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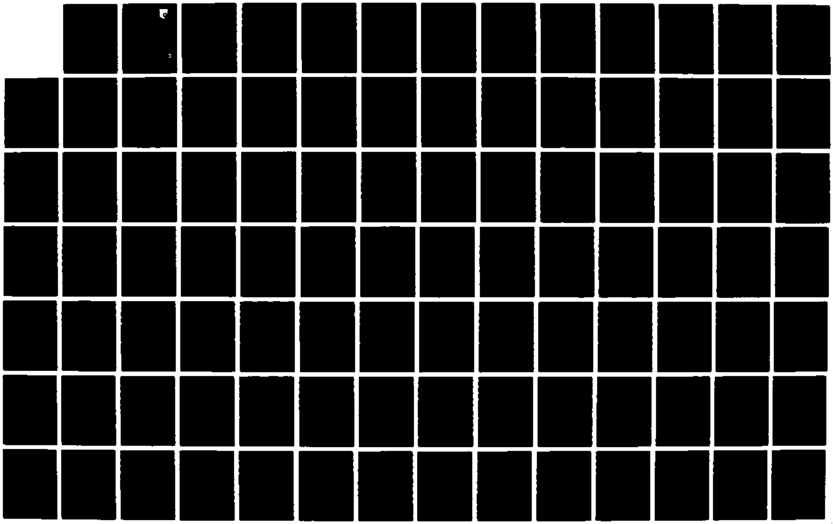

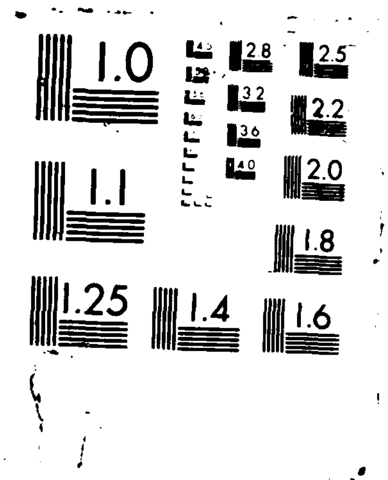
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AF WRIGHT AERONAUTICAL LABORATORIES

TURBINE FUELS FROM TAR SANDS BITUMEN AND HEAVY OIL

VOL II - Phase III Process Design Specifications for a Turbine Fuel Refinery Charging San Ardo Heavy Crude Oil

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September 1987

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An engineering design was developed for a 50,000 BPSD grass-roots refinery to produce aviation turbine fuel grades JP-4 and JP-8 from San Ardo heavy crude oil. The design was based on the pilot plant studies described in Phase III - Volume I of this report. The detailed plant design described in this report was used to determine estimated production costs.

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Several individuals merit recognition for their valued contributions to the development of the final process design package. Mr. Al Talbot, senior staff research engineer and overall program manager, established the design basis reactor yields from experimental pilot plant data and helped to establish the overall refinery process flow scheme. Mr. Vasant Patel, senior research engineer, developed and ran many of the computer simulations which generated rigorous heat and material balances plus size specifications for major equipment. Mr. Len Krawitz, process design consultant, specified the major equipment for the Crude Unit. Mr. Tom Harlan and Mr. Tom Sedlak, cost engineers, supervised by Mr. Bob Turner and Mr. Lou Marchesani, determined the entire refinery capital cost estimate and coordinated the computer-drawing of process flow diagrams.

Special recognition is deserved by co-author Lloyd Magill, process design consultant, whose broad experience and many talents were essential in the successful completion of the entire refinery design effort from the preliminary stages to the final design package, including the development of final refinery process flow schemes, selection of auxiliary processes, and specification of major refinery equipment.

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I. INTRODUCTION

The following process design specifications describe a new "grassroots" heavy oil upgrading refinery whose purpose is to produce principally JP-4 or JP-8 aviation turbine fuel from San Ardo (California) heavy crude oil at a crude charge rate of 50,000 barrels per operating day. The importance of the design is that it represents a strategic alternative for the production of U.S. military jet fuel using a domestic, rather than foreign, hydrocarbon resource. The feedstock is generally considered to be difficult to process due to its high viscosity and molecular weight, and high sulfur and nitrogen contents.

The purpose of the refinery design was to obtain an accurate assessment of construction and operating costs, which in turn would be used to determine the selling price of refinery fuel products to maintain an economically viable operation. The total installed capital cost for the refinery based on fourth quarter 1985 prices for a Salt Lake City, Utah, location was estimated to be $1.126 billion. Components of the refinery operating costs also are listed later in this report. Results of the economic study to determine product fuel pricing appear in a separate report of the overall Phase III project [1].

The distinguishing heavy oil upgrading process in the refinery design is the "hydrovisbreaking" of vacuum reduced crude oil in the presence of a coke-suppressing molybdenum-based additive. The operation converts reduced crude to lower molecular weight hydrocarbons which can be converted to high-quality fuels by conventional petroleum refinery hydrotreating and hydrocracking processes. The attractiveness of hydrovisbreaking as described here is its high conversion of the reduced crude with suppression of coke formation by a non-proprietary process using conventional processing equipment.

The design basis for each of the hydroprocessing units in the refinery including hydrovisbreaking, hydrotreating, and hydrocracking was developed

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[1] Talbot, A. F. et al, AFWAL-TR-87-2043 " Volume I - Phase III Pilot Plant Testing, Final Design, and Economics", August 1987.

from pilot plant experiments conducted for this project.

Most of the process design calculations were done with the "PROCESS" computer simulation program developed by Simulation Sciences, Inc. Comprehensive heat and material balances were computed for the six major refinery plants including the Crude Unit, Hydrovisbreaker, Naphtha Hydrotreater, Distillate Hydrotreater, Distillate Hydrocracker, and the Gas Plant. Consequently, their capital cost estimates are based upon detailed, major equipment specifications.

The other process units have very standardized "packaged" designs for which the literature and reputable vendors have provided detailed estimates of construction and operating costs. For these units it was, therefore, unnecessary to perform computer simulations and derive rigorous heat and material balances. However, the large compressor systems for the Hydrogen Plant and Hydrogen Purification Unit, were specified individually to permit a compressor manufacturer to determine their costs.

II. OVERALL PROJECT DESCRIPTION

This design package was one element of a much larger project performed under U.S. Air Force contract No. F33615-83-C-2352, entitled "Turbine Fuels from Tar Sands Bitumen and Heavy Oil". The program of work was subdivided into the following three phases:

Phase I - Preliminary Process Analysis

A series of case studies of potential upgrading and refining processes for the purpose of selecting a candidate conversion scheme.

Phase II - Laboratory Sample Production

Preliminary bench-scale experiments with a variety of heavy crude oil and tar sand bitumen feedstocks to demonstrate the candidate conversion scheme, to determine overall processing requirements, and to supply small product samples for evaluation.

Phase III - Pilot Plant Studies, Final Design and Economics

Pilot plant testing of a specific heavy crude oil, i.e., San Ardo heavy crude, final process design of a commercial-scale refinery, and an economic evaluation of the refinery capital construction and operating costs. Phase III entailed scale-up from preliminary work to demonstrate operability, to generate a design basis, to project fuel product costs, and to provide larger representative fuel samples.

The overall objective of the program was to assess the costs, yields, and physical and chemical characteristics of aviation turbine fuels made from U.S. domestic tar sands bitumen and heavy crude oil. The program required that conversion of these low grade feedstocks to high quality finished fuels be accomplished by commercially viable upgrading and refining processes to achieve product slates emphasizing either JP-4 or JP-8 turbine fuel, or a mixture of transportation fuels.

III. REFINERY PROCESS DESCRIPTION

The basic refinery process flow scheme includes twelve onsite processing units and is illustrated in Figure 1. A more detailed working sketch of all interplant streams is provided in Figure 2. The major processing units are:

1. Crude Unit
2. Hydrovisbreaker Unit
3. Naphtha Hydrotreating Unit
4. Distillate Hydrotreating Unit
5. Distillate Hydrocracking Unit (with product fractionation)
6. Gas Plant

Additional auxiliary units include:

7. Hydrogen Plant (Steam-Hydrocarbon Reforming)
8. Hydrogen Purification Unit (Pressure Swing Adsorption)
9. Low Pressure Amine Unit
10. Sour Water Stripper and Ammonia Plant (Chevron WWT Process)
11. Sulfur Recovery Unit (Claus unit followed by BSR/MDEA tail gas unit)
12. Flue Gas Desulfurization Unit (Wellman-Lord/Davy Powergas Process)

The refinery process concept emerged from the Phase I case studies and was demonstrated in the Phase II bench-scale work. The processing objective was the exclusive production of wide-cut gasoline, or JP-4 type aviation turbine fuel. However, the refinery has been configured to allow the production of kerosene, or JP-8 type turbine fuel with a minimum of equipment or operational changes.

To simplify the change from one product slate to the other, the refinery has been designed so that all process operations upstream of the Distillate Hydrocracker and Main Fractionator are identical for both JP-4 and JP-8 production. Consequently, switching from one product slate to the other requires changing only one primary control parameter (the fractionation end-point of the turbine fuel product from the Main Fractionator Tower) and

Note: Dotted line show products flow during JP-8 operation.

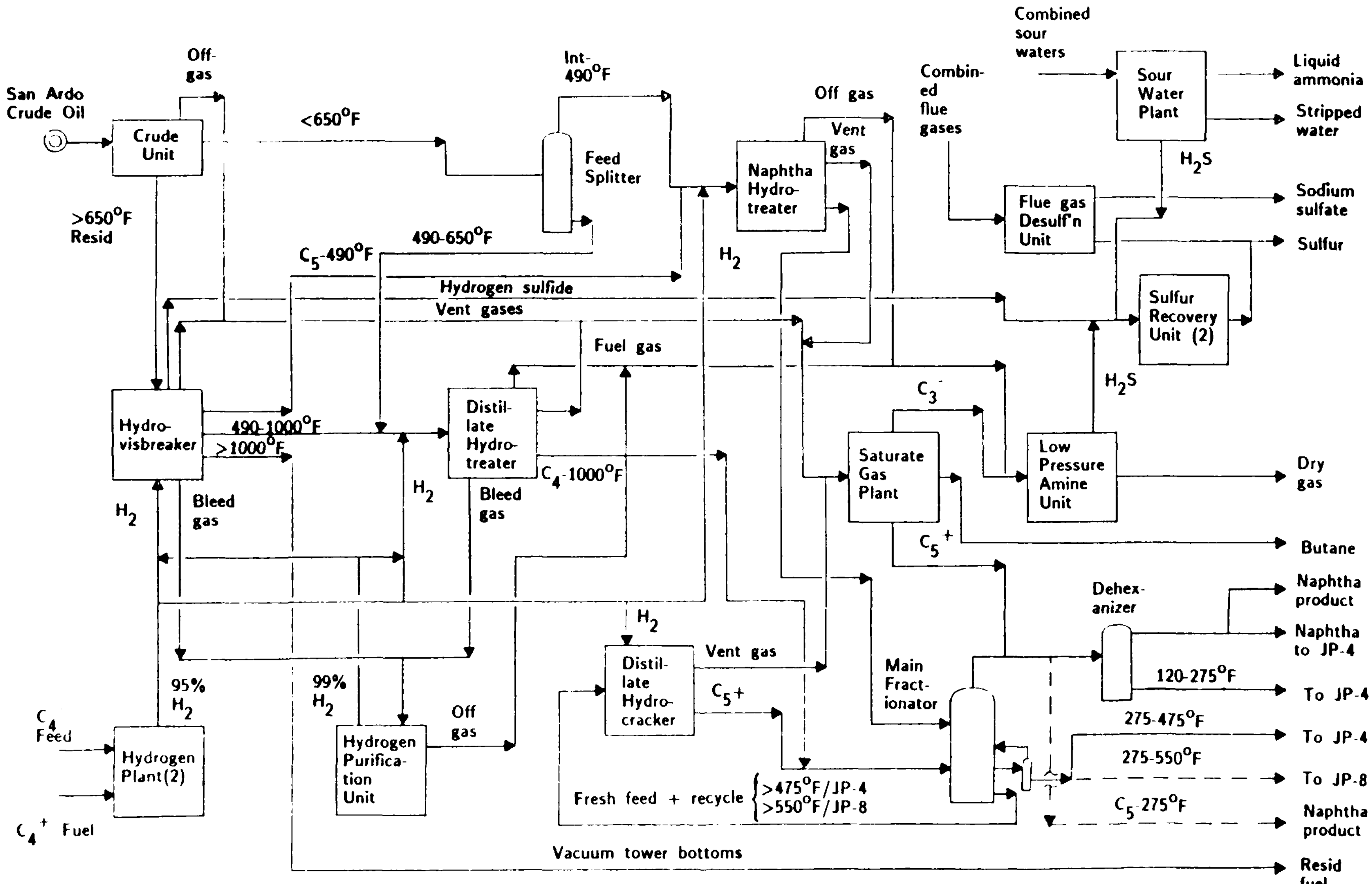

FIGURE 1
REFINERY PROCESS FLOW SCHEME

HEAVY OIL UPGRADING REFINERY

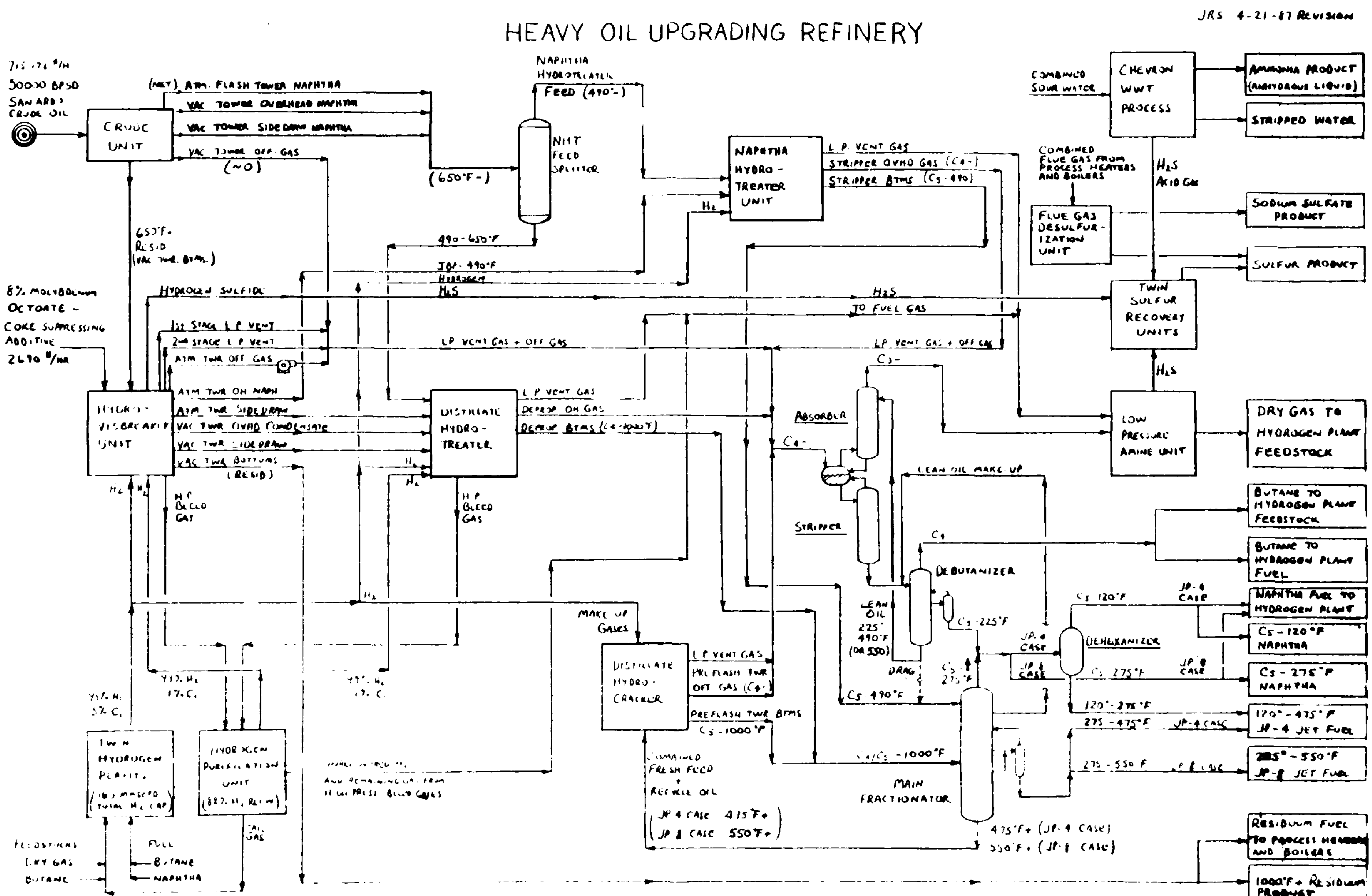

FIGURE 2
SKETCH OF INTERPLANT STREAMS

placing the Dehexanizer Tower downstream of the Main Fractionator in or out of service. During JP-4 operations the Dehexanizer is in operation; during JP-8 production it is out of service.

Descriptions of individual refinery operating units follow.

Crude Unit

The refining process begins with 50,000 BPSD of crude oil being charged to the Crude Unit, where straight-run distillate boiling below 650°F is separated from the >650°F vacuum reduced crude, which is to be upgraded at the Hydrovisbreaker. The incoming crude oil is first diluted with 16,000 BPSD recycled straight-run naphtha to reduce the crude viscosity to nearly 2 centipoise which is optimal for the subsequent 2-stage desalting operation. In the desalters, inorganic contaminants (sediment and water-soluble) are removed from the crude.

The desalted crude is flashed at atmospheric pressure to recover a large quantity of naphtha, most of which is recycled for crude dilution. The remainder is removed from the Crude Unit as a net straight-run naphtha stream. Sharp fractionation of the recycled naphtha is unnecessary, and the atmospheric flash is adequate. This reduces the load on the downstream vacuum distillation tower to which the atmospheric flash tower bottoms is fed.

The vacuum tower fractionates this stream at a true-boiling cut point of 650°F. The straight-run <650°F vacuum distillate is combined with the net straight-run naphtha from the atmospheric flash tower and routed to the Naphtha Hydrotreater Feed Splitter Tower. The vacuum reduced crude boiling above 650°F, representing 79 volume percent of the whole crude, becomes the liquid feed for the Hydrovisbreaker.

Hydrovisbreaker

The hydrovisbreaker feed rate is 39,366 BPSD. Approximately 60 volume percent of this boils above 975°F. Because this material cannot be converted directly to high-quality turbine fuels by conventional hydrotreating and hydrocracking alone, it is first upgraded to lighter products in the hydrovisbreaker. In the hydrovisbreaker reactors, the residuum is thermally cracked at 850°F and 2500 psig in the presence of hydrogen and a molybdenum-

based coke-suppressing additive. Molybdenum concentration is 367 ppm (wt.) of reactor liquid feed. About 70 percent of the >975°F fraction is converted to lower boiling products.

The hydrovisbreaker reactor effluent is separated into recycle gas, naphtha, middle and heavy distillates, and a vacuum residuum by a series of phase separators and atmospheric and vacuum fractionation towers.

Since feed sulfur conversion exceeds 50 percent, a high pressure amine scrubber is included to remove hydrogen sulfide from the recycled hydrogen gas stream. The recovered hydrogen sulfide is routed directly to the refinery Sulfur Recovery Unit.

Feed Splitter Tower (at the Naphtha Hydrotreater Unit)

The straight-run naphtha plus distillate mixture from the crude unit is charged to the feed splitter tower at the Naphtha Hydrotreating Unit, where it is fractionated more sharply into naphtha and middle distillate fractions at a nominal 490°F cut-point.

The feed splitter overhead stream needs only to be hydrotreated to be suitable for JP-4 blend stock. It is combined with hydrovisbroken naphtha of the same boiling range and processed in the Naphtha Hydrotreating Unit.

The feed splitter bottoms is straight-run distillate boiling nominally from 490-650°F. It needs to be more severely hydrotreated and hydrocracked to make acceptable turbine fuel blend stock. This refining takes place in the distillate hydrotreater/hydrocracker complex.

Naphtha Hydrotreater Unit

The straight-run and hydrovisbroken naphthas are combined and catalytically hydrotreated at the Naphtha Hydrotreating Unit to reduce olefin, aromatic, sulfur, and nitrogen contents to acceptable levels. Yields are based upon pilot plant results with a nickel-molybdenum-on-alumina catalyst. The reactor design temperature and pressure are 650°F and 1250 psig, respectively.

Before further processing, the hydrotreated liquid product is stripped of light ends to permit safe intermediate storage if that becomes necessary. It is then routed to the Main Fractionator Tower at the Distillate Hydrocracker Unit, where it is separated into naphtha and turbine fuel products.

Distillate Hydrotreater Unit

The feed to the Distillate Hydrotreater Unit consists of the straight run gas oil from the Naphtha Hydrotreater Feed Splitter Tower bottoms, and the middle and heavy distillate cuts from the Hydrovisbreaker atmospheric and vacuum fractionation towers.

The combined distillates are catalytically hydrotreated to reduce olefin, heteroatom, and aromatics contents, producing acceptable quality hydrocracker feed. Pilot plant experiments, using the same nickel-molybdenum-on-alumina catalyst as in the Naphtha Hydrotreater Unit, formed the yield basis for this design. Operating conditions were 750°F and 2500 psig.

Distillate Hydrotreater Unit processing conditions are relatively severe, producing considerable reduction in feed molecular weight and distillation range. Therefore, hydrotreater plant product, after preliminary stripping/stabilization, is directed to the main product fractionator, rather than to the hydrocracking reactor, to separate the lighter products from the heavier gas oil feed intended for the Hydrocracker. This step reduces charge rate to the Hydrocracker Unit and avoids excessive light ends production in the Hydrocracker Unit.

Main Fractionator Tower & Distillate Hydrocracker Unit

The Main Fractionator Tower is located at the Distillate Hydrocracker Unit. It serves to 1) fractionate final refinery products, 2) to separate light components from the the Distillate Hydrocracker fresh feed, and 3) to separate hydrocracker products from the unconverted heavy gas oil which is recycled to extinction in the hydrocracker.

Stabilized naphtha from the Naphtha Hydrotreater Unit is supplied to the upper part of the Man Fractionator Tower becoming overhead (light naphtha) and side stream (turbine fuel) products.

The Distillate Hydrotreater liquid product, which is the source of fresh feed for the Distillate Hydrocracker, contain a significant amount of light ends. It is fed to the lower part of the Main Fractionator Tower, where the naphtha and turbine fuel components are removed from the heavy gas oil, which is routed to the Hydrocracker reactor.

The same feed tray also receives liquid product from the Hydrocracker Unit. This stream as also been stabilized, by high pressure and low pressure flashes, to unload the Main Fractionator and to permit safe intermediate storage if required.

The Main Fractionator bottoms product is the total liquid feed for the Distillate Hydrocracker. Under design conditions 60 volume percent of it is fresh feed originating from the Distillate Hydrotreater and 40 percent is unconverted oil recycled from the Hydrocracker product stream.

Operating conditions within the hydrocracking reactor are established to maintain 60 percent conversion of total reactor liquid feed per pass through the reactor. By recycling all unconverted gas oil back to the reactor the Distillate Hydrocracker achieves overall 100% conversion, catalytically cracking all of the heavy gas oil to turbine fuel and lighter products.

Turbine fuel sidestream product is removed from the Main Fractionator and is steam-stripped. Stripper tower vapor is returned to the Main Fractionator above the sidedraw, and the stripped bottoms is sent to turbine fuel storage. During JP-4 operations this turbine fuel stream is combined with the Dehexanizer bottoms to form the entire JP-4 turbine fuel product. During JP-8 production, the sidestream is drawn from a lower tray of the Main Fractionator, and after being stripped, comprises the entire JP-8 product.

A lean oil purge stream from the Gas Plant Debutanizer bottoms is fed to the upper part of the Main Fractionator for removal of light naphtha. A lean oil makeup stream is drawn from an upper tray and returned to the Debutanizer.

Switching Product Slates

Combining these various fractionation duties in the one Main Fractionator column reduces to three the number of process changes necessary to switch from JP-4 to JP-8 turbine fuel production. All of them occur at the Main Fractionator and Distillate Hydrocracker Unit. They include:

(1) The fractionation cut-point between the Main Fractionator sidestream turbine fuel and the bottoms product (which is Distillate Hydrocracker feed) must be increased, nominally from the 475°-490°F range up to 550°F. This is done by drawing the sidestream from a lower tower tray and adjusting the reboiler duty upward.

(2) In a response to the altered cut-point mentioned above, the Distillate Hydrocracker liquid charge rate is lowered and the initial boiling point of the feed is increased by about 60°F. This will require an adjustment to the hydrocracker reactor temperature in order to maintain the nominal 60 percent conversion per pass.

(3) For both JP-4 and JP-8 operations the Main Fractionator overhead, which boils nominally below 275°F, is combined with the Gas Plant Debutanizer naphtha sidestream. During JP-4 operations this combined stream is separated into light naphtha, boiling below about 120°F, and a 120°-275°F turbine fuel component in the Dehaxanizer Tower. The turbine fuel portion is then combined with the stripped sidestream from the Main Fractionator to form the entire JP-4 turbine fuel product.

During JP-8 production, the Main Fractionator overhead and Debutanizer sidestream are combined as naphtha product because they are not within the 275°-550°F boiling range of the JP-8 product. Consequently, the Dehexanizer tower may be taken out of service and the entire JP-8 product comes from from the Main Fractionator sidedraw.

Gas Plant

The Gas Plant is comprised of a combination Absorber-Stripper Tower, a Debutanizer Tower and a small Debutanizer Sidestripper Tower. The plant processes the combined gaseous products and light condensibles which originate at certain low pressure separator vents, plus all of the tower overhead gases.

The Gas Plant produces a dry gas stream containing hydrogen and C_1-C_3 hydrocarbons, a butane product stream, and a naphtha stream.

Gas Plant feed enters the top of the Stripper section of the Absorber-Stripper tower. Gas travels upward through the Absorber tower, while lean oil introduced at the top of the Absorber recovers condensibles from the gas. The Stripper removes dissolved gases from the rich oil, which leaves as Stripper bottoms enroute to the Debutanizer.

The rich oil is combined with makeup lean oil from the Main Fractionator, to form the total Debutanizer feed. The Debutanizer produces a butane product overhead plus a stabilized naphtha sidestream. Debutanizer bottoms is recovered as absorber lean oil. A Debutanizer Sidestripper tower strips light ends from the naphtha before it leaves the unit.

A small lean oil purge stream is drawn from the Debutanizer bottoms and routed back to the Main Fractionator Tower.

The Absorber dry gas is sent to the Low Pressure Amine unit with other light refinery gases for removal of hydrogen sulfide before it is used as hydrogen plant feed. The butane product is consumed partly as feedstock for the hydrogen plant and partly as fuel for the hydrogen plant furnaces. The naphtha from the gas plant is mixed with the overhead distillate from the Main Fractionator upstream of the Dehexanizer tower.

Low Pressure Amine Unit

The dry gas from the Gas Plant is combined with low pressure vent gas from both hydrotreaters and the tail gas from the Hydrogen Purification Unit to form the feed to the Low Pressure Amine Unit. Hydrogen sulfide in these gases must be removed before the dry gas can be used as feedstock to the hydrogen plant.

The hydrogen sulfide is absorbed by a lean alkanolamine solution in an amine contactor tower. The H_2S-rich amine leaving the bottom of the contactor enters the top of an amine still, where the hydrogen sulfide is stripped overhead from the circulating amine and is directed to the Sulfur Recovery Unit. The lean amine is recycled to the top of the Absorber.

The H_2S-free dry gas from the Low Pressure Amine Unit is totally consumed as feedstock for the Hydrogen Plant (Steam-Hydrocarbon Reformer).

Hydrogen Plant

Two parallel hydrogen plants convert light hydrocarbon gases to hydrogen by a steam reforming process. Two are required, since the total refinery hydrogen requirements are nearly twice the capacity of the largest packaged hydrogen plant normally constructed.

The primary feedstock for the Hydrogen Plant is the dry gas product from the Low Pressure Amine Unit. Butane product from the Gas Plant is supplemental feed. The remaining butane fuels the hydrogen plant reformer furnaces, which require a relatively clean, sulfur-free fuel. Since the reformer furnace duties exceed the available butane fuel, some naphtha product is also fired.

Hydrogen Plant feedstock is further desulfurized and combined with water (plant condensate). Tubes of catalyst in the reformer furnace convert the steam and hydrocarbons to hydrogen and to carbon oxides. Any carbon monoxide is converted to carbon dioxide in a high-temperature shift reactor at 750°F followed by a low-temperature shift reactor at 400°F.

Potassium carbonate solution removes carbon dioxide from the gas products at an absorber, then releases the CO_2 to an atmospheric vent at a stripper tower while being regenerated for recycle to the absorber. A methanation reactor converts residual amounts of carbon monoxide in the gas to methane. The product is a makeup gas containing 95 percent hydrogen and 5 percent methane, which is then supplied to the hydrovisbreaking unit, both hydrotreaters, and the hydrocracker unit.

Hydrogen Purification Unit

A 95 percent purity for makeup hydrogen is adequate for the Naphtha Hydrotreater and Distillate Hydrocracker plants. Neither unit requires a high pressure purge gas be drawn from the recycle hydrogen stream to maintain high purity, because potential impurities are satisfactorily carried away in the liquid products.

However, if the Hydrogen plant were the only source of fresh hydrogen for the Hydrovisbreaker and Distillate Hydrotreater units, very large high-pressure purge rates, and correspondingly high makeup hydrogen rates, would be necessary to meet the hydrogen partial pressure requirements. The operations would approach expensive "once-through" hydrogen flow with little gas recycled.

To avoid this, a Hydrogen Purification Unit recovers, purifies, and recycles the hydrogen present in the high-pressure purge gases from the Hydrovisbreaker and Distillate Hydrotreater. The Pressure Swing Adsorption (PSA) process, which is a cyclic operation, is used. Its five distinct steps require installation of five identical vessels, which are filled with molecular sieve separation media.

Feed entering at high pressure is expanded through a turboexpander to recovery energy, and is charged to one of the five vessels. During the on-sream cycle, the hydrocarbons in the feed are selectively adsorbed on the molecular sieve. Hydrogen containing a small amount of hydrocarbon, principally methane, passes through as purified product. Meanwhile the other

four vessels are undergoing varying degrees of depressurization, desorption of hydrocarbons, and purging to a tail gas stream. Periodically, each of the vessels switches to the next process step in the series, and feed is routed to a different vessel.

Hydrogen recovery from the PSA feed gas is nearly 90 percent, and the resulting purity is 99 percent, with 1 percent methane. The purified hydrogen is recompressed and directed to the Hydrovisbreaker and Distillate Hydrotreater reactors. The purged tail gas is processed at the Low Pressure Amine Unit, eventually to be consumed as feedstock for the Hydrogen Plant.

Sour Water Stripper and Ammonia Plant

Sour process water is generated at several operating units and requires treatment before reuse or disposal. Inorganic contaminants are ammonia, hydrogen sulfide, or chemical combinations of the two in the form of ammonium sulfides, pentasulfides or hydrosulfide. Traditional two-stage water stripping would consume both caustic soda and acid to recover ammonia and hydrogen sulfide separately.

However, the proprietary Chevron WWT process for sour water clean-up does not require caustic and acid, and permits reuse of the stripped water for hydroprocessing injection, crude unit desalting water, and other process uses. The reduced refinery water usage and disposal is important in the arid environment in which the refinery would be constructed.

The plant first strips incoming sour water of residual dissolved gases, then sequentially steam strips the water of hydrogen sulfide, then ammonia. Plant products are the cleaned-up water available for re-use, anhydrous liquid ammonia for sale, and hydrogen sulfide, which is supplied to the sulfur recovery unit.

Sulfur Recovery Unit

Accepted environmental practice requires that hydrogen sulfide be removed from vented gases throughout the refinery. Typically, the hydrogen sulfide is converted at a Sulfur Recovery Unit to elemental sulfur, which is sold.

In this refinery design, hydrogen sulfide is recovered from three sources: 1) the High Pressure Amine Unit that processes the Hydrovisbreaker recycle gas, 2) the Low Pressure Amine Unit which cleans the refinery dry gas and vent gas, and 3) the Chevron WWT Unit (Sour Water Stripper and Ammonia Plant) which recovers hydrogen sulfide from refinery sour water.

The Sulfur Recovery Unit consists a Claus unit and a tail gas clean-up unit. The Claus unit partially reacts hydrogen sulfide and oxygen (air) to produce molten elemental sulfur. Because the resulting combustion gases include low concentrations of sulfur oxides, they cannot be vented directly to the atmosphere. The tail gas unit reduces the sulfur content to acceptable levels by catalytic reduction to hydrogen sulfide, followed by extraction of the hydrogen sulfide with alkanolamine. The hydrogen sulfide is returned to the front end of the Claus unit, and the scrubbed gases are vented. The primary plant product is saleable molten sulfur.

Flue Gas Desulfurization Unit

With the exception of the Hydrogen Plant Reformer Furnace, all refinery process heaters plus the main refinery boiler are fueled by vacuum residuum produced at the Hydrovisbreaker Vacuum Distillation Tower. Flue gas from these furnaces contains sulfur dioxide which cannot be vented to the atmosphere. In addition, the resid fuel contains appreciable trace metals (nickel, vanadium, and molybdenum from the Hydrovisbreaker coke-suppressing additive), which become fly ash during fuel combustion.

Therefore all refinery flue gas (except from the Hydrogen Plant reformer furnace) is processed in the Flue Gas Desulfurization Unit. Flue gas first passes through an electrostatic precipitator to capture fly ash, after which it is desulfurized.

The regenerative Wellman Lord/Davy Powergas process was selected to desulfurize the flue gas. Because it is regenerative, it produces a molten sulfur product and thus avoids a significant disposal problem associated with spent treating agent, which non-regenerative processes have (e.g., the limestone slurry throw-away processes).

Furnace Fuels

The vacuum residuum from the Hydrovisbreaker Vacuum Distillation Tower becomes fuel for the refinery main boiler and all process heaters with the exception of the Hydrogen Plant reformer furnace. While its sulfur content of 1.5 weight percent is tolerable in the process heaters, the residual fuel is not suitable for the high temperature Hydrogen plant reformer furnace, where it would tend to hasten corrosion of the furnace tubing and risk catastrophic hydrogen leaks.

The primary clean fuel used in the Hydrogen Plant reformer furnace is that portion of the butane product from the Gas Plant which has not been used as feedstock for the hydrogen plant. The butane fuel is supplemented by naphtha product to meet the firing requirements.

Commercial operations using vacuum residuum as furnace fuel indicate that there should be no problem in firing undiluted Hydrovisbreaker residuum, provided it can be stored and circulated at temperatures to 450°F. However, it would be necessary to establish the appropriate burner design to obtain adequate atomization. Separate burners for firing a lighter oil to control the heater duty more accurately may be helpful.

Because the residuum is an undesirable net product, its use as furnace fuel helps to solve the problem of its sale or disposal.

IV. IMPACT OF SWITCHING TO JP-8 PRODUCTION

Rigorous design calculations were completed only for the case of JP-4 turbine fuel production. Separate calculations for the JP-8 case would have been redundant. However, JP-8 production does impact operations and economics of the refinery, specifically at the Main Fractionator, the Distillate Hydrocracker, and the Dehexanizer tower.

Raising the cut-point between the Main Fractionator turbine fuel sidedraw and the tower bottoms from 475°F to 550°F will produce little, if any, change in the total combined production of naphtha and turbine fuel distillates at the tower. The net effect is that slightly more of the fresh gas oil feed from the Distillate Hydrotreater will pass directly through the Main Fractionator to the liquid product pools without first having to be hydrocracked.

Obviously, the change in initial boiling point of the turbine fuel product, from about 120°F for JP-4 to about 275°F for JP-8, means that more of the Main Fractionator overhead distillate is going to exit the refinery as naphtha, and less as turbine fuel. However, the economic bases employed in this project assigned equal market values to the naphtha and turbine fuel. Consequently, although the ratio of naphtha to turbine fuel is greater for the JP-8 case than the JP-4 case, it does not change the economics; the combined sales revenue from these two products remains the same. Of course, if separate values were assigned to naphtha, JP-4, and JP-8, an economic impact could be calculated.

Switching from JP-4 to JP-8 production will reduce refinery operating costs modestly. Shutting down the Dehexanizer tower obviously eliminates the consumption of reboiler steam, condenser cooling water, and electrical demand for pumps, etc. The Distillate Hydrocracker will operate in a less severe mode. With the slower charge rate and increased reactor residence time, a lower reaction temperature can be used to achieve the same 60% conversion per pass, and less charge preheating will be needed. However, this may be somewhat off-set by a potentially greater reboiler temperature at the Main Fractionator to achieve the higher cut-point.

For equipment sizing, JP-4 production is the size-determining Hydrocracker operation; less throughput is required for the JP-8 mode of operation. Total fresh liquid feed to the Main Fractionator from the two hydrotreaters remains the same for both cases. Thus, switching to JP-8 would not bottleneck the refinery in any way. JP-8 operation did impact the size of the naphtha storage tank. It is sized for the larger naphtha flow rate that results from the shutdown of the Dehexanizer tower throughout JP-8 operations.

Concern was raised that the processing change from JP-4 to JP-8 could alter the quality, primarily sulfur content, of the naphtha being fired in the Hydrogen Plant reformer furnace. Review of the respective stream flows and qualities indicated the naphtha sulfur content would remain at extremely low levels.

Overall, the impact of switching to JP-8 production is negligible.

Table 1

TURBINE FUEL REFINERY CAPITAL COST SUMMARY

ONSITES	Installed Cost [1]
Crude Unit	$ 19,968,000
Hydrovisbreaker Unit	168,119,000
Naphtha Hydrotreater Unit	24,154,000
Distillate Hydrotreater Unit	140,183,000
Distillate Hydrocracker Unit	94,724,000
Gas Plant	9,380,000
Hydrogen Plant	99,075,000
Hydrogen Purification Unit	60,915,000
Low Pressure Amine Unit	3,079,000
Sour Water Stripper and Ammonia Plant	33,091,000
Sulfur Recovery Unit	37,119,000
Flue Gas Desulfurization Unit	54,328,000
Total Onsites	$ 744,135,000
OFFSITES	
Tankage	$ 45,061,000
Other: Specified by U.S. Air Force as 45% of onsite costs	334,861,000
SPARE PARTS	1,498,000
ROUND UP TO NEAREST MILLION DOLLARS	445,000
TOTAL REFINERY INSTALLED COST	$ 1,126,000,000

[1] Based on 4th Quarter 1985 prices, Salt Lake City, Utah location

Table 2

SCOPE OF ONSITE AND OFFSITE FACILITIES

ONSITES	Crude Unit
	Hydrovisbreaker Unit
	Naphtha Hydrotreater Unit
	Distillate Hydrotreater Unit
	Distillate Hydrocracker Unit
	Gas Plant
	Hydrogen Plant
	Hydrogen Purification Unit
	Low Pressure Amine Unit
	Sour Water Stripper and Ammonia Plant
	Sulfur Recovery Unit
	Flue Gas Desulfurization Unit
OFFSITES	
TANKAGE:	Crude tankage
	Intermediate tankage
	Product tankage
	Fuel tankage
OTHERS:	Site preparation, grading, dyking and piling
	Paved roads and railroad spur
	Office building, cafeteria, change rooms
	Maintenance buildings, warehouse, and spare parts
	Medical facilities
	Powerhouse
	Electrical power substation and grid
	Boiler feed water treating and water storage
	Steam boilers, distribution piping, and condensate tank
	Air systems - plant and instrument
	Firehouse and trucks
	Fire water pond, fire water pumps, and distribution system
	Foam fire system on tanks
	Cooling towers and water supply
	Sanitary drinking water
	Hydrogen and gas flare system
	Butane treating
	Product loading for sulfur, ammonia
	Crude and product receiving and pumping station
	Communication systems
	Offsite piping and pipeways
	Nitrogen purge system
	Sewer systems (3): contaminated, sanitary, run-off
	Waste water treatment plant, API separators, slop tanks
	Duct work from fired heaters
	Receiving truck rack and chemical storage
	Sludge disposal storage
	Spent catalyst disposal site

Table 3

SUMMARY OF MAJOR REFINERY STREAM RATES

The stream rates below were calculated by computer simulations of individual operating plants and were used to specify major equipment sizes. Generally, the individual plant weight balances achieved 100 percent recoveries. However, the simulations dealt principally with the distribution of hydrocarbons and hydrogen gas, not the precise flow of sulfur and nitrogen throughout the refinery. Sulfur and nitrogen flows were determined separately and were superimposed on the overall refinery design. The resulting overall refinery material balance slightly exceeded 100 percent weight recovery, and therefore some reduction of refinery hydrocarbon product rates was necessary to establish 100 percent closure and determine product yields. Consequently, the data below, used for equipment sizing, will differ somewhat from the final product yields, intended for refinery economic evaluation, but in either case the values are conservative for their respective purposes.

