NUREG/CR-3840

Cost Analysis for Potential Modifications to Enhance the Ability of a Nuclear Plant to Endure Station Blackout

Prepared by R. A. Clark, B. J. Riordon, W. R. Thomas, B. E. Watlington

Science and Engineering Associates, Inc.

MATHTECH, Inc.

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ABSTRACT

Cost estimates were required to serve as partial bases for decisions on four potential nuclear reactor facility modifications being considered in the resolution of USI A-44, Station Blackout. The modifications constituting the four Subtasks in this report are:

1. Increasing battery capacity
2. Adding an AC-independent charging pump for reactor coolant seal injection
3. Increasing condensate storage tank capacity
4. Increasing compressed air supply for instrument air

Science and Engineering Associates, Inc., established the engineering requirements for the facility modifications; MATHTECH, Inc., supported the effort by estimating costs related to those modifications. The cost estimates contained in this report include those for the following:

1. Engineering and design
2. Equipment, material, and structures
3. Installation
4. Present worth of the annual operation and maintenance over the remaining useful life of the reactor

In addition to providing engineering requirements for the four modifications, SEA, Inc., evaluated the potential for synergistic solutions. It was found that some modifications to provide for reactor coolant seal injection would effectively satisfy the DC system augmentation requirements, with the costs

for solving both problems being competitive with that of additional batteries alone. SEA Inc. also identified an innovative potential solution to the DC system capacity problem through the use of high energy density primary batteries which would be far more cost effective than the addition of traditional lead acid batteries for mitigating extended station blackout effects.

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1.0 INTRODUCTION AND TASK OBJECTIVES

This report describes engineering evaluations and cost estimates for potential modifications which would enhance the ability of a nuclear plant to endure a station blackout condition. The work was done for the Nuclear Regulatory Commission's Cost Analysis Group within the Office of Resource Management as a part of the effort to resolve USI A-44, Station Blackout. As directed by the NRC, the following modifications were considered:

1. Increasing battery capacity
2. Adding an AC-independent charging pump for reactor coolant pump seal injection
3. Increasing condensate storage tank capacity
4. Increasing compressed air supply for instrument air

The engineering work and management for this project was the responsibility of Science and Engineering Associates, Inc. (SEA). A subcontractor, MATH TECH, provided cost analyses for each option. Due to contractual obligations, this entire task was accomplished in two months. This includes information gathering, engineering, and cost analyses, NRC reviews, and preparation of the final report.

Analyses were performed for two base case reactors, in particular, an operating PWR (ANO-1) and an operating BWR (Quad Cities 1). In addition, upper and lower bound cost estimates were also made to reflect design differences between the base case reactors and other plants. The base case plants were chosen from a group of 3 PWR and 3 BWR candidate plants provided by NRC.

The final selection of ANO-1 and Quad Cities 1 was based on the type and amount of plant specific information SEA personnel could gather within a short time. Engineering material used to analyze the base case plants included various plant layout drawings, piping and instrumentation drawings, electrical one line drawings, and dated versions of Final Safety Analysis Reports. In addition, SEA also used the recently published Arkansas IREP study. Even with this information, however, various plant design and construction details, which could only be obtained from site visits, were not available. As will become apparent in the following sections, the lack of this information introduced uncertainties into the final results.

The basic approach used in this analysis was to handle each subtask individually with emphasis placed on the first 3 subtasks, as directed by the NRC. In view of some of the areas of commonality recognized in Subtasks 1, 2, and 3, information was shared to reduce the overall effort level. In addition, it was recognized that certain candidate modifications are common to these subtasks and, therefore, cost estimates for synergistic solutions were also made.

1.1 ASSUMPTIONS

The cost estimates were made in accordance with the following general assumptions which include those proposed by NRC.

1. Modifications will be made during normal plant operation or during scheduled shutdowns such that no replacement energy cost will occur;

2. Occupational radiological exposure during installation and subsequent operation and maintenance of the added equipment will be minimal or zero and will not be included as an increment of cost;

3. Socio-economic impacts will be considered as being minimal and, therefore, will not be included as an increment of cost;

4. All equipment, structures, etc., added to implement the proposed modifications will not be designed to meet seismic category requirements;

5. All equipment and components added to implement the proposed modifications located outside containment will not require harsh environment equipment qualification;

6. To ensure reliability, all electrical components and equipment will be assumed to meet class 1E requirements (other than seismic) and the quality assurance in design and installation afforded safety grade components.

The cost estimates provided were based on best available cost information. Uncertainties or ranges of cost were acknowledged where necessary. The cost and engineering design information provided in reports issued by EG&G[1] and Sandia National Laboratories[2] were used as examples in the analysis. The cost analysis was limited to:

1. Engineering and design costs

2. Cost of equipment, materials, and structures

3. Installation cost (labor and associated overhead including supervisory personnel).

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[1] Study of the Value and Impact of Alternative Decay Heat Removal Concepts for Light Water Reactors NUREG/CR-2883, SAND82-1796, June 1983.

[2] Cost Analysis for Enhancement of DC Systems Reliability and Adequacy of Safety Related DC Power Systems, EG&G-RE&ET-6151, January, 1983.

The present worth of the annual operation and maintenance cost (associated with the added equipment, etc.) over the remaining useful life of the reactor (25 years) was also calculated.

1.2 COST ESTIMATES

Costs for the various options have been calculated according to standard engineering practice. Such standard practice involves an initial design and the compilation of equipment and work specifications. Each specification is assigned a cost based on conventional labor hour and material factors. These costs are accumulated to the subtask level, adjusted for predictable factors, and then built up to reflect the actual cost to a utility.

The following sections explain the methodology, data sources and key parameters used in the cost derivations. Following this discussion, the actual costs are summarized and interpreted.

1.2.1 Sources of Information

Cost estimates for the four options were developed from two types of sources -- (1) standard construction cost handbooks and (2) telephone quotations from vendors. This information was then reviewed and adjusted, as necessary, according to the contractors' experience and judgement. As shown in the detailed cost worksheets (see Appendix A through D), a one-line description is listed for each item in the engineering specifications. Given these descriptions, comparable information was then obtained on (1) material unit costs, (2) unit labor

hours, and (3) labor rates (columns 2, 3, and 5 of the work-sheets, Appendices A, B, C, and D).

Estimates on material unit costs and labor hours were taken mainly from cost information manuals. The primary source was McGraw-Hill's 1983 Dodge Manual for Building Construction Pricing and Scheduling. This manual lists the unit costs of specific material (e.g., two inch galvanized rigid steel underground conduit) and the amount of labor necessary to install it. If a particular item was not included in the Dodge Manual, the prime supplemental source was R.S. Means' 1983 Edition of Mechanical and Electrical Cost Data.

Cost estimates for several specialty items (e.g., steam turbine generators) were not available from these published sources. Their prices were supplied through telephone quotations by vendors. Prior to these contacts, The Handbook of New and Used Construction Equipment Values, published by The Equipment Guidebook Company, was consulted to identify appropriate manufacturers. These vendors were then contacted, read the specifications of the equipment and asked to quote a price. All estimates obtained from vendors were upper bound or conservative prices that excluded any discounts for bulk purchases, inventory adjustments, etc.

Hourly wage rates for construction trades also were taken from 1983 Dodge Manual. The rates represent the total cost to the contractor including base rate, fringes, insurance, taxes and other overhead allowances. In addition these rates incorporate a composite crew rate, which includes the total hourly rate of the particular occupation plus a portion of the

hourly wages for allied workers. For instance, the fully loaded 1983 rate for an electrician is derived as follows:

Composite Crew Rates			
Electrician Foreman	$20.40/hr	20%	4.08
Electrician	19.90	100%	19.90
Equipment Operator	23.45	10%	2.34
Laborer	17.80	10%	1.78
			$28.10/hr

1.2.2 Productivity Adjustment

Standard labor hour estimates for particular tasks are stated in units of effective time, that is, the actual work time to do the job. Such units ignore nonproductive time that occurs inevitably in conjunction with each job. The ratio of effective to total labor hours is termed the productivity rate. For example, if six hours of each eight hour day are spent on productive work, the productivity rate is 6/8 or 75 percent.

Even under the best of circumstances, productivity is unlikely to be more than 75 percent. Since construction personnel are paid portal-to-portal, a half hour must be allowed each day for travel from gate to site and for work preparation. The same must be added at the end of the work day for termination, clean-up, etc. In addition, breaks in the morning and afternoon lose another quarter hour apiece, plus additional time for unscheduled breaks, fixing tools, random socializing, etc.

The productivity factor deteriorates rapidly as additional factors come into play: restrictive work rules, hazardous

conditions, severe weather, material shortages, difficult site conditions. This analysis presupposes a base case of 67 percent productivity, with a high and low case of 50 percent and 75 percent, respectively. In addition, in those cases where labor hours must be spent inside the containment building (it is assumed that the plant continues to operate), those hours are adjusted to half the non-containment productivity rate (i.e., 37.5, 33 and 25 percent) to compensate for the difficulty of the working conditions. For example, a two hour task at 50 percent productivity (one hour effective labor) outside the containment would take 4 hours at 25 percent productivity inside the containment building.

Labor and material costs are also broken down to show these costs associated with the installation of safety related equipment and those associated with necessary changes in civil structures.

1.2.3 Geographic Variation

Cost estimates will vary with the geographic location of the site. These variations are due to differences in local material and equipment prices, labor wage scales and transportation costs. In addition to listing unit cost data, the Dodge Manual contains a locality adjustment index for 152 U.S. cities. With 1.00 as a base, this index provides adjustment factors for relative material, labor and overall costs in a given city.

This index was reviewed to determine appropriate geographic adjustment factors for this analysis. Generally, an inverse relationship existed between the labor and material

indices of a city. For example, labor rates in rural areas might be lower due to lack of unionization, while material costs would be higher due to increased distance from major manufacturing centers. For a high percentage of cities, however, the overall cost variations range between ± 15 percent of the base. Given this tendency, this analysis selected 85, 100, and 115 percent as geographical adjustment factors in the low, base and high cases, respectively.

The high and low geographical adjustments are combined with high and low productivity adjustments to form extreme upper and lower bounds for the cost estimates. These bounds are very likely to encompass almost all cost figures, except those associated with very unusual design or site considerations.

1.2.4 Engineering and Quality Control

In this report, engineering and quality control costs are considered together. Engineering normally refers to site inspection and initial estimation, design and specification preparation and review, and drafting and plan preparation. Quality control includes quality design specification, field inspection and documentation, and acceptance testing. The combined costs are estimated as a percentage of the installed cost of a complete system.

This analysis selected a 25 percent factor, which is widely used by Architech and Engineering (AE) firms. Approximately 20 percent can be allocated to engineering costs and five percent to quality control. In certain cases quality control costs might be notably higher, for instance where Nuclear

Steam Supply System (NSSS) components and significant welding are required.

1.2.5 Contractor's Overhead and Fee

The prime contractor can always be expected to charge an additional amount to cover his overhead items and to provide a profit over and above costs. Overhead items would typically include management, accounting and administrative services, rent, office supplies and equipment, insurance, and a number of other fixed expenses. The conventional rate charged is approximately 25 percent of the sum of installed cost plus engineering and quality control costs.

1.2.6 Periodic Costs

In addition to the costs associated with the initial installation of new plant systems, future costs associated with the operation and maintenance of the systems and replacement of components have been estimated. To place the proper perspective on future costs, the future life of a typical nuclear plant was assumed to be 25 years. Yearly expenditures for operations and maintenance were estimated and also converted to present worth using a ten percent rate and a present value factor for a 25 year stream of expenditures. Inflation estimates were not applied since results were desired in constant dollars.

1.2.7 Contingency Allowance

The figures calculated for this report include explicit allowance for normal variation in conditions affecting labor productivity (union rules, unusual site conditions, weather, etc.) and for geographical variation in labor and material costs. They do not include allowance for abnormal occurrences or for radical changes in engineering design.

In addition, response to regulatory initiatives can involve costs of a procedural nature. Such costs would include response to NRC interrogatories, meetings with regulatory personnel, preparation of formal reports, staff training, and other activities unrelated to the actual installation and operation of new safety systems. Allowances covering the above items are often incorporated arbitrarily into a "contingency" figure and added directly to the estimate. Such a practice increases these cost estimates by substantial amounts. Thus, conventional cost estimates based on the same physical characteristics could easily exceed those shown in this report.

2.0 SUBTASK 1: INCREASE BATTERY CAPACITY

2.1 INTRODUCTION

The objective of this subtask was to develop cost estimates for extending the capacity of the DC system considering the following two alternatives:

1. Adding batteries
2. Adding a battery charger independent of the (existing) AC power system

For the first alternative, cost estimates were required for extending the capacity of the DC system from 4 to 8 hours and from 4 to 16 hours. In addition, the contractor was to determine whether space in the existing battery rooms would be sufficient to accommodate the expansions and to consider the ability of the plants to shed non-essential loads as a means of extending existing capacity.

2.2 ASSUMPTIONS

The following assumptions were deemed reasonable and appropriate to the effort and served as a basis for the cost estimates:

1. The existing DC system in each plant studied has the capacity to satisfy DC power requirements for 4 hours under station blackout conditions.
2. The added systems must be capable of meeting loads similar to those imposed upon the existing system under blackout conditions.
3. The added systems perform operational functions only during blackout conditions.
4. Added batteries must meet physical isolation requirements similar to those imposed on the existing batteries to prevent failure propagation.

5. Cross-tie capability between units at some plants was not considered a blackout negating factor since the entire plant would be experiencing blackout.

2.3 TECHNICAL APPROACH

Technical data available to the contractor were reviewed to identify requirements for DC systems augmentation, determine acceptable locations for additions, and to develop integration schemes which allowed the additions to be brought on line during blackout without degrading the reliability of the existing systems during normal operations. For the first alternative, batteries were sized corresponding to multiples of existing capacity, the multiple depending on the expansion option. Chargers associated with the added batteries were sized to charge and maintain the new batteries only; these chargers were not intended to provide power to the DC bus system. Charging rates were chosen to approximate those of the existing battery system to prevent operational impacts imposed by the added batteries. As a result, the chargers will impose a minor load on the AC system only during periods when the new batteries are in a low charge state (e.g., prior to start up) and a negligible load at all other times. The interfaces between the added batteries and the DC buses consist of the two-pole circuit breakers that are maintained open during normal operations. The cost analysis for battery additions include those associated with batteries, racks, chargers, breakers, conduit and wiring, monitors, and any necessary facilities. Zone III racks were specified for all battery installations since the cost differential

represents a minor portion of the system cost and since, in accordance with advice received from power supply vendors, the use of these racks reflects good engineering practice for this type of installation.

For the second alternative two sources of electrical energy were considered; these sources, when aligned with existing chargers, would represent chargers independent of the existing AC power system. The two energy sources considered were a diesel driven generator and a gas turbine (diesel fuel option) driven generator. The potential for very high current surges over and above steady state loads was factored into the sizing of the generators. Electrical interface between the 480 Volt 3 phase generators and the 480 volt buses is accomplished by three pole circuit breakers normally maintained in the open position. Cost estimates for these modifications are summarized in Section 6 and provided in detail in Appendix A.

2.4 SUBTASK 1 MODIFICATIONS

2.4.1 Alternative 1 - Adding Batteries

2.4.1.1 PWR

The DC power system for the selected PWR consists of two 125 volt DC divisions per unit, each division having its own battery and battery charger, plus a swing charger capable of providing power to either division. Each battery consists of 60 cells with a capacity of 1350 ampere - hours.

Plant drawings were evaluated to determine whether sufficient space exists in the battery rooms to accommodate additional battery strings. Based upon indicated equipment

sizes, additional batteries could not be installed in existing battery rooms because of the necessity for additional space for access (maintenance, testing, and cell replacement) and the requirement for physical isolation (fire walls) between battery strings. It was therefore concluded that new facilities would be required for either expansion option at the PWR. A candidate location, shown in Fig. 1 was selected to minimize conduit runs and pose minimum interference problems with other plant facilities and operations.

Cost estimates were developed for two expansion options which include the addition of two 1350 ampere-hour (4-hour expansion) and six 1350 ampere-hour (12-hour expansion) batteries. Electrical diagrams showing how the 4-hour and 12-hour expansions interface with the existing system are provided in Figures 2 and 3, respectively.

2.4.1.2 BWR

The DC power system for the selected BWR consists of a 250 volt 913 ampere-hour battery, for high energy demand loads, and a 125 volt 498 ampere-hour battery, for instrumentation, illumination, etc., installed in each unit. The 250 volt battery consists of 120 cells while the 125 volt battery has 60 cells.

Plant drawings were evaluated to determine whether sufficient space exists in the battery room to accommodate the additional batteries. It was determined that new facilities would be required for battery additions. A candidate location, shown in Figure 4, was selected to minimize conduit runs and pose minimum interference problems with other plant facilities and

operations. Cost estimates were developed for two expansion options which include: a) the addition of one 125 volt 500 ampere-hour and one 250 volt 900 ampere-hour battery (4-hour expansion) and b) the addition of three each of these batteries (12-hour expansion). Electrical diagrams showing how the 4-hour and 12-hour expansions interface with the existing system are provided in Figures 5 through 8.

2.4.2 Alternative 2 - Adding a Battery Charger Independent of the (Existing) AC Power System

Cost analyses for two approaches for providing independently derived electrical power to essential functions were developed; these consisted of a gas turbine/generator and a diesel driven generator. By tying the 480V three-phase outputs to the appropriate buses, the generators in combination with the unit chargers would constitute the required subtask sytem. An advantage to this approach is that the instrumentation inverters would be provided an AC source thereby relieving the DC buses of inverter loads.

The primary motivating factor for considering a gas turbine/generator for this role was that, since the gas turbine operating principle is different from the station diesels and since the gas turbine has about one-tenth the number of moving parts compared to reciprocating engines, the potential for maintenance induced common cause failure should be significantly less for a gas turbine than for an additional backup diesel. The cost of the liquid (diesel) fuel option was estimated since diesel fuel is already available as emergency fuel and would not introduce any new handling or storage problems. New facilities to house the

turbine and diesel generator sets were planned for the same locations used in the battery cost analyses.

2.4.3 Load Shedding

During a station blackout the DC power system performs several functions. These are, in general:

a. Emergency Illumination

b. DC Motor Operated Valve (MOV) Operations

c. Instrumentation and Displays

d. Station Diesel Control, Field Flashing

e. Switchgear Control

f. Computer

g. DC Driven Emergency Oil Pumps

The first five functions (a through e) are Class 1E and must remain operable, to varying degrees, throughout the blackout period. The computer should be shutdown shortly into the blackout period and the plant revert to manual control. The DC driven emergency oil pumps, which protect major equipment during coastdown following a reactor trip with AC power outage, are very large but short duration loads.

The following represents loads, attributable to these seven functions, gathered from Safety Analysis Reports (SARs) and other studies performed on blackout conditions.

a. Emergency Illumination

During the initial stages of station blackout emergency illumination is essential to allow evacuation of personnel, alignment of DC MOVs, control of lube oil pumps, purging of H_2 from the main generator, and investigation of causes for failure of the diesels to start. Initial actions should be completed within 15 minutes with spot lighting needed for main generator purging, diesel

inspection, and limited areas of the control room. After 30 minutes the generator purge should be completed and limited emergency and portable lighting could be used for remaining activities. The electrical load imposed by the emergency illumination is a nominal 100 amps at 125 volts.

b. DC MOV Operations

DC operated valves are nominally rated at 2 hp and are installed to permit realignment of the plant to an optimum configuration in the event of loss of all AC power. The normally assumed time of operation of a DC MOV is one minute. Many of the DC MOVs will already be in the desired position at the onset of station blackout; in addition, most will be accessible for manual operation. For the purpose of the evaluation, it is assumed that realignment of the plant requires operation of 30 MOVs of which 15 are operated electrically. The energy demand for this loading on the DC Bus is 30 hp-minutes or 6 ampere-hours at 125 volts (24 amp over a 15 minute duration).

c. Instrumentation and Displays

The instrumentation inverters represent a significant load, both in terms of power demand and period of operation, on the station batteries. The universal approach, as is the case for the two facilities evaluated, is to have four instrumentation channels each of which monitor an entire set of plant parameters. Outputs of individual monitors are transmitted to logic units; the logic units will usually provide a trip signal only if more than one monitor indicates a condition outside the envelope permitted for a particular operational status. The basic motivation for more than one channel is to assure that reactor scram will occur for unsafe conditions; the need for four channels with the associated logic is for avoidance of erroneous trips (primarily an economic concern). Once station blackout occurs with the reactor shutdown, the instrumentation has achieved one of its major functions. Although monitoring of the NSSS remains essential, four channels of full range instrumentation are no longer a reasonable requirement. Therefore, after shutdown has been assured, two instrumentation inverters with associated loads should be sufficient to determine plant conditions. It is assumed that the remaining channels could be activated on demand to provide additional confidence in the instrumentation being used. Typical loads imposed by instrument inverters are 75 amps at 125 volts each.

Display lighting for a typical reactor instrumentation provides a load of 20 amps. Actual load for the BWR is 16 amps; specific load for the PWR could not be obtained but should not deviate excessively from that of the BWR. Display power is provided by 125V batteries at both reactors.

d. Station diesel control and field flashing power for the station diesel, provided by the Class 1E batteries, represents a relatively minor load, 10 amps nominal. However, it still appears wasteful to provide this power continuously (as opposed to on request) for diesels undergoing repair. Field flashing occurs during start attempts to establish the initial magnetic field for the generator; this load, rated at 2 amps, is therefore intermittent (several start attempts) for an accumulated duration of one minute. The energy allocated for diesel start attempts, at 12 amp minutes, 125 VDC, is too small for further consideration.

e. Switchgear Control

Switchgear operations for blackout conditions occur basically during the first minute. During this time attempts are made to restore AC and load stripping is accomplished in preparation for the diesels to come on line. This activity represents a high current short duration load. Based on other examples, a demand of 260 amps, 125 VDC, for 1 minute is attributed to this function. This load is appropriate since neither reactor has separate switchyard batteries.

f. Computer

Many nuclear plants use separate uninterruptable power supplies with dedicated batteries to assure computer survival during short power outages. No computer loads were identified on the Class 1E DC Busses for the plants investigated and, therefore, it is concluded that at these two facilities, the computer does not load the Class 1E batteries during power outages.

g. DC Driven Emergency Oil Pumps

DC Bus loads were identified at both facilities for emergency lube oil pumps providing coast down lubrication for large rotating equipments such as Reactor Coolant Pumps (RCPs), feedwater pumps, and the main turbine-generator. These motor loads, although associated with specific components peculiar to the reactor type, represent similar functions with the same approximate demands in power and in duration on both the PWR and BWR. With the exception of the main generator H_2 seal oil pump (7 HP Nominal), these loads can be terminated when the equipment comes to rest. The hydrogen seal oil pump must remain in operation until the H_2 is purged from the generator.

The basic philosophy to load shedding for the purpose of extending battery life is to divest the system of all loads not performing essential functions. Based upon that philosophy, Table 1 portrays an extended load cycle for station blackout. Based on Table 1, a nuclear reactor could endure a blackout situation for a period of 8 hours with an expenditure of 923 ampere hours at 125V DC with each additional hour consuming 190 ampere hours. To translate these findings to the cases evaluated, it should be realized that the discharge capacity of batteries is heavily dependent upon discharge conditions (temperature and loads) as well as the original battery health condition (which is not likely to be known with great accuracy). Therefore, the actual capacity is derated to 60% of the assigned capacity as a conservative measure for the following evaluation:

a. The PWR Class 1E batteries consist of two banks of 1350 Amp-Hr 125V batteries. Derating to 60% yields a combined capacity of 1620 amp hrs. Based upon Table 1, these batteries could maintain the plant for a period of 11.6 hours under blackout conditions.

b. The BWR Class 1E DC busses are powered by one 913 Amp-Hr 250 volt and one 498 Amp-Hr 125V battery. The stored energy equates to 2324 Amp-Hr at 125 VDC or 1394.4 Amp-Hr, 125 VDC, after derating. Based upon Table 1, the BWR could endure blackout condition with Table 1 load shedding for a period of 10.4 hours.

Table 1. Blackout Load Cycle

Load (Amps)	Elapsed Time (Min After Loss of AC) 1	2	15	30	60	120	240	480
Inverters	300	300	300	300	160	160	160	160
DC Lighting	100	100	100	50	25	10	10	10
Switchgear	260	-	-	-	-	-	-	-
DC MOVs	24	24	24	-	-	-	-	-
Displays	20	20	20	20	20	20	20	20
Emergency Oil Pumps (80 HP Total)	530	530	-	-	-	-	-	-
H_2 Seal Oil Pump (7 HP)	50	50	50	50	-	-	-	-
Total Load (Amp)	1284	1024	494	420	205	190	190	190
Accum. Consumption (Amp Hrs)	21.4	38.4	145.5	250.5	356	543	723	923

2.5 Quiet Systems

SEA, Inc. conducted a survey of industry and available literature to obtain technical information on new state-of-the-art electrochemical energy storage systems for the purpose of estimaing the potential of these systems as an improved solution to the reserve energy problem associated with station blackout. An improved solution should provide reasonable cost, simple implementation, and minimal or zero maintenance while meeting the basic energy requirements supplied by straight forward lead acid battery additions. To meet these criteria, the investigation focused on sealed systems with extremely long shelf lives. Although limited in time and other resources expendable for this portion of the effort, SEA has identified a more economical solution to the battery expansion problem than paralleling additional banks of traditional lead acid batteries. Two different approaches were found to have direct application to the station blackout; both have been evaluated, and one selected, for application to a very similar military situation.

The first approach uses lead acid batteries with immobilized electrolyte consisting of sealed cells with a nominal voltage of 2 volts/cell. Batteries can be constructed of series strings of cells sized according to anticipated energy demand. Like typical lead acid batteries, this battery can be recharged. Unlike typical lead acid batteries, however, the fixed electrolyte battery does not vent, requires no maintenance and has a virtually unlimited storage life (10 years if exercised). The following characterize this type of battery:

Energy Density: 2277 W hr per cubic foot or
11.32 W hr per pound

Cost: 1.125 W hr per dollar

Scaling these factors to the 4 hour expansion case, the following would be appropriate for the PWR and BWR:

a. PWR

Required Capacity: 1,350 A hr X 125 V = 168,750 W hr per battery

Fixed Electrolyte Batteries (Requires two):

Cost: $150,000 for each 125 V 1350 A hr battery

Volume: 74.1 cu. ft., each battery

Weight: 14,906 lb., each battery

b. BWR

Required Capacity:

(1) 498 A hr X 125 V = 62,250 W hr

Fixed Electrolyte Battery:

Cost: $55,340

Volume: 27.33 cu. ft.

Weight: 5,498 lb.

(2) 913 A hr X 250 V = 228,250 W hr

Fixed Electrolyte Battery:

Cost: $202,890

Volume: 100.23 cu. ft.

Weight: 25,600 lb.

The foregoing calculated costs are for the batteries only, based upon recent quotations to a defense agency for 32 volt 600 Amp-Hr modules. Weight and volumes are based upon these same modules and includes the cells, intercell straps, and metal

enclosures. The installed costs, if a new building were constructed, would exceed that previously extimated for the vented lead acid batteries with maintenance and replacement (if the batteries are not used) costs deleted. However, the non-venting characteristic of these batteries make them more adaptable to locations not suitable for traditional batteries, and it is likely that available space near existing battery rooms could be found in many facilities.

The second approach is the use of the lithium (lithium thionyl chloride) primary battery. Development of large lithium batteries has been accomplished during the past few years due to newly surfaced requirements for high energy density, long shelf life, inconspicuous sources of standby emergency electrical energy. Previously lithium batteries had only been used for small applications requiring high reliability, long life, and low power (e.g., pacemaker applications). The major large scale requirement that surfaced was that for the MinuteMan III ICBM post attack survival. In that application, the need for large sources of electrical energy to provide for long term functional survival, after loss of both grid power and surface located back up power sources, was identified. Because of limited space available in Minuteman silos, candidate systems for meeting these requirements would also have to have an exceptionally high energy density.

Since, in this application, the lithium batteries would have to be located in an existing space (no additional construction), colocated with nuclear weapons on constant alert, the batteries were required to pass extremely rigid qualification

requirements. It should be noted that the qualification requirements for the Minuteman III parts list are the most stringent in the country for terrestrial applications. Abuse testing for qualification included drop, acceleration, overtemperature, short circuit, and overdischarge. Extensive functional testing to fully characterize this type of battery with regard to current and voltage profiles under various load cycle conditions were also accomplished. Complete data on results of the qualification testing could not be analyzed during the time allocated to this study; these batteries, however, were qualified for the MinuteMan program and are currently being installed.

Lithium batteries can be produced according to the needs of a specific application (terminal voltage and Amp-Hr capacity). Based on the characteristics and costs associated with 32 Volt 10,000 Amp-Hr modules now being produced for Minuteman, the following are important aspects of lithium systems:

Energy Density:	25,957 W hr per cu. ft. or 250 W hr per pound
Cost:	$15,000 per 100,000 W hr or 6.67 W hr per dollar

Scaling these factors to the 4 hour expansion, the following would be appropriate for the PWR and BWR cases studied:

a. PWR

Required Capacity: 1,350 A hr X 125 V = 168,750 W hr per battery

Cost: $25,313 each

Volume: 6.5 cu. ft

Weight: 675 lbs.

b. BWR

Required Capacity:

(1) 498 A hr X 125 V = 62,250 W hr

Lithium Battery:

Cost: $9,338

Volume: 2.4 cu. ft.

Weight: 249 lb.

(2) 913 A hr X 250 V = 228,250 W hr

Lithium Battery:

Cost: $34,275

Volume: 8.79 cu. ft.

Weight: 913 lb.

The foregoing cost information is based upon recent quotations to a defense agency for batteries now being delivered and do not include costs associated with research and development that may be necessary for these applications. Weights and volumes are based upon these same 10,000 Amp-Hr batteries and include cells, intercell strapping, and stainless steel cases. Due to the exceptionally high energy density (greater than an order of magnitude improvement over lead acid) and the resulting small sizes and weights, these batteries can easily be placed in existing battery rooms at both locations drastically reducing installation costs. Since these batteries do not vent to the environment, there is no additional imposition on the

ventillation system. There is no maintenance associated with these batteries. Since these are primary batteries, there is no requirement for a charger or tie-in to the 480 Volt system. Electrical interface with the DC Busses would consist of two-pole circuit breakers maintained open until, during station blackout, approximately half the station battery capacity had been expended (this would assure that the lithium batteries are not expended for short outages).

Table 2 provides a comparison of the characteristics and costs of the lithium, fixed electrolyte lead acid, and the vented lead acid as applied to the 4 hour expansion option of alternative 1 of this Subtask. Costs of the vented lead acid batteries were extracted from cost information provided by MATHTECH.

SEA Inc. concludes that the lithium battery approach to expanding the DC capacity for improving station blackout endutance is far superior to that of adding additional strings of lead acid cells. Installed costs should be far less that that of lead acid systems, and, once installed, the imposed operational burden (maintenance, test, inspection) is negligible. Since these batteries, until blackout occurs, remain essentially new (one percent degradation per year in standby mode), they are more reliable than lead acid whose overall health is never accurately known until energy demands are imposed upon them. The advantages of the new lithium battery systems warrant serious consideration, a thorough evaluation and discussions with manufacturers to establish their applicability as a more economic and reliable alternative for station blackout.

TABLE 2
COMPARISON MATRIX

SUBTASK 1 ALTERNATIVE 1 (4 HOUR APPLICATION)

		LITHIUM	LEAD ACID FIXED ELEC.	LEAD ACID VENTED
A.	GENERAL			
	Energy Density (W hr/Cu. Ft.)	25,957	2,277	(1)
	Energy Density (W hr/lb.)	250	11.32	(1)
B.	PWR Application (2)			
	Battery Cost, Dollars	25,313	150,000	35,600
	Battery Weight, lb.	675	14,906	(3)
	Battery volume, Ft^3	6.5	74.1	(3)
C.	BWR Application			
	(1) 125 V System			
	Battery Cost, Dollars	9,338	55,340	13,200
	Battery Weight, lb.	249	5,498	(3)
	Battery Volume, Ft^3	2.4	27.3	(3)
	(2) 250 V System			
	Battery Cost, Dollars	34,275	202,890	49,000
	Battery Weight, lb.	913	20,163	(3)
	Battery Volume, Ft^3	8.79	100	(3)

NOTES:

(1) Unknown, but less than that of the other types.

(2) Installation of two batteries required

(3) Unknown, but greater than that of the other types.

3.0 SUBTASK 2: RCP SEAL COOLING

3.1 INTRODUCTION AND OBJECTIVES

During a station blackout transient at a PWR, RCP seal cooling auxiliaries will be disabled. If this cooling is lost for an extended period of time, significant seal damage may be caused. A Loss of Coolant Accident (LOCA) can result from the passage of primary system water through damaged seals. For some plants, it would be desirable to maintain the integrity of the pump seals by having a means of supplying seal injection water to cool the RCP seals.

During a station blackout at BWRs, recirculating pump seal cooling will also be lost. Note, however, that recirculating pumps at some BWRs do not have seal injection systems. In this case, potential seal failure could probably be mitigated by the use of AC independent High Pressure Coolant Injection (HPCI) or Reactor Core Isolation Cooling (RCIC) systems (if available). An alternative approach would be to close isolation valves on the inlet and discharge of each pump, though modifications may be necessary to allow operation of these valves in the absence of AC power. For some BWRs without AC-independent makeup systems it may be desirable to have a means of supplying seal injection water during a station blackout. However, for reasons discussed above, this modification would more likely be needed at PWRs.

For each of the two base case reactors, four potential add-on systems were evaluated. These are listed below:

2A) A steam-driven turbine-generator providing power to an existing motor-driven pump

2B) A steam-driven turbine coupled directly to the charging pump

2C) A dedicated diesel coupled directly to the charging pump

2D) A dedicated diesel-generator providing power to an existing motor-driven pump

As directed by the NRC cost estimates were not required for alternatives obviously not cost effective relative to the others. In addition, the NRC indicated that pumps used in any of these options be capable of supplying 50 - 100 gpm at full system pressure. The following sections discuss the engineering evaluation of these options. Cost estimates for these options are summarized in Section 6 and provided in detail in Appendix B.

