FE-2583-13
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CONCEPTUAL DESIGN FOR AN ATMOSPHERIC FLUIDIZED-BED DIRECT COMBUSTION POWER GENERATING PLANT
Phase I - Commercial Plant Conceptual Design

Annual Report for the
Period January 14, 1977-January 31, 1978

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Boston, Massachusetts 02107

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PREPARED FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Under Contract No. EF-77-C-01-2583

ABSTRACT

The conceptual design of a commercial size (560 MW), complete power generating station incorporating an atmospheric fluidized bed boiler was developed for two parallel cases presenting the boiler designs of two major boiler manufacturers. These were preceded by the presentation of the basis for comparison, which was also a 560 MW unit, which incorporated a conventional pulverizer coal suspension fired boiler with associated facilities including, particularly, a wet limestone flue gas scrubber.

The product of the project was presented to DOE in the form of technical notes issued at intervals during the year as progress evolved. A ring binder, with provision for the sequential issue of the following parts, was provided with issuance of the first part:

I 570 MWe Base Plant Definition and General Design Criteria

II AFB State-of-the-Art

III 570 MWe AFB Plant Definition

IV Evaluation of Merit

V AFB Demonstration Plant Definition

Part III subsequently followed with Parts II and IV scheduled for issue by March 14, 1978. Part V was deleted from the scope of work by direction of DOE and replaced by development of a mathematical model of AFB control functions and analysis of load following capability. A report covering the latter will be issued by completion of the contract, March 14, 1978.

Eleven electric utility companies were contacted in the course of the year to apprise them of the AFB project and to engage their interest in review of the progress of the project as it developed. Oral and visual presentations were made to engineers of each company and a copy of the Base Plant Reference dated June 1977, was given to them at the presentation or soon thereafter. Later in the year, a second volume titled Comparison Plant Exhibits, Incorporating Manufacturers Unique AFB Boiler Design and Ancillary Systems, dated December 1977, was distributed for comparison to the base. A third volume, covering systematic comparison with the base of the cost and functional aspects of the AFB cases, is scheduled to be issued in March 1978.

OBJECTIVE AND SCOPE OF WORK

The overall objective of the project has been to prepare a conceptual design for an electric power generating plant that will directly combust high sulfur coal in an atmospheric fluidized-bed boiler and generate electric power in an environmentally acceptable manner.

The work to attain the overall objective was originally planned in two overlapping phases. Phase I involved the development of conceptual designs and examination of merit of contemporary size (560 MW) plants including atmospheric fluidized-bed boilers. The designs were projected by each of two major boiler manufacturers, specifically Babcock & Wilcox and Foster Wheeler. The purpose of this first phase is to provide convincing evidence to the electric utilities to show that fluidized-bed combustion is a better choice for future coal burning facilities than current conventional methods such as suspension burning of pulverized coal.

Phase II was to have been the conceptual design of a suitably sized demonstration plant, based on the results of Phase I. However, at the direction of DOE, Phase II was deleted from the scope of work. In its place, the AFB Model Analysis for Load Following Capability was assigned.

SUMMARY OF PROGRESS IN THE YEAR

The description of the conventional plant base for comparison of the AFB combustion equivalent plants was issued to DOE at the outset of the second quarter in the form of technical notes. Subsequently, modifications and additions were made to the Part I section and Parts II and III were to be issued as developed for addition to the notes. Part II covers the updated state-of-the-art (as of October 1977) and Part III presents the two complete AFB plant designs - one for each manufacturer's AFB boiler design. An additional section, Part IV, covering evaluation of the merit of AFB combustion, remained to be issued during the brief extension of the contract schedule to March 14, 1978.

Separate volumes, paraphrasing respectively the material of Parts I and III, were prepared and given to 11 electric utilities, each of whose interest in the subject had been solicited in the early part of the year. A third separate volume, derived from Part IV of the notes, is scheduled to be sent to the utilities during March 1978.

The project activities during the year, divided between nine major tasks, numbered 1,000 through 9,000. The following pages describe the work under each in greater detail.

