EMGT 835 FIELD PROJECT:

Front End Loading (FEL) and Process Engineering Workflow

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Executive Summary

Project development for the oil refining industry is typically performed through a process called Front End Loading (FEL). In recent years, the Process and Industrial Division of Burns and McDonnell has performed several FEL efforts for various refining industry clients. A review of past FEL efforts indicates significant variation in the FEL deliverables provided, the content of these deliverables, and the overall quality. The primary objective of this field project report was to perform a review of past projects, and develop a comprehensive list of "standard" FEL deliverables. Once these deliverables were defined, a review of engineering workflow activities for each stage of the FEL process was performed. The list of deliverables and the engineering workflow activities provide a solid basis for the planning and execution of future FEL efforts.

As a byproduct to this report, a standard FEL sample report was also developed. This sample report is intended to benefit the division in three areas; 1) as a training tool for the introduction of FEL to new employees, 2) as a template or guide for future FEL efforts, and 3) as a sales tool for the demonstration of an FEL document to potential clients.

Finally, several recommendations were made regarding the management of an FEL, effort, execution of FEL engineering, and the transition of FEL to detailed design. For management of FEL, four key recommendations have been identified:

- Use of a 3-Phase FEL approach.
- Managing and maintaining consistent client "buy-in" throughout the FEL process.

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- Utilizing early involvement of individual design disciplines and construction.
- Conducting PDRI reviews following each stage of FEL to measure progress.
- Use independent FEL benchmarking for larger or more complex projects.

For execution of FEL engineering, four key recommendations were identified:

- Emphasis on the development of a written Process Design Basis in early FEL.
- Focus on thorough documentation of design assumptions by individual engineering disciplines.
- Obtain operations input from the client in early FEL.
- Improve quality review procedures specifically for FEL projects.

Finally, five recommendations were made for transition of FEL to detailed design.

- Maintain strong continuity of project team, specifically with lead engineers and piping designers.
- Improve format standard for FEL data to streamline communication of data in detail design.
- Maintain adherence to FEL design assumptions were at all possible to minimize scope creep.
- Limit unresolved issues from FEL by conducting a final open items review to track all uncertain or outstanding issues prior to start of detailed design.
- Implement management of change process in FEL to ease transition to detail design.

I. Introduction

A. Historical Perspective

The oil refining industry is one of the largest and most dynamic industries in the world. In the United States, the oil refining industry has grown out of necessity since the late 1800's, producing the fuels required to drive the economical expansion of the 20^{th} century. The products of a modern day refinery include gasoline, diesel, jet fuel, home heating oil, and petroleum based lubricants. Also produced are various petrochemical byproducts, used as raw materials to make numerous products from plastics and synthetic fibers, to beauty products and pharmaceuticals.

There are currently 149 operating refineries in the United States, processing more than 16.9 million barrels per day (BPD) of raw crude oil (NPRA, 2004). Many of the companies that own and operate the modern day refineries are descendents of the country's first oil companies, who started in the early days of oil field exploration, and developed refining and product marketing capabilities as the industry grew. These companies are typically referred to as the "fully integrated" or "major" refiners, reflecting their capability to compete in all aspects of the oil and gas industry including exploration, transportation (pipeline), refining, and product marketing. These companies tend to be the largest oil refiners due to their established assets and infrastructure, and are the product of long, storied histories, steady growth, and strategic mergers and consolidation. In the U.S., these companies primarily include six major oil companies; ConocoPhillips, Exxon Mobil, BP Amoco, ChevronTexaco, Marathon Oil, and Royal Dutch/Shell Oil. Each of these companies have total U.S. refining capacity (in terms of total

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crude oil processing capacity) of more than 500K BPD. Together, the six "majors" process more than 9.0 million BPD of crude oil (roughly 55% of the market).

The balance of the industry is controlled by the "independent" refining companies. These companies generally have little or no exploration or transportation capability, and therefore must purchase crude oil on the open market, and refine this oil to finished products. Some independent refiners own wholesale or retail marketing outlets, while others sell their products to independent marketing companies. There is a wide range of processing capabilities within the independent refiners. Some of the largest independents include Valero Energy, Sunoco, Premcor, Tesoro, and Koch Industries. Each of these companies process more than 500K BPD of crude oil. There are also dozens of smaller independents, which process anywhere from a few thousand barrels to 100K BPD or more. The smaller independents include those such as Sinclair Oil, Frontier Oil, NCRA/Cenex, Coffeyville Resources (formerly Farmland), Ergon/Lion Oil, Western Refining, Suncor Energy, and Hunt Refining.

B. <u>Definition of FEL</u>

The FEL (Front End Loading) process is a common strategy in the development of capital projects for the oil refining industry. For other process industries, this may also be referred to as FED (Front End Design), or FEED (Front End Engineering Design). However, in all cases, the overall idea of an FEL process is the same, and includes all project development activities from early project conceptualization to project authorization and funding. The FEL process is typically broken down into two or three project development phases. Figure 1

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illustrates a typical FEL timeline, assuming a three-phase approach (FEL 1, FEL 2, and FEL 3).

