# SUMMARY

## CCD UNIT 6

## ECONOMIC EVALUATION OF ALTERNATIVES

REPORT PREPARED FOR

THE CINCINNATI GAS & ELECTRIC COMPANY
COLUMBUS & SOUTHERN OHIO ELECTRIC COMPANY
THE DAYTON POWER AND LIGHT COMPANY

FEBRUARY 17, 1969

VOLUME I

REPORT SL-2561

SARGENT & LUNDY
ENGINEERS
CHICAGO

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February 17, 1969

Subject:
CCD Unit 6
The Cincinnati Gas & Electric Company

SL-2561

Mr. A. E. Rothenberg, Chief Engineer
and Manager
General Engineering Department
The Cincinnati Gas & Electric Company
P.O. Box 960
Cincinnati, Ohio 45201

Dear Mr. Rothenberg:

We are attaching for your review ten (10) copies of Volume I - SL-2561 - Summary CCD Unit 6 - Economic Evaluation of Alternatives, and twenty (20) copies of Volume II - SL-2561 - CCD Unit 6 - Economic Evaluation of Alternatives, dated February 17, 1969. These documents present the results of the evaluation which we have made of the technical and economic facets of the expansion of the CCD system by the installation of either nuclear or fossil units at the Moscow site of The Cincinnati Gas & Electric Company.

As discussed in detail during our presentation in Cincinnati on February 6, there are several relevant conclusions to be drawn from the evaluations:

> The best nuclear offerings appear to be those of the General Electric Company.
>
> In the 800 to 900 MWe size range the fossil unit may be somewhat more economical than the nuclear unit depending on the mode of nuclear fuel procurement.

In the 900 to 1,000 MWe range the nuclear unit is comparable from an economic standpoint to that of the fossil unit.

In the 1,000 to 1,200 MWe range the nuclear unit is clearly the economic choice.

When assessing the intangible factors we believe that there are several advantages to the utilization of nuclear units that may outweigh the indicated economic differences in the smaller size unit. Factors such as the influence of potential regulatory requirements for air pollution control would tend to reduce if not completely offset the indicated cost differences in the smaller size.

Coupled with these economic factors, as well as the system expansion and reserve requirements, are other subjective considerations which we feel indicate that the installation of a nuclear unit in the 900 to 1,000 MWe range would be appropriate on your system. Included are factors such as the ability of the nuclear unit to take advantage of future advances in nuclear fuel element design and operating limits, differences in obsolescence rates between nuclear and fossil design, etc. It is on the basis of these economic and subjective considerations, in addition to the other factors discussed in the report, that we recommend that you proceed with your expansion plans by utilizing the General Electric 2856 MWt offering. This offering would meet the indicated system needs of a 900 to 1,000 MWe unit for a commercial service date of January, 1975.

The decision on the mode of fuel supply must be considered in detail by the CCD companies. We again wish to note that the low revenue requirements associated with the leasing of nuclear fuel may be offset by the legal,regulatory, financial and tax implications associated with this method of fuel financing relative to that of your ownership. The system load growth should be evaluated in detail prior to exercising the quoted option for the second unit.

We believe that our conclusions and recommendations are based on a conservative engineering approach with any bias being directed in favor of the fossil units. As you are aware, several of the reactor manufacturers have contacted The Cincinnati Gas & Electric Company with modifications to their proposal offerings. These modifications include design changes in the product line which can affect the balance of plant construction cost, modifications to the scope of fuel supply and possible price changes in both the nuclear steam supply offering and the nuclear fuel offerings. It is noted that the effects of these changes have not been incorporated in the reports as agreed. We are, however, continuing to assess their effect on the various offerings from the vendors on the overall evaluation. A ready examination of the marketing conditions for nuclear plants during the past calendar year relative to 1966 and 1967 would further suggest that economic advantages could accrue through detailed negotiations with the apparent low bidder.

As you are aware the proposals from the reactor manufacturers were received in October. Their expiration dates were subsequently extended to January and then to a date of March 3, 1969. If a decision cannot be made prior to March 3 which will permit the initiation of negotiations with the apparent low bidders or the rejection of all bids, it will be necessary to consider in detail the best method of proceeding. In some instances the reactor vendors have suggested that they may wish to withdraw their bids should a decision be postponed beyond March 3. In that event it will be necessary to re-bid the project with due consideration being given to the overall project schedules.

Should any questions arise concerning the methods used in our studies of r the results obtained from our evaluation, we will, of course, be most pleased to review them in detail at your convenience.

Yours truly,

SARGENT & LUNDY

BY W. R. Steur

WRSteur/gp
Enclosures
cc: C. R. Mede (10 of I, 20 of II)
J. H. Inskeep (10 of I, 20 of II)

COPY

# SUMMARY

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## TABLE OF CONTENTS

# LIST OF EXHIBITS

# SUMMARY
# CCD UNIT 6
# ECONOMIC EVALUATION OF ALTERNATIVES

## I INTRODUCTION

The CCD System Study (SL-2394) recommends,as one means of meeting the expansion requirements of the three CCD companies, the installation of a nuclear unit of approximately 919 MWe (net) capacity for service in January, 1975. Exhibit S-1 indicates the CCD System growth pattern and existing capability as of October, 1967. This peak load pattern was exceeded during the summer of 1968 by approximately 16% which may indicate that the predicted growth is at a somewhat greater rate than expected. However, even if this should not be the case, Exhibit S-1 clearly indicates the need for a minimum of 1800 MWe (net) additional capacity by 1976 in order to meet the 15% reserve capacity requirement recommended in the System Study.

## II OBJECTIVES OF THIS STUDY

In the summer of 1968, Sargent & Lundy prepared Specifications H-2210 and H-2211 to cover the requirements for a Nuclear Steam Supply System (NSSS) of the light water reactor and the high temperature gas-cooled reactor concept, respectively. The basic specification calls for:

a. A NSSS capable of 800-900 MWe.

b. An alternate NSSS capable of 1000-12000 MWe.

c. Nuclear fuel and fuel services.

d. Nuclear services and training.

e. An option for a second duplicate unit.

The plant schedule specified is as follows:

| | Unit 1 | Unit 2 |
|---|---|---|
| Award | Dec. '68 | Dec. '68 |
| AEC License Application | June '69 | June '69 |
| Start Substructure | July '70 | July '71 |
| Fuel Loading | June '74 | June '75 |
| Commercial Service | Jan. '75 | Jan. '76 |

Should the award be made in March, 1969, the total time from award to service will be 68 months. This schedule is considered adequate by all vendors.

In October, 1968 proposals were received from five reactor manufacturers. Each offers at least one NSSS of the base or alternate rating. No price, however, has been included in the Gulf General Atomic proposal for the NSSS.