3.2 PWR

For the PWR(ANO-1) detailed cost estimates were performed for options 2A, 2B, and 2D. No estimates were performed for case 2C, since initial inspection revealed that this option would not be cost effective relative to the Options 2A and 2B. To employ option 2C, it appeared that it would be necessary to construct a new building to house the diesel pump. A new building would not be required for alternatives 2A and 2B. Even though option 2D also requires the construction of a new building, it is a possible synergistic solution, and thus detailed cost analyses were performed.

A simplified representation of the seal injection system at ANO-1 is given in Figure 9 . Note that the normal seal bleed-off is returned to the seal injection system after being cooled by the seal return coolers. The water source used to cool

these heat exchangers requires AC power, and would thus be unavailable during a station blackout. To implement options 2A, 2B, and 2D, it was determined that it would be necessary to install piping to drain RCP bleed-off water to the sump (Figure 10). Even though this design does not fall within the existing guidelines, practical factors require the installation of this equipment inside containment.

During blackout conditions, the two DC valves would be opened, and the isolation valve upstream of the seal return coolers closed. The bleed-off water from each RCP is estimated to be 1 gpm and thus the total bleed-off flow from all 4 pumps will be 4 gpm. After 16 hours, it is calculated that this water will add less than 1 psi to the containment pressure.*

3.2.1 Option 2A

The proposed modifications for subtask 2A (exclusive of the seal drain piping) are shown in Figure 11. It was determined that the best location for the turbine generator would probably be the ground floor of the turbine building (Figure 12). Seismic grade components would be required up to and including the DC steam isolation valve so as not to degrade existing seismic grade secondary equipment. This generator would power one of the existing 700 HP make-up pumps.

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*This calculation was performed using an SEA-developed computer code for modeling containment thermal hydraulics.

3.2.2 Option 2B

Figure 13 depicts the flow modifications needed to implement Option 2B. The turbine driven pump would be located in the auxiliary building as shown in Figure 14. This location was chosen since it appeared that not enough space was available in any of the rooms containing makeup pumps. Again, seismic grade components would be required on the turbine steam supply line. As is indicated, the pump would draw water from the borated water storage tank, which contains about 380,000 gallons of water. Only 96,000 gallons would be needed to supply 100 gpm of seal injection water for 16 hours.

3.2.3 Option 2D

To implement this option, it would be necessary to construct a new building to house the diesel generator (see Figure 1). This diesel would power one of the existing 700 hp makeup pumps shown in Figure 9. The diesel generator output should be approximately twice the required load to ensure that the makeup pump will not damage the generator during the initial loading process.

3.3 BWR

A typical BWR seal injection system is shown in Figure 15. Injection water is drawn from the condensate storage tank by the control rod drive (CRD) pumps and subsequently delivered to the recirculation pump seals. Bleed water from these seals (not shown) is routed to drywell equipment drain sumps. Due to the lack of plant specific information, it was assumed that a similar

seal injection configuration exists at the base case BWR (Quad Cities - 1).

Detailed cost estimates were not performed for Options 2A and 2B because these alternatives would be far more costly than the remaining two options. In particular, steam used to power a turbine would have to be drawn upstream of the inboard set of main steam isolation valves, which would be closed during a station blackout. Because these valves are located inside reactor containment, a new drywell pipe penetration would have to be made. This would be very expensive, since extensive tests would have to be conducted after this installation to ensure primary containment pressure integrity. Furthermore, much of this piping would have to be seismically qualified. Provisions would also have to be made to route the turbine exhaust steam back to the suppression pool, though it might be possible to make a connection with existing HPCI or RCIC steam exhaust piping.

3.3.1 Option 2C

The proposed modifications for this option are outlined in Figure 16. It would be necessary to install a new building to house the diesel driven pump (see Figure 4). As is indicated, this pump would draw suction water from the condensate storage tank. The inventory in this tank will be sufficient to supply both seal injection water and suction for the HPCI or RCIC systems. This topic is addressed more thoroughly in Section 4.

3.3.2 Option 2D

To implement this option, it would be necessary to construct a new building to house the diesel generator (see

Figure 4). It is proposed that this diesel would supply power to one of the existing CRD pumps shown in Figure 15.

The diesel generator output should be approximately twice the required load (250 HP) to ensure that the generator will not be damaged during the loading process.

4.0 SUBTASK 3: INCREASE CONDENSATE STORAGE TANK CAPACITY

4.1 INTRODUCTION AND OBJECTIVES

During a prolonged station blackout, condensate storage tank inventory may be depleted by the operation of turbine driven auxiliary feedwater pumps at PWRs and HPCI/RCIC pumps at BWRs. It would be desirable to have the capability of refilling these tanks during a prolonged station blackout.

For each of the base case reactors, possible modifications for increasing or replenishing condensate storage tank water were evaluated. The following sections discuss engineering designs for each plant. Cost estimates are summarized in Section 6 and provided in detail in Appendix C.

4.2 PWR

At ANO-1, makeup to the condensate storage tank may be needed for prolonged operation of the turbine driven auxiliary feedwater pump. In an emergency, water used for this purpose does not have to be particularly pure, and thus river water is a possible water source.

A number of water sources were considered, such as the river, condenser hotwell, and demineralized water storage tank. The use of a portable diesel driven fire pump to transfer river water to the condensate storage tank was determined to be the most cost-effective approach. This setup is schematically shown in Figure 17. The only piping modification needed for this configuration would be the installation of a fire hose connection to the existing condensate storage tank refill line. Other

options would require the installation of permanent underground piping. Note that the pump and fire hose can be stored virtually anywhere on the plant site. Sufficient time would be available to set up the pump and fire hose, as the existing condensate storage tank inventory would be adequate for approximately 8-10 hours. The capacity of the pump was conservatively rated at 150 gpm, the amount of water needed to remove decay heat at 4 hours into the station blackout transient.

Use of a similar set up at other plants depends in part on the expected weather conditions. Plants located in areas where temperatures can fall well below freezing should not attempt to implement this method, as the water in the fire hose could freeze, thus preventing flow.

4.3 BWR

In contrast to the PWR, water used to provide makeup to the condensate storage tank (CST) should be quite pure. Specifically, the CST would be used for seal injection (see Subtask 2) as well as HPCI or RCIC suction sources. Impurities in seal injection water could cause degradation of the recirculating pump seals. Therefore, river water would be unsuitable as a source of makeup water.

Other water sources were considered, such as the condenser hotwell, well water storage tanks, and demineralized water storage tank. The most feasible option involved use of the condenser hotwell as a water source (Figure 17). The hotwell has several hundred thousand gallons of water, more than enough to refill the condensate storage tank. The pump would be

located in the turbine building as shown in Figure 4. The capacity of the pump (250 gpm) is sufficient to provide make up for 1) 100 gpm seal injection flow and 2) 150 gpm for HPCI/RCIC pumps. The latter figure was conservatively based on the amount of water needed to remove decay heat at four hours into the station blackout transient.

5.0 INCREASE INSTRUMENT AIR SUPPLY

5.1 INTRODUCTION AND OBJECTIVES

The instrument air system is designed to provide a supply of high purity air for the operation of various instruments and controls. During normal operation, AC powered air compressors maintain a continuous supply of 80-100 psig air. As is shown in Figures 18 and 19, air from the compressors is cooled, dryed, and filtered before being discharged to air receivers. The air receivers are used to create a smooth flow of air by eliminating pulsations in the compressor discharge line and to provide storage capacity when the demand exceeds the compressor capacity. During emergency conditions, the service air system can be used as a backup source of air. Service air is normally used for the operation of pneumatic tools as well as for miscellaneous cleaning and maintenance purposes.

For each base case reactor, engineering and cost analyses were performed for increasing the existing air supplies from 4 to 8 hours, and from 4 to 16 hours. The following sections discuss the engineering evaluation of these options. Cost estimates are summarized in Section 6 and provided in detail in Appendix D.

5.2 ASSUMPTIONS

Due to the lack of plant specific information, the following assumptions were made:

1. Air stored in the service air system could be used to operate instrument air loads.

2. Following the occurrence of a station blackout, enough air is stored within the instrument and service air systems to provide enough air for 4 hours.

3. The total volume of the instrument and service air systems is dependent on capacities of the air receivers, coolers, air piping, etc. Unfortunately no information was available on the total air system volumes. Therefore, it was conservatively assumed that the air receiver capacity of each system would be 10% of the total air system capacity. This number was based on the fact that the air receiver capacity should be a reasonable fraction of the total air system volume. Otherwise, the air receiver would not be useful in performing its functions.

4. Increasing air supplies from 4 to 8 hours, and 4 to 16 hours would involve adding an additional air capacity of either 100% or 300% of the initial stored air supply. This assumption was made necessary because not enough information could be obtained concerning possible air system demands during the first 4 hours versus demands during periods beyond 4 hours.

5. The initial air supply pressure is 100 psig. Once the air system pressure drops below 80 psig, the air system loads are no longer functional.

5.3 PWR

No information was available on the air receiver capacities at ANO-1. Therefore, an attempt was made to gather similar data for other PWRs. Unfortunately, information could only be obtained for 2 other plants, Ft. Calhoun and Palisades. For Ft. Calhoun, the total instrument and service air receiver capacity was determined to be approximately 3100 scf. At Palisades, this capacity was much lower, about 1000 scf. It was assumed that the ANO-1 air receiver capacity was an average of these two figures, or 2000 scf. Using assumptions 1-5, the total quantity of air needed for 4 hours was calculated to be 4000 scf. To extend the air supply from 4-8 hours and 4-16 hours would there-

fore require 4000 scf and 12000 scf, respectively.

Installation of an AC-independent air compressor to supply additional air is not a feasible option since the air coolers and dryers require a source of AC power. Therefore, engineering and cost analyses were made for bottled air supplies. A standard 2000 psi gas bottle can supply about 250 scf of air. Thus, to extend the air supply from 4-8 hours and 4-16 hours, the plant would require 15 and 45 bottles, respectively. These bottles can probably be located in the room containing the instrument air receivers. The proposed modifications are presented in Figure 20.

5.4 BWR

For Quad Cities-1, the total air receiver capacity was calculated to be 1100 scf. Using assumptions 1-5, estimates were made of the air supply needed to extend operation from 4-8 hours, and 4-16 hours. These air supplies were 2200 scf and 6600 scf, respectively.

As in the preceding case, the use of an air compressor is not a feasible option. Therefore, engineering and cost analyses were made for bottled air supplies. To extend the air supply from 4-8 hours and 4-16 hours, the plant would require 10 and 30 bottles, respectively. These bottles can probably be housed in the area containing the instrument air receivers. Refer to Figure 20 for the proposed modifications.

6.0 RESULTS AND CONCLUSIONS

The results of the cost analysis are summarized in Table 3 and 4. Table 3 details the various components of base cost for each option while Table 4 presents total base cost with associated high and low values derived from a range of labor productivity and geographical variances. It is difficult to generalize about such a dissimilar set of options, but a few observations are pertinent. First of all, equipment costs tend to dominate throughout. This is particularly true for the higher cost options, where certain equipment requirements compose a very large portion of overall cost. For instance, in Subtask 2, Option 2A, a turbine generator costing $379,500 drives the total PWR cost to levels above Options 2B and 2D.

Second, while initial capital costs mostly predominate, operating and maintenance costs are never trivial, and in some instances are of prime importance. Generally speaking, operation and maintenance cost becomes more important the lower the total cost. In Subtask 3, for instance, the discounted present value of PWR O&M costs are actually three to four times the initial cost.

Overall, it should again be noted that the cost ranges shown do not explicitly account for design and site specific differences that will undoubtedly be found among nuclear plants.

Table 3. Base Cost Components by Subtask and Options
Station Blackout (thousands of 1983 dollars)

PWR		Labor and Materials Attributable to Equipment	Labor and Materials Atttributable to Structures	Engineering and Quality Assurance	Contractor Overhead	Operation & Maintenance (present value)	Total Cost
Subtask 1:	Increase Battery Capacity						
Option 1:	Add 4 hr Capacity	$138.8	$ 36.7	$ 43.9	$ 54.8	$ 16.7	$290.8
Option 2:	Add 12 hr Capacity	681.4	108.0	176.1	220.0	45.2	$1,145.8
Option 3:	Add Battery Charger/ Diesel Generator	$115.3	$ 31.4	$ 36.7	$ 45.8	$ 55.9	$285.1
Option 4:	Add Battery Charger/ Gas Turbine Generator	263.1	30.1	73.3	91.6	28.0	486.1
Subtask 2:	Add Ac-Independent Charging Pump						
Option 2A:	Turbine Generator/ Motor Pump	538.9	0	134.7	168.4	28.0	870.0
Option 2B:	Turbine Powered Charging Pump	512.8	0	128.2	160.0	28.0	829.2
Option 2C:	Diesel Powered Motor Pump	NA	NA	NA	NA	NA	NA
Option 2D:	Diesel Generator/ Charging Pump	166.4	34.1	50.1	62.7	55.9	369.2
Subtask 3:	Increase Condensate Storage Tank Capacity	6.1	0	1.5	1.9	28.0	37.4
Subtask 4:	Increase Compressed Instrument Air Supply						
Option 1:	Increase Air Supply to 8 hours	12.4	0	3.1	3.9	6.4	25.8
Option 2:	Increase Air Supply to 16 hours	32.0	0	8.0	10.0	6.4	56.4

Note: Components may not add exactly to total due to rounding.

Table 3. Base Cost Components by Subtask and Options
Station Blackout (thousands of 1983 dollars)
Page 2

BWR		Labor and Materials Attributable to Equipment	Labor and Materials Atttributable to Structures	Engineering and Quality Assurance	Contractor Overhead	Operation & Maintenance (present value)	Total Cost
Subtask 1:	Increase Battery Capacity						
Option 1:	Add 4 hr Capacity	$145.1	$ 45.9	$ 47.7	$ 59.7	$ 16.7	$315.1
Option 2:	Add 12 hr Capacity	412.1	95.8	127.0	158.7	45.2	838.8
Option 3:	Add Battery Charger/ Diesel Generator	$122.8	$ 30.4	$ 38.3	$ 47.9	$ 55.9	$295.2
Option 4:	Add Battery Charger/ Gas Turbine Generator	269.3	30.2	74.9	93.6	28.0	495.8
Subtask 2:	Add Ac-Independent Charging Pump						
Option 2A:	Turbine Generator/ Motor Pump	NA	NA	NA	NA	NA	NA
Option 2B:	Turbine Powered Charging Pump	NA	NA	NA	NA	NA	NA
Option 2C:	Diesel Powered Motor Pump	49.5	30.4	20.0	25.0	55.9	180.8
Option 2D:	Diesel Generator/ Charging Pump	117.8	30.6	37.1	46.4	55.9	288.0
Subtask 3:	Increase Condensate Storage Tank Capacity	28.7	0	7.2	9.0	28.0	72.8
Subtask 4:	Increase Compressed Instrument Air Supply						
Option 1:	Increase Air Supply to 8 hours	13.1	0	3.3	4.1	6.4	26.9
Option 2:	Increase Air Supply to 16 hours	20.9	0	5.2	6.5	6.4	39.1

Note: Components may not add exactly to total due to rounding.

Table 4. Total Incremental Costs for Station Blackout - Subtasks and Options
(in thousands of 1983 dollars)

	PWR			BWR		
	Low	Base	High	Low	Base	High
Subtask 1: Increase Battery Capacity						
Option 1. Add 4 Hour Battery Capacity	$ 237.6	$ 290.8	$ 375.7	$259.9	$315.1	$399.8
Option 2. Add 12 Hour Battery Capacity	947.5	1,145.8	1,431.4	689.8	838.8	1,064.3
Option 3. Add Alternative Battery Charger/ Diesel Generator	234.6	285.1	361.4	242.7	295.3	375.2
Option 4. Add Alternative Battery Charger/ Gas Turbine Generator	400.2	486.1	579.8	416.2	495.8	593.1
Subtask 2: Add AC-Independent Charging Pump for Reactor Coolant Pump Seal Injection						
Option A Add Turbine Generator/Motor Pump	723.8	870.0	1,068.5	N.A	N.A.	N.A.
Option B Add Turbine-powered Charging Pump	686.7	829.2	1,028.4	N.A.	N.A.	N.A.
Option C Add Diesel-powered Charging Pump	NA	NA	NA	144.8	188.8	246.1
Option D Add Diesel Generator/Charging Pump	304.5	369.2	464.4	237.1	287.9	363.9
Subtask 3: Increase Condensate Storage Tank Capacity						
Option 1: Increase CST Capacity	29.2	37.4	54.3	58.6	72.8	98.1
Subtask 4: Increase Compressed Air Supply for Instrument Air						
Option 1. Increase Air Supply From 4 to 8 Hours	20.3	25.8	34.2	21.3	26.9	37.6
Option 2. Increase Air Supply From 4 to 16 Hours	46.3	56.4	72.1	31.9	39.1	50.8

Note: This Table reflects cost ranges induced by productivity and geographic variations in labor rates only.

6.1 COST VARIANCES---ENGINEERING

DC Systems-

A. Battery Systems (Alternative 1)

The major factors that would significantly impact the cost of expanding the capacity of Class 1E Batteries in multiples of existing capacity at other PWR and BWR facilities are: (1) the amount of existing capacity, (2) the proximity of a suitable location for new batteries to the DC busses, and (3) the need for new construction. The cost of the batteries are a nominal 20% of the installed system. The cost of conduits and cables could contribute an aditional 10% for long conduit runs due to the fact that these runs could dictate upgrading conductor sizes to maintain voltage drops and since such longer runs would indicate more complex installations. Existing battery rooms were sized to accommodate the planned battery system(s) and ancillary equipment; it is doubtful that at any operating facility, the room would be sufficient to house twice the existing capacity without seriously compromising the reliability of the DC system. Therefore, the need for new battery locations would very likely be applicable to all battery expansion cases. It is unlikely that space, available within the plant suitable for a duplication of the existing battery room(s) without extensive modification, could be found. Because of this, new battery facilities were considered baseline. Load shedding was not within the scope of this portion of Subtask 1.

Based upon the above, variances in the cost associated with battery system expansion are estimated to range from 10%

below the BWR case to 30% above the PWR case (driven primarily by capacity and conduit distances).

B. Independent Charging Systems (Alternative 2)

The charging systems were sized to handle loads typical of all plants to include surges during start-up of major equipments. As a result, the turbine generator and diesel generator would be suitable for universal application. The major difference would consist of the cost of interconnection with proper busses. Since smaller conductors, due to transmission by three phase, are appropriate, the plant differences would account for a variance of 5% below the low case (PWR) to 10% above the high case (BWR). Indicated cost ranges are given in Table 5.

Charging Pump for Seal Injection-

As noted previously, the costs associated with option 2A (PWR) are dominated by the expense of the turbine generator. The charging pumps used at ANO-1 have a larger capacity than pumps used at most of the other PWRs. Therefore, the needed generator output at ANO-1 is probably close to an upper limit, and would be considerably less at other PWRs. The lower limit costs associated with this option would involve a smaller capacity generator and shorter piping and cabling runs. Costs for subtasks 2B (PWR) and 2D (PWR) are dominated by the need of a new building. For ANO-1, such a building was not needed for option 2B, and therefore this is probably close to a lower limit case. The lower limit estimate includes shorter piping and cabling runs than required for ANO-1. Option 2D required the construction of a new building, however, and would tend to be an

Table 5. Total Incremental Costs Based on Engineering Differences among Plants
(in thousands of 1983 dollars)

	PWR			BWR		
	Low	Base	High	Low	Base	High
Subtask 1: Increase Battery Capacity						
Option 1. Add 4 Hour Battery Capacity	$ 261.7	$ 298.8	$ 489.6	$261.7	$315.1	$489.6
Option 2. Add 12 Hour Battery Capacity	754.9	1,145.8	1,489.5	754.9	838.8	1,489.5
Option 3. Add Alternative Battery Charger/ Diesel Generator	270.8	285.1	324.8	270.8	295.3	324.8
Option 4. Add Alternative Battery Charger/ Gas Turbine Generator	461.8	486.1	545.4	461.8	495.8	545.4
Subtask 2: Add AC-Independent Charging Pump for Reactor Coolant Pump Seal Injection						
Option 2A Add Turbine Generator/Motor Pump	600.0	870.0	1,000.0	N.A.	N.A.	N.A.
Option 2B Add Turbine-powered Charging Pump	760.0	829.2	1,060.0	N.A.	N.A.	N.A.
Option 2C Add Diesel-powered Charging Pump	N.A.	N.A.	N.A.	140.0	180.8	300.0
Option 2D Add Diesel Generator/Motor Pump	300.0	369.2	500.0	240.0	287.9	500.0
Subtask 3: Increase Condensate Storage Tank Capacity						
Option 1. Increase CST Capacity	30.0	37.4	200.0	50.0	72.8	200.0
Subtask 4: Increase Compressed Air Supply for Instrument Air						
Option 1. Increase Air Supply From 4 to 8 Hours	20.0	25.8	200.0	20.0	26.9	200.0
Option 2. Increase Air Supply From 4 to 16 Hours	50.0	56.4	200.0	30.0	39.1	200.0

Note: This table reflects cost ranges induced by engineering differences in plants only.

upper bound case. This upper bound estimate for this option also includes possible piping and cabling variations.

For the BWR, options 2C and 2D would also tend to be dominated by the need for a new building. Table 5 provides rough estimates of the possible cost variations for this subtask. Again, possible cabling and piping variations were factored into these estimates.

Increase CST Capacity

Tne cost estimates associated with the PWR would tend to be lower bound estimates, since it was not necessary to provide for the installation of permanent piping or a new building. Costs associated with the BWR would also tend to be lower bound, since a new building was not required. The upper bound cost estimates include the construction of a new building, as well as additional piping and cabling. These considerations are summarized in Table 5 .

Increase Instrument Air Supply

Costs associated with this subtask would also be dominated by the need to construct a new building. Costs for both the PWR and BWR are probably close to lower bound, since a new building was not required in either case. Again, the upper bound cost estimates include the contruction of a new building and additional piping and cabling. Table 5 summarizes these considerations.

6.2 SYNERGISTIC POSSIBILITIES

6.2.1 INTRODUCTION

At the initiation of this task it became apparent that proposed additions for Subtask 2 requiring installation of steam turbine-and-diesel-generator packages to power existing motor-driven pumps had the potential for providing sufficient energy to alleviate the need for installing additional batteries or other energy sources required in Subtask 1.

For those generator packages priced for Subtask 2, sizing included an accommodation of motor start-up currents; this results in approximately half the capacity of the generator output being available for other uses once the primary load has achieved rated speed. By manual alignment of breakers, this excess capacity can be provided, without additional equipment or construction, via the 3 phase 480 volt system to the battery chargers and the instrumentation system.

The PWR seal injection required sufficient power to drive a 700 horsepower (574 KW at 91% efficiency) motor driven pump. After that pump has attained speed, over 500 KW would be available to the DC system. The BWR scenario used one of the 250 horsepower (205 KW at 91% efficiency) CRD pumps; after run-up, the specified generator would have an excess of over 200 KW for use by the DC system. To place this power in a perspective associated with the 125 VDC system, 200 KW translates to 1600 amperes (neglecting transformer and converter losses) available to those busses continuously - far in excess of long-term requirements. By making the excess capacity of these generators

available to the DC system, the station batteries could function indefinitely (as long as the diesel or steam turbine can maintain the generator load).

6.2.2 SYNERGISTIC COST SUMMARY

The following summarizes the costs associated with the Subtasks 1 and 2 by solving the problems individually and synergistically using the base case costs for the Subtask 1 (4-hour expansion) and the Subtask 2 options cited earlier (costs in thousands of dollars):

a. PWR

(1) Steam Turbine/Generator Seal Injection

Batteries (4 hour)	290.8
Seal Injection	369.2
Subtasks 1 & 2 Total	660.0
Synergistic Cost	369.2

(2) Diesel/Generator Seal Injection

Batteries (4 hour)	290.8
Seal Injection	829.2
Subtasks 1 & 2 Total	1,120.0
Synergistic Cost	829.2

b. BWR

Diesel/Generator Seal Injection

Batteries (4 hour)	315.1
Seal Injection	287.9
Subtasks 1 & 2 Total	603.0
Synergistic Cost	287.9

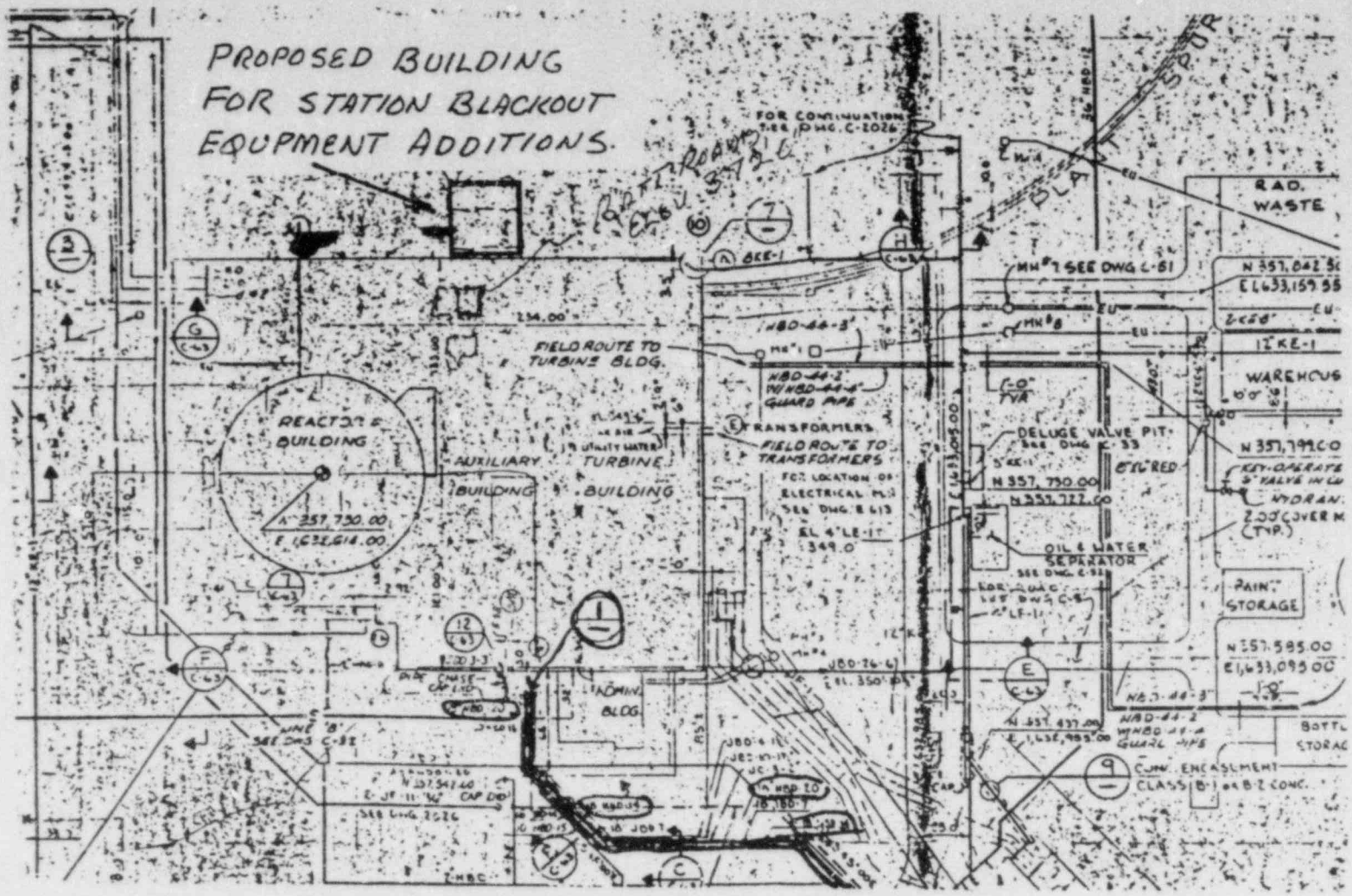
6.2.3 CONCLUSIONS

All electrical generator systems costed for Subtask 2 have sufficient excess capacity to satisfy the requirements of the DC systems. Furthermore, some of the emergency DC requirements can be satisfied by the AC busses (e.g., instrumentation inverters, illumination) reducing the demands

placed on the DC busses and their associated chargers. The costs associated with the generator systems were lower in all cases than the 12-hour lead acid battery system expansions alone. The diesel-generator systems, for both plants, were estimated to be competitive with the 4-hour lead acid battery system expansion cost. Based on cost estimates only, it is more cost effective to satisfy Subtask 1 requirements through the use of excess electrical capacity installed for RCP seal injection than to expand the battery systems.

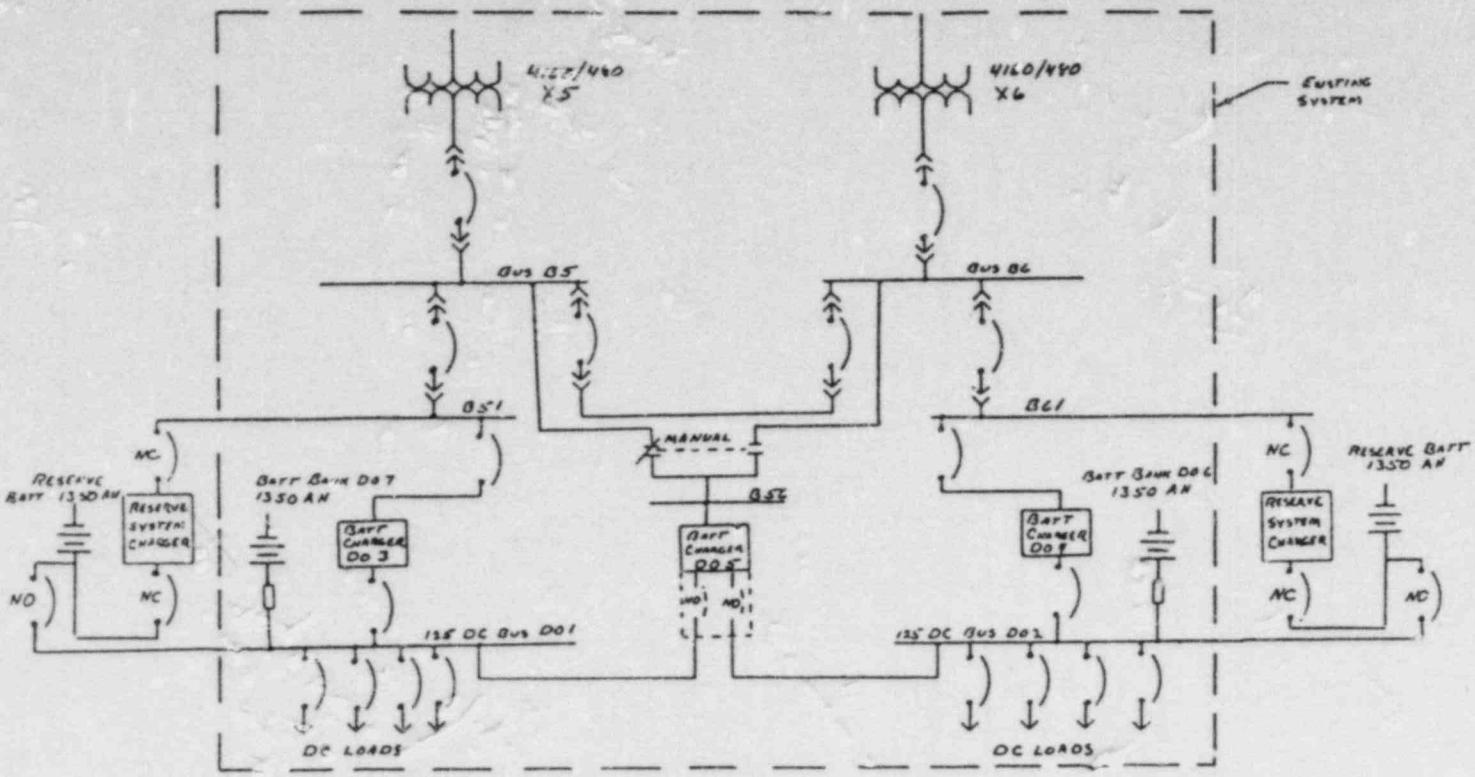
LIST OF ACRONYMS

AC	ALTERNATING CURRENT
A & E	ARCHITECH AND ENGINEERING
ANO	ARKANSAS NUCLEAR ONE
BWR	BOILING WATER REACTOR
CRD	CONTROL ROD DRIVE
CST	CONDENSATE STORAGE TANK
DC	DIRECT CURRENT
GPM	GALLON(S) PER MINUTE
HP	HORSEPOWER
HPCI	HIGH PRESSURE COOLANT INJECTION
IREP	INTERIM RELIABILITY EVALUATION PROGRAM
LOCA	LOSS OF COOLANT ACCIDENT
LPCI	LOW PRESSURE COOLANT INJECTION
MOV	MOTOR OPERATED VALVE
NRC	NUCLEAR REGULATORY COMMISSION
NSSS	NUCLEAR STEAM SUPPLY SYSTEM
PSI	POUND(S) PER SQUARE INCH
PWR	PRESSURIZED WATER REACTOR
RCIC	REACTOR CORE ISOLATION COOLING
RCP	REACTOR COOLANT PUMP
SAR	SAFETY ANALYSIS REPORT
SCF	STANDARD CUBIC FOOT (FEET)
SEA	SCIENCE AND ENGINEERING ASSOCIATES, INC.



