STUDY OF REMOTE MILITARY POWER APPLICATIONS

REPORT NO. 1

SUMMARY

FOR

UNITED STATES ATOMIC ENERGY COMMISSION

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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 economic evaluation of the construction and operation of nuclear power plants at several designated military installations, where increased power generating capabilities of 5 to 40 mwe may be required by the Government for the period 1963 through 1970.

Upon initiation of the study information was obtained from the Atomic Energy Commission and the Department of Defense concerning those military installations for which an analysis of the cost of nuclear power was desired. After an evaluation of the economic factors involved, certain sites were eliminated from further consideration, leaving 10 sites for inclusion in the study.

This report includes a summary of the information contained in the site reports, an analysis of the method of performing the work, and the method used in screening the sites.

This is Report No. 1 of a series of reports completed under Contract No. AT (30-1)-2441. The completed study comprises the Summary Report, a Selection of Applicable Reactor Concepts Report, and ten site reports. A complete list of all reports comprising the study is contained in the Appendix.

SECTION II

GENERAL CONSIDERATIONS

A. Scope

The study consists of the evaluation of those factors affecting the cost of nuclear and conventional power plants for installation at remote military bases where increased generating facilities in the 5 to 40 megawatt range may be required during the period 1963 - 1970 (Ref. 1).

Through a process of evaluation, a total of 10 sites or transient applications were selected for the final study. The 10 sites are those for which the cost of nuclear power is most nearly economically competitive with the cost of conventional power.

For each of the 10 sites or transient applications finally selected, sufficient engineering was accomplished to determine the most suitable nuclear power plant and conventional power plant. Finally, reports were prepared giving a description, outline specifications, and reasonable cost estimate for each power plant.

B. List of Sites

Of the total of 13 sites evaluated, one was eliminated after it was determined that the total power requirements at the site did not fall between the 5 to 40 mwe limits established for the study. Two others were eliminated as not being as favorable, from an economic standpoint, for the use of nuclear power as other sites.

The 10 sites selected for final study are (Ref. 4):

<u>Site</u>	<u>Location</u>	<u>Power Requirement</u>	<u>Date of Initial Operation</u>
Okinawa - 1st Incr.	Ryukyus Is.	40 mwe	1963
Okinawa - 2nd Incr.		40 mwe	1965
Guam	Mariana Is.	20 mwe	1963
Thule	Greenland	25 mwe plus 150,000,000 Btu/hr of heat	1963
NORAD	U.S.A.	7 mwe	1963
Asmara	Eritrea	5 mwe	1963
Super Sage	U.S.A.	5 mwe	1963
Nike-Zeus	Eastern Site U.S.A.	10 mwe	- -
Inchon	Korea	10 mwe	1963
Atlantic Barge	Atlantic Ocean area	20 mwe	1963
McMurdo Sound	Antarctica	5 mwe 6 mwe	1963 1964

Additional sites evaluated and then eliminated from further consideration were:

<u>Site</u>	<u>Location</u>	<u>Reason for Elimination</u>
Pacific Barge	Pacific Ocean area	Power requirement of 5 mwe made a nuclear power plant economically unfavorable for a power barge.
Panama	Canal Zone	Nuclear power much more costly than conventional power due to low fuel oil costs.
Hokkaido	Japan	Power requirement below 5 mwe.

The selection of a specific location for the power plants within the general area of each site will be found in the individual site reports.

C. Study Criteria

An understanding of the basic ground rules or criteria established for the study is essential in using the results shown in the study, particularly in evaluating costs. Since the study was prepared for power plants to be used at military bases, certain cost factors normally used in computing costs for commercial power plants were not included.

The power plant designs, both nuclear and conventional, chosen for each application are believed to be the most economical concepts suitable to meet the particular power requirements for the site or transient application. Due to the limited time available for the study, and the preliminary nature of the design study, the plant layouts have not been entirely optimized.

Other study criteria are:

1. No interest on the initial investment has been used in computing annual fixed charges (Ref. 5).
2. An assumed plant life of 20 years has been used in computing annual fixed charges (Ref. 5).
3. No taxes, insurance (including nuclear indemnity insurance), or interest on the cost of spare parts and fuel oil in storage have been included in computing operation and maintenance costs (Ref. 5).
4. Nuclear fuel costs exclude the nuclear fuel use charge (Ref. 5).
5. Fuel oil costs are based on 1959 commercial rates plus transportation by commercial carriers, and total escalation of 20% over the 20-year life of the plant.
6. Operating labor costs have been based on the going wage rates of the area involved, or in the case of plants to be operated by the military, on an average yearly cost per man for military operating and maintenance personnel of \$6,500 in the United States and \$7,500 outside the United States; plus escalation over the 20-year life of the plant (Ref. 6).

7. The nuclear and conventional power plant selected for each site is the plant having the lowest over-all cost.
8. Land for the plants has been assumed to be available at no cost.
9. Acquisition cost for vessels from the laid-up fleet has not been included (Ref. 7).
10. Government costs, estimated to be 6% of the total construction cost excluding contingency, are shown as a separate line item in each estimate in Section IV but are not included in the total project cost, nor are they included in calculating annual cost and unit power cost.

D. Method of Performing the Work

The study work involved 10 distinct but overlapping phases, as follows:

1. Collection of site information
2. Selection of the 10 study sites
3. Determination of power requirements
4. Selection of applicable reactor concepts
5. Selection of specific reactor designs
6. Selection of conventional power plant
7. Selection of type of installation
8. Design engineering
9. Preparation of cost estimates
10. Preparation of reports

Collection of Site Information

Site data were obtained principally from cognizant agencies of the three military services. The data requested included information concerning the existing power plants at the site, topography, geology, climatology, hydrography, seismology, availability of construction labor and materials, types of construction suitable to the area, available construction plant

and equipment, and construction costs. In the event such data were not readily available from the military for any particular site, other sources were used or assumptions made.

In addition, data concerning costs of permanent equipment and materials, fuel costs, and shipping costs were obtained, usually from commercial sources.

Selection of the 10 Study Sites

The 10 sites to be selected for inclusion in the final study were those at which nuclear power would be the most competitive with conventional power.

Alternative concepts were developed for each site and preliminary cost estimates prepared for each concept. Concepts developed included land based power plants, barge mounted power plants on new and converted hulls, mobile marine platform mounted power plants, and prepackaged power plants as applicable to each site. After selection of the most economical type of power plant, nuclear and conventional, for each site, the nuclear and conventional power costs were derived, on the basis of 20-year operation. On the basis of these data the 10 sites were then selected.

Determination of Power Requirements

In those cases where the proposed generating facilities were an addition to an existing power generating system, forecasts of the expected load growth were made and curves drawn showing existing and proposed generating facilities and forecasted power requirements for the period 1963 - 1970. An analysis was then made of the existing power generating system and the load growth curves to determine the optimum unit generator size for the proposed new power plant.

For those installations operating as an isolated military base, power requirements were obtained from the using agency, and the unit generator sizes selected on an analysis of the firm power, average power, and maximum power requirements. Firm power is defined as the power available with the single largest unit in the power plant out of service, or, in the case of the diesel engine power plants, any two units out of service.

Selection of Applicable Reactor Concepts

To select those reactors which best meet the criteria for the nuclear power plants for remote military bases, preliminary

evaluations were made of the major reactor concepts presently under development. These concepts include the water cooled and moderated reactors - both direct and indirect cycle - organic cooled and moderated reactors, heavy water cooled and moderated reactors, gas cooled reactors, sodium cooled graphite moderated reactors, fast breeder reactors, and fluid fuel reactors. Each evaluation consisted of a study of the basic reactor characteristics, inherent advantages and disadvantages, technological status, plant economics for construction in the period 1963 - 1970, and the future potential for a particular reactor concept. These preliminary evaluations were based primarily upon reviews of recent literature upon the subject. In examining the eight concepts listed above, it became apparent that three concepts, sodium cooled graphite moderated reactors, fast breeder reactors, and fluid fuel reactors, were less suitable than the others for power plants at remote military installations. In general, these three concepts have greater technological uncertainty than the other five concepts for the period under consideration, 1963 - 1970. The remaining five concepts were further evaluated through a more detailed review of the literature, as well as discussions with some of the leading reactor designers and manufacturers in the U. S., nuclear consultants, and AEC technical personnel.

As a result of this study it was concluded that two reactor concepts are suitable for those applications requiring power before 1965, namely, direct cycle boiling water reactors (bwr) and pressurized water reactors (pwr). It was concluded that organic cooled and moderated reactors (ocmr) could be considered in addition to the water reactors only for plants to be in operation in 1965 and later. By 1965 UO_2 fuel elements suitable for organic cooled reactors probably will be developed and the background of experience in this type of reactor should be substantially increased.

The process of selection of the suitable reactor concepts for use in this study is discussed in Report No. 12 in this series, "Evaluation and Selection of Applicable Reactor Concepts", NYO-2948.

Selection of Specific Reactor Designs

Because of the limited time to perform this study and the requirement that the power plants under consideration be in operation by 1965 and earlier, the selection of specific reactors for each application was limited to modifications of "existing reactor designs". In this connection existing reactor designs are defined as designs of plants which have been or are being built, or upon which firm price quotations have been or are being made. This criterion ensures that good cost information for the reactor plant equipment can be obtained in a relatively

short time and that sufficient information is available to design and estimate the remaining portions of the complete nuclear power plant.

To determine the availability of existing designs of bwr, pwr and ocmr plants, the following nuclear reactor manufacturing concerns were contacted: General Electric Company, AMF Atomics, Allis-Chalmers, Combustion Engineering, Inc. (including General Nuclear Engineering Corporation), Westinghouse Electric Company, Martin Company, Babcock & Wilcox Company, Alco Products, Inc., American Radiator and Sanitary Corporation, and Atomics International. In each case sufficient information was requested on the existing designs to allow a determination of the capital and fuel costs, the extent to which the design had been developed, whether special features (such as adaptability to shipboard use) had been included in the design, and the cost of making minor modifications to adapt a design to a specific requirement. All of the manufacturers contacted submitted the required information.

Based on the information obtained from the reactor manufacturers and recently published reports on the status of boiling water and pressurized water reactors, curves were prepared showing the range of capital costs and fuel costs for recent designs of these reactor concepts. See Figures 1, 2 and 3, pages 10, 11, and 12.

In selecting the specific reactor design for each application, a determination was first made as to the power required per reactor. Following this a determination was made, first, as to the most appropriate reactor concept, and, second, whether or not an existing design could be used. In three applications no existing designs could be used without modifications. In these cases modifications of existing designs were prepared under subcontract by the appropriate reactor designer. In each such case extrapolation required from the existing designs was small enough so that the reliability of the cost estimates were not jeopardized. In some cases where the thermal power required per reactor-steam generator was only slightly less than was achievable from existing designs, the existing design was used without changing the equipment cost estimate, on the assumption that the additional engineering cost required to modify the reactor design would at least offset any reduced equipment and facility costs.

Selection of the Conventional Power Plant

In selecting the type of thermal power plant to be used as a basis for economic comparison with the nuclear power plant at each site, consideration was given to three types of power plants as follows:

1. Steam turbine-generator

FIGURE 1
CAPITAL COSTS
BOILING WATER REACTOR POWER PLANT
(BASED ON 1959 COSTS)

FIGURE 2

CAPITAL COSTS

PRESSURIZED WATER REACTOR POWER PLANT

(BASED ON 1959 COSTS)

FIGURE 3
FUEL COSTS FOR BOILING WATER
AND
PRESSURIZED WATER REACTOR POWER PLANT

2. Diesel engine generator

3. Gas turbine-generator

For those sites requiring the use of generating units rated at about 12,000 kw or larger, steam turbine-generators were selected. This selection was made because of the lower unit capital and power production costs for steam power plants in this size range over any other type of thermal power plant, based on the experience record of the U. S. power industry.

For those sites requiring the use of generating units considerably smaller than 12,000 kw, diesel engine generators were used. This selection was based on the conclusions shown in a study prepared for the U. S. Corps of Engineers (Ref. 8). In this study an analysis was made of the capital, fuel and operating costs of steam turbine, diesel engine, and gas turbine power plants for use at isolated military installations. The conclusion of this study was that for small isolated power plants, multiple unit diesel engine generators were the most economical of the three types under consideration.