FIGURE 1 – Project Development and Execution Timeline

Front End Loading (FEL)			Project Execution	
FEL 1 - Business Planning - Market Studies - Technology Evaluation - Conceptual Design - Project Economics - Risk Analysis	FEL 2 - Review of Alternates - Preliminary Design - Preliminary Estimates - Project Economics - Risk Analysis	FEL 3 - Class "A" Design - Hazards Analysis - Definitive Estimate - Project Economics - Risk Analysis	DETAIL DESIGN - Detailed Engineering - Equipment Purchase - Subcontract Bid Spec Development	CONSTRUCTION - Mobilization - Construction - Commissioning and Start-up

TIMELINE →

C. Value of FEL in Project Development

For an engineering contractor in the oil refining business, it is critical to develop effective FEL processes and procedures for working with both the major and independent refiners. For the major refiners, it is essential for all engineering contractors who bid on the development and execution of large capital projects to demonstrate a complete understanding of the FEL process. In general, the major refiners tend to have established and structured methods to project development. These companies are committed to the FEL process and recognize the value of FEL in developing successful projects.

When working for a major refining company, the engineering contractor must be flexible enough to tailor their FEL process to the needs of the client. Typically, a major refiner will have specific expectations regarding the type of FEL deliverables required and the quality of such deliverables. It is up to the

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engineering contractor to demonstrate an understanding of the critical elements of a thorough FEL package, and be willing to provide this information in a way that meets the expectations of the client.

For the independent refiner, project development is often a greater challenge. These operating companies typically have limited engineering resources and less corporate structure in the execution of capital projects. Nevertheless, this does not make FEL any less important when working for an independent. In fact, working for an independent often requires the engineering contractor to have an even better understanding of the FEL process. Many independent refiners tend to spend less in FEL engineering, opting to skip over some of the later FEL activities and award directly to an EPC contractor on a lump sum basis. This strategy is based on the perception that this minimizes up-front investment, streamlines the process of project funding, and shifts the project responsibility and risk to an EPC contractor. However, perception is not always reality, and it is up to the engineering contractor in this scenario to sell the benefits of a good FEL process to a client who may not appreciate the advantages of such an approach. An incomplete FEL process inevitably results in poor scope definition. If the scope is poorly defined, there is a greater chance for major scope changes or surprises in detailed design. This creates added costs, project delays and engineering rework, which could often be avoided with a thorough FEL approach.

II. Project Scope

A. Objective

The objective of this field project report is to perform a review of recent FEL efforts in the Process and Industrial Division of Burns & McDonnell, with a focus on developing a standard list of FEL deliverables, and a complete definition of the Process Engineering Workflow required to support these deliverables. It is intended that this report will benefit the division in several areas:

- Training

  Provide an introduction to the FEL process for new process department employees.

- Benchmarking

  Provide a starting point for development of future FEL efforts, and a standard by which to measure and evaluate FEL performance.

- Sales Tool

  Provide a sample document to demonstrate the value of a structured FEL approach for potential clients.

As a byproduct to this report, a "standard" FEL template report will be developed, which can function as a guide for future FEL efforts, and/or demonstration document for sales of the FEL process to potential clients.

B. Review Approach

This report focuses only on the FEL process from the initial stages of project development, to the release of engineering for detailed design (point at which project funds are approved to initiate detailed design). Process workflow activities during detailed design and construction are outside the scope of this report. However, proper execution of an FEL package must be developed with an eye to the final end product (a fully functional process plant, built on schedule and on budget). Therefore, the review of FEL deliverables and any recommendations proposed will be made in the context of promoting effective transition from the FEL stage to detailed design and construction.

C. Selection of Sample Projects

A thorough discussion of the workflow required to effectively execute an FEL project requires definition of a proper set of FEL deliverables. To achieve this objective, a search of recent projects was performed to identify a sample of significant FEL efforts completed by the division over the past 4 years. The selected project list is shown in Table 1, and includes FEL projects for one major refiner and two independent refiners. These FEL efforts provide the basis for this report.

TABLE 1 – FEL Projects List - (Selected sample from Jan 2001 to Dec 2004)

Client Project	FEL Scope	Proceed to Detail Design?
ConocoPhillips		
ULSG – Ponca	FEL3	Yes
Crude Unit Revamp	FEL1/FEL2/FEL3	Yes
Coker Revamp	FEL2/FEL3	No
NOx Reduction Project	FEL1/FEL2/FEL3	No
ULSD – Denver	FEL1/FEL2/FEL3	No
Coker Project	FEL1/FEL2/FEL3	Yes
ULSD – Ponca	FEL1/FEL2/FEL3	Yes
ULSG – Lake Charles	FEL1/FEL2/FEL3	Yes
ULSD – Lake Charles	FEL1/FEL2/FEL3	Yes
Sinclair Oil Corporation		
HTU Revamp	FEL1/FEL2/FEL3	Yes
NHDS Project	FEL1/FEL2/FEL3	Yes
Sulfur Block Project	FEL1/FEL2/FEL3	Yes
CRU Revamp	FEL3	Yes
National Cooperative Refinery Assoc. (NCRA)		
Amine Regenerator	FEL3	Yes
Sour Water Stripper	FEL3	Yes

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III. Review of FEL Deliverables

A. Definition of FEL Deliverables

The list of sample projects identified in Table 1 covers a wide range of project types and scope. A review was performed to evaluate the FEL deliverables provided for each of these projects. The result of this review was the development of a comprehensive list of FEL deliverables for each phase of FEL. Table 2 lists the FEL deliverables identified, and indicates in which phase or phases a specific deliverable is typically issued. For documents to be issued in more than one FEL phase, these documents are issued in multiple revisions as project information is better defined from one phase to the next.