	BPSD	MSCFH	M LB/HR
CRUDE UNIT			
Crude Oil Charge	50,000	-	715,195
Naphtha Recycled as Crude Oil Diluent	16,008	-	200,947
HYDROVISBREAKER UNIT			
Liquid Charge	39,366	-	577,565
Additive Feed	-	-	2,690
Naphtha Recycled as Additive Diluent	600	-	6,724
Fresh Hydrogen Feeds			
from Hydrogen Plant	-	1,670	11,960
from Hydrogen Purification Unit	-	1,546	8,785
Recycled Gas	-	6,355	90,381
Total Reactor Gas Feed	-	9,571	111,126
NAPHTHA HYDROTREATER UNIT			
Feed Splitter Charge	10,542	-	136,443
Naphtha Hydrotreater Charge:			
Feed Splitter Overhead Naphtha	4,267	-	53,271
Hydrovisbroken Naphtha	11,875	-	135,003
Total Liquid Charge	16,142	-	188,274

Table 3

SUMMARY OF MAJOR REFINERY STREAM RATES

(continued)

	BPSD	MSCFH	M LB/HR
NAPHTHA HYDROTREATER UNIT (continued)			
Makeup Hydrogen	-	374	2,677
Recycle Gas	-	2,885	34,680
Total Reactor Gas Feed	-	3,259	37,357
DISTILLATE HYDROTREATER UNIT			
Charge:			
Feed Splitter Bottoms	6,276	-	83,172
Hydrovisbroken Distillates	24,376	-	337,644
Total Liquid Charge	30,652	-	420,816
Fresh Hydrogen Feeds			
from Hydrogen Plant	-	2,290	16,398
from Hydrogen Purification Unit	-	1,663	9,450
Recycled Gas	-	2,430	21,286
Total Reactor Gas Feed	-	6,383	47,134
GAS PLANT			
Total Gas Feed (to Absorber-Stripper)	-	1,413	111,806
Lean Oil Makeup (to Debut. Feed)	975	-	10,745
Absorber Overhead Dry Gas	-	944	37,062
Debutanizer Overhead Butane	7,165	-	59,512
Debutanizer Sidedraw Naphtha	1,798	-	16,585
Lean Oil Purge (from Debut. Bottoms)	843	-	9,396
DISTILLATE HYDROCRACKER UNIT			
Total Liquid Charge			
(Main Fractionator Bottoms)	44,184	-	563,618
Makeup Hydrogen	-	2,416	17,301
Recycled Gas	-	3,107	41,312
Total Reactor Gas Feed	-	5,524	58,613

Table 3

SUMMARY OF MAJOR REFINERY STREAM RATES

(continued)

	BPSD	MSCFH	M LB/HR
DISTILLATE HYDRCRACKER UNIT (continued)			
MAIN FRACTIONATOR			
Feeds:			
Naph. Hydrotreater Liquid Prod.	15,770	-	187,498
Dist. Hydrotreater Liquid Prod.	33,354	-	422,847
Dist. Hydrocracker Liquid Prod.	41,983	-	487,938
Lean Oil Purge from Gas Plant	843	-	9,396
Lean Oil Makeup to Gas Plant	975	-	10,745
Sidestripped Turbine Fuel	26,052	-	301,799
DEHEXANIZER TOWER			
Feeds:			
Main Fractionator Overhead	23,180	-	246,028
Gas Plant Naphtha Product	1,975	-	18,155
Overhead Naphtha Product	5,505	-	50,986
Bottoms Turbine Fuel Product	19,650	-	213,197
HYDROGEN PLANT			
Total Dry Gas Feedstock	-	2,015	69,889
Butane Feedstock	1,425	-	11,833
Reaction Water Feed	422	-	147,728
Makeup Gas Product	-	6,752	48,336
Carbon Dioxide Product	-	1,562	181,114
HYDROGEN PURIFICATION UNIT			
Feedstocks:			
Hydrovisbreaker High Pres. Bleed Gas	-	2,035	28,951
Dist. Hydrotreater High Pres. Bleed	-	1,982	17,358
Purified Hydrogen Product	-	3,209	18,235
Tail Gas (used as Hydrogen Plant feed)	-	808	28,074

M = thousands, e.g. 1 MSCFH = 1 thousand standard cubic feet per hour

Table 4

REFINERY PRODUCT YIELDS

Basis: JP-4 Turbine Fuel Production

Net Salable Products	BPSD	Vol% of Crude Oil Charge	lb/hour	Wt% of Crude Oil charge
JP-4 Turbine Fuel	44,298	88.60	499,180	69.80
Naphtha	3,290	6.58	30,468	4.26
Residuum	681	1.36	10,770	1.50
Ammonia (101.4 Tons/Day)	-	-	8,367	1.17
Sulfur (172.8 Tons/Day)	-	-	14,398	2.01
Sodium Sulfate	-	-	272	0.04
Net Unsold Product				
Carbon Dioxide (1.514 MMSCFH)	-	-	175,552	24.55
Totals			739,007	103.33

Table 5

REFINERY WEIGHT BALANCE

Basis: JP-4 Turbine Fuel Production

Boundary Limits:

Boundary limits for this balance include the oil and gas processing operations at all the major processing units and auxiliary units with these exceptions: combustion of refinery products used as fuels for all fired heaters, plus the desulfurization of resulting flue gases are considered outside the boundary.

Refinery Inputs:		lb/hr
Crude Oil		715,195
Coke-suppressing Additive		2,690
Natural Gas to Sulfur Recovery Unit		1,012
Reaction water for Hydrogen Plant steam reformer		147,728
Total Input		866,625
Refinery Outputs:		
To Fuels:	Butane	46,215
	Naphtha	18,952
	Residum	63,365
To Sales:	Naphtha	30,468
	JP-4 Turbine Fuel	499,180
	Residuum	10,770
	Sulfur (from Sulfur Recovery Unit)	13,757
	Ammonia	8,367
Vented:	Carbon Dioxide from Hydrogen Plant	175,552
Total Output		866,625

Streams outside Boundary Limits defined above:

Additional Refinery Input:

Natural Gas to the Flue Gas Desulfurization Unit	823

Additional Refinery Byproducts:

From the Flue Gas Desulfurization Unit

Sulfur	641
Sodium Sulfate	272

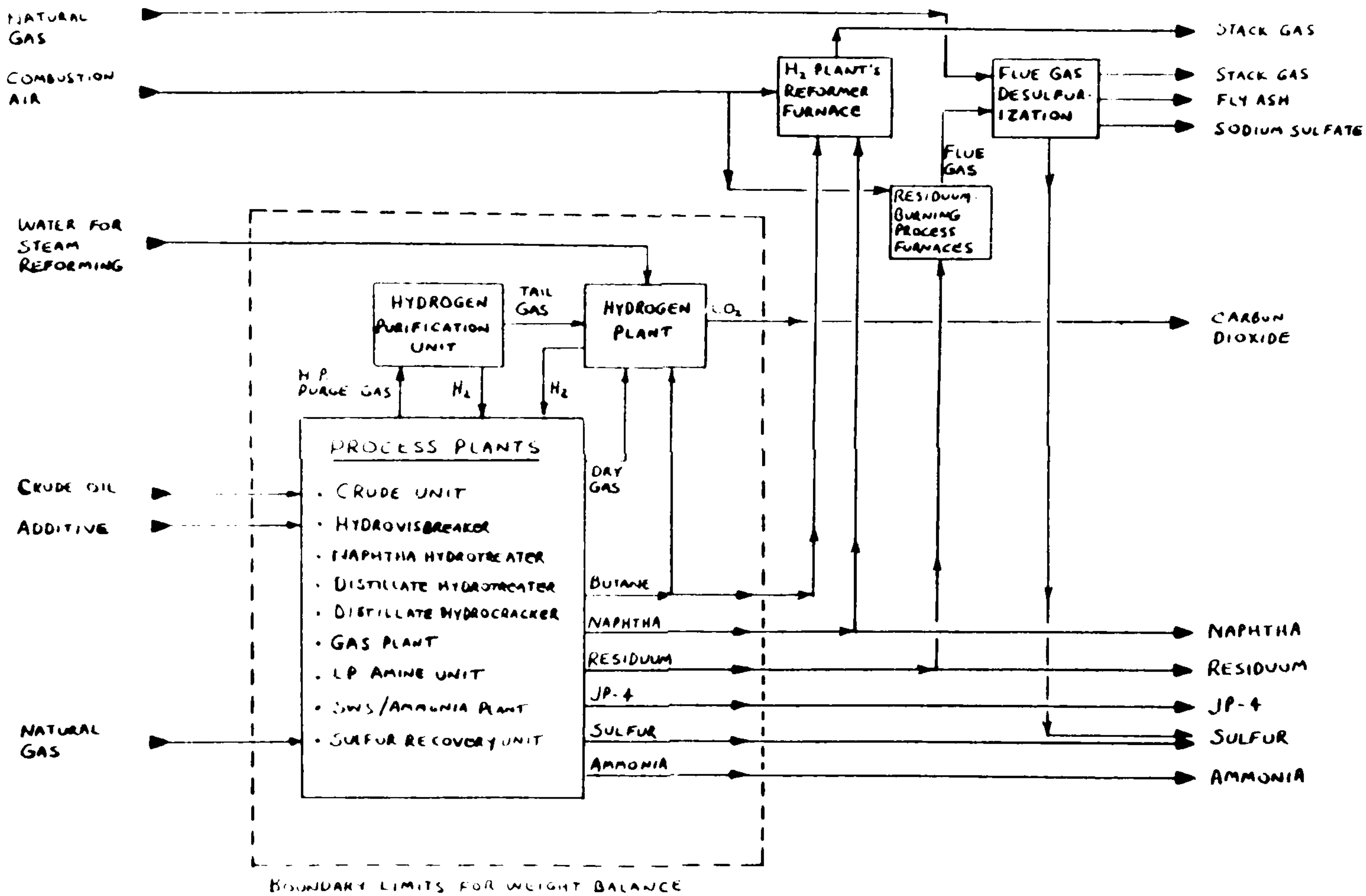

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Figure 3 - Refinery Weight Balance Boundary Limits

Table 6

REFINERY HYDROGEN BALANCE

Basis: JP-4 Turbine Fuel Production

	MAKE-UP HYDROGEN (95% hydrogen) from Hydrogen Plant		PURIFIED HYDROGEN (99% Hydrogen) from H2 Purification Unit	
HYDROGEN USERS	lb/hour	MMSCFD	lb/hour	MMSCFD
Hydrovisbreaker	11,960	40.08	8,785	37.11
Naphtha Hydrotreater	2,677	8.97	-	-
Distillate Hydrotreater	16,398	54.96	9,450	39.92
Distillate Hydrocracker	17,301	57.99	-	-
Totals	48,336	162.00	18,235	77.03
HYDROGEN SUPPLIERS				
Hydrogen Plant (Steam Reforming)				
From Dry Gas	42,085	141.1	-	-
From Butane	6,251	21.0	-	-
Hydrogen Purification (Pressure Swing Adsorption)				
From Recovered High-Pressure Purge Gases from the Hydro-Visbreaker and Distillate Hydrotreater Units	-	-	18,235	77.03
Totals	48,336	162.0	18,235	77.03

Table 7

REFINERY FUEL BALANCE

Basis: JP-4 Turbine Fuel Production

RESIDUUM FUEL REQUIREMENTS	Fired Duty MMBTU/HR	Residuum Fuel FOEB/DAY
MAIN REFINERY BOILER	244.0	976
PROCESS HEATERS		
Crude Unit		
H-1 Flash Tower Feed Heater	115.4	462
H-2 Vacuum Tower Feed Heater	53.7	215
Hydrovisbreaker		
H-1 Recycle Gas Heater	110.1	440
H-2 Atmospheric Tower Feed Heater	101.1	404
H-3 Vacuum Tower Feed Heater	60.7	243
Naphtha Hydrotreater		
H-1 Feed Splitter Reboiler	40.23	161
H-2 Recycle Gas Heater	28.34	113
H-3 Stripper Reboiler	14.23	57
Distillate Hydrotreater		
H-1 Recycle Gas Heater	48.55	194
H-2 Feed Heater	19.35	77
Distillate Hydrocracker		
H-1 Recycle Gas Heater	15.44	62
H-2 Main Fractionator Reboiler	182.87	732
TOTAL RESIDUUM FUEL REQUIREMENT	1034.0	4136
TOTAL RESIDUUM AVAILABLE		4839
REMAINING RESIDUUM NET PRODUCT		703

BUTANE & NAPHTHA FUEL REQUIREMENTS	Fired Duty MMBTU/HR	Fuel Consumed BBL/DAY @ 60°F
HYDROGEN PLANT REFORMER FURNACE		
Butane Product used as Fuel	917.5	5,743
Naphtha Product used as Fuel	371.5	2,111
Total Fired Duty	1289.0	

Table 8

REFINERY THERMAL EFFICIENCY

Basis: JP-4 Turbine Fuel Production

DEFINITION

$$\text{Thermal Efficiency} = \frac{\text{Heat of Combustion of Hydrocarbon Products} + \text{Energy Outputs}}{\text{Heat of Combustion of Hydrocarbon Feeds} + \text{Energy Inputs}} \times 100\%$$

		THERMAL VALUE BTU/HR
FEEDS:	Crude Oil	13,352,000,000
	Natural Gas	38,800,000
ENERGY INPUT:	Electrical Power	181,890,000
TOTAL INPUT:		13,572,690,000
PRODUCTS:	Naphtha to Sales	765,930,000
	JP-4 Turbine Fuel to Sales	10,238,770,000
	Residuum to Sales	190,420,000
TOTAL OUTPUT:		11,195,120,000

REFINERY THERMAL EFFICIENCY = 100 % x (11,195,120,000 / 13,572,690,000)

= 82.5 %

Table 9

REFINERY ELECTRICAL REQUIREMENTS

Basis: JP-4 Turbine Fuel Production

	Brake Horsepower Operating	Brake Horsepower Installed
Crude Unit	2,000	3,500
Hydrovisbreaker Unit	5,716	10,132
Naphtha Hydrotreater Unit	2,262	3,525
Distillate Hydrotreater Unit	3,522	6,021
Distillate Hydrocracker Unit	6,745	12,290
Gas Plant	395	790
Hydrogen Plant	29,377	35,448
Hydrogen Purification Unit	4,000	4,000
Low Pressure Amine Unit	31	62
Sour Water Stripper/Ammonia Plant	1,314	2,628
Sulfur Recovery Unit	257	514
Flue Gas Desulfurization Unit	2,950	2,950
Boiler House and Water Treating	1,200	2,400
Cooling Water System	7,200	14,400
Crude Oil and Product Transfer	1,600	3,200
Plant Air Compression	2,400	2,400
Waste Water Treating & Misc.	500	1,000
Totals BHP	71,469	105,260
Equivalent Kilowatts	53,294	78,492
MMBTU/HR	181.89	267.89

Table 10

REFINERY STEAM BALANCE

Basis: JP-4 Turbine Fuel Production

	STEAM CONSUMED, lb/hr			
	450 psig	150 psig	50 psig	Total
Crude Unit	20,000	11,000	10,000	41,000
Hydrovisbreaker	19,200	31,460	41,200	91,860
Naphtha Hydrotreater	1,000	5,000	5,000	11,000
Distillate Hydrotreater	25,080	5,000	10,000	40,080
Distillate Hydrocracker	91,500	34,500	-	126,000
Gas Plant	33,294	39,600	14,376	87,270
Hydrogen Plant	-	-	-	-
Hydrogen Purification	-	19,200	-	19,200
Low Pressure Amine Unit	1,310	-	12,500	13,800
Sour Water Strip/Ammonia Plant	-	90,000	118,000	208,000
Sulfur Recovery Unit	-	-	-	-
Flue Gas Desulfurization	-	45,007	-	45,007
Boiler House and Water Treating	-	-	116,131	116,131
Totals	191,384	280,767	327,207	799,358

	STEAM PRODUCED, lb/hr			
	450 psig	150 psig	50 psig	Total
Crude Unit	-	36,000	-	36,000
Hydrovisbreaker	32,450	126,025	90,625	249,100
Naphtha Hydrotreater	-	18,900	10,000	28,900
Distillate Hydrotreater	44,970	10,600	46,700	102,270
Distillate Hydrocracker	51,000	43,400	-	94,400
Gas Plant	-	-	-	-
Hydrogen Plant	-	-	-	-
Hydrogen Purification	-	-	-	-
Low Pressure Amine Unit	-	-	-	-
Sour Water Strip/Ammonia Plant	-	-	-	-
Sulfur Recovery Unit	9,000	-	28,900	37,900
Flue Gas Desulfurization	-	-	-	-
Boiler House and Water Treating	53,964	45,842	150,982	250,788
Totals	191,384	280,767	327,207	799,358

Table 11

REFINERY BOILER FEED WATER BALANCE

Basis: JP-4 Turbine Fuel Production

Steam Condensate Recycled as Boiler Feed Water

Condensate Recycled from:	Condensate Recycled lb/hr
Crude Unit	-
Hydrovisbreaker Unit	31,510
Naphtha Hydrotreater Unit	-
Distillate Hydrotreater Unit	-
Distillate Hydrocracker Unit	94,500
Gas Plant	77,270
Hydrogen Plant	-
Hydrogen Purification Unit	19,200
Low Pressure Amine Unit	13,810
Sour Water Stripper and Ammonia Plant	182,000
Sulfur Recovery Unit	-
Flue Gas Desulfurization Unit	45,007
Boiler House and Water Treating	116,131
Total	579,428

Boiler feed water to produced steam	799,358	lb/hr
Boiler feed water to blowdown loss	79,939	lb/hr
Total boiler feedwater supply required	879,297	lb/hr
Condensate recycled as boiler feed water	579,428	lb/hr
Makeup boiler feedwater required	299,869	lb/hr

Table 12
REFINERY COOLING WATER REQUIREMENTS

Basis: JP-4 Turbine Fuel Production

	Cooling Water gal/min
Crude Unit	3,000
Hydrovisbreaker Unit	11,228
Naphtha Hydrotreater Unit (air-cooled)	-
Distillate Hydrotreater Unit	2,973
Distillate Hydrocracker Unit	12,650
Gas Plant	7,460
Hydrogen Plant	49,232
Hydrogen Purification Unit	3,821
Low Pressure Amine Unit	480
Sour Water Stripper and Ammonia Plant	1,720
Sulfur Recovery Unit	3,390
Flue Gas Desulfurization Unit	2,403
Total	98,357

Table 13

REFINERY OPERATING REQUIREMENTS

CATALYST AND CHEMICALS

COKE-SUPPRESSING ADDITIVE FOR HYDROVISBREAKER

Trade name:	8% Molybdenum Octoate
Chemical name:	Molybdenum 2-ethyl hexoate
Chemical family:	Metal carboxylate
Molecular formula:	$Mo(C_8H_{15}O_2)_2$
Normal physical state:	Liquid

Design dosage:

Based on pilot plant experiments which used an additive concentration of 1.63 wt% of Hydrovisbreaker fresh feed (i.e. Crude Unit vacuum residuum). This is equivalent to 367 wt. ppm molybdenum in the total reactor liquid feed (including combined fresh feed, recycled naphtha and additive). Elemental molybdenum is 8 wt% of the additive before dilution in recycled naphtha.

Consumption:

2690 lb/hr of 8% Molybdenum Octoate (undiluted)
21,207,960 lb/yr for 90% on-stream operation.

Cost:

Manufacturer's estimate, if additive were produced on a large scale, is $2/lb. Total annual cost is $42,415,920.

Table 13

REFINERY OPERATING REQUIREMENTS

CATALYST AND CHEMICALS
(continued)

HYDROPROCESSING CATALYSTS

Naphtha Hydrotreating Unit

Design basis: Ketjen KF-840 hydrotreating catalyst (Nickel-Moly on alumina). Single reactor with 1272 cu.ft. volume, operated at 2.5 liquid hourly space velocity. Initial fill is 59,784 lb. costing $209,244.

Expect 24 month run-life and 5-year total use with in-situ regeneration after second and fourth year. Replace after fifth year of use. Each regeneration would cost $89,676.

Distillate Hydrotreating Unit

Design basis: Ketjen KF-840 hydrotreating catalyst (Nickel-Moly on alumina). Three identical reactors with a combined volume of 14,844 cu.ft. operated in series with overall 0.49 liquid hourly space velocity. Initial total fill is 679,668 lb. costing $2,378,838.

Expect 24-month run-life and 4-year total use with in-situ regeneration once after second year. Replace after fourth year. Each regeneration would cost $1,019,502.

Distillate Hydrocracking Unit

Design basis: a high-activity hydrocracking catalyst (Nickel-Moly on zeolite). Single reactor with 2477 cu.ft. volume operated at a 2.5 liquid hourly space velocity. Initial fill is 116,420 lb. costing $1,629,880.

Expect 24 month run-life and 4-year total use with ex-situ regeneration after second years of use. Replace after fourth. Each regeneration would cost $465,680.

Table 13

REFINERY OPERATING REQUIREMENTS

CATALYST AND CHEMICALS
(continued)

HYDROGEN PLANT REQUIREMENTS

Consumption estimated from Stanford Research Institute data.

	Annual consumption cu.ft./year	Annual Cost $/year
Hydrodesulfurization catalyst	449	47,052
Zinc oxide	1,373	128,111
Reformer catalyst	634	73,838
High-temperature shift catalyst	1,848	107,613
Low-temperature shift catalyst	2,112	368,959
Methanation catalyst	243	28,417
	lb/year	$/year
Potassium carbonate	369,600	77,565
98% Hydrosulfuric acid	1,845,360	64,521
50% Sodium Hydroxide	546,480	51,011

HYDROGEN PURIFICATION UNIT

Cost of molecular sieves is non-recurring and included in capital cost.

SULFUR RECOVERY UNIT

	$/year
Claus catalyst (per vendor estimate)	32,430

FLUE GAS DESULFURIZATION UNIT

Estimated from Stanford Research Institute data.		$/year
Soda ash	871 tons/year	99,679
Catalyst		23,319

Table 14

REFINERY OPERATING REQUIREMENTS

FEEDSTOCK, UTILITIES, AND LABOR

FEEDSTOCKS

Crude oil	50,000 barrels per operating day at $20 per barrel, $328,500,000 per year for 90% on-stream operations
Natural gas	Used as reducing gas for Claus Units at the Sulfur Recovery Unit and the Flue Gas Desulfurization Unit.
	38.8 MMBTU/hour at $20 per FOE Barrel (6 MMBTU), $1,019,664 per year for 90% on-stream operations

UTILITIES

Cooling Water	98,357 gal/min at $.07/1000 gal $3,256,876 per year for 90% on-stream operations
Boiler Feed Water	880,000 lb/hr circulation at $.40/1000 lb $2,775,000 per year for 90% on-stream operations
Electrical Power	53,294 KW at $.05/KW•HR $21,008,495 per year for 90% on-stream operations
Steam	450 psig: 191,384 lb/hr produced 150 psig: 280,767 lb/hr produced 50 psig: 327,207 lb/hr produced

The cost of steam is essentially the cost of boiler feedwater (above), because no imported fuel is used to produce steam. Nearly 69% of all the steam is made using recovered heat, and only 31% is made at the main refinery boiler. The main boiler is fueled by 976 FOE BBL/DAY of the Residuum product from the Hydrovisbreaker, whose cost essentially was already included in the cost of crude oil. Theoretically the 976 FOEB/DAY is equivalent to $19,520 day, or $6,412,320 per year (90% on-stream) of unrealized resid sales. Realistically, the resid is difficult to sell.

LABOR AND RELATED EXPENSES

Labor	16 Operator positions per shift:	$ 2,470,000 per year
	8 Helper positions each shift:	1,080,000 per year
	Total labor:	3,550,000 per year
Supervision @ 25 % of labor:		890,000 per year
Overhead @ 100 % of labor:		3,550,000 per year
Total:		$ 7,990,000 per year

Table 15

ROYALTY PAYMENTS

SOUR WATER STRIPPER AND AMMONIA RECOVERY PLANT

Licensor:	Chevron
Process:	Chevron WWT Process
Fixed Royalty:	$400,000 paid over 2 years
Running Royalty:	$ 87,500 per year, based on projected recovery of hydrogen sulfide and ammonia. This will vary with actual recovery rates.

SULFUR RECOVERY UNIT

A royalty is required for the BSR/MDEA Tail Gas Unit, which follows the twin Claus sulfur recovery units. There is no royalty on the Claus units.

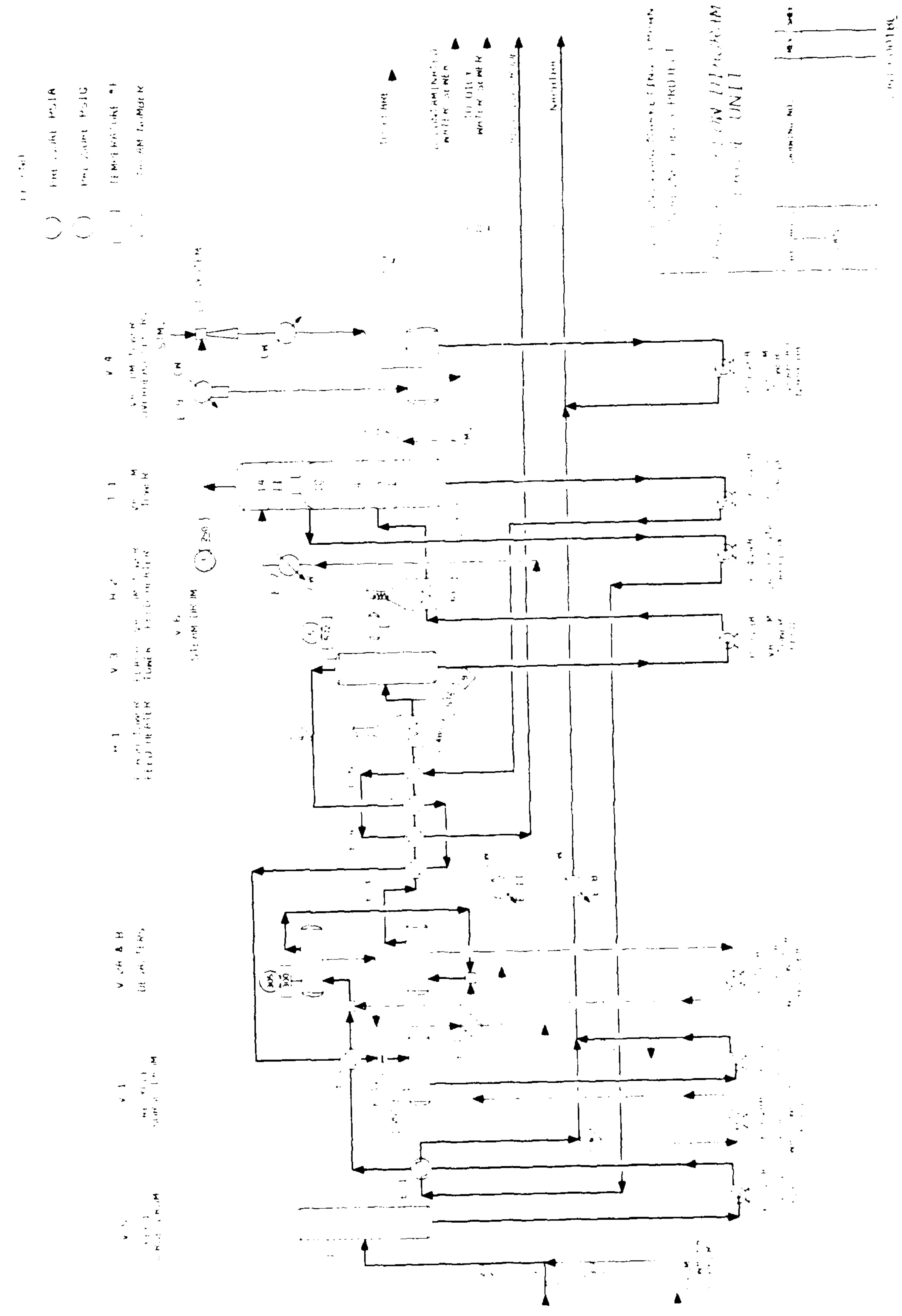
Licensor:	Ralph M. Parsons Company
Process:	BSR/MDEA Tail Gas Unit
Total royalty:	$172,000 (based on 165 tons/day sulfur production)
	25% payable upon signing the licensing agreement 25% payable upon the start of construction 25% payable upon completion of mechanical construction 25% payable after performance guarantee is met

V. PROCESS DESIGN SPECIFICATIONS AND PROCESS FLOW DIAGRAMS

PROCESS DESIGN SPECIFICATIONS

for the

CRUDE DISTILLATION UNIT



CRUDE DISTILLATION UNIT
MATERIAL BALANCE AND STREAM PROPERTIES

Stream Number	1	2	3	4	5	6	7	8	9
Stream Label	Crude Oil Feed	Diluted Crude	Diluent	Flash Vapor	Flash Product	Vacuum Naphtha	Vacuum Tower Overhead	Naphtha Product	Flashed Crude
Stream Conditions									
Temperature, F	150	175	250	572	250	368	250	100	572
Physical state	Liquid	Liquid	Liquid	Vapor	Liquid	Liquid	Vapor	Liquid	Liquid
API Gravity	12.7	17.1	32.8	32.8	32.8	25.4	36.7	28.0	11.7
Sp.Gr. @ 60 F	0.981	0.952	0.861	-	0.861	0.902	0.842	0.887	0.988
Sp.Gr. @ Temp.	0.950	0.910	0.800	-	0.800	0.800	-	-	0.830
Pressure, psia	50	50	50	21	105	7.1	7.0	100	21
BBLS/DAY @ 60 F	50,000	66,008	16,008	18,568	2,560	7,209	778	10,547	47,440
lb/hr	714,000	914,948	200,948	233,089	32,142	94,760	9,543	136,445	683,054
GPM @ 60 F	1,458	1,925	467	-	75	210	-	310	1,384
Vis., cSt @ Temp.	450	22	0.66	-	0.66	-	-	1.7	2.0

Stream Number	10	11	12	13
Stream Label	Reduced Crude	Desalter Water	Steam	Vacuum Tower Vent
Stream Conditions				
Temperature, F	572	110	300	100
Physical state	Liquid	Liquid	Vapor	Vapor
API Gravity	11.7	10.0	-	(29 mole wt.)
Sp.Gr. @ 60 F	0.988	1.00	-	-
Sp.Gr. @ Temp.	0.830	-	-	-
Pressure, psia	21	100	55	20
BBLS/DAY @ 60 F	47,440	3,960	-	-
lb/hr	683,054	57,750	10,000	400 (a)
GPM @ 60 F	1,384	116	-	-
Vis., cSt @ Temp.	2.0	1	-	-

(a) Non-condensables

CRUDE UNIT DESIGN BASIS

Crudes and Rates

The unit is designed to process 50,000 BPSD of 12.7 °API San Ardo California crude. This unit will be capable of maintaining a 95% on stream factor.

Plant Processing Steps

The crude is first mixed with 16,000 BPSD of recycled distillate and is desalted under pressure at 300°F in the presence of 6 volume percent water containing a demulsifying chemical. This water extraction step is necessary to remove compounds such as sodium chloride which would cause system corrosion and pluggage. The naphtha recycle is necessary to reduce viscosity for effective desalting.

For maximizing thermal efficiency the desalted crude is heated to 480°F by heat exchange against distillation products. The crude is then heated to 570°F and the pressure reduced in a low pressure chamber (flash tower). A fired heater is required to raise the temperature from 480° to 570°F. Light naphtha is vaporized off the flash tower, cooled and liquified to produce the 16,000 BPSD of naphtha recycle required for desalting.

The flashed crude temperature is then further heated to 630°F with fired heat. The heater effluent is fed to a vacuum tower to vaporize an overhead distillate product having a nominal boiling range of 160-650°F. This overhead is fed to the feed splitter tower at the Naphtha Hydrotreater Unit.

Distillation Products

A small amount of net naphtha product is recovered from the flash tower vapors and is mixed with the light distillate overhead product from the vacuum tower. The crude oil residuum boiling above 650°F is recovered as feedstock for the hydrovisbreaker unit.

Product	BPSD	Volume% of Crude	Nominal Boiling range	Gravity °API
Flashed Naphtha to recycle	16,008	32.0%	160-650°F	32.8
Flashed Naphtha to Product	2,560	5.1%	160-650	32.8
Vac. Twr. Distillate Prod.	8,074	16.1%	160-650	32.8
Total Distillate Products	10,634	21.3%	160-650	32.8
Vac. Twr. Btms. Product	39,366	78.7%	650-1250+	9.1

CRUDE DISTILLATION UNIT

Utilities and Chemical Requirements

Saturated Steam Produced, lb/hr

Steam Generators:	450 psig	150 psig	50 psig	Total
H-1	-	24,160	-	24,160
V-6 at Heater H-2	-	11,370	-	11,370
Totals	-	35,530	-	35,530

Steam Used, lb/hr

	450 psig	150 psig	50 psig	Condensate Recovered
Heater H1	13,650	-	-	
Heater H2	6,350	-	-	-
Vacuum jet system		11,000	-	-
Miscellaneous	-	-	10,000	-
Totals	20,000	11,000	10,000	-
Net Steam Export	-20,000	24,530	-10,000	

Boiler Feed Water, lb/hr

Steam production (rounded)	36,000	
For 10% blowdown	3,600	
Total BFW needed	39,600	
Condensate recovered	-	
Net BFW make-up	39,600	=79 GPM

Cooling Water Circulated

Exchanger	Rate	Supply	Return	Duty
E-7	510	85	105	5.1 MMBTU/hr
E-8	700	85	105	7.0
E-9 Vacuum System	1733	85	100	13.0
Total	2943			25.1 MMBTU/hr

Make-up, at 3% circulation rate 88 GPM

CRUDE DISTILLATION UNIT

Utilities and Chemical Requirements
(continued)

Heater Fuel Fired (Hydrovisbreaker vacuum residuum)

Heater H-1	115.44 MMBTU/HR
Heater H-2	53.7
	169.1 MMBTU/HR = 28.1 BBL/hr
	= 9,840 lb/hr Residuum Fuel

Electrical Power

Pumps:		Brake Horsepower Operating	Brake Horsepower Connected
P-1,1A	Crude feed	700	1,400
P-2,2A	Diluent recycle	50	100
P-3,3A	Vacuum Tower feed	325	650
P-4,4A	Circulating reflux	125	250
P-5,5A	Reduced crude	200	200
P-6,6A	Vacuum tower overhead	6	8
P-7,7A	Wash water booster	20	40
P-8,8A	Desalter wash water	60	120
P-9,9A	Boiler feed water	20	40
P-10,10A	Desalting chemical	1	2
Other:			
V-2A,B	Desalters	350	350
	Total Brake Horsepower	1855 BHP	3360 BHP
	Kilowatts (220 & 440V)	1383 KW	2505 KW

Air Requirements

Instrument air	50 psig	100 SCFM
Plant air	120 psig	

Chemicals

Demulsifier for desalters 33 gal/day

CRUDE DISTILLATION UNIT

List of Major Equipment

Heat Exchangers

E-1	Circulating reflux - Desalter feed exchanger
E-2	Flash tower overhead - Desalter feed exchanger
E-3	Flash tower preheater - No. 1
E-4	Flash tower preheater - No. 2
E-5	Flash tower preheater - No. 3
E-6	Flash tower preheater - No. 4
E-7	Circulating reflux trim cooler
E-8	Naphtha product cooler
E-9	Vacuum tower overhead condenser
E-10	Desalter water feed - effluent exchanger
E-11	Desalter effluent water cooler
E-12	Vacuum tower after-condenser
E-13	Recycle air cooler

Fired Heaters

H-1	Flash tower feed heater
H-2	Vacuum tower feed heater

Pumps

P-1,1A	Crude feed pumps
P-2,2A	Recycle pumps
P-3,3A	Vacuum tower feed pumps
P-4,4A	Circulating reflux pumps
P-5,5A	Reduced crude pumps
P-6,6A	Vacuum tower overhead naphtha product pumps
P-7,7A	Desalter wash water booster pumps
P-8,8A	Desalter wash water feed pumps
P-9,9A	Boiler feed water pumps
P-10,10A	Desalting chemical pumps

Distillation towers

T-1	Vacuum distillation tower

Vessels

V-1	Recycle surge drum
V-2A	Desalter No. 1
V-2B	Desalter No. 2
V-3	Flash tower
V-4	Vacuum tower overhead receiver
V-5	Crude feed surge drum
V-6	Steam drum

CRUDE DISTILLATION UNIT

San Ardo Crude Oil Assay Data

Whole Crude Properties		1984 Analyses		1985 Analyses
Gravity, °API		12.8		12.68
Sp.Gr. @ 60°F		0.9806		0.9814
Density, g/cc				0.9523
Kinematic Visc.	@ 77°F	12,698.2		-
	@ 100°F	3,293.6		3,935.55
	@ 210°F	-		77.37
Pour Point, °F		35		-
Flash Point, °F		194		-
Carbon, Wt%		81.62		-
Hydrogen, Wt%		10.51		-
Oxygen, Wt%		1.82		-
Sulfur, Wt%		1.89		1.9
Nitrogen, Basic, ppm		2,287	(.2287 wt%)	3009
Total, ppm		13,200		10,544
Metals, ppm	Fe	42		59
	Ni	78		70
	Cu	0.9		<0.1
	V	96		68
Ash, Wt%		0.12		-
Ramscarbon, Wt%		8.68		-
Salt content, lb/1000 BBL		34		6.27
BS&W, Vol%		-		0.34

True Boiling Point Fractions:

	Spec. Grav. 60/60°F		Kinematic Viscosity, cSt			Sulfur
	Hydrometer	Densitometer	100°F	160°F	210°F	Wt%
IBP-400°F	0.8272	0.8224	1.18	0.80	-	0.328
400-475	0.8655	0.8617	1.94	-	0.76	0.446
475-550	0.8874	0.8877	3.33	-	2.08	0.822
550-650	0.9124	0.9105	8.49	-	2.10	1.119
650-725	0.9377	0.9372	40.15	-	4.61	1.365
725-800	0.9486	0.9479	88.02	-	6.73	1.376
800-900	0.9673	0.9674	829.40	-	18.81	1.372
900-932	0.9716	0.9761		189.61	-	1.504
932+	1.0329	-	-	-	-	-
Whole Crude	0.9806	0.9814	3935.55	-	77.37	1.9

CRUDE DISTILLATION UNIT

San Ardo Crude Oil Assay Data
(continued)

True Boiling Point Distillation

Accumulated Volume % Distilled	Temperature
0	179
2	335
5	445
7	465
10	504
15	560
20	612
25	655
30	708
35	752
40	795
45	840
50	883
55	925
60	968
65	1010
70	1050
75	1088
80	1126
85	1165
90	1205
95	1300
100	1300+

