INTERN EXPERIENCE AT

FLUOR ENGINEERS, INC. - HOUSTON DIVISION

An Internship Report

by

BURANAWONG SOWAPRUX

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

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December 1983

ABSTRACT

Intern Experience with

Fluor Engineers, Inc. - Houston Division. (December 1983)

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This report describes the author's activities and experiences gained during the internship served at Fluor Engineers, Inc. - Houston Division, from Summer Term I, 1982 through the Spring Semester 1983. The purpose of the internship was to allow the author to become familiar with project planning and control management in the petrochemical engineering and construction industry. The author held the position of Associate Cost/Scheduling Engineer and worked on two refinery modernization projects during the twelve-month internship.

A brief discussion of the author's responsibilities and internship objectives are presented first, followed by Fluor's history, organizational structure and project organization. Process technology of petroleum refining is overviewed along with an examination of how to build a "grass roots" refinery plant. Cost and scheduling engineering aspects are then discussed. Finally, the author's work assignments are described along with development of a computer software for manpower planning.

The internship was successful in satisfying both the Doctor of Engineering Program and personal objectives. This report is intended to demonstrate that all objectives have been met.

To My Parents, Banchong and Udomporn Sowaprux

ACKNOWLEDGEMENTS

I would like to express my appreciation to those who contributed to the success of my graduate study at Texas A&M University and to making the internship a meaningful experience.

In particular I am very grateful to Dr. Fox and Dr. A. Garcia-Diaz for their most valuable help, guidance and encouragement through my graduate study. Thanks also to the other committee members, Dr. M.A. Colaluca, Dr. B. Das, Dr. T. Sastri, Dr. D.T. Ward and Dr. G.R. Ferris for their suggestions and support.

Deep appreciation is expressed to Mr. E.E.A. Jansen and the management at Fluor Engineers, Inc. - Houston Division for making the internship possible. Mr. Jansen and Dr. Fox deserve much credit for the success of the internship.

Special thanks is owed to Mrs. C. Runyon for her many hours of typing the monthly internship reports; to Mr. C. Homwong and Mr. R. Ungchusri for their special help in preparing the final draft; to Dr. B.T. Afiesimama for his suggestions and assistance during the internship; and to those friendly colleagues at Fluor who made the internship an enjoyable experience.

Finally, my much gratitude is expressed to Noi for her understanding, patience and support.

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CHAPTER I

INTRODUCTION

PURPOSE

This report covers the author's activities and experiences during a twelve-month internship period served at Fluor Engineers, Inc. - Houston Division. The primary purpose of the report is to demonstrate that the internship objectives have been met.

CONTENT AND ORGANIZATION OF THE REPORT

The author's position with the company, the scope of responsibility and the internship objectives are presented in Chapter II. Some background information about the Fluor organization is provided in Chapter III. The areas of discussion in this chapter are the history of the Fluor Corporation, its major subsidiaries and divisions, the Fluor Engineers, Inc. - Houston Division, where the internship was served, and the project organization.

Chapter IV describes the process technology of petroleum refinery and the building of a "grass roots" refinery plant. Chapter V discusses cost engineering, scheduling engineering, and project planning and control. The contents regarding the author's work assignments and contributions are presented in Chapter VI. In this chapter development of a microcomputer program for manpower planning is presented and the

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This report follows the general style and format of the Institute of Industrial Engineers Transactions (1983).

input and output of the program are discussed.

Two examples of Manpower Analysis Program output are given in Appendix A and the program code is listed in Appendix B. Brief descriptions of cost and scheduling engineering functions are contained in Appendix C. Appendices D and E are the internship objectives and monthly progress reports. Appendix F is the schedule of work assignments that the author performed during the internship. Finally, the Intern Supervisor's report and resume are in Appendices G and H.

CHAPTER II

DESCRIPTION OF INTERNSHIP

POSITION

The author served his internship in the Cost and Scheduling Department and held the position of Associate Cost/Scheduling Engineer. Appendix C contains a brief description of cost and scheduling engineering functions. The intern supervisor was Mr. Earle E. A. Jansen, a Cost/Scheduling Manager, who directly supervised the author throughout the internship. Mr. Jansen has his degree in Mechanical Engineering and has more than twenty-five years experience in engineering and construction including fourteen years at Fluor Engineers, Inc. His resume is in Appendix H.

During the first six months of the internship, the author was assigned as a scheduling engineer to a $300 million refinery modernization. The work included an analysis in the 'Phased" approach in engineering; forecasting, analyzing and compiling field labor progress and performance;revision of field budget manhours; and preparation of management slides and charts.

As the project was effectively completed, the author was assigned to another on-going refinery modernization project, valued at more than $500 million. At that time the engineering was 35% complete and construction had just started. The majority of the author's time was spent in cost aspects during the latter half of the internship. This division of work assignments thus covered the primary functions of cost and scheduling

engineering.

The cost engineering responsibilities on the second assignment included the maintenance of the Project Cost Reporting System and short term and long term forecasting of the project's cash flow. The author also performed scheduling engineering work which included utilization of the Manpower Distribution Analysis Computer System to generate plan construction curves, manpower loading curves, labor craft mix and all associated labor costs; maintenance and updating of equipment and materials procurement status; and development and updating of the home office manpower plan.

INTERNSHIP OBJECTIVES

The Doctor of Engineering Program, in principle, is intended to prepare individuals for professional engineering activities in business, industry and in the public sector. It emphasizes engineering practice, not research, in an environment of potential leadership.

A student in the internship program must meet general objectives set by the College of Engineering as well as objectives set by the graduate advisory committee chairman, the intern supervisor, and the intern. Following are the general objectives of the Doctor of Engineering Internship Program [14:19]:

(1) To enable the student to demonstrate his or her ability to apply his or her knowledge and technical training by making an identifiable engineering contribution in an area of practical concern to the organization or industry in which the internship is served, and

(2) To enable the student to function in a non-academic environment in a position where he or she will become

> aware of the organizational approach to problems in addition to traditional engineering design or analysis. These may include, but are not limited to: problems of management, labor relations, public relations, environmental protection, and economics.

A preliminary set of internship objectives was set prior to the internship. Appendix D contains the preliminary and final objectives. The final internship objectives were set one month into the internship. These final objectives are:

(1) Observe Fluor's general approach to project implementation;

(2) Become familiar with the process industry technology;

(3) Take responsibility in cost and scheduling engineering and implement Fluor's techniques on a project;

(4) Develop at least one new system or method that will improve the quality and efficiency of the cost/scheduling department, and

(5) Observe management practices at the project level.

The remainder of this report will demonstrate that all these objectives have been met.

CHAPTER III

FLUOR ORGANIZATION

HISTORY OF FLUOR CORPORATION

During the last seventy years, Fluor Corporation (hereinafter referred to as Fluor or the Company) has evolved from a small general construction firm into a corporation with annual revenues of more than $7 billion. Fluor provides worldwide engineering, construction, procurement and project management services to energy, natural resource, industrial, commercial, and utility clients. The Company is a major producer of diversified natural resources, principally coal, oil and gas, as well as lead, gold, silver, zinc, and iron ore. Other subsidiaries are involved in contract drilling and oil and gas services [5:1].

Fluor was founded in 1912 by John Simon Fluor, Sr., a Swiss emigrant [4:7]. Skilled as a carpenter, he came to the United States in 1888 and joined his two elder brothers who worked for other builders. In 1890, they founded their own company known as the Fluor Brothers Construction.

In 1912, Simon opened his own business, the Fluor Construction Company, at Santa Ana, California. The company started as a general contractor, but later entered into oil and gas industry. By 1925, Fluor was virtually out of the general contracting business and was deeply tied to developing energy industries.

Fluor was incorporated in 1924 with approximately 100 employees. Five years later, the company reincorporated as The Fluor Corporation, Ltd. In the 1930's, Fluor expanded its work outside the state of

California to where there were big oil discoveries in East Texas and throughout the Mid-Continent area. Fluor's first venture into foreign operations came in 1933 when it erected cooling towers at a refinery under construction at Bahrain Island in the Persian Gulf.

In 1942 the United States entered World War II, and the demand for high-octane gasoline for army vehicles sky-rocketed. Fluor-built plants produced more than 30 percent of all the 100-octane gasoline in the United States. In 1945, contracts to Fluor from outside the United States increased substantially.

Just prior to his death in 1944, John Simon Fluor, Sr. was elected Chairman of the Board and Peter E. Fluor, Simon's son, was named president. Peter held the presidency until his death in 1947. J. Simon Fluor, Jr., Simon's youngest son who joined the corporation in 1919, became president in 1952. Under his leadership, the Company diversified its services through new endeavors in the chemical, petrochemical, nuclear and power fields.

The Houston Division was formed in 1948 as a Gas-Gasoline Division. Fluor (Great Britain) Ltd. was formed in 1957, and Fluor Nederland B.V. and Fluor Canada Ltd. were formed in 1959. Three years later, Simon Fluor, Jr. was elected Chairman of the Board. The presidency passed to J. R. "Bob" Fluor, Peter's son, who joined the corporation in 1946. After Simon Fluor, Jr.'s retirement in 1968, Bob Fluor became Chairman of the Board and Chief Executive Officer of the corporation. In the summer of that year, the corporation founded Fluor Ocean Services, Inc., a new subsidiary for offshore engineering and construction services. Its

headquarters is in Houston.

One year later, Fluor entered drilling and distribution services by acquiring Pike Corporation of America and its three major divisions: Western Offshore Drilling and Exploration Company, Republic Supply Company of California and Kilsby Tubesupply. During the same year, Fluor purchased the construction division of Utah Construction and Mining Company. This subsidiary consists of Fluor Mining & Metals, Inc., headquartered in San Mateo, California, and Fluor Australia, operating in Melbourne.

In 1970, Fluor GmbH was opened in West Germany, and Fluor Europe was formed to oversee all services over Europe. In 1974, Fluor acquired Pioneer Service & Engineering Company, which provides engineering-construction services to the power industry.

Fluor made its largest acquisition - Daniel International Corporation in 1977. Daniel is an industrial contractor headquartered in Greenville, South Carolina. With the acquisition of Daniel, Fluor's total assets were raised to $1 billion and its employee population was more than 21,000. In 1981, Fluor entered the mining and metal industry when it purchased the St. Joe Minerals Corporation.

A number of organizational changes were made during 1982 to meet changing market conditions. In 1982, the Company had five major operating groups: Engineering and Construction, St Joe Minerals, Oil and Gas, Drilling Services, and Distribution.

In mid-1983, in order to focus corporate resources on Fluor's primary areas of business, the Distribution Services group was divested. This group includes Republic Supply, Kilsby-Roberts, Fluor Supply and

Goldston Transportation Group [9:1].

Despite the recession from July 1981 through December 1982, the Company gained solid profit performance in Fiscal 1982. The revenues for the year were a record--above $7 billion [5:29]. The Company was also able to retain all its high credit ratings from major credit rating agencies. These financial standings reflect the Company's underlying strength and flexibility in adjusting to changing markets and economic conditions.

MAJOR SUBSIDIARIES AND DIVISIONS

After the reorganization in 1982 and the strategic move in mid-1983, Fluor has four operating groups: Engineering and Construction, Metals and Coal, Oil and Gas, and Drilling Services. Figure 1 shows all principal subsidiaries and divisions of the Fluor Corporation.

Engineering and Construction

This group provides worldwide engineering, procurement, construction and project management services to energy, chemical, natural resources and industrial clients. Essentially all of the engineering and construction business is conducted under cost-reimbursable fixed or percentage fee contracts [6:1]. This group is the largest among the four operating groups and generates the biggest portion of Fluor's revenues. It offers expertise in petroleum processing, refinery modernization, and chemical and petrochemical services. Fluor is responsible for many of the modernization projects, including some of the largest in the United States and Europe. Many of the refinery processes such as hydrocracking,

ENGINEERING AND CONSTRUCTION

FLUOR ENGINEERS, INC.
Irvine, California

ADVANCED TECHNOLOGY DIVISION
Irvine, California

HOUSTON DIVISION
Houston, Texas

MINING & METALS DIVISION
Redwood City, California

OCEAN SERVICES DIVISION
Houston, Texas

POWER DIVISION
Chicago, Illinois and Irvine, California

SOUTHERN CALIFORNIA DIVISION
Irvine, California

FLUOR ARABIA LIMITED
Al-Khobar, Saudi Arabia

FLUOR AUSTRALIA PTY. LIMITED
Melbourne, Victoria, Australia

FLUOR CANADA LTD.
Calgary, Alberta, Canada

FLUOR EUROPE LIMITED
London, England

FLUOR (GREAT BRITAIN) LIMITED
London and Manchester, England

FLUOR GmbH
Dusseldorf, West Germany

FLUOR NEDERLAND B.V.
Haarlem, The Netherlands

FLUOR OCEAN SERVICES LIMITED
London, England

Figure 1. Fluor's Principal Subsidiaries and Divisions.

FLUOR SOUTH AFRICA (PTY) LIMITED
Johannesburg, South Africa

FLUOR CONSTRUCTORS, INC.
Irvine, California

DANIEL INTERNATIONAL CORPORATION
Greenville, South Carolina

DANIEL CONSTRUCTION COMPANY

DANIEL INDUSTRIAL SERVICES

METALS AND COAL

ST. JOE MINERALS CORPORATION
New York, New York

A. T. MASSEY COAL COMPANY, INC.
Richmond, Virginia

ST. JOE INTERNATIONAL CORPORATION
New York, New York

ST. JOE LEAD COMPANY
Clayton, Missouri

ST. JOE RESOURCES COMPANY
Clayton, Missouri

OIL AND GAS

FLUOR OIL AND GAS CORPORATION
Denver, Colorado

ST. JOE PETROLEUM CORPORATION
Houston, Texas

DRILLING SERVICES

FLUOR DRILLING SERVICES, INC.
Irvine, California

CORAL DRILLING DIVISION
New Orleans, Louisiana

WESTERN OFFSHORE DRILLING AND EXPLORATION CO.
Irvine, California

Figure 1. (Cont'd)

hydrosulfurization, coking, visibreaking and catalytic cracking, and catalytic reforming are designed, engineered and constructed by Fluor world wide. In the United States, Fluor conducts its business primarily through Fluor Engineers, Inc. and Fluor Constructors, Inc.

In gas treatment and the processing industry, Fluor has served for more than 60 years and its experience includes a wide variety of processes in more than 250 plants of all sizes [7:12].

Fluor also develops new technology to supplement client needs, and through licensing arrangements the Company has access to virtually all of the world's commercially proven petrochemical processes.

Metal and Coal

This group emerged as a result of the acquisition of St. Joe's metals and coal operations. The principal subsidiary is the St. Joe Minerals Corporation. St. Joe is the largest integrated producer of lead and zinc in the United States. Overseas activities are conducted through St. Joe International Corporation, headquartered in New York. At present, it has significant operations in Chile, Argentina, Peru and Australia. St. Joe's domestic metals operations encompass the mining, milling and smelting of lead and zinc, as well as the mining, milling and pelletizing of iron ore. Three divisions make up the Domestic Metals Group: St. Joe Lead Company, the nation's largest integrated lead operation, consisting of three mine and mill complexes and a lead smelter and refinery in southeastern Missouri; St. Joe Resources Company, the largest integrated zinc producer in the United States with zinc mining

and a mill in the Balmat area of upstate New York and smelting at Monaca, Pennsylvania; and the Pea Ridge Iron Ore Company, which mines iron ore and runs a pelletizing plant near Sullivan, Missouri.

A. T. Massey Coal Company, a 50-50 joint venture between St. Joe and a member company of the Royal/Dutch Shell Group, is a major producer of low sulfur, Appalachian coal for electric utilities and the second largest exporter of coal in the United States. Massey has 23 coal-mining complexes and 17 preparation plants. The company's coal reserves exceed one billion tons.

The group also has its own research centers. St. Joe's Energy Research Corporation (ERC) ranks as one of the largest electrochemical research and development firms in the United States. ERC is working on advanced batteries and fuel cells. St. Joe Minerals also maintains a natural resource research and development center in Monaca, Pennsylvania. The facility develops new products and extractive metallurgical processes, works on improving existing products and provides state-of-the-art technical support for operations and customers.

Oil and Gas

This group consists of Fluor Oil and Gas Corporation, headquartered in Denver, Colorado and St. Joe Petroleum Corporation, headquartered in Houston, Texas. Its activities cover exploration, development, and production both on shore and offshore. Worldwide, Fluor Oil and Gas Corporation holds nearly 1.6 million undeveloped net acres. Proven oil and oil equivalent reserved were 48.2 million barrels at the end of 1982 [5:19]. Fluor Oil and Gas and St. Joe Petroleum have interests in

several countries including Greece, Agentina, Mexico, England and Indonesia.

Drilling Services

Headquartered in Irvine, California, Fluor Drilling Services, Inc. is the principal subsidiary of this group. Its divisions are Coral Drilling Division, New Orleans, Lousiana, and Western Offshore Drilling and Exploration Company, Irvine, California. Both companies offer complete technical planning and exploration management services for projects of every sizes.

Among the world's most experienced drilling contractors, Fluor operates a fleet of self-propelled drillships, floating drilling barges, jack-up rigs and self-contained platform rigs. This rig mix facilitates successful drilling operations under a variety of conditions in either shallow or deep water. The drillships are capable of long-term drilling programs far from any land supply base. At the end of 1982, the group operated fourteen rigs worldwide.

FLUOR ENGINEERS, INC. - HOUSTON DIVISION

Fluor's Houston Division was formed in 1948 to service industry requirements in the Gulf Coast. The company was originally known as the Mid-Continent or Gas-Gasoline Division since most of the work involved gas plants and small compressor stations in the mid-continent area.

By the late 1950's, the office began handling more petrochemical projects and acquired early experience in planning and executing overseas projects. Therefore, in 1960, the office was renamed the Houston Division to reflect the change in project emphasis and expansion beyond its original geographic area.

The present office space is over 600,000 square feet accommodating nearly 3,000 employees. In 1984, a new facility will be completed providing 1.5 million square feet of office space.

The organizational structure of the Houston Division is shown in Figure 2. But in executing a project, Fluor operates under the "Task-Force" concept. The central element of this concept is the collection of all home office personnel assigned to a project in one location and forming the project organization under the overall supervision of a project director. Personnel in a task force are drawn from several functional departments. As work is performed through line functions within the task force as well as through vertical lines of authority within the departments, a matrix organization is formed. More details on matrix organization and the task force concept are discussed in the next section.

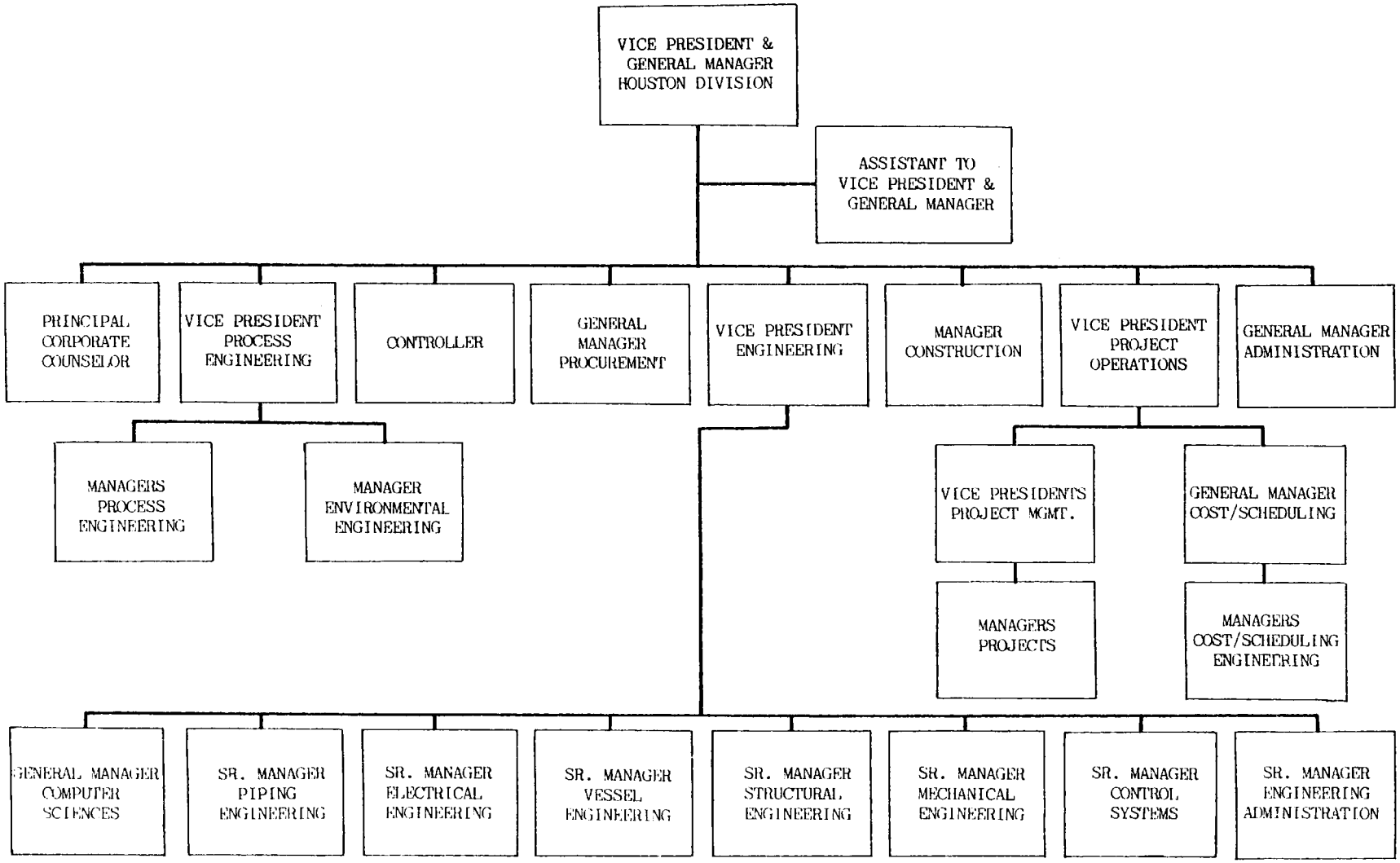


Figure 2. The Organization Chart of the Houston Division.

PROJECT ORGANIZATION

Task Force Organization

Fluor executes and manages its projects under the "Task-Force" concept. All personnel participating in a particular project will form a task force to work at one location and will remain there until their specific work assignment is completed. They form a project organization under the overall supervision of a project director or project manager.

The task force organization has three main features, i.e., the concentration of a team effort on a single project, the location of members of the project team in close proximity with one another, and the provision of office space for the client representatives adjacent to or commingled with the task force.

There are several advantages to this type of organization. It enhances the commitment of assigned personnel who do not have to share their time to other projects, and builds individual and team motivation. It also facilitates rapid communication between the client and the task force. Finally, it gives tighter control of project activities because the project director posesses responsibility and authority over all personnel assigned to the project.

The task force organization is specifically tailored to meet the requirements of a particular project. The size of a project organization ranges from a few individuals for a small project to several hunderd people for a large project. The task force also has to be closely interfaced with the client team to provide a step-by-step progress for each phase of work. Thus, the size of the task force will vary from one

phase to another, usually peaking during the period of detailed design activities and then decreasing as the project approaches its end.

