reactor plant valves, piping, fittings and insulation not installed on skids at the factory will be shipped separately and installed at the site. This piping includes the main steam lines from the reactors to the turbines and the feed-water return lines from the feed and condensate skids to the reactors. It is expected that two airlifts will be sufficient to ship this material to the site.

4.0 Turbine-Generator Plant

4.1 Turbine-Generator Skid

Each turbine-generator skid will include the turbine-generator, turbine-generator auxiliaries and local controls, and a lube oil purifier and motor controller. The marine type turbine will be designed to operate with saturated steam at 600 psia. A single extraction point at 65 psia will be provided. Each generator will be capable of 1,250 kva, 4 wire at 0.8 power factor, 3-phase, 60 cycle, 480 volts.

Each turbine-generator is assembled on its skid before shipment to the site. Installation at the site consists of locating the skids on the turbine-generator foundations provided in the turbine building and making interconnections to the reactors and condensers.

4.2 Condenser Skid

Each installed condenser skid will consist of an air cooled condenser capable of condensing 10,000 lb/hr of steam at a pressure of 6 in. Hg abs, louvered side panels, and intake and exhaust ductwork. The equipment will be shipped as seven airlifts, four for the skid mounted condenser fans and tubes and three for the louvers and ductwork. On site installation will consist of placing the skids in the separate condenser buildings, installation of the louvers and ductwork, and connecting the piping from the turbines and to the feed and condensate skids.

4.3 Piping

The turbine-generator plant piping will include the following systems:

- Main steam
- Turbine exhaust
- Condensate drain
- Lube oil
- Make-up water
- Service water

It is expected that this material will be shipped as a part of an airlift containing other miscellaneous equipment (see item 6.0).

4.4 Turbine-Generator Foundations

Each of the turbine-generators will be mounted on a steel skid at the factory. The skids will be supported by a heavy timber frame separated from the building floor framing. Braced timber columns will carry the load to a timber mat 2 ft below the tunnel floor.

After installation of the substructure, snow will be backfilled to the level of the tunnel floor. Provision will be made to facilitate jacking and shimming to correct for differential settlement.

5.0 Accessory Electrical Equipment

5.1 Electrical Skids

Each electrical skid will include metal clad switchgear for 480 v service, a static exciter for the generator, voltage regulator, batteries, and controls. Also included will be the plant control console, nuclear instrumentation, radiation monitoring, indicators, recorders, alarms, controllers, test equipment and instrument wiring. The equipment will be skid mounted in the factory and the control console will be wired. Site installation will consist of locating the skids in the turbine building, making the required wiring interconnections to other skids and the reactors, and installing the reactor core instrumentation.

5.2 Main Switchgear

Additional 480 v switchgear with 50,000 amp interrupting capacity breakers will be provided for connection of the main breakers or the packaged units to a common bus for parallel operation, as well as for the control of the distribution feeders.

6.0 Miscellaneous Power Plant Equipment

6.1 Fire Extinguishing Equipment

Fire extinguishing equipment will consist of portable dry type chemical extinguishers located throughout the plant.

6.2 Fire Alarm System

The fire alarm system will consist of temperature rate-of-rise detection stations throughout the plant to actuate electrically operated alarms.

6.3 Shop Equipment

Shop equipment will include a 200 amp output d-c generator welder, a milling machine, a drill press, a bench grinder, a lathe, a machinist's bench vise, and miscellaneous hand tools.

6.4 Office Furniture and Equipment

Furniture and equipment for the office will be provided.

6.5 Start-up and Emergency Heating Equipment

A package boiler rated at 3,000 lb/hr of saturated steam at 70 psig and a diesel oil day tank will be provided for emergency heating during reactor shutdown. Start-up power will be provided by a 100 kw, 480 v diesel generator set. The package boiler and diesel generator can be shipped as a single airlift of miscellaneous equipment.

6.6 Laboratory Equipment

Laboratory equipment will consist of the equipment necessary for personnel monitoring, coolant sample testing and radiation survey tests. Included will be a hand and foot counter, portable survey instruments, a water monitor, a counter-scaler, film badges and dosimeters and associated equipment. Also included will be the equipment for blood testing and urinalysis and assorted hardware and glassware. This equipment will be crated for export shipment and shipped as a portion of one of the airlifts required for miscellaneous equipment.

7.0 Transmission Plant

Cable and supports to the access tunnel only will be provided.

8.0 Communication System

Telephone facilities will be provided.

9.0 Indirect Cost

9.1 General Field Expense

General field expense includes the cost of supervision by the Navy and by contractors' representatives, Navy service personnel, warehousing, warehouse equipment, small tools, consumable supplies, and maintenance of temporary facilities.

9.2 Export Packing and Transportation Costs

9.2.1 Export Packing

Export packing includes the cost of packing and crating sufficient for severe shipping conditions in Antarctic waters and over-the-ice transportation to NAF McMurdo. In addition packages must be finally assembled on sleds or skids for transportation by C-130-B aircraft from McMurdo to Byrd Station and to facilitate unloading at Byrd Station and final movement to the construction site. Packing, crating and palletizing preferably will be done at the factory or at Davisville, Rhode Island. However, it is anticipated that some work will have to be done by Navy Construction Battalion personnel after arrival at McMurdo. The cost of export packaging of the PL-2 nuclear power plant has been included in the equipment prices.

9.2.2 Ocean Freight

Ocean freight includes domestic freight forwarding charges, port handling and wharfage charges, and ocean freight from Davisville, Rhode Island to McMurdo Sound. The estimate is based on a shipping quantity of 1,158 short tons of cargo (Table 7), a stowage factor of 1.5, and an estimated unit cost for ocean freight of $100/mt (Appendix A).

Marine insurance is not included since shipment will be in U. S. Government owned vessels.

9.2.3 Icebreaker Cost

Icebreaker cost is based on an estimated cargo of 1,158 short tons, a stowage factor of 1.5, and an estimated unit cost for icebreaker service of $76/mt (Appendix B).

9.2.4 Cost of Airlift

All personnel, materials, and equipment must be flown from NAF McMurdo to Byrd Station, and in addition, certain materials and equipment airlifted from New Zealand. The estimate of cost is based on a total of 87 round trip airlifts (Table 7) and an estimated unit airlift cost of $7,570 per round trip (Appendix C). In addition, the estimate includes an allowance for the ferrying cost (Appendix C) of four cargo aircraft (Table 7) from the United States and return.

9.3 Start-up and Testing

9.3.1 Shop Testing

Shop testing includes the complete testing and operation of the assembled nuclear power plant systems, and physical dimensional matching of all parts and components at the nuclear manufacturer's plant prior to shipment.

9.3.2 Field Start-up and Testing

Field start-up and testing includes all labor, materials, equipment and personnel transportation cost for the initial testing, start-up and regulating of the power plant. Acceptance tests to verify the performance of components and the completed power plant in accordance with the specifications will be performed.

9.4 Contractor's Field Overhead

This item includes an allowance of $14,000 per man-year for Navy personnel for special clothing and transportation of men and supplies. Also included is an allowance for similar items for contractor's personnel used to supervise the installation of the nuclear power plant and purchasing and expediting, field tests, survey, project photographs and field office supplies.

9.5 Construction Plant

It is assumed that construction personnel will make maximum use of the existing facilities at Byrd Station and NAF McMurdo. However, the facilities at Byrd Station will have to be augmented with additional temporary housekeeping facilities for some of the construction personnel. It is also assumed that necessary temporary construction buildings, such as shops, warehouses, and field offices will be provided.

9.6 Camp Expenses

This includes messing and billeting of contractor's personnel, which will be furnished by the Navy at a cost of $2.25 per day per man (Ref. 15).

9.7 Insurance, Bond, and Financing

Since all field work will be done by Navy personnel, the cost of these items is not included.

9.8 Personnel Mobilization

This includes the pay of Navy construction personnel in the U. S. while in training and in transit to and from the Byrd Station.

9.9 Construction Equipment

Costs are included for the Peter Snow Miller, two D-6 tractors, welding machines and miscellaneous tools and equipment required for building and equipment erection.

10.0 Escalation

Escalation is based on an over-all escalation of 6% on labor, equipment and materials.

11.0 Design Engineering

Design engineering costs include the cost of over-all project planning, site layout, concept and detail design of the snow tunnels, buildings, utilities, and site-adapting the PL-2 nuclear power plant. Also included is the cost of preparing operating manuals, test procedures and maintenance manuals.

The administrative cost involved in the purchase of equipment is not included.

12.0 Contingency

The contingency is 20% of the cost of the plant including escalation and design engineering.

13.0 Fuel Oil in Storage

Costs are shown for the initial complement of fuel oil in the amount of 121,500 gal. This is sufficient oil for one year's supply of oil for heating purposes. Purchase cost of the oil in the U. S., shipping cost to McMurdo, handling and air transport to the Byrd Station are included.

C. Estimate of Project Cost

SUMMARY

800 KW NUCLEAR POWER PLANT

	Description	Labor	Permanent Materials and Equipment	Total
1.0	Land and Land Rights	$ --	$ --	$ --
2.C	Structures and Improvements	158,000	390,000	548,000
3.0	Reactor Plant	83,000	2,033,000	2,116,000
4.0	Turbine-Generator Plant	44,000	642,000	686,000
5.0	Accessory Electrical Equipment	30,000	456,000	486,000
6.0	Miscellaneous Power Plant Equipment	15,000	78,000	93,000
7.0	Transmission Plant	2,000	5,000	7,000
8.0	Communication System	3,000	3,000	6,000
	Total Direct Construction Cost	$ 335,000	$3,607,000	$3,942,000
9.0	Indirect Cost	190,000	2,715,000	2,905,000
	Total Construction Cost	$ 525,000	$6,322,000	$6,847,000
10.0	Escalation			413,000
	Total Including Escalation			$7,260,000
11.0	Design Engineering			400,000
	Total Excluding Contingency			$7,660,000
12.0	Contingency			1,540,000
	Total Including Contingency			$9,200,000
13.0	Fuel Oil in Storage			400,000
	Total Project Cost			$9,600,000

ESTIMATE OF CONSTRUCTION COST

800 KW NUCLEAR POWER PLANT

	Description	Labor	Permanent Materials and Equipment	Total
1.0	Land and Land Rights	- -	- -	- -
2.0	Structures and Improvements			
.1	General Improvements			
.1.1	Snow Tunnels	$ 6,000	$ - -	$ 6,000
.1.2	Tunnel Roofs	8,000	36,000	44,000
.1.3	Water Supply	1,000	2,000	3,000
.1.4	Sanitary Sewage Disposal	1,000	2,000	3,000
.1.5	Tunnel Lighting	3,000	10,000	13,000
.1.6	Fire Extinguishing Equipment	1,000	2,000	3,000
	Sub-Total	$ 20,000	$ 52,000	$ 72,000
.2	Turbine-Generator Building			
.2.1	Substructure	12,000	6,000	18,000
.2.2	Superstructure	50,000	160,000	210,000
.2.3	Heating and Ventilation	8,000	22,000	30,000
.2.4	Plumbing	4,000	8,000	12,000
.2.5	Building Electrical	12,000	16,000	28,000
.2.6	Painting	2,000	6,000	8,000
.2.7	Cranes and Hoists	2,000	4,000	6,000
	Sub-Total	$ 90,000	$ 222,000	$ 312,000
.3	Reactor Building			
.3.1	Substructure	$ 14,000	$ 21,000	$ 35,000
.3.2	Superstructure	27,000	81,000	108,000
.3.3	Cooling System	4,000	10,000	14,000
.3.4	Building Electrical	3,000	4,000	7,000
	Sub-Total	$ 48,000	$ 116,000	$ 164,000
	Total Structures and Improvements	$ 158,000	$ 390,000	$ 548,000
3.0	Reactor Plant			
.1	Reactor	$ 30,000	$1,151,000	$1,181,000
.2	Feed and Condensate Skid	8,000	435,000	443,000
.3	Waste and Spent Fuel Storage Tanks	19,000	59,000	78,000
.4	Purification Skid	8,000	88,000	96,000
.5	Miscellaneous Equipment	10,000	59,000	69,000
.6	Piping	8,000	241,000	249,000
	Total Reactor Plant	$ 83,000	$2,033,000	$2,116,000

ESTIMATE OF CONSTRUCTION COST

800 KW NUCLEAR POWER PLANT
(Cont'd)

	Description	Labor	Permanent Materials and Equipment	Total
4.0	Turbine-Generator Plant			
.1	Turbine-Generator Skid	$ 15,000	$ 341,000	$ 356,000
.2	Condenser Skid	14,000	223,000	237,000
.3	Piping	9,000	75,000	84,000
.4	Turbine-Generator Foundations	6,000	3,000	9,000
	Total Turbine-Generator Plant	$ 44,000	$ 642,000	$ 686,000
5.0	Accessory Electrical Equipment			
.1	Electrical Skids	$ 22,000	$ 426,000	$ 448,000
.2	Main Switchgear	8,000	30,000	38,000
	Total Accessory Electrical Equipment	$ 30,000	$ 456,000	$ 486,000
6.0	Miscellaneous Power Plant Equipment			
.1	Fire Extinguishing Equipment	$ 2,000	$ 7,000	$ 9,000
.2	Fire Alarm System	2,000	7,000	9,000
.3	Shop Equipment	1,000	12,000	13,000
.4	Office Furniture and Equipment	-	6,000	6,000
.5	Start-up and Emergency Heating Equipment	8,000	30,000	38,000
.6	Laboratory Equipment	2,000	16,000	18,000
	Total Miscellaneous Power Plant Equipment	$ 15,000	$ 78,000	$ 93,000
7.0	Transmission Plant	$ 2,000	$ 5,000	$ 7,000
8.0	Communication System	$ 3,000	$ 3,000	$ 6,000
	Total Direct Construction Cost	$ 335,000	$3,607,000	$3,942,000
9.0	Indirect Cost			
.1	General Field Expense	$ 82,000	$ 80,000	$ 162,000
.2	Export Packing and Transportation Costs			
.2.1	Export Packing	$ - -	$ 25,000	$ 25,000
.2.2	Ocean Freight	- -	155,000	155,000
.2.3	Icebreaker Cost	- -	118,000	118,000
.2.4	Cost of Airlift	- -	874,000	874,000
	Sub-Total	$ - -	$1,172,000	$1,172,000

ESTIMATE OF CONSTRUCTION COST

800 KW NUCLEAR POWER PLANT
(Cont'd)

	Description	Labor	Permanent Materials and Equipment	Total
.3	Start-up and Testing			
.3.1	Shop Testing	$ - -	$ 210,000	$ 210,000
.3.2	Field Start-up and Testing	35,000	7,000	42,000
	Sub-Total	$ 35,000	$ 217,000	$ 252,000
.4	Contractor's Field Overhead	$ 45,000	$ 800,000	$ 845,000
.5	Construction Plant	18,000	54,000	72,000
.6	Camp Expenses	- -	7,000	7,000
.7	Insurance, Bond, and Financing	- -	- -	- -
.8	Personnel Mobilization	- -	200,000	200,000
.9	Construction Equipment	10,000	185,000	195,000
	Total Indirect Cost	$ 190,000	$2,715,000	$2,905,000
	TOTAL CONSTRUCTION COST	$ 525,000	$6,322,000	$6,847,000

D. Project Schedule

The project schedule on page 46 for the 800 kw nuclear power plant has been prepared to serve as a basis for the estimate of cost. The schedule indicates that design and construction activities span a period of 26 months. Starting of engineering by January 1961, will permit completion and operation of the nuclear power plant by February 1963.

Based on the ability of aircraft to fly between NAF McMurdo and Byrd Station, the construction season is approximately 115 days. For periods up to one month after the start of the summer season it is not possible to get a vessel into McMurdo Sound due to ice conditions. A construction schedule based on bringing materials, equipment and personnel in by vessel would be limited to a maximum of two months of construction time.

It is assumed that existing facilities at Byrd Station would be enlarged to accommodate the construction crew, and at a later date the operation personnel, prior to the start of construction in 1961-1962 (Ref. 14). The schedule is based on such an expansion of facilities.

The schedules and cost estimates are based on the shipment of all materials from Davisville, Rhode Island which is the CONUS marshalling point.

The estimated weights of the equipment and material required for construction of the plant are shown in Table 7 in Section III-D.

In addition, the following factors were considered in preparing the schedule and form a further basis for it:

1. Performance of construction work by U. S. Navy Construction Battalion personnel under the direction of a contractor selected to be responsible for the performance of the plant. Billeting and messing facilities will be furnished by the Navy.