Section	Item	No.	E-1 Shell	E-1 Tube	E-2 Shell	E-2 Tube	E-3 Shell	E-3 Tube	E-4 Shell	E-4 Tube	E-5 Shell	E-5 Tube
SERVICE	ITEM NO	1	E-1		E-2		E-3		E-4		E-5	
	SERVICE	2	CIRC REFLUX -		FLASH TOWER [illegible]		FLASH TOWER		FLASH TOWER		FLASH TOWER	
		3	DESALTER FEED		DESALTER [illegible]		[illegible]		[illegible]		PREHEATER NO 3	
	MANUFACTURER - NO SHELLS	4		2		1		[illegible]		1		1
	SIZE AND TYPE	5		AES		AJS		AJS		AES		AJS
	SURFACE/UNIT - /SHELL FT²	6	15,200	7,600	6,000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5,000	[illegible]
UNIT PERFORMANCE		7	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE
	CONNECTED IN	8	SERIES	SERIES	—	—	—					
	FLUID CIRCULATED	9	CIRC REFL	[illegible]	FLASH TWR	[illegible]	FLASH TWR	[illegible]	[illegible]	VACUUM	FLASH TWR	[illegible]
		10	S.S NAPH	[illegible] DESALT-D)	CMD WATER	[illegible]	[illegible]			TWR BTMS	OHD VAPOR	[illegible]
	QUANTITY LBS/HR (M.#) — LIQUID	11	[illegible]	915.0	[illegible]	915.0	[illegible]	915.0	915.0	5776	—	915.0
	VAPOR / MW	12		—	92 7/446	—	1290/109	—	—	—	2331	—
	FIXED GASES MW	13	—	—		—		—	—	—	—	—
	STEAM	14	—		—	—		—	—	—	—	—
	TOTAL	15	5340	915.0	2331	915.0	2331	915.0	915.0	5776	2331	915.0
	FLUID VAPORIZED OR CONDENSED	16	—	—	470	—	363	—	—		1041	—
	STEAM CONDENSED	17	—	—	—	—	—	—	—	—	—	—
	GRAVITY · LIQUID (SG) AT °F (AV)	18	0.82	[illegible]	0.77	0.87	.78	[illegible]	0.85	0.8[illegible]	0.74	0.84
	VISCOSITY · LIQUID (CP) AT °F (AV)	19	[illegible]	9.0	0.8	4.0	0.6	2.7	2.5	56	0.5	1.7
	SPEC HEAT · LIQUID · BTU/LB	20	0.54	0.48	0.53	0.49	0.5[illegible]	0.52	0.53	0.57	0.52	0.56
	LATENT HEAT · VAPOR · BTU/LB	21		—	—	—		—				—
	OPER TEMP °F IN OUT	22	[illegible]	[illegible]/212	36[illegible]/3[illegible]	212/[illegible]	[illegible]	[illegible]	[illegible]/36[illegible]	[illegible]	512/[illegible]	345/405
	OPER PRESSURE PSIG	23	50	340	4	330	[illegible]	[illegible]	265	[illegible]	[illegible]	[illegible]
	MINIMUM FOULING FACTOR	24										
	NUMBER OF PASSES	25										
	VELOCITY · FT/SEC	26										
	PRESSURE DROP · PSI [illegible]	27	[illegible]	15	[illegible]	[illegible]	[illegible]	10		10	[illegible]	[illegible]
	HEAT EXCHANGED · BTU/HR (MM)	28	4.8		[illegible]		[illegible]		[illegible]		32.0	
	MTD CORRECTED · WEIGHTED	29	[illegible]		34[illegible]		[illegible]		120		84.6	
	TRANSFER RATE SERVICE · CLEAN	30	[illegible]		[illegible]				40		75	
CONSTRUCTION	DESIGN PRESSURE · PSIG	31	[illegible]	[illegible]	[illegible]	450	[illegible]	[illegible]	450	[illegible]	50	450
	TEST PRESSURE · PSIG	32	[illegible]	[illegible]	[illegible]	675	[illegible]	[illegible]	675	135	[illegible]	[illegible]
	DESIGN TEMPERATURE · °F	33	[illegible]	[illegible]	[illegible]	450	450	[illegible]	550	550	625	625
	CORROSION ALLOWANCE	34	1/8	[illegible]	[illegible]	1/8"	1/8	[illegible]	1/8"	1/8"	1/8	1/8
	CONNECTIONS SIZE · STD · TYPE — IN	35										
	OUT	36										
	TUBES — MAT'L / NO	37	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	CS	[illegible]	[illegible]	[illegible]
	OD / BWG	38		3/4 / [illegible]		3/4 / [illegible]	[illegible]			1" [illegible]		3/4 [illegible]
	LENGTH / PITCH	39		24' / [illegible]		[illegible]	[illegible]			2' / 1 3/4		[illegible]
	SHELL · ID · OD	40	[illegible]		50		[illegible]		[illegible]		4[illegible]	
		41	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS
	STATIONARY TUBE SHEET	42										
	FLOATING TUBE SHEET	43	[illegible]		[illegible]							
	CROSS BAFFLES	44										
	LONGITUDINAL BAFFLES	45										
	TUBE SUPPORTS	46										
	SHELL	47										
	SHELL COVERS	48										
	FLOATING HEAD COVER	49										
	CHANNEL	50										
	CHANNEL COVER	51										
	CROSS BAFFLES TYPE · SPACING	52										
	LONGITUDINAL BAFFLE TYPE	53										
	GASKETS	54										
	WELDING FLANGES AND NOZZLES	55										
	STUDS	56										
	WEIGHT EXCHANGER DRY WET	57										
	WEIGHT BUNDLE	58										
	CODE REQUIREMENTS	59										
	SUN OIL CO DRAWING NO	60										
	REQUISITION NO	61										
	PURCHASE ORDER NO	62										

NOTES

SR = STRESS RELIEVED
XR = X RAYED

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

HEAT EXCHANGER SCHEDULE

PLANT Air Force - Crude Unit

PLANT NO. UNIT NO

LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
L				1

DATE [illegible]

FORM [illegible] REV

		No.										
SERVICE	ITEM NO	1	E-6		E-7		E-8		E-9		E 10	
	SERVICE	2	[illegible]		[illegible]		NAPHTHA PRODUCT		VACUUM TOWER		DEAERATOR WATER	
		3	[illegible]		[illegible]		COOLER		OVERHEAD COND		[illegible]	
	MANUFACTURER — NO SHELLS	4		2		1						2
	SIZE AND TYPE	5		AES		AES		AES		ATS		AEC
	SURFACE/UNIT — /SHELL	6	[illegible]	[illegible]	76.0	[illegible]	25.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		7	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE
UNIT PERFORMANCE	CONNECTED IN	8	SERIES									
	FLUID CIRCULATED	9	CRUDE	VACUUM	[illegible]	COOLING	NAPHTHA	COOLING	[illegible]	[illegible]	FRESH	[illegible]
		10	OIL	TWR BTMS	[illegible]	WATER		WATER	STEAM	[illegible]	WATER	WATER
	QUANTITY LBS/HR — LIQUID	11	915.0	[illegible]	534.0	[illegible]	26.9	[illegible]		[illegible]	[illegible]	[illegible]
	VAPOR MW	12	—	—	—	—	—	—	[illegible]	—	—	—
	FIXED GASES MW	13	—	—	—	—	—	—		—	—	—
	STEAM	14		—	—	—	—	—	[illegible]	—	—	—
	TOTAL	15	915.0	[illegible]	534.0	[illegible]	126.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	FLUID VAPORIZED OR CONDENSED	16	—		—	—			95	—		
	STEAM CONDENSED	17	—						10.0			
	GRAVITY — LIQUID (SG) AT °F AVE	18	0.82	0.83	[illegible]		0.86	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	VISCOSITY — LIQUID (CP) AT °F AVE	19	[illegible]	3.0	1.6	[illegible]	1.9	[illegible]	0.8	[illegible]	0.2	[illegible]
	SPEC HEAT — LIQUID — BTU/LB	20	[illegible]	[illegible]	[illegible]	[illegible]	0.47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	LATENT HEAT — VAPOR — BTU/LB	21										
	OPER TEMP °F — IN — OUT	22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	OPER PRESSURE — PSIG	23	65	65	[illegible]	[illegible]	4		[illegible]	[illegible]	[illegible]	[illegible]
	MINIMUM FOULING FACTOR	24										
	NUMBER OF PASSES	25										
	VELOCITY — FT/SEC	26										
	PRESSURE DROP — PSI	27										
	HEAT EXCHANGED — BTU/HR MM	28	[illegible]		5.1				[illegible]			
	MTD CORRECTED — WEIGHTED	29							[illegible]			
	TRANSFER RATE SERVICE — CLEAN	30										
CONSTRUCTION	DESIGN PRESSURE — PSIG	31	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TEST PRESSURE — PSIG	32	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	DESIGN TEMPERATURE — °F	33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	CORROSION ALLOWANCE	34	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	CONNECTIONS — IN	35										
	SIZE — STD TYPE — OUT	36										
	TUBES — MAT'L — NO	37		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]
	O.D. — BWG	38		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]
	LENGTH — PITCH	39		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]
	SHELL — I.D. — O.D.	40	[illegible]		[illegible]			[illegible]		[illegible]		[illegible]
		41	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS
	STATIONARY TUBE SHEET	42										
	FLOATING TUBE SHEET	43	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
	CROSS BAFFLES	44	[illegible]		[illegible]		[illegible]		[illegible]			
	LONGITUDINAL BAFFLES	45										
	TUBE SUPPORTS	46	[illegible]									
	SHELL	47	[illegible]				[illegible]					
	SHELL COVERS	48	[illegible]		[illegible]		[illegible]					
	FLOATING HEAD COVER	49	[illegible]									
	CHANNEL	50										
	CHANNEL COVER	51										
	CROSS BAFFLES TYPE — SPACING	52										
	LONGITUDINAL BAFFLE TYPE	53										
	GASKETS	54										
	WELDING FLANGES AND NOZZLES	55										
	STUDS	56										
	WEIGHT EXCHANGER — DRY — WET	57										
	WEIGHT BUNDLE	58										
	CODE REQUIREMENTS	59										
	SUN OIL CO DRAWING NO	60										
	REQUISITION NO	61										
	PURCHASE ORDER NO	62										

NOTES

SR STRESS RELIEVED
XR = X RAYED

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

HEAT EXCHANGER SCHEDULE

PLANT [illegible]

PLANT NO — UNIT NO

LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
[illegible]				2

DATE [illegible]/25/87

FORM [illegible]

Item	No.										
ITEM NO	1	E-11		E-12		E-13					
SERVICE	2	DESALTER EFFLUENT		VACUUM TOWER		RECYCLE AIR					
	3	WATER COOLER		AFTER COND.		COOLER					
MANUFACTURER - NO SHELLS	4		1		1		1				
SIZE AND TYPE	5		AES	BY CRILL							
SURFACE/UNIT - /SHELL	6	1400	1400	REYNOLDS			450*				
	7	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE
CONNECTED IN	8	—	—								
FLUID CIRCULATED	9	BRACKISH	COOLING		COOLING WATER		FL. TWR				
	10	WATER	WATER			AIR	CNHD				
Entering QUANTITY LBS/HR (M.lb) — LIQUID	11	60.0	92.0		50		189.4				
VAPOR MW	12	—	—				43.9				
FIXED GASES MW	13	—	—								
STEAM	14	—	—								
TOTAL	15	60.0	92.0				233.3				
FLUID VAPORIZED OR CONDENSED	16	—	—				43.9				
STEAM CONDENSED	17	—	—								
GRAVITY - LIQUID (SG)(API) AT °F	18	1.0	1.0				.75				
VISCOSITY - LIQUID (SSU)(CP) AT °F (av)	19	C.5	0.8				1.0				
SPEC HEAT - LIQUID - BTU/LB (av)	20	1.0	1.0				.55				
LATENT HEAT VAPOR - BTU/LB	21	—	—								
OPER TEMP °F IN OUT	22	90/110	85/110		85/105	10/120	300/150				
OPER PRESSURE PSIG	23	285	50		50						
MINIMUM FOULING FACTOR	24										
NUMBER OF PASSES	25										
VELOCITY - FT/SEC	26										
PRESSURE DROP - PSI (allowable)	27		10				5				
HEAT EXCHANGED - BTU/HR (MM)	28	4.8		1.0		12.5					
MTD CORRECTED - WEIGHTED	29	35.3				165					
TRANSFER RATE SERVICE - CLEAN	30	90				80*					
DESIGN PRESSURE - PSIG	31	4..	75								
TEST PRESSURE - PSIG	32	600	105								
DESIGN TEMPERATURE - °F	33	300	300								
CORROSION ALLOWANCE	34	1/8"	1/8"								
CONNECTIONS IN	35		[illegible]								
SIZE STD TYPE OUT	36		[illegible]								
TUBES MAT'L NO	37	25	ADM								
TUBES OD BWG	38		3/4 / [illegible]								
TUBES LENGTH PITCH	39		20 / [illegible]								
SHELL ID OD	40	24"									
	41	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS
STATIONARY TUBE SHEET	42	NKE									
FLOATING TUBE SHEET	43	MUNTZ									
CROSS BAFFLES	44										
LONGITUDINAL BAFFLES	45										
TUBE SUPPORTS	46	[illegible]									
SHELL	47										
SHELL COVERS	48					1					
FLOATING HEAD COVER	49										
CHANNEL	50										
CHANNEL COVER	51										
CROSS BAFFLES TYPE - SPACING	52										
LONGITUDINAL BAFFLE TYPE	53										
GASKETS	54										
WELDING FLANGES AND NOZZLES	55										
STUDS	56										
WEIGHT EXCHANGER DRY - WET	57										
WEIGHT BUNDLE	58					* BARE TUBE					
CODE REQUIREMENTS	59					EQUIVALANT					
SUN OIL CO DRAWING NO	60										
REQUISITION NO	61										
PURCHASE ORDER NO	62										

Section labels: SERVICE (lines 1–6); UNIT PERFORMANCE (lines 7–30); CONSTRUCTION (lines 31–56).

NOTES

SR = STRESS RELIEVED
XR = X-RAYED

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

HEAT EXCHANGER SCHEDULE

PLANT Air Force Crude Unit

PLANT NO UNIT NO

LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
[illegible]				3
DATE 4/25/87				

FORM P-951 REV

~~SERVICE~~ ITEM NO	H-1							
SERVICE	FLASH TOWER FEED HEATER							
TYPE								
MANUFACTURER								
TOTAL DUTY OF HEATER, MM BTU PER HR ABSORBED/FIRED	99.2 / [illegible]							
PROCESS DESIGN CONDITIONS								
HEATER SECTION	RADIANT	CONV	CONV	CONV	CONV			
SERVICE	PROCESS	PROCESS	STM SUPRHT	STM GENER	BFW			
HEAT ABSORPTION MM BTU/HR	69.2	5.8	0.3	21.2	2.8			
FLUID	CRUDE OIL	CRUDE OIL	STEAM	STM + BFW	BFW			
FLOW RATE, LB/HR	916,100	916,100	10,000	121,160	25,370			
FLOW RATE, BPD (STD)	66,000	66,000	—	—				
PRESSURE DROP, PSI (ALLOWABLE)	← 125 →		0	6.5	20			
PRESSURE DROP, PSI (CALCULATED)								
AVERAGE FLUX DENSITY, BTU/HR/SQ FT (MAX ALLOW)	← 19000 →							
FOULING FACTOR								
INLET CONDITIONS								
TEMPERATURE, DEG F		480	315	365	240			
PRESSURE (PSIA)(PSIG)		165	65	165	200			
LIQUID FLOW, LB/HR		916,100	—	121,160	25,370			
VAPOR FLOW, LB/HR		—	10,000	—	—			
LIQUID (DEG API) (~~[illegible]~~)		7	—	—	—			
VAPOR MOLECULAR WEIGHT		—	18	18	—			
LIQUID VISCOSITY, CP	—	2.2	—	0.1	0.35			
OUTLET CONDITIONS								
TEMPERATURE, DEG F	[illegible]		380	365	340			
PRESSURE (PSIA)(PSIG)	[illegible]		55	165	[illegible]			
LIQUID FLOW, LB/HR	[illegible]			[illegible]	25,370			
VAPOR FLOW, LB/HR	[illegible]		[illegible]	24,160	—			
LIQUID (DEG API) (~~[illegible]~~)	[illegible]			—	—			
VAPOR MOLECULAR WEIGHT	34		[illegible]	[illegible]				
LIQUID VISCOSITY, CP	0.5			0.1	[illegible]			
FUEL CHARACTERISTICS:								
TYPE OF FUEL	[illegible]							
HEATING VALUE LHV								
SPECIFIC GRAVITY								
SULFUR/NITROGEN, WEIGHT %								
COIL DESIGN								
HEATER SECTION	RADIANT	[illegible]	CONV	[illegible]	CONV			
DESIGN PRESSURE, PSIG	225	225	[illegible]	225	200			
DESIGN FLUID TEMPERATURE, DEG F	[illegible]	[illegible]	[illegible]	[illegible]	600			
CORROSION ALLOWANCE TUBES	[illegible]	[illegible]	1/16	1/16	[illegible]			
FITTINGS								
HYDROSTATIC TEST PRESSURE, PSIG								
NUMBER OF PASSES								
OVERALL TUBE LENGTH, FT								
EFFECTIVE TUBE LENGTH, FT								
BARE TUBES NUMBER								
TOTAL EXPOSED SURFACE, SQ FT								
EXTENDED SURFACE TUBES NUMBER								
TOTAL EXPOSED SURFACE, SQ FT								
TUBE SPACING, CENTER TO CENTER, IN (STAGGERED)(IN LINE)								
TUBE CENTER TO FURNACE WALL, IN MIN								
HEAT TREATMENT	[illegible]	—	NO	NO	NO			
WELD INSPECTION REQUIREMENTS, X-RAY OR OTHER								
TUBES								
VERTICAL OR HORIZONTAL	H	H	H	H	H			
TUBE MATERIAL (ASTM SPECIFICATION AND GRADE)	[illegible]	[illegible] Cr	CS	[illegible]	[illegible]			
OUTSIDE DIAMETER, IN								

NOTES

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

FIRED HEATER DESIGN

PLANT [illegible] CRUDE UNIT

PLANT NO UNIT NO

LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
[illegible]				4
DATE 4/25/83				

SERVICE ITEM NO.	H-2			
SERVICE	VACUUM TOWER FEED HEATER			
TYPE				
MANUFACTURER				
TOTAL DUTY OF HEATER MM BTU PER HR ABSORBED/FIRED	46.2/53.7			
PROCESS DESIGN CONDITIONS				
HEATER SECTION	RADIANT	CONVECTION	CONV	CONV
SERVICE	PROCESS	PROCESS	STM GENER	BFW
HEAT ABSORPTION MM BTU/HR	32.2	2.7	10.0	1.3
FLUID	FLASHED	CRUDE	STM BFW	BFW
FLOW RATE, LB/HR	683 100	683 100		11 940
FLOW RATE, BPD (STD)	47 400	47 400		—
PRESSURE DROP, PSI (ALLOWABLE)	100		05	20
PRESSURE DROP, PSI (CALCULATED)				
AVERAGE FLUX DENSITY, BTU/HR/SQ FT ALLOWABLE	12 400			
FOULING FACTOR				
INLET CONDITIONS				
TEMPERATURE DEG F		572	365	240
PRESSURE (PSIA)(PSIG)		120	165	200
LIQUID FLOW, LB/HR		683 100	56 870	11 940
VAPOR FLOW, LB/HR				—
LIQUID (DEG API)(SP GR AT 60 F)		22		—
VAPOR MOLECULAR WEIGHT		—	18	18
LIQUID VISCOSITY, CP		0.7	[illegible]	0.25
OUTLET CONDITIONS				
TEMPERATURE DEG F	630		365	[illegible]
PRESSURE (PSIA)(PSIG)	20		[illegible]	[illegible]
LIQUID FLOW, LB/HR	586 000		45 500	[illegible] 940
VAPOR FLOW, LB/HR	97100		11 370	—
LIQUID (DEG API)(SP GR AT 60 F)	11.7			—
VAPOR MOLECULAR WEIGHT	204		18	—
LIQUID VISCOSITY, CP	0.8		0.1	0.1
FUEL CHARACTERISTICS:				
TYPE OF FUEL	OIL			
HEATING VALUE LHV				
SPECIFIC GRAVITY				
SULFUR/NITROGEN, WEIGHT %				
COIL DESIGN				
HEATER SECTION	RADIANT	CONV	CONV.	CONV.
DESIGN PRESSURE PSIG	200	200	225	300
DESIGN FLUID TEMPERATURE DEG F	675	675	600	600
CORROSION ALLOWANCE TUBES	1/8" (ALLOY)	1/8" (CS)	[illegible]	1/16
FITTINGS				
HYDROSTATIC TEST PRESSURE PSIG				
NUMBER OF PASSES				
OVERALL TUBE LENGTH FT				
EFFECTIVE TUBE LENGTH FT				
BARE TUBES NUMBER				
TOTAL EXPOSED SURFACE SQ FT				
EXTENDED SURFACE TUBES NUMBER				
TOTAL EXPOSED SURFACE SQ FT				
[illegible]				
TUBE CENTER TO FURNACE WALL IN MIN				
HEAT TREATMENT	[illegible]	183	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
OUTSIDE DIAMETER IN				

NOTES

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

FIRED HEATER DESIGN

PLANT [illegible] CRUDE UNIT

PLANT NO. UNIT NO.

LOCATION

BY DATE DRAWING NO. REV SHEET 5

PUMP ITEM NO		P-1, 1A	P-2, 2A	P-3, 3A	P-4, 4A	P-5, 5A	P-6, 6A	P-7, 7A	P-8, 8A	P-9, 9A	P-10, P10B
SERVICE		CRUDE FEED	[illegible]	[illegible]	[illegible]	REDUCED CRUDE	[illegible]	[illegible]	[illegible]	BOILER FEED WATER	NALCO DESALTING CHEMICAL
OPERATING CONDITIONS											
LIQUID	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	WATER	WATER	DEVELOP
PUMPING TEMPERATURE °F	2	125	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	WITH
SPECIFIC GRAVITY AT P T	3	0.91	[illegible]	0.81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NALCO
VISC SSU, CP, ~~SSF~~, AT P T	4	20.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
GPM AT P T [illegible]	5	2000/2300	5.5 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30/100	1/2 GAL/HR
SUCTION PRESSURE (PSIG)	6	[illegible]	[illegible]	8	[illegible]	[illegible]		[illegible]	[illegible]	50	0
DISCHARGE PRESSURE (PSIG)	7	350	65	65	35	[illegible]	[illegible]	[illegible]	[illegible]	200	350
DIFFERENTIAL HEAD (FT)	8	[illegible]	[illegible]	470	255	225	[illegible]	[illegible]	716	376	
N P S H AVAILABLE	9	AS REQ'D	AS REQ'D	AS REQ'D	AS REQ'D	AS REQ'D	AS REQ'D	AS REQ'D	AS REQ'D	AS REQ'D	
RPM	10										
BHP AT RATED GPM [illegible]	11	620	32	287	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14	
MAX BHP FOR INSTALLED IMP	12										
PUMP SPECIFICATIONS											
MANUFACTURER	13										
TYPE AND SIZE	14										
STAGES	15										
SUCT FLG, SIZE, RATING, FACE	16										
DISCH FLG, SIZE, RATING, FACE	17										
NOZZLE ARRG'T SUCTION	18										
NOZZLE ARRG'T DISCHARGE	19										
IMPELLER DIA REQUIRED	20										
MAX IMP DIA AND HEAD	21										
IMP EYE AREA	22										
N P S H REQUIRED	23										
HYDROSTATIC TEST PRESSURE	24										
THRUST BEARING	25										
RADIAL BEARING	26										
COUPLING	27										
COUPLING GUARD	28										
ROTATION FROM COUPLING END	29										
MECHANICAL SEALS — MFG	30										
MECHANICAL SEALS — TYPE	31										
MECHANICAL SEALS — AUX BOX	32										
WATER COOLED — BOX	33										
WATER COOLED — BEARING	34										
WATER COOLED — PEDESTAL	35										
WEIGHT OF PUMP AND BASE	36										
MATERIAL SPECIFICATIONS											
CASING	37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
CASE WEARING RINGS	38										
STAGE PIECES	39										
BUSHINGS — THROAT	40										
BUSHINGS — INTERSTAGE	41										
IMPELLER	42	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]	
IMPELLER WEARING RINGS	43										
SHAFT	44										
SHAFT SLEEVES	45										
GLAND	46										
LANTERN RINGS	47										
BEARING HOUSING	48										
BASE PLATE	49										
GASKET	50										
[illegible]	51										
[illegible]	52										
[illegible]	53										
MANUFACTURER'S [illegible]	54										
PERFORMANCE CURVE	55										
[illegible] NUMBER	56										
[illegible] DRAWING NO	57										

NOTES

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

CENTRIFUGAL PUMP SCHEDULE

PLANT [illegible]

PLANT NO | UNIT NO

LOCATION

BY | DATE | DRAWING NO | REV | SHEET

		T-1		V-1	V-2A	V-2B	V-3	V-4	V-5	V-6	
SERVICE	ITEM NO	T-1		V-1	V-2A	V-2B	V-3	V-4	V-5	V-6	
	TITLE	VACUUM TOWER		RECYCLE SURGE DRUM	DESALTER	DESALTER	FLASH TOWER	VACUUM TOWER OVERHEAD RECEIVER	FEED SURGE TANK	STEAM DRUM	
	SERIAL NO										
	DWG NO — ASSEMBLY										
	DWG NO — DETAILS										
	DWG NO — TRAYS										
	DWG NO — PLATFORMS										
DESIGN	CODE										
	PRESSURE	FULL VACUUM		5	[illegible]	[illegible]	[illegible]	50	[illegible]	200	
	TEMPERATURE °F	700		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	300	[illegible]	
	CORROSION ALLOWANCE			1/8	1/8	[illegible]	1/8	[illegible]	1/8"	[illegible]	
	WIND LOADING										
	HYDROSTATIC TEST PRESSURE	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	75	75	600	
	HAMMER TEST PRESSURE										
	STRESS RELIEVED	[illegible]		N	YES	YES	[illegible]	NO	NO	NO	
	RADIOGRAPHED										
	VERTICAL OR HORIZONTAL	V		H	H	H	V	H	[illegible]	H	
	INSULATION THICKNESS										
DIMENSIONAL	O D / I D	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	5'0"	[illegible]	[illegible]	
	LENGTH SEAM TO SEAM	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	10'0"	[illegible]	[illegible]	
	LENGTH BASE SECTION										
	HEIGHT OF SKIRT			[illegible]	SADDLES	SADDLES	[illegible]	SADDLES	[illegible]	SADDLES	
	℄ TO BOTTOM OF SUPPORTS										
	TOTAL SHELL THICKNESS			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	HEAD THICKNESS			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	SKIRT THICKNESS			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	NO REQ'D				[illegible]	[illegible]					
	SIZE	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
	SERIES & FACING										
	TYPE	[illegible]					[illegible]				
	THICKNESS						[illegible]				
	LOCATION	[illegible]					[illegible]				
	[illegible]	[illegible]									
	TYPE OF TRAY	[illegible]									
	NO OF CAPS/TRAY & TYPE	[illegible]									
	[illegible]	[illegible]									
	[illegible]										
	[illegible]										
	[illegible]	[illegible]									
	TYPE OF TRAY	[illegible]									
	[illegible]	[illegible]									
MATERIAL / DATA	SHELL & HEADS	[illegible]		[illegible]	21 [illegible]		[illegible]	[illegible]	[illegible]	[illegible]	
	SKIRT	[illegible]		[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	
	STRUCTURAL MEMBERS			[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	
	REQUISITION NO										
	PURCHASE ORDER										
	PURCHASED FROM										
	FABRICATOR S/O										
	SHIPPING WEIGHT										

NOTES

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

TOWER & VESSEL SCHEDULE

PLANT Air Force [illegible] UNIT

PLANT NO UNIT NO

LOCATION

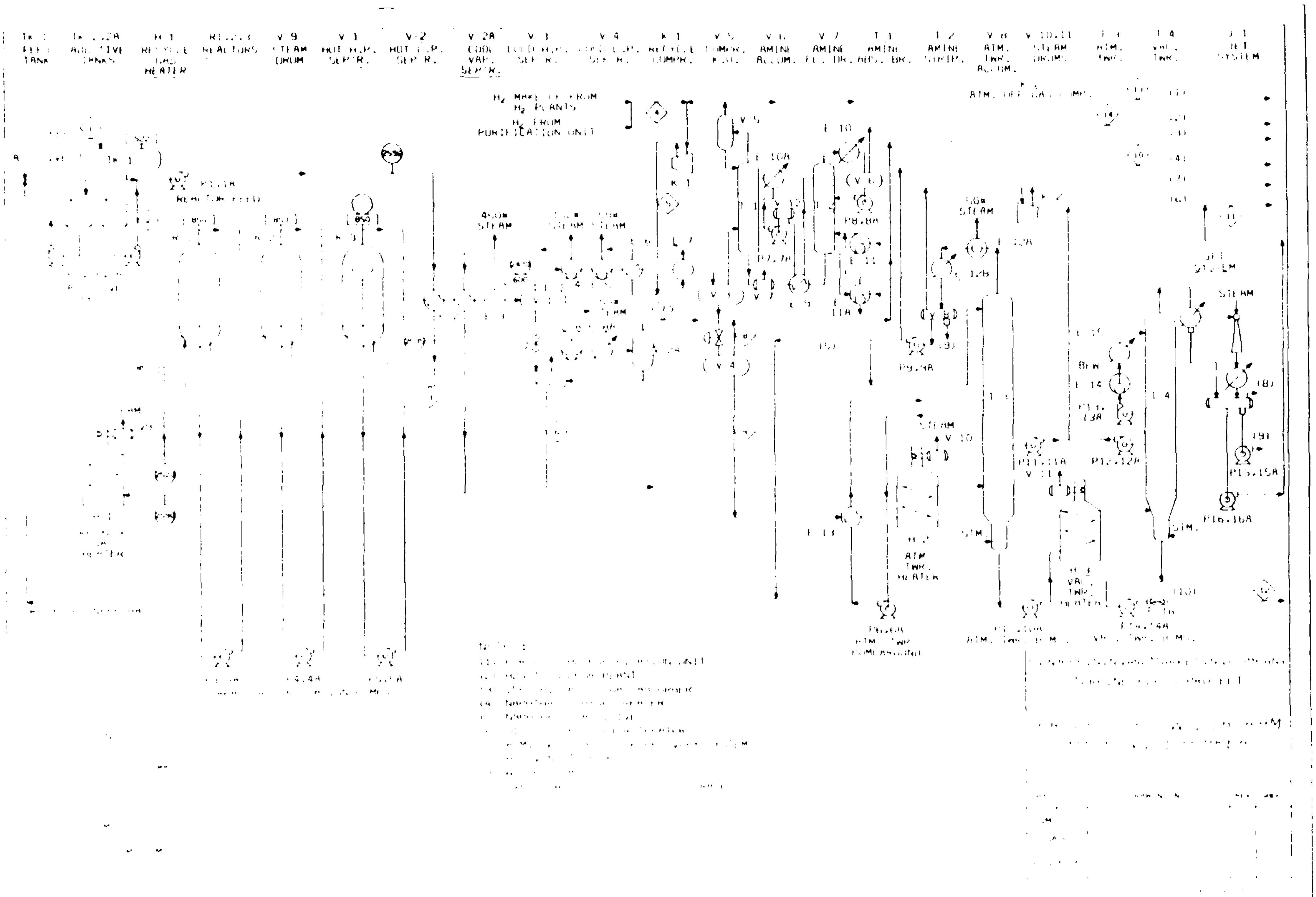
BY	APP'D	DRAWING NO	REV	SHEET
X				7

DATE 4/15/81

PROCESS DESIGN SPECIFICATIONS

for the

HYDROVISBREAKER UNIT


V 9 STEAM DRUM
V 1 HOT H.P. SEP'R.
V 2 HOT L.P. SEP'R.
V 2A COOL VAP. SEP'R.
V 5 COMPR. K.O.
V 6 AMINE ACCUM.
V 7 AMINE FL. DR.
T 2 AMINE STRIP.
T 4 VAC. TWR.
J 1 JET SYSTEM
H_2 MAKE UP FROM H_2 PLANTS
H_2 FROM PURIFICATION UNIT
450# STEAM
STEAM
H 2 ATM. TWR. HEATER
H 3 VAC. TWR. HEATER
P15,15A
P16,16A

HYDROVISBREAKER UNIT
MATERIAL BALANCE AND STREAM PROPERTIES

Stream Number	1	2	3	4	5	6	7	8	9
Stream Label	Fresh Feed	Additive	Reactor Liquid Feed	Hydrogen Make-up	Total Gas Feed to Reactor 1	1st Low Pressure Separator Liquid	1st Low Pressure Sep. Vapor (from V-2A)	2nd Low Pressure Vapor (from V-4)	2nd Low Pressure Liquid (from V-4)
Overhead Stream Conditions									
Temperature, F	480	60	750	125	131	565	110	107	107
Physical state	Liquid	Liquid	Liquid	Vapor	Vapor	Liquid	Vapor	Vapor	Liquid
API Gravity	9.1	47.1	9.7	-	-	15.3	-	-	50.7
Sp.Gr. @ 60 F									
Sp.Gr. @ Temp.	0.87	0.79	0.83	(2.7)	(4.4)	0.78	(10.2)	(16.2)	0.76
Pressure, psia	20	20	2550	2450	2635	165	155	165	165
BBLS/DAY @ 60 F	39,366	815	40,181	-	-	30,326	-	-	12,245
MMSCFD, (60 F, 1 atm)	-	-	-	40.0	229.5	-	5.2	2.86	-
M lb/hr	577.6	9.4	587.0	11.96	111.6	426.0	5.85	5.1	138.6
GPM @ 60 F									
Vis., cSt @ Temp.	2.2	2.6	0.9	-	-	0.8	-	-	1.0

Stream Number	10	11	12	13	14
Stream Label	Naphtha Product	490-1000 F Distillate	Vacuum Tower Bottoms	High-Pressure Hydrogen Vent	H_2S from Amine
Stream Conditions					
Temperature, F	100	495	380	100	120
Physical state	Liquid	Liquid	Liquid	Vapor	Vapor
API Gravity	52.5	17.4	-1.01	-	-
Sp.Gr. @ 60 F					
Sp.Gr. @ Temp.	0.77	0.80	1.0	(5.2 Mol Wt)	(32.4 Mol Wt)
Pressure, psia	90	80	145	2440	23
BBLS/DAY @ 60 F	12,045	24,377	4,839	-	-
MMSCFD, (60 F, 1 atm)	-	-	-	29.96	1.72
M lb/hr	135.0	337.6	76.5	17.1	6.126
GPM @ 60 F					
Vis., cSt @ Temp.	0.6	0.9	15	-	-

HYDROVISBREAKER DESIGN BASIS

Unit Feed Rate

The unit is designed to hydroprocess 39,366 BPSD of San Ardo reduced crude boiling above a true-boiling-point 5% point of 650°F. The unit will convert 71 vol% of the feed boiling above 975°F to lighter hydrocarbons. It is anticipated that a 90% on-stream factor can be maintained.

Plant Processing Steps

The 650°F crude unit bottoms at a temperature of 450° to 480°F is mixed with an additive that reduces coke formation in the reactor system. This mixed stream is preheated by heat exchange with the reactor effluent and charged to the reactor system. Three reactors in series with internal circulation are used.

The reactor system operates at 2500 psig and 850°F and a one liquid hourly space velocity. External circulating pumps are used with block valving for maintenance access. Preheated circulating hydrogen is injected into the first reactor at 750°F. A total of 5700 SCF of 85% hydrogen is circulated per barrel of reactor feed.

The effluent mix of hydrogen gas and liquid product from the reactors is cooled to 600°F by heat exchange and separated. The hydrogen gas is further cooled to 100°F, separated, compressed, and recirculated along with make-up hydrogen.

Fresh hydrogen makeup gas is obtained from two sources. The hydrogen plant supplies hydrogen of 95% purity. This source alone is insufficient to maintain the desired hydrogen purity and partial pressure in the reactor gas

feed, so a hydrogen purification unit is used to recover hydrogen at 99% purity from the high pressure bleed gas of the Hydrovisbreaker and Distillate Hydrotreater Units.

The hydrocarbon liquids separated in the 600°F and 100°F separators (hot and cold high-pressure separators, V-1 and V-3) are reduced in pressure and vented in V-2 and V-4 prior to reheating for fractionation. A naphtha cut, light and heavy distillate cuts and resid fuel cuts are recovered in the fractionation. This requires an atmospheric and vacuum tower.

HYDROVISBREAKING UNIT
Utility and Chemical Requirements

Steam Balance

Steam Production, lb/hr	450 psig	150 psig	50 psig	Totals
Steam generators:				
E-3	32,450	-	-	32,450
E-4	-	66,570	-	66,570
E-5	-	-	25,100	25,100
E-8A	-	-	8,035	8,035
E-12A	-	-	18,840	18,840
E-14	-	-	38,650	38,650
V-10 at Heater H-1	-	24,040	-	24,040
V-11 at Heater H-2	-	22,170	-	22,170
V-12 at Heater H-3	-	13,245	-	13,245
Totals	32,450	126,025	90,625	249,100

Steam consumed, lb/hr	450 psig	150 psig	50 psig	Recovered Condensate
E-11 Reboiler	-	-	31,200	31,200
E-11A Reclaimer	-	310	-	310
T-3 stripping	-	11,150	-	-
T-4 stripping	-	10,000	-	-
H-1 heater	1,300	-	-	-
H-2 heater	9,200	-	-	-
H-3 heater	8,700	-	-	-
Vacuum Jet Motive Steam	-	10,000	-	-
Miscellaneous	-	-	10,000	-
Totals	19,200	31,460	41,200	31,510
Net steam export, lb/hr	13,000	94,000	49,000	

Boiler Feed Water Required

Steam production (rounded)	250,000	lb/hr
10% condensate loss to blowdown	25,000	
Total gross BFW needed	275,000	lb/hr
Total condensate recovered for use as BFW	- 31,500	
Net Boiler Feed Water make-up required	243,500	lb/hr = 487 GPM

HYDROVISBREAKING UNIT
Utility and Chemical Requirements
(continued)

Fuel fired (Hydrovisbreaker Vacuum Residuum)

H-1 heater	110.1 MMBTU/HR
H-2 heater	101.1
H-3 heater	60.7
Total	271.9 MMBTU/HR = 45.2 FOE Bbl/hr = 15,822 #/hr Resid fuel

Air Requirements

Instrument Air	50 psig	300 SCFM
Plant Air	120 psig	

Cooling Water Circulation	GPM	Supply	Return	MMBTU/HR
E-7 cooler	2480	85°F	110°F	31.00
E-8B	510	85	110	6.37
E-10 Amine condenser		85		
E-10A Amine cooler		85		
E-12B Condenser	3738	85	110	46.73
Vac. Jet System	4500	85	100	33.75
Totals	11,228	85	106	117.85
Assume 3% make-up	337			

Coke-suppressing Additive

8% Molybdenum Octoate dissolved in Naphtha to establish 367 wppm Molybdenum in the Total Reactor Liquid Feed.