In the early stage, Fluor usually forms a relatively small, highly qualified task force to establish basic design philosophy and work procedures for the entire project. This is done to ensure that conceptual activities progress in a unified manner and to ensure that the intent and the needs of the client are fully considered during the work execution period.

For a typical modernization project, a small site engineering team will be organized in parallel with and as a part of the task force. This group is responsible for developing and providing information required for storage relocation, site clearance, plant tie-ins and other service support activities.

After these activities have been completed, the emphasis will turn to production engineering, procurement and construction work. At this point, area project managers will be assigned responsibilities on a contiguous geographic plant area basis. Dividing the project on this basis provides a close association between all employees and clients throughout the project life and ensures detailed requirements are properly followed. Figure 3 shows a consolidated organization chart for a typical project. It embodies the functions necessary to establish an organization for a specific project. Figures 4 through 7 show project organization charts based on reponsibility assignments by geographic areas.

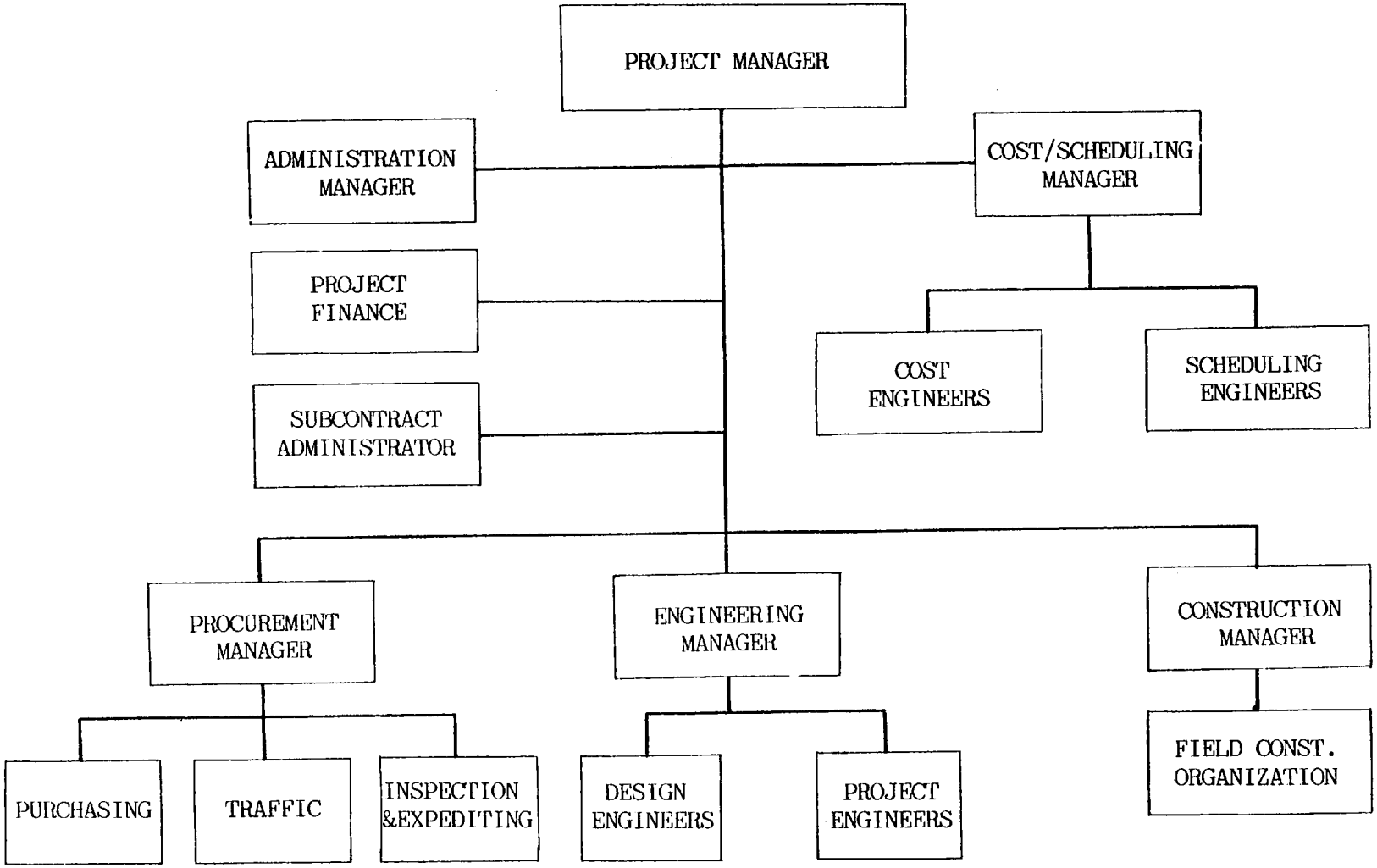


Figure 3. Consolidated Project Organization Chart.

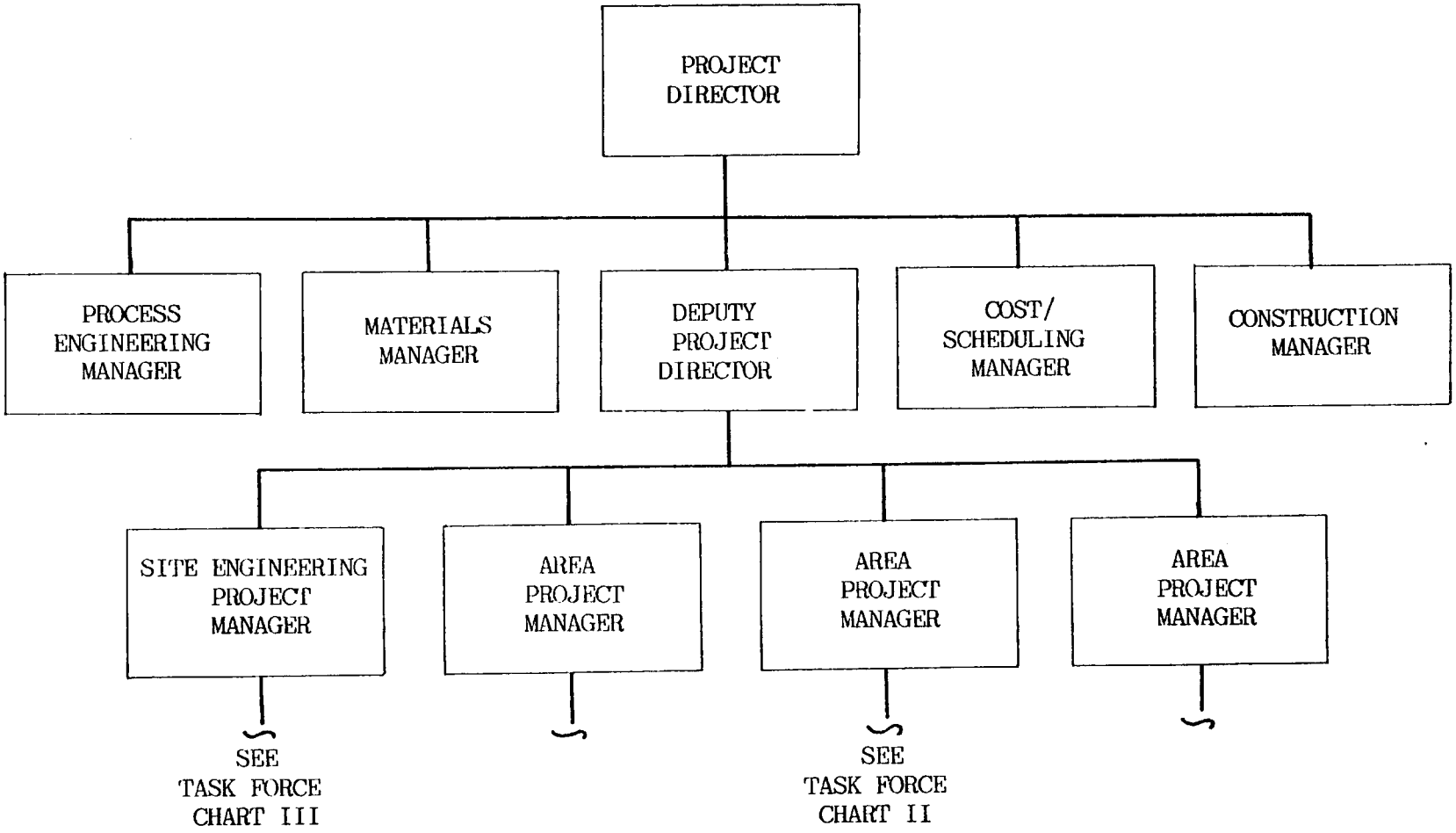


Figure 4. Project Organization - Chart I.

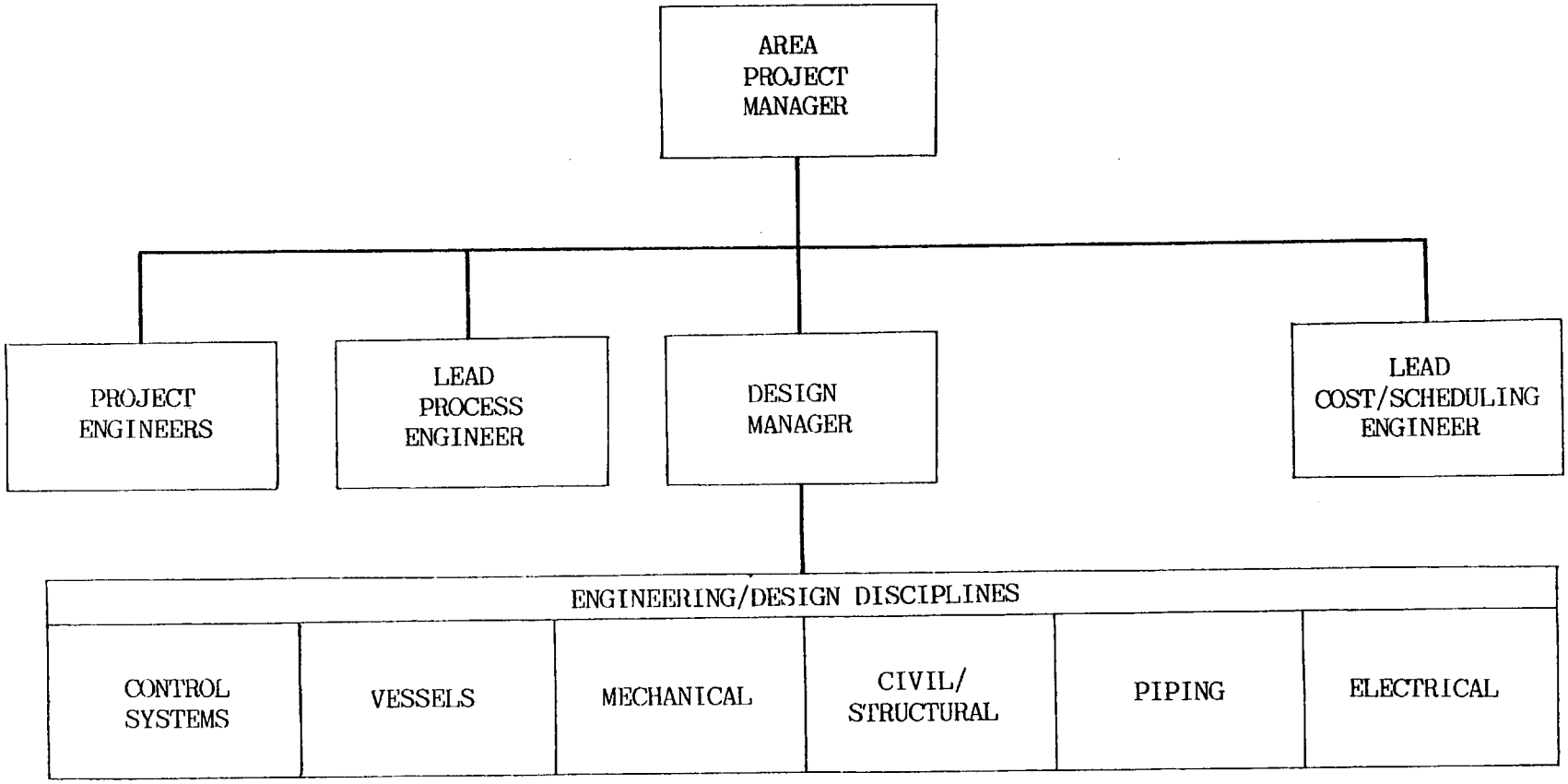


Figure 5. Task Force Organization - Chart II.

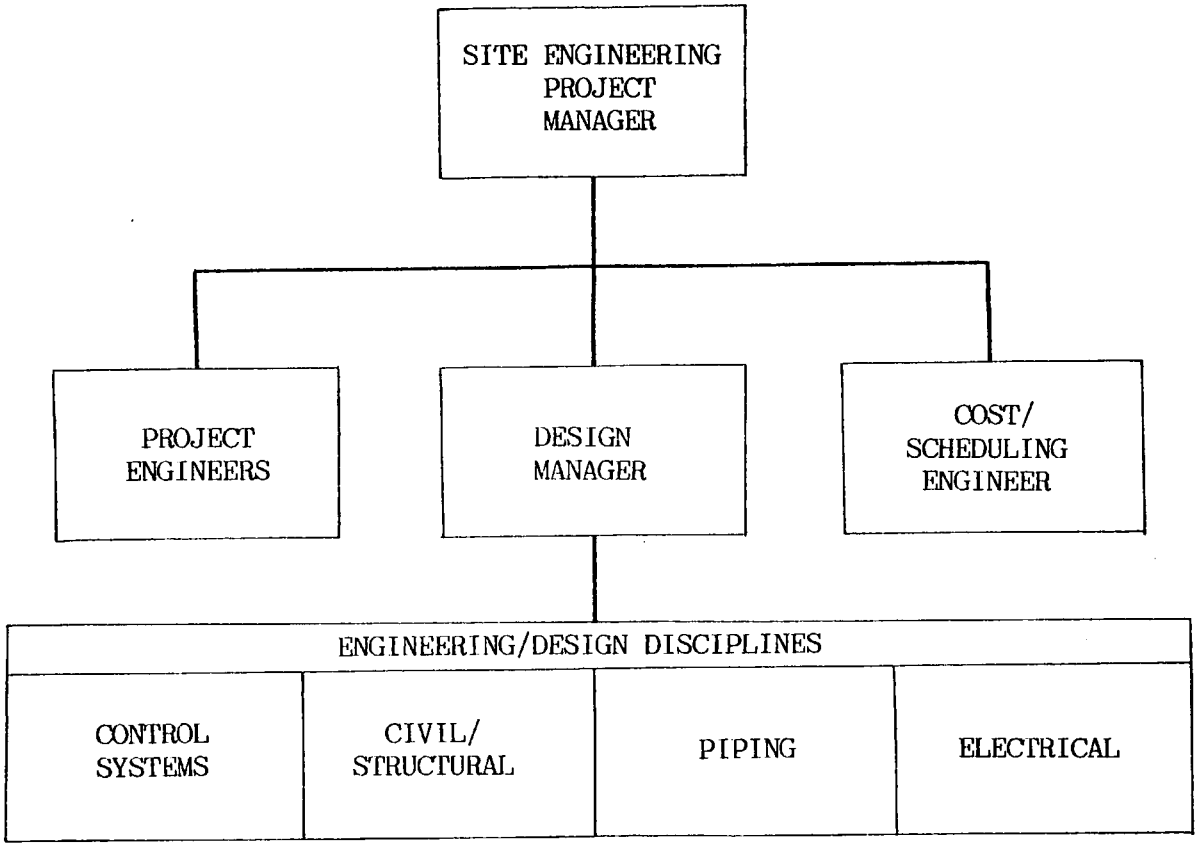


Figure 6. Site Task Force Organization - Chart III.

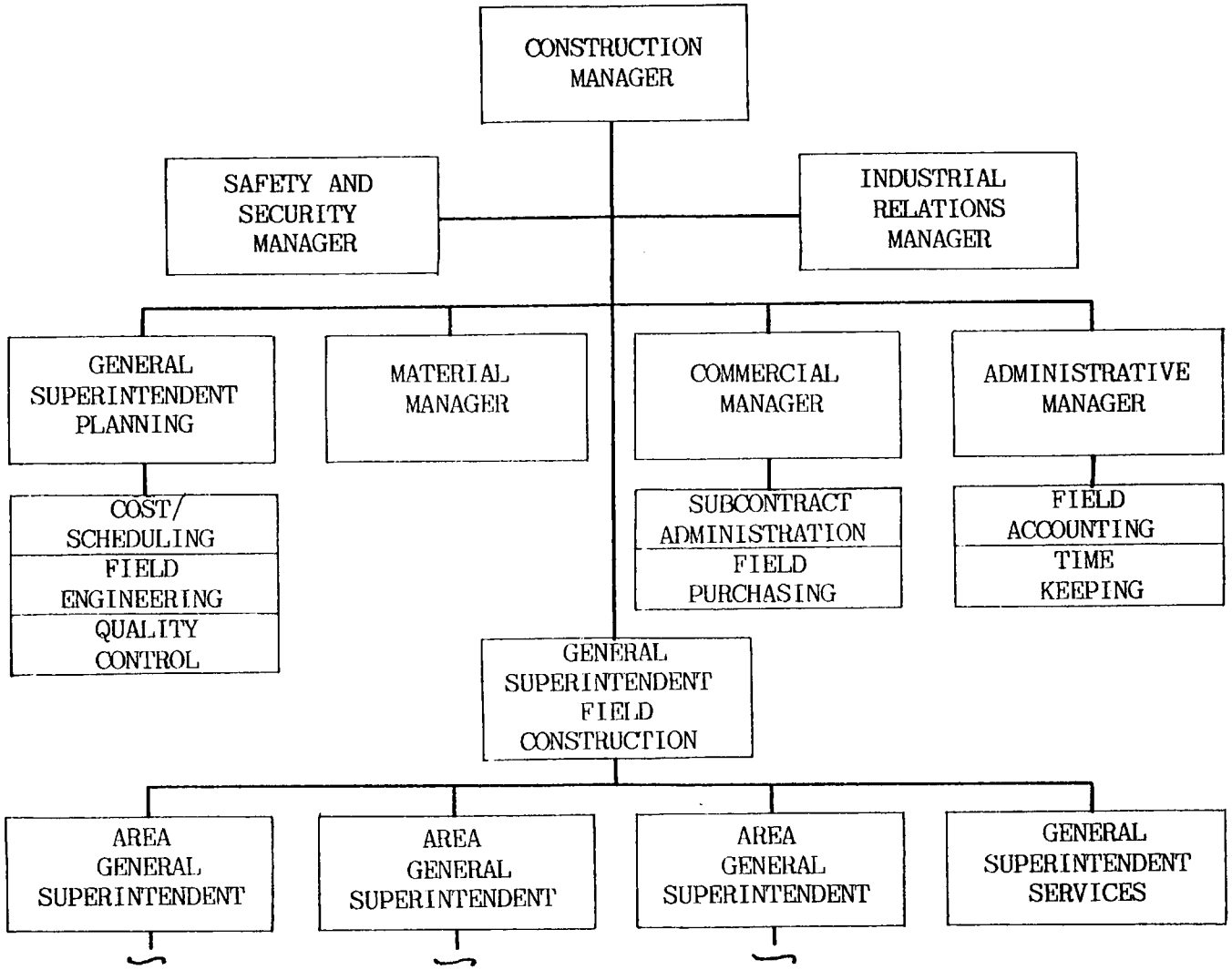


Figure 7. Field Construction Organization.

Project Management Staff

A project director is responsible for and oversees the entire task force. He is engaged in the development of the project budget, the overall schedule, project procedures, and organizing and staffing the project teams. He coordinates and interfaces with the client management team. The project director has as his immediate staff the deputy project director, the area project managers, and the managers of process engineering, materials, cost/scheduling and construction. All information from the task force to the client must pass through the project director.

A deputy project director organizes and directs the detailed daily activities during the initial phase. He reports directly to the project director. He is assisted by project engineers in any specific assignments associated with the development of definitions, procedures, and licensor coordination. As the project progresses, he becomes responsible for all engineering activities performed by the task force. He will assist or, when required, act in behalf of the project director.

The area project managers are responsible for all engineering and cost/scheduling activities in their assigned plant area. They are assisted by project engineers and design engineers and are responsible for their specific disciplines on each area task force.

Process engineers are responsible for the development of the basic design for all processes or obtain design information from licensors. They are directed by the process engineering manager. The group performs their activities from the beginning of the project until all installations are checked out.

A material manager supervises all purchasing, expediting, subcontracting, inspecting and traffic activities. He reports directly to the project director. The material manager must be involved in planning and control during the early stages and remains on the project to control procurement activities as work progresses.

A cost/scheduling manager is responsible for estimates, budgets, schedules, cost control and progess reports. Daily cost and scheduling activities are performed at both home office and construction sites.

A construction manager is responsible for the field organization and reports to the project director. Generally, the field staff is formed at an early date, well before construction starts. The field organization is quite similar to the home office organization in a way that most disciplines have their personnel at both offices. In this way, a lead cost/scheduling engineer in the field has to report to the construction manager as well as the cost/scheduling manager in the home office. This can be viewed as a third dimension of the matrix organization.

In the following chapter, the process technology of petroleum refining along with its facilities are described. Then, the process is presented to show how the construction of a "grass roots" refinery plant is handled by both the owner and the contractor. Fluor practices are given as examples when appropriate.

CHAPTER IV

PETROLEUM REFINING

PROCESS TECHNOLOGY

Crude oil as it is found in nature consists of a complex mixture of compounds containing hydrogen and carbon (hydrocarbons) plus contaminants such as hydrogen sulfide. It is the different combination of carbon atoms and hydrogen atoms that determines the characteristics and types of crude oil. Generally, there are three types of crude oil: paraffin base, asphalt base and mixed base. Paraffin based crudes have a high paraffin content and little or no asphalt. Asphalt based crudes are thicker and darker while mixed based crudes contain both.

The purpose of petroleum refining is to use a variety of processes and equipment to rearrange the hydrocarbons to make the most useful products. Refinery processes can be divided into three major types of processes: separation, conversion and finishing [15:253].

Separation

The first step in the refinery process is "fractional distillation." The separation is made on the basis of boiling-point. The boiling-range cuts may vary depending on the type of crude oil and processing scheme to be employed and there is no fixed way of cutting up or separating the various components of crude oil.