The Objective of this study is to:

a. Present the results of the evaluation of the most economic nuclear plan.

b. Compare the most economic nuclear plan with a cost estimate of a fossil fuel plant.

c. Determine the most economic plan for system expansion on the basis of the comparative analysis.

The study involves an analysis of estimated construction and fuel costs for a total of 13 alternate plans: 11 nuclear and 2 fossil. These plans are summarized on Exhibit S-5. This exhibit is appended as the last page of this report in the form of a foldout page so that it can be continually displayed for ready reference as this report is studied.

## III. CONCLUSIONS AND RECOMMENDATIONS

When each of the factors considered in the evaluation are combined, the following conclusions can be drawn:

A. Nuclear Plan Economics

1. "Small Size" Nuclear Plans (800-900 MWe)
In comparing Plans 5 and 9, the General Electric NSSS plan is significantly more economic.

2. "Intermediate Size" Nuclear Plans (900-1050 MWe)
A comparison of the economics of Plans 1, 3, 6, and 10 shows the General Electric Company's offering to result in the most economic plan (No cost data is available for Plan 8).

3. "Large Size" Nuclear Plans (>1050 MWe)
The plans considered are 2, 4, 7, and 11. In this size range the economics of the Combustion Engineering, and General Electric plans are nearly equal.

B. Nuclear vs Fossil Plan Economics

1. Best Small Size Nuclear vs. 908 MWe (net) Fossil Plan
Plan 5 results in energy cost of between 7.49 and 7.85 mills/kWh, depending on the fuel supply and fuel financing options selected. The fossil plan is estimated to produce energy at 7.35 mills/kWh on the basis of 5% overpressure operation. When evaluated on the basis of no overpressure operation, a levelized energy cost of about 7.47 mills/kWh results. The economics appear to favor the coal plant by a slight margin. The choice in this size range is influenced by:

   a. The possibility of a requirement to add $SO_2$ removal equipment to the coal plant.

   b. A qualitative assessment of the technical advantages of entering the nuclear power field early in order to develop the expertise required of the next generation of nuclear plants, the breeder reactors, in the late 1980's.

c. An appraisal of the reliability of large sized fossil units.

d. A realistic look at the trends in coal prices as compared with the 1% per year escalation used in this study.

2. Best Intermediate Size Nuclear vs 908 MWe Fossil Plan
Plan 6 results in energy costs of between 7.18 and 7.46 mills/kWh, depending upon the fuel supply and fuel financing options selected. The coal plant energy cost is 7.35 mills/kWh with, and 7.47 mills/kWh without, 5% overpressure operation. Again, a careful appraisal of the considerations listed in paragraph B1 above is prudent. However, the economics show a slight margin in favor of the nuclear plan.

3. Best Large Size Nuclear vs. 1109 MWe Fossil Plan
Plans 4 and 7 result in nearly identical energy costs, 6.8 - 7.1 mills/kWh. The large fossil plan is estimated to produce energy for 7.2 mills/kWh with, or 7.32 mills/kWh without, overpressure operation. In this size range there is a clear advantage to installing nuclear capacity. The choice as to which nuclear plant, the GE BWR or the CE PWR, depends on an analysis of qualitative and subjective considerations, some of which are discussed in Section VIII.

C. Unit Size

Exhibit S-1, taken from the CCD System Study (Report SL-2304), shows the projected loads and capability requirements for the CCD Group. The exhibit has not been corrected for any changes in capability of units planned or being constructed. Neither has it been corrected for such factors as the 16% increase in the 1968 summer peak load over the 1967 summer peak.

If a 850 MWe unit is added to the system in 1975, it is seen that the system capability would fall short of the 12% reserve requirement. A 1,000 MWe unit may just provide the 12% reserve requirement.

D. Recommended Steam Supply System

In the size range recommended, the plan with the General Electric 2856 MWt NSSS demonstrates the most favorable economics. This is true notwithstanding the fact that the most conservative approach possible is taken in the nuclear cost analysis. On the other hand, optimistic views have been taken of fossil plant and coal prices, as well as the need for capital equipment to account for potential sulfur and nitrous oxide control regulations. Accordingly, it is recommended that:

1. A nuclear unit, incorporating the General Electric 2856 MWt NSSS be contracted for, with the service date specified as January, 1975.

2. System load and reserve requirements be received so that early consideration can be given to exercising the second unit option.

## IV. CONSTRUCTION COST STUDIES

In order to optimize the effort required in the analysis, Plans 1, 3, 6, 8, 10 and 12 have been selected for detailed cost analysis and the results extrapolated to provide cost data for all 13 plans. A conceptual plant design has been completed for each of the plans selected for detailed analysis. The schedule for the evaluation precludes the optimization of the overall plant designs; however, the resulting arrangements are considered representative of current projects for each NSSS concept. These plant designs are the basis of the estimated cost summaries shown by Exhibit S-2.

The following paragraphs describe certain details of the construction cost estimates in Exhibit S-2 that deserve emphasis:

A. Site Preparation (Line 5)
The Ohio River site requires extensive preparation including nearly 30 feet of fill in order to bring the plant grade level to an elevation exceeding the high water level of the river.

B. Structures and Improvements (Line 6)
The basic structures include:

1. Reactor Containment Structure
2. Reactor Auxiliary Building
3. Fuel Building
4. Turbine Building
5. Service Building
6. Crib House

C. Other Nuclear Equipment (Line 8)
In order to compare the NSSS bids on an equitable basis, each of the nuclear plans has been reviewed with the goal of insuring that each system will perform on a comparable basis. This requires the addition of certain features to some plans that are provided in another plan and are considered necessary. In addition, features have been added to all plans to insure that this large capacity generating unit will experience as few forced outages as possible. An example of this is the radioactive steam generator blowdown system added to all PWR plans to allow operation with a small leak in a steam generator tube which could normally require a plant shutdown.

D. Total Nuclear Steam Supply System (Line 9)
This total is made up of the vendor's bid price and the equipment added to insure comparability. It should be noted that this price, the cost of the NSSS, amounts to approximately 20% of the total estimated plant cost before top charges.

E. Total Estimated Cost of Power Station Including Main Power Transformer (Line 20)
As can be seen by reviewing Exhibit S-3 this cost, which does not include top charges, overtime labor or escalation, varies from $131 to $160/KW for the nuclear plans and from $119 to $124/KW for the fossil plans, when based on gross generation.

F. Indirect Expenses (Line 21)
Based upon the economic data supplied by the CCD Group, the indirect expenses have been estimated at 19-1/2% for the nuclear plans and 17% for the fossil plans. The primary reason for the 2-1/2% difference is the additional year of construction required for a nuclear plant. An allowance of $1,800,000 has been added to the nuclear plans for licensing expenses, training costs and public relations activities, including a Nuclear Information Center.

