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SUMMARY AND EVALUATION OF THE CONCEPTUAL DESIGN STUDY OF A POTENTIAL EARLY COMMERCIAL MHD POWER PLANT (CSPEC)

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Summary

The "Conceptual Design Study of a Potential Early Commercial MHD Power Plant" (CSPEC) was a study to assess an open-cycle MHD/steam power plant using oxygen enriched combustion air preheated to an intermediate temperature in a metallic heat exchanger. Two contractors, the Avco Everett Research Laboratory and the General Electric Company, each did a conceptual design of a plant producing about 1000 MW of electrical power. The Avco plant design had an estimated overall plant efficiency of 43.9 percent, an estimated overnight capital cost of $644/kWe, and an estimated levelized cost of electricity of 43.99 mills/kW-hr. The General Electric design had an estimated overall plant efficiency of 42.7 percent, an estimated overnight capital cost of $907/kWe, and an estimated levelized cost of electricity of 56.47 mills/kW-hr. (Costs are expressed in mid-1978 dollars.) The contractors' cost estimates for major components were about the same, but General Electric had significantly higher cost estimates for Balance-of-Plant material, installation labor, indirect, contingency, and operating and maintenance costs. Avco concluded that its MHD plant design compared favorably in cost of electricity with conventional coal-fired steam plants. General Electric will make such a comparison as part of a follow-on study. Both contractors concluded, on the basis of preliminary analyses, that their plant designs had reasonable part power performance. Both concluded that dual MHD power trains were not cost effective.

NASA studies have investigated the effect of plant size and preheat temperature on the performance of CSPEC-type power plants. The results show that, for a given preheat temperature, a 1000 MWe plant is about three points higher in efficiency than a 200 MWe plant. Preheating to 1600 F gives an efficiency about one and one-half points higher than preheating to 800 F for all plant sizes from 200 to 1000 MWe. For each plant size and preheat temperature there is a combination of oxidizer enrichment level and MHD generator length which gives the highest plant efficiency.

Introduction

The "Conceptual Design Study of a Potential Early Commercial MHD Power Plant" (CSPEC)[1,2] is Task II of a study to assess the potential of "moderate technology" open-cycle MHD/steam power plants. Task I of the study, the "Parametric Study of Potential Early Commercial MHD Power Plants" (PSPEC)[3,4,5] parametrically investigated power-plant configurations with the potential for earlier commercial implementation than more advanced MHD plants such as those studied in ECAS.[6,7] Task I showed that MHD plants using oxygen-enriched combustion air preheated to an intermediate temperature are attractive candidates for an early commercial MHD plant. Such a plant compared favorably in cost and performance with the other two power plant configurations studied in Task I. These had separately-fired high-temperature combustion-air heaters fired with a coal gasifier, but they differed in the technology level assumed for these components. The cost and performance of the higher technology separately-fired plants was comparable to the oxygen-enriched plants. However, the more advanced separately-fired plants require technological development in a number of subsystems which are not needed for the oxygen-enriched plants.

Task II was primarily a conceptual design study of an MHD plant using oxygen-enriched combustion air heated to 1200 F and having a net power output of about 1000 MWe. The goal of the study was to obtain better performance and cost estimates for such a plant than was possible in the more wide-ranging study of Task I. The CSPEC Study was done under contract to NASA Lewis Research Center and was funded by the U. S. Department of Energy under an interagency agreement.

Two contractor teams performed parallel conceptual designs. Avco Everett Research Laboratory, Inc., led a team which included Combustion Engineering, Inc., and Chas. T. Main, Inc., as subcontractors. The General Electric Company Space Sciences Laboratory led the other team which included Bechtel National, Inc., The Babcock and Wilcox Company, Mine Safety Appliances Company, and the General Electric Energy Systems Programs Department (ESPD) as subcontractors.

Each contractor team also did studies in addition to the conceptual design. Both contractors investigated the part-load performance of their power-plant designs in a preliminary fashion. Both looked at the influence on the plant availabilbity of a number of factors, including the use of a dual MHD power train. Avco investigated the sensitivity of the plant performance to a ±100 F change in preheat temperature. Avco also compared the seed reprocessing requirements for 70 percent sulfur removal (the minimum removal required to meet the NSPS emission standards) and for 100 percent sulfur removal. General Electric compared sulfur control using a Formate seed reprocessing system with sulfur control using dry stack-gas scrubbing.

This report briefly describes the main features of each conceptual design. It summarizes and compares the contractors' performance and cost estimates. It points out those areas of the plant designs that contribute the most to the difference in the estimated performance and those areas of the cost estimates that contribute the most to the difference in the estimated overall cost. The report also briefly presents the results of the contractor's additional studies. It also presents the results of work done at NASA Lewis Research Center to investigate the effect of power-plant size and preheat temperature on plant performance.