Figure 8 shows the principles of separation of a fractional distillation unit [1:181]. Crude oil is pumped and heated to a

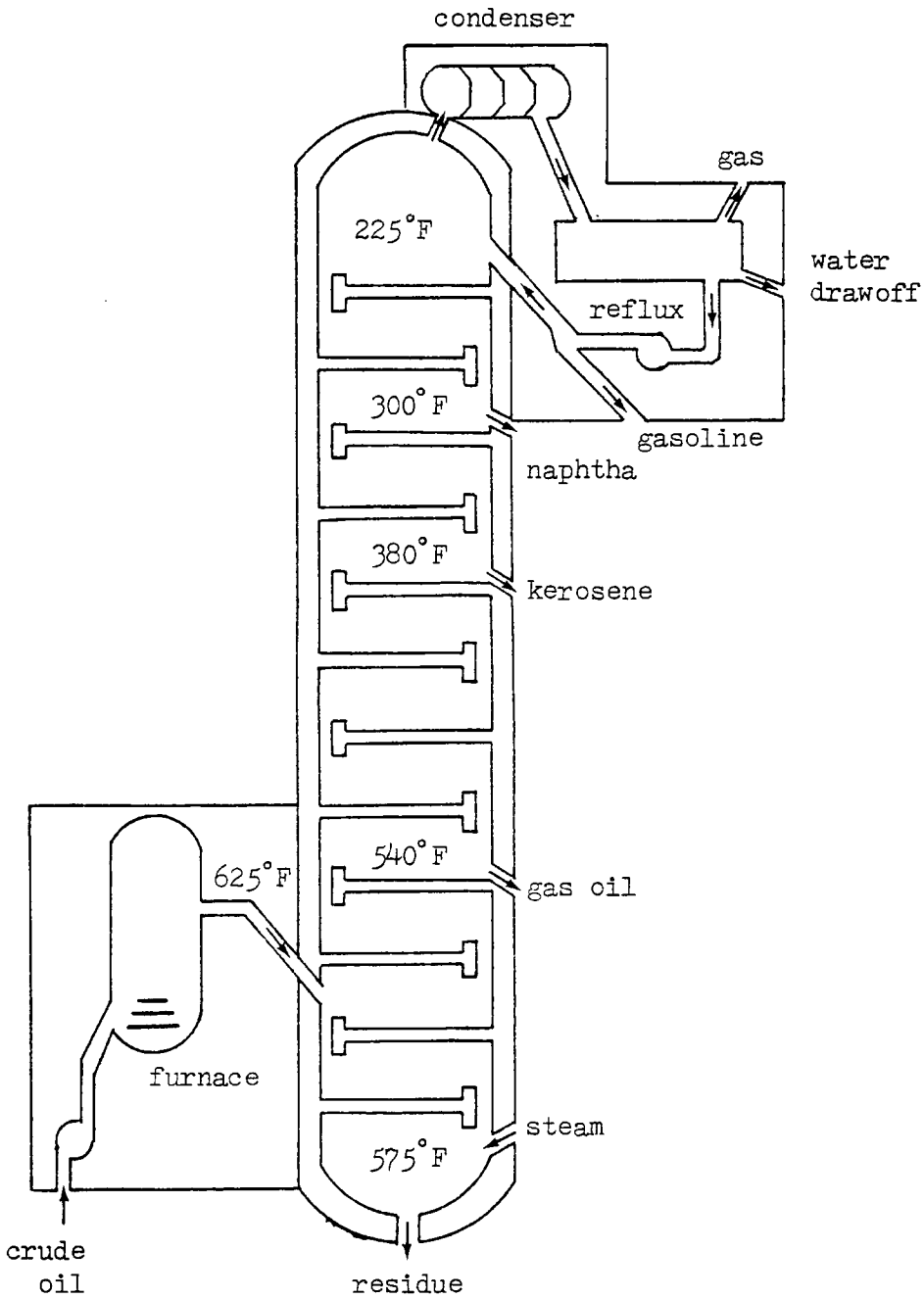


Figure 8. A Fraction Distillation Unit.

temperature between 600° and 700° F, depending on the type of crude oil input. A great portion of the crude oil is vaporized. A combination of liquid and vapor is sent from the furnace into a vertical cylindical tower known as a fractionating column. The column is as high as 150 feet and has 30 or 40 perforated fractionating trays spaced at regular intervals. The bubble-cap tray is the most common type used, but the less expensive sieve tray is sometimes employed.

As the vapors rise through the column, different hydrocarbons condense (liquefy) at different levels in the tower and are drawn off by a series of horizontal trays. At the upper levels, products such as kerosene, naphtha and gasoline are drawn off, along with butane and propane. The boiling ranges for various products withdrawn from the column are shown in Table 1 [1:181].

Table 1: Boiling Ranges of Crude Oil Products.

PRODUCTS	BOILING RANGE °F
Light Gasoline	75° - 200° F
Naphtha	200° - 300° F
Kerosene	300° - 450° F
Gas Oil	450° - 650° F

The degree of fractionation or sharpness of separation between hydrocarbons depends on the number of trays and their individual efficiency in achieving equilibrium between vapor and liquid. It also depends on the ratio between the volume of liquid pumped back into the upper portion of the column and the volume of overhead product. This ratio is called reflux ratio and is usually between 1:1 and 3:1.

Unvaporized oil entering the column flows down over another set of trays in the lower part of the column called stripping trays, which remove any light constituents remaining in the liquid. Steam is injected to assist the reaction. The heavier, thicker liquids at the bottom of the column are sometimes referred to as residual fuels, or simply "resid."

The resid may be distilled a second time under vacuum conditions to produce starting material for manufacturing lubricating oil or as feedstock for catalytic cracking. The process is called vacuum distillation. Its principles resemble those of fractional distillation, except that the column has a larger diameter in order to maintain comparable vapor velocities at the reduced pressures. The vacuum pressure is produced in the column by steam ejectors. Components that are less volatile can be distilled without raising the temperature to the range at which cracking occurs, as it would at atmospheric pressure.

Conversion

Conversion is a major refinery process that alters the molecular structure of hydrocarbons from less valuable compounds into more desirable compounds. The conversion processes can be categorized into

five groups [15:254-276]:

1) Cracking Reactions,

2) Hydrogenation,

3) Isomerization,

4) Alkylation, and

5) Polymerization.

Cracking Reactions.

A. Thermal Cracking. When hydrocarbons are heated to temperature between 850° and 1000° F at pressures of 250 to 500 psi., they begin to decompose, the larger molecules breaking or "cracking" into smaller ones. Paraffins are the most easily cracked followed by naphthenes. Aromatics are extremely refactory. At one time thermal-cracking processes were widely used to improve the octane number of naphthas or to produce gasoline from kerosene or gas oil. Today, the quality of gasoline from thermal cracking of naphtha is not high enough for present day automotive engines and the process has fallen out of use.

However, there are several thermal-cracking processes presently in common use. One is the visibreaking process which is used to reduce the viscosity of heavy crude oil residues by breaking down the larger complex molecules to smaller ones. Another thermal-cracking process is delayed coking. The atmospheric or vacuum residues from low sulfur crudes are heated to about 950° F and passed to the bottom of a large drum where the cracking reaction proceeds by breaking down the high-boiling materials. The lower boiling materials which are formed vaporize at the high temperature in the drum and pass out of the top to the fractionation

system where they are separated into gas, gasoline and gas oil and leave behind in the drum a porous mass of coke.

Thermal reforming, a modification of the thermal cracking process, reforms or alters the properties of low-grade components such as naphthas by converting their molecules into molecules of higher octane number. At 1000°F under a higher pressure than in cracking, it is possible to obtain gasolines with octane numbers of 70-80 from components of less than 40 octane.

B. Catalytic Cracking. The catalytic cracking process is one of the most important processes for the manufacture of gasoline. The process utilizes a catalyst to break or "crack" the heavy fractions from the distillation column into gasoline and lighter products under less severe operating conditions than in thermal cracking. Temperatures inside the reaction chamber can get as high as 950° F at much lower pressures of 10-20 psi. Cracking may be accomplished either with a "fixed bed" of catalyst, with a "moving bed" of granular catalyst, or with a "fluid" catalyst. The latter is a finely divided solid having properties analogous to a liquid when agitated by air or oil vapors.

The fluid catalytic cracking process is one of the most successful methods. Figure 9 shows the principles of operation of a fluid catalytic cracking unit (FCCU) [13:148].

The oil is fed into the reactor and vaporized when it meets the hot catalyst at point A. The vapors force the catalyst into a turbulent condition forming a bed to float in the upper part of the reactor. The depth of the bed can be varied to regulate reaction time. The oil vapors

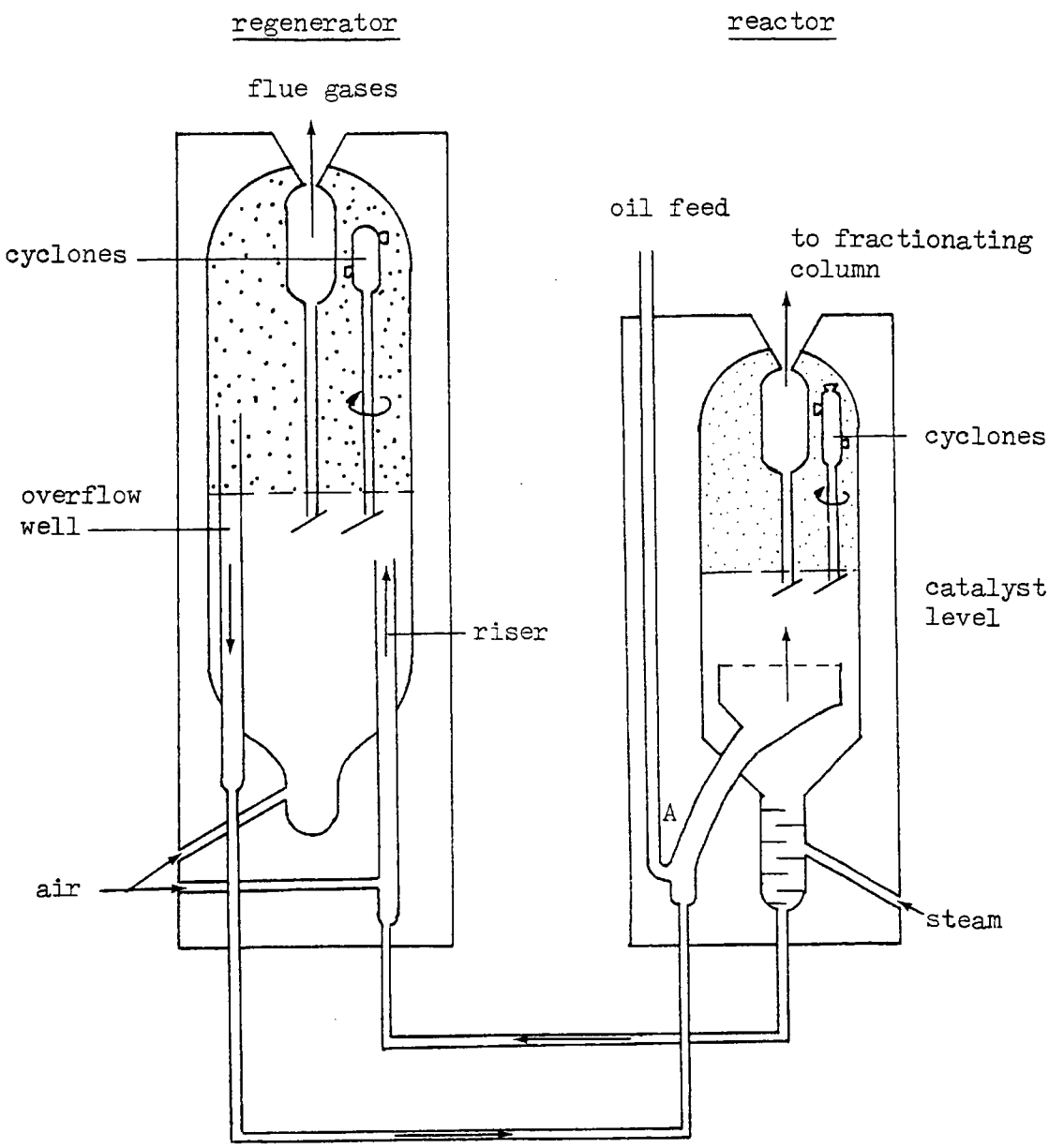


Figure 9. Fluid Catalytic Cracking Unit.

contacting the catalyst cause the cracking reaction and deposition of carbon on the catalyst particles. Since these deposits impair its efficiency, catalyst is continuously withdrawn from the base of the reactor and regenerated in the other vessel by burning off the carbon with a current of hot air. This also heats up the catalyst to the required reaction temperature.

Product vapors are sent to the fractionating column while the catalyst is separated by the centrifugal force caused by separators called cyclones. In the regenerator, similar cyclones recover catalysts from flue gases. A small amount of catalyst is added to the system from time to time and a similar amount withdrawn. The products are fractionated in a distillation column. The yield of gasoline is in the region of 40-60 percent of the gas oil feed.

C. Catalytic Reforming. Catalytic reforming is another important process for the production of gasoline and has almost entirely replaced thermal reforming. This process uses catalysts to mold molecular structure into desirable forms. Naphtha is used as the feedstock.

Despite the metal's high cost, most catalytic reforming processes use platinum as the active catalyst because of its long life and the high yield of products obtained. The main reactions taking place are: dehydrogenation of naphthenes to aromatics, isomerization, dehydrocyclization and hydrocracking [11:66]. All four reactions result in an increase in octane number, usually between 95 and 100.

The reactions are carried out at temperatures in the region of 900-1000° F and pressures of 200 to 800 psi. First, heated gas mixture of naphtha and hydrogen passses downward through catalyst contained in three

series reactors. Because heat is absorbed in the reforming reactions, the mixture is reheated in intermediate heater(s) between reactors.

Then, after leaving the third reactor, the liquid product is condensed, separated, and passed to the stabilizer column, where hydrocarbon gases produced in the reactions are removed. The product is then available for blending into gasoline without further treatment. The hydrogen leaving the products separator is returned to the reactors.

Hydrogenation. Reforming with hydrogen is now becoming popular, in part as the result of the availability of hydrogen as a byproduct of catalytic reforming. Today, two main types of hydrogenation exist: hydrotreatment and hydrocracking.

Hydrotreatment is used to remove impurities such as sulfur, nitrogen and oxygen. Popular active hydrogenation catalysts are nickel, palladium, platinum, cobolt, iron, nickel-promoted copper, and copper chromite.

Hydrocracking converts heavy oils into gasoline and lighter products. The presence of hydrogen and a catalyst causes the process to yield end products without simultaneous formation of coke and large quantities of gas. The activity of the catalyst can be maintained for long periods. Continuous regeneration is not neccessary, as it is in catalytic cracking. The process is accomplished at temperatures which range from 500° to 800° F and at very high pressures which range from 1000 to 2000 psi.

Isomerization. Isomerization is an octane number improvement process for materials boiling in the 85-150° F range. Its advantage is

its ability to convert normal butane into isobutane which is needed for making alkylate for aviation gasoline. The isomerization catalyst is aluminum chloride supported on alumina, promoted by hydrogen chloride gas, or platinum-containing catalyst. Both are very reactive but can lead to undesirable side reactions. These reactions can be controlled by the addition of inhibitors to the hydrocarbon feed or by carrying out the reaction in the presence of hydrogen.

Alkylation. Alkylation, the opposite of cracking, is a process which combines two smaller molecules, i.e. olefins and paraffins, to make longer chain molecules. As a result, the alkylate product has a higher octane rating which ranges from 89 to 95.

There are two types of catalysts in the commercial process, i.e., sulfuric acid and hydrofluoric acid. Sulfuric acid alkylation is carried out in reaction vessels of mild steel, as corrosion of this material with concentrated acid is relatively low. The reaction must be carried out at low temperatures, 35° to 45° F. Refrigeration is needed to remove heat generated by the reaction. For aviation fuel, butylene fractions are usually used as feedstocks. After the addition of tetraethyl lead (TEL), octane numbers of more than 100 are attainable. However, the use of TEL in the manufacture of gasoline is greatly restricted in the United States today.

Hydrofluoric acid alkylation has similar chemical reactions but can be used at higher temperatures. Thus, refrigeration is not needed. Hydrofluoric acid can be recovered by distillation, but it is highly corrosive and toxic.

Polymerization. Byproduct hydrocarbon gases produced in thermal and catalytic cracking processes may be converted to heavier fractions suitable for use as high-octane fuels by polymerization. The process transforms a substance of low molecular weight into one of the same composition but of higher molecular weight while maintaining the atomic arrangement presented in the basic molecule.

Early commercial processes used sulfuric acid as a catalyst but were soon superseded by processes using catalysts of phosphoric acid on kieselguhr or the phosphates of copper and cadmium. Required temperatures range from 350° to 450° F at the pressures of 400 to 1200 psi. The polymer gasolines derived from petroleum fractions containing propylene and butylene have octane numbers above 90, and when tetraethyl lead is added, above 100.

Finishing

Processes that remove undesirable components or impurities from petroleum products are known as treating processes. These processes are used not only to finish products for the market, but also to prepare feedstocks for other processes in which catalysts would be harmed by impurities.

The most common impurities are sulfur compounds; the naturally occurring acidic and nitrogeneous compounds occur in smaller amounts. Sometimes olefins must be eliminated from a feedstock or aromatics removed from a solvent. Similarly, polymerized material, asphaltic material, or resins may be impurities, depending on whether their presence in a finished product is harmful.

Sweetening. Petroleum products containing obnoxious sulfur compounds are called "sour." Sweetening processes remove hydrogen sulfide and mercaptans and convert products into relatively innoxious disulfides. Fractions that are free of obnoxious sulfur compounds, either naturally or because of treatment, are called "sweet," but a sweet fraction may contain sulfur compounds that have no odor.

One of the original methods to reduce odor is the "Doctor Treatment." This process consists in agitating the oil with an alkaline solution of sodium plumbite and a small amount of sulfur. The neccessity of adding sulfur to make the reactions proceed causes an increase in the total sulfur content of the oil.

Modern processes are therefore aimed at removing sulfur-containing compounds. An example is the copper chloride process where the feedstock oil is heated and then brought into contact with slurry catalyst while being agitated by a stream of air or oxygen that oxidizes the mercaptans to disulfides.

Hydrogen Treatment. Hydrogen treatment reduces the sulfur in heavy fractions and resids. Hydrogen or hydrogen-donor liquids and a catalyst are used to treat lighter distillates, removing nitrogen, sulfur, and some metallic contaminants.

The sulfur in the oil is converted to hydrogen sulfide, which is eliminated from the circulating hydrogen by absorption in a solution such as diethanolamine, which can be heated to remove the hydrogen sulfide and then reused. The recovered hydrogen sulfide is useful for manufacturing a very pure elemental sulfur.

Refining Facilities

More and more modern refineries have become integrated process plants as they have to economize and optimize in the areas of services, intermediate tankage and manpower. A simple refinery plant contains a distillation unit, catalytic reformer and various treatment units. It may produce gasolines of differ octane numbers, lamp kerosene, jet fuel, gas and diesel oil, and residual fuels.

In the eastern part of the world, processes in a plant simply may be to manufacture easily marketable residual fuels which may amount to 40 to 50 percent of the crude oil processed. But in the United States and Canada, where large quantities of gasoline are required, less fuel oil is used for heating as natural gas is available within reach of consuming areas. To solve this problem, cracking units and vacuum distillation units may be used to produce fractions for use as feedstock. The production of gasolines can be further augmented by polymerization, alkylation, superfractionation and hydrocracking.

It is possible to complete a fully integrated plant by adding solvent extraction (of kerosene), hydrodesulfurization, lubricating-oil plant (propane de-asphalting, solvent extraction, dewaxing, and clay treatment or hydrofining), plus a plant for the production of asphalt, wax sulfur, and special products. Figure 10 is a generalized flow chart of the refinery process showing how process units are interrelated [1:188].

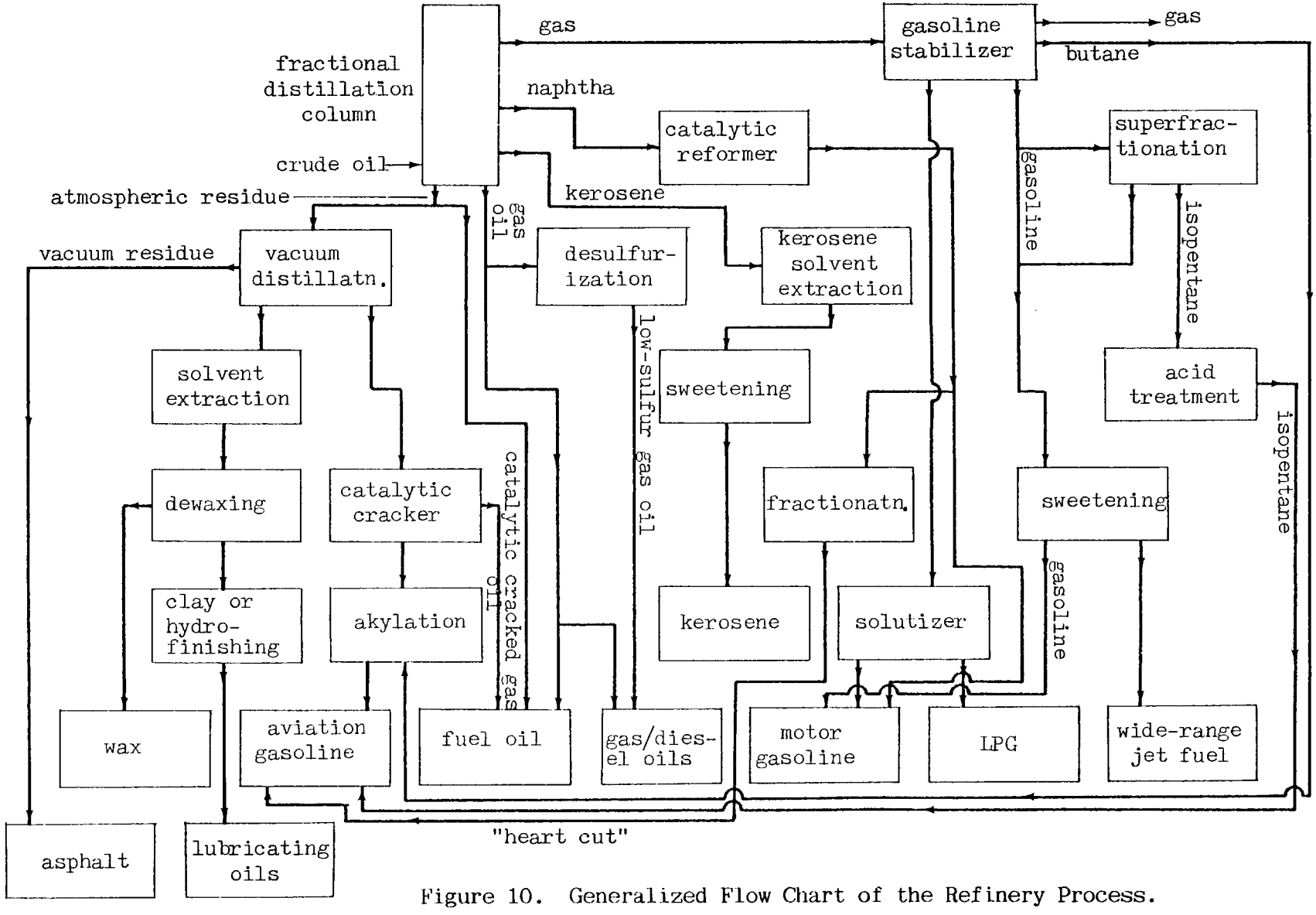


Figure 10. Generalized Flow Chart of the Refinery Process.

BUILDING A GRASS ROOTS REFINERY

Defining the Scope of the Project

If a "grass roots" refinery is required in a new area, the commercial side of the oil company should make a market survey to ascertain the most suitable area for the location of the potential facility [16:275]. (A "grass roots" refinery is a complete refinery plant erected on a virgin site. Investment includes all costs of land, site preparation, battery-limits facilities, and auxiliary facilities.) The future product requirement of the entire region must be estimated and analyzed, and the minimal transportation costs should be considered.

Then, the technical departments are responsible for choosing the best site within the area selected by the commercial department and order a soil survey. The site must have reasonable access to roads, rails, water and pipelines; other factors may include availability of labor, ease of effluent disposal, availability of cooling water. They are also responsible for selecting process equipment best suited to meet the quantitative and qualitative product requirements indicated in the survey.