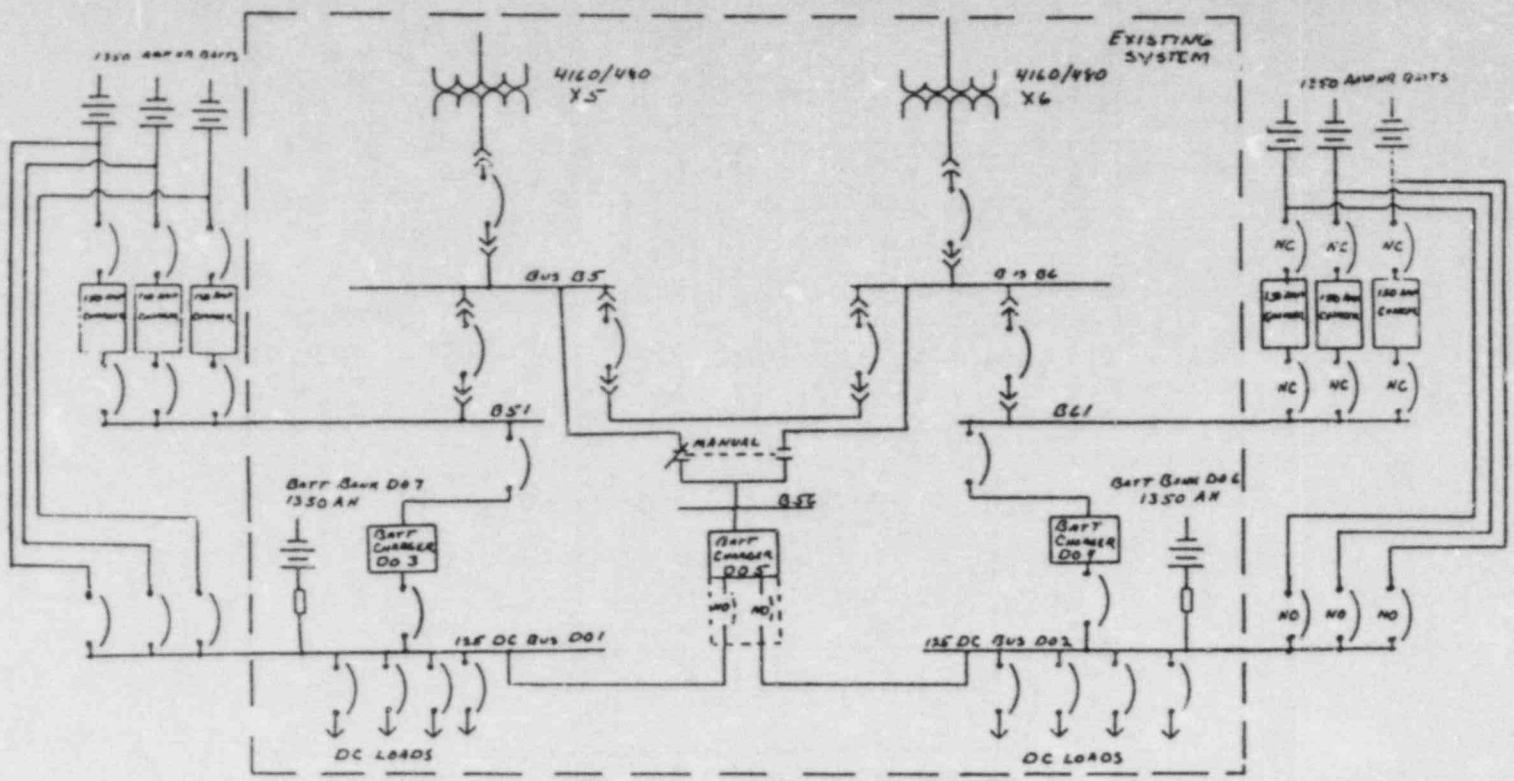
PWR ADDITION

FIGURE 1



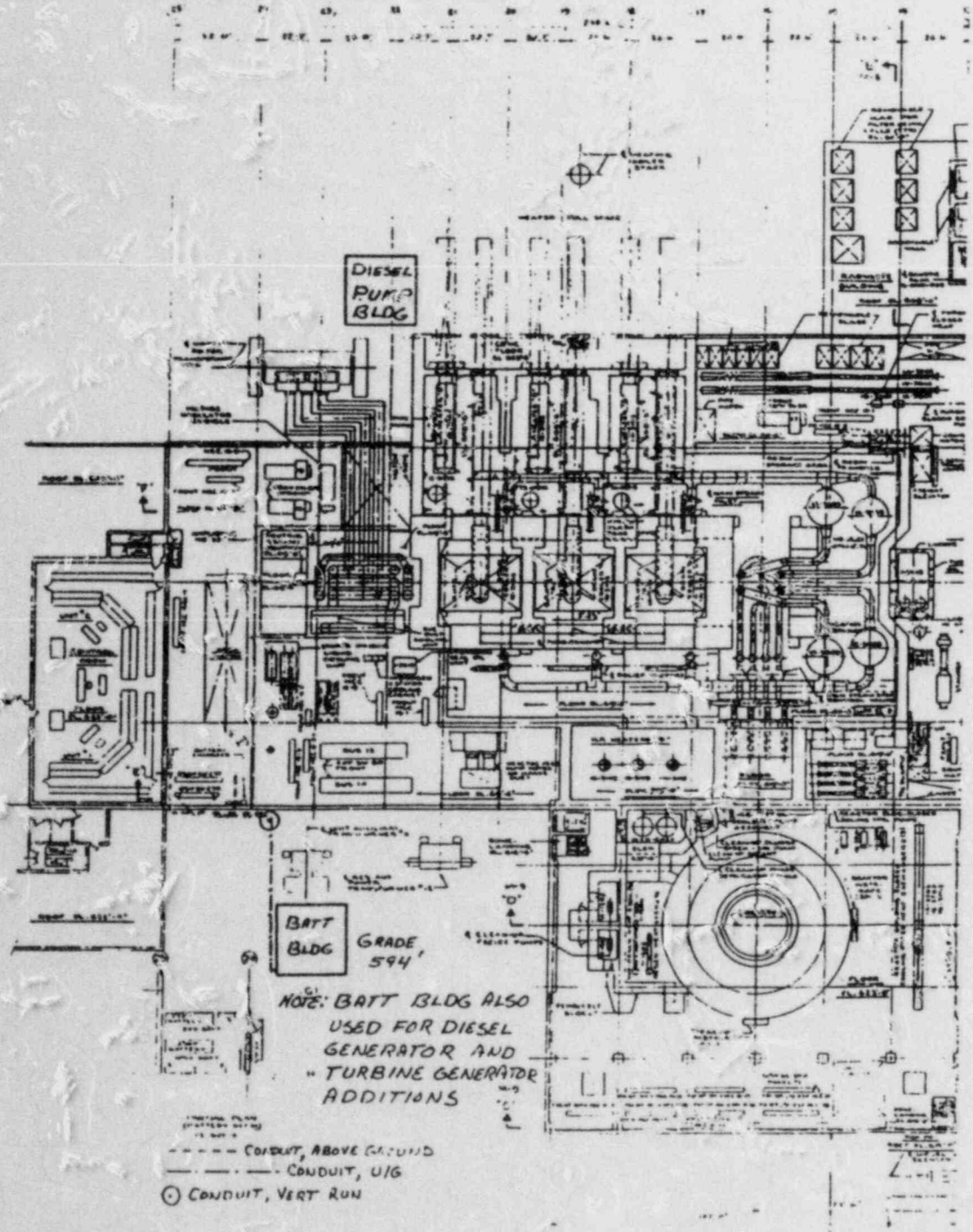
4-HOUR EXPANSION PWR 125 VOLT SYSTEM

FIGURE 2



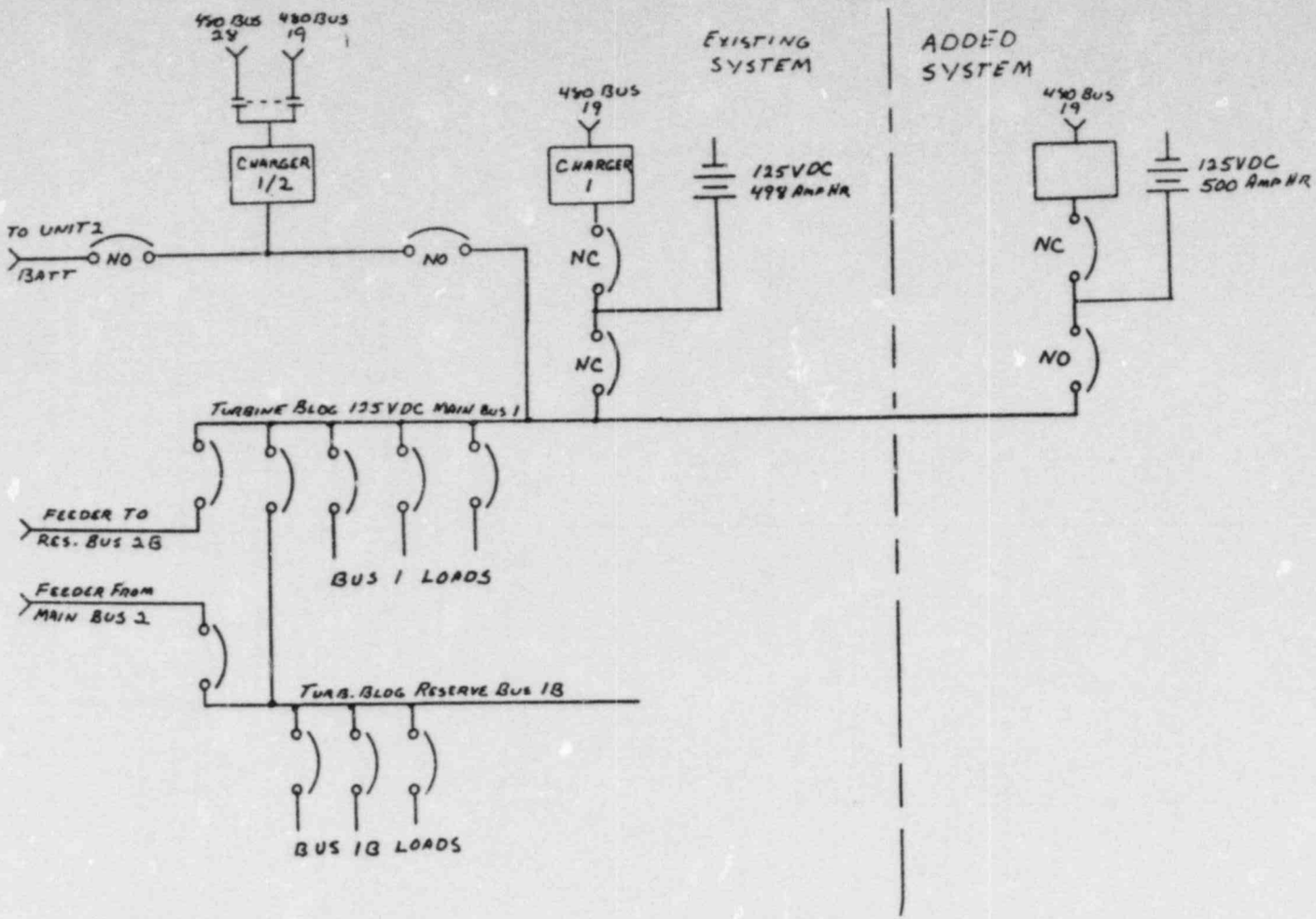
12 HOUR EXPANSION PWR 125 VOLT SYSTEM

FIGURE 3



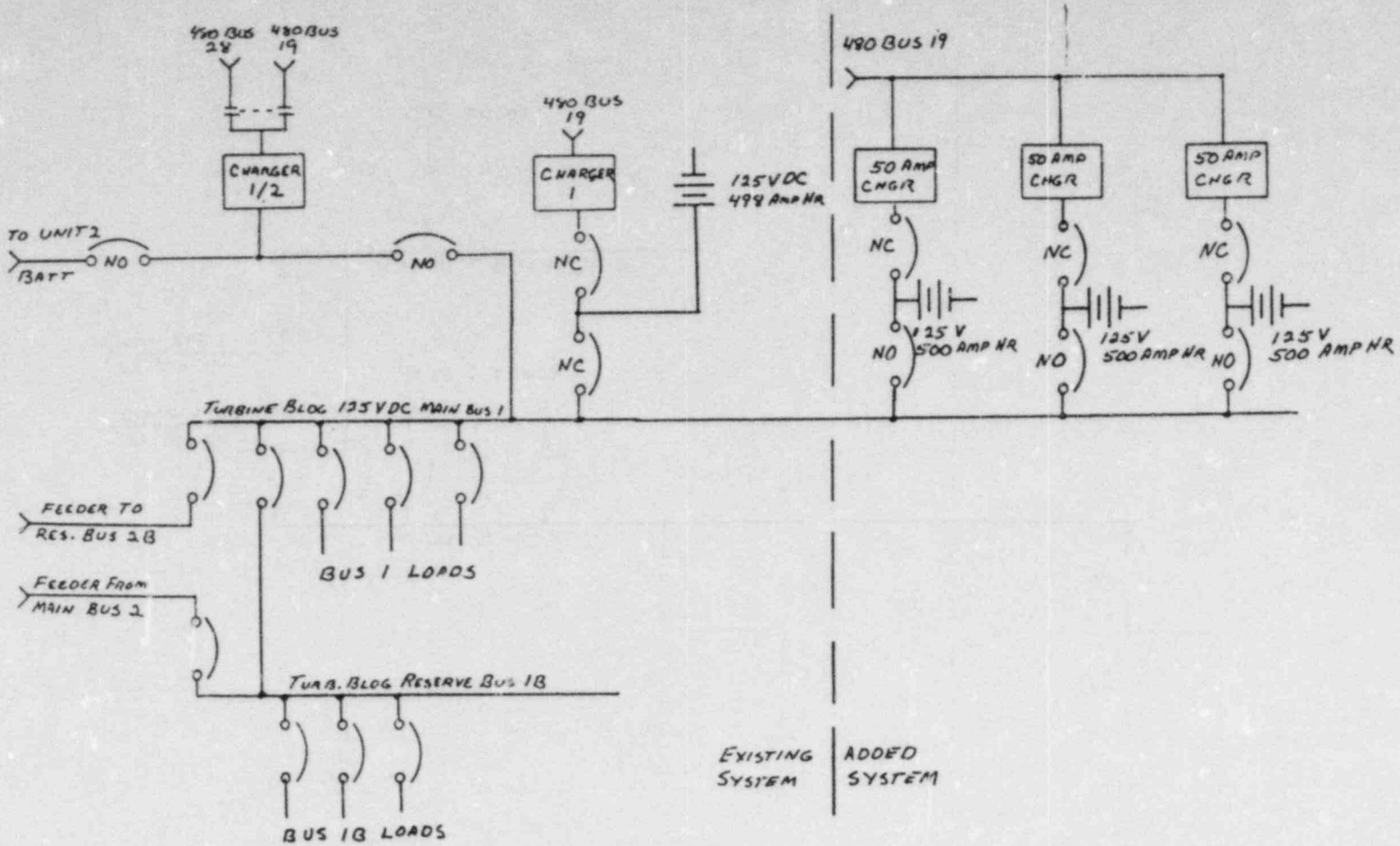
BWR ADDITIONS

FIGURE 4



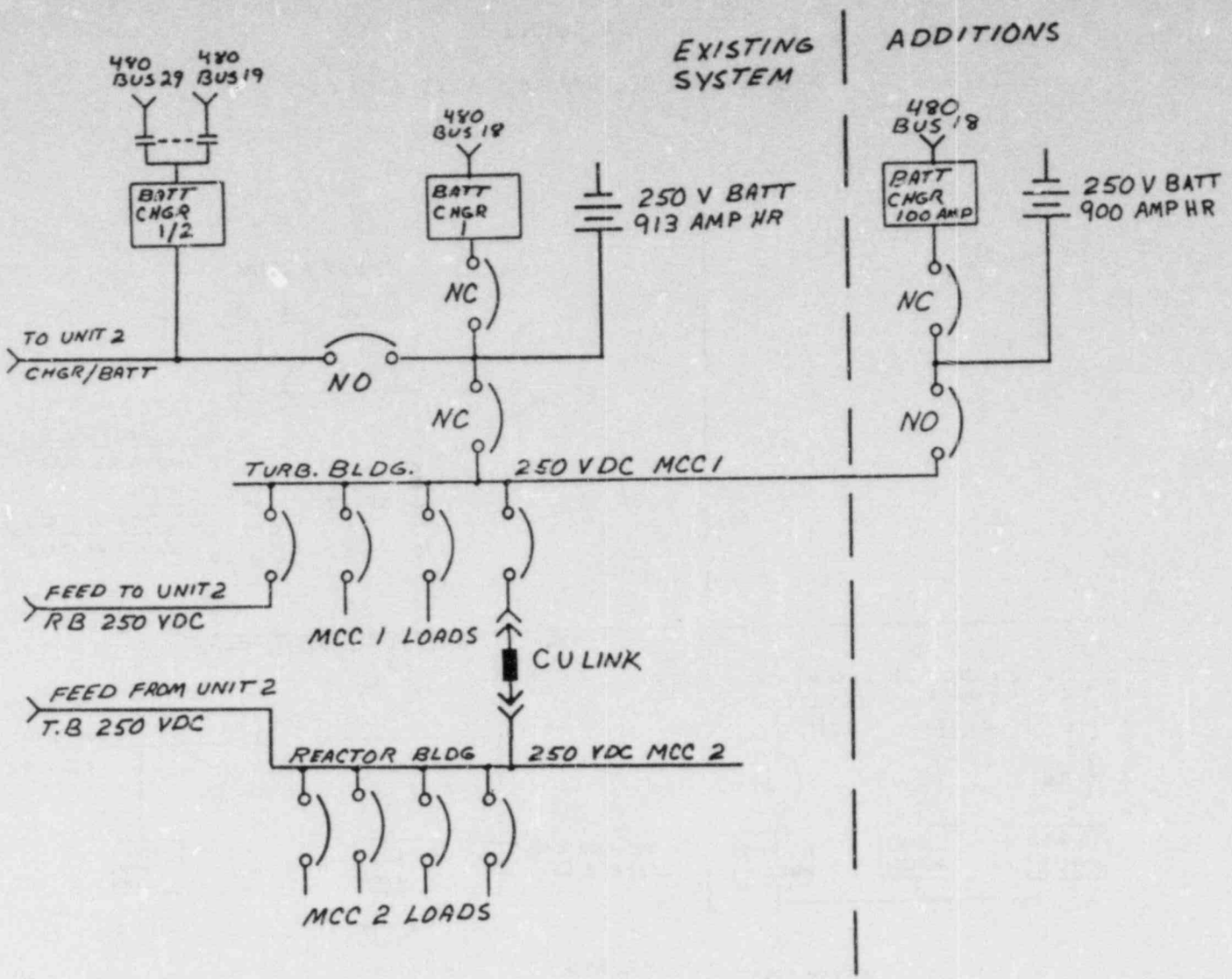
4-HOUR EXPANSION BWR 125 VOLT SYSTEM

FIGURE 5



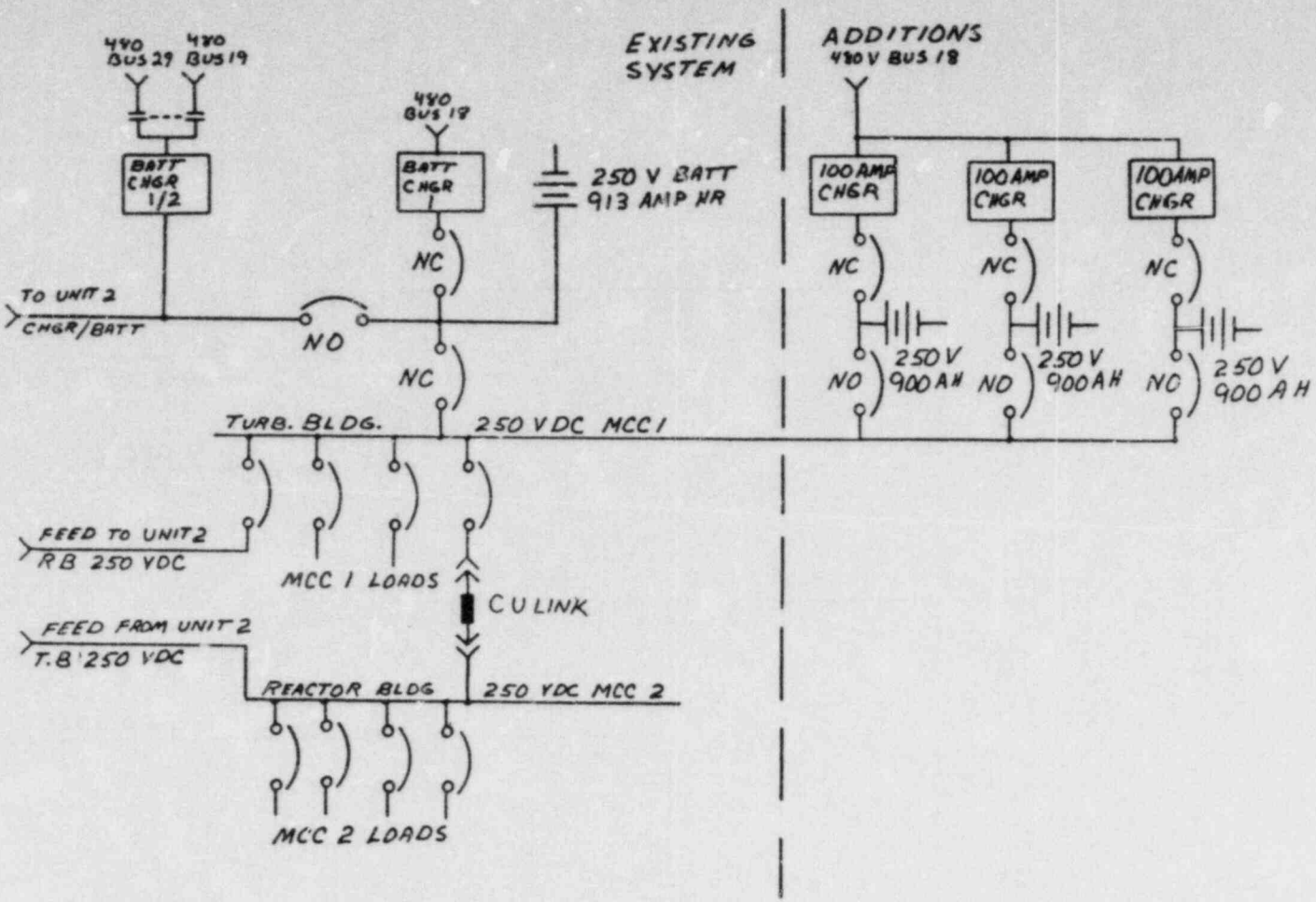
12-HOUR EXPANSION BWR 125 VOLT SYSTEM

FIGURE 6



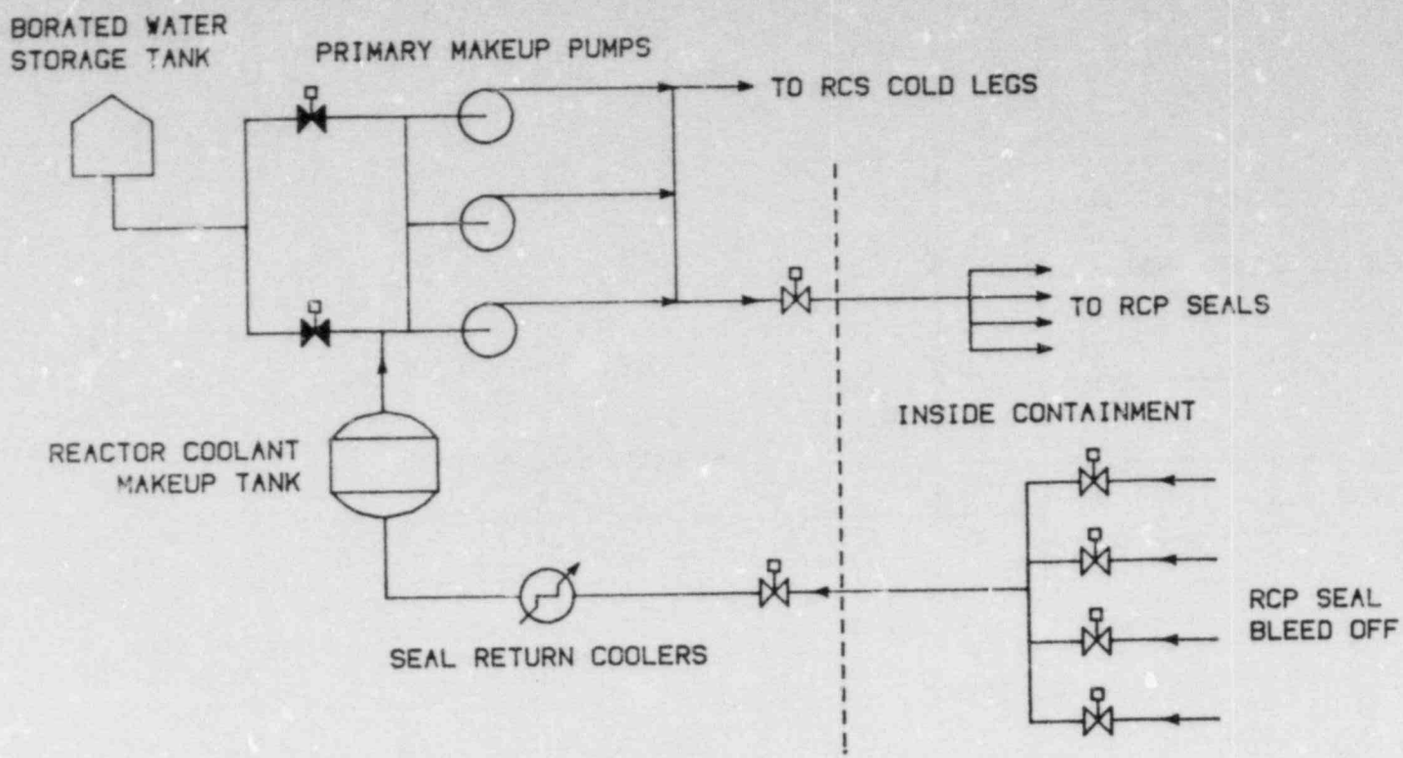
4 HOUR EXPANSION BWR 250 VOLT SYSTEM

FIGURE 7



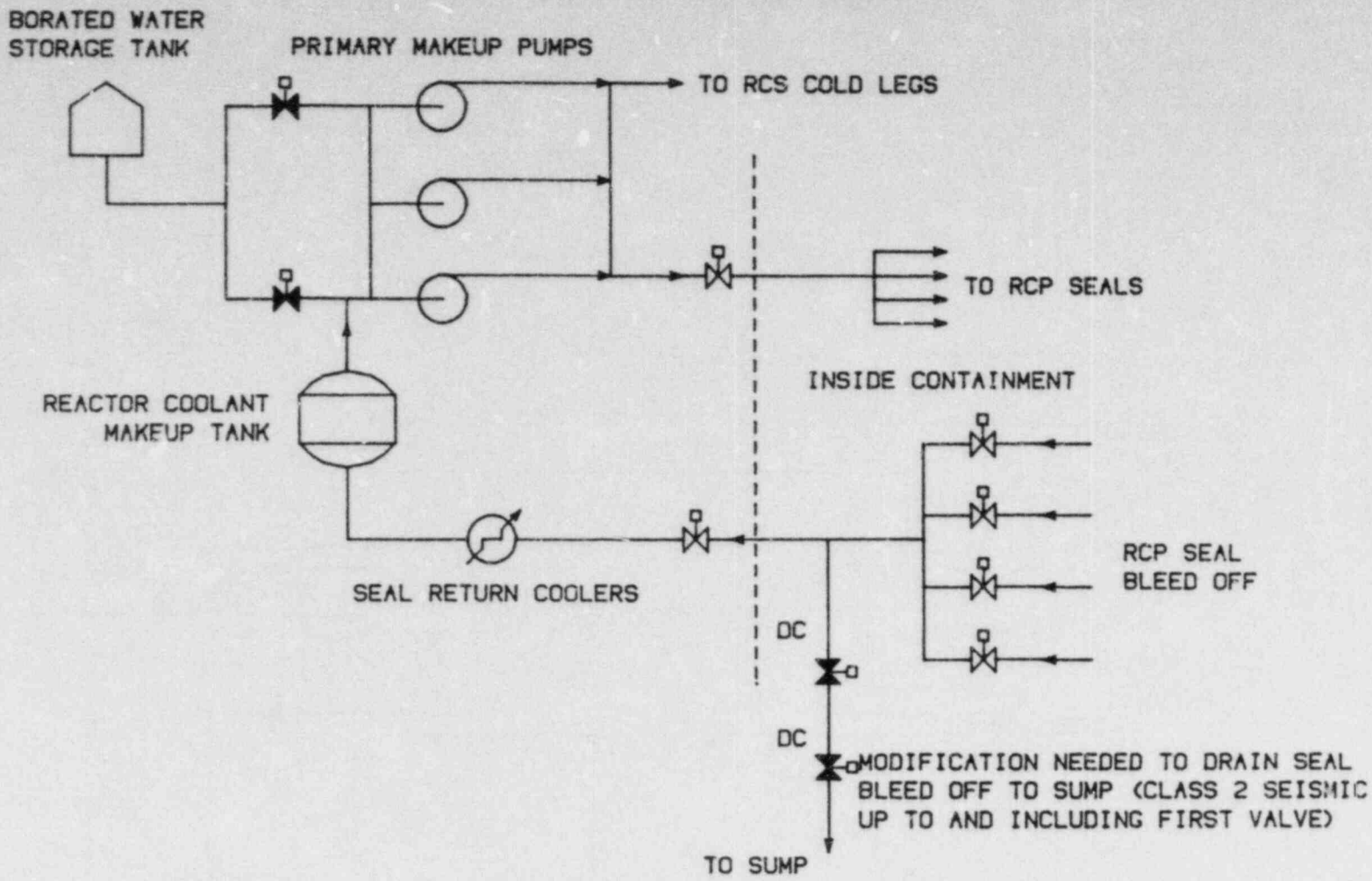
12 HOUR EXPANSION BWR 250 VOLT SYSTEM

FIGURE 8



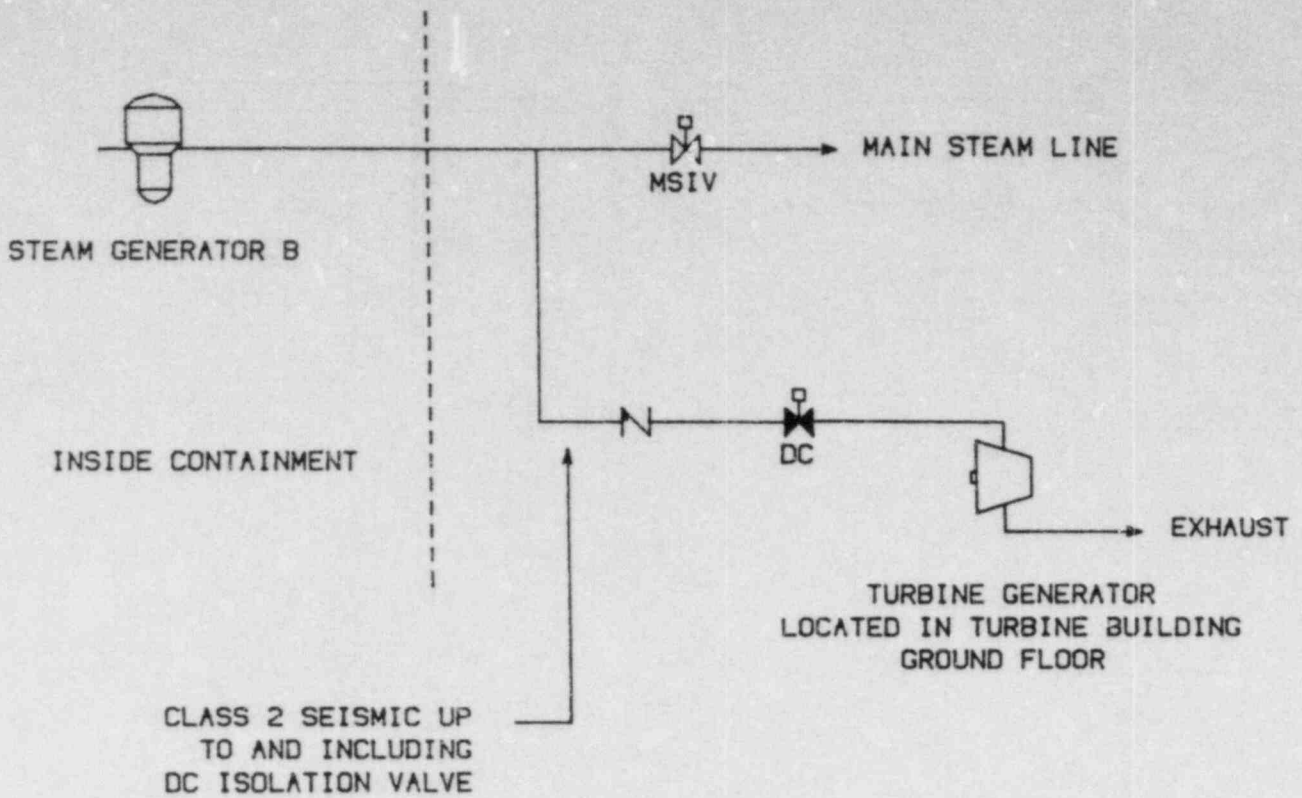
SIMPLIFIED SEAL INJECTION SYSTEM AT ANO-1

FIGURE 9



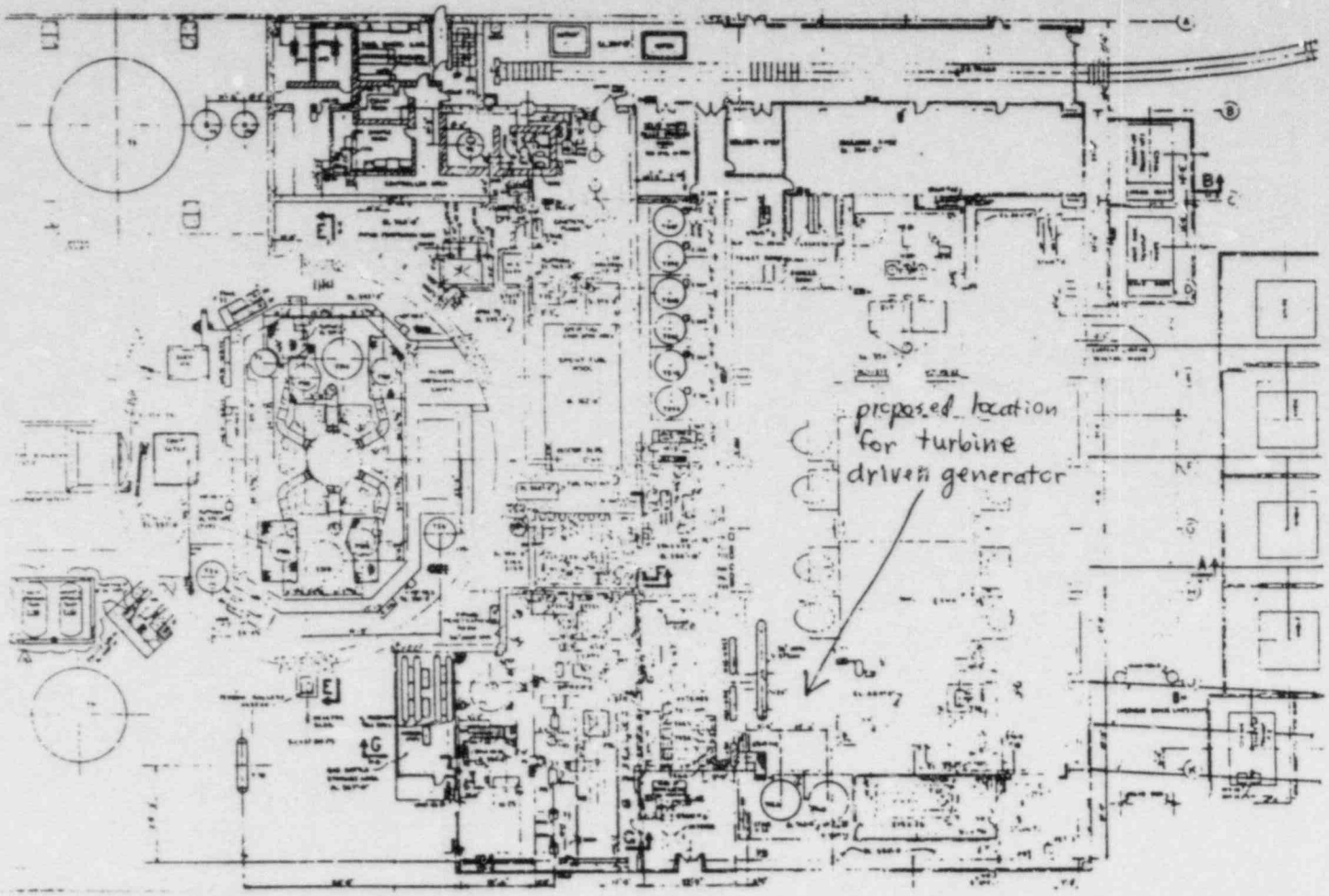
PROPOSED CONFIGURATION OF SEAL INJECTION SYSTEM FOR SUBTASKS 2A, 2B, 2D (PWR)