The CSPEC Power Plants

Table 1 lists important design features and operating conditions of each contractor's power-plant design. The General Electric design described in this report is a preliminary design and differs somewhat from the design that will be described in the contractor's final report. GE is making a few improvements and corrections as part of the Task III study which is described below. However, the cost and performance comparison with the Avco design will remain essentially unchanged.

Avco's plant design includes one large single-stage combustor. General Electric's two-stage combustor consists of eight operating first-stage units (four spare units are also included) feeding a single second-stage unit. Both contractors sought the level of oxygen enrichment that would give the best performance for their plant. The General Electric plant required a slightly higher enrichment. Both contractors placed their MHD generators inside square-bore superconducting magnets. The pressure vessel for the GE MHD generator has a circular cross section; the pressure vessel for the Avco MHD generator has a rectangular cross section. As a consequence Avco requires a considerably smaller magnet warm-bore area for the same MHD generator flow area. Both contractors used 2400 psig/1000 F/1000 F steam bottoming cycles, but they arranged them differently and integrated them with the rest of the plant differently. In the Avco cycle, the steam turbines that drive the generator are in a tandem-compound arrangement. In parallel to these turbines is another turbine, driven by main throttle steam, to run the cycle and air separation plant (ASU) compressors. In the GE bottoming cycle, the steam turbines which drive the generators are in a cross-compound arrangement. Individual low-pressure steam turbines drive the five parallel cycle compressors and the five parallel ASU compressors (one of each type of compressor for each ASU train). Both plant designs have intercooled and aftercooled ASU compressors. In the GE design, the cycle compressors are also intercooled, and part of the heat of intercooling and aftercooling is recovered in the feedwater train. The GE cycle has four regenerative feedwater heaters, the Avco cycle seven. In Avco's design, coal drying is done with nitrogen from the air separation plant after it has been heated by the flue gas. In GE's design the flue gas itself is used to dry the coal. The seed-regeneration systems of both designs are sized to meet the NSPS SOx emission standards.[8] The NSPS standards specify that at least 70 percent of the sulfur in the Montana Rosebud subbituminous coal be removed from the combustion gas stream. Both contractors used the NASA-specified Lotepro design[9] for the air separation plant, but GE substituted compressors of slightly higher efficiency.

Summary and Comparison of Results

Table 2 summarizes the CSPEC performance and cost estimates. Table 3 lists the economic assumptions used to calculate the levelized cost of electricity (COE).[10] Figure 1 compares the results for the conceptual designs of the CSPEC study with each other and with the results of the PSPEC study. The estimated overall plant efficiencies of the CSPEC plants are within the range of efficiencies estimated for similar (type III) plants in the PSPEC study. Both contractors estimated slightly higher COEs for their CSPEC plants than for their similar PSPEC plants. Furthermore, the difference in the COE estimates between the two contractors is about the same in CSPEC as in PSPEC.

Table 4 lists significant power ratios for the two CSPEC plants. These ratios help to identify the reasons for the difference in the efficiency estimates. Ratios 1 and 4 show that the General Electric plant's lower efficiency results mainly because its combustor has a higher heat loss and because its bottoming steam cycle has a lower efficiency. Because of the difference in combustor designs, GE's estimated combustor heat loss is about twice Avco's. General Electric's bottoming-cycle efficiency is lower than Avco's for two main reasons. First, because all the GE plant's compressors are intercooled and feedwater is heated by recovering some of the heat of intercooling and aftercooling, the GE bottoming cycle can incorporate fewer regerative feedwater heaters than the Avco cycle. Second, the multiple, small, compressor-drive turbines used in the GE cycle are lower in efficiency than the single large turbine used to drive the compressors in the Avco cycle.

Table 5 is a summary of the estimated plant capital cost, in mid-1978 dollars per kilowatt of electric power generated. The cost shown is the total estimated "overnight" capital cost which does not include interest and escalation during construction. The estimated costs are listed by cost accounts and by cost categories. Figure 2 is a comparison of the capital cost estimates, in dollars per kilowatt, by cost accounts. The GE estimate is higher for almost every account. However, for most of the accounts, the fraction of each contractor's total cost in that account is about the same. The GE estimate for structures and improvements is appreciably higher, and its estimate for accessory electrical equipment appreciably lower. GE has distributed some of the equipment included by Avco in the latter account among several other accounts.

Figure 3 shows the allocation of the total capital cost among the cost categories. The contractors' estimates for major component cost are nearly the same. However, the estimates for Balance-of-Plant (BOP) material cost, for the installation labor cost, and for the "adders" (indirect cost and contingency cost) are all significantly higher for the GE plant. This is primarily a reflection of the estimating methods used and the plant layouts devised by the respective A&E subcontractors, Chas. T. Main for Avco and Bechtel National for GE. Both A&Es used the same labor rate in determining the installation cost. The "adders" are higher for the GE plant because higher multipliers were used, as is shown in figure 3.

