3. Operations Input

A large component of FEL that is often overlooked is the need for full involvement from the client's operations staff during project development. Many times, project development is performed with a focus on input from engineering and upper management only. However, operations can often identify various requirements and design features that will be required for maintenance, operating ergonomics, and safety. If identified late in FEL or during detailed design, these requirements can add significant scope and cost to the overall project. Many times, operations requirements may have a significant impact on early FEL decisions. In this scenario, significant redesign may be required, which could have been avoided through early involvement of operations in the FEL process.

4. Quality Review Procedures

One significant issue in the execution of FEL projects is the consistent use of proper quality control processes to ensure company quality standards are maintained. Typical quality control procedures are directed to the preparation of general study reports, or to the execution of detailed engineering design calculations. FEL is a challenge, because the product of FEL is a collection of deliverables in a report type format. However, the development an FEL design requires significant engineering effort, and the results of the engineering activities need to be reviewed to maintain quality.

For a process engineer, the most significant activity of FEL is often the development of the process simulation. In the oil refining industry, these

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simulations are typically performed using a software package such as Hysys, Aspen, or Pro II. The setup of a process simulation is typically performed by a single engineer, and the output of the simulation provides the material and energy balance basis for the entire project. Therefore, it is absolutely critical that the simulation be set-up correctly and that the results are accurate.

Performing a quality review of a simulation file is difficult. Many of the specific calculation methods and/or assumptions get hidden in the details of the simulation and are nearly impossible to "check" in the traditional sense by an outside quality reviewer. Based on these challenges, one method of quality review that is recommended is the use of a simulation design review meeting. This meeting should be conducted as early as possible in FEL, once the process simulation is reasonably complete. The format of this meeting should be a detailed presentation of the simulation, by the lead process engineer, to the quality review team. The quality review team should include other process engineers on the project, at least one independent reviewer from outside the project, and the client. The lead process engineer should go though the simulation step-by-step to illustrate the calculation methods used and the variables specified for all major pieces of equipment. Comments and questions should be documented, and the simulation should be revised following the meeting as required.

C. Transition from FEL to Detailed Design

The focus of this report has been the project development activities of FEL. However, it should be stressed that FEL must be performed in a way that promotes a successful transition from FEL to detailed design. During detailed

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design, many of the deliverables prepared in FEL will continue to be key documents, used by the engineering design team for the communication of information between disciplines. These deliverables will also be used by construction for the definition of scope to contractors and by project controls for tracking the execution of work. Several recommendations can be made regarding the transition from FEL to detailed design:

1. <u>Continuity of Project Team</u>

   The goal of FEL should be to develop a set of deliverables that are good enough to stand alone as a full definition of the design intent. However, regardless of how well these deliverables are prepared, there is no better way to ensure a successful transition from FEL to detailed design than maintaining project team continuity. Where at all possible, the same project team that executes the FEL should be responsible for executing the detailed design. This includes all engineering leads and piping designers. In today's fast-track mode of project execution, project team continuity is absolutely critical to avoid the leaning curve inefficiencies that can occur at the start of detailed design when key project team members are not maintained.

2. <u>Format of FEL Data</u>

   One issue that is critical for transition of FEL to detailed design is the format of FEL data. There are at least two different types of format standards to be considered. The first is format standards for engineering drawings. This includes drawings such as P&IDs, Site Plans, Layouts, and Electrical One-Lines. Where possible, drawing format standards that will be required for detailed design should be fully defined as early as possible in FEL. If sufficient effort is taken in FEL, then many of the drawings developed for the FEL deliverables can be transferred straight to detailed design. This prevents rework and minimizes delay that can occur at the start of detailed design as drawing standards are defined.

The second type of format standard is in regard to the formatting of FEL data. This includes data such as process stream data, utility data, instrument data, and equipment design data. In the review of past FEL efforts, it is clear that there is a significant amount of variation in the way FEL project data is collected, tabulated and maintained. At the very least, this variation between projects results in significant rework and duplicated effort at the beginning of detailed design. However, a more significant issue is the fact that this variation can also result in data errors and/or inconsistencies, which can result in incorrectly specified equipment or instrumentation.

A typical example of the issue of data management is process stream data for a project. In FEL, process stream data is usually contained in a material balance table, which is cross-referenced to the PFDs to provide full process data for each flow stream on the PFD. In reviewing the sample projects, this flow data was found to be maintained in many different types of formats. Some projects collected and maintained process stream data in a simple spreadsheet format, while others used a database table, direct output from a process simulation file, or some combination of the three. In FEL, the format of this data is not that critical, because the project team is small (making communication of data easier to manage), and the uses for this data are limited. However, once detailed design begins the management and

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communication of process stream data to the design team is more critical. This data must be available and accessible for the use in preparing detailed specifications for instruments and equipment, and performing design calculations for vessels, heat exchangers, control valves, relief valves, and piping systems. One of the most important recommendations that can be made from this report is the improvement of processes to manage and maintain FEL design data.

3. Adherence to FEL Design Assumptions

Once detailed design begins, it is critical to execute the detailed engineering with strict adherence to the design assumptions that were established in FEL. This requires 1) that all design basis documents from FEL be transferred to the detailed design team, and 2) these documents must be fully understood and followed in execution of detailed design. Deviation from the FEL design basis can be a significant contributor to scope creep and increased costs in detailed design.

4. Limit Unresolved Issues from FEL

For many FEL efforts, the momentum of the project team builds rapidly through FEL 3, and the tendency is to move as quickly as possible from FEL 3 to detailed design. This is especially common for projects that require fast track scheduling, or contain long-lead equipment which must be placed on order as soon as possible in detailed design. This rushed transition from FEL 3 to detail design will inevitably leave several open issues, which must be resolved in early detail design. As a standard practice, it is recommended that one of the activities for completion of FEL 3 should be a review of open

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issues. This review should take place as a meeting of the entire project team, and should result in a comprehensive work list or action item list of open issues. The open issues should be ranked in

5. Management of Change

While not ideal, change will occur in detailed design. These changes may be due to several factors, including general design development, changing business objectives, changing environmental factors, specific client requests, unanticipated site conditions, etc. The key to handling change is to establish an effective procedure for addressing change. This procedure should be initiated in FEL and transitioned to detailed design and construction.