Oil flow sheets will be prepared to determine what size plant would require to give maximum flexibility to the refinery. Seasonal fluctuations in demand for each product and possible developments of petrochemicals plants in the same area also must be considered.

Process specifications must be prepared defining the requirements for each process, feedstocks needed, product specifications and information on process design. Engineering specifications will then be

prepared. They will specify the material and engineering design requirements for all facilities of the new refinery including furnaces, stacks, towers, vessels, heat exchangers, coolers, pumps, compressors, and piping. Studies must be taken and dicisions made on the quantity of tankage required and the offsites units such as road, administrative buildings, cooling water supply and distribution, power supply and distribution, fire fighting facilities, and drainage systems.

Contract Negotiation

At this point, the owner is in a position to approach contractors. It is normal for the owner to consult several contractors. Contractors will present proposals summarizing their experience, special resources, qualifications and skills in the particular area of work. The owner will reduce the number of contractors after examining all applicants and transmittal of the technical scope of the new plant, need dates, and other required data.

Usually, contractors are required to submit proposals on the technical and commercial aspects of the project. This will take a few months for contractors to prepare and it will take the owner some months to evaluate the proposals and select a contractor.

The technical aspect of a proposal covers the client's scope of work which is described as component process units and support units. All units are broken down into smaller units with estimated manhours, materials required and costs. Potential vendors and licensors are generally identified in the document. Included in the technical aspect of

the proposal is preliminary schedule of the work plan.

The commerical aspect covers legal terms for providing the proper services commensurate with the scope of work. The basis for computing home office costs and indirect costs are included along with the contractor's reimbursement pattern. Generally for petrochemical projects, the form of contracts are "cost-plus" type. Under "cost-plus," the contractor is reimbursed on the basis of all direct costs incurred plus a percentage of these costs to cover the contractor's overhead costs and profits. Petrochemical projects usually have uncertain contents and there is the likelihood of many changes to the project scope and specifications. Thus the cost-plus form of contract provides flexibility.

During the negotiation period, the owner and the contractor each will name project management teams to handle the project from inception to completion. When the proposal is accepted and a contract is finally signed, this stage is often called the project kick-off.

Project Implementation

At Fluor, the early stage of a project calls for a relatively small, highly qualified task force which will materially assist in minimizing changes during the production engineering phase. This provides a cost effective approach to executing major projects. In general, Fluor identifies six phases of engineering activities: Conceptual Engineering, Preliminary Engineering, Design Engineering, Early Production Engineering, Production Engineering and Field Support Engineering [11]. Table 2 shows these six phases.

Table 2: The Six Phases of Project Engineering.

Phase Number	Name of Phase	Major Milestones Achieved
	Project Scope Definition	Scope Defined
I	Conceptual Engineering	Mechanical Flow Diagram Issued
II	Preliminary Engineering	Mechanical Flow Diagram (Rev.2) Unit Plot Plan Issued
III	Design	Client Model Review
IV	Early Production Engineering	Pipeway Installation Drawings Completed and Start of Construction
V	Production Engineering	100 Percent Approved for Construction Drawing Issued
VI	Field Support Engineering	Mechanical Completion
	Post Mechanical Completion	Start-Up and Final Project Functions

After formative activities are completed, additional task forces are established to perform finite geographic areas of work for easy management. Division of work by geographic area also provides continuity and close association between the home office and field effort and results in close attention to detail.

Procurement activities generally start when the preliminary engineering work has been completed. Procurement will be performed by

the purchasing, expediting, inspection, subcontracting and traffic control functions under a material manager who reports directly to the project director.

For construction, activities usually start at 30-50% of engineering progress. Testing all various sections of the plant ends the construction phase.

Project Planning and Control

One of the primary requirements for executing a major project on time and within a budget is a proper planning and control system. Each level of management can monitor and detect early warnings of deviations from the established plan. A team will be organized as part of the project director's staff to implement a planning, scheduling, estimating and cost control program for the project. This team consists of personnel from the cost/scheduling department.

A project schedule and budget will be prepared early in the work to provide a basis for control. These documents are continually refined and become more detailed as the project progresses to more defined levels. Physical progress, along with manhour and dollar expenditures, are tracked on a timely basis and at varying levels of detail to ensure that deviations can be detected at any level of management and in time for remedial action. In the next chapter, cost engineering and scheduling engineering will be discussed.

CHAPTER V

COST AND SCHEDULING ENGINEERING

INTRODUCTION

The objectives of project planning and control are to define realistic work and expenditure plans for executing a project and to provide summary and exception reporting against these plans. Ultimately, these goals are to ensure that the project is completed on schedule and within budget.

In order to control the execution of a project, a well defined plan must first be established. An organization of the project is formed. Decisions are made regarding who does what, when, how, and why. The required resources are determined and allocated on a time-phased basis.

In small projects, various stages of work have a simple logical sequence and planning can be done informally. But in large and more complex projects, formal planning is necessary to ensure efficiency. Therefore, several methods and techniques are required to provide effective planning.

The purpose of this chapter is to present general techniques, methods and systems used in project planning and control which are the functions of cost and scheduling engineers.

SCHEDULING ENGINEERING

In general, scheduling engineers are responsible for developing, maintaining and reporting various levels of work schedules for project management and the client. On large projects, there are usually three levels: a summary schedule, an intermediate schedule and a detailed schedule [12:63].

The summary schedule is used at the management level for the project managers and the client. They are function-oriented and concerned with the overall budget and duration of the job. The intermediate schedule is aimed at project level personnel--the cost and scheduling engineers and the project engineers. These people are concerned with keeping account of reportable work items. But the schedule still is not of a size to permit day-to-day or even week-to-week scheduling or control of work. The third level is the highest level of detail. Each activity is broken down into segmented tasks so that discipline engineers can control the tasks on a day-by-day basis. Figure 11 shows a hierarchy of network plans [12:62].

The computer scheduling system at Fluor, called FAST (Fluor Analytical Scheduling Technique), is capable of producing all three levels of schedules. It facilitates analysis of schedule data, update of the data base and generation of scheduling reports. For reporting, there are three forms of schedules commonly used: bar charts, critical path method (CPM) diagrams and progress curves.

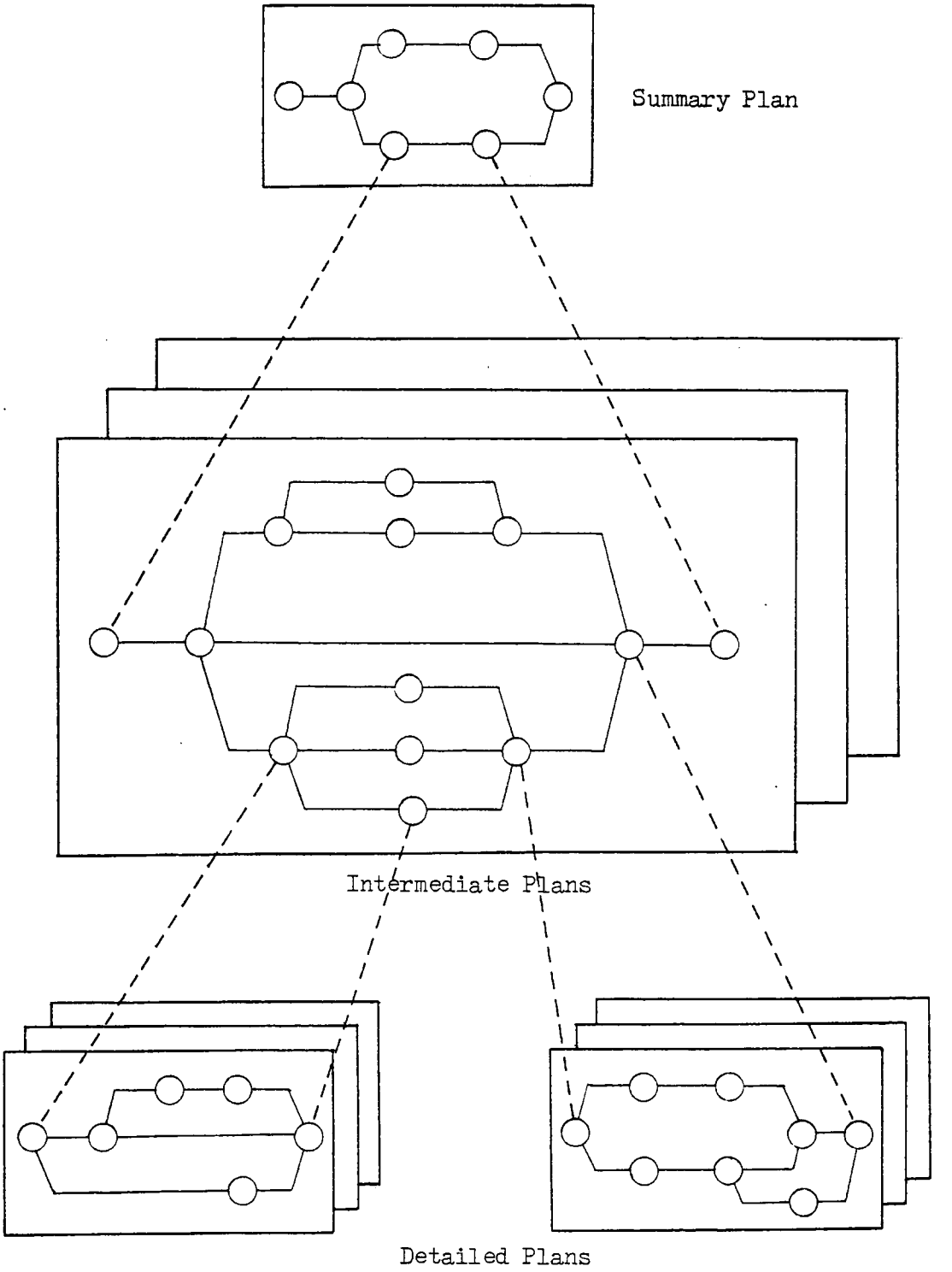


Figure 11. A Hierarchy of Network Plans.

Bar charts provide an initial and general layout of the sequence and time frame for major blocks of engineering, procurement, and construction activities. They constitute the basis for initial project planning including major milestones and manpower needs.

The bar chart has several advantages. It is simple and often clear. It also can be used to show progress of work. However, its major disadvantage is that it cannot show interrelationships between activities on large, complex projects.

The critical path method (CPM), a technique developed in the late 1950's, provides the capability to handle large, complex project networks in systematic ways with the objective of optimizing the duration of the projects. Project scheduling by CPM consists of three basic phases: planning, scheduling and controlling [17:361].

In the planning phase of project scheduling by CPM, the project is divided into distinct activities. The time needed to complete these activities is estimated when detailed information becomes available and network diagrams are constructed with each arc representing an activity. The entire diagram gives a graphic representation of the interdependencies between activities of the project. The CPM networks are stored in the computer data base. The construction of the network as a planning phase has the advantage of showing different acitivities in detail, perhaps suggesting improvements before the project actually starts.

The objective of the scheduling phase is to obtain the start and conclusion times for each activity as well as its relationship to other project activities. The schedule must also determine the critical path

where activities must be given special attention if the project is to be completed on time. For noncritical activities the schedule must show the amount of slack or float times which can be used advantageously when such activities are delayed or when limited resources are to be used effectively.

The last phase of project scheduling by CPM is to control the schedule of the project. CPM diagrams, time charts and graphs are used to display time schedules, progress and resources. The network should be updated and analyzed periodically and a new schedule determined for the remaining portion of the job.

Another form of scheduling consists of progress curves. These are manpower curves and S-plots showing the projected manhour expenditures and projected progress, measured by percent completion. These curves are sometimes generated by the computer. When detailed planning is completed, all manpower plans will be stored in CPM schedules.

There is also a special computer program, called MADAP, which is specially designed for manpower planning at Fluor. The purpose of this system is to forecast anticipated progress and manning requirements over the duration of a job. Using the weighted CPM schedule and estimated productivity for each remaining work period, MADAP will calculate actual manpower requirements for each activity. It also can be used to forecast cash flow and performance. The program recognizes the effects of weather and other variables such as saturation (worker crowding) and quantity of supervision. It can spread the number of men for an assigned craft mix which may be input by the user or selected from a stored data

base.

Construction progress can also be computerized by using the Construction Progress Reporting System (CPRS). In this system, a detailed listing of all activities by account is developed and, as work is completed, progress is indicated against each item. The computer calculates the overall progress at any specified level, i.e., unit, area, or total job.

There are at least five more computerized scheduling systems used at Fluor: Risk Analysis System, Interactive Graphic Drawing System, Report Generator System, and Project Performance Reporting System. Since most projects contain extremely large amounts of data, computer applications are mandatory. It is also important to have interfacing among the systems. The interfacing reduces set-up time and costs and provides consistent information important for effective project execution.

COST ENGINEERING

Cost engineering differs from finance and accounting. For cost engineering, the tasks involved are estimating, analyzing, and reporting cost data to project management. It projects the needed funds through these methods, analyzes and justifies changes in the cost projections and reports on the status of the projected cost picture throughout the project life. On the other hand, finance and accounting functions involve securing needed funds, analyzing the overall profitability and monitoring and reporting cash commitments and expenditures.

A good cost control system should have a well-defined budget and accurate reports of actual expenditures and commitments. It should also

have a good system for identifying deviations from the control base and for initiating corrective action.

Upon release of the work, a group of cost engineers will be organized to implement cost programs as follows: a) Project Code of Accounts, b) Cost Estimating and c) Cost Control and Trending.

Code of Accounts

To aid in the collection of all data, codes of accounts are developed to fit specific needs of the project and the client's requirements. All estimates, cost reports, and expenditures/commitments are based on these codes to assure conformity throughout the project.

At Fluor, the cost code divides project costs into 10 prime accounts, numbered 0-9. The sequence of accounts generally corresponds to the order in which work is done. Table 3 shows a list of prime accounts.

An account code is six digits long. First digit is for the prime accounts mentioned above. Second digit is for subaccount. An example is a cost code 460002. The first number, "4," is the prime account indicating this is a machine or equipment. The second number, "6," is the subaccount indicating pumps. The next three digits, "000," are the detail account. For a particular contract, this can be any three digit number to identify a specific pump. The last number, "2," is called a significant digit, indicating field material and expense.

Table 3: Major Prime Accounts.

ACCOUNT NUMBER	DESCRIPTION
0	Excavation
1	Concrete
2	Structure Steel
3	Buildings
4	Machinery and Equipment
5	Piping
6	Electrical
7	Instrumentation
8	Scaffolding, Insulation and Painting
9	Home Office and Indirect Field costs

Cost Estimating

As many as five different project cost estimates may be made for a given project. Each estimate is more accurate than the previous one. They are capacity-factored, machinery and equipment factored, semi-detailed, detailed and check estimates.

Capacity-Factored Estimate. To develop this estimate, costs of the units in the proposed project are factored from the costs of similar sized units installed by the company on other projects. This is normally used in the preliminary sales effort to assist the client in economic

evaluations and preparation of a rough budget. It is generally accurate to within 30 to 35% of final job costs. However, it is the least expensive type of estimates and takes only a day or two to complete.

Machinery and Equipment Factored Estimate. This type of estimate requires detailed prices for all major machinery and equipment. It is generally accurate to within 20 to 25% of final job costs. The estimate may cost from several hundred to several thousand dollars, and may take from five to thirty days to complete.

Semi-Detailed Estimate. This type of estimate is prepared based on mechanical flow diagrams, priced machinery and equipment lists, plot plans, design drawings and other available details. Indirect field and home office costs can be estimated by using curves generated from statistical data.

Detailed Estimate. A detailed estimate is one in which each component or group of components comprising a project scope definition has been quantitatively surveyed and priced using the most realistic unit prices available. Normally, Fluor prepares the detailed estimate when the project scope definition in terms of plot plan, mechanical flow diagrams, equipment and material specifications, and preliminary design and layouts have been developed to the point where they reasonably represent the final quantitative evaluation of the project.

Check Estimate. This type of estimate is performed when engineering is 100% complete. Discipline engineers will assist and provide cost information to cost engineers who will compile all costs and come up with the total project cost. This type of estimate is the most accurate one and may take a few months to complete.

Cost Control and Trending

The key to cost control is the early detection of deviation from plan. The monitoring, controlling and forecasting of office and field labor costs against the planned budget are accomplished through the use of the control estimates and the following reports:

a) Project Cost Reporting System (PCRS),

b) Financial and Management Reports,

c) Trend Reports, and

d) Change Orders.

Project Cost Reporting System (PCRS). PCRS is a computerized cost reporting system used to store and retrieve cost data from both cost engineering and accounting. The data is input from both departments into a common data base which permits selected retrieval of data relevant to the cost engineer's analysis.

There are five categories of data stored in the PCRS: budget, indicated total cost (ITC), obligations, commitments and expenditures. The budget, ITC, and obligations are input into the single data base by cost engineering. Commitments and expenditures are input by accounting.

Financial and Management Reports. Information from cost reports is used to prepare financial and status reports for project and corporate management. Two major reports on which cost engineers are involved are the Quarterly Forecast of Operations and the Project Financial Status Report.

The Forecast of Operations is a financial report dealing with the company's profit. It provides management with the current outlook for

potential project income. The report shows the distribution of expenditures and profit through the life of the project.

The Project Financial Status Report is a monthly report to management of the current project status. It includes financial status and schedule status of the project.

Trend Reporting. A trend is defined as any known condition which could result in a deviation from the current budget or schedule. The trend alerts project management of conditions which might impact the budget or schedule so that appropriate action may be taken. Trends initially impact only the project forecast (ITC). Only after they have been approved as change orders do they affect the budget.

Change Orders. A change order is a formally documented and approved change to the budget which involves a change in the scope of work as defined in the original contract. Before client approval, the change order affects only the ITC. Once the client has approved the change, it is put in the budget. A change order may increases or decreases the budget. It can be initiated in the home office or in the field. In either case, an analysis of the proposed change will be prepared, including a detailed description of the work, costs associated with the change and the impact of the change on the schedule.

Cash Flow Forecast

The purpose of cash flow forecast is to advise the project management, the Fluor Corporate finance department and the client of cash requirements throughout the project life. Usually, cash flow analysis is done monthly.

The first step to control cash flow is the preparation of a cash flow curve. The simplest way is to generate one using historical data. The second and more complicated method is to generate a curve from a schedule. At Fluor, the second type of cash flow curves are generated from the CPM schedule. The Fluor's computer scheduling system has the capability of accepting dollar resources required to perform each acitivity in the schedule. Actual expenditures are plotted against cash flow curves and deviations are analyzed for remedial actions.

PROJECT PLANNING AND CONTROL

The success of any project requires the work to be completed on schedule and within budget. The key to successful completion of a job is project planning and control, which is the primary function of cost and scheduling engineers.

Management is provided with an early warning of deviations from the established plan or potential problems via the application of techniques, procedures, computer programs and reports. They are usually tailored to fit specific needs of a particular project.

The principle of project planning and control for refinery construction projects is like those for any other industrial construction project. For each project, objectives, strategies and plans are defined and translated into a concrete schedule and budget.

When construction begins, actual results become available as data. First, data are analyzed and reported in forms of percent completion, productivity, and labor and material costs. Then, the reports are

interpreted and compared with the budget and schedule to determine if the project is operating smoothly. Through these analyses, the actual conditions can be determined and a forecast developed for the remainder of the project.

If no problems are perceived, the status of the project is reported to project management. If there is a problem, the status is reported and possible solutions suggested. With information from cost and scheduling engineers, the project management can revise the strategies, objectives and plans. Thus, effective project control would certainly help the job to be completed on schedule and within the budget.

CHAPTER VI

WORK ASSIGNMENTS AND CONTRIBUTIONS

INTRODUCTION

The author is the third intern from Texas A&M University to be employed by the cost/scheduling department of the Fluor Engineers, Inc. - Houston Division. B. Afiesimama and S. Dobbs were his predecessors. Their experiences at Fluor were described by internship reports [1,3].

During the one-year internship, the author was involved in two refinery modernization projects. Fluor was responsible for managing and performing engineering, procurement and construction of the projects. Both projects had similar scopes of work, i.e., to upgrade the existing refineries to process heavy, high sulfur content crude oils and to increase gasoline production.

The author was initially assigned to a cost/scheduling task force of approximately fifteen engineers. The task force was divided into a scheduling group, in which the author worked, and a cost group. At that time, the three-year refinery modernization project was winding down and was six months from completion. Most assignments were non-routine.

The author then was transferred to another on-going project about 35% completed in engineering and construction which was about to start. The organization of the cost/scheduling task force on this project differed from that of the previous one. There were three groups: the on-site group, the off-site group and the central group. The on-site and the off-site group were responsible for planning and controlling cost and

scheduling activities of area/units under their supervision. The central group was responsible for reporting cost and scheduling activities to the management and client. The author worked in the central group and reported to the central group leader who reported to Mr. Jansen, the cost/scheduling task force manager.

TASKS AND WORK ASSIGNMENTS

In the following sections, the author's assignments are described. The schedule of these assignments is shown in Appendix F. Due to proprietary restraints, no specific data nor detailed results will be given. The names of clients and construction locations will not be mentioned. The author will refer to the first assigned project as Project A and the second as Project B.

Studying Cost/Scheduling Computer Software Systems

During the first two weeks, the author was assigned to study a few computer software systems used in the cost/scheduling department. These were Fluor Analytical Scheduling Technique (FAST), Report Generator System (RGS) and Manpower Distribution Analysis Program (MADAP). This study was important as the author later dealt with many of the same, as well as other, computer-related systems throughout the internship.

Revision of Progress Base

The author's first work assignment on Project A was the revision of field progress base manhours. The "Progress Base" is the estimated base manhours used for calculating construction progress and productivity.

The work involved the collection of information from cost engineers and field engineers. Estimated manhours for all accounts, all units, for both direct field labor and subcontract labor were gathered and prepared in matrix form. Before the Progress Base was officially issued, all values were verified to ensure that cost, scheduling, and field engineers had the same information. Usually, Progress Base is updated every time there is a new estimate. For Project A, the Progress Base was revised on the basis of a new project estimate made just prior to the internship.

MADAP Assignments

Manpower Distribution Analysis Program (MADAP) is one of the computer systems frequently used. On Project A, the author utilized MADAP to forecast the job progress. Manpower, labor performance and craft mix data for each prime account were gathered and applied as input. The capability of MADAP is briefly described in Chapter IV. More details, such as its input and output, can be found in the next section as a simpler BASIC version of MADAP is presented.

MADAP can be used as a tool for planning, forecasting and control. It can be used to spread manpower and dollars over time periods. On Project B, the author used MADAP to spread the project's forecast cash flow. It was the end of the year and the client wanted to spend a specific amount of money during the following two years. With the expenditure restrictions, the project management had to verify that planned expenditures would occur according to the plan and would match

the client's needs.

The assignment involved preparing thirty-four separate cash flows. The start dates, end dates and anticipated progress were obtained from the detailed schedule. Budgets for field and home office costs, escalation, contingency, and fees were obtained from the detailed estimate. With this information, MADAP produced the project's forecast cash flow. Fortunately, the results indicated that only minor adjustments would be needed in construction plans to meet the client's limited capital expenditure plan.