As figure 1 shows, the difference between contractors in the COE estimates is about the same in PSPEC and CSPEC. The reasons for the difference are not entirely the same in PSPEC and CSPEC, however. Figure 4 shows the portions of the CSPEC COE estimate difference attributable to capital, operating and maintenance (O&M), and fuel costs. The relative contributions of these three costs to the COE difference is about the same in CSPEC as in PSPEC, but the source of the capital cost difference has changed. GE's PSPEC capital cost estimate was higher primarily because of a higher major component cost estimate. The MHD topping cycle cost and, in particular, the superconducting magnet cost contributed the most to the higher major component cost.[5] In CSPEC, GE used a much different and lower cost magnet design based on GE ESPD's design for the CDIF magnet. The GE CSPEC magnet is also significantly shorter than the GE PSPEC magnet because GE was able to use a much shorter generator for the CSPEC plant. Avco's and GE's magnet cost estimates are now in substantial agreement. As a result, their capital cost estimates for the MHD topping cycle and for the major components are about the same. The capital cost estimate differences are now in the more conventional areas of the plant designs.

The O&M estimate difference is about the same as it was in PSPEC. The primary reason for the O&M cost difference is a higher estimate by GE for replacement material costs.

Additional Contractor Studies

Both contractors looked at the part-load performance of their plant designs in a preliminary way. Avco did an analysis at an MHD generator mass flow 75 percent of the design value. Avco examined the details internal to the heat- and seed-recovery system (HRSR) as part of the analysis, but did not attempt to design the HRSR to achieve the best possible part-load performance. GE did a less detailed analysis over a mass flow range 25 to 100 percent of the design value. GE did not examine the details internal to the HRSR. Both contractors kept the oxygen-enrichment level fixed at the full-load value. Avco found that the reheat steam temperature and oxidizer preheat temperature could not be maintained at 75 percent load (they were 955 F and 1070 F, respectively). GE assumed that these temperatures remained unchanged over the entire part-load operating range. This assumption is almost certainly unrealistic and gives part-load efficiencies that are too high. GE found that the overall plant efficiency remained above 40 percent down to a mass flow 35 percent of full load. Table 6 compares the contractors' results for 75 percent mass flow.

Both contractors looked at the influence of various factors on the power plant availability. They both concluded that a dual power train would not increase the plant availability sufficiently to justify the additional cost of a second combustor-generator-magnet-diffuser train. GE concluded on the basis of an estimated availability of the first-stage combustor that a spare set of four modules was beneficial. Avco concluded that for mean-times-between-failures of the MHD generator of 5000 hours or more, the mean-time-to-replace the MHD generator becomes a dominating influence on the plant availability. For this reason, Avco concluded that a spare MHD generator is cost effective.

Avco found that oxidizer preheat temperatures between 1100 F and 1300 F had very little effect on the overall plant efficiency (43.6 to 44.1 percent). Avco also investigated the possibility of 100 percent sulfur removal to reduce gas-flow-path corrosion problems. Complete sulfur removal gave a one-quarter point reduction in plant efficiency and a 40 percent increase in seed reprocessing plant size. From this Avco concluded that it was reasonable to consider including 100 percent sulfur removal in the plant design. General Electric looked at the possibility of replacing the Formate seed reprocessing system with dry flue-gas scrubbing of SOx. GE found the cost of dry scrubbing to be only very slightly higher and concluded that deciding which sulfur-control system to use will depend on other factors (operational considerations, waste products generated, developmental problems, etc.).

The relationships between the power-plant size and performance and between power-plant size and cost are important aspects to the commercialization of MHD. It is important to know how these relationships compare to those for other advanced power plants and for conventional coal-fired steam power plants. An additional task, Task III, of the early commercial MHD plant studies is addressing some of these questions. Avco and C. T. Main have already provided, in Tasks I and II, data for the capital cost and COE of conventional coal-fired steam power plants over a range of plant sizes. Figure 5 shows this COE data for the 400 to 1000 MWe range. The figure also shows the levelized COE of the Avco CSPEC MHD plant and data for coal-fired steam plants from EPRI. The estimated COE of the Avco MHD plant compares favorably with the COE data for the conventional steam plants. In Task III, Avco will provide COE estimates for MHD plants down to a size of 200 MWe. GE and Bechtel will also provide estimates for the variation of COE with plant size for both MHD and conventional coal-fired steam plants. These estimates should provide a better comparison of the GE CSPEC MHD plant with conventional steam plants.