TABLE 2 – Standard FEL Deliverables

Deliverable	Phase		
	FEL 1	FEL 2	FEL 3
Project Scope Documents			
Project Description	X	X	X
Project Execution Plan		X	X
Design Basis Documents			
Process Design Basis	X	X	X
Material and Energy Balance		X	X
Utility Summary		X	X
Emissions Summary		X	X
Equipment Design Basis		X	X
Piping Design Basis			X
Civil/Structural Design Basis			X
Electrical Design Basis			X
Instrument and Controls Design Basis			X
Fire Protection Design Basis			X
Insulation Design Basis			X
Protective Coatings Design Basis			X
Cost Estimate Basis	X	X	X
Key Drawings			
Block Flow Diagrams	X		
Process Flow Diagrams		X	X
Piping and Instrumentation Diagrams			X
Materials of Construction Diagrams			X

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Site Plan		X	X
General Arrangements		X	X
Piping One-Line Drawings			X
Electrical One-Line Diagrams			X
Specifications			
Equipment Specifications			X
Piping Specifications			X
Instrument Specifications			X
Motor Specifications			X
Insulation Specifications			X
Lists/Summaries			
Line List			X
Tie-in List			X
Equipment List	X	X	X
Instrument List			X
I/O List			
Datasheets			
Process Data Sheets		X	
Equipment Data Sheets			X
Control Valve Data Sheets			X
Relief Valve Data Sheets			X
Instrument Data Sheets			X
Schedules			
Overall Project Schedule	X	X	X
Estimates			
Factored Cost Estimate	X		
Preliminary Estimate		X	
Definitive Estimate			X
Project Definition Reports			
PDRI Summary			X

B. Scope of Deliverables

A review of deliverables from the sample projects indicates significant variation, both in the content of the deliverables and the overall quality. In many cases, some variation is required due to the different types of projects defined. However, all FEL reports should follow the same general outline, providing the same basic types of information. In general, the deliverables provided in a

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complete FEL package should include the following:

1. <u>Project Scope Documents</u>

   The Project Scope Documents include the Project Description and Project Execution Plan. The purpose of these documents is to provide the overall summary of the project scope and intent, and to outline the key factors to successful project execution, including key assumptions, limitations and challenges.

   In general, the Project Description must include the general scope (what), location (where), purpose (why), and the infrastructure and utilities required (how).

   The Project Execution Plan describes the key activities required for project completion. The execution plan must consider requirements and limitations based on engineering, equipment deliveries, and construction duration. This document should also evaluate the contracting and procurement strategies for the project, and interface responsibilities between the owner and various contractors/sub-contractors.

2. <u>Design Basis Documents</u>

   The design basis documents define the overall engineering basis of design for each specific discipline required for execution of the project. For most process plant design projects, this would typically include:

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- **Process Design Basis**

  The Process Design Basis is the most important design basis document in early FEL. This document defines the unit operations required, the characteristics and quality of available feed stocks, the minimum performance criteria or product quality standards, and the assumed conditions for any supporting utilities. The Process Design Basis also includes the project Material and Energy Balance, Utility Summary, and Emissions Summary.

- **Equipment Design Basis**

  The Equipment Design Basis describes the key parameters required for all critical process equipment, including the sizing basis, performance requirements, materials of construction, spare equipment philosophies, over-design margin, and future expandability. The Equipment Design Basis also identifies specific design codes or standards, as well as client-specific specifications and preferences required.

- **Civil/Structural Design Basis**

  The Civil/Structural Design Basis describes the overall general site conditions, structural design codes and standards, special geotechnical or foundation requirements, and region-specific wind, snow and earthquake design requirements. This section also defines the style or type of facilities that will be provided based on the client's requirements. This can include design features such as special access, landscaping, types of paving, fireproofing, building materials, and architectural requirements.

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- **Electrical Design Basis**

  The Electrical Design Basis defines the requirements for design of new electrical power systems, including a summary of new power loads required, the electric distribution systems needed to support these new loads, major electrical equipment required, such as substations or transformers, and low voltage distribution requirements for instrumentation and controls. This section also identifies any electrical requirements related to general lighting, grounding, lightning or cathodic protection, and heat tracing systems for piping. Finally, this section defines the required design codes and standards, electrical area classifications for equipment, and physical design requirements and philosophies to be followed in regard to wiring, conduit, cable tray, electric motors, design redundancy, emergency power, and utility power (welding and general purpose receptacles).