II DETAILED DESCRIPTION OF QUARTERLY TECHNICAL PROGRESS

Task 1000 - Preliminary Engineering and General Administration

Work Accomplished

Planning Program and Network Diagram - Throughout the year, the progress of the work was monitored in terms of the individual activities shown graphically on the network diagram. The diagram was updated with each monthly report and interpreted in an accompanying Schedule Analysis. The current update and analysis is included at the end of this report.

Work Forecast

Monitoring of progress will continue throughout the remainder of the project.

To allow for additional time to complete the evaluation of merit, DOE has authorized an extension of the AFB Study contract date to March 15, 1978, while maintaining the original contract price.

Task 2000 - Base Plant Definition

Work Accomplished

The base plant description, in technical notes form, was issued and transmitted to DOE on July 21, 1977. This report included the pulverized coal plant description of work, heat and material balances, flow diagrams, plant arrangement drawings, and all other design drawings for related power plant equipment. This base plant report was used as a basis for comparison with the AFB plant designs developed during the project. An additional report entitled, Base Plant Reference, Conventional Coal-Fired Power Plant, was distributed to 11 electric utilities for their use in comparing subsequent AFB plant designs.

At DOE's request, additional detail of the flue gas desulfurization system and cost estimate was prepared and issued on January 15, 1978. This remains within the original budget. No further work is planned on Task 2000 for this contract.

Task 3000 - Pope, Evans & Robbins

Work Accomplished

Pope, Evans, & Robbins (PER) provided review and evaluation of the boiler manufacturers' designs. Their efforts were primarily concentrated on plant material balances, AFB related system design evaluations, and three state-of-the-art reports on AFB technology, research and development needs, and sorbent regeneration.

Work Forecast

The state-of-the-art reports which are designated Part II of the technical notes will be issued to DOE by February 28, 1978. During the month of February and March, PER will assist Stone & Webster Engineering Corporation (S&W) in the completion and review of the evaluation of merit of the two AFB plant designs and the comparison of AFB versus pulverized coal plant designs.

Task 4100 - Babcock & Wilcox Company

Work Accomplished

A conceptual design was developed for a 570 MW atmospheric fluidized-bed boiler (AFB) capable of burning high sulfur coal in an environmentally acceptable manner without recourse to flue gas desulfurization. This preliminary design is described in Babcock & Wilcox (B&W) final report dated November 30, 1978, which is included in Appendix IIIA-B of the Technical Notes. Their report includes design drawings, material and energy balances, boiler thermodynamic design, material handling systems, and other AFB related systems and equipment. In addition, B&W prepared a capital cost estimate of the AFB boiler and related equipment for use by S&W in developing overall plant cost. B&W's work on this contract has been completed.

Task 4200 - Foster Wheeler Energy Corporation

Work Accomplished

Foster Wheeler (FW) has completed the AFB conceptual design effort and submitted their report dated November 1977. Their report was incorporated as Appendix III B-B of the Technical Notes. The report includes boiler design drawings, material and energy balances, boiler thermodynamic design, material handling systems, and other AFB related systems and equipment. In addition, FW prepared a capital cost estimate of the AFB boiler and related equipment for use by S&W in developing overall plant cost. FW's work on this contract has been completed.

Task 5000 - AFB Design and Description

Subtask 5100 - AFB Turbine Room

Work Accomplished

Based on the boiler manufacturers' designs, it was determined that little redesign of the base plant turbine room was required. One needed modification was the addition of a turbine bypass system for protection of superheater and reheater surfaces in the event of a turbine trip. The work in this area of the plant is complete.

Subtasks 5200 and 5300 - Boiler Rooms for B&W and FW

The objective of this subtask was to prepare a description of work of the AFB electric generating plant with related drawings for comparison with the base plant design. This effort required equipment designs, flow and utility diagrams, general arrangements, composite drawings, structural steel designs, control logic diagrams, and electrical drawings be prepared. The result of this work was an understanding of differences in plant design features between the base plant and the AFB plants to enable system designs to be developed. Major areas of difference between the base plant and the AFB plant include:

Boiler Plant
Particulate Control Equipment
Materials Handling and Feed Systems
Ash Handling Systems
FD Fans
Control System
Electrical System
Waste Treatment System

The above systems were designed and incorporated in plant drawings as a basis for preparing a capital cost estimate of the AFB plant designs. The scope summarized above is presented in Part III of the Technical Notes dated December 22, 1977.

