INTERN EXPERIENCE AT

PHILLIPS PETROLEUM COMPANY

AN INTERNSHIP REPORT

by

Craig Douglas Harrington

Submitted to the College of Engineering
of Texas A&M University
in partial fulfillment of the requirement for the degree
of

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Major Subject: Mechanical Engineering

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ABSTRACT

This internship report documents Craig Douglas Harrington's internship with Phillips Petroleum Company in Bartlesville, Oklahoma. The internship was undertaken as partial fulfillment of the requirements of the Doctor of Engineering degree at Texas A&M University. For ten months during 1981, the author was employed in the Process Engineering Division of Phillips' Corporate Engineering. His work assignments involved two oil shale retorting projects and a coal-fired boiler installation feasibility study. These projects exposed the author to a broad spectrum of both technical and non-technical problems. The experience proved to be an appropriate and valuable addition to his over-all education.

ACKNOWLEDGEMENTS

In a sense, this report represents the culmination of the author's years of academic education. The fact that he was able to arrive at this point can be traced to the support and encouragement of many people. A list would certainly begin with his family and more recently his wife, Lisa, all of whom often joked about his "continuing education", but always supported his educational efforts. Many friends from all those years at TAMU have helped him along the path in ways both large and small. Dr. Jenkins and all of the author's graduate committee members have been both teachers and friends. Their efforts and support have been greatly appreciated. This report would not be possible without the internship opportunity provided by Phillips Petroleum Company through the efforts of Mr. Lucien Vautrain. Jim Schmitz, John Hutto and all the other people in the Process Engineering Division added immeasureably to the author's education and made the internship an enjoyable experience.

Two people who deserve special recognition, though, are Dr. C. A. Rodenberger and Mrs. Kathy Shearer. Dr. Rodenberger has played an active role in every major organization and academic program that the author has participated in while at A&M. He was involved in the life and work of the A&M Wesley Foundation and A&M United Methodist Church, both of which were vital parts of the author's life at A&M. He directed the Engineering Co-operative Education program during the years the author participated and he played a central role in the development, guidance and growth of the Doctor of Engineering program, as well. Above all, he has been a good friend for these eight years and has provided guidance and encouragement throughout.

Without Kathy Shearer's help and guidance, most Doctor of Engineering students feel they would never graduate. She has been an invaluable source of information, answers, advice and direction to the author. She has patiently worked with the program and has provided a sense of continuity and stability during times of change. Most importantly though, she has been a friend and patient listener, for which the author is grateful.

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INTRODUCTION

In order to fulfill the internship requirements of the Doctor of Engineering degree, the author had the opportunity to work for Phillips Petroleum Company in Bartlesville, Oklahoma. For ten months in 1981, he was employed as an engineer by the Process Engineering Division of Phillips' Corporate Engineering. The technical aspects of the job assignments related well with the intern's educational background but the job assignments themselves were in fields that were generally unfamiliar to him. This provided an educational opportunity to become familiar with new fields, and yet did not preclude the author from making viable contributions to the projects. It is the intent of this report to relate both the experience and the education gained through this internship. Any material presented is for that purpose and should not be construed as a specific source of either technical or non-technical information. The work experience was a very welcome change of pace after six years of school and afforded an opportunity to apply those years of education to problems in the "real world."

INTERNSHIP OBJECTIVES

The author's goals and objectives, defined early in the internship, are as follows:

1. Gain practical engineering experience in a non-academic environment while making a valuable contribution to Phillips.
   a) Complete one or more major technical projects involving engineering design and/or analysis.
   b) Be actively involved in the non-technical aspects of the aforementioned projects or other non-technical problems, possibly including the following areas:
      i) Economic project analysis
      ii) Participation in or observation of project management
      iii) Legal considerations
      iv) Related environmental considerations
2. Learn as much as possible about the structure, operation and management of Phillips.
   a) Become acquainted with the structure and management methods employed in Corporate Engineering and specifically in the Process Engineering Division.

b) Take advantage of all available opportunities to become familiar with the operation of the rest of the company.

The technical aspects of these goals were more than fulfilled. The job assignments were technically challenging and provided an educational opportunity largely unavailable in the classroom. The non-technical aspects of the listed goals were also adequately fulfilled although often in much more subtle ways than were the technical ones. The projects that were assigned were at a level that afforded a broad overview of the many interrelated aspects of large engineering projects. These brief comments will be clarified in the ensuing sections of this report.

THE INTERNSHIP COMPANY

PROFILE

Phillips Petroleum Company was founded in 1917 as a small, local crude oil producer with 27 employees. It now employs over 30,000 people and has assets approaching ten billion dollars. The company operates internationally and yet has "stayed home", maintaining its corporate headquarters in Bartlesville, Oklahoma, a town of approximately forty thousand people. Based on revenues, Phillips ranks among the nation's top twenty industrial concerns and is tenth among petroleum companies. The basic business of the company as stated in company brochures is " ...to seek out and develop important natural resources and transform them into useful products." It is a fully integrated oil company but is also broadly diversified into petrochemicals. Its primary emphases as an energy company are oil, natural gas and natural gas liquids, but it has interests in such alternate energy sources as coal, oil shale, tar sands, geothermal and uranium. Phillips has long been recognized as an industry leader for its product innovations and research and development efforts. Additionally, it ranks first in the petroleum industry in the number of U. S. patents held.

CORPORATE STRUCTURE

Five primary worldwide operating groups conduct the company's activities. They are as follows:

Exploration and Production

Gas and Gas Liquids

Minerals

Petroleum Products

Chemicals

These groups are supported by a number of corporate staff groups which include those listed in Table 1. This report will focus on Corporate Engineering, the staff group within which the author's internship was served.

TABLE 1

Phillips Corporate Staff Groups

Comptrollers
Corporate Engineering
Corporate Services
Internal Auditing
Management Services
Legal Planning and Budgeting
Public Affairs
Real Estate and Insurance
Research and Development
Tax and Treasury

INTERNSHIP POSITION

Phillips' Corporate Engineering provides a broad range of services to the various operating groups within the company. These services range from detailed engineering to project management, routine testing and evaluation to "in-house" consulting. There are a number of separate divisions within Corporate Engineering with responsibility for these and other services. The author's internship was in the Process Engineering Division. This division is comprised of three branches: Refining, Petrochemicals and Gas Processing, each of which has several subsections. Figure 1 is a general outline of the division organization; the organizational location of the internship position is in the Energy and Minerals section of the Refining branch.

The general purpose of the Process Engineering Division is to provide process engineering services by preparing process designs, conducting feasibility studies and functioning as an "in-house" consulting group. Such services are provided for revisions and additions to existing Phillips' facilities as well as for proposed new facilities and for licensees of Phillips' processes. The

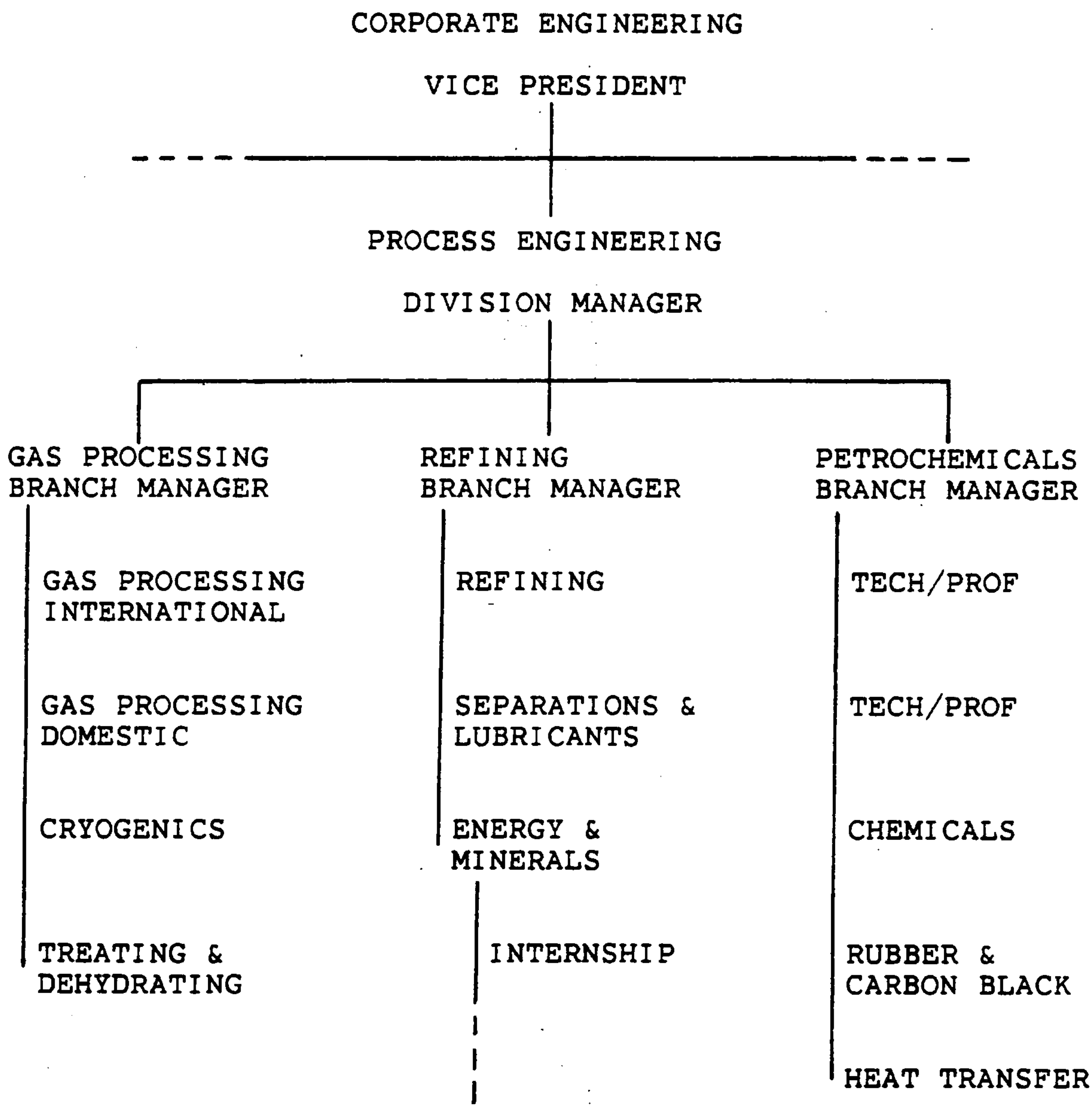

Figure 1: Organizational Location of Internship Position

goal of these efforts is to insure that all units are safely and properly designed, constructed and operated. The division is also a pool of experience and expertise, which is available to assist in solving operational problems that may arise throughout the company. In the final analysis, as a group, the engineers in the division are called on to be a collective "jack-of-all-trades." Written job descriptions do exist for the engineers but are sufficiently broad that they exclude very little that in any way relates to process engineering. The division handles a multitude of projects at any given time ranging from the mundane to those on the forefront of technology.

At the beginning of the internship, the author was assigned to the Energy and Chemicals Section. However, during the course of the year the section was split into the Chemicals Section and the Energy and Minerals Section to more accurately reflect the work that was being done. Mr. Jim Schmitz, section supervisor for Energy and Minerals, was the primary intern supervisor along with Mr. John Hutto, the Refining Branch Manager. The Energy and Minerals Section is generally responsible for projects ranging from energy conservation to the development of alternate energy sources. Projects included oil shale retort development, coal gasification and liquifaction and solar energy as well as more conventional energy sources and conservation efforts. The diversity of the projects exposed the author to current chemical process technology as well as several new, developing process technology fields. There was ample time for discussion of the broader aspects and implications of a wide range of projects, in addition to the time spent directly on the assigned projects. The lack of a chemical engineering background, in general, was not a significant handicap due largely to the nature of the assigned projects. Everyone in the division was extremely generous with their time as demonstrated by their willingness to explain various aspects of process technology when the need arose. This added tremendously to the educational value of the internship, giving the author a much greater appreciation for and improved understanding of chemical process technology.