- **Instrument and Controls Design Basis**

  The Instrument and Controls Design Basis defines the type of instruments to be installed (manufacturer, technology, materials of construction) for each process service and function, including control valves, process instrumentation (flow, level, pressure and temperature), and any special analyzers. This document also defines control philosophy (DCS, PLC, or other), applicable codes and standards, client preferences, acceptable manufacturers, units of measure, calibration requirements, and winterization (freeze protection) philosophy.

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3. Key Drawings

There are several key drawings that must be developed during FEL. In early FEL, these drawings are generally preliminary in nature, with the purpose of illustrating options or assumptions. In late FEL, these drawings should be issued for review and approval, and provide the basis for the start of detailed design. The key drawing documents include:

- **Block Flow Diagram**

  The Block Flow Diagram is a simplified drawing that illustrates the major process steps required for the overall process design. This drawing indicates the major feed stocks required (inputs), the process steps to be performed (unit operations), and the resulting products created (outputs). The Block Flow Diagram may be issued as an independent drawing, or incorporated into the written Process Design Basis for reference.

- **Process Flow Diagrams (PFDs)**

  The Process Flow Diagrams illustrate the overall process flow scheme in order to define all unit operations required and their relative sequence in the overall process operation. This drawing is typically used as a reference document for the Material and Energy Balance to provide overall flow data and process conditions for all major process and utility streams.

- **Piping and Instrumentation Diagrams (P&IDs)**

  In the FEL process, the P&IDs are the most important single document used to illustrate the process design required and the overall scope of

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equipment, instrumentation and piping for the project. The P&IDs are based on the same flow scheme illustrated by the PFDs, but with significantly more detail. At the end of FEL, the P&IDs should contain all information required for the start of detailed design and should illustrate all equipment, piping, valves, special fittings, instruments and safety devices required to construct a complete, safe, and operable refinery process plant.

- **Materials of Construction Diagrams (MSDs)**

  The Materials of Construction Diagrams (MSDs) are very similar to the PFDs, with added information to define the equipment and piping metallurgy requirements for the project. These requirements are based on client preferences, required corrosion resistance, and the economic plant life expectancy.

- **Site Plan**

  The Site Plan Drawing illustrates the overall layout of the new process unit in relation to the overall facility and any key infrastructure and access features of the site (roads, railways, sewer and fire water systems, etc.). This drawing is also used to illustrate the availability of major utility streams (cooling water, service water, instrument air, plant air, etc.) when required to be obtained from locations outside the scope boundaries (battery limits) of the new process unit.

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- **General Arrangements**

  The General Arrangement Drawings illustrate the relative layout of equipment within the process unit boundaries of the project. This drawing shows the outline dimensions and orientation of all equipment in the project, as well as any major buildings or structures. The General Arrangement drawings are used to evaluate access issues associated with safety, operability, maintenance, and constructability.

- **Piping One-Line Drawings**

  The Piping One-Line Drawings provide a simplified one-line illustration of all major pipe runs required for the project. This drawing is typically produced with the General Arrangement or Site Layout as the background for consistency. The Piping One-Line Drawings are critical in the development of a thorough FEL project cost estimate, because they are often used in the tabulation of piping material take-offs and preliminary design of major support structures and piperacks.

- **Electrical One-Line Drawings**

  The Electrical One-Line Drawings illustrate the overall electrical interconnects required for the project in a simplified, one-line format. This drawing illustrates the power feed to all electric motors, and shows all major electrical equipment including main power feeders, generators, transformers, switches, contactors and motor control centers (MCCs).

4. Specifications

The specification documents define the quality of design, fabrication, and installation required for equipment and materials in the project. The extent and type of specifications developed in FEL may vary significantly based on the type of project being considered. However, the specification documents typically include:

- **Major Equipment Specifications**

  Includes written specifications for major equipment such as storage tanks, pressure vessels, fired heaters, heat exchangers, pumps and compressors. These specifications may be based on standard in-house specifications, client specifications, and/or industry standard specifications (such as PIP (Process Industry Practices) or other).

- **Piping Specifications**

  The piping specifications define the design and installation requirements for all piping materials on the project. The full compliment of piping specifications for a typical project covers a wide range of metallurgy and pressure classifications to cover the various types of piping services required.

- **Instrument Specifications**

  The instrument specifications define the specific design and installation requirements for process instrumentation, control valves and relief devices on the project. The instrument specifications may be in a written format to cover general requirements, or may be communicated via

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individual instrument datasheets for each required device (discussed further below).

- **Motor Specifications**

  The motor specifications define the general sizing, selection, and performance requirements for electric motors on the project. These specifications are typically broken down based on motor voltage and horsepower, and typically identify enclosure types, service factors, acceptable manufacturers, minimum efficiencies, and other client preferences as required.

- **Insulation Specifications**

  The insulation specifications define insulation materials, types and design criteria for piping and equipment insulation on the project. These specifications are typically based on client specific preferences or industry standards, and vary based on process specific requirements and local environmental conditions.