8% Molybdenum Octoate	2,690 lb/hr
(Molybdenum 2-ethyl hexoate)	
Naphtha	6,724 lb/hr
Total additive mixture	9,414 lb/hr

HYDROVISBREAKING UNIT

Utility and Chemical Requirements
(continued)

Electical Power Requirement

Equipment		Operating Horsepower	Connected Horsepower
Pumps:			
P-1,1A	Reactor Feed	3800	7600
P-2,2A	Additive Feed	5	10
P-3,3A	Reactor R-1 Circulation	100	200
P-4,4A	Reactor R-2 Circulation	100	200
P-5,5A	Reactor R-2 Circulation	100	200
P-6,6A	Atmospheric Tower Pumparound	25	50
P-7,7A	Lean Amine	1100	2200
P-8,8A	Amine Reflux	4	8
P-9,9A	Atmospheric Tower Reflux & Product	40	80
P-10,10A	Atmospheric Tower Bottoms	75	150
P-11,11A	Atmospheric Tower Gas Oil Sidedraw	15	30
P-12,12A	Vacuum Tower Gas Oil Sidedraw	50	100
P-13,13A	Vacuum Tower Pumparound	60	120
P-14,14A	Vacuum Tower Residuum	35	70
P-15,15A	Vacuum Tower Sour Water	3	6
P-16,16A	Vacuum Tower Bottoms Residuum	8	16
Compressors:			
K-1	Recycle Gas	1500	1500
K-2	Atmospheric Tower Off-Gas	50	100
	TOTALS	7020 BHP	12,540 BHP
	KILOWATTS = (.7457 x HORSEPOWER)	5235 KW	9,351 KW

HYDROVISBREAKING UNIT

Major Equipment List

Heat Exchangers

E-1	Reactor Feed - Effluent Exchanger
E-2	Reactor Effluent - Recycle Gas Exchanger
E-3	Reactor Effluent - 450 psig Steam Generator
E-4	Hot Separator Vapor - 150 psig Steam Generator
E-5	Hot Separator Vapor - 50 psig Steam Generator
E-6	Hot Separator Vapor - Recycle Gas Exchanger
E-7	Hot Separator Vapor Cooler
E-8A	Hot Low-Pressure Separator Gas - Steam Generator
E-8B	Hot Low-Pressure Separator Gas Cooler
E-9	Rich Amine - Lean Amine Exchanger
E-10	Amine Stripper Overhead Condenser
E-10A	Lean Amine Cooler
E-11	Amine Stripper Reboiler
E-11A	Amine Reclaimer
E-12A	Atmospheric Tower Overhead - 50 psig Steam Generator
E-12B	Atmospheric Tower Overhead Condenser
E-13	Atmospheric Tower Feed - Pumparound Exchanger
E-14	Vacuum Tower Pumparound - 50 psig Steam Generator
E-15	Vacuum Tower Pumparound - Boiler Feed Water Exchanger
E-16	Vacuum Tower Bottoms Aircooler

Fired Heaters:

H-1	Recycle Gas Heater
H-2	Atmospheric Tower Feed Heater
H-3	Vacuum Tower Feed Heater

Towers, Tanks, and Reactors:

T-1	Amine Absorber
T-2	Amine Stripper (Regenerator)
T-3	Atmospheric Tower
T-4	Vacuum Tower
TK-1	Hydrovisbreaker Feed Tank
TK-2,2A	Coke-Suppressing Additive Feed Tanks
R-1,2,3	Hydrovisbreaker Reactors

Vacuum Jet System - Consisting of Vacuum Jets, Condensers, and Knockout Drum

HYDROVISBREAKING UNIT

Major Equipment List
(continued)

Vessels:

V-1	Hot High-Pressure Separator
V-2	Hot Low -Pressure Separator
V-3	Cold High-Pressure Separator
V-4	Cold Low -Pressure Separator
V-5	Recycle Compressor Knockout Drum
V-6	Amine Stripper Overhead Accumulator
V-7	Amine Flash Drum
V-8	Atmospheric Tower Overhead Accumulator
V-9	Steam Drum at H-1 Recycle Gas Heater
V-10	Steam Drum at H-2 Atmospheric Tower Feed Heater
V-11	Steam Drum at H-3 Vacuum Tower Feed Heater
V-12	Lean Amine Surge Drum

Compressors and Pumps:

K-1	Recycle Gas Compressor
K-2	Atmospheric Tower Off-Gas Compressor
P-1,1A	Reactor Feed
P-2,2A	Coke-Suppressing Additive Feed
P-3,3A	Reactor R-1 Circulation
P-4,4A	Reactor R-2 Circulation
P-5,5A	Reactor R-3 Circulation
P-6,6A	Atmospheric Tower Pumparound
P-7,7A	Lean Amine
P-8,8A	Amine Stripper Reflux
P-9,9A	Atmospheric Tower Overhead Reflux and Product
P-10,10A	Atmospheric Tower Bottoms (Vacuum Tower Feed)
P-11,11A	Atmospheric Tower Sidestream Gas Oil
P-12,12A	Vacuum Tower Sidestream Gas Oil
P-13,13A	Vacuum Tower Pumparound
P-14,14A	Vacuum Tower Bottoms (Refinery Vacuum Residuum Product)
P-15,15A	Vacuum Overhead Accumulator Sour Water
P-16,16A	Vacuum Tower Overhead Gas Oil Product

Section	Item	No.	E-1 Shell	E-1 Tube	E-2 Shell	E-2 Tube	E-3 Shell	E-3 Tube	E-4 Shell	E-4 Tube	E-5 Shell	E-5 Tube
SERVICE	ITEM NO	1	E-1		E-2		E-3		E-4		E5	
	SERVICE	2	REACTOR FEED		REACTOR EFFLUENT		REACTOR EFFLUENT		HOT SEPR VAP		HOT SEPR VAP	
		3	EFFLUENT EXCH.		RECYCLE GAS		450# STM GEN.		150# STM GEN.		50# STM GEN.	
	MANUFACTURER - NO SHELLS	4				1		1		1		1
	SIZE AND TYPE	5	52 X 20'	AES	32" X 20'	AAS	60"X30"X20	AKU	96"X50"X20	AKU	90"X45X20	AKU
	SURFACE / UNIT - / SHELL FT²	6	12,200	6100	2620		2236		7974			
		7	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE
UNIT PERFORMANCE	CONNECTED IN	8	SERIES	SERIES	—	—						
	FLUID CIRCULATED	9										
		10	FEED	Rx EFF	RECY GAS	Rx EFF	450# STM	Rx EFF	150# STM	HT SEP VAP	50# STM	HT SEP VAP
	ENTERING QUANTITY ~~LBS/HR~~ M LBS/HR — LIQUID	11	586.98	222.77	—	344.893		388.79				67.27
	VAPOR (MW)	12		480.32(7.1)	116.94	358.175		314.30		281.917		214.65
	FIXED GASES MW	13										
	STEAM	14										
	TOTAL	15	586.98	703.09	116.94	703.09		703.09		281.917		281.917
	FLUID VAPORIZED OR CONDENSED M#/HR	16	—	122.128		43.886C	32.450V	32.382C	66.590V	67.27C	25.1V	27.50C
	STEAM CONDENSED	17	—									
	GRAVITY LIQUID (SG)(API) AT °F AVG	18	.85	.66	—	.75	—	.75	—	.68		.67
	VISCOSITY LIQUID (SSU)(CP) AT °F AVG	19	3.2	2.0	.02	3.0	—	4.0	—	.18		1.5
	SPEC HEAT LIQUID BTU/LB	20	.1	.77								
	LATENT HEAT VAPOR BTU/LB	21										
	OPER TEMP °F IN OUT	22	514/750	450/710	115/325	710/650	460/460	630/600	366/366	600/400	300/300	400/325
	OPER PRESSURE PSIG	23	2550	2490	2595	2480	450	2475	150	2470	50	2465
	MINIMUM FOULING FACTOR	24										
	NUMBER OF PASSES	25										
	VELOCITY FT/SEC	26										
	PRESSURE DROP PSIG	27	2	10	5	5	1	5	1	5	1	5
	HEAT EXCHANGED BTU/HR MM	28	15.25		40.0			33.0	67.1			34.9
	MTD CORRECTED WEIGHTED	29	130		254.4			164		19		34
	TRANSFER RATE SERVICE CLEAN	30	60		60			90		85		85
CONSTRUCTION	DESIGN PRESSURE PSIG	31	2800	2740	2855	2730	500	2730	200	2240	100	2710
	TEST PRESSURE PSIG	32	4200	4110	4280	4095	750	4095	300	4110	150	4065
	DESIGN TEMPERATURE °F	33	700	750°F	650	800	650	700	650	700	650	650
	CORROSION ALLOWANCE	34	1/8	1/8	1/8"	1/8"	1/8"	1/8"	1/8"	1/8	1/8"	1/8"
	CONNECTIONS SIZE STD TYPE — IN	35										
	OUT	36										
	TUBES — MAT'L	37		347		347		347		347		347
	O D BWG	38		1"-12		3/4"-12		3/4"-12		3/4"-12		3/4"-12
	LENGTH PITCH	39		20'-1"Ø		20'-1"Ø		20'-1"Ø		20'1"Ø		20'1"Ø
	SHELL I D ~~O D~~	40	32"		32"		60"		96"		90"	
		41	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS
	STATIONARY TUBE SHEET	42										
	FLOATING TUBE SHEET	43										
	CROSS BAFFLES	44										
	LONGITUDINAL BAFFLES	45										
	TUBE SUPPORTS	46										
	SHELL	47	SCH/1¼ Moly		SCH/Moly		CS		CS		CS	
	SHELL COVERS	48										
	FLOATING HEAD COVER	49										
	CHANNEL	50										
	CHANNEL COVER	51										
	CROSS BAFFLES TYPE SPACING	52										
	LONGITUDINAL BAFFLE TYPE	53										
	GASKETS	54										
	WELDING FLANGES AND NOZZLES	55										
	STUDS	56										
	WEIGHT EXCHANGER DRY WET	57										
	WEIGHT BUNDLE	58										
	CODE REQUIREMENTS	59										
	SR & MC DRAWING NO	60										
	REQUISITION NO	61										
	PURCHASE ORDER NO	62										

NOTES

SR - STRESS RELIEVED

XR - X RAYED

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

HEAT EXCHANGER SCHEDULE

PLANT AIR FORCE

PLANT NO HYDROCRACKER UNIT NO

LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
LGM				1
DATE 4/25/87				

Section	Line item	No.	E6 Shell	E6 Tube	E-7 Shell	E-7 Tube	E-8A Shell	E-8A Tube	E-8B Shell	E-8B Tube	E-9 Shell	E-9 Tube
SERVICE	ITEM NO	1	E6		E-7		E-8A		E-8B		E-9	
	SERVICE	2	HOT SEPR VAP		HOT SEPR VAP		HOT LP SEPR		HOT LP SEPR		AMINE	RICH
		3	RECYCLE GAS		WATER COOLER		GAS STM GEN		GAS COOLER		LEAN	EXCH
	MANUFACTURER - NO SHELLS	4		3 SHELLS		2 SHELLS		1 SHELL		1 SHELLS		2 SHELLS
	SIZE AND TYPE	5	39"X20'	AES	40X20	AES	42X21 X20	AKU	24"X20'	AES	30"X20'	AES
	SURFACE/UNIT - /SHELL FT²	6	11745	3915	7880	3940		1054		1500	4500	2250
		7	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE
UNIT PERFORMANCE	CONNECTED IN	8										
	FLUID CIRCULATED	9										
		10	RECYGAS	HT SEP VAP	HT SEP VAP	WATER	50# STM	HOT LP SEP VAP	HOT LP SEP VAP	WATER	LEAN AMINE	RICH AMINE
	ENTERING QUANTITY MLBS/HR — LIQUID	11		74.77	124.77	1480 GPM		—	19.93	510 GPM	400 GPM	
	VAPOR (MW)	12	116.94 (4.6)	87.18 (7.1)	157.15 (6.1)			36.98	17.05			
	FIXED GASES MW	13										
	STEAM	14										
	TOTAL	15	116.94	281.92	281.92			36.98	36.98		201.0	206.7
	FLUID VAPORIZED OR CONDENSED M#/HR	16	0	30.0C	24.43C		8.034V	19.93C	11.94C			5.0V
	STEAM CONDENSED	17										
	GRAVITY - LIQUID (SG) AT °F AVG	18	—	.685	.72			.76	.74		.97	.98
	VISCOSITY - LIQUID (CP) AT °F AVG	19	—	1.0	2.0			.4	1.0		.4	.7
	SPEC HEAT - LIQUID - BTU/LB AT AVG T	20	—	.59	.49			.66	.56		.995	.96
	LATENT HEAT - VAPOR - BTU/LB	21										
	OPER TEMP °F - IN - OUT	22	31/325	325/280	220/100	35/110	300/300	590/329	329/110	85/110	235/145	105/195
	OPER PRESSURE PSIG	23	2615	2460	2445		50	150	150	75	15	1100
	MINIMUM FOULING FACTOR	24										
	NUMBER OF PASSES	25										
	VELOCITY - FT/SEC	26										
	PRESSURE DROP - PSIG	27	15	15	10	10	1	5	5	5	10	10
	HEAT EXCHANGED - BTU/HR (MM)	28	23.5		31.0		7.97		6.37		18.00	
	MTD CORRECTED WEIGHTED	29	36.8		46.3		198		60.8		30	
	TRANSFER RATE SERVICE CLEAN	30	80		85		70		70		133	
CONSTRUCTION	DESIGN PRESSURE - PSIG	31	2880	2705	2690	150	100	125	175	150	75	250
	TEST PRESSURE - PSIG	32	4320	4255	4035	225	150	265	265	225	112	385
	DESIGN TEMPERATURE - °F	33	650	650	650	650	650	650	650	650	650	650
	CORROSION ALLOWANCE	34	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"
	CONNECTIONS SIZE - STD - TYPE — IN	35										
	OUT	36										
	TUBES — MAT'L NO.	37		347		347		347		347		304
	O.D. BWG	38		3/4" 12		3/4 12		3/4" 12		3/4 12		3/4" 12
	LENGTH PITCH	39		20', 1.0		20', 1.0		20', 1.0		20', 1.0		20', 1.0
	SHELL - I.D. - O.D.	40	39"		40"		42"		24"			
		41	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS
	STATIONARY TUBE SHEET	42										
	FLOATING TUBE SHEET	43										
	CROSS BAFFLES	44										
	LONGITUDINAL BAFFLES	45										
	TUBE SUPPORTS	46										
	SHELL	47	2 1/4 CR 1/2 MO		CS		CS		CS		CS	
	SHELL COVERS	48										
	FLOATING HEAD COVER	49										
	CHANNEL	50										
	CHANNEL COVER	51										
	CROSS BAFFLES TYPE - SPACING	52										
	LONGITUDINAL BAFFLE TYPE	53										
	GASKETS	54										
	WELDING FLANGES AND NOZZLES	55										
	STUDS	56										
	WEIGHT EXCHANGER DRY - WET	57										
	WEIGHT BUNDLE	58										
	CODE REQUIREMENTS	59										
	SR & MC DRAWING NO	60										
	REQUISITION NO	61										
	PURCHASE ORDER NO	62										

NOTES

SR - STRESS RELIEVED
XR - X-RAYED

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

HEAT EXCHANGER SCHEDULE

PLANT AIR FORCE
PLANT NO HYDROVISBREAKER UNIT NO
LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
LGM				2
DATE 4/21/87				

		No.	E 10 Shell	E 10 Tube	E 11 Shell	E 11 Tube	E 12A Shell	E 12A Tube	E 12B Shell	E 12B Tube	E-13 Shell	E-13 Tube
SERVICE	ITEM NO	1	E 10		E 11		E 12A		E-12B		E-13	
	SERVICE	2	AMINE STILL		AMINE STILL		ATM TWR OVHD.		ATM TWR OVHD		ATM. TWR	
		3	CONDENSER		REBOILER		STM. GEN.		CONDENSER		P. A-FD EXCH	
	MANUFACTURER · NO SHELLS	4		1 SHELL		1 SHELL		1 SHELL		2 SHELLS		1 SHELL
	SIZE AND TYPE	5	26"X20'	EAU	84"42.25'	AKU	20"X32.25'	AKU	36"X20'	AES	26"X20'	AES
	SURFACE/UNIT · /SHELL	6	1	1700	1	4524		2560	6660	3330		1695
UNIT PERFORMANCE		7	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE
	CONNECTED IN	8										
	FLUID CIRCULATED	9	WATER &	WATER	WATER			HC VAPOR	H C VAPOR	COOLING	PA GAS	TOWER
		10	ACID GAS		AMINE	STEAM	50# STM		& LIQ	WATER	OIL	LT FEED
	ENTERING QUANTITY LBS/HR M#/HR · LIQUID	11		1200GPM	4006A	31.17			84.02	3738GPM	157.48	114.91
	VAPOR · MW	12						190.45	106.44			0.12
	FIXED GASES · MW	13	5590									
	STEAM	14	16236		32.0							
	TOTAL	15	21826					190.45	190.45		157.48	145.03
	FLUID VAPORIZED OR CONDENSED M#/HR	16			32.0	31.17V	18.840V	84.02C	93.07C			11.18V
	STEAM CONDENSED	17	15700									
	GRAVITY · LIQUID (SG)(API) AT °F AVG	18						.7	.73		.74	.72
	VISCOSITY · LIQUID (SSU)(CP) AT °F	19						.4	.6		.6	.7
	SPEC HEAT · LIQUID · BTU/LB	20						.65	.55		.635	.56
	LATENT HEAT · VAPOR BTU/LB	21										
	OPER TEMP °F · IN · OUT	22	220/120	85/115	235/235	287/281	300/300	427/338	338/100	85/110	315/315	107/344
	OPER PRESSURE · PSIG	23	10	50	15	35	50	22	17	75	75	115
	MINIMUM FOULING FACTOR	24										
	NUMBER OF PASSES	25										
	VELOCITY · FT/SEC	26										
	PRESSURE DROP · PSIG	27	5	5	2	2		5	10	10	5	5
	HEAT EXCHANGED · BTU/HR · MM	28	18.0		28.8		18.69		46.73		23.0	
	MTD CORRECTED · WEIGHTED	29		76		46	73		73		[illegible]	
	TRANSFER RATE · SERVICE · ~~CLEAN~~	30		138		138	100		90		85	
CONSTRUCTION	DESIGN PRESSURE · PSIG	31	75	75	75	75	100	100	100	150	100	150
	TEST PRESSURE · PSIG	32	112	112	112	112	150	150	150	225	150	225
	DESIGN TEMPERATURE · °F	33	650	650	650	650	650	650	650	650	650	650
	CORROSION ALLOWANCE	34	1/8	1/8	1/8"	1/8"	1/8	1/8	1/8"	1/8"	1/8	1/8"
	CONNECTIONS · SIZE STD TYPE · IN	35										
	OUT	36										
	TUBES · MAT'L	37		CS		304		CS		ADM		CS
	O.D. · BWG	38		3/4", 12		3/4", 12		3/4", 12		3/4", 14		3/4", 12
	LENGTH · PITCH	39		20', 1" ◇		20', 1" ◇	20'	1" ◇	20'	1" ◇	20'	1" ◇
	SHELL · I.D. · O.D.	40	26"		84"		60"		36"		26"	
		41	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS
	STATIONARY TUBE SHEET	42										
	FLOATING TUBE SHEET	43										
	CROSS BAFFLES	44										
	LONGITUDINAL BAFFLES	45										
	TUBE SUPPORTS	46										
	SHELL	47	Bi METAL		CS		CS		CS		CS	
	SHELL COVERS	48										
	FLOATING HEAD COVER	49										
	CHANNEL	50										
	CHANNEL COVER	51										
	CROSS BAFFLES TYPE · SPACING	52										
	LONGITUDINAL BAFFLE TYPE	53										
	GASKETS	54										
	WELDING FLANGES AND NOZZLES	55										
	STUDS	56										
WEIGHT EXCHANGER · DRY · WET		57										
WEIGHT BUNDLE		58										
CODE REQUIREMENTS		59										
SR & MFG DRAWING NO		60										
REQUISITION NO		61										
PURCHASE ORDER NO		62										

NOTES

SR - STRESS RELIEVED
XR - X RAYED

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

HEAT EXCHANGER SCHEDULE

PLANT AIR FORCE HYDROVISBREAKER

PLANT NO · UNIT NO

LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
LLM				3
DATE 4/25/87				

		No.	Shell	Tube	Shell	Tube	Shell	Tube	Shell	Tube	Shell	Tube
SERVICE	ITEM NO	1	E 14		E-15		E-16		E-10A		E11A	
	SERVICE	2	VAC TWR PA		VAC TWR PA		VAC BTMS		AMINE		AMINE	
		3	50# STM GEN.		BFW HTR		AIR COOLER		COOLER		RECLAIMER	
	MANUFACTURER — NO SHELLS	4				1		1		2		1
	SIZE AND TYPE	5	78x44x20	AKU	21X20'	AES	12X40'		28x20'	AEU	56"x15x20'	AKU
	SURFACE/UNIT — / SHELL	6		5012		1010		2284	3800	1900		450
		7	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE
UNIT PERFORMANCE	CONNECTED IN	8										
	FLUID CIRCULATED	9	50# STM	GAS OIL	GAS OIL	BFW		VAC TWR	WATER	AMINE	[illegible]	STEAM
		10					AIR	BTMS				
	QUANTITY LBS/HR M#/HR — LIQUID	11		246.582	246.582			76,406	600	400		
	VAPOR MW	12										
	FIXED GASES MW	13										
	STEAM	14										
	TOTAL	15		246.582	246.582	140.CAM		76.486			106 AM	[illegible]
	FLUID VAPORIZED OR CONDENSED #/HR	16	28,650									
	STEAM CONDENSED	17										
	GRAVITY LIQUID (SG)(API) AT °F	18		[illegible] 542°	[illegible] 312°	[illegible]		[illegible]				
	VISCOSITY LIQUID (SSU)(CP) AT °F	19		[illegible]	[illegible]	[illegible]		[illegible]				
	SPEC HEAT LIQUID BTU/LB °F	20		57	.5	5C		58				
	LATENT HEAT VAPOR BTU/LB	21										
	OPER TEMP °F IN OUT	22	[illegible]	542/417	312/240	[illegible]/240	10,100	631/330	85/116	145/105	375/375	339
	OPER PRESSURE PSIG	23	52	47	50	[illegible]		150	60	2185	[illegible]	[illegible]
	MINIMUM FOULING FACTOR	24										
	NUMBER OF PASSES	25										
	VELOCITY FT/SEC	26										
	PRESSURE DROP PSI	27	[illegible]	5	5	5		[illegible]	10	10	2	2
	HEAT EXCHANGED BTU/HR	28	[illegible]					[illegible]	9.6		2.88	
	MTD (CORRECTED) (WEIGHTED)	29	[illegible]				[illegible]		[illegible]		[illegible]	
	TRANSFER RATE	30	[illegible]				[illegible]		104		[illegible]	
CONSTRUCTION	DESIGN PRESSURE PSIG	31		[illegible]		[illegible]		[illegible]	75	2750	75	200
	TEST PRESSURE PSIG	32	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	300
	DESIGN TEMPERATURE °F	33	[illegible]	650	[illegible]	650		650	250	450	450	550
	CORROSION ALLOWANCE	34	[illegible]	1/8"	[illegible]	1/8"		1/8"	1/8"	1/8"	1/8"	1/8"
	CONNECTIONS IN	35										
	SIZE STD TYPE OUT	36										
	TUBES NO. MATL	37						5 CR		CS ADM		304
	TUBES OD BWG	38		[illegible]		[illegible]		1/2"		3/4" 14		3/4" 12
	LENGTH PITCH	39		[illegible]		[illegible]		40' 1/4"		20' 1"		16', 1.0
	SHELL	40	[illegible]		[illegible]				23"		36"	
		41	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS
	STATIONARY TUBE SHEET	42										
	FLOATING TUBE SHEET	43										
	CROSS BAFFLES	44										
	LONGITUDINAL BAFFLES	45										
	TUBE SUPPORTS	46										
	SHELL	47			CS				CS-ADM		CS	
	SHELL COVERS	48							LINER			
	FLOATING HEAD COVER	49										
	CHANNEL	50										
	CHANNEL COVER	51										
	CROSS BAFFLES TYPE SPACING	52										
	LONGITUDINAL BAFFLE TYPE	53										
	GASKETS	54										
	WELDING FLANGES AND NOZZLES	55										
	STUDS	56										
	WEIGHT EXCHANGER DRY WET	57										
	WEIGHT BUNDLE	58										
	CODE REQUIREMENTS	59							* BIMETAL TUBES			
	SR & MF DRAWING NO	60										
	REQUISITION NO	61										
	PURCHASE ORDER NO	62										

NOTES

SR - STRESS RELIEVED
XR - X RAYED

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

HEAT EXCHANGER SCHEDULE

PLANT AIR FORCE
HYDROCRACKER
PLANT NO UNIT NO

LOCATION

BY	APPD	DRAWING NO	REV	SHEET
LGM				4
DATE 4/25/87				

SERVICE	H-1 RECYCLE GAS HEATER				H-2 ATM. TOWER FEED HEATER			
TYPE								
MANUFACTURER								
TOTAL DUTY OF HEATER MM BTU PER HR ABSORBED/FIRED	94.9/110.1				86.9/101.1			
PROCESS DESIGN CONDITIONS								
HEATER SECTION	RADIANT	CONVECTION			RADIANT	CONVECTION		
SERVICE	PROCESS	PROCESS	STM GENR	BFW	PROCESS	PROCESS	STM GEN	BFW
HEAT ABSORPTION MM BTU/HR	66.0	5.4	20.6	2.7	60.46	4.94		
FLUID	RECY. GAS		STM & WATER	BFW	GAS OIL	GAS OIL	STM & WATER	BFW
FLOW RATE LB/HR (M LB/HR)	116.94	116.94	120.19	26.44	561.0	145.0	110.85	24.39
FLOW RATE ~~BPD~~ TO COIL B/H ACTUAL			389	76	2113	874	359	70
PRESSURE DROP PSI (ALLOWABLE)	20		1.0	10	80		1.0	10
PRESSURE DROP PSI (CALCULATED)								
AVERAGE FLUX DENSITY BTU/HR/SQ FT								
FOULING FACTOR								
INLET CONDITIONS								
TEMPERATURE DEG F	531	505	366	260	520°F	344	366	260
PRESSURE ~~PSIA~~ (PSIG)	2585	2590	150	162	110	115	150	166
LIQUID FLOW LB/HR			120.19	26.44	548.0	133.7	110.85	24.39
VAPOR FLOW LB/HR	116.94	116.94		—	13.0	11.3		
LIQUID ~~DEG API~~ (SP GR AT 60 F)					.91	.78		
VAPOR MOLECULAR WEIGHT								
LIQUID VISCOSITY CP								
OUTLET CONDITIONS								
TEMPERATURE DEG F	850	531	366	366	650	381	366	366
PRESSURE ~~PSIA~~ (PSIG)	2515		150	152	30	110	150	152
LIQUID FLOW LB/HR (M LB/HR			96.149	26.44	383.5	135	88.68	24.39
VAPOR FLOW LB/HR (M LB/HR)	116.94	116.94	24.04	—	178.5	15	22.17	
LIQUID ~~DEG API~~ (SP GR AT 60 F)			1.0	1.0	.97	.80	1.0	1.0
VAPOR MOLECULAR WEIGHT	4.63	4.36	18		143		18	
LIQUID VISCOSITY CP			.11	.2			.1	.2
FUEL CHARACTERISTICS								
TYPE OF FUEL	10 API Resid				10 API Resid			
HEATING VALUE LHV								
~~SPECIFIC GRAVITY~~ LBS/HR REQUIRED	6423				5895			
SULFUR NITROGEN WEIGHT %								
COIL DESIGN								
HEATER SECTION								
DESIGN PRESSURE PSIG	2850	2850	200	200	200	200	200	200
DESIGN FLUID TEMPERATURE DEG F	950	950	650	650	800	800	650	650
CORROSION ALLOWANCE TUBES	1/8"	1/8"	1/8"	1/8	1/8"	1/8"	1/8"	1/8
FITTINGS								
HYDROSTATIC TEST PRESSURE PSIG								
NUMBER OF PASSES								
OVERALL TUBE LENGTH FT								
EFFECTIVE TUBE LENGTH FT								
BARE TUBES NUMBER								
TOTAL EXPOSED SURFACE SQ FT								
EXTENDED SURFACE TUBES NUMBER								
TOTAL EXPOSED SURFACE SQ FT								
TUBE SPACING CENTER TO CENTER IN (STAGGERED) (IN LINE)								
TUBE CENTER TO FURNACE WALL IN MIN								
HEAT TREATMENT								
WELD INSPECTION REQUIREMENTS X RAY OR OTHER								
TUBES								
VERTICAL OR HORIZONTAL								
TUBE MATERIAL (ASTM SPECIFICATION AND GRADE)	5 CR	5 CR	CS	C[illegible]	5 CR	5 CR	CS	CS
OUTSIDE DIAMETER IN								
WALL THICKNESS (MINIMUM) (AVERAGE) IN								

NOTES

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

FIRED HEATER DESIGN

PLANT AIR FORCE

PLANT NO HYDROVISBREAKER UNIT NO

LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
LGM				5
DATE 4/25/87				

SERVICE	$^{H-3}$ VAC TWR FEED HEATER			
TYPE				
MANUFACTURER				
TOTAL DUTY OF HEATER MM BTU PER HR ABSORBED/FIRED	52.2 / 60.7			
PROCESS DESIGN CONDITIONS				
HEATER SECTION	RADIANT	CONVECTION		
SERVICE	PROCESS	PROCESS	STM GEN	BFW
HEAT ABSORPTION MM BTU/HR	36.38	2.98	11.35	1.49
FLUID	RESID	RESID	STM & H_2O	BFW
FLOW RATE LB/HR (M LB/HR)	328.02	328.02	66.227	14.57
FLOW RATE ~~BPD~~ To Coil B/H		1163	215	42
PRESSURE DROP PSI (ALLOWABLE)	← 80	→	1.0	10
PRESSURE DROP PSI (CALCULATED)				
AVERAGE FLUX DENSITY BTU/HR/SQ FT				
FOULING FACTOR				
INLET CONDITIONS				
TEMPERATURE DEG F	633	619	366	260
PRESSURE ~~(PSIA)~~ (PSIG)	75	80	150	162
LIQUID FLOW LB/HR (M LB/HR)	328.02	328.02	66.227	26.44
VAPOR FLOW LB/HR	–	–		
LIQUID (DEG API) (SP GR AT 60 F)	1.00	1.00		
VAPOR MOLECULAR WEIGHT				
LIQUID VISCOSITY CP	3.5	4		
OUTLET CONDITIONS				
TEMPERATURE DEG F	775	633	366	366
PRESSURE ~~(PSIA)~~ (PSIG)	0	75	150	152
LIQUID FLOW LB/HR (M LB/HR)	281.97		52.98	26.44
VAPOR FLOW LB/HR (M LB/HR)	46.05		13.25	–
LIQUID ~~(DEG API)~~ (SP GR AT 60 F)	1.01	1.00	1.0	1.0
VAPOR MOLECULAR WEIGHT	260	–	18	–
LIQUID VISCOSITY CP	1.5	3.5	.1	.1
FUEL CHARACTERISTICS				
TYPE OF FUEL	10 API Resid			
HEATING VALUE LHV				
~~SPECIFIC GRAVITY~~ #/HR REQUIRED	3539			
SULFUR/NITROGEN WEIGHT %				
COIL DESIGN				
HEATER SECTION				
DESIGN PRESSURE PSIG	200	200	200	200
DESIGN FLUID TEMPERATURE DEG F	900	900	650	650
CORROSION ALLOWANCE TUBES	1/8"	1/8"	1/8"	1/8"
FITTINGS				
HYDROSTATIC TEST PRESSURE PSIG				
NUMBER OF PASSES				
OVERALL TUBE LENGTH FT				
EFFECTIVE TUBE LENGTH FT				
BARE TUBES NUMBER				
TOTAL EXPOSED SURFACE SQ FT				
EXTENDED SURFACE TUBES NUMBER				
TOTAL EXPOSED SURFACE SQ FT				
TUBE SPACING CENTER TO CENTER IN (STAGGERED) (IN LINE)				
TUBE CENTER TO FURNACE WALL IN MIN				
HEAT TREATMENT				
WELD INSPECTION REQUIREMENTS X RAY OR OTHER				
TUBES				
VERTICAL OR HORIZONTAL				
TUBE MATERIAL (ASTM SPECIFICATION AND GRADE)	5CR	5CR	CS	CS
OUTSIDE DIAMETER IN				
WALL THICKNESS (MINIMUM) (AVERAGE) IN				

NOTES

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

FIRED HEATER DESIGN

PLANT AIR FORCE

PLANT NO HYDROVISBREAKER UNIT NO

LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
LGM				6
DATE 4/15/87				

		T-1	T-2	T-3	T-4	R1,2,3	TK1	TK-2,2A	[illegible]	V-11	V-12
SERVICE	TITLE	AMINE ABSORB	AMINE STILL	ATMOS. TOWER	VACUUM TOWER	HYDVISBK REACTOR	FEED TANK	ADDITIVE TANKS	STEAM DRUM	STEAM DRUM	AMINE SURGE
	SERIAL NO										
	DWG NO ASSEMBLY										
	DWG NO DETAILS										
	DWG NO TRAYS										
	DWG NO PLATFORMS										
DESIGN	CODE										
	PRESSURE	2700	75	75	FULL VAC	2265	75	ATM	[illegible]	[illegible]	[illegible]
	TEMPERATURE °F	650	650	700°MAX	800°F MAX	900°F	650	200	[illegible]	[illegible]	250
	CORROSION ALLOWANCE	.15	.125	.17"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	.25"
	WIND LOADING										
	HYDROSTATIC TEST PRESSURE	4050		112		4150	112	–	300	300	–
	HAMMER TEST PRESSURE										
	STRESS RELEIVED	NO	NOT	NO	NO	YES	NO	NO	NO	NO	NO
	RADIOGRAPHED	SPOT	SPOT	SPOT	SPOT	YES	SPOT	SPOT	SPOT	SPOT	SPOT
DESCRIPTION	VERTICAL OR HORIZONTAL	V	V	V	V	V	H	V	H	H	H
	INSULATION THICKNESS										
DIMENSIONAL	OD - ID	5'6"	6'6"	6'3"/12'	32'6"	13'	12'	20'	5'	7'0"	10'
	LENGTH SEAM TO SEAM	50'	50'	82'	40'	43'	30'	16'	15'	21'	25'
	LENGTH BASE SECTION							(CONE BTM)			
	HEIGHT OF SKIRT	10'	12'	NONE	NONE	12'					
	℄ TO BOTTOM OF SUPPORTS										
	TOTAL SHELL THICKNESS	7.5"	.375"	.375 to .50	7/8" 11/16	12"+OVERLAY	7/16+OVERLAY	3/8"	9/16"	7/16"	.25"
	HEAD THICKNESS	7.5"	.375	.375 & .4375		8"+OVERLAY	7/16+OVERLAY		9/16"	9/16"	.25"
	SKIRT THICKNESS	1"	.375	–				3/16 TOP			
MH	NO REQ'D	2	2	5	4	2	1	2	1	1	1
	SIZE	24"	24"	24"	24"	24"	24"	24"	24"	24"	24"
	SERIES & FACING										
LINING	TYPE			12 CR	12 CR	347	12				
	THICKNESS	NONE	NONE	3/32"	3/16"	3/16"	1/8"	NONE	NONE	NONE	NONE
	LOCATION			OVERLAY BTM 56'	OVERLAY TOTAL	OVERLAY TOTAL	OVERLAY TOTAL				
TRAY A	NO TRAYS REQ'D & SPACING	20@24"	22@24"	32@24"	12@24"	1					
	TYPE OF TRAY	12CR	12 CR	12CR	12CR	12 CR					
	NO OF CAPS/TRAY & TYPE	VALVE	VALVE	VALVE	VALVE	SIEVE					
	SIZE OF CAPS										
	SIZE OF RISERS										
	TYPE OF DOWNCOMER										
TRAY B	NO TRAYS REQ'D & SPACING										
	TYPE OF TRAY										
					2 STIFFENING RINGS						
	VESSEL WEIGHT 2 1/4 CR					810,000					
	CS SKIRT LBS					15,500					
	3/16" 347 OVERLAY					13,000					
MAT'L SPEC	SHELL & HEADS										
	SKIRT										
	STRUCTURAL MEMBERS										
PURCHG DATA	REQUISITION NO										
	PURCHASE ORDER										
	PURCHASED FROM										
	FABRICATOR S/O										
	SHIPPING WEIGHT, EA. TOTAL	272,000	24,000	67,000	113,[illegible]	838,500	52,000	27,000	[illegible]	14C[illegible]	
	TEST WEIGHT										

NOTES

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

TOWER & VESSEL SCHEDULE

PLANT AIR FORCE HYDROVISBREAKER

PLANT NO UNIT NO

LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
[illegible] DATE 4/23/[illegible]				1

	V-1	V-2	V-2A	V-3	V-4	V-5	V-6	V-7	V-8	V-9
SERVICE — ITEM NO.	V-1	V-2	V-2A	V-3	V-4	V-5	V-6	V-7	V-8	V-9
TITLE	HOT HP SEPR.	HOT LP SEPR	COOLED HT VAP SEPR	COLD HP SEPR	COLD LP SEPR	COMPR KO DRUM	AMINE ACCUM	AMINE FL DRUM	ATM TWR ACCUM	STEAM DRUM
SERIAL NO										
DWG. NO — ASSEMBLY										
DWG. NO — DETAILS										
DWG. NO — TRAYS										
DWG. NO — PLATFORMS										
DESIGN — CODE										
PRESSURE PSIG	2715	200	200	2680	200	2670	75	200	[illegible]	200
TEMPERATURE °F	650	650	650	650	650	650	650	650	[illegible]	650
CORROSION ALLOWANCE	3/16" OVRLAY	1/8" OVRLAY	.1735"	[illegible] OVRLAY	.134	.195"	.125	.185	.128	.16
~~WIND LOADING~~ C/PLATING °F	600	600	110	100	[illegible]	124	100	110	[illegible]	366
HYDROSTATIC TEST PRESSURE PSIG	4075	300	300	4020	300	4005	113	300	113	300
HAMMER TEST PRESSURE										
STRESS RELEIVED	YES	NO	NO	YES	NO	YES	NO	NO	NO	NO
RADIOGRAPHED	YES	SPOT	SPOT	YES	SPOT	YES	[illegible]	SPOT	SPOT	SPOT
DESCRIPTION — VERTICAL OR HORIZONTAL	H	H	V	H	H	V	H	H	H	H
INSULATION THICKNESS										
DIMENSIONAL — O D - I D	9'	7'	3'	8'	7'	4'6"	3'	5'	6'	3'
LENGTH SEAM TO SEAM	22'	26'	7'	24'	24'	10'	15'	20'	24'	15'
LENGTH BASE SECTION										
HEIGHT OF SKIRT			12'			10'				
℄ TO BOTTOM OF SUPPORTS										
TOTAL SHELL THICKNESS	[illegible] OVRLAY	[illegible]	[illegible]	[illegible] OVRLAY	3/4"	6.25"	.25"	[illegible]	[illegible]	[illegible]
HEAD THICKNESS	[illegible]	[illegible]	[illegible]	[illegible] OVRLAY	3/4'	3.25"	.65"	[illegible]	[illegible]	[illegible]
SKIRT THICKNESS										
MH — NO REQ'D	1	1	1	1	1	1	1	1	1	1
MH — SIZE	24"	24"	24"	24"	24"	24"	24"	24"	24"	24"
MH — SERIES & FACING										
LINING — TYPE	347	347	NONE	347	NONE	NONE	NONE	NONE	NONE	NONE
LINING — THICKNESS	3/16"	1/8		.5'						
LINING — LOCATION	TOTAL	TOT	—	TOTAL	—					
TRAY A — NO TRAYS REQ'D & SPACING										
TYPE OF TRAY										
NO OF CAPS/TRAY & TYPE										
SIZE OF CAPS										
SIZE OF RISERS										
TYPE OF DOWNCOMER										
TRAY B — NO TRAYS REQ'D & SPACING										
TYPE OF TRAY										
MAT'L SPEC — SHELL & HEADS	1¼ CR ½ MO	CS.	CS	CS	CS	CS	CS	CS	CS	CS
SKIRT			CS			CS				
STRUCTURAL MEMBERS										
PURCHG DATA — REQUISITION NO										
PURCHASE ORDER										
PURCHASED FROM										
FABRICATOR S/O										
SHIPPING WEIGHT [illegible]	65,000	18,000	4000	320,000	[illegible]	15000	1750	12,000	12000	[illegible]
~~TEST WEIGHT~~ [illegible]	[illegible]300	[illegible]	—	4,200						

NOTES

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

TOWER & VESSEL SCHEDULE

PLANT AIR FORCE HYDROVISBREAKER

PLANT NO UNIT NO

LOCATION

BY	APPD	DRAWING NO	REV	SHEET
LGM				8
DATE 4/25/81				

	No.	PUMP ITEM NO	P1,1A	P2,2A,2B	P3,3A	P4,4A	P5,5A	P6,6A	P7,7A	P8,8A	P-9,9A	P10,10A
		SERVICE	REACTOR FEED	ADDITIVE FEED	REACTOR CIRCULATING PUMPS			ATM. TWR P. A	LEAN AMINE	AMINE REFLUX	ATM TWR REFL & PROD	ATM TWR BOTTOMS
OPERATING CONDITIONS	1	LIQUID	RESID.	NAPHTHA	R. PROD.		→	GAS OIL	AMINE	WATER	NAPHTHA	RESID
	2	PUMPING TEMPERATURE °F	514	90	850		→	515	145	105	100	619
	3	SPECIFIC GRAVITY AT P T	.894	.79	.74		→	.7	.99	.99	.75	.81
	4	VISC SSU, CP, CSTK, AT P T	4CP	2CP	2CP		→	1CP	.6CP	.7CP	2CP	4CP
	5	GPM AT P T	1444	100	14,280		→	495	440	40	519	895
	6	SUCTION PRESSURE (PSIG)	5	0	2510		→	33	0	0	10	33
	7	DISCHARGE PRESSURE (PSIG)	2700	30	2515		→	79	2980	50	76	111
	8	DIFFERENTIAL HEAD (FT)	6933'	88'	15.6'		→	152'	5787	117'	204'	224
	9	N P S H AVAILABLE	12'	12'	12		→	12'	12'	12	12'	12'
	10	RPM										
	11	BHP AT RATED GPM	3495	3	70		→	22	1061	2.4	33	68
	12	MAX BHP FOR INSTALLED IMP	3800	5	100		→	25	1100	4	40	75
PUMP SPECIFICATIONS	13	MANUFACTURER										
	14	TYPE AND SIZE							RECIP			
	15	STAGES										
	16	SUCT FLG, SIZE, RATING, FACE										
	17	DISCH FLG, SIZE, RATING, FACE										
	18	NOZZLE ARRG'T - SUCTION										
	19	NOZZLE ARRG'T - DISCHARGE										
	20	IMPELLER DIA REQUIRED										
	21	MAX IMP DIA AND HEAD										
	22	IMP EYE AREA										
	23	N P S H REQUIRED										
	24	HYDROSTATIC TEST PRESSURE										
	25	THRUST BEARING										
	26	RADIAL BEARING										
	27	COUPLING										
	28	COUPLING GUARD										
	29	ROTATION FROM COUPLING END										
	30	MECHANICAL SEALS - MFG										
	31	MECHANICAL SEALS - TYPE										
	32	MECHANICAL SEALS - AUX BOX										
	33	WATER COOLED - BOX										
	34	WATER COOLED - BEARING										
	35	WATER COOLED - PEDESTAL										
	36	WEIGHT OF PUMP AND BASE										
MATERIAL SPECIFICATIONS	37	CASING	CS	CS	12CR		→	CS	CS	CS	CS	CS
	38	CASE WEARING RINGS										
	39	STAGE PIECES										
	40	BUSHINGS - THROAT										
	41	BUSHINGS - INTERSTAGE										
	42	IMPELLER	2CR	12CR	12CR		→	12CR	—	12CR	12CR	12CR
	43	IMPELLER WEARING RINGS										
	44	SHAFT										
	45	SHAFT SLEEVES										
	46	GLAND										
	47	LANTERN RINGS										
	48	BEARING HOUSING										
	49	BASE PLATE										
	50	GASKETS										
	51	SEAL - STATIONARY RING										
	52	SEAL - ROTATING RING										
	53	SEAL - PACKING										
	54	MANUFACTURERS SERIAL NO										
	55	PERFORMANCE CURVE										
	56	PO NUMBER										
	57	SR & MC DRAWING NO.										