Work Forecast

Comments received on the draft copy of Part III will be resolved and incorporated in a final draft of Part III.

Task 6000 - AFB Plant Investment & Performance

Cost Development

Work Accomplished

As a result of the engineering and design work in Task 5000, capital cost estimates for the B&W and FW electric power generating plants were prepared. The basis for the estimate was to change the base plant cost estimate only for the areas of difference as identified in Task 5000. Equipment and system costs were solicited from suppliers as well as S&W in-house data for use in developing the plant costs. The results of the cost estimates are included in Part III of the Technical Notes, and can be summarized as follows. The B&W plant design capital cost is approximately 10% higher than the base plant and the FW plant design capital cost is approximately 10% lower than the base plant capital cost.

Operating cost estimates were prepared taking the following areas into account: fixed charges, fuel and limestone cost, operation and maintenance, and waste disposal. The results of this assessment are as follows. The levelized cost of electricity for the B&W plant case is approximately 40 mils/kw-hr and for FW plant case approximately 37 mils/kw-hr compared to 39 mils/kw-hr for the base plant case. In considering these values, it must be recognized that the cost assessment was made between a mature versus a developing technology, and improvements in the AFB plant may ultimately decrease both capital and operating costs.

Work Forecast

Capital cost estimates are being reviewed within S&W and will be finalized in Part III of the Technical Notes after comments have been received and incorporated.

Task 7000 - Evaluation of Merit

Work Accomplished

The evaluation of each of the boiler manufacturer's designs and the AFB designs compared with the base plant has been underway. A draft of the B&W versus FW AFB designs has been reviewed within S&W and PER.

During the course of the year, the following electric utility companies were enlisted to follow the work as it developed:

- New England Power Service Company
- Boston Edison Company
- Tampa Electric Company
- New England Gas and Electric Company
- Consumers Power Company
- Florida Power Company
- Kentucky Utilities Company
- East Kentucky Power Company
- Wisconsin Electric Power Company
- Savannah Electric Company
- Detroit Edison Company

Separate documents describing first, the base plant, and second, the AFB combustion plants, were sent to each company.

Work Forecast

Every effort will be made to complete the evaluation of merit section of the notes by March 1, 1978. A third document, paraphrasing Section IV of the notes, will be sent to the electric utilities companies by the end of the extended contract term.

Task 8000 - Reports

Work Accomplished

The following reports were issued during the last 12 months:

- Part I of the Technical Notes
- Parts III A and B of the Technical Notes (Draft for Comments)
- Base Plant Reference - Conventional Coal-Fired Power Plant
- Comparison Plant Exhibits-Incorporating Manufacturers' Unique AFB Boiler Design and Ancillary Systems
- Monthly and Quarterly Progress Reports
- Monthly Financial Reports

Monthly progress meetings have been held with DOE, Radian, Hartford Steam Boiler and Insurance Company, PER, and S&W to review the project status. The most recent meeting was January 11, 1978.

