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AEC Research and
Development Report
UC-81, Reactors - Power
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**evaluation of single and dual
turbine-generator units
for PL-3**

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

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

EVALUATION OF SINGLE AND DUAL
TURBINE-GENERATOR UNITS
FOR PL-3

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Issued: March 1, 1962

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with U. S. Atomic Energy Commission
New York Operations Office

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ABSTRACT

This report describes the investigation performed relative to the selection of a turbine-generator unit for the PL-3 portable nuclear power plant, Byrd Station, Antarctica. The report surveys available conventional equipment to minimize air shipment, installation and cost requirements and considers pertinent details of functional performance. A comparison is drawn between the alternatives of utilizing either a single turbine-generator unit shipped partially disassembled or twin, half-capacity units shipped assembled. The conclusion reached is that a single turbine-generator unit should be used with the turbine and generator shipped separately.

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1.0 SUMMARY

This report describes investigations performed relative to the selection of the turbine-generator unit for use in the PL-3 nuclear power plant having a net output of 1000 KWe. The plant is designed for air transportation to the installation site at New Byrd Station, Antarctica.

Preliminary surveys indicated that no suitable turbine-generator unit is available that could be shipped as a complete assembly within the specified 20,000 pound weight limit. As a result, this study was undertaken to evaluate alternate arrangements of turbine-generator equipment which will meet specification requirements. The alternate arrangements investigated are:

Plant I - A single unit 1500 gross KWe turbine-generator shipped in two packages.

Plant II - Two identical units of 750 gross KWe each shipped pre-assembles in two packages.

Investigations of these plants were performed with respect to suitable turbine-generator equipment available, required control equipment and layouts of suitable plant equipment and structure. In comparing the plant components, consideration was given to the requirements for shipment, installation effort, alignment effort, material cost, reliability, at full and partial loads maintenance and operation.

Manufacturers of turbine-generators and control equipment were contacted to determine the characteristics of available equipment. Preliminary designs and estimates were developed to evaluate requirements for turbine-generator inter-connecting piping and electrical equipment and evaluate variations in other plant components resulting from the turbine-generator selection. These additional variations occur in the heat rejection system, fuel requirements, electrical equipment and plant housings.

It is concluded that the most favorable alternate solution is to use a single turbine-generator unit shipped in two packages (Plant I). This conclusion is based on a comparison of the two plants which estimates that Plant II requirements exceed Plant I by 39,500 pounds shipping weight, (which requires one additional plane load in each of the two construction seasons). 625 man-hours installation effort (three days construction time the first season and four days the second season) and \$108,000 in cost. The plants are about equal in alignment requirements, but Plant II is regarded less favorable with respect to maintenance and operation.

Plant II is regarded less favorable with respect to reliability at design load, but more favorable at loads up to half the design load. However, since full plant and camp back-up capacity is planned in diesel generator units, the more favorable reliability of Plant II for part load operation was not regarded as an overruling factor in arriving at the conclusion.

2.0 INTRODUCTION

This report describes investigations performed relative to the selection of the turbine-generator unit for the PL-3 portable nuclear power plant being designed by Alco Products, Inc. under U. S. Atomic Energy Commission contract AT(30-1)-2900. The plant must produce a net output of 1000 KWe to comply with the contract specification⁽¹⁾, and a required gross output of 1500 KWe is indicated by the requirements of the preliminary design. This plant will be transported by air and installed by U. S. Navy personnel at New Byrd Station, Antarctica. The report is prepared pursuant to the provisions of the above mentioned contract and in response to specific instructions of the Atomic Energy Commission⁽²⁾.

Preliminary surveys of currently available turbine-generator units indicate that all functionally suitable units exceed the specified, preferred, shipping package weight limit of 20,000 lbs if the turbine and generator are shipped pre-assembled on a common base frame. Consequently, it is necessary to investigate alternate power generation equipment arrangements which will comply with the specified shipping limitations.

One possible alternate arrangement is presumed to be precluded from this study because the specification defines that the plant output shall be at 60 cycles and that plant shipping requirements shall be kept to a minimum. Generation at 400 cycles would involve a substantially lighter turbine generator; however, if the entire net plant output must be converted to 60 cycles, the required conversion equipment would make the total weight greater than with generation at 60 cycles. If it were possible to generate at 400 cycles and convert only an essential portion of the net output to 60 cycles, than a substantial overall weight saving might be realized and the turbine-generator module could be shipped within the 20,000 lb limit. Further study of this alternative would be in order if it can be established that only a small percentage of the plant output requires conversion to 60 cycles.