NOTES

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

CENTRIFUGAL PUMP SCHEDULE

PLANT AIR FORCE HYDROVISBREAKER

PLANT NO UNIT NO

LOCATION

BY	APPD	DRAWING NO	REV	SHEET
LCM				9
DATE 4/25/67				

Pump Item No	No.	P11,11A	P12,12A	P13,13A	P14,14A	P15,15A	P16,16A			K-2,2A	K-1
Service		ATM TWR GAS OIL	VACUUM GASOIL	VACUUM P.A.	VACUUM BOTTOMS	VAC ACC WATER	VAC ACC LT. OIL			ATM TOWER OFF GAS COMPRESS.	RECYCLE COMPR.
Operating Conditions											
Liquid	1	GAS OIL	VAC GAS OIL	—	P11-12	DIL H_2O	.7 DIST.			30 MW GAS	[illegible]
Pumping temperature °F	2	543°	542°	542	.831	1.00	160			100	125°F
Specific gravity at P.T.	3	.694	.824	.824	.701	.99	.702			K-1.16	K=1.38
Visc SSU, CP, CSTK, at P.T.	4	.5CP	2CP	2CP	2CP	1.0CP	.5CP			537 SCFM	[illegible]
GPM at P.T.	5	274	564	792	121	31	126				
Suction pressure (PSIG)	6	20	1 PSIA	1 PSIA	1 PSIA	14 PSIA	14 PSIA			20	2425
Discharge pressure (PSIG)	7	64	67	52	133	55	55			150	2620
Differential head (FT)	8	146'	227'	185'	397'	130'	143				
N P S H available	9	12'	12'+	12'+	12'	12'+	12'+				
RPM	10										
BHP at rated GPM	11	12	44	51	27	1.7	5.8			42.6	1395
Max BHP for installed imp	12	15	50	60	35	3.0	8.0			50	1500
Pump Specifications											
Manufacturer	13										
Type and size	14										
Stages	15										
Suct flg. size, rating, face	16										
Disch flg. size, rating, face	17										
Nozzle arrg't - suction	18										
Nozzle arrg't - discharge	19										
Impeller dia required	20										
Max imp dia and head	21										
Imp eye area	22										
N P S H required	23										
Hydrostatic test pressure	24										
Thrust bearing	25										
Radial bearing	26										
Coupling	27										
Coupling guard	28										
Rotation from coupling end	29										
Mechanical seals — MFG	30										
Mechanical seals — Type	31										
Mechanical seals — Aux box	32										
Water cooled — Box	33										
Water cooled — Bearing	34										
Water cooled — Pedestal	35										
Weight of pump and base	36										
Material Specifications											
Casing	37	CS	CS	CS	CS	CS	CS			CS	CS
Case wearing rings	38										
Stage pieces	39										
Bushings — Throat	40										
Bushings — Interstage	41										
Impeller	42	12CR	12CR	12CR	12CR	12CR	12CR			12 CR	12CR
Impeller wearing rings	43										
Shaft	44										
Shaft sleeves	45										
Gland	46										
Lantern rings	47										
Bearing housing	48										
Base plate	49										
Gaskets	50										
Seal — Stationary ring	51										
Seal — Rotating ring	52										
Seal — Packing	53										
Manufacturers serial no	54										
Performance curve	55										
P.O. number	56										
SR & MC drawing no	57										

NOTES

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

CENTRIFUGAL PUMP SCHEDULE & COMPRESSORS

PLANT AIR FORCE

HYDROVISBREAKER

PLANT NO UNIT NO

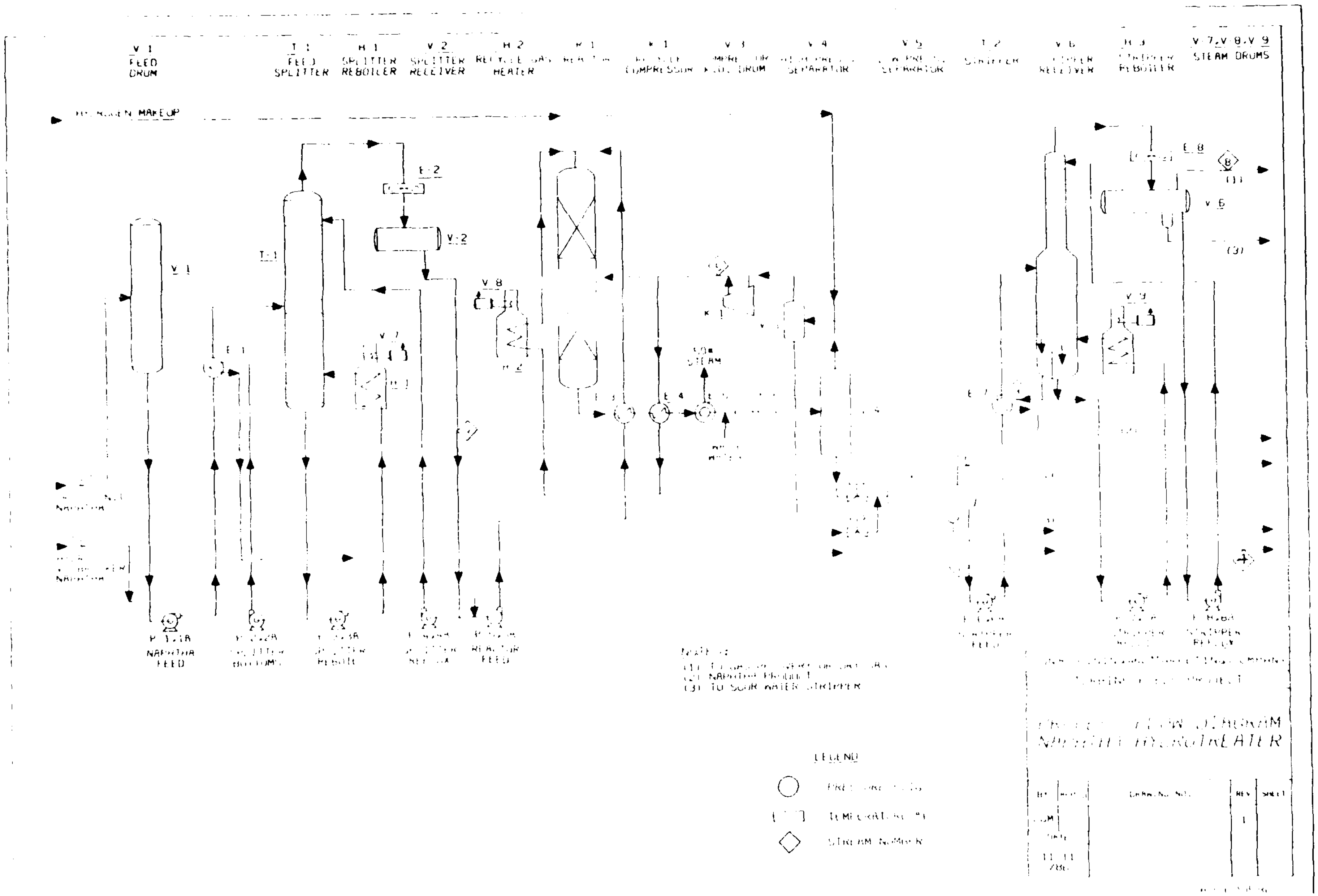
LOCATION

BY	APPD	DRAWING NO	REV	SHEET
LCM				10
DATE 4/25/87				

PROCESS DESIGN SPECIFICATIONS

for the

NAPHTHA HYDROTREATING UNIT


V-1 FEED DRUM
T-1 FEED SPLITTER
H-1 SPLITTER REBOILER
V-2 SPLITTER RECEIVER
H-2 RECYCLE GAS HEATER
K-1 RECYCLE COMPRESSOR
V-4 SEPARATOR
T-2 STRIPPER
V-6 RECEIVER
H-3 STRIPPER REBOILER
V-7, V-8, V-9 STEAM DRUMS
HYDROGEN MAKEUP
V-1
T-1
E-1
E-2
V-2
V-7
V-8
H-2
E-4
STEAM
E-8
V-6
V-9
P-1A/B NAPHTHA FEED
SPLITTER BOTTOMS
SPLITTER REBOIL
REACTOR FEED
STRIPPER FEED
STRIPPER REFLUX
NOTES:
(2) NAPHTHA PRODUCT
(3) TO SOUR WATER STRIPPER
LEGEND
TEMPERATURE
STREAM NUMBER
NAPHTHA HYDROTREATER
DRAWING NO.
REV
SHEET

NAPHTHA HYDROTREATING UNIT
MATERIAL BALANCE AND STREAM PROPERTIES

Stream Number	1	2	3	4	5	6	7
Stream Label	Naphtha from Crude Unit	Naphtha from Hydrovisbreaker	Feed Splitter Overhead	Feed Splitter Bottoms	Recycle Gas	Low-Pressure Separator Gas	Low-Pressur Separator Liquid
Stream Conditions							
Temperature, °F	332	100	259	595	126	116	116
Physical state	Liquid	Liquid	Liquid	Liquid	Vapor	Vapor	Liquid
API Gravity	27.8	49.9	33.7	24.1	-	-	42.9
Sp.Gr. @ 60°F							
Sp.Gr. @ Temp.	0.78	0.77	0.78	0.70	(4.35 mol wt)	(13.5 mol wt)	0.79
Pressure, psia	70	35	15	23	1325	165	165
BBLS/DAY @ 60°F	10,542	11,875	4,267	6,276	-	-	15,966
M lb/hr	136.44	135.00	53.27	83.17	37.36	1.92	188.76
GPM @ 60°F							
Vis., cSt @ Temp.	0.3	0.6	0.3	0.2	0.01	0.01	0.5

Stream Number	8	9
Stream Label	Stripper Overhead Gas	Stripper Bottoms
Stream Conditions		
Temperature, °F	100	506
Physical state	Vapor	Liquid
API Gravity	-	42.0
Sp.Gr. @ 60°F		
Sp.Gr. @ Temp.	(29.9 mol wt)	0.61
Pressure, psia	165	175
BBLS/DAY @ 60°F	-	15,790
M lb/hr	1.26	187.50
GPM @ 60°F	-	
Vis., cSt @ Temp	0.01	0.02

NAPHTHA HYDROTREATING UNIT DESIGN BASIS

Naphtha Feed Rate

The unit is designed to hydrotreat 16,327 BPSD of 47.3°API San Ardo naphtha with an ASTM end-point of 490°F. The sulfur and nitrogen concentrations in the feed are 3820 and 70 wppm, respectively. Both the sulfur and nitrogen content of the hydrotreated product will be less than 10 ppm. The feed naphtha is a blend of 4451 BPSD of crude unit naphtha and 11,875 BPSD of hydrovisbreaker naphtha. The unit will be capable of maintaining a 94% on-stream factor.

Plant Processing Steps

The naphtha from the crude unit is fractionated in the Naphtha Hydrotreater feed splitter tower to obtain an overhead naphtha with a 490°F end-point. The feed splitter bottoms (490-650°F cut) is fed to the Distillate Hydrotreater. The overhead naphtha is combined with the 490°F end-point naphtha from the Hydrovisbreaker to form the total liquid feed to the Naphtha Hydrotreater. It is heated by exchange with the Naphtha Hydrotreater Reactor effluent to 690°F and then fed to the top of the reactor.

Recirculated hydrogen plus make-up hydrogen heated to 650-700°F by heat exchange and fired heat is also fed to the top of the reactor. The reactor operates at 650 to 750°F and 1565 psig over its operating cycle of about two years.

The reactor effluent is cooled and water-washed to prevent fouling and corrosion of the effluent aircooler. The unreacted hydrogen is separated and recycled to the reactor.

The hydrotreated naphtha product is stripped (debutanized) at the unit, and this permits it to be stored at atmospheric pressure in intermediate tankage, if needed. Thus a short emergency outage of the refinery Gas Plant

fractionation will not force a shutdown of the Naphtha Hydrotreater. The hydrotreated naphtha can bypass the Absorber-Stripper and Debutanizer Towers at the Gas Plant and, instead, flow directly to the Main Fractionator at the Distillate Hydrocracker Unit.

NAPHTHA HYDROTREATER UNIT

Utilities and Chemical Requirements

Saturated Steam Produced, lb/hr

Steam Generators:	450 psig	150 psig	50 psig	Total
V-7 AT Heater H-1	-	8,750	-	8,750
V-8 at Heater H-2	-	6,200	-	6,200
V-9 at Heater H-3	-	4,050	-	4,040
E-5	-	-	10,000	-
Totals	-	19,000	10,000	29,000

Steam Used, lb/hr

	450 psig	150 psig	50 psig	Total	Condensate Recovered
Heaters H1,H2,H3	1,000	-	-	1,000	-
Misc. heating	-	5,000	5,000	10,000	-
Total used	1,000	5,000	5,000	11,000	-
Net export stream	-1,000	14,000	5,000	18,000	

Boiler Feed Water

For steam produced	29,000 lb/hr
For 10% blowdown & wash water	9,000
Total gross BFW needed	38,000 lb/hr
Condensate recovered (reused as BFW)	-
Net BFW needed	38,000 lb/hr=76 gpm

Cooling Water Circulated	Supply	Return	Duty
None required			

Heater Fuel Fired

Fuel: Vacuum Residuum Product from the Hydrovisbreaker Unit.

Heater H-1	402 MMBTU/Hr
Heater H-2	28.3
Heater H-3	18.8
Total	87.3 MMBTU/Hr=14.5 FOE Bbl/Hr =5,080 lb/hr residuum fuel

NAPHTHA HYDROTREATER UNIT

Utilities and Chemical Requirements
(continued)

Electrical Power

		Brake Horsepower Operating	Brake Horsepower Connected
P-1,1A	Naphtha splitter feed pumps	30	60
P-2,2A	Splitter bottoms pumps	30	60
P-3,3A	Splitter reboiler pumps	70	140
P-4,4A	Splitter reflux pumps	20	40
P-5,5A	Reactor feed pumps	700	1,400
P-6,6A	Product stripper feed pumps	75	150
P-7,7A	Stripper reboiler pumps	75	150
P-8,8A	Stripper reflux pumps	10	20
E-2,E-6, E-8	Fans	260	260
K-1	Recycle Gas Compressor	800	800
	Total Brake Horsepower:	2,070	3,080 BHP
	Kilowatts:	1,543 KW	2,297 KW

Air Requirements

Dry Instrument Air	50 psig	150 SCFM
Plant Air	120 psig	

Hydrotreating Catalyst

See table of Refinery Operating Requirements, Catalyst and Chemicals in the overall refinery description.

Type: Nickel-molybdenum-on-alumina
Initial fill: 59,784 lb at 47 lb/ft^3
Life: 4 years total, includes one regeneration

NAPHTHA HYDROTREATER UNIT

Major Equipment List

Heat Exchangers

E-1	Feed Splitter Tower Feed - Bottoms Exchanger
E-2	Feed Splitter Overhead Condenser (aircooler)
E-3	Reactor Effluent - Reactor Naphtha Feed Exchanger
E-4	Reactor Effluent - Reactor Gas Feed Exchanger
E-5	Reactor Effluent - 50 psig Steam Generator
E-6	Reactor Effluent Cooler (aircooler)
E-7	Stripper Feed - Bottoms Exchanger

Fired Heaters

H-1	Feed Splitter Reboiler
H-2	Recycle Gas Heater
H-3	Stripper Reboiler

Towers

T-1	Feed Splitter
T-2	Product Stripper (product debutanization)

Reactor

R-1	Naphtha Hydrotreater Reactor

Compressor

K-1	Recycle Compressor

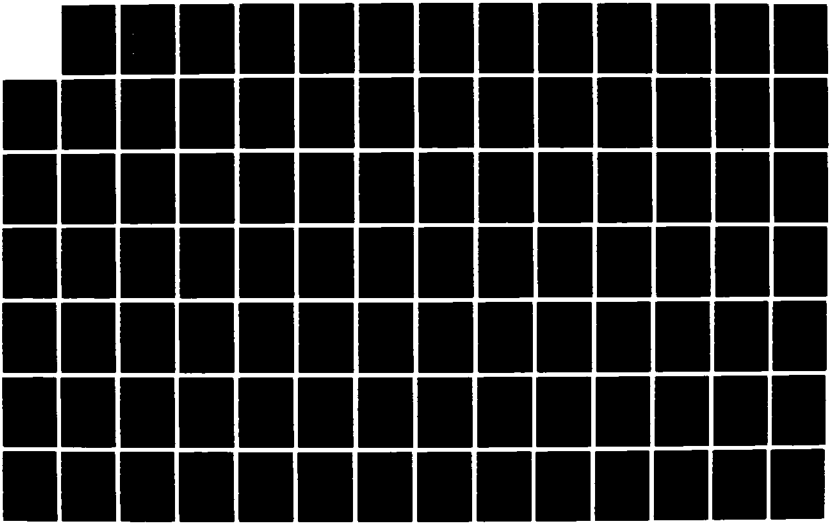
Pumps

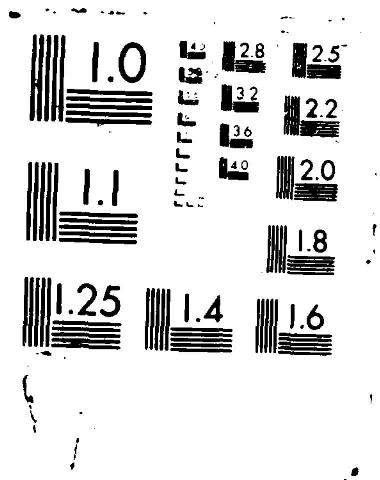
P-1,1A	Straight-run Naphtha Feed
P-2,2A	Feed Splitter Bottoms
P-3,3A	Feed Splitter Reboiler
P-4,4A	Feed Splitter Reflux
P-5,5A	Reactor Feed
P-6,6A	Product Stripper Feed
P-7,7A	Product Stripper Reboiler
P-8,8A	Product Stripper Reflux

Vessels

V-1	Naphtha Hydrotreater Feed Drum (for straight-run naphtha)
V-2	Feed Splitter Overhead Accumulator Drum
V-3	Recycle Compressor Knockout Drum
V-4	High Pressure Separator
V-5	Low Pressure Separator
V-6	Stripper Overhead Accumulator Drum
V-7	Steam Drum for H-1 Heater
V-8	Steam Drum for H-2 Heater
V-9	Steam Drum for H-3 Heater

AD-A190 120 TURBINE FUELS FROM TAR SANDS BITUMEN AND HEAVY OIL 2/3
VOLUME 2 PHASE 3 PROCE..(U) SUN REFINING AND MARKETING
CO MARCUS HOOK PA APPLIED RESEARCH.. A F TALBOT ET AL.
UNCLASSIFIED SEP 87 AFWAL-TR-87-2043-VOL-2 F/G 21/4 NL




1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

SERVICE	ITEM NO	1	E-1		E-2		E-3		E-4		E-5	
	SERVICE	2	SPLITTER FEED		SPLITTER		R-1 EFFLUENT TO		R-1EFF-NAPH.		R-1 EFF STEAM	
		3	BOTTOMS EXCH		OVHD COND.		RECYCLE GAS EXCH		EXCHANGER		GENERATOR	
	MANUFACTURER - NO SHELLS	4		2	AIR COOLER			2	2		1	
	SIZE AND TYPE	5	AES	21"X20'	1-12' X 36'		AEUA	21"X20'	24"X20'	AEU A	AKS 48"X32"X20'	
	SURFACE/UNIT - /SHELL FT²	6	[illegible]	1130	10,000 BARE SQ.		2320	1120	[illegible]	1880	1250	
		7	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE
UNIT PERFORMANCE	CONNECTED IN	8	SERIES	SERIES	—	—	SERIES	SERIES	SERIES	SERIES	—	
		9					RECYCLE					
	FLUID CIRCULATED	10	FEED	BTMS	AIR	OVHD	GAS	R-1 EFF	NAPH.	R-1 EFF	STEAM	R-1 EFF
	QUANTITY ENTERING M-LB/HR LIQUID	11	136.44	83.19				94.6	100.3		10.0	144.6
	VAPOR MW	12	—			126.95	48.3(6.6)	142.2		236.8		92.2
	FIXED GASES MW	13	—									
	STEAM	14	—									
	TOTAL	15	136.44	83.19		126.95	48.3	236.8	100.3	236.8	10.0	236.8
	FLUID VAPORIZED OR CONDENSED M-LB/HR	16	—	—		126.95	—	COND.	100.3	94.6 C	10.0	7
	STEAM CONDENSED	17										
	GRAVITY · LIQUID (SG)(API) AT °F AVG	18	.8	.74		.78		.82	.86 @60°F			
	VISCOSITY · LIQUID (CP) AT °F AVG	19	.4	.5		.6	.02 VAP	.93	.44 @60°F	.4 " "		.5 " "
	SPEC HEAT · LIQUID · BTU/LB °F	20	.64	.66		.55 @ 250	—	.32	.55 @ 60°F	.7 " "		.6 " "
	LATENT HEAT · VAPOR · BTU/LB	21				214	—	—				
	OPER TEMP °F IN · OUT	22	232/476	595/366	90/150°	424/259	473-410	465-380	181-640	750-465	300/300	380-330
	OPER PRESSURE PSIG	23	50	50		5	1310	1205	1265	1220	50	1195
	MINIMUM FOULING FACTOR	24										
	NUMBER OF PASSES	25										
	VELOCITY · FT/SEC	26										
	PRESSURE DROP · PSIG	27	10	10		5	10	10	15	15	.5	5
	HEAT EXCHANGED · BTU/HR (MM)	28	11.7		26.90		19		65		10.0	
	MTD CORRECTED · WEIGHTED	29	59		200		85		169		50	
	TRANSFER RATE SERVICE · CLEAN	30	65		70 (BARE TUBE)		100		90		160	
CONSTRUCTION	DESIGN PRESSURE · PSIG	31	100	100		50	1880	1325	1395	1345	150	1315
	TEST PRESSURE · PSIG	32	150	150		75						
	DESIGN TEMPERATURE · °F	33	650	650		650	650	650	800	850	400°F	650
	CORROSION ALLOWANCE	34	1/8"	1/8"		1/8"	1/8	1/8	1/8"	1/8"	1/8"	1/8"
	CONNECTIONS SIZE · STD · TYPE IN	35										
	OUT	36										
	TUBES MAT'L NO	37		CS		CS	1CR+1/2 347	347	1CR+1/2 347	347	CS	CS
	O.D. BWG	38		3/4"/12		1"/10	3/4/10	3/4/14		3/4/14		3/4"/12
	LENGTH PITCH	39		20'/1"◇		32' FINS		20'/1"◇		30'/1"◇		20'/1"◇
	SHELL I.D. · O.D.	40	21"		12' WIDE		21"		24"		48"	
		41	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS
	STATIONARY TUBE SHEET	42										
	FLOATING TUBE SHEET	43	CS									
	CROSS BAFFLES	44										
	LONGITUDINAL BAFFLES	45										
	TUBE SUPPORTS	46										
	SHELL	47										
	SHELL COVERS	48										
	FLOATING HEAD COVER	49										
	CHANNEL	50										
	CHANNEL COVER	51										
	CROSS BAFFLES TYPE · SPACING	52										
	LONGITUDINAL BAFFLE TYPE	53										
	GASKETS	54										
	WELDING FLANGES AND NOZZLES	55										
	FANS	56			2@25HP							
	WEIGHT EXCHANGER DRY · WET	57										
	WEIGHT BUNDLE	58										
	CODE REQUIREMENTS	59										
	SR & XR DRAWING NO	60										
	REQUISITION NO	61										
	PURCHASE ORDER NO	62										

NOTES

SR - STRESS RELIEVED
XR - X-RAYED

NO	DATE	REVISION	BY
R1	10/29/8	E-3, E-4 E-5	[illegible]

Sun Refining and Marketing Company

HEAT EXCHANGER SCHEDULE

PLANT AIR FORCE - NAPHTHA HYDROTREATER

PLANT NO UNIT NO

LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
ICM				1
DATE 4/25/87				

		No										
SERVICE	ITEM NO	1	E-6		E-7				E-8			
	SERVICE	2	R-1 EFF-AIR		STRIPPER FEED		STRIPPER		STRIPPER-			
		3	COOLER		BOTTOMS-EXCH.		PREHEATER		CONDENSER			
	MANUFACTURER - NO SHELLS	4		2		5				1		
	SIZE AND TYPE	5	*18 x 40		26" x 20'				12 x 36			
	SURFACE/UNIT - /SHELL	6	*10,100	*5050	9820	1964			2813	2813		
		7	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE
UNIT PERFORMANCE	CONNECTED IN	8		PARALLEL	SERIES	SERIES						
	FLUID CIRCULATED	9			BOTTOMS					OVHD		
		10	AIR	R-1 EFF.	HVY NAPH	FEED NAPH	STEAM	FEED NAPH	AIR	LT. H.C.		
	QUANTITY LBS/HR MLB/HR — LIQUID HC	11		*151.6	187.5	*188.8						
	VAPOR MW HC	12		*85.2						42.2		
	FIXED GASES MW	13										
	STEAM	14		H₂O 44.8								
	TOTAL	15		*281.6	187.5	*188.8				42.2		
	FLUID VAPORIZED OR CONDENSED	16		*15 C		*2.2 V				38.1 C		
	STEAM CONDENSED	17										
	GRAVITY - LIQUID (SG)(API) AT °F AVG	18		*.80 HC	*.67	*.69				.51		
	VISCOSITY - LIQUID (SSU)(CP) AT °F AVG	19		.6	.5	.5				.3		
	SPEC HEAT - LIQUID - BTU/LB	20										
	LATENT HEAT - VAPOR - BTU/LB	21										
	OPER TEMP °F - IN - OUT	22	90/160	*285-110	*505/192	*146/445			*90/140	176/114		
	OPER PRESSURE - PSIG	23		*1190	165	245				150		
	MINIMUM FOULING FACTOR	24										
	NUMBER OF PASSES	25										
	VELOCITY - FT/SEC	26										
	PRESSURE DROP - PSIG	27	-	10	25	25				5		
	HEAT EXCHANGED - BTU/HR	28	* 38.6 MM		* 35.55 MM				6.3 MM			
	MTD CORRECTED - WEIGHTED	29	45		* 68				28			
	TRANSFER RATE SERVICE - CLEAN	30	85 BARE TUBE EQ.		65				80			
CONSTRUCTION	DESIGN PRESSURE - PSIG	31		*1310	200	300	ELIMINATED		—	200		
	TEST PRESSURE - PSIG	32										
	DESIGN TEMPERATURE - °F	33		650	650	650				650		
	CORROSION ALLOWANCE	34		1/8	1/8	1/8"				1/8"		
	CONNECTIONS SIZE - STD - TYPE — IN	35										
	OUT	36										
	TUBES — MAT'L - NO	37		410SS	CS	CS	*		CS	CS		
	OD - BWG	38		1"/10		3/4" 12				1"/10		
	LENGTH - PITCH	39		40' FINS		20'0"				36' FINNED		
	SHELL - ID - OD	40	* 18' WIDE		* 26"				12' WIDE			
		41	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS
	STATIONARY TUBE SHEET	42										
	FLOATING TUBE SHEET	43										
	CROSS BAFFLES	44										
	LONGITUDINAL BAFFLES	45										
	TUBE SUPPORTS	46										
	SHELL	47										
	SHELL COVERS	48										
	FLOATING HEAD COVER	49										
	CHANNEL	50										
	CHANNEL COVER	51										
	CROSS BAFFLES TYPE - SPACING	52										
	LONGITUDINAL BAFFLE TYPE	53										
	GASKETS	54										
	WELDING FLANGES AND NOZZLES	55										
	~~DRIVES~~ FANS	56	* 4 @ 40 HP						2 @ 25 HP			
	WEIGHT EXCHANGER - DRY - WET	57										
	WEIGHT BUNDLE	58							* REVISED OVHD			
	CODE REQUIREMENTS	59							TEMP 204 → 100°F			
	SR & MC DRAWING NO	60							DUTY LESS			
	REQUISITION NO	61							KEEP ABOVE			
	PURCHASE ORDER NO	62							RATING			

NOTES

SR - STRESS RELIEVED

XR - X RAYED

NO	DATE	REVISION	BY
R 1	4/29/86	E 6, E 7, E 8, E 9	LGM

Sun Refining and Marketing Company

HEAT EXCHANGER SCHEDULE

PLANT AIR FORCE - NAPHTHA HYDROTREATER

PLANT NO UNIT NO

LOCATION

BY	APPD	DRAWING NO	REV	SHEET
LGM				2
DATE 4/25/67				

SERVICE	H-1	SPLITTER REBOILER			H-2 RECYCLE GAS HEATER			
TYPE								
MANUFACTURER								
TOTAL DUTY OF HEATER MM BTU PER HR ABSORBED/FIRED	34.1/40.2				* 24.44/28.34			
PROCESS DESIGN CONDITIONS								
HEATER SECTION	RADIANT	CONVECTION →			RADIANT	CONVECTION →		
SERVICE	PROCESS	PROCESS	STM GENER	BFW	PROCESS	PROCESS	STM GENER	BFW
HEAT ABSORPTION MM BTU/HR	24.2	2.6	7.4	1.0	*17.14	*1.36	*5.24	*0.7
FLUID	NAPHTHA	→	STM & WATER	BFW	RECYCLE GAS	→	STM & WATER	BFW
FLOW RATE LB/HR M	314.46	314.46	43.25	9.62	*48.3	*48.3	*30.8	*6.2
FLOW RATE BPD ACTUAL	31158	31158	3409	679				
PRESSURE DROP PSI (ALLOWABLE)	← 50	→	1.0	10	← 50	→	1.0	10
PRESSURE DROP PSI (CALCULATED)								
AVERAGE FLUX DENSITY BTU/HR/SQ FT								
FOULING FACTOR								
INLET CONDITIONS								
TEMPERATURE DEG F	580	528	366	260	*431	*410	*366	*260
PRESSURE ~~(PSIA)~~ (PSIG)	68	70	152	168	*1300	*1300	152	162
LIQUID FLOW LB/HR	314.96	314.46	43.25	9.685	–	–	*30.7	*6.7
VAPOR FLOW LB/HR	–		–	–	*48.3	*48.3	–	–
LIQUID ~~(DEG API)~~ (SP GR AT 60 F)	.89	.89	1.0	1.0			1.0	1.0
VAPOR MOLECULAR WEIGHT					5.6	8.4		
LIQUID VISCOSITY CP	.3	.3	.4	.4			.4	.4
OUTLET CONDITIONS								
TEMPERATURE DEG F	595	580	366	366	700	*431	366	366
PRESSURE ~~(PSIA)~~ (PSIG)	18	70	150	152	1250	1300	151	152
LIQUID FLOW LB/HR M	83.17	314.46	35.00	9.625		–	*24.5	*6.7
VAPOR FLOW LB/HR M	232.29	–	8.25	–	*48.3	*48.3	*6.2	–
LIQUID ~~(DEG API)~~ (SP GR AT 60 F)	.90	.9	1.0	1.0				
VAPOR MOLECULAR WEIGHT	213	–	18	–			18	–
LIQUID VISCOSITY CP	.3	.3	.1	.2	–	–	.1	.2
FUEL CHARACTERISTICS								
TYPE OF FUEL	10 API				10 API			
HEATING VALUE LHV								
~~SPECIFIC GRAVITY~~ #AIR REQUIRED	2348				*1654			
SULFUR/NITROGEN WEIGHT %								
COIL DESIGN								
HEATER SECTION	RADIANT	CONVECTION →			RADIANT	CONVECTION →		
DESIGN PRESSURE PSIG	150	150	200	200	*1500	*1500	200	200
DESIGN FLUID TEMPERATURE DEG F	850°	650	650	650	1000	1000	650	650
CORROSION ALLOWANCE TUBES	1/8"	1/8"	1/8"	1/8"				
FITTINGS								
HYDROSTATIC TEST PRESSURE PSIG								
NUMBER OF PASSES								
OVERALL TUBE LENGTH FT								
EFFECTIVE TUBE LENGTH FT								
BARE TUBES NUMBER								
TOTAL EXPOSED SURFACE SQ FT								
EXTENDED SURFACE TUBES NUMBER								
TOTAL EXPOSED SURFACE SQ FT								
TUBE SPACING CENTER TO CENTER IN (STAGGERED) (IN LINE)								
TUBE CENTER TO FURNACE WALL IN MIN								
HEAT TREATMENT								
WELD INSPECTION REQUIREMENTS X RAY OR OTHER								
TUBES								
VERTICAL OR HORIZONTAL	H	H	H	H	H	H	H	H
TUBE MATERIAL (ASTM SPECIFICATION AND GRADE)	5CR	5CR	C.S	C.S	347	347	C.S	C.S
OUTSIDE DIAMETER IN								
WALL THICKNESS (MINIMUM) (AVERAGE) IN								

NOTES

NO	DATE	REVISION	BY
R1	10/29/81	H-2	[illegible]

Sun Refining and Marketing Company

FIRED HEATER DESIGN

PLANT AIR FORCE - NAPHTHA HYDROTREATER

PLANT NO UNIT NO

LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
LGM				3
DATE 4/25/81				

SERVICE	H-3 STRIPPER REBOILER			
TYPE				
MANUFACTURER				
TOTAL DUTY OF HEATER MM BTU PER HR ABSORBED/FIRED	* 16.21 MB.A.S.			