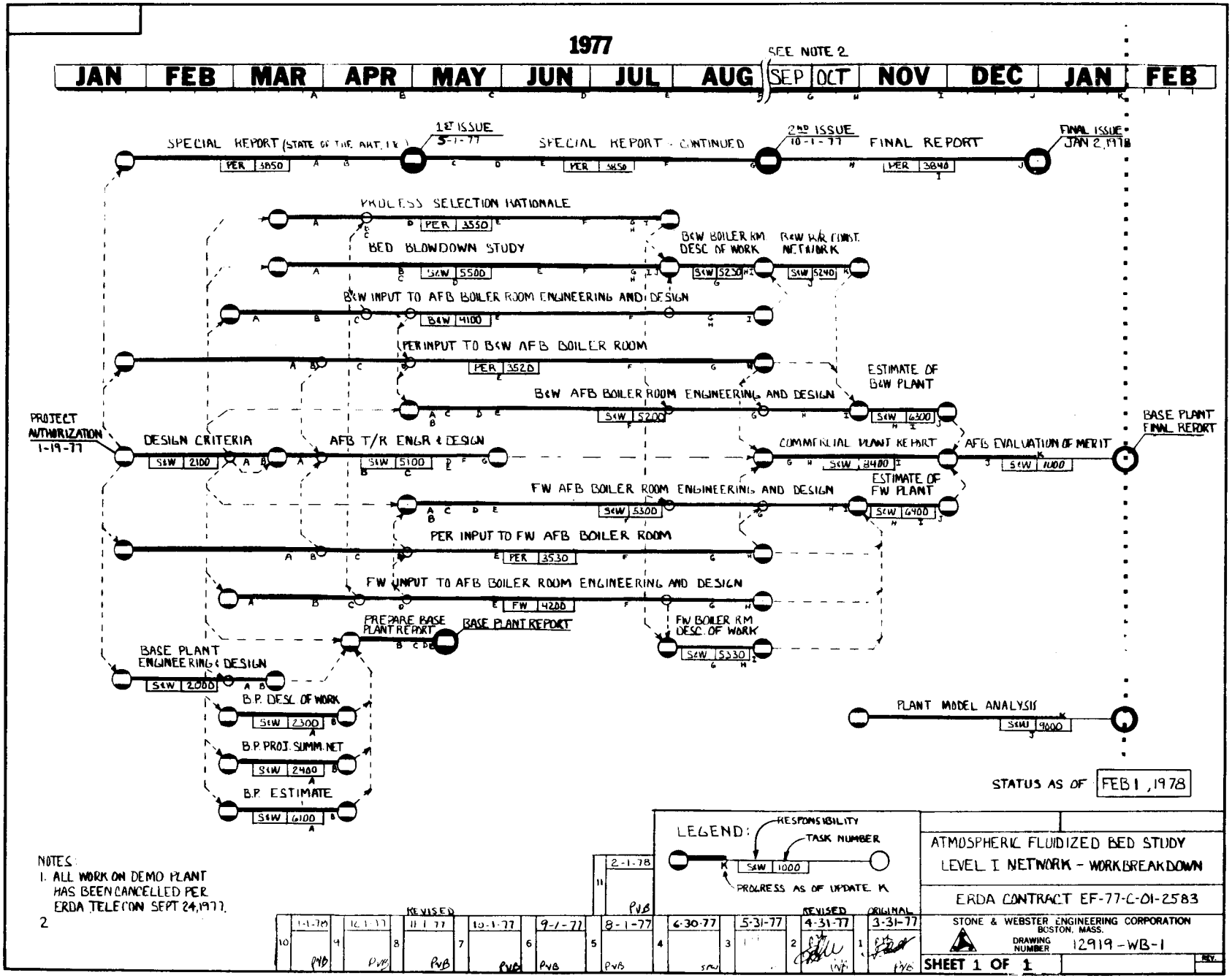
Task 9000 - AFB Plant Model Analysis for Load Following Capability

Work Accomplished

The objective of the study is to predict the open loop response characteristics of the FW AFB plant to step changes in control variables for comparison with typical results for conventional pulverized coal-fired, once-through utility unit, in order to ascertain the AFB load following capabilities. The computer model to predict the load following capability of the once-through boiler has been completed and programmed.

Work Forecast

During the next reporting period, step response runs will be made with the system model for comparison with the base plant. A preliminary draft of the final report will be completed by February 28, 1978.