The designs of the steam power plants are based on U. S. standard power plant practice, using AIEE-ASME Preferred Standard turbines and generators where practicable. Because of firm power requirements, the design of the diesel engine power plants includes provisions for two spare units over and above those required to meet normal load requirements, that is, one hot and one cold spare.

The selection of the type of fuel to be used at each site was based primarily on availability and cost, and secondarily on the conditions prevailing at the site. For instance, at Okinawa and Guam either heavy fuel oil or coal could be used for the steam power plants. For these plants the decision to use No. 5 (Navy Special) fuel oil was based on economics and the fact that the Navy prefers to handle and store only one type of fuel oil suitable for both stationary steam power plants and Navy vessels.

Selection of Type of Installation

Of the ten installations or sites selected for inclusion in the study, two (Atlantic Barge and Korea) were specified by the Department of Defense to be mobile marine power plants, and two (NORAD and Super Sage) were specified to be underground and "hardened". Three sites (Okinawa, Guam and Thule) offered the opportunity of using mobile marine power plants in addition to construction on land. Three sites (Nike-Zeus, McMurdo Sound and Asmara) were so located that only land based plants were feasible.

Two types of barges were investigated for the Atlantic and Korea installations: new, specially designed hulls, and converted vessels from the laid-up fleet. In addition to new hulls and converted vessels, mobile marine platform barges were investigated for use at Guam, Okinawa and Thule.

Preliminary layouts and cost estimates of the power plants were then made for the various types of barges under consideration for each site. Cost estimates included costs for the installation of the barges at the various sites and the cost of shore based facilities. The type of installation having the lowest over-all cost including operating and maintenance costs was selected for the final design study.

During this phase of the work a firm of naval architects, George G. Sharp, Inc., was employed to render assistance in designing the new barge hulls and in the selection and design of converted vessels from the laid-up fleet.

Design Engineering

The design of the nuclear and conventional power plants proceeded as information was received from the nuclear manufacturers, the naval architect, and the various sources of site information. Sufficient design was done to properly define the selected power plants so that reasonable and comparable construction cost estimates could be prepared. Layout, process and concept drawings were prepared for inclusion in the reports.

Preparation of Cost Estimates

Cost estimates were prepared using developed cost data appropriate to each site. The estimated costs of construction labor and materials and permanent equipment are based on conditions peculiar to the individual site. Wherever possible local materials and indigenous labor were used. Equipment from foreign sources was also used where feasible. The cost of nuclear reactors was based on procurement from the United States in all cases. Also the cost of building new barges or mobile marine platforms and the cost of converting vessels from the laid-up fleet was based on doing the work in U. S. shipyards using U. S. equipment and materials.

Escalation has generally been computed at 6% of labor and materials for those plants to be completed in 1963. An average contingency of approximately 12% has been added to the total construction and design engineering costs for the nuclear power plants, and approximately 8% to the construction and design engineering costs for the conventional power plants. The contingency in each case represents an allowance for modifications to

the plant design, minor changes in location of the plant, unusual site conditions, etc. The "Total Project Cost Including Escalation" shown for each plant represents an estimate of what should be expected as a reasonable bid for performance of the construction work.

Preparation of Reports

The preparation of the reports proceeded concurrently with the other phases of the work. In all a total of 12 reports constitute the completed study. These are a Summary Report, Selection of Applicable Nuclear Reactors report, and 10 site reports. See Appendix for a complete listing of the reports.

SECTION III

SUMMARY AND CONCLUSIONS

A. Conclusions

Certain conclusions can be made from an analysis of the cost data developed for the 10 study sites. These conclusions are only valid for the 10 sites under consideration using the criteria established for the study. Criteria affecting the costs shown and therefore the conclusions are listed in Section II-C.

Although other factors such as location do have an effect on over-all construction costs, and may modify the over-all conclusion slightly, the size of the nuclear reactor itself, the size of the power plant, and the cost of fossil fuels are the most important considerations when determining whether the cost of nuclear power is competitive with the cost of conventional power.

Figure 4, page 18, shows the effect of fuel cost at the various sites on the relative economics of nuclear and conventional power. For those sites where the combination of reactor size and fuel oil cost place the installation in the zone of "Lower Nuclear Power Cost", the cost of over-all power generation is less for a nuclear power plant than for a conventional power plant. Conversely for those installations shown in the zone of "Lower Conventional Power Cost", the cost of over-all power generation is less for a conventional power plant than for a nuclear power plant. The "Marginal Zone" indicates the area where the difference in over-all power generation cost between a nuclear and conventional power plant is less than 10%. For installations falling within this zone, a minor adjustment in the price of fuel oil could change the determination of which type of plant is more economical.

Figure 4 also shows the effect of the size of the selected nuclear reactor on the over-all power cost for the sites shown. For example, based on a fuel oil cost of about \$1.00 per million Btu, a nuclear reactor having a net electrical capability as low as 12.5 mw could be economical for installation at Thule.

Data for McMurdo Sound and NORAD are not included in Figure 4 because of the special conditions existing at these two sites. For McMurdo Sound the high cost of fuel oil definitely makes nuclear power more economical than conventional power despite the small size of the reactors. For NORAD 100% nuclear stand-by capacity was specified by the Air Force. Therefore, two reactors

FIGURE 4
EFFECT OF FUEL COST
ON
RELATIVE ECONOMICS
OF
NUCLEAR AND CONVENTIONAL POWER

were used and costs for nuclear power produced by this installation are high. If only one 5 mwe reactor had been used, then NORAD would be approximately in the same position on Figure 4 as Super Sage.

To illustrate further the effect of the cost of conventional fuel on the economics of installing either a nuclear power plant or a conventional power plant, a comparison of the average price of fuel oil at any site (as used in the study) with the fuel oil price necessary to make the cost of power produced by nuclear and conventional power plants equal is shown in the tabulation below. Sites are listed in order of total annual power produced.

<u>Site</u>	<u>Power Plant Size mwe</u>	<u>Annual Power Production 10⁶ kwhr</u>	<u>Average Fuel Oil Price Per Gal Used In Study</u>	<u>Average Fuel Oil Price Per Gal Required for Equal Power Costs</u>
Okinawa - 1st Incr.	40	290	\$ 0.104	\$ 0.084
Thule	25	178	0.144	0.071
Atlantic Barge	20	140	0.096	0.107
Guam	20	145	0.108	0.110
Nike-Zeus	10	87.6	0.209	0.211
Korea	10	70	0.104	0.185
NORAD	7	52.6	0.156	0.259
Asmara	5	43.8	0.160	0.223
Super Sage	5	28	0.156	0.305
McMurdo Sound 1st Incr.	5	26.3	1.10	0.400

When other costs, such as would be applicable to a commercial power plant built by private capital, are added to the costs shown in the study, the cost of producing nuclear power increases at a more rapid rate than does the cost of producing conventional power. This is due, of course, primarily to the much greater first cost of a nuclear power plant. Any conclusions drawn from a comparison of nuclear and conventional power costs at any of the study sites would then be quite different from the ones shown here.

At a remote site bordering on navigable water, the use of a floating power plant generally offers a good possibility if local construction costs are appreciably higher than in the United States. Other factors such as size of plant and berthing facilities will influence the use of floating power plants, but, in general, if local construction costs are high, floating power plants may provide a lower over-all project cost. This proved to be true in the case of the Thule nuclear and conventional power plants and the Guam nuclear power plant.

The use of vessels from the laid-up fleet provided a lower over-all project cost than the use of new hulls in all cases where fully mobile floating power plants were used. This was true to a large extent because no purchase price was included for vessels from the laid-up fleet. Figure 5, page 21, shows a comparison of the hull costs for new hulls and vessels from the laid-up fleet. Figure 6, page 22, shows the comparative sizes of new hulls and vessels from the laid-up fleet as used for each installation.

FIGURE 5
TOTAL HULL CONSTRUCTION COSTS

NEW BARGE

CONVERTED VESSEL

— NUCLEAR —
 — CONVENTIONAL —

1. HULL COSTS INCLUDE:

- a - HULL STEEL
- b - SUPERSTRUCTURE
- c - FOUNDATIONS
- d - QUARTERS OUTFIT
- e - HULL OUTFIT

2. COST OF VAPOR CONTAINER NOT INCLUDED IN NUCLEAR BARGE COSTS.

ATLANTIC BARGE

NUCLEAR PLANT - C3 HULL

CONVENTIONAL PLANT - C3 HULL

NUCLEAR PLANT - NEW HULL

CONVENTIONAL PLANT - NEW HULL

THULE

NUCLEAR PLANT - C3 HULL

CONVENTIONAL PLANT - C3 HULL

NUCLEAR PLANT - NEW HULL

CONVENTIONAL PLANT - NEW HULL

KOREA

NUCLEAR PLANT - EC2 HULL

CONVENTIONAL PLANT - C1 HULL

NUCLEAR PLANT - NEW HULL

CONVENTIONAL PLANT - NEW HULL

COMPARISON OF
BARGE PROFILES

FIGURE NO. 6

B. Summary of Power Plant Data and Costs

A summary of power plant data and costs for all 10 sites is shown on Table 1. Figure 7, page 25, shows a comparison between the capital cost for the nuclear power plant and the conventional power plant for all sites. Figure 8, page 26, shows a comparison between the annual operating and maintenance and fuel costs for the nuclear and conventional power plants. Figure 9, page 27, is a composite of total plant costs for a 20-year period for the power plants for all sites, and Figure 10, page 28, shows the unit power costs.

The cost data presented in the tables and charts were developed using the criteria established for the study as outlined in Section II-B and should be used with these limitations in mind.

In addition, the annual cost of operating and maintenance labor and supplies and the yearly fuel oil cost have been escalated to arrive at an average annual cost that could be applied over the assumed 20-year life of the plant. Nuclear fuel costs have not been escalated on the theory that technological advances in the production of nuclear fuel will at least offset the added fabricating costs due to escalation.

For the smaller power plants to be used at such military bases as NORAD, Super Sage, and McMurdo Sound, the firm power requirements are quite low in comparison with the total installed capacity of the plant. Since the yearly power production is based on 100% of either the firm or average power requirements, for these installations the cost per kwhr is higher than what it would be if the power plant were a part of a power system consisting of several power plants where the annual power produced would be more closely related to the total plant capacity.

FIGURE 7

TOTAL PROJECT COST

NUCLEAR POWER PLANT
 CONVENTIONAL POWER PLANT

FIGURE 8

AVERAGE ANNUAL OPERATING
MAINTENANCE AND FUEL COSTS

FIGURE 9

TOTAL PROJECT COST PLUS TOTAL
OPERATING, MAINTENANCE AND FUEL COST
FOR A 20-YEAR PERIOD

FIGURE 10
UNIT POWER COST

SECTION IV

ANALYSIS OF SITE REPORTS

A. General

Abstracts of pertinent power plant data, costs, and site information from the site reports are presented in this section in sufficient detail to show in general the nuclear and conventional power plants proposed for each of the 10 sites and the costs applicable to each.

B. Okinawa, Ryukyu Islands

Okinawa, a major United States military base in the Far Eastern defense sector and the largest of 63 islands comprising the Ryukyu Group, lies some 970 miles southwest of Tokyo, Japan. The island is under the administration of the U. S. Civil Administration, Ryukyus. The Island Power System, utilizing electric power generated by two floating and one land-based steam turbine-generator power plants and several diesel engine generator power plants, is operated by the Engineer, U. S. Army, Ryukyu Islands.

The requirement for additional electric generating capacity is such that by 1963, 40 mwe of new capacity will be required, followed by a second 40 mwe increment in 1965.

PROPOSED 40 MWe NUCLEAR POWER PLANT

The proposed nuclear power plant would be located at Kin on the northern shore of Kin Bay on the south coast of the island. The first 40 mwe increment of this plant would consist of a 150 mwt, direct cycle, natural circulation, boiling water reactor, two

22,000 kw (gross) steam turbine-generators, and a stand-by oil fired steam boiler capable of operating one turbine-generator. Sea water would be used for condenser cooling. The estimated over-all cost of the first increment is \$22,700,000.

For cost comparison purposes, a conventional steam power plant consisting of two oil fired steam boilers and two 22,000 kw (net) turbine-generators was selected for each power plant increment. The estimated cost of the first 40 mwe increment is \$10,200,000.