2. A period of three months has been allowed for the mobilization and briefing of construction personnel. In addition supervisory and key construction personnel should spend approximately one month in the nuclear subcontractor's plant during the period when the nuclear plant packages are being assembled and tested prior to shipment, to familiarize them with the equipment and techniques and problems in assembly.

3. The construction schedule is based on a six-day work week, two 10-hour shifts per day.

4. It has been assumed that construction materials required the first season will be ordered far enough in advance to reach McMurdo Sound not later than December 15, 1961. Shipment of the reactor packages the following year will be such as to assure arrival at Byrd Station not later than December 15, 1962. The reactor equipment will be shipped by sea to New Zealand for transshipment by air to McMurdo and then to Byrd Station.

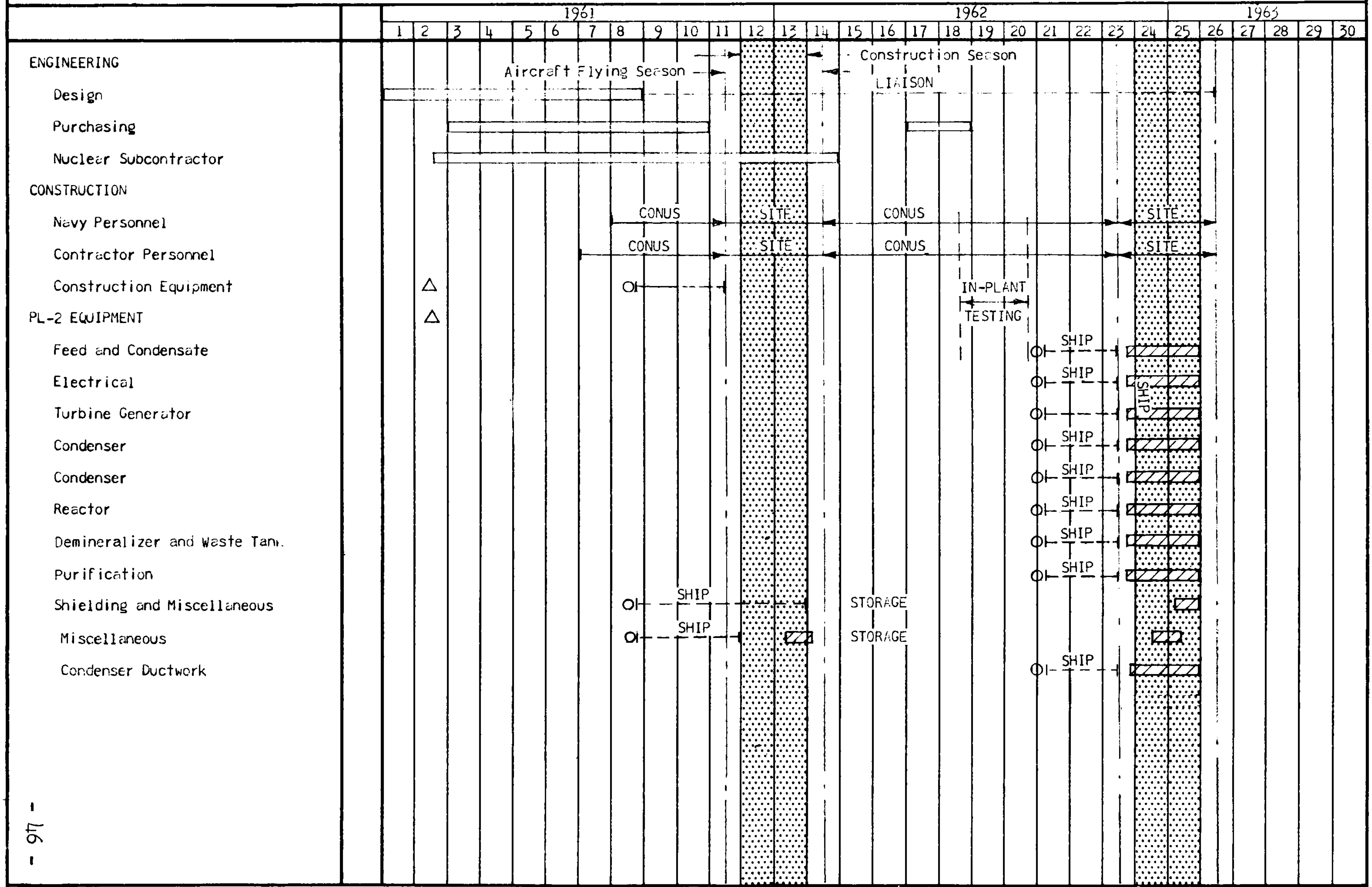
5. The schedule is based on maximum utilization of prefabricated and preassembled units, including mechanical, nuclear and electrical equipment and piping.

6. The engineering phase of the project is predicated on adapting the available design of the PL-2 packaged nuclear power plant to the site at Byrd Station.

7. The schedule is based on a single contractor assuming responsibility for the design and performance of the nuclear power plant.

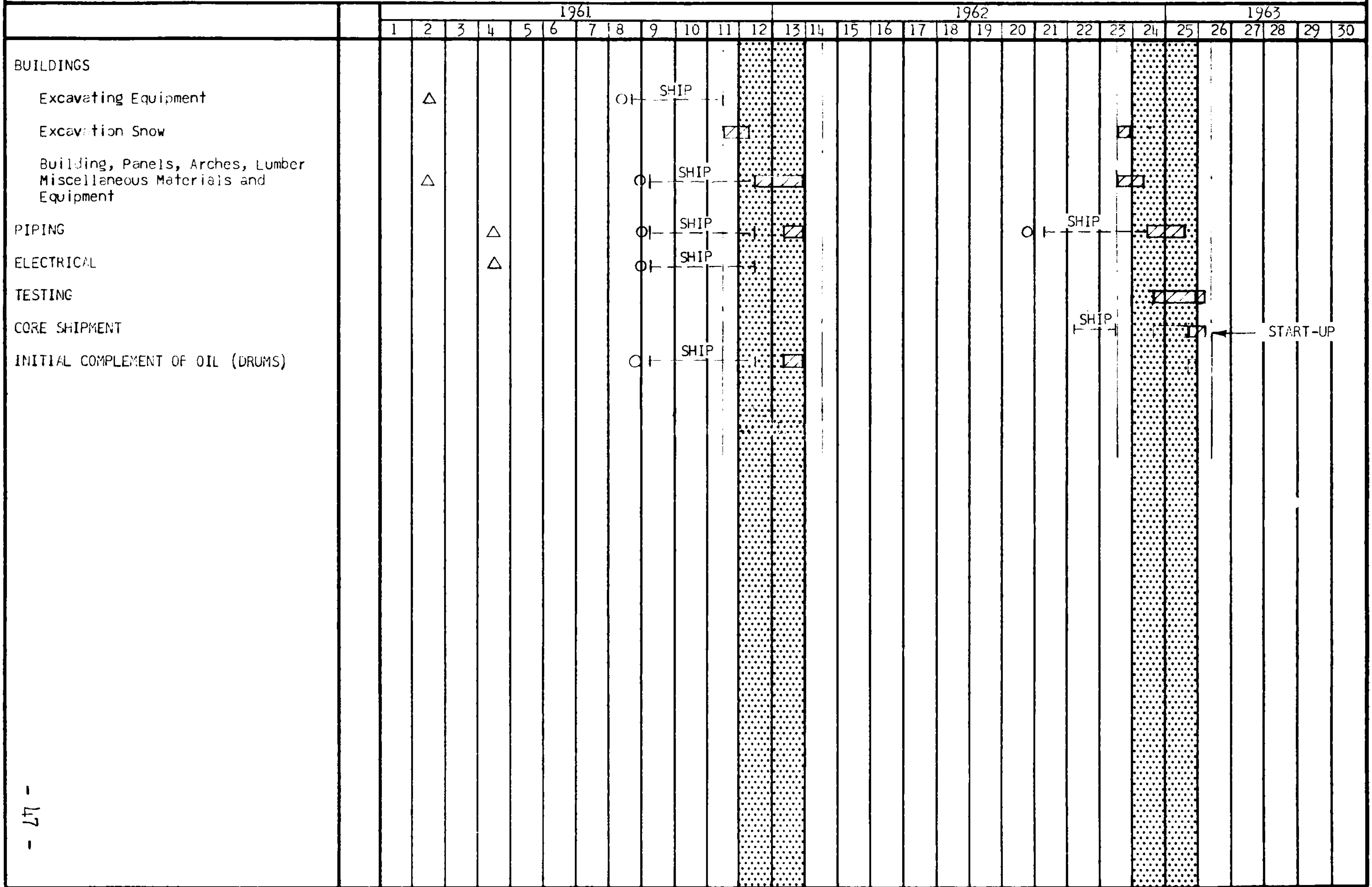
LEGEND
○ FOB Factory
▨ Installation
△ Purchase

PROJECT SCHEDULE
800 KW NUCLEAR POWER PLANT
BYRD STATION



KAISER ENGINEERS
DIVISION OF HENRY J. KAISER COMPANY

PROJECT SCHEDULE
800 KW NUCLEAR POWER PLANT
BYRD STATION



KAISER ENGINEERS
DIVISION OF HENRY J KAISER COMPANY

E. Estimate of Unit Power Cost

Unit power costs have been based on a plant operating factor equivalent to 100% of the firm power requirement of 800 kw.

Annual Fixed Charges

Annual fixed charges are based on a 20-year plant life equivalent to 5% of the total project cost. No interest on the investment has been included (Ref. 16).

$$0.05 \times \$9,600,000 = \$480,000$$

Operating and Maintenance Costs

Operating and maintenance labor cost based on an estimated complement of nine military personnel is shown on Table 9, page 49. Labor costs are based on an average annual rate for overseas military personnel of $20,350, including base pay, transportation of supplies, messing and special clothing (Ref. 10). Labor escalation of 2% per year has been included in the estimate for a 20-year period beginning in 1963. The average annual cost of maintenance materials and operating supplies for the reactor plant has been estimated at 1% of the U. S. purchase cost. Tunnel and building maintenance costs have been added to this cost. The estimate includes allowances for export packing, shipping cost and prorated icebreaker cost, and in addition a 20% allowance for average escalation of materials and supplies over a 20-year period.

The computation and allocation of icebreaker costs and shipping costs is in accordance with methods indicated in Section IV-B, indirect costs.

TABLE 9

AVERAGE OPERATING AND MAINTENANCE COSTS

Labor	No. of Personnel	Rate	Annual Cost
Supervision			
Plant Superintendent	1		
Operation			
Reactor Operators	5		
Turbine and Auxiliary Operator	1		
Maintenance			
Master Mechanic	1		
Instrument Technician	1		
Sub-Total	9	$20,350	$183,000
Escalation			50,000
Total Operating and Maintenance Labor			$233,000
Maintenance Materials and Operating Supplies			31,000
Escalation			6,000
Total Maintenance Materials and Operating Supplies			$ 37,000
TOTAL AVERAGE ANNUAL OPERATING AND MAINTENANCE COST			$270,000

Fuel Costs

Table 10, page 51, summarizes the fuel costs for the modified PL-2 proposed for the Byrd Station. The total annual power generated is based on 100% of the 800 kw firm power requirement, divided between the two reactors. Included in the annual fuel cost is the fuel requirement for heating the power plant buildings. The estimate of fuel cost includes the costs of fuel preparation and fabrication, fuel burnup and spent fuel processing, and is based upon information derived from the reactor designer, Combustion Engineering, Inc. and U. S. Atomic Energy Commission published cost data. Interest on fabrication cost and fuel use charges (except during the fabrication period) are not included (Ref. 16). The nuclear fuel costs have not been escalated since it is anticipated that improvements in technology will more than offset increases in raw material or labor costs.

The core approximates a right circular cylinder of 35.6 in. equivalent diameter with a 38 in. active height. There are 24 fuel assemblies, 5.5 in. by 5.5 in. by 50 in., each containing 60 fuel tubes and 4 burnable poison (boron) tubes. The fuel tubes, on a 0.716 in. square pitch, consist of 0.48 in. diameter partially enriched UO_2 pellets clad in stainless steel. There are 9 cruciform control elements consisting of silver-indium-cadmium control material clad with stainless steel.

The fuel cycle costs calculated below are based upon a single region core with no fuel rearrangement. The entire core of 24 fuel assemblies and 9 control elements will be discharged to the spent fuel storage tank and replaced with new elements at the end of the useful core lifetime. Based on a 50% plant operating factor for each reactor and the design burnup of 25.5 mwt-yr per core, each reactor will be shut down for refueling approximately once every 9 to 10 years.

TABLE 10

SUMMARY OF NUCLEAR FUEL COSTS

General Data

Number of reactors	2
Gross capability, kw (per reactor)	975
Net capability, kw (per reactor)	800
Power plant heating, kwt	500
Reactor thermal power, mwt (including plant heating)	5.5
Plant operating factor per reactor	0.5
Core loading, kg U	1,480
Core lifetime, mwt-yr	25.5
Core lifetime at 0.5 plant operating factor, yr	9.27
Initial enrichment, % U-235	4.5
Depleted enrichment, % U-235	3.7
Pu concentration, g Pu/kg U	3.04
Cost of fabrication of first core (1) (includes control elements)	$330,000

Cost Analysis

Description	Cost Per kg U	Cost Per Year /Reactor
Fuel Preparation and Fabrication (1)		
UF_6 to UO_2 conversion and scrap recovery (1)	$ 20.70	$ 3,300
Fabrication and assembly (1) (including control elements)	169.30	26,800
Losses (1)	13.90	2,200
Use charge during fabrication (1)	19.90	3,200
Sub-Total	$223.80	$35,500
Fuel Burnup		
Value of fuel charged (2)	$615.00	$98,100
Value of fuel discharged (2)	- 487.00	- 77,700
Gross burnup	$128.00	$20,400
Pu credit (3)	- 31.90	- 5,100
Net burnup	$ 96.10	$15,300

TABLE 10 (Cont'd)

Description	Cost Per kg U	Cost Per Year /Reactor
New and Spent Fuel Transportation		
Continental U. S. (4)	$ 15.00	$ 2,400
Davisville, R.I., to McMurdo Sound (5)	3.80	600
McMurdo Sound to Byrd Station (6)	17.50	2,800
Sub-Total	$ 36.30	$ 5,800
Fuel Reprocessing		
Processing to UNH (7)	$ 46.60	$ 7,400
UNH to UF_6 conversion (1)	5.60	900
Material losses (9)	6.60	1,100
Sub-Total	$ 58.80	$ 9,400
TOTAL FUEL COST	$415.00	$ 66,000
TOTAL FOR TWO REACTORS		$132,000

(1) Based on Ref. 12. Costs due to losses and use charge modified to allow for higher enrichment.

(2) Based on U. S. AEC enriched UF_6 cost schedule (Ref. 17).

(3) Based on $12/g Pu as metal and $1.50/g Pu for processing plutonium nitrate to metal.

(4) Assumes shipment by commercial carrier including insurance for new fuel from Windsor, Connecticut to Davisville, Rhode Island and for spent fuel cask round trip from Davisville, Rhode Island to Richland, Washington.

(5) Based on a 15 ton load for 1/3 core, $126/ton round trip.

(6) Based on a 15 ton load for 1/3 core, $583/ton round trip.

(7) Based on Ref. 18. Batch size is one full core loading.

(8) Based on U. S. AEC charge of $5.60 per kg U as per AEC press release dated March 12, 1958.

(9) Assumes 1% and 0.3% losses of uranium in processing to nitrate and conversion to UF_6, respectively. Also assumes a total of 1% losses of Pu in processing to nitrate and then to metal.