G. Allowance for a Work Week of Five 10 Hour Days (Line 23)
Experience has shown that in order to attract sufficient skilled labor, the inducement of overtime work must generally be applied in the current labor market. Experience to date indicates that this overtime work schedule does not shorten the construction period in any significant manner.

H. Escalation of Labor and Materials to 1975 (Line 25)
Escalation has been applied in the amount of 10%/year on labor and 4%/year on materials and equipment. These rates are currently being experienced throughout the utility industry. While these same rates may not continue in the future, they have been used in this evaluation to assess their impact on the total estimated plant construction cost.

The Grand Total cost, shown in line 26 of Exhibit S-2, is considered to be a realistic figure based upon current experience and recognized the escalating trends of both equipment and labor and their influence on projected construction costs.

Exhibit S-3 summarizes the $/kW cost for each nuclear and fossil plan and the effect of changing the bases for calculating this measure of cost.

## V. FUEL COST ANALYSIS

Bids have been received from each reactor vendor to provide fuel services for Unit 6. The bids vary in scope and these variations affect the economics of the fuel cycle.

A. Fuel Supply Mode for Light Water Reactors

1. Fabrication Only
   All vendors offer to receive enriched uranium in the form of uranium hexafloride ($UF_6$) for conversion to uranium dioxide ($UO_2$) and subsequent fabrication into complete and delivered fuel assemblies. This will be referred to as the FAB only option.

2. Uranium plus Fabrication
   All vendors except the B&W Co. offer to provide uranium ore concentrate and provide for its conversion to UF6. B&W does not offer sufficient $U_3O_8$ to allow an equitable comparison, and its bid for this scope is therefore not considered. All vendors except GE will assume responsibility for uranium enrichment. To put the bids on a comparable basis, enrichment at current AEC rates was added to the GE bid.

   This scope of fuel supply will be referred to as the U+FAB option.

B. Fuel Supply Modes for the HTGR
Gulf General Atomic provides for a much more diversified fuel supply selection which is detailed in Table 1.

TABLE 1

SUMMARY OF FUEL OFFERS

HIGH TEMPERATURE GAS-COOLED REACTOR

| | Scope #1 | Scope #2 | Scope #3 | Scope #4 |
|---|---|---|---|---|
| | Fuel Cycle Service | Fuel Fabrication with Buy Back | Fuel Fabrication Service | Fuel Lease Service (Financed by GGA) |
| Acquire thorium | GGA | GGA | GGA | GGA |
| Acquire uranium | GGA | Purchaser | Purchaser | GGA |
| Convert to $UF_6$ | GGA | Purchaser | Purchaser | GGA |
| Enrich uranium | GGA | Purchaser | Purchaser | GGA |
| Fabricate fuel | GGA | GGA | GGA | GGA |
| Ship fresh fuel | GGA | GGA | GGA | GGA |
| Irradiation | Purchaser | Purchaser | Purchaser | GGA |
| Ship irradiated fuel | GGA | GGA | Purchaser | GGA |
| Reprocess fuel | GGA | GGA | Purchaser | GGA |
| Disposition of Uranium | GGA | GGA | Purchaser | GGA |

C. Fuel Financing Options

Each of the vendors'fuel offerings have been analyzed on the basis of either an ownership or lease option in combination with any of the fuel supply modes selected.

D. Fuel Cost Analysis

With the exception of B&W, who does not provide the U+FAB option, each vendor has bid sufficient fuel to provide for from 6 to 8 years of plant operation. Since the evaluation covers a period of 15 years, the vendors' bids have been extended for the 15 year period by maintaining the final fuel fabrication prices constant from the 6 to 8 year limit of their respective bids, to 15 years. This results in the evaluation indicating slightly higher fuel costs during the last half of the evaluation than would be anticipated. Decreases in fuel fabrication costs are expected to continue and have been accounted for in the sensitivity studies. The results of the fuel analysis are shown in Table 2.

E. Nuclear Fuel Inventory

The nuclear fuel cycle, which begins with the ore procurement and ends with the reprocessing, and reconversion of the depleted fuel, lasts approximately 5 to 7 years. During this period, and on a continuing basis, approximately $25 million is required to maintain the fuel inventory for a single 800-1000 MWe nuclear plant.

F. Coal Prices

Coal price data has been furnished by the CCD Group and escalated at 1% per year compounded after the third year as specified by CCD. The resultant coal price levelized over the 15 year evaluation period is 25¢/MBTU.

TABLE 2

COMPARISON OF NUCLEAR FUEL CYCLE COST

15 YEAR CASE PERIOD

| | | FABRICATION ONLY | | U + FABRICATION | |
|---|---|---|---|---|---|
| | | OWNERSHIP | LEASE | OWNERSHIP | LEASE |
| IN-CORE FIXED CHARGE RATE | | 17.54% | 9.89% | 17.54% | 9.89% |
| BABCOCK & WILCOX COMPANY | | | | | |
| 2650 MWt | mills/kWh | 1.755 | 1.561 | - | - |
| | ¢ /MBTU | 17.87 | 15.892 | - | - |
| 3700 MWt | mills/kWh | 1.672 | 1.491 | - | - |
| | ¢ /MBTU | 16.995 | 15.155 | - | - |
| COMBUSTION ENGINEERING | | | | | |
| 2960 MWt | mills/kWh | 1.657 | 1.525 | 1.699 | 1.602 |
| | ¢ /MBTU | 16.697 | 15.363 | 17.122 | 16.137 |
| 3800 MWt | mills/kWh | 1.584 | 1.421 | 1.656 | 1.493 |
| | ¢ /MBTU | 16.151 | 14.481 | 16.881 | 15.219 |
| GENERAL ELECTRIC | | | | | |
| 2436 MWt | mills/kWh | 1.632 | 1.415 | 1.743 | 1.535 |
| | ¢ /MBTU | 16.669 | 14.446 | 17.798 | 15.677 |
| 2853 MWt | mills/kWh | 1.641 | 1.422 | 1.688 | 1.474 |
| | ¢ /MBTU | 16.57 | 14.359 | 17.044 | 14.885 |
| 3293 MWt | mills/kWh | 1.655 | 1.432 | 1.766 | 1.553 |
| | ¢ /MBTU | 16.829 | 14.562 | 17.957 | 15.793 |
| WESTINGHOUSE ELECTRIC | | | | | |
| 2660 MWt | mills/kWh | 1.727 | 1.534 | 1.697 | 1.512 |
| | ¢ /MBTU | 17.072 | 15.169 | 16.779 | 14.949 |
| 3040 MWt | mills/kWh | 1.704 | 1.507 | 1.679 | 1.489 |
| | ¢ /MBTU | 17.271 | 15.274 | 17.02 | 15.093 |
| 3423 MWt | mills/kWh | 1.685 | 1.502 | 1.656 | 1.480 |
| | ¢ /MBTU | 16.729 | 14.916 | 16.441 | 14.699 |

## VI. ECONOMIC ANALYSIS

In order to accomplish the objectives of this report, the unit cost of producing energy levelized on a 15 year period is used as the criteria of economic choice. The development of this unit energy cost, in mills/kWh, is graphically outlined in Exhibit S-4.