Additional NASA Studies

Work done at NASA Lewis Research Center investigated the dependence of plant efficiency on plant power output and oxidizer preheat temperature for MHD plants of the type studied in CSPEC. Plants with power outputs of 200, 500, and 1000 MWe and preheat temperatures of 800, 1100, and 1600 F were analyzed. The power outputs range from the 200 MWe output of the proposed Engineering Test Facility (ETF)[11] through the outputs likely to be considered for base load power plants. The range of preheat temperatures was viewed as the range for practical design of metallic and ceramic oxidizer heaters for CSPEC-type power plants.

In CSPEC, the contractors assumed that the oxidizer was preheated to between 1100 and 1300 F in metallic heat exchangers which operate in the slag- and seed-laden environment of the MHD combustion gases. For reasons of cost and reliability, a metallic heater may have to be designed for a considerably lower preheat temperature. The 800 F preheat temperature was chosen as representative of such a lower temperature. The 1600 F preheat temperature was chosen to investigate the gains in performance that are possible if a ceramic regenerative oxidizer heater operating with MHD combustion gases below the seed-melting (and, therefore, slag-melting) temperature can be used in the power plant. Burns & Roe, Inc., under contract to NASA Lewis Research Center, is doing a design study for such heaters.[12] The procedure used for the performance analysis was the same as that used in a number of previous papers.[13,14,15,16] Except for the preheat temperature, the MHD-generator, topping- cycle, and bottoming-cycle operating points and conditions are identical to those in reference 16. All the cases shown use low-pressure and -temperature boiler-feedwater cooling of the MHD generator and are thus comparable to the CSPEC plants.

Figure 6 shows the plant thermodynamic efficiency (the gross AC power generated divided by the higher heating value of the coal fed to the MHD combustor) as a function of oxidizer oxygen content for preheat temperatures of 800, 1100, and 1600 F, plant sizes of 200, 500, and 1000 MWe, and MHD-generator lengths of 10, 15, and 20 meters. The curves in figure 6 show that for each preheat temperature there is a combination of enrichment level and generator length that gives the highest plant efficiency. The generator length which gives the highest efficiency increases with increasing power-plant size. The oxygen-enrichment level which gives the highest efficiency decreases with increasing plant size and with increasing preheat temperature. For an 800 F preheat temperature the oxygen-enrichment level at maximum plant efficiency is about 35 mole percent oxygen at all plant sizes. For 1100 F it is about 32 percent and for 1600 F it is about 27 percent.

Figure 7 shows the maximum plant efficiency as a function of the plant power output for the three different generator lengths considered. This figure shows the generator length that gives the best performance for each plant size. It also shows that the change in plant efficiency with preheat temperature is about the same for all plant sizes. Preheating to 1600 F offers an efficiency improvement of about a point over preheating to 1100 F. Preheating to 800 F gives an efficiency about one-half point lower than preheating to 1100 F.

Conclusions

The performance and cost estimates for the CSPEC conceptual designs are about the same as those for the same contractor's similar PSPEC plants. Avco's efficiency estimate is slightly higher than GE's, as it was for PSPEC. There is still a substantial difference between contractors in the COE estimates. In both PSPEC and CSPEC, about two-thirds of the COE difference is attributable to the capital cost estimates, the remainder to the O&M cost estimates. GE's capital cost estimate is higher for a different reason in CSPEC. In PSPEC, GE's major equipment cost estimate was substantially higher than Avco's. For CSPEC, GE's major equipment cost estimate is slightly lower than Avco's, but its estimates for BOP, installation labor, indirect, and contingency costs are all substantially higher. Avco's COE estimate for the CSPEC MHD plant compares favorably with estimates for conventional coal-fired steam plants provided by Avco's A&E subcontractor, Chas. T. Main. The Avco estimate also compares favorably with some recent EPRI estimates for coal-fired steam plants. As part of Task III, GE's A&E subcontractor, Bechtel, is to obtain cost estimates for conventional coal-fired steam plants. These estimates should provide a better comparison with the GE CSPEC MHD plant estimate.

Both contractors concluded that their MHD plants should have reasonable part-power performance. They both concluded that a dual MHD power train is not cost effective. Avco concluded that a spare MHD generator is cost effective.

A NASA Lewis Research Center performance analysis shows the effect of plant size and preheat temperature on plant efficiency. The efficiency of a 1000 MWe plant is about 3 points higher than the efficiency of a 200 MWe plant. The efficiency varies by about one and one-half points over an oxidizer preheat temperature range of 800 to 1600 F. This temperature range reflects the preheater technology and design range which could be used in this kind of MHD plant.

The Task III study will produce cost estimates for MHD plants over the 200 to 1000 MWe size range. This will give a basis for comparing the performance and cost of oxygen-enriched MHD plants and other types of power plants over this size range. It should also give an idea of the minimum size MHD plants that are competitive with these other power plants.