Average Unit Power Cost

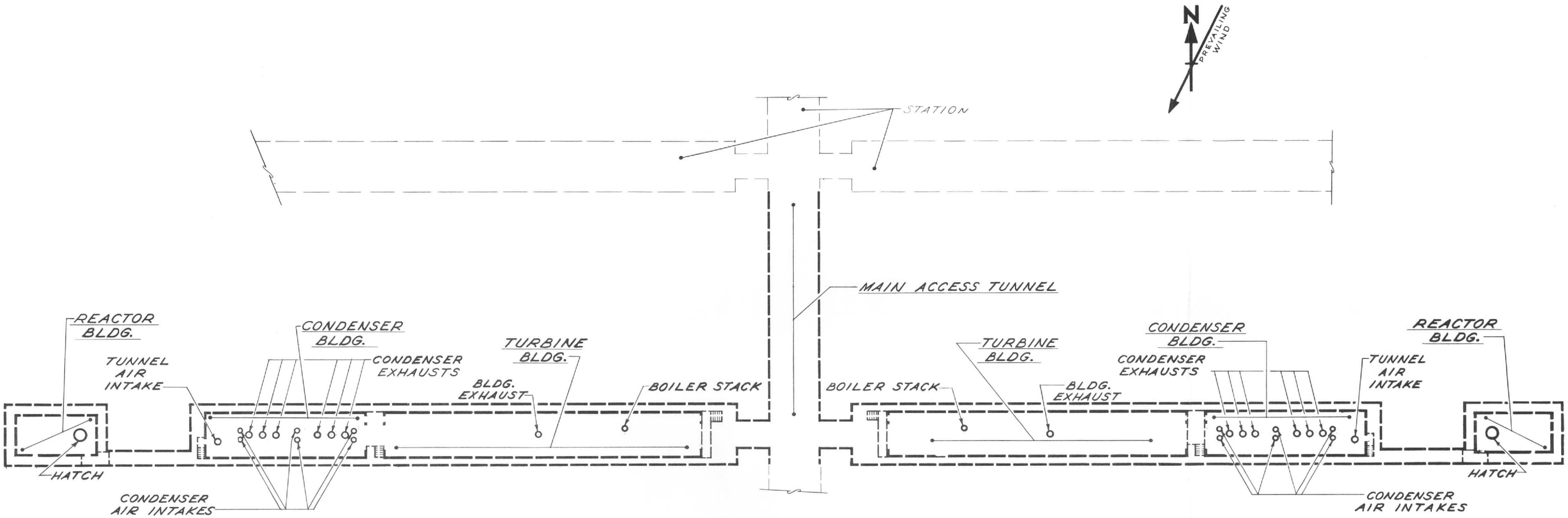
The unit power cost is based on the production of 7,000,000 kwhr per year.

	Average Annual Cost	Mills Per kwhr
Fixed Charges	$480,000	68.6
Operating and Maintenance	270,000	38.5
Nuclear Fuel	132,000	18.9
	$882,000	126.0

F. Concept Drawings

The following drawings present the conceptual design of the proposed 800 kw nuclear power plant.

Drawing No.	Title
1403-C	Plot Plan
1402-G	General Arrangement - Plans
1403-C	General Arrangement - Elevations
1401-M	PL-2 Core Cross Section and Fuel Assembly
1402-M	PL-2 Reactor Pressure Vessel and Core
1401-P	Heat Balance
1402-F	Piping Diagram
1402-E	One Line Diagram



PLOT PLAN

GRAPHIC SCALE

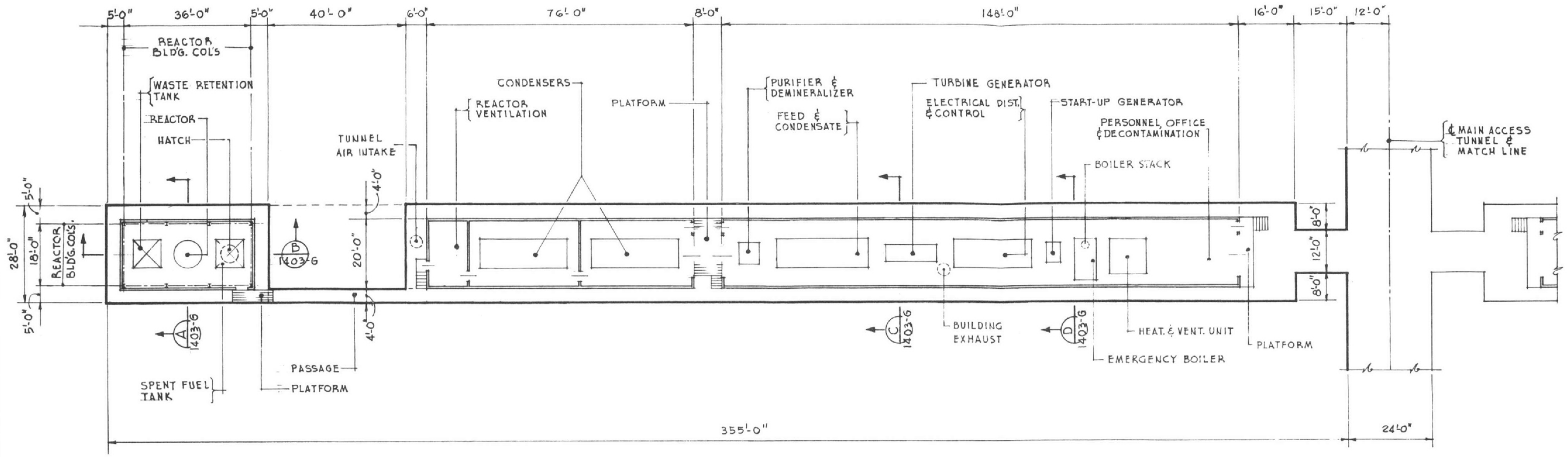
20' 0 20' 40' 60'

APPROVAL	DATE
PROJECT ENGINEER D. A. Daly	5/5/60
CHIEF ENGINEER	

STUDY OF REMOTE MILITARY POWER APPLICATIONS
FOR
U. S. ATOMIC ENERGY COMMISSION

DIVISION OF HENRY J. KAISER COMPANY — **KAISER ENGINEERS** — OAKLAND CALIFORNIA

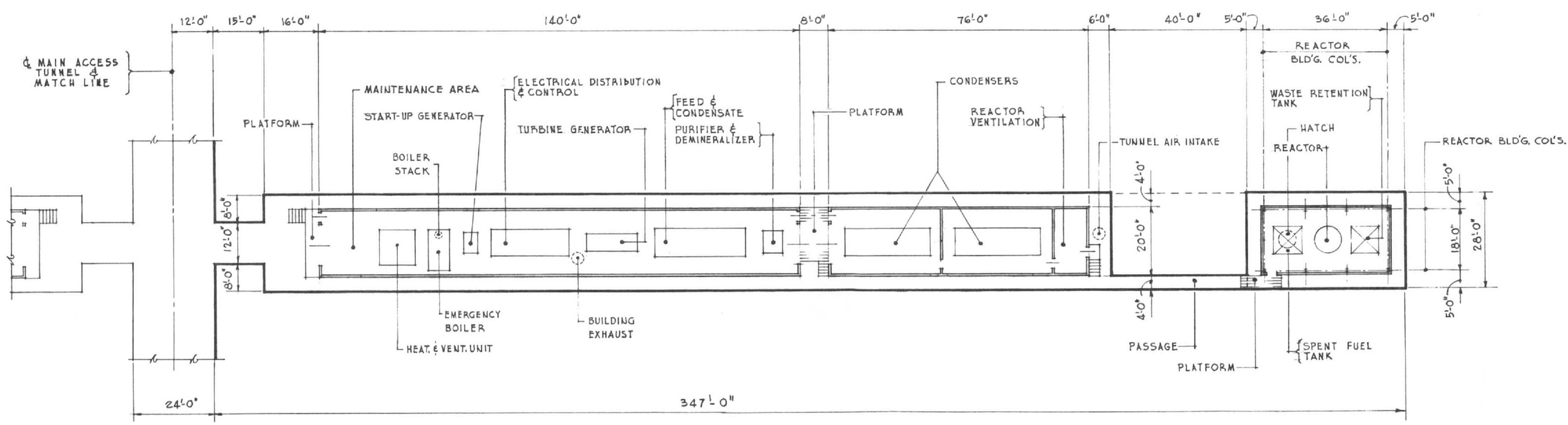
SCALE —	DATE	
DRAWN BY J. MICHEAL	5-4-60	BYRD STATION, ANTARCTICA
CHECKED BY A. J. BECKWITH	5-4-60	800 KW NUCLEAR POWER PLANT PLOT PLAN
APPROVED BY A. H. Winkler D. Hauser	5-4-60	
CHIEF DESIGN ENGINEER M. Tobias	5-5-60	JOB No. 5929 — DWG. No. 1403-C



PARTIAL PLAN

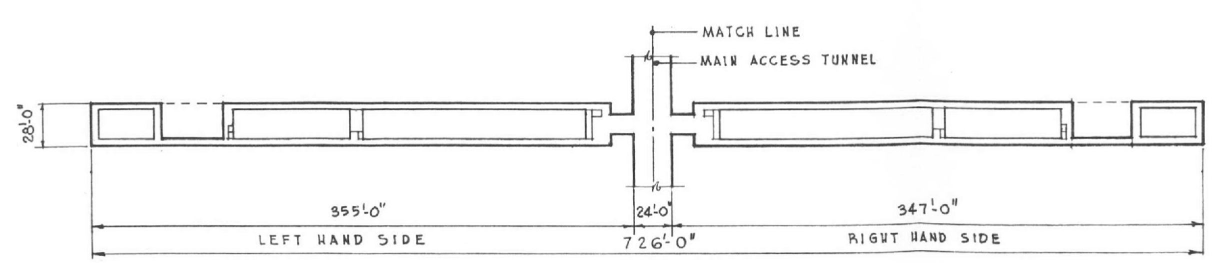
LEFT HAND SIDE

GRAPHIC SCALE 0 10 20 30 40 50



PARTIAL PLAN

RIGHT HAND SIDE



KEY PLAN

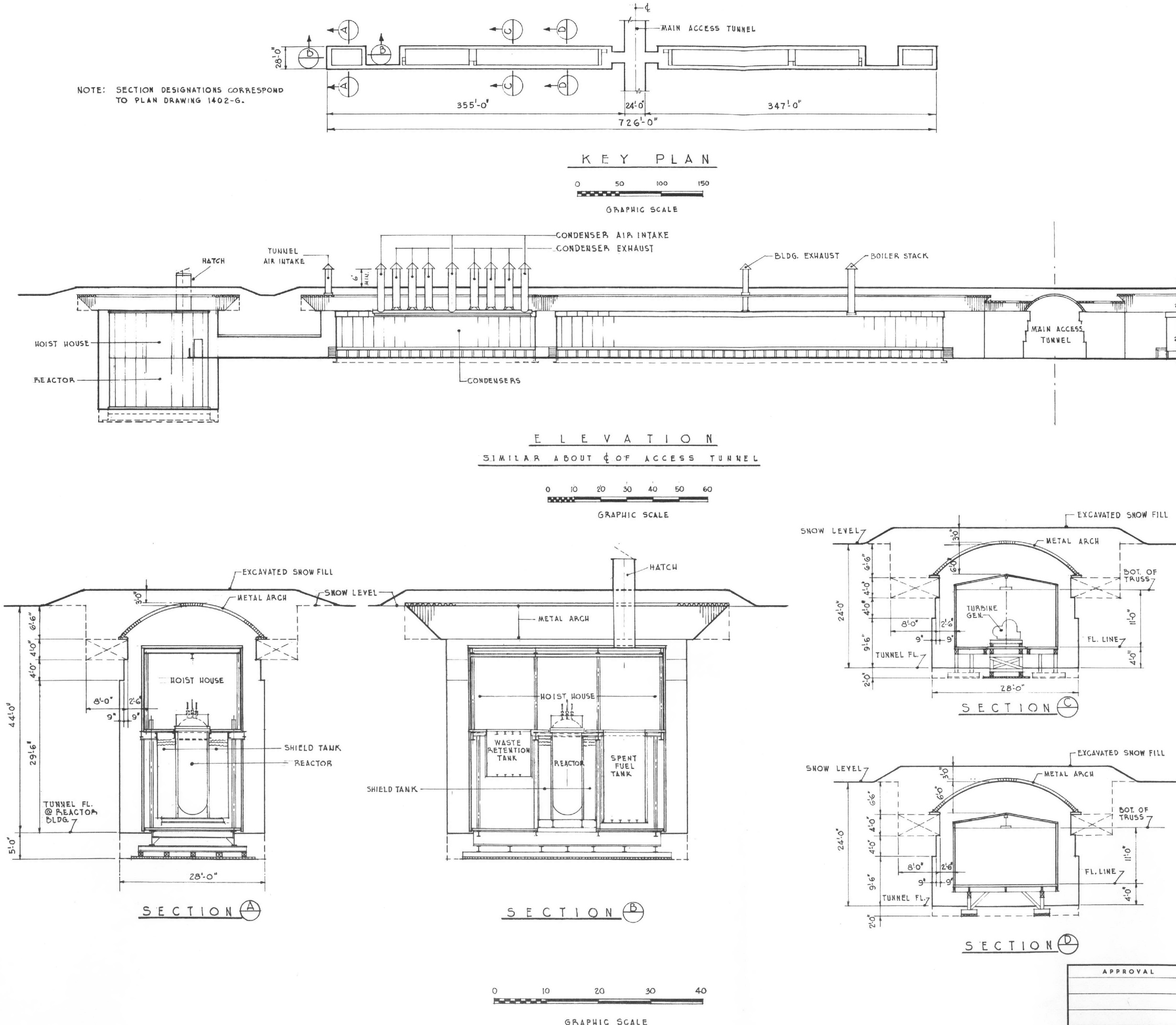
GRAPHIC SCALE 0 50 100 150 200 250

APPROVAL	DATE	
PROJECT ENGINEER D. Daly	5/5/60	
CHIEF ENGINEER		

STUDY OF REMOTE MILITARY POWER APPLICATIONS FOR U. S. ATOMIC ENERGY COMMISSION

DIVISION OF HENRY J. KAISER COMPANY — **KAISER ENGINEERS** — OAKLAND CALIFORNIA

		DATE	
SCALE			BYRD STATION, ANTARCTICA
DRAWN BY	C. ROYLANCE	3/25/60	800 KW NUCLEAR POWER PLANT
CHECKED BY	R. A. WILSON	5/4/60	GENERAL ARRANGEMENT-PLANS
APPROVED BY	Rawdson D. Hansen	5-4-60	
CHIEF DESIGN ENGINEER	[signature]	5-5-60	JOB No. 5929 DWG. No. 1402-G



STUDY OF REMOTE MILITARY POWER APPLICATIONS
FOR
U. S. ATOMIC ENERGY COMMISSION

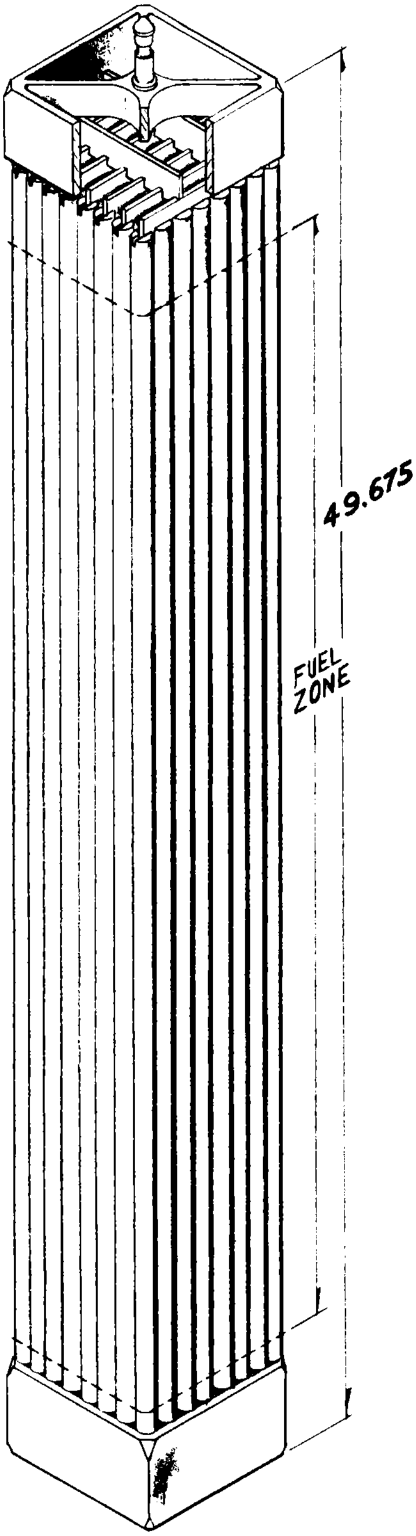
DIVISION OF HENRY J. KAISER COMPANY — **KAISER ENGINEERS** — OAKLAND CALIFORNIA

BYRD STATION, ANTARCTICA

800 KW NUCLEAR POWER PLANT
GENERAL ARRANGEMENT - ELEVATIONS

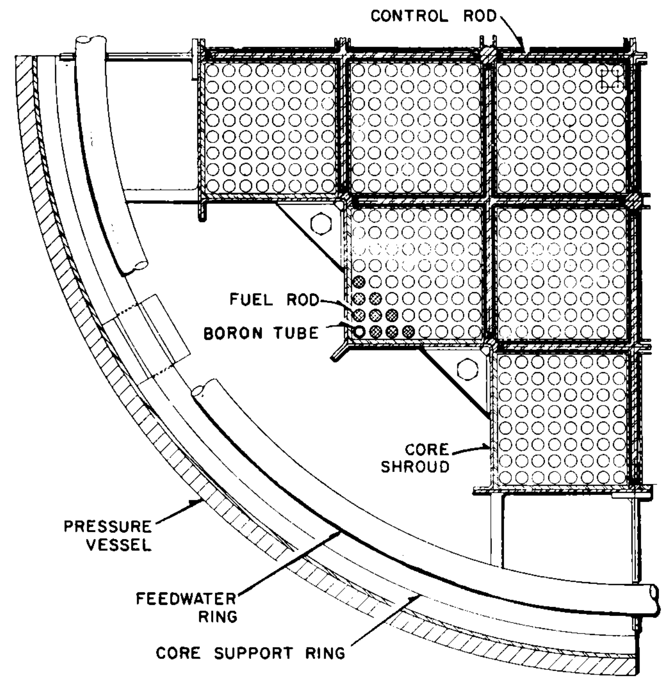
APPROVAL		DATE			DATE
PROJECT ENGINEER	D.W. Daly	5/5/60	DRAWN BY	C. ROYLANCE	4/12/60
CHIEF ENGINEER			CHECKED BY	R.A. WILSON	5/4/60
			APPROVED BY	Rawlson D. Hansen	5-4-60
			CHIEF DESIGN ENGINEER	[illegible]	5-5-60