Two alternate arrangements have been considered in detail and will be identified and constituted as follows:

- Plant I - A single unit 1500 gross KWe turbine-generator shipped in two packages.
- Plant II - Two identical units of 750 gross KWe each shipped pre-assembled in two packages.

These plants have been investigated with respect to suitable turbine-generator equipment available, required control equipment and layouts of suitable plant equipment and structure. In comparing these plant components, consideration was given to the requirements for shipment, installation effort,

alignment effort, material cost, reliability, maintenance and operation. The evaluation approach defines the difference in requirements between the two plants rather than the absolute values of each whenever this approach simplifies the extent of effort required in the study. The difference between the two plants is considered sufficient basis to substantiate a selection.

3.0 INVESTIGATIONS & DATA COMPILED

3.1 POWER GENERATION EQUIPMENT

Because a single turbine-generator unit exceeds the shipping weight limitations, it has been necessary to investigate what equipment is available which can be suitably arranged to comply with the shipping requirements. Preliminary design established basic plant characteristics, and vendors were contacted to obtain equipment data for comparing Plant I (single unit shipped in two pieces) with Plant II (dual units).

This section of the report enumerates items of equipment which are readily available and functionally suitable for use in the alternate plants. The investigation is limited to the items of equipment which are different between the plants.

3.1.1 Turbine-Generator

The turbine-generator unit is the primary variable between the two plants, and variations in other items of equipment are consequences of the differences in this item.

Six turbine-generator manufacturers were solicited for suggestions for the two proposed plants to determine size, weight, cost, field alignment requirements and reliability. The manufacturers contacted were General Electric, Westinghouse, Worthington, Allis Chalmers, DeLaval and Elliott. A satisfactory evaluation of differences between the plants was made from information received from several of these manufacturers.

All responding manufacturers indicated that no single turbine-generator unit which can be shipped complete at less than 20,000 pounds will comply with NEMA Standards for generator insulation. If a single unit scheme is selected, all manufacturers recommended either that it be shipped in two sections with the base frame split or with the generator removed from the base frame and shipped separately. All replies indicated no problem would exist with respect to shipping dimension limits. All recommended units utilize a gear drive and are designed for 300 psia steam and 6 in. Hg absolute exhaust pressure discharging to a single condenser.

3.1.1.1 Size, Shipping Weight, Cost and Steam Rate

The data on hand relative to size, weight, cost and steam rate of available turbine-generator equipment is summarized in Table 3-1.

Two manufacturers indicated a possibility of reducing the weight of a single 1500 kw turbine-generator unit to about 20,000 pounds by using special

TABLE 3-1

CHARACTERISTICS OF TURBINE-GENERATOR UNITS

Manu- facturer	1500 kw Unit			750 kw Unit			Increase for 2- 750 kw Units Compared to 1-1500 kw Unit		
	Plan Dimensions	Weight	Cost	Plan Dimensions	Weight	Cost	Weight	Cost	Steam Rate
A	14'-6x7'-3	T. Skid 17,500 G. Skid 18,300 <u>35,800</u>	142,000	12'-11x5'-8	less than 113,000 (not firm) 20,000 (not firm)			84,000	6%
B	13'x6'-9	T. Skid 14,450 G. Skid 13,500 <u>27,950</u>	-	11'x5'-4	19,450	-	10,950	-	6%
C	14'-6x5'-3	T. Skid 18,500 G. Skid 7,500 <u>26,000</u>	144,000	14'x5'-3	19,500	104,600	14,000	65,200	-
D	11'-6x8'-4 12'-2x6'-6	T. Skid 18,000 G. Skid 24,350 <u>42,350</u>	-						

Approximate Values for Comparison of Plants

12,500 # 74,700 6%

Note: Manufacturer's costs quoted are for Plant I & II comparison purposes only.

insulation (such as Class H) in the generator. Although this insulation is rapidly becoming commonplace, it is not currently covered by NEMA Standards and its resistance to extreme cold has not been demonstrated. Since further investigation is required prior to recommending this usage, these units are not included in Table 3-1. However, the possibility of demonstrating the suitability of these lighter units will be pursued during the final design; at this time, they will only be considered as lending support to the single unit scheme of Plant I.