PROJECT ASSIGNMENTS

During the course of the internship, the author was principally involved in two oil shale projects and a coal-fired boiler feasibility study. Each of these projects will be discused individually in the order that they were assigned to the author. In all three instances the projects involved much more than simple engineering calculations and resulted in exposure to many areas which simply are not covered in the classroom.

EASTERN OIL SHALE

Background

The initial project assignment was to study the available information relating to Phillips' involvement in oil shale retorting, eastern oil shale in particular. Phillips has been a participant in oil shale development for many years and is continuing that involvement in their current projects. Phillips and another firm are jointly developing a retorting process specifically designed for eastern Devonian oil shales. Western oil shales have received virtually all of the attention in recent years. The economic recovery of a valuable resource from any ore depends upon its concentration within the ore and the processing required to extract it. Different oil shales are frequently compared on the basis of their Fischer Assay. This is a combined measure of the concentration of kerogen in the rock and of the potential recovery of that kerogen, in the form of "oil", from the ore. Direct comparison of Fischer Assay data indicates that eastern Devonian shales contain significantly less recoverable "oil" than do the western shales. However, the two shale types are geologically different in many respects and, consequently, they will react differently to various processes such as assaying techniques. The retorting process typically involves heating the oil shale to a temperature sufficiently high to cause the conversion of kerogen, the organic material contained in the rock, to oil. This also drives the oil from the rock in both gaseous and liquid forms which are collected for further processing. For western shales, this process typically occurs at temperatures approaching 1000 degrees Fahrenheit and relatively low pressures. Retorting eastern shales in a similar manner typically results in significantly lower oil yields. However, a noticeable improvement in the yield has been shown to occur when the shale is retorted in a high pressure, hydrogen environment. If ultimately proven to be economical, development of such a process would result in a tremendous increase in the U. S. recoverable domestic oil reserves.

Project Organization

At the beginning of the internship, Phillips had been directly involved in the development of this oil shale retorting process for a relatively short period of time. This meant that the amount of material to read through and digest was not large. Fully understanding the process and the complex chemical and thermodynamic interactions involved proved to be a much more difficult task. That was a goal for the entire duration of the internship and was still out of reach at the end. Mr. Doug Piotter was the engineer in the Energy and Minerals section with primary responsibility for the eastern oil shale project. By working closely with Mr. Piotter, the author was able to stay abreast of the new developments and continually gain new understanding and insight into the process. This also afforded ample opportunity to "observe" and follow the management of the project. The process is being developed jointly by Phillips and the organization that originally conceived it. A third firm is supplying engineering and technical services primarily for pilot plant design. Project decisions were made by two committees composed of representatives of the three companies. As in any complex undertaking, decisions frequently had to be made between conflicting alternatives, often with less than complete, easily interpreted technical information. The motivation for each group's involvement was different and viewing the committees' decisions in the context of those underlying motivations was often quite informative. Management is often a somewhat difficult task within a given company, but management of a project composed of several companies with different goals can be a formidable and highly political undertaking.

Technical Project Analysis

Simply being generally informed about the oil shale retorting project was not the goal of the author's assignment. This retorting process presented significant engineering challenges on several fronts relative to the amount of material to be processed and the conditions that must be maintained within the process equipment. Additionally, the company's ultimate objective is not to produce a product as much as it is to make a profit, which demands an economical process. There is no doubt that oil can be extracted from eastern shale but to do so economically is an entirely different problem. A significant factor in the over-all economics is the energy consumed in the process. Equally important is the capital expenditure required to construct and maintain the plant. Both of these factors will be affected by the method used to supply the heat required to raise the rock temperature sufficiently for retorting to occur. Several alternative methods and devices could be used for this purpose. However, sufficient uncertainty existed as to the trade-offs involved, that further investigation was warranted. That investigation became the focus of the author's involvement in the project.

The specific heating method used, is a major distinguishing characteristic of many of the retorting processes being developed. Broadly defined, heating can be accomplished either directly or indirectly. Direct heating would include any process whereby the heat is supplied directly to the shale with no intermediate heat transfer medium. Indirect heating would be any process in which an intermediate medium, such as a gas, is heated external to the retort and subsequently undergoes a secondary heat exchange with the shale. The initial concept of the eastern shale retorting process included a direct retort heating mode with combustion occuring within the retort. Some coking occurs during retorting, indicating that less than 100% of the carbon content of the shale is converted to hydrocarbon form. This carbon residue was to be burned as it passed through the lower portion of the retort. The heat of combustion would thus be recovered and used to supply the heat necessary for retorting to occur in the shale above this combustion zone in the retort. Several of the western oil shale retort designs employ this method of heating in an attempt to improve the over-all process efficiency. This approach poses some significant problems when it is incorporated into the proposed eastern oil shale retort design. Typically, a gas stream is recycled through the bed of shale in the retort vessel as a heat transfer medium and/or to aid in removing the evolved product. In the eastern shale process, maintaining a high partial pressure of hydrogen, particularly within the retort zone, is essential. In order to burn the coke deposited on the retorted or spent shale without excessive hydrogen dilution, relatively pure oxygen would have to be supplied to the combustion zone. Hydrogen dilution becomes a problem if air is used as the oxygen supply due to the high nitrogen content in air. This dilution would result in raising the total system pressure in order to maintain the required hydrogen partial pressure. The retorting process as depicted in Figure 2 occurs generally as follows:

1. Cool, raw shale is introduced into the top of the retort and slowly flows downward through the vessel and out the bottom.
2. A cool gas stream, largely hydrogen, enters the bottom of the retort, recovering the residual heat left in the spent shale and thus preheating the gas stream.
3. At the coke combustion zone, oxygen is injected to burn the coke thus heating the shale above it to retorting temperature.
4. Retorting of the shale occurs and the product oil and gas is evolved.
5. The product is carried out through the top of the retort by the recirculating gas stream, to be recovered in downstream processing steps.
6. The recirculating gas is returned to continue the cycle.

Conceptually this process cycle was acceptable, but in reality several practical problems were observed. First, combustion of the coke could not actually occur without also combusting at least some of the hydrogen present. The hydrogen would be produced from an on-site separation plant at some unit cost. To first produce the hydrogen and then allow it to oxidize in simple combustion made

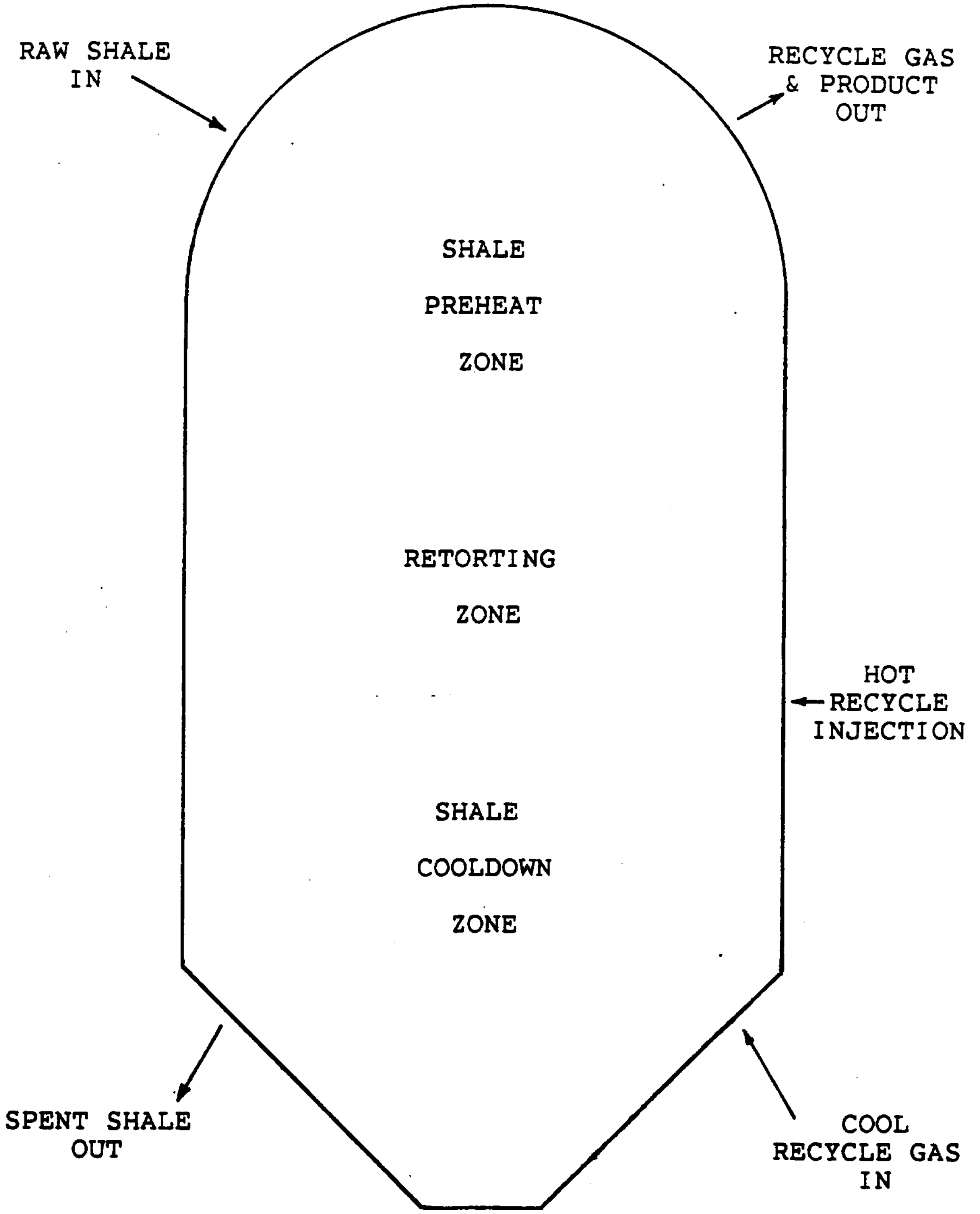

Figure 2: Oil Shale Retort Schematic - Typical

little energy sense and reflected even worse economics. A potentially more significant concern had to do with controlling such a process. Several people observed that a device with high concentrations of oxygen and hydrogen present in a combustion zone closely resembled a bomb. As a result of these and other factors, the direct heating mode was dropped in favor of indirect heating. This would be compatible with the process due to the need for a recirculating hydrogen stream to remove the evolved product and maintain the desired hydrogen concentration. A fired process heater would be used to heat the recycle gas stream to the required temperature at the retort operating pressure. The hot gas stream would then be injected into the retort vessel at the retorting zone to boost the preheated shale to the retorting temperature, resulting in product evolution from the shale. Questions soon arose as to the technical and economic feasibility of constructing a process heater capable of meeting the operating requirements dictated by the process. Due to the combination of the high temperature and pressure compounded by the hydrogen concentration level, the metallurgical ramifications were a major concern. The principal alternative to such a heater was an external combustor which would exhaust hot combustion products directly into the recycle stream to be heated. The two devices had significantly different effects on the over-all heat and material balances for the process and consequently comparing them was not a straightforward task.