FIGURE 10



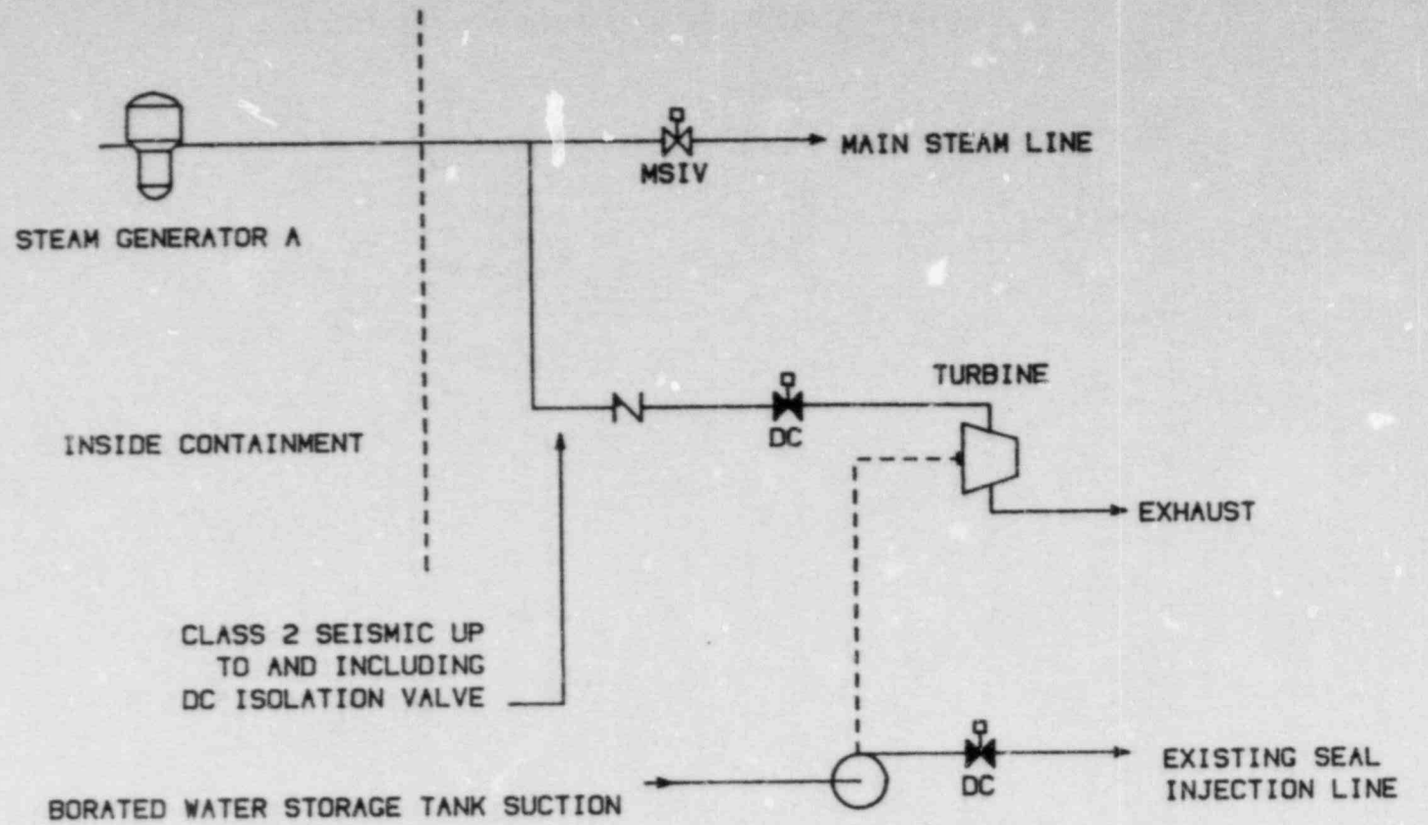
PROPOSED MODIFICATIONS FOR SUBTASK 2A (PWR)

FIGURE 11



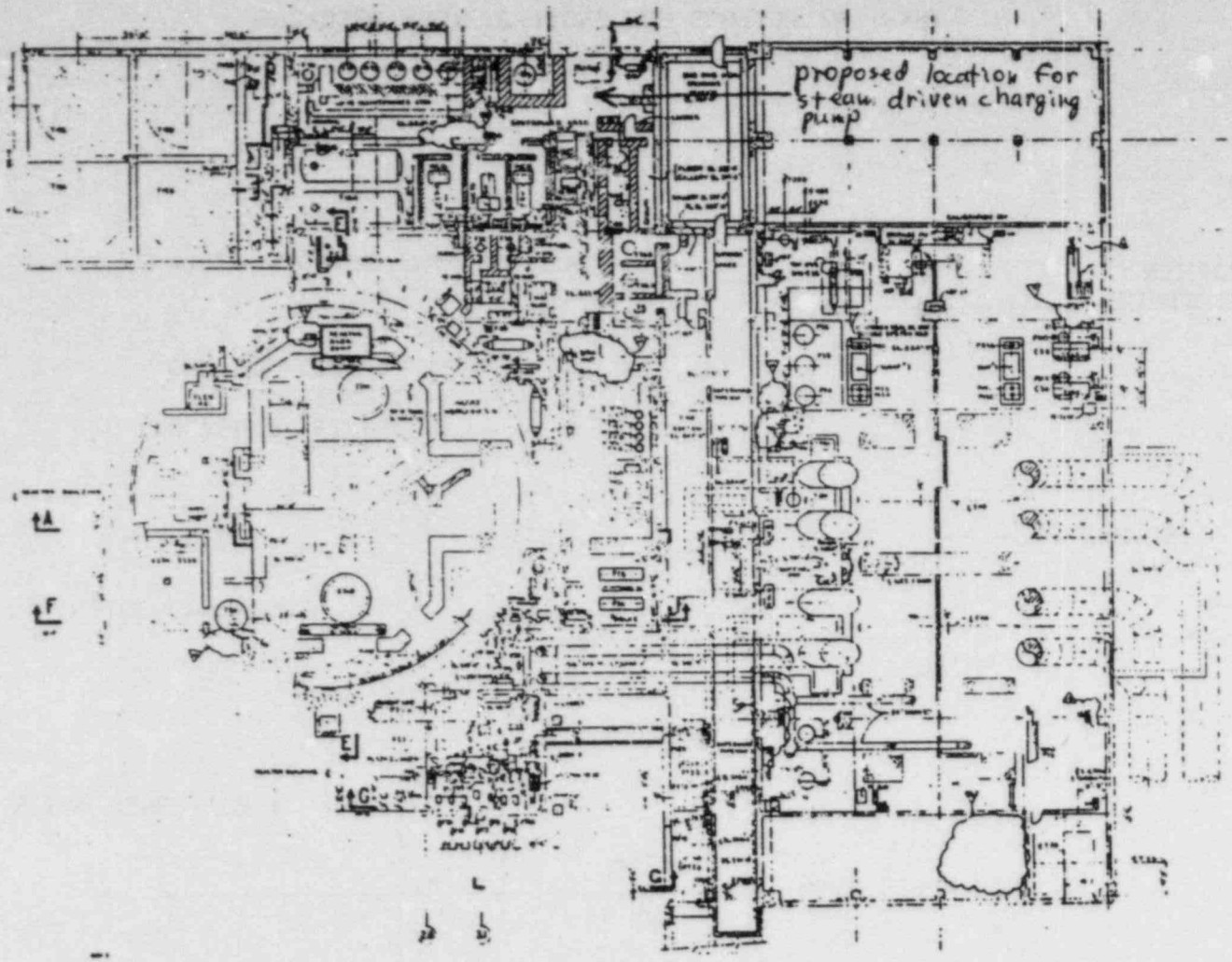
EQUIPMENT LOCATION GROUND FLOOR PLAN (ANO-1)

FIGURE 12



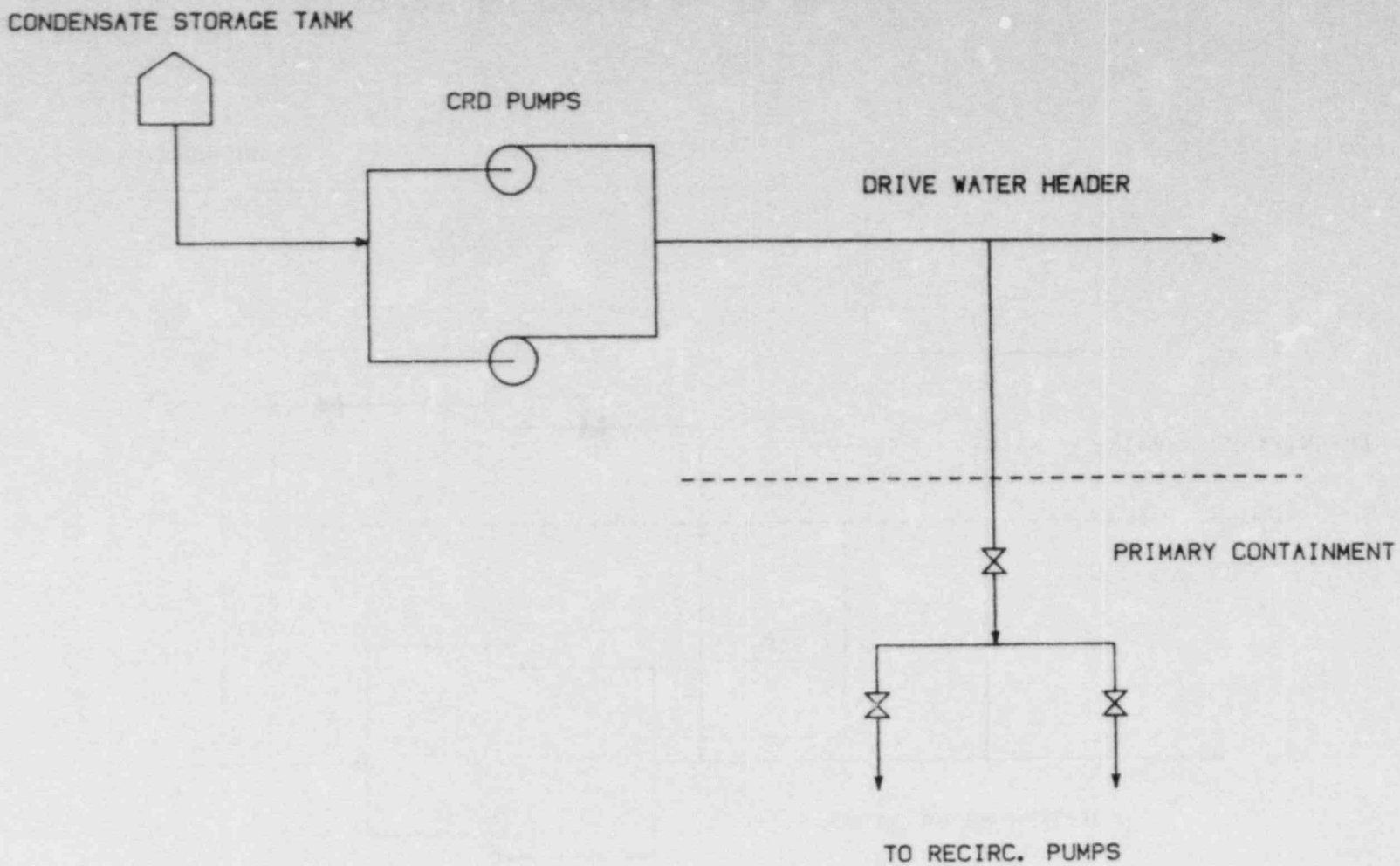
PROPOSED MODIFICATIONS FOR SUBTASK 2B (PWR)

FIGURE 13



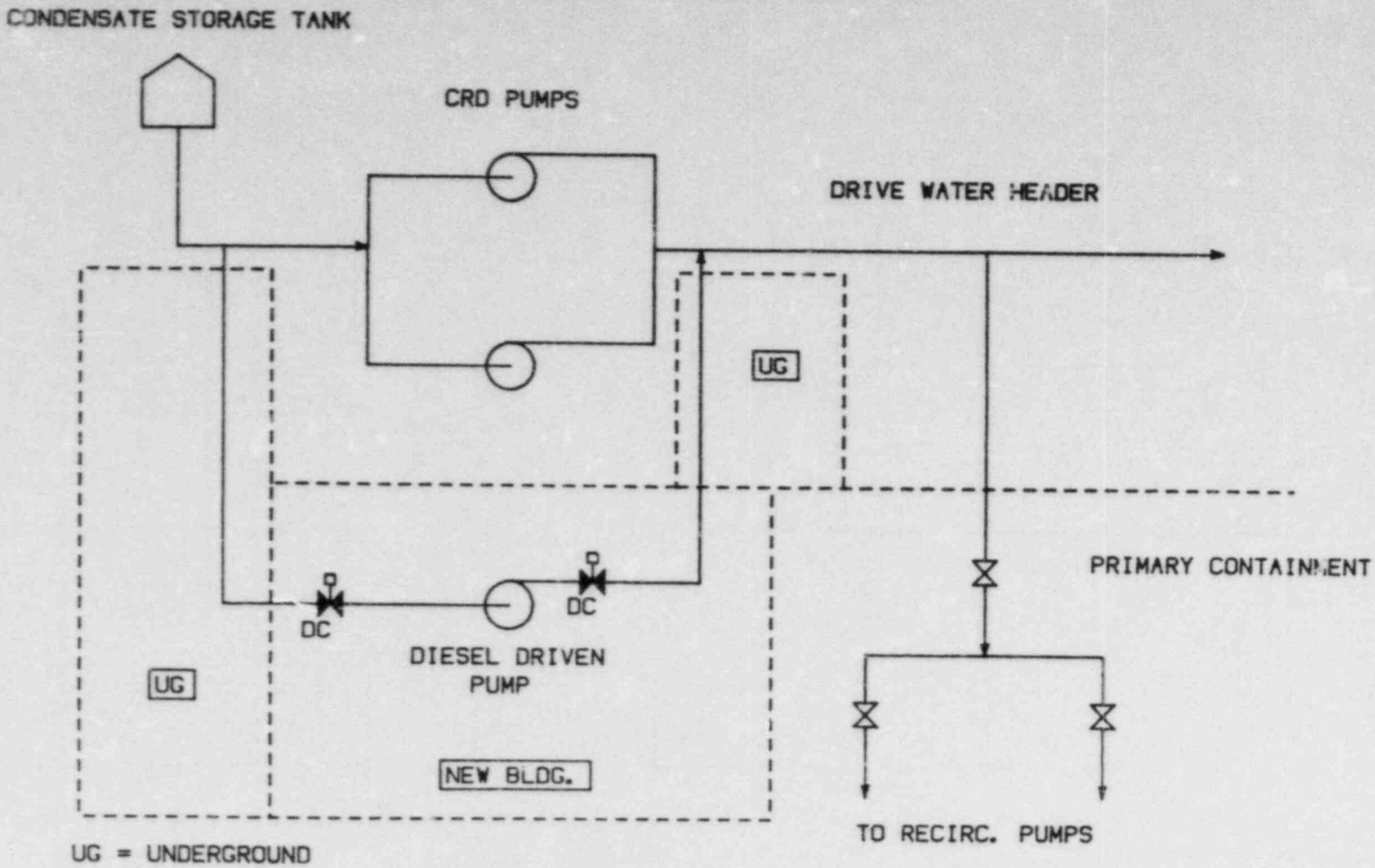
EQUIPMENT LOCATION PLAN BELOW GRADE (ANO-1)

FIGURE 14



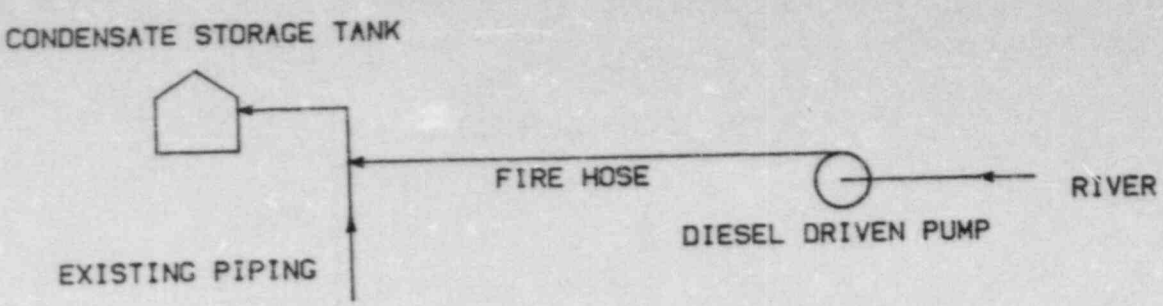
TYPICAL BWR SEAL INJECTION SUPPLY SYSTEM

FIGURE 15

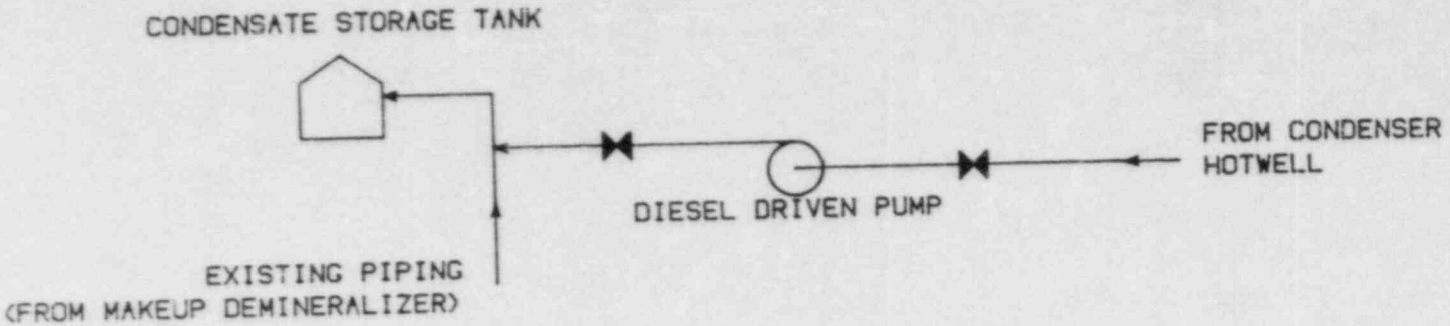


PROPOSED MODIFICATIONS FOR SUBTASK 2C (BWR)

FIGURE 16

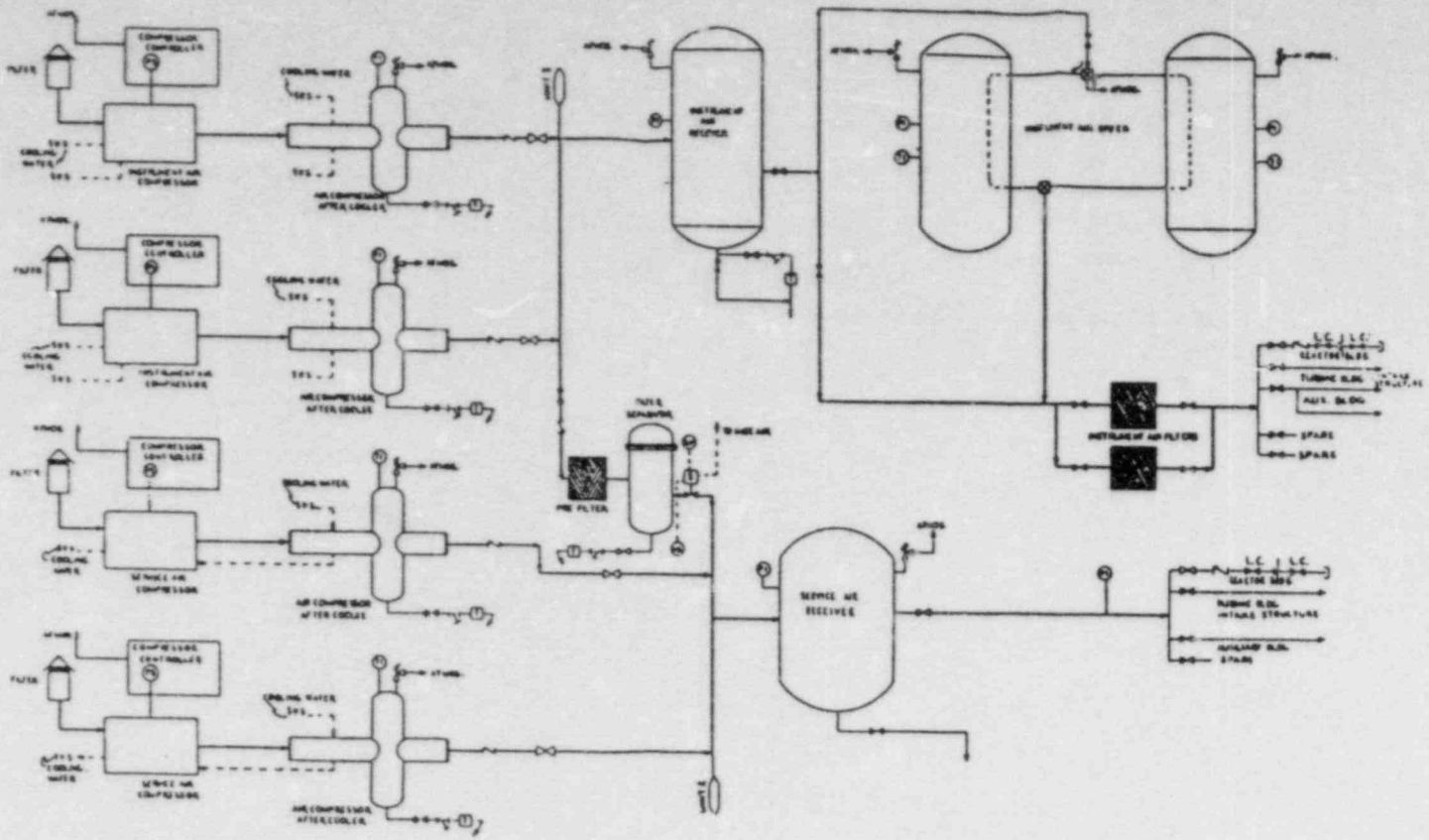


PROPOSED MODIFICATIONS FOR SUBTASK 3 (PWR)



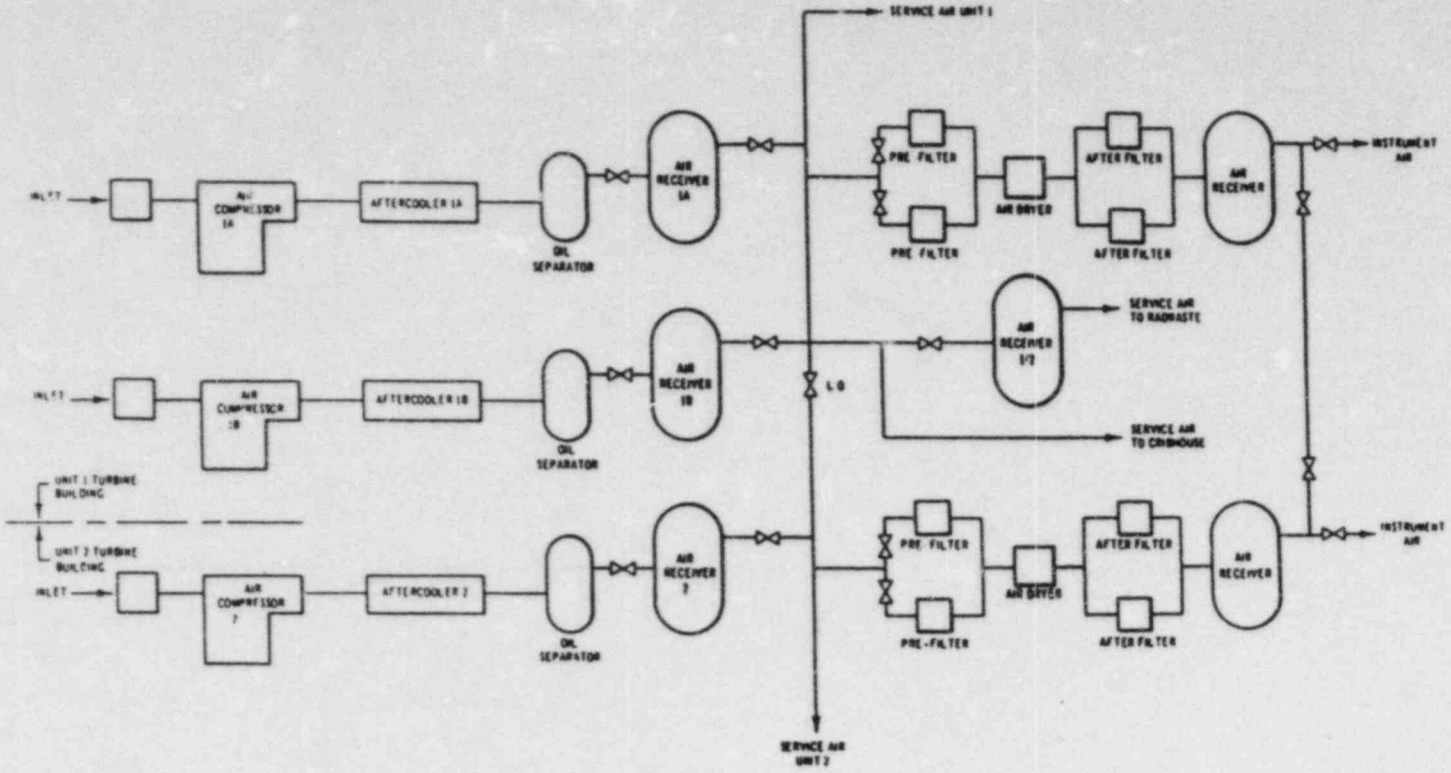
PROPOSED MODIFICATIONS FOR SUBTASK 3 (BWR)

FIGURE 17



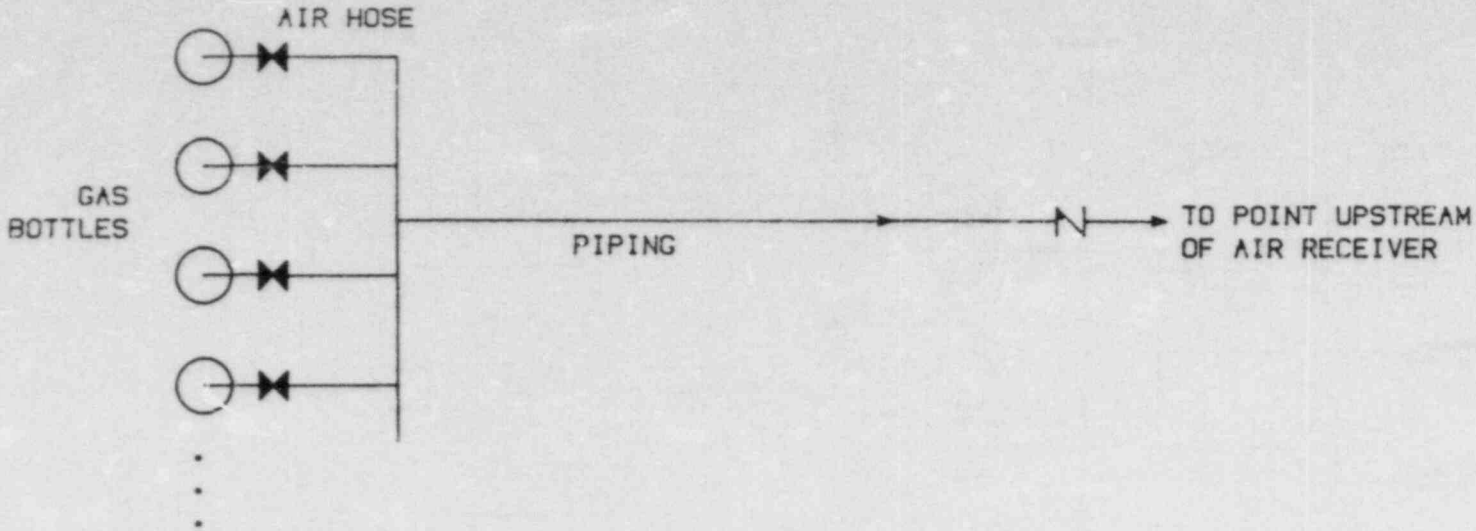
INSTRUMENT AIR SYSTEM AT ANO-1

FIGURE 18



INSTRUMENT AIR SYSTEM AT QUAD CITIES

FIGURE 19



PROPOSED MODIFICATIONS FOR SUBTASK 4 (PWR AND BWR)

FIGURE 20

Appendix A

Increase Battery Capacity

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 1 COST ANALYSIS FOR ADDING 2 X 1350 A-HR, 125 VDC

FACILITY TYPE PWR Page 1 of 5

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Original Installation							
480V 3 ph Pwr To Chargers Conduit, 2 1/2" GRS	130ft	3.95	.19	24.7	28.10	694.07	513.50
Hangers & Supports	12 ea	3.30	0.4	4.8	28.10	134.88	39.60
Conduit, 90 deg ELS, 2 1/2" GRS	12 ea	13.11	1.4	16.8	28.10	472.08	157.32
Locknuts & Bushings	16 ea	3.43	.65	10.4	28.10	292.24	54.88
Wire, 2/0 THW	520 ft	1.39	0.03	15.6	28.10	438.36	722.80
Terminations, Testing, ID	16 ea	2.87	0.2	3.2	28.10	89.92	45.92
50 AMP BKR 480 VAC 3 Pole w/Aux Contacts, NEMA 7 Enclosures	2 ea	250.00	4.0	8.0	28.10	224.80	500.00
Concrete Wall Penetrations	5 ea	25.00	2.0	10.0	28.10	281.00	125.00
125V 1350 A-Hr Batt Systems 125V 150 AMP Charger, Fully Regulated	2 ea	5000.00	40.0	80.0	28.10	2248.00	10000.00
200 AMP 125V DC BKR, 2 Pole W/Aux Contacts NEMA 1 Enclosures	2 ea	620.00	10.0	20.0	28.10	562.00	1240.00
1350 AMP-HR 125V Battery	2 ea	35600.00	80.0	160.0	28.10	4496.00	71200.00
w/Zone III Racks, Disconnects, Shunts, Terminations	2 ea	12000.00	24.0	48.0	28.10	1348.80	24000.00
Batt To DC Bus Hookups, WD06 Backup Conduit, 4" GRS	105 ft	7.84	0.36	37.8	28.10	1062.18	823.20
Hangers & Supports	9 ea	5.19	0.75	6.8	28.10	191.00	46.71
Conduit, 90 deg ELS, 4" GRS	5 ea	44.36	2.9	14.5	28.10	407.45	221.80
Locknuts & Bushings	12 ea	9.89	1.0	12.0	28.10	337.20	118.68
Concrete Wall Penetrations	4 ea	25.00	2.0	8.0	28.10	224.80	100.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 1 COST ANALYSIS FOR ADDING 2 X 1350 A-HR, 125 VDC

FACILITY TYPE PWR Page 2 of 5

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Wire, 500 MCM	420 ft	4.46	0.05	21.0	28.10	590.10	1873.21
Terminations, Testing, ID	8 ea	11.02	0.4	3.2	28.10	89.92	88.16
1350 AMP BKR, 2 Pole W/Aux Contacts, NEMA 1 Enclosure	1 ea	11500.00	24.00	24.00	28.10	674.40	11500.00
Batt to DC Bus Hookup, WD87 Backup Conduit, 4" GRS	165 ft	7.84	0.36	59.4	28.10	1669.14	1293.60
Hangers & Supports	15 ea	5.19	0.75	11.3	28.10	317.53	77.85
Conduit, 90 deg. ELS, 4" GRS	9 ea	44.36	2.9	26.1	28.10	733.41	399.24
Locknuts & Bushings	20 ea	9.89	1.0	20.00	28.10	562.00	197.80
Concrete Wall Penetration	6 ea	25.00	2.0	12.00	28.10	337.20	150.00
Wire, 500 MCM	660ft	4.46	0.05	33.00	28.10	927.30	2943.60
Terminations, Testing, ID	8 ea	11.20	0.55	4.4	28.10	123.64	88.16
1350 AMP BKR, 2 Pole W/Aux Contacts, NEMA 1 Enclosure	1 ea	11500.00	24.0	24.00	28.10	674.40	11500.00
Instrumentation Ammeter	4 ea	804.00	1.25	5.0	28.10	140.50	3216.00
Voltmeter	2 ea	838.00	1.25	2.5	28.10	70.25	1676.00
MV to I Transmitter	4 ea	800.00	10.00	40.00	28.10	1124.00	3200.00
Ground Fault Detectors	2 ea	792.00	4.00	8.00	28.10	224.80	1584.00
Conduit, 2" GRS	180 ft	2.85	0.14	25.2	28.10	708.12	513.00
Hangers & Supports	16 ea	2.85	0.7	11.2	28.10	314.72	45.60
Pull Boxes	2 ea	21.78	0.25	.5	28.10	14.05	43.56
Locknuts & Bushings	34 ea	1.47	0.35	11.90	28.10	334.39	49.98
Conduit, 90 deg. ELS, 2" GRS	13 ea	7.10	0.5	6.5	28.10	182.65	92.30