Table 2, page 33, shows the estimated construction and operating costs for the first power plant increment of 40 mwe to be completed in 1963. Table 3, page 34, shows these costs for the total 80 mwe power plant to be completed by 1965.

Table 4, page 35, shows in summary form pertinent power plant data for the first 40 mwe increment. The second 40 mwe nuclear power plant increment would duplicate the equipment shown for the first increment except a second stand-by boiler would not be required.

TABLE 2
OKINAWA, RYUKYU ISLANDS
ESTIMATED CONSTRUCTION AND OPERATING COSTS
40 MWe POWER PLANT INCREMENT
Estimated Construction Costs

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
Total Construction Cost	\$17,452,000	\$ 8,550,000
Escalation through 1963	1,048,000	500,000
Total Including Escalation	\$18,500,000	\$ 9,050,000
Design Engineering	1,700,000	450,000
Total Cost Excluding Contingency	\$20,200,000	\$ 9,500,000
Contingency	2,500,000	700,000
Total Project Cost	\$22,700,000	\$10,200,000
Government Costs (6)	\$ 1,210,000	\$ 570,000

Estimated Average Annual and Unit Power Costs

	<u>Nuclear Power Plant</u>		<u>Conventional Power Plant</u>	
	<u>Average Annual Cost</u>	<u>Unit Cost in Mills per kwhr (4)</u>	<u>Average Annual Cost</u>	<u>Unit Cost in Mills per kwhr (4)</u>
Fixed Charges (1)	\$1,135,000	3.91	\$ 510,000	1.8
Operating and Maintenance Cost (2)	360,000	1.24	214,000	0.7
Nuclear Fuel Cost (3)	1,040,000	3.59	-	-
Stand-by Fuel Oil Cost (5)	179,000	0.62	-	-
Fuel Oil Cost (5)	-	-	2,423,000	8.4
Total Cost	\$2,714,000	9.36	\$3,147,000	10.9

- 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.
- (4) Unit power cost is based on 80% plant operating factor equivalent to 2.9×10^8 net kilowatt hours per year.
- (5) Based on 1959 commercial rates plus an average escalation over the life of the plant.
- (6) Government costs estimated at 6% of the total cost excluding contingency, include the cost of site investigation and administration of the engineering and construction contracts.

TABLE 3
OKINAWA, RYUKYU ISLANDS
ESTIMATED CONSTRUCTION AND OPERATING COSTS

COMBINED 80 MWe POWER PLANT

Estimated Construction Costs

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
Total Construction Cost	\$31,786,000	\$16,250,000
Escalation through 1965	2,474,000	1,270,000
Total Including Escalation	\$34,260,000	\$17,520,000
Design Engineering	2,560,000	680,000
Total Cost Excluding Contingency	\$36,820,000	\$18,200,000
Contingency	4,480,000	1,300,000
Total Project Cost	\$41,300,000	\$19,500,000
Government Costs (6)	\$ 2,210,000	\$ 1,090,000

Estimated Average Annual and Unit Power Costs

	<u>Nuclear Power Plant</u>		<u>Conventional Power Plant</u>	
	<u>Average Annual Cost</u>	<u>Unit Cost in Mills per kwhr (4)</u>	<u>Average Annual Cost</u>	<u>Unit Cost in Mills per kwhr (4)</u>
Fixed Charges (1)	\$2,065,000	3.56	\$ 975,000	1.7
Operating and Maintenance Cost (2)	547,000	0.94	310,000	0.5
Nuclear Fuel Cost (3)	2,080,000	3.59	-	-
Stand-by Fuel Oil Cost (5)	179,000	0.31	-	-
Fuel Oil Cost (5)	-	-	4,846,000	8.4
Total Cost	\$4,871,000	8.40	\$6,131,000	10.6

- 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
- (4) Unit power cost is based on 80% plant operating factor equivalent to 580,000,000 net kilowatt hours per year.
- (5) Based on 1959 commercial rates plus an average escalation over the life of the plant.
- (6) Government costs estimated at 6% of the total cost excluding contingency, include the cost of site investigation and administration of the engineering and construction contracts.

TABLE 4

OKINAWA, RYUKYU ISLANDS

SUMMARY OF POWER PLANT DATA FOR THE FIRST 40 MWe INCREMENT

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
<u>1. Over-all Performance</u>		
Primary steam supply	Direct cycle, natural circulation, boiling water reactor	Oil fired steam boilers
No. of reactors/boilers	1	2
No. of turbine-generators	2	2
Reactor thermal power	150 mwt	- -
Size of steam boilers		Each boiler capable of producing 200,000 lb of steam per hr
Gross electrical capacity	44,000 kw	44,000 kw
Net electrical capacity	41,400 kw	41,400 kw
Primary steam flow	521,000 lb/hr	378,000 lb/hr
Primary steam pressure	1,025 psig	900 psig
Primary steam temperature	549° F	905° F
Feed water return temperature	270° F	350° F
<u>2. Reactor Characteristics</u>		
Fuel Assembly:		
Fuel material	UO ₂	
Initial enrichment	1.9% U-235	
Weight of fuel in core	14,300 kg U	
Irradiation at discharge	13,200 mwd/metric ton	
Cladding material	Zircaloy-2	
No. of assemblies	172	
No. of control rods	32	
Control rod material	Boron-stainless steel	
Reactor Vessel:		
Internal diameter	10 ft	
Inside height	41 ft	
Material	Stainless Clad carbon steel	
<u>3. Containment</u>		
	120 ft diam steel sphere	

TABLE 4 (Cont'd)

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
4. <u>Turbine-Generator Characteristics</u>		
Number	2	2
Type	Single casing, single flow turbine- direct connected generator	Single casing, single flow turbine- direct connected generator - AIEE-ASME Preferred Standard
Gross capacity at 2 in. Hg abs	22,000 kw	22,000 kw
Generator coolant	Hydrogen	Hydrogen
Generator voltage	13.8 kv	13.8 kv
5. <u>Condensers</u>		
Number	2	2
Type	Single pass, divided water box	Single pass, divided water box
Condensing surface	21,000 sq ft	15,000 sq ft
Pressure (77° F sea water)	2 in. Hg abs	2 in. Hg abs
Cooling water flow	32,000 gpm	28,000 gpm
6. <u>Stand-by Boiler</u>		
Number	1	
Size	To produce 260,000 lb of steam per hr	
Pressure	1,025 psig	
Fuel	No. 5 oil	
7. <u>Turbine Building</u>		
Size	160 ft by 165 ft	110 ft by 145 ft with 72 ft by 80 ft boiler house
Type	Reinforced concrete substructure, 22 ft high Structural steel super- structure with rein- forced concrete roof deck and wall panels, 44 ft high	Reinforced concrete substructure, 22 ft high Structural steel super- structure with rein- forced concrete roof deck and wall panels, 45 ft high

C. Guam, Mariana Islands

Guam lies at the southern end of the Mariana Islands approximately 1,600 miles due east of Manila. Guam is a U. S. possession under the jurisdiction of the Department of the Interior. Electric power for military and civilian use is provided by the Island-Wide Power System of Guam, Mariana Islands, owned and operated by the Navy. The requirement for additional generating capacity is such that by 1963, 20 mwe of new capacity will be required.

PROPOSED 20 Mwe NUCLEAR POWER PLANT

The proposed nuclear power plant would be located on a mobile marine platform at Tumon Bay on the west coast of Guam. The plant would consist of one 75 mwt direct cycle, natural circulation, boiling water reactor and one 22,000 kw (gross) turbine-generator. Sea water will be used for condenser cooling. The estimated cost of this installation is \$16,500,000.

For cost comparison purposes, a conventional steam power plant consisting of one oil fired steam boiler and one 22,000 kw (gross) turbine-generator was selected. The steam plant would be of conventional construction located on the shore of Tumon Bay. The estimated cost of this installation is \$7,700,000.

Table 5, page 39, shows the estimated construction and operating costs for the 20 mwe nuclear and conventional power plants to be completed in 1963. Table 6, page 40, shows, in summary form, pertinent power plant data for each type of plant.

TABLE 5
GUAM, MARIANA ISLANDS
ESTIMATED CONSTRUCTION AND OPERATING COSTS

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
Total Construction Cost	\$13,044,000	\$ 6,449,000
Escalation through 1963	786,000	371,000
Total including Escalation	13,830,000	\$ 6,820,000
Design Engineering	900,000	350,000
Total Cost excluding Contingency	\$14,730,000	\$ 7,170,000
Contingency	1,770,000	530,000
Total Project Cost	\$16,500,000	\$ 7,700,000
Government Costs (6)	\$ 880,000	\$ 430,000

Estimated Average Annual and Unit Power Costs

	<u>Nuclear Power Plant</u>		<u>Conventional Power Plant</u>	
	<u>Average Annual Cost</u>	<u>Unit Cost in Mills per kwhr (4)</u>	<u>Average Annual Cost</u>	<u>Unit Cost in Mills per kwhr (4)</u>
Fixed Charges (1)	\$ 825,000	5.7	\$ 385,000	2.7
Operating and Maintenance Cost (2)	437,000	3.0	292,000	2.0
Nuclear Fuel Cost (3)	655,000	4.5	-	-
Fuel Oil Cost (5)	-	-	1,245,000	8.6
Total Cost	\$1,917,000	13.2	\$1,922,000	13.3

- NOTE: (1) Based on a 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.
- (4) Unit power cost is based on an 80% plant operating factor equivalent to 145,000,000 net kilowatt hours per year.
- (5) Based on 1959 commercial rates plus an average escalation over the life of the plant.
- (6) Government costs, estimated at 6% of the total cost excluding contingency, include the cost of site investigation and administration of the design and construction contracts.

TABLE 6
GUAM, MARIANA ISLANDS
SUMMARY OF POWER PLANT DATA

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
<u>1. Over-all Performance</u>		
Primary steam supply	Direct cycle, natural circulation, boiling water reactor	Oil fired steam boilers
No. of reactors/boilers	1	1
No. of turbine-generators	1	1
Reactor thermal power	75 mwt	- -
Size of steam boilers		200,000 lb of steam per hr
Gross electrical capacity	22,000 kw	22,000 kw
Net electrical capacity	20,700 kw	20,700 kw
Primary steam flow	260,000 lb/hr	189,000 lb/hr
Primary steam pressure	1,025 psig	900 psig
Primary steam temperature	549° F	905° F
Feed water return temperature	270° F	350° F
<u>2. Reactor Characteristics</u>		
Fuel Assembly		
Fuel material	UO ₂	
Initial enrichment	3.4% U-235	
Weight of fuel in core	5,560 kg U	
Irradiation at discharge	13,200 mwd/metric ton	
Cladding material	Stainless steel	
No. of assemblies	96	
No. of control rods	21	
Control rod material	Boron-stainless steel	
Reactor Vessel		
Internal diameter	7 ft 6 in.	
Inside height	32 ft 5 in.	
Material	Stainless clad carbon steel	
<u>3. Containment</u>	44 ft diam by 92 ft high steel cylinder	

TABLE 6 (Cont'd)

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
4. <u>Turbine-Generator Characteristics</u>		
Number	1	1
Type	Single casing, single flow turbine direct connected generator	Single casing, single flow turbine direct connected generator - AIEE-ASME Preferred Standard
Gross capacity at 2 in. Hg abs	22,000 kw	22,000 kw
Generator coolant	Hydrogen	Hydrogen
Generator voltage	13.8 kv	13.8 kv
5. <u>Condensers</u>		
Number	1	1
Type	Single pass, divided water box	Single pass, divided water box
Condensing surface	24,000 sq ft	18,000 sq ft
Pressure (83° F sea water)	2 in. Hg abs	2 in. Hg abs
Cooling water flow	42,000 gpm	34,000 gpm
6. <u>Turbine-Generator Building</u>		
Size		85 ft by 110 ft
Construction		Substructure: Rein- forced concrete, 22 ft high. Superstructure: Struc- tural steel frame with reinforced concrete roof deck and wall panels, 45 ft high
7. <u>Platform Barge</u>		
Length	290 ft	
Width	80 ft	
Depth from main deck	31 ft	
Draft	16 ft

D. Thule Air Base, Greenland

Thule Air Base, located on the northwest coast of Greenland, is the northernmost strategic air base of the U. S. Air Force. In addition, an Air Force operated BMWS installation is located in the general area. At the present time, electric power for the air base and BMWS is provided by a floating steam turbine power plant and several diesel engine power plants. Heat is provided by the floating power plant and separate package boilers located throughout the area. The Air Force has established the following power and heat requirements for the proposed new power plant:

Total power	25,000 kwe
Firm power	15,000 kwe
Heat (none firm)	150,000,000 Btu/hr (Export steam)

PROPOSED 25 MWe NUCLEAR POWER PLANT

The proposed nuclear power plant would be installed in a converted C3 hull located in the existing barge berth adjacent to the shore of North Star Bay. The plant would consist of one 130 mwt direct

cycle, natural circulation, boiling water reactor and two 16,500 kw (gross) turbine-generators. Stand-by power would be provided by one 200,000 lb/hr oil fired steam boiler. Sea water would be used for condenser cooling. Export steam for heating will be furnished from a steam generator using turbine extraction steam as a source of heat.