5. Engineering Lists

   The engineering list documents include the key project tabulations for identifying and quantifying equipment items (Equipment List), as well as material commodities such as piping and insulation (Line List), process instrumentation (Instrument List), motors (Motor List), and control system components (I/O List). The engineering lists may be issued in preliminary format in early FEL, but are typically most valuable at the end of FEL for use in development of the definitive cost estimate.

6. Data Sheets

Includes individual datasheets for equipment and critical instrumentation (analyzers, control valves and relief devices). In early FEL, these datasheets typically only include key process data (capacity, flow, temperature, pressure) and general metallurgy requirements. In late FEL, additional information may be specified, such as model numbers, connection sizes, and special features.

7. Schedules

The project schedule is a key reference document throughout the entire process of FEL. In early FEL, a preliminary schedule should be developed to analyze requirements for engineering workload, long lead equipment deliveries, and general construction schedule requirements (key completion dates, milestones, shut-down durations, etc.) At the end of FEL, a comprehensive overall schedule should be prepared, which will serve as the basis for project execution through detailed design and construction.

8. Cost Estimates

Overall project cost estimates should be prepared at the end of each phase of FEL. Assuming a three-phase FEL process, the cost estimates to be prepared include:

- **FEL 1 Estimate**

  Typically referred to as an "Order of Magnitude" or "Factored Cost Estimate." There are several methods by which an FEL 1 estimate can be developed. One method is to prepare an order of magnitude estimate

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based on published project data (literature search) or through comparison to similar projects executed by the client or engineering company. This method may be sufficient for certain types of well understood projects. A second method is based on utilizing assumed installation factors, which are multiplied by budgetary cost estimates of equipment to obtain the total installed cost. The cost factors used are typically based on industry standard cost factors with adjustments based on in-house experience, comparison to similar projects, and special project conditions. Depending on the method used, and the quality of the reference data available, the overall accuracy for this type of estimate is typically +/- 30 to 70%.

- **FEL 2 Estimate**

  Typically referred to as a "Preliminary Estimate." This type of estimate requires additional engineering effort to develop sufficient scope definition to allow preliminary quantities of basic materials to be estimated. This includes piping, insulation, instrumentation, steel, concrete, etc. Typically, equipment costs are based on budgetary vendor quotes and preliminary sizing. The overall accuracy for this type of estimate is typically +/- 15 to 30%.

- **FEL 3 Estimate**

  Typically referred to as a "Definitive Estimate." The key differences between an FEL 2 estimate and an FEL 3 estimate are improved equipment pricing, and sharpened take-off quantities for all bulk materials. Equipment costs for an FEL 3 estimate are based on multiple vendor quotations, with sufficient bid conditioning to ensure firm pricing

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on all major equipment items. Take-off quantities are improved through additional engineering, including one-line piping studies, preliminary design of foundations and structures, and vendor quotations on control valves, major instrumentation and control systems. The overall accuracy for this type of estimate is typically +/- 5 to 10%. The FEL 3 estimate is typically the basis used for the final application for project funding.

9. Project Definition Rating Index (PDRI) Reports

The Project Definition Rating Index (PDRI) is a method for evaluating whether the FEL process has been performed with sufficient detail and effort to provide a reasonable level of confidence that the project will be successful. This is a technique that was originally developed by John Hackney (Hackney, 1992), and is endorsed by the Construction Industry Institute (CII). Determination of a PDRI score requires working through a list of typical project topics and issues, and assigning points based on the level of definition accomplished in FEL. The PDRI rating is typically developed through a joint effort of all major project participants and should be done at multiple points in the FEL process. For a three phase approach (FEL 1, FEL 2, FEL 3) it is recommended to perform a PDRI review at the end of each FEL phase.

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IV. Process Engineering Workflow

A. FEL Deliverables and Responsibilities

A review of Process Engineering Workflow activities for FEL requires a definition of the responsibilities for each of the FEL deliverables defined in Section III – Review of FEL Deliverables. Table 3 lists each of the identified FEL deliverables and indicates the responsible project team member for each deliverable. The process engineering responsibilities are indicated by "PE". The other project team abbreviations are provided in Appendix II.

TABLE 3 – FEL Deliverables and Responsibilities

Deliverables	**FEL 1**	**FEL 2**	**FEL 3**
Project Scope Documents			
Project Description	**PE**	PM	PM
Project Execution Plan	PM	PM	PM
Design Basis Documents			
Process Design Basis	**PE**	**PE**	**PE**
Material and Energy Balance		**PE**	**PE**
Utility Summary		**PE**	**PE**
Emissions Summary		**PE**	**PE**
Equipment Design Basis		**PE**(1)	ME
Piping Design Basis			PL
Civil/Structural Design Basis			CE
Electrical Design Basis			EE
Instrument and Controls Design Basis			IE
Fire Protection Design Basis			ME
Insulation Design Basis			ME
Protective Coatings Design Basis			ME
Cost Estimate Basis	PM	PM	PM
Key Drawings			
Block Flow Diagrams	**PE**		
Process Flow Diagrams		**PE**	**PE**
Piping and Instrumentation Diagrams		**PE**	**PE**
Materials of Construction Diagrams		**PE**	**PE**
Site Plan		CE	CE
General Arrangements		PL	PL
Piping One-Line Drawings			PL
Electrical One-Line Diagrams			EE