The operating schedule used in the analysis is the same for both fossil and nuclear plants and is tabulated in Table 3. This is the schedule which forms the basis of the nuclear fuel designs and warranties, and results in an average annual capacity factor of 76.7%.

TABLE 3

AVERAGE UNIT LOADING, HOURS PER YEAR

| | 90-100% load | 80-89% load | 70-79% load | 50-69% load | 1-49% load | 0 load |
|---|---|---|---|---|---|---|
| 1st 5-year period (80% c.f.) | 6000 | 800 | 500 | 360 | 150 | 950 |
| 2nd 5-year period (77.5% c.f.) | 5500 | 800 | 700 | 460 | 300 | 1000 |
| 3rd 5-year period (72.5% c.f.) | 4500 | 900 | 900 | 910 | 350 | 1200 |

The fixed charge rate, based on economic data furnished by the CCD Group and levelized over the 15 year evaluation period, is applied to the capital costs developed for each plan to provide an annual fixed charge. This is added to an annual nuclear fuel cost, calculated by the CINCAS computer program, or an annual fossil fuel cost calculated by the SCOPE computer program. The operating schedule was applied by CCD. An annual operating, maintenance and supply expense is combined with the nuclear insurance requirements to complete the annual generating costs. The SCOPE computer program applies appropriate present worth arithmetic to compute a levelized generating cost in mills/kWh for each plan.

These levelized generating costs in mills/kWh based upon the various modes of fuel supply are shown in Table 4.

## VII. COMMENTS ON LEASED FUEL

The generating costs indicated in Table 4 for the leased fuel supply mode should not be considered as the actual costs that would be incurred should a leasing contract be executed. They are provided merely as an indication of the relative savings resulting from a decrease in the inventory carrying charge rates from those applicable to fuel ownership. The details of a leasing contract have not been finalized. A more accurate appraisal of the fuel revenue requirements would necessitate consideration of such factors as the length of the fuel lease, the ownership of the fuel residuals, timing of lease payments, and the financial effects a lease might have on the credit rating of the CCD Group. Legal, regulatory, tax and accounting implications of leasing should all be carefully reviewed prior to entering into a lease agreement for which there is presently no commercial precedent.

TABLE 4

COST OF PRODUCING ENERGY

LEVELIZED OVER THE PERIOD 1975-1990

(mills/kWh) (1)

| Plan No. | FAB ONLY (2) Ownership (3) | U+FAB (2) Ownership | FAB ONLY Lease (3) | U+FAB Lease |
|---|---|---|---|---|
| 1 | 8.14 | n.a. | 7.92 | n.a. |
| 2 | 7.21 | n.a. | 7.05 | n.a. |
| 3 | 7.83 | 7.88 | 7.63 | 7.70 |
| 4 | 7.03 | 7.10 | 6.82 | 6.89 |
| 5 | 7.74 | 7.85 | 7.49 | 7.61 |
| 6 | 7.41 | 7.46 | 7.18 | 7.22 |
| 7 | 6.96 | 7.08 | 6.72 | 6.84 |
| 8 | ---- | ---- | ---- | ---- |
| 9 | 8.23 | 8.20 | 8.01 | 7.99 |
| 10 | 7.84 | 7.82 | 7.61 | 7.60 |
| 11 | 7.52 | 7.50 | 7.32 | 7.30 |
| Coal Price 25¢/MBTU (levelized) | | | | |
| 12 | 7.35 (5% overpressure) | | 7.47 (no overpressure) | |
| 13 | 7.20 (5% overpressure) | | 7.32 (no overpressure) | |

Note: (1) Bond on Construction Cost escalated to 1975.

(2) Fab Only - Owner procures ore concentrate, arranges conversion and enrichment, provides enriched $UF_6$ to fabricator

U+FAB - Vendor provides ore concentrate, conversion, enriching & fabrication

(3) Ownership- CCD owns the fuel
Lease - fuel is leased from third party lessor

## VIII. QUALITATIVE AND SUBJECTIVE CONSIDERATIONS

A. Load Follow Capability

Although CCD Unit 6 is specified to be a base-load unit, it must be recognized that in the future, as newer and more economical units are added to the system, its ability to follow load will become increasingly important. Of the light water reactors, the BWR system, with its ability to change load as much as 35% by changing the recirculation flow without repositioning control rods, is more responsive and offers fewer operational intricacies than do the PWR systems. Changing load on a PWR requires rod movement followed by an adjustment of the boron concentration in the reactor coolant water. This latter change is accomplished by a "feed and bleed" process which becomes more time consuming with the age of the reactor core and increases the operating costs of the unit.

B. Xenon Override

Xenon is a "poison" (neutron absorber) produced by the decay of fission products. Its steady state concentration at any time is directly related to the power level. Within a large reactor core that is subject to frequent load changes, the xenon concentration will vary spatially, tending to set up xenon concentration oscillations and, therefore, power oscillations throughout the core. The BWR system with its large negative coefficient of reactivity tends to dampen out these oscillations much more rapidly than does the PWR system, thereby providing a more uniform power distribution.

As the reactor core "ages" and the concentration of U-235 diminishes, the xenon becomes a more significant factor. In fact, the inability of the core to overcome the negative influence of xenon, even with all the control rods withdrawn (and all boron removed from the PWR reactor coolant water) is defined as the "end of core life". The BWR core is presently designed to provide an additional margin of core reactivity specifically for this problem.

C. Operation With A Major Component Out Of Service

The major components considered in this analysis are the recirculation pumps and steam generators.

1. Reactor Circulating Pumps

The PWR plans incorporate one steam generator and one (or two) reactor coolant pumps per loop. In the CE and B&W plants, two half capacity pumps are provided in each loop thereby providing a capability for continued operation of a loop at reduced power upon the loss of one pump. The Westinghouse PWR has one pump per loop, which if lost reduces that loop's power output to zero. Loss of one of the two BWR recirculation pumps causes a reduction in power of approximately 40%.