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 1 COST ANALYSIS FOR ADDING 2 X 1350 A-HR, 125 VDC

FACILITY TYPE PWR Page 3 of 5

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Wall Penetrations	8 ea	25.00	2.0	16	28.10	449.60	200.00
Wire, #12 THW	7920 ft	0.06	0.01	79.2	28.10	2225.52	475.2
Panel, Control Room Termination Testing, ID	88 Term.	1.00	1.0	88.0	28.10	2472.80	88.00
New 800 sq. ft Bldg Site Preparation	Allow	250.00	8.0	8.0	25.00	200.00	250.00
Excavation/Backfill	30 CY	1.00	1.0	30.0	18.00	540.$\phi\phi$	30.00
Footing/Foundation, Concrete	13 CY	56.00	0.20	2.6	18.00	46.80	728.00
Floor Slab, Concrete	15 CY	58.00	0.16	2.4	18.00	43.20	870.00
Concrete Blkwall,	1200 sq. ft.	1.00	0.05	60.0	30.00	1800.00	1200.00
Blkwall, Int, Fire Break	860 sq. ft.	1.0	.05	43.0	30.00	1290.00	860.00
Concrete T Slab Roof	800 sq. ft.	3.85	0.02	16.0	30.00	480.00	3080.00
Roof, Finish & Insulate	800 sq. ft.	0.55	0.03	24.0	30.00	720.00	440.00
Roll Up Door, 8 x 10 Electric	1 ea	2000.00	8.0	8.0	30.00	240.00	2000.00
Personnel Door 3 x 7 Ext	2 ea	300.00	8.0	16.0	20.00	320.00	600.00
Personnel Door 3 x 7 int	2 ea	223.00	2.5	5.0	20.00	100.00	446.00
200 AMP Service Panel	1 ea	891.00	7.0	7.0	30.00	210.00	891.00
Lights, Explosion Proof	10 ea	40.50	1.2	12.0	28.10	337.20	405.00
3/4" Couduit & Fittings	350 ft	0.86	0.00	28.0	28.10	786.80	301.00
3 #12 Wire	350 ft	0.18	0.01	3.5	28.10	98.35	63.00
Vent Fan & Louver	2 ea	1800.00	4.0	8.0	28.10	224.80	3600.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 1 COST ANALYSIS FOR ADDING 2 X 1350 A-HR, 125 VDC

FACILITY TYPE PWR Page 4 of 5

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
New 800 sq. ft. Bldg (cont'd)							
Plumbing/Utilities	800 sq. ft.	1.00	0.03	24.0	30.00	720.00	800.00
Halon Fire Sup. Sys	1 ea	12500.00					12500.00
Hydrogen Detection Sys	1 ea	5000.00					5000.00
Heater,Electric, 7.5 KW, Explosion Proof	1 ea	350.00	3.0	3.0	28.10	84.30	350.00
Emergency Lighting, Self-contained Explosion Proof	2 ea	1650.00	10.0	20.0	28.10	562.00	3300.00
Excavation (For Tie-in to Main Bldg)							
Trenching (1 ft x 3 ft Deep)	45 ft	1.00	1.0	45.0	19.00	855.00	45.00
Backfill	4CY	1.00	0.25	1.0	19.00	19.00	4.00
Concrete Red.	1CY	60.00	0.2	0.2	19.00	3.80	60.00
SUBTOTAL				1379.7		38126.55	118540.00
Maintenance and Testing							
(1) 2 hours/month, Electrolyte level & temperature, pilot cell specific gravity, terminal voltage	Annual			24.0	40.00	960.00	
(2) 2 hours, semi annual visual inspection	Annual			4.0	40.00	160.00	
(3) 6 hours/18 months resistance measurements	Annual			4.0	40.00	120.00	
SUBTOTAL				32.0		1240.00	

Original Installation	Low Case	Base Case	High Case
Labor Productivity Adjustment			
Labor Hours	1848(75%)	2059(67%)	2759(50%)
Labor Cost	$ 50,835	$ 56,905	$ 76,253
Labor + Material Cost (subtotal)	$169,375	$ 175,445	$194,793
Attributable to Equipment	$134,965	$138,790	$154,927
Attributable to Structures	$ 34,410	$ 36,655	$ 39,866
Geographical Adjustment	(85%)	(0%)	(115%)
Labor + Material Cost (subtotal)	$143,969	$175,445	$224,012
Engineering and Quality Assurance (25%)	$ 35,992	$ 43,861	$ 56,003
Subtotal	$179,961	$219,306	$280,015
Prime Contractor Markup (25%)	$ 44,990	$ 54,826	$ 70,004
Subtotal	$224,951	$274,132	$360,514
Operations and Maintenance			
Labor Productivity Adjustment			
Labor Hours	43(75%)	48(67%)	64(50%)
Labor Costs	$ 1,653	$ 1,851	$ 2,480
Labor + Material Cost (subtotal)	$ 1,653	$ 1,851	$ 2,480
Geographical Adjustment	(85%)	(0%)	(115%)
Labor and Material Cost (subtotal)	$ 1,405	$ 1,851	$ 2,852
Present Value Factor (10%,25 yrs=9.007 cumulative)			
Subtotal	$ 12,655	$ 16,672	$ 25,688
Total	$237,606	$290,804	$375,707

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC PWR SYSTEM

OPTION 2 COST ANALYSIS
6 X 1350 A-HR, 125 VDC

FACILITY TYPE PWR Page 1 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
480V 3 Ph Pwr to Chargers							
Conduit, 3" GRS	160 ft	5.31	0.23	36.8	28.10	1034.08	849.60
Hangers & Supports	15 ea	3.00	0.5	7.5	28.10	210.75	45.00
Conduit, 90 deg Els, 3" GRS	9 ea	21.07	1.8	16.2	28.10	455.22	189.63
Locknuts & Bushings	29 ea	4.30	1.0	29.0	28.10	814.90	124.70
Wire, 4/0 THW	480 ft	2.11	0.03	14.4	28.10	404.64	1012.80
Wire, #2 Bare Copper (Sys Grnd)	160 ft	0.65	0.02	3.2	28.10	89.92	104.00
Terminations, Testing, ID	48	5.20	0.25	12.0	28.10	337.20	249.60
50 Amp Bkr, 480V AC, 3 Pole w/ Aux Contacts, NEMA 7 Enclosures	6 ea	250.00	4.0	24.0	28.10	674.40	1500.00
Concrete Wall Penetrations	3 ea	25.00	2.0	6.0	28.10	168.60	75.00
125V 1350-HR Batt Systems							
125V 150 AMP Chargers, Fully Regulated	6 ea	5000.00	40.0	240.0	28.10	6744.00	30000.00
200 AMP 125V Bkr, 2 Pole w/ Aux contacts, NEMA 7 Enclosures	6 ea	620.00	10.0	60.0	28.10	1686.00	3720.00
1350 Ampere Hour, 125V	6 ea	35600.00	80.0	480.0	28.10	13488.00	213600.00
Battery w/Zone III Racks, Disconnects, Shunts, Terminations	6 ea	12000.00	24.0	144.0	28.10	4046.40	72000.00
Batts to DC Bus Hookups WD06 Backups							
Conduit, 4" GRS	405 ft	7.84	0.36	145.8	28.10	4096.98	3175.20
Hangers & Supports	27 ea	5.19	0.75	20.3	28.10	570.43	140.13

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC PWR SYSTEM

OPTION 2 COST ANALYSIS
6 X 1350 A-HR, 125 VDC

FACILITY TYPE PWR Page 2 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Conduit, 90 deg Els, 4" GRS	15 ea	44.36	2.9	43.5	28.10	1222.35	665.40
Locknuts & Bushings	48 ea	9.89	1.0	48.0	28.10	1348.80	474.72
Concrete Wall Penetrations	12 ea	25.00	2.0	24.0	28.10	674.40	300.00
Wire, 500 MCM	1620 ft	4.46	0.05	81.0	28.10	2276.10	7225.20
Terminations, Testing ID	24	11.02	0.4	9.6	28.10	269.76	264.48
1350 AMP Bkr, 2 Pole w/ Aux Contacts, NEMA 7 Enclosure	3 ea	11500.00	24.0	72.0	28.10	2023.20	34500.00
Batt to DC Bus Hookup MD-07 Back up							
Conduit, 4" GRS	585 ft	7.84	0.36	210.6	28.10	5917.86	4586.40
Hangers & Supports	45	5.19	0.75	33.8	28.10	949.78	233.55
Conduit, 90 deg Els, 4" GRS	27 ea	44.36	2.9	78.3	28.10	2200.23	1197.72
Concrete Wall Penetrations	18 ea	25.00	2.0	36.0	28.10	1011.60	450.00
Wire, 500 MCM (4/C)	2340 ft	4.46	0.05	117.0	28.10	3287.70	10436.40
Terminations, Testing, ID	24	11.02	0.4	9.6	28.10	269.76	264.48
1350 AMP Bkr, 2 Pole w/ Aux Contacts, NEMA I Enclosure	3 ea	11500.00	24.0	72.0	28.10	2023.20	34500.00
Instrumentation							
Ammeter	12 ea	804.00	1.25	15.0	28.10	421.50	9648.00
Voltmeter	6 ea	838.00	1.25	7.5	28.10	210.75	5028.00
MV to I transmitter	12 ea	800.00	10.0	120.0	28.10	3372.00	9600.00
Ground Fault Detectors	6 ea	792.50	4.0	24.0	28.10	674.40	4755.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC PWR SYSTEM

OPTION 2 COST ANALYSIS
6 X 1350 A-HR, 125 VDC

FACILITY TYPE PWR Page 3 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Conduit, 2" GRS	570 ft	2.85	0.14	79.8	28.10	2242.38	1624.50
Hangers & Supports	48 ea	2.85	0.7	33.6	28.10	944.16	136.80
Pull Boxes	6 ea	21.78	0.25	1.5	28.10	42.15	130.68
Locknuts & Bushings	102 ea	1.47	0.35	35.7	28.10	1003.17	149.94
Conduit, 90 deg Els, 2" GRS	13 ea	7.10	0.5	6.5	28.10	182.65	92.30
Wall Penetrations	24 ea	25.00	2.0	48.0	28.10	1348.80	600.00
Wire, #12 THW	25000 ft	0.06	0.01	250.0	28.10	7047.48	1504.80
Panels, Control Room (30 Analog, 42 Discrete Displays)	1 ea	15000.00	40.0	40.0	28.10	1124.00	15000.00
Terminations, Testing, ID	264 Term	1.00	1.0	264.0	28.10	7418.40	264.00
New 2400 sq.ft. Bldg							
Site Preparations	Allow	750.00	24.0	24.0	25.00	600.00	750.00
Excavation/Backfill	90 cy	1.00	1.0	90.0	18.00	1620.00	90.00
Footing, Foundation, Concrete	39 cy	56.00	0.2	7.8	18.00	140.40	2184.00
Flour Slab, Concrete	45 cy	58.00	0.16	7.2	18.00	129.60	2610.00
Concrete Block Wall, Ext	2000 sq.ft.	1.00	0.05	100.0	30.00	3000.00	2000.00
Block Wall, Interior, Fire	1400 sq.ft.	1.00	0.05	70.0	30.00	2100.00	1400.00
Concrete T Slab Roof	2400 sq.ft.	3.85	0.02	48.0	30.00	1440.00	9240.00
Roof, Finish & Insulate	2400 sq.ft.	0.55	0.03	72.0	30.00	2160.00	1320.00
Roll Up Door, 8X10 Elec	1 ea	2000.00	8.0	8.0	30.00	240.00	2000.00
Personnel Door 3X7 Ext	2 ea	300.00	8.0	16.0	20.00	320.00	600.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC PWR SYSTEM

OPTION 2 COST ANALYSIS
6 X 1350 A-HR, 125 VDC

FACILITY TYPE PWR Page 4 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Personnel Door, 3X7 Int	6 ea	223.00	2.5	15.0	20.00	300.00	1338.00
500 AMP Service Panel	1 ea	2350.00	4.0	4.0	30.00	120.00	2350.00
Lights, Explosion Proof	27 ea	40.50	1.2	32.4	28.10	910.44	1093.50
3/4" Conduit & Ftngs w/3 #12 Wire	1050 ft	0.86	0.08	84.0	28.10	2360.40	903.00
Vent Fan & Louver	6 ea	2965.00					17790.00
Plumbing/Utilities	2400 sq.ft.	1.00	0.03	72.0	30.00	2160.00	2400.00
Halon Fire Sup. Sys	1 ea	12500.00					12500.00
Hydrogen Det. Sys, 2400 sq.ft. Coverage	1 ea	5000.00					5000.00
Heater, 7.5KW Exp. Proof	3 ea	350.00	3.0	9.0	28.10	252.90	1050.00
Energ. Lighting, Self-Contained Expl. Proof	6 ea	1650.00	10.0	60.0	28.10	1686.00	9900.00
Excavation (for Conduit routing to Main Bldg.							
Trenching 2 ft x 3 ft Deep	10 ft	1.00	2.00	20.0	19.00	380.00	10.00
Trenching 1 ft x 3 ft deep	40 ft	.90	1.5	60.0	19.00	1140.00	36.00
Backfill	4.4 cy	1.00	0.25	1.1	19.00	20.90	4.40
Concrete Red	1.2 cy	60.00	0.20	0.2	19.00	3.80	72.00
SUBTOTAL				3801.7		105412.74	547050.33

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC PWR SYSTEM

OPTION 2 COST ANALYSIS
6 X 1350 A-HR, 125 VDC

FACILITY TYPE PWR Page 5 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Maintenance and Testing							
(1) 6 hours/month electrolyte level and temperature, Pilot cell specific gravity terminal voltage	Annual			72.0	40.00	2880.00	
(2) 2 hours, semi annual visual inspection	Annual			4.0	40.00	160.00	
(3) 12 hours/18 months resistance measurements	Annual			8.0	40.00	320.00	
SUBTOTAL				84.0	40.00	3360.00	

Original Installation	Low Case	Base Case	High Case
Labor Productivity Adjustment			
Labor Hours	5869(75%)	5674(69%)	7604(50%)
Labor Cost	$140,550	$157,332	$210,825
Labor + Material Cost (subtotal)	$687,600	$ 704,390	$757,883
Attributable to Equipment	$586,916	$601,388	$645,712
Attributable to Structures	$100,682	$103,010	$112,171
Geographical Adjustment	(85%)	(0%)	(115%)
Labor + Material Cost (subtotal)	$504,967	$704,390	$871,565
Engineering and Quality Assurance (25%)	$145,617	$176,098	$217,891
Subtotal	$730,584	$880,488	$1,089,456
Prime Contractor Markup (25%)	$182,646	$220,122	$272,364
Subtotal	$913,230	$1,110,610	$1,361,820
Operations and Maintenance			
Labor Productivity Adjustment			
Labor Hours	112 (75%)	125 (67%)	168 (50%)
Labor Costs	$ 4,480	$ 5,015	$ 6,720
Labor + Material Cost (subtotal)	$ 4,480	$ 5,015	$ 6,720
Geographical Adjustment	(85%)	(0%)	(115%)
Labor and Material Cost (subtotal)	$ 3,808	$ 5,015	$ 7,726
Present Value Factor (10%,25 yrs=9.007 cumulative)			
Subtotal	$ 34,299	$ 45,170	$ 69,606
Total	$947,529	$1,145,780	$1,431,426

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 3 ALT POWER SOURCE, DIESEL GEN. FACILITY TYPE PWR Page 1 of 4

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Original Installation							
Diesel Powered Generator							
Diesel Generator Set Model 16 VGD w/480V 3 Phase Output Radiator Cooled Engine, Generator Switchgear Set, with Breakers	1 ea	100000.00	100.0	100.0	28.16	2819.00	100000.00
Fuel Storage Tank, 750 gal	1 ea	700.00	8.0	8.0	18.00	144.00	700.00
Fuel Pump, 25 psi, 5 GPM	1 ea	125.00	3.0	3.0	27.50	82.50	125.00
Fuel Line, 3/4"	25 ft	1.05	2.0	50.0	27.50	1375.00	26.25
Intake Duct, 12"	11 ft	1.85	0.1	1.1	27.50	30.25	20.35
Exhaust Duct, 20 in	5 ft	3.25	0.1	0.5	27.50	13.75	16.25
Diesel Powered Gen. (Cont'd) Exhaust Sound Attenuator	1 ea	25.00	1.0	1.0	27.50	27.50	25.00
Start System, Fill generator w/750 gal of fuel	1 ea	750.00	1.0	1.0a	27.50	27.50	750.00
400 sq. ft. Bldg for B/u Generator							
Site Preparation	Allow	250.00	8.0	8.0	25.00	200.00	250.00
Excavation & Backfill	36CY	1.00	1.0	36.0	18.00	648.00	36.00
Footing & Foundation	9 CY	56.00	0.2	1.8	18.00	32.40	504.00
Concrete Floor Slab	8 CY	58.00	0.16	1.3	18.00	23.40	464.00
Concrete Block Wall	800 sq. ft	1.00	0.05	40.0	30.00	1200.00	800.00
Concrete T Slab Roof	400 sq. ft	3.85	0.02	8.0	30.00	240.00	1540.00
Build Up Roof w/Insulation	400sq. ft	0.55	0.03	12.0	30.00	360.00	220.00
Roll Up Door, 8 x 10 Electric	1 ea	2000.00	8.0	8.0	30.00	240.00	2000.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 3 ALT POWER SOURCE, DIESEL GEN. FACILITY TYPE PWR Page 2 of 4

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Utility, Plumbing & Piping	400 sq. ft.	1.00	0.03	12.0	30.00	360.00	400.00
3/4" Conduit w/3 #12 Wire, Fittings	200 ft	0.86	0.08	16.0	28.10	449.60	172.00
Heater, Electric, 7.5KW, Explosion Proof	1 ea	350.00	3.0	3.0	28.10	84.30	350.00
Lights, Explosion Proof	5 ea	40.50	1.2	6.0	28.10	168.60	202.50
200A bldg Service Panel	1 ea	891.00	7.0	7.0	30.00	210.00	891.00
Fire Detection/Protection Systes	1 ea						12500.00
Vent Fan & Louver	1 ea	2000.00	8.0	8.0	27.50	220.00	2000.00
Paint	1200 sq. ft.	0.03	0.01	12.0	21.20	254.40	36.00
Penetrations:							
Sleeve Intake 12"	1 ea	5.00	1.0	1.0	27.50	27.50	5.00
Sleeve Exhaust 20"	1 ea	10.00	1.0	1.0	27.50	27.50	10.00
Sleeve Fuel Line, 3/4"	1 ea	1.00	1.0	1.0	27.50	27.50	1.00
Sleeve Elec. Service, 2"	1 ea	1.00	1.0	1.0	27.50	27.50	1.00
Plumbing, Inlet & Drains	2 ea	25.00	2.0	4.0	30.00	120.00	50.00
Excavation, Fuel Tank	6 CY	1.00	1.0	6.0	19.00	114.00	6.00
Backfill, Fuel Tank	2 Cy	1.00	1.0	2.0	19.00	38.00	2.00
Excavation, Elec. Conduit	2.5 CY	1.00	1.0	2.5	19.00	47.50	2.50
Concrete Red	.8 CY	60.00	0.2	0.2	19.00	3.80	48.00
Backfill	2 CY	1.00	0.25	0.5	19.00	9.50	2.00
Tie In Generator to ESF 480V Bus Conduit, 4" GRS	106 ft	7.84	0.36	38.2	28.10	1073.42	831.04

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 3 ALT POWER SOURCE, DIESEL GEN. FACILITY TYPE PWR Page 3 of 4

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Conduit, 90 deg Elbows, 4" GRS	8 ea	44.36	2.9	23.2	28.10	651.92	354.88
Pull Box	1 ea	25.00	1.0	1.0	28.10	28.10	25.00
Hangers & Supports	11 ea	5.19	.75	8.3	28.10	233.23	57.09
Locknuts & Bushings	4 ea	9.89	1.0	4.0	28.10	112.40	39.56
Wire, 500 MCM	318 ft	4.46	0.05	15.9	28.10	446.79	1418.28
Wire, 3/0 Bare (Half Dty Neutral)	106 ft	1.10	0.02	2.1	28.10	59.01	116.60
Terminations, Testing, ID	16 ea	11.02	0.4	6.4	28.10	179.84	176.32
500 Amp Bkr, 480 Vac	1 ea	250.00	4.0	4.0	28.10	112.40	250.00
3 Pole w/Aux Contacts, NEMA 1 Enclosure							
Concrete Wall Penetrations	5 ea	25.0	2.0	10.0	28.10	281.00	125.00
SUBTOTAL				476.0		12822.11	127549.62
Operations & Maintenance							
Check generator oil and water, start and load 2 hrs/week	Annual			104.0	40.00	4160.00	

Original Installation	Low Case	Base Case	High Case
Labor Productivity Adjustment			
Labor Hours	635(75%)	710(67%)	952(58%)
Labor Cost	$ 17,096	$ 19,137	$ 25,644
Labor + Material Cost (subtotal)	$144,646	$146,687	$153,193
Attributable to Equipment	$114,058	$115,299	$119,214
Attributable to Structures	$ 30,588	$ 31,397	$ 33,979
Geographical Adjustment	(85%)	(0%)	(115%)
Labor + Material Cost (subtotal)	$122,949	$146,687	$176,172
Engineering and Quality Assurance (25%)	$ 30,737	$ 36,672	$ 44,043
Subtotal	$153,686	$183,359	$220,215
Prime Contractor Markup (25%)	$ 38,422	$ 45,840	$ 55,054
Subtotal	$192,108	$229,199	$ 275,269
Operations and Maintenance			
Labor Productivity Adjustment			
Labor Hours	139 (75%)	155(67%)	208(58%)
Labor Costs	$ 5,547	$ 6,209	$ 8,320
Labor + Material Cost (subtotal)	$ 5,547	$ 6,209	$ 8,320
Geographical Adjustment	(85%)	(0%)	(115%)
Labor and Material Cost (subtotal)	$ 4,715	$ 6,209	$ 9,568
Present Value Factor (10%,25 yrs=9.077 cumulative)			
Subtotal	$ 42,468	$ 55,924	$ 86,179
Total	$234,576	$285,123	$361,448

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 4 ALT POWER SOURCE, GAS TURBINE GEN. FACILITY TYPE PWR Page 1 of 4

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Original Installation							
Diesel Fuel powered Elect. System Garrett 831-500 Gas Turbine Generator Set, Liquid Fuel Option, 480V 3 ph Output includes, a-b-c-d	1 ea	250000.00	72.0	72.0	28.10	2032.20	250000.00
a)Enclosure, Indoor, Sound Attenuating	1 ea						
b)Generator Switchgear Set, with Breakers	1 ea						
c)Electric Start System (24V DC Motor,Batt, & Charger)	1 ea						
d) Exhaust Silencer	1 ea						
Inlet Duct, 14" with grid,	11 ft	2.25	0.1	1.1	27.50	30.25	24.75
Personnel, FOD, Inlet	1 ea						
Exhaust Duct, 10" x 26", Double Wall	5 ft	20.00	1.5	7.5	27.50	206.25	100.00
Fuel Storage Tank, 750 gal	1 ea	700.00	8.0	8.0	27.50	220.00	700.00
Fuel Pump, 5 GPM @ 25 PSI	1 ea	100.00	3.0	3.0	27.50	82.50	100.00
Fuel Line, 3/4"	25 ft	1.05	0.08	2.0	27.50	55.00	26.25
400 Sq. ft Bldg. For B/U Generator							
Site Preparation	Allow	250.00	8.0	8.0	25.00	200.00	250.00
Excavation & Backfill	36 CY	1.00	1.0	36.0	18.00	648.00	36.00
Footing & Foundation	9 CY	56.00	0.2	1.8	18.00	32.40	504.00
Concrete Floor Slab	8 CY	58.00	0.16	1.3	18.00	23.40	464.00
Concrete Block Wall	800 sq. ft	1.00	0.05	40.0	30.00	1200.00	800.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 4 ALT POWER SOURCE, GAS TURBINE GEN. FACILITY TYPE PWR Page 2 of 4

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Concrete T Slab Roof	400 sq. ft	3.85	0.02	8.0	30.00	240.00	1540.00
Build Up Roof w/Insulation	400 sq. ft	0.55	0.12	12.0	30.00	360.00	220.00
Roll Up Door, 8 x 10 Electric	1 ea	2000.00	8.0	8.0	30.00	240.00	2000.00
Utility, Plumbing & Piping	400 sq. ft	1.00	0.03	12.0	30.00	360.00	400.00
3/4" Conduit w/3 #12 Wire, Fittings	200 ft	0.86	0.08	16.0	28.10	449.60	172.00
Heater, Electric, 7.5 KW, Explosion Proof	1 ea	350.00	3.0	3.0	28.10	84.30	350.00
Lights, Explosion Proof	5 ea	40.50	1.2	6.0	28.10	168.60	202.50
200A Bldg. Service Panel	1 ea	891.00	7.0	7.0	30.00	210.00	891.00
Vent Fan & Louver	1 ea	2000.00	8.0	8.0	27.50	220.00	2000.00
Fire Detection/Protection System	1 ea						12500.00
Paint	1200 sq. ft.	0.03	0.01	12.0	21.20	254.40	36.00
Penetrations:							
Inlet 14"	1 ea	6.00	1.0	1.0	27.50	27.50	6.00
Exhaust 10 x 26	1 ea	72.00	1.0	1.0	27.50	27.50	72.00
Fuel Line, 3/4"	1 ea	1.00	1.0	1.0	27.50	27.50	1.00
Elec. Service, 2"	1 ea	1.00	1.0	1.0	27.50	27.50	1.00
Plumbing, Inlet & Drains	2 ea	25.00	2.0	4.0	30.00	120.00	50.00
Excavation, Fuel Tank	6 CY	1.00	1.0	6.0	19.00	114.00	6.00
Backfill, Fuel Tank	2 CY	1.00	1.0	2.0	19.00	38.00	2.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 4 ALT POWER SOURCE, GAS TURBINE GEN FACILITY TYPE PWR Page 3 of 4

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Excavation, Elec. Conduit	2.5CY	1.00	1.0	1.0	19.60	19.00	2.50
Concrete Red	.8CY	60.00	0.2	0.2	19.00	3.80	48.00
Backfill,	2 CY	1.00	0.25	0.5	19.00	9.50	2.00
Tie in, Generator to ESF 480V Bus							
Conduit, 4" GRS	106 ft	7.84	.36	38.2	28.10	1073.42	831.04
Conduit, 90deg Elbows, 4" GRS	8 ea	44.36	2.9	23.2	28.10	651.92	354.88
Pull Box	1 ea	25.00	1.0	1.0	28.10	28.10	25.00
Hangers & Supports	11 ea	5.19	.75	8.3	28.10	233.23	57.09
Locknuts & Bushings	4 ea	9.89	1.0	4.0	28.10	112.40	39.56
Wire, 500 MCM	318 ft	4.46	6.05	15.9	28.10	446.79	1418.28
Wire, 3/0 Bare (Half DTY Neutral)	106 ft.	1.10	0.02	2.1	28.10	59.01	116.60
Terminations, Testing, ID	16 ea	11.62	0.4	6.4	28.10	179.84	176.32
500 AMP BKR, 480 VAC 3 Pole W/Aux Contacts, NEMA 1 Enclosure	1 ea	250.00	4.0	4.0	28.10	112.40	250.00
Concrete Wall Penetrations	5 ea	25.00	2.0	10.0	28.19	281.00	125.00
SUBTOTAL				403.5		10,909.31	276,900.77
Operations and Maintenance							
Start-up Test Weekly: 1 hr	Annual			52.0	40.00	2080.00	

COST SUMMARY

Original Installation	Low Case	Base Case	High Case
Labor Productivity Adjustment			
Labor Hours	532(75%)	602(67%)	307(50%)
Labor Cost	$ 14,546	$ 16,283	$ 21,818
Labor + Material Cost (subtotal)	$291,449	$293,186	$298,721
Attributable to Equipment	$262,195	$263,102	$266,061
Attributable to Structures	$ 29,274	$ 30,084	$ 32,660
Geographical Adjustment	(85%)	(0%)	(115%)
Labor + Material Cost (subtotal)	$247,732	$293,186	$343,529
Engineering and Quality Assurance (25%)	$ 61,933	$ 73,297	$ 85,882
Subtotal	$209,665	$366,483	$429,411
Prime contractor Markup (25%)	$ 77,416	$ 91,621	$107,353
Subtotal	$387,081	$458,016	$ 536,764
Operations and Maintenance			
Labor Productivity Adjustment			
Labor Hours	69 (75%)	78 (67%)	104(50%)
Labor Costs	$ 2,773	$ 3,104	$ 4,160
Labor + Material Cost (subtotal)	$ 2,773	$ 3,104	$ 4,160
Geographical Adjustment	(85%)	(0%)	(115%)
Labor and Material Cost (subtotal)	$ 2,357	$ 3,104	$ 4,784
Present Value Factor (10%,25 yrs=9.077 cumulative)			
Subtotal	$ 21,229	$ 27,958	$ 43,089
Total	$408,227	$486,062	$ 579,853

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 1 COST ANALYSIS FOR ADDING 125V 500AHr & 250V 900AHr Systems

FACILITY TYPE BWR Page 1 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Original Installation							
Power to Chargers, 480 V 3 ph; From Existing Batt Charger Rm to New Batt Bldg							
Conduit, 2 1/2" GRS	120 ft	3.95	0.19	22.8	28.10	640.68	474.00
Hangers & Supports	6 ea	3.30	0.4	2.4	28.10	67.44	19.80
Conduit, GRS 90 deg Elbows 2 1/2"	7 ea	13.11	1.4	9.8	28.10	275.38	91.77
Locknuts & Bushings	18 ea	3.43	0.65	11.7	28.10	328.77	61.74
Wire, 2/0 THW	480 ft	1.39	0.03	14.4	28.10	404.64	667.20
Terminations, Testing, ID	8 ea	2.87	0.20	1.6	28.10	44.96	22.96
25 AMP BKR 480 VAC 3 Pole w/Aux Contacts NEMA 7 Enclosure (For 125 V Batt Charger in New Batt Bldg)	1 ea	226.00	4.0	4.0	28.10	112.40	226.00
50 AMP BKR 480 VAC 3 Pole w/Aux Contact NEMA 7 Enclosure (for 250V Batt Charger in New Batt Bldg)	1 ea	303.00	6.6	6.6	28.10	185.46	303.00
Concrete Wall Penetrations	2 ea	25.00	2.0	4.0	28.10	112.40	50.00
125V 500 AMP H Batt System							
125V 50 AMP Charger Fully Regulated w/Equalizing charge capacity	1 ea	4000.00	40.0	40.0	28.10	1124.00	4000.00
75 AMP 125V DC BKR, 2 Pole w/Aux contacts, NEMA 7 Encl	1 ea	300.00	6.6	6.6	28.10	185.46	300.00
500 AMP-Hr 125V Batt	1 ea	13200.00	40.0	40.0	28.10	1124.00	13200.00
w/Zone III Rack Disconnect, Shunts, Terminations	1 ea	4000.00	16.0	16.0	28.00	449.60	4000.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 1 COST ANALYSIS FOR ADDING 125V 500AHr & 250V 900AHr Systems

FACILITY TYPE BWR Page 2 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Batt Bank to DC Bus Hookup Conduit, 4" GRS	120 ft	7.84	.36	43.2	28.10	1213.92	940.80
Conduit, 4" Elbows, GRS	7 ea	44.36	2.9	20.3	28.10	570.43	310.52
Locknuts & Bushings	16 ea	9.89	1.0	16.0	28.10	449.60	158.24
Hangers & Supports	6 ea	5.19	0.75	4.5	28.10	126.45	31.14
Concrete Wall Penetrations	2 ea	25.00	2.0	4.0	28.10	112.40	50.00
Wire, 350 MCM	240 ft	3.23	0.04	9.6	28.10	269.76	775.20
Terminations, Testing, ID	4 ea	11.02	0.40	1.6	28.10	44.96	44.00
500 AMP 125 V DC BKR 2 P, w/Aux contacts, NEMA 7 Enclosure	1 ea	1515.00	30.0	30.0	28.10	843.00	1515.00
250 VDC 900 AMP Hr Batt System							
480 V 3ph Input 250V DC 100 AMP Charger, Fully Regulated	1 ea	5000.00	56.0	56.0	28.10	1573.60	5000.00
150 AMP 250 V DC BKR 2 Pole w/Aux Contact	1 ea	369.00	5.0	5.0	28.10	140.50	369.00
900 AMP Hr 250V Batt	1 ea	49000.00	60.0	60.0	28.10	1686.00	49000.00
w/Zone II Rack, Disconnect, Shunts, Terminations	1 ea	4000.00	16.0	16.0	28.10	449.60	4000.00
Batt to DC Bus Hookup Conduit, 4" GRS	140 ft	7.84	0.36	50.4	28.10	1416.24	1097.60
Conduit, 4" 90 deg Elbow GRS	8 ea	44.36	2.9	23.2	28.10	651.92	354.88
Locknuts & Bushings	18 ea	9.89	1.0	18.0	28.10	505.80	178.02
Hangers & Supports	8 ea	5.19	0.75	6.0	28.10	168.60	41.52
Wall Penetrations	2 ea	25.00	2.0	4.0	28.10	112.40	50.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 1 COST ANALYSIS FOR ADDING 125V 500AHr & 250V 900AHr Systems