PROCESS DESIGN CONDITIONS

HEATER SECTION	RADIANT	CONVECTION	→	
SERVICE	PROCESS	PROCESS	STM GEN.	BFW
HEAT ABSORPTION MM BTU/HR	* 11.23	.93	3.67	.40
FLUID	NAPHTHA	→	STM & WATER	BFW
FLOW RATE LB/HR	*233,185		20 245	4454
FLOW RATE BPD ACTUAL			1578	377
PRESSURE DROP PSI (ALLOWABLE)	← 25	→	1.0	10
PRESSURE DROP PSI (CALCULATED)				
AVERAGE FLUX DENSITY BTU/HR/SQ FT				
FOULING FACTOR				
INLET CONDITIONS				
TEMPERATURE DEG F	405	481	366	260
PRESSURE ~~PSIA~~ PSIG	188	170	152	162
LIQUID FLOW LB/HR	*233 185	*233 185	20 245	*4454
VAPOR FLOW LB/HR				
LIQUID (DEG API) (SP GR AT 60F)			1.0	1.0
VAPOR MOLECULAR WEIGHT				
LIQUID VISCOSITY CP				
OUTLET CONDITIONS				
TEMPERATURE DEG F	*505	447	366	366
PRESSURE ~~PSIA~~ PSIG	*63	188	152	152
LIQUID FLOW LB/HR	*187 378	*233 185	*16 196	*4454
VAPOR FLOW LB/HR	45 807		4049	—
LIQUID (DEG API) (SP GR AT 60F)			1.0	1.0
VAPOR MOLECULAR WEIGHT			18	—
LIQUID VISCOSITY CP			.5	.5
FUEL CHARACTERISTICS				
TYPE OF FUEL	10 API			
HEATING VALUE LHV				
~~SPECIFIC GRAVITY~~ #/HR REQUIRED	1100			
SULFUR NITROGEN WEIGHT %				
COIL DESIGN				
HEATER SECTION	RADIANT	CONVECTION		
DESIGN PRESSURE PSIG	250	250	200	200
DESIGN FLUID TEMPERATURE DEG F	650	650	650	650
CORROSION ALLOWANCE TUBES	1/8"	1/8"	1/8"	1/8"
FITTINGS				
HYDROSTATIC TEST PRESSURE PSIG				
NUMBER OF PASSES				
OVERALL TUBE LENGTH FT				
EFFECTIVE TUBE LENGTH FT				
BARE TUBES NUMBER				
TOTAL EXPOSED SURFACE SQ FT				
EXTENDED SURFACE TUBES NUMBER				
TOTAL EXPOSED SURFACE SQ FT				
TUBE SPACING CENTER TO CENTER IN (STAGGERED) (IN LINE)				
TUBE CENTER TO FURNACE WALL IN MIN				
HEAT TREATMENT				
WELD INSPECTION REQUIREMENTS X-RAY OR OTHER				
TUBES				
VERTICAL OR HORIZONTAL	H	H	H	H
TUBE MATERIAL (ASTM SPECIFICATION AND GRADE)	5CR	5CR	CS	CS
OUTSIDE DIAMETER IN				
WALL THICKNESS (MINIMUM) (AVERAGE) IN				

NOTES

NO	DATE	REVISION	BY
R-1	11/11/86	H 3	LGM

Sun Refining and Marketing Company

FIRED HEATER DESIGN

PLANT AIR FORCE NAPHTHA HYDROTREATER

PLANT NO UNIT NO

LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
LGM				4
DATE 4/23/87				

SERVICE	ITEM NO	T-1	T-2	R-1	V-1	V-2	V-3	V-4	V-5	V-6	V-7
	TITLE	FEED SPLITTER	STRIPPER	REACTOR	FEED DRUM	SPLITTER RECEIVER	LOW PR'R KO DRUM	HI PRESS SEP'R	LOW PRESS SEP'R	STRIPPER RECEIVER	STEAM DRUM
	SERIAL NO										
	DWG NO ASSEMBLY										
	DWG NO DETAILS										
	DWG NO TRAYS										
	DWG NO PLATFORMS										
DESIGN	CODE										
	PRESSURE PSIG	75	200	*1375	40	50	*1350	*1300	200	200	200
	TEMPERATURE °F	650	650	775°F	650	650	300	300	*650	550	650
	CORROSION ALLOWANCE	.16"	.143	3/16 (1)	1/8"	1/8"	*.225"	*.14"	*.171	0.14	0.14
	WIND LOADING										
	HYDROSTATIC TEST PRESSURE PSIG	103	300	*2060	60	75	*2025	*1850	300	300	300
	HAMMER TEST PRESSURE										
	STRESS RELEIVED	NO	NO	YES	NO	NO	YES	YES	NO	NO	NO
	RADIOGRAPHED	SPOT	SPOT	YES	SPOT	SPOT	YES	YES	SPOT	SPOT	SPOT
	VERTICAL OR HORIZONTAL	V	V	V	V	H	V	V	H	H	H
	INSULATION THICKNESS										
DESCRIPTION – DIMENSIONAL	O D / I D	7'	6'/13.5'	8' 6"	10'	8'	3'	*6'	*8'	5'	5'
	LENGTH SEAM TO SEAM	74'	56'/30'	31	32'	16'	10'	18'	25'	20'	15'
	LENGTH BASE SECTION										
	HEIGHT OF SKIRT	12'	12'	12'	12'	—	10'	10'			
	℄ TO BOTTOM OF SUPPORTS										
	TOTAL SHELL THICKNESS	*[illegible]	*[illegible]/7/16"	*4.25 (1)	3/8"	3/8"	*2.125"	2.25"	*.875	*.625"	*.625"
	HEAD THICKNESS	*7/16"	[illegible]/7/16"	*3.00 (2)	3/8"	3/8"	*1.75"	*1.75" (2)	*.875	*.625"	*.625"
	SKIRT THICKNESS	[illegible]	.5	1"	3/16"	—	3/8"	3/8"	—	—	
MH	NO REQD	3	3	2	1	1	1	1	1	1	1
	SIZE	24"	24"	24"	24"	24"	24"	24"	24"	24"	24"
	SERIES & FACING										
LINING	TYPE	*12 CR	—								
	THICKNESS	1/8"	—								
	LOCATION	BTM 20'	—								
TRAY A	NO TRAYS REQD & SPACING	30 @ 24"	36 @ 24"								
	TYPE OF TRAY	VALVE	VALVE								
	NO OF CAPS/TRAY & TYPE										
	SIZE OF CAPS										
	SIZE OF RISERS										
	TYPE OF DOWNCOMER										
TRAY B	NO TRAYS REQD & SPACING										
	TYPE OF TRAY										
MAT'L SPEC	SHELL & HEADS	CS	CS	NOTE (1)	CS	CS	CS	CS	CS	CS	CS
	SKIRT	CS	CS	CS	CS		CS	CS			
	STRUCTURAL MEMBERS	CS	CS	ALLOY	CS	CS	CS	CS	CS	CS	CS
PURCHG DATA	REQUISITION NO										
	PURCHASE ORDER OVERLAY LBS			*8100							
	PURCHASED FROM										
	FABRICATOR S/O										
	SHIPPING WEIGHT LBS LOCAL ~~TEST WEIGHT~~ EX TRAYS	*68000	*50 000	191,100	24500	8200	*14,000	*77000	*28 000	*19,000	*8000

NOTES

(1) SHELL 4.25" OF 2¼ CR. 1 MOLY PLUS 3/16" 347 CR OVERLAY OVERLAY IS CORROSION ALLOWANCE EX. OVERLAY 183,000 LBS HEADS 3.0 + 3/16 OVERLAY HEMISPHERICAL

(2) HEADS HEMISPHERICAL

NO	DATE	REVISION	BY
1	7/7/86	R-1, V-3, V-4, V-5, V-6, T-1, T-2,	LGM
2	12/30/86	HP VESSEL WTS	LGM

Sun Refining and Marketing Company

TOWER & VESSEL SCHEDULE

PLANT AIR FORCE - NAPHTHA HYDROTREATER

PLANT NO   UNIT NO

LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
LGM				5
DATE 4/15/87				

Section	Item		
SERVICE	ITEM NO	V-8	V-9
	TITLE	STEAM DRUM	STEAM DRUM
	SERIAL NO		
	DWG NO ASSEMBLY		
	DWG NO DETAILS		
	DWG NO TRAYS		
	DWG NO PLATFORMS		
DESIGN	CODE		
	PRESSURE	200	200
	TEMPERATURE °F	650	650
	CORROSION ALLOWANCE	.135"	.205
	WIND LOADING		
	HYDROSTATIC TEST PRESSURE	300	300
	HAMMER TEST PRESSURE		
	STRESS RELIEVED	NO	NO
	RADIOGRAPHED	SPOT	SPOT
DESCRIPTION	VERTICAL OR HORIZONTAL	H	H
	INSULATION THICKNESS		
DIMENSIONAL	O D I D	4'	4'
	LENGTH SEAM TO SEAM	12'	8'
	LENGTH BASE SECTION		
	HEIGHT OF SKIRT		
	℄ TO BOTTOM OF SUPPORTS		
	TOTAL SHELL THICKNESS	*.50	* .50
	HEAD THICKNESS	*.50	* .58
	SKIRT THICKNESS		
MH	NO REQ'D	1	1
	SIZE	24"	24"
	SERIES & FACING		
LINING	TYPE		
	THICKNESS		
	LOCATION		
TRAY A	NO TRAYS REQ'D & SPACING		
	TYPE OF TRAY		
	NO OF CAPS/TRAY & TYPE		
	SIZE OF CAPS		
	SIZE OF RISERS		
	TYPE OF DOWNCOMER		
TRAY B	NO TRAYS REQ'D & SPACING		
	TYPE OF TRAY		
MAT'L SPEC	SHELL & HEADS	CS	CS
	SKIRT		
	STRUCTURAL MEMBERS	CS	CS
PURCHG DATA	REQUISITION NO		
	PURCHASE ORDER		
	PURCHASED FROM		
	FABRICATOR S/O		
	~~SHIPPING WEIGHT~~	*4500#	2900 #
	TEST WEIGHT		

NOTES

NO	DATE	REVISION	BY
R-1	1/11/88	V-8, V-9	

Sun Refining and Marketing Company

TOWER & VESSEL SCHEDULE

PLANT AIR FORCE – NAPHTHA HYDROTREATER

PLANT NO UNIT NO

LOCATION

BY	APPD	DRAWING NO	REV	SHEET
JRS DATE 4/25/87				6

PUMP ITEM NO			P1,1A	P2,2A	P3,3A	P4,4A	P5,5A	P6,6A	P7,7A	P8,8A		K-1
SERVICE			NAPHTHA FEED	SPLITTER BOTTOMS	SPLITTER REBOIL	SPLITTER REFLUX	REACTOR FEED	STRIPPER FEED	STRIPPER REBOIL	STRIPPER REFLUX		RECYCLE [illegible]
OPERATING CONDITIONS	LIQUID	1	NAPHTHA									
	PUMPING TEMPERATURE °F	2	332	396	574	259	*150	*116	445	114		109°F
	SPECIFIC GRAVITY AT P T	3	.79	.69	.69	.71	.76	.8	*.58	*.57		*9.4 MW
	VISC SSU, CP, CSTK, AT P T	4	.5	4	.4	.5	.4	1.5	.4	.7		*K = 1.38
	GPM AT P T	5	387	258	1000	21	*541	*529	*886	*105		*59, 295 SCFM
	SUCTION PRESSURE (PSIG)	6	0	8	[illegible]	0	0	150	165	150		*1175
	DISCHARGE PRESSURE (PSIG)	7	70	110	70	68	*1370	*270	273	211		*1310
	DIFFERENTIAL HEAD (FT)	8	210'	341'	208	204'	*4187	360'	*313'	248'		
	N P S H AVAILABLE	9	12'	12'	12'	12'	12'	12'	12	12		
	RPM	10										
	BHP AT RATED GPM	11	26.3	26.3	60.9	14.0	*665	*61	*67	6		*716
	MAX BHP FOR INSTALLED IMP	12	30	30	70	20	*700	*75	*75	10		*800
PUMP SPECIFICATIONS	MANUFACTURER	13										
	TYPE AND SIZE	14										
	STAGES	15										
	SUCT FLG, SIZE, RATING, FACE	16										
	DISCH FLG, SIZE, RATING, FACE	17										
	NOZZLE ARRG'T SUCTION	18										
	NOZZLE ARRG'T DISCHARGE	19										
	IMPELLER DIA REQUIRED	20										
	MAX IMP DIA AND HEAD	21										
	IMP EYE AREA	22										
	N P S H REQUIRED	23										
	HYDROSTATIC TEST PRESSURE	24										
	THRUST BEARING	25										
	RADIAL BEARING	26										
	COUPLING	27										
	COUPLING GUARD	28										
	ROTATION FROM COUPLING END	29										
	MECHANICAL SEALS — MFG	30										
	MECHANICAL SEALS — TYPE	31										
	MECHANICAL SEALS — AUX BOX	32										
	WATER COOLED — BOX	33										
	WATER COOLED — BEARING	34										
	WATER COOLED — PEDESTAL	35										
	WEIGHT OF PUMP AND BASE	36										
MATERIAL SPECIFICATIONS	CASING	37	CS	12CR	12CR	12CR	12CR	12CR	12CR	12CR		CS
	CASE WEARING RINGS	38										
	STAGE PIECES	39										
	BUSHINGS — THROAT	40										
	BUSHINGS — INTERSTAGE	41										
	IMPELLER	42	12CR	12CR	12CR	12CR	12CR	12CR	12CR	12CR		ALLOY
	IMPELLER WEARING RINGS	43										
	SHAFT	44										
	SHAFT SLEEVES	45										
	GLAND	46										
	LANTERN RINGS	47										
	BEARING HOUSING	48										
	BASE PLATE	49										
	GASKETS	50										
	SEAL — STATIONARY RING	51										
	SEAL — ROTATING RING	52										
	SEAL — PACKING	53										
MANUFACTURERS SERIAL NO		54										
PERFORMANCE CURVE		55										
P. NUMBER		56										
CHEMI DRAWING NO		57										

NOTES

NO	DATE	REVISION	BY
R1	1/1/88	P5,5A, P6,6A	

Sun Refining and Marketing Company

CENTRIFUGAL PUMP SCHEDULE & COMPRESSORS

PLANT AIR FORCE - NAPHTHA HYDROTREATER

PLANT NO — UNIT NO

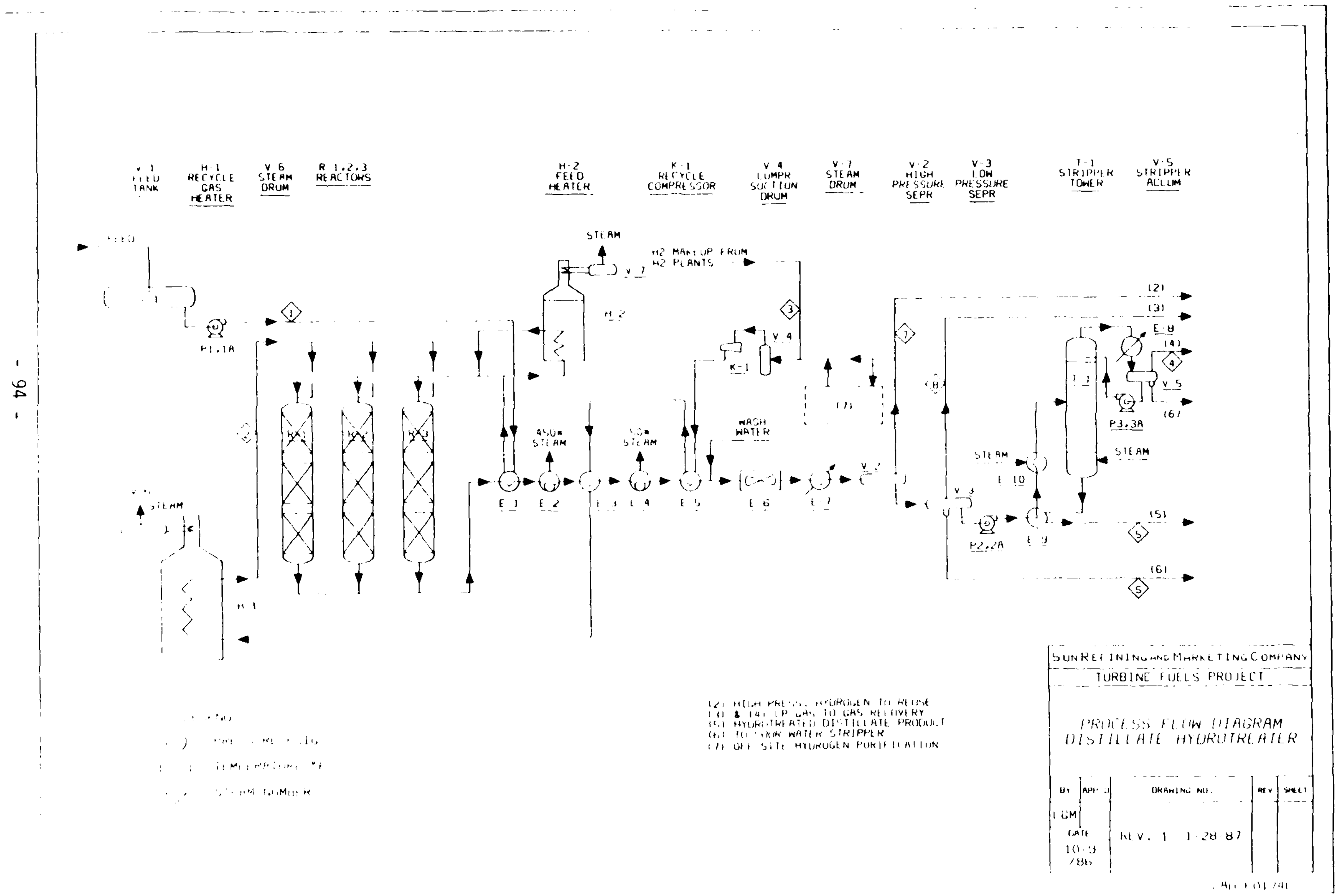
LOCATION

BY	APPD	DRAWING NO	REV	SHEET
IKS				7
DATE 4/13/87				

PROCESS DESIGN SPECIFICATIONS

for the

DISTILLATE HYDROTREATING UNIT


V-1 FEED TANK
H-1 RECYCLE GAS HEATER
V-6 STEAM DRUM
R-1,2,3 REACTORS
H-2 FEED HEATER
K-1 RECYCLE COMPRESSOR
V-4 COMPR SUCTION DRUM
V-7 STEAM DRUM
V-2 HIGH PRESSURE SEPR
V-3 LOW PRESSURE SEPR
T-1 STRIPPER TOWER
V-5 STRIPPER ACCUM
FEED
STEAM
H2 MAKEUP FROM H2 PLANTS
P1,1A
450# STEAM
50# STEAM
WASH WATER
E-1
E-2
E-3
E-4
E-5
E-6
E-7
E-8
E-9
E-10
P2,2A
P3,3A
(2)
(3)
(4)
(5)
(6)
(7)
(2) HIGH PRESS. HYDROGEN TO REUSE
(3) & (4) LP GAS TO GAS RECOVERY
(5) HYDROTREATED DISTILLATE PRODUCT
(6) TO SOUR WATER STRIPPER
(7) OFF SITE HYDROGEN PURIFICATION
TEMPERATURE °F
STREAM NUMBER
SUN REFINING AND MARKETING COMPANY
TURBINE FUELS PROJECT
PROCESS FLOW DIAGRAM
DISTILLATE HYDROTREATER
BY
APP'D
DRAWING NO.
REV
SHEET
LGM
DATE
10-3/86
REV. 1 1-28-87

DISTILLATE HYDROTREATER UNIT
MATERIAL BALANCE AND STREAM PROPERTIES

Stream Number	1	2	3	4	5	6	7	8
Stream Label	Liquid Feed	Reactor Gas Feed	Hydrogen Makeup	Stripper Tower Gas	Stripper Tower Bottoms	Sour Water from Low-Pres. Separator	High-Pressure Hydrogen Bleed Gas	Low-Pressure Separator Vent Gas
Stream Conditions								
Temperature, deg F	470	700	125	110	150	105	(normally)	121
Physical state	Liquid	Vapor	Vapor	Vapor	Liquid	Liquid	(none)	Vapor
API Gravity	18.7	-	-	-	31.1	10	-	-
Sp.Gr. @ 60 deg F								
Sp.Gr. @ Temp.	0.795	-	-	-	0.84	0.99	-	-
Molecular Weight		2.80	2.72	32.8				7.32
Pressure, psia	2635	2565	2515	160	150	160	-	165
BBLS/DAY @ 60 deg F	30,652	-	-	-	33,354	19,141	-	-
MMSCFD	-	153.0	54.89	0.98	-	-	-	3.56
M lb/hr	420.82	47.13	16.40	3.51	422.85	279.14*	-	2.84
Vis., cSt @ Temp.	0.7	-	-	-	3.0	0.7	-	-

* Does not include 5000 lb/hr sour water from the Stripper Overhead Accumulator Drum

DISTILLATE HYDROTREATER DESIGN BASIS

Distillate Feed Rate

The unit is designed to hydrotreat 30,652 BPSD of 18.7 °API San Ardo distillate with an ASTM end-point of 1000°F. The sulfur and nitrogen content of the feed is 0.85 and 0.79 weight percent. The sulfur and nitrogen content of the hydrotreated product will be less than 10 ppm. The feed distillate is a blend of 6,276 BPSD of crude unit light distillate and 24,376 BPSD of Hydrovisbreaker distillate. The unit will be capable of maintaining a 94% on-stream factor.

Plant Processing Steps

All the straight-run naphtha and atmospheric gas oil from the crude unit boiling up to 650°F is fractionated for a 490°F cut point at the Naphtha Hydrotreater Feed Splitter. The 490-650°F bottoms product from the splitter is combined with all the 490-1000°F gas oil from the Hydrovisbreaker Unit to form the feedstock for the Distillate Hydrotreater.

The total distillate hydrotreater feed is heated by heat exchange with the reactor effluent followed by fired heating. This is fed to the top of the reactor at 700°F.

Recirculated hydrogen plus makeup hydrogen heated to 650 to 700°F by heat exchange and fired heat is also fed to the top of the reactor. A portion of the recirculated hydrogen is upgraded by a hydrogen purification unit from 92 to 99% hydrogen to remove excess methane from the system.

The reactor operates at 650 to 750°F and 2550 psig maximum over its operating cycle of about two years.

The reactor product is cooled and water washed to prevent fouling and corrosion of the final coolers. The unreacted hydrogen is separated and recycled to the reactor.

The distillate product is debutanized at the unit which permits the use of intermediate atmospheric pressure storage prior to the final recovery of the JP-4 and JP-8 by fractionation. Thus a short emergency outage of final fractionation will not force a shutdown of the Distillate Hydrotreater. Also the distillate can bypass the Gas Plant Debutanizer and can enter directly into the Main Fractionator at the Distillate Hydrocracker Unit.

DISTILLATE HYDROTREATER UNIT

Utilities and Chemical Requirements

Saturated Steam Produced, lb/hr

Steam Generators:	450 psig	150 psig	50 psig	Total
E-2	44,970	-	-	44,970
E-4	-	-	46,700	46,700
V-6 at Heater H-1	-	10,600	-	10,600
V-7 at Heater H-2	-	4,240	-	4,240
Totals	44,970	14,840	46,700	106,510

Steam Used, lb/hr

	450 psig	150 psig	50 psig	Total	Condensate Recovered
Heaters H1 & H2	8,800	-	-	8,800	-
Stripper tower	5,000	-	-	5,000	-
E-10 preheater	13,080	-	-	13,080	13,080
Misc. heating	-	5,000	10,000	15,000	-
Total used:	26,880	5,000	10,000	41,880	13,080
Net export steam:	18,090	9,840	36,700	64,630	

Boiler Feed Water

For steam produced	106,510 lb/hr
For 10% blowdown & wash water	10,651
Total gross BFW needed	117,161 lb/hr
Condensate recovered (reused as BFW)	-13,000
Net BFW needed	104,161 lb/hr=208 gpm

Cooling Water Circulated		Supply	Return	Duty
E-7	2500 GPM	85°F	105°F	19.0 MMBTU/HR
E-8	473	85	110	5.92 MMBTU/HR
Total	2973 GPM			24.9 MMBTU/HR

Make-up Cooling Water at 3% of total circulation = 90 GPM filtered water to replace loss to evaporation

DISTILLATE HYDROTREATER UNIT

Utilities and Chemical Requirements
(continued)

Hydrotreating Catalyst

See Operating Requirements in overall refinery description section

Fuel Fired

Fuel: Vacuum Residuum Product from the Hydrovisbreaker Unit.

Heater H-1	48.6 MMBTU/HR
Heater H-2	19.4
Total	68.0 MMBTU/HR = 11.3 FOE BBLS/HR
	= 3957 lb/hr Residuum Fuel

Electrical Power

		Brake Horsepower Operating	Brake Horsepower Connected
P-1,1A	Feed Pumps	3000	6000
P-2,2A	Stripper Feed	120	240
P-3,3A		3	6
E-6	Fans	80	80
K-1	Recycle Compressor	1200	1200
	Total	4403 BHP	7526 BHP
	Kilowatts	3283 KW	5612 KW

Air Requirements

Dry Instrument Air	50 psig	250 SCFM
Plant Air	120 psig	

DISTILLATE HYDROTREATING UNIT

List of Major Equipment

Heat Exchangers

E-1	Reactor Feed - Effluent Exchanger
E-2	Reactor Effluent - 450 psig Steam Generator
E-3	Reactor Effluent - Recycle Gas Exchanger No. 2
E-4	Reactor Effluent - 50 psig Steam Generator
E-5	Reactor Effluent - Recycle Gas Exchanger No. 1
E-6	Reactor Effluent Aircooler
E-7	Reactor Effluent Trim Water Cooler
E-8	Stripper Overhead Condenser
E-9	Stripper Feed - Bottoms Exchanger
E-10	Stripper Feed Preheater

Fired Heaters

H-1	Recycle Gas Heater
H-2	Feed Heater

Distillation tower

T-1	Stripper Tower

Reactors

R-1	Distillate Hydrotreater Reactor No. 1
R-2	Distillate Hydrotreater Reacter No. 2
R-3	Distillate Hydrotreater Reactor No. 3

Vessels

V-1	Feed Tank
V-2	High Pressure Separator
V-3	Low Pressure Separator
V-4	Compressor Suction Knockout Drum
V-5	Stripper Overhead Accumulator Drum
V-6	150 psig Steam Drum at Heater H-1
V-7	150 psig Steam Drum at Heater H-2

Pumps

P-1,1A	Feed Pumps
P-2,2A	Stripper Feed Pumps
P-3,3A	Stripper Reflux Pumps

Compressor

K-1	Recycle Gas Compressor

Section	Item	No.	E-1 Shell	E-1 Tube	E-2 Shell	E-2 Tube	E-3 Shell	E-3 Tube	E-4 Shell	E-4 Tube	E-5 Shell	E-5 Tube
SERVICE	ITEM NO	1	E-1		E-2		E-3		E 4		E 5	
	SERVICE	2	REACTOR FEED		450 # STEAM		#2 RECYCLE -		50 # STEAM		#1 RECYCLE	
		3	EFFLUENT EXCH		GENERATOR		EFFLUENT EXCH		GENERATOR		EFFLUENT EXCH	
	MANUFACTURER - NO SHELLS	4		1	" "	1		1	"	1		1
	SIZE AND TYPE	5	39"x20'	BEU	96x54x20'	AKU	41"x20'	BEU	96x52x20'	AKU		BEU
	SURFACE/UNIT - / SHELL	6	1260 ft²	[illegible]	7948	7948	4225	4225	7456	7456	4341	4341
UNIT PERFORMANCE		7	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE
	CONNECTED IN	8	SERIES	SERIES		—	—	—				
	FLUID CIRCULATED	9					H_2				H_2	
		10	FEED	R_x EFF.	STEAM	R_x EFF	RECYCLE	R_x EFF	STEAM	R_x EFF	RECYCLE	R_x EFF
	QUANTITY M #/HR. LIQUID	11	400.81	228.7	50.0	350		390	51.5	395		419
	VAPOR MW	12		[illegible]		118 9	48,168	78 (7)		23 6	48.168	49 4
	FIXED GASES MW	13										
	STEAM	14										
	TOTAL	15	420.81	467.6		468.49	48.17(2.9)	468.49		468.49	48.17(2.9)	468.49
	FLUID VAPORIZED OR CONDENSED M#/HR	16	—	111 C	45.0 V	40 C		5 C	46.7 V	16 C		3 C
	STEAM CONDENSED	17										
	GRAVITY LIQUID (SG)(API) AT 60°F	18	.74	.83	H_2O	.84		.84		.84		.84
	VISCOSITY LIQUID (SSU)(CP) AT 100°F	19	3	2	-	2		2		2		2
	SPEC HEAT LIQUID BTU/LB	20										
	LATENT HEAT VAPOR BTU/LB	21										
	OPER TEMP °F IN OUT	22	420 650	750 635	460 460	610 - 500	300 - 450	500 - 455	300 300	455 - 325	123 - 300	325 - 265
	OPER PRESSURE PSIG	23	2625	2500	450	2490	2625	2475	300	2470	2635	2465
	MINIMUM FOULING FACTOR	24										
	NUMBER OF PASSES	25										
	VELOCITY FT/SEC	26										
	PRESSURE DROP PSIG	27	10	10	1#	5#	5#	5#	1#	5#	5#	5#
	HEAT EXCHANGED BTU/HR	28	* 53.70 MM		46.18 MM		18.65 MM		46.97 MM		21.88	
	MTD CORRECTED WEIGHTED	29	123.5		83		73.6		70		63	
	TRANSFER RATE SERVICE CLEAN	30	60		70		60		90		80	
CONSTRUCTION	DESIGN PRESSURE PSIG	31	* 2890	2750	500	2740	2890	2720	100	2720	2900	2715
	TEST PRESSURE PSIG	32	4345	4125	750	4110	4335	4080	150	4080	4350	4070
	DESIGN TEMPERATURE °F	33	800	850	650	700	650	650	650	650	650	650
	CORROSION ALLOWANCE	34	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"
	CONNECTIONS SIZE STD TYPE IN	35										
	OUT	36										
	TUBES MAT'L NO	37		347		347		347		347		347
	O D BWG	38		1" 10		3/4" 12		3/4" 12		3/4" 12		3/4" 12
	LENGTH PITCH	39		20' 1¼"		20' 1" ◇		20' 1" ◇		20' 1" ◇		20' 1" ◇
	SHELL I D O D	40	37"									
		41	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS
	STATIONARY TUBE SHEET	42										
	FLOATING TUBE SHEET	43										
	CROSS BAFFLES	44										
	LONGITUDINAL BAFFLES	45										
	TUBE SUPPORTS	46										
	SHELL	47	SCK [illegible]		[illegible]		SCK		CS		CS	
	SHELL COVERS	48										
	FLOATING HEAD COVER	49										
	CHANNEL	50										
	CHANNEL COVER	51										
	CROSS BAFFLES TYPE SPACING	52										
	LONGITUDINAL BAFFLE TYPE	53										
	GASKETS	54										
	WELDING FLANGES AND NOZZLES	55										
	STUDS	56										
	WEIGHT EXCHANGER DRY WET	57										
	WEIGHT BUNDLE	58										
	CODE REQUIREMENTS	59										
	SR & MC DRAWING NO	60										
	REQUISITION NO	61										
	PURCHASE ORDER NO	62										

NOTES

SR - STRESS RELIEVED
XR - X-RAYED

NO	DATE	REVISION	BY
2	12/4/86	E-1, E-6-7 Revised	[illegible]
1	2/86	E-1 Revised	

Sun Refining and Marketing Company

HEAT EXCHANGER SCHEDULE

PLANT AIR FORCE DISTILLATE HYDROTREATER
PLANT NO UNIT NO

LOCATION

BY	APPD	DRAWING NO	REV	SHEET
LGM				1
DATE 4/25/87				

Section	Item	No.	E-6 Shell	E-6 Tube	E-7 Shell	E-7 Tube	E-8 Shell	E-8 Tube	E-9 Shell	E-9 Tube	E-10 Shell	E-10 Tube
SERVICE	ITEM NO	1	E-6		E 7		E-8		E9		E 10	
	SERVICE	2	EFFLUENT		EFFLUENT		STRIPPER OVHD		STRIPPER FEED		STRIPPER FEED	
		3	AIR COOLER		WATER COOLER		CONDENSER		BTMS EXCH.		PREHEATER	
	MANUFACTURER - NO SHELLS	4		1		1		1		6		1
	SIZE AND TYPE	5	12X40	AIR COOL	54"X20'	BEU	19"X20'	ABU	40"X20	AES	25"X20	BEU
	SURFACE/UNIT - / SHELL	6	6510#	3255#	8688*	8688*	865	865	25140	4192	1632	1632
UNIT PERFORMANCE		7	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE
	CONNECTED IN	8										
	FLUID CIRCULATED	9							HC	HC		HC
		10	AIR	Rx EFF	WATER	Rx EFF	LT HC	WATER	BTMS	FEED	STEAM	FEED
	QUANTITY LBS/HR M LBS/HR — LIQUID	11		426		428		423GPM	425.37	426.38	13.08	426.29
	VAPOR HC MW	12		41		39	4.2240					.09
	FIXED GASES MW	13							–			–
	STEAM WATER	14		279		279						
	TOTAL	15		747	2500GPM	747	5.41 C		425.37	426.38		426.38
	FLUID VAPORIZED OR CONDENSED #/hr	16		2 C		2 C			–	.09V		.25V
	STEAM CONDENSED	17										
	GRAVITY LIQUID (SG)(API) AT °F 60	18		.84 HC		.84	.66		.87	.86		.86
	VISCOSITY LIQUID (SSU)(CP) AT °F	19										
	SPEC HEAT LIQUID BTU/LB	20										
	LATENT HEAT VAPOR BTU/LB	21										
	OPER TEMP °F IN OUT	22	70 150	205-164	85-165	167-121	378-100	85-110	397-150	110-360	450 450	360 400
	OPER PRESSURE PSIG	23		2955	75	2445	145	75	160	250	450	230
	MINIMUM FOULING FACTOR	24										
	NUMBER OF PASSES	25										
	VELOCITY FT/SEC	26										
	PRESSURE DROP PSIG	27		5#	5#	5#	5#	5#	30#	30#	1#	5#
	HEAT EXCHANGED BTU/HR	28	25 MM *		25 MM *		5.92 MM		58.1 MM		9.99 MM	
	MTD CORRECTED WEIGHTED	29	64		48		26		30.8		68	
	TRANSFER RATE SERVICE ~~CLEAN~~	30	60		60		90		75		90	
CONSTRUCTION	DESIGN PRESSURE PSIG	31		2210	115	2690	225	115	200	275	500	225
	TEST PRESSURE PSIG	32		4065	170	4035	338	123	300	390	750	482
	DESIGN TEMPERATURE °F	33		650	300	300	650	650	650	650	650	650
	CORROSION ALLOWANCE	34		1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"
	CONNECTIONS SIZE STD TYPE IN	35										
	OUT	36										
	TUBES MAT'L NO	37		347		347		ALM		CS		CS
	O.D. BWG	38		1" 12		3/4" 12		3/4" 14		3/4" 12		3/4" 12
	LENGTH PITCH	39		40'		20' 1"		20' 1"		20' 1"		20' 1"
	SHELL I.D. O.D.	40			49"		19"		40"		25"	
		41	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS
	STATIONARY TUBE SHEET	42										
	FLOATING TUBE SHEET	43										
	CROSS BAFFLES	44										
	LONGITUDINAL BAFFLES	45										
	TUBE SUPPORTS	46										
	SHELL	47			CS*		CS		CS		CS	
	SHELL COVERS	48										
	FLOATING HEAD COVER	49										
	CHANNEL	50										
	CHANNEL COVER	51										
	CROSS BAFFLES TYPE SPACING	52										
	LONGITUDINAL BAFFLE TYPE	53										
	GASKETS	54										
	WELDING FLANGES AND NOZZLES	55										
	STUDS	56										
	WEIGHT EXCHANGER DRY WET	57										
	~~WEIGHT BUNDLE~~ ELEC MOTOR FANS	58	2@ 40 HP									
	CODE REQUIREMENTS	59			* CORROSION							
	SR & MC DRAWING NO	60			PROTECTION							
	REQUISITION NO	61			OVERLAY							
	PURCHASE ORDER NO	62										

NOTES

SR - STRESS RELIEVED

XR - X RAYED

NO	DATE	REVISION	BY
	4/30/86	E-6, E-7, E-10 ADDED	

Sun Refining and Marketing Company

HEAT EXCHANGER SCHEDULE

PLANT AIR FORCE DISTILLATE HYDROTREATER

PLANT NO UNIT NO

LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
LGM DATE 4/25/87				2

	H-1 RECYCLE GAS HEATER				H-2 FEED HEATER			
SERVICE								
TYPE								
MANUFACTURER								
TOTAL DUTY OF HEATER MM BTU PER HR ABSORBED/FIRED	41.65/48.55				16.67/19.35			
PROCESS DESIGN CONDITIONS								
HEATER SECTION	RADIANT	CONVECTION			RADIANT	CONVECTION		
SERVICE	PROCESS	PROCESS	STM GENER.	BFW	PROCESS	PROCESS	STM GEN	BFW
HEAT ABSORPTION MM BTU/HR	29.00	2.38	9.08	1.19	11.58	0.95	3.63	0.4
FLUID	RECYCLE	GAS	STM & WATER	BFW	FEED	FEED	STM & WATER	BFW
FLOW RATE ~~LB/HR~~ M LB/HR	48.168		52.984	3707	420.81	420.81	21.180	4.660
FLOW RATE BPD								
PRESSURE DROP PSI (ALLOWABLE)	65	5	1	10	35	5	1	10
PRESSURE DROP PSI (CALCULATED)								
AVERAGE FLUX DENSITY BTU/HR/SQ FT								
FOULING FACTOR								
INLET CONDITIONS								
TEMPERATURE DEG F	465	450	366	260	650	650	366	260
PRESSURE ~~PSIA~~ PSIG	2615	2620	52	162	2610	2615	152	162
LIQUID FLOW LB/HR			52.984	11.656	420.81	420.81	21.180	4.66
VAPOR FLOW LB/HR	48.168	48.168						
LIQUID (DEG API) (SP GR AT 60 F)								
VAPOR MOLECULAR WEIGHT	2.86	2.86						
LIQUID VISCOSITY CP								
OUTLET CONDITIONS								
TEMPERATURE DEG F	700	465	366	366	700	655	366	366
PRESSURE ~~PSIA~~ PSIG	2350	2615	151	152	2570	2610	151	152
LIQUID FLOW LB/HR			42.387	11.656	420.81	420.81	16.9	4.66
VAPOR FLOW LB/HR	48.168	48.168	10.597				4.24	
LIQUID (~~DEG API~~) (SP GR AT 60 F)			1.0	1.0	.94	.94	1.0	1.0
VAPOR MOLECULAR WEIGHT	2.86	2.86	18				18	
LIQUID VISCOSITY CP			.1	.1	1	1	.1	.1
FUEL CHARACTERISTICS								
TYPE OF FUEL								
HEATING VALUE LHV								
SPECIFIC GRAVITY								
SULFUR NITROGEN WEIGHT %								
COIL DESIGN								
HEATER SECTION	RADIANT	CONVECTION			RADIANT	CONVECTION		
DESIGN PRESSURE PSIG	2830	2835	230	245	2870	2880	230	245
DESIGN FLUID TEMPERATURE DEG F	1000	1000	650	650	900	900	650	650
CORROSION ALLOWANCE TUBES	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"
FITTINGS								
HYDROSTATIC TEST PRESSURE PSIG								
NUMBER OF PASSES								
OVERALL TUBE LENGTH FT								
EFFECTIVE TUBE LENGTH FT								
BARE TUBES NUMBER								
TOTAL EXPOSED SURFACE SQ FT								
EXTENDED SURFACE TUBES NUMBER								
TOTAL EXPOSED SURFACE SQ FT								
TUBE SPACING CENTER TO CENTER IN (STAGGERED) (IN LINE)								
TUBE CENTER TO FURNACE WALL IN MIN								
HEAT TREATMENT								
WELD INSPECTION REQUIREMENTS X RAY OR OTHER								
TUBES								
VERTICAL OR HORIZONTAL	H	H	H	H	H	H	H	H
TUBE MATERIAL (ASTM SPECIFICATION AND GRADE)	347	347	[illegible]	[illegible]	5Cr ½Mo	5Cr ½Mo	CS	CS
OUTSIDE DIAMETER IN								
WALL THICKNESS (MINIMUM) (AVERAGE) IN								

NOTES

NO	DATE	REVISION	BY
1	1/16/68	H-2 ADDED	

Sun Refining and Marketing Company

FIRED HEATER DESIGN

PLANT AIR FORCE DISTILLATE HYDROTREATER

PLANT NO | UNIT NO

LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
				3

DATE 4/25/67

	ITEM NO.	V-1	V-2	V-3	V-4	V-5	V-6	V-7	R-123	T-1	
SERVICE	TITLE	FEED TANK	HI PRESS SEPR	L PRESS SEPR	[illegible] SUCTION DRUM	STRIPPER ACCUM	STEAM DRUM	STEAM DRUM	REACTORS	STRIPPER	
	SERIAL NO										
	DWG NO — ASSEMBLY										
	DWG NO — DETAILS										
	DWG NO — TRAYS										
	DWG NO — PLATFORMS										
DESIGN	CODE										
	PRESSURE	75	2685	200	2670		200	200	2805	200	
	TEMPERATURE °F	250	650	650	650		650	650	825	250	
	CORROSION ALLOWANCE	.125	.125*	.171	.13		.167	.15	3/16*	.141	
	WIND LOADING										
	HYDROSTATIC TEST PRESSURE	113	4030	300	4005		300	300		300	
	HAMMER TEST PRESSURE										
	STRESS RELIEVED	NO	YES	[illegible]	YES		NO	NO	YES	NO	
	RADIOGRAPHED	SPOT	YES	[illegible]	YES		SPOT	SPOT	YES		
	VERTICAL OR HORIZONTAL	H	H	H	V		H	H	V	V	
	INSULATION THICKNESS										
DIMENSIONAL	I.D.	12'	8'	8'	3'6"		4'6"	4'	10'	5'6"	
	LENGTH SEAM TO SEAM	56'	24'	24'	[illegible]		10'	10'	68'3"	42'	
	LENGTH BASE SECTION										
	HEIGHT OF SKIRT										
	℄ TO BOTTOM OF SUPPORTS										
	TOTAL SHELL THICKNESS	[illegible]	10.2"	.875	[illegible]		.5625"	.50	10.5"	.625	
	HEAD THICKNESS	[illegible]	7"	.875	3"		.5625	.50	7.0	.625	
	SKIRT THICKNESS							—	1.25"		
MH	NO REQ'D	1	1	1	1		1	1		2	
	SIZE	24"	24"	24"	24"		24"	24"		24"	
	SERIES & FACING										
LINING	TYPE		347	—					347	—	
	THICKNESS		3/16"	—					.125"	—	
	LOCATION		HDS & SHELL	—					HDS & SHELL	—	
[redacted]	NO TRAYS REQ'D & SPACING										
	TYPE OF TRAY										
	NO OF CAPS/TRAY & TYPE										
	SIZE OF CAPS										
	SIZE OF RISERS										
	TYPE OF DOWNCOMER										
TRAY	NO TRAYS REQ'D & SPACING									16@2'	
	TYPE OF TRAY									VALVE	
										12 CR.	
	[illegible]	ELLIP	[illegible]	ELLIP	[illegible]		[illegible]	ELLIP	HEMI	ELLIP	
MAT'L SPEC	SHELL & HEADS		[illegible]	[illegible]	[illegible]		[illegible]	CS	[illegible]	[illegible]	
	SKIRT										
	STRUCTURAL MEMBERS										
PURCHG DATA	REQUISITION NO	[illegible]							[illegible]	[illegible]	
	PURCHASE ORDER	[illegible]	56,300	[illegible]	30000		[illegible]	3233	55[illegible]	[illegible]	
	PURCHASED FROM		300						[illegible]		
	FABRICATOR S/O								[illegible]	[illegible]	
	SHIPPING WEIGHT	[illegible]	366300	17,000	34500		[illegible]	3500	193,282 EACH	3,480	
	TEST WEIGHT										