Retort Simulation

The initial step in simulating the retort was to develop a sound, basic understanding of the heat and material balances from the pilot plant test data. At the time the author became involved, the project's technical committee was nearing agreement on the design case heat and material balances for the process development and engineering work that was being done. A computer model was subsequently developed by the author and Mr. Piotter based on that design case. This was not a simple task as the previous statement might appear to indicate. As the model evolved through several distinct stages, many hours were spent with Mr. Piotter analyzing the process in order to accurately reflect the many discrete elements of which it was composed. The process simulation system used to build the model was designed principally for more standard process simulation applications and numerous problems were encountered in attempting to force it to simulate a retort. It seemed that each time all the factors had been accounted for and the modeling program had once again been debugged, some new fact would come to light that would essentially invalidate the most recent results. However, these intermediate versions of the model did define the operational parameters sufficiently to allow the analysis of the heating devices to proceed somewhat independent from the model. The model allowed the study of the effects that changing various operating parameters (flow rates, temperatures, gas stream component concentrations, heating devices, etc.) within the model would have on the parameters held constant. Initially, modeling the retort answered questions about the feasibility of such a device as the external combustor. A primary concern was the potential dilution of the hydrogen stream with combustion products. Ultimately, it became a tool for comparing the over-all efficiency with which the heater or combustor would be able to supply heat to the retort. Just prior to the end of the internship, a new subroutine for simulating a combustor was developed as a part of another project with which the author was involved. This subroutine, along with several additional routines, significantly increased the versatility and usefulness of the model. At this stage, the model could compare the heater and the combustor directly on the basis of the heat actually supplied to the retort per Btu of heating value of the fuel consumed. Not surprisingly, the improved understanding of the retorting process dynamics that resulted from the model development, was as valuable as were the answers it computed.

Equipment - Availability and Estimated Costs

Simulation of the retort was an extremely useful tool in studying the process variables but it told nothing about the physical devices that would actually implement the process. Vital to the comparison of the two alternatives were such factors as their technical feasibility, their life, any maintenance requirements and their installed cost. Manufacturers of fired process heaters were located that claimed to be capable of designing and constructing a heater to fit the necessary process conditions. They willingly supplied information relating to costs and design. Information was not readily available for the external combustor because there are no known existing applications of such a device. Just as the heater must operate at a high pressure, so must the combustor. Expertise in high pressure combustion is not widespread but does exist, even within Phillips' own research and development organization. The problems associated with hydrogen dilution, dictated that relatively pure oxygen be supplied to the combustor. This conclusion was based on retort/combustor simulation results. The obvious similarity of the combustor to a rocket engine led to discussions with the Rocketdyne Division of Rockwell International. They agreed to consider the feasibility of a commercial device consisting of a combustor cooled by a portion of the gas stream being recycled through the retort. The gas would flow around the combustor for wall cooling and then mix downstream with the combustion products. The net result would be a hot gas stream, the temperature of which would be a function of the two component streams' flow rates and the specific fuel being burned. The result of Rocketdyne's study was a fascinatingly small device, simple in concept and reasonable in price on a production basis. Their letter of response is included as a part of Appendix A.

At the conclusion of the internship, there was a discrepancy in the price estimates for the process heater that had not been resolved. Although Mr. Piotter continued working to determine a reasonable estimate as part of an over-all project study, the author proceeded to prepare a report reflecting the data available at that time. The report, in its entirety, constitutes Appendix A. Based on the information available, there was no clear-cut advantage either way and consequently no definite recommendation could be made. The combustor itself resulted in a higher efficiency than the heater but information obtained from an oxygen plant vendor indicated that the energy savings would be more than offset by the energy chargeable to oxygen production. It was noted in the report that if the possibility existed to somehow incorporate oxygen production with some other process, the chargeable energy might be reduced. The capital costs were based on a demonstration-scale plant roughly one-tenth the capacity of a commercial plant. It did appear that the first combustor, including all the development and testing costs, would likely be no more expensive than a heater. The significant cost factor however, was that subsequent commercial-scale combustors would actually be lower in price than the one-tenth size demonstration unit. Prices for comparable heaters would increase roughly proportionally with their increase in scale. This fact, along with the potentially lower maintenance and longer life of the combustor, would weigh heavily in its favor. However, the final choice would depend on the over-all plant and any synergistic effects that might improve the relative merits of one device over the other.

Summary

Involvement in this project was a tremendous opportunity for the author in several respects. The entire field of oil shale retorting was a virtual unknown to him prior to his internship. The exposure to the problems of developing such a new technology was not only informative, but also challenging as explanations and solutions for problems were sought. Regardless of the physical results of these efforts, the experience obtained could not have been gained in the classroom. The model development similarly challenged the author's basic understanding of chemistry and thermodynamics and resulted in a much sounder understanding of both. As will be discussed, this experience was further enhanced by involvement in another very different oil shale project.

COAL-FIRED BOILER

Introduction

The author was assigned a second project that was quite different from working with oil shale. Due to the high cost being paid for fuel oil used to fire the boilers at a Phillips Chemicals plant in Puerto Rico, a feasibility study of conversion to coal-fired boilers was requested. Additionally, their cost for electricity was extremely high and the reliability was poor. These facts resulted in the possibility of cogenerated power being included in the study options. Initially, the author's time was again devoted as much to education as to analysis. It was necessary to become familiar with the terminology and the technology of the various aspects of such a coal project.

A number of resources were available to aid this effort including materials from a similiar study done previously for a Phillips refinery. Such material indicated the general types of information to be gathered as well as being a source of information and ideas. Because the plant was in Puerto Rico, some plant-related information was more difficult to obtain than if the plant had been nearby. As contacts at the plant were established, this problem was alleviated to a great extent and most plant personnel proved to be quite helpful. Many of the component systems in a coal-fired power plant are similar to those in a typical process plant. Consequently, there was a wealth of experience available to draw on within the various divisions of Phillips. Information sources outside the company were also established to answer questions about equipment, coal, operations and many similiar topics.

Project Scope

To adequately consider the feasibility of burning coal, the entire operation had to be considered from coal source to waste disposal. This broad scope necessitated a multi-disciplined approach drawing on the experience and expertise available within the appropriate branches of Corporate Engineering, as well as other divisions of the company. The author was responsible for co-ordinating the efforts of those involved to try to ensure the timely completion of the study. Consequently, he was able to be involved with all aspects of the project and gain experience working in something like a matrix project group organization. As the project became more clearly defined, four somewhat distinct elements emerged. These functional groupings helped the author more effectively analyze the total project and more efficiently allocate his time and the work to be done by others. The four elements are listed below and will be discussed briefly in the material that follows. A more complete discussion of each can be found in the full report which constitutes Appendix B.

1. Coal - Source and Shipping
2. Material Handling - Coal and Ash
3. Boilers and Auxiliaries
4. Cogeneration

Project Description

Coal

Virtually all large coal-fired installations are designed for a particular range of coal characteristics, if not for a specific coal. It quickly became apparent that such a selection needed to be made rather early in this study.

However, due to the preliminary nature of the study, considering specific coal sources was all but pointless. It was, however, certainly reasonable to make some assumptions and identify the most desirable range of characteristics for the coal. This depended on coal costs, shipping requirements, combustion characteristics, pollution considerations, ash and many other factors. Ultimately, a set of coal characteristics was established for design purposes which could be met by coal available on the market.

Shipping the coal to Puerto Rico proved to be one of the most difficult issues to consider. To select the size and type of vessel to be used, such key factors as the port of origin and the resultant shipping distance would have to be known. As previously stated, a coal source could not be specified for this study and consequently, little could be determined conclusively about coal shipping factors, including costs. The report did include a proposed plan that was reasonably flexible to allow its application to the project, given more specific information.

Material Handling

A great portion of the complexity of a modern coal-fired power plant is attributable to the material handling equipment. Coal must be moved to the plant, conveyed within the plant, pulverized and then burned. The resulting ash is then collected and disposed of in some manner. Each step in this sequence can be accomplished in any of several ways. Between the port and the plant for example, coal can be moved by truck, rail, conveyor, slurry pipeline or possibly even a pneumatic transport system. An assessment must be made of all options at each step to determine the advantages and disadvantages of each and to make an intelligent decision between them.

Ash collection and disposal presents similar problems. This ash is not simply a waste product to be disposed of; it often can be constructively used as a land-fill material and also has many applications in the cement industry. Such uses are strongly dependent on the chemical composition of the ash, which is a function of the particular coal from which it results. Consequently, in the project report the disposal options were only generally discussed since definitive recommendations could not be made.

Boilers

Coal-fired boilers constitute an entire field of their own. Being an oil company, Phillips' direct experience in coal-fired boilers is understandably limited. However, for the purposes of the feasibility study, it was unnecessary to be overly concerned with the details of the boiler itself. Some general criteria had to be established to define the type, size and other broad parameters of the boiler and its auxilaries for cost estimating and other considerations. Engineering firms in the business of designing and constructing coal-fired boilers were consulted often in the development of the design criteria to answer the author's many questions. Their help was invaluable and resulted in a much more accurate and complete study.

Cogeneration

As the study progressed, it quickly became apparent that the potential advantages of cogeneration were sufficiently significant to make its inclusion virtually imperative. Electric power supplied to the plant was not only expensive but also unreliable. The Puerto Rico Electric Power Authority had practically no available excess capacity; consequently, the plant was subject to fairly frequent curtailments. This can cause unacceptable operating problems in a chemical process plant and any efforts to alleviate this problem would likely be very desirable to pursue. The author presented this material to the original requestor of the study and it was agreed that the cases that would be presented for actual cost estimates should include cogeneration.

Summary

The final project report is included as Appendix B and addresses each of these areas in greater detail. The project as a whole was almost ideally suited to the author's interests and internship objectives. It provided a good framework to experience the group oriented approach to engineering problems as well as some opportunity to direct that effort. The author occasionally had to do some subtle lobbying to encourage others to place a higher priority on this project than the other pressing projects also vying for their attention. There was perhaps no better way to become familiar with the resources available within the company than by being given the responsibility for this type project. The author discussed nearly every aspect of the project with outside firms for advice, information, ideas, experience and equipment information. This exposure was invaluable to the project and it significantly enhanced and broadened the author's personal education as well. This project, like the one previously discussed, was both technically challenging and educational. The author applied and enhanced his basic understanding of steam cycle thermodynamics in the context of a "real world" problem. In a much broader view, the exposure to the wide ranging aspects of the project, from coal source to the steam and power delivered, should be tremendously valuable.

WESTERN OIL SHALE

Introduction

Shortly before the end of the author's internship, he had the opportunity to help with work being done in connection with a western oil shale project. Phillips is one of three partners in a company formed to develop certain western oil shale deposits. Project plans call for the staged construction of a number of individual retorts of several different designs. A large sample of shale was supplied to a retort design licensor for tests essential to their design process. As these tests progressed, some unexplained phenomenon was observed and an effort was mounted within the appropriate Phillips' groups to investigate further. The author was primarily involved with the development of a computer model to simulate both the tests that were being run and ultimately the retort itself.

Analysis

This particular retort was physically very different than the device being developed for eastern shale. The retorting concept was not significantly different but the sequence of events was certainly different. The western shale retort model being developed also differed radically from the eastern shale retort model discussed previously.

It was for the author, however, an excellent means of developing an understanding of this particular retorting technology and the advantages and disadvantages associated with it.

Several subroutines had to be written for the model and the author assisted in the debugging phase as the various routines were combined. One routine, after being given the fuel and oxidizer stream flows, compositions and conditions, simulated an equilibrium combustion process. Exhaust gas composition and state properties were determined and supplied to subsequent subroutines. The author was also able to use this routine with the eastern shale retort model described elsewhere in this report to significantly enhance that model's utility.

Summary

Although the author's direct involvement in this project was brief, he had become somewhat familiar with it through informal discussions throughout the internship. The opportunity to become more directly involved allowed him the chance to obtain a more detailed knowledge of the retorting process under primary consideration at the time, as well as the project as a whole. The two oil shale projects exposed the author to many of the broader aspects of that part of the synfuels industry: its possibilities, problems, potential solutions and the results that may one day be realized.