JOB No. 5929 DWG. No. 1403-G



FUEL ASSEMBLY

CORE CROSS SECTION

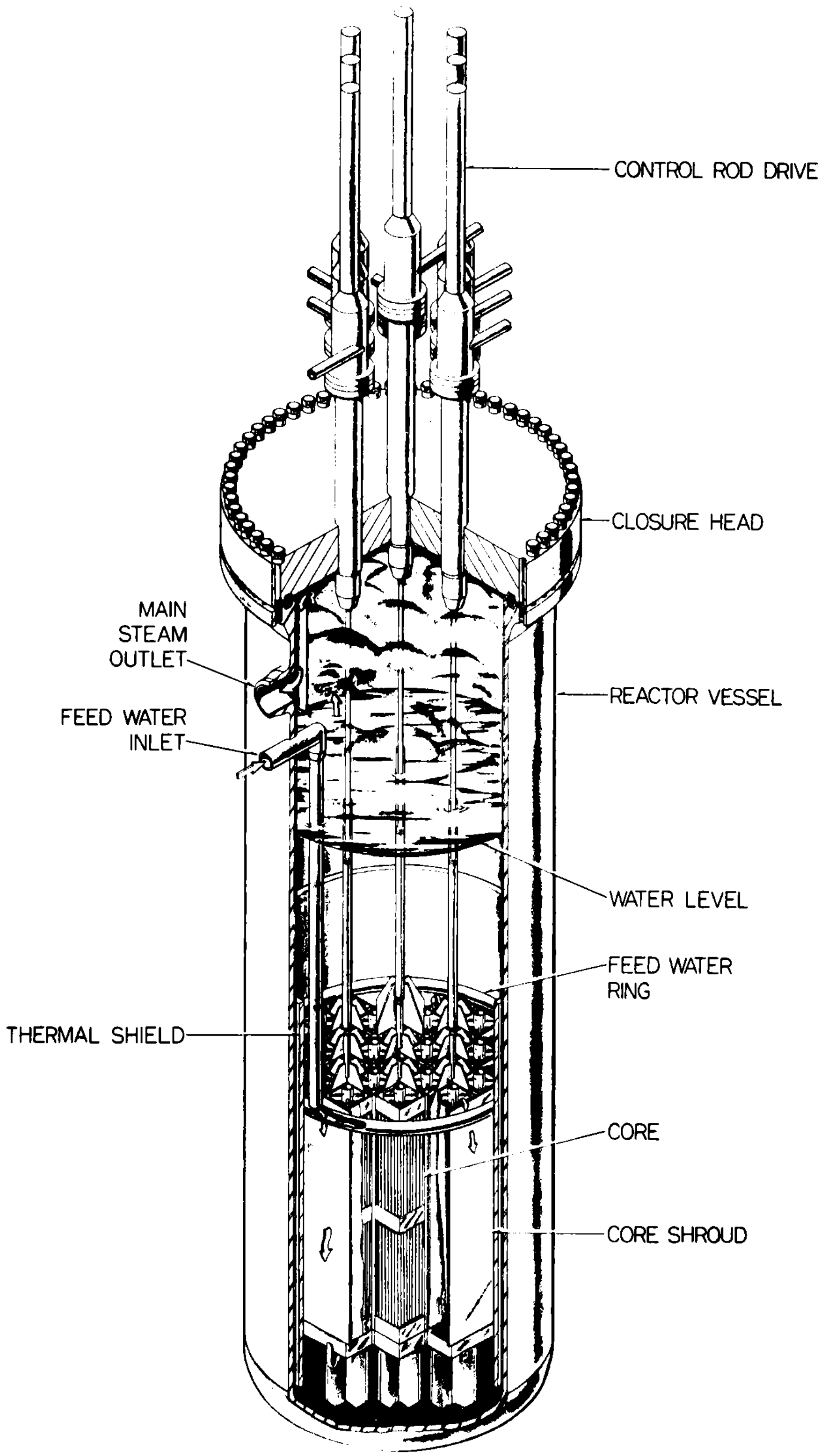


800 KW NUCLEAR POWER PLANT

PL-2 CORE CROSS SECTION
AND FUEL ASSEMBLY

COURTESY OF
COMBUSTION ENGINEERING, INC.

DWG. NO. 1401-M

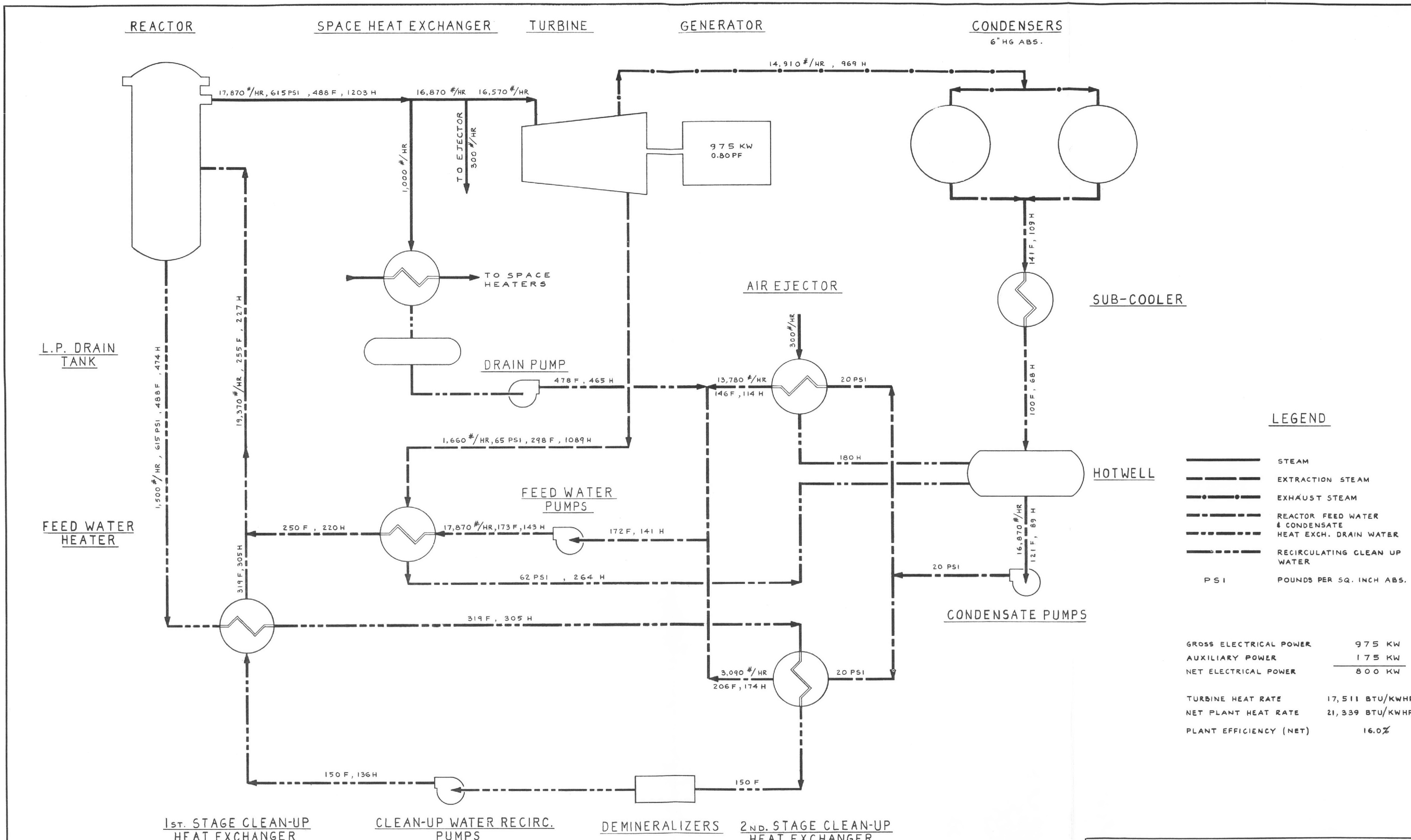


800 KW NUCLEAR POWER PLANT

PL-2 REACTOR PRESSURE VESSEL
AND CORE

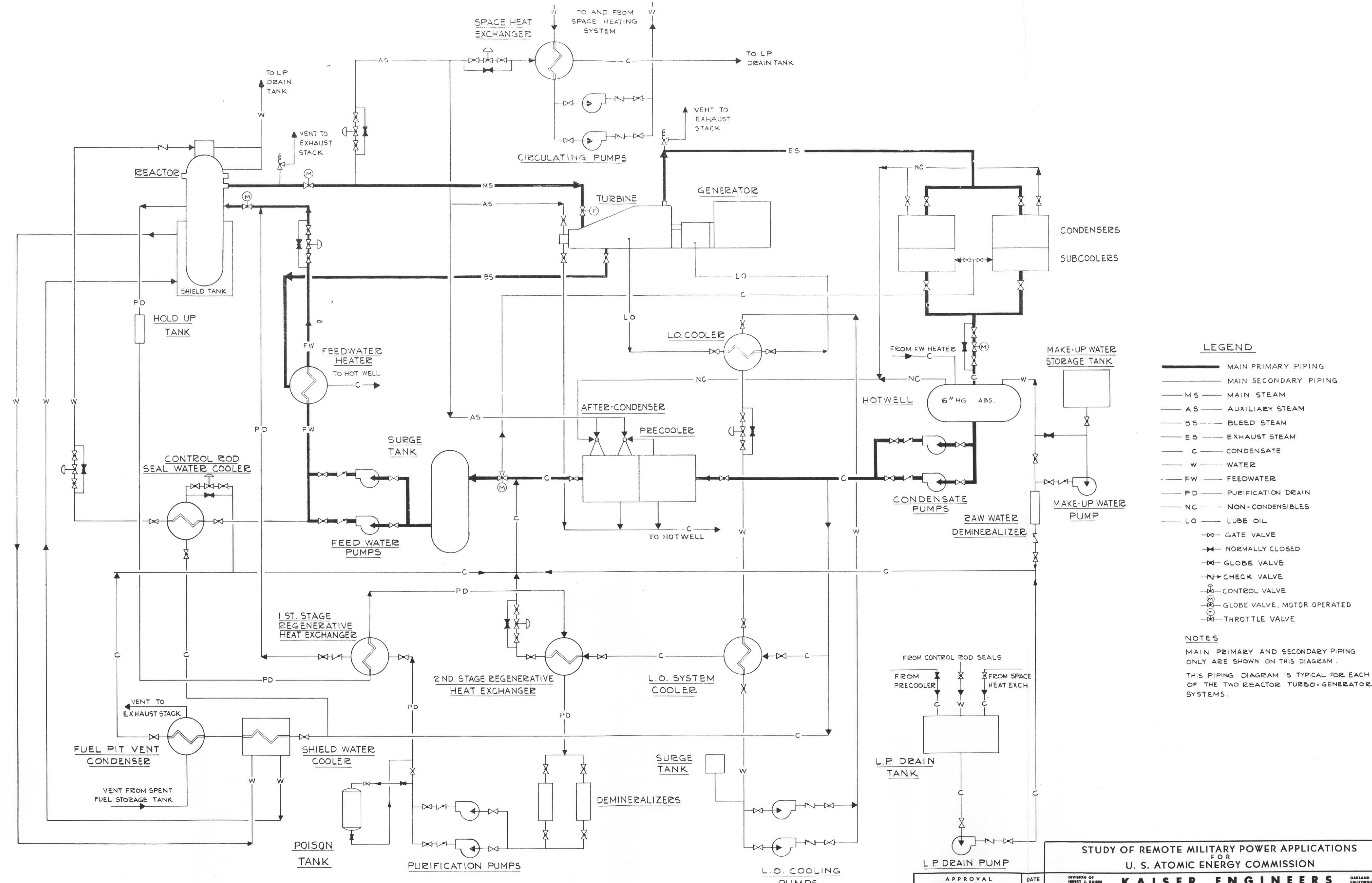
COURTESY OF
COMBUSTION ENGINEERING, INC.

DWG. NO. 1402-M



STUDY OF REMOTE MILITARY POWER APPLICATIONS
FOR
U. S. ATOMIC ENERGY COMMISSION

APPROVAL	DATE			
		DIVISION OF HENRY J. KAISER COMPANY	KAISER ENGINEERS	OAKLAND CALIFORNIA
		SCALE NONE	DATE	BYRD STATION, ANTARCTICA
		DRAWN BY V. V. RODIONOFF	5-2-60	800 KW NUCLEAR POWER PLANT HEAT BALANCE
		CHECKED BY [signature]	5/5/60	
PROJECT ENGINEER [signature]	5/5/60	APPROVED BY [signature]	5-5-60	
CHIEF ENGINEER		CHIEF DESIGN ENGINEER [signature]	5-5-60	JOB No. 5929 DWG. No. 1401-P