All PWR plants can operate with one loop out of service because of pump failure(s) but none, even the four loop design, is recommended for continued operation with more than one loop out of service. The BWR design will provide 20% power on natural circulation with no recirculation pump operating. This is significant for "black start-up" considerations.

The HTGR, with six helium circulators serving the reactor circulating pump function, may provide flexibility for continual operation with inoperative equipment. However, a minimum of four helium circulators must be available for emergency cooling.

2. Steam Generator

The BWR design eliminates the steam generator. The PWR plans all have a single unit, of the U-tube or once-through design, per loop.

While the possibility of failure of a steam generator tube is small and the current experience has been good, the probability of a tube or tube-to-tube sheet leak, admitting primary water into the secondary cycle, is greater than zero. A leak will permit boronated water, and some radioactive contamination, into the steam generator feed water raising the dissolved solids content, primarily because of boron. This can result in carry-over, but also may dramatically alter the chemistry of the feedwater within the steam generator. If in addition, there exists a fuel element cladding failure, radioactive gases will appear in the steam and eventually be discharged to the atmosphere through the air ejector discharge. A 1% fuel failure rate combined with a 1 gpm steam generator tube leak will quickly result in unacceptable feedwater quality. A high capacity steam generator blow-down system, with an estimated cost of $375,000, that will allow continued operation under this condition, with a continuous 100-125 gpm blow-down, has been included in the PWR balance of plant construction cost estimates. If either the fuel failure rate or the leak rate exceed 1% or 1 gpm respectively, the off-gas limits may be exceeded at the air ejector exhaust and the loop must be shut down.

The BWR avoids this problem by design as it must accommodate the continuous release of radioactive gases within the AEC regulations.

The HTGR with six steam generators, may provide flexibility for isolating defective components and continuous operation.

D. Radioactive Waste Generation

The light water reactors each generate some quantity of liquid and gaseous wastes. The PWR must process greater quantities of liquid waste than the BWR to maintain the tritium activity within acceptable limits for plant maintenance.

During normal operation the HTGR generates no liquid wastes, and since liquid wastes are the most difficult to process and require the most involved processing equipment, this is a significant advantage for the HTGR.

E. Core Monitoring

As reactor cores become larger the "coupling", or interaction between segments of the core, diminishes. A single large core acts more like many independent smaller cores. While this is an over-simplification, the fact remains that with "loosely coupled" cores it is difficult for an out-of-core neutron detector to provide as reliable information on core dynamics as in-core monitors. The PWR system designs all rely on out-of-core detectors for reactor control and safety and provide varying degrees of coverage by in-core detectors for operating information. The GE BWR relies solely on in-core information from an elaborate system of monitors.

This tends to provide for more precise reactor control and should result in more efficient use of the fuel.

F. Component Experience

Both GE and Westinghouse have reactors operating with the components proposed for the CCD unit. Both are preeminent in the commercial nuclear power field and each has had commercial size power reactors in utility system operation for eight years. While the other bidders are each considered fully qualified, they do not, as yet, have the demonstrated abilities of General Electric and Westinghouse.

G. Auxiliary Systems

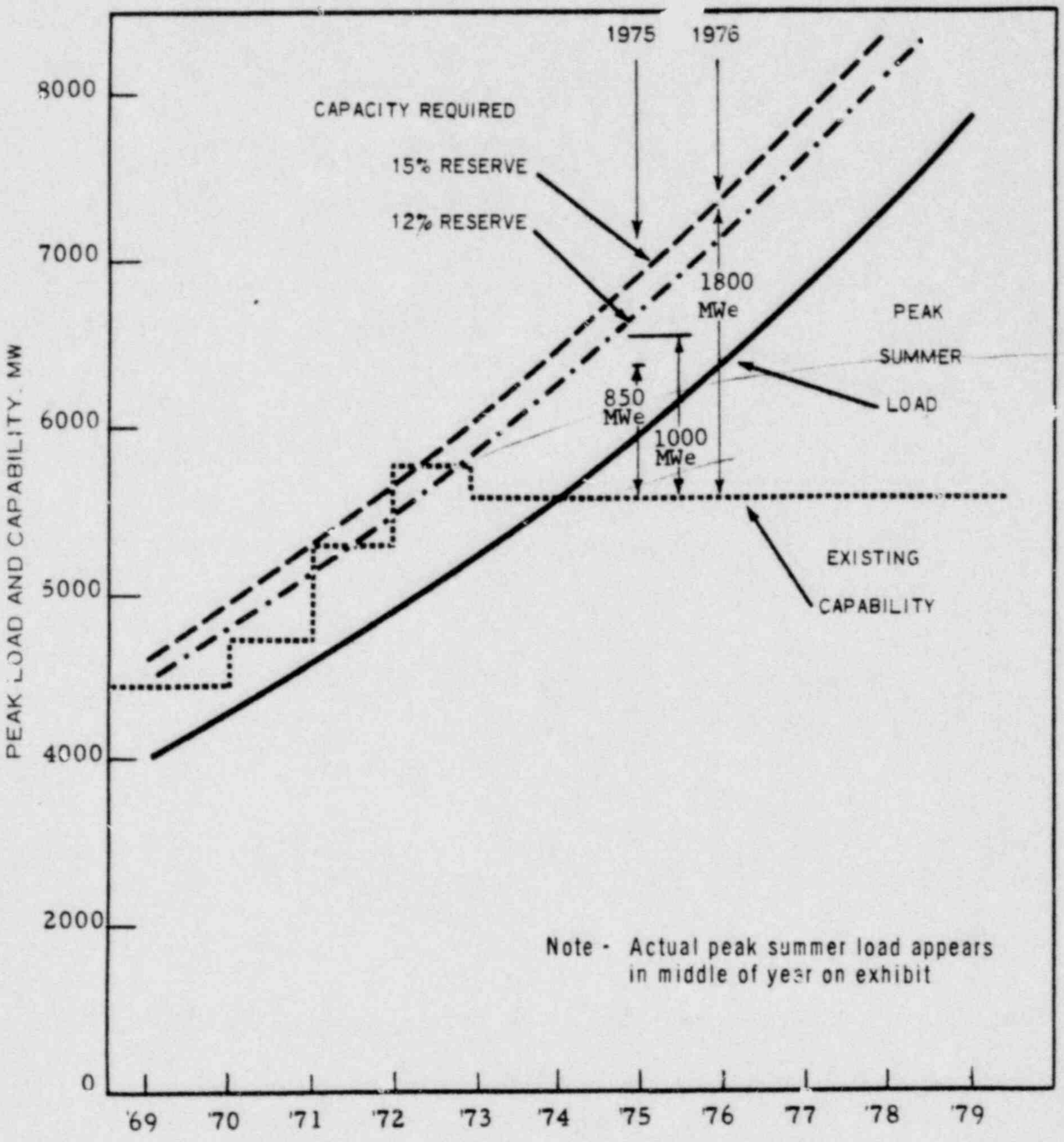
The HTGR design with all primary components housed within the pre-stressed concrete reactor vessel (PCRV) simplifies the reactor auxiliary systems.