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TABLE 1. - CSPEC POWER PLANTS

	Avco	GE
Plant size, MWe	949	1090
Coal type	Montana Rosebud	
Percent moisture as fired	5	4.8
Coal drying medium	Nitrogen	Flue gas
Combustor type	Single stage	Two stage
Percent ash rejection	80	90
Design pressure, atm	8.3	9.0
Oxidizer, mole percent oxygen	34	37.6
Oxidizer/fuel ratio, percent of stoichiometric	0.9	
Seed, percent potassium by weight	1.0	1.6
MHD generator type	Diagonal	
Generator length, m	21.5	18.0
Generator load parameter	0.7862	Variable
Generator cooling	Low pres./temp. boiler feedwater	Separate low temp. cooling circuit
Peak magnetic field, T	6.5	6.0
Magnet warm bore area/generator flow area	1.5	3.0
Seed regeneration	Formate	
Emission standards	NSPS	
Bottoming steam cycle	2400 psig/1000 F/1000 F	
Generator drive turbine arrangement	Tandem compound	Cross compound
Cycle and ASU drive turbines, no.	1	2x5
Type	High pressure	Low pressure
Air separation plant		
Trains	3	5
Capacity, TPD contained oxygen	7344	9828
Product purity, mole percent oxygen	80	
Approx. power consumption, kW-hr/ton equivalent pure oxygen	200	

TABLE 2. - SUMMARY OF RESULTS

	Avco	GE
Overall efficiency, percent	43.9	42.7
Levelized cost of electricity (LEV = 2.004)	42.99	56.47
Overnight capital cost M$, mid 1978	614.4	989.1
Overnight captial cost $/kWe, mid 1978	644	907
Construction period, years	5.75	6.0

TABLE 3. - ECONOMIC PARAMETERS USED IN CALCULATING

LEVELIZED COST OF ELECTRICITY

Captial cost portion including escalation and interest during construction

- "Overnight" construction cost estimated by contractor
- Construction period estimated by contractor
- ECAS[7] cash flow curve during construction
- 6.5 percent annual escalation rate
- 10 percent annual interest rate
- 18 percent fixed charge rate
- 65 percent capacity factor

Fuel cost portion

- $1.05 per million Btu mid-1978 fuel price

Operation and Maintenance (O&M) cost portion

- Estimated by contractor

Fuel and O&M costs levelized with factor 2.004[10]; this corresponds to

- Escalation and interest as above
- No real fuel price escalation
- 30 year plant life

Final levelized COE is expressed in mid-1978 dollars

TABLE 4. - CSPEC PLANT POWER RATIOS

	Avco	GE
1. $\frac{\text{MHD generator input}}{\text{Combustor input}}$	0.975	0.943
2. $\frac{\text{MHD DC output}}{\text{MHD generator input}}$	.224	.231
3. $\frac{\text{MHD AC output}}{\text{Power plant output}}$	.542	.555
4. $\frac{\text{Bottoming cycle output}}{\text{Bottoming cycle input}}$	.418	.403
5. $\frac{\text{ASU compressor drive}}{\text{Coal input (HHV)}}$	.027	.031
6. $\frac{\text{Plant auxiliary}}{\text{Coal input}}$	.018	.017
7. $\frac{\text{Stack loss}}{\text{Coal input}}$	.096	.106
8. $\frac{\text{Other losses}}{\text{Coal input}}$	.014	.019
9. $\frac{\text{Coal/Coke to seed reprocessing}}{\text{Coal input}}$	.014	.014
10. Overall power plant efficiency	.439	.427

TABLE 5. - CAPITAL COST SUMMARY, MID-1978 $/kWe

	Direct						Indirect		Contingency		Total		Percent of total	
	Major component		BOP material		Installation labor									
	Avco	GE	Avco	GE	Avco	GE	Avco	GE	Avco	GE	Avco	GE	Avco	GE
310. Land			1.1	11.1					0.1	-----	1.2	11.1	0.2	1.2
311. Structures and improvements			21.1	49.7	15.9	40.6	8.0	36.6	4.5	12.7	49.4	139.6	7.6	15.4
312. Boiler plant	84.8	69.7	26.9	48.5	32.5	39.8	16.2	35.8	16.0	19.4	176.4	213.2	27.2	23.5
314. Turbines/generator	24.3	27.7	11.0	22.9	6.1	13.3	3.1	12.0	4.5	7.6	49.0	83.5	7.6	9.2
315. Accessory electrical equipment			13.4	0.5	12.9	0.2	6.5	0.2	3.3	0.1	36.1	0.9	5.6	0.1
316. Miscellaneous power plant equipment			1.4	5.1	0.4	2.9	0.2	2.6	0.2	1.0	2.2	11.6	0.3	1.3
317. MHD topping cycle	186.1	174.8	7.7	31.9	30.2	44.2	15.0	39.8	30.9	58.1	270.0	348.9	41.7	38.5
350. Transmission and switchyard			5.1	13.4	0.9	2.6	0.4	2.3	0.6	1.8	7.1	20.2	1.1	2.2
Total	295.2	272.3	87.6	183.1	99.0	143.6	49.4	129.2	60.1	100.8	591.4	829.0		
Percent of total	45.6	30.0	13.5	20.2	15.3	15.8	7.6	14.2	9.3	11.1				
									Engineering services		56.0	78.5	8.6	8.7
									Total		647.4	907.4		