SUMMARY

The author's internship with Phillips Petroleum Company exposed him to unfamiliar fields and new challenges. The job assignments primarily involved familiar concepts applied to those unfamiliar fields. This resulted in both an educational and technical challenge. The author's primary field of interest is energy, from source to end use. Although coal is widely used as an energy source, he was largely unacquainted with the technical aspects of its use. Direct involvement in a coal project provided the author with an opportunity to develop a basic understanding of the associated processes, equipment, advantages and disadvantages. His background in synfuels technology was superficial at best, particularly with respect to oil shale. Through the two oil shale projects, he was able to develop a fundamental understanding of the use of this abundant energy resource and its role in the over-all energy picture.

The internship as a whole was a valuable addition to the author's education. Working in the Process Engineering Division and being constantly exposed to a variety of chemical process related projects significantly enhanced his knowledge of and respect for that engineering discipline.

CONCLUSIONS

In the author's opinion, his internship with Phillips Petroleum Company was an unqualified success. As the material presented in this report demonstrates, the internship objectives were all met or exceeded. The position in the company was commensurate with both his previous work experience and technical background. Job assignments and the working environment both proved to be challenging. Most of all, the internship was an enjoyable experience due largely to the people with whom the author worked.

Appendix A

EASTERN OIL SHALE RETORT HEATING

December 15, 1981

INTER-OFFICE CORRESPONDENCE / SUBJECT: HYTORT Retort Heating Alternatives
BARTLESVILLE, OKLAHOMA

Jim Schmitz
Office

The attached report summarizes my work investigating the development and use of an external combustor as an alternative for supplying retort heat in the HYTORT process. Until the cost of a fired heater is determined more accurately, it will be hard to compare the two directly. The device proposed by Rocketdyne is intriguing and may have applications in other areas as well. The major economic drawback appears to be the oxygen supply because the combustor's higher efficiency doesn't appear to offset the energy cost of oxygen production. This device is, however, rather simple with very low expected maintenance and long service life. There is no clear-cut, obvious advantage either way at this point between the heater and combustor. Each has good and bad points and careful consideration should be given to all the relevant factors prior to a decision.

Craig D. Harrington

~~C.~~ D. Harrington

abv

cc: J. F. Hutto
(r) File:E19586.00 - RC
D. R. Piotter

External Combustor For Retort Heating

In the early stages of Phillips involvement in the HYTORT oil shale retorting process development work, the retort heating method was conceived to be controlled combustion within the retort vessel itself. The direct heating approach has several significant drawbacks, and as a result, was finally dropped in favor of an indirect heating mode. Direct heating consumed valuable hydrogen and required relatively pure oxygen, rather than air, be supplied to minimize the nitrogen dilution in the process gas stream. Maintaining controlled combustion in the retort bed in an oxygen-hydrogen mixture seemed risky at best and the "bomb-like" nature of the design was cited more than once.

Indirect heating is an improvement, but is far from being the perfect solution. Fired heaters capable of meeting the temperature-pressure requirements of the process gas stream can be designed, but due to the high hydrogen content of that gas stream, they are exotic. Concern over the feasibility of such a heater and an interest in achieving the highest possible operating efficiency, resulted in the investigation of an external combustor as an alternative to the fired heater. This device would pass the process gas stream around the combustor walls to preheat the stream. It would then mix the flue gases with the preheated process gas to achieve a given outlet stream temperature and flow rate.

The total economics of the HYTORT process are adversely affected by increased total retort system pressure. The critical variable is the hydrogen partial pressure and adding diluents to the process stream has the immediate effect of raising the total pressure. A computer simulation of the retort heat and material balance was developed and employed to determine how a combustor would affect the balance. Total pressure could only be maintained at acceptable levels by consuming a high purity oxygen stream in place of air, and thus reducing the nitrogen introduced into the system. Oxygen plants and sources of supply were of three types: cryogenic, Pressure Swing Adsorption (PSA), and supply contracts. In a commericial scale plant the cryogenic option would likely be chosen over the PSA unit due to its lower operating costs and higher purity products (95% vs. 90% purity O_2). The 95% purity was therefore selected for the remainder of this study.

Given that the combustor is compatible with the system constraints and knowing the available oxygen purity, a detailed comparison of efficiencies can be made. The heater and combustor were also simulated with computer programs which allow the two to be directly compared on the basis of the heat actually supplied to the retort by the heated recycle gas stream. The model allows the temperatures of all streams to be set as well as the heat duty to be supplied to the retort. The flow rates of the streams are then determined to converge on the temperature set points. An efficiency is then calculated as the ratio of the heat actually transferred from the recycle stream in the retort and the total heat of combustion available in the fuel.

For the purpose of comparison, the heater was assumed to have an overall efficiency of 88% including stack losses and an excess combustion air requirement of 10%. The combustor was assumed to be 96% efficient excluding stack losses with a 2% excess combustion oxygen requirement. These numbers were obtained from manufacturers of the types of equipment being considered. Methane was chosen as the fuel for comparison due to the ease of hand checking the combustion calculations. The heat duty supplied to the retort was 15 MMBTU/Hr in both cases. The exit and inlet temperatures for all streams were also the same for each device.

The program calculated an efficiency for the heater excluding stack losses of 94.6% by backing out the heat loss in the flue gases. Based on the 1.4% difference in these efficiencies, the calculated system efficiencies for the combustor and heater were 82.4% and 76.2% respectively. The difference between the numbers is primarily a result of the large volume of heat carried out of the system by the nitrogen in the flue gases. The combustor efficiency does not include the energy consumed in supplying the oxygen or in bringing the fuel and oxygen up to pressure. The oxygen alone, supplied at 800 psia, will have an energy cost of 1200 Btu/#, totaling 4.3 MMBTU/Hr for the 15 MMBTU/Hr duty supplied in this comparison study. The energy required for pressurizing the fuel will depend on whether a liquid or gaseous fuel is to be used. The energy savings of the combustor as compared to the heater amount to 1.5 MMBTU/Hr. Even ignoring fuel compression, the energy savings alone do not justify the combustor. However, if oxygen could be supplied at a lower chargeable energy cost, by recovering the nitrogen for other plant uses for instance., then the outlook could change. It appears that only some synergistic relationship with the total plant would allow the combustor to compete with a carefully controlled, efficient furnace.

A request for proposal was sent to Rocketdyne for consideration and their reply is attached. They did sufficient design work to determine their interest and capability for producing such a device. The estimate of the cost for a demonstration scale first unit, designed and tested, turnkey is \$525,000. Subsequent commercial scale units would cost roughly \$275,000 each. The cost of oxygen supplied to the plant for the 15 MMBTU/Hr comparison duty amounted to \$1.6 million/yr based on a two year oxygen plant life, continuous use, and electricity @ 3¢/kwh for all power requirements. A letter from Airco Industrial Gases relative to oxygen plant costs, etc. is attached.

Part of the initial impetus behind this project was a feeling that the severe conditions a heater would be required to meet might be beyond reasonable economic or metalurgical limitations. On the contrary, this has not been the case, although it would not be an ordinary furnace by any means. The capital cost of the furnace is still being determined. There was a rather wide discrepancy in the early estimates and consequently a second look is being taken.

All indications at this time place the two devices at roughly the same total installed cost and energy consumption. Until the final cost and operating information is in hand, a final comparison will not be accurate.

klm:015

AIRCO Industrial Gases

575 MOUNTAIN AVENUE, MURRAY HILL, NEW JERSEY 07974 • TELEPHONE: 201-464-8100

October 13, 1981

Mr. Craig Harrington
Philips Petroleum Company
10B2 PB
Bartlesville, Oklahoma 74004

Dear Mr. Harrington:

This will confirm our recent telephone discussion regarding oxygen supply systems for use in your proposed shale oil recovery project.

To meet your requirements of 1.5 tons of oxygen per hour delivered at 750 to 800 psi, we suggest consideration to the following:

1. PSA Oxygen Plant

   Airco offers an oxygen generating plant based on the Pressure Swing Adsorption (PSA) principle. This process uses selective adsorption at elevated pressure to separate oxygen from air. By "swinging" the system to low pressure, the undesired components on the adsorbent are released to the atmosphere, and the process is ready to start again. The entire system operates at ambient temperature. Product is produced at 90% purity at pressures up to 45 psig. Full product purity is attained in 30 minutes.

   To achieve the 750-800 psig product pressure required for your process, we would add an oxygen product compressor. Machines for this application are not usually stocked and therefore have a lead time of at least 14 to 15 months. We would use an electrically driven machine of four stages, with appropriate intercoolers and pulsation dampeners.

We currently estimate an installed price of $1,655,000 for this system including oxygen generation and compression and a lead time of about 18 months is required to make product available in the field.

An important aspect of the PSA oxygen plant is that it can be started and stopped rapidly. Therefore, unlike cryogenic plants, it can be operated intermittently. The PSA plant can also be operated over a wide range of production with proportional decrease in power as throughput is reduced. Thus, the PSA oxygen plant can track the load and conserve power when oxygen demand is low.

PSA plants are shop fabricated and skid mounted for ease in transport and installation. A plant capable of delivering 1.5 tons per hour would probably be built on three skids with final piping connections made in the field. However, plants of this type are relatively easy to move if relocation is necessary. Power and cooling water are the necessary utilities and in some circumstances cooling water can be eliminated by use of air cooled compressors.

2. <u>Cryogenic Oxygen Generator</u>

Airco also offers cryogenic oxygen generators which deliver 95% purity product. These plants employ low temperature distillation to effect the separation and deliver product at low pressure. The same type of oxygen compressor as proposed for the PSA plant would be required to boost product pressure to 800 psig from the cryogenic plant.

We currently estimate an installed price of $2,155,000 for the system and a lead time of at least 18 to 20 months.

Unlike the PSA plants, cryogenic generators take several days to start and shutdown. Therefore, they are not suited to intermittent operation. In addition, although fabricated in modules, erection and assembly require several months in the field.

3. <u>Economics</u>

Recognizing that your project will be of short duration, I have estimated the cost of oxygen for one and two year periods for each type of plant, based on the following assumptions:

Mr. Craig Harrington
Page 3
October 13, 1981

- Product is used at the rate of 1.5 tons per hour, 24 hours per day, 350 days per year.
- Power is available for 3¢/Kwh.
- Entire capital is depreciated over the 1 or 2 year operating period.
- Cost of capital, maintenance, labor, insurance, spare parts, etc., is not included.
- Power costs include product compression.

Cost of product from the above plants is as follows:

Plant Type	Cryogenic		PSA	
Operating Period	1 year	2 years	1 year	2 years
Fixed cost based on capital, cents/ccf	70.7	35.4	54.3	27.2
Power cost, cents/ccf	8.3	8.3	12.0	12.0
Total cost, cents/ccf	79.0	43.7	66.3	39.2

Because the capital associated with the PSA plant is lower than the cryogenic plant, the higher operating power cost can be tolerated. If the project life is likely to be longer than two years or the cost of power is appreciably higher than 3¢/Kwh, the cryogenic plant will be favored economically.

Depending on the plant location and general business conditions, in addition to outright sale of the oxygen plant, Airco may be willing to offer the following alternatives:

Gas Supply Contract

In this type of arrangement, Airco will provide a plant at the Philips' site. The plant will be dedicated to provide oxygen for your use in return for a monthly fee. Included in the Airco scope is supply of the plant, erection in the field, operation and maintenance, spare parts, replacements, etc. At the end of the contract period, Airco will remove the plant or renew the contract.

Mr. Craig Harrington
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October 13, 1981

Repurchase Agreement

After completion of the Philips project, Airco will have the option to repurchase the plant at a price related to its age and condition.

With the limited information available, I believe that the factors not included in my calculation of product cost are about equal to the cost benefits of the supply contract or repurchase agreement. A more rigorous estimate will be possible when more information regarding the circumstances of the project are available.