The estimated cost of this installation, including the cost of modifying the existing barge berth to accommodate the larger vessel, is \$21,700,000.

For cost comparison purposes, a conventional steam power plant consisting of two oil fired steam boilers and two 16,500 kw (gross) turbine-generators was selected. The conventional power plant is also installed on a converted C3 hull. The estimated cost of this installation is \$11,100,000.

Table 7, page 45, shows the estimated construction and operating costs for the 25 mwe power plants to be completed in 1963. Table 8, page 46, shows in summary form pertinent power plant data for the two types of power plants.

TABLE 7
THULE AIR BASE, GREENLAND
ESTIMATED CONSTRUCTION AND OPERATING COSTS

<u>Estimated Construction Costs</u>		
	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
Total Construction Cost	\$17,137,000	\$ 9,261,000
Escalation through 1963	1,013,000	559,000
Total Including Escalation	\$18,150,000	\$ 9,820,000
Design Engineering	1,200,000	500,000
Total Cost Excluding Contingency	\$19,350,000	\$10,320,000
Contingency	2,350,000	780,000
Total Project Cost	\$21,700,000	\$11,100,000
Government Costs (6)	\$ 1,160,000	\$ 619,200
<u>Estimated Average Annual Costs</u>		
	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
Fixed Charges (1)	\$ 1,085,000	\$ 555,000
Operating and Maintenance Cost (2)	597,000	469,000
Nuclear Fuel Cost (3)	898,000	-
Stand-by Fuel Oil Cost (4)	207,000	3,370,000
Total Cost	\$ 2,787,000	\$ 4,394,000
Portion of Total Average Annual Cost		
Allocated to Steam Production	307,000	1,376,000
Portion of Total Average Annual Cost		
Allocated to Electric Power Production	\$ 2,480,000	\$ 3,018,000
Estimated Unit Power Cost in Mills/kwhr (5)	14.0	17.0

- NOTE: (1) Fixed charges are based on a 20-year plant life equivalent to 5% of the total project cost. No interest on investment has been included.
- (2) Operating and maintenance cost 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.
- (4) Based on 1959 commercial rates, plus an average escalation of 20% over the life of the plant.
- (5) Based on the production of 178,000,000 net kilowatt hours per year, and only the fixed charges, operating and maintenance cost and fuel costs applicable to the production of electric power.
- (6) Government costs, estimated at 6% of the total cost excluding contingency, include the cost of site investigation and the administration of the design and construction contracts.

TABLE 8
THULE AIR BASE, GREENLAND
SUMMARY OF POWER PLANT DATA

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
<u>1. Over-all Performance</u>		
Primary steam supply	Direct cycle, natural circulation, boiling water reactor	Oil fired steam boilers
No. of reactors/boilers	One	Two
No. of turbine-generators	Two	Two
Reactor thermal power	130 mwt	- -
Capacity of steam boilers		175,000 lb/hr
Gross capability	27,000 kwe and 1.5 x 10 ⁸ Btu/hr	27,000 kwe and 1.5 x 10 ⁸ Btu/hr
Net capability	25,400 kwe and 1.5 x 10 ⁸ Btu/hr	25,400 kwe and 1.5 x 10 ⁸ Btu/hr
Primary steam flow	457,000 lb/hr	340,000 lb/hr
Primary steam pressure	1,000 psig	900 psig
Primary steam temperature	546° F	900° F
Extraction steam pressure	185 psig	115 psig
Feed water return temperature	272° F	342° F
<u>2. Reactor Characteristics</u>		
Fuel Assembly		
Fuel material	UO ₂	
Initial enrichment	2.2% U-235	
Initial core loading	10,200 kgU	
Irradiation at discharge	13,200 mwd/metric ton	
Cladding material	Zircaloy-2	
No. of assemblies	132	
No. of control rods	25	
Control material	Boron-stainless steel	
Reactor Vessel		
Internal diameter	8 ft 6 in.	
Inside height	38 ft	
Material	Stainless clad carbon steel	
<u>3. Containment</u>	50 ft diam by 94 ft high steel cylinder	

TABLE 8 (Cont'd)

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
<u>4. Turbine-Generator Characteristics</u>		
Number	Two	Two
Type	Single casing, single flow turbine, direct connected to generator. Turbine equipped for automatic extraction at 185 psig.	Single casing, single flow turbine, direct connected to generator. Turbine equipped for automatic extraction at 115 psig.
Gross capacity, straight condensing, at 1 in. Hg abs	16,500 kw	16,500 kw
Generator coolant	Hydrogen	Hydrogen
Generator voltage	13.8 kv	13.8 kv
<u>5. Condensers</u>		
Number	Two	Two
Type	Single pass, divided water box	Single pass, divided water box
Condensing surface	8,700 sq ft	6,000 sq ft
Pressure (50° F sea water)	1 in. Hg abs	1 in. Hg abs
Cooling water flow	18,000 gpm	15,000 gpm
<u>6. Stand-by Boiler</u>		
Number	One	
Capacity	200,000 lb/hr	
Pressure	1,030 psig	
Fuel	Arctic grade diesel	
<u>7. Converted C3 Barge</u>		
Length over-all	492 ft	492 ft
Beam	69 ft 6 in.	69 ft 6 in.
Design draft	20 ft 3 in.	17 ft
Displacement (full load)	11,835 tons	9,650 tons

E. North American Air Defense Command Operations Center

The North American Air Defense Command Operations Center (NORAD), near Camp Carson, Colorado, is a "hardened" facility housed within several underground chambers tunneled into Cheyenne Mountain. Power requirements established by the Air Force for NORAD in 1963 are:

Firm power	4,000 kw
Peak operating load	7,000 kw
Average operating load	6,000 kw

In addition, the Air Force has directed that the power requirements be met without the use of conventional power units as a source of stand-by power, and that at least the firm power requirement be met for an emergency period of 5 days with all surface facilities destroyed.

PROPOSED 6 MWe NUCLEAR POWER PLANT

The proposed nuclear power plant would be located in an underground chamber within the NORAD complex and would consist of two 28 mwt (SM-2) pressurized water reactors and two 6,000 kw (gross) turbine-

generators. During normal operation condenser cooling water would be provided by the use of an above ground cooling tower. Should the surface facilities be destroyed the turbine will be operated as a non-condensing unit exhausting to the atmosphere; plant make-up and service cooling water being supplied from an emergency reservoir within the tunnel system. The estimated cost of this installation is \$11,100,000.

For cost comparison purposes, a diesel engine generator power plant consisting of six 1,500 kw units was selected. Engine cooling water would be provided by the use of above ground air cooled condensers during normal operation and by water from an underground reservoir during the 5 day emergency period. The estimated cost of this installation is \$4,700,000.

Table 9, page 51, shows the estimated construction and operating costs for the proposed nuclear and conventional power plants to be completed in 1963. Table 10, page 52, shows in summary form the pertinent power plant data for each type of plant.

TABLE 9

NORAD

ESTIMATED CONSTRUCTION AND OPERATING COSTS

Estimated Construction Costs

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
Total Construction Cost	\$ 8,679,000	\$3,897,000
Escalation through 1963	521,000	243,000
Total Including Escalation	\$ 9,200,000	\$4,140,000
Design Engineering	700,000	212,000
Total Excluding Contingency	\$ 9,900,000	\$4,352,000
Contingency	1,200,000	348,000
Total Project Cost	\$11,100,000	\$4,700,000
Government Costs (6)	\$ 600,000	\$ 260,000

Estimated Average Annual and Unit Power Costs

	<u>Nuclear Power Plant</u>		<u>Conventional Power Plant</u>	
	<u>Average Annual Cost</u>	<u>Unit Cost in Mills per kwhr (4)</u>	<u>Average Annual Cost</u>	<u>Unit Cost in Mills per kwhr (4)</u>
Fixed Charges (1)	\$ 555,000	10.5	\$ 235,000	4.5
Operating and Maintenance Cost (2)	308,000	5.9	163,000	3.1
Nuclear Fuel Cost (3)	771,000	14.7	-	-
Fuel Oil Cost (5)	-	-	624,000	11.9
Total Cost	\$1,634,000	31.1	\$1,022,000	19.5

- 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.
- (4) Unit power cost is based on 100% of the average operating load (6,000 kw net) equivalent to 52,600,000 net kilowatt hours per year.
- (5) Based on 1959 commercial rates plus an average escalation over the life of the plant.
- (6) Government costs, estimated at 6% of the total cost excluding contingency, include the cost of site investigation and administration of the engineering and construction contracts.

TABLE 10
NORAD
SUMMARY POWER PLANT DATA

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
<u>1. Over-all Performance</u>		
Type of reactor/conventional power source	Pressurized water reactors	Diesel engine driven generators
Number of reactors	2	
Number of turbine-generators/diesel engine	2	6
Electrical capability		
Gross	12,000 kw	9,000 kw
Net	10,800 kw	6,000 kw (Firm)
Turbine steam		
Flow	166,000 lb/hr	
Pressure	600 psia	
Temperature	486° F (saturated)	
Feed water return temperature	339° F	
<u>2. Reactor Characteristics</u>		
Fuel Assembly (each reactor)		
Fuel material	UO ₂ in stainless steel matrix	
Initial enrichment	90+% U-235	
Weight of fuel in the core	36.2 kg, U-235	
Fuel burnup at discharge	38.8%	
Cladding material	Stainless steel	
No. of stationary fuel assemblies	38	
No. of "control-rod-followers"	7	
No. of control rods	7	
Control material	Europium	
Reactor Vessel		
Internal diameter	41 in.	
Internal height	12 ft 5 in.	
Material	Stainless steel	

TABLE 10 (Cont'd)

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
3. <u>Containment</u>		
Type	Vertical steel cylinder - 2 required	
Over-all height	63 ft	
Diameter	24 ft	
4. <u>Turbine-Generator Characteristics</u>		
Number	2	
Type	3,600 rpm single casing	
Gross capability ($1\frac{1}{2}$ in. Hg abs)	6,000 kw	
Generator coolant	Air	
Generator voltage	2,400/4,160 v	
5. <u>Condensers</u>		
Number	2	
Type	Two pass, divided water box	
Condensing surface	9,000 sq ft	
Pressure (at 100% capability and 75° F cooling water)	$1\frac{1}{2}$ in. Hg abs	
6. <u>Stand-by Power</u>	Nuclear	
7. <u>Diesel Engine Generator Characteristics</u>		
Number		6
Type		Heavy Duty
Rating		1,500 kw
Generator voltage		2,400/4,160 v
8. <u>Emergency Cooling Water Reservoir</u>	3,500,000 gal	1,000,000 gal
9. <u>Size of Underground Chamber</u>		
Turbine-generator plant	50 ft by 132 ft by 49 ft high	
Each reactor	29 ft by 37 ft by 68 ft high	
Diesel engine generator plant		50 ft by 132 ft by 54 ft high

F. Fourth U. S. ASA Field Station, Asmara, Eritrea

The Fourth U. S. Army Security Agency is located at Asmara, Eritrea on the east coast of Africa about 65 miles inland from the Red Sea. Formerly an Italian Colony, Eritrea was federated with Ethiopia in 1952.