NOTES

NO	DATE	REVISION	BY
2	12/30/86	CHANGED T-1 VESSEL WT	[illegible]
1	12/8/86	V-7 ADDED	[illegible]

Sun Refining and Marketing Company

TOWER & VESSEL SCHEDULE

PLANT [illegible]
[illegible] HYDROTREATER
PLANT NO — UNIT NO
LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
				4

DATE

PUMP ITEM NO		P1,1A		P2,2A		P3,3A				K-1	
SERVICE		DISTL FEED		STRIPPER FEED		STRIPPER REFLUX				RECYCLE COMPRESSOR	
OPERATING CONDITIONS — LIQUID	1	DIST		DIST		LT HC				GAS-H2	RECYCLE
PUMPING TEMPERATURE	2	420		105		110				110	
SPECIFIC GRAVITY AT P T	3	.795		.848		.64				MOL WT	2.36
VISC SSU, CP, CSTK, AT P T	4	1.0 CP		20 CP		.3 CP				K VALUE	1.39
GPM AT P T	5	1165		1109		30				ACFM	786
SUCTION PRESSURE (PSIG)	6	0		150		145				2435	
DISCHARGE PRESSURE (PSIG)	7	2766		244		200				2635	
DIFFERENTIAL HEAD (FT)	8	8037		255'		199'					
N P S H AVAILABLE	9	12		12		12					
RPM	10										
BHP AT RATED GPM	11	2892		101		1.75				115	
MAX BHP FOR INSTALLED IMP	12	3200		120		3.0				INSTALL	1200HP
PUMP SPECIFICATIONS — MANUFACTURER	13										
TYPE AND SIZE	14									ELECTRIC	MOTOR
STAGES	15									CENTRIF.	COMP
SUCT FLG SIZE RATING FACE	16										
DISCH FLG SIZE RATING FACE	17										
NOZZLE ARRGT SUCTION	18										
NOZZLE ARRGT DISCHARGE	19										
IMPELLER DIA REQUIRED	20										
MAX IMP DIA AND HEAD	21										
IMP EYE AREA	22										
N P S H REQUIRED	23										
HYDROSTATIC TEST PRESSURE	24										
THRUST BEARING	25										
RADIAL BEARING	26										
COUPLING	27										
COUPLING GUARD	28										
ROTATION FROM COUPLING END	29										
MECHANICAL SEALS — MFG	30										
MECHANICAL SEALS — TYPE	31										
MECHANICAL SEALS — AUX BOX	32										
WATER COOLED — BOX	33										
WATER COOLED — BEARING	34										
WATER COOLED — PEDESTAL	35										
WEIGHT OF PUMP AND BASE	36										
MATERIAL SPECIFICATIONS — CASING	37	CS		CS		CS				CS	
CASE WEARING RINGS	38										
STAGE PIECES	39										
BUSHINGS — THR AT	40										
BUSHINGS — INTERSTAGE	41										
IMPELLER	42	12 CR		12 CR		12 CR				ALLOY	
IMPELLER WEARING RINGS	43										
SHAFT	44										
SHAFT SLEEVES	45										
GLAND	46										
LANTERN RINGS	47										
BEARING HOUSING	48										
BASE PLATE	49										
GASKETS	50										
SEAL — STATIONARY RING	51										
SEAL — ROTATING RING	52										
SEAL — PACKING	53										
MANUFACTURERS SERIAL NO	54										
PERFORMANCE CURVE	55										
P.O. NUMBER	56										
SR & MC DRAWING NO	57										

NOTES

NO	DATE	REVISION	BY
	7/30/84	[illegible] REVISED	

Sun Refining and Marketing Company

CENTRIFUGAL PUMP SCHEDULE

PLANT AIR FORCE DISTILLATE HYDROTREATER

PLANT NO UNIT NO

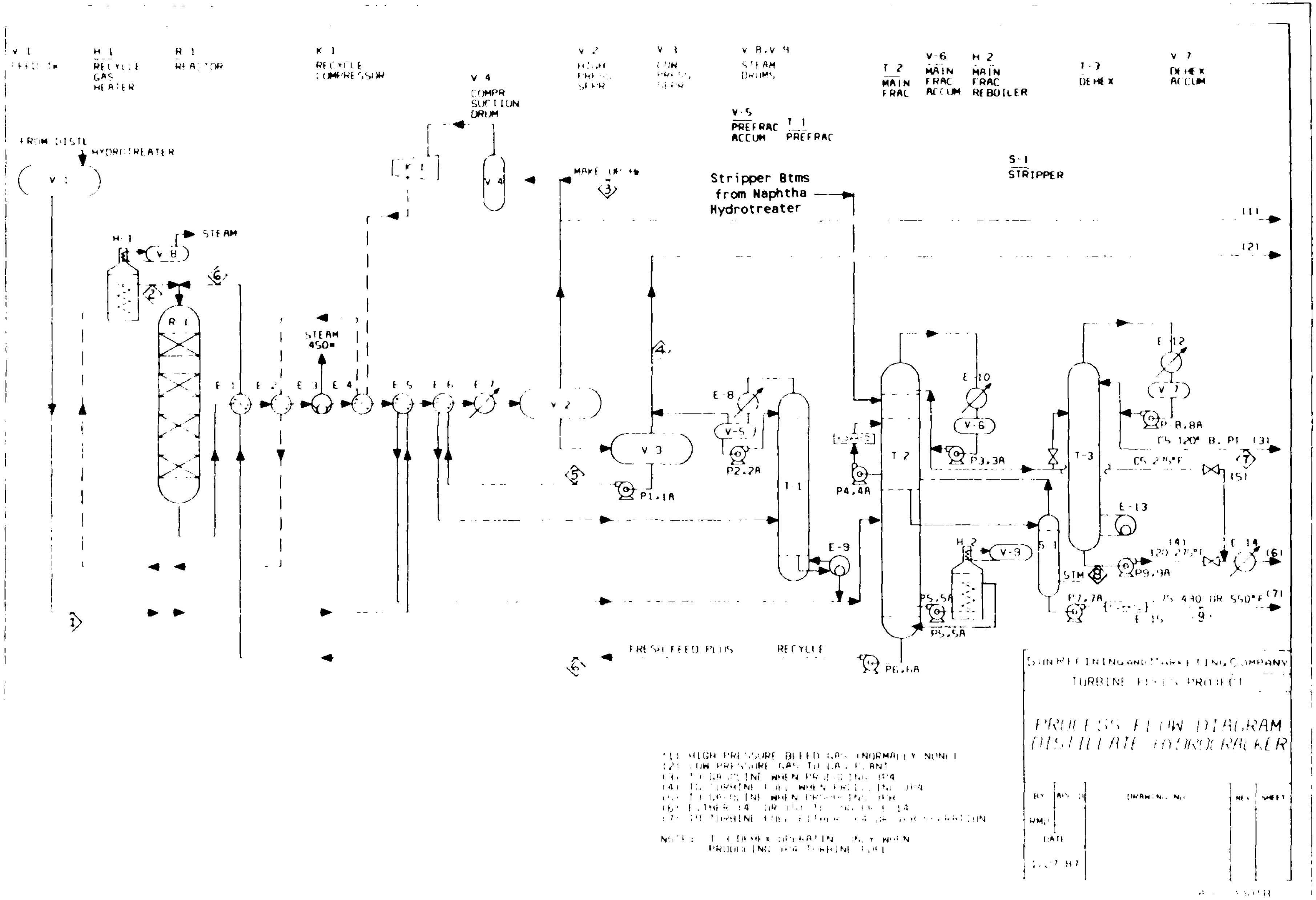
LOCATION

BY	APPD	DRAWING NO	REV	SHEET
...M				5
DATE 4/13/67				

PROCESS DESIGN SPECIFICATIONS

for the

DISTILLATE HYDROCRACKING UNIT



V 1
H 1 RECYCLE GAS HEATER
R 1 REACTOR
K 1 RECYCLE COMPRESSOR
V 4 COMPR SUCTION DRUM
V 8, V 9 STEAM DRUMS
V-5 PREFRAC ACCUM
T 1 PREFRAC
T 2 MAIN FRAC
V-6 MAIN FRAC ACCUM
H 2 MAIN FRAC REBOILER
T-3 DEHEX
V 7 DEHEX ACCUM
S-1 STRIPPER
FROM DISTL HYDROTREATER
STEAM
STEAM 450#
MAKE UP H2
Stripper Btms from Naphtha Hydrotreater
FRESH FEED PLUS RECYCLE
P1,1A
P2,2A
P3,3A
P4,4A
P5,5A
P6,6A
P7,7A
P-8,8A
P9,9A
E-8
E-9
E-10
E-12
E-13
E-14
CS 120° B. PT. (3)
CS 275°F
120-275°F
CS 430 OR 550°F (7)
STM
TURBINE FUELS PROJECT
PROCESS FLOW DIAGRAM DISTILLATE HYDROCRACKER
(1) HIGH PRESSURE BLEED GAS (NORMALLY NONE)
(2) LOW PRESSURE GAS TO GAS PLANT
DRAWING NO.
BY
RMD
DATE
REV
SHEET

DISTILLATE HYDROCRACKER UNIT
MATERIAL BALANCE AND STREAM PROPERTIES

Stream Number	1	2	3	4	5	6	7	8	9
Stream Label	Unit Feed	Reactor Gas Feed	Makeup Hydrogen	Low Pressure Gas	Low Pressure Liquid	Total Reactor Liquid Feed	Dehexanizer Overhead Product	Dehexanizer Bottoms	Stripper Bottoms
Stream Conditions									
Temperature, deg F	150	116	125	156	118	588	112	242	120
Physical state	Liquid	Vapor	Vapor	Vapor	Liquid	Liquid	Liquid	Liquid	Liquid
API Gravity	33.3	-	-	-	55.9	30.2	91.1	58.6	46.5
Sp.Gr. @ 60 deg F									
Sp.Gr. @ Temp.	0.86	-	-	-	0.73	0.68	0.60	0.65	0.68
Molecular Weight	-	4.0	2.7	36	-	-	-	-	-
Pressure, psia	150	2306	2305	165	165	31	27	34	75
BBLS/DAY @ 60 deg F	33,503	-	-	-	50,900	44,184	5,505	19,650	26,051
MMSCFD	-	132.39	57.9	23.7	-	-	-	-	-
M lb/hr	422.9	-	-	-	560.2	563.6	51.0	213.2	301.8
Vis., cSt @ Temp.	3	-	-	-	0.4	0.3	0.2	0.2	0.5

DISTILLATE HYDROCRACKER DESIGN BASIS

Unit Feed Rate

The unit is designed to process 33,503 BPSD of fresh hydrotreated distillate from the Distillate Hydrotreater Debutanizer Bottoms. This stream is fed into the main fractionator where the <490°F boiling point feed and converted hydrocarbons are distilled off to final product.

The fresh feed plus recycle boiling above 490°F is routed from the bottom of the main fractionator to the reactor (26,505 plus 17,679 BPSD). The nominal 490°F cut point is used when producing JP-4; when producing JP-8 the cut point is 550°F. The above operation is based on 60% conversion per pass at the hydrocracker reactor.

The sulfur and nitrogen in the feed have been almost completely removed in the distillate hydrotreater before entering the hydrocracker.

Plant Processing Steps

The fresh feed is routed through the main fractionator. The fresh feed plus recycle from the main fractionator bottoms is heat exchanged with reactor effluent and fed to the reactor mixed with preheated hydrogen. The mixture flows down through four beds of hydrocracking catalyst. The effluent is cooled by heat exhange, steam generation, and water cooling to 110°F. Hydrogen gas is separated in the high pressure separator, compressed, preheated and recycled to the reactor along with make-up hydrogen. The reactor operates at an inlet pressure of 2455 psig and 750°F. A liquid hourly space rate of 2.5/hour was selected based on pilot plant tests.

The liquid from the high pressure separator at 110°F and 2300 psig is flashed at 150 psig in the low pressure separator. The low pressure separator liquid is fed to the prefractionator. Prefractionator overhead product plus low pressure separator vapors are routed to the gas plant for butane recovery. The prefractionator bottoms is routed to the main fractionator to separate products from recycle liquid.

The main fractionator produces a <275°F cut overhead, a stripped side cut boiling between 275°F and 490°F (or 550°F for JP-8 production). The bottoms is reactor fresh feed plus recycle.

On JP-4 operation a downstream dehexanizer is operated to remove pentanes and hexanes overhead with the bottoms boiling between 120°F and 275°F blended into jet fuel boiling between 120°F and 490°F. The dehexanizer overhead is routed to naphtha storage for use as hydrogen plant furnace fuel and for sales for motor fuel blending.

When producing JP-8 which boils between 275°F and 550°F the dehexanizer is not operated and the main fractionator overhead C5-275°F cut is used for fuel at the hydrogen plant and is sold for motor fuel blending. The main fractionator stripped side cut boiling between 275°F and 550°F is the JP-8 product.

DISTILLATE HYDROCRACKER UNIT

Utilities and Chemical Requirements

Saturated Steam Produced, lb/hr

Steam Generators:	450 psig	150 psig	50 psig	Total
E-3 Exchanger	51,000	-	-	51,000
V-8 at Heater H-1	-	3,400	-	3,400
V-7 at Heater H-2	-	40,000	-	40,000
Totals	51,000	43,400	-	94,400

Steam Used, lb/hr

	450 psig	150 psig	50 psig	Total	Condensate Recovered
Heaters H1 & H2	25,000	-	-	25,000	-
S-1 Stripper tower	-	2,000	-	2,000	-
T-20 Main Fract. Twr.	-	4,000	-	4,000	-
E-9 Reboiler	66,000	-	-	66,000	66,000
E-13 Reboiler	-	28,500	-	28,500	28,500
Totals	91,500	34,500		126,000	94,500
Net Steam Import(export)	40,500	(8,900)	-	31,600	

Boiler Feed Water

For steam produced	94,400	lb/hr
For 10% blowdown & wash water	9,440	lb/hr
Total gross BFW needed	103,840	lb/hr
Condensate recovered (reused as BFW)	-94,500	
Net BFW needed	9,340	lb/hr=19 gpm

Cooling Water Circulated

Exchanger	Rate	Supply	Return	Duty
E-8	3536 GPM	85°F	110°F	44.2 MMBTU/HR
E-10	4627	85	115	69.4
E-12	1668	85	105	16.7
E-14	1539	85	105	15.4
Totals	11,370 GPM			145.7 MMBTU/HR

Make-up Cooling Water at 3% of total circulation = 341 GPM filtered water to replace loss to evaporation

DISTILLATE HYDROCRACKER UNIT

Utilities and Chemical Requirements
(continued)

Heater Fuel Fired

Fuel: Vacuum Residuum Product from the Hydrovisbreaker Unit.

Heater H-1 55.44 MMBTU/HR
Heater H-2 182.87
198.31 MMBTU/HR = 33 FOE BBL/hr
= 11,568 lb/hr Residuum Fuel

Electrical Power

		Brake Horsepower Operating	Brake Horsepower Connected
P-1,1A	Prefractionator Tower Feed Pumps	175	350
P-2,2A	Prefractionator Tower Reflux Pumps	55	110
P-3,3A	Main Fract. Ovhd. Prod. & Reflux Pumps	115	230
P-4,4A	Main Fract. Pumparound Pumps	35	70
P-5,5A	Main Fract. Reboiler Pumps	550	1100
P-6,6A	Reactor Feed Pumps	4500	9000
P-7,7A	Turbine Fuel Product Pumps	60	120
P-8,8A	Dehexanizer Ovhd. Prod. & Reflux Pumps	20	40
P-9,9A	Dehexanizer Bottoms Product Pumps	35	70
K-1	Recycle Gas Compressor	1200	1200
	Total Brake Horsepower	5,636 BHP	12,290 BHP
	Kilowatts:	4,203 KW	9,165 KW

DISTILLATE HYDROCRACKER UNIT

List of Major Equipment

Heat Exchangers

E-1	Reactor Feed - Effluent Exchanger
E-2	Reactor Effluent - Recycle Gas Exchanger
E-3	Reactor Effluent - 450 psig Steam Generator
E-4	Reactor Effluent - Recycle Gas Exchanger
E-5	Reactor Effluent - Main Fractionator Feed Exchanger
E-6	Reactor Effluent - Low Pressure Separator Liquid Exchanger
E-7	Reactor Effluent Cooler
E-8	Prefractionator Overhead Condenser
E-9	Prefractionator Reboiler
E-10	Main Fractionator Overhead Condenser
E-11	Main Fractionator Pumparound Reflux Aircooler
E-12	Dehexanizer Overhead Condenser
E-13	Dehexanizer Reboiler
E-14	Dehexanizer Bottoms Cooler
E-15	Turbine Fuel Product Aircooler

Fired Heaters

H-1	Recycle Gas Heater
H-2	Main Fractionator Reboiler

Fractionation Towers

T-1	Prefractionator
T-2	Main Fractionator
T-3	Dehexanizer
S-1	Main Fractionator Sidestripper

Reactor

R-1	Distillate Hydrocracker Reactor

Vessels

V-1	Feed Tank
V-2	High Pressure Separator
V-3	Low Pressure Separator
V-4	Compressor Suction Knockout Drum
V-5	Prefractionator Overhead Accumulator Drum
V-6	Main Fractionator Overhead Accumulator Drum
V-7	Dehexanizer Overhead Accumulator Drum
V-8	150 psig Steam Drum at Heater H-1
V-9	150 psig Steam Drum at Heater H-2

DISTILLATE HYDROCRACKER UNIT

List of Major Equipment
(continued)

Pumps

P-1,1A	Prefractionator Feed Pumps
P-2,2A	Prefractionator Reflux Pumps
P-3,3A	Main Fractionator Reflux Pumps
P-4,4A	Main Fractionator Pumparound Reflux Pumps
P-5,5A	Main Fractionator Reboiler Pumps
P-6,6A	Main Fractionator Bottoms (Reactor Feed) Pumps
P-7,7A	Sidestripper Bottoms Pumps
P-8,8A	Dehexanizer Reflux Pumps
P-9,9A	Dehexanizer Bottoms Pumps

Compressor

K-1	Recycle Gas Compressor

	No.	E-1 Shell	E-1 Tube	E-2 Shell	E-2 Tube	E-3 Shell	E-3 Tube	E-4 Shell	E-4 Tube	E-5 Shell	E-5 Tube
SERVICE											
ITEM NO	1	E-1		E-2		E-3		E-4		E-5	
SERVICE	2	REACTOR FEED		REACTOR EFFLUENT		REACTOR EFFLUENT		REACTOR EFFLUENT		MAIN FRAC	
	3	EFFLUENT EXCH.		- RECYCLE GAS		450# STM GEN		- RECYCLE GAS		FEED EXCH	
MANUFACTURER - NO SHELLS	4		3		2		1		1		2
SIZE AND TYPE	5	55" x 20'	BEU	22 x 20'	BEU	66 x 35 x 20'	BKU	24 x 20'	BEU	33" x 20	BEU
SURFACE/UNIT - /SHELL	6	16500	5500	3400	1700	3000	3000	1230	1230	5500	2750
	7	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE
UNIT PERFORMANCE											
CONNECTED IN	8	SERIES	SERIES	SERIES	SERIES	-	-	-	-	SERIES	SERIES
FLUID CIRCULATED	9										
	10	FEED	Rx EFF.	RECY. GAS	Rx EFF.	450# STM	Rx EFF	RECY GAS	Rx EFF	M. FR. FD	Rx EFF
QUANTITY LBS/HR M #/HR — LIQUID	11	563.6	123.9		208		252		344	341	394
VAPOR (MW)	12		498.3(36)	58.6(4.0)	414.1(33)		370(31)	58.6(4.0)	278(25)		228
FIXED GASES (MW)	13										
STEAM	14					51050					
TOTAL	15	563.6	622.	58.6	622.		622.	58.6	622	341	622
FLUID VAPORIZED OR CONDENSED	16	0	84.6 C	0	44 C		72 C	0	50 C	14 V	96 C
STEAM CONDENSED	17										
GRAVITY LIQUID (SG)(API) AT °F 60°F	18	.88	.77		.77		.77		.75	.75	.76
VISCOSITY LIQUID (CP) AT °F AVG	19	1.	1.		1.0		1.5		2.0	3.0	2.0
SPEC HEAT LIQUID BTU/LB	20										
LATENT HEAT VAPOR BTU/LB	21										
OPER TEMP °F IN OUT	22	389/600	700/535	465/620	535/600	440/460	600/528	125/405	528/475	150/400	475/360
OPER PRESSURE PSIG	23	2490	2395	2515	2366	450	2350	2520	2345		2340
MINIMUM FOULING FACTOR	24										
NUMBER OF PASSES	25										
VELOCITY FT/SEC	26										
PRESSURE DROP PSIG	27	15	15	10	10	1	5	5	5	10	10
HEAT EXCHANGED BTU/HR (MM)	28	38.0		26.0		39.2		27.0		58.0	
MTD CORRECTED WEIGHTED	29	27		65.5		100		220		124	
TRANSFER RATE SERVICE CLEAN	30	85		90		130		100		35	
CONSTRUCTION											
DESIGN PRESSURE PSIG	31	2720	2615	2770	2600	500	2585	2775	2580	200	2575
TEST PRESSURE PSIG	32	4080	3825	4155	3900	750	3865	4165	3870	300	3765
DESIGN TEMPERATURE °F	33	800	800	700	700	650	650	65			
CORROSION ALLOWANCE	34	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"
CONNECTIONS SIZE STD TYPE — IN	35										
OUT	36										
TUBES — MAT'L	37		347		347		CS		CS		CS
O D — BWG	38		3/4" - 10		3/4 - 10		3/4" 10		3/4" 12		3/4" 12
LENGTH — PITCH	39		20' 1" ◇		20' 1" ◇		20' 1" ◇		20' 1" ◇		20' 1" ◇
SHELL I D	40	55"		27"							
	41	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS
STATIONARY TUBE SHEET	42										
FLOATING TUBE SHEET	43										
CROSS BAFFLES	44										
LONGITUDINAL BAFFLES	45										
TUBE SUPPORTS	46										
SHELL	47	5Cr ½ Mo		1¼Cr ½ Mo		CS		CS		CS	
SHELL COVERS	48										
FLOATING HEAD COVER	49										
CHANNEL	50										
CHANNEL COVER	51										
CROSS BAFFLES TYPE SPACING	52										
LONGITUDINAL BAFFLE TYPE	53										
GASKETS	54										
WELDING FLANGES AND NOZZLES	55										
STUDS	56										
WEIGHT EXCHANGER DRY WET	57										
WEIGHT BUNDLE	58										
CODE REQUIREMENTS	59										
SR & XR DRAWING NO	60										
REQUISITION NO	61										
PURCHASE ORDER NO	62										

NOTES

SR - STRESS RELIEVED
XR - X-RAYED

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

HEAT EXCHANGER SCHEDULE

PLANT AIR FORCE
DISTILLATE HYDROCRACKER
PLANT NO — UNIT NO

LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
LGM				1
DATE 4/25/67				

	No.										
ITEM NO	1	E-6		E 7		E 8		E-9		E-10	
SERVICE	2	LP FLASH LIQ		REACTOR EFF		PREFRAC		PREFRAC		MAIN FRAC	
	3	REACTOR EFF.		COOLER		CONDENSER		REBOILER		STAB COND.	
MANUFACTURER – NO SHELLS	4		4		2		1		2		2
SIZE AND TYPE	5	48"x20'	BEU	51"x20'	BEU	38"x20'	BEU	90"x45"x20'	BKU	42"x20'	BEU
SURFACE/UNIT /SHELL	6	24200	6050	14400	7200	3750	3750	10800	5400	8700	4350
	7	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE
CONNECTED IN	8										
FLUID CIRCULATED	9	LPR LIQ	Rx EFF	WATER	Rx EFF	PREF OVHD	WATER	PREFR BTM	STEAM	MFR OVHD	WATER
	10										
QUANTITY ~~LBS/HR~~ M#/HR – LIQUID	11		490		562			738			
VAPOR MW	12		132		60	281 (58)				236(84)	
FIXED GASES MW	13										
STEAM	14			GPM			GPM		66.0		GPM
TOTAL	15	560	622	3540	622	281	2830	738		236 C	4630
FLUID VAPORIZED OR CONDENSED	16	49 V	72 C		18 C	208 C		250 V			
STEAM CONDENSED	17										
GRAVITY LIQUID (SG)(API) AT °F 60	18	.75	.74		.73	.58		.80		.73	
VISCOSITY LIQUID (SSU)(CP) AT °F AVG	19	.3	.3		.3	.2		.5		.5	
SPEC HEAT LIQUID BTU/LB	20										
LATENT HEAT VAPOR BTU/LB	21										
OPER TEMP °F IN OUT	22	110/330	460/190	75/110	190/110	214/167	85/105	439/393	460/460	237/154	85/115
OPER PRESSURE PSIG	23	200	2330	75	2310	150	75	165	450	5	75
MINIMUM FOULING FACTOR	24										
NUMBER OF PASSES	25										
VELOCITY FT/SEC	26										
PRESSURE DROP PSIG	27										
HEAT EXCHANGED BTU/HR (MM)	28	78.0		34.0		28.3		51.5		67.5	
MTD CORRECTED WEIGHTED	29	43		41		84		53		74	
TRANSFER RATE SERVICE CLEAN	30	75		75		90		90		85	
DESIGN PRESSURE PSIG	31	250	2565	120	2545	200	100	200	500	50	100
TEST PRESSURE PSIG	32	375	3850	180	3820	300	150	300	750	75	150
DESIGN TEMPERATURE °F	33	650	650	650	650	400	400	650	650	650	400
CORROSION ALLOWANCE	34	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"
CONNECTIONS SIZE STD TYPE – IN	35										
OUT	36										
TUBES – MAT'L ~~NO~~	37		CS		CS		ADM		CS		ADM
O.D. BWG	38	3/4"	12	3/4"	12		14		12	3/4"	14
LENGTH PITCH	39	20'	1" ◇	20'	1" ◇	20'	1" ◇	20'	1" ◇	20'	1" ◇
SHELL I.D. ~~O.D.~~	40	48"		51"		38"		90"		42"	
	41	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS
STATIONARY TUBE SHEET	42										
FLOATING TUBE SHEET	43										
CROSS BAFFLES	44										
LONGITUDINAL BAFFLES	45										
TUBE SUPPORTS	46										
SHELL	47	CS		CS		CS		CS		CS	
SHELL COVERS	48										
FLOATING HEAD COVER	49										
CHANNEL	50										
CHANNEL COVER	51										
CROSS BAFFLES TYPE SPACING	52										
LONGITUDINAL BAFFLE TYPE	53										
GASKETS	54										
WELDING FLANGES AND NOZZLES	55										
STUDS	56										
WEIGHT EXCHANGER DRY WET	57										
WEIGHT BUNDLE	58										
CODE REQUIREMENTS	59										
SR & MC DRAWING NO	60										
REQUISITION NO	61										
PURCHASE ORDER NO	62										

Row groups: SERVICE (lines 1–6); UNIT PERFORMANCE (lines 7–30); CONSTRUCTION (lines 31–56).

NOTES

SR - STRESS RELIEVED
XR - X RAYED

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

HEAT EXCHANGER SCHEDULE

PLANT AIR FORCE
DISTILLATE HYDROCRACKER
PLANT NO UNIT NO

LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
				1

CGH
DATE 4/25/83

			E-11		E-12		E-13		E-14		E-15	
SERVICE	ITEM NO	1	E-11		E-12		E-13		E-14		E-15	
	SERVICE	2	M. FR. P.A. REF		DEHEX. OVHD		DEHEX.		DEHEX BTM		TURB. FUEL	
		3	AIR COOLER		CONDENSER		REBOILER		COOLER		AIR COOLER	
	MANUFACTURER - NO SHELLS	4		1		2		1		1		2
	SIZE AND TYPE	5	12X40'	—	43X20	BEU	54x25x25	AKU		BEU	16X36	—
	SURFACE/UNIT - / SHELL	6		2100	9800	4900	1530	1530	3900	3900	7700	3450
		7	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE
UNIT PERFORMANCE	CONNECTED IN	8			PARALLEL	PARALLEL						PARALLEL
	FLUID CIRCULATED	9		PA NAPH	DEH. OVHD	WATER	DEHEX BTM	STEAM	DEHEX			STRIPPER
		10	AIR	47API GR					BTMS	WATER	AIR	BTMS
	QUANTITY ~~LB/HR~~ M#/HR — LIQUID	11		262.0	105.8		361.7		213.2			302
	VAPOR MW	12										
	FIXED GASES MW	13										
	STEAM	14				GPM		28,500		GPM		
	TOTAL	15			105.8	1670	361.7		213.2	1540		302
	FLUID VAPORIZED OR CONDENSED	16			105.8C		188.5V		0			
	STEAM CONDENSED	17										
	GRAVITY - LIQUID (SG)(API) AT °F 60	18		.79	.64		.74		.74			.8
	VISCOSITY - LIQUID (SSU)(CP) AT °F AVG	19		3	.3		.3		.3			
	SPEC HEAT - LIQUID BTU/LB	20										
	LATENT HEAT - VAPOR BTU/LB	21										
	OPER TEMP °F IN OUT	22	70/150	339/214	36/112		242/223	366/366	242/110	95/105	70/120	322/120
	OPER PRESSURE PSIG	23	—	40	22	75	35	150	60	75	2	80
	MINIMUM FOULING FACTOR	24										
	NUMBER OF PASSES	25										
	VELOCITY FT/SEC	26										
	PRESSURE DROP PSIG	27		20			5	5	5	5	–	20
	HEAT EXCHANGED BTU/HR	28	19.2		16.7		24.4		15.4		34.2	
	MTD CORRECTED WEIGHTED	29	152		26		133		65.7		72	
	TRANSFER RATE SERVICE CLEAN	30	60 Bare Equiv		65		120		60		60	
CONSTRUCTION	DESIGN PRESSURE PSIG	31		75	75	100	75	200	100	100	–	25
	TEST PRESSURE PSIG	32		115	115	150	115	300	150	150		190
	DESIGN TEMPERATURE °F	33		650	650	400	650	650	650	400		650
	CORROSION ALLOWANCE	34		1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/16"	1/5"	1/8"
	CONNECTIONS IN	35										
	SIZE - STD - TYPE OUT	36										
	TUBES MAT'L ~~NO.~~	37		5 CR		ADM		CS		ADM		CS
	TUBES O D BWG	38		1" 12		3/4" 14		3/4" 12		3/4" 14		1" 12
	TUBES LENGTH PITCH	39		40', 2 3/8"		20', 1" ◇		20', 1" ◇		20', 1" ◇		36', 2 3/8"
	SHELL I D O D	40										
		41	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS
	STATIONARY TUBE SHEET	42										
	FLOATING TUBE SHEET	43										
	CROSS BAFFLES	44										
	LONGITUDINAL BAFFLES	45										
	TUBE SUPPORTS	46										
	SHELL	47			CS		CS		CS			
	SHELL COVERS	48										
	FLOATING HEAD COVER	49										
	CHANNEL	50										
	CHANNEL COVER	51										
	CROSS BAFFLES TYPE SPACING	52										
	LONGITUDINAL BAFFLE TYPE	53										
	GASKETS	54										
	WELDING FLANGES AND NOZZLES	55										
	STUDS	56										
WEIGHT EXCHANGER DRY WET		57										
WEIGHT BUNDLE		58										
CODE REQUIREMENTS		59										
SR & MC DRAWING NO		60										
REQUISITION NO		61										
PURCHASE ORDER NO		62										

NOTES

SR - STRESS RELIEVED
XR - X RAYED

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

HEAT EXCHANGER SCHEDULE

PLANT AIR FORCE

DISTILLATE HYDROCRACKER
PLANT NO UNIT NO

LOCATION

BY	APPD	DRAWING NO	REV	SHEET
LCA				3
DATE 4/25/87				

	H-1				H-2			
SERVICE	RECYCLE GAS HEATER				MAIN FRAC REBOILER			
TYPE								
MANUFACTURER								
TOTAL DUTY OF HEATER MM BTU PER HR ABSORBED/FIRED	13.3/15.4				157.3/182.9			
PROCESS DESIGN CONDITIONS								
HEATER SECTION	RADIANT	CONVECTION			RADIANT	CONVECTION		
SERVICE	PROCESS	PROCESS	STM GEN	BFW	PROCESS	PROCESS	STM GEN	BFW
HEAT ABSORPTION MM BTU/HR	9.24	.76	2.90	.38	109.43	9.00	34.34	4.50
FLUID	RECYCLE GAS		STM & WTR	BFW	MAIN FR BTMS		STM & WTR	BFW
FLOW RATE M#/HR (MW)	58.6 (4.0)		16.9	3.7				
FLOW RATE BPD								
PRESSURE DROP PSI (ALLOWABLE)	50		1.0	10	50		1.0	10
PRESSURE DROP PSI (CALCULATED)								
AVERAGE FLUX DENSITY BTU/HR SQ FT								
FOULING FACTOR								
INLET CONDITIONS								
TEMPERATURE DEG F	531	620	366	260	600	598	366	260
PRESSURE PSIG	2500	2505	150	162	110	115	150	162
LIQUID FLOW LB/HR M#/HR			16.9	3.7	1766	1766	200.3	44.08
VAPOR FLOW M#/HR	58.6	58.6	3.4					
LIQUID GRAVITY API/SP GR AT 60 F					.67	.67 ET		
VAPOR MOLECULAR WEIGHT	4.0		18					
LIQUID VISCOSITY CP								
OUTLET CONDITIONS								
TEMPERATURE DEG F	750	631	366	366	625	600	366	366
PRESSURE PSIG	2455	2500	150	152	50	110	150	152
LIQUID FLOW LB/HR M#/HR			13.5	3.7	696	1766	160.3	44.08
VAPOR FLOW M#/HR	58.6	58.6	3.4		1070		40.0	
LIQUID GRAVITY API/SP GR AT 60 F								
VAPOR MOLECULAR WEIGHT	4	4	18	—	200	—	18	—
LIQUID VISCOSITY CP								
FUEL CHARACTERISTICS								
TYPE OF FUEL								
HEATING VALUE LHV								
SPECIFIC GRAVITY								
SULFUR NITROGEN WEIGHT %								
[illegible]								
HEATER SECTION								
DESIGN PRESSURE PSIG	2750	2750	200	200	150	150	200	200
DESIGN TUBE TEMPERATURE DEG F	900	900	650	650	750	750		
CORROSION ALLOWANCE TUBES	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"
FITTINGS								
HYDROSTATIC TEST PRESSURE PSIG								
NUMBER OF PASSES								
OVERALL TUBE LENGTH FT								
EFFECTIVE TUBE LENGTH FT								
BARE TUBES NUMBER								
TOTAL EXPOSED SURFACE SQ FT								
EXTENDED SURFACE TUBES NUMBER								
TOTAL EXTENDED SURFACE SQ FT								
TUBE SPACING CENTER TO CENTER IN STAGGERED IN LINE								
TUBE CENTER TO FURNACE WALL MIN								
[illegible]								
[illegible]								
[illegible]								
[illegible]								
TUBE MATERIAL [illegible]	[illegible]	[illegible]	CS	CS	CS	CS	CS	CS
[illegible]								
[illegible]								

NOTES

NO.	DATE	REVISION	BY

Sun Refining and Marketing Company

FIRED HEATER DESIGN

PLANT AIR FORCE
DISTILLATE HYDROCRACKER
PLANT NO. UNIT NO.