1977
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
SEE NOTE 2.
SPECIAL REPORT (STATE OF THE ART, I &)
1ST ISSUE 5-1-77
SPECIAL REPORT - CONTINUED
2ND ISSUE 10-1-77
FINAL REPORT
FINAL ISSUE JAN 2, 1978
PER 3850
PER 3850
PER 3840
PROCESS SELECTION RATIONALE
PER 3550
BED BLOWDOWN STUDY
S&W 5500
B&W BOILER RM DESC OF WORK
S&W 5230
B&W H/R CONST. NETWORK
S&W 5240
B&W INPUT TO AFB BOILER ROOM ENGINEERING AND DESIGN
B&W 4100
PER INPUT TO B&W AFB BOILER ROOM
PER 3520
ESTIMATE OF B&W PLANT
B&W AFB BOILER ROOM ENGINEERING AND DESIGN
S&W 5200
S&W 6300
PROJECT AUTHORIZATION 1-19-77
DESIGN CRITERIA
S&W 2100
AFB T/R ENGR & DESIGN
S&W 5100
COMMERCIAL PLANT REPORT
S&W 8400
AFB EVALUATION OF MERIT
S&W 4000
BASE PLANT FINAL REPORT
FW AFB BOILER ROOM ENGINEERING AND DESIGN
S&W 5300
ESTIMATE OF FW PLANT
S&W 6400
PER INPUT TO FW AFB BOILER ROOM
PER 3530
FW INPUT TO AFB BOILER ROOM ENGINEERING AND DESIGN
FW 4200
PREPARE BASE PLANT REPORT
BASE PLANT REPORT
FW BOILER RM DESC. OF WORK
S&W 5330
BASE PLANT ENGINEERING & DESIGN
S&W 2000
B.P. DESC. OF WORK
S&W 2300
B.P. PROJ. SUMM. NET
S&W 2400
B.P. ESTIMATE
S&W 6100
PLANT MODEL ANALYSIS
S&W 9000
STATUS AS OF FEB 1, 1978
LEGEND:
RESPONSIBILITY
TASK NUMBER
S&W 1000
PROGRESS AS OF UPDATE K
NOTES:
1. ALL WORK ON DEMO PLANT HAS BEEN CANCELLED PER ERDA TELECON SEPT 24, 1977.
2
11 2-1-78 PVB
10 1-1-78 PVB
9 12-1-77 PVB
8 11-1-77 PVB
7 10-1-77 PVB
6 9-1-77 PVB
5 8-1-77 PVB
4 6-30-77 SCW
3 5-31-77
2 REVISED 4-31-77
1 ORIGINAL 3-31-77
REVISED
ATMOSPHERIC FLUIDIZED BED STUDY
LEVEL I NETWORK - WORK BREAKDOWN
ERDA CONTRACT EF-77-C-01-2583
STONE & WEBSTER ENGINEERING CORPORATION BOSTON, MASS.
DRAWING NUMBER 12919-WB-1
SHEET 1 OF 1
REV.

SCHEDULED ANALYSIS

AS OF FEBRUARY 1, 1978

TASK 1000

The only activity that is continuing in this task is the Planning and Scheduling effort which will continue until the project is complete.

TASK 2000

All activities in this task are complete.

TASK 3000

All activities that were scheduled have been completed. Pope Evans and Robbins are assisting Stone and Webster in the evaluation of merit report.

TASK 4000

Subtask 4100 - All Babcock and Wilcox work was completed as of November 30, 1977
Subtask 4200 - All Foster-Wheeler work was completed as of November 30, 1977.

TASK 5000

All activities scheduled for this task are complete.

TASK 6000

All activities scheduled for this task are complete.

TASK 7000

The only activity left in this task is the evaluation of merit which will be completed by March 1, 1978.

TASK 8000

All activities in this task are complete.