STUDY OF REMOTE MILITARY POWER APPLICATIONS
FOR
U. S. ATOMIC ENERGY COMMISSION

APPROVAL	DATE
PROJECT ENGINEER Pd Daly	5/5/60
CHIEF ENGINEER	

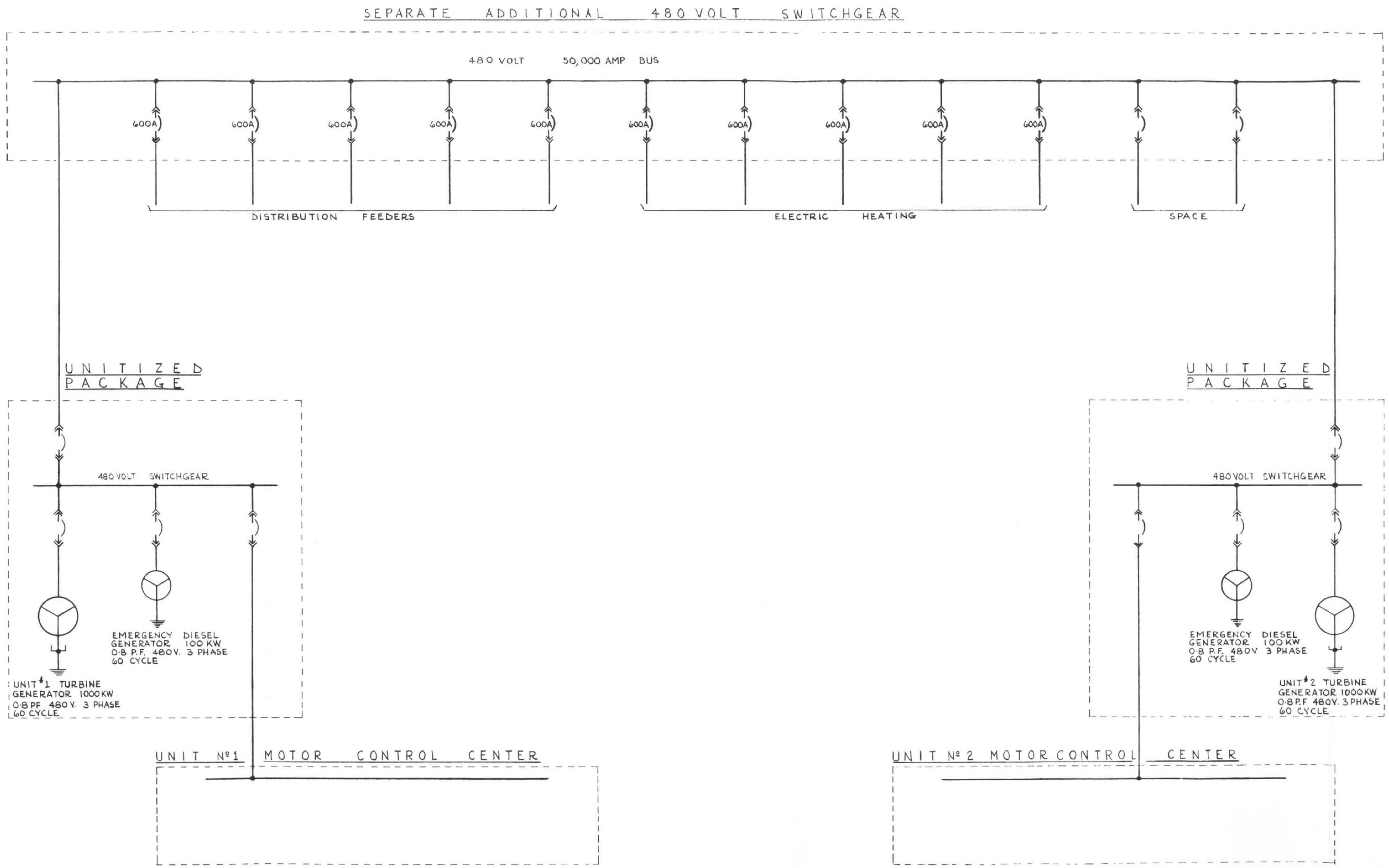
DIVISION OF HENRY J. KAISER COMPANY — **KAISER ENGINEERS** — OAKLAND CALIFORNIA

		DATE
SCALE	NONE	
DRAWN BY	J. Sarty.	5/4/60
CHECKED BY	W. Brooks	5-5-60
APPROVED BY	[illegible]	5-5-60
CHIEF DESIGN ENGINEER	[illegible]	5-5-60

BYRD STATION, ANTARCTICA

800 KW NUCLEAR POWER PLANT
PIPING DIAGRAM

JOB No. 5929 DWG. No. 1402-P



LEGEND

- DRAWOUT AIR CIRCUIT-BREAKER
- AIR CIRCUIT-BREAKER

NOTE

GROUNDING INDICATED ON THIS DWG. WILL BE PATTERNED AFTER A METHOD OF GROUNDING MATS OR GRIDS AS DESCRIBED BY E.T.B. GROSS IN THE A.I.E.E. TRANSACTION PAPERS ISSUED IN AUG 1953, OCT 1955 AND OCT. 1956
THIS METHOD IS APPLIED WHERE OTHER GROUNDING SCHEMES ARE UNWORKABLE DUE TO THE HIGH RESISTIVITY OF THE GROUNDING MEDIUM.

STUDY OF REMOTE MILITARY POWER APPLICATIONS
FOR
U. S. ATOMIC ENERGY COMMISSION

APPROVAL	DATE
PROJECT ENGINEER [signature]	5/5/60
CHIEF ENGINEER	

DIVISION OF HENRY J. KAISER COMPANY — **KAISER ENGINEERS** — OAKLAND CALIFORNIA

	DATE
SCALE NONE	
DRAWN BY G. H. HUGHES	4-29-60
CHECKED BY O. NIEPONICE	4-29-60
APPROVED BY [signatures]	4-29-60
CHIEF DESIGN ENGINEER [signature]	5-?-60

BYRD STATION, ANTARCTICA

800 KW NUCLEAR POWER PLANT
ONE LINE DIAGRAM

JOB No. 5929 DWG. No. 1402-E

SECTION V

PROPOSED CONVENTIONAL POWER PLANT

A. General Description

The conventional power plant will consist of four diesel electric generators each rated at 400 kw. Fuel will be arctic grade diesel oil having a minimum pour point of -80° F. Electrical power for base heating and power will be supplied at 480 volts.

All plant facilities will be placed within snow tunnels excavated to a depth of 24 ft below the surface. A Peter Snow Miller will be used to excavate a trench to the required size and to prepare a level bench for supporting the roof arches spanning the tunnel. After erecting the steel arches, the Miller will be used to place about 3 ft of snow fill over the tunnel. Clearance between the buildings and the tunnel walls will be provided to allow for reduction in the tunnel cross section due to plastic flow and consolidation of the snow over the life of the plant.

The power plant will be housed in a heavily insulated prefabricated building designed for erection under arctic conditions with a minimum of time. Buildings and equipment will be supported by timber posts and cribbing bearing on timber mats. The mats or foundations will bear on dense snow at a depth of 2 ft below the tunnel floor. Snow will be backfilled over the foundations.

The diesel generator building, 16 ft wide, 12 ft high, and 184 ft long, will provide space for the diesel generators and accessories, electrical switchgear, shop and office equipment, and heating and ventilating equipment. The plant tunnel will be 24 ft wide by 220 ft long, and will have a 12 ft wide connecting passageway to the main base access tunnel. Ventilation and exit shafts will be constructed through the tunnel roof.

Space for oil storage will be provided in two tunnels, one on each side of the main base access tunnel, constructed approximately 100 ft from the diesel generator plant in a direction away from the base installation. Each tunnel will be 24 ft wide by 515 ft long. A 14-month supply of fuel oil will be stored in 12 - 53,000 gallon inflatable rubber tanks, six located in each tunnel. The tanks will rest on the floor of the tunnel and when filled will be 19 ft wide, 77 ft long, and 6 ft high. Oil from the storage tunnel will be pumped to a day tank in the power plant building. Fuel oil will be delivered to the site by air in 4,000 gal heavy duty rubber tanks mounted on skid bases.

At McMurdo Sound two 5,480 barrel steel storage tanks will be constructed for the bulk storage of fuel oil for delivery to the site.

Heating and ventilation will be provided for the power plant building. Warm air from the building will be utilized for tempering combustion air to the diesel engines. Cold outside air will be conveyed through the plant tunnel for the removal of heat loss from the building. This tunnel ventilation will be sufficient to maintain the snow temperature close to its yearly average and thereby minimize foundation settlements.

Potable water and make-up water to the plant will be supplied from existing station facilities.

Fire protection equipment will consist of portable dry type chemical extinguishers located in the building, plant, and oil storage tunnels.

B. Basis for Project Cost Estimate

1.0 Land and Land Rights

Land and property acquisition are not included in this estimate.

2.0 Structures and Improvements

2.1 General Improvements

2.1.1 Snow Tunnels

Snow excavation for plant tunnels and the oil storage area is based on the use of the Peter Snow Miller as manufactured by the Konrad Peter, Ltd., Liestol, Switzerland. The Miller is capable of cutting a trench to a depth of at least 24 ft below the snow's surface, the depth being determined by the limitation in ejecting the snow to the surface. Snow fill deposited by the Miller sets up in a firm mass having a density equal to that of natural snow at a depth of 30 ft or more. This fill provides a suitable foundation material. As indicated on the drawings, the sills supporting the roof arch bear on a pad of this redeposited snow fill.

The diesel generator building will require 5,900 cu yd of excavation and 2,600 cu yd of fill for the tunnel, approximately 210 ft long, 24 ft wide and 24 ft deep. A portion of the main access tunnel, 250 ft long, 24 ft wide, and 24 ft deep, will provide access from the Station to the power plant and fuel oil storage tunnels and will require 6,500 cu yd of excavation and 2,700 cu yd of fill.

Each of two fuel oil storage tunnels will require an excavation 515 ft long, 24 ft wide, and 24 ft deep. This will result in 31,700 cu yd of excavation and 7,800 cu yd of snow back-fill.

Access ramps and connecting tunnel sections to and from the floor of the tunnels will require an additional 2,500 cu yd of snow excavation.

2.1.2 Tunnel Roofs

Tunnel roofs will consist of steel arch construction covered with 3 ft of snow at the arch centerline.

The arch will consist of double curved and corrugated, zinc coated, 18 gauge steel, (Series 3510), as manufactured by the Wonder Building Corporation of America, Chicago, Illinois. Major corrugations are 7-7/8" deep.

Arches over the diesel generator building will span 23 ft with a rise of one-fourth the span. The top of the arch will be approximately at original snow level. This location permits a minimum clearance of 4 ft at any point between the arch and the building beneath it, and places the foundation pad of the arch at 6 ft 6 in. below the original snow level.

The arches over the oil storage area will span 19 ft with a rise of one-fourth the span. The top of this arch will be approximately 3 ft below the original snow level and places the foundation pad of the arch at 7 ft 9 in. below the original snow level.

2.1.3 Water Supply

Power plant and domestic water requirements of approximately 45 gal per day will be supplied from existing station snow melting facilities and delivered in drums to the power plant where it will be stored in a 250 gal storage tank.

2.1.4 Sanitary Sewage Disposal

Sanitary waste will be collected in containers and disposed of by methods conforming to existing station procedures.

2.1.5 Tunnel Lighting

General tunnel lighting will be provided.

2.1.6 Fire Extinguishing Equipment

Exterior fire extinguishing equipment will consist of portable chemical extinguishers located throughout the tunnel system and oil storage area.

2.2 Diesel Generator Building

2.2.1 Substructure

The substructure of the building will consist of timber floor joists at 4 ft centers spanning 16 ft. A continuous timber sill will run at the longitudinal edges of the building. These sills will be supported by timber columns at 4 ft centers. The columns will be supported by a short transverse beam spreading the load to a continuous timber plank mat running longitudinally the length of the building.

Footing area for the building will be designed to minimize differential settlement. Snow bearing pressures under the footings will not exceed 500 psf from both dead load and live load.

Footings will be founded 2 ft below the tunnel floor. After installation of the footings snow will be backfilled to the level of the tunnel floor.

The substructure will be designed to facilitate jacking and shimming the foundation for leveling the building in the event of unequal settlement.

2.2.2 Superstructure

The superstructure is based on an Army T-5 building as developed by the Engineering Research and Development Laboratory, U. S. Army at Fort Belvoir, Virginia for Arctic use.

The building will measure 16 ft wide by 12 ft high by 184 ft long and will consist of heavily insulated, prefabricated, 4 ft wide plywood panels for floor, roof, and walls. The panels will have a heat transmission factor of not more than 0.10 Btu/hr/sq ft/°F. Floor panels will be designed for 100 psf. A pair of doors will be provided at each end of the building for equipment and personnel.

Interior surfaces will be clad with aluminum to minimize fire hazard. Floors will be covered with a suitable abrasive and fire resistant, nonslip floor covering. Exterior surfaces will be treated with fire retardant paints at the manufacturer's plant.

The prefabricated panels and trusses of the T-5 building will be manufactured to minimize site erection time. They will be pre-assembled at the plant to ensure proper fit-up and packaged for air transport. It will be erected in the completed snow tunnel with finish floor 4 ft above the tunnel floor.

2.2.3 Heating and Ventilation

The building heating and ventilation and the tunnel cooling will be a single combined system.

A heating and ventilating unit in the building will draw 4,500 cfm of outside air through the tunnel, heat it, humidify it, and deliver it via an air duct to the ceiling diffusers.

Air will leave the building either through an exhaust fan or relief dampers into the diesel engine combustion air intake plenum. Approximately four air changes an hour will be provided in both the building and in the tunnel.

Fuel oil storage tunnel ventilation will consist of one exhaust fan and one air intake to provide approximately one air change per hour.

2.2.4 Plumbing

One chemical type toilet and a lavatory will be provided.

2.2.5 Building Electrical

Facilities will consist of building lighting, grounding, power for building services, and structures supporting the cable trays and electrical equipment associated with the generators main circuits.

2.2.6 Miscellaneous Cranes and Hoists

Heavy equipment will be lifted from a portable steel tripod. A three-ton manual hoist will be provided for the heavy lifts. A one-ton light duty manual hoist will be provided for miscellaneous service.

2.2.7 Painting

Interior wood surfaces (not factory treated) will be coated with a fire retardant paint. Interior carbon steel surfaces will be painted.

3.0 Fuel Oil Storage and Distribution System

3.1 Fuel Oil Storage System

The fuel oil storage system will consist of twelve static storage tanks (inflatable type), of 53,000 gal capacity each, 19 ft wide, 77 ft long, and 6 ft high when full, and 22 ft wide by 80 ft long when empty. Total storage capacity is 15,100 barrels, providing 14 months' supply of fuel oil.

They will be distributed in two 24 ft wide by 515 ft long fuel oil storage tunnels located one on either side of the main access tunnel, with a minimum insulating cover of 3 ft on top of the corrugated metal arch tunnel roof. The storage tanks placed lengthwise directly on the finished tunnel floor and to one side. The remaining space will be used by unloading and distribution piping, and service aisle.

There will be 45 drums of lube oil delivered to the site and placed in the lube oil storage area.

3.2 Fuel Oil Distribution

The fuel distribution system is designed for arctic grade diesel fuel oil with a pour point of -80° F.

The fuel oil distribution system will consist of 1,250 lf of flexible hose pipe connected to two positive displacement pumps placed in separate pits located at the head of each of the fuel oil storage tunnels.

These pumps will be manifolded to the fuel oil piping system and will automatically supply fuel to the day tanks located within the diesel generator building.

3.3 Fuel Oil Unloading - Byrd Station

Fuel oil will be delivered to the site by air from McMurdo Sound in skid mounted 4,000 gal heavy duty inflatable rubber tote tanks, 7.5 ft wide, 37 ft long, and 7 ft high when full. These tanks will be unloaded at the airstrip where two skid mounted gasoline engine driven fuel oil transfer pumps will pump fuel oil through 1,000 lf of 4 in. flexible hose to the plant's permanent fuel oil storage tanks.

3.4 Fuel Oil Storage - McMurdo Sound

At McMurdo Sound two 5,480 barrel steel bulk storage tanks, 70 ft in diameter and 8 ft high will be required as temporary storage. The tote tanks will be filled from these storage tanks.

4.0 Diesel Generator Plant

4.1 Diesel Generators and Accessories

The plant will include four diesel electric generators, each rated at 400 kw. The diesel engines will be rated at 574 hp at 720 rpm. The engines will be vertical, inline, single acting, two or four cycle, solid injection, suitable for operation at 5,000 ft elevation, completely enclosed, and full pressure lubricated.

Accessories for each engine will include an exhaust gas turbo-charger, exhaust silencer, lube oil pump and cooler, fuel oil booster pump, strainer and filter, floor mounted gaugeboard, automatic start-stop and synchronizing controls, electric starter, water cooled exhaust manifold, and a structural steel subbase to support the generator.

The generators will be 500 kva, 4-wire, 0.80 power factor, 3-phase, 60 cycle, 480 v, 720 rpm with 125 v, d-c, V-belt connected exciters rated for operation at 5,000 ft elevation. The quality of the power will be consistent with the system requirements.

4.2 Combustion Air System

The diesel engines will draw combustion air from a common plenum with an outside air intake through dry impingement type air filters. Relief dampers will be provided between this plenum and the engine room so that during normal operation, combustion air will be drawn from the engine room.

4.3 Cooling System

A cooling water system common to all units will provide cooling for the operating engines. A circulating pump with a stand-by will circulate water through the system. Heat will be rejected from the engine cooling system to the space heating units, the air cooled exchanger, and jackets of the stand-by engines.

4.4 Diesel Generator Foundations

The diesel generators will be mounted on steel skid frames by the vendor. Beneath each steel skid frame will be 16 vibration control devices. These in turn will be supported by a heavy timber frame which is separated from the building floor framing. Timber columns will carry the load to a timber mat founded 2 ft below the tunnel floor. After installation of the footings, snow will be backfilled to the level of the tunnel floor. Provision will be made to facilitate jacking and shimming the foundation to maintain proper relation to the building floor, and for leveling the frame in the event of unequal settlement.

4.5 Diesel Engine Lubrication System

Each diesel generating unit will have an independent lube oil cooling and circulating system. The circulating pump will be engine driven. A separate operating pump and a stand-by pump will be provided to transfer dirty crankcase oil to a storage tank and clean oil from a storage tank to the crankcases. A centrifuge, complete with transfer pumps, will be provided.