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Specifications			
Equipment Specifications			ME
Piping Specifications			PL
Instrument Specifications			IE
Motor Specifications			EE
Insulation Specifications			ME
Lists/Summaries			
Line List			**PE**[1]/PL
Tie-in List			**PE**[1]/PL
Equipment List		**PE**[1]	ME
Instrument List		**PE**[1]	IE
I/O List			IE
Datasheets			
Process Data Sheets		**PE**	
Equipment Data Sheets			**PE**[1]/ME
Control Valve Data Sheets			**PE**[1]/IE
Relief Valve Data Sheets			**PE**[1]/IE
Instrument Data Sheets			**PE**[1]/IE
Schedule			
Overall Project Schedule	PM	PM	PS
Estimate			
Factored Cost Estimate	ES		
Preliminary Estimate		ES	
Definitive Estimate			ES
Project Definition Reports			
PDRI Summary			PM

(1) Initiated by Process Engineering. To be completed by the lead discipline at the end of FEL3.

B. FEL1 Activities

The purpose of FEL 1 is the economic and feasibility review of a process design scenario, proposed as a potential solution to a specific business objective. For an engineering contractor, the customer typically performs the earliest stages of FEL 1. The customer is the operating company (refiner) who continually reviews their own position in the market, and identifies potential projects that will provide

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some economic advantage. Once the business objective is identified, it is at that point that an engineering contractor is often hired to perform many of the FEL 1 activities. Table 4 highlights the major activities that must be performed for a typical FEL 1 effort.

TABLE 4 – FEL 1 Workflow - Activities and Responsibilities

Workflow Code	Activity Description	Responsible Lead
1.1	Business Planning	
	1.1.1 Identify Business Need or Opportunity	Owner
	1.1.2 Assess Economic Factors for Success	Owner
	1.1.3 Review General Feasibility With Engineering	Owner
1.2	Market Studies	
	1.2.1 Perform Market Review	Owner
	1.2.2 Evaluate Availability of Critical Feedstocks	Owner
	1.2.3 Evaluate Marketability of Products/By-products	Owner
	1.2.4 Identify Market Risk Factors (i.e. – Competitors, Market Variability, Emerging Technologies, Regulations)	Owner
1.3	Technology Evaluation	
	1.3.1 Perform Literature Search / Industry Survey	**PE**
	1.3.2 List Potential Process Alternatives	**PE**
	1.3.3 Identify Technology Providers/Licensers	**PE**
	1.3.4 Perform Preliminary Screening of Alternatives	**PE**
	1.3.5 Finalize List of Potential Alternatives	**PE**
1.4	Conceptual Design	
	1.4.1 Prepare Preliminary Process Design Basis	**PE**
	1.4.2 Develop Preliminary Block Flow Diagram(s)	**PE**
	1.4.3 Prepare Preliminary Project Description	**PE**/PM
	1.4.4 Develop Milestone Project Schedule	Owner/PM
	1.4.5 Develop Preliminary Cost Estimate Basis	PM/ES
1.5	Project Economics and Risk Analysis	
	1.5.1 Develop Order-of-Magnitude/Factored Cost Estimate	PM/ES
	1.5.2 Prepare Preliminary Economic Scenario	Owner
	1.5.3 Run Economic Model to Check Project Benefit	Owner
	1.5.4 Identify Risk Factors / Uncertain Variables	Owner
	1.5.5 Run Economic Model With Variation (Monte Carlo)	Owner
	1.5.6 Make Go / No-Go Decision on FEL 2	Owner
	1.5.7 Perform PDRI Analysis for FEL Measurement	Team

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C. FEL 2 Activities

The purpose of FEL 2 is the continuation of project development, with the objective of selecting the most appropriate technology and overall design approach. Table 5 highlights the major activities that must be performed for a typical FEL 2 effort.