The author used MADAP for the third time in early 1983 to prepare a construction manpower plan. Construction had just begun and the author was solely responsible for the assignment. Similar to the cash flow analysis, the input needed were the start and end dates of all units from the detailed estimates and the planned progress from management. Major requirements for each period in the construction plan were steady manpower buildups, no excessive peaks, and no fluctuations plus all requirements subject to the budget and schedule. The construction manpower was over two thousand workmen at the peak and there were more than twenty units. Where each unit required various types of craft laborers, during the planning stage, management often used "trial and error" estimates or set up "what-if" situations to set manpower needs.

All the input of this assignment was stored in a computer file via a computer system, called Fluor Universal Data Entry System (FUDES), with a newly added feature for MADAP. The data file contained more than eight hundred image cards.

With the capability of the FUDES to interactively update data, preparation of construction manpower plan using MADAP was made easier. However, FUDES is a general purpose data entry system designed to be used with several other computer systems at Fluor, and a user needs to be familiar with it and the FUDES-MADAP interface to use both more efficiently. After manipulating MADAP file for almost two months, the author decided to create a simpler version of MADAP with a full interactive data editing capability. Results of this project will be presented later in this chapter.

Phased Engineering Study

Mr. Jansen was assigned to do an in-house study to determine the effect of Fluor's "Phased" engineering approach on the job progress. The assignment was part of a worldwide program to examine project execution and technical excellence within Fluor Engineers, Inc. [7:3].

Under his direction, the author made a detailed study and prepared a 63-page report. The report covered the "Phased" engineering concept, how the study was conducted, its results, conclusions and recommendations. Due to proprietary restraints, the contents of this report will not be discussed in detail. Only the "Phased" engineering concept and how the study was conducted are presented in this section.

The "Phased" engineering approach provides the guideline for the execution of a project encompassing a sequence of discipline functions which are designed to: a) achieve greater efficiency in staffing the project task force; b) minimize the premature start of work; c) reduce recycling of information and d) support efficient construction staffing

[10]. At the beginning of this assignment, areas needing further study were identified. They were:

- Review requirements, timing, etc. to accomplish process development functions without major staffing of engineering personnel in order to turn over a "package" of process engineering to other engineering disciplines.

- Examine past jobs to identify causes of delays in engineering, procurement and construction.

- Examime past jobs for actual manpower history and try to identify key milestones in manpower buildup.

- Investigate material commitments versus job progress for possible relationship.

- Examine incentives for timely receipt of vendor information.

- Investigate construction move-in delays to minimize engineering field support.

- Study phasing of design disciplines to minimize home office staffing build-up without effecting overall project completion.

- Examine methods to plan overall project execution using the "Phased" approach prior to dividing the project into detailed engineering, procurement and construction schedules.

As areas of study were identified, tools for comparing performance of one job to another were chosen. Manpower curves, in conjunction with progress curves, were used to determine if there were any patterns among jobs. Also, major engineering activities were chosen as key milestones to plot actual schedules against the norm for various jobs.

At the beginning, data were collected from six on-going jobs at the Houston Division. Later the effort was expanded to other divisions. Questionnaires were sent to London, Calgary, Manchester and Southern California Divisions. Altogether, there were twenty-six jobs available for study.

Data received from the questionnaires were reviewed and then reformatted for easy comparison. The data for engineering activity schedules were converted into percentage of the total contract time. The contract award time was considered 0% of the total time and the mechanical completion time was considered 100% of the total time. For each job, the major engineering activities were plotted against the typical "Phased" engineering schedule. Months and years were shown along with the time percentage.

Home office manpower curves of jobs in each division were superimposed on the same plate for comparisons. Similarly, the home office progress curves were prepared and grouped in the same format. Also, ratios of indicated total home office manhours per million dollars of the selling price of the projects were prepared. These ratios were used to see if there was a correlation between productivity and schedule.

In addition to the information obtained via questionnaire, meetings with control team leaders of the six on-going Houston jobs were held and lead engineers in several disciplines of Project A were interviewed. A survey of the amount of rework done in each discipline was conducted, to indicate the efficiency of the "Phased" and "Non-Phased" approach. The results, conclusions, and recommendations of this study are being omitted because they are confidential information.

Analysis of Construction Progress and Performance

Progress and performance are the two most important key measurements in scheduling. While working on Project A, the author was assigned to analyze and predict field labor progress and performance for three construction disciplines, namely, piping, electrical and instrumentation. These disciplines were behind the original schedule and project management was paying particular attention to these areas. Graphs of performance against progress were prepared from historical data of five past jobs. Using the aggregate trends of these past jobs, the forecast performances of the project were achieved. Factors influencing performances were investigated. These factors included the number of weekly field labor and the number of weekly absentees. The analysis showed that the number of absentees had an impact not only on the progress, but also on the performance. This may be explained by the fact that absentees on the part of a few skilled laborers from a group reduce the efficiency of an entire team assignment.

The Collection of Historical Data

The author was engaged in compiling historical data of Project A as it ended. Expenditures, progress, performance, manpower, and manhours of most construction accounts were recorded over the project life. Factors, ratios, bar charts and graphs of key attributes were prepared for future use. For example, important ratios in the machinery and equipment account might be the ratios of the total material costs over the total

direct field costs. These ratios would be calculated at the time of the detailed estimate and the check estimate and then compared with the ratio of the final costs. These ratios reflected how cost/scheduling engineers performed the estimates. In addition, the ratios would also be kept for future references.

Determining the accuracy of estimating equipment costs of the factor estimate, the detailed estimate and the check estimate were also the author's responsibility. Accuracy factors are important figures for management and require additional and more detailed study if any factors are higher than expected. Before comparisons could be made, a few important parameters had to be considered during these calculations; i.e., the scope changes, escalation, and allowance costs.

Graphs were made of manhours of all accounts against progress, progress against performance, indicated total costs (ITC), commitments and expenditures against duration or against engineering progress. Several other graphs were also prepared. In all, there were more than fifty graphs produced.

Preparation of Management Reports

Toward the end of Project A, the author, the only engineer left on the scheduling task force in the home office, was responsible for preparing slides used in management meetings. These slides showed monthly manpower requirements, accident rate, engineering and construction progress, and the progress of a few outstanding construction activities.

Attendance of Scheduling Classes

The author had the opportunity to attend two scheduling classes arranged by the analysis and development group of the cost/scheduling department. He joined a four-day course covering the FAST82-PREMIS scheduling system. It was a new scheduling computer program and would be implemented on new projects at the Houston Division. This system has two major improvements over the existing FAST system. It can handle multiple activities between two given nodes and the interfacing capability between cost data base systems and scheduling data base systems. In other words, the new FAST82-PREMIS is an integrated cost/scheduling computer system. During the four-day period, the author learned the basic concepts, how to set up networks, how to input data, and how to run the program. It was a valuable experience.

The author also attended a presentation on the Project Performance Reporting System (PPRS) for scheduling engineers on the Project Task Force A. Introduction, objectives and system overview of the PPRS were presented. Planned progress, manpower and performance are used as input for generation of the Project Performance Report. The PPRS provides the home office and construction management with the basic information needed to evaluate and measure project performance. Often, MADAP output is used as PPRS input. This can be handled by the computer by transfering MADAP cumulative progress percentages onto a MADAP/PPRS interface file for later processing by the PPRS system. The cumulative percentages correlate to the PPRS plan file.

Project Cost Reporting System

The author was involved with the Project Cost Reporting System (PCRS) on two occasions. The first time was on Project A involving a special task assignment to implement the Report Generator System (RGS) by producing a one-page summary showing the monthly financial status of the project. RGS is a flexible reporting program that has the ability to obtain special reports, input data, and print out selected PCRS records. A few test runs were performed and the results indicated that RGS could not produce the desired financial figures directly. Two separate runs were required and their results were combined manually for the desired results. The assignment took about one week and gave the author the first opportunity to become familiar with the Project Cost Reporting System (PCRS). Six months later, the author had to maintain and update the Project Cost Reporting System of Project B which became his main responsibility for the rest of the internship.

Cost engineers reported detailed project costs monthly to the project management and the client. These reports included the present project costs with respect to original and current budgets, indicated total costs and commitments. It reflected the amount of money and manhours expended for the current month and the accumulation to the date of the report.

After the fiscal cutoff date, expenditure and commitment data would be transferred from the accounting file to the PCRS file. It was the author's responsibility to update any known changes or correct the file. Trends and change orders issued during the month had to be placed into

the PCRS data base thus yielding the current budgets and indicated total costs. Any other costs that were not maintained by the accounting department such as material commitments and subcontractors' home office costs would be put in a separate cost file.

Projects vary from one to another, thus the ways to handle the PCRS and cost file structures also vary. For the $500-million-plus project, the project organizational structure was complicated, causing the cost file structure to also be complicated. Experiencing difficulties in becoming familiar with the cost file structure of the project, the author prepared a 20-page document about the structure of the cost files, type of reports needed and procedures on how to produce those reports. A copy of this document is not included for confidential reasons. Normally, it would take about two weeks to complete cost reporting activities. Several types of reports would be produced for the client, for the project management, and for interal use.

Two Month Cash Flow Projection

The client of Project B required monthly cash flow projections for the following two months to allocate bi-monthly funds. The projection would be calculated at the most detailed level possible. Costs were broken down into major categories such as home office, field labor, equipment and material, subcontractor costs and fees. Home office costs, which were based on the number of home office staff planned, included salaries and overhead costs such as for reproduction and computer use. Field labor costs were based on the number of field laborers planned. Material and equipment costs were projected based on information obtained

from expediting and procurement groups. For major equipment, types of payments and shipping plans were important factors to be considered. Sometimes payment was made 30 days after equipment arrived at the site, but often they were under progress payment plans in which payment is made under various conditions. Subcontractor costs can be projected from the expediting information obtained from the field.

The cash flow task usually took about one week. The author was responsible for this asssignment for two months. Later, as he took two additional assignments; i.e., maintaining the PCRS system and preparing the construction manpower plan, the cash flow projection task was transferred to another cost engineer. The author still assisted the engineer in performing the cash flow task during the next three months.

Equipment and Material Procurement Status Report

The equipment and material procurement status report is one of the scheduling activities that the author performed while he was on Project B. As an engineer in the central group of the cost/scheduling task force, the author coordinated and gathered equipment and material procurement progress information from about fifteen scheduling engineers. The information included the releases of Request for Quotation (RFQ's), Purchase Orders (P.O.'s) and the receipts of equipment and materials at the field. Once the data were compiled and tabulated, the results, upon approval of the cost/scheduling manager, would be sent to the graphic department where color graphics were produced for monthly progress reports. The process took about one week. Most cost and scheduling

activities can be performed only after the end cf each month when information becomes available. Therefore, cost and scheduling engineers' work loads are not uniform. The work load peaks during the first two weeks of each month, then decreases after reports have been issued.

Monthly Progress Support Documents

When the author was first transferred to Project B, one of his assignments was to prepare and issue "Monthly Progress Support Documents." This required working with several task force engineers during the first half of each month. The documents contained a detailed project cost report, office labor recap and billable payroll, trend and change order logs, home office manpower plan and progress, and engineering schedules. The author was responsible for this work for two months until the project management decided to change the format of these reports and have them issued individually.

Home Office Manpower Planning

Two months after the detailed estimate of Project B was completed, the author was assigned to revise the home office manpower planning. The plan was based on anticipated manpower utilization from all home office disciplines and the manhours estimated in the recent budget. The plan let project management and all disciplines see their revised staffing plans based upon the budgeted manhours available.

A Visit to the Construction Site

During the last month of the internship, the author visited the construction site of Project B for two days. The purpose of the trip was two-fold: a) to observe work practices of the field organization and b) to serve as cost/scheduling computer laison.

The author assisted a field cost engineer in setting up a computer file to maintain expended subcontractor's manhours. Two computer programs were prepared and tested and the task was successfully completed.

As a result of the trip, the author gained a better understanding of the role of field staff, especially in the cost/scheduling area. He observed how field staff functioned and how it fit together with the home office staff. These observations already have been discussed under Project Management in Chapter III.

A MICROCOMPUTER SOFTWARE DEVELOPMENT

Microcomputers have become essential tools in the operation and management of all types of firms. At the Houston Division, several microcomputers are used for applications such as estimating, data base, and word processing. The following sections present the development of a computer software where the author used his academic training and technical knowledge to make an identifiable contribution in the area of cost and scheduling to the company.

Specifically, the author developed a computer program for microcomputers that is capable of finding anticipated progress or manning

requirements over specified time periods. It is an interactive MADAP-like program for use in small to medium size manpower planning applications. The program was written in Microsoft BASIC language, 8086 version. It was developed for a VICTOR 9000 microcomputer and the output code was designed for an EPSON FX-80 dot matrix printer. It is expected that the program can be used with most computer systems with minimal changes.

Description of the Manpower Analysis Program

Purpose. The purpose of the program is to forecast anticipated progress or manning requirements over time periods.

Features.

- Finding the manpower required to sustain a given incremental progress plan.
- Finding the progress rate associated with a given manpower plan.
- Totaling any desired cases.
- Creating data files for new input. Thus, a user can update or add data to existing files or can simply rerun a job with a few entries.
- Having simple input and data manipulation processes with the interactive capability.
- Helping users learn how to perform manpower planning in a shorter period of time with this simple version of the manpower distribution analysis program.
- Taking up to 20 cases and having a maximum limit of 30 time periods.

Input Description

Following are the inputs requested by the interactive program. They are listed in the order of their appearances on the CRT screen.

1. DATA FILE NAME: A file name containing up to eight characters. Assign a unique name for each application.
2. CONTRACT NUMBER: The contract number will be printed on the first page of the output.
3. PROGRAM DESCRIPTION: The program description will be printed on the first page of the output.
4. MAXIMUM INTERVAL: The maximum interval is the maximum number of time periods required for the run. The maximum for this program is 30 periods.
5. COLUMN HEADING FOR PERIOD: This is the heading for period number n, e.g., "JAN 83", " 1 QTR". Each column heading should be six characters long.
6. AVAILABLE MANHOURS FOR PERIOD: This is the number of manhours that each man is expected to work in each time period.
7. TYPE OF INPUT: For manning input, reponse with an "m"; for progress input, response with an "p".
8. CASE I.D. NO.: Assign case I.D. number for each case entered. The I.D. No. should begin with 1, and 20 is the maximum.
9. CASE DESCRIPTION: Assign any description desired for each case.
10. START PERIOD NO.: This is the first time period for a particular case as it relates to the entire run.

11. END PERIOD NO.: This the last time period for the case, i.e., 100% complete.

12. BUDGET MANHOURS: This is the total manhours budgeted for the case.

13. ACTUAL % PROGRESS: This is the actual physical percent progress accomplished as of the status date.

14. ACTUAL MANHOURS: This is the actual manhours used to complete the physical progress as of the status date.

15. FORECAST MANHOURS: This is the current forecast manhours to complete all work in the case. This information is optional, as "0" or blank entries will default the forecast manhours equal to the budget manhours if incremental progress is used or it will calculate the new forecast manhours if manning (m) is the input.

16 a). INCREMENTAL PERCENT PROGRESS FOR PERIOD: Enter incremental percent progress for all periods for the case, if the response to the type of input no. 7 was progress input (p).

16 b). EQUIVALENT MEN FOR PERIOD: Enter equivalent men for all periods for the case, if the response to the type of input no. 7 was manning input (m).

There are still a few questions asked by the program, but those are simple and self documented.

Output Despcription

1. CONTRACT NUMBER: Manual input.

2. RUN DESCRIPTION: Manual input.

3. FILE NAME: Manual input.

4. CASE ID: Manual input.

5. CASE DESCRIPTION: Manual input.

6. BUDGET MHRS: Manual input.

7. ACTUAL MHRS: Manual input.

8. FORECAST MHRS: Forecast manhours estimated to complete all work on the case. This value will either be manually entered or calculated by the program.

9. PERCENT COMPL: Actual physical percent progress complete to date. Manual input.

10. START PERIOD: Manual input.

11. END PERIOD: Manual input.

12. MH'S AV/MAN/PERIOD: The number of scheduled manhours per man for each specific period. Manual input.

13. RELATIVE EFFICIENCY: Manual input.

14. REM MH'S/1 PCT: The number of manhours required to complete one percent of the remaining job, adjusted for relative efficiency.

15. PROGRESS

    INCR PCNT: The incremental progress plan for the job. When PROGRESS INPUT is used, this data is input. When MANNING INPUT is used, this data is calculated and shown as output.

    CUML PCNT: Total cumulative percent progress. This includes the actual percent complete input from the user plus the sum of the incrementals for each period through 100%.

    INCR PCNT BUDG: This is the incremental percent of the budget spent each period, based on the number of manhours expended for

each period.

CUML PCNT BUDG: This is the cumulative percent budget spent each period, based upon the actual manhours spent (divided by the budget) plus the sum of the incrementals for each period.

16. MANHOURS:

INCR MH'S EXPENDED: Number of manhours to be expended each period, adjusted for the relative efficiency.

CUML MH'S EXPENDED: Cumulative manhours to be expended each period, adjusted for the relative efficiency.

INCR FOR PROG: Number of manhours to be expended each period, omitting the relative efficiency.

CUML FOR PROG: Cumulative manhours to be expended each period, omitting the relative efficiency.

17. MEN: Number of men required to sustain the progress plan shown in the INCR PCNT PROGRESS. This is output data, if PROGRESSS INPUT is used. When MANNING INPUT is used, this is input data.

18. PERFORMANCE:

INCR PERF: Incremental performance for each period.

CUML PERF: Cumulative performance for each period.

Examples of Output

Two examples of output are given in Appendix A. In the first example, progress is input along with budget manhours, actual manhours, percent complete as well as other data as described in the Input Description section. There are three cases in the first example. In Example II, manning is input and the example has two cases.

CHAPTER VII

SUMMARY AND CONCLUSION

This report has described the author's work during the twelve-month internship with Fluor Engineers, Inc. - Houston Division, where he served as a cost/scheduling engineer on two refinery modernization projects.

His scheduling responsibilities included forecasting, analyzing, and compiling field labor progress and performance; developing and updating home office manpower plan; preparing plan construction progress and budget manhours; preparing management reports and performing an across-division analysis in "Phased" approach in engineering. As a cost engineer, the author was responsible for the computerized cost reporting system of the second project and for short-term and long-term forecasts of cash flow.

The first internship objective was to observe Fluor's general approach to project implementation. The involvement in the Phased Engineering Study provided a good opportunity for the author to achieve this objective. Project implementation was discussed along with contract negotiation and project planning and control under the topic of how to build a "grass roots" refinery plant in Chapter IV. In this chapter, the process technology of petroleum refining was described to demonstrate that the second objective had been met.

The third objective was to take responsibility in cost and scheduling engineering and implement Fluor's techniques on a project. During the internship, the author had assignments in both cost and

scheduling aspects. The essence of cost/scheduling engineering learned and Fluor's practices were presented in chapter V and his assignments were described in the following chapter.

The next objective was to develop at least one new system or method that would improve the quality and efficiency of the cost/scheduling department. The author developed a computer program for microcomputers that is capable of finding anticipated progress or manning requirements over time periods. This interactive program is simple and easy to use. It will be very useful for small to medium-sized manpower planning projects. Its features, input and output descriptions were given in Chapter VI. Examples and the program listing is contained in Appendices A and B.

The last objective was to observe management practices at the project level. Being a cost/scheduling engineer in the central group, the author was in an excellent position in the task force to observe management practices. These observations were presented in Chapter III under the topic of Project Organization.

In conclusion, the internship allowed the author to become familiar with project planning and control management in the petrochemical engineering and construction industry. The internship was completed successfully and all the internship objectives were met.

REFERENCES

[1] Adler, M. J., ed. "Petroleum Refining," Encyclopaedia Britannica, Helen Hemingway Benton, Chicago, **14**, 181-185 (1981).

[2] Afiesimama, B. T., Intern Experience at Fluor Engineer and Constructors, Inc., Unpublished Doctor of Engineering Internship Report, Texas A&M University, College Station (1982).

[3] Dobbs, S. B., Intern Experience at Fluor Engineers, Inc., Unpublished Doctor of Engineering Internship Report, Texas A&M University, College Station (1983).

[4] Fluor, J. R., Fluor Corporation: A 65-Year History, Newcomen, New York (1978).

[5] Fluor Corporation, 1982 Annual Report, Irvine (1983).

[6] Fluor Corporation, FORM 10-K for 1982 (1982).

[7] Fluor Corporation, Looking Forward, Irvine (1981).

[8] Fluor Corporation, The International Roundup, **31**, 7 (July 1982).

[9] Fluor Corporation, The International Roundup, **32**, 6 (July 1983).

[10] Fluor Engineers, Inc., Project Execution Manual, Houston, (Typewritten 1980).

[11] Gary, J. H. and G. E. Handwerk, Petroleum Refining: Technology and Economics, Marcel Decker, New York (1975).

[12] Harrison, F. L., Advanced Project Management, John Wiley & Sons, New York (1983).

[13] Hoffman, H. L., ed., "1968 Refining Processes Handbook," Hydrocarbon Processing, **47**, 9, 135-180 (September 1968).

[14] Office of the Dean, "Student Manual: Doctor of Engineering Program," College of Engineering, Texas A&M University, College Station (Typewritten 1979).

[15] Speight, J. G., The Chemistry and Technology of Petroleum, Marcel Dekker, New York (1980).

[16] Stockil, P. A., ed., Our Industry Petroleum, British Petroleum Company, London (1977).

[17] Taha, H. A., Operations Research: An Introduction, Macmillan Publishing Co., New York (1976).