TASK 9000

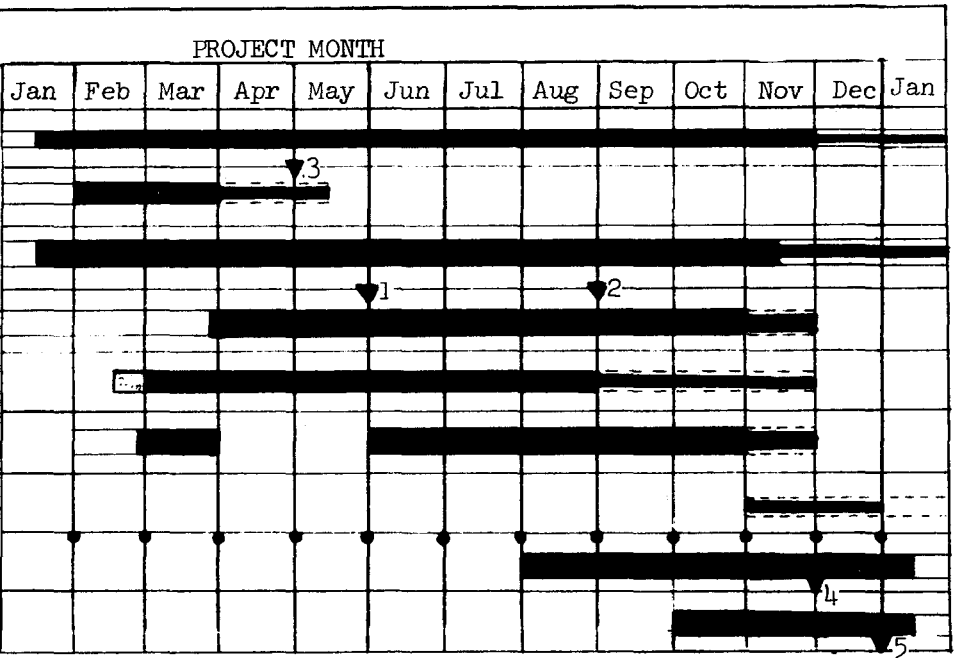
The only activity left in this task is the Plant Model Analysis Study which will be completed by February 28, 1978.

J.O.No. 12919

PLANNING PROGRAM CONTROL
DOE - AFB STUDY

Issued: Sept. 2, 1976
Revised: Jan. 31, 1978

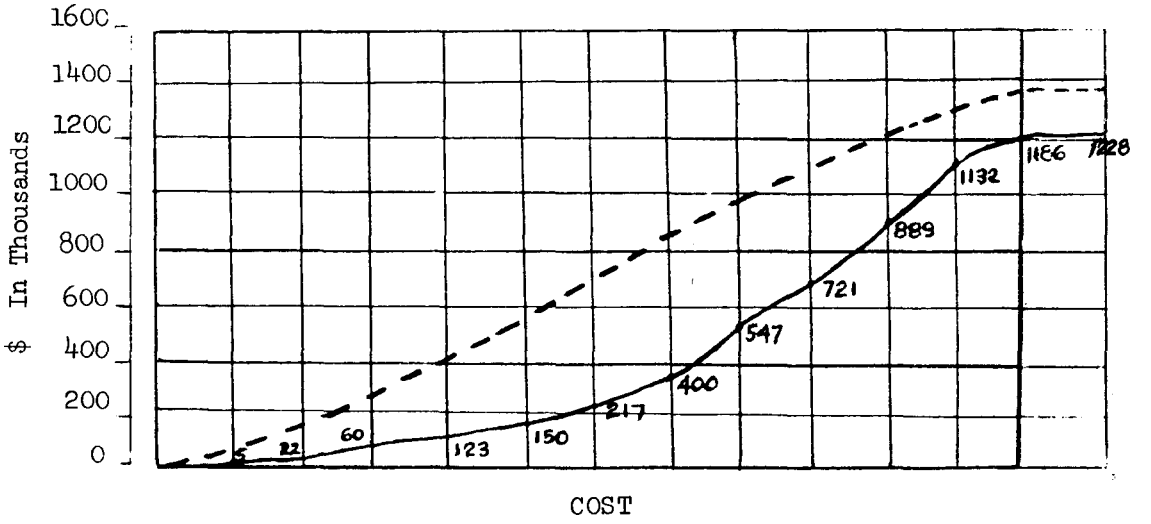
TASK	DESCRIPTION
1000	Preliminary Engineering and General Administration
2000	Base Plant Definition
3000	Pope, Evans & Robbins Efforts
4000	Boiler Manufacturer's Efforts
5000	AFB Plant Design & Description of Work
6000	Investment & Performance Cost Development
7000	Evaluation of Merit
8000	Reports
9000	Plant Model Analysis



- ● Monthly Progress Reports
- ▼1 Boiler Manufacturer's Technical Data
- ▼2 Boiler Manufacturer's Pricing Data
- ▼3 Base Plant Report
- ▼4 Commercial Plant Report
- ▼5 Demonstration Plant Report

BUDGET REPORT (1000's)

	$	MH
Total	1354	52.4
Spent	1228	46.7
Planned	1354	52.3
Variance	126	5.7



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