I trust the above provides sufficient information for your current evaluation. If you need additional information or you would like to discuss this project in greater detail, I would be happy to be of assistance.

Very truly yours,

Arthur M. Feibush
Sales Manager
On-Site Products

AMF/sk

cc: W. Deegan/Airco Houston

Rockwell International

Rocketdyne Division
6633 Canoga Avenue
Canoga Park, California 91304

Telex: 698478

In reply refer to 81RC12516

Phillips Petroleum Company
10 B-1 Phillips Building
Bartlesville, Oklahoma 74004

Attention: Mr. Craig D. Harrington

Subject: Rough Order of Magnitude ("ROM") Proposal
Oil Shale Retorting Process Combustor

Reference: Phillips letter dated 1 June 1981

Gentlemen:

In accordance with the referenced letter, we are pleased to submit our Rough Order of Magnitude estimate to provide a high pressure combustor for use in Phillips development work involving a high pressure oil shale retorting process.

As requested in the referenced letter and as further described in the enclosed technical discussion, we propose to provide a demonstrator unit in 1983 at an ROM price of $525,000 and twelve full scale units in 1985 at an ROM price of $275,000 per assembly. We estimate that delivery of the demonstrator unit could be made twelve months after program commencement, and that delivery of the 12 full scale units could be made twelve months after receipt of an order for those units.

It should be noted that the estimates quoted herein are for budgetary and planning purposes only and are not to be construed as firm commitments on the part of Rockwell International Corporation.

Should there be any questions of a business nature, or when a firm proposal is desired, please contact Mr. D. B. Vandiver at (213) 700-4506.

Very truly yours,

ROCKWELL INTERNATIONAL CORPORATION
Rocketdyne Division

A. T. Fiore
Vice President & Controller
Finance & Administration

RW:kk
1-1532-A

Enclosure: (1) Technical Discussion (2 copies)

Rockwell International Corporation
Canoga Park, California

Enclosure (1) to
Letter 81RC12516

TECHNICAL DISCUSSION

OIL SHALE RETORTING PROCESS COMBUSTOR

As requested in Phillips Petroleum RFP letter of 1 June 1981 from Mr. C. D. Harrington, it was requested that Rocketdyne investigate the feasibility of providing a high pressure combustor to use as a direct fired heat exchanger in Phillip's high presssure oil shale retorting process. Below is a Rocketdyne Technical discussion in response to that request.

We at Rocketdyne believe that such a combustor is feasible and potentially competitive with process heaters over the range of operations as specified in the RFP. We have done preliminary design work in the demonstrator plant size for heating one pound per second of process gas (15 x 106 BTU/hr input) and in the full size for heating seven or eight pounds per second (100 x 106 BTU/hr). (We understand that 12 to 15 full size combustors would be used in a full size plant.)

Thermal and stress limitations are the most severe constraints on the design of such a combustor. The most severe level of thermal stresses will exist with combustion of fuel with pure oxygen. Thus our preliminary calculations have been based on the use of #2 fuel and pure oxygen. Operation with oxygen having some nitrogen diluent will be less severe and will only require some changes in combustor design details with no change in the design and development effort.

To hold down costs, the design concept for this combustor has been kept simple. One of the major techniques for achieving simplicity is the insert approach. For the demonstrator unit, the combustor is a simple single insert which can be placed inside a pipe carrying the hydrogen rich process stream. The process stream goes around the outside of the combustor and provides cooling for the combustor walls. Combustion products are then mixed with the process stream in an internally insulated section downstream of the combustion region after combustion is complete. For the full sized unit which requires 7 or 8 times as much process stream flow and combustion heat, the combustion region is made up of 7 inserts inside a larger process pipe. Each of these combustor devices is identical to that to be developed for the demonstrator unit. Again, combustor wall cooling is obtained by passing the process stream around the outside of each combustor. Combustion gases are mixed with the process stream downstream of the combustors in an internally insulated pipe.

The demonstrator unit will be about 4-1/2 inches in diameter by 6 feet long, flanged at both ends. Most of the length is taken up with the mixing process. If less complete mixing is required, the unit can be shortened. The combustion and injection manifold is less than 2 feet long. The full scale unit is about 18 inches in diameter by 7 feet long. Again, the length is largely devoted to mixing. These characteristics are summarized in the table below.

Rockwell International Corporation
Canoga Park, California

Enclosure (1) to
Letter 81RC12516

TECHNICAL DISCUSSION

OIL SHALE RETORTING PROCESS COMBUSTOR

DIRECT HEAT EXCHANGER DESIGN SUMMARY

Process Stream Flow Rate 16/sec.	Heat Input BTU/hr	Heat Exchanger: Pipe Outside Diameter Inches	Heat Exchanger: Maximum Length Feet
1	15×10^6	4-1/2	6
7-8	100×10^6	18	7

Simplicity and reliability have also guided the selection of the ignition technique for the combustors. The selected technique is the use of a pyrophoric fluid, triethylboron (TEB). This fluid ignites immediately upon contact with air or oxygen over an extremely wide range of pressure and temperature conditions. TEB and mixtures of TEB with other fluids have been used extensively by Rocketdyne for igniting rocket engines under a wide range of conditions. It is presently planned as the technique for igniting our downhole steam generators.

Controls for the heater have also been kept simple. It has been assumed that the process stream flow rate is essentially constant and that the combustor fuel and oxidizer flows may therefore also be held constant. Constant combustor flows will be held with simple orifices when supply pressures are held constant. In the event that you require a wider range of operations, active controls can be applied to the combustor. Present cost estimates have assumed the minimal control scheme. Control valves and timer have been included for the ignition system.

The heater is shown schematically in Figure 1. Flow rates shown are those for initial demonstrator unit based on heating 1 lb/sec of process stream flow. Flow rates for the full size heater would be about 7 times those values. Pressures would be comparable in both cases. The process stream pressure drop shown (85 psi) is based on preliminary analysis and is conservative. Further analysis should make it possible to reduce this value somewhat. The use of 90% pure oxygen will also allow some reduction in process stream pressure drop because of reduced combustion temperature and heat flux.

Rockwell International Corporation
Canoga Park, California

Enclosure (1) to
Letter 81RC12516

TECHNICAL DISCUSSION

OIL SHALE RETORTING PROCESS COMBUSTOR

We would like to point out that the design concept described here, a direct fired heat exchanger using a submerged combustor, has great versatility. It can be applied with various process streams, various fuels and oxidizers, and at varying pressure and temperature conditions. Rocketdyne has extensive experience with combustion of various high energy propellants at pressures to 8000 psia and at temperatures in excess of 7000°F.

It presently appears that a demonstrator unit could be provided in the 15 x 10^6 BTU/hr size at a ROM estimated price of $525,000 within 12 months of receipt of order. This unit will have been tested at full combustor flow conditions with an alternate coolant and at half flow with hydrogen as the coolant. Testing at full hydrogen flow rate is possible but will add about $300,000 to the ROM price elsewhere herein.

To produce and deliver 12 fully tested assemblies each rated at least 100 x 10^6 BTU/hr, we estimate the price at $275,000 per assembly. This ROM price is based on using the combustor and injection inserts developed for the demonstrator unit. Because of this limit on development testing, we also believe we could deliver the 12 units within 12 months of receipt of order. Each unit will have been tested at full hydrogen flow.

Should you prefer to have a single large combustor to provide the full 100 x 10^6 BTU/hr, this could also be provided. Since it involves additional design and development expense and time, such a unit would cost somewhat more and take a little longer than the suggested approach.

A final advantage to the suggested modular insert approach should be mentioned. Control of heat output in steps of 1/7 of the rated output is easily possible by shutting off individual inserts. This gives a wide possible range of operation with simple control equipment.

Appendix B

COAL-FIRED BOILER FEASIBILITY STUDY

March 23, 1982

cc: J. F. Hutto
(r) J. A. Schmitz
(r) File:E35055. (RC)
W. F. Tuckett wo/a

INTER-OFFICE CORRESPONDENCE / SUBJECT: Puerto Rico Coal-Fired Boilers
BARTLESVILLE, OKLAHOMA
Corporate Engineering

Tracy T. Word (3)

The enclosed material is my report on the feasibility of installing coal-fired boilers in the Phillips Puerto Rico Core Plant. Cost estimates for the two selected cases are included. The estimates are noticeably higher than the preliminary estimate we discussed several months ago which was prepared by General Electric. I suspect that GE's cost estimate data is not as accurate as they indicated it was. The estimate from Campbell, Deboe & Associates was based on current similar projects and was the basis for our final estimate.

Total estimate installed cost:	Case I	$ 91MM
	Case II	$115MM

These costs include a 20% contingency and escalation of 30% based on an engineering and construction period of 7-1-82 to 7-1-85. The accuracy range of this feasibility estimate is considered to be -15% to +40%.

Case I provides for generation of entire plant demands for power and 600 psi steam based on current operations. Case II includes the Case I requirements plus the additional power and steam for a STAR Unit processing 10,000 BBL/D of raffinate. Fuel for the STAR heaters is not included.

The two cases were selected on the results of the GE study and their estimates were assumed to be accurate. In light of the significantly higher final number, the report also includes some options for altering those cases to improve the project economics.

Craig Harrington
Craig D. Harrington by JMS

CDH:klm:015
Attachments

PUERTO RICO CORE - COAL FIRED BOILER

CASE DEVELOPMENT

The primary sources of energy for Phillips Puerto Rico Core are fuel oil, electricity and plant gas derived from feedstock processing. The price of fuel oil heavily impacts the economics of the plant due to both direct purchases as fuel and indirect purchases as electricity. The primary fuel consumed by the Puerto Rico Power Authority is fuel oil and likely will be so for some years to come. This heavy dependance on an increasingly more expensive fuel led to this study of the feasibility of installing a new coal-fired boiler plant possibly designed for cogeneration. The final cases selected for cost estimates do not reflect the consideration given to other alternative system designs. These alternatives and their comparative advantages and disadvantages are detailed in the following material. Hopefully this will provide some direction to any further work done on this project. The final cases submitted for cost estimation are described in Attachment #1.

The original scope of the study was to consider coal-fired boilers to supply steam under four possible scenarios:

I. Present process steam requirements
II. Present plus STAR process steam requirements
III. Present process plus cogeneration steam requirements
IV. Present plus STAR process plus cogeneration steam requirements

To facilitate work on the project, it was divided into four functional areas:

A) Coal supply (landed price at the port)

B) Materials storage and handling

C) Boiler plant and auxilaries

D) Cogeneration equipment requirements

Each of these areas in turn will be discussed individually, however, the interdependant nature of them all should be kept in mind.

A. Coal Supply

The issue of coal supply cannot be covered in any depth as a part of a feasibility study of this nature. It is a complex area involving multi-year supply contracts, widely varying coals in both composition and price, and transportation uncertainties ranging from point of origin to the size and frequency of loads to the cost per ton delivered. Should this project be seriously pursued past this initial phase, the subject of coal supply must be one of the first to be tackled. Much of the actual design is dependant on various coal properties which vary widely between coal deposits and at times even within deposits. The type of coal and its analysis must be determined early in the project and it may be necessary to make contractual agreements to insure supply. It is possible to design for a range of coals and would be advisable to do so, but the coal selection process must still occur early to define that range with available, economical sources.

Given the point of origin, the mode of transport can be selected. The study was predicated on the use of ocean going barges as this seemed to be the tonnage range that fit the consumption rate. Ships would require expensive port facilities capable of high unloading rates to minimize demurrage charges. This equipment would be infrequently used and large coal storage capacity would be necessary. Several operational options exist with barges, ranging from a complete supply contract with another firm for coal delivery to our port, to the purchase of barges and contracting for tug service. As coal becomes more widely used in the Caribbean area the possibility of chartering or contracting for services in conjunction with another consumer might be beneficial to both parties. The most challenging aspect of the transportation problem is these logistic timing problems in maintaining a stable supply with minimum storage requirements.