APPENDICES

APPENDIX A

Examples of Manpower Analysis Program Output

Example I

CONTRACT: 600006 MICRO-MADAP FILE NAME: data
Manpower Planning - Example I

CASE ID: 1
Case 1

BUDGET MHRS :	100000	PERCENT COMPL:	20.00
ACTUAL MHRS :	20000	START PERIOD :	1
FORECAST MHRS:	100000	END PERIOD :	6

	Jan 83	Feb 83	Mar 83	Apr 83	May 83	Jun 83
MH'S AV/MAN/PERIOD	152.	200.	160.	160.	200.	160.
RELATIVE EFFICIENCY	100.00	100.00	90.00	90.00	90.00	90.00
REM MH'S/1 PCT	1000.00	1000.00	1111.11	1111.11	1111.11	1111.11
PROGRESS						
INCR PCNT	12.00	16.00	12.00	12.00	16.00	12.00
CUML PCNT	32.00	48.00	60.00	72.00	88.00	100.00
INCR PCNT BUDG	12.00	16.00	13.33	13.33	17.78	13.33
CUML PCNT BUDG	32.00	48.00	61.33	74.67	92.44	105.78
MANHOURS						
INCR MH'S EXPENDED	12000.	16000.	13333.	13333.	17776.	13333.
CUML MH'S EXPENDED	32000.	48000.	61333.	74667.	92444.	105778.
INCR FOR PROG	12000.	16000.	12000.	12000.	16000.	12000.
CUML FOR PROG	32000.	48000.	60000.	72000.	88000.	100000.
MEN	78.9	80.0	83.3	83.3	88.9	83.3
PERFORMANCE						
INCR PERF	100.00	100.00	90.00	90.00	90.00	90.00
CUML PERF	100.00	100.00	97.83	96.43	95.19	94.34

CASE ID: 2
Case 2

BUDGET MHRS :	200000	PERCENT COMPL:	0.00
ACTUAL MHRS :	0	START PERIOD :	2
FORECAST MHRS:	200000	END PERIOD :	5

	Feb 83	Mar 83	Apr 83	May 83
MH'S AV/MAN/PERIOD	200.	160.	160.	200.
RELATIVE EFFICIENCY	100.00	90.00	90.00	90.00
REM MH'S/1 PCT	2000.00	2222.22	2222.22	2222.22
PROGRESS				
INCR PCNT	30.00	20.00	20.00	30.00
CUML PCNT	30.00	50.00	70.00	100.00
INCR PCNT BUDG	30.00	22.22	22.22	33.33
CUML PCNT BUDG	30.00	52.22	74.44	107.78
MANHOURS				
INCR MH'S EXPENDED	60000.	44444.	44444.	66667.
CUML MH'S EXPENDED	60000.	104444.	148889.	215556.
INCR FOR PROG	60000.	40000.	40000.	60000.
CUML FOR PROG	60000.	100000.	140000.	200000.
MEN	300.0	277.8	277.8	333.3
PERFORMANCE				
INCR PERF	100.00	90.00	90.00	90.00
CUML PERF	100.00	95.74	94.03	92.78

CASE ID: 3
Case 3

BUDGET MHRS :	50000	PERCENT COMPL:	25.00
ACTUAL MHRS :	15000	START PERIOD :	1
FORECAST MHRS:	60000	END PERIOD :	5

	Jan 83	Feb 83	Mar 83	Apr 83	May 83
MH'S AV/MAN/PERIOD	152.	200.	160.	160.	200.
RELATIVE EFFICIENCY	100.00	100.00	90.00	90.00	90.00
REM MH'S/1 PCT	600.00	600.00	666.67	666.67	666.67
PROGRESS					
INCR PCNT	13.00	18.00	13.00	13.00	18.00
CUML PCNT	38.00	56.00	69.00	82.00	100.00
INCR PCNT BUDG	15.60	21.60	17.33	17.33	24.00
CUML PCNT BUDG	45.60	67.20	84.53	101.87	125.87
MANHOURS					
INCR MH'S EXPENDED	7800.	10800.	8667.	8667.	12000.
CUML MH'S EXPENDED	22800.	33600.	42267.	50933.	62933.
INCR FOR PROG	7800.	10800.	7800.	7800.	10800.
CUML FOR PROG	22800.	33600.	41400.	49200.	60000.
MEN	51.3	54.0	54.2	54.2	60.0
PERFORMANCE					
INCR PERF	83.33	83.33	75.00	75.00	75.00
CUML PERF	83.33	83.33	81.62	80.50	79.45

SUBTOTAL PART I

BUDGET MHRS : 350000
ACTUAL MHRS : 35000
FORECAST MHRS: 360000

PCNT COMP : 9.29
PCNT BUDG EXP: 10.00

	Jan 83	Feb 83	Mar 83	Apr 83	May 83	Jun 83
MHRS EXPENDED						
INCREMENTAL						
Case 1	12000.	16000.	13333.	13333.	17778.	13333.
Case 2	0.	60000.	44444.	44444.	66667.	0.
Case 3	7800.	10800.	8667.	8667.	12000.	0.
INCREMENTAL MANNING SUMMARY						
Case 1	78.9	80.0	83.3	83.3	88.9	83.3
Case 2	0.0	300.0	277.8	277.8	333.3	0.0
Case 3	51.3	54.0	54.2	54.2	60.0	0.0
CUMMULATIVE						
Case 1	32000.	48000.	61333.	74667.	92444.	105778.
Case 2	0.	60000.	104444.	148889.	215556.	0.
Case 3	22800.	33600.	42267.	50933.	62933.	0.
INCREMENTAL MHRS	19800.	86800.	66444.	66444.	96444.	13333.
CUML MHRS EXPD	54900.	141600.	208044.	274489.	370933.	105778.
MEN	130.3	434.0	415.3	415.3	482.2	83.3
INCR PCNT BUDG EXPD	5.66	24.80	18.98	18.98	27.36	3.81
CUM PCNT BUDG EXPD	15.66	40.46	59.44	78.43	105.98	109.79
AVG. REL EFF	100.00	100.00	90.00	90.00	90.00	90.00

SUBTOTAL PART II

	Jan 83	Feb 83	Mar 83	Apr 83	May 83	Jun 83
MHRS PROGRESS						
INCREMENTAL						
Case 1	12000.	16000.	12000.	12000.	16000.	12000.
Case 2	0.	60000.	40000.	40000.	60000.	0.
Case 3	7800.	10800.	7800.	7800.	10800.	0.
CUMMULATIVE						
Case 1	32000.	48000.	60000.	72000.	88000.	100000.
Case 2	0.	60000.	100000.	140000.	200000.	0.
Case 3	22800.	33600.	41400.	49200.	60000.	0.
INCREMENTAL MHRS	19800.	86800.	59800.	59800.	86800.	12000.
CUML MHRS EXPD	54800.	141600.	201400.	261200.	348000.	100000.
INCR PCNT PROG	5.48	24.04	16.56	16.56	24.04	3.32
CUML PCNT PROG	14.77	38.81	55.37	71.93	95.96	99.29
INCR PCNT PROD	96.92	96.92	87.23	87.23	87.23	87.23
CUML PCNT PROD	94.33	95.92	93.14	91.71	90.55	90.43

Example II

CONTRACT: 600066 MICRO-MADAP FILE NAME: data2
Manpower Planning - Example II (Manning Input)

CASE ID: 1
Process Units

BUDGET MHRS :	44000	PERCENT COMPL:	20.00
ACTUAL MHRS :	7550	START PERIOD :	1
FORECAST MHRS:	51990	END PERIOD :	4

	Jan 83	Feb 83	Mar 83	Apr 83
MH'S AV/MAN/PERIOD	152.	200.	160.	160.
RELATIVE EFFICIENCY	130.00	120.00	110.00	100.00
REM MH'S/1 PCT	427.31	427.31	427.31	427.31
PROGRESS				
INCR PCNT	17.79	25.92	19.01	17.28
CUML PCNT	37.79	63.71	82.72	100.00
INCR PCNT BUDG	17.27	25.17	18.46	16.78
CUML PCNT BUDG	34.43	59.61	78.07	94.85
MANHOURS				
INCR MH'S EXPENDED	7600.	11077.	8123.	7385.
CUML MH'S EXPENDED	15150.	26227.	34350.	41735.
INCR FOR PROG	9880.	14400.	10560.	9600.
CUML FOR PROG	17430.	31830.	42390.	51990.
MEN	50.0	60.0	60.0	60.0
PERFORMANCE				
INCR PERF	102.97	102.97	102.97	102.97
CUML PERF	109.74	106.88	105.96	105.43

CASE ID: 2
Offsite Units

BUDGET MHRS :	100000	PERCENT COMPL:	0.00
ACTUAL MHRS :	0	START PERIOD :	2
FORECAST MHRS:	100480	END PERIOD :	4

	Feb 83	Mar 83	Apr 83
MH'S AV/MAN/PERIOD	200.	160.	160.
RELATIVE EFFICIENCY	120.00	110.00	100.00
REM MH'S/1 PCT	837.33	837.33	837.33
PROGRESS			
INCR PCNT	42.99	31.53	25.48
CUML PCNT	42.99	74.52	100.00
INCR PCNT BUDG	36.00	26.40	21.33
CUML PCNT BUDG	36.00	62.40	83.73
MANHOURS			
INCR MH'S EXPENDED	36000.	26400.	21333.
CUML MH'S EXPENDED	36000.	62400.	83733.
INCR FOR PROG	43200.	31680.	25600.
CUML FOR PROG	43200.	74880.	100480.
MEN	180.0	180.0	160.0
PERFORMANCE			
INCR PERF	119.43	119.43	119.43
CUML PERF	119.43	119.43	119.43

SUBTOTAL PART I

BUDGET MHRS :	144000	PCNT COMP :	6.11
ACTUAL MHRS :	7550	PCNT BUDG EXP:	5.24
FORECAST MHRS:	152470		

	Jan 83	Feb 83	Mar 83	Apr 83
MHRS EXPENDED				
INCREMENTAL				
Process Units	7600.	11077.	8123.	7385.
Offsite Units	0.	36000.	26400.	21333.
INCREMENTAL MANNING SUMMARY				
Process Units	50.0	60.0	60.0	60.0
Offsite Units	0.0	180.0	180.0	160.0
CUMMULATIVE				
Process Units	15150.	26227.	34350.	41735.
Offsite Units	0.	36000.	62400.	83733.
INCREMENTAL MHRS	7600.	47077.	34523.	28718.
CUML MHRS EXPD	15150.	62227.	96750.	125468.
MEN	50.0	240.0	240.0	220.0
INCR PCNT BUDG EXPD	5.28	32.69	23.97	19.94
CUM PCNT BUDG EXPD	10.52	43.21	67.19	87.13
AVG. REL EFF	130.00	122.35	122.35	122.57

SUBTOTAL PART II

	Jan 83	Feb 83	Mar 83	Apr 83
MHRS PROGRESS				
INCREMENTAL				
Process Units	9880.	14400.	10560.	9600.
Offsite Units	0.	43200.	31680.	25600.
CUMMULATIVE				
Process Units	17430.	31830.	42390.	51990.
Offsite Units	0.	43200.	74880.	100480.
INCREMENTAL MHRS	9880.	57600.	42240.	35200.
CUML MHRS EXPD	17430.	75030.	117270.	152470.
INCR PCNT PROG	6.46	37.66	27.62	23.02
CUML PCNT PROG	12.57	50.23	77.85	100.87
INCR PCNT PROD	122.40	115.20	115.20	115.41
CUML PCNT PROD	119.49	115.25	115.87	115.77