TABLE 5 – FEL 2 Workflow – Activities and Responsibilities

Workflow Code	Activity Description	Responsible Lead
2.1	Review of Alternates	
	2.1.1 List Alternate Technologies/Methods from FEL 1	**PE**
	2.1.2 Collect Additional Data / Research Alternatives	**PE**
2.2	Preliminary Design	
	2.2.1 Revise Process Design Basis	**PE**
	2.2.2 Revise Block Flow Diagram(s)	**PE**
	2.2.3 Develop Preliminary Process Flow Diagram(s)	**PE**
	2.2.4 Prepare Material and Energy Balance(s)	**PE**
	2.2.5 Prepare Utility Summary	**PE**
	2.2.6 Prepare Emissions Summary	**PE**
	2.2.7 Develop Preliminary Plot Plan	CE
	2.2.8 Develop Preliminary General Arrangement(s)	**PE**/ME
	2.2.9 Prepare Process Data Sheets on Equipment	**PE**
	2.2.10 Prepare Preliminary Equipment List	**PE**
	2.2.11 Revise Project Description	PM
	2.2.12 Prepare Project Execution Plan	PM
2.3	Preliminary Estimates	
	2.3.1 Obtain Budget Quotations on Equipment	**PE**/ME
	2.3.2 Develop Preliminary Take-offs on Long Run Piping	**PE**/PL
	2.3.3 Develop Preliminary Quantities of Materials for Major Foundations and Structures	CE
	2.3.4 Revise Preliminary Cost Estimate Basis	PM/ES
2.4	Review Project Economics and Risk Analysis	
	2.4.1 Develop Preliminary Estimate	PM/ES
	2.4.2 Revise Economic Scenarios	Owner
	2.4.3 Revise Economic Model	Owner
	2.4.4 Update Risk Factors / Uncertain Variables	Owner
	2.4.5 Run Economic Model With Variation (Monte Carlo)	Owner
	2.4.6 Select Preferred Project Alternative	Owner
	2.4.6 Make Go/No-Go on FEL 3	Owner
	2.4.7 Perform PDRI Analysis for FEL Measurement	Team

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D. FEL 3 Activities

The purpose of FEL 3 is the continuation of project development, with the objective of developing a full definition of the project scope based on the process alternative selected in FEL 2. At the end of FEL 3, the project should have a definitive cost estimate, which is sufficient for application of project funding. Table 6 highlights the major activities that must be performed for a typical FEL 3 effort.

TABLE 6 – FEL 3 Workflow - Activities and Responsibilities

Workflow Code	Activity Description	Responsible Lead
3.1	Class "A" Design	
	3.1.1 Revise Process Design Basis	**PE**
	3.1.2 Revise Block Flow Diagram	**PE**
	3.1.3 Revise Process Flow Diagram(s)	**PE**
	3.1.4 Prepare Materials of Construction Diagram(s)	**PE**
	3.1.5 Finalize Material and Energy Balance(s)	**PE**
	3.1.6 Revise Utility Summary	**PE**
	3.1.7 Revise Emissions Summary	**PE**
	3.1.8 Revise Plot Plan	CE
	3.1.9 Revise General Arrangement(s)	ME/CE
	3.1.10 Revise Equipment Design Basis	ME
	3.1.11 Prepare Equipment Data Sheets	ME
	3.1.12 Revise Equipment List	ME
	3.1.13 Develop Piping One-Line Drawings	PL/**PE**
	3.1.14 Develop Electrical One-Line Diagrams	EE
	3.1.15 Develop Equipment Specifications	ME
	3.1.16 Develop Piping Specifications	PL
	3.1.17 Develop Instrument Specifications	IE
	3.1.18 Develop Motor Specifications	EE
	3.1.19 Develop Insulation Specifications	PL
	3.1.20 Prepare Line List	**PE**/PL
	3.1.21 Prepare Tie-in List	**PE**/PL
	3.1.22 Prepare Instrument List	**PE**/IE
	3.1.23 Prepare I/O List	IE
	3.1.24 Prepare Control Valve Data Sheets	**PE**/IE
	3.1.25 Prepare Relief Valve Data Sheets	**PE**/IE
	3.1.26 Prepare Instrument Data Sheets	**PE**/IE
	3.1.27 Develop Piping Design Basis	PL
	3.1.28 Develop Civil/Structural Design Basis	CE
	3.1.29 Develop Electrical Design Basis	EE
	3.1.30 Develop Instrument and Controls Design Basis	IE
	3.1.31 Develop Fire Protection Design Basis	ME

	3.1.32 Develop Insulation Design Basis	ME/PL
	3.1.33 Develop Protective Coatings Design Basis	ME/PL
	3.1.34 Revise Project Description	PM
	3.1.35 Revise Project Execution Plan	PM
3.2	Hazards Analysis	
	3.2.1 Issue P&IDs for HAZOP Review	**PE**
	3.2.2 Conduct HAZOP Review	Team
	3.2.3 Implement HAZOP Recommendations in Design	**PE**
3.3	Definitive Estimate	
	3.3.1 Obtain Multiple, Firm Quotations on Equipment	**PE**/ME
	3.3.2 Condition Bids to Ensure Firm Pricing	PM/ME
	3.3.3 Develop Refined Take-offs on Long Run Piping	PL
	3.3.4 Develop Refined Quantities of Materials for Major Foundations and Structures	CE
	3.3.5 Revise Cost Estimate Basis	PM/ES
	3.3.6 Develop Overall Project Definitive Estimate	ES
3.4	Review Project Economics and Risk Analysis	
	3.4.1 Finalize Economic Scenarios	Owner
	3.4.2 Finalize Economic Model	Owner
	3.4.3 Update Risk Factors / Uncertain Variables	Owner
	3.4.4 Run Economic Model With Variation (Monte Carlo)	Owner
	3.4.5 Make Go/No-Go on Project Funding to Detail Design	Owner
	3.4.6 Perform PDRI Analysis for FEL Measurement	Team

E. <u>Development of Sample Report</u>

This report has developed a comprehensive list of FEL deliverables based on a review of past FEL efforts. This report also defines the activities required to support these deliverables in the actual execution of an FEL effort. Using this information as a basis, an FEL sample report has been developed, and is included as Appendix III. This report is intended to further illustrate the type of information required for a complete FEL package, and may serve as a guide for future FEL efforts, and/or demonstration document for sales of the FEL process to potential clients.