TABLE 6. - PART LOAD PERFORMANCE COMPARISON

	Overall plant efficiency	
Percent of MHD generator design mass flow	Avco	GE
100	43.9	42.7
75	41.8	42.3

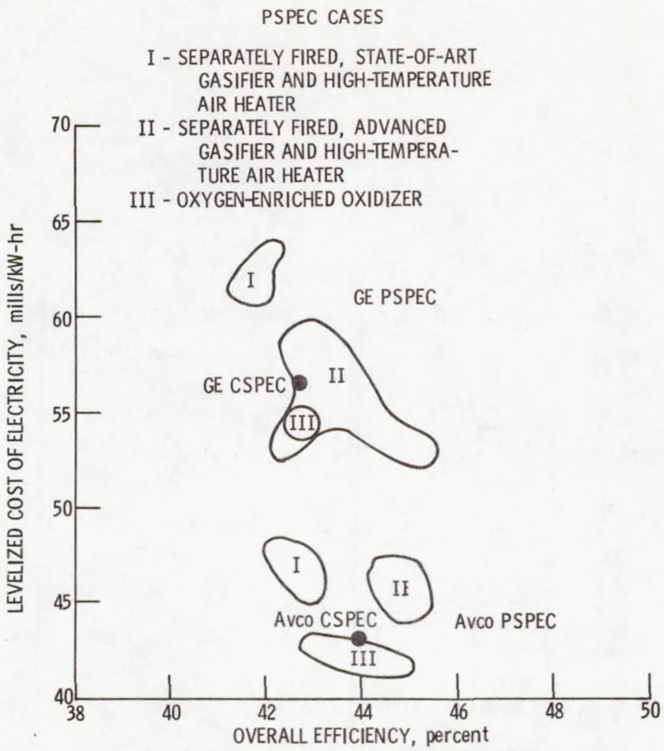


Figure 1. - Summary of PSPEC and CSPEC results. Levelized cost of electricity calculated as described in table 3.

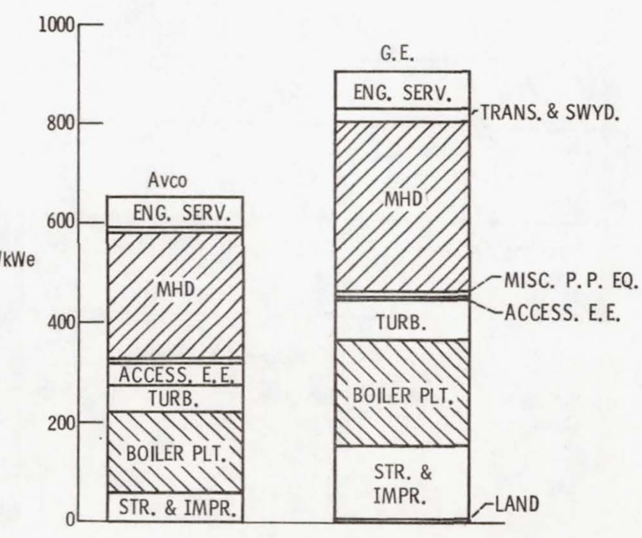


Figure 2. - Comparison of CSPEC overnight capital cost estimates by cost accounts. Costs expressed in mid-1978 dollars.

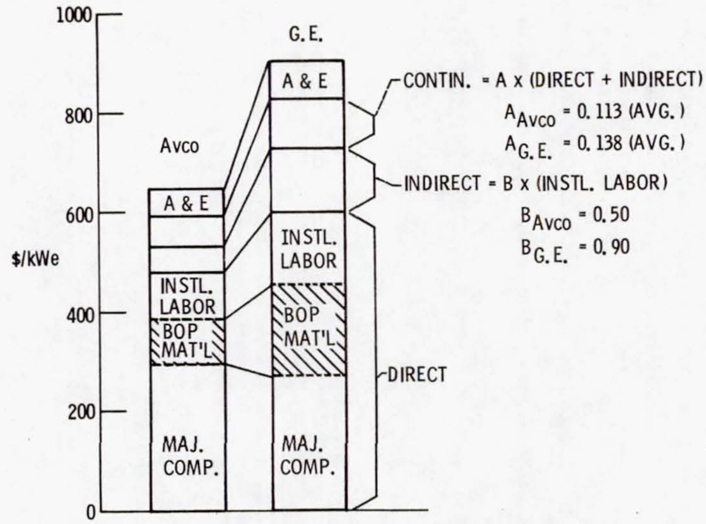


Figure 3. - Comparison of CSPEC overnight capital cost estimates by cost categories and multipliers used by each contractor for determining indirect and contingency costs. Costs expressed in mid-1978 dollars.