The Army Security Agency occupies several areas, called tracts, in an around Asmara, secured from the Eritrean Government by treaty. Electric power for these installations is supplied principally by U. S. owned and operated diesel engine power plants, with some minor amount of power being obtained from local municipal sources

PROPOSED 5 MWe NUCLEAR POWER PLANT

Power requirements for the new generating facilities have been established by the Army at 5 mwe of firm power in 1963. Location of the proposed power plant would be at New Kagnev Station, Tract "E".

The proposed nuclear power plant would consist of a 28 mwt (SM-2) pressurized water reactor and one 6,000 kw (gross) turbine-generator. Condenser cooling water would be provided by use of a cooling tower. Stand-by capacity would be provided by the existing diesel engine power plants. The estimated cost of this installation is \$5,800,000. For cost comparison purposes a diesel engine generator power plant consisting of six 1,250 kw units was selected. The estimated cost of this installation is \$2,915,000.

Table 11, page 57, shows the estimated construction and operating costs for the proposed nuclear and conventional power plants to be completed in 1963. Table 12, page 58, shows in summary form the pertinent power plant data for each type of plant.

TABLE 11
ASMARA, ERITREA
ESTIMATED CONSTRUCTION AND OPERATING COSTS
Estimated Construction Costs

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
Total Construction Cost	\$4,660,000	\$2,402,000
Escalation through 1963	280,000	144,000
Total including Escalation	\$4,940,000	\$2,546,000
Design Engineering	250,000	153,000
Total excluding Contingency	\$5,190,000	\$2,699,000
Contingency	610,000	216,000
Total Project Cost	\$5,800,000	\$2,915,000
Government Costs (6)	\$ 310,000	\$ 160,000

Estimated Average Annual and Unit Power Costs

	<u>Nuclear Power Plant</u>		<u>Conventional Power Plant</u>	
	<u>Average Annual Cost</u>	<u>Unit Cost in Mills per kwhr (4)</u>	<u>Average Annual Cost</u>	<u>Unit Cost in Mills per kwhr (4)</u>
Fixed Charges (1)	\$ 290,000	6.6	\$146,000	3.3
Operating and Maintenance Cost (2)	239,000	5.5	156,000	3.6
Nuclear Fuel Cost (3)	586,000	13.4	- -	-
Fuel Oil Cost (5)	27,000	0.6	532,000	12.1
Total Cost	\$1,142,000	26.1	\$834,000	19.0

- 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.
- (4) Unit power cost is based on 100% of the firm power demand equivalent to 43,800,000 kilowatt hours per year.
- (5) Based on 1959 commercial rates plus an average escalation over the life of the plant.
- (6) Government costs, estimated at 6% of the total cost, excluding contingency, include the cost of site investigation and administration of the engineering and construction contracts.

TABLE 12
ASMARA, ERITREA
SUMMARY OF POWER PLANT DATA

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
1. <u>Over-all Performance</u>		
Type of reactor/conventional power source	Pressurized water reactor	Diesel engine driven generators
No. of reactors	1	
No. of turbine-generators/diesel engine generators	1	6
Electrical capability		
Gross	6,000 kw	7,500 kw
Net	5,400 kw	5,000 kw (firm)
Turbine steam		
Flow	83,000 lb/hr	
Pressure	600 psia	
Temperature	486° F (saturated)	
Feed water return temperature	339° F	
2. <u>Reactor Characteristics</u>		
Fuel Assembly		
Fuel material	UO ₂ in stainless steel matrix	
Initial enrichment	90+% U-235	
Weight of fuel in the core	36.2 kg, U-235	
Fuel burnup at discharge	38.8%	
Cladding material	Stainless steel	
No. of stationary fuel assemblies	38	
No. of "control-rod-followers"	7	
No. of control rods	7	
Control material	Europium	
Reactor Vessel		
Internal diameter	41 in.	
Internal height	12 ft 5 in.	
Material	Stainless steel	

TABLE 12 (Cont'd)

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
3. <u>Containment</u>		
Type	Vertical steel cylinder	
Over-all height	63 ft	
Diameter	24 ft	
4. <u>Turbine-Generator Characteristics</u>		
Number	1	
Type	3,600 rpm single casing	
Gross capability (1½ in. Hg abs)	6,000 kw	
Generator coolant	Air	
Generator voltage	2,400/4,160 v	
5. <u>Condensers</u>		
Number	1	
Type	Two pass, divided water box	
Condensing surface	9,000 sq ft	
Pressure (at 100% capability and 75° F cooling water)	1½ in. Hg abs	
6. Stand-by Power	None provided - existing or projected diesel generating units will be used as stand-by for the nuclear plant	
7. <u>Diesel Engine Generator Characteristics</u>		
Number		6
Type		Heavy duty
Rating		1,250 kw
Generator voltage		2,400/4,160 v
8. <u>Turbine/Diesel Generator Building</u>		
Size	40 ft by 88 ft	78 ft by 161 ft
Type	Reinforced concrete foundations, struc- tural steel frame with brick walls and metal roof deck.	Reinforced concrete foundations, struc- tural steel frame with brick walls and metal roof deck.

G. Super Sage

Super Sage is an Air Force "hardened" facility housed within several underground chambers tunneled into a mountain in the Rocky Mountains area. The exact location is classified. Power requirements established by the Air Force for Super Sage in 1963 are:

Firm Power	3,200 kw
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In addition, the Air Force has directed that the power plant be capable of generating at least the firm power requirement for an emergency period of 5 days with all surface facilities destroyed.

PROPOSED 5 MWe NUCLEAR POWER PLANT

The proposed nuclear power plant would be located in an underground chamber within the Super Sage complex and would consist of a 28 mwt (SM-2) pressurized water reactor and one 6,000 kw (gross) turbine-generator. Stand-by power would be provided by

four 1,100 kw diesel engine generators. During normal operation condenser and diesel engine cooling water will be provided from an above ground cooling tower. Should the surface facilities be destroyed, the nuclear power plant turbine will be operated as a non-condensing unit exhausting to the atmosphere. Plant make-up water and service cooling water for the nuclear power plant, or cooling water for the stand-by diesel generator power plant will be supplied from an underground reservoir within the tunnel complex. The estimated cost of this installation is \$8,700,000.

For cost comparison purposes a diesel engine generator power plant consisting of six 800 kw units was selected. Engine cooling water would be provided by the use of above ground air cooled condensers during normal operation and by water from an underground reservoir during the 5 day emergency period. The estimated cost of this installation is \$3,800,000.

Table 13, page 63, shows the estimated construction and operating costs for the proposed nuclear and conventional power plants to be constructed in 1963. Table 14, page 64, shows in summary form the pertinent power plant data for each type of plant.

TABLE 13
SUPER SAGE

ESTIMATED CONSTRUCTION AND OPERATING COSTS

	<u>Estimated Construction Costs</u>	
	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
Total Construction Cost	\$6,891,000	\$3,135,000
Escalation through 1963	409,000	185,000
Total Including Escalation	\$7,300,000	\$3,320,000
Design Engineering	530,000	170,000
Total Excluding Contingency	\$7,830,000	\$3,490,000
Contingency	870,000	310,000
Total Project Cost	\$8,700,000	\$3,800,000
Government Costs (6)	\$ 470,000	\$ 210,000

Estimated Average Annual and Unit Power Costs

	<u>Nuclear Power Plant</u>		<u>Conventional Power Plant</u>	
	<u>Average Annual Cost</u>	<u>Unit Cost in Mills per kwhr (4)</u>	<u>Average Annual Cost</u>	<u>Unit Cost in Mills per kwhr (4)</u>
Fixed Charges (1)	\$ 435,000	15.5	\$190,000	6.8
Operating and Maintenance Cost (2)	235,000	8.4	126,000	4.5
Nuclear Fuel Cost (3)	388,000	13.9	-	-
Fuel Oil Cost (5)	17,000	0.6	331,000	11.8
Total Cost	\$1,075,000	38.4	\$647,000	23.1

- 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.
- (4) Unit power cost is based on 100% of firm power demand equivalent to 28,000,000 net kilowatt hours per year.
- (5) Based on 1959 commercial rates plus an average escalation over the life of the plant.
- (6) Government costs, estimated at 6% of the total cost excluding contingency, include the cost of site investigation and administration of the engineering and construction contracts.

TABLE 14
SUPER SAGE
SUMMARY OF POWER PLANT DATA

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
<u>1. Over-all Performance</u>		
Type of reactor/conventional power source	Pressurized water reactor	Diesel engine driven generators
No. of reactors	1	
No. of turbine-generators/ diesel engine generators	1	6
Electrical capability		
Gross	6,000 kw	4,800 kw
Net	5,400 kw	3,200 kw (firm)
Turbine steam		
Flow	83,000 lb/hr	
Pressure	600 psia	
Temperature	486° F (saturated)	
Feed water return temperature		
	339° F	
<u>2. Reactor Characteristics</u>		
Fuel Assembly		
Fuel material	UO ₂ in stainless steel matrix	
Initial enrichment	90+% U-235	
Weight of fuel in the core	36.2 kg, U-235	
Fuel burnup at discharge	38.8%	
Cladding material	Stainless steel	
No. of stationary assemblies	38	
No. of "control-rod-followers"	7	
Control rods		
Number	7	
Control material	Europium	
Reactor vessel		
Internal diameter	41 in.	
Internal height	12 ft 5 in.	
Material	Stainless steel	

TABLE 14 (Cont'd)

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
3. <u>Containment Vessel</u>		
Over-all height	63 ft	
Diameter	24 ft	
4. <u>Turbine-Generator Characteristics</u>		
Number	1	
Type	3,600 rpm single casing	
Gross capability (1½ in. Hg abs)	6,000 kw	
Generator coolant	Air	
Generator voltage	2,400/4,160 v	
5. <u>Condensers</u>		
Number	1	
Type	Two pass, divided water box	
Condensing surface	9,000 sq ft	
Pressure (at 100% capability and 75° F cooling water)	1½ in. Hg abs	
6. <u>Stand-by Power</u>		
Type of unit	No. 2 diesel oil	
Number of units	4	
Electrical capability (per unit)	1,100 kw	
Type of fuel	Grade 2 fuel oil	
7. <u>Diesel Engine Generator Characteristics</u>		
Number		6
Type		Heavy duty
Rating		800 kw
Generator voltage		2,400/4,160 v
8. <u>Emergency Cooling Water Reservoir</u>	2,000,000 gal	700,000 gal
9. <u>Size of Underground Chamber</u>		
Turbine-generator plant	45 ft by 172 ft by 50 ft high	
Reactor	25 ft by 36 ft by 68 ft high	
Diesel engine generator plant		45 ft by 114 ft by 50 ft high

H. Nike-Zeus FAR Site

The Nike-Zeus FAR sites will include operational and billeting facilities, requiring 10,000 kw of firm power. The exact location of the sites is classified information. A site similar to an isolated area in the northern Great Lakes region of the United States was selected for study purposes. Because of the isolated location, the proposed power plant would be the only source of power for the Nike-Zeus installation. In addition, function of the installation requires high quality power with respect to voltage and frequency variations.

PROPOSED 10 MWe NUCLEAR POWER PLANT

The proposed nuclear power plant would consist of two 28 mwt (SM-2) pressurized water reactors and two 6,000 kw (gross) turbine-generators. Condenser cooling water will be supplied from a river assumed to be within 1,000 ft of the power plant site. Stand-by power would be provided by a packaged diesel engine generator plant (MU-80). The estimated cost of this installation is \$11,300,000.

For cost comparison purposes, a conventional power plant consisting of six 2,500 kw diesel engine generators would be provided. The estimated cost of this installation is \$5,300,000.

Table 15, page 69, shows the estimated construction and operating costs for the proposed nuclear and conventional power plants to be completed in 1963. Table 16, page 70, shows in summary form pertinent power plant data for each type of plant.