3.1.1.2 Installation Effort

Manpower requirements to off-load, haul and position the turbine-generator equipment for the two plants are substantially equal. This is apparent when it is noted that Plant I requires the installation of two heavy skids (turbine skid and generator skid), and that Plant II requires two heavy turbine-generator skids. A discussion of the effort required to align the various components and make up shaft connections will follow.

3.1.1.3 Field Alignment Effort

The manufacturers were asked to comment on the extent of field work required to align the turbine-generator in Plant I compared to Plant II. The consensus indicates that the difference is not substantial. For Plant I, it will be necessary to align and connect the two base frame sections and to align and make up the shaft connection between the turbine and generator. For Plant II, although it will not be necessary to perform any base frame alignment and doweled connections, it will be necessary to make an alignment check and shaft connection on both units. It is considered mandatory that any unit shipped should have shaft connections free during shipment to prevent damage by forces imposed during transportation; thus, any unit will require an alignment check and shaft connection.

3.1.1.4 Reliability

With regard to the turbine-generator unit itself, it is apparent that Plant II, with dual 50 percent capacity units, will exhibit greater reliability to carry loads equal to 50 percent of design capacity or less. However, it is considered that Plant I will more reliably maintain loads in excess of 50 percent of design capacity, because the number of components which could fail is minimized. A turbine-generator should be regarded as a very reliable item of plant equipment, particularly after initial adjustments have been completed. With regard to initial operational adjustment requirements, past experience has shown that this can be problematical. The mathematical probability of initial operational difficulties must be regarded as greater with two units. Utilization of dual units will not enhance the likelihood of making the plant operational (for part load) at an earlier date. It is of interest to note that some manufacturers' experience is that the larger units generally tend to be more reliable than smaller ones.

3.1.1.5 Maintenance Requirements

There is consistent difference in routine maintenance requirements between large and small turbine-generator units. Consequently, it is evident that differences in maintenance requirements for the two plants will vary directly with the number of units involved.

3.1.2 Interconnecting Piping

Plant II will require additional piping and valving for interconnection of the turbine-generator units. Additional requirements exist in the main steam and exhaust steam lines, steam extraction lines, gland seal system, turbine drains and lube-oil system. The preliminary layouts shown as Figs. 1 and 2 indicate the basic piping requirements for the plants.

3.1.2.1 Shipping Weight, Cost and Installation Effort

The additional requirements for piping and valves were determined and estimates made of shipping requirements, cost and installation manpower requirements. The extra requirements of Plant II were estimated as:

Shipping weight	5000 pounds
Cost (materials)	\$8,000
Installation effort	100 man hours

3.1.2.2 Reliability

The variation between plants with respect to reliability of interconnecting piping and valves is not considered substantial. However, since additional items are required for Plant II, it must be considered that some unpredictable decrease in reliability exists because of these items.

3.1.2.3 Maintenance

With respect to variations in maintenance requirements, statements can be made similar to those made for reliability. No significant variation is anticipated, but the presence of additional components in Plant II can potentially increase maintenance requirements.

3.1.3 Control Equipment

Plant II, with dual turbine-generator units operating in parallel, will require control equipment which would not be required for Plant I. The control equipment will consist of governor controls used in conjunction with a load divider to prevent hunting and to obtain equal loading of the units for both real and reactive power. These functions must be performed under the specified load changes and transient conditions. A suitable arrangement of

FIGURE I. PRELIMINARY TURBINE ROOM LAYOUT PLANT I

FIGURE 2. PRELIMINARY TURBINE ROOM LAYOUT PLANT II

control would utilize a frequency sensing unit such as those manufactured by Leeds & Northrup or General Electric to control the two turbine governors.

3.1.3.1 Shipping Weight, Cost and Installation Effort

The preceeding described control system, representing an additional requirement of Plant II over Plant I, is a negligible item with regard to shipping weight and field installation requirements. A few hours of initial adjustment time may be expected. The cost of additional control equipment is estimated to be about \$2000.