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V. Recommendations

Several recommendations can be made, based on the review of past FEL efforts. These recommendations are classified as one of three types; 1) recommendations for effective management of FEL, 2) recommendations for execution of FEL engineering or 3) recommendations for transition from FEL to detailed design.

A. Effective Management of FEL

Management plays a significant role in the execution of a successful FEL effort. Some critical recommendations that should be emphasized for effective management of FEL include:

1. Three-Phase Approach

The recommended FEL strategy described in this report focuses on FEL management through a three-phase approach. The three-phase FEL is a common method used by many refining companies in the development of projects. The three phases each have a specific objective and should not be combined or skipped if at all possible. Following each phase, a documented package of deliverables should be prepared, and project economics should be evaluated to provide justification for moving to the next FEL phase.

2. Client "Buy-In"

All phases of a successful FEL effort must be performed with close contact to the client to ensure 100% "buy-in" to all FEL decisions and assumptions. In the development of any project, many assumptions must be made in the early phases where information is either not available or will require further work to

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define. Often times these assumptions will make or break a project, and therefore all key assumptions should be clearly stated, documented, and reviewed with the client to ensure the best available information is being considered. Interface between the client and the FEL team to maintain client "buy-in" is one of the most important tasks of FEL management.

3. Early Involvement of Design Disciplines and Construction

Typically, the process engineering group leads FEL 1 and 2, utilizing a small project team with direct interface to the client. This is due to the fact that most engineering activities in early FEL are related to early conceptual design, and technology evaluation. By FEL 3, the project development starts to become more focused, and additional discipline engineers (mechanical, piping, electrical, structural) are required. However, by this time, many of the key project decisions may have already been made, and the project suffers due to a lack of early input from the key disciplines. To avoid this missed opportunity for value added input, it is recommended that periodic design reviews be performed with project leads from all disciplines, starting at the end of FEL 1. Additionally, these reviews should also include representatives from construction to receive early input on constructability issues and safety. Inclusion of these project team members as early as possible will maximize design efficiency in the later stages of project development and will help to avoid costly design changes and/or rework in detail design.

4. PDRI (Project Development Rating Index) Reviews

One common way to measure FEL progress from a managerial perspective is the use of PDRI reviews. At a minimum, it is recommended that PDRI

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reviews be performed at the end of each FEL phase. This provides a gauge by which the overall FEL progress can be measured. At the end of FEL 3, the PDRI analysis is used to indicate whether the overall FEL effort is sufficiently complete to provide a reasonable probability of success. The Construction Industry Institute (CII) indicates that projects that score a 200 or less in the PDRI index are significantly more likely to succeed based on overall cost, schedule and scope creep. For the Process and Industrial Division it is recommended that all FEL 3 efforts should score 175 or less before being considered complete. In cases where a significantly higher score is obtained, the weak areas of scope definition should be identified and improved. If FEL cannot be extended to improve the PDRI score, the final score obtained should be a consideration in the analysis of project risk and the establishment of project contingency for detailed design and construction.

5. FEL Benchmarking

In addition to PDRI scoring, which is an internal measurement activity, there are several companies that specialize in performing independent project reviews and analysis for FEL efforts. One such company is IPA (Independent Project Analysis), based in Ashburn, VA. IPA specializes in providing FEL project evaluations, and can provide empirical statistics based on a database of past projects to analyze a project's probability of success. This type of independent analysis may not be required for all projects, but should be strongly considered for the larger and more complex capital projects.

B. Execution of FEL Engineering

Besides the managerial aspects of FEL, the other key component to a successful FEL effort is the execution of FEL engineering. Several recommendations can be made regarding FEL engineering. Some of the more critical recommendations that should be emphasized include:

1. Process Design Basis

One of the earliest and most critical activities of an FEL effort is development of the process design basis. The information contained in the process design basis will significantly impact the type of process developed, the technologies considered, and the overall project economics. Too often the process design basis is developed based on preliminary information or poorly defined assumptions. Any information considered preliminary or tentative in nature should be noted within the process design basis, and a plan should be developed for improving the certainty of such data (pilot plant testing, lab analysis, literature search, etc). Significant effort should be taken to ensure that the process design basis is as complete and accurate as possible before any additional FEL activities are performed.

2. Documentation of Discipline Design Assumptions

While the process design basis is the most critical in early FEL, the other discipline design basis documents are essential in the complete definition of the project scope. Typically, the design basis assumptions are documented in the Design Basis section of the FEL report. It is critical that these documents include sufficient detail to define all key design parameters required for the project.

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