



UNITED STATES  
NUCLEAR REGULATORY COMMISSION  
WASHINGTON, D. C. 20555

MAY 29 1979

MEMORANDUM FOR: Harold R. Denton, Director  
Office of Nuclear Reactor Regulation

FROM: Saul Levine, Director  
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER #55 - THE CONCEPT COMPUTER  
CODE AND CAPITAL COSTS FOR HIGH AND LOW SULFUR COAL  
PLANTS - 1200 MWe

Introduction

This memorandum transmits the results of completed research updating and expanding the CONCEPT computer code for forecasting capital costs of high and low sulfur coal plants -1200MWe. The work was performed by United Engineers and Constructors, Inc., Philadelphia, Pennsylvania, under the direction of the Environmental Effects Research Branch of RES in response to a research request from your office (RR-NRR 76-6).

In 1971 the Atomic Energy Commission authorized power plant investment cost studies, which culminated in the WASH-1230 reports (1000 MWe Central Station Power Plants - Investment Cost Study) published in 1972. Their purpose was to facilitate policy and economic decisions about electric generation facilities in the public and private sectors. The WASH-1230 report series consists of five volumes: Pressurized Water Reactor, Boiling Water Reactor, Coal-Fired, Oil-Fired and High Temperature Gas-Cooled Reactor power plants. National priorities on energy, the regulatory environment and the costs of labor, equipment and material have changed significantly. These changes dictated the necessity of updating this series of studies, and expanding the scope to consider the fuel cycle and the total generating cost. As a result, a program to study, reassess and produce a new set of updated reports was authorized and undertaken.

The current series includes investment cost reports for a Pressurized Water Reactor Plant, a Boiling Water Reactor Plant, High Sulfur Coal Plants, and Low Sulfur Coal Plants. The Oil Fired Power Plant Study was not updated because utilities are no longer expected to build significant numbers of these plants, and the High Temperature Gas-Cooled Reactor Plant Study was not updated because these reactors are not now being marketed. Investment cost reports on multi-unit stations and for different cooling system types are included. In addition, the series addresses fuel supply investment costs and total generating costs for both nuclear and coal fired power plants.

Results of the Boiling Water Reactor Plant study were transmitted in RIL #45, dated 2/11/79, and results of the Pressurized Water Reactor Plant study were transmitted in RIL #51, dated 4/11/79.

The studies in these series have a uniform set of economic and technical criteria and a uniform accounting system as contained in Guide for Economic Evaluation of Nuclear Reactor Plant Designs, NUS-531, January 1969. The investment cost estimates in these series are developed for reference plants constructed at a hypothetical site called "Middletown, USA."

The reference investment and total generating cost estimates can be used for baseline comparisons of different generating systems. However, the major use of the investment cost data is as input to the CONCEPT computer code which was developed for DOE at the Oak Ridge National Laboratory (ORNL). The CONCEPT computer program adjusts the baseline cost estimates contained in these studies for different plant sizes, regional variations in material and craft labor rates, different construction schedule lengths, and different escalation and interest rates. These adjustments result in preliminary sets of alternative cost estimates for electric power plants constructed anywhere in the United States.

This Commercial Electric Power Cost Study for 1200 MWe (Nominal) high and low sulfur coal plants consists of three volumes. The high sulfur coal plant is described in Volumes I and II, while Volume III describes the low sulfur coal plant.

The design bases and cost estimate for the 1232 MWe high sulfur coal plant is presented in Volume I, and the drawings, equipment list and site description are contained in Volume II. The reference design includes a lime flue gas desulfurization system. A regenerative sulfur dioxide removal system using magnesium oxide is also presented as an alternate in Section 7, Volume II.

The design bases, drawings and summary cost estimate for a 1243 MWe low sulfur coal plant are presented in Volume III. This information was developed by redesigning the high sulfur coal plant for burning low sulfur sub-bituminous coal.

These coal plants utilize a mechanical draft (wet) cooling tower system for condenser heat removal. Costs of alternate cooling systems are provided in Report No. 7 in this series of studies of costs of commercial electrical power plants.

### High Sulfur Coal Plant

This Commercial Electric Power Cost Study for the 1232 MWe High Sulfur Coal Plant is presented in two volumes. Volume I includes the Legal Notice, Foreword, Preface, Summary for High Sulfur Coal Plant, Plant Description and the Detailed Cost Estimate. Volume II contains the Drawings, Equipment List, Site Description and a description of the alternate Magnesium Oxide Sulfur Removal System.