TABLE 15

NIKE-ZEUS

ESTIMATED CONSTRUCTION AND OPERATING COSTS

Estimated Construction Costs

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
Total Construction Cost	\$ 9,096,000	\$ 4,371,000
Escalation	574,000	269,000
Total Including Escalation	\$ 9,670,000	\$ 4,640,000
Design Engineering	400,000	240,000
Total Excluding Contingency	\$10,070,000	\$ 4,880,000
Contingency	1,230,000	420,000
Total Project Cost	\$11,300,000	\$ 5,300,000
Government Costs (6)	\$ 600,000	\$ 290,000

Estimated Average Annual and Unit Power Costs

	<u>Nuclear Power Plant</u>		<u>Conventional Power Plant</u>	
	<u>Average Annual Cost</u>	<u>Unit Cost in Mills per kwhr (4)</u>	<u>Average Annual Cost</u>	<u>Unit Cost in Mills (4) per kwhr</u>
Fixed Charges (1)	\$ 565,000	6.4	\$ 265,000	3.0
Operating and Maintenance Cost (2)	324,000	3.7	241,000	2.7
Nuclear Fuel Cost (3)	1,146,000	13.1	- -	-
Fuel Oil Cost (5)	<u>71,000</u>	<u>0.8</u>	<u>1,420,000</u>	<u>16.2</u>
Total Cost	\$2,106,000	24.0	\$1,926,000	21.9

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.

(4) Unit power cost is based on 100% of firm power requirement equivalent to 87,600,000 net kilowatt hours per year.

(5) Based on 1959 commercial rates plus an average escalation over the life of the plant.

(6) Government costs, estimated at 6% of the total cost excluding contingency, include the cost of site investigation and administration of the engineering and construction contracts.

TABLE 16
NIKE-ZEUS
SUMMARY OF POWER PLANT DATA

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
1. <u>Over-all Performance</u>		
Type of reactor/conventional power source	Pressurized water reactor	Diesel engine generators
Number of reactors/diesel engine generators	2	6
Number of turbine-generators	2	
Electrical capability		
Gross	12,000 kw	15,000 kw
Net	10,800 kw	10,000 kw (firm)
Turbine steam		
Flow	166,000 lb/hr	
Pressure	600 psia	
Temperature	486° F (saturated)	
Feed water return temperature	339° F	
2. <u>Reactor Characteristics</u>		
Fuel Assembly (each reactor)		
Fuel material	UO ₂ in stainless steel matrix	
Initial enrichment	90+% U-235	
Weight of fuel in the core	36.2 kg, U-235	
Fuel burnup at discharge	38.8%	
Cladding material	Stainless steel	
No. of stationary fuel assemblies	38	
No. of "control-rod-followers"	7	
Control rods (each reactor)		
Number	7	
Control material	Europium	
Reactor vessel (each reactor)		
Internal diameter	41 in.	
Internal height	12 ft 5 in.	
Material	Stainless steel	
3. <u>Containment</u>		
Type	Vertical steel cylinder (2 required)	
Over-all height	63 ft	
Diameter	24 ft	

TABLE 16 (Cont'd)

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
4. <u>Turbine-Generator Characteristics</u>		
Number	2	
Type	3,600 rpm single casing	
Gross capability (1½ in. Hg abs)	6,000 kw	
Generator coolant	Air	
Generator voltage	2,400/4,160 v	
5. <u>Condensers</u>		
Number	2	
Type	Two pass, divided water box	
Condensing surface	9,000 sq ft	
Pressure (at 100% capability and 75° F cooling water)	1½ in. Hg abs	
6. <u>Stand-by Power</u>		
Type of unit	Diesel engine generator plant	
Number of units	4	
Electrical capability (per unit)	2,000 kw	
Type of fuel oil	Arctic grade diesel	
7. <u>Diesel Engine Generator Characteristics</u>		
Number		6
Type		Heavy duty
Rating		2,500 kw
Generator voltage		2,400/4,160 v
Type of fuel oil		Arctic grade diesel
8. <u>Turbine/Diesel Generator Building</u>		
Size	40 ft by 160 ft	80 ft by 175 ft
Type	Reinforced concrete foundations, struc- tural steel frame, insulated metal sid- ing and roof deck	Reinforced concrete foundations, struc- tural steel frame, insulated metal sid- ing and roof deck

I. Inchon, Korea

Power for the U. S. Government installations in Korea is now purchased largely from the Republic of Korea, with the greatest demand being in the area around Inchon. Since the Republic of Korea is critically short of power at this time, there is a need for new generating capacity to supply power to the public utility system so the power supply of the U. S. installations will not be curtailed. This additional power requirement has been established at 10 mwe in 1963 which is approximately the amount of power now used by the U. S. Government. Inchon Harbor was selected as the location for the proposed power plant.

PROPOSED 10 MWe NUCLEAR POWER PLANT

The proposed nuclear power plant would consist of one 40 mwt pressurized water reactor and one 10,820 kw (gross) turbine-generator. The estimated cost of this power plant installed in a converted EC2-S-C1 hull is \$11,100,000, including towing cost to the site and the cost of moving facilities.

For cost comparison purposes a conventional diesel engine generator power plant consisting of five 2,500 kw units was selected. The estimated cost of this power plant installed in a converted Cl-M-AV1 hull is \$4,700,000, including towing cost to the site, and the cost of mooring facilities.

Table 17, page 75, shows the estimated construction and operating costs for the 10 mwe power plants to be completed in 1963. Table 18, page 76, shows in summary form pertinent power plant data for the two types of plants.

TABLE 17
INCHON, KOREA
ESTIMATED CONSTRUCTION AND OPERATING COSTS
10,000 KW POWER PLANT
Estimated Construction Costs

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
Total Construction Cost	\$ 8,812,000	\$3,865,000
Escalation through 1963	528,000	235,000
Total Including Escalation	\$ 9,340,000	\$4,100,000
Design Engineering	600,000	240,000
Total Excluding Contingency	\$ 9,940,000	\$4,340,000
Contingency	1,160,000	360,000
Total Project Cost	\$11,100,000	\$4,700,000
Government Cost (6)	600,000	260,000

Estimated Annual and Unit Power Costs

	<u>Nuclear Power Plant</u>		<u>Conventional Power Plant</u>	
	<u>Average Annual Cost</u>	<u>Unit Cost In Mills per kwhr (4)</u>	<u>Average Annual Cost</u>	<u>Unit Cost In Mills per kwhr (4)</u>
Fixed Charges (1)	\$ 555,000	7.9	\$ 235,000	3.4
Operating and Maintenance Cost (2)	358,000	5.1	272,000	3.9
Nuclear Fuel Cost (3)	472,000	6.7	-	-
Fuel Oil Cost (5)	-	-	520,000	7.4
Total Cost	\$1,385,000	19.7	\$1,027,000	14.7

- 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.
- (4) Unit power cost is based on 80% plant operating factor equivalent to 70,000,000 net kilowatt hours per year.
- (5) Based on 1959 commercial rates plus an average escalation over the life of the plant.
- (6) Government costs, estimated at 6% of the total cost excluding contingency, include the cost of site investigation and the administration of the design and construction contracts.

TABLE 18
INCHON, KOREA

SUMMARY OF POWER PLANT DATA

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
<u>1. Over-all Performance</u>		
Type of reactor/conventional power source	Pressurized water	Diesel engine driven generators
Number of reactors	1	
Number of turbine-generators/diesel engine generators	1	5
Reactor thermal power	40 mwt	
Electrical capability		
Gross	10,820 kw	10,000 kw
Net	10,000 kw	10,000 kw
Turbine steam		
Flow	147,400 lb/hr	
Pressure	375 psia	
Temperature	438° F	
Feed water return temperature	320° F	
<u>2. Reactor Characteristics</u>		
Fuel Assembly		
Fuel material	UO ₂	
Initial enrichment	4% U-235	
Weight of fuel in core	3,335 kg U	
Irradiation at discharge	9,200 mwd/metric ton	
Cladding material	Stainless steel	
No. of stationary fuel assemblies	49	
No. of "control-rod-followers"	12	
Control rods		
Number	12	
Control material	Europium	
Reactor Vessel		
Internal diameter	6.5 ft	
Inside height	20.3 ft	
Material	Stainless clad carbon steel	

TABLE 18 (Cont'd)

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
3. <u>Containment</u>		
Type	Vertical steel cylinder	
Over-all height	73 ft	
Diameter	28 ft	
4. <u>Turbine-Generator Characteristics</u>		
Number	1	
Type	3,600 rpm single casing	
Gross capability (1½ in. Hg abs)	10,820 kw	
Generator coolant	Air	
Generator voltage	13.8 kv	
5. <u>Condensers</u>		
Number	1	
Type	Single pass marine type	
Condensing surface	12,300 sq ft	
Pressure (73° F sea water)	1½ in. Hg abs	
6. <u>Diesel Engine Generator Characteristics</u>		
Number		5
Type		Heavy duty
Rating		2,500 kw
Generator voltage		2,400/4,160 kv
7. <u>Barge Hull</u>		
Length over-all	441 ft 6 in.	338 ft 9 in.
Beam	56 ft 10-3/4 in.	50 ft 5-3/8 in.
Design draft	17 ft 10 in.	14 ft 9 in.
Displacement (long tons)		5,030

J. Atlantic Barge

The concept of an Atlantic Barge, with the New York harbor area as the base of operations, has been developed to provide the Navy with a mobile source of emergency electrical power for use in the Atlantic ocean area. The barge would be utilized primarily at Naval installations but could be used at any riparian site as a source of emergency power.

The total power requirement for the Atlantic Barge has been established by the Navy at 20 mwe in 1963.

PROPOSED 20 MWe NUCLEAR POWER PLANT

The proposed nuclear power plant would consist of one 83 mwt two loop, pressurized water reactor and two 11,500 kw turbine-generators. Stand-by power would be provided by one 160,000 lb/hr oil fired steam boiler, capable of operating one turbine-generator. The estimated cost of this power plant installed in a converted C3 hull is \$20,000,000.

For cost comparison purposes, a conventional steam power plant consisting of two oil fired steam boilers and two 11,500 kw turbine-generators was selected. The estimated cost of this power plant installed in a converted C3 hull is \$7,100,000.

Table 19, page 81, shows the estimated construction and operating costs for the 20 mwe nuclear and conventional power plants to be completed in 1963. Table 20, page 82, shows in summary form pertinent power plant data for each type of plant.

TABLE 19
ATLANTIC BARGE
ESTIMATED CONSTRUCTION AND OPERATING COSTS

	<u>Estimated Construction Costs</u>	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
Total Construction Cost	\$15,974,000	\$5,892,000	
Escalation through 1963	956,000	358,000	
Total Including Escalation	\$16,930,000	\$6,250,000	
Design Engineering	960,000	320,000	
Total Cost Excluding Contingency	\$17,890,000	\$6,570,000	
Contingency	2,110,000	530,000	
Total Project Cost	\$20,000,000	\$7,100,000	
Government Costs (6)	\$ 1,070,000	\$ 390,000	

	<u>Estimated Average Annual and Unit Power Costs</u>			
	<u>Nuclear Power Plant</u>		<u>Conventional Power Plant</u>	
	<u>Average Annual Cost</u>	<u>Unit Cost in mills per kwhr (4)</u>	<u>Average Annual Cost</u>	<u>Unit Cost in mills per kwhr (4)</u>
Fixed Charges (1)	\$1,000,000	7.2	\$ 355,000	2.5
Operating and Maintenance Cost (2)	384,000	2.7	290,000	2.1
Nuclear Fuel Cost (3)	647,000	4.6	-	-
Stand-by Fuel Cost (5)	93,000	0.7	-	-
Fuel Oil Cost (5)	-	-	1,253,000	9.0
Total Cost	\$2,124,000	15.2	\$1,898,000	13.6

- NOTE: (1) Based on a 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.
- (4) Unit power cost is based on 80% plant operating factor equivalent to 149,000,000 net kilowatt hours per year.
- (5) Based on 1959 commercial rates plus an average escalation over the life of the plant.
- (6) Government costs, estimated at 6% of the total cost excluding contingency, include the cost of administration of the design and construction contracts.