D. Additional Work

The review performed in this report and the recommendations made are only the start of what will be required to improve the methods by which FEL is executed in the Process and Industrial Division of Burns & McDonnell. When done well, FEL engineering can be a major competitive advantage to getting in on the early development of projects, which provides an advantage to securing the detailed design and construction of these projects.

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Appendix I – References

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Appendix II - Project Team Abbreviations

Team Member	Abbreviation
Project Management	PM
Process Engineer	PE
Mechanical Engineer	ME
Piping Engineer	PL
Civil/Structural Engineer	CE
Electrical Engineer	EE
Instrument/Controls Engineer	IE
Project Scheduling	PS
Project Estimating	ES

Appendix III – Sample Report

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PROJECT DESCRIPTION

I. SUMMARY

Provide a general summary of the overall project including client, location, project intent, sizing basis (capacity), and performance basis.

II. PROJECT SCOPE

A. Process Equipment

1. *Process Step 1*

   Provide a short description of the equipment required for each process step in the overall design. Include major existing equipment and any new equipment required.

2. *Process Step 2*

   Provide a short description of the equipment required for each process step in the overall design. Include major existing equipment and any new equipment required.

3. *Process Step 2*

   Provide a short description of the equipment required for each process step in the overall design. Include major existing equipment and any new equipment required.

B. Layout

Describe site location within the overall facility. Include any modifications required for major infrastructure and access ways.

C. Utilities

1. Electrical

   Summarize new electrical loads and distributions systems required.

2. Steam

   Summarize new steam loads and supply systems required.

3. Cooling Water

Summarize new cooling water loads and supply systems required.

4. Instrument Air / Plant Air

   Summarize new instrument air and plant air loads and supply systems required.

5. Service Water

   Summarize new service water / utility water loads and supply systems required

6. Refinery Fuel Gas

   Summarize new refinery fuel gas users and supply systems required

7. Natural Gas

   Summarize new natural gas users and supply systems required

8. Nitrogen

   Summarize new nitrogen users and supply systems required

9. Utility Stations and Safety Showers/Eye Wash Stations

   Include basis for new utility stations and safety showers/eye wash stations.

D. Civil

Summarize civil requirements for the project including general site conditions and drainage systems (closed sewers and storm sewers).

E. Structural

Summarize all new major buildings, structures, and support systems (piperacks).

F. Instrument and Controls

Summarize requirements for new instrumentation and controls.

G. Fire Protection

Summarize requirements for fire protection.

III. SCHEDULE

Describe general schedule requirements, major milestones and key completion dates.

IV. COST

Total project cost is estimated at $__________ , not including Owner costs.

V. PLANT SITE

Provide site location and address.

* * * * *

PROJECT EXECUTION PLAN

I. SUMMARY

<This is a typical execution plan for an EPC project. Edit as required for specific project.>

The project execution plan is based on the Work, as described in this document and an associated Agreement with <*OWNER*>, by a General Contractor (Contractor) that is responsible for engineering, procurement, and construction (EPC). <*OWNER*> is responsible for related Owner activities, coordinating unit shutdowns, and review/approval of design by the Contractor.

II. ENGINEERING

The Contractor shall provide detail design engineering including development of construction documents and record documents. Engineering is required to complete key project documents (P&ID's and equipment layouts), assist in the procurement of equipment and instruments (technical bid tabs and vendor document review), conduct field checks during construction, and perform shop inspection of key equipment.

III. PROCUREMENT

Procurement services by the Contractor include development of commercial terms and conditions, solicitation and award of purchase orders, expediting documentation and delivery, and commercial administration.

IV. CONSTRUCTION

The Contractor is responsible for construction of the Work, including site preparation, foundations and structural steel, equipment installation, aboveground and underground piping, protective coatings (painting and fire proofing), insulation, instrumentation, and electrical. The Work includes cleanup, flushing, testing, and loop checks of control wiring. The Contractor is responsible for safety and security of the Work area.

V. COMMISSIONING

Commissioning and startup is by <*OWNER*>.

VI. PERMITTING

Environmental permits are required for construction and operation. No local building permits are required. Permit application and coordination is by *<OWNER>*.

* * * * *

DESIGN BASIS DOCUMENTS

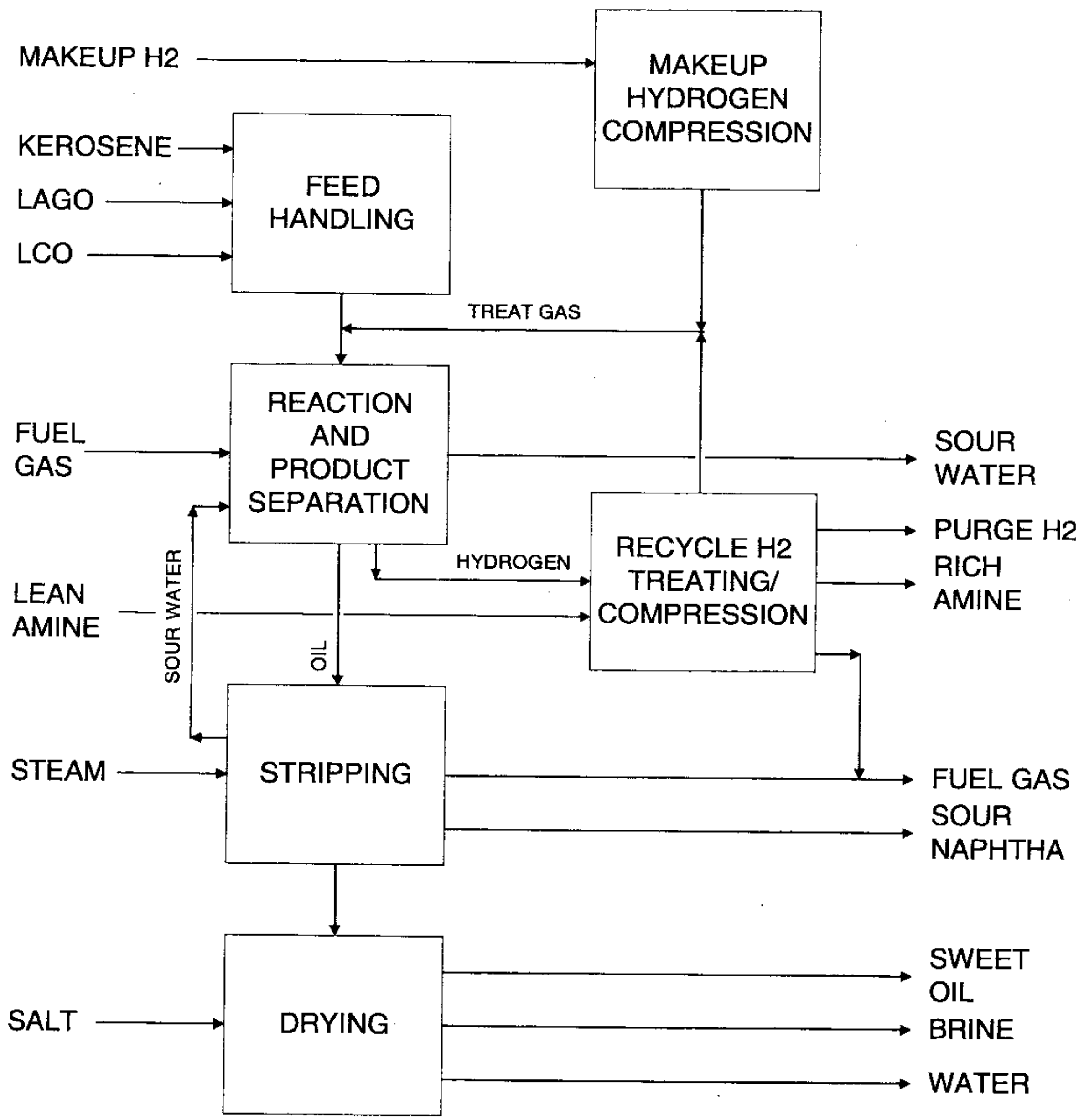
PROCESS DESIGN BASIS

I. SUMMARY

<Sample Design Basis is provided for reference. Edit as required per specific project.>

The diesel hydrotreater process configuration for is shown in Figure 1. The unit is comprised of equipment for oil charge handling, reaction and reactor product separation, recycle and makeup hydrogen handling, and product stripping and drying.

Figure 1. Block Flow Diesel Hydrotreater



II. PROCESS DESCRIPTION

A. Feed Handling

The diesel hydrotreater is designed to receive 20% cold feed and 80% hot feed. Cold oil streams from the refinery tank farm are passed through Cold Charge Filters, F-001A/B. After filtering, the cold feed is preheated to 250°F against hot product in the 1E-101 Cold Charge/Stripper Bottoms Exchanger. Hot stripper bottoms are bypassed around 1E-101 to achieve temperature control. The heated stream is mixed with hot feed and passed through the Combined Charge Filters, F-002A/B. The combined feed stream flows to the existing F-101 Charge Surge Drum. Feed stream flow rates are reset to maintain level control in F-101. The existing Reactor Charge Pumps pump hot oil from 1F-101 into the reactor circuit.

B. Reaction and Reactor Product Separation

Most of the oil charge to the reactor circuit is split equally to three banks of existing charge/effluent exchangers in the reactor circuit. Hydrogen is also split equally and is mixed with the oil charge upstream of the exchangers. The mixed oil/hydrogen charge streams flow to the E-102A-F Charge/Effluent Exchangers where heat is recovered from the hot reactor effluent stream. Each of the three banks of exchangers is comprised of two shells.

A new control valve station is provided to bypass a portion of the oil charge from the charge pumps around the exchangers to control the firing rate on the charge heater. The bypass flow rate is set to regulate the inlet temperature to the H-101 Reactor Charge Heater such that the firing rate is as low as possible while still maintaining good temperature control on the reactor feed.

Hot charge from H-101 is fed to the Reactors. Hot charge is introduced to the reactors at 1,100 psig. The temperature of the charge increases as it flows through the catalyst beds due to highly exothermic desulfurization and saturation reactions. Cool quench hydrogen is introduced between the reactors to provide intermediate cooling of the charge and to increase the partial pressure of hydrogen in the second reactor. The capability exists to quench between the top and bottom beds in the second reactor, but normal operating conditions (provided by the catalyst vendor) do not require introduction of quench gas in this zone.

Hot effluent from the second reactor flows to the tube side of the feed/effluent exchangers to exchange heat with the reactor charge before passing on to the new Hot High-Pressure Separator, F-105 (HHPS). Liquid diesel is separated from hydrogen-rich vapor in F-105. Hot oil is pressured to the unit stripping column to control drum level. The hot vapor stream flows to the HHPS Vapor/Hydrogen Exchangers to preheat the reactor hydrogen feed. The vapor stream is cooled further by air and water cooled exchangers, EA-101A/B Effluent Coolers and E-102A/B Effluent Trim Coolers. Water is injected upstream of the coolers to dissolve ammonia salt formed during the cooling process. Hydrogen-rich recycle gas, light oil, and salt-bearing water are separated in the Cold High-Pressure Separator, F-106. Recycle hydrogen flows to amine treating and compression. Light oil is pressured on level control to mix with HHPS liquid feeding the stripper. Spent wash water flows to the sour water drum.

C. Recycle Hydrogen

Recycle hydrogen from F-106 flows to new amine treating equipment before being compressed and recycled to the reactors. The recycle stream flows through the Recycle Gas Filter/Coalescer, D-001. The filter/coalescer removes entrained hydrocarbon liquid and solids upstream of the amine absorber to minimize foaming and heat-stable salt formation in the existing amine regeneration equipment. Liquid removed in D-001 is pressured on level control to stripper feed.

Recycle gas flows from D-001 to the F-001 Recycle Hydrogen Amine Contactor. Valve trays in F-001 contact the recycle gas with MDEA solvent to remove hydrogen sulfide generated in the reactors. Lean amine from outside the battery limits of the unit is pumped by P-001A/B Lean Amine Booster Pumps on flow control to the top tray of F-001. Rich amine leaving the bottom of F-001 flows on level control to the new F-006 Rich Amine Flash Drum. The flash drum F-006 feeds offgas absorber, 1F-104, on pressure control. As the pressure is reduced between F-001 and F-006, excess hydrogen and hydrogen sulfide are removed from the rich amine stream and flow to F-104. Rich amine is level controlled from F-006 to existing amine regeneration equipment outside the battery limits of the unit.

Sweet recycle hydrogen leaving F-001 contains about 60 ppm hydrogen sulfide by volume. The recycle gas flows to the new F-002 Knockout Drum which is equipped with a wire mesh pad to facilitate removal of entrained water and amine. Dry recycle hydrogen mixes with spillback hydrogen from the anti-surge controls on the recycle compressor and flows to the existing F-108 Recycle Compressor Knockout Drum. Liquid removed in F-108 is sent to the sour water drum. Recycle gas flows from F-108 to the C-101 Recycle Compressor, a centrifugal compressor.

D. Makeup Hydrogen

Makeup hydrogen from outside the battery limits flows to the C-102A/B Makeup Gas Compressors.

E. Product Stripping

Oil products from the high-pressure separators are combined and steam-stripped to remove hydrogen sulfide and other light components from the treated diesel product. The existing F-110 H2S Stripper is converted from reboiled to steam-stripped operation. Stripping steam is routed from the existing 250-psig steam header in the unit to F-110 and introduced below the bottom tray on flow control.

Overhead vapor from F-110 flows through an air-cooled Stripper Condenser and water-cooled Stripper Overhead Trim Cooler to condense most of the water and naphtha-range hydrocarbon in the stream. The cooled stream flows to the Stripper Accumulator to separate sour gas, sour water, and wild naphtha. Sour gas is pressure-controlled to the existing offgas amine absorber. Sour water is pressured on boot-level control to the sour water drum, for use as wash water in the reactor effluent condensing system. Sour naphtha is pumped out of the stripper accumulator by the Stripper Reflux Pumps. Reflux is flow controlled to the column. Naphtha product is pumped on level control to the battery limits of the unit.

Hot product from the stripper bottoms is pressured on column level control through a series of equipment to cool and dry the product before it goes to product storage. Hot bottoms first pass through the shell side of E-125 to preheat cold HTU feed before it flows through the new air-cooled EA-003A/B Diesel Product Coolers and new water-cooled E-004A/B Diesel Trim Coolers. Most of the free water formed in the cooling process is removed in the new F-003 Stripper Bottoms Coalescer. Any remaining insoluble water and some soluble water is removed in the F-004A/B Salt Dryers (to meet refinery haze requirements). Dry product flows to the battery limits of the unit.

III. FEED BASIS

The modified process configuration for this project is indicated on the Process Flow Diagram, PF-001. The reactor is designed to run at 1100 psig with feed combinations of light atmospheric gas oil (LAGO) and light cycle oil (LCO) as shown in Table 1. The design basis of the product is 8 parts per million by weight (wppm) sulfur.

Table 1. Feed Cases for HTU Design

	Mixed Feed (Vol. % of Feed)	Diesel (Vol. % of Feed)
LAGO (CDU Dist.)	55	83.3
LCO	45	16.7
Sulfur in Feed, wt %	0.69	0.84
Sulfur in Product, wppm	8	8

The mixed feed case is the primary feed for the unit and the base case for the project. Material balances for all feed cases include start-of-run (SOR) and end-of-run (EOR) conditions at both 25,000 BPD and 30,000 BPD charge rates. Material balance spreadsheets are included in the Heat & Material Balance section. Key operating parameters for all cases are summarized in Table 2.

IV. CAPACITY

The hydrotreater for ultra-low sulfur diesel is designed to process 25,000 BPD of light atmospheric gas oil (LAGO) and light cycle oil (LCO) feed streams. New equipment, instruments, and piping are designed for future increased flows of 30,000 BPD (Future Case).

Existing equipment in the unit were evaluated for both Base Case and Future Case conditions. Most existing equipment is adequate for operation at 30,000 BPD. Results of the equipment evaluations are summarized in the Equipment List.

V. BATTERY LIMIT CONDITIONS AND UTILITY STREAMS

Battery limit conditions for most feed and utility streams are shown in Table 6.

VI. REFERENCE

Provide any reference data, including test results, vendor performance data, pilot plant results, etc.

* * * * *

Heat and Material Balance
Diesel Feed

Stream Number						3	4	5	6	7	8	9	12
Stream Description	Feed 1	Feed 2	Feed 3	Cold Charge	Hot Charge	Oil Feed	Bypass Around E101s	Hot H2 Feed	Oil/H2 to E101s	Oil/H2 to H101	Oil/H2 to F101	Quench to F102 Inlet	Effluent to E101s
Overall Properties													
Pressure, psig	50.2	50.2	50.2	50.2	50.2	50.2	1252.7	1182.5	1178.8	1151.4	1102.0	1195.2	983.9
Temperature, °F	170.0	215.0	335.0	100.0	309.5	297.9	302.6	430.1	335.3	599.2	623.9	162.6	692.0
Std. Vol Flow (V), MMSCFD	---	---	---	---	---	---	---	59.8	---	---	---	20.5	---
Std. Vol Flow (L), barrel/day	4,825	0	24,176	5,800	23,201	29,001	6,293	---	---	---	---	---	---
Mass Flow, lb/hr	61,752	0	311,196	74,590	298,359	372,948	80,930	38,499	330,517	411,447	411,447	13,972	425,419
Mole Flow, lbmole/hr	291.4197791	0	1339.358744	326.1557047	1304.622819	1630.778523	353.8789396	6566.529689	7843.429273	8197.308212	8197.308212	2248.20169	9105.841557
Vapor Weight Fraction	0	0	0	0	0	0	0	1	0.1086	0.1973	0.2344	1	0.4907
Vapor Mole Fraction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.81	0.80	0.81	1.00	0.88
Enthalpy Flow, MMBtu/hr	-54.93	0.00	-249.27	-68.62	-243.37	-306.60	-66.05	-19.02	-257.34	-239.90	-230.71	-13.44	-206.17
Composition, mass%													
H2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.15	3.40	2.73	2.73	26.64	2.84
H2S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.78
NH3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
C1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.54	2.39	1.92	1.92	24.47	2.67
C2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.31	2.71	2.18	2.18	25.86	2.97
C3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.92	1.74	1.40	1.40	14.85	1.85
iC4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.38	0.39	0.32	0.32	2.95	0.41
nC4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.66	0.43	0.34	0.34	2.87	0.43
iC5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.17	0.14	0.11	0.11	0.72	0.14
nC5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.06	0.05	0.05	0.27	0.06
C6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.84	0.33	0.27	0.27	0.72	0.30
C7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01
C8+	100.00	100.00	100.00	100.00	100.00	100.00	100.00	0.05	88.36	90.65	90.65	0.07	87.48
H20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.05	0.04	0.04	0.59	0.02
NH4SH*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MDEAmine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vapor Phase Properties													
Mole Flow, lbmole/hr	---	---	---	---	---	---	---	6,567	6,386	6,535	6,617	2,248	8,043
Mass Flow, lb/hr	---	---	---	---	---	---	---	38,499	35,904	81,178	96,428	13,972	208,757
Actual Volumetric Flow, ACFM	---	---	---	---	---	---	---	894	780	1,087	1,174	211	1,681
Density, lb/ft3	---	---	---	---	---	---	---	0.7174	0.7673	1.2452	1.3689	1.1036	2.0693
Viscosity, cP	---	---	---	---	---	---	---	0.0148	0.0134	0.0219	0.0236	0.0114	0.0298
Heat Capacity, Btu/lb-F	---	---	---	---	---	---	---	1.46	1.47	1.04	0.98	1.31	0.85
Thermal Conductivity, Btu/hr-ft-F	---	---	---	---	---	---	---	0.12	0.11	0.12	0.12	0.08	0.10
Molecular Weight	---	---	---	---	---	---	---	5.86	5.62	12.42	14.57	6.21	25.96
H2 Partial Pressure, psia	---	---	---	---	---	---	---	1014.7	846.9	791.7	758.2	993.3	657.5
Liquid Phase Properties													
Mole Flow, lbmole/hr	291	0	1,339	326	1,305	1,631	354	---	1,457	1,663	1,580	---	1,063
Mass Flow, lb/hr	61,752	0	311,196	74,590	298,359	372,948	80,930	---	294,614	330,269	315,019	---	216,662
Actual Volumetric Flow, USGPM	148	0	799	172	758	941	200	---	752	991	963	---	740
Std. Vol. Flow, barrel/day	4,825	0	24,176	5,800	23,201	29,001	6,293	---	22,950	25,710	24,512	---	17,176
Density, lb/ft3	52.18	51.02	48.54	54.10	49.11	49.40	50.47	---	48.87	41.57	40.78	---	36.52
Viscosity, cP	1.5219	1.0169	0.5070	4.3875	0.5844	0.6313	0.6221	---	0.4551	0.1178	0.1032	---	0.0647
Heat Capacity, Btu/lb-F	0.4777	0.5038	0.5685	0.4386	0.5549	0.5487	0.5482	---	0.5715	0.7059	0.7183	---	0.7677
Thermal Conductivity, Btu/hr-ft-F	0.0848	0.0819	0.0750	0.0903	0.0765	0.0773	0.0770	---	0.0655	0.0474	0.0456	---	0.0386
Molecular Weight	211.9	214.3	232.3	228.7	228.7	228.7	228.7	---	202.2	198.6	199.3	---	203.9

Heat and Material Balance
Diesel Feed

Stream Number	14	15	16	17	18	19	20	21	22	23	24	25	26
Stream Description	Effluent to HHP Separator	HHPS Liquid to F106	HHP Separator Vapor	HHP Vapor to Air Cooler	Wash Water	HHP Vapor to Trim Cooler	Feed to CHP Separator	CHP Separator Liquid	Sour Water from CHP Separator	CHP Vapor to Amine Scrubber	Lean MDEA to Booster Pump	Recycle Gas from Scrubber	Rich MDEA to Flash Drum
Overall Properties													
Pressure, psig	973.5	973.5	973.5	970.2	1100.7	966.3	952.9	952.9	952.9	952.9	350.4	950.4	120.4
Temperature, °F	474.1	474.1	474.1	303.4	111.3	140.0	100.0	100.0	100.0	100.0	110.0	116.4	119.7
Std. Vol Flow (V), MMSCFD	---	---	67.1	---	---	---	---	---	---	65.8	---	65.1	---
Std. Vol Flow (L), barrel/day	---	28,555	---	---	697	---	---	1,594	707	---	4,619	---	---
Mass Flow, lb/hr	425,419	359,140	66,279	66,279	10,316	76,596	76,596	19,047	10,467	47,082	69,691	44,392	72,380
Mole Flow, lbmole/hr	9105.841557	1743.290904	7362.550652	7362.550652	572.429708	7930.008355	7930.008355	133.7291272	571.5717992	7224.707428	2719.355	7146.027342	2798.005733
Vapor Weight Fraction	0.1558	0	1	0.7830	0	0.6291	0.6147	0	0	1	0	1	0.0002
Vapor Mole Fraction	0.81	0.00	1.00	0.99	0.00	0.92	0.91	0.00	0.00	1.00	0.00	1.00	0.00
Enthalpy Flow, MMBtu/hr	-289.64	-254.31	-35.34	-49.29	-69.76	-130.35	-133.87	-17.83	-69.60	-46.44	-28.96	-45.28	-29.35
Composition, mass%													
H2	2.84	0.07	17.87	17.87	0.00	15.46	15.46	0.05	0.00	25.14	0.00	26.65	0.01
H2S	0.78	0.08	4.57	4.57	0.10	3.74	3.74	0.49	0.12	5.87	0.02	0.00	3.83
NH3	0.02	0.00	0.11	0.11	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C1	2.67	0.13	16.48	16.48	0.00	14.26	14.26	0.24	0.00	23.10	0.00	24.49	0.01
C2	2.97	0.25	17.68	17.68	0.00	15.30	15.30	1.22	0.00	24.40	0.00	25.87	0.01
C3	1.85	0.25	10.57	10.57	0.00	9.15	9.15	2.20	0.00	14.00	0.00	14.84	0.00
iC4	0.41	0.08	2.25	2.25	0.00	1.95	1.95	0.99	0.00	2.77	0.00	2.94	0.00
nC4	0.43	0.09	2.29	2.29	0.00	1.98	1.98	1.32	0.00	2.69	0.00	2.86	0.00
iC5	0.14	0.04	0.70	0.70	0.00	0.61	0.61	0.77	0.00	0.67	0.00	0.72	0.00
nC5	0.06	0.02	0.29	0.29	0.00	0.25	0.25	0.38	0.00	0.25	0.00	0.27	0.00
C6	0.30	0.12	1.31	1.31	0.00	1.13	1.13	2.88	0.00	0.68	0.00	0.72	0.00
C7	0.01	0.00	0.03	0.03	0.00	0.03	0.03	0.09	0.00	0.01	0.00	0.01	0.00
C8+	87.48	98.88	25.72	25.72	0.00	22.26	22.26	89.35	0.00	0.06	0.00	0.07	0.00
H20	0.02	0.00	0.12	0.12	99.81	13.54	13.54	0.01	97.45	0.36	64.97	0.59	62.44
NH4SH*	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.00	2.43	0.00	0.00	0.00	0.00
MDEAmine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34.94	0.00	33.64
CO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.06
Vapor Phase Properties													
Mole Flow, lbmole/hr	7,363	0	7,363	7,280	---	7,257	7,225	0	0	7,225	---	7,146	2
Mass Flow, lb/hr	66,279	0	66,279	51,900	---	48,184	47,082	0	0	47,082	---	44,392	16
Actual Volumetric Flow, ACFM	1,268	0	1,268	1,027	---	804	756	0	0	756	---	773	2
Density, lb/ft3	0.8709	0.8709	0.8709	0.8419	---	0.9989	1.0382	1.0382	1.0382	1.0382	---	0.9573	0.1551
Viscosity, cP	0.0171	0.0171	0.0171	0.0135	---	0.0112	0.0106	0.0106	0.0106	0.0106	---	0.0107	0.0114
Heat Capacity, Btu/lb-F	1.13	1.13	1.13	1.21	---	1.22	1.22	1.22	1.22	1.22	---	1.29	1.11
Thermal Conductivity, Btu/hr-ft-F	0.11	0.11	0.11	0.09	---	0.08	0.08	0.08	0.08	0.08	---	0.08	0.07
Molecular Weight	9.00	9.00	9.00	7.13	---	6.64	6.52	6.52	6.52	6.52	---	6.21	7.18
H2 Partial Pressure, psia	650.7	---	788.2	785.6	---	726.5	716.6	---	---	786.0	---	792.3	0.1
Liquid Phase Properties													
Mole Flow, lbmole/hr	1,743	1,743	---	83	572	673	705	134	572	---	2,719	---	2,796
Mass Flow, lb/hr	359,140	359,140	---	14,379	10,316	28,411	29,514	19,047	10,467	---	69,691	---	72,364
Actual Volumetric Flow, USGPM	1,030	1,030	---	38	21	66	68	47	21	---	136	---	136
Std. Vol. Flow, barrel/day	28,556	28,556	---	1,174	697	2,032	2,135	1,594	707	---	4,619	---	4,598
Density, lb/ft3	43.48	43.48	---	46.61	62.09	53.50	54.16	50.50	62.38	---	63.71	---	66.28
Viscosity, cP	0.2186	0.2186	---	0.4154	0.6437	2.8775	3.3611	1.1094	0.7945	---	2.2222	---	1.9934
Heat Capacity, Btu/lb-F	0.6567	0.6567	---	0.5737	1.0284	0.6762	0.6609	0.4656	1.0164	---	0.8732	---	0.8558
Thermal Conductivity, Btu/hr-ft-F	0.0552	0.0552	---	0.0631	0.3673	0.1204	0.1183	0.0706	0.3601	---	0.2448	---	0.2478
Molecular Weight	206.0	206.0	---	174.3	18.0	42.2	41.8	142.4	18.3	---	25.6	---	25.9

Heat and Material Balance
Diesel Feed

Stream Number	27	29	30	31	32	33	34	35	36	37		38	39
Stream Description	Rich Amine Off-Gas	Rich Amine	Recycle H2 Purge	C-101 Suction	C-101 Discharge	Cooled PK101 Recycle	Recycle H2 to Process	Makeup H2 to PK102	Makeup H2 to Process	Hydrogen Feed	Combined Stripper Feed	F106 Stripping Steam	F106 Overhead Vapor
Overall Properties													
Pressure, psig	120.4	120.4	950.3	950.0	1195.7	1030.7	1195.7	339.9	1195.7	1195.0	170.7	249.9	158.7
Temperature, °F	119.7	119.7	116.4	116.4	162.6	100.0	162.6	96.2	201.0	174.2	460.3	500.0	350.0
Std. Vol Flow (V), MMSCFD	0.0	---	3.2	61.8	61.8	---	61.8	18.4	18.4	59.8	---	6.1	8.5
Std. Vol Flow (L), barrel/day	---	4,598	---	---	---	0	---	---	---	---	---	---	---
Mass Flow, lb/hr	16	72,364	2,214	42,178	42,178	0	42,196	10,275	10,275	38,499	378,187	12,000	25,880
Mole Flow, lbmole/hr	2.296752322	2795.708981	356.3959626	6789.631379	6789.631379	0	6789.631379	2025.1	2025.1	6566.529689	1877.020032	666.1078585	937.513705
Vapor Weight Fraction	1	0	1	1	1	0	1	1	1	1	0.0125	1	1
Vapor Mole Fraction	1.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	0.11	1.00	1.00
Enthalpy Flow, MMBtu/hr	0.01	-29.37	-2.26	-43.02	-40.56	0.00	-40.58	-7.46	-5.84	-32.98	-272.14	-66.92	-70.35
Composition, mass%													
H2	21.58	0.00	26.65	26.65	26.65	26.64	26.64	36.06	36.06	29.15	0.07	0.00	1.00
H2S	10.36	3.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	1.65
NH3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
C1	25.20	0.00	24.49	24.49	24.49	24.47	24.47	9.74	9.74	20.54	0.13	0.00	1.95
C2	26.29	0.00	25.87	25.87	25.87	25.86	25.86	16.30	16.30	23.31	0.30	0.00	4.73
C3	12.66	0.00	14.84	14.84	14.84	14.85	14.85	15.12	15.12	14.92	0.34	0.00	6.09
iC4	0.16	0.00	2.94	2.94	2.94	2.95	2.95	4.58	4.58	3.38	0.12	0.00	2.57
nC4	0.15	0.00	2.86	2.86	2.86	2.87	2.87	5.84	5.84	3.66	0.15	0.00	3.44
iC5	0.05	0.00	0.72	0.72	0.72	0.72	0.72	2.42	2.42	1.17	0.08	0.00	2.25
nC5	0.02	0.00	0.27	0.27	0.27	0.27	0.27	1.28	1.28	0.54	0.04	0.00	1.13
C6	0.41	0.00	0.72	0.72	0.72	0.72	0.72	8.66	8.66	2.84	0.26	0.00	9.45
C7	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.26
C8+	0.00	0.00	0.07	0.07	0.07	0.07	0.07	0.00	0.00	0.05	98.40	0.00	25.24
H20	2.93	62.45	0.59	0.59	0.59	0.59	0.59	0.00	0.00	0.43	0.00	100.00	40.21
NH4SH*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MDEAmine	0.00	33.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	0.17	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vapor Phase Properties													
Mole Flow, lbmole/hr	2	0	356	6,790	6,790	0	6,790	2,025	2,025	6,567	202	666	938
Mass Flow, lb/hr	16	0	2,214	42,178	42,178	0	42,196	10,275	10,275	38,499	4,712	12,000	25,880
Actual Volumetric Flow, ACFM	2	0	39	735	637	0	637	572	203	629	179	407	752
Density, lb/ft3	0.1551	0.1551	0.9572	0.9569	1.1035	1.0656	1.1040	0.2995	0.8438	1.0195	0.4390	0.4916	0.5739
Viscosity, cP	0.0114	0.0114	0.0107	0.0107	0.0114	0.0105	0.0114	0.0098	0.0114	0.0114	0.0208	0.0184	0.0144
Heat Capacity, Btu/lb-F	1.11	1.11	1.29	1.29	1.31	1.29	1.31	1.51	1.57	1.38	0.73	0.51	0.55
Thermal Conductivity, Btu/hr-ft-F	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.09	0.10	0.09	0.07	0.02	0.03
Molecular Weight	7.18	7.18	6.21	6.21	6.21	6.21	6.21	5.07	5.07	5.86	23.33	18.02	27.61
H2 Partial Pressure, psia	103.6	---	792.2	792.0	993.7	---	993.6	321.4	1098.1	1025.3	12.6	0.0	23.6
Liquid Phase Properties													
Mole Flow, lbmole/hr	---	2,796	---	---	---	0	---	---	---	---	1,675	---	---
Mass Flow, lb/hr	---	72,364	---	---	---	0	---	---	---	---	373,474	---	---
Actual Volumetric Flow, USGPM	---	136	---	---	---	0	---	---	---	---	1,071	---	---
Std. Vol. Flow, barrel/day	---	4,598	---	---	---	0	---	---	---	---	29,665	---	---
Density, lb/ft3	---	66.28	---	---	---	62.41	---	---	---	---	43.47	---	---
Viscosity, cP	---	1.9934	---	---	---	0.6799	---	---	---	---	0.2409	---	---
Heat Capacity, Btu/lb-F	---	0.8558	---	---	---	1.0286	---	---	---	---	0.6500	---	---
Thermal Conductivity, Btu/hr-ft-F	---	0.2478	---	---	---	0.3633	---	---	---	---	0.0599	---	---
Molecular Weight	---	25.9	---	---	---	18.0	---	---	---	---	223.0	---	---

Heat and Material Balance
Diesel Feed

Stream Number	41	42	43	44	45	46	47	48	49	50	51	52
Stream Description	F106 Ovhd Vapor to E106A/B	Cooled Ovhds to F107	Off-gas from F107	Sour Water from F107	F106 Reflux	F106 Naphtha	Hot Diesel	Diesel to Air Cooler	Diesel to Trim Cooler	Diesel to Coalescer	Coalescer Water	Diesel to Dryers /Storage
Overall Properties												
Pressure, psig	153.7	150.7	150.7	150.7	150.7	150.7	163.7	164.5	154.5	144.5	144.5	144.5
Temperature, °F	140.0	111.0	110.0	110.0	110.0	110.0	456.7	434.2	140.0	95.0	95.0	95.0
Std. Vol Flow (V), MMSCFD	---	---	2.3	---	---	---	---	---	---	---	---	---
Std. Vol Flow (L), barrel/day	---	---	---	701	739	243	---	29,417	29,417	29,417	107	29,423
Mass Flow, lb/hr	25,880	25,880	4,855	10,385	8,012	2,629	372,319	372,319	372,319	372,319	1,581	370,738
Mole Flow, lbmole/hr	937.513705	937.513705	257.1407851	576.213748	78.43940896	25.73587316	1684.053594	1684.053594	1684.053594	1684.053594	87.74011394	1596.31348
Vapor Weight Fraction	0.2179	0.1886	1	0	0	0	0.0000	0	0	0	0	0
Vapor Mole Fraction	0.29	0.27	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Enthalpy Flow, MMBtu/hr	-84.87	-85.58	-5.08	-70.28	-7.71	-2.53	-276.43	-281.80	-343.92	-351.70	-10.74	-340.96
Composition, mass%												
H2	1.00	1.00	5.30	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
H2S	1.65	1.65	7.62	0.09	0.45	0.45	0.00	0.00	0.00	0.00	0.00	0.00
NH3	0.03	0.03	0.01	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C1	1.95	1.95	10.20	0.00	0.09	0.09	0.00	0.00	0.00	0.00	0.00	0.00
C2	4.73	4.73	23.03	0.00	0.99	0.99	0.00	0.00	0.00	0.00	0.00	0.00
C3	6.09	6.09	24.90	0.00	3.45	3.45	0.00	0.00	0.00	0.00	0.00	0.00
iC4	2.57	2.57	8.03	0.00	2.58	2.58	0.00	0.00	0.00	0.00	0.00	0.00
nC4	3.44	3.44	9.31	0.00	4.12	4.12	0.00	0.00	0.00	0.00	0.00	0.00
iC5	2.25	2.25	3.70	0.00	3.79	3.79	0.00	0.00	0.00	0.00	0.00	0.00
nC5	1.13	1.13	1.54	0.00	2.05	2.05	0.00	0.00	0.00	0.00	0.00	0.00
C6	9.45	9.45	5.34	0.00	20.55	20.55	0.05	0.05	0.05	0.05	0.00	0.05
C7	0.26	0.26	0.06	0.00	0.61	0.61	0.00	0.00	0.00	0.00	0.00	0.00
C8+	25.24	25.24	0.20	0.00	61.29	61.29	99.51	99.51	99.51	99.51	0.00	99.94
H20	40.21	40.21	0.78	99.84	0.02	0.02	0.43	0.43	0.43	0.43	100.00	0.01
NH4SH*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MDEAmine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vapor Phase Properties												
Mole Flow, lbmole/hr	272	258	257	---	0	---	0	---	---	---	0	0
Mass Flow, lb/hr	5,640	4,881	4,855	---	0	---	0	---	---	---	0	0
Actual Volumetric Flow, ACFM	169	156	155	---	0	---	0	---	---	---	0	0
Density, lb/ft3	0.5548	0.5227	0.5218	---	0.5218	---	0.4952	---	---	---	0.6304	0.6304
Viscosity, cP	0.0136	0.0130	0.0130	---	0.0130	---	0.0150	---	---	---	0.0078	0.0078
Heat Capacity, Btu/lb-F	0.59	0.59	0.59	---	0.59	---	0.52	---	---	---	0.54	0.54
Thermal Conductivity, Btu/hr-ft-F	0.04	0.04	0.04	---	0.04	---	0.02	---	---	---	0.01	0.01
Molecular Weight	20.72	18.95	18.88	---	18.88	---	26.03	---	---	---	19.36	19.36
H2 Partial Pressure, psia	22.9	22.5	81.9	---	---	---	0.0	---	---	---	---	---
Liquid Phase Properties												
Mole Flow, lbmole/hr	665	680	---	576	78	26	1,684	1,684	1,684	1,684	88	1,596
Mass Flow, lb/hr	20,240	20,999	---	10,385	8,012	2,629	372,318	372,319	372,319	372,319	1,581	370,738
Actual Volumetric Flow, USGPM	49	50	---	21	22	7	1,050	1,035	890	873	3	870
Std. Vol. Flow, barrel/day	1,493	1,570	---	701	739	243	29,417	29,417	29,417	29,417	107	29,423
Density, lb/ft3	51.75	51.92	---	62.00	44.82	44.82	44.19	44.83	52.13	53.18	62.43	53.15
Viscosity, cP	1.8406	1.8428	---	0.6511	0.4157	0.4157	0.2587	0.2891	2.4312	4.3702	0.7185	4.3137
Heat Capacity, Btu/lb-F	0.7800	0.7631	---	1.0304	0.5011	0.5011	0.6477	0.6356	0.4746	0.4487	1.0302	0.4463
Thermal Conductivity, Btu/hr-ft-F	0.1450	0.1391	---	0.3669	0.0652	0.0652	0.0718	0.0738	0.0865	0.0891	0.3612	0.0888
Molecular Weight	30.4	30.9	---	18.0	102.1	102.1	221.1	221.1	221.1	221.1	18.0	232.2

Utility Summary

Utility Service	Phase units	Flow Rate	Density (lb/ft^3)	MW	Operating Conditions psig	 °F	Remarks
250# Steam	**V**						
F-100 Stripping Steam	lb/hr	10,000	0.464	18.02	235	500	
	Total	**10,000**					
Boiler Feed Water	**L**						
F-101 - Wash Water Make-up	gpm	20	60.1	18.02	350	200	
	Total	**20**					
Cooling Water	**L**						
E-101 A/B - Effluent Trim Cooler	gpm	640	62.1	18.02	47	90	
E-102 - Stripper Ovhd Trim Cooler	gpm	660					
E-103 - Diesel Trim Cooler	gpm	775					
	Total	**2,075**					
Fuel Gas	**V**						
H-101 - Reactor Charge Heater	SCFD	277,500	0.159	16.01	45	100	
	Total	**277,500**					
Hydrogen	**V**						
C-101 - Make-up H2 Comp	MMSCFD	17.4	0.076	8.1	340	100	
	Total	**17.4**					
Lean Amine	**L**						
F-002 - Amine Absorber	gpm	98	64.0	--	400	97	
	Total	**98**					
Rich Amine (Produced)	**L**						
F-002 - Amine Absorber	gpm	100	64.0	--	75	115	
	Total	**100**					

Utility Summary

Utility	Phase	Flow Rate	Density	MW	Operating Conditions		Remarks
Service	units		(lb/ft^3)		psig	°F	
Sour Water (Produced)	L		61.9	--	20	110	
F-102 - Stripper Ovhd Accumulator	gpm	17					
F-103 - Cold High Pressure Sep	gpm	17					
	Total	**34**					
	Net	**17**					
Electrical	**Motor HP**	**VOLTS**					
EA-003A - Diesel Prod Cooler (Fan #1)	30	480					
EA-003A - Diesel Prod Cooler (Fan #2)	30	480					
EA-003B - Diesel Prod Cooler (Fan #1)	30	480					
EA-003B - Diesel Prod Cooler (Fan #2)	30	480					
P-001A - Amine Booster Pump	200	480					
P-001B - Amine Booster Pump	200	480					
P-002A - Stripper Reflux Pump	20	480					
P-002B - Stripper Reflux Pump	20	480					
P-003A - Recycle Wash Water Pump	100	480					
P-003B - Recycle Wash Water Pump	100	480					
Notes							