Appendix B

Manpower Analysis Program Listing

```
10      DIM EFF(30),IPCT(20,30),AVMH(30),ACTMH(20),ACTPCT(20)
20      DIM COLH$(30),CASEID(20),CSDES$(20),START(20),ENDD(20)
30      DIM BGTMH(20),FCTMH(20),ARMP1(20,30),IMHEXP(20,30)
40      DIM CMHEXP(20,30),IMHPRG(20,30),CMHPRG(20,30),CPCT(20,30)
50      DIM IPCTB(20,30),CPCTB(20,30),MEN(20,30),PERF(20,30),CPERF(20,30)
60      DIM SCPCTB(30),SIMHXP(30),SCMHXP(30),SMEN(30),SIPCTB(30)
70      DIM SAVEFF(30),SIMHPG(30),SCMHPG(30),SCPTPG(30),SIPTPG(30)
80      DIM SIPERF(30),SCPERF(30)
90      FOR J =1 TO 6 : PRINT : NEXT J
100     PRINT TAB(18);"*********************************************"
110     PRINT TAB(18);"Micro-Manpower Distribution Analysis Program"
120     PRINT TAB(18);"*********************************************"
130     PRINT TAB(34);"Date: 8/1/83"
140     PRINT : PRINT TAB(39);"by"
150     PRINT TAB(30);"Buranawong Sowaprux"
160     PRINT : PRINT : PRINT
170     REM ************
180     REM      MENU
190     REM ************
200     PRINT "INPUT SELECTION" : PRINT "_______________"
210     PRINT : PRINT : PRINT"ENTER MADAP DATA FILE NAME"
220     PRINT "(A file name contains up to 8 characters)"
230     INPUT ":"; FILENAME$
240     PRINT : PRINT
250     PRINT TAB(10) "ENTER 1 TO INPUT DATA"
260     PRINT TAB(10) "ENTER 2 TO UPDATE OR REVIEW DATA"
270     PRINT TAB(10) "ENTER 3 TO RUN ONLY"
280     PRINT TAB(10); : INPUT "(1,2, or 3)"; SEL : PRINT
290     ON SEL GOTO 360,310,330
300     PRINT "INCORRECT INPUT!!" :  GOTO 240
310     GOSUB 1800
320     GOTO 2070
330     GOSUB 1800
340     GOTO 860
350     GOTO 200
360     INPUT "CONTRACT NO.         :"; CONTRACT$
370     INPUT "PROGRAM DESCRIPTION :"; DESC$
380     INPUT "MAXIMUM INTERVALS    :"; MXINT
390     PRINT
400     FOR J = 1 TO MXINT
410     PRINT "ENTER COLUMN HEADING FOR PERIOD     ";J;: INPUT":";COLH$(J)
420     PRINT "ENTER AVAILABLE MHRS FOR PERIOD     ";J;: INPUT":";AVMH(J)
430     PRINT "ENTER RELATIVE EFFICIENCY FOR PERIOD";J;
440     INPUT":";EFF(J) : PRINT
450     NEXT J
460     PRINT "FOR MANNING INPUT  -- TYPE 'm'"
470     PRINT "FOR PROGRESS INPUT -- TYPE 'p'"
480     INPUT "ENTER 'm' OR 'p' "; TYPE$
490     PRINT
500     I = 0
```

```
510     I = I + 1
520     INPUT "ENTER  CASE ID NO. (1-20) :"; CASEID(I)
530     INPUT "ENTER CASE DESCRIPTION    :"; CSDES$(I)
540     INPUT "ENTER START PERIOD NO.    :"; START(I)
550     INPUT "ENTER END PERIOD NO.      :"; ENDD(I)
560     INPUT "ENTER BUDGET MANHOURS     :"; BGTMH(I)
570     INPUT "ENTER ACTUAL % PROGRESS   :"; ACTPCT(I)
580     INPUT "ENTER ACTUAL MANHOURS     :"; ACTMH(I)
590     INPUT "ENTER FORECAST MANHOURS   :"; FCTMH(I)
600     IF TYPE$ = "m" THEN GOSUB 1230 ELSE 650
610     GOTO 770
620     REM **************
630     REM PROGRESS INPUT
640     REM **************
650     PC100 = ACTPCT(I)
660     FOR J = START(I) TO ENDD(I)
670     PRINT "ENTER INCREMENTAL % PROGRESS FOR PERIOD";J;
680     INPUT ":"; IPCT(I,J)
690     PC100 = PC100+IPCT(I,J)
700     NEXT J
710     IF PC100 = 100 THEN 770
720     PRINT CHR$(7) : PRINT
730     PRINT "INCREMENTAL % PROGRESS FOR CASE ";I;"ADD UP TO ";PC100
740     PRINT "CUMMULATIVE % PROGRESS FOR LAST PERIOD MUST = 100%"
750     PRINT : PRINT "PLEASE REENTER" : PRINT
760     GOTO 650
770     PRINT
780     INPUT"ENTER 'y' IF YOU HAVE ANOTHER CASE, ELSE HIT 'RETURN'";AN$
790     PRINT
800     IF AN$ = "y" THEN 510
810     INPUT "TYPE 'y' IF YOU WANT TO MODIFY YOUR INPUT"; AN$
820     IF AN$="y" THEN 2070
830     REM ***********
840     REM CALCULATION
850     REM ***********
860     N = I
870     IF SEL <> 3 THEN GOSUB 1530
880     IF TYPE$ = "m" THEN 1270
890     FOR I = 1 TO N
900     CPCT(I,START(I)-1) = ACTPCT(I)
910     CMHEXP(I,START(I)-1) = ACTMH(I)
920     CMHPRG(I,START(I)-1) = ACTMH(I)
930     IF FCTMH(I) = 0 THEN FCTMH(I) = BGTMH(I)
940     RMHP1 = (FCTMH(I)-ACTMH(I))/(100-ACTPCT(I))
950     FOR J = START(I) TO ENDD(I)
960     ARMP1(I,J) = RMHP1*100/EFF(J)
970     IMHEXP(I,J) = IPCT(I,J)*ARMP1(I,J)
980     CMHEXP(I,J) = CMHEXP(I,J-1) + IMHEXP(I,J)
990     IMHPRG(I,J) = IPCT(I,J)*RMHP1
1000    CMHPRG(I,J) = CMHPRG(I,J-1) + IMHPRG(I,J)
```

```
1010    CPCT(I,J) = CPCT(I,J-1) + IPCT(I,J)
1020    IPCTB(I,J) = IMHEXP(I,J)*100/BGTMH(I)
1030    CPCTB(I,J) = CMHEXP(I,J)*100/BGTMH(I)
1040    MEN(I,J) = IMHEXP(I,J)/AVMH(J)
1050    PERF(I,J) = IPCT(I,J)*100/IPCTB(I,J)
1060    CPERF(I,J) = CPCT(I,J)*100/CPCTB(I,J)
1070    NEXT J
1080    NEXT I
1090    PRINT : INPUT "TYPE 'y' TO GET A HARD COPY OF CASE SUMMARY:"; AN$
1100    IF AN$ <> "y" THEN 1180
1110    LPRINT "CONTRACT: ";CONTRACT$ TAB(30) CHR$(14);
1120    LPRINT "MICRO-MADAP";CHR$(20);TAB(50) "FILE NAME: ";FILENAME$
1130    LPRINT DESC$
1140    LPRINT : LPRINT
1150    FOR I = 1 TO N
1160    GOSUB 2870
1170    NEXT I
1180    PRINT : INPUT "TYPE 'y' TO GET A HARD COPY OF SUBTOTAL:"; AN$
1190    IF AN$ = "y" THEN 3680 ELSE END
1200    REM *************
1210    REM MANNING INPUT
1220    REM *************
1230    FOR J = START(I) TO ENDD(I)
1240    PRINT "ENTER EQUIVALENT MEN FOR PERIOD";J; : INPUT ":"; MEN(I,J)
1250    NEXT J
1260    RETURN
1270    FOR I = 1 TO N
1280    CPCT(I,START(I)-1) = ACTPCT(I)
1290    CMHEXP(I,START(I)-1) = ACTMH(I)
1300    CMHPRG(I,START(I)-1) = ACTMH(I)
1310    FOR J = START(I) TO ENDD(I)
1320    IMHPRG(I,J) = MEN(I,J)*EFF(J)*AVMH(J)/100
1330    CMHPRG(I,J) = CMHPRG(I,J-1) + IMHPRG(I,J)
1340    NEXT J
1350    IF FCTMH(I)=0 THEN FCTMH(I)=CMHPRG(I,ENDD(I))
1360    RMHP1 = (FCTMH(I)-ACTMH(I))/(100-ACTPCT(I))
1370    FOR J = START(I) TO ENDD(I)
1380    IPCT(I,J)=IMHPRG(I,J)*(100-ACTPCT(I))/(CMHPRG(I,ENDD(I))-ACTMH(I))
1390    CPCT(I,J) = CPCT(I,J-1) + IPCT(I,J)
1400    ARMP1(I,J) = RMHP1*100/EFF(I)
1410    IMHEXP(I,J) = IPCT(I,J)*ARMP1(I,J)
1420    CMHEXP(I,J) = CMHEXP(I,J-1) + IMHEXP(I,J)
1430    IPCTB(I,J)  = IMHEXP(I,J)*100/BGTMH(I)
1440    CPCTB(I,J)  = CMHEXP(I,J)*100/BGTMH(I)
1450    PERF(I,J) = IPCT(I,J)*100/IPCTB(I,J)
1460    CPERF(I,J) = CPCT(I,J)*100/CPCTB(I,J)
1470    NEXT J
1480    NEXT I
1490    GOTO 1090
1500    REM **********************
```

```
1510    REM WRITE DATA TO DISK FILE
1520    REM ***********************
1530    OPEN "O", #1, FILENAME$
1540    PRINT #1,CONTRACT$;",";DESC$;",";MXINT
1550    FOR J = 1 TO MXINT : PRINT #1,COLH$(J);",";  : NEXT J
1560    FOR J = 1 TO MXINT : PRINT #1,AVMH(J);",";  : NEXT J
1570    FOR J = 1 TO MXINT : PRINT #1,EFF(J);",";  : NEXT J
1580    PRINT #1, TYPE$;",";N
1590    FOR J = 1 TO N
1600    PRINT #1, CASEID(J);",";CSDES$(J);",";START(J);",";ENDD(J);",";
1610    PRINT #1, BGTMH(J);",";ACTPCT(J);",";ACTMH(J);",";FCTMH(J)
1620    NEXT J
1630    IF TYPE$ = "m" THEN 1700
1640    FOR K = 1 TO N
1650    FOR J = START(K) TO ENDD(K)
1660    PRINT #1, IPCT(K,J);",";
1670    NEXT J
1680    NEXT K
1690    GOTO 1750
1700    FOR K = 1 TO N
1710    FOR J = START(K) TO ENDD(K)
1720    PRINT #1, MEN(K,J);",";
1730    NEXT J
1740    NEXT K
1750    CLOSE 1
1760    RETURN
1770    REM ************************
1780    REM READ DATA FROM DISK FILE
1790    REM ************************
1800    OPEN "I", #1, FILENAME$
1810    INPUT #1, CONTRACT$,DESC$,MXINT
1820    FOR J = 1 TO MXINT : INPUT #1,COLH$(J) : NEXT J
1830    FOR J = 1 TO MXINT : INPUT #1,AVMH(J)  : NEXT J
1840    FOR J = 1 TO MXINT : INPUT #1,EFF(J)   : NEXT J
1850    INPUT #1,TYPE$,I
1860    FOR J = 1 TO I
1870    INPUT #1, CASEID(J),CSDES$(J),START(J),ENDD(J)
1880    INPUT #1,BGTMH(J),ACTPCT(J),ACTMH(J),FCTMH(J)
1890    NEXT J
1900    IF TYPE$ = "m" THEN 1970
1910    FOR K = 1 TO I
1920    FOR J = START(K) TO ENDD(K)
1930    INPUT #1, IPCT(K,J)
1940    NEXT J
1950    NEXT K
1960    GOTO 2020
1970    FOR K = 1 TO I
1980    FOR J = START(K) TO ENDD(K)
1990    INPUT #1, MEN(K,J)
2000    NEXT J
```

```
2010    NEXT K
2020    CLOSE 1
2030    RETURN
2040    REM ***********
2050    REM MODIFY DATA
2060    REM ***********
2070    PRINT "CONTRACT NO. :"; CONTRACT$
2080    INPUT "TYPE 'm' TO MODIFY, OTHERWISE HIT 'RETURN'"; AN$
2090    IF AN$ = "m" THEN INPUT CONTRACT$
2100    PRINT "PROGRAM DESCRIPTION :"; DESC$
2110    INPUT "TYPE 'm' TO MODIFY, OTHERWISE HIT 'RETURN'"; AN$
2120    IF AN$ = "m" THEN INPUT DESC$
2130    PRINT "TYPE 'm' TO MODIFY 'MAXIMUM INTERVALS"
2140    PRINT "                    'COLUMN HEADINGS'"
2150    PRINT "                   ,'AVAI MH'S PER PERIOD'"
2160    PRINT "                OR,'EFFICIENCY'"
2170    INPUT AN$
2180    IF AN$ <> "m" THEN 2330
2190    PRINT "MAXIMUM INTERVALS:"; MXINT
2200    INPUT "TYPE 'm' TO MODIFY, OTHERWISE HIT 'RETURN'"; AN$
2210    IF AN$ = "m" THEN INPUT MXINT
2220    FOR J = 1 TO MXINT
2230    PRINT "COLUMN HEADING FOR PERIOD";J; ":"; COLH$(J)
2240    INPUT "TYPE 'm' TO MODIFY, OTHERWISE HIT 'RETURN'"; AN$
2250    IF AN$ = "m" THEN INPUT COLH$(J)
2260    PRINT "AVAIL MANHOURS FOR PERIOD";J; ":"; AVMH(J)
2270    INPUT "TYPE 'm' TO MODIFY, OTHERWISE HIT 'RETURN'"; AN$
2280    IF AN$ = "m" THEN INPUT AVMH(J)
2290    PRINT "RELATIVE EFF.  FOR PERIOD";J; ":"; EFF(J)
2300    INPUT "TYPE 'm' TO MODIFY, OTHERWISE HIT 'RETURN'"; AN$
2310    IF AN$ = "m" THEN INPUT EFF(J)
2320    NEXT J
2330    PRINT : PRINT "CASE MODIFICATION" : PRINT "_________________"
2340    PRINT "TYPE 'm' TO MODIFY"
2350    PRINT "TYPE 'a' TO ADD ANOTHER CASE"
2360    PRINT "TYPE 's' TO SAVE"
2370    INPUT AN$
2380    IF AN$ = "m" THEN 2420
2390    IF AN$ = "a" THEN 510
2400    IF AN$ = "s" THEN 860
2410    PRINT "INCORRECT INPUT!!" : GOTO 2330
2420    INPUT "ENTER CASE ID TO BE MODIFIED"; II
2430    PRINT "CASE DESCRIPTION:"; CSDES$(II)
2440    INPUT "TYPE 'm' TO MODIFY, OTHERWISE HIT 'RETURN'"; AN$
2450    IF AN$ = "m" THEN INPUT CSDES$(II)
2460    PRINT "START PERIOD NO.:"; START(II)
2470    INPUT "TYPE 'm' TO MODIFY, OTHERWISE HIT 'RETURN'"; AN$
2480    IF AN$ = "m" THEN INPUT START(II)
2490    PRINT "END PERIOD NO.:"; ENDD(II)
2500    INPUT "TYPE 'm' TO MODIFY, OTHERWISE HIT 'RETURN'"; AN$
```

```
2510    IF AN$ = "m" THEN INPUT ENDD(II)
2520    PRINT "BUDGET MANHOURS:"; BGTMH(II)
2530    INPUT "TYPE 'm' TO MODIFY, OTHERWISE HIT 'RETURN'"; AN$
2540    IF AN$ = "m" THEN INPUT BGTMH(II)
2550    PRINT "ACTUAL % PROGRESS:"; ACTPCT(II)
2560    INPUT "TYPE 'm' TO MODIFY, OTHERWISE HIT 'RETURN'"; AN$
2570    IF AN$ = "m" THEN INPUT ACTPCT(II)
2580    PRINT "ACTUAL MANHOURS:"; ACTMH(II)
2590    INPUT "TYPE 'm' TO MODIFY, OTHERWISE HIT 'RETURN'"; AN$
2600    IF AN$ = "m" THEN INPUT ACTMH(II)
2610    PRINT "FORECAST MANHOURS:"; FCTMH(II)
2620    INPUT "TYPE 'm' TO MODIFY, OTHERWISE HIT 'RETURN'"; AN$
2630    IF AN$ = "m" THEN INPUT FCTMH(II)
2640    IF TYPE$ = "m" THEN 2780
2650    PC100 = ACTPCT(II)
2660    FOR J = START(II) TO ENDD(II)
2670    PRINT "PROGRESS FOR PERIOD";J;":";IPCT(II,J)
2680    INPUT "TYPE 'm' TO MODIFY, OTHERWISE HIT 'RETURN'"; AN$
2690    IF AN$ ="m" THEN INPUT IPCT(II,J)
2700    PC100 = PC100 + IPCT(II,J)
2710    NEXT J
2720    IF PC100 = 100 THEN 2330
2730    PRINT CHR$(7) : PRINT
2740    PRINT "INCREMENTAL % PROGRESS FOR CASE ";II;"ADD UP TO ";PC100
2750    PRINT "CUMMULATIVE % PROGRESS FOR LAST PERIOD MUST = 100%"
2760    PRINT : PRINT "PLEASE REENTER" : PRINT
2770    GOTO 2650
2780    FOR J = START(II) TO ENDD(II)
2790    PRINT "EQUIVALENT MEN FOR PERIOD";J;":"; MEN(II,J)
2800    INPUT "TYPE 'm' TO MODIFY, OTHERWISE HIT 'RETURN'"; AN$
2810    IF AN$ = "m" THEN INPUT MEN(II,J)
2820    NEXT J
2830    GOTO 2330
2840    REM ******************
2850    REM PRINT CASE SUMMARY
2860    REM ******************
2870    LPRINT "CASE ID: "; CASEID(I)
2880    LPRINT CSDES$(I) : LPRINT
2890    LPRINT TAB(10) : LPRINT USING "BUDGET MHRS  :########";BGTMH(I);
2900    LPRINT TAB(50) : LPRINT USING "PERCENT COMPL:#####.##"; ACTPCT(I)
2910    LPRINT TAB(10) : LPRINT USING "ACTUAL MHRS  :########"; ACTMH(I);
2920    LPRINT TAB(50) : LPRINT USING "START PERIOD :########"; START(I)
2930    LPRINT TAB(10) : LPRINT USING "FORECAST MHRS:########"; FCTMH(I);
2940    LPRINT TAB(50) : LPRINT USING "END PERIOD   :########"; ENDD(I)
2950    A=START(I) : GOTO 2970
2960    A=A+6
2970    IF ENDD(I)-A<6 THEN B=ENDD(I) ELSE B=A+5
2980    LPRINT : LPRINT : LPRINT TAB(25);
2990    FOR J = A TO B
3000    LPRINT COLH$(J);"  ";
```

```
3010    NEXT J
3020    LPRINT : LPRINT : LPRINT "MH'S AV/MAN/PERIOD" TAB(25);
3030    FOR J = A TO B
3040    LPRINT USING "#######.";AVMH(J);
3050    NEXT J
3060    LPRINT : LPRINT "RELATIVE EFFICIENCY" TAB(25);
3070    FOR J = A TO B
3080    LPRINT USING "#####.##"; EFF(J);
3090    NEXT J
3100    LPRINT : LPRINT "REM MH'S/1 PCT" TAB(25);
3110    FOR J = A TO B
3120    LPRINT USING "#####.##";ARMP1(I,J);
3130    NEXT J
3140    LPRINT : LPRINT : LPRINT "PROGRESS"
3150    LPRINT "INCR PCNT" TAB(25);
3160    FOR J = A TO B
3170    LPRINT USING "#####.##"; IPCT(I,J);
3180    NEXT J
3190    LPRINT : LPRINT "CUML PCNT" TAB(25);
3200    FOR J = A TO B
3210    LPRINT USING "#####.##"; CPCT(I,J);
3220    NEXT J
3230    LPRINT : LPRINT "INCR PCNT BUDG" TAB(25);
3240    FOR J = A TO B
3250    LPRINT USING "#####.##"; IPCTB(I,J);
3260    NEXT J
3270    LPRINT : LPRINT "CUML PCNT BUDG" TAB(25);
3280    FOR J = A TO B
3290    LPRINT USING "#####.##"; CPCTB(I,J);
3300    NEXT J
3310    LPRINT : LPRINT : LPRINT "MANHOURS"
3320    LPRINT "INCR MH'S EXPENDED" TAB(25);
3330    FOR J = A TO B
3340    LPRINT USING "#######."; IMHEXP(I,J);
3350    NEXT J
3360    LPRINT : LPRINT "CUML MH'S EXPENDED" TAB(25);
3370    FOR J = A TO B
3380    LPRINT USING "#######."; CMHEXP(I,J);
3390    NEXT J
3400    LPRINT : LPRINT "INCR FOR PROG" TAB(25);
3410    FOR J = A TO B
3420    LPRINT USING "#######."; IMHPRG(I,J);
3430    NEXT J
3440    LPRINT : LPRINT "CUML FOR PROG" TAB(25);
3450    FOR J = A TO B
3460    LPRINT USING "#######."; CMHPRG(I,J);
3470    NEXT J
3480    LPRINT : LPRINT : LPRINT "MEN"; TAB(25);
3490    FOR J = A TO B
3500    LPRINT USING "######.#"; MEN(I,J);
```

```
3510    NEXT J
3520    LPRINT : LPRINT : LPRINT "PERFORMANCE"
3530    LPRINT "INCR PERF" TAB(25);
3540    FOR J = A TO B
3550    LPRINT USING "#####.##"; PERF(I,J);
3560    NEXT J
3570    LPRINT : LPRINT "CUML PERF" TAB(25);
3580    FOR J = A TO B
3590    LPRINT USING "#####.##"; CPERF(I,J);
3600    NEXT J
3610    LPRINT : LPRINT
3620    IF B<ENDD(I) THEN 2960
3630    LPRINT CHR$(12);
3640    RETURN
3650    REM ********
3660    REM SUBTOTAL
3670    REM ********
3680    PRINT : PRINT : PRINT "     SUBTOTAL OUTPUT"
3690    PRINT "                  "
3700    PRINT : PRINT
3710    INPUT "ENTER NUMBER OF CASES TO BE SUBTOTALED :",NCASES
3720    FOR I = 1 TO NCASES
3730    INPUT "ENTER CASE ID TO BE SUBTOTALED :" ,NID(I)
3740    NEXT I
3750    SBGTMH = 0 : SACTMH = 0 : SFCTMH = 0
3760    ST = 1 : EN = 1
3770    FOR J = 1 TO NCASES
3780    IF START(NID(J))<ST THEN ST=START(NID(J))
3790    IF ENDD(NID(J))>EN THEN EN=ENDD(NID(J))
3800    NEXT J
3810    FOR I = 1 TO NCASES
3820    SBGTMH = SBGTMH + BGTMH(NID(I))
3830    SACTMH = SACTMH + ACTMH(NID(I))
3840    SFCTMH = SFCTMH + FCTMH(NID(I))
3850    SACTPCT = SACTPCT + ACTPCT(NID(I))*BGTMH(NID(I))
3860    NEXT I
3870    SACTPCT = SACTPCT/SBGTMH
3880    SACTPTB = SACTMH*100/SBGTMH
3890    SCPTPG(ST-1) = SACTPCT
3900    SCPCTB(ST-1) = SACTPTB
3910    FOR J = ST TO EN
3920    SIMHXP(J) = 0
3930    SCMHXP(J) = 0
3940    SMEN(J) = 0
3950    SIPCTB(J) = 0
3960    SIMHPG(I) = 0
3970    SCMHPG(I) = 0
3980    NEXT J
3990    FOR I = ST TO EN
4000    FOR J = 1 TO NCASES
```

```
4010    SIMHXP(I) = SIMHXP(I) + IMHEXP(NID(J),I)
4020    SMEN(I)   = SMEN(I) + MEN(NID(J),I)
4030    SCMHXP(I) = SCMHXP(I) + CMHEXP(NID(J),I)
4040    SIMHPG(I) = SIMHPG(I) + IMHPRG(NID(J),I)
4050    SCMHPG(I) = SCMHPG(I) + CMHPRG(NID(J),I)
4060    SIPTPG(I) = SIMHPG(I)*(100-SACTPTB)/(SFCTMH-SACTMH)
4070    NEXT J
4080    SIPCTB(I) = SIMHXP(I)*100/SBGTMH
4090    SCPCTB(I) = SCPCTB(I-1) + SIPCTB(I)
4100    SAVEFF(I) = SIMHPG(I)*100/SIMHXP(I)
4110    SCPTPG(I) = SCPTPG(I-1) + SIPTPG(I)
4120    SIPERF(I) = SIPTPG(I)*100/SIPCTB(I)
4130    SCPERF(I) = SCPTPG(I)*100/SCPCTB(I)
4140    NEXT I
4150    REM **************
4160    REM PRINT SUBTOTAL
4170    REM **************
4180    LPRINT TAB(25) CHR$(14); "SUBTOTAL PART I"
4190    LPRINT : LPRINT
4200    LPRINT TAB(10) : LPRINT USING "BUDGET MHRS  :########"; SBGTMH;
4210    LPRINT TAB(50) : LPRINT USING "PCNT COMP    :#####.##"; SACTPCT
4220    LPRINT TAB(10) : LPRINT USING "ACTUAL MHRS  :########"; SACTMH;
4230    LPRINT TAB(50) : LPRINT USING "PCNT BUDG EXP:#####.##"; SACTPTB
4240    LPRINT TAB(10) : LPRINT USING "FORECAST MHRS:########"; SFCTMH
4250    LPRINT : LPRINT
4260    A = ST : GOTO 4280
4270    A = A+6
4280    IF EN-A<6 THEN B=EN ELSE B=A+5
4290    LPRINT TAB(25);
4300    FOR J = A TO B
4310    LPRINT COLH$(J);"  ";
4320    NEXT J
4330    LPRINT:LPRINT:LPRINT"MHRS EXPENDED":LPRINT TAB(10)"INCREMENTAL";
4340    FOR I = 1 TO NCASES
4350    LPRINT : LPRINT CSDES$(NID(I)) TAB(25);
4360    FOR J = A TO B
4370    LPRINT USING "#######."; IMHEXP(NID(I),J);
4380    NEXT J
4390    NEXT I
4400    LPRINT : LPRINT
4410    LPRINT TAB(10) "INCREMENTAL MANNING SUMMARY";
4420    FOR I = 1 TO NCASES
4430    LPRINT : LPRINT CSDES$(NID(I)) TAB(25);
4440    FOR J = A TO B
4450    LPRINT USING "######.#"; MEN(NID(I),J);
4460    NEXT J
4470    NEXT I
4480    LPRINT : LPRINT
4490    LPRINT TAB(10) "CUMMULATIVE";
4500    FOR I = 1 TO NCASES
```

```
4510    LPRINT : LPRINT CSDES$(NID(I)) TAB(25);
4520    FOR J = A TO B
4530    LPRINT USING "#######."; CMHEXP(NID(I),J);
4540    NEXT J
4550    NEXT I
4560    LPRINT : LPRINT : LPRINT : LPRINT
4570    LPRINT "INCREMENTAL MHRS" TAB(25);
4580    FOR J = A TO B
4590    LPRINT USING "#######."; SIMHXP(J);
4600    NEXT J
4610    LPRINT : LPRINT : LPRINT
4620    LPRINT "CUML MHRS EXPD" TAB(25);
4630    FOR J = A TO B
4640    LPRINT USING "#######."; SCMHXP(J);
4650    NEXT J
4660    LPRINT : LPRINT : LPRINT
4670    LPRINT "MEN" TAB(25);
4680    FOR J = A TO B
4690    LPRINT USING "######.#"; SMEN(J);
4700    NEXT J
4710    LPRINT : LPRINT : LPRINT
4720    LPRINT "INCR PCNT BUDG EXPD" TAB(25);
4730    FOR J = A TO B
4740    LPRINT USING "#####.##"; SIPCTB(J);
4750    NEXT J
4760    LPRINT : LPRINT "CUM PCNT BUDG EXPD" TAB(25);
4770    FOR J = A TO B
4780    LPRINT USING "#####.##"; SCPCTB(J);
4790    NEXT J
4800    LPRINT : LPRINT : LPRINT
4810    LPRINT "AVG. REL EFF" TAB(25);
4820    FOR J = A TO B
4830    LPRINT USING "#####.##"; SAVEFF(J);
4840    NEXT J
4850    LPRINT CHR$(12);
4860    IF B<EN THEN 4270
4870    LPRINT TAB(25) CHR$(14); "SUBTOTAL PART II"
4880    A = ST : GOTO 4900
4890    A = A+6
4900    IF EN-A<6 THEN B=EN ELSE B=A+5
4910    LPRINT : LPRINT : LPRINT TAB(25);
4920    FOR J = A TO B
4930    LPRINT COLH$(J); "  ";
4940    NEXT J
4950    LPRINT : LPRINT "MHRS PROGRESS"
4960    LPRINT  TAB(10) "INCREMENTAL";
4970    FOR I = 1 TO NCASES
4980    LPRINT : LPRINT CSDES$(I) TAB(25);
4990    FOR J = A TO B
5000    LPRINT USING "#######."; IMHPRG(NID(I),J);
```

```
5010    NEXT J
5020    NEXT I
5030    LPRINT : LPRINT
5040    LPRINT TAB(10) "CUMMULATIVE" TAB(25);
5050    FOR I = 1 TO NCASES
5060    LPRINT : LPRINT CSDES$(I); TAB(25);
5070    FOR J = A TO B
5080    LPRINT USING "#######."; CMHPRG(NID(I),J);
5090    NEXT J
5100    NEXT I
5110    LPRINT : LPRINT : LPRINT : LPRINT
5120    LPRINT "INCREMENTAL MHRS" TAB(25);
5130    FOR J = A TO B
5140    LPRINT USING "#######."; SIMHPG(J);
5150    NEXT J
5160    LPRINT : LPRINT : LPRINT
5170    LPRINT "CUML MHRS EXPD" TAB(25);
5180    FOR J = A TO B
5190    LPRINT USING "#######."; SCMHPG(J);
5200    NEXT J
5210    LPRINT : LPRINT : LPRINT
5220    LPRINT "INCR PCNT PROG" TAB(25);
5230    FOR J = A TO B
5240    LPRINT USING "#####.##"; SIPTPG(J);
5250    NEXT J
5260    LPRINT : LPRINT "CUML PCNT PROG" TAB(25);
5270    FOR J = A TO B
5280    LPRINT USING "#####.##"; SCPTPG(J);
5290    NEXT J
5300    LPRINT : LPRINT : LPRINT
5310    LPRINT "INCR PCNT PROD" TAB(25);
5320    FOR J = A TO B
5330    LPRINT USING "#####.##"; SIPERF(J);
5340    NEXT J
5350    LPRINT : LPRINT "CUML PCNT PROD" TAB(25);
5360    FOR J = A TO B
5370    LPRINT USING "#####.##"; SCPERF(J);
5380    NEXT J
5390    LPRINT CHR$(12);
5400    IF B<EN THEN 4890
5410    END
```

APPENDIX C

Cost and Scheduling Engineering Functions

COST ENGINEERING

Cost Engineering is involved in all stages of an engineering or construction project. During the proposal phase, the Cost Engineer develops economic feasibility studies and prepares a competitive bid. After a contract is awarded, a budget is prepared for the project. The Cost Engineer compares actual project costs to this budget and proposes cost control measures when required. Throughout the life of a project, the Cost Engineer uses computerized estimating, cost control and forecasting systems. At a project's conclusion, the Cost Engineer performs a detailed cost analysis and suggests improvements in estimating and cost control methods.

SCHEDULING ENGINEERING

Planning is an essential element required for profitable project execution. The Scheduling Engineer translates broadly stated project plans into definitive schedules. These schedules provide a means for the optimum allocation of engineering and construction manpower, as well as furnishing standards for project performance measurement. To prepare and analyze schedules, Fluor has developed a sophisticated, computerized "critical path method" of scheduling and project performance analysis known as FAST (Fluor Analytical Scheduling Technique). By comparing actual performance against the original plan, the Scheduling Engineer identifies potential scheduling problems and develops alternative solutions.

APPENDIX D

Internship Objectives

May 7, 1982

Memorandum

To: Advisory Committee

From: Buranawong Sowaprux

Subject: Preliminary Internship Objectives

Please find listed below my preliminary objectives for the Doctor of Engineering internship with Fluor Engineers and Constructors in Houston, Texas, which will begin June 7, 1982. A final set of objectives will be presented for your approval by July 7, 1982.

1. Observe the overall organization of the company and learn how the parts work together to produce results.

2. Become familiar with the Process Industry technology.

3. Study the Cost Engineering and Scheduling methods, and take responsibility on one aspect of a project.

4. Observe management practices at the project level.

5. Combine my technical background and the knowledge gained in the previous objectives to make an indentifiable contribution to one or more projects.

Approved by:

Dr. M. J. Fox, Jr., I.En.
Committee Co-Chairman

Dr. A. Garcia-Diaz, I.En.
Committee Co-Chairman

Dr. Biman Das, I.En.
Committee Member

Dr. L. D. Crumbley, Acct.
Graduate College Rep.

Dr. N. C. Ellis, P.En.
Department Head

Mr. E. E. A. Jansen, Fluor
Internship Supervisor

Dr. M. A. Colaluca, M.E.
Committee Member

Dr. D. T. Ward, Aero.E.
College of Engineering Rep.

Buranawong Sowaprux
Intern

Approved. Leo Romero Jr.
Assoc. Dean, 21 May 1982

XC: Dr. M. J. Fox
Dr. A. Garcia
Dr. L. S. Fletcher

June 30, 1982

Memorandum

To: Advisory Committee

From: Buranawong Sowaprux

Subject: Internship Objectives

06.03.82
Approved.
H. I. Kiehl
(Asst. Dean
Graduate College)

Please find listed below my final internship objectives for the Doctor of Engineering internship with Fluor Engineers, Inc. in Houston, Texas.

1. Observe Fluor's general approach to project implementation.

2. Become familiar with the process industry technology.

3. Take responsibility in cost and scheduling engineering and implement Fluor's techniques on a project.

4. Develop at least one new system or method that will improve the quality and efficiency of the Cost/Scheduling department.

5. Observe management practices at the project level.

Approved by:

Dr. M. J. Fox, Jr., I.En.
Committee Co-Chairman

Mr. E. E. A. Jansen, Fluor
Internship Supervisor

Dr. A. Garcia-Diaz, I.En.
Committee Co-Chairman

Dr. M. A. Colaluca, M.E.
Committee Member

Dr. Biman Das, I.En.
Committee Member

Dr. D. T. Ward, Aero.E.
College of Engineering Rep.

Dr. L. D. Crumbley, Acct.
Graduate College Rep.

Buranawong Sowaprux
Intern

Dr. N. C. Ellis, I.En.
Department Head

Leroy S. Fletcher, D.E. Program Director

APPENDIX E

Monthly Internship Progress Reports

June 30, 1982

Memorandum

TO: Advisory Committe

FROM: Buranawong Sowaprux

SUBJECT: MONTHLY INTERNSHIP REPORT NO. 1
JUNE, 1982

I started my internship on June 7, 1982 in the Cost/Scheduling Department of Fluor Engineers, Inc. under the supervision of Mr. Earle E. A. Jansen. Mr. Jansen is a Cost/Scheduling Manager. I am in a group of approximately 15 cost and scheduling engineers working on a refinery modernization project.

As for the first month, I have been assigned to study a few of the computer user's manuals used in scheduling, namely:

a) Fluor Analytical Scheduling Technique (FAST) - A computerized method for integration of project planning and control in modern plant design and construction.

b) Report Generator System (RGS) - A flexible reporting program that has the ability to obtain special reports, input data, and print out any of the FAST records.

c) Manpower Distribution Analysis Program (MADAP) - A computerized method used to forecast anticipated progress, manning, and cash requirements over the duration of a job.

In addition, my first piece of work was a revision of the "Progress Base," which is the estimated manhours used in the project and is the basis for calculating construction progress and productivity.

July 30, 1982

Memorandum

TO: Advisory Committee

FROM: Buranawong Sowaprux

SUBJECT: MONTHLY INTERNSHIP REPORT NO. 2
JULY, 1982

During the second month of my internship, I have been working more closely with Mr. Earle Jansen. He is conducting a research on Phased Engineering Schedule to see its effect on job progress. Under his direction, I have been preparing bar charts and graphs from data obtained from five ongoing jobs to see if there is a correlation between Phased and "Non-Phased" Engineering. A part of this work has been done and from now most of my time will be devoted to this work. This study is expected to be finished by the end of September 1982.