All attempts to determine costs on any meaningful basis bore little fruit. For coal delivered from Columbia (~600 miles), estimates varied from less than ten to more than thirty dollars per ton. There is currently no trade in that area in barged coal and consequently no direct comparisons are available. The various costs associated with coal supply are finally only determinable once it is possible to seek commitments from the companies. This aspect of this study will have the greatest degree of uncertainty.

The Phillips Coal Company did a survey of coal sources and prepared an estimate of landed costs per MM Btu for several source regions (Att. #2). For purposes of the study the high end of the price range indicated in their report was used, placing the price at the hopefully conservative figure of $2.50/MM Btu ($48/ton). Their estimate was based on a low-sulphur coal of roughly 10% ash and 12,000 Btu/Lb.

A source within Dravo reported that they are currently negotiating with a Caribbean firm to deliver 3% sulphur, ~12,000 Btu/# coal for $2.50/MM Btu ($48/ton) ($30/ton FOB Mobile, $18/ton freight) from Alabama.

B. Materials Storage and Handling

As discussed in the previous section, coal is assumed to be shipped via ocean-going barge to Puerto Rico. The two ports that might reasonably be used for coal are the Puerto de las Mareas harbor and the barge wharf used during plant construction. The barges would draw at least 19' of water and could easily navigate the channel into las Mareas. The barge wharf channel is only maintained at 15' and likely would be difficult to maintain at a greater depth. This effectively eliminated it from consideration even though a suitable area for coal storage was located nearby. In order to accommodate coal barges in the las Mareas harbor, a barge wharf would have to be constructed. The location selected appeared to involve the least amount of work to construct and would minimize interference with the primary port operations (Att. #3).

It is desirable both economically and environmentally to handle the coal as little as possible. Outdoor storage would require that the coal be unloaded from the barge, transported to the storage site, and then reclaimed for delivery to the plant. Storage could be located at the port, at the plant or at an intermediate site. In order to minimize demurrage, the coal would have to be unloaded reasonably rapidly and moved to storage. This would require a relatively high volume, infrequently used conveying or trucking operation if the storage was not at the port. The high capital cost and low use factor of this approach makes it impractical to consider storage other than at the port. An analysis of the information available here and discussion with people familiar with the port, led to the conclusion that storage on land was also rather impractical due to space limitations and the load bearing capability of the soil. The result was the suggestion of floating storage in place in the barge. This would require two barges, one in transit while the other remains in port and would accumulate daily port fees unless special rates could be negotiated. A letter was sent (Att. #4) to the port manager for information pertaining to the applicable fees, however no reply was received. The optimum barge capacity would equal roughly the daily coal consumption rate multiplied by the number of days per barge round trip. This would make it possible to contract for a tug on a full-time basis, thus assuring its availability. While larger loads might be more economical, the logistics of tug availability must be considered. Although the floating storage concept does tend to constrain the load size, it also offers some significant advantages. Environmental problems of fugitive dust and water runoff, which open storage suffers from, would be reduced or eliminated. Such barges are covered with movable lids which could be removed only as needed to unload the coal, protecting the remainder from the environment. Coal handling would be reduced to a minimum since the coal would only be handled once and moved directly to the plant coal bunkers. Further investigation may reveal fatal flaws in this plan but at present such an approach seems to be optimum.

The only feasible means of unloading the barges is a crane with grab bucket unloaders. A small wharf bulkhead would be constructed with room for the crane and whatever additional equipment might be necessary. A series of dolphins would then complete the barge wharf and a barge positioner would be used to move the barge past the crane as it is emptied.

Once unloaded, the coal must be conveyed to the plant. The distance is much too short for a slurry pipeline to be economical and the consumption rate is too small for an economical conveyor. This leaves trucks as the remaining primary means of transportation. With the exception of a short distance inside the port area, there is already a good, heavy duty road to the plant from the port.

Coal conveying from the truck unloading point to the coal bunkers could be done several ways. Mechanical conveyors of all sorts are the more conventional means, however, the alternative of pneumatic conveying systems should be considered carefully as they appeared to offer several advantages over conventional mechanical conveyors. They are potentially more reliable, help maintain a cleaner plant and are less mechanically complex than other available conveyor systems. The various makes of conveyors should also be compared as they vary in their approach. The same factors apply to the fly and bottom ash conveying systems.

Ash disposal also falls in this area but is another area of uncertainty. All indications are that virtually all of the ash should be marketable if reasonable care is taken in the coal selection phase relative to the ash composition. There is a large enough cement industry on the island to absorb all the ash for use in cement. It should be noted though that the cement industry is also moving toward burning coal there and would likely use their own ash first. There should still be a ready market though, greatly reducing the need for a large disposal area. The ash can also be used as a land fill material if suitable areas can be found. Some careful study in this area could eliminate the need for an ash disposal area and possibly even result in a positive cash flow. Due to these factors and the difficulty of determining land costs, an ash disposal site was not included in the cost estimate. Use, rather than disposal, would be by far the most attractive alternative. The costs or profit from this approach however, cannot be determined at this stage. An estimate of the total quantity of ash produced per year would be roughly 12-18 acre-feet with Case 1 near the low end and Case 2 near the high value.

C. Boiler Plant and Auxiliaries

The boiler is the central element in the system and as such its design criteria are established by the rest of the system. The steam flow rates and conditions for the four initial cases were determined first. In the first two cases, this presented little difficulty, but with the inclusion of cogeneration the problem became more complex. The steam conditions influenced steam flow rates, boiler type and the net electrical power generated. The section on cogeneration outlines the factors which resulted in the boiler design criteria used in the study. The size and application of the boiler plant motivated the choice of pulverized coal firing over stoker fired.

For the purposes of a feasibility study, the boiler plant becomes somewhat of a black box demanding little concern for detail. This is certainly not the case if a more detailed design phase is undertaken. The most important questions to be answered for this study were simply the general coal type, steam flow rates and conditions and general background information.

Additionally, for this study, low sulphur coal was assumed as fuel. Puerto Rico is apparently exempt from the New Source Performance Standards (NSPS) which would require removal of 90% of the sulphur in the coal. The applicable standard then would be to release a maximum of 1.2# SO_2/MM Btu of fuel fired. Coal is available which can meet this requirement and therefore eliminate the need for sulphur scrubbing equipment which is capital intensive and difficult to operate well. Such equipment was not considered in this study.

D. Cogeneration Equipment Requirements

The initial set of four cases can be expanded dramatically if all the possible cogeneration options are included. A variety of temperature and pressure combinations are feasible as inlet conditions to turbines.

Condensing, non-condensing and extraction turbines must be considered and each will affect the steam flow rate and net power generated. General Electric proved to be the key to unlocking this maze of possibilities by doing an incremental economic analysis of the most promising cogeneration options relative to a coal-fired plant providing only process steam. The G.E. report provided several critical pieces of information including:

1) The economic benefits of cogeneration are such that to not cogenerate is impractical.

2) The benefits of an 1800 psig turbine over a 1500 psig turbine do not justify the more stringent operating requirements.

3) The price of electricity is sufficient to justify the expense of providing the capacity to supplement cogenerated power and supply the total plant requirements.

4) The added investment for three 50% size boilers over one 100% boiler is relatively small.

On the basis of this information, two cases were selected to complete cost estimates for. The cases were essentially the third and fourth of the original four with slight modifications. The case that includes the STAR unit will ultimately require more careful analysis to better determine the steam requirements of the total plant. It does however, raise the real possibility of having excess power available for sale to the utility if acceptable terms can be arranged. The spare boiler will provide a backup for steam requirements but no backup is included for the turbine-generator. This means that the plant must still depend on the utility as a backup source of power should the turbine fail. The spare boiler does present another alternative which might be explored at a later date. The power company's spare generating capacity is very small and outages do occur from time to time. The Power Authority plans for the construction of a new coal fired generating station it seems, are still in limbo at best, indicating that they may have little opportunity for relief from their capacity problem. If in fact this is the case, Core should consider a mutually beneficial arrangement whereby the spare boiler could be fired and the steam supplied "across the fence" to the power company to power a turbine-generator and add twenty to forty megawatts to their generating capacity. Should one of the primary boilers go down the spare would revert back to supplying the plant's steam requirements.

The cost estimate from Campbell, DeBoe and Associates calls into question the fourth item listed in this section. The G.E. study indicated that the total capital investment would be much lower and the added expense of three 50% size boilers over a single 100% sized boiler was minor. Depending upon the accuracy of the C.D.&A. estimate, this assumption may be invalid. The remaining three points are likely still valid although they should be reviewed in the light of the final cost estimate.

E. Possible Project Alternatives

The cost estimate obtained from Campbell DeBoe and Associates was on the order of twice that supplied by General Electric in their less rigorous analysis. The request to CD&A was based largely on the results of the GE study and therefore the following options are presented as ways the two final cases can be modified to improve the project economics.

The capital investment could be reduced by erecting two 50% size boilers and maintaining a portion of the existing boiler capacity as backup.

This also requires a greater dependance on the Puerto Rico Electric Power Authority (PREPA) for backup electric power, particularly in the case that does not include the STAR unit. This should reduce the investment in the boiler plant proper by very nearly one third. The obvious tradeoff is that the plant would not be quite as self sufficient.

A second option would be to consider an arrangement whereby Core sells steam "across the fence" to PREPA. A possible arrangement would be for PREPA to install a steam turbine generator set nearby the plant and buy excess 1500 psia steam from Core. The steam would be supplied by the backup boiler with the understanding that should it be required for plant operations, the steam will be diverted back to the plant system. This arrangement could be beneficial to both parties. It would provide PREPA with a new source of relatively inexpensive power while providing Core with a new source of cash flow to pay out the spare boiler. Core also would have the advantage of a hot standby boiler which can be on line quickly to pick up plant load.

klm:015

Attachment 1

PUERTO RICO COAL-FIRED BOILER
FEASIBILITY STUDY

Case 1 - Current steam and electrical power requirements

- 1500 PSIG/950°F Inlet to turbine
- 3-220,00#/hr boilers (one spared)
- Pulverized coal/oil/gas fired
- Single Automatic Extraction Condensing Turbine
  Extraction @ 600 PSIG, 600°F ~ 365,000#/hr
  Exhaust @ 3.25"Hg ~ 64,100#/hr
- Generator rated at 16,500 kw gross power
- Condenser - 64,100#/hr steam @ 3.25" Hg
- Cooling tower - 65.8 x 10^6 Btu/hr heat load
- Net power to plant ~ 15,500 kw
- Existing 600 PSI steam plant shut down

Case 2 - Projected steam rate with new process unit

- 1500 PSIG/950°F inlet to turbine
- 3-340,000#/hr boilers (one spared)
- Pulverized coal/oil/gas fired
- 2 stage feedwater heating-exit BFW @ 428.9°F
- Single Automatic Extraction Non-condensing Turbine
  Extraction @ 600 PSIG, 600°F ~ 500,000#/hr
  Exhaust @ 150 PSIG, 438°F ~ 185,000#/hr
- Generator rated @ ~ 21,000 kw gross power

Existing requirements	15,500 kw
P.H. requirements	1,500 kw
STAR requirements	2,500 kw
Excess	2,500 kw

- To provide existing 600 PSI steam generator requirements plus 275,000 pounds per hour of 150 PSI steam to STAR.

GENERAL DATA

COAL

- No specific coal has been selected at this point
- Assume bituminous coal @ ~ 12,000 Btu/lb
- Bituminous type ash
- Low sulphur < 1.2# SO_2/MMBtu
- 8-10% Ash
- 10% Moisture
- No SO_2 Scrubbers

BOILER HOUSE AUXILARIES

- Employ steam drives where practical
- Steam for boiler house mechanical drive turbines is included in boiler capacity.