4.6 Instruments

A gauge board will be provided for each diesel generating unit. In addition to the unit controls, instruments will be provided for integrated plant operation of the diesel generating units.

4.7 Plant Piping

Piping for the plant will include the following systems:

Exhaust
Lube oil
Fuel oil
Jacket cooling water

4.8 Engine Starting System

Each engine will be equipped for electric starting from a battery source. The starting system will include an electric starting motor, magnetic and hand starting switches, voltage regulator, and battery charging equipment listed under Section 5.3.

4.9 Auxiliaries Foundations

Auxiliaries equipment will be mounted on the building floor.

5.0 Accessory Electrical Equipment

5.1 Main Switching, Control and Protective Equipment

This equipment will include 480 v switchgear, indoor, metal enclosed, with 25,000 amp interrupting capacity air circuit breakers; and controls, relaying and metering for the generators, exciters and outgoing feeders.

5.2 Auxiliary Electrical Equipment

This will consist of wire, cable, and auxiliary equipment associated with the power generating facilities.

5.3 Auxiliary Switching, Control and Protective Equipment

The equipment will consist of one distribution panelboard, 480 v, 3-phase, 60 cycle; one 125 v d-c distribution panel; and station battery and battery chargers.

6.0 Miscellaneous Power Plant Equipment

6.1 Fire Extinguishing Equipment

The fire protection equipment will consist of portable dry chemical extinguishers located throughout the plant.

6.2 Fire Alarm System

The fire alarm system will consist of thermal rate of rise detectors actuating electrically operated sound equipment.

6.3 Plant Air Equipment

The plant air supply will consist of one motor driven, air cooled, tank mounted, compressor rated at 10 cfm at 100 psig.

6.4 Shop Equipment

A pump and fuel injector repair room will be provided complete with injector test stand. Shop equipment will include small hand tools and racks for storing miscellaneous spare parts.

6.5 Office Furniture and Equipment

Furniture and equipment for the office area will be provided.

7.0 Transmission Plant

Cable and supports to the access tunnel only will be provided.

8.0 Communication System

Telephone facilities will be provided.

9.0 Indirect Cost

9.1 General Field Expense

General field expense includes the cost of supervision by the Navy and by contractors' representatives, Navy service personnel, warehousing, warehouse equipment, small tools, consumable supplies, and maintenance of temporary facilities.

9.2 Export Packing and Transportation Costs

9.2.1 Export Packing

Export packing includes the cost of packing and crating sufficient for severe shipping conditions in Antarctic waters and over-the-ice transportation to NAF McMurdo. In addition packages must be finally assembled on sleds or skids for transportation by C-130-B aircraft from McMurdo to Byrd Station and final movement to the construction site. Packing, crating and palletizing will be done preferably at the factory or at Davisville, Rhode Island. However, it is anticipated that some work will have to be done by Navy Construction Battalion personnel after arrival at McMurdo.

9.2.2 Ocean Freight

Ocean freight includes domestic freight forwarding charges, port handling and wharfage charges, and ocean freight from Davisville, Rhode Island to McMurdo Sound. The estimate is based on an estimated cargo of 646 short tons (Table 8), a stowage factor of 1.5, and a unit cost of ocean freight of $100/mt (Appendix A).

Marine insurance is not included since shipment will be in U. S. Government owned vessels.

9.2.3 Icebreaker Cost

Icebreaker cost is based on an estimated cargo of 646 short tons (Table 8), a stowage factor of 1.5, and an estimated unit cost of icebreaker service of $76/mt (Appendix B).

9.2.4 Cost of Airlift

All personnel, materials, and equipment must be flown from NAF McMurdo to Byrd Station, and in addition, certain materials and equipment airlifted from New Zealand. The estimate of cost is based on a total of 45 round trip airlifts (Table 8) and an estimated unit airlift cost of $7,570 per round trip (Appendix C). In addition, the estimate includes an allowance for the ferrying cost (Appendix C) of one cargo aircraft each construction season (Table 8) from the United States and return.

9.3 Start-up and Testing

9.3.1 Shop Testing

Shop testing includes witnessing of the complete testing and operation of the assembled diesel engine power plant by Naval Personnel at the manufacturer's plant.

9.3.2 Field Start-up and Testing

Field start-up and testing includes all labor, materials, equipment and personnel transportation cost for the initial testing, start-up and regulating of the power plant. Acceptance tests to verify the performance of components and the completed power plant in accordance with the specifications will be performed.

9.4 Contractor's Field Overhead

This item includes an allowance of $14,000 per man-year for Navy personnel for special clothing and transportation of men and supplies. Also included is an allowance for purchasing and expediting, field tests, survey, project photographs and field office supplies.

9.5 Construction Plant

It is assumed that construction personnel will make maximum use of the existing facilities at Byrd Station and NAF McMurdo. However, the facilities at Byrd Station will have to be augmented with additional temporary housekeeping facilities for some of the construction personnel. It is also assumed that necessary temporary construction buildings such as shops, warehouses, and field offices will be provided. This expansion of facilities would be required to be completed prior to commencement of power plant construction.

9.6 Camp Expenses

This includes messing and billeting of contractor's personnel, which will be furnished by the Navy at a cost of $2.25 per day per man.

9.7 Insurance, Bond, and Financing

Since all field work will be done by Navy personnel, the cost of these items is not included.

9.8 Personnel Mobilization

This includes the pay of Navy construction personnel in the U. S. while in training and in transit to and from Byrd Station.

9.9 Construction Equipment

Costs are included for the Peter Snow Miller, two D-6 tractors, welding generators and miscellaneous tools and equipmant required for building and equipment erection.

10.0 Escalation

Escalation is based on an over-all escalation of 6% on labor, equipment and materials.

11.0 Design Engineering

Design engineering costs include the cost of over-all project planning, site layout, concept and detail design of the snow tunnels, buildings, diesel engine generator plant, fuel handling and storage facilities, and utilities. Also included is the cost of preparing operating manuals, test procedures and maintenance manuals.

The administrative cost involved in the purchase of equipment is not included.

12.0 Contingency

The contingency is 15% of the cost of the plant including escalation and design engineering.

13.0 Fuel Oil in Storage

Cost of a two-month supply (91,000 gal) of diesel oil is included in the cost of the plant. This amount of fuel oil represents an emergency reserve which would always be on hand.

C. Estimate of Project Cost

SUMMARY

800 KW CONVENTIONAL POWER PLANT

	Description	Labor	Permanent Materials and Equipment	Total
1.0	Land and Land Rights	$ - -	$ - -	$ - -
2.0	Structures and Improvements	67,000	138,000	205,000
3.0	Fuel Oil Storage and Distribution System	43,000	166,000	209,000
4.0	Diesel Generator Plant	45,000	282,000	327,000
5.0	Accessory Electrical Equipment	18,000	78,000	96,000
6.0	Miscellaneous Power Plant Equipment	4,000	16,000	20,000
7.0	Transmission Plant	2,000	2,000	4,000
8.0	Communication System	2,000	2,000	4,000
	Total Direct Construction Cost	$ 181,000	$ 684,000	$ 865,000
9.0	Indirect Cost	113,000	1,250,000	1,363,000
	Total Construction Cost	$ 294,000	$1,934,000	$2,228,000
10.0	Escalation			132,000
	Total Including Escalation			$2,360,000
11.0	Design Engineering			100,000
	Total Estimated Cost Excluding Contingency			$2,460,000
12.0	Contingency			340,000
	Total Including Contingency			$2,800,000
13.0	Fuel Oil in Storage			300,000
	Total Estimated Project Cost			$3,100,000

ESTIMATE OF CONSTRUCTION COST

800 KW CONVENTIONAL POWER PLANT

	Description	Labor	Permanent Materials and Equipment	Total
1.0	Land and Land Rights	- -	- -	- -
2.0	Structures and Improvements			
.1	General Improvements			
.1.1	Snow Tunnels	$ 6,000	$ - -	$ 6,000
.1.2	Tunnel Roofs	9,000	43,000	52,000
.1.3	Water Supply	1,000	2,000	3,000
.1.4	Sanitary Sewage Disposal	1,000	2,000	3,000
.1.5	Tunnel Lighting	4,000	8,000	12,000
.1.6	Fire Extinguishing Equipment	1,000	2,000	3,000
	Sub-Total	$ 22,000	$ 57,000	$ 79,000
.2	Diesel Generator Building			
.2.1	Substructure	$ 17,000	$ 8,000	$ 25,000
.2.2	Superstructure	17,000	55,000	72,000
.2.3	Heating and Ventilation	3,000	7,000	10,000
.2.4	Plumbing	2,000	3,000	5,000
.2.5	Building Electrical	4,000	5,000	9,000
.2.6	Miscellaneous Cranes and Hoists	1,000	1,000	2,000
.2.7	Painting	1,000	2,000	3,000
	Sub-Total	$ 45,000	$ 81,000	$ 126,000
	Total Structures and Improvements	$ 67,000	$ 138,000	$ 205,000
3.0	Fuel Oil Storage and Distribution System			
.1	Fuel Oil Storage System	$ 4,000	$ 90,000	$ 94,000
.2	Fuel Oil Distribution	4,000	12,000	16,000
.3	Fuel Oil Unloading - Byrd Station	2,000	37,000	39,000
.4	Fuel Oil Storage - McMurdo Sound	33,000	27,000	60,000
	Total Fuel Oil Storage and Distribution System	$ 43,000	$ 166,000	$ 209,000

ESTIMATE OF CONSTRUCTION COST

800 KW CONVENTIONAL POWER PLANT
(Cont'd)

	Description	Labor	Permanent Materials and Equipment	Total
4.0	Diesel Generator Plant			
.1	Diesel Generators and Accessories	$ 23,000	$ 240,000	$ 263,000
.2	Combustion Air System	1,000	6,000	7,000
.3	Cooling System	1,000	6,000	7,000
.4	Diesel Generator Foundations	5,000	3,000	8,000
.5	Diesel Engine Lubrication System	2,000	8,000	10,000
.6	Instruments	3,000	5,000	8,000
.7	Plant Piping	8,000	12,000	20,000
.8	Engine Starting System	1,000	1,000	2,000
.9	Auxiliary Foundations	1,000	1,000	2,000
	Total Diesel Generator Plant	$ 45,000	$ 282,000	$ 327,000
5.0	Accessory Electrical Equipment			
.1	Main Switching, Control and Protective Equipment	$ 5,000	$ 39,000	$ 44,000
.2	Auxiliary Electrical Equipment	5,000	16,000	21,000
.3	Auxiliary Switching, Control and Protective Equipment	8,000	23,000	31,000
	Total Accessory Electrical Equipment	$ 18,000	$ 78,000	$ 96,000
6.0	Miscellaneous Power Plant Equipment			
.1	Fire Extinguishing Equipment	$ 1,000	$ 2,000	$ 3,000
.2	Fire Alarm System	1,000	3,000	4,000
.3	Plant Air Equipment	1,000	4,000	5,000
.4	Shop Equipment	1,000	5,000	6,000
.5	Office Furniture and Equipment	- -	2,000	2,000
	Total Miscellaneous Power Plant Equipment	$ 4,000	$ 16,000	$ 20,000
7.0	Transmission Plant	$ 2,000	$ 2,000	$ 4,000
8.0	Communication System	$ 2,000	$ 2,000	$ 4,000
	Total Direct Construction Cost	$ 181,000	$ 684,000	$ 865,000

ESTIMATE OF CONSTRUCTION COST

800 KW CONVENTIONAL POWER PLANT
(Cont'd)

	Description	Labor	Permanent Materials and Equipment	Total
9.0	Indirect Cost			
.1	General Field Expense	$ 49,000	$ 34,000	$ 83,000
.2	Export Packing and Transportation			
.2.1	Export Packing	$ - -	$ 35,000	$ 35,000
.2.2	Ocean Freight	- -	87,000	87,000
.2.3	Icebreaker Cost	- -	65,000	65,000
.2.4	Cost of Airlift	- -	448,000	448,000
	Sub-Total	$ - -	$ 635,000	$ 635,000
.3	Start-up and Testing			
.3.1	Shop Testing	$ 5,000	$ - -	$ 5,000
.3.2	Field Start-up and Testing	13,000	4,000	17,000
	Sub-Total	$ 18,000	$ 4,000	$ 22,000
.4	Contractor's Field Overhead	$ 30,000	$ 340,000	$ 370,000
.5	Construction Plant	11,000	33,000	44,000
.6	Camp Expenses	- -	2,000	2,000
.7	Insurance, Bond, and Financing	- -	- -	- -
.8	Personnel Mobilization	- -	75,000	75,000
.9	Construction Equipment	5,000	127,000	132,000
	Total Indirect Cost	$ 113,000	$1,250,000	$1,363,000
	TOTAL CONSTRUCTION COST	$ 294,000	$1,934,000	$2,228,000

D. Project Schedule

The project schedule on page 74 for the 800 kw conventional power plant has been prepared to serve as a basis for the estimate of cost. The schedule indicates that design and construction activities span a period of 26 months. Starting of engineering by January 1961, will permit completion and operation of the conventional power plant by February 1963.

Based on the ability of aircraft to fly between NAF McMurdo and Byrd Station, the construction season is approximately 115 days. For periods up to one month after the start of the summer season it is not possible to get into McMurdo Sound by ship due to the ice pack. A construction schedule based on bringing materials, equipment and personnel in by vessel would be limited to a maximum of two months of construction time.

It is assumed that existing facilities at Byrd Station would be enlarged to accommodate the construction crew, and at a later date the operating personnel, prior to the start of construction in 1961-1962 (Ref. 14). The schedule is based on this expansion of facilities being done during December and January of 1960-1961.

The schedules and cost estimates are based on the shipment of all materials from Davisville, Rhode Island which is the CONUS marshalling point.

The estimated weights of the equipment and material required for construction of the plant are shown on Table 8 in Section III-D for estimated costs and the schedule presented herein.

In addition, the following factors were considered in preparing the schedule and form a further basis for it:

1. Performance of construction work by U. S. Navy Construction Battalion personnel. Billeting and messing facilities will be furnished by the Navy.

2. A period of three months has been allowed for the mobilization and briefing of construction personnel. In addition, supervisory and key construction personnel should spend approximately one month in the diesel generator subcontractor's plant during the period when the units are being assembled and tested prior to shipment, to familiarize them with the equipment and techniques and problems in assembly.

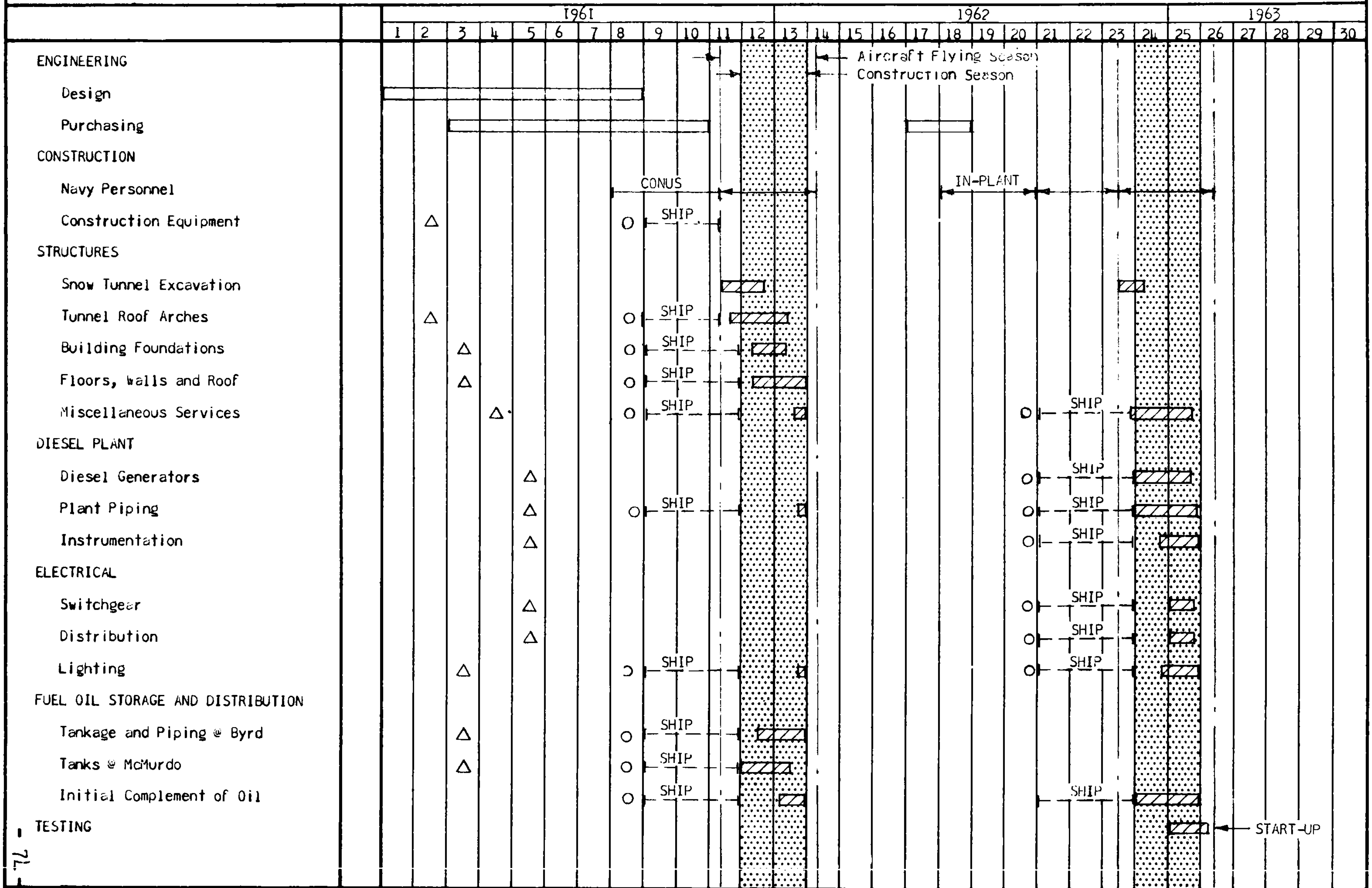
3. The construction schedule is based on a six-day work week, two 10-hour shifts per day.