Additionally, Volume II, Section 6 presents the "Site Description" and major criteria used in the high sulfur coal plant study as follows:

- o The plant design incorporates a once-through supercritical pressure single reheat type steam generator to supply steam to a cross compound eight flow turbine. The heat balance shown on drawing 6509.001-HSC-6 (Volume II, Section 4) reflects steam conditions for a 1200 MWe nominally rated plant.
- o The steam generator is designed for a high sulfur eastern coal. The coal selection criteria are discussed in Section 2.2.2. The characteristics of the design basis coal seam and the design basis coal specification are presented in Tables 2-3 and 2-4 respectively.
- o Key plant parameters for the steam supply system, and the steam and power conversion system are shown in Tables 2-1 and 2-2 respectively.
- o The plant coal handling system is designed to unload a 100 car coal unit train in five hours. The design provides indoor coal storage silos with a capacity sufficient for eight hours consumption at full load and an outdoor storage area with a capacity sufficient for 60 days consumption at full load.
- o The reference plant design includes a lime scrubber system for removal of sulfur dioxide ( $SO_2$ ) from the flue gas. A discussion of an alternate  $SO_2$  removal system utilizing magnesium oxide ( $MgO$ ) is included as an alternate (Volume II, Section 7).
- o A full complement of environmental and siting criteria circa January 1, 1976 are utilized. Structural design criteria for the major structures are addressed in Section 2.2.3.
- o The main heat rejection system incorporates mechanical draft wet cooling towers.

- o The design provides a connection to the utility grid at two different voltage levels; 500 kV for the generator connection and 230 kV for the reserve auxiliary transformer connection.
- o The detailed cost estimate is developed for a single unit, with sufficient land area to accommodate an identical second unit.
- o The detailed cost estimate is developed in accordance with a Code of Accounts as expanded from that presented in the USAEC Report NUS-531.
- o Cost data is based on prices effective as of July 1, 1976.
- o Escalation and interest during construction are not included in the cost estimate.
- o The plant design life is 40 years during the first part of which it will be baseloaded.

### Results

The estimated total base construction cost for the 1200 MWe (Nominal) High Sulfur Coal Plant reference design is \$465,498,393 or \$378/kW based on July 1, 1976 prices. The cost estimate does not include normal contingency costs for the equipment, material and labor components of the total base construction cost; nor does it include escalation and interest during construction. As noted, for a specific site, this baseline cost estimate must be adjusted for regional variations in material and labor rates, different construction schedule lengths, and escalation and interest rates incurred during construction.

Table 1-3 is a summary breakdown of the direct craft labor costs and hours for this 1232 MWe reference design. The total direct craft labor cost of approximately \$108,000,000 corresponds to a weighted average hourly rate of \$12.45. Approximately 8,675,000 craft labor man hours average 7.0 manhours/kW.

### Low Sulfur Coal Plant

This Commercial Electric Power Cost Study for the 1243 MWe Low Sulfur Coal Plant is presented in Volume III of the three volume series. This volume contains the Legal Notice, Preface, Summary for Low Sulfur Coal Plant, Plant Description, Cost Estimate, Drawings, Equipment List and Site Description.

Additionally, Section 13 presents the "Site Description" and major criteria used in the low sulfur coal plant study as follows:

- o The plant design incorporates a once-through supercritical pressure single reheat type steam generator to supply steam to a cross compound eight flow turbine. The heat balance shown on drawing 6515.002-LSC-6 (Volume III, Section II) reflects steam conditions for a 1200 MWe nominally rated plant.
- o Key plant parameters for the steam supply system, and the steam and power conversion system are shown in Tables 9-1 and 9-2 respectively.
- o The steam generator is designed for a low sulfur western coal. The coal selection criteria are discussed in Section 9.2.2. The characteristics of the design basis coal seam and the design basis coal specification are presented in Tables 9-3 and 9-4 respectively.
- o The plant coal handling system is designed to unload a 100 car coal unit train in four hours. The design provides indoor coal storage silos with a capacity sufficient for eight hours consumption at full load and an outdoor storage area with a capacity sufficient for 60 days consumption at full load.
- o A full complement of environmental and siting criteria circa January 1, 1976 are utilized. Structural design criteria for the major structures are addressed in section 9.2.3.
- o The main heat rejection system incorporates mechanical draft wet cooling towers.
- o The design provides a connection to the utility grid at two different voltage levels; 500 kV for the generator connection and 230 kV for the reserve auxiliary transformer connection.
- o The cost estimate is developed for a single unit, with sufficient land area to accommodate an identical second unit.
- o The cost estimate is developed in accordance with a Code of Accounts as expanded from that presented in the USAEC Report NUS-531.
- o Cost data is based on prices effective as of July 1, 1976.
- o Escalation and interest during construction are not included in the cost estimate.
- o The plant design life is 40 years during the first part of which it will be baseloaded.

## Results

The estimated total base construction cost for the 1200 MWe (Nominal) Low Sulfur Coal Plant reference design is \$402,825,229 or \$324/kW based on July 1, 1976 prices. The cost estimate does not include normal contingency costs for the equipment, material and labor components of the total base construction. Other items not included in the cost estimate are listed in the beginning of Section 10, Cost Estimate. As noted, for a specific site, this baseline cost estimate must be adjusted for regional variations in material and labor rates, different construction schedule lengths, and escalation and interest rates incurred during construction.