3.1.3.2 Reliability

The load balancing control system presents an additional opportunity for malfunction to occur. This system could be designed to fail safe and not present a hazard to plant equipment, but it would necessitate manual operation procedures or possibly plant shutdown under an unfavorable sequence of events. The load divider is basically a very reliable item of equipment; however, as a result of the possibility of circuit failures, the reliability of Plant II is considered slightly lower than that of Plant I.

3.1.3.3 Maintenance

Comments on the effect of additional control equipment on the reliability of Plant II indicate that additional maintenance requirements can be anticipated because of the load divider. However, the frequency of maintenance needs can not be firmly predicted. Maintenance of this equipment will not require any specialized knowledge, but will require plant crew familiarization.

3.1.3.4 Operation

After initial installation and adjustment of the control equipment, normal operation will not require any substantial effort by the plant operator other than periodic monitoring of the additional parameters. However, in the event of control malfunction and continued plant operation, monitoring and manual adjustment of load will be continuously required of the operator.

3.2 VARIATIONS IN OTHER EQUIPMENT

As a consequence of the difference in turbine-generators between the two plants, differences in other plant components will exist. The increase in steam rate for Plant II is indicated in Table 3-1 to be in the order of 6 percent, resulting from the lower efficiency of the smaller units. This leads to increases in the heat rejection equipment and fuel requirements. Also, the dual units of Plant II require duplication of generator electrical connections, instrumentation and controls.

3.2.1 Heat Rejection Equipment

For the purpose of determining the variation between the plants in the heat rejection system, preliminary designs for both, consisting of a single condenser with a liquid coupling to air-blast coolers, were formulated. The higher steam rate required for Plant II will increase the duty imposed upon the condenser, the air blast coolers and the liquid coupling system between them; this increased duty must be provided for in the system design. Condenser variables which can be adjusted by design are tube surface area and coolant flow rate. Similarly, air blast cooler design variables are surface area and air flow velocity. The liquid coupling has the design variable of flow rate. All variables within the heat rejection system are dependent variables and adjustment of any of them changes equipment size and weight and/or changes auxiliary power requirements.

As the preliminary design indicates that the condenser module and the air blast cooler modules will approach allowable shipping weight limits for Plant I, a comparison between the two plants cannot be based on an estimate of increase in equipment size and consequent increase in shipping weight and cost. The remaining alternative is to base the comparison on auxiliary power capacity required by the heat rejection system's pumps and fans. Since all components of this system are affected by each dependent variable, an exact determination of the change in auxiliary power capacity caused by a change in system duty requires a more extensive study than is considered warranted for the purpose of this report. However, a significant indication can be gained by noting that an increase of 6 percent in steam rate results in an increase of slightly more than 6 percent in the power capacity required by the heat rejection system. Preliminary design estimates show that the system power requirement for Plant I is about 160 kw; hence, the increase of Plant II over Plant I is in the order of 10 kw. In the absence of a known value for the capital cost of an increment in kw capacity, an evaluation of the increase in plant capital cost is not possible, but it should be noted that a significant difference exists.

3.2.2 Fuel Requirements

The 6 percent increase in steam rate required for Plant II will be reflected in a reactor core life decrease of slightly more than 6 percent. As with the problem incurred above in evaluating auxiliary power capacity, the capital cost of an increment in core life can not be readily evaluated at this time. As a result, no cost evaluation is presented of the increased fuel requirement (shorter core life) for Plant II, but this is considered a significant disadvantage.

3.2.3 Electrical Equipment

In addition to turbine-generator control equipment, there is other extra electrical equipment required for Plant II, consisting of generator electrical connections, instrumentation and controls. Approximate estimates have been made of these items, showing the following results:

1. Generator electrical connections such as generator leads, circuit breakers, control transformers and other wiring cost \$7000 and ship at 2500 pounds.
2. Instrumentation and controls, including turbine and generator read-outs and control console addition, cost \$6500 and ship at 1000 pounds.
3. Installation effort required for additional electrical equipment is 280 man-hours.

3.3 VARIATIONS IN PLANT HOUSING

After determining the variations in equipment components for each of the two plants, the differences in plant housing requirements must be determined. These differences, reflected by the plant equipment arrangement layouts, exist in the building superstructure, foundations and snow tunnels.

3.3.1 Plant Arrangements

Plant equipment arrangement layouts have been determined for each plant with a view toward minimizing building space required to house the selected equipment.