4. It has been assumed that construction materials required the first season will be ordered far enough in advance to reach McMurdo Sound by ship not later than December 15, 1961. Shipment of the diesel-generator packages the following year will be such as to assure arrival at Byrd Station not later than December 15, 1962.

5. The schedule is based on maximum utilization of prefabricated and preassembled units, including mechanical and electrical equipment and piping.

LEGEND
○ FOB Factory
▨ Installation
△ Purchase

PROJECT SCHEDULE
800 KW CONVENTIONAL POWER PLANT
BYRD STATION



KAISER ENGINEERS
DIVISION OF HENRY J. KAISER COMPANY

E. Estimate of Unit Power Cost

Unit power costs have been based on a plant operating factor equivalent to 100% of the firm power requirement of 800 kw.

Annual Fixed Charges

Annual fixed charges are based on a 20-year plant life equivalent to 5% of the total project cost. No interest on the investment has been included (Ref. 16).

$$0.05 \times \$3{,}100{,}000 = \$155{,}000$$

Operating and Maintenance Costs

Operating and maintenance labor cost based on an estimated complement of seven military personnel is shown on Table 11, page 77. Labor costs are based on an average annual rate for overseas military personnel of $20,350, including base pay, transportation of supplies, messing and special clothing as follows (Ref. 10):

Pay	$ 7,500 per year
Transportation of Supplies	12,250
Messing	400
Special Clothing	200
Total	$20,350 per man per year

The average annual cost of power plant maintenance materials and operating supplies has been obtained by estimating such costs, excluding cost of major overhauls, at a rate of 1.0 mills per kilowatt hour generated, based on published data of the U. S. Department of Agriculture, Rural Electrification Administration and State of Wisconsin Power Commission. Lubricating oil is also estimated separately because of the high cost of transportation to the Station.

Because the engine generator sets weigh approximately 17 tons each assembled and because of the operating characteristics selected for the engines, i.e., slow speed and low BMEP, it is more economical and less hazardous to perform major overhauls at approximately 25,000-hr intervals than to replace the engines. The estimate of cost therefore is based on a total of 12 major overhauls on the engines during the life of the plant. The estimate also includes allowances for export packing, freight and shipping costs, prorated icebreaker costs for replacement parts, materials, supplies and lubricating oils, and, in addition, a 20% allowance for average escalation of materials and supplies over a 20-year period.

Annual Maintenance Cost

$0.001 x 7,000,000 kwhr/yr	=	$ 7,000
Shipping cost	=	1,500
Sub-Total Annual Maintenance Cost		$ 8,500

Lubricating Oil Cost

$$\frac{7{,}000{,}000 \text{ kwhr/yr} \times \$3.63/\text{gal}}{3{,}750 \text{ kwhr/gal}} = \$\ 7{,}000$$

Major Overhaul Cost

Labor:			
12 overhauls x 8 man months each	=	8 man years	
8 man years x $20,350/man year	=	$163,000	
Materials:			
12 overhauls x $8,500 each	=	102,000	
Total for 20-year period		$265,000	
Total Average Annual Overhaul Cost			$13,000

Tunnel Maintenance Cost

Assume 10% of tunnel construction cost (Ref. 19): 0.10 x $25,000	=	$ 2,500
TOTAL MAINTENANCE MATERIALS AND OPERATING SUPPLIES		$31,000

TABLE 11

CONVENTIONAL PLANT

AVERAGE ANNUAL OPERATING AND MAINTENANCE COST

Labor	No. of Personnel	Rate	Annual Cost
Supervision			
Plant Superintendent	1		
Operation			
Power Plant Operators	3		
Auxiliary Operator	1		
Maintenance			
Mechanic	1		
Electrician	1		
Sub-total	7	$20,350	$142,000
Escalation			42,000
Total Operating and Maintenance Labor			$184,000
Maintenance Materials and Operating Supplies			$ 31,000
Escalation			6,000
Total Maintenance Materials and Operating Supplies			$ 37,000
TOTAL AVERAGE ANNUAL OPERATING AND MAINTENANCE COST			$221,000

Annual Fuel Costs

The average annual cost of fuel oil for the diesel engine generator power plant is based on an estimated average unit cost of $3.87 per gallon for arctic grade diesel oil delivered to fuel storage tanks at the Byrd Station, and an estimated annual fuel consumption of 543,000 gal/yr, as follows:

Annual Fuel Consumption

Annual fuel consumption is based on a fuel rate of 0.55 lb/kwhr of arctic grade diesel fuel (API 34.5 gravity, 7.10 lb/gal) and an average annual power production of 7,000,000 kwhr (operation at 100% of firm power demand of 800 kw).	543,000 gal/yr

Unit Cost of Fuel Oil at Byrd Station

Fuel will be transported from the United States in MSTS AOG tankers and transshipped at NAF McMurdo to Byrd Station in specially designed 4,000 gal tanks carried by C-130-B aircraft.

Fuel cost f a s CONUS	$0.12/gal
Ocean freight (Appendix A)	0.33
Icebreaker cost (Appendix B)	0.37
Handling cost at McMurdo (Tanker unloading, and filling, handling, and loading of portable tanks for transport to Byrd Station)	0.10
Cost of airlift (Appendix C) $\frac{\$7{,}570/\text{round trip}}{4{,}000\ \text{gal/round trip}} =$	1.90
Ferrying cost of cargo aircraft (Appendix C) assuming three aircraft are required to airlift the annual requirement of 543,000 gal: $\frac{3 \times \$54{,}000}{543{,}000\ \text{gal}} =$	0.30
Handling cost at Byrd Station (include unloading full tanks from aircraft, filling of Station tanks, and reloading empty tanks into aircraft)	0.10
Sub-Total Fuel Oil at Byrd Station	$3.22/gal

Escalation at 20%	0.65
Total Average Cost of Fuel Oil at Byrd Station	$3.87

Annual Fuel Cost

543,000 gal x $3.87/gal = $2,101,000

Unit Power Costs

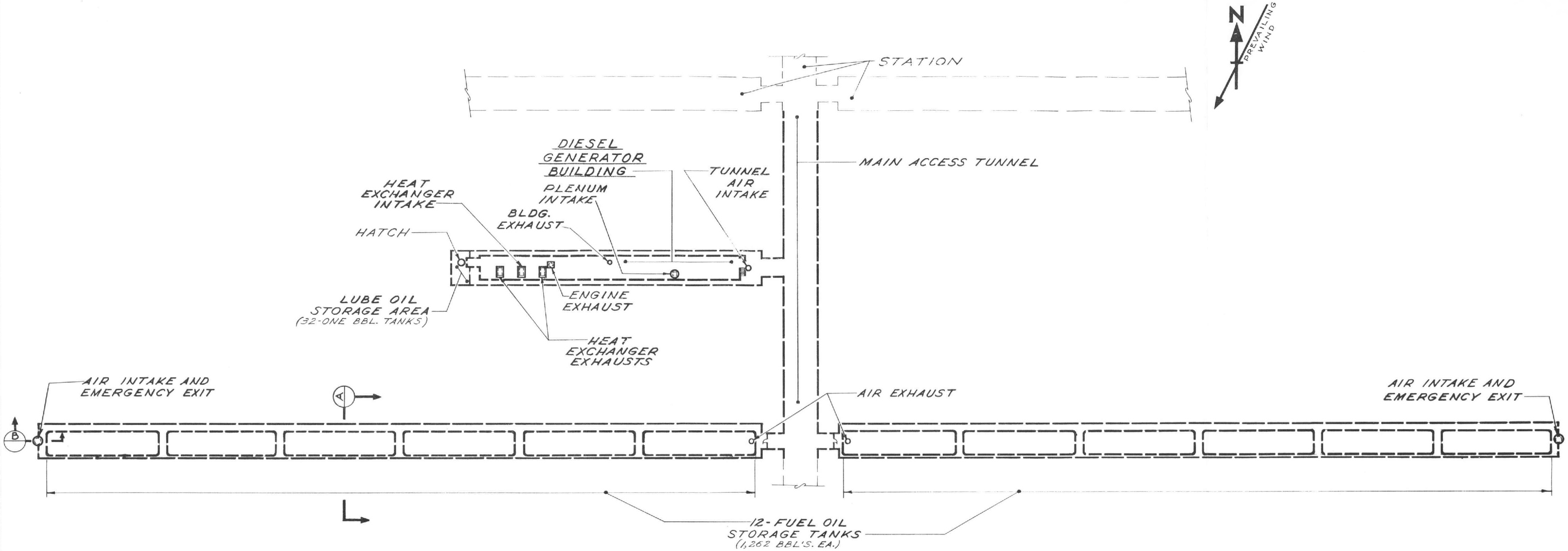
The unit power cost is based on annual power production of 100% of firm power equivalent to 7,000,000 kwhr per year.

	Average Annual Cost	Mills per kwhr
Fixed Charges	$ 155,000	22.2
Operating and Maintenance	221,000	31.6
Fuel Cost	2,101,000	300.1
Total	$2,477,000	353.9

F. Concept Drawings

The following drawings present the conceptual design of the proposed 800 kw conventional power plant.

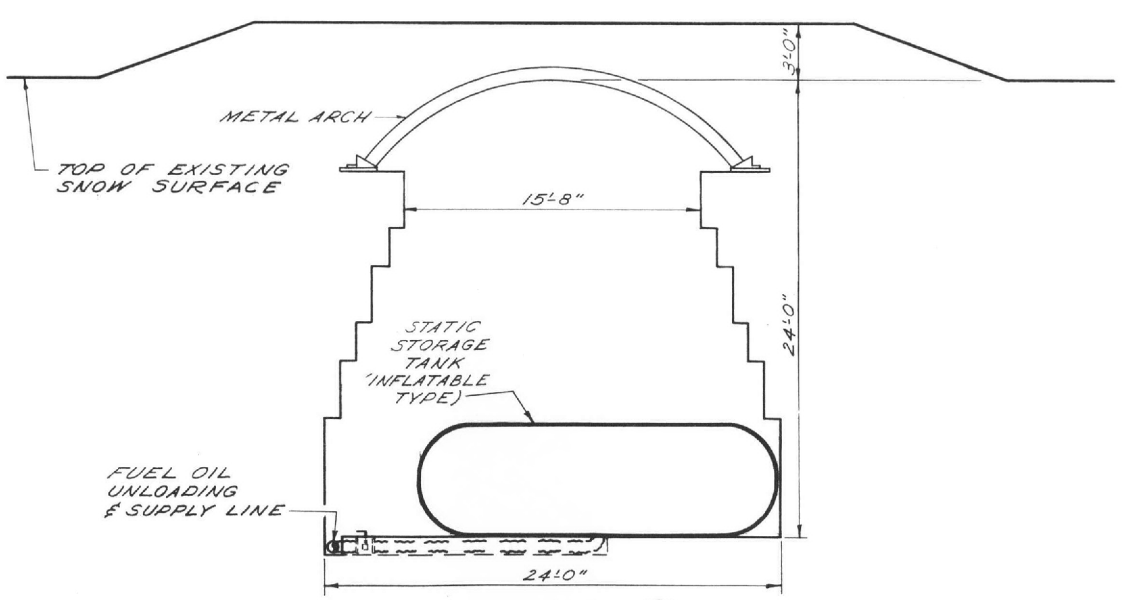
Dwg. No.	Title
1402-C	Plot Plan
1401-G	General Arrangement
1401-E	One Line Diagram



PLOT PLAN

GRAPHIC SCALE

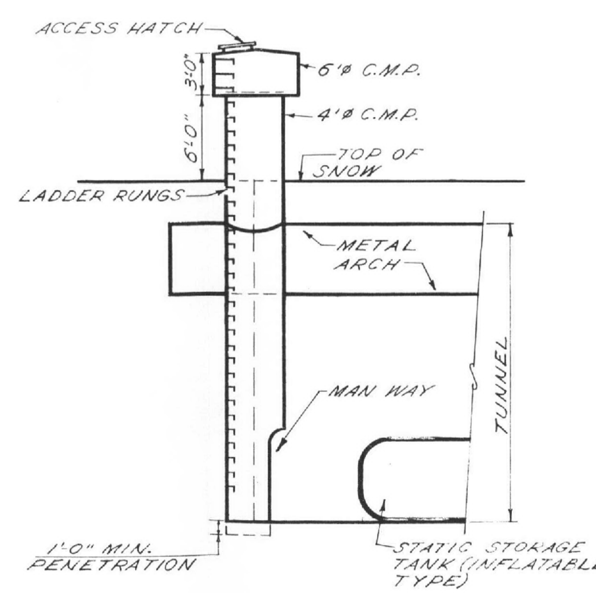
30' 0 30' 60' 90'



SECTION (A)

GRAPHIC SCALE

5' 4' 3' 2' 1' 0' 5' 10'



SECTION (B)

GRAPHIC SCALE

5' 0 5' 10'