Table 20
ATLANTIC BARGE

SUMMARY OF POWER PLANT DATA

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
1. <u>Over-all Performance</u>		
Primary steam supply	Two-loop, pressur- ized water reactor	Oil fired steam boilers
No. of reactors/boilers	1	2
No. of turbine-generators	2	2
Reactor thermal power	83 mwt	
Size of steam boilers		123,000 lb/hr max. continuous
Gross electrical capacity	23,000 kw	23,000 kw
Net electrical capacity	20,000 kw	20,000 kw
Steam		
Flow	320,000 lb/hr	228,000 lb/hr each
Pressure	530 psia	615 psia
Temperature	473° F	850° F
Feed-water return temper- ature	325° F	377° F
2. <u>Reactor Characteristics</u>		
Fuel Assembly		
Fuel material	UO ₂	
Initial enrichment	3.63% and 4.55% U-235	
Weight of fuel in core	3,900 kg U	
Fuel burnup at discharge	14,500 mwd/metric ton	
Cladding material	Stainless steel	
No. of assemblies	52	
No. of control rods	21	
Control rod material	Cadmium-Indium-Silver	
Reactor Vessel		
Internal diameter	71 in.	
Over-all height	18.5 ft	
Material	Stainless clad carbon steel	
3. <u>Containment</u>	48 ft diam steel sphere	

TABLE 20 (Cont'd)

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
4. <u>Turbine-Generator Characteristics</u>		
Number	2	2
Type	Tandem compound, single flow turbine- reduction gear driven generator	Tandem compound, single flow turbine- reduction gear driven generator
Rated capacity at 2 in. Hg abs	11,500 kw	11,500 kw
Generator coolant	Air	Air
Generator voltage	13.8 kv	13.8 kv
Generator frequency	50 or 60 cycles	50 or 60 cycles
5. <u>Condensers</u>		
Number	2	2
Type	Two pass	Two pass
Condensing surface	13,100 sq ft	10,000 sq ft
Pressure (75° F sea water)	2 in. Hg abs	2 in. Hg abs
Cooling water flow	12,600 gpm	9,750 gpm
6. <u>Stand-by Boiler</u>		
Number	1	
Size	160,000 lb/hr max. continuous	
Pressure	530 psia	
7. <u>Barge Hull</u>		
Length over-all	492 ft	492 ft
Beam	69 ft 6 in.	69 ft 6 in.
Design draft	21 ft 5 in.	19 ft
Displacement (full load)	12,660 tons	10,980 tons

K. McMurdo Sound, Antarctica

The United States Government has established weather and scientific observation stations in several locations in Antarctica. The base of operations for these installations is the Naval Air Facility, McMurdo Sound, where the Navy maintains camp facilities for up to 400 men. Power requirements for this camp, principally for space heating, have been established by the Navy at 3 mwe of firm power in 1963 and 4 mwe of firm power in 1964.

PROPOSED 5 MWe NUCLEAR POWER PLANT

The first increment of the proposed nuclear power plant would consist of three 11.4 mwt (PM-1) pressurized water reactors and three 1,760 kw (gross) turbine-generators. Six outside air cooled condensers, two for each turbine, would be utilized for steam condensing. Containment would not be required. The estimate of cost of the first increment of this power plant (3,000 kw firm power in 1963) is \$10,100,000. The estimated cost of increasing the firm plant capacity to 4,000 kw in 1964 is \$3,500,000.

The requirement for 4,000 kw firm in 1964 may be met either by the addition of another 1,500 kw reactor/turbine-generator unit to the three installed in 1963, or by increasing the capacity of each of the units installed in 1963 to 2,000 kw. To achieve a total firm capacity of 4,000 kw (2,000 kw per unit), the reactor thermal output would have to be increased above its present rating by about 15%. A larger turbine-generator unit and additional condenser capacity would also be required. Since the extrapolation of the PM-1 design to a 2,000 kw net output has not been studied, the estimate of cost to furnish the additional generating capacity required in 1964 has been based on the addition of a fourth 1,500 kw PM-1 unit.

For cost comparison purposes a diesel engine generator power plant consisting of six 800 kw units was selected. Engine cooling will be provided by two air cooled condensers. The estimate of cost for this installation is \$4,100,000.

The cost of conventional power at McMurdo Sound is very high due principally to two reasons: first, the high cost of diesel oil estimated at \$1.10 per gallon, and second, replacement of the diesel engines after every 25,000 hours of operation rather than the performance of major overhaul work at the site. In addition fuel oil storage for 15 months is required at the site since bulk fuel deliveries can be made only during approximately one month of the year.

For the comparative conventional power plant, the requirement for 4,000 kw firm power in 1964 may be met by the addition of one 800 kw diesel engine generator, and additional bulk fuel oil storage facilities. The estimated construction cost of these additional facilities is \$650,000.

Table 21, page 87, shows the estimated construction and operating costs for the 3,000 kw firm capacity nuclear and conventional power plants.

Table 22, page 88, shows the estimated construction and operating costs for the 4,000 kw firm capacity nuclear and conventional power plants.

Table 23, page 89, shows in summary form the pertinent power plant data for the 3,000 kw firm capacity 1st increment nuclear and conventional power plants.

TABLE 21

McMURDO SOUND

ESTIMATED CONSTRUCTION AND OPERATING COSTS

3,000 KW (FIRM) NUCLEAR POWER PLANT (1963)

Estimated Construction Costs

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
Total Construction Cost	\$ 7,982,000	\$3,238,000
Escalation	478,000	192,000
Total Including Escalation	\$ 8,460,000	\$3,430,000
Design Engineering	400,000	180,000
Total Excluding Contingency	\$ 8,860,000	\$3,610,000
Contingency	1,240,000	490,000
Total Project Cost	\$10,100,000	\$4,100,000
Government Costs (6)	\$ 530,000	\$ 216,000

Estimated Average Annual and Unit Power Costs

	<u>Nuclear Power Plant</u>		<u>Conventional Power Plant</u>	
	<u>Average Annual Cost</u>	<u>Unit Cost in mills (4) per kwhr</u>	<u>Average Annual Cost</u>	<u>Unit Cost in mills (4) per kwhr</u>
Fixed Charges (1)	\$ 505,000	19.2	\$ 205,000	7.8
Operating and Maintenance Cost (2)	382,000	14.5	222,000	8.4
Nuclear Fuel Cost (3)	609,000	23.1	- -	-
Fuel Oil Cost (5)	- -	-	2,244,000	85.5
Total Cost	\$1,496,000	56.8	\$2,671,000	101.7

- 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.
- (4) Unit power cost is based on 100% of firm power requirement equivalent to 26,300,000 net kilowatt hours per year.
- (5) Based on 1959 commercial rates plus an average escalation over the life of the plant.
- (6) Government costs, estimated at 6% of the total cost excluding contingency, include the cost of site investigation and administration of the engineering and construction contracts.

TABLE 22

McMURDO SOUND

ESTIMATED CONSTRUCTION AND OPERATING COSTS

ADDITION OF 1,000 KW (FIRM) GENERATING CAPACITY (1964)

Estimated Construction Costs

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
Total Construction Cost	\$ 2,694,000	\$ 500,000
Escalation through 1964	236,000	40,000
Total Including Escalation	\$ 2,930,000	\$ 540,000
Design Engineering	100,000	40,000
Total Excluding Contingency	\$ 3,030,000	\$ 580,000
Contingency	470,000	70,000
Total Project Cost	\$ 3,500,000	\$ 650,000
Government Costs (6)	\$ 182,000	\$ 350,000

Estimated Average Annual and Unit Power Costs

Combined 4,000 kw (firm) Power Plant (1964)

	<u>Nuclear Power Plant</u>		<u>Conventional Power Plant</u>	
	<u>Average Annual Cost</u>	<u>Unit Cost in mills (4) per kwhr</u>	<u>Average Annual Cost</u>	<u>Unit Cost in mills (4) per kwhr</u>
Fixed Charges (1)	\$ 680,000	19.4	\$ 238,000	6.8
Operating and Maintenance Cost (2)	490,000	14.0	246,000	7.0
Nuclear Fuel Cost (3)	810,000	23.1	- -	-
Fuel Oil Cost (5)	- -	-	2,987,000	85.4
Total Average Cost	\$1,980,000	56.5	\$3,471,000	99.2

NOTE: (1) Based on a 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.

(4) Unit power cost is based on 100% of firm power requirement equivalent to 35,000,000 net kilowatt hours per year.

(5) Based on 1959 commercial rates plus an average escalation over the life of the plant.

(6) Government costs, estimated at 6% of the total cost excluding contingency, include the cost of site investigation and administration of the engineering and construction contracts.

TABLE 23
McMURDO SOUND
SUMMARY OF POWER PLANT DATA - 3 MWe POWER PLANT

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
<u>1. Over-all Performance</u>		
Type of reactor/conventional power source	Pressurized water reactor, single loop	Diesel engine driven generators
No. of reactors	3	
No. of turbine-generators/ diesel engine generators	3	6
Electrical capability		
Gross	5,280 kw	4,800 kw
Net	4,635 kw	3,000 kw (firm)
Turbine Steam		
Flow	34,600 lb/hr	
Pressure	300 psia	
Temperature	417° F	
Feed water return temperature	308° F	
<u>2. Reactor Characteristics (per reactor)</u>		
Fuel Assembly		
Fuel material	UO ₂	
Initial enrichment	90% +	
Weight of fuel in core	23.0 kg, U-235	
Fuel burnup at discharge	31.8%	
Cladding material	Stainless steel	
No. of fuel elements	727	
No. of control rods	6	
Control material	Europium	
Reactor Vessel		
Outside diameter	40 in.	
Over-all height	100 in.	
Material	Stainless steel	
<u>3. Containment</u>	None	

TABLE 23 (Cont'd)

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
4. <u>Turbine-Generator Characteristics</u>		
Number	3	
Type	Single casing, 8,050/1,200 rpm geared unit	
Gross capability (6 in. Hg abs)	1,750 kw	
Generator coolant	Air	
Generator voltage	4,160 v	
5. <u>Condensers</u>		
Number	6	2
Type	Air-cooled	Air-cooled
6. <u>Diesel-Engine Generator Characteristics</u>		
Number		6
Type		Heavy Duty
Rating		800 kw
Generator voltage		4,160 v
7. <u>Turbine/Diesel Generator Building</u>		
Size		
Type		

SECTION V

REFERENCES AND GLOSSARY

A. References

1. Contract No. AT (30-1)-2441, United States Atomic Energy Commission, New York Operations Office.
2. Status of Pressurized Water Reactors (WCAP-1196), Westinghouse Electric Corporation, Revised July 15, 1959.
3. Survey of PWR Power Plants - 10 to 30 MWe Size 1(TID-8513), Alco Products, Inc., October 10, 1959.
4. Letter dated December 15, 1959, Chief, Army Reactors Branch, Technical Programs Division, New York Operations Office, AEC.
5. Letter dated September 23, 1959, Chief, Army Reactors Branch, Technical Programs Division, New York Operations Office, AEC.
6. Letter dated November 3, 1959, Chief, Army Reactors Branch, Technical Programs Division, New York Operations Office, AEC.
7. Wire dated October 15, 1959, Chief, Army Reactors Branch, Technical Programs Division, New York Operations Office, AEC.
8. Nike-Zeus Weapons System - Analysis and Report on Prime Power Generation Equipment for Tactical LAR/FAR Sites, the Ralph M. Parsons Co., April 10, 1959.