  Case 1 ~ 3660 hp
  Case 2 ~ 6140 hp

ELECTRICAL SERVICE

- 120V, 60 Hz, 1Ø
- 480V, 60 Hz, 3Ø
- 4160V, 60 Hz, 3Ø

FOUNDATIONS

- 1000#/ft^2 soil bearing capacity

CONSUMPTIONS

- 12,000 Btu/lb, low sulfur coal

  Case 1 ~ 485 tons/operating day
  Case 2 ~ 775 tons/operating day

- Process Water (1)

  Case 1 - 110,000 Gallons/operating day
  Case 2 - 175,000 Gallons/operating day

- Chemicals (2)

  Case 1: 32,000 gal. 66° H_2SO_4/yr
  57,000 gal. 50% NaOH/yr

  Case 2: 51,000 gal. 66° H_2SO_4/yr
  91,000 gal. 50% NaOH/yr

GENERAL DATA (Continued)

OPERATING & MAINTENANCE REQUIREMENTS

- Operating Labor - 24 employees
- Maintenance Costs - 2% of total installed cost/yr.

(1) These quantities represent the increase in water consumption over present usage.

(2) These are total quantities for the new high pressure steam system. Current requirements for the 600 PSI steam system would be eliminated.

klm:015

Attachment 2

PHILLIPS COAL COMPANY

INTER-OFFICE CORRESPONDENCE / SUBJECT.

July 31, 1981

Estimated Delivered Prices of Coal to Puerto Rico

TO: Craig Harrington
Bartlesville - 10 B1 PB

FROM: Rod Wimer RDW

Confirming our telephone conversation of Friday, July 31, attached please find our estimates of 1981 delivered coal prices to Puerto Rico from supply sources in the U.S. (Central Appalachia and Alabama), South Africa, and Colombia. Please note that steam coal exports from Colombia will not commence until at least the mid-1980's; the price information in the attachment is based on published ARCO and Exxon 1988 price estimates that have been deescalated to current dollars.

I hope this information satisfies your requirements. If we can be of further assistance, please feel free to give me a call. Best of luck in your refinery conversion feasibility studies.

RDW:lw
Attachment

ESTIMATED 1981 DELIVERED PRICES OF

COAL TO PUERTO RICO

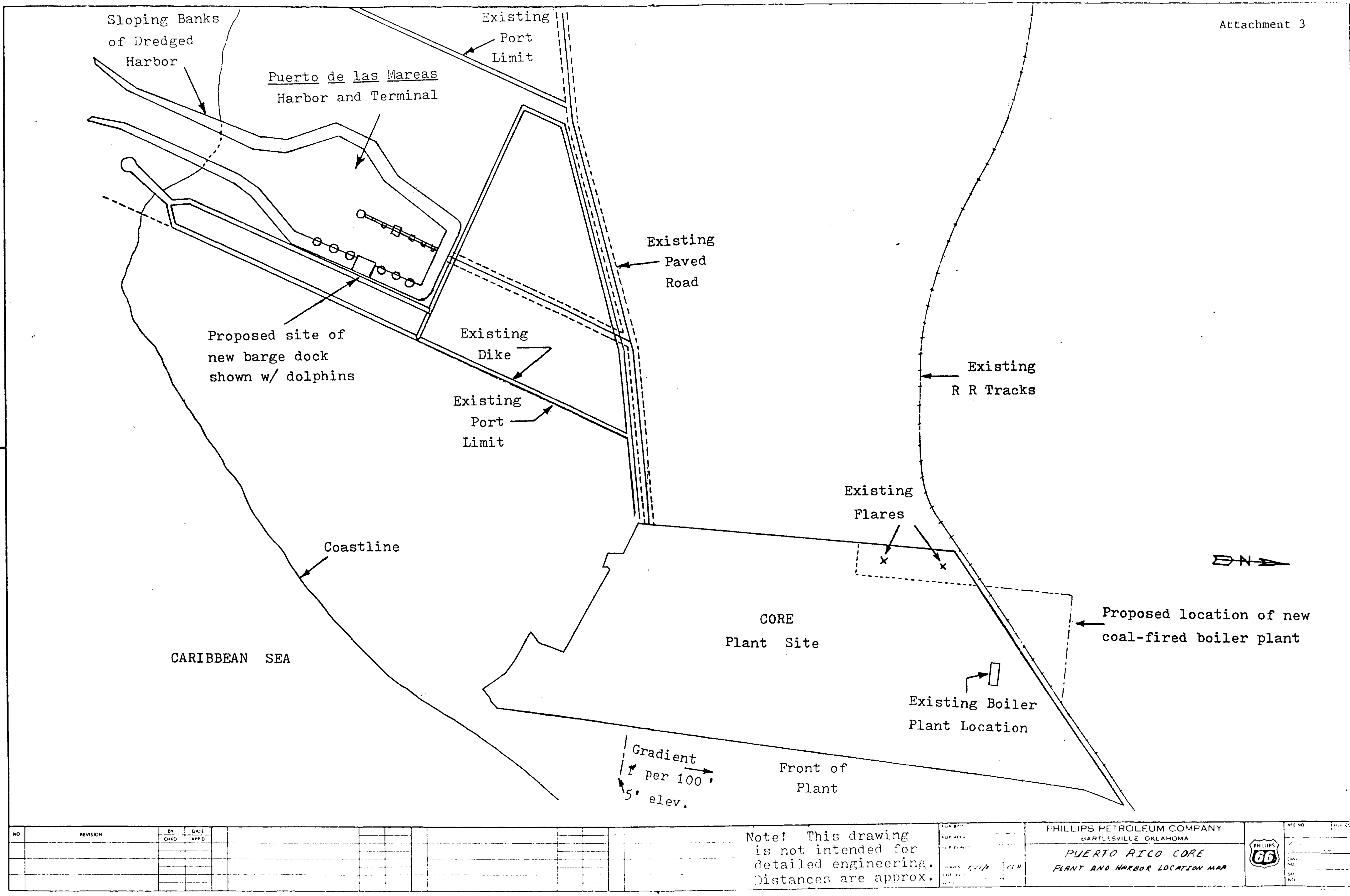
Source	Estimated Cost ($/short ton)				Total Landed Price	
	FOB Mine	FOB Piers	Loading	Ocean Freight	$/T	$/MMBtu
Central Appalachia (E.Ky., S.W.Va.) 13,000 Btu, 0.7%S, 9%A	$38	$52.50[1]	$4.00	$8-$10	$64.50-$66.50	$2.48-$2.56
Alabama (Central) 12,500 Btu, 0.75%S, 10%A	35	40.50-45[2]	4.00	7.50-9.50	52-58.50	2.08-2.35
South Africa (Richards Bay) 12,500 Btu, 1.0%S, 13%A	N.A.	40	2.50	18.00-19.00	60.50-61.50	2.42-2.46
Colombia (El Cerron) 11,800 Btu, 1%S	N.A.	44.00-48.00[3]	2.50	3.00-4.00	49.50-54.50	2.10-2.31

[1] Assumes barge delivery via Mississippi River System and export from New Orleans.

[2] Lower end assumes barge delivery to Mobile via Warrior-Tombigbee Waterway; higher end based on railroad transportation to Mobile.

[3] Low price is based on a 1988 estimate developed by ARCO and high price is based on comparable year costs developed by Exxon; both have been deescalated to 1981 dollars using PCC's coal price escalation rates.

Attachment 3



Attachment 4

September 2, 1981

INTER-OFFICE CORRESPONDENCE / SUBJECT: Puerto Rico Core Coal Fired Boiler
BARTLESVILLE, OKLAHOMA

Corporate Engineering

Mr. Alberto Sola

As you are aware, a feasibility study is currently being conducted for the installation of a coal fired boiler facility at the Puerto Rico Core Plant. I understand that you spoke with Mr. Garmia Daniel some time back and expressed doubts about storing coal adjacent to the existing port. We feel that the deeper channel at the Core port as well as its proximity to the plant make it a more desireable location for our coal unloading facility than the old Jobo barge dock. However, in light of several potential problems with storage on land at the port, we are considering the possibility of using the barge as "floating storage." This would require two barges, one being left in port while the other is in transit. We anticipate barge loads of approximately 10,000 short tons and an estimated barge gross register tonnage of 4000 tons. I have read the Port Information Manual that Core makes available but I am unsure how the various harbor fees might apply to this type of operation. Any information you could supply us regarding the expenses we would incur in such an operation would be very helpful.

We would anticipate constructing a new barge wharf on the eastern side of the existing harbor by dredging back toward the existing levee. This would be designed to minimize interference with the current shipping activity in the port. We would provide our own unloading facilities (lease or purchase a small crane) and would load trucks directly from the barge for transfer to the plant on a daily basis.

Any comments you might have that would help minimize the interference with regular port activities would also be beneficial to the study. Should you have any questions, please feel free to call me at any time.

Craig D. Harrington
10 B2 PB
Ext. 9204

CDH:abv

cc: Richard Bennett
Garmia Daniel
J. F. Hutto (r) E35055.00 (RC)
J. A. Schmitz (r) C. D. Harrington

COST ESTIMATE FOR CASE 1 CO.–GROUP/STAFF

DESCRIPTION OF JOB: COAL FIRED BOILER STUDY
PUERTO RICO

FILE NO. 48-53-81
J.A. NO. 48-0337
AFE NO.
PAGE NO. 1 OF 5
DATE JAN 1982

COST CENTER	CLASS	ITEM	DESCRIPTION (Show Condition of Used Material and Equipment)	QTY	UNIT COST	MATERIAL COST	LABOR COST	FOUNDATION M & L	STRUCTURAL M & L	INSULATION SUB CONTR	TOTAL
			BARGE DOCKING FACILITIES								
			DREDGING - MOBILIZATION			25 000					25 000
			DREDGING - 6700 CY			54 000					54 000
			SHEET PILING 1020 FT			1 119 000					1 119 000
			DYWIDAG ROD - 300			146 000	60 000				206 000
			HP14 x 75 - 340			765 000	92 000				857 000
			CONCRETE 700 CY					280 000			280 000
			C15 x 50 2000 FT			80 000	27 000				107 000
			TIMBERS 10 000 FT			32 000	12 000				44 000
			CREOSOTE			8000					8000
			INDIRECT COSTS			751 000					751 000
			LOCATION - PUERTO RICO	6%		207 000					207 000
			CONTINGENCY	20%		732 000					732 000
					TOTAL	3 919 000	191 000	280 000			4 390 000

REQUESTED BY: JH SCHMITZ PREPARED BY: D. Bybee CHECKED: APPROVED:

FORM 3308 S 6 81

COST ESTIMATE FOR CASE 1 CO.—GROUP/STAFF

DESCRIPTION OF JOB:

FILE NO.
J.A. NO. PAGE NO. 2 OF 5
AFE NO. DATE

COST CENTER	CLASS	ITEM	DESCRIPTION (Show Condition of Used Material and Equipment)	QTY.	UNIT COST	MATERIAL COST	LABOR COST	FOUNDATION M&L	STRUCTURAL M&L	INSULATION SUB CONTR.	TOTAL
			MATERIAL HANDLING								
			UNLOADING CRANE	500	T/DAY	580,000	S/C				580,000
			BARGE POSITIONER			100,000	INSTALLED				160,000
			FOUNDATION, FREIGHT, ERECTION			80,000	"				30,000
			SILO	20,000	CF	60,000	"				60,000
			SILO DISCHARGE	250	T/HR	40,000	"				40,000
			TRUCKS (2)	25	TON	190,000	"				190,000
			BUCKET ELEVATOR	100	T/HR	51,000	"				57,000
			FOUNDATION, FREIGHT, ERECTION			15,000	"				15,000
			SILO & DUMP PIT	500	T/DAY	75,000	"				75,000
			ASH DISPOSAL	DRY		600,000	"				600,000
			ERECTION			300,000	"				300,000
			INDIRECTS			730,000					130,000
			S/T			2,771,000					2,771,000
			PUERTO RICO LOCATION	6%		166,000					166,000
			CONTINGENCY	20%		582,000					582,000
					TOTAL	3,519,000					3,519,000