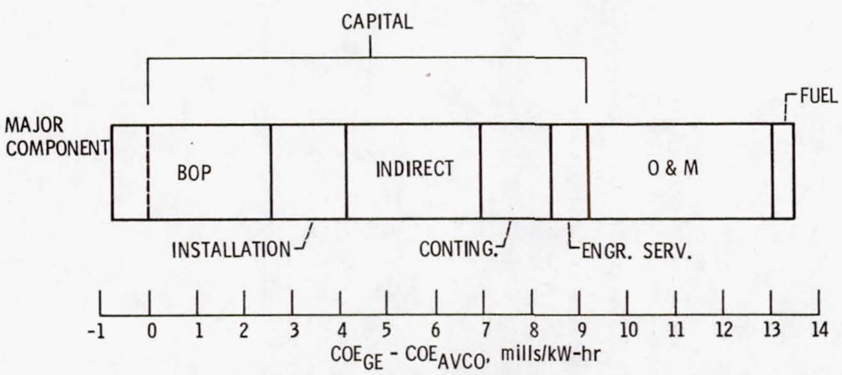


Figure 4. - Contributions to the difference in estimated levelized cost of electricity between Avco and General Electric.

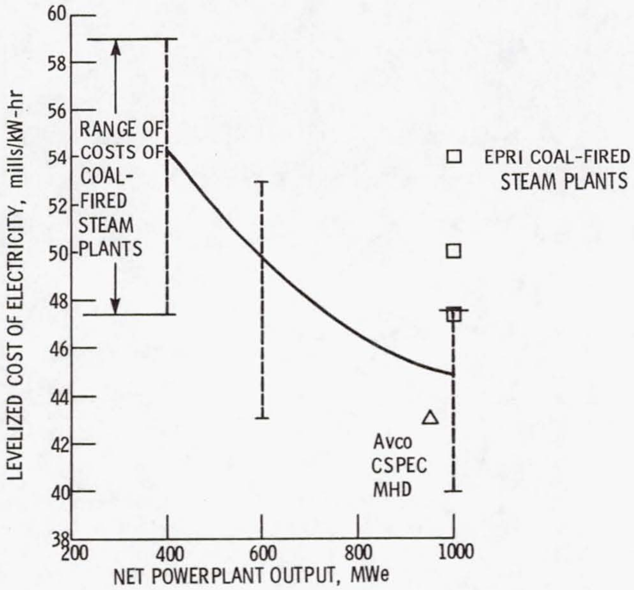
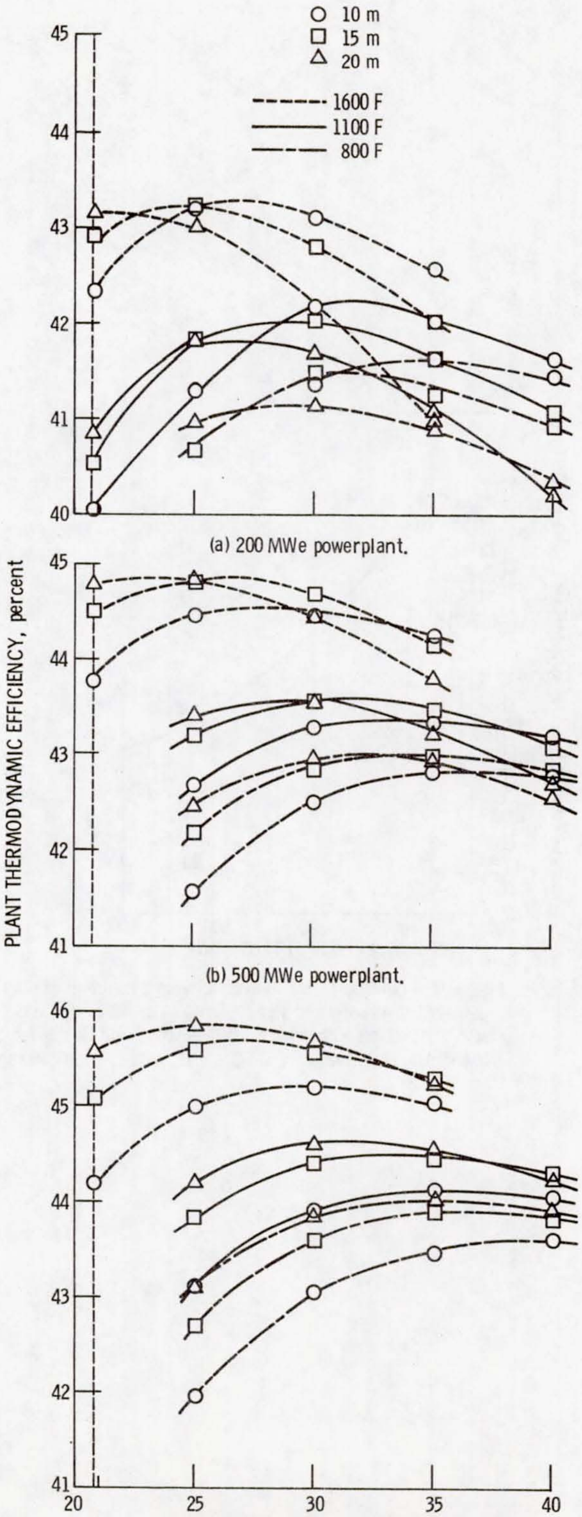