FACILITY TYPE BWR Page 3 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Wire, 500 MCM	560 ft	4.46	0.05	28.0	28.10	786.80	2497.60
Terminaitons, Testing, ID	8 ea	11.02	0.55	4.4	28.10	123.64	88.16
1000 AMP 250 VDC BKR, 2 Pole w/Aux contacts, NEMA 7 Enclosure	1 ea	1875.00	40.0	40.0	28.10	1124.00	1875.00
Batt Bldg Instrumentation							
Ammeter	4 ea	804.00	1.25	5.0	28.10	140.50	3216.00
Voltmeter	2 ea	838.00	1.25	2.5	28.10	70.25	1676.00
MV to I Transmitter	4 ea	800.00	10.0	40.0	28.10	1124.00	3200.00
Ground Fault Detectors	2 ea	792.0	4.0	8.0	28.10	224.80	1584.00
Conduit, 2" GRS	230 ft	2.85	0.14	32.2	28.10	904.82	655.50
Pull Boxes or C Condulets	2 ea	21.78	0.70	1.4	28.10	39.34	43.56
Conduit, 90 deg. Elbows, 2" GRS	8 ea	7.10	0.25	2.0	28.10	56.20	56.80
Hangers & Supports	17 ea	2.85	0.35	6.0	28.10	168.60	48.45
Locknuts & Bushings	18 ea	1.47	0.5	9.0	28.10	252.90	26.46
Wall Penetrations	2 ea	25.00	2.0	4.0	28.10	112.40	50.00
Wire, #12 THW	1012 ft	0.06	0.01	101.2	28.10	2843.72	607.20
Panel, Control Rm, 125V Sys	1 ea	1421.00	20.0	20.0	28.10	562.00	1421.00
Panel, Control Rm, 250V Sys	1 ea	1527.00	25.0	25.0	28.10	702.50	1527.00
New 800 sq ft Bldg Site Preparation	Allow	250.00	8.0	8.0	25.00	200.00	250.00
Excavation/Backfill	30 cy	1.0	1.0	30.0	18.00	540.00	30.00
Concrete Footing & Foundation	13 cy	56.00	0.20	2.6	18.00	46.80	728.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 2 & COST ANALYSIS FOR ADDING 125V 500A & 250V 900 A-H

FACILITY TYPE BWR Page 4 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Concrete Floor Slab	15 CY	58.00	0.16	2.4	18.00	43.20	870.00
Concrete Block Wall, 10 ft	1200 sq. ft.	1.00	0.05	60.0	30.00	1800.00	1200.00
Concrete T Slab Roof	800 SF	3.85	0.02	16.0	30.00	480.00	3080.00
Roof, Finish & Insulate	800 SF	0.55	0.03	24.0	30.00	720.00	440.00
Roll up Door, 8 x 10 Electric	1 ea	2000.00	8.0	8.0	30.00	240.00	2000.00
Personnel Door 3 x 7	2 ea	300.00	8.0	16.0	20.00	320.00	600.00
Plumbing, Utility	800 SF	1.00	0.03	24.0	30.00	720.00	800.00
200 A Service Panel	1 ea	891.00	7.0	7.0	30.00	210.00	891.00
Lights, Explosion Proof	7 ea	40.50	1.2	8.4	28.10	236.04	283.50
3/4" Conduit & Fittings	350 ft	0.86	0.08	28.0	28.10	786.80	301.69
w/3 #12 Wire	350	0.18	0.01	3.5	28.10	98.35	63.00
Vent Fan & Louver	1 ea	2965.00					2965.00
Halon Fire System	1 ea	12500.00					12500.00
Hydrogen Detection Sys	1 ea	5000.00					5000.00
Heater, Electric, 7.5 KW, Explosion Proof	1 ea	350.00	3.0	3.0	28.10	84.30	350.00
Emergency Lighting, Self-Contained, Explosion Proof 500 Watts	2 ea	1650.00	10.0	20.0	28.10	562.00	3300.00
Excavation (For Tie-In to Turbine Bldg)							
Trenching	66 ft	1.00	1.0	66.0	19.00	1254.00	66.00
Backfill	7.3CY	1.00	0.25	1.9	19.00	36.10	7.30
Concrete Red	1.5	60.00	0.20	0.3	19.00	5.70	90.00
SUBTOTAL				1205.7		33810.13	141719.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 1 COST ANALYSIS FOR ADDING 125V 500AHr & 250V 900 A-Hr

FACILITY TYPE BWR Page 5 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Maintenance and Testing							
(1) 2 hours/month, electrolyte level & temperature, Pilot cell specific gravity, terminal voltage	Annual			24.0	40.00	960.00	
(2) 2 hours, semi annual visual inspection	Annual			4.0	40.00	160.00	
(3) 6 hours/18 months resistance measurements	Annual			4.0	40.00	120.00	
SUBTOTAL				32.0		1240.00	

Original Installation	Low Case	Base Case	High Case
Labor Productivity Adjustment			
Labor Hours	1615 (75%)	1000 (67%)	2423 (50%)
Labor Cost	$ 44,014	$ 49,269	$ 66,020
Labor + Material Cost (subtotal)	$185,733	$190,988	$207,739
Attributable to Equipment	$141,010	$145,122	$158,232
Attributable to Structure	44,723	45,866	49,507
Geographical Adjustment	(85%)	(0%)	(115%)
Labor + Material Cost (subtotal)	$157,872	$190,988	$230,900
Engineering and Quality Assurance (25%)	$ 39,468	$ 47,747	$ 59,725
Subtotal	$197,340	$238,735	$298,625
Prime Contractor Markup (25%)	$ 49,335	$ 59,684	$ 74,656
Subtotal	$246,675	$298,419	$ 373,281
Operations and Maintenance			
Labor Productivity Adjustment			
Labor Hours	43	48	64
Labor Costs	$ 1,653	$ 1,851	$ 2,480
Labor + Material Cost (subtotal)	$ 1,653	$ 1,851	$ 2,480
Geographical Adjustment	(85%)	(0%)	(115%)
Labor and Material Cost (subtotal)	$ 1,405	$ 1,851	$ 2,852
Present Value Factor (10%,25 yrs=9.000 cumulative)			
Subtotal	$ 12,655	$ 16,672	$ 25,688
Total	$259,000	$315,091	$398,969

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 2 COST ANALYSIS FOR ADDING 12 Hr RESERVE CAPACITY

FACILITY TYPE BWR Page 1 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Original Installation							
480V 3 ph Pwr To Chargers							
Conduit, 3" GRS	150ft	5.31	.23	34.5	28.10	969.45	796.50
Supports & Hangers	9 ea	3.00	0.5	4.5	28.10	126.45	27.00
Conduit, 90 deg Elbows, 3" GRS	7 ea	21.07	1.8	12.6	28.10	354.06	147.49
Locknuts & Bushings	18 ea	4.30	1.0	18.0	28.10	505.80	77.40
Wire, 4/0 THW Single Conductor	450 ft	2.11	.03	13.5	28.10	379.35	949.50
Terminations, Testing, ID	8 ea	5.20	0.25	2.0	28.10	56.20	41.60
Concrete Wall Penetrations	2 ea	25.00	2.0	4.0	28.10	112.00	50.00
Wire, #2 Bare copper	150 ft	0.65	0.02	3.0	28.10	84.30	97.50
300 AMP BKR, 3 Pole W/Aux Contacts,NEMA 7 Enclosure	1 ea	1085.00	12.0	12.0	28.10	337.20	1085.00
125 Volt System							
125 Volt 50 AMP Charger Fully Regulated	3 ea	4000.0	40.0	120.0	28.10	3372.00	12000.00
75 AMP 2 Pole 125 VDC BKR W/Aux Contacts NEMA 7 Enclosure	3 ea	303.0	6.6	19.8	28.10	556.38	909.00
500 AMP-HR 125V Batt	3 ea	13200.00	40.0	120.0	28.10	3372.0	39600.00
W/Zone III Rack Disconnect, Shunts,Terminations	3 ea	4000.00	16.0	48.0	28.10	1348.80	12,000.00
Batt Banks to DC Bus Hookup							
Conduit, 4" GRS	350 ft	7.83	0.36	126.0	28.10	3540.60	2740.50
Conduit, 90 deg ELS, 4" GRS	21	44.36	2.9	60.9	28.10	1711.29	931.56
Locknuts & Bushings	48	9.89	1.0	48.0	28.10	1348.80	474.72

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 2 COST ANALYSIS FOR ADDING 12 Hr RESERVE CAPACITY

FACILITY TYPE BWR Page 2 of 4

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Hangers & Supports	27	5.18	.75	20.25	28.10	569.03	139.86
Concrete Wall Penetration	6	25.00	2.0	12.0	28.10	337.20	150.00
Wire, 350 MCM	700 ft	3.23	0.04	28.0	28.10	786.80	2261.00
Terminations, Testing, ID	12	11.02	0.40	4.8	28.10	134.88	132.24
500 AMP 125V DC BKR, 2 Pole w/Aux Contacts NEMA 7 Enclosure	3 ea	1515.00	30.0	90.0	28.10	2529.00	4545.00
250 Volt System 480V 3ph Input 250VDC Charger, 100 AMP, Fully Regulated	3 ea	5000.00	56.0	168.0	28.10	4720.80	15000.00
150 AMP 250 VDC BKR 2 Pole W/Aux Contacts NEMA 7 Enclosure	3 ea	369.00	5.0	15.0	28.10	421.50	1107.00
900 AMP-Hr 250V Batt	3 ea	49000.00	60.0	180 .0	28.10	5058.00	147000.00
W/Zone III Rack, Disconnect, Shunts, Terminations	3 ea	4000.00	16.0	48 .0	28.10	1348.80	12000.00
Batt to 250V DC Bus Hookup Conduit, 4" GRS	510 ft	7.84	0.36	183.6	28.10	5159.16	3998.40
Conduit, 90 deg ELS, 4" GRS	21	44.36	2.9	60.9	28.10	1711.29	931.56
Locknuts & Bushings	48	9.89	1.0	48.0	28.10	1348.80	474.72
Hangers & Supports	27	5.19	0.75	20.25	28.10	569.03	140.13
Wall Penetrations	6 ea	25.00	2.0	12.0	28.10	337.20	150.00
Wire, 500 MCM	1020 ft	4.46	0.05	51.0	28.10	1433.10	4549.20
Terminations, Testing, ID	12	11.02	0.55	6.6	28.10	185.46	132.24
1000 AMP 2 Pole 250VDC BKR w/Aux Contacts, NEMA 7 Encl	3	1875.00	40.0	120 .0	26.10	3372.00	5625.00
Batt Bldg Instrumentation Ammeter	12 ea	804.00	1.25	15 .0	28.10	421.50	9648.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 2 COST ANALYSIS FOR ADDING 12 Hr RESERVE CAPACITY

FACILITY TYPE BWR Page 3 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Voltmeter	6 ea	838.00	1.25	7.5	28.10	210.75	5028.00
MV to I Transmitter	12 ea	800.00	10.0	120 .0	28.10	3372.00	9600.00
Ground Fault Detector	6 ea	792.00	4.0	24 .0	28.10	674.40	4752.00
Conduit, 2" GRS	690 ft	2.84	.14	96.6	28.10	2714.46	1959.60
Conduit, 90 deg ELS, 2" GRS	24 ea	7.10	0.75	18.0	28.10	505.80	170.40
Pull Boxes or C-Condulets	6 ea	21.78	0.70	4.2	28.10	118.02	130.68
Hangers/Supports	51 ea	2.85	0.35	17.85	28.10	501.58	145.35
Locknuts & Bushings	54 ea	1.47	0.50	27.0	28.10	758.70	79.38
Wall Penetrations	6 ea	25.00	2.0	12.0	28.10	337.20	150.00
Wire, #12 THW	30000	0.06	0.01	300.00	28.10	8430.00	1800.00
Panel, Control Room (3x125V Batt)	1 ea	1421.00	20.0	20.00	28.10	562.00	1421.00
Panel, Control Room (3x250V Batt)	1 ea	1527.00	25.0	25.0	28.10	702.50	1527.00
New 2400 sq ft Bldg							
Site Preparation	Allow	500.00	24.0	24.0	25.00	600.00	500.00
Excavation/Backfill	90CY	1.00	1.0	90.0	18.00	1620.00	90.00
Concrete Footing & Foundation	30CY	56.00	0.20	6.0	18.00	108.00	1680.00
Concrete Floor Slab	45CY	58.00	0.16	7.2	18.00	129.60	2610.00
Concrete Block Wall, Ext	2000 ft^2	1.00	0.05	100.0	30.00	3000.00	2000.00
Concrete Block Fire Wall, INT	1200 ft^2	1.00	0.05	60.0	30.00	1800.00	1200.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 2 COST ANALYSIS FOR ADDING 12 Hr RESERVE CAPACITY

FACILITY TYPE BWR Page 4 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Concrete T-Slab Roof	2400 ft^2	3.85	.02	48.0	30.00	1440.00	9240.00
Roof, Finish & Insulate	2400 ft^2	0.55	.03	72.0	30.00	2160.00	1320.00
Roll-Up Door, Electric, 8x10	1 ea	2000.00	8.0	8.0	30.00	240.00	2000.00
Personnel Door, 3x7, Ext	3 ea	300.00	8.0	24.0	20.00	480.00	900.00
Personnel Door, 3x7, Int	3 ea	225.00	4.0	12.0	20.00	240.00	675.00
Plumbing, Utility	2400 ft^2	1.00	0.03	72.0	30.00	2160.00	2400.00
600 AMP Service Panel	1 ea	2089.00	5.0	5.0	30.00	150.00	2089.00
Lights, Explosion Proof	20	40.50	1.2	24.0	28.10	674.40	810.00
3/4 Conduit & Fitting	1050 ft	0.86	0.08	84.0	28.10	2360.40	903.00
W/3 #12 Wire, THW	1050	0.18	0.01	10.5	28.10	295.05	189.00
Vent Fan & Louver	3 ea	2965.00					8895.00
Halon Fire System	1 ea	12500.00					12500.00
Hydrogen Detection System	1 ea	5000.00					5000.00
Heater, Electric 7.5KW	3 ea	350.00	3.0	9.0	28.10	252.90	1050.00
Explosion Proof Emerg Lighting, Self Contained	6 ea	1650.00	10.0	60.0	28.10	1686.00	9900.00
Excavation for Turbine Bldg to Batt Bldg Conduit Runs							
Trenching 2'w x 3' d	90 ft	1.00	2.0	180.0	19.00	3420.00	90.00
Backfill	20CY	1.00	0.25	5.0	19.00	95.00	20.00
Concrete Red Pad	4CY	60.00	0.20	0.8	19.00	15.20	240.00
SUBTOTAL				3303.9		98432.59	372976.53

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 2 COST ANALYSIS FOR ADDING 12 Hr RESERVE CAPACITY

FACILITY TYPE BWR Page 5 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Maintenance and Testing							
(1) 6 hours/month electrolyte level & temperature, Pilot cell specific gravity, terminal voltage	Annual			72.0	40.00	2880.00	
(2) 2 hours, semi annual visual inspection	Annual			4.0	40.00	160.00	
(3) 12 hours/18 months resistance measurements	Annual			8.0	40.00	320.00	
SUBTOTAL				84.0	40.00	3360.00	

Original Installation	Low Case	Base Case	High Case
Labor Productivity Adjustment			
Labor Hours	4405 (75%)	4931 (67%)	6608 (50%)
Labor Cost	$120,577	$134,974	$180,865
Labor + Material Cost (subtotal)	$493,554	$507,951	$553,842
Attributable to Equipment	$400,804	$412,109	$448,147
Attributable to Structures	$ 92,750	$ 95,842	$105,695
Geographical Adjustment	(85%)	(0%)	(115%)
Labor + Material Cost (subtotal)	$419,521	$507,951	$656,718
Engineering and Quality Assurance (25%)	$104,880	$126,988	$159,230
Subtotal	$524,401	$634,939	$796,148
Prime Contractor Markup (25%)	$131,100	$158,735	$199,037
Subtotal	$665,501	$793,674	$995,185
Operations and Maintenance			
Labor Productivity Adjustment			
Labor Hours	112 (75%)	125 (67%)	1689 (50%)
Labor Costs	$ 4,480	$ 5,015	$ 6,720
Labor + Material Cost (subtotal)	$ 4,480	$ 5,015	$ 6,720
Geographical Adjustment	(85%)	(0%)	(115%)
Labor and Material Cost (subtotal)	$ 3,808	$ 5,015	$ 7,728
Present Value Factor (10%,25 yrs=9.007 cumulative)			
Subtotal	$ 34,299	$ 45,170	$ 69,606
Total	$689,800	$838,844	$1,064,291

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC POWER SYSTEM

OPTION 3 COST ANALYSIS FOR Alt Pwr Source, Diesel Gen

FACILITY TYPE BWR Page 1 of 5

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Original Installation							
Diesel Powered Generator							
Diesel Generator Set Model 16 V6D M/480V 3 Phase output, Radiator Cooled Engine, Day Generator Switchgear Set, With Breakers	1 ea	100000.00	100.0	100.0	28.10	2810.10	100000.00
Fuel Storage Tank, 750 gal	1 ea	700.00	8.0	8.0	18.00	144.00	700.00
Fuel Pump, 25psi, 5 GPM	1 ea	125.00	3.0	3.0	27.50	82.50	125.00
Fuel Line, 3/4"	25 ft	1.05	2.0	50.0	27.50	1375.00	26.25
Intake Duct, 12"	11 ft	1.85	0.1	1.1	27.50	30.25	20.35
Exhaust Duct, 20 in	5 ft	3.25	0.1	0.5	27.50	13.75	16.25
Exhaust Sound Attenuator	1 ea	25.00	1.0	1.0	27.50	27.50	25.00
Start System	1 ea	750.00	1.0	1.0	27.50	27.50	750.00
400 sq. ft. Bldg for B/U Generator							
Site Preparation	Allow	250.00	8.0	8.0	25.00	200.00	250.00
Excavation & Backfill	36 CY	1.0	1.0	36.0	18.00	648.00	36.00
Footing & Foundation	9 CY	56.00	0.2	1.8	18.00	32.40	504.00
Concrete Floor Slab	8 CY	58.00	0.16	1.3	18.00	23.40	464.00
Concrete Block Wall	800 sq. ft.	1.00	0.05	40.0	30.00	1200.00	800.00
Concrete T Slab Roof	400 sq. ft.	3.85	0.02	8.0	30.00	240.00	1540.00
Build Up Roof w/Insulation	400 sq. ft.	0.55	0.03	12.0	30.00	360.00	220.00
Roll Up Door, 8 x 10 Electric	1 ea	2000.00	8.0	8.0	30.00	240.00	2000.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC POWER SYSTEM

OPTION 3 COST ANALYSIS FOR Alt Pwr Source, Diesel Gen

FACILITY TYPE BWR Page 2 of 5

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Utility, Plumbing & Piping	400 sq. ft.	1.00	0.03	12.0	30.00	360.00	400.00
3/4" Conduit w/3 #12 Wire, Fittings	200 ft	0.86	0.08	16.0	28.10	449.60	172.00
Heater, Electric, 7.5 KW, Explosion Proof	1 ea	350.00	3.0	3.0	28.10	84.30	350.00
Lights, Explosion Proof	5 ea	40.50	1.2	6.0	28.10	168.60	202.50
200A Bldg Service Panel	1 ea	891.00	7.0	7.0	30.00	210.00	891.00
Vent Fan & Louver	1 ea	2000.00	8.0	8.0	27.50	220.00	2000.00
Fire Detection/Protection System	1 ea	12500.00					12500.00
Paint	1200 sq. ft.	0.03	0.01	12.0	21.20	254.40	36.00
Penetrations:							
Intake 12"	1 ea	5.00	1.0	1.0	27.50	27.50	5.00
Exhaust 20"	1 ea	10.00	1.0	1.0	27.50	27.50	10.00
Fuel Line, 3/4"	1 ea	1.00	1.0	1.0	27.50	27.50	1.00
Elec. Service, 2"	1 ea	1.00	1.0	1.0	27.50	27.50	1.00
Plumbing, Inlet & Drains	2 ea	25.00	2.0	4.0	30.00	120.00	50.00
Excavation, Fuel Tank	6 CY	1.00	1.0	6.0	19.00	114.00	6.00
Backfill, Fuel Tank	2 CY	1.00	1.0	2.0	19.00	38.00	2.00
Excavation, Elec. Conduit	10CY	1.00	1.0	10.0	19.00	190.00	10.00
Concrete Red	1 CY	60.00	0.2	0.2	19.00	3.80	60.00
Backfill,	9 CY	1.00	0.25	2.3	19.00	43.70	9.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC POWER SYSTEM

OPTION 3 COST ANALYSIS FOR
Alt Pwr Source, Diesel Gen

FACILITY TYPE BWR Page 3 of 5

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Tie,In, Gen to 480MCC 19-2 & 18-2							
Conduit, 4" GRS	221 ft	7.84	.36	79.6	28.10	2236.76	1732.64
Conduit, 90 deg Elbows, 4" GRS	8 ea	44.36	2.9	23.2	28.10	651.92	354.88
Pull Box	1 ea	25.00	1.0	1.0	28.10	28.10	25.00
Hangers & Supports	14 ea	5.19	0.75	10.5	28.10	295.05	72.66
Locknuts & Bushings	6 ea	9.89	1.0	6.0	28.10	168.60	59.34
Wire, 500 MCM	663 ft	4.46	0.05	33.2	28.10	932.92	2956.98
Wire, 3/0 Bare Neutral	221 ft	1.10	0.02	4.4	28.10	123.64	243.10
Terminations, Testing, ID	32 ea	11.02	0.4	12.8	28.10	359.68	352.64
500 AMP BKR, 480VAC 3 Pole w/Aux Contacts NEMA 1 Enclosure	2 ea	250.00	4.0	8.0	28.10	224.80	500.00
Concrete Wall Penetrations	5 ea	25.00	2.0	10.0	28.10	281.00	125.00
SUBTOTAL				560.9		15123.17	130604.59

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC POWER SYSTEM

OPTION 3 COST ANALYSIS FOR Alt Pwr Source, Diesel Gen

FACILITY TYPE BWR Page 4 of 5

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Operations & Maintenance Check Generator and water, start and load weekly, 2 hrs	Annual			104	40	4160	

COST SUMMARY

Original Installation	Low Case	Base Case	High Case
Labor Productivity Adjustment			
Labor Hours	748(75%)	887(67%)	1122(50%)
Labor Cost	$ 20,164	$ 22,512	$ 30,246
Labor + Material Cost (subtotal)	$150,769	$153,177	$160,851
Attributable to Equipment	$121,204	$122,770	$127,763
Attributable to Structures	$ 29,565	$ 30,387	$ 33,085
Geographical Adjustment	(85%)	(0%)	(115%)
Labor + Material Cost (subtotal)	$128,153	$153,177	$184,978
Engineering and Quality Assurance (25%)	$ 32,038	$ 38,294	$ 46,245
Subtotal	$160,191	$191,471	$231,223
Prime Contractor Markup (25%)	$ 40,048	$ 47,867	$ 57,806
Subtotal 1	$200,238	$239,338	$289,028
Operations and Maintenance			
Labor Productivity Adjustment			
Labor Hours	139(75%)	155(67%)	208(50%)
Labor Costs	$ 5,547	$ 6,209	$ 8,328
Labor + Material Cost (subtotal)	$ 5,547	$ 6,209	$ 8,328
Geographical Adjustment	(85%)	(0%)	(115%)
Labor and Material Cost (subtotal)	$ 4,715	$ 6,209	$ 9,568
Present Value Factor (10%,25 yrs=9.077 cumulative)			
Subtotal	$ 42,468	$ 55,924	$ 86,179
Total	$242,706	$295,262	$375,207

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 4 COST ANALYSIS FOR ADDING Alt Pwr Source, Turbine Gen

FACILITY TYPE BWR Page 1 of 4

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Original Installation							
Diesel Fuel Powered Elect. System							
Garrett 831-500 Gas Turbine Generator Set, Liquid Fuel Option, 480V 3 ph output includes a-b-c-d	1 ea	250000.00	72.0	72.0	28.10	2023.20	250000.00
a-Enclosure, Indoor, Sound Attenuating							
b-Generator Switchgear set, with Breakers							
c-Electric Start System (24 V DC Motor, Batt, & Charger)							
d-Exhaust Silencer							
Inlet Duct, 14" with grid	11 ft	2.25	0.1	1.1	27.50	30.25	24.75
Personnel, FOD, Inlet Guard	1 ea						
Exhaust Duct, 10" x 26", Double Wall	5 ft	20.00	1.5	7.5	27.50	206.25	100.00
Fuel Storage Tank, 750 Gal	1 ea	700.00	8.0	8.0	27.50	220.00	700.00
Fuel Pump, 5 GPM @ 25psi	1 ea	100.00	3.0	3.0	27.50	82.50	100.00
Fuel Line, 3/4"	25 ft	1.05	0.08	2.0	27.50	55.00	26.25
400 sq. ft. Bldg. for B/U Generator							
Site Preparation	Allow	250.00	8.0	8.0	25.00	200.00	250.00
Excavation & Backfill	36 CY	1.00	1.0	36.0	18.00	648.00	36.00
Footing & Foundation	9CY	56.00	0.2	1.8	18.00	32.40	504.00
Concrete Floor Slab	8 CY	58.00	0.16	1.3	18.00	23.40	464.00
Concrete Block Wall	800 sq. ft.	1.00	0.05	40.0	30.00	1200.00	800.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 4 COST ANALYSIS FOR ADDING Alt Pwr Source, Turbine Gen

FACILITY TYPE BWR Page 2 of 4

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Concrete T Slab Roof	400 sq. ft.	3.85	.02	8.0	30.00	240.00	1540.00
Build up Roof w/Insulation	400 sq. ft.	0.55	0.03	12.0	30.00	360.00	220.00
Roll Up Door, 8 x 10 Electric	1 ea	2000.00	8.0	8.0	30.00	240.00	2000.00
Utility, Plumbing & Piping	400 sq. ft.	1.0	0.03	12.0	30.00	360.00	400.00
3/4" Conduit w/3 #12 Wire, Fittings	200 ft	0.86	0.08	16.0	28.10	449.60	172.00
Heater, Electric, 7.5 KW, Explosion Proof	1 ea	350.00	3.00	3.0	28.10	84.30	350.00
Lights, Explosion Proof	5 ea	40.50	1.2	6.0	28.10	168.60	202.50
200 A Bldg Service Panel	1 ea	891.00	7.0	7.0	30.00	210.00	891.00
Vent Fan & Louver	1 ea	2000.00	8.0	8.0	27.50	220.00	2000.00
Fire Detection/Protection	1 ea	12,500.00					12,500.
Paint	1200 sq. ft.	0.03	0.01	12.0	21.20	254.40	36.00
Penetrations:							
Sleeve Inlet 14"	1 ea	6.00	1.0	1.0	27.50	27.50	6.00
Sleeve Exhaust 10 x 26	1 ea	72.00	1.0	1.0	27.50	27.50	72.00
Sleeve Fuel Line, 3/4"	1 ea	1.00	1.0	1.0	27.50	27.50	1.00
Sleeve Elec. Service, 2"	1 ea	1.00	1.0	1.0	27.50	27.50	1.00
Plumbing, Inlet & Drains	2 ea	25.00	2.0	4.0	30.00	120.00	50.00
Excavation, Fuel Tank	6 CY	1.00	1.0	6.0	19.00	114.00	6.00
Backfill, Fuel Tank	2 CY	1.00	1.0	2.0	19.00	38.00	2.00
Excavation, Elec. Conduit	10 CY	1.00	1.0	1.0	19.00	19.00	10.00
Concrete Red	1 CY	60.00	0.2	0.2	19.00	3.80	60.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 1 DC SYSTEM

OPTION 4 COST ANALYSIS FOR ADDING Alt Pwr Source, Turbine Gen

FACILITY TYPE BWR Page 3 of 4

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Backfill	9 CY	1.00	0.25	2.3	19.00	43.70	9.00
Tie-In, Gen to 480MCC 19-2 and 18-2							
Conduit, 4" GRS	221 ft.	7.84	0.36	79.6	28.10	2236.76	1732.64
Conduit, 90 deg Elbows, 4" GRS	8 ea	44.36	2.9	23.2	28.10	651.92	354.88
Pull Box	1 ea	25.00	1.0	1.0	28.10	28.10	25.00
Hangers & Supports	14 ea	5.19	0.75	10.5	28.10	295.05	72.66
Locknuts & Bushings	6 ea	9.89	1.0	6.0	28.10	168.60	59.34
Wire, 500 MCM	663ft	4.46	0.05	33.2	28.10	932.92	2956.98
Wire, #6 Bare Neutral	221 ft	1.10	0.02	4.4	28.10	123.64	243.10
Terminations, Testing, ID	32 ea	11.02	0.4	12.8	28.10	359.68	352.64
500 AMP BKR, 480 VAC 3 Pole w/Aux Contacts NEMA 1 Enclosure	2 ea	250.00	4.0	8.0	28.10	224.80	500.00
Concrete Wall Penetrations	5 ea	25.00	2.0	10.0	28.10	281.00	125.00
SUBTOTAL				488.9		13858.87	279955.74
Operations & Maintenance							
Start-up test weekly-1 hr	Annual			52.0	40.00	2080.00	

COST SUMMARY

Original Installation	Low Case	Base Case	High Case
Labor Productivity Adjustment			
Labor Hours	641(75%)	718(67%)	964(50%)
Labor Cost	$ 17,410	$ 19,488	$ 26,114
Labor + Material Cost (subtotal)	$297,365	$299,443	$306,069
Attributable to Equipment	$267,994	$269,261	$273,301
Attributable to Structures	$ 29,371	$ 30,182	$ 32,768
Geographical Adjustment	(85%)	(0%)	(115%)
Labor + Material Cost (subtotal)	$252,760	$299,443	$351,979
Engineering and Quality Assurance (25%)	$ 63,190	$ 74,861	$ 87,995
Subtotal	$315,950	$374,304	$439,974
Prime contractor Markup (25%)	$ 78,988	$ 93,575	$109,994
Subtotal	$394,938	$467,880	$549,968
Operations and Maintenance			
Labor Productivity Adjustment			
Labor Hours	69 (75%)	78 (67%)	104(50%)
Labor Costs	$ 2,773	$ 3,104	$ 4,160
Labor + Material Cost (subtotal)	$ 2,773	$ 3,104	$ 4,160
Geographical Adjustment	(85%)	(0%)	(115%)
Labor and Material Cost (subtotal)	$ 2,357	$ 3,1045	$ 4,784
Present Value Factor (10%,25 yrs=9.077 cumulative)			
Subtotal	$ 21,229	$ 27,958	$ 43,098
Total	$416,167	$495,838	$593,066

Appendix B

RCP Seal Cooling

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2A

OPTION COST ANALYSIS FOR STEAM DRIVEN TURBINE GENERATOR SUPPLYING POWER TO MOTOR DRIVEN PUMP

FACILITY TYPE PWR

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Original Installation							
Turbine Generator, steam supply 900 psi, 520 deg F, moisture content <1 deg > 0, 1100 KW Output @ 0.8 Power Factor, 60 Hz 4160V 3 ph with exciter, voltage regulator, short circuit protections instrumentation transformer and baseplate	1	379500.00	1500.6	1500.6	28.10	42150.00	379500.00
4" ID Carbon Steel Piping, 1200 psig design pressure, 570 deg F design temperature, class 2 seisaic	20ft	18.75	0.16	3.2	27.50	88.00	375.00
Motor Operated Valve, 125 VDC, 4" ID, 1200 psig design pressure, 570 deg F design temperature, class 2	1	1050.00	4.0	4.0	27.50	110.00	1050.00
Seisaic with Flanges	2	70.00	3.0	6.0	27.50	165.00	140.00
Check Valve, 4" ID, 1200 psig design pressure, 570 deg F design	1	725.00	4.0	4.0	27.50	110.00	725.00
Temp, class 2 seisaic with flanges	2	56.00	1.6	3.2	27.50	88.00	112.00
4" ID Carbon Steel Piping, 1200 psig design pressure, 570 deg F design temp	100 ft	18.75	0.16	16	27.50	440.00	1875.00
Pipe Penetrations through 12" concrete wall (for above piping)	3	125.00	4.0	12.0	27.50	330.00	375.00
Pipe Hangers (for above piping)	10	43.00	0.1	1.0	27.50	27.50	430.00
8" ID Carbon Steel Piping, 150 psig design pressure, 350 deg design temp	100 ft	29.00	0.25	25.06	27.50	687.50	2900.00
Pipe Penetration through 12" concrete wall (for preceding piping)	2	100.00	6.0	12.0	27.50	330.00	200.00
Pipe Hangers (for preceding piping)	10	70.00	0.15	1.5	27.50	41.25	700.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2A

OPTION COST ANALYSIS FOR STEAM DRIVEN TURBINE GENERATOR SUPPLYING POWER TO MOTOR DRIVEN PUMP

FACILITY TYPE PWR

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
3" ID Stainless Steel Piping, 150 psig design pressure, 225 deg F design temp, Class 2 Sesimic, installation in reactor containment	50 ft	38.00	0.4	20.0	27.50	550.00	1900.00
Hangers	6	12.00	0.8	4.8	27.50	132.00	72.00
Pipe Tee - 3" Stainless Steel, 150 psig design pressure, 225 deg F class 2 seisaic	1	175.00	3.2	3.2	27.50	88.00	175.00
Motor Operated Valve, 125 VDC, 3"ID, 150 psig design pressure, 225 deg F design temp., class 2 seisaic	1	4600.00	4.0	4.0	27.50	110.00	4600.00
with 4 Flanges, S.S.,	4	340.00	2.0	8.0	27.50	220.00	1360.00
Motor Operated Valve, 125 VDC, 3" ID 150 psig design pressure, 225 deg F design temp., non-seisaic	1	4600.00	4.0	4.0	27.50	110.00	4600.00
Turbine Control & Instrumentation to Control Room							
Conduit, 2" GRS	205 ft	2.85	0.14	28.7	28.10	806.47	584.25
Conduit, 2" GRS, 90 deg ELS	7 ea	7.10	0.5	3.5	28.10	98.35	49.70
Pull Boxes	2 ea	21.78	0.25	0.5	28.10	14.05	43.56
Hangers ' Supports	21 ea	2.85	0.7	14.7	28.10	413.07	59.85
Locknuts & Bushings	8 ea	1.47	0.35	2.8	28.10	78.68	11.76
Wire, #12 THW	7400 ft	0.06	0.01	74.0	28.10	2079.40	444.00
Concrete Wall Pen.	3 ea	25.00	2.0	6.0	28.10	166.80	75.00
Terminations (Testing & ID)	72 ea	1.00	1.0	72.0	28.160	2023.00	72.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2A