Both plant layouts utilize buildings twenty feet wide by twelve feet high. These dimensions were selected with consideration given not only to the turbine room equipment, but also to the arrangement and space requirements of the other equipment comprising each plant. Further, consideration was given to standard modular building and tunnel dimensions.

3.3.1.1 Plant I Turbine Room Layout

The equipment layout for the turbine room of the single turbine-generator plant, shown in Fig. 1, indicates that the required length of turbine room is 61 feet.

In addition to attempting to minimize the space required in the turbine room, the following factors were considered in selecting the equipment arrangement:

1. To minimize interconnecting piping:
 - a. The secondary auxiliaries skid, the feedwater skid and the condenser skid should all be located as close together as possible.
 - b. The turbine-generator should be close to the condenser.
 - c. The condenser should be located near the air-blast coolers.

- d. The turbine lube oil equipment should be near the turbine.
- e. The turbine-generator skid and condenser skid should be near the entrance to the primary system.
- 2. To minimize generator main leads, the generator should be near the switchgear.
- 3. All turbine room equipment should be serviceable by overhead crane.
- 4. Provision should be made for laydown area for disassembly of any equipment.
- 5. Provision should be made for tube withdrawal space.
- 6. Piping and wiring runs should be:
 - a. Accessible for facility of installation and maintenance.
 - b. Out of the way of passages and work areas.

It is considered that the selected arrangement is the most satisfactory in achieving a rational compromise of these characteristics.

3.3.1.2 Plant II Turbine Room Layout

The equipment layout of the turbine room for the dual turbine-generator plant is shown in Fig. 2. The required length of the turbine room for this plant is 71 feet.

The preceding discussion of factors affecting the development of an equipment arrangement layout for Plant I is also pertinent to Plant II. Further, the layout for Plant II should locate the two turbine-generators close together to facilitate interconnecting piping and valve arrangement and to permit installation of both units on a common foundation. A common foundation eliminates the need for extensive construction effort in aligning two separate foundations with each other to permit subsequent installation of interconnecting steam piping. A common foundation also precludes differential settlement between the units and consequent stresses in the interconnections.

3.3.2 Building Superstructure

Variations in building superstructures can be determined from equipment arrangement layouts. Significant variations occur only in the turbine room. Although differences in equipment located outside this area do exist, as enumerated in Section 3.2, they affect space requirements negligibly. Review of the turbine room layouts shows that Plant II requires a 10 foot longer room than

Plant I, which results in a building volume increase of 2400 cubic feet for Plant II.

After differences in plant cubages were determined, variations in shipping weight of superstructure materials, installation effort and cost were estimated. Application of the known cubage difference to unit values of weight, manpower and cost determined in preliminary project estimates leads to approximate values representative of differences between the two plants.

3.3.2.1 Shipping Weight

The shipping weight of superstructure materials has been estimated to be 2.2 pounds per cubic foot of structure volume. The 2400 cubic foot differential thus indicates that the Plant II superstructure is about 5300 pounds heavier than Plant I.

3.3.2.2 Installation Effort

The manpower effort required to off-load, handle and erect the superstructure is evaluated at 0.02 man-hours per cubic foot. Thus, Plant II superstructure installation requires about 50 hours in excess of Plant I requirements.

3.3.2.3 Cost

Preliminary estimates of superstructure materials cost indicate a value of about \$1.50 per cubic foot. Thus, the Plant II superstructure cost exceeds Plant I by about \$3600.

3.3.3 Building Foundations

The variation between the plants with respect to building foundation requirements (including leveling devices) for shipping, installation and cost have been determined in a manner similar to that described above for the building superstructure. The 10 foot longer turbine room required for Plant II represents an increase of 200 square feet in gross foundation area. Since Plant II requires a second turbine-generator foundation (requirements for which are discussed separately), the area of this foundation (60 sq ft) should be deducted to determine the net increase in general building foundation area. The net value of 140 square feet can then be applied to unit values.

3.3.3.1 Shipping Weight

The shipping weight of general building foundation materials, as determined in preliminary estimates, is 22.6 pounds per square foot of foundation area. The net differential of 140 square feet between plants thus indicates that foundations for Plant II are about 3200 pounds heavier than for Plant I.