Figure 5. - Levelized cost of electricity as a function of plant size for conventional coal-fired steam plants as provided by Chas. T. Main and comparison with Avco CSPEC MHD. Solid line is for "Middletown" site also used in CSPEC. EPRI data is from reference 10.



(a) 200 MWe powerplant.

(b) 500 MWe powerplant.

(c) 1000 MWe powerplant.

Figure 6. - MHD powerplant thermodynamic efficiency as a function of oxygen enrichment for three oxidizer preheat temperatures and three MHD generator lengths. MHD generator is cooled with low-temperature and -pressure boiler feedwater. Power required to produce oxygen is 200 kW-hr/ton equivalent pure oxygen.

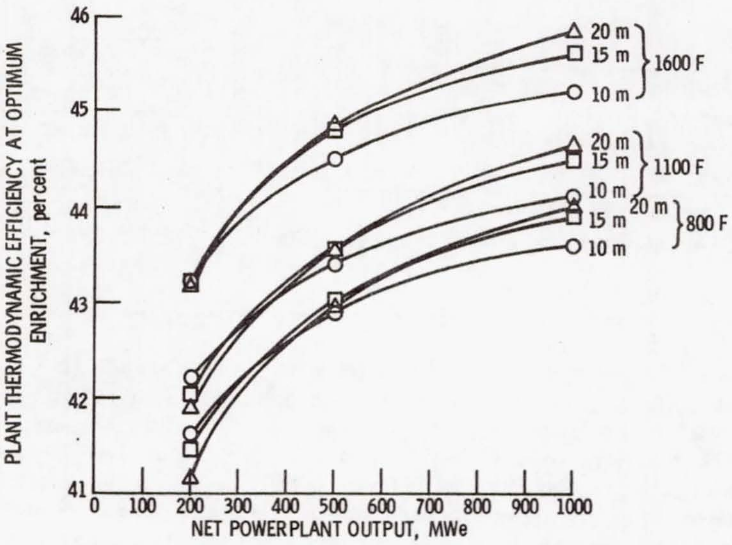


Figure 7. - MHD powerplant thermodynamic efficiency at optimum enrichment as a function of powerplant electrical output for three oxidizer preheat temperatures and three MHD generator lengths. Other conditions are the same as those for figure 6.

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16. Abstract

The conceptual design study of a potential early commercial MHD power plant (CSPEC) is described and the results of the study are summarized. For this study, each of two contractors did a conceptual design of an approximately 1000 MWe open-cycle MHD/steam plant with oxygen enriched combustion air preheated to an intermediate temperature in a metallic heat exchanger. The contractors were close in their overall plant efficiency estimates but differed in their captial cost and cost of electricity estimates, primarily because of differences in Balance-of-Plant material, installation, contingency, and operating and maintenance cost estimates. One contractor concluded that its MHD plant design compared favorably in cost of electricity with conventional coal-fired steam plants. The other contractor is making such a comparison as part of a follow-on study. Each contractor did a preliminary investigation of part-load performance and plant availability. The results of NASA studies investigating the effect of plant size and oxidizer preheat temperature on the performance of CSPEC-type MHD plants are also described. The efficiency of a 1000 MWe plant is about three points higher than that of a 200 MWe plant. Preheating to 1600 F gives an efficiency about one and one-half points higher than preheating to 800 F for all plant sizes. For each plant size and preheat temperature there is an oxidizer enrichment level and MHD generator length that gives the highest plant efficiency.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
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