OPTION COST ANALYSIS FOR STEAM DRIVEN TURBINE GENERATOR SUPPLYING POWER TO MOTOR DRIVEN PUMP

FACILITY TYPE PWR Page 3 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Panel Space Control RM 3 di[illegible]etes (BKR Positions) 2 Control SW 13 Turbine/Gen Variables	1	3400.00	31.0	31.0	28.10	871.10	3400.00
Control & Instruaentation to Control Rm. For MOVs (Use Existing Penetration for Containaent MOVs)							
Conduit, 1" GRS	185 ft	1.10	0.08	14.8	28.10	415.88	203.50
Conduit, 90 deg ELS, 1" GRS	6	3.00	0.35	2.1	28.10	59.01	18.00
Hangers & Supports	19 ea	3.00	0.5	9.5	28.10	266.95	57.00
Pull Boxes	2 ea	21.78	0.7	1.4	28.10	39.34	43.56
Locknuts & Busings, 1"	3 ea	0.50	0.5	1.5	28.10	42.15	1.50
Conduit, 1 1/2" GRS	230 ft	1.85	0.1	23.0	28.10	646.30	425.5
Conduit, 1 1/2" GRS, 90 deg ELS	6 ea	4.65	0.5	3.0	28.10	84.30	27.90
Hangers & Supports	24 ea	3.00	0.5	12.0	28.10	337.20	72.00
Pull Boxes	2 ea	21.78	0.7	1.4	28.10	39.34	43.56
Wire, #12 THW	6290 ft	0.06	0.01	62.9	28.10	1767.43	377.40
Penetrations, Concrete Wall	4 ea	25.00	2.0	8.0	28.10	224.80	100.00
Panel Space in Control RM	1 ea	5000.00	4.0	4.0	28.10	112.40	5000.00
Terminations (Testing, ID)	36	3.00	0.2	7.2	28.10	202.32	108.00
Power to MOVs in Containaent (Incl Relay Control)							
Conduit Grs, 1 1/2"	90 ft	1.85	0.1	9	28.10	252.9	166.50

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2A

OPTION COST ANALYSIS FOR STEAM DRIVEN TURBINE GENERATOR SUPPLYING POWER TO MOTOR DRIVEN PUMP

FACILITY TYPE PWR Page 4 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Wire, #6 THW	180 ft	0.26	0.06	10.8	28.10	303.48	46.80
Locknuts & Bushings, 1 1/2"	5 ea	1.00	1.0	5.0	28.10	140.50	5.0
Wire, #12 THW	360 ft	0.06	0.01	3.6	28.10	101.16	21.60
Elbows, GRS 90 deg, 1 1/2	4 ea	4.65	0.5	2.0	28.10	56.20	18.60
Hangers & Supports	10 ea	3.00	0.5	5.0	28.10	140.50	30.00
Power to MOV Outside Containment (-1 Relay Control)							
Conduit, GRS, 1 1/2"	25 ft	1.85	0.1	2.5	28.10	70.25	46.25
Conduit, 90 deg Elbow, 1 1/2" GRS	2 ea	4.65	0.5	1.0	28.10	28.10	9.30
Wire, #6 THW	50 ft	0.26	0.06	3.0	28.10	84.30	13.00
Wire, #12 THW	100 ft	0.06	0.01	1.0	28.10	28.10	6.00
Hangers & Supports	3 ea	3.00	0.5	1.5	28.10	42.15	9.00
4160V PWR From Gen To SWGR (Emergency SG #3)							
Conduit, 3" GRS	135 ft	5.31	0.23	31.2	28.10	876.70	716.85
Conduit, 3" GRS, 90 deg ELS	5 ea	21.07	1.8	9.0	28.10	252.90	105.35
Pull Box	1 ea	65.00	1.0	1.0	28.10	28.10	65.00
Wire, 4/0, TWH (WYE)	540 ft	2.11	.03	16.2	28.10	455.20	1139.40
Hangers & Supports	14 ea	3.00	0.5	7.0	28.10	196.70	42.00
Locknuts & Bushing	4 ea	4.30	1.0	4.0	28.10	112.40	17.20
Concrete Wall Pen.	2 ea	25.0	2.0	4.0	28.10	112.40	50.00
Breaker, 3 Pole w/Aux Contacts, 500 AMP 4160V, NEMA 1 Enclosure	1 ea	1750.00	8.0	8.0	28.10	224.80	1750.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2A

OPTION COST ANALYSIS FOR STEAM DRIVEN TURBINE GENERATOR SUPPLYING POWER TO MOTOR DRIVEN PUMP

FACILITY TYPE PWR Page 5 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Reseal Existing Containment Pen.	1 EA	200.0	16.0	16.0	22.30	356.80	200.00
SUBTOTAL				2156.7		60431.23	47364.89
(Containment Labor)				(41.9)		(1989.69)	
Operations and Maintenance							
Start up test	Annual			52.0	40.00	2080.00	
Weekly: 1 hr							

COST SUMMARY

Original Installation	Low Case	Base Case	High Case
Labor Productivity Adjustment‡			
Labor Hours	2900(74%)	3260(66%)	4391(49%)
Labor Cost	$ 81,664	$ 91,562	$123,329
Labor + Material Cost (subtotal)	$529,029	$538,927	$570,694
Attributable to Equipment	$529,029	$538,927	$570,694
Attributable to Structures	$ 0	$ 0	$ 0
Geographical Adjustment	(85%)	(0%)	(115%)
Labor + Material Cost (subtotal)	$449,675	$538,927	$656,298
Engineering and Quality Assurance (25%)	$112,419	$134,732	$164,075
Subtotal	$562,094	$673,659	$820,373
Prime contractor Markup (25%)	$140,524	$168,415	$205,093
Subtotal	$702,618	$842,074	$1,025,466
Operations and Maintenance			
Labor Productivity Adjustment			
Labor Hours	69 (75%)	78 (67%)	104(58%)
Labor Costs	$ 2,773	$ 3,104	$ 4,160
Labor + Material Cost (subtotal)	$ 2,773	$ 3,104	$ 4,160
Geographical Adjustment	(85%)	(0%)	(115%)
Labor and Material Cost (subtotal)	$ 2,357	$ 3,104	$ 4,784
Present Value Factor (10%,25 yrs=9.007 cumulative)			
Subtotal	$ 21,229	$ 27,958	$ 43,084
Total	$723,847	$870,032	$1,068,550

are ‡Productivity factor is average weighted by hours both inside and outside containeatn. Productivity factors inside containeent half those outside.

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2B

OPTION COST ANALYSIS FOR STEAM DRIVEN TURBINE COUPLED TO CHARGING PUMP

FACILITY TYPE PWR Page 1 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Original Installations							
Turbine Driven Pump, capable of supplying 100 gpm at 2200 psi rated for 225 deg F suction supply temp; steam supply 900 psi, 520 deg F. moisture content < 1%	1	379,500.00	1,500.00	1,500.00	27.50	41,250.00	379,500.00
3" ID Carbon Steel Piping, 1200 psig design pressure, 570 deg F design temp, class 2 seismic	20 ft	11.40	0.07	1.4	27.50	38.50	228.00
Motor operated Valve, 125 VDC 3" ID, 1200 psig design pressure, 500 deg F design temp., Class 2	1	465.00	4.0	4.0	27.50	110.00	465.00
Seismic, with Flanges	2	40.00	2.3	4.6	27.50	126.50	80.00
Check Valve, 3" ID, 1200 psig design pressure, 570deg F design temp, class 2 seismic with 2 flanges	1	500.00	4.0	4.0	27.50	110.00	500.00
	2	40.00	2.3	4.6	27.50	126.50	80.00
3" ID Carbon Steel Piping, 1200 psig design pressure, 570 deg F design temp	100 ft	11.40	0.07	7.0	27.50	192.50	1140.00
Pipe Penetrations through 12" Concrete wall (for above piping)	2	100.00	4.0	8.0	27.50	220.00	200.00
Pipe Hangers (for above piping)	10	40.00	0.1	1.0	27.50	27.50	400.00
8" ID Carbon Steel Piping, 1500 psig design pressure, 350 deg F design temp	50 ft	29.00	0.15	7.5	27.50	206.25	1450.00
Pipe Penetrations through 12" concrete wall (for preceding piping)	2	100.00	4.0	8.0	27.50	220.00	200.00
Pipe Hangers (for preceding piping)	5	70.00	0.15	0.8	27.50	22.00	350.00
3" Stainless Steel Piping, 3000 psig design pressure, 200 deg F design temp	50 ft	90.00	0.66	33.0	27.50	907.50	4500.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2B

OPTION COST ANALYSIS FOR STEAM DRIVEN TURBINE COUPLED TO CHARGING PUMP

FACILITY TYPE PWR

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Pipe Penetrations through 12"	1	100.00	4.0	4.0	27.50	110.00	100.00
Pipe Hangers (for preceding piping)	5	40.00	0.1	0.5	27.50	13.75	200.00
Motor Operated Valve, 125 VDC 3" ID, 3000 psig design pressure 200 deg F design temp	1	6600.00	10.3	10.3	27.50	283.25	6600.00
Pipe Tee, 4" to 32" reducing, 3000 psig design pressure, 200 deg F design temp.	1	450.00	8.0	8.0	27.50	220.00	450.00
3" ID Stainless Steel Piping, 150 psig design pressure, 225 deg F design temp., Class 2 Seismic, installed in reactor containment with	50 ft	30.00	0.4	20.0	27.50	550.00	1900.00
6 hangers	6	12.00	0.8	4.8	27.50	132.00	72.00
Pipe Tee - 3" Stainless Steel 150 psig design pressure, 225 deg F design temp., Class 2 Seismic	1	175.00	3.2	3.2	27.50	88.00	175.00
Motor Operated Valve, 125 VDC 3" ID 150 psig design pressure, 225 deg F design temp., Class 2 Seismic	1	805.00	6.3	6.3	27.50	173.25	805.00
Motor Operated Valve, 125 VDC, 3" ID 150 psig design pressure;, 225 deg F design temp, non-seismic	1	805.00	6.3	6.3	27.50	173.25	805.00
PWR & Contr to MOVs Inside Containment							
Conduit, 1 1/2" GRS	162 ft	1.85	0.1	16.2	28.10	455.22	299.70
Conduit, 1 1/2" GRS, 90 deg ELS	4 ea	4.65	0.5	2.0	28.10	56.20	18.60
Hangers & Supports	16 ea	3.00	0.5	8.00	28.10	224.80	48.00
Pull Box	1 ea	21.70	0.7	0.7	28.10	19.67	21.70
Locknuts & Bushings	3 ea	1.00	1.00	3.00	28.10	84.30	3.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2B

OPTION COST ANALYSIS FOR STEAM DRIVEN TURBINE COUPLED TO CHARGING PUMP

FACILITY TYPE PWR Page 3 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Wire, #6 THW	650 ft	0.26	0.06	39.00	28.10	1095.90	169.00
Wire,#12 THW (8)	1300 ft	0.06	0.01	13.00	28.10	365.30	78.00
PWR & Contr to MOV in Piping Area							
Conduit, 1 1/2" GRS	70 ft	1.85	0.1	7.0	28.10	196.70	129.50
Conduit, 1 1/2" GRS, 90 deg ELS	3 ea	4.65	0.5	1.5	28.10	42.15	13.95
Hangers & Supports	16 ea	3.00	0.5	8.00	28.10	224.80	48.00
Pull Box	1 ea	21.70	0.7	0.7	28.10	19.67	21.70
Locknuts & Bushings	3 ea	1.00	1.00	3.00	28.10	84.30	3.00
Wire, #6 THW	650 ft	0.26	0.06	39.00	28.10	1095.90	169.00
Wire #12 THW (8)	1300 ft	0.06	0.01	13.00	28.10	365.30	78.00
PWR & Contr to MOV in Piping Area							
Conduit, 1 1/2" GRs	70 ft	1.85	0.1	7.00	28.10	196.70	129.50
conduit, 1 1/2" GRS, 90 deg ELS	3 ea	4.65	0.5	1.5	28.10	42.15	13.95
Hangers & Supports	7 ea	3.00	0.5	3.5	28.10	98.35	21.00
Wire, #6 THW	140 ft	0.26	0.06	8.4	28.10	236.04	36.40
Wire, #12 THW	280 ft	0.06	0.01	2.8	28.10	78.68	16.80
Concrete Wall Penetrations	3 ea	25.00	2.0	6.00	28.10	168.60	75.00
PWR & Contr to MOV (4-5/A-8)							
Conduit, 1 1/2" GRS	86 ft	1.85	0.1	8.6	28.10	241.66	159.10
Conduit, 1 1/2 GRS, 90 deg ELS	3 ea	4.65	0.5	1.5	28.10	42.15	13.95
Supports & Hangers	9 ea	3.00	0.5	4.5	28.10	126.45	27.00
Wire, #6 THW	180 ft	0.26	0.06	10.8	28.10	303.48	46.80

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2B

OPTION COST ANALYSIS FOR STEAM DRIVEN TURBINE COUPLED TO CHARGING PUMP

FACILITY TYPE PWR Page 4 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Wire, #12 THW	360 ft	0.06	0.01	3.6	28.10	101.16	21.60
Concrete Wall/Floor Pens	3 ea	25.00	2.00	6.0	28.10	168.60	75.00
Terminations (Test/ID),a All MOV PWR	48	3.00	1.00	48.0	28.10	1348.80	144.00
MOV Monitor/Control Circuits Containment MOVs							
Conduit, 1" GRS	60 ft	1.10	0.08	4.8	28.10	134.88	66.00
Conduit, 1" GRS, 90 deg ELS	2 ea	3.00	0.35	0.7	28.10	19.67	6.00
*Conduit, 1 1/2" GRS	195 ft	1.85	0.1	19.5	28.10	547.95	360.75
Conduit, 1 1/2" GRS, 90 deg ELS	4 ea	4.65	0.5	2.0	28.10	56.20	18.60
Pull Box	1 ea	21.78	0.7	0.7	28.10	19.67	21.78
Supports & Hangers	25 ea	3.00	0.5	12.5	28.10	351.25	75.00
Wire, #12 THW	3050 ft	0.06	0.01	30.5	28.10	857.05	183.00
Piping Area MOV							
Conduit, 1" GRS, 90 deg EL	2 ea	3.00	0.35	0.7	28.10	19.67	6.00
Conduit, 1" GRS	33 ft	1.10	0.08	2.6	28.10	73.06	36.30
Conduit, 1" GRS, 90 deg EL	2 ea	3.00	0.35	0.7	28.10	19.67	6.00
Hangers & Supports	4 ea	3.00	0.5	2.0	28.10	56.20	12.00
Wire, #12 THW	1310 ft	0.06	0.01	13.1	28.10	368.11	78.60
Locknuts & Bushings	4 ea	0.5	1.0	4.0	28.10	112.40	2.00
Locknuts & Busings, 1 1/2"	2 ea	1.00	1.00	2.0	28.10	56.20	2.00

*Note; 3 MOVs share 1 1/2" Conduit

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2B

OPTION COST ANALYSIS FOR STEAM DRIVEN TURBINE COUPLED TO CHARGING PUMP

FACILITY TYPE PWR Page 5 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
MOV Monitor/Contr Ckts							
MOV (4-S/A-B)							
Conduit, 1" GRS	96 ft	1.1Ø	Ø.ØØ	7.7	28.1Ø	216.37	1Ø5.6Ø
Conduit, 9Ø deg ELS	3 ea	3.ØØ	Ø.35	1.1	28.1Ø	3Ø.91	9.ØØ
Hangers & Supports	1Ø ea	3.ØØ	Ø.5	5.ØØ	28.1Ø	14Ø.5Ø	3Ø.ØØ
Locknuts & bushings, 1"	2 ea	Ø.5Ø	1.ØØ	2.ØØ	28.1Ø	56.2Ø	1.ØØ
Wire, #12 THW	6ØØ ft	Ø.Ø6	Ø.Ø1	6.ØØ	28.1Ø	168.6Ø	36.ØØ
Terminations, Tests, ID (All MOV Man)	48 ea	3.ØØ	Ø.2	9.6	28.1Ø	269.76	144.ØØ
Concrete Wall/Floor Pens (4 MOV Man./Contr)	8 ea	25.ØØ	2.Ø	16.ØØ	28.1Ø	449.6Ø	2ØØ.ØØ
Panel Space, Control Rm, 4 MOVs	1 ea	5ØØØ.ØØ	4.Ø	4.Ø	28.1Ø	112.4Ø	5ØØØ.ØØ
Reseal Existing Containment Pens	1 ea	2ØØ.ØØ	16.Ø	16.Ø	22.3Ø	356.ØØ	2ØØ.ØØ
SUBTOTAL				2ØØ3.9		55,2Ø8.41	4ØØ,211.21
(containment labor)				(186.9)		(5231.31)	
Operations and Maintenance							
Start up test	Annual			52.Ø	4Ø.ØØ	2ØØØ.ØØ	

COST SUMMARY

Original Installation	Low Case	Base Case	High Case
Labor Productivity Adjustment‡			
Labor Hours	3349(62%)	3775(55%)	5064(41%)
Labor Cost	$ 92,350	$104,104	$139,652
Labor + Material Cost (subtotal)	$501,025	$512,779	$548,327
Attributable to Equipment	$501,025	$512,779	$548,327
Attributable to Structures	$ 0	$ 0	$ 0
Geographical Adjustment	(85%)	(0%)	(115%)
Labor + Material Cost (subtotal)	$425,871	$512,779	$630,570
Engineering and Quality Assurance (25%)	$106,468	$128,195	$157,644
Subtotal	$532,331	$640,974	$788,220
Prime contractor Markup (25%)	$133,085	$160,244	$197,055
Subtotal	$665,424	$801,218	$985,275
Operations and Maintenance			
Labor Productivity Adjustment			
Labor Hours	69 (75%)	78 (67%)	104 (50%)
Labor Costs	$ 2,773	$ 3,104	$ 4,160
Labor + Material Cost (subtotal)	$ 2,773	$ 3,104	$ 4,160
Geographical Adjustment	(85%)	(0%)	(115%)
Labor and Material Cost (subtotal)	$ 2,357	$ 3,104	$ 4,784
Present Value Factor (10%,25 yrs=9.007 cumulative)			
Subtotal	$ 21,229	$ 27,958	$43,089
Total	$686,653	$829,176	$1,018,679

‡Productivity factor is average weighted by hours both inside and outside containment. Productivity factors inside containment are half those outside.

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2D

OPTION COST ANALYSIS FOR DEDICATED DIESEL SUPPLYING POWER TO MOTOR DRIVEN PUMP

FACILITY TYPE PWR Page 1 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Original Installation							
3" ID Stainless Steel Piping, 150 psig design pressure, 225 degF design temp., Class 2 Seismic, installable to reactor containment with 6 hangers	50'	38.00	0.4	20.0	27.50	550.00	1,900.00
	6	12.00	0.8	4.8	27.50	132.00	72.00
Pipe Tee - 3" Stainless Steel, 150 psig design pressure, 225 degF design temp., Class 2 Seismic	1	175.00	3.2	3.2	27.50	88.00	175.00
Motor Operated Valve, 125 VDC, 3" ID 150 psig design pressure, 225 degF design temp., Class 2 Seismic	1	4,600.00	4.0	4.0	27.50	110.00	4,600.00
w/2 Flanges, 3" SS	2	340.00	2.3	4.6	27.50	126.50	680.00
Motor Operated Valve, 125VDC, 3" ID 150 psig design pressure, 225 degF design temp., non-seismic with	1	4,600.00	4.0	4.0	27.50	110.00	4,600.00
2 Flanges, 3" SS	2	340.00	2.3	4.6	27.50	126.50	680.00
PWR & Control for MOVs in Containment							
Conduit, 1 1/2" GRS	162'	1.85	0.1	16.2	28.10	455.22	299.70
Conduit, 1 1/2" GRS, 90 deg ELS	4 ea	4.65	0.5	2.0	28.10	56.20	18.60
Hangers & Supports	16 ea	3.00	0.5	8.0	28.10	224.80	48.00
Pull Box	1 ea	21.78	0.7	0.7	28.14	19.67	21.78
Locknuts & Bushings	3 ea	1.00	1.0	3.0	28.10	84.30	3.00
Wire, #6 THW	650'	0.26	0.06	39.00	28.10	1,095.90	169.00
Wire, #12 THW	1300'	0.06	0.01	13.00	28.10	365.30	78.00
MOV Monitor & Control							
Conduit, 1" GRS	255'	1.10	0.08	20.4	28.10	573.24	280.50
Conduit, 1" GRS, 90 deg EL	6 ea	3.00	0.35	2.1	28.10	59.01	18.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2D

OPTION COST ANALYSIS FOR DEDICATED DIESEL SUPPLYING POWER TO MOTOR DRIVEN PUMP

FACILITY TYPE PWR Page 2 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Pull Box	2 ea	21.78	0.7	1.4	28.10	39.34	43.56
Locknuts & Bushings	7 ea	0.50	1.0	7.0	28.10	196.70	3.50
Hangers & Supports	26 ea	3.00	0.5	13.00	28.10	365.30	78.00
Concrete Wall/Floor Penns	4 ea	25.00	2.0	8.0	28.10	224.80	100.00
Reseal Existing Containment Penn	1 ea	200.00	16.0	16.0	22.30	356.80	200.00
Panel Space, Control Rm, 2 Mcvs	1 ea	5,000.00	4.0	4.0	28.10	112.40	5,000.00
Power For 4160VSWGR 4							
Diesel Generator Set, 16V149GD, 500-1100 KW, 4160V 60HZ, .8PF, Radiator Cooled Engine	1 ea	115,000.00	100.00	100.00	27.50	2,750.00	115,000.00
Fuel Storage Tank, 750 Gal.	1 ea	160.00	2.00	2.00	27.50	55.00	160.00
Fuel Pump, 25 PSI,5 GPM	1 ea	100.00	4.0	4.0	27.50	110.00	100.00
Fuel Line, 3/4"	25 Ft	1.05	0.16	4.0	27.50	110.00	26.25
Intake Duct, 12"	11 Ft	20.00	0.4	4.4	27.50	121.00	220.00
Exhaust Duct, 20 In	5 Ft	40.00	0.8	4.0	27.50	110.00	200.00
Generator Switchgear Set w/Breakers	1 ea	Included in DG Set					
Exhaust Sound Attenuator	1 ea						
Start System	1 ea	750.00	8.0	8.0	27.50	220.00	750.00
500 Sq Ft Bldg For D/G							
Site Preparation	Allow	250.00	8.0	8.0	25.00	200.00	250.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2D

OPTION COST ANALYSIS FOR DEDICATED DIESEL SUPPLYING POWER TO MOTOR DRIVEN PUMP

FACILITY TYPE PWR Page 3 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Excavation & Backfill	45 Cy	1.00	1.0	45.0	18.00	810.00	45.00
Footing & Foundation	11.25 Cy	56.00	0.2	2.3	18.00	41.40	630.00
Concrete Floor Slab	10 Cy	58.00	0.16	1.6	18.00	28.80	580.00
Concrete Block Wall	1000 sq.ft.	1.00	0.05	5.4	30.00	1,620.00	100.00
Concrete T Slab Roof	500 sq.ft.	3.85	.02	10.0	30.00	300.00	1925.00
Build Up, Insulate Roof	500 sq.ft.	0.55	0.03	15.0	30.00	450.00	275.00
Roll Up Door, 10x10 Elec	1 ea	2000.00	8.0	8.0	30.00	240.00	2000.00
Utility, Plumbing, & Piping	500 sq.ft.	1.0	0.03	15.0	30.00	450.00	500.00
3/4 Conduit w/3 #12 Wire, Fittings	250 Ft	0.86	0.00	20.0	28.10	562.00	215.00
Heater, Electric, 7.5 KW Explosion Proof	1 ea	350.00	3.0	3.0	28.10	84.30	350.00
Lights, Explosion Proof	7 ea	40.50	1.2	8.4	28.10	236.04	283.50
200 A Bldg Service & Panel	1 ea	891.00	7.0	7.0	30.00	210.00	891.00
Vent Fan & Louver	1 ea	2,000.00	8.0	8.0	27.50	220.00	2000.00
Fire Detection/Protection System	1 ea	12500.00	0.00	0.0	0.0	0.0	12500.00
Paint	1500 sq.ft.	0.03	0.01	15.0	21.20	318.00	45.0
Personnel Doors, 3x7	2 ea	300.00	0.0	16.0	20.00	320.00	600.00
Penetrations							
Intake 12"	1 ea	5.00	1.0	1.0	27.50	27.50	5.00
Exhaust, 20 in	1 ea	10.00	1.0	1.0	27.50	27.50	10.00
Fuel Line, 3/4"	1 ea	1.0	1.0	1.0	27.50	27.50	1.00
Elec Service, 2"	1 ea	1.00	1.0	1.0	27.50	27.50	1.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 20

OPTION COST ANALYSIS FOR DEDICATED DIESEL SUPPLYING POWER TO MOTOR DRIVEN PUMP

FACILITY TYPE PWR Page 4 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Plumbing, Inlet, & Drains	2 ea	25.00	2.0	4.0	30.00	120.00	50.00
D/G Output, 3"	1 ea	25.00	2.0	2.0	28.10	56.20	25.00
D/G Control/Monitor, 1"	1 ea	25.00	2.0	2.0	28.10	56.20	25.00
Excavation, 750 Cal Tank	6 Cy	1.00	1.0	6.0	19.00	114.00	6.00
Backfill	2 Cy	1.00	1.0	2.0	19.00	38.00	2.00
Tie-in, DG To 4160V SWGR 4							
Conduit, 3" GRS	115'	5.31	0.23	26.5	28.10	744.65	610.65
Conduit, 3" GRS, 90 deg ELS	4 ea	21.07	1.8	7.2	28.10	202.32	84.28
Hangers & Supports	12 ea	3.00	0.5	6.0	28.10	168.60	36.00
Wire, 4/0 THW (WYE)	460'	2.11	0.03	13.8	28.10	387.78	970.60
Terminations, Testing, ID	8 ea	5.20	0.25	2.0	28.10	56.20	41.60
Concrete Wall Penetrations	4 ea	25.00	2.0	8.0	28.10	224.80	100.00
Breaker, 3 Pole W/Aux Contacts 4160V 500 Amp, NEMA 1 Enclosure	1 ea	2000.00	14.0	14.0	28.10	393.40	2000.00
D/G Monitor and Control							
Conduit, 1 1/2" GRS	50 Ft	1.85	0.1	5.0	28.10	140.50	92.50
Conduit, 1 1/2" GRS ELS	3 ea	4.65	0.5	1.5	28.10	42.15	13.95
Hangers & Supports	5 ea	3.00	0.5	2.5	28.10	70.25	15.00
Wire, #12 THW	1,500 Ft	0.06	0.01	15.0	28.10	421.50	90.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2D

OPTION COST ANALYSIS FOR DEDICATED DIESEL SUPPLYING POWER TO MOTOR DRIVEN PUMP

FACILITY TYPE PWR Page 5 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Wire #12 THW	1500 ft	0.06	0.01	15.0	28.10	421.50	90.00
Panel Space Control Rm							
Ammeter	1 ea	915.00	2.0	2.0	28.10	56.20	915.00
Voltmeter	1 ea	915.00	2.0	2.0	28.10	56.20	915.00
Tachometer	1 ea	1000.00	2.0	2.0	28.10	56.20	1000.00
Start Sw	1 ea	280.00	0.5	0.5	28.10	14.05	280.00
Exciter (Initial) Sw	1 ea	280.00	0.5	0.5	28.10	14.05	280.00
Diesel Temp Gauge	1 ea	380.00	0.5	0.5	28.10	14.05	380.00
Gen Temp Gauge	1 ea	250.00	0.5	0.5	28.10	14.05	250.00
Fire Indicator	1 ea	1000.00	2.0	2.0	28.10	56.20	1000.00
BKR Indicator	3 ea	105.00	0.5	1.5	28.10	42.15	315.00
BKR Pull In Switch	1 ea	450.00	1.0	1.0	28.10	28.10	450.00
Concrete Wall Pen	1 ea	25.00	2.0	2.0	28.10	56.20	25.00
SUBTOTAL				697.7		18,792.52	169,683.47
(Containment Labor)				(118.5)		(3,307.87)	
Operations and Maintenance							
Check generator oil & water, start and load							
Weekly: 2 Hrs.	Annual			104.0	40.00	4,160.00	

COST SUMMARY

Original Installation	Low Case	Base Case	High Case
Labor Productivity Adjustment[1]			
Labor Hours	1026(68%)	1144(61%)	1517(46%)
Labor Cost	$ 27,637	$ 30,808	$ 40,854
Labor + Material Cost (subtotal)	$197,320	$200,491	$210,537
Attributable to Equipment	$164,306	$166,436	$173,169
Attributable to Structures	$ 33,014	$ 34,055	$ 37,372
Geographical Adjustment	(85%)	(100%)	(115%)
Labor + Material Cost (subtotal)	$167,722	$200,491	$242,118
Engineering and Quality Assurance (25%)	$ 41,930	$ 50,123	$ 60,529
Subtotal	$209,652	$250,614	$302,647
Prime Contractor Markup (25%)	$ 52,413	$ 62,653	$ 75,662
Subtotal	$262,065	$313,267	$378,309
Operations and Maintenance			
Labor Productivity Adjustment			
Labor Hours	139(75%)	155(67%)	200(50%)
Labor Costs	$ 5,547	$ 6,209	$ 8,320
Labor + Material Cost (subtotal)	$ 5,547	$ 6,209	$ 8,320
Geographical Adjustment	(85%)	(0%)	(115%)
Labor and Material Cost (subtotal)	$ 4,715	$ 6,209	$ 9,568
Present Value Factor (10%,25 yrs=9.007 cumulative)			
Subtotal	$ 42,468	$ 55,924	$ 86,179
Total	$304,533	$369,191	$464,449

n1 [1]Productivity factor is an average weighted by hours both inside and outside containment. Productivity factors inside containment are half these outside.