3.3.3.2 Installation Effort

Manpower requirements to off-load, haul and erect the building foundations were estimated at 0.67 man-hours per square foot. This value indicates that Plant II requires 95 man-hours more installation effort than Plant I.

3.3.3.3 Cost

The cost of building foundation materials was estimated to be about \$18 per square foot of building area, which indicates that foundations for Plant II exceed those for Plant I by about \$2500.

3.3.4 Turbine-Generator Foundation

Another variation between plants which results in differentials in shipping, installation and cost requirements is in the turbine-generator foundations.

Preliminary design effort led to a turbine-generator foundation representative of that which will be produced in the final design. A materials and manpower estimate was performed on this representative design. One such foundation is required for Plant I and two substantially similar ones are required for Plant II; hence, the difference between the two plants can be estimated as the requirement for one turbine-generator foundation. This foundation, as estimated, is independent of the general building foundations for vibration isolation and consists of a stiff, metal, truss or girder frame supported on stressed-skin bearing mats. Provision is also included to permit ballasting the foundation if it should be required for vibration control; however, it is assumed that ice or snow can be used as ballast, and no charge is assessed for shipping ballast.

It is presumed in this study that paragraph 2.4.2 of the specifications⁽¹⁾ does not intend to specifically require vibration isolation mountings which might be problematical, but intends to require that the design shall be such as to avoid hazard or interference with plant function caused by vibration.

3.3.4.1 Shipping Weight

The estimated turbine-generator foundation shipping weight is 10,000 pounds; this is the approximate extra requirement of Plant II.

3.3.4.2 Installation Effort

The turbine-generator foundation installation manpower requirement extra for Plant II is approximately 100 man-hours.

3.3.4.3 Cost

The extra turbine-generator foundation materials chargeable against Plant II is estimated to be \$3700.

3.3.5 Tunnels

No allowance has been made for variations in tunnel requirements, although the 10 foot difference in turbine room length between Plants I and II will result in variations. It is considered that the material shipping weight, installation effort and cost differences involved are negligible when compared to the magnitude of the other variables.

4.0 EVALUATION OF DATA AND CONCLUSIONS

It is concluded that if it is not acceptable to ship a single turbine-generator unit which weighs more than 20,000 lbs, the most favorable alternate solution is to use a single turbine-generator unit shipped in two packages (Plant I). It is considered less desirable to use dual, half-capacity units (Plant II).

The conclusion that Plant I is more advantageous can be substantiated by comparing requirements for shipment, installation effort, alignment effort, material costs, reliability, maintenance and operation. The evaluation which follows shows that Plant II requirements exceed Plant I by 39,500 lbs shipping weight, 625 man-hours installation and \$108,000 cost. The plants are about equal in alignment requirements, but Plant II is regarded less favorable with respect to reliability, maintenance and operation.

4.1 COMPARISON OF SHIPPING REQUIREMENTS

Since the problem under consideration with regard to the selection of turbine-generator equipment evolves as a result of shipping limitations, a determination of the difference between the total shipping requirements of the two plants is of prime interest. Table 4-1 summarized the additional requirements of Plant II. It should be noted that the extra for Plant II will require one additional plane load in each of the two construction seasons.

TABLE 4-1
ADDITIONAL SHIPPING REQUIREMENTS OF PLANT II

<u>Item</u>	<u>Additional Shipping Weight</u>
Turbine-Generator	12,500
Interconnecting Piping	5,000
Control Equipment	0
Heat Rejection System	0
Fuel Requirements	-
Electrical Equipment	3,500
Building Superstructure	5,300
Building Foundations	3,200
Turbine-Generator Foundation	<u>10,000</u>
	39,500

4.2 COMPARISON OF INSTALLATION REQUIREMENTS

A second item of substantial interest in making a selection between the two plants is the difference between the total manpower requirements for them as affected by the variation in turbine-generators. Table 4-2 summarizes the additional requirements for Plant II installation.