However, the turbine plant auxiliaries must be specially designed to support the reactor systems. Of the light water reactor systems, the BWR with a single water cycle for primary and secondary water, has the fewer reactor auxiliary requirements.

H. Maintenance

Maintenance of the PWR and HTGR turbine plant equipment is similar to that of any conventional power plant since the steam cycle of these concepts (PWR and HTGR) employs non-radioactive steam. The BWR plant with the single water cycle results in radioactive steam and therefore radioactive contamination of the turbine plant. In addition to the problem of removing the shielding from turbine plant equipment in order to perform maintenance, some form of protective clothing may be required for maintenance personnel during certain operations depending on the operating history of the unit.

EXHIBIT S-1
SL-2561
SUMMARY




**PROJECTED LOADS AND CAPABILITY REQUIREMENTS**

SARGENT & LUNDY
ENGINEERS
CHICAGO

CCD - UNIT 6
SUMMARY
CONSTRUCTION COSTS

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Plan No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 2. | Designation | B2650 | B3700 | C2960 | C3800 | G2439 | G2856 | G3928 | A2537 | W2660 | W3040 | W3423 | F955 | F1167 |
| 3. | NSSS Vendor | B & W | B & W | CE Co. | CE Co. | GE Co. | GE Co. | GE Co. | GGA | WE Corp. | WE Corp. | WE Corp. | Fossil | Fuel |
| 4. | Barging Facilities | $ 1,500,000 | $ 1,500,000 | $ 1,500,000 | $ 1,500,000 | $ 1,500,000 | $ 1,500,000 | $ 1,500,000 | $ 1,500,000 | $ 1,500,000 | $ 1,500,000 | $ 1,500,000 | $ 1,500,000 | $ 1,500,000 |
| 5. | Site Improvements | 4,134,000 | 4,134,000 | 4,134,000 | 4,134,000 | 4,134,000 | 4,134,000 | 4,134,000 | 4,134,000 | 4,134,000 | 4,134,000 | 4,134,000 | 5,506,000 | 5,506,000 |
| 6. | Total Structures & Improvements | 40,109,000 | 43,136,000 | [illegible] | 45,261,000 | 31,895,000 | 35,183,000 | 37,705,000 | 27,259,000 | 42,391,000 | 44,321,000 | 44,916,000 | 26,835,000 | 30,281,000 |
| 7. | Vendor NSSS Base Bid | 31,195,000 | 42,125,000 | 37,300,000 | 46,600,000 | 28,950,000 | 32,450,000 | 33,850,000 | | 29,100,000 | 34,500,000 | 34,500,000 | --- | --- |
| 8. | Other Nuclear Equipment | 4,215,000 | 4,215,000 | 4,780,000 | 4,380,000 | 2,433,000 | 2,433,000 | 2,433,000 | | 5,355,000 | 5,355,000 | 5,355,000 | --- | --- |
| 9. | Total Nuclear Steam System | 35,410,000 | 46,340,000 | 42,080,000 | 50,980,000 | 31,383,000 | 34,883,000 | 36,283,000 | | 34,455,000 | 39,855,000 | 39,855,000 | --- | --- |
| 10. | Mechanical Equipment | 38,505,000 | 52,850,000 | 42,407,000 | 53,800,000 | 34,100,000 | 39,092,000 | 46,550,000 | 31,983,000 | 35,830,000 | 43,033,000 | 49,250,000 | --- | --- |
| 11. | Total Boiler Plant - Plans 12 & 13 | | | | | | | | | | | | 59,566,000 | 71,018,000 |
| 12. | Total Turbine Plant - Plans 12 & 13 | | | | | | | | | | | | 19,305,000 | 23,311,000 |
| 13. | Misc. Power Plant Equipt. Plans 12 & 13 | | | | | | | | | | | | 1,227,000 | 1,400,000 |
| 14. | Unloading, Erecting & Placing In Operation - Mechanical Equipt. | 3,465,000 | 4,150,000 | 3,616,400 | 4,160,000 | 3,160,000 | 3,416,000 | 3,700,000 | 3,157,000 | 3,360,000 | 3,665,900 | 3,980,000 | --- | --- |
| 15. | Unloading, Erecting & Placing In Operation - NSSS | 5,350,000 | 5,750,000 | 5,350,000 | 5,750,000 | 4,950,000 | 5,055,000 | 5,160,000 | | 5,525,000 | 5,725,000 | 5,725,000 | --- | --- |
| 16. | Total Piping Incl. Circ. W. | 13,850,000 | 16,550,000 | 15,025,000 | 17,300,000 | 12,100,000 | 13,100,000 | 14,200,000 | 20,925,000 | 14,200,000 | 15,475,000 | 16,780,000 | --- | --- |
| 17. | Insulation of Pipe & Equipt. | 1,525,000 | 1,770,000 | 1,575,000 | 1,770,000 | 1,410,000 | 1,500,000 | 1,600,000 | 1,500,000 | 1,490,000 | 1,600,000 | 1,711,000 | --- | --- |
| 18. | Electrical | 9,855,000 | 10,500,000 | 9,955,000 | 10,550,000 | 9,400,000 | 9,664,000 | 9,950,000 | 9,446,000 | 9,890,000 | 10,204,000 | 10,510,000 | 9,234,000 | 10,937,000 |
| 19. | Heating System | [illegible] | 600,000 | 550,000 | 600,000 | 500,000 | 550,000 | 600,000 | 550,000 | 500,000 | 550,000 | 600,000 | --- | --- |
| 20. | Total Estimated Cost of Power Station incl. Main Power Tfr. | [illegible],119,000* | 181,646,000* | 165,554,400* | 190,171,000* | 130,898,000 | 143,950,600 | 155,748,000 | | 149,141,000* | 165,929,400* | 174,827,000 * | 117,667,000 | 138,447,000 |
| 21. | Indirect Expenses | 31,073,000 | 37,221,000 | 34,083,600 | 38,883,000 | 27,325,000 | 29,870,400 | 32,171,000 | | 30,882,000 | 34,156,600 | 35,891,000 | 19,900,000 | 23,536,000 |
| 22. | Total Estimated Cost - 1968 Prices & 40 Hr. Week | 181,192,000 | 218,867,000 | 199,638,000 | 229,054,000 | 158,223,000 | 173,821,000 | 187,919,000 | | 180,023,000 | 200,086,000 | 210,718,000 | 137,567,000 | 161,983,000 |
| 23. | Allowance For Work Week of 5 - 10 Hr. Days | 7,125,000 | 8,628,000 | 7,880,000 | 9,033,000 | 6,218,000 | 6,835,000 | 7,398,000 | | 7,084,000 | 7,880,000 | 8,304,000 | 7,500,000 | 8,861,000 |
| 24. | Total Estimated Cost - 1968 Prices & Overtime | 188,317,000 | 227,495,000 | 207,518,000 | 238,087,000 | 164,441,000 | 180,656,000 | 195,317,000 | | 187,107,000 | 207,966,000 | 219,022,000 | 145,067,000 | 170,844,000 |
| 25. | Escalation of Labor And Materials | 35,027,000 | 42,314,000 | 34,200,000 | 39,300,000 | 30,668,000 | 33,692,000 | 36,427,000 | | 34,802,000 | 38,682,000 | 40,738,000 | 30,200,000 | 35,536,000 |
| 26. | Grand Total Estimated Cost | $223,344,000 | $269,809,000 | $241,718,000 | $277,387,000 | $195,109,000 | $214,348,000 | $231,744,000 | | $221,909,000 | $246,648,000 | $259,760,000 | $175,267,000 | $206,380,000 |
| 27. | Expected Net Gen., KW | 915,800 | 1,275,500 | 1,018,000 | 1,322,000 | 846,600 | 980,200 | 1,140,700 | 1,046,000 | 892,800 | 1,046,400 | 1,156,800 | 908,200 | 1,109,800 |
| 28. | $/KW, Net (26 ÷ 27), $/KW | 243.88 | 211.53 | 237.44 | 209.82 | 230.46 | 218.68 | 203.16 | | 248.55 | 235.71 | 224.55 | 192.98 | 185.96 |
| 29. | Cost Over Nuclear Base, $ | + 28,235,000 | + 74,700,000 | + 46,609,000 | + 82,278,000 | BASE | +19,239,000 | + 36,639,000 | | + 26,800,000 | + 51,539,000 | + 64,651,000 | ---- | --- |
| 30. | Cost Percent Over Nuclear Base | + 14.5% | + 38.2% | + 23.9% | + 42.2% | BASE | + 10.0% | + 18.6% | | + 13.8% | + 26.5% | 33.0% | --- | --- |
| 31. | Cost Over Plan 12, Base, $ | + 48,077,000 | + 94,542,000 | + 66,451,000 | +102,120,000 | + 19,842,000 | + 39,081,000 | + 56,477,000 | | + 46,742,000 | + 71,381,000 | + 84,493,000 | BASE | + 31,113,000 |
| 32. | Cost Percent Over Plan 12 Base | + 27.3% | + 53.8% | + 37.9% | + 58.4% | + 11.2% | + 22.3% | + 32.0% | | + 26.5% | + 40.8% | + 48% | BASE | + 17.9% |