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2C

OPTION COST ANALYSIS FOR DEDICATED DIESEL COUPLED DIRECTLY TO CHARGING PUMP

FACILITY TYPE BWR Page 1 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Original Installation							
Diesel Driven Pump, capable of supplying 100 gpm at 1000 psi, self priming, battery start, radiator cooled, 120 degF suction supply, NPSH=20 ft	1	15000.00	100.0	100.0	27.50	2750.00	15000.00
Diesel Fuel Storage Tank, 100 gallons	1	150.00	3.0	3.0	27.50	82.50	150.00
4" ID Carbon Steel Piping, 250 psig design pressure, 150 degF design temp., underground installation	50'	18.75	0.07	3.5	27.50	96.25	937.50
4" ID Carbon Steel Piping, 250 psig design presure, 150 degF design temp.	50'	18.75	0.16	8.0	27.50	220.00	937.50
Pipe Penetrations through 12" concrete wall (for preceeding piping)	1	100.00	4.0	4.0	27.50	110.00	100.00
Pipe Hangers (for preceeding piping)	5	43.00	0.5	2.5	27.50	68.75	215.00
Pipe Tee - 4" ID Carbon Steel, 250 psig design pressure, 150 degF design temp.	1	206.00	18.5	18.5	27.50	508.75	206.00
Motor Operated Valve, 250VDC, 4" ID	1	790.00	4.0	4.0	27.50	110.00	790.00
250 psig design pressure, 150 degF design temp. with Flanges	2	70.00	3.1	6.2	27.50	170.50	140.00
2" ID Carbon Steel Piping, 1750 psig design pressure, 150 degF design temp., underground installation	50'	6.20	0.05	2.5	27.50	68.75	310.00
2" ID Carbon Steel Piping, 1750 psig design pressure, 150 degF design temp	50'	6.20	0.08	4.0	27.50	110.00	310.00
Pipe Penetrations through 12"							

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2C

OPTION COST ANALYSIS FOR DEDICATED DIESEL COUPLED DIRECTLY TO CHARGING PUMP

FACILITY TYPE BWR Page 2 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Concrete wall (for preceeding piping)	1	100.00	4.0	4.0	27.50	110.00	100.00
Pipe Hangers (for preceeding piping)	5	30.00	2.0	10.0	27.50	275.00	150.00
Pipe Tee - 2" ID Carbon Steel, 1750 psig design pressure, 150 degF design temp.	1	75.00	9.6	9.6	27.50	264.00	75.00
Motor Operated Valve 250VDC, 2" ID, 1750 psig design pressure, 150 degF design temp. with 2 flanges	1	955.00	5.0	5.0	27.50	137.50	955.00
	2	17.00	1.0	2.0	27.50	55.00	34.00
PWR & CONTROL, MOVS							
Conduit, 1 1/2 GRS	200 Ft	1.8	0.1	20.0	28.10	786.80	510.00
Conduit, 1 1/2 GRS, 90 deg El	6	4.65	0.5	3.0	28.10	84.30	27.90
Hangers & Supports	20	3.00	0.5	14.0	28.10	393.40	84.00
Pull Boxes	2 ea.	21.70	0.7	1.4	28.10	39.34	43.56
Locknuts & Bushings	6 ea.	1.00	1.00	6.0	28.10	168.60	6.00
Wire, #8 THW	1120 Ft.	0.10	0.01	11.2	28.10	314.72	201.60
Wire, #12 THW	2240 Ft.	0.06	0.01	22.4	28.10	629.44	134.40
Concrete Wall Penetrations	3 ea.	25.00	2.0	6.0	28.10	168.60	75.00
MONITOR & CONTROL, 2 MOVs							
Conduit, 1" GRS	25'	1.10	0.00	2.0	28.10	56.20	27.50
Conduit, 1" GRS 90 deg El	3 ea.	3.00	.35	1.1	28.10	30.91	9.00
Hangers & Supports	3 ea	3.00	0.5	1.5	28.10	42.15	9.00
Locknuts & Bushings	2 ea	0.50	1.0	2.0	28.10	56.20	1.00
Wire, #12 THW	300'	0.06	0.01	3.0	28.10	84.30	18.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2C

OPTION COST ANALYSIS FOR DEDICATED DIESEL COUPLED DIRECTLY TO CHARGING PUMP

FACILITY TYPE BWR Page 3 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Concrete Wall Penetrations	1 ea	25.00	2.0	2.0	28.10	56.20	25.00
Panel Space, Control Room	1 ea	5,000.00	4.0	4.00	28.10	112.40	5,000.00
Terminations, Testing & ID	48 ea	3.00	1.0	48.00	28.10	1,348.80	144.00
400 SQ. FT. BLDG FOR DIESEL & PUMP							
Site Preparation	ALLOW	250.00	8.0	8	25.00	200.00	250.00
Excavation & Backfill	36 Cy	1.00	1.0	36	18.00	648.00	36.00
Footing & Foundation	9 Cy	56.00	0.2	1.8	18.00	32.40	504.00
Concrete Floor Slab	8 Cy	58.00	.16	1.3	18.00	23.40	464.00
Concrete Block Wall	800 sq.ft.	1.00	0.05	40.0	30.00	1,200.00	800.00
Concrete T Slab Roof	400 sq.ft.	3.85	0.02	8.0	30.00	240.00	1,540.00
Build up Roof w/Insulation	400 sq.ft.	0.55	0.03	12.00	30.00	360.00	220.00
Roll Up Door, 8x10 Elect.	1 ea	2,000.00	8.0	8.0	30.00	240.00	2,000.00
Personnel Doors, 3x7	2 ea	300.00	8.0	16.0	20.00	320.00	600.00
Utility, Plumbing & Piping	400 sq.ft.	1.00	.03	12.0	30.00	360.00	400.00
3/4" Conduit w/3 #12 Wire, Fittings	200 Ft	0.86	0.08	16.0	28.10	449.60	172.00
Heater, Electric, 7.5 KW, Explosion Proof	1 ea	350.00	3.0	3.0	28.10	84.30	350.00
200 Amp Bldg Service Panel	1 ea	891.00	7.0	7.00	30.00	210.00	891.00
Vent Fan & Louver	1 ea	1,000.00	4.0	4.0	28.10	112.40	1,000.00
Fire Detection/Protection System	1 ea	12,500.00					12,500.00
Paint	1,200 sq.ft.	0.03	0.01	12.0	21.20	254.40	36.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2C

OPTION COST ANALYSIS FOR DEDICATED DIESEL COUPLED DIRECTLY TO CHARGING PUMP

FACILITY TYPE BWR Page 4 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Diesel Intake (Allow 6")	1 ea	25.00	1.0	1.0	27.50	27.50	25.00
Diesel Exhaust (Allow 14")	1 ea	50.00	1.0	1.0	27.50	27.50	50.00
Electric Service, 2"	1 ea	25.00	1.0	1.0	27.50	27.50	25.00
Diesel Control/Monitor, 1"	1 ea	25.00	1.0	1.0	27.50	27.50	25.00
Light, Explosion Proof	5 ea	40.50	1.2	6.0	28.10	168.60	202.50
DIESEL/PUMP CONTROL/MONITOR							
Conduit, 1" GRS	300 Ft	1.10	.08	24.0	28.10	674.40	330.00
Conduit, 1" GRS, ELS, 90 DegF	8 ea	3.00	0.35	2.8	28.10	78.68	24.00
Hangers & Supports	30 ea	3.00	0.5	15.0	28.10	421.50	90.00
Pull Boxes	2 ea	21.78	0.7	1.4	28.10	39.34	43.56
Locknuts & Bushings	6 ea	0.50	1.0	6.0	28.10	168.60	3.00
Wire, #12 THW	3,600 Ft	0.0	0.01	36.0	28.10	1,011.60	216.00
PANEL SPACE, CONTROL RM	1 ea						
INSTRUMENTATION/CONTROL							
Start Switch	1	280.00	0.5	0.5	28.10	14.05	280.00
Shut Down Switch	1	450.0	1.0	1.0	28.10	28.10	450.00
Tachometer	1	1,000.00	2.0	2.00	28.10	56.20	1,000.00
Diesel Temp	1	300.00	0.5	0.5	28.10	14.05	300.00
Pressure, Pump Outlet	1	250.00	0.5	0.5	28.10	14.05	250.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2C DC SYSTEM

OPTION COST ANALYSIS FOR DEDICATED DIESEL COUPLED DIRECTLY TO CHARGING PUMP

FACILITY TYPE BWR Page 5 of 6

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Flow Rate, Pump	1	250.00	0.5	0.5	28.10	14.05	250.00
Terminations, Testing, ID	24	3.00	1.0	24.0	28.10	674.40	72.00
Concrete Wall Peds, 1'	4 ea	25.00	2.0	8.0	28.10	224.80	100.00
SUBTOTAL				659.0		17,956.00	53,113.00
OPERATIONS & MAINTENANCE							
Check engine oil and water; start and load. Weekly: 2 hrs	Annual			104.00	40.00	4160.00	

COST SUMMARY

Original Installation	Low Case	Base Case	High Case
Labor Productivity Adjustment			
Labor Hours	880(75%)	985(67%)	1320(50%)
Labor Cost	$ 23,941	$ 26,800	$ 35,912
Labor + Material Cost (subtotal)	$ 77,854	$ 79,913	$ 89,825
Attributable to Equipment	$ 47,480	$ 49,514	$ 56,200
Attributable to Structures	$ 29,574	$ 30,372	$ 32,916
Geographical Adjustment	(85%)	(0%)	(115%)
Labor + Material Cost (subtotal)	$ 65,496	$ 79,913	$102,379
Engineering and Quality Assurance (25%)	$ 16,374	$ 19,978	$ 25,595
Subtotal	$ 81,870	$ 99,891	$127,974
Prime contractor Markup (25%)	$ 20,468	$ 24,973	$ 31,994
Subtotal	$102,338	$124,864	$159,968
Operations and Maintenance			
Labor Productivity Adjustment			
Labor Hours	139(75%)	155(67%)	208(50%)
Labor Costs	$ 5,547	$ 6,209	$ 8,320
Labor + Material Cost (subtotal)	$ 5,547	$ 6,209	$ 8,320
Geographical Adjustment	(85%)	(0%)	(115%)
Labor and Material Cost (subtotal)	$ 4,715	$ 6,209	$ 9,568
Present Value Factor (10%,25 yrs=9.007 cumulative)			
Subtotal	$ 42,468	$ 55,924	$ 86,179
Total	$144,806	$180,788	$246,147

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2D

OPTION COST ANALYSIS FOR DIESEL GENERATOR POWERING MOTOR DRIVEN PUMP

FACILITY TYPE BWR Page 1 of 5

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Original Installation							
Diesel Generator Set, 12V6D, 4160V 3Ø 175 - 440 KW Output, .8 PF, Radiator Cooled Engine, Includes	1 ea	101,200.00	100.0	100.0	28.10	2,810.00	101,200.00
Generator Switchgear Set, With Breakers	1 ea						
Generator Start System	1 ea	750.00	8.0	8.0	28.10	224.80	750.00
Fuel Tank, 750 Gal	1 ea	160.00	2.0	2.0	28.10	56.20	160.00
Fuel Pump, 25 PSI, 56 GPM	1 ea	100.00	4.0	4.0	28.10	112.40	100.00
Fuel Line, 1/2"	25 Ft	1.00	0.16	4.0	28.10	112.40	25.00
Intake Duct, 10"	11 Ft	18.00	0.36	4.0	28.10	112.40	198.00
Exhaust Duct, 16"	5 Ft	24.00	0.5	2.5	28.10	70.25	120.00
Exhaust Sound Attenuator	1 ea	(Included in Duct Set)					
400 Sq Ft Bldg For D/G							
Site Preparation	Allow	250.00	8.0	8.0	25.00	200.00	250.00
Excavation & Backfill	36 Cy	1.00	1.0	36.0	18.00	648.00	36.00
Footing & Foundation	9 Cy	56.00	0.2	1.8	18.00	32.40	504.00
Concrete Floor Slab	8 Cy	58.00	0.16	1.3	18.00	23.40	464.00
Concrete Block Wall	800 sq.ft.	1.00	0.05	40.06	30.00	1,200.00	800.00
Concrete T Slab Roof	400 sq.ft.	3.85	0.02	8.0	30.00	240.00	1,540.00
Build Up Roof/Insulate	400 sq.ft.	0.55	0.03	12.0	30.00	360.00	220.00
Roll Up Door, 8x10 ELEC	1 ea	2,000.00	8.0	8.0	30.00	240.00	2,000.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2D

OPTION COST ANALYSIS FOR DIESEL GENERATOR POWERING MOTOR DRIVEN PUMP

FACILITY TYPE BWR Page 2 of 5

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Personnel Doors, 3x7	2 ea	300.00	8.0	16.0	20.00	320.00	600.00
Utility, Plumbing, & Piping	400 sq.ft.	1.00	.03	12.0	30.00	360.00	400.00
3/4 Conduit w/3 #12 Wire & Fittings	200 Ft	0.86	0.08	16.0	28.10	449.60	172.00
Heater, Electric, 7.5 KW Explosion Proof	1 ea	350.00	3.0	3.0	28.10	84.30	350.00
Lights, Explosion Proof	5 ea	40.50	1.2	6.0	28.10	168.60	202.50
200 Amp Bldg Service Panel	1 ea	891.00	7.0	7.0	30.00	210.00	891.00
Vent Fan & Louver	1 ea	1,800.00	4.0	4.0	28.10	112.40	1,[illegible]0.00
Fire Detection/Protection System	1 ea	12,500.00	0.0	0.0	0.0	0.0	12,500.00
Paint	1,200 Ft^2	0.03	0.01	12.0	21.20	254.40	36.00
Penetrations							
Intake, 16"	1 ea	5.00	1.0	1.0	28.10	28.10	5.00
Exhaust, 16"	1 ea	10.00	1.0	1 0	28.10	28.10	10.00
Elec. Service 2 In	1 ea	1.00	1.0	1.0	28.10	28.10	1.00
Plumbing	2 ea	25.00	2.0	4.0	28.10	112.40	50.00
D/G Monitor/Control	1 ea	25.00	2.0	2.0	28.10	56.20	25.00
D/G 4160V Power Out	1 ea	25.00	2.0	2.0	28.10	56.20	25.00
Excavation, Conduit, D/G Bldg To Main Bldg							
Trenching	2.5 Cy	1.00	1.0	2.5	19.00	47.50	2.50
Concrete Red	.8 Cy	60.00	0.2	0.2	19.00	3.80	48.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 2D

OPTION COST ANALYSIS FOR DIESEL GENERATOR POWERING MOTOR DRIVEN PUMP

FACILITY TYPE BWR Page 3 of 5

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Backfill	2 Cy	1.00	0.25	0.5	19.00	9.50	2.00
Tie-in, D/G to 4160V Bus 13							
Conduit, 2" GRS	75 Ft	2.85	0.14	10.5	28.10	295.05	213.75
Conduit, 2" GRS, 90° ELS	5 ea	7.10	0.5	2.5	28.10	70.25	35.50
Hangers & Supports	5 ea	2.85	0.7	3.5	28.10	98.35	14.25
Locknuts & Bushings	4 ea	1.47	0.35	1.4	28.10	39.34	5.88
Pull Box	1 ea	21.78	0.25	0.3	28.10	8.43	21.78
Wire, 1/0 THW (WYE)	300 Ft	0.06	0.01	3.0	28.10	84.30	18.00
Breaker, 4160V 100 Amp, 3 Pole W/Aux Contacts, NEMA 1 Enclosure	1 ea	475.00	6.0	6.0	28.10	168.60	475.00
Concrete Wall Pen	1 ea	25.00	2.0	2.0	28.10	56.20	25.00
Terminations, Testing, ID	8 ea	1.00	1.0	8.0	28.10	224.80	8.00
DG Control/Instrumentation							
Conduit, 1 1/2" GRS	150 Ft	1.85	0.1	15.00	28.10	421.50	277.50
Conduit, 1 1/2" GRS, 90 deg ELS	6 ea	4.65	0.5	3.0	28.10	84.30	27.90
Supports & Hangers	13 ea	3.00	0.5	6.5	28.10	182.65	39.00
Pull Box	1 ea	21.78	0.7	0.7	28.10	19.67	21.78
Locknuts & Fittings	4 ea	1.00	1.0	4.0	28.10	112.40	4.00
Concrete Wall Penetrations	3 ea	25.00	2.0	6.0	28.10	168.60	75.00
Wire, #12 THW	3,000 Ft	0.06	0.01	30.00	28.10	843.00	180.00

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 20

OPTION COST ANALYSIS FOR DIESEL GENERATOR POWERING MOTOR DRIVEN PUMP

FACILITY TYPE BWR Page 4 of 5

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Panel Space, Control Rm							
Voltmeter	1 ea	915.00	2.0	2.0	28.10	56.20	915.00
Ammeter	1 ea	915.00	2.0	2.0	28.10	56.20	915.00
Diesel Temp. Gauge	1 ea	380.00	1.0	1.0	28.10	28.10	380.00
Gen. Temp. Gauge	1 ea	250.00	1.0	1.0	28.10	28.10	250.00
BKR Indicator	3 ea	105.00	0.5	1.5	28.10	42.15	315.00
BKR Control	1 ea	280.00	0.5	0.5	28.10	14.05	280.00
Start Control	1 ea	280.00	0.5	0.5	28.10	14.05	280.00
Shut-Down SW	1 ea	450.00	1.0	1.0	28.10	28.10	450.00
SUBTOTAL				441.7		11,951.84	130,714.26
Operations & Maintenance							
Check generator oil and water; start and load Weekly: 2 Hrs.	Annual	--	--	104.0	40.00	4,160.00	--

COST SUMMARY

Original Installation	Low Case	Base Case	High Case
Labor Productivity Adjustment			
Labor Hours	589(75%)	659(67%)	883(50%)
Labor Cost	$ 15,888	$ 17,785	$ 23,832
Labor + Material Cost (subtotal)	$146,602	$148,499	$154,546
Attributable to Equipment	$116,771	$117,836	$121,240
Attributable to Structures	$ 29,831	$ 30,661	$ 33,306
Geographical Adjustment	(85%)	(100%)	(115%)
Labor + Material Cost (subtotal)	$124,612	$148,499	$177,728
Engineering and Quality Assurance (25%)	$ 31,153	$ 37,125	$ 44,448
Subtotal	$155,765	$185,624	$222,176
Prime Contractor Markup (25%)	$ 38,941	$ 46,406	$ 55,544
Subtotal	$194,706	$232,030	$277,720

Operations and Maintenance			
Labor Productivity Adjustment			
Labor Hours	139(75%)	155(67%)	208(50%)
Labor Costs	$ 5,547	$ 6,209	$ 8,320
Labor + Material Cost (subtotal)	$ 5,547	$ 6,209	$ 8,320
Geographical Adjustment	(85%)	(0%)	(115%)
Labor and Material Cost (subtotal)	$ 4,715	$ 6,209	$ 9,568
Present Value Factor (10%,25 yrs=9.007 cumulative)			
Subtotal	$ 42,468	$ 55,924	$ 86,179
Total	$237,174	$287,954	$363,899

Appendix C

Increase Condensate Storage Tank Capacity

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 3

OPTION Cost Analysis for Increasing CST Capacity

FACILITY TYPE PWR

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Original Installation							
Diesel Driven pump - Capable of Supplying 150 GPM at 100 psi, self priming, NPSH = 50 ft battery start, radiator cooled, rated for 100 deg F suction supply (No installation involved - pump should be small enough to fit on a moveable cart) cart to hold above pump - should be portable (Included)	1	4000.00	2	2	28.10	56.20	4000.00
Fire Hose, 2 1/2" ID, rated for 200 psi	400'	2.50	0.002	0.8	19.00	15.20	1000.00
Coupling, 2 1/2"	2	15.00	0.5	1.0	27.50	27.50	30.00
Reducing Pipe Tee - 6" to 2 1/2", Carbon Steel, related for 200 psi, 120 deg F	1	420.00	8.0	8.0	27.50	220.00	420.00
Suction Hose, 2 1/2" ID, rated for 200 psi	50 ft	2.50	0.002	0.1	19.00	1.90	125.00
SUBTOTAL				11.9		320.8	5575.00
Operations and Maintenance							
Start up test Weekly: 1 hr	Annual			52.0	40.00	2080.00	

Subtask 3
Option Increased CST Capacity

Facility Type PWR

COST SUMMARY

Original Installation	Low Case	Base Case	High Case
Labor Productivity Adjustment			
Labor Hours	16(75%)	18 (67%)	24 (50%)
Labor Cost	$ 428	$ 479	$ 642
Labor + Material Cost (subtotal)	$ 6,003	$ 6,054	$ 6,217
Attributable to Equipment	$ 6,003	$ 6,054	$ 6,217
Attributable to Structures	$ 0	$ 0	$ 0
Geographical Adjustment	(85%)	(0%)	(115%)
Labor + Material Cost (subtotal)	$ 5,103	$ 6,054	$ 7,150
Engineering and Quality Assurance (25%)	$ 1,276	$ 1,514	$ 1,787
Subtotal	$ 6,379	$ 7,568	$ 8,937
Prime Contractor Markup (25%)	$ 1,595	$ 1,892	$ 2,234
Subtotal	$ 7,974	$ 9,460	$ 11,171
Operations and Maintenance			
Labor Productivity Adjustment			
Labor Hours	69 (75%)	78 (67%)	104(50%)
Labor Costs	$ 2,773	$ 3,104	$ 4,160
Labor + Material Cost (subtotal)	$ 2,773	$ 3,104	$ 4,160
Geographical Adjustment	(85%)	(0%)	(115%)
Labor and Material Cost (subtotal)	$ 2,357	$ 3,104	$ 4,784
Present Value Factor (10%,25 yrs=9.007 cumulative)			
Subtotal	$ 21,229	$ 27,958	$ 43,089
Total	$ 29,203	$ 37,418	$ 54,260

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 3

OPTION COST ANALYSIS FOR Increasing CST Capacity

FACILITY TYPE BWR

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Original Installation							
Diesel Driven PUmp - Capable of supplying 250 gpm at 100 psi, self-priming, NPSH = 50 ft, battery start, radiator cooled, rated for 250 deg F suction supply	1	21000.00	96.0	96.0	27.50	2640.00	21000.00
Diesel Fuel Storage Tank, 100 gallons	1	150.00	4.0	4.0	27.50	110.00	150.00
4" carbon steel piping, 200 psi 250 deg F	100 ft	10.75	0.2	20.0	27.50	550.00	1075.00
Pipe penetration through 12" concrete wall	1	100.00	4.0	4.0	27.50	110.00	100.00
4" Manual Gate Valve, 200 psi, 250 deg F	2	390.00	2.0	4.0	27.50	110.00	780.00
Reducing tee - 6" to 4" - carbon steel, 200 psi, 250 deg F	1	68.00	1.5	1.5	27.50	41.25	68.00
Connect 4" to 6" piping using above tee (included in labor cost)							
4" simple cut and welded to 24" pipe carbon steel, 200 psi, 250 deg F	1	50.00	3.0	3.0	27.50	82.50	50.00
Covert 4" & 24" piping using above tee (included in labor cost)							
Pipe hanger	10	2.50	0.1	1.0	27.50	27.50	25.00
SUBTOTAL				133.5		3671.25	23248.00
Operations and Maintenance							
Start up test weekly: 1 hr	Annual			52.0	40.00	2080.00	

COST SUMMARY

Original Installation	Low Case	Base Case	High Case
Labor Productivity Adjustment			
Labor Hours	179(75%)	200(67%)	268(50%)
Labor Cost	$ 4,895	$ 5,479	$ 7,342
Labor + Material Cost (subtotal)	$ 28,143	$ 28,727	$ 30,590
Attributable to Equipment	$ 28,143	$ 28,727	$ 30,590
Attributable to Structures	$ 0	$ 0	$ 0
Geographical Adjustment	(85%)	(0%)	(115%)
Labor + Material Cost (subtotal)	$ 23,922	$ 28,727	$ 35,178
Engineering and Quality Assurance (25%)	$ 5,980	$ 7,182	$ 8,795
Subtotal	$ 29,902	$ 35,909	$ 43,973
Prime Contractor Markup (25%)	$ 7,476	$ 8,977	$ 10,993
Subtotal	$ 37,376	$ 44,886	$ 54,966
Operations and Maintenance			
Labor Productivity Adjustment			
Labor Hours	69 (75%)	78 (67%)	104(50%)
Labor Costs	$ 2,773	$ 3,104	$ 4,160
Labor + Material Cost (subtotal)	$ 2,773	$ 3,104	$ 4,160
Geographical Adjustment	(85%)	(0%)	(115%)
Labor and Material Cost (subtotal)	$ 2,357	$ 3,104	$ 4,784
Present Value Factor (10%,25 yrs=9.007 cumulative)			
Subtotal	$ 21,229	$ 27,958	$ 43,089
Total	$ 58,605	$ 72,844	$ 98,055

Appendix D

Increase Instrument Air Supply

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 4

OPTION Cost Analysis for Increasing Air Supply From 4 Hours to 8 Hours

FACILITY TYPE PWR Page 1 of 2

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Original Installation							
Gas Bottle Containing ~ 285 Scf of air, pressure 2000 - 2500 psig, dewpoint of -40 deg F at 100 psig	15	250.00	1.0	15.0	27.50	412.50	3750.00
Air pressure indicator /air regulator attach directly to gas bottle; air pressure accuracy +5% air regulator accuracy +2%	15	100.00	0.5	7.5	27.50	206.25	1500.00
Gas bottle rack - sized to hold 45 standard size gas bottles (each bottle ~ 10" diameter, ~ 55" high)	1	1500.00	8.0	8.0	27.50	220.00	1500.00
15' Section of 3/8" ID rubber tubing, 1000lb. bursting strength, 250 lb working pressure, 3/8" female fittings on both ends	15	50.00	1.0	15.00	27.50	412.50	750.00
3/8" Double male coupling	15	2.50	0.5	7.5	27.50	206.25	37.50
2 1/2" ID Carbon steel piping - 250 lb. working pressure	110'	8.20	0.1	11.0	27.50	302.50	902.00
2 1/2" Carbon Steel Pipe Tee - 250 lb. working pressure	1	50.00	0.5	0.5	27.50	13.75	50.00
2 1/2" Check Valve	1	295.00	4.0	4.0	27.50	110.00	295.00
Blind Flange - 2 1/2" Carbon Steel	1	40.00	4.0	4.0	27.50	10.00	40.00
Pipe Hanger	11	10.00	1.0	11.0	27.50	302.50	110.00
SUBTOTAL				83.5		2296.25	8934.50
Operations & Maintenance							
Check Pressure, visual observation monthly: 1 hr	Annual			12.0	40.00	480.00	

COST SUMMARY

Original Installation	Low Case	Base Case	High Case
Labor Productivity Adjustment			
Labor Hours	112(75%)	125 (67%)	168(50%)
Labor Cost	$ 3,861	$ 3,427	$ 4,592
Labor + Material Cost (subtotal)	$ 11,995	$ 12,361	$ 13,526
Attributable to Equipment	$ 11,995	$ 12,361	$ 13,526
Atributable to Structures	$ 0	$ 0	$ 0
Geographical Adjustment	(85%)	(0%)	(115%)
Labor + Material Cost (subtotal)	$ 10,196	$ 12,361	$ 15,555
Engineering and Quality Assurance (25%)	$ 2,549	$ 3,090	$ 3,889
Subtotal	$ 12,745	$ 15,451	$ 19,444
Prime Contractor Markup (25%)	$ 3,186	$ 3,863	$ 4,861
Subtotal	$ 15,931	$ 19,314	24,305
Operations and Maintenance			
Labor Productivity Adjustment			
Labor Hours	16 (75%)	18 (67%)	24 (50%)
Labor Costs	$ 648	$ 716	$ 968
Labor + Material Cost (subtotal)	$ 648	$ 716	$ 968
Geographical Adjustment	(85%)	(0%)	(115%)
Labor and Material Cost (subtotal)	$ 544	$ 716	$ 1,104
Present Value Factor (10%,25 yrs=9.077 cumulative)			
Subtotal	$ 4,900	$ 6,449	$ 9,944
Total	$ 20,831	$ 25,763	$ $ 34,249

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 4

OPTION Cost Analysis for Increasing Air Supply From 4 Hours to 16 Hours

FACILITY TYPE PWR

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Original Installation							
Gas Bottle containing ~ 285 Scf of air, pressure 2000 - 2500 psig, dewpoint of -40 def F at 100 psig	45	250.00	1.0	45.0	27.50	1237.50	11250.00
Air pressure indicator/air regulator, Attach directly to gas bottle; air pressure accuracy +5% air regulator accuracy +2%	45	100.00	0.5	22.5	27.50	618.75	4500.00
Gas bottle rack - sized to hole 15 standard size gas bottles (each bottle ~ 18" diameter, ~55" high)	3	1500.00	4.0	12.0	27.50	330.00	4500.00
15' Section of 3/8" ID rubber tubing, 1000 lb bursting strength, 250 lb working pressure, 3/8" female fittings on both ends	45	50.00	1.0	45.0	27.50	1237.50	2250.00
3/8" Double male coupling	45	2.50	0.5	22.5	27.50	618.75	112.50
2 1/2" ID Carbon Steel Piping - 250 lb. working pressure	150 ft	8.20	0.1	15.0	27.50	412.50	1230.00
2 1/2" Carbon STeel Pipe Tee - 250 lb working pressure	1	50.00	0.5	0.5	27.50	13.75	50.00
2 1/2" Check Valve - 250 lb working pressure	1	295.00	4.0	4.0	27.50	110.00	295.00
Blind Flange - 2 1/2" Carbon Steel	1	40.00	4.0	4.0	27.50	110.00	40.00
Pipe Hanger	15	10.00	1.0	15.0	27.50	412.50	150.00
SUBTOTAL				185.5		5101.25	24377.50
Operations & Maintenance							
Check pressure, visual observation Monthly: 1 hr	Annual			12.0	40.00	480.00	

Subtask 4
Option Increase Air Supply to 16 Hours

Facility Type PWR

COST SUMARY

Original Installation	Low Case	Base Case	High Case
Labor Productivity Adjustment			
Labor Hours	247(75%)	277(67%)	371(50%)
Labor Cost	$ 6,802	$ 7,614	$ 10,203
Labor + Material Cost (subtotal)	$ 31,180	$ 31,992	$ 34,581
Attributable to Equipment	$ 31,180	$ 31,992	$ 34,581
Attributable to Structures	$ 0	$ 0	$ 0
Geographical Adjustment	(85%)	(0%)	(115%)
Labor + Material Cost (subtotal)	$ 26,503	$ 31,992	$ 39,768
Engineering and Quality Assurance (25%)	$ 6,626	$ 7,998	$ 9,942
Subtotal	$ 33,129	$ 39,990	$ 49,710
Prime Contractor Markup (25%)	$ 8,282	$ 9,998	$ 12,428
Subtotal	$ 41,411	$ 49,988	$ 62,138
Operations and Maintenance			
Labor Productivity Adjustment			
Labor Hours	16 (75%)	18 (67%)	24 (50%)
Labor Costs	$ 640	$ 716	$ 960
Labor + Material Cost (subtotal)	$ 640	$ 716	$ 960
Geographical Adjustment	(85%)	(0%)	(115%)
Labor and Material Cost (subtotal)	$ 544	$ 716	$ 1,104
Present Value Factor (10%,25 yrs=9.007 cumulative)			
Subtotal	$ 4,900	$ 6,449	$ 9,944
Total	$ 46,311	$ 56,437	$ 72,082

DETAILED COST ESTIMATE WORKSHEET

SUBTASK 4

OPTION 1 COST ANALYSIS FOR Increasing Air Supply Supply From 4 Hours to 8 Hours FACILITY TYPE BWR Page 1 of 2

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Original Installation							
Gas Bottle containing ~ 285 scf of air, Pressure 2000 - 2500 psig, dewpoint of -40 deg F	10	250.00	1.0	10.0	27.50	275.00	2500.00
Air pressure indicator/air regulator attach directly to gas bottle; air pressure accuracy + 5% air regulator accuracy + 2%	10	100.00	0.5	5.0	27.50	137.50	1000.00
Gas bottle rack - sized to hold 10 standard size gas bottles (each bottle ~ 10" diameter, ~ 55" high)	1	1000	6.0	6.0	27.50	165.00	1000.00
15' section of 3/8" ID rubber tubing, 1000 lb. bursting strength, 250 lb working pressure, 3/8" female fittings	10	50.00	1.0	10.0	27.50	275.00	500.00
3/8" double male coupling	10	2.50	0.5	5.0	27.50	137.50	25.00
2 1/2" ID Carbon Steel Piping - 250 lb. working pressure	100 ft	8.20	0.1	10.0	27.50	275.00	820.00
2 1/2" Carbon Steel Pipe Tee - 250 lb working pressure	1	50.00	0.5	0.5	27.50	13.75	50.00
2 1/2" Check Valve - 250 lb Working Pressure	1	295.00	4.0	4.0	27.50	110.00	295.00
Blind Flange - 2 1/2" Carbon Steel	1	40.00	4.0	4.0	27.50	110.00	40.00
Pipe Hanger	10	10.00	0.1	1.0	27.50	27.50	100.00
SUBTOTAL				55.5		1526.25	6330.00
Operational Maintenance							
check pressure, visual observation monthly 1 hr	Annual			12.0	40.00	480.00	

COST SUMMARY

Original Installation	Low Case	Base Case	High Case
Labor Productivity Adjustment			
Labor Hours	73(75%)	82(67%)	110(50%)
Labor Cost	$ 6,035	$ 6,755	$ 9,052
Labor + Material Cost (subtotal)	$ 12,365	$ 13,085	$ 15,382
Attributable to Equipment	$ 12,365	$ 13,085	$ 15,382
Attributable to Structures	$ 0	$ 0	$ 0
Geographical Adjustment	(85%)	(0%)	(115%)
Labor + Material Cost (subtotal)	$ 10,510	$ 13,085	$ 17,689
Engineering and Quality Assurance (25%)	$ 2,628	$ 3,271	$ 4,422
Subtotal	$ 13,138	$ 16,356	$ 22,111
Prime Contractor Markup (25%)	$ 3,284	$ 4,089	$ 5,528
Subtotal	$ 16,422	$ 20,445	$ 27,629
Operations and Maintenance			
Labor Productivity Adjustment			
Labor Hours	16 (75%)	18 (67%)	24 (50%)
Labor Costs	$ 640	$ 716	$ 960
Labor + Material Cost (subtotal)	$ 640	$ 716	$ 960
Geographical Adjustment	(85%)	(0%)	(115%)
Labor and Material Cost (subtotal)	$ 544	$ 716	$ 1,104
Present Value Factor (10%,25 yrs=9.007 cumulative)			
Subtotal	$ 4,900	$ 6,449	$ 9,944
Total	$ 21,322	$ 26,894	$ 37,573

DETAILED COST ESTIMATE WORKSHEET

SUBTASK A

OPTION COST ANALYSIS FOR Increasing Air Supply Supply From 4 Hours to 16 Hours FACILITY TYPE BWR Page 1 of 2

Description	Material Quantity & Units	Material Unit Cost	Unit Labor Hours	Total Labor Hours	Labor Rates	Labor Cost	Material Cost
Original Installation							
Gas Bottle Containing ~ 285 set of Air, Pressusre 2000 - 2500 psig, Dewpoint of -40 deg F	30	250.00	1.0	30.0	27.50	825.00	7500.00
Air Pressure indicator/air regulator Attach directly to gas bottle; air pressure accuracy +5% air regulator accruracy +2%	30	100.00	0.5	15.0	27.50	412.50	3000.00
Gas bottle rack - sized to hold 30 standard size gas bottles (each bottle ~ 10" diameter, ~ 55" high)	1	2000.00	8.0	8.0	27.50	220.00	2000.00
15' Section of 3/8" ID rubber tubing 1000 lb. bursting strength, 250 lb working pressure, 3/8" female fitting on both ends	30	50.00	1.0	30.0	27.50	825.00	1500.00
3/8" double male coupling	30	2.50	0.5	15.0	27.50	412.50	75.00
2 1/2" ID Carbon Steel Piping - 250 lb. working pressure	120 ft	8.20	0.1	12.0	27.50	330.00	984.00
2 1/2" Carbon Steel + Pipe Tee - 250 lb. working pressure	1	50.00	0.5	0.5	27.50	13.75	50.00
2 1/2" Check Valve - 250 lb working pressure	1	295.00	4.0	4.0	27.50	110.00	295.00
Blind Flange - 2 1/2" Carbon Steel	1	40.00	4.0	4.0	27.50	110.00	40.00
Pipe Hanger	12	10.00	1.0	12.0	27.50	330.00	120.00
SUBTOTAL				130.5		3588.75	15564.00
Operations & Maintenance							
Check pressure, visual observation Monthly: 1 hr.	Annual		12.0	12.0	40.00	480.00	

COST SUMMARY

Original Installation	Low Case	Base Case	High Case
Labor Productivity Adjustment			
Labor Hours	173(75%)	194(67%)	260(50%)
Labor Cost	$ 4,785	$ 5,357	$ 7,178
Labor + Material Cost (subtotal)	$ 20,349	$ 20,921	$ 22,742
Attributable to Equipment	$ 20,349	$ 20,921	$ 22,742
Attributable to Structures	$ 0	$ 0	$ 0
Geographical Adjustment	(85%)	(0%)	(115%)
Labor + Material Cost (subtotal)	$ 17,297	$ 20,921	$ 26,153
Engineering and Quality Assurance (25%)	$ 4,324	$ 5,230	$ 6,538
Subtotal	$ 21,621	$ 26,151	$ 32,691
Prime Contractor Markup (25%)	$ 5,405	$ 6,538	$ 8,173
Subtotal	$ 27,026	$ 32,689	$ 40,864
Operations and Maintenance			
Labor Productivity Adjustment			
Labor Hours	16 (75%)	18 (67%)	24 (50%)
Labor Costs	$ 640	$ 716	$ 960
Labor + Material Cost (subtotal)	$ 640	$ 716	$ 960
Geographical Adjustment	(85%)	(0%)	(115%)
Labor and Material Cost (subtotal)	$ 544	$ 716	$ 1,104
Present Value Factor (10%,25 yrs=9.007 cumulative)			
Subtotal	$ 4,900	$ 6,449	$ 9,944
Total	$ 31,926	$ 39,138	$ 50,808

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13 ABSTRACT (200 words or less)

Cost estimates were required to serve as partial bases for decisions on four potential nuclear reactor facility modifications being considered in the resolution of USI A-44, Station Blackout. The modifications constituting the four subtasks in this report are (1) increasing battery capacity, (2) adding an AC-independent charging pump for reactor coolant seal injection, (3) increasing condensate storage tank capacity, and (4) increasing compressed air supply for instrument air.

The cost estimates contained in this report include those for the following: (1) engineering and design, (2) equipment, materials, and structures, (3) installation, and (4) present worth of the annual operation and maintenance over the remaining useful life of the reactor.

In addition to providing engineering requirements for the four modifications, the report evaluates the potential for synergistic solutions. It was found that some modifications to provide for reactor coolant seal injection would effectively satisfy the DC system augmentation requirements, with the costs for solving both problems being competitive with that of additional batteries alone. The report also identifies an innovative potential solution to the DC system capacity problem through the use of high energy density primary batteries which would be far more cost effective than the addition of traditional lead acid batteries for mitigating extended station blackout effects.

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