TABLE 4-2
ADDITIONAL INSTALLATION MANPOWER REQUIREMENTS FOR PLANT II

<u>Item</u>	<u>Additional Man-Hours</u>
Turbine-Generator	0
Interconnecting Piping	100
Control Equipment	-
Heat Rejection System	-
Fuel Requirements	-
Electrical Equipment	280
Building Superstructure	50
Building Foundations	95
Turbine-Generator Foundation	100
Total	625 man-hours

This value of additional manpower required should be regarded in the light of scheduling construction crew operations. Because of the required sequence of operations during plant installation, it is considered most rational to evaluate this additional manpower as requiring an average crew of four or five men one week longer to install plant II. Of this week, about three days are required for plant housing installation during the first season, and about four days are required for equipment installation during the second season.

4.3 COMPARISON OF FIELD ALIGNMENT REQUIREMENTS

As indicated in Section 3.0, no significant difference exists between the plants with respect to requirements of field alignment or realignment of turbine-generator equipment. It is expected that the alignment operations required for either plant can be performed with reasonable ease by competent personnel. The probability of occurrence of alignment difficulties is considered to be similar in both plants; it is anticipated that the use of a relatively rigid turbine foundation will minimize alignment problems.

4.4 COMPARISON OF COSTS

The difference which exist between Plant I and Plant II will result in a cost differential. The approximate additional materials cost of Plant II as determined in the preliminary estimates is summarized in Table 4-3.

TABLE 4-3
ADDITIONAL MATERIALS COST FOR PLANT II

<u>Item</u>	<u>Additional Cost</u>
Turbine-Generator	\$ 74,700
Interconnecting Piping	8,000
Control Equipment	2,000
Heat Rejection System	- *
Fuel Requirements	- *
Electrical Equipment	13,500
Building Superstructure	3,600
Building Foundations	2,500
Turbine-Generator Foundation	3,700
	<u>\$ 108,000</u>

*These items incur additional costs which cannot be readily estimated at this time.

4.5 COMPARISON OF RELIABILITY

In making a selection, some consideration must be given to the relative reliability of the two plants. This consideration should include general conditions of plant operation, the specific condition of low-load operation and the specific condition of heavy-load operation.

In regard to general conditions of plant operation, a disadvantage in Plant II should be recognized as a result of additional piping and valves, controls for parallel operation, generator electrical connections, instrumentation and controls. These additional components must be regarded as increasing the probability of malfunction, which results in lower reliability for Plant II. Further, the experience of turbine-generator manufacturers indicates that larger units generally tend to be more reliable than smaller units; the dual units of Plant II are regarded as increasing the probability of malfunction both in initial operation and subsequent plant life.

In regard to the specific condition of low-load operation, Plant II, with its dual turbine-generator units, exhibits a greater reliability to carry loads equal to 50 percent of design capacity or less. For this New Byrd Station application, the ability to generate part load in the event of a single failure may be of value, although the probability of failures is greater.

Considering the specific condition of high-load operation (in excess of 50 percent of design capacity), Plant I shows greater reliability to maintain load, since the probability of malfunction is reduced by the lower number of components.

In considering reliability of the two plants, it should be kept in mind that it is planned to provide auxiliary diesel generator capacity to back-up the loads of both the plant and the camp.

4.6 COMPARISON OF MAINTENANCE

Brief consideration of relative maintenance requirements is in order when making a selection between the two plants. Additional piping and valves, controls for parallel operation, generator electrical connections, instrumentation and controls necessitates increased maintenance for Plant II. Maintenance of turbine-generator units may be facilitated in Plant II if the camp load permits scheduling shutdown of individual units. However, in either plant, all major turbine-generator maintenance could be scheduled during refueling of the reactor.

4.7 COMPARISON OF OPERATION

The final factor which may be given consideration as a variable is the requirement for operation. Plant II is regarded to have a disadvantage because it requires the plant operator to duplicate monitoring and control functions. In addition, the load balancing equipment for the dual units requires periodic monitoring of additional parameters. Further, in the event of a malfunction in the load balancing equipment, the operator will be required to continuously monitor and manually adjust the loads to the units if plant shutdown is to be avoided.

5.0 REFERENCES

1. U. S. Atomic Energy Commission, New York Operations Office, Appendix B - Technical Provisions to Contract No. AT(30-1)-2900 Alco Products, Inc., Dated September 15, 1961.
2. Letter from Capt. T. W. Dowler, U.S. Atomic Energy Commission, New York Operations Office to Mr. N. F. Taylor, Alco Products, Inc., Dated December 7, 1961 (RA:TWD:2900/7.10).