* NOTE: This total includes $3,100,000 in additional building space and equipment intended for Unit #7; and $1,675,000 for loop isolation valves.

POOR ORIGINAL

EXHIBIT S-2
SL-2561
SUMMARY

SARGENT & LUNDY
ENGINEERS
CHICAGO

EXHIBIT S-3
SL-2561
SUMMARY

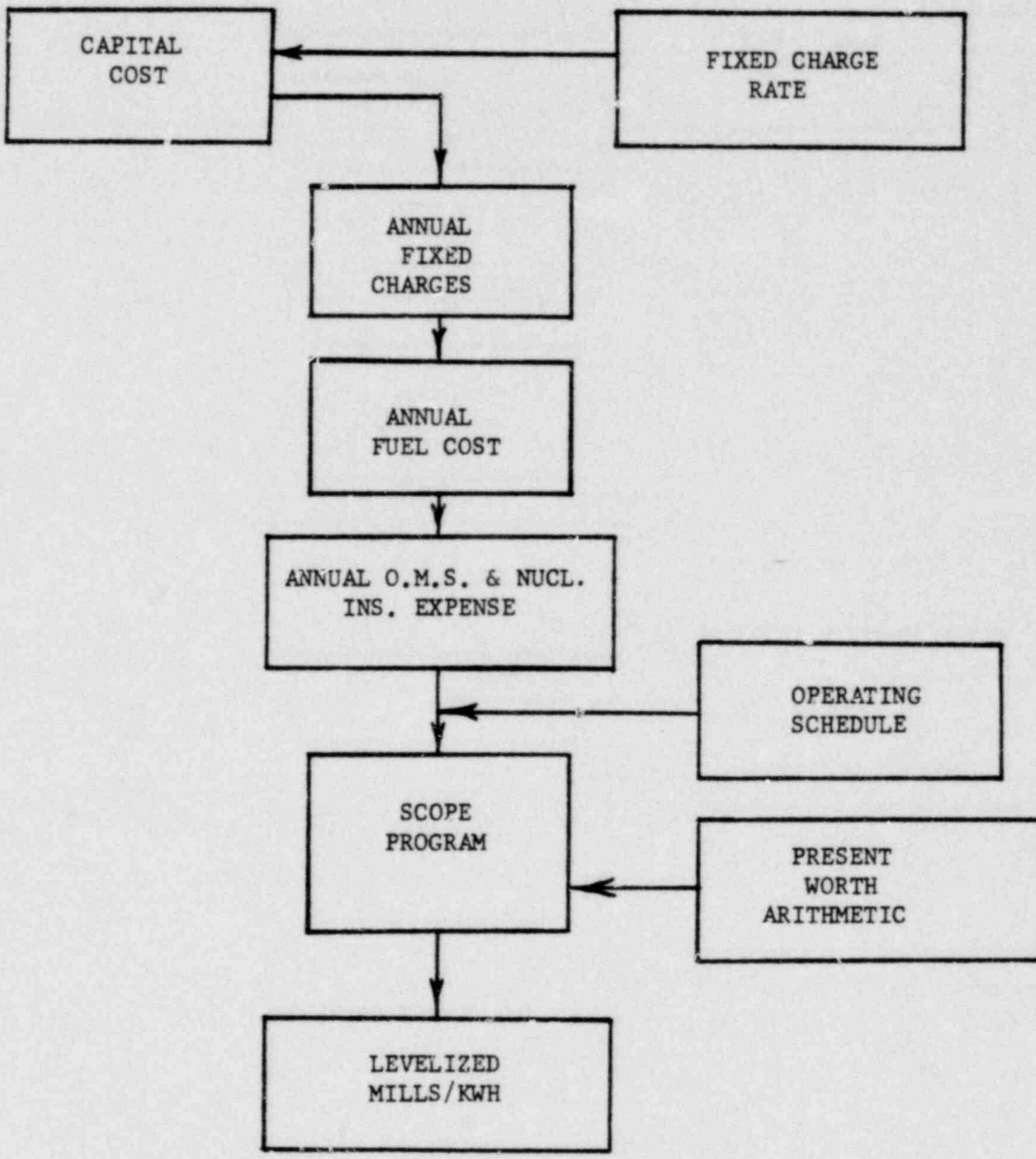
## COST PER KW FOR CONSTRUCTION BASED ON EXPECTED NET GENERATION AND ON GROSS GENERATION AT VWO & 1.5" Hg