Besides the Phased Engineering Study, I have also worked on two other assignments. The MADAP (Manpower Distribution Analysis Program), a computerized method, was used to forecast the job progress from June 1982 to December 1982 which is the end of this project. Forecast labor performances are obtained by using the average of the past three months and spread over the projected duration by proportioning to the typical labor performance for each period. Some forecasting techniques such as moving average and exponential smoothing had been considered. However, this was dropped later because the data available was only for the past three months, not enough to forecast for the next six months.

Another assignment was to implement an existing computer program, RGS (Report Generator System), to produce the financial status of the project, which has previously been done manually. I found that a part of the work can be reduced by using the RGS but yet another part still has to be done manually. The reasons for this are: a) RGS is not a program designed mainly for this purpose and b) the way the cost codes (a system in which items of expense of fixed capital such as material, labor and subcontracts are identified with numerical figures) were set up did not exactly match the standard. Thus, one useful built-in feature of the RGS cannot be fully utilized.

On July 20, 1982, I was sent to join a 4-day course covering FAST82-PREMIS system, a entirely new scheduling computer program which will be used on every new project instead of the FAST (Fluor Analytical Scheduling Technique) program.

August 30, 1982

Memorandum

TO: Advisory Committee

FROM: Buranawong Sowaprux

SUBJECT: MONTHLY INTERNSHIP REPORT NO. 3
AUGUST, 1982

To sum up my experience for the first quarter of the internship, I have been involved in both cost engineering and scheduling engineering work. Generally, my assignments were to generate computerized reports, specifically assigned by Mr. Earle Jansen. The details have already been described in the two preceding reports.

Most of the activities in August were carried out for the Phased Engineering Study. It required interacting with various other disciplines to obtain input for the study. Lead engineers in several disciplines primarily on this project, and also cost/scheduling Managers, were interviewed. They provided technical information as well as their opinions. Also, questionnaires were prepared and distributed to other divisions in Irvine, California; Calgary, Canada; London, England and Manchester, England. Information was requested on key milestones in engineering, engineering manpower and engineering progress. Recently, an office has sent back questionnaire forms containning information for eight projects. Bar charts, progress curves and manpower curves are being done. However, no analysis is performed until all the information has been gathered.

On August 17, 1982, I attended a presentation on the PPRS (Project Performance Reporting System) which was scheduled for the schedulers on the task force. The presentation included introduction, objective and system overview. Mr. Earle Jansen planned to have us familiar with the system for the future use and there is no plan of implementing the PPRS on this project which will end by the middle of December 1982.

As engineering function of this project is about 99% complete, things are relatively slow now. For the month, I have no assignment directly related to the job and have been working full-time on the Phased Engineering Study.

September 30, 1982

Memorandum

TO: Advisory Committee

FROM: Buranawong Sowaprux

SUBJECT: MONTLY INTERNSHIP REPORT NO. 4
SEPTEMBER, 1982

A majority of my time was spent in the Phased Engineering Study. A preliminary report of this study has recently been issued to Mr. Jansen. The report covers: a brief Phased Engineering concept overview; a discussion of how the study was conducted; the result of the study; and the conclusion. This study will be described in detail in my internship report which I intend to present to the Advisory Committee by the end of June 1983, approximately one month after my internship is over.

In addition to the Phased Engineering Study, I performed a few specific scheduling engineering assignments. Most of them were related to analyzing and predicting field labor progress and performance for three paticular construction disciplines, namely, piping, electrical and instrument.

The progress in each of these three disciplines is behind the original plan and the project management is paying particular attention to these areas. I obtained historical data of five past jobs and prepared graphs of Performance VS. Progress. Using the aggregate trends of these past jobs, the forecast performances of this project were achieved. Factors influencing performances were investigated and these included the number of weekly field labor and the number of weekly absentees. It was interesting to note that the number of absentees has impact not only on the progress, but also the performance.

Another interesting exercise was revising an instrument loop-check progress forecast. With a suggestion from Mr. Jansen, I utilized an 'S Curve' concept (also known as 'Learning Curve') to estimate the amount of loops checked for different sets of instruments in all units. The final product was an aggregate 'S' shape progress curve which I believe to be a better forecast than the one we have had.

October 29, 1982

Memorandum

TO: Advisory Committee

FROM: Buranawong Sowaprux

SUBJECT: MONTLY INTERNSHIP REPORT NO. 5
OCTOBER, 1982

The scheduling functions of the project are now minimal. My routine work is to maintain and update progress of major field activities to go into the management montly report. This occasionally involves interaction with a few other disciplines.

The study of the Phased Engineering Approach is still under way. A second questionnaire form is being prepared for distribution to the projects utilizing the Phased Engineering Approach. In this questionnaire, opinions towards the approach will be requested rather than technical data. As it has already turned out, the study done so far yeilds no solid conclusion. This is due to the facts that we cannot find any effective means to measure and compare the engineering performance, nor can we find the extent to which the projects implemented the approach.

I am also engaged in compiling historical data of this project. Factors, ratios, bar charts and graphs of key attributes are being prepared for future use. Actual manpower and actual cost in all major accounts will be compared to the estimates done earlier in the project life.

This month I have done a little literature survey on Project Management. I have reviewed a few Project Management books and articles and begun observing management practices in the Fluor Organization. My particular interest at this time is the matrix organizational practice of the company. Certain areas include the integration of project responsibility and functional responsibility, how the responsibility can be shared and problem-solving techniques at project level.

November 30, 1982

Memorandum

TO: Advisory Committee

FROM: Buranawong Sowaprux

SUBJECT: MONTHLY INTERNSHIP REPORT NO. 6
NOVEMBER, 1982

This is the last month I will be on this refinery modernization project, as the scheduling functions in the home office are completely terminated. Mr. Jansen has been assigned to another refinery project effective December 6, 1982; and with his hard efforts, I will also be transferred to this project effective December 3, 1982. I would like to express my appreciation to Mr. Jansen for his high concern regarding the role of my Doctor of Engineering internship with the company.

I have been spending a lot of time collecting historical data. Expenditures, progress, performance, manpower and manhours of most construction accounts are recorded over the project life. This information is presented in graphic form as graphs and bar charts. I have also been working on finding the accuracy of the estimates of equipment costs. This is one of the important accuracy factors the management would like to know and will take a serious study if any one of these factors are higher than expected. I have gained a lot of benifites while going through all kinds of reports since I have been exposed to several aspects of cost and scheduling I had not previously encountered.

For the Phased Engineering Study, Mr. Jansen had reported subjective results to the Technical Excellence Committee, comprising the highest management personnel of the corporation, and recommended a next step of reviewing and expanding the current Phased Engineering procedures. As a result, the idea of sending out a second questionnaire form was dropped. The next phase of this work will require a highly experienced engineer to revise the Project Execution Manual ,and therefore, my assignment on the Phased Engineering Study is now over.

I also took over the responsibility of preparing all slides used in the management meeting as I am now the only engineer on the scheduling task force in the home office. These slides present: monthly manpower requirements, accident rate, engineering and construction progress, and progress of a few outstanding construction activities.

January 11, 1983

Memorandum

TO: Advisory Committee

FROM: Buranawong Sowaprux

SUBJECT: MONTLY INTERNSHIP REPORT NO. 7
DECEMBER, 1982

I am now working on another modernization project. The project is currently 50% complete in engineering and 10% in construction and will cost approximately $600 million. The Cost/Scheduling Task Force is divided into three groups as onsites group, offsites group and central group, containing 34 engineers and technicians. And unlike the previous project, each group performs both cost and scheduling functions.

I belongs to the central group and report to the control team leader, who reports to Mr. Jansen. The group is primarily responsible for project reporting and special assignments, such as cash flow analysis and development of guidelines for cost control.

I have been assigned to: 1) maintain and update equipment and materials procurement status, and 2) collect and issue montly progress support documents, which basically are project cost reports, manpower plans and engineering schedules. This work required coordination with several engineers in the task force and took time during the first two weeks of the month.

In addition to the routine work mentioned, I assisted an engineer in preparing an unrecoverable costs analysis to report to the client. And during the last two weeks of the month, I did a special assignment on a cash flow analysis of the entire project. This exercise involved integrating 34 seperate cash flows into a single cash flow using the MADAP computer system. The work took about ten days and was completed successfully.

February 10, 1983

Memorandum

TO: Advisory Committee

FROM: Buranawong Sowaprux

SUBJECT: MONTHLY INTERNSHIP REPORT NO. 8
JANUARY, 1983

Some transitions were made in the Cost/Scheduling Task Force during the past month. As a result, I have been assigned to perform two important tasks in addition to my routine assignments.

First, I have to prepare a "Two-Month Cash Flow Projection" for the project. The forecasts cover home office costs, field labor costs, purchased materials, subcontract engineering and construction, and fees. Some of these costs are based on reports from other disciplines and this provides me with exposure to other aspects of work such as expediting, accounting and procurement.

My second new assignment is to maintain and produce the computerized cost report of the project. This report is the means by which cost engineers and management analyze the present contract cost with respect to original budgets, current budgets, expenditures and commitments. It reflects the amount of money and manhours expended for the current month and to date. Basically, most of the data will be transferred from accounting files. But it is the responsibilities of cost engineers to update the report, and input other known changes and other costs that are not included in the accounting file so that the report will depict all costs closer to the actuals as much as possible.

I also worked on home office manpower planning. The plan was based on the recent budget and the anticipated manpower utilization received from each discipline. This plan lets management and all disciplines see their staffing plans based upon the budgets available.

Finally, I performed my routine task in updating equipment and materials procurement status, a part of the information that is reported to the client.

March 18, 1983

Memorandum

TO: Advisory Committee

FROM: Buranawong Sowaprux

SUBJECT: MONTHLY INTERNSHIP REPORT NO. 9
FEBRUAARY, 1983

Attached are tentative outlines of my internship report. The report will contain 7 chapters including summary and conclusion.

On February 4th 1983, Dr. M. J. Fox, Jr. visited Fluor Engineers. He was welcomed by Mr. H. J. Kirchner, project director; Mr. J. E. Wendt, project manager and former industrial representative of the Doctor of Engineering Program; and Mr. E. E. A. Jansen, the internship supervisor. Dr. Fox was informed about my work assignments and the contents of the report were discussed.

For the past month, I performed only two but very important activities. And the amount of work was so substantial that I frequently worked over time especially during the reporting cycle, which is the first two weeks of each month.

The first activity involved the preparation of construction manpower plan. I was responsible for setting up a new computer data base which is the combination of MADAP (Manpower Distribution Analysis Program) and FUDES (Fluor Universal Data Entry System), as an alternative to FAST (Fluor Analytical Scheduling Technique) system, which is a more complex data-based system and is more expensive to maintain. With the use of FUDES, the input for MADAP can be stored in a file and can be updated interactively. Thus, the combination of the two systems provides the same flexibility in updating data as the FAST system, but its costs are considerable less, and as much as ten times. In addition, MADAP is designed especially for manpower analysis, and thus it has more features such as craft mix distribution, labor costs distribution, etc.

The other activity was to produce the computerized cost reports for the project. Several cost reports were generated for the client, for the management and for internal use. As the structure of the costs file and the process in obtaining cost reports for this $600 million project are quite complicated, I therefore have prepared a document on how to generate the cost reports for the project. This will be very useful for the engineer who will assume my responsibility in near future.

April 18, 1983

Memorandum

TO: Advisory Committee

FROM: Buranawong Sowaprux

SUBJECT: MONTHLY INTERNSHIP REPORT NO. 10
MARCH, 1983

The activities I performed in March were basically the same as in the previous month. I spent time revising plan progress and manhours for the Manpower Distribution Analysis Program. The plan has been revised a few times because there are changes due to priorities of work and client needs.

During the first three weeks I worked with the Project Cost Reporting System. In addition to producing routine computerized reports, I set up a new computer file that contains the budgets with accuracy allowance breakout. (The accuracy allowances are allowances for anticipated but not identified quantities required for the project to cover the difference between neat take-offs at the time of the estimate and actual construction quantities.) Input was provided by area cost engineers and I was responsible for putting it into the computer system, verifying the information, and replacing the old budget file with the new one. The work was completed and has now been used in the current cost reports.

May 19, 1983

Memorandum

TO: Advisory Committee

FROM: Buranawong Sowaprux

SUBJECT: INTERNSHIP REPORT NO. 11
APRIL - MAY 1983

May 20th, 1983 will be my last day of work at Fluor. I have now completed my one-year internship. I am certain that my internship objectives have been fulfilled. At the end of this month, I will return to Texas A&M University and take two courses during the summer.

In April and May I continued to work with the Project Cost Reporting System (PCRS) producing computerized cost reports. This has been my main reponsibility for the past few months.

On May 4th and 5th I was given an opportunity to visit the construction site. The purpose of the trip was two fold: a) to observe work practices of the field organization, b) to serve as cost/scheduling computer laison. I assisted a field cost engineer in setting up a computer file to maintain subcontractors' manhours expended. Two programs were prepared to generate subcontract manhour reports. The programs were tested and produced reports as expected. The task was completed successfully.

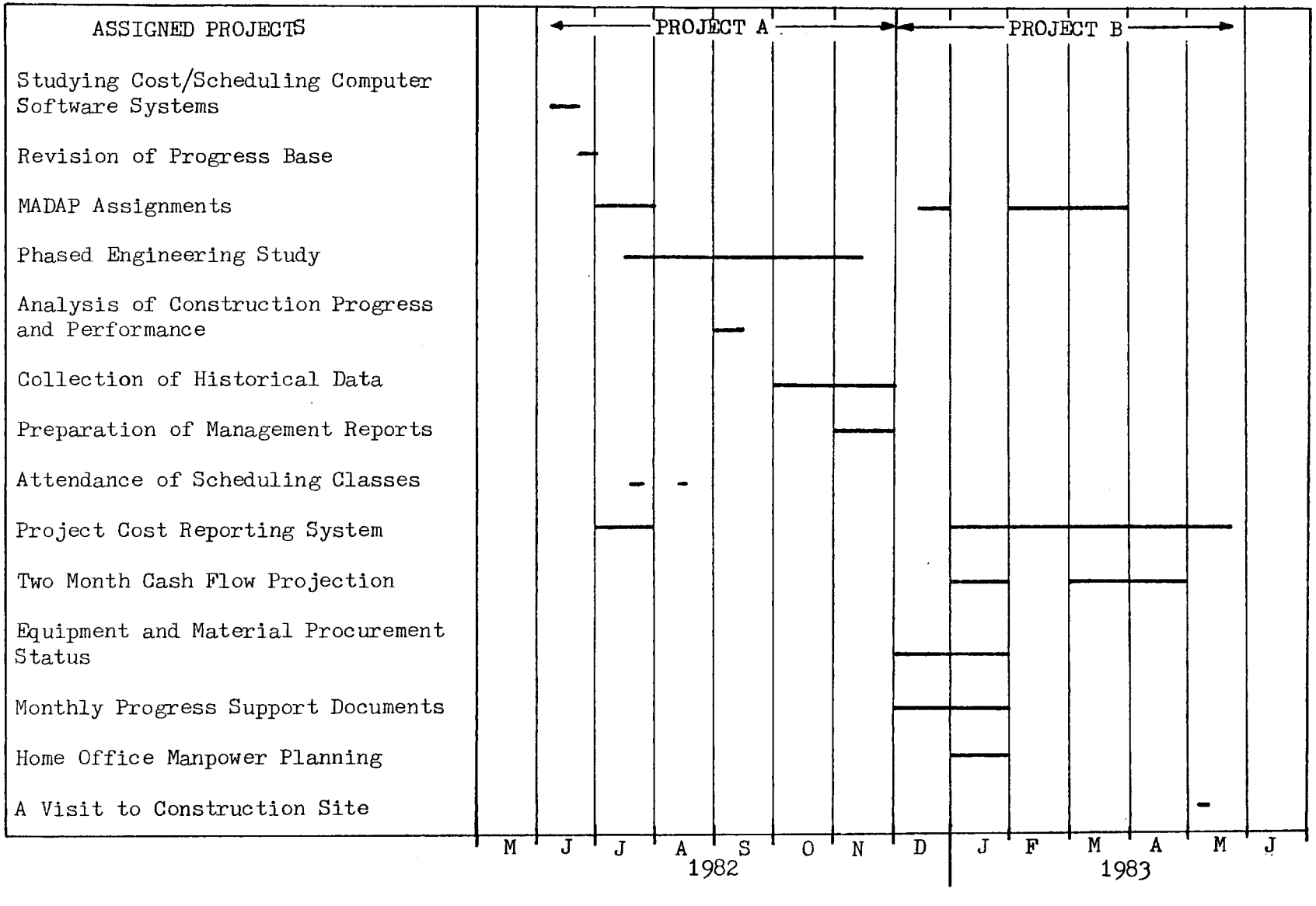
As a result of this trip, I have a better understanding of the role of field staff, especially in the cost/scheduling area. I saw how home office staff and field staff function and how they fit together. I also observed how scheduling engineers status job progress and productivity.

In April I also assisted an engineer in performing a Two-Month Cash Flow Forecast, an activity for which I was previously responsible. During the last week I have spent time interfacing with the engineer who will replace me on the task force. I am also preparing a computer file to maintain a subcontractor manhour base which will be used as a basis for subcontractors' progress.

APPENDIX F

Schedule of Assignments

SCHEDULE OF ASSIGNMENTS



Appendix G

Intern Supervisor's Report

FLUOR ENGINEERS, INC.
HOUSTON DIVISION

4620 NORTH BRAESWOOD
HOUSTON, TEXAS 77096
TELEPHONE: (713) 662-3000

September 27, 1983

M. J. Fox, Jr., P.E., Ph.D.
Co-Chairman, Graduate Committee
Texas A&M University
Industrial Engineering Dept.
College Station, TX 77843-3131

Re: B. Sowaprux - Internship Report

Dear Dr. Fox:

Nui served his internship with Fluor from June 7, 1982 until May 23, 1983. All this time was spent under my direct supervision and I have no hesitation in advising the other members of the Advisory Committee that he has fulfilled his final internship objectives.

He was constantly challenged with problems that had no text book style answers and more often than not came up with solutions. His strength lies in fragmenting a problem to get to the core of it and then attacking the core. He is also very quick to learn, fast in what he does, and communicates well. He got hands on experience on all cost and scheduling systems and took total responsibility for some.

His final accomplishment was to write a software package for microcomputer application of Fluor's Manpower Distribution Analysis Program (MADAP).

Sincerely,

Earle E. Jansen
Manager Cost/Scheduling

EEJ:cr

APPENDIX H

Intern Supervisor's Resume

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FLUOR

Resumé

EARLE E. A. JANSEN

PROJECT PLANNING AND CONTROL MANAGEMENT

DATE AND PLACE OF BIRTH:
February 29, 1932, Colombo, Ceylon

EDUCATION:
Diploma in Mechanical Engineering
University of Ceylon, Technical College, 1955

Industrial Administration
University of Manchester, 1958

Evening School toward Masters Degree
University of Houston

SUMMARY OF EXPERIENCE:

Twenty-two years experience in engineering and construction of major petrochemical plants with emphasis on project planning and control. Current assignment is Control Team Manager for a $360 MM refinery modernization. Responsible for preparation of engineering and construction cost estimates, project schedules, cost reporting and analysis, construction progress reporting and analysis, cost and schedule trending, corrective action recommendation for cost or schedule anomalies. Other projects include refinery expansion in Louisiana, natural gas processing plant in Saudi Arabia, petrochemical plant in Virgin Islands, substitute natural gas plant in Pennsylvania, and a gas conservation plant in Canada.

Prior to Fluor, was Project Engineer for a large nylon polymer plant expansion and a pharmaceutical plant project; Senior Construction Planning Engineer for naphtha and gas reforming plants; Senior Mechanical Engineer for polyethylene plant and magnesia plant projects in United Kingdom; Field Office Engineer with responsibility for "hand-over" of completed systems to client.

LANGUAGES:	READ	SPEAK
Ceylonese (Singhalese)	Well	Well
Indian (Tamil)		Moderately

TECHNICAL SOCIETIES:
Member, Institute of Mechanical Engineers - United Kingdom

2-3
9/0

RESUME: EARLE E. A. JANSEN

LICENSE:
Chartered Engineer - United Kingdom

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FLUOR - HOUSTON DIVISION (1970 to Present)

CONTROL TEAM MANAGER:

Borger Refinery Modernization ARDS Plant Addition	Phillips Petroleum Company Texas

CONTROL TEAM LEADER:

FCCU Addition Refinery Expansion	Marathon Oil Company Louisiana

FIELD COST/SCHEDULING MANAGER:

Ju'aymah Fractionation Center Natural Gas Processing Plant	Arabian American Oil Company Saudi Arabia

FIELD COST/SCHEDULING MANAGER:

Paraxylene Plant Grass Roots Chemical Project	St. Crois Paraxylene Corp. (Hercules-Hess) U.S. Virgin Islands

CONTROL TEAM LEADER:

Crude Oil Gasification Plant Synthetic Natural Gas Processing	Transco Energy Co. Pennsylvania

LEAD SCHEDULING ENGINEER:

Gas Conservation Plant Turbo-Expander Project	Imperial Oil Co. Canada

BECHTEL CORPORATION (1966 - 1970)

PROJECT ENGINEER:

Project duties included management of engineering task force for a number of construction projects.

3-3
9/0

RESUME: EARLE E. A. JANSEN

HUMPHREYS & GLASGOW, LTD. (UNITED KINGDOM) (1965 - 1966)

SENIOR CONSTRUCTION PLANNING ENGINEER:

Duties included planning construction activities (manpower requirements, cost controls, and trend forecasting) for naphtha and gas reforming plants located in England.

GEORGE WIMPEY & COMPANY, LTD. (UNITED KINGDOM) (1960 - 1965)

SENIOR MECHANICAL ENGINEER:

Project Engineer on oil refinery expansion, polyethylene plant and magnesia plant. Other duties included design engineer on piping, vessels, heat exchangers, and bulk conveyor systems for various projects located throughout the United Kingdom. Worked as field office engineer and was responsible for coordinating design changes, planning, scheduling, cost and material control, punch listing, and hand-over of completed system to Clients.

DESIGNERS SUPPLY COMPANY (UNITED KINGDOM) (1957 - 1960)

DESIGNER:

Duties included mechanical design and engineering on chemical plant projects.

VITA

Buranawong Sowaprux
32 Soi Prompak, Sukumvit 49
Bangkok, Thailand

DATE OF BIRTH: Febuary 28, 1958

PLACE OF BIRTH: Bangkok, Thailand

PARENTS: Banchong and Udomporn Sowaprux

EDUCATION: B.Eng., Mechanical Engineering
Chulalongkorn University, Bankok, Thailand (1979)

M.Eng., Industrial Engineering
Texas A&M University, College Station, Texas (1981)

EXPERIENCE: June 1982 - May 1983
Doctor of Engineering Internship
Associate Cost/Scheduling Engineer
Fluor Engineers, Inc.
Houston, Texas

September 1981 - May 1982
Graduate Assistant
Mechanical Engineering Department
Texas A&M University
College Station, Texas

February 1980 - January 1981
Graduate Research Assistant
Mechanical Engineering Department
Texas A&M University
College Station, Texas

ACTIVITIES: September 1981 - August 1982
President, Thai Student Association
Texas A&M University

June 1977 - May 1978
President, Mechanical Engineering Student Club
Chulalongkorn University

Associate Member
American Institute of Industrial Engineers

This report was typed by the author.