REQUESTED BY: PREPARED BY: CHECKED: APPROVED:

FORM 3308 S 6-81

PHILLIPS 66

COST ESTIMATE FOR ______ CO.—GROUP/STAFF

DESCRIPTION OF JOB: ______

FILE NO. ______
J.A. NO. ______ PAGE NO. 3 OF 5
AFE NO. ______ DATE ______

COST CENTER	CLASS	ITEM	DESCRIPTION (Show Condition of Used Material and Equipment)	QTY.	UNIT COST.	MATERIAL COST	LABOR COST	FOUNDATION M & L	STRUCTURAL M & L	INSULATION SUB CONTR	TOTAL
			ADDITIONAL EQUIPMENT-CASE I								
			SURFACE CONDENSER	4520	FT²	424,000	INSTALLED				424 000
			COOLING WATER PUMPS (2)	11,000	GPM	281,000	INSTALLED				281 000
			COOLING TOWER	11,000	GPM	640,000	INSTALLED				640 000
			INDIRECTS			673,000					673 000
			PUERTO RICO LOCATION	6%		121 000					121 000
			CONTINGENCY	20%		431 000					431 000
				TOTAL		2,570,000					2,570,000

REQUESTED BY: ______ PREPARED BY: ______ CHECKED: ______ APPROVED: ______

FORM 3308-S 6 81

COST ESTIMATE FOR CASE 1 CO.—GROUP/STAFF

FILE NO.

DESCRIPTION OF JOB:

J.A. NO. PAGE NO. 4 OF 5

AFE NO. DATE

COST CENTER	CLASS	ITEM	DESCRIPTION (Show Condition of Used Material and Equipment)	QTY.	UNIT COST	MATERIAL COST	LABOR COST	FOUNDATION M&L	STRUCTURAL M&L	INSULATION SUB CONTR	TOTAL
			STEAM PLANT								
			STEAM GENERATOR UNITS	3		23,100,000	INSTALLED				23,100,000
			BUNKERS	3		285,000	"				285,000
			BFW PUMPS	3		605,000	"				605,000
			FOUNDATION, BUILDINGS			3,550,000	"				3,550,000
			STACKS	3		780,000	"				780,000
			SWITCHGEAR	1		750,000	"				750 000
			BAGHOUSE	3		4,650,000	"				4 650 000
			TURBINES/GENERATORS	1		3,650,000	"				3 650 000
			PIPING/MECHANICAL			4,900,000	"				4 900 000
			STATION WIRING			3,400,000	"				3 400 000
			FW HEATERS	4		215,000	"				215 000
			OH CRANE	1		130 000	"				130 000
			INSTRUMENTS, CONTROLS			760 000	"				760 000
			WATER TREATMENT			1 700 000	"				1 700 000
			COAL HANDLING			1 000 000	"				1 000 000
			MISC			350 000	"				350 000
			CONTINGENCY & ENGINEERING	20%		9,965,000					9 965 000
				TOTAL		59 790 000					59 790 000

REQUESTED BY: PREPARED BY: CHECKED: APPROVED:

FORM 3308 S 6-81

PHILLIPS 66

COST ESTIMATE FOR Case I CO.—GROUP/STAFF

DESCRIPTION OF JOB: Coal Fired Boiler Study

Puerto Rico Core

FILE NO. 4B-53-81

J.A. NO. 41-0337

AFE NO.

PAGE NO. 5 OF 5

DATE January 1982

COST CENTER	CLASS	ITEM	DESCRIPTION (Show Condition of Used Material and Equipment)	QTY.	UNIT COST	MATERIAL COST	LABOR COST	FOUNDATION M & L	STRUCTURAL M & L	INSULATION SUB CONTR	TOTAL
			Summary								
			Barge Dock			4 390 000					4 390 000
			Material Handling			3,519,000					3 519 000
			Additional Equip			2,570 000					2 570 000
			Steam Plant			59,790,000					59 790 000
			Total Project, 1981 Dollars			70,269,000					70,269,000
			Escalation	30%		20 731 000					20 731 000
			Project Release 7-1-82								
			Construction Start 7-1-83								
			Mechanical Completion 7-1-85								
				TOTAL		91 000 000					91 000 000

REQUESTED BY: J.A. Schmitz PREPARED BY: T. Byers CHECKED: Hugh Fraser APPROVED: [signature]

FORM 3308-S 6-81

PHILLIPS 66

COST ESTIMATE FOR CASE 2 CO.—GROUP/STAFF

DESCRIPTION OF JOB: COAL FIRED BOILER STUDY
PUERTO RICO COKE

FILE NO. 48-53-81
J.A. NO. 48-0337
AFE NO.
PAGE NO. 1 OF 4
DATE JAN 1982

COST CENTER	CLASS	ITEM	DESCRIPTION (Show Condition of Used Material and Equipment)	QTY.	UNIT COST	MATERIAL COST	LABOR COST	FOUNDATION M&L	STRUCTURAL M&L	INSULATION SUB CONTR	TOTAL
			BARGE DOCKING FACILITIES								
			DREDGING - MOBILIZATION			25 000					25 000
			DREDGING - 6700 CY			54 000					54 000
			SHEET PILING 1020 FT			1 119 000					1 119 000
			DYWIDAG ROD - 300			146 000	60 000				206 000
			HP 14 x 75 - 340			765 000	92 000				857 000
			CONCRETE 700 CY					280 000			280 000
			C15 x 50 2000 FT			80 000	27 000				107 000
			TIMBERS 10000 FT			32 000	12 000				44 000
			CREOSOTE			8 000					8 000
			INDIRECT COSTS			751 000					751 000
			LOCATION - PUERTO RICO	6%		207 000					207 000
			CONTINGENCY	20%		732 000					732 000
			BARGE DOCKING FACILITIES —	TOTAL		3 919 000	191 000	280 000			4 390 000

REQUESTED BY: JA SCHMITZ PREPARED BY: J. BYERS CHECKED: APPROVED:

FORM 3308-S 6-81

COST ESTIMATE FOR PRO-CHEM CO.—GROUP/STAFF

FILE NO.

DESCRIPTION OF JOB: COAL FIRED BOILER STUDY - CASE 2

PUERTO RICO CORE

J.A. NO.

PAGE NO. 2 OF 4

AFE NO.

DATE

COST CENTER	CLASS	ITEM	DESCRIPTION (Show Condition of Used Material and Equipment)	QTY.	UNIT COST	MATERIAL COST	LABOR COST	FOUNDATION M&L	STRUCTURAL M&L	INSULATION SUB CONTR.	TOTAL
			MATERIAL HANDLING								
			CRANE	800	T/DAY	580 000	S/C				580 000
			BARGE POSITIONER			100 000	INSTALLED				100 000
			EQN. FREIGHT. ERECTION			30 000	"				30 000
			SILO	32,000	CF	96 000	"				96 000
			SILO DISCHARGE	250	T/HR	40 000	"				40 000
			TRUCKS (2)	25	TON	190 000	"				190 000
			BUCKET ELEVATOR	160	T/HR	63 000	"				63 000
			EQN. FREIGHT. ERECTION			19 000	"				19 000
			SILO - DUMP PIT	800	T/DAY	120 000	"				120 000
			ASH DISPOSAL SYSTEM	DRY	SYSTEM	695 000	"				695 000
			ERECTION			348 000	"				348 000
			S/T			2,281,000					2,281,000
			INDIRECTS			851 000					851 000
			Puerto Rico Location	6%		188 000					188 000
			Contingency	20%		664 000					664 000
					TOTAL	3 984 000					3 984 000

REQUESTED BY: PREPARED BY: CHECKED: APPROVED:

FORM 3308-S 6 81

COST ESTIMATE FOR ______ CO.—GROUP/STAFF FILE NO. ______

DESCRIPTION OF JOB: ______ J.A. NO. ______ PAGE NO. 3 OF 4

AFE NO. ______ DATE ______

COST CENTER	CLASS	ITEM	DESCRIPTION (Show Condition of Used Material and Equipment)	QTY.	UNIT COST	MATERIAL COST	LABOR COST	FOUNDATION M&L	STRUCTURAL M&L	INSULATION SUB CONTR.	TOTAL
			STEAM PLANT								
			STEAM GENERATING UNITS			35 800 000	INSTALLED				35 800 000
			BUNKERS			335 000	"				335 000
			BFW PUMPS			655 000	"				655 000
			FOUNDATION, BUILDINGS			4 050 000	"				4 050 000
			STACKS			780 000	"				780 000
			SWITCHGEAR			750 000	"				750 000
			BAGHOUSE			5 560 000	"				5 560 000
			TURBINE/GENERATOR			4 460 000	"				4 460 000
			PIPING - MECHANICAL			5 900 000	"				5 900 000
			WIRING			3 400 000	"				3 400 000
			FW HEATERS			330 000	"				330 000
			OH CRANE			130 000	"				130 000
			INSTRUMENTS - CONTROLS			760 000	"				760 000
			WATER TREATMENT			2 100 000	"				2 100 000
			COAL HANDLING			1 450 000	"				1 450 000
			MISC			350 000	"				350 000
			S/T			66 810 000					66 810 000
			CONTINGENCY AND ENGINEERING	20%		13 360 000					13 360 000
				TOTAL		80 170 000					80 170 000

REQUESTED BY: ______ PREPARED BY: ______ CHECKED: ______ APPROVED: ______

FORM 3308-S 6 81

COST ESTIMATE FOR Case 2 CO.—GROUP/STAFF

DESCRIPTION OF JOB: Coal Fired Boiler Study
Puerto Rico Core

FILE NO. 48-53-81
J.A. NO. 48-0337 PAGE NO. 4 OF 4
AFE NO. DATE January 1982

COST CENTER	CLASS	ITEM	DESCRIPTION (Show Condition of Used Material and Equipment)	QTY.	UNIT COST	MATERIAL COST	LABOR COST	FOUNDATION M&L	STRUCTURAL M&L	INSULATION SUB CONTR.	TOTAL
			SUMMARY								
			BARGE DECK			4 390 000					4 390 000
			MATERIAL HANDLING			3 984 000					3 984 000
			STEAM PLANT			80 170 000					80 170 000
			TOTAL PROJECT, 1981 Dollars			88 544 000					88 544 000
			ESCALATION	30%		26 456 000					26 456 000
			PROJECT RELEASE 7-1-82								
			CONSTRUCTION START 7-1-83								
			MECHANICAL COMPLETION 7-1-85								
					TOTAL						115 000,000

REQUESTED BY: J.A. Schmitz PREPARED BY: J. Byers CHECKED: Hugh Fraser APPROVED: [illegible]
1/5/82

FORM 3308 S 6-81

VITA

Craig Douglas Harrington was born in Wharton, Texas on February 21, 1956 to Frank Allen and Lois Rutz Harrington. He lived, grew up and attended school in Sweeny, Texas, graduating from Sweeny Senior High School in May 1974. He enrolled at Texas A&M University in the fall of that year and in December 1978, was awarded a Bachelor of Science in Nuclear Engineering. Continuing his education at Texas A&M, he was awarded a Master of Engineering in Mechanical Engineering in May 1981. He is currently completing the degree requirements of the Doctor of Engineering program at Texas A&M and expects to graduate in August 1982.
This report was typed by the author.

803 Avenue B
Sweeny, Texas 77480