| | Plan | Not Incl. Indirect Cost 1968 Prices 40 Hr. Wk. | | Incl. Indirect Costs 1968 Prices 40 Hr. Wk. | | Incl. Indirect Costs 1968 Prices 50 Hr. Wk. | | Incl. Indirect Costs 1975 Prices 50 Hr. Wk. | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| 1 | B2650 | 164 | 158 | 198 | 190 | 206 | 197 | 244 | 234 |
| 2 | B3700 | 143 | 138 | 172 | 165 | 179 | 172 | 212 | 204 |
| 3 | C2960 | 160 | 157 | 193 | 189 | 199 | 196 | 237 | 233 |
| 4 | C3900 | 144 | 141 | 173 | 170 | 180 | 177 | 210 | 206 |
| 5 | G2439 | 155 | 149 | 187 | 179 | 194 | 186 | 230 | 221 |
| 6 | G2856 | 147 | 141 | 177 | 170 | 184 | 177 | 219 | 211 |
| 7 | G3298 | 136 | 131 | 165 | 159 | 171 | 164 | 203 | 195 |
| 8 | A2537 | NOT AVAILABLE | | | | | | | |
| 9 | W2660 | 167 | 160 | 202 | 194 | 210 | 202 | 249 | 239 |
| 10 | W3040 | 159 | 153 | 192 | 184 | 199 | 191 | 236 | 226 |
| 11 | W3423 | 152 | 146 | 183 | 176 | 190 | 183 | 225 | 216 |
| 12 | F955 | 130 | 124 | 151 | 143 | 160 | 152 | 193 | 183 |
| 13 | F1167 | 125 | 119 | 146 | 139 | 154 | 146 | 186 | 177 |

1. $/KW net

2. $/KW gross

## DEVELOPMENT OF UNIT ENERGY COST



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February 17, 1969

Subject:
CCD Unit 6
The Cincinnati Gas & Electric Company

SL-2561

Mr. A. E. Rothenberg, Chief Engineer
and Manager
General Engineering Department
The Cincinnati Gas & Electric Company
P.O. Box 960
Cincinnati, Ohio 45201

Dear Mr. Rothenberg:

We are attaching for your review ten (10) copies of Volume I - SL-2561 - Summary CCD Unit 6 - Economic Evaluation of Alternatives, and twenty (20) copies of Volume II - SL-2561 - CCD Unit 6 - Economic Evaluation of Alternatives, dated February 17, 1969. These documents present the results of the evaluation which we have made of the technical and economic facets of the expansion of the CCD system by the installation of either nuclear or fossil units at the Moscow site of The Cincinnati Gas & Electric Company.

As discussed in detail during our presentation in Cincinnati on February 6, there are several relevant conclusions to be drawn from the evaluations:

> The best nuclear offerings appear to be those of the General Electric Company.
>
> In the 800 to 900 MWe size range the fossil unit may be somewhat more economical than the nuclear unit depending on the mode of nuclear fuel procurement.

In the 900 to 1,000 MWe range the nuclear unit is comparable from an economic standpoint to that of the fossil unit.

In the 1,000 to 1,200 MWe range the nuclear unit is clearly the economic choice.

When assessing the intangible factors we believe that there are several advantages to the utilization of nuclear units that may outweigh the indicated economic differences in the smaller size unit. Factors such as the influence of potential regulatory requirements for air pollution control would tend to reduce if not completely offset the indicated cost differences in the smaller size.

Coupled with these economic factors, as well as the system expansion and reserve requirements, are other subjective considerations which we feel indicate that the installation of a nuclear unit in the 900 to 1,000 MWe range would be appropriate on your system. Included are factors such as the ability of the nuclear unit to take advantage of future advances in nuclear fuel element design and operating limits, differences in obsolescence rates between nuclear and fossil design, etc. It is on the basis of these economic and subjective considerations, in addition to the other factors discussed in the report, that we recommend that you proceed with your expansion plans by utilizing the General Electric 2856 MWt offering. This offering would meet the indicated system needs of a 900 to 1,000 MWe unit for a commercial service date of January, 1975.

The decision on the mode of fuel supply must be considered in detail by the CCD companies. We again wish to note that the low revenue requirements associated with the leasing of nuclear fuel may be offset by the legal, regulatory, financial and tax implications associated with this method of fuel financing relative to that of your ownership. The system load growth should be evaluated in detail prior to exercising the quoted option for the second unit.

We believe that our conclusions and recommendations are based on a conservative engineering approach with any bias being directed in favor of the fossil units. As you are aware, several of the reactor manufacturers have contacted The Cincinnati Gas & Electric Company with modifications to their proposal offerings. These modifications include design changes in the product line which can affect the balance of plant construction cost, modifications to the scope of fuel supply and possible price changes in both the nuclear steam supply offering and the nuclear fuel offerings. It is noted that the effects of these changes have not been incorporated in the reports as agreed. We are, however, continuing to assess their effect on the various offerings from the vendors on the overall evaluation. A ready examination of the marketing conditions for nuclear plants during the past calendar year relative to 1966 and 1967 would further suggest that economic advantages could accrue through detailed negotiations with the apparent low bidder.

As you are aware the proposals from the reactor manufacturers were received in October. Their expiration dates were subsequently extended to January and then to a date of March 3, 1969. If a decision cannot be made prior to March 3 which will permit the initiation of negotiations with the apparent low bidders or the rejection of all bids, it will be necessary to consider in detail the best method of proceeding. In some instances the reactor vendors have suggested that they may wish to withdraw their bids should a decision be postponed beyond March 3. In that event it will be necessary to re-bid the project with due consideration being given to the overall project schedules.

Should any questions arise concerning the methods used in our studies of the results obtained from our evaluation, we will, of course, be most pleased to review them in detail at your convenience.

Yours truly,

SARGENT & LUNDY

BY W R. Steur

WRSteur/gp
Enclosures
cc: C. R. Mede (10 of I, 20 of II)
J. H. Inskeep (10 of I, 20 of II)