APPROVAL	DATE
PROJECT ENGINEER D. A. Daly	5/5/60
CHIEF ENGINEER	

STUDY OF REMOTE MILITARY POWER APPLICATIONS
FOR
U. S. ATOMIC ENERGY COMMISSION

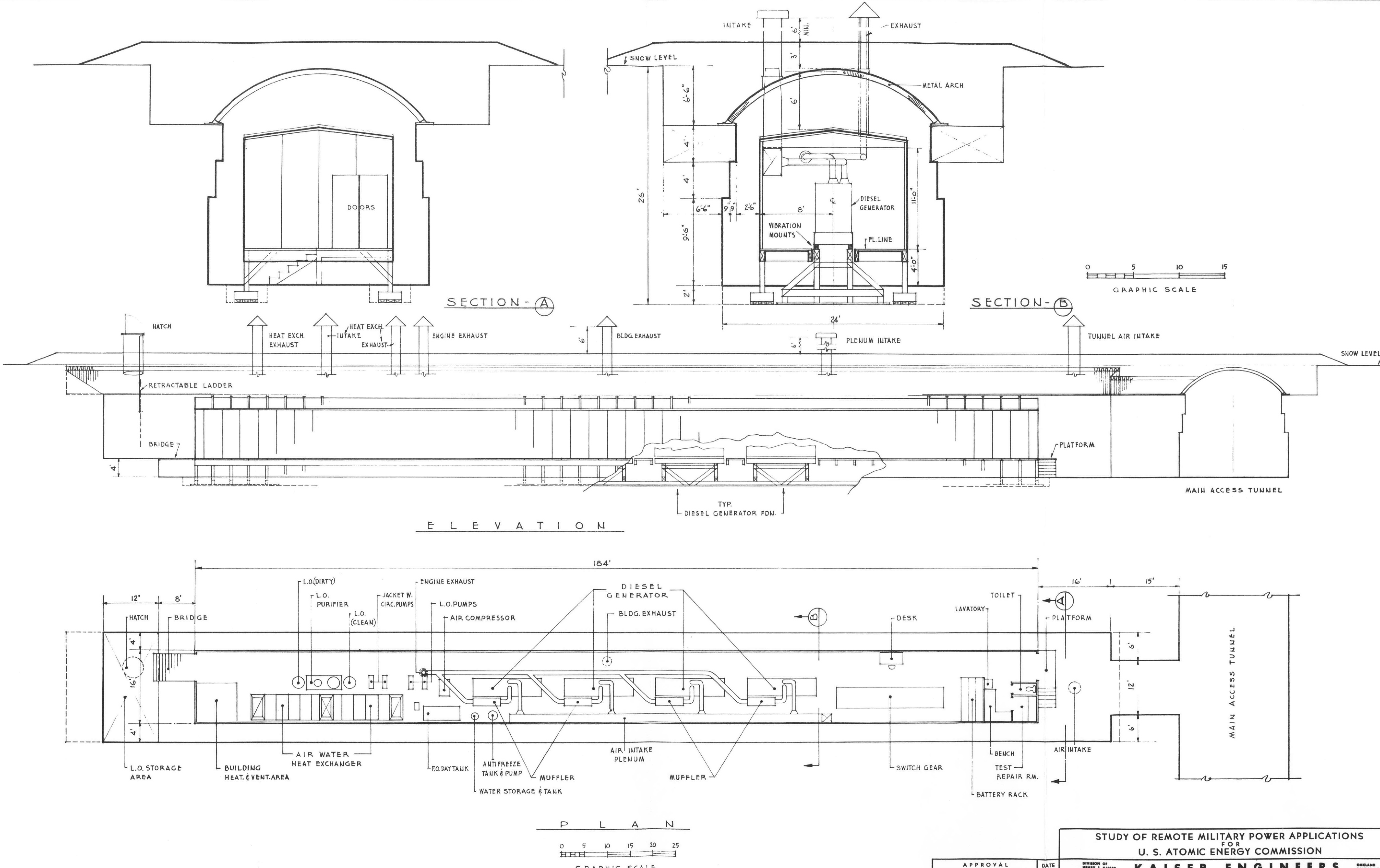
DIVISION OF HENRY J. KAISER COMPANY **KAISER ENGINEERS** OAKLAND CALIFORNIA

		DATE
SCALE		
DRAWN BY	J. MICHEAL	4-28-60
CHECKED BY	A. J. BECKWITH	5-2-60
APPROVED BY	[signatures]	5-4-60
CHIEF DESIGN ENGINEER	[signature]	5-5-60

BYRD STATION, ANTARCTICA

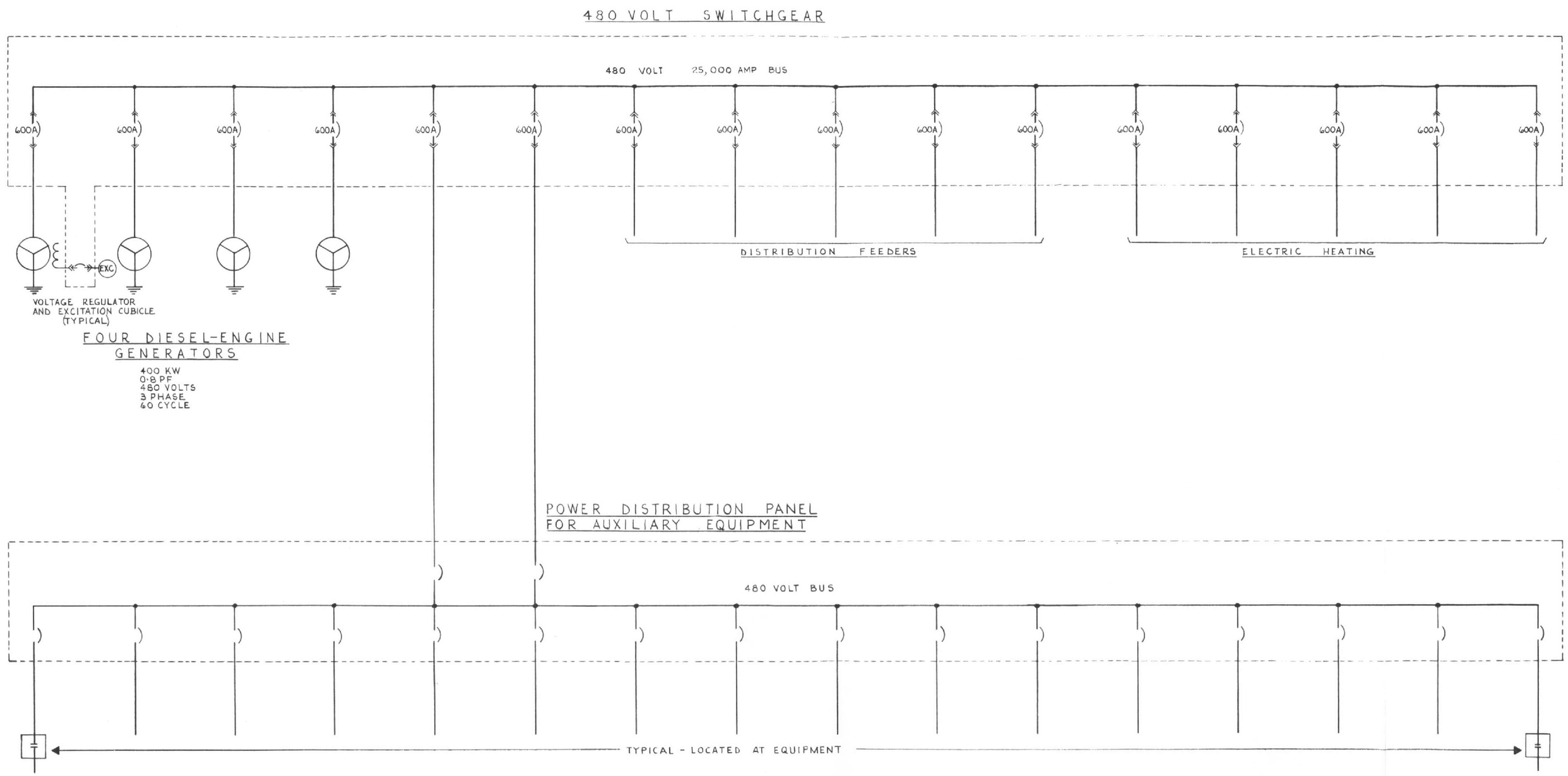
800 KW CONVENTIONAL POWER PLANT
PLOT PLAN

JOB No. 5929 DWG. No. 1402-C

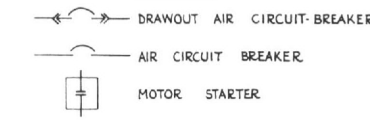


STUDY OF REMOTE MILITARY POWER APPLICATIONS
FOR
U. S. ATOMIC ENERGY COMMISSION

APPROVAL	DATE	DIVISION OF HENRY J. KAISER COMPANY — KAISER ENGINEERS — OAKLAND CALIFORNIA		
		SCALE	DATE	BYRD STATION, ANTARCTICA
		DRAWN BY C/W/JACKSON	3/7/60	800 KW CONVENTIONAL POWER PLANT GENERAL ARRANGEMENT
		CHECKED BY R.A. WILSON	4/29/60	
PROJECT ENGINEER [signature]	5/5/60	APPROVED BY [signatures]	5-4-60	
CHIEF ENGINEER		CHIEF DESIGN ENGINEER [signature]	5-5-60	JOB No. 5929 — DWG. No. 1401-G



LEGEND



NOTE

GROUNDING INDICATED ON THIS DWG WILL BE PATTERNED AFTER A METHOD OF GROUNDING MATS OR GRIDS AS DESCRIBED BY E.T.B. GROSS IN THE A.I.E.E. TRANSACTION PAPERS ISSUED IN AUG. 1953, OCT 1955 AND OCT 1956
THIS METHOD IS APPLIED WHERE OTHER GROUNDING SCHEMES ARE UNWORKABLE DUE TO THE HIGH RESISTIVITY OF THE GROUNDING MEDIUM.

APPROVAL	DATE
PROJECT ENGINEER [signature]	5/5/60
CHIEF ENGINEER	

STUDY OF REMOTE MILITARY POWER APPLICATIONS
FOR
U. S. ATOMIC ENERGY COMMISSION

DIVISION OF HENRY J. KAISER COMPANY — KAISER ENGINEERS — OAKLAND CALIFORNIA

		DATE
SCALE	NONE	
DRAWN BY	G. H. HUGHES	4-26-60
CHECKED BY	O. NIEPONICE	4-26-60
APPROVED BY	[signatures]	4-26-60
CHIEF DESIGN ENGINEER	[signature]	5-5-60

BYRD STATION

800 KW CONVENTIONAL POWER PLANT
ONE LINE DIAGRAM

JOB No. 5929 DWG. No. 1401-E

SECTION VI

REFERENCES AND GLOSSARY

A. References

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18. U. S. Federal Register, 22, March 12, 1957, Page 1591.

19. Letter dated March 11, 1960, Division of Reactor Development, U.S. AEC, Germantown, Maryland.

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B. Glossary

abs	- absolute
AKA	- Navy attack cargo vessel
amp	- ampere (s)
Ag	- silver
bbl	- barrel (s) - 42 U. S. gallons
BMEP	- brake mean effective pressure
Btu	- British thermal unit (s)
Cd	- cadmium
CONUS	- Continental United States
cfm	- cubic foot (feet) per minute
cu ft	- cubic foot (feet)
cu yd	- cubic yard (yards)
d-c	- direct current
diam	- diameter
^{o}F	- degrees Fahrenheit
f a s	- free alongside ship
ft	- foot (feet)
g	- gram (s)
gal	- U. S. gallon (s)
GCRE	- Gas Cooled Reactor Experiment
gpm	- gallons per minute
GTTF	- Gas Turbine Test Facility
hp	- horsepower
hr	- hour (s)
ID	- inside diameter
in.	- inch (es)
In	- indium
kg	- kilogram (s)
kva	- kilovoltamperes
kw	- kilowatt (s)
kwhr	- kilowatt hours
kwt	- thermal kilowatts
lb	- pound (s)
lb/hr	- pounds per hour
mph	- miles per hour
MSTS	- Military Sea Transport Service
mt	- measurement ton - 40 cu ft
mwt	- thermal megawatts
psf	- pounds per square foot
psi	- pounds per square inch
psia	- pounds per square inch absolute
psig	- pounds per square inch gauge
Pu	- plutonium
rpm	- revolutions per minute
U	- uranium
UF_6	- uranium hexafluoride
UNH	- uranium nitrate hexahydrate
UO_2	- uranium oxide
v	- volt (s)
yr	- year (s)

APPENDIX A

OCEAN FREIGHT COST

The cost of ocean freight from Davisville, Rhode Island to McMurdo Sound is based on data [1] prepared by the U. S. Naval Support Force, Antarctica (Task Force 43) for Military Sea Transportation Service Cargo Vessels.

Dry Cargo

Type of ship utilized	AKA
Cargo capacity	6,000 measurement tons
Daily ship charge	$3,000
Average round trip time	100 days

The unit cost then is:

$$\frac{\$3,000/\text{day} \times 100 \text{ days}}{6,000 \text{ mt}} = \$50/\text{mt}$$

The cost of stevedoring, port handling and wharfage charges in the United States is estimated to be $10.00 per measurement ton. No further allowance is made for cost of these items at New Zealand or McMurdo Sound.

The average cost of domestic freight forwarding charges to Davisville, Rhode Island has been estimated to be $40 per measurement ton.

The estimated total average unit cost for shipment of power plant equipment and construction materials (dry cargo) to McMurdo Sound is summarized as follows:

Ocean Freight	$ 50/mt
Port Handling and Wharfage	10/mt
Domestic Freight Forwarding	40/mt
	$100/mt

Fuel Oil

Type of ship utilized	AOG
Capacity	1,250,000 gal
Daily ship charge	$4,100
Average round trip time	100 days

The estimated unit cost of ocean freight for transporting fuel oil from Davisville, Rhode Island to McMurdo Sound is estimated as follows:

$$\frac{\$4{,}100/\text{day} \times 100 \text{ days}}{1{,}250{,}000 \text{ gal}} = \qquad \$0.33/\text{gal}$$

(1) Report: "Economic Study of Nuclear Power vs. Conventional Power for Antarctica", February, 1960, prepared by the Department of the Navy.

APPENDIX B

ICEBREAKER COST

The estimate of icebreaker cost is based on the assumption that one icebreaker will be required for every two cargo ships which enter McMurdo Sound. The average in-service period for icebreakers in Antarctic service is 150 days each year at a daily operating cost of $6,100(1).

Dry Cargo

Based on the use of a 6,000 measurement ton capacity cargo ship, the unit cost of icebreaker service for dry cargo shipped into McMurdo Sound is estimated as follows:

$$\frac{\$6{,}100/\text{day} \times 150 \text{ days} \times 0.5}{6{,}000 \text{ mt}} = \$76/\text{mt}$$

Fuel Oil

Based on the use of an MSTS AOG tanker of 1,250,000 gal capacity, the unit cost of icebreaker service for fuel oil shipped into McMurdo Sound is estimated as follows:

$$\frac{\$6{,}100/\text{day} \times 150 \text{ days} \times 0.5}{1{,}250{,}000 \text{ gal}} = \$0.37/\text{gal}$$

(1) Report: "Economic Study of Nuclear Power vs. Conventional Power for Antarctica", February 1960, prepared by the Department of the Navy.

APPENDIX C

COST OF AIRLIFT FROM McMURDO SOUND

All personnel, materials, and equipment must be flown from NAF McMurdo to the Station. Based on the use of C-130-B aircraft for the airlift, the factors affecting the cost of an airlift are as follows (Appendix D):

Payload	15 short tons (dry cargo) 4,000 gal (fuel oil)
Average hourly operating cost	$510
Round trip flying time	7 hours
Fuel cost per round trip	$4,000

Utilizing the above factors, the unit cost of a round trip airlift (maximum 15 tons) from NAF McMurdo to the Station is estimated as follows:

$4,000 + (7 hr x $510) = $7,570/round trip

It is assumed that for each construction season airplanes required for the airlift will be ferried from the United States to NAF McMurdo and returned at the close of the season. Assuming that it takes 73 hours of flying time for the round trip and 66,000 gallons of jet fuel at $0.25 per gallon, the total cost of one round trip, by one aircraft, U. S. to NAF McMurdo and return is:

$510/hr x 73 hr =	$37,000
$0.25/gal x 66,000 gal =	17,000
	$54,000 per round trip

APPENDIX D

OPERATING CHARACTERISTICS OF THE C-130-B CARGO AIRCRAFT

Data presented is based on an estimated round trip distance of 1,600 nautical miles between NAF McMurdo Sound and Byrd Station. Pay load shown is based on the plane carrying sufficient fuel for the round trip plus 3 hours reserve, including an allowance for a 20 knot head wind in each direction.

1. Maximum gross cargo weight for takeoff at McMurdo is 30,200 lb. This is predicated on a maximum gross aircraft takeoff weight of 135,000 lb, which is limited by ski strength.

2. The maximum load which can be taken off from Byrd Station is 40,800 lb gross, based on a 26,100 lb load being taken off at McMurdo. A 30,000 lb load can be taken off from Byrd Station based on a 27,000 lb load being taken off from McMurdo. These figures are based on the provision of a 5,000 ft compacted snow runway at the Station and the continued operation of engines during the loading and unloading periods at the Station.

3. Maximum package size which can be carried in the C-130-B aircraft is as follows:

   Height .... 109 in.
   Width with ramp support straps folded down .... 120.45 in.
   Width with ramp support straps in place .... 115 in.
   Maximum length of rectangular package .... 481.6 in.

   The use of timber or snow unloading ramps will be required when loading or unloading packages of maximum length. An approximate 6 in. clearance should be allowed on each side of a package within the maximum widths listed above.

4. The estimated fuel consumption of a C-130-B aircraft based on carrying a full pay load from McMurdo Sound and returning empty is 23,600 lb of J-P-4. The estimated fuel consumption for a round trip is 27,700 lb based on carrying a full pay load to the Station and returning with a full pay load. Based upon an approximate weight of J-P-4 fuel of 6½ lb per gallon, these consumption figures above are converted to gallonage figures as follows:

   Full pay load from McMurdo and return empty .. 3,600 gal J-P-4
   Full pay load from McMurdo and full pay ...... 4,300 gal J-P-4
   load return

5. Time required for one round trip is approximately 7 hours.

6. Average hourly operating cost of the plane is $510, excluding fuel costs.