B. Glossary

abs	- absolute
AIEE	- American Institute of Electrical Engineers
ASME	- American Society of Mechanical Engineers
Btu	- British thermal unit
bwr	- boiling water reactor
°F	- degrees Fahrenheit
ft	- foot (feet)
gal	- gallon(s)
gpm	- gallons per minute
Hg	- mercury
in.	- inch(es)
kg	- kilogram(s)
kv	- kilovolt(s)
kw	- kilowatt(s)
kwhr	- kilowatt hour(s)
lb/hr	- pounds per hour
mw	- megawatt(s)
mwd	- megawatt day(s)
mwe	- electrical megawatt(s)
mwt	- thermal megawatt(s)
ocmr	- organic cooled and moderated reactor
psia	- pounds per square inch absolute
psig	- pounds per square inch gauge
Pu	- plutonium
pwr	- pressurized water reactor
rpm	- revolutions per minute
sq ft	- square foot (feet)
U	- uranium
UO ₂	- uranium oxide
v	- volt(s)

APPENDIX

The following is a list of the reports comprising the completed study:

<u>Report No.</u>	<u>Title</u>	<u>AEC Designation</u>
1	Summary	NYO-2937
2	Okinawa, Ryukyu Islands	NYO-2938
3	Guam, Mariana Islands	NYO-2939
4	Thule Air Base, Greenland	NYO-2940
5	North American Air Defense Command Operation Center	NYO-2941
6	Fourth U. S. ASA Field Station Asmara, Eritrea	NYO-2942
7	Super Sage	NYO-2943
8	Nike-Zeus FAR Site	NYO-2944
9	Inchon, Korea	NYO-2945
10	Atlantic Barge	NYO-2946
11	McMurdo Sound, Antarctica	NYO-2947
12	Selection of Applicable Reactor Concepts	NYO-2948

TABLE 1
SUMMARY OF POWER PLANT DATA AND COSTS
NUCLEAR POWER PLANTS

SITE	OKINAWA RYUKYU ISLANDS	GUAM MARIANA ISLANDS	THULE GREENLAND	NORAD USA	ASMARA ERITHEA	SUPER SAGE USA	YUBA USA	INCHON KOREA	ATLANTIC BARGE	McMURDO SOUND ANTARCTICA
POWER REQUIREMENT	40 Mwe in 1963 (1st inc) 80 Mwe in 1965	20 Mwe in 1963	25 Mwe Plus 150,000,000 Btu/hr of heat in 1963	7 Mwe in 1963 (4 Mwe firm)	5 Mwe in 1963	5 Mwe in 1963 (3.2 Mwe firm)	10 Mwe (firm)	10 Mwe in 1963	20 Mwe in 1963 (10 Mwe firm)	4.5 Mwe in 1963 (3.0 Mwe firm) 6 Mwe in 1964
POWER PRODUCTION	<u>1st INCREMENT</u>									<u>1st INCREMENT</u>
Total yearly power produced	290,000,000 kwhr	145,000,000 kwhr	178,000,000 kwhr	52,600,000 kwhr	43,800,000 kwhr	28,000,000 kwhr	87,600,000 kwhr	70,000,000 kwhr	149,000,000 kwhr	26,300,000 kwhr
Plant operating factor	80%	80%	80%	100% of average power	100% of firm power	100% of firm power	100% of firm power	80%	80%	100% of firm power
POWER PLANT DATA	<u>1st INCREMENT</u>									
Reactor size	150 mwt	75 mwt	130 mwt	28 mwt (SM-2)	28 mwt (SM-2)	28 mwt (SM-2)	28 mwt (SM-2)	40 mwt	83 mwt	11.4 mwt (PM-1)
Reactor type	Direct cycle, natural circulation, boiling water	Direct cycle, natural circulation, boiling water	Direct cycle, natural circulation, boiling water	Pressurized water	Pressurized water	Pressurized water	Pressurized water	Pressurized water	Two loop, pressurized water	Pressurized water
Number of reactors	One	One	One	Two	One	One	Two	One	One	Three
Containment	120 ft diam steel sphere	92 ft by 44 ft steel cylinder	94 ft by 50 ft steel cylinder	63 ft by 24 ft steel cylinder	63 ft by 24 ft steel cylinder	63 ft by 24 ft steel cylinder	63 ft by 24 ft steel cylinder	73 ft by 28 ft steel cylinder	48 ft diameter steel sphere	None
Size of turbine-generators	22,000 kw	22,000 kw	27,000 kw	6,000 kw	6,000 kw	6,000 kw	6,000 kw	10,820 kw	11,500 kw	1,760 kw
Number of units	Two	One	Two	One	One	One	Two	One	Two	Three
Type of stand-by unit	260,000 lb/hr oil fired steam boiler	None	200,000 lb/hr oil fired steam boiler	None	None	1,100 kw diesel- engine generator	2,000 kw diesel- engine generator	None	160,000 lb/hr oil fired steam boiler	None
Number of stand-by units	One		One			Four	Four		One	
Rated capacity of plant	44,400 kw	20,700 kw	25,400 kw	10,800 kw	5,400 kw	6,000 kw	12,800 kw	10,000 kw	20,000 kw	4,635 kw
Net firm power	20,700 kw	0	15,000 kw	4,000 kw (6,000 kw average)	5,000 kw	5,400 kw	10,000 kw	0	10,000 kw	3,090 kw
Type of installation	Land based	Platform barge	C3 hull	Hardened	Land based	Hardened	Land based	EC2-S-C1 hull	C3 hull	Land based
Location	Kin	Tumon Bay	Barge basin	Camp Carson	Tract "E"	(Classified)	(Classified)	Inchon Harbor	Atlantic Ocean area	Naval Air Facility
PROJECT COST										
Total project cost	\$22,700,000	\$16,500,000	\$21,700,000	\$11,100,000	\$ 5,800,000	\$ 8,700,000	\$11,300,000	\$11,100,000	\$20,000,000	\$10,100,000
Government costs at 6% of total project cost excluding contingency	<u>1,210,000</u>	<u>880,000</u>	<u>1,160,000</u>	<u>600,000</u>	<u>310,000</u>	<u>470,000</u>	<u>600,000</u>	<u>600,000</u>	<u>1,070,000</u>	<u>530,000</u>
Total DOD budgeted cost	\$23,910,000	\$17,380,000	\$22,860,000	\$11,700,000	\$ 6,110,000	\$ 9,170,000	\$11,900,000	\$11,700,000	\$21,070,000	\$10,630,000
AVERAGE ANNUAL COST OF POWER										
Average annual operating and maintenance cost	\$ 360,000	\$ 437,000	\$ 597,000	\$ 308,000	\$ 239,000	\$ 235,000	\$ 324,000	\$ 358,000	\$ 384,000	\$ 382,000
Annual nuclear fuel cost	1,040,000	655,000	898,000	771,000	586,000	388,000	1,146,000	472,000	647,000	609,000
Average annual fuel oil cost	<u>179,000</u>	<u>- -</u>	<u>207,000</u>	<u>- -</u>	<u>27,000</u>	<u>17,000</u>	<u>71,000</u>	<u>- -</u>	<u>93,000</u>	<u>- -</u>
Total average annual operating, maintenance, and fuel cost	\$ 1,579,000	\$ 1,092,000	\$ 1,702,000	\$ 1,079,000	\$ 852,000	\$ 640,000	\$ 1,541,000	\$ 830,000	\$ 1,124,000	\$ 991,000
Cost per kwhr	5.4 mills	7.5 mills	8.2 mills (power cost only)	20.5 mills	19.4 mills	22.9 mills	17.6 mills	11.9 mills	7.6 mills	37.8 mills
Annual fixed charges (5% of total project cost)	\$ 1,135,000	\$ 825,000	\$ 1,085,000	\$ 555,000	\$ 290,000	\$ 435,000	\$ 565,000	\$ 555,000	\$ 1,000,000	\$ 505,000
Total average annual cost	\$ 2,714,000	\$ 1,917,000	\$ 2,787,000	\$ 1,634,000	\$ 1,142,000	\$ 1,075,000	\$ 2,106,000	\$ 1,385,000	\$ 2,124,000	\$ 1,496,000
Cost per kwhr	9.4 mills	13.2 mills	14.0 mills	31.1 mills	26.1 mills	38.4 mills	24.0 mills	19.7 mills	15.2 mills	56.6 mills
CONSTRUCTION PERIOD	42 months	41 months	38 months (power cost only)	26 months	24 months	25 months	25 months	30 months	36 months	29 months

TABLE 1 (cont'd)
SUMMARY OF POWER PLANT DATA AND COSTS
CONVENTIONAL POWER PLANTS

SITE	OKINAWA RYUKYU ISLANDS	GUAM MARIANA ISLANDS	THULE GREENLAND	NORAD USA	ASHARA ERITREA	SUPER SAGE USA	NIKE ZEUS USA	INCHON KOREA	ATLANTIC BARGE	McMURDO SOUND ANTARCTICA
POWER REQUIREMENT	40 MWe in 1963 (1st inc) 80 MWe in 1965	20 MWe in 1963	25 MWe Plus 150,000,000 Btu/hr of Heat in 1963	7 MWe in 1963 (4 MWe firm)	5 MWe in 1963	5 MWe in 1963 (3.2 MWe firm)	10 MWe (firm)	10 MWe in 1963	20 MWe in 1963 (10 MWe firm)	4.5 MWe in 1963 (3.0 MWe firm) 6 MWe in 1964
POWER PRODUCTION	1st INCREMENT Total yearly power produced Plant operating factor	145,000,000 kwhr 80%	178,000,000 kwhr 80%	52,600,000 kwhr 100% of average power	43,800,000 kwhr 100% of firm power	28,000,000 kwhr 100% of firm power	87,600,000 kwhr 100% of firm power	70,000,000 kwhr 80%	149,000,000 kwhr 80%	1st INCREMENT 26,300,000 kwhr 100% of firm power
POWER PLANT DATA	1st INCREMENT Type Size of boilers Number of boilers Size of turbine-generators Size of diesel engine generators Number of units Rated capacity of plant Net firm power Type of installation Location Type of fuel Average cost per gallon	Steam turbine- generator 200,000 lb/hr Two 22,000 kw 20,700 kw Land based Tinian No. 5 oil \$0.104	Steam turbine- generator 175,000 lb/hr Two 27,000 kw 15,000 kw C3 hull Barge basin Arctic grade diesel \$0.114	Diesel engine generator 1,500 kw Six 9,000 kw 4,000 kw (6,000 kw average) Hardened Camp Carson No. 2 diesel oil \$0.156	Diesel engine generator 1,250 kw Six 7,500 kw 5,000 kw Land based Tract "E" No. 2 diesel oil \$0.160	Diesel engine generator 800 kw Six 4,800 kw 3,200 kw Hardened (Classified) No. 2 diesel oil \$0.156	Diesel engine generator 2,500 kw Six 15,000 kw 10,000 kw Land based (Classified) Arctic grade diesel \$0.209	Diesel engine generator 2,500 kw Five 12,500 kw 7,500 kw C-1-M-AV1 hull Inchon Harbor No. 5 oil \$0.104	Steam turbine- generator 123,000 lb/hr Two 11,500 kw 20,000 kw 10,000 kw C3 hull Atlantic Ocean area No. 5 oil \$0.096	Diesel engine generator 800 kw Six 4,000 kw 3,000 kw Land based Naval Air Facility Arctic grade diesel \$1.10
PROJECT COST	Total project cost Government costs at 6% of total project cost excluding contingency Total DOD budgeted cost	\$10,200,000 570,000 \$ 8,130,000	\$11,100,000 620,000 \$11,720,000	\$ 4,700,000 260,000 \$ 4,960,000	\$ 2,915,000 160,000 \$ 3,075,000	\$ 3,800,000 210,000 \$ 4,010,000	\$ 5,300,000 290,000 \$ 5,590,000	\$ 4,700,000 260,000 \$ 4,960,000	\$ 7,100,000 390,000 \$ 7,490,000	\$ 4,100,000 216,000 \$ 4,316,000
AVERAGE ANNUAL COST OF POWER	Average annual operating and maintenance cost Average annual fuel oil cost Total average annual operating, maintenance, and fuel cost Cost per kwhr Annual fixed charges (5% of project cost) Total average annual cost Cost per kwhr	\$ 214,000 2,423,000 \$ 2,637,000 9.1 mills \$ 510,000 \$ 3,147,000 10.9 mills	\$ 292,000 1,245,000 \$ 1,537,000 10.8 mills \$ 385,000 \$ 1,922,000 13.3 mills	\$ 469,000 3,370,000 \$ 3,839,000 14.1 mills (power cost only) \$ 555,000 \$ 4,394,000 17.0 mills (power cost only)	\$ 163,000 624,000 \$ 787,000 14.9 mills \$ 235,000 \$ 1,022,000 19.5 mills	\$ 156,000 532,000 \$ 688,000 15.6 mills \$ 146,000 \$ 834,000 19.0 mills	\$ 126,000 331,000 \$ 457,000 16.3 mills \$ 190,000 \$ 647,000 23.1 mills	\$ 241,000 1,420,000 \$ 1,661,000 19.0 mills \$ 265,000 \$ 1,926,000 21.9 mills	\$ 272,000 520,000 \$ 792,000 11.3 mills \$ 235,000 \$ 1,027,000 14.7 mills	\$ 290,000 1,253,000 \$ 1,543,000 10.4 mills \$ 355,000 \$ 1,898,000 13.6 mills
CONSTRUCTION PERIOD	34 months	33 months	29 months	23 months	19 months	23 months	19 months	28 months	24 months	27 months