### Comparison of High and Low Sulfur Coal Plants - 1200 MWe

The coal summary for the high sulfur coal (HSC) plant is presented in Section 1.3, Cost Summary, while the low sulfur coal (LSC) plant cost summary is shown in Section 8.3, Volume III. Significant features of each reference plant are summarized as follows:

	<u>High Sulfur</u>	<u>Low Sulfur</u>
Design Basis Coal	Eastern Bituminous	Western Sub-Bituminous
Coal Sulfur Content	3.61 percent	0.5 percent
Net Output	1232 MWe	1243 MWe
Base Construction Cost	\$465.5 x 10 <sup>6</sup>	\$403.8 x 10 <sup>6</sup>
Unit Capital Cost	\$378/kW	\$324/kW

The gross output from the turbine generator is identical (1309 MWe) for both plants. The difference in net plant output between the HSC plant and the LSC plant is due to the variation in auxiliary power requirements. For the design basis coals selected, the net output of the LSC plant is 11 MWe (0.9 percent) greater than the HSC plant.

### Comparison with WASH-1230 Results

The total base construction cost for the coal-fired power plant (1000 MWe net output) reference in WASH-1230 which did not have flue gas desulfurization is approximately \$174,000,000 or \$174/kW, based upon prices effective January 1971. Thus, this 1977 study indicates approximately a 87.9 percent increase in the cost of the plant in terms of \$/kW. The principal factors contributing to this increase are as follows:

- o Cost escalation from January 1971 to July 1976.
- o Environmental consideration affecting the magnitude of the plant design, analysis and siting requirements.

These result in increased engineering, management, labor, equipment and material costs due to escalation, increased scope and lengthened schedules.

The increase in direct construction costs of the current plant design over those estimated in WASH-1230 are directly related to increases in the quantities of the various construction materials required for compliance with environmental and siting criteria circa January 1, 1976, and the fact that the current plant is larger, with a new output approximately 24 percent greater than the power plant referenced in WASH-1230.

Following are examples of the differences in the quantities of some of these construction materials:

	<u>WASH-1230 Coal Plant - 1000 MWe Net Output (1/71)</u>	<u>Low Sulfur Coal Plant - 1243 MWe Net Output (1/76)</u>	<u>High Sulfur Coal Plant - 1232 MWe Net Output (1/76)</u>
Concrete, cu. yds.	76,000	81,600	111,200
Reinforcing Steel, lbs.	$7.5 \times 10^6$	$11.8 \times 10^6$	$15.2 \times 10^6$
Structural Steel, lbs.	$32.0 \times 10^6$	$47.0 \times 10^6$	$58.4 \times 10^6$

Table 8-2 is a summary breakdown of the direct craft labor costs and hours for the 1243 MWe Low Sulfur plant reference design. The total direct craft labor cost of approximately \$88,000,000 corresponds to a weighted average hourly rate of \$12.38. Approximately 7,146,000 craft labor man hours average 5.8 man hours/kW. These compare to averages of \$9.08/hour and 5.6 man hours/kW respectively for the earlier 1000 MWe design reported in WASH-1230.

This study provides the NRC cost-benefit analyst with an updated methodology for forecasting investment costs of high and low sulfur coal plants - 1200 MWe. In the performance of NEPA obligations to evaluate alternatives to the proposed action, the NRR staff must reach a conclusion as to the comparative costs of generating power among the feasible alternatives. For the past five years, the NRR staff has used the CONCEPT computer code to obtain forecasts of plant capital costs. The code was developed

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and used on the premise that basic designs for a given type of steam power plant are sufficiently similar so that capital costs for any plant can be reliably estimated given parametric specifications for the regional cost variation, labor efficiency and interest cost.

The study and its methodologies have been reviewed extensively while in progress by the RES project manager and various staff members from NRR. RES recommends that the updated methodology be used by NRR for application to the identified regulatory need (RR-NRR-76-6). Technical questions related to these results may be directed to David Barna at 427-4362.



Saul Levine, Director  
Office of Nuclear Regulatory Research

Enclosures:

1. NUREG-0243, Volume 1
2. NUREG-0243, Volume 2
3. NUREG-0243, Volume 3



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The study and its methodologies have been reviewed extensively while in progress by the RES project manager and various staff members from NRR. RES recommends that the updated methodology be used by NRR for application to the identified regulatory need (RR-NRR-76-6). Technical questions related to these results may be directed to David Barna at 427-4362.

Original Signed by  
Saul Levine

Saul Levine, Director  
Office of Nuclear Regulatory Research

Enclosures:

1. NUREG-0243, Volume 1
2. NUREG-0243, Volume 2
3. NUREG-0243, Volume 3

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