LOCATION

BY APP'D | DRAWING NO. | REV. | SHEET
[illegible] | | | 4
DATE
4/15/87

ITEM NO	T-1	T-2	T-3	[illegible]	V-1	V-2	V-3	V-4	V-5	V-6
TITLE	PREFRAC	MAIN FRAC	DE HEX	STRIPPER	FEED TANK	HI. PRESS SEP'R	LO. PRESS SEP'R	COMP SUCT DRUM	PREFRAC ACCUM	MAIN FRAC ACCUM
SERVICE — SERIAL NO										
DWG NO — ASSEMBLY										
DWG NO — DETAILS										
DWG NO — TRAYS										
DWG NO — PLATFORMS										
DESIGN — CODE										
PRESSURE	200	41	[illegible]	[illegible]	75	2530	215	[illegible]	200	[illegible]
TEMPERATURE °F	650	250	[illegible]	650	[illegible]	650	650	[illegible]	[illegible]	650
CORROSION ALLOWANCE	[illegible]	[illegible]	[illegible]	.156	[illegible]	[illegible]	.175	[illegible]	.175	.125
[redacted]										
HYDROSTATIC TEST PRESSURE										
HAMMER TEST PRESSURE										
STRESS RELIEVED	NO	NO	[illegible]	[illegible]	NO	YES	NO	[illegible]	[illegible]	NO
RADIOGRAPHED	SPOT	SPOT	[illegible]	SPOT	SPOT	YES	SPOT	[illegible]	[illegible]	SPOT
VERTICAL OR HORIZONTAL	[illegible]	V	V	V	HORIZ	HORIZ	HORIZ	V	HORIZ	HORIZ
INSULATION THICKNESS										
DIMENSIONAL — O.D. / I.D.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8'	8'	3'	5'	5'
LENGTH SEAM TO SEAM	28'	[illegible]	[illegible]	[illegible]	[illegible]	24'	24'	12'	24'	24'
LENGTH BASE SECTION										
HEIGHT OF SKIRT	2'	[illegible]	12'	2'				10'		
℄ TO BOTTOM OF SUPPORTS										
TOTAL SHELL THICKNESS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7/8"	4"	[illegible]	7/8"
HEAD THICKNESS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7"	7/8"	2.5"	[illegible]	7/8"
SKIRT THICKNESS	[illegible]	[illegible]	[illegible]	[illegible]						
MH — NO REQ'D	3	6	3	2	1	1	1	1	[illegible]	[illegible]
SIZE	24"	24"	24"	24	24"	24"	24"	24"	24"	24"
SERIES & FACING										
LINING — TYPE						347				
THICKNESS						1/8"				
LOCATION										
TRAY A — NO TRAYS REQ'D & SPACING	32, 24"	[illegible] 24"	20, 24"	8, 24"						
TYPE OF TRAY	1/2 CR	2 CR	1/2 CR	12 CR						
NO OF CAPS/TRAY & TYPE	VALVE	VALVE	VALVE	VALVE						
SIZE OF CAPS										
SIZE OF RISERS										
TYPE OF DOWNCOMER										
TRAY B — NO TRAYS REQ'D & SPACING										
TYPE OF TRAY										
PURCHASING MAT'L SPEC — SHELL & HEADS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
SKIRT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]
STRUCTURAL MEMBERS										
DATA — REQUISITION NO										
PURCHASE ORDER										
PURCHASED FROM										
FABRICATOR S/O										
SHIPPING WEIGHT [illegible]	[illegible]	[illegible]	72,400	[illegible]	[illegible]	249,200	27,700	[illegible]	[illegible]	[illegible]
TEST WEIGHT										

NOTES

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

TOWER & VESSEL SCHEDULE

PLANT AIR FORCE

[illegible] HYDROCRACKER

PLANT NO UNIT NO

LOCATION

BY APP'D DRAWING NO REV SHEET

DATE 5

SERVICE	ITEM NO.	V-7	V-8	V-9	[illegible]					
	TITLE	DEHEX ACCUM	STEAM DRUM	STEAM DRUM	[illegible]					
	SERIAL NO									
	DWG NO ASSEMBLY									
	DWG NO DETAILS									
	DWG NO TRAYS									
	DWG NO PLATFORMS									
DESIGN	CODE									
	PRESSURE	40	200	200	2735					
	TEMPERATURE °F	650	650	650	650					
	CORROSION ALLOWANCE	.275	.148	.13	1/16 OVERLAY					
	WIND LOADING									
	HYDROSTATIC TEST PRESSURE									
	HAMMER TEST PRESSURE									
	STRESS RELIEVED	NO	NO	NO	YES					
	RADIOGRAPHED	SPOT	SPOT	SPOT	YES					
DESCRIPTION	VERTICAL OR HORIZONTAL	HORIZ	HORIZ	HORIZ	VERT					
	INSULATION THICKNESS									
DIMENSIONAL	I D	5'	4'	7'	8'					
	LENGTH SEAM TO SEAM	17.5'	10'	20'	80'					
	LENGTH BASE SECTION									
	HEIGHT OF SKIRT									
	℄ TO BOTTOM OF SUPPORTS									
	TOTAL SHELL THICKNESS	.375"	.50	.75	8.8" + OVERLAY					
	HEAD THICKNESS	.375"	.50	.75	5"					
	SKIRT THICKNESS									
MH	NO REQ'D	1	1	1	5					
	SIZE	24"	24"	24"	24"					
	SERIES & FACING									
LINING	TYPE				347					
	THICKNESS				3/16"					
	LOCATION				SHELL & HEADS					
TRAY A	NO TRAYS REQ'D & SPACING									
	TYPE OF TRAY									
	NO OF CAPS/TRAY & TYPE									
	SIZE OF CAPS									
	SIZE OF RISERS									
	TYPE OF DOWNCOMER									
TRAY B	NO TRAYS REQ'D & SPACING									
	TYPE OF TRAY									
MAT'L SPEC	SHELL & HEADS									
	[illegible]									
	STRUCTURAL MEMBERS									
PURCHASE DATA	REQUISITION NO									
	PURCHASE ORDER									
	PURCHASED FROM									
	FABRICATOR S/O									
	SHIPPING WEIGHT									
	TEST WEIGHT									

NOTES

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

TOWER & VESSEL SCHEDULE

PLANT A.R. FORCE

[illegible] HYDROCRACKER

PLANT NO UNIT NO

LOCATION

BY	APP	DRAWING NO	REV	SHEET
				6

DATE

PUMP ITEM NO			P 1-1A	P 2-2A	P 3-3A	P-4-4A	P5-5A	P6-6A	P7-7A	P8-8A	P9-9A	K-1
SERVICE			PREFRAC FEED	PREFRAC REFLUX	MAIN FRAC REFLUX	MAIN FRAC P-A [illegible]	MAIN FRAC REBOIL	REACTOR FLT RECY.	STRIPPER BOTTOM	DEHEX REFLUX	DEHEX BOTTOMS	RECYCLE COMPR
OPERATING CONDITIONS	LIQUID	1	MIX. HC	LT HC	MIX. HC	MIX HC	HVY HC	HVY HC	LT HC	LT HC	LT HC	[illegible] MOL WT [illegible]
	PUMPING TEMPERATURE	2	110 F	67	154	339	598	588	322	112	292	115 F
	SPECIFIC GRAVITY AT P.T.	3	.733	.505	[illegible]	.67	.67	.68	.68	.64	.66	[illegible] .32
	VISC SSU CP CSTK AT P.T.	4	.5 CP	.2 CP	.3 CP	.1 CP	.3 CP	.3 CP	.13	.2	.25	[illegible]
	GPM AT P.T.	5	1686	106	1064	860	5800	1833	121	385	712	
	SUCTION PRESSURE (PSIG)	6	150	145	5	13	15	15	17	14	19	2290
	DISCHARGE PRESSURE (PSIG)	7	255	208	110	42	100	2691	80	54	57	2520
	DIFFERENTIAL HEAD (FT)	8	321	188	372	38	345	5972	214	135	140	
	NPSH AVAILABLE	9										
	RPM	10										
	BHP AT RATED GPM	11	157	[illegible]	104	31	521	4320	55	4	26	1133
	MAX BHP FOR INSTALLED IMP	12	175	55	115	35	550	4500	60	20	35	1200
PUMP SPECIFICATIONS	MANUFACTURER	13										
	TYPE AND SIZE	14										
	STAGES	15										
	SUCT FLG SIZE RATING FACE	16										
	DISCH FLG SIZE RATING FACE	17										
	NOZZLE ARRG'T SUCTION	18										
	NOZZLE ARRG'T DISCHARGE	19										
	IMPELLER DIA REQUIRED	20										
	MAX IMP DIA AND HEAD	21										
	IMP EYE AREA	22										
	NPSH REQUIRED	23										
	HYDROSTATIC TEST PRESSURE	24										
	THRUST BEARING	25										
	RADIAL BEARING	26										
	COUPLING	27										
	COUPLING GUARD	28										
	ROTATION FROM COUPLING END	29										
	MECHANICAL SEALS — MFG	30										
	MECHANICAL SEALS — TYPE	31										
	MECHANICAL SEALS — AUX BOX	32										
	WATER COOLED — BOX	33										
	WATER COOLED — BEARING	34										
	WATER COOLED — PEDESTAL	35										
	WEIGHT OF PUMP AND BASE	36										
MATERIAL SPECIFICATIONS	CASING	37	CS	CS	CS	CS	CS	CS	CS	CS	CS	CS
	CASE WEARING RINGS	38										
	STAGE PIECES	39										
	BUSHINGS — THROAT	40										
	BUSHINGS — INTERSTAGE	41										
	IMPELLER	42	12 CR	12 CR	12 CR	12 CR	12 CR	12 CR	12 CR	12 CR	12 CR	12 CR
	IMPELLER WEARING RINGS	43										
	SHAFT	44										
	SHAFT SLEEVES	45										
	GLAND	46										
	LANTERN RINGS	47										
	BEARING HOUSING	48										
	BASE PLATE	49										
	GASKETS	50										
	SEAL — STATIONARY RING	51										
	SEAL — ROTATING RING	52										
	SEAL — PACKING	53										
MANUFACTURERS SERIAL NO		54										
PERFORMANCE CURVE		55										
P.O. NUMBER		56										
SH & MC DRAWING NO		57										

NOTES

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

CENTRIFUGAL PUMP SCHEDULE

PLANT AIR FORCE

DISTILLATE HYDROCRACKER

PLANT NO | UNIT NO

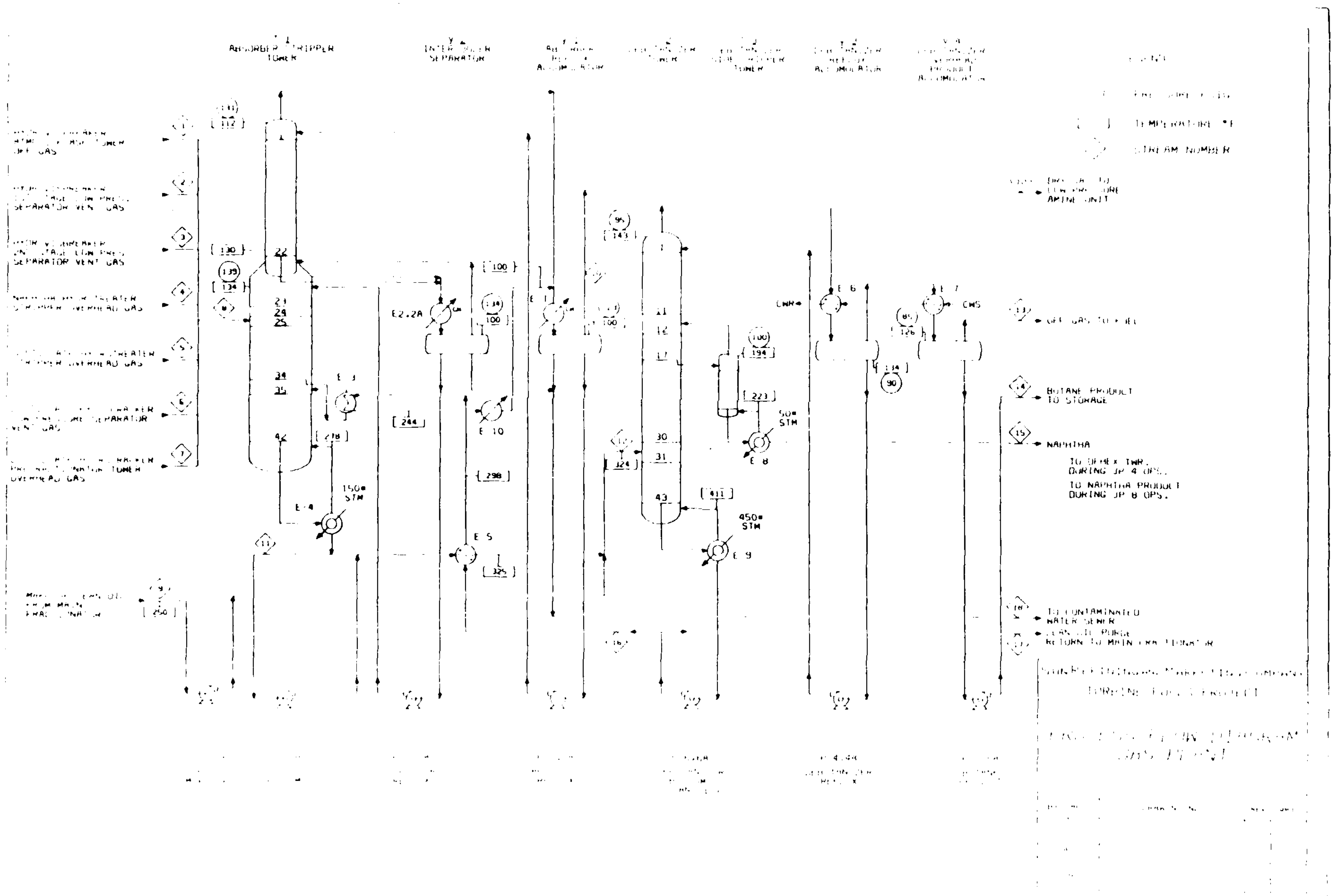
LOCATION

BY	APPD	DRAWING NO	REV	SHEET
LGM				7
DATE 4/25/87				

PROCESS DESIGN SPECIFICATIONS

for the

GAS PLANT


ABSORBER STRIPPER TOWER
INTER COOLER SEPARATOR
SEPARATOR VENT GAS
TEMPERATURE °F
STREAM NUMBER
OFF GAS TO FUEL
BUTANE PRODUCT TO STORAGE
NAPHTHA
TO DEHEX TWR. DURING JP-4 OPS.
TO NAPHTHA PRODUCT DURING JP-8 OPS.
TO CONTAMINATED WATER SEWER
RETURN TO MAIN FRACTIONATOR
AMINE UNIT
E-4
E-5
E-6
E-7
E-8
E-9
E-10
E-2,2A
150# STM
50# STM
450# STM
CWR
CWS

GAS PLANT
MATERIAL BALANCE AND STREAM PROPERTIES

Stream Number	8	9	10	11	13	14	15	16	17
Stream Label	Feed Gas	Lean Oil Makeup	Dry Gas	Rich Oil	Debut Gas (normally) (none)	Butane Product	Naphtha to Dehex	Lean Oil	Lean Oil Purge
Stream Conditions									
Temperature, deg F	141	250	100	278	-	120	223	411	411
Physical state	Vapor	Liquid	Vapor	Liquid	-	Liquid	Liquid	Liquid	Liquid
API Gravity	-	65.6	-	68.8	-	117	92	66	66
Sp.Gr. @ Temp.	-	.60	-	.58	-	.57	.62	.66	.66
Molecular Weight	30	-	14.8	-	-	-	-	-	-
Pressure, psia	154	165	138	156	-	100	118	221	221
BBLS/DAY @ 60 deg F	-	975	-	30,394	-	7160	1790	21519	864
MMSCFD	33.93	-	22.64	-	-	-	-	-	-
M lb/hr	111.910	10.75	36.760	312.92	-	59.52	16.59	237.90	9.54
Vis., cSt @ Temp.	-	0.3	-	0.2	-	0.3	0.3	0.3	0.3

NOTE: Stream 1 is composed of the following:

Stream No.	1	2	3	4	5	6	7	Total
lb/hr	2515	5857	5106	1264	3529	20,719	72,920	111,910
Molecular Weight	29.6	10.2	16.2	29.8	32.7	16.5	54.0	-

GAS PLANT DESCRIPTION

Feeds and Products

Each of the major processing plants in the refinery produces low-pressure vent gases and/or tower overhead gases, which are valuable sources of fuel gas, hydrogen plant feed, and liquid hydrocarbon products. Most also contain high levels of hydrogen sulfide which must be removed and converted to elemental sulfur to reduce environmental pollution.

Some of the vented refinery gases are sufficiently pure in hydrogen, methane, ethane and propane so that they can be used directly as fuel gas and hydrogen plant feed with no further processing. Those streams bypass the Gas Plant. Included in this group are:

(1) Naphtha Hydrotreater Low-Pressure Vent Gas
(2) Distillate Hydrotreater Low-Pressure Vent Gas
(3) Hydrogen Purification Unit Vent Gas

However, the Gas Plant feed streams contain significant quantities of butane and naphtha which can be recovered as liquid products. These streams include:

(1) Hydrovisbreaker Atmospheric Flash Tower Off-Gas
(2) Hydrovisbreaker 1st-stage Low-Pressure Separator Vent Gas
(3) Hydrovisbreaker 2nd-stage Low-Pressure Separator Vent Gas
(4) Naphtha Hydrotreater Stripper Overhead Gas
(5) Distillate Hydrotreater Stripper Overhead Gas
(6) Distillate Hydrocracker Low-Pressure Separator Vent Gas
(7) Distillate Hydrocracker Prefractionator Tower Overhead Gas

Consequently the purpose of the Gas Plant is to separate the gas feed mixture into three main products:

(1) Dry Gas - enroute to sulfur removal prior to use as fuel gas or hydrogen plant feedstock
(2) Butane - enroute to treating for sulfur removal prior to sale
(3) Naphtha - to be mixed with the Main Fractionator naphtha product

Process Flow Description

The Gas Plant consists primarily of an Absorber-Stripper Tower and a Debutanizer Tower with a Sidestripper. The Absorber-Stripper has a total of 42 trays. It actually consists of two towers constructed in piggy-back fashion with a 22-tray absorber section on top of a 20-tray stripper section. The Debutanizer has 43 trays and its Sidestripper has 9 trays.

The Absorber-Stripper separates the dry gas from the butane and heavier hydrocarbon products with the aid of "lean oil" circulated from the Debutanizer bottoms. The Debutanizer and Sidestripper towers subsequently separate the butane, naphtha, and lean oil.

The feedstock gas mixture for the Gas Plant is fed to the Absorber-Stripper column near the top of the Stripper section. The only other feed stream entering the column is the lean oil (Debutanizer bottoms product) which is fed to the top of the Absorber to recover butane and heavier components that may be entrained in the dry gas.

The Absorber bottoms liquid and the Stripper overhead vapor are routed through the Absorber intercoolers and pass into a phase separator drum. Drum liquid is pumped to the Stripper top tray, and drum vapor is fed to the bottom of the Absorber.

The Absorber intercoolers serve to reduce the minimum required capacity (diameter) of the Absorber section by moving some of the overhead condenser duty to a point below the Absorber section. This condenses some of the higher-boiling components that would otherwise flow upward into the Absorber from the Stripper, and thereby reduces the vapor/liquid traffic through the entire Absorber.

Liquids traveling down the Stripper are stripped of light hydrocarbons by addition of heat from an interheater and a bottoms reboiler. The interheater is placed higher in the Stripper than the reboiler for reasons similar to those above concerning placement of the Absorber intercooler. By placing the interheater higher in the column, it strips out some of the lower-boiling components that would otherwise flow down through the Stripper section. Consequently this reduces the vapor/liquid traffic in the lower Stripper, which reduces the minimum required diameter of the Stripper section.

Debutanizer bottoms serves as the lean oil for the Absorber. It is fed to the Absorber overhead vapor stream upstream of the condenser and enters the Absorber with the liquid reflux. The hot Debutanizer bottoms first is cooled by heat exchange with the Stripper bottoms (rich oil), then the Stripper interheater, and finally with a lean oil cooler prior to being fed to the Absorber overhead condenser.

The heated Stripper bottoms (rich oil) is combined with make-up lean oil to form the Debutanizer feed. The make-up lean oil stream is drawn from an upper tray of the Main Fractionator Tower at the Distillate Hydrocracker Unit.

The Debutanizer overhead vapor is combined with lean oil and passed through the overhead condenser and into the reflux accumulator drum. The condensate with the lean oil is returned to the Absorber as reflux. The uncondensed vapors are sent to a secondary condenser to form bubble-point butane product in the overhead product accumulator drum.

Naphtha is drawn from the middle section of the Debutanizer and stripped in the Sidestripper by reboiler heat. The Sidestripper overhead is returned to a higher tray in the Debutanizer tower. The light naphtha from the Sidestripper bottoms is blended with other naphtha from the Main Fractionator overhead.

GAS PLANT
DESIGN BASIS

FEED STREAMS

(See Material Balance and Stream Properties for more detail.)

1. Hydrovisbreaker Atmospheric Flash Tower Off-Gas
2. Hydrovisbreaker 1st-stage Low-Pressure Separator Vent Gas
3. Hydrovisbreaker 2nd-stage Low-Pressure Separator Vent Gas
4. Naphtha Hydrotreater Stripper Overhead Gas
5. Distillate Hydrotreater Stripper Overhead Gas
6. Distillate Hydrocracker Low-Pressure Separator Vent Gas
7. Distillate Hydrocracker Prefractionator Tower Overhead Gas
8. Lean Oil Make-Up

OPERATING SPECIFICATIONS

1. *Absorber-Stripper*

C4 recovery in Stripper bottoms (Rich Oil):	99% of C4 feed
$C4^+$ in Absorber overhead (Dry Gas):	2 mole% $C4^+$ MAX.
Adjust $C3^-$ in Stripper bottoms (Rich Oil) so that $C3^-$ in Debut Ovhd. product is:	2 mole% $C3^-$ MAX.

GAS PLANT

DESIGN BASIS

(continued)

2. Debutanizer

C4 recovery in overhead butane product:	99% of C4 feed
$C3^-$ in Ovhd. product (see Abs-Stripper above):	2 mole% $C3^-$ MAX.
$C5^+$ in Ovhd. product	3 mole% $C5^+$ MAX.
Sidedraw TBP boiling range	C5 - 175°F
Bottoms TBP boiling range	175°F$^+$

3. Debutanizer Sidestripper

$C4^-$ in stripped bottoms	5 mole% $C4^-$ MAX.
Bottoms TBP boiling range	C5 - 175°F

UTILITIES

1. Cooling water: supply at 85°F / return at 105°F

2. Saturated steam pressures available: 450, 150, 50 psig

GAS PLANT
LIST OF MAJOR EQUIPMENT

TOWERS		Height	I.D.	No. of Trays
T-1	Absorber-Stripper	123 ft.	6 ft/9 ft	42
T-2	Debutanizer	110 ft.	8.5 ft	43
T-3	Debutanizer Sidestripper	36 ft.	3.5 ft	9

VESSELS	(all horizontal)	I.D.	S-S Length
V-1	Absorber Reflux Accumulator	6.5 ft	21 ft
V-2	Intercooler Separator	9 ft	20 ft
V-3	Debutanizer Reflux Accumulator	5 ft	11 ft
V-4	Debutanizer Overhead Product Accumulator	5 ft	12 ft

HEAT EXCHANGERS, REBOILERS, CONDENSERS		Duty, MMBTU/hr
E-1	Absorber Overhead Condenser	3.110
E-2,2A	Absorber Intercoolers	19.753
E-3	Stripper Interheater	8.000
E-4	Stripper Reboiler	34.072
E-5	Debutanizer Feed/Bottoms Heat Exchanger	17.543
E-6	Debutanizer Overhead Condenser	23.657
E-7	Debutanizer Overhead Product Condenser	8.105
E-8	Debutanizer Sidestripper Reboiler	4.021
E-9	Debutanizer Reboiler	25.470
E-10	Lean Oil Cooler	18.525

GAS PLANT

LIST OF MAJOR EQUIPMENT

(continued)

PUMPS

P-1,1A	Absorber Reflux
P-2,2A	Stripper Reflux
P-3,3A	Stripper Bottoms (Rich Oil)
P-4,4A	Debutanizer Reflux
P-5,5A	Butane Product
P-6,6A	Debutanizer Bottoms (Lean Oil)
P-7,7A	Lean Oil Make-Up

GAS PLANT

UTILITY REQUIREMENTS

Saturated Steam		lb/hr
450 psig	E-9 Debutanizer Reboiler:	33294
150 psig	E-4 Stripper Reboiler:	39555
50 psig	E-8 Debutanizer Sidestripper Reboiler:	4376
	Total Boiler Feed Water:	77225 lb/hr

Cooling Water	(85°F supply; 105°F return)	gal/min
E-1	Absorber Condenser:	415
E-2,2A	Absorber Intercoolers:	1975
E-6	Debutanizer Overhead Condenser and	
E-7	Debutanizer Overhead Product Condenser:	3175
E-10	Lean Oil Cooler:	1853
	Total Cooling Water:	7418 gpm

Process Electricity	(requirement for one pump from each pair)	KW
P-1,1A	Absorber Reflux	50
P-2,2A	Intercooler Separator Liquid	55
P-3,3A	Stripper Bottoms (Rich Oil)	15
P-4,4A	Debutanizer Reflux	35
P-5,5A	Butane Product	25
P-6,6A	Debutanizer Bottoms	75
P-7,7A	Lean Oil Make-up	5
	Total	260 KW

Section	Item	No.	E-1 Shell	E-1 Tube	E-2, 2A Shell	E-2, 2A Tube	E-3 Shell	E-3 Tube	E-4 Shell	E-4 Tube	E-5 Shell	E-5 Tube
SERVICE	ITEM NO	1	E-1		E-2, 2A		E-3		E-4		E-5	
	SERVICE	2, 3	~~ABSORBER~~ CONDENSER		ABSORBER INTERCOOLERS		STRIPPER INTERHEATER		STRIPPER REBOILER		DEBUT. FEED/BOTTOMS HEAT EXCHANGER	
	MANUFACTURER - NO SHELLS	4		1		2		1		1		1
	SIZE AND TYPE	5	37" x 20'	BEU	48" x 20'	BEU	25" x 20'	BEU	66", 33" x 20'	BKU	48" x 20'	BEU
	SURFACE / UNIT - / SHELL	6	3347		11660	5830	1607		2629		6297	
UNIT PERFORMANCE		7	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE
	CONNECTED IN	8			SERIES	SERIES						
	FLUID CIRCULATED	9, 10	THE TOP GAS & LEAN OIL	COOLING WATER	ABS BTMS + STRIPPER OVHD	COOLING WATER	STRIPPER TRAY 16 LIQUID	LEAN OIL	STRIPPER BOTTOMS	150 PSIG SAT'D STEAM	STRIPPER BOTTOMS	DEBUT BOTTOMS
	ENTERING QUANTITY LBS/HR — LIQUID	11	238,145	415 GPM	320,560	1975 GPM	531784	247442	475,271		312793	247442
	VAPOR MW	12	54,926		148,955							
	FIXED GASES MW	13										
	STEAM	14								39555		
	TOTAL	15	293,071	415 GPM	469,514	1975 GPM	531784	247442	475,271	39555	312793	247442
	FLUID VAPORIZED OR CONDENSED LB/HR	16	2,492		56,853		49162 (V)		162,484		75048	
	STEAM CONDENSED	17								39555		
	GRAVITY - LIQUID (SG) (API) AT °F 60°	18	.73		.72		.65	.76	.71			
	VISCOSITY - LIQUID (SSU) (CP) AT °F	19	.5		.5		.2	.3	.2			
	SPEC HEAT - LIQUID - BTU/LB	20										
	LATENT HEAT - VAPOR BTU/LB	21										
	OPER TEMP °F IN - OUT	22	117.5/100	85/100	146/100	85/105	193/200	298/200	224/278	361	278/325	411/298
	OPER PRESSURE PSIG	23	131	75	139	75	140	151	141	150	122	161
	MINIMUM FOULING FACTOR	24										
	NUMBER OF PASSES	25	1	2	1	2	1	2	1	2	2	4
	VELOCITY - FT/SEC	26										
	PRESSURE DROP - PSIG	27	8	5	5	10	2	10	1	5	10	10
	HEAT EXCHANGED - BTU/HR (MM)	28	3.11012		19.7528		8.0000		34.0724		17.54328	
	MTD CORRECTED - WEIGHTED	29	13.3		24.2		71.1		107.6		39.8	
	TRANSFER RATE SERVICE - CLEAN	30	70		70		70		120		70	
CONSTRUCTION	DESIGN PRESSURE - PSIG	31	156	75	164	75	165	176	166	175	186	150
	TEST PRESSURE - PSIG	32	234	112	246	112	248	264	249	262	279	225
	DESIGN TEMPERATURE - °F	33	400	400	400	400	650	650	650	650	650	650
	CORROSION ALLOWANCE	34	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"
	CONNECTIONS SIZE - STD - TYPE — IN	35										
	OUT	36										
	TUBES — MAT'L / NO	37		ADMIRALTY		ADMIRALTY		C.S.		C.S.		C.S.
	O.D. / BWG	38		3/4" 14		3/4" 14		3/4" 14		3/4" 14		3/4" 14
	LENGTH / PITCH	39		20' 1" ◇		20' 1" ◇		20' 1" ◇		20' 1" ◇		20' 1" ◇
	SHELL - I.D. - O.D.	40	37"		42"		25"		66"/33"		48"	
		41	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS
	STATIONARY TUBE SHEET	42										
	FLOATING TUBE SHEET	43										
	CROSS BAFFLES	44										
	LONGITUDINAL BAFFLES	45										
	TUBE SUPPORTS	46										
	SHELL	47	C.S.		C.S.		C.S.		C.S.		C.S.	
	SHELL COVERS	48										
	FLOATING HEAD COVER	49										
	CHANNEL	50										
	CHANNEL COVER	51										
	CROSS BAFFLES TYPE - SPACING	52										
	LONGITUDINAL BAFFLE TYPE	53										
	GASKETS	54										
	WELDING FLANGES AND NOZZLES	55										
	STUDS	56										
	WEIGHT EXCHANGER DRY - WET	57										
	WEIGHT BUNDLE	58										
	CODE REQUIREMENTS	59										
	SR & RC DRAWING NO	60										
	REQUISITION NO	61										
	PURCHASE ORDER NO	62										

NOTES

SR - STRESS RELIEVED
XR - X-RAYED

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

HEAT EXCHANGER SCHEDULE

PLANT GAS PLANT

PLANT NO UNIT NO

LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
JRS DATE 4/25/67				1

	Line										
ITEM NO	1	E-6		E-7		E-8		E-9		E-10	
SERVICE	2, 3	DEBUTANIZER OVHD CONDENSER		DEBUTANIZER OVHD PRODUCT CONDENSER		DEBUT SIDESTRIPPER REBOILER		DEBUTANIZER REBOILER		LEAN OIL COOLER	
MANUFACTURER - NO SHELLS	4		1		1		1		1		1
SIZE AND TYPE	5	50" × 20'	BEU	29" × 20'	BEU	30" × 15½" × 20'	BKU	18" × 39" × 20'	BKU	41" × 20'	BEU
SURFACE/UNIT - /SHELL	6	6889		2109		465		4121		4947	
	7	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE
CONNECTED IN	8										
FLUID CIRCULATED	9, 10	DEBUT TWR TOP VAPOR	COOLING WATER	BUTANE PRODUCT	COOLING WATER	SIDESTRIPPER BOTTOMS	50 PSIG SAT'D STEAM	DEBUT BOTTOMS	450 PSIG SAT'D STEAM	LEAN OIL	COOLING WATER
QUANTITY LBS/HR — LIQUID	11		3175 GPM		3175 GPM	49003		457148		247442	1853 GPM
VAPOR MW	12	233250		59512							
FIXED GASES MW	13										
STEAM	14						4376		33294		
TOTAL	15	233250	3175 GPM	59512	3175 GPM	49003		457148		247442	1853 GPM
FLUID VAPORIZED OR CONDENSED	16	173789		59512		32370		201706			
STEAM CONDENSED	17						4376		33294		
GRAVITY LIQUID (SG) (API) AT °F 60°	18	.57		.56		.63		.75			
VISCOSITY LIQUID (SSU) (CP) AT °F	19	.15		.1		.1		.2			
SPEC HEAT LIQUID BTU/LB	20										
LATENT HEAT VAPOR BTU/LB	21										
OPER TEMP °F IN OUT	22	143/134	90/105	134/126	85/101	247/253	298	400/411	457	244/100	85/105
OPER PRESSURE PSIG	23	95	70	90	75	103	50	105	450	141	75
MINIMUM FOULING FACTOR	24										
NUMBER OF PASSES	25	1	2	1	2	1	2	1	2	2	4
VELOCITY FT/SEC	26										
PRESSURE DROP PSIG	27										
HEAT EXCHANGED BTU/HR (MM)	28	23.6566		6.10488		4.0211		25.4497		18.525	
MTD CORRECTED WEIGHTED	29	40.4		42.7		66.6		51.5		53.5	
TRANSFER RATE SERVICE CLEAN	30	85		70		130		120		60	
DESIGN PRESSURE PSIG	31	120	100	115	100	128	75	130	500	115	100
TEST PRESSURE PSIG	32	180	150	173	150	192	113	195	750	173	150
DESIGN TEMPERATURE °F	33	400	400	400	400	650	650	650	650	400	400
CORROSION ALLOWANCE	34	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"
CONNECTIONS SIZE STD TYPE IN	35										
OUT	36										
TUBES MAT'L NO	37		ADMIRALTY		ADMIRALTY		CS		CS		ADMIRALTY
O.D. BWG	38		3/4" 14		3/4" 14		3/4" 14		3/4" 14		3/4" 14
LENGTH PITCH	39		20' 1"◇		20' 1"◇		20' 1"◇		20' 1"◇		20' 1"◇
SHELL I.D. O.D.	40	50"		29"		30" × 15½"		78" × 39"		43" × 20'	
	41	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS
STATIONARY TUBE SHEET	42										
FLOATING TUBE SHEET	43										
CROSS BAFFLES	44										
LONGITUDINAL BAFFLES	45										
TUBE SUPPORTS	46										
SHELL	47	CS		CS		CS		CS		CS	
SHELL COVERS	48										
FLOATING HEAD COVER	49										
CHANNEL	50										
CHANNEL COVER	51										
CROSS BAFFLES TYPE SPACING	52										
LONGITUDINAL BAFFLE TYPE	53										
GASKETS	54										
WELDING FLANGES AND NOZZLES	55										
STUDS	56										
WEIGHT EXCHANGER DRY WET	57										
WEIGHT BUNDLE	58										
CODE REQUIREMENTS	59										
SR & MC DRAWING NO	60										
REQUISITION NO	61										
PURCHASE ORDER NO	62										

Sections: SERVICE (lines 1–6); UNIT PERFORMANCE (lines 7–30); CONSTRUCTION (lines 31–56)

NOTES

SR - STRESS RELIEVED
XR - X RAYED

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

HEAT EXCHANGER SCHEDULE

PLANT GAS PLANT

PLANT NO UNIT NO

LOCATION

BY	APPD	DRAWING NO	REV	SHEET
JRS				2
DATE 4/25/87				

		T-1	T-2	T-3	V-1	V-2	V-3	V-4			
	ITEM NO.	T-1	T-2	T-3	V-1	V-2	V-3	V-4			
SERVICE	TITLE	ABSORBER STRIPPER TOWER	DEBUTANIZER TOWER	DEBUTANIZER SIDESTRIPPER TOWER	ABSORBER REFLUX ACCUMULATOR	INTERCOOLER SEPARATOR	DEBUTANIZER REFLUX ACCUMULATOR	DEBUTANIZER OVERHEAD PRODUCT ACCUMULATOR			
SERVICE	SERIAL NO										
SERVICE	DWG NO ASSEMBLY										
SERVICE	DWG NO DETAILS										
SERVICE	DWG NO TRAYS										
SERVICE	DWG NO PLATFORMS										
DESIGN	CODE										
DESIGN	PRESSURE PSIG	166	130	128	150	162	115	110			
DESIGN	TEMPERATURE °F	650	650	650	650	650	650	650			
DESIGN	CORROSION ALLOWANCE UPPER/LOWER	.125"/.16"	.14"	.18"	.133"	.17"	.15"	.133"			
DESIGN	WIND LOADING										
DESIGN	HYDROSTATIC TEST PRESSURE PSIG	250	195	192	225	243	173	165			
DESIGN	HAMMER TEST PRESSURE										
DESIGN	STRESS RELIEVED	NO	NO	NO	NO	NO	NO	NO			
DESIGN	RADIOGRAPHED	SPOT	SPOT	SPOT	SPOT	SPOT	SPOT	SPOT			
DESCRIPTION	VERTICAL OR HORIZONTAL	VERT	VERT	VERT	HORIZ	HORIZ	HORIZ	HORIZ			
DESCRIPTION	INSULATION THICKNESS										
DIMENSIONAL	DIA I.D. (UPPER/LOWER)	6'0"/9'0"	8'6"	3'6"	6'6"	9'0"	7'0"	5'0"			
DIMENSIONAL	LENGTH SEAM TO SEAM	111'0"	98'0"	24'0"	20'0"	20'0"	17'0"	12'0"			
DIMENSIONAL	LENGTH BASE SECTION										
DIMENSIONAL	HEIGHT OF SKIRT	12'0"	12'0"	12'0							
DIMENSIONAL	℄ TO BOTTOM OF SUPPORTS										
DIMENSIONAL	TOTAL SHELL THICKNESS (UPPER/LOWER)	.5625"/.8125"	.625"	.375"	.5625	.8125"	.5000"	.3750			
DIMENSIONAL	HEAD THICKNESS (UPPER/LOWER)	.5625"/.8125"	.625	.375"	.5625"	.8125"	.5000"	.3750			
DIMENSIONAL	SKIRT THICKNESS	.8125"	.625"	.375"							
MH	NO REQ'D	6	5	2	1	1	1	1			
MH	SIZE	24"	24"	24"	24"	24"	24"	24"			
MH	SERIES & FACING										
LINING	TYPE										
LINING	THICKNESS	NONE	NONE	NONE	NONE	NONE	NONE	NONE			
LINING	LOCATION										
TRAY A	NO TRAYS REQ'D & SPACING	42 @ 24"	43 @ 24"	9 @ 24"							
TRAY A	TYPE OF TRAY	12 CR	12 CR	12 CR							
TRAY A	NO OF CAPS/TRAY & TYPE	VALVE	VALVE	VALVE							
TRAY A	SIZE OF CAPS										
TRAY A	SIZE OF RISERS										
TRAY A	TYPE OF DOWNCOMER										
TRAY B	NO TRAYS REQ'D & SPACING										
TRAY B	TYPE OF TRAY										
	TYPE OF HEAD	ELLIP	ELLIP	ELLIP	ELLIP	ELLIP	ELLIP	ELLIP			
MAT'L SPEC	SHELL & HEADS	CS	CS	CS	CS	CS	CS	CS			
MAT'L SPEC	SKIRT	CS	CS	CS	CS	CS	CS	CS			
MAT'L SPEC	STRUCTURAL MEMBERS										
PURCH. DATA	REQUISITION NO										
PURCH. DATA	PURCHASE ORDER										
PURCH. DATA	PURCHASED FROM										
PURCH. DATA	FABRICATOR S/O										
	SHIPPING WEIGHT	113,776	[illegible]	[illegible]	13000	26000	10500	4500			
	TEST WEIGHT										

NOTES

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

TOWER & VESSEL SCHEDULE

PLANT GAS PLANT

PLANT NO. UNIT NO.

LOCATION

BY	APP'D	DRAWING NO.	REV	SHEET
RS				3
DATE 4/3/81				

PUMP ITEM NO			P1, 1A	P2, 2A	P3, 3A	P 4, 4A	P 5, 5A	P-6, 6A	P-7, 7A			
SERVICE			ABSORBER REFLUX	STRIPPER REFLUX	STRIPPER BOTTOMS	DEBUTANIZER REFLUX	BUTANE PRODUCT	DEBUTANIZER BOTTOMS	LEAN OIL MAKE-UP			
OPERATING CONDITIONS	LIQUID	1	LEAN OIL	RICH OIL	RICH OIL	BUTANE	BUTANE	LEAN OIL	LEAN OIL			
	PUMPING TEMPERATURE °F	2	100	100	278	134	126	411	260			
	SPECIFIC GRAVITY AT P.T.	3	.7318	.6622	.5789	.5170	.5188	.5607	.6693			
	VISC SSU, CP, CSTK, AT P.T.	4	.34 CP	.22 CP	.13 CP	.11 CP	.11 CP	.11 CP	.23 CP			
	GPM AT P.T.	5	717.3	1178.6	1079.2	671.3	229.1	881.5	32.3			
	SUCTION PRESSURE (PSIG)	6	127	137	143	93	88	108	63			
	DISCHARGE PRESSURE (PSIG)	7	208	193	152	154	205	206	159			
	DIFFERENTIAL HEAD (FT)	8	244'	193'	57'	272'	321'	404'	316'			
	N.P.S.H. AVAILABLE	9	12'	12'	8'	12'	12'	12'	183'			
	RPM	10										
	BHP AT RATED GPM	11	55	65	16	40	27	85	3			
	MAX. BHP FOR INSTALLED IMP.	12	65	77	20	48	35	110	5			
PUMP SPECIFICATIONS	MANUFACTURER	13										
	TYPE AND SIZE	14										
	STAGES	15										
	SUCT. FLG. SIZE, RATING, FACE	16										
	DISCH. FLG. SIZE, RATING, FACE	17										
	NOZZLE ARRG'T SUCTION	18										
	NOZZLE ARRG'T DISCHARGE	19										
	IMPELLER DIA. REQUIRED	20										
	MAX. IMP. DIA. AND HEAD	21										
	IMP. EYE AREA	22										
	N.P.S.H. REQUIRED	23										
	HYDROSTATIC TEST PRESSURE	24										
	THRUST BEARING	25										
	RADIAL BEARING	26										
	COUPLING	27										
	COUPLING GUARD	28										
	ROTATION FROM COUPLING END	29										
	MECHANICAL SEALS – MFG	30										
	MECHANICAL SEALS – TYPE	31										
	MECHANICAL SEALS – AUX BOX	32										
	WATER COOLED – BOX	33										
	WATER COOLED – BEARING	34										
	WATER COOLED – PEDESTAL	35										
	WEIGHT OF PUMP AND BASE	36										
MATERIAL SPECIFICATIONS	CASING	37	C.S.	C.S.	C.S.	C.S.	C.S.	C.S.				
	CASE WEARING RINGS	38										
	STAGE PIECES	39										
	BUSHINGS – THROAT	40										
	BUSHINGS – INTERSTAGE	41										
	IMPELLER	42	12 CR	12 CR	12 CR	[illegible]	12 CR	12 CR				
	IMPELLER WEARING RINGS	43										
	SHAFT	44										
	SHAFT SLEEVES	45										
	GLAND	46										
	LANTERN RINGS	47										
	BEARING HOUSING	48										
	BASE PLATE	49										
	GASKETS	50										
	SEAL – STATIONARY RING	51										
	SEAL – ROTATING RING	52										
	SEAL – PACKING	53										
MANUFACTURERS SERIAL NO		54										
PERFORMANCE CURVE		55										
[illegible] NUMBER		56										
SHOP DRAWING NO		57										

NOTES

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

CENTRIFUGAL PUMP SCHEDULE

PLANT: GAS PLANT

PLANT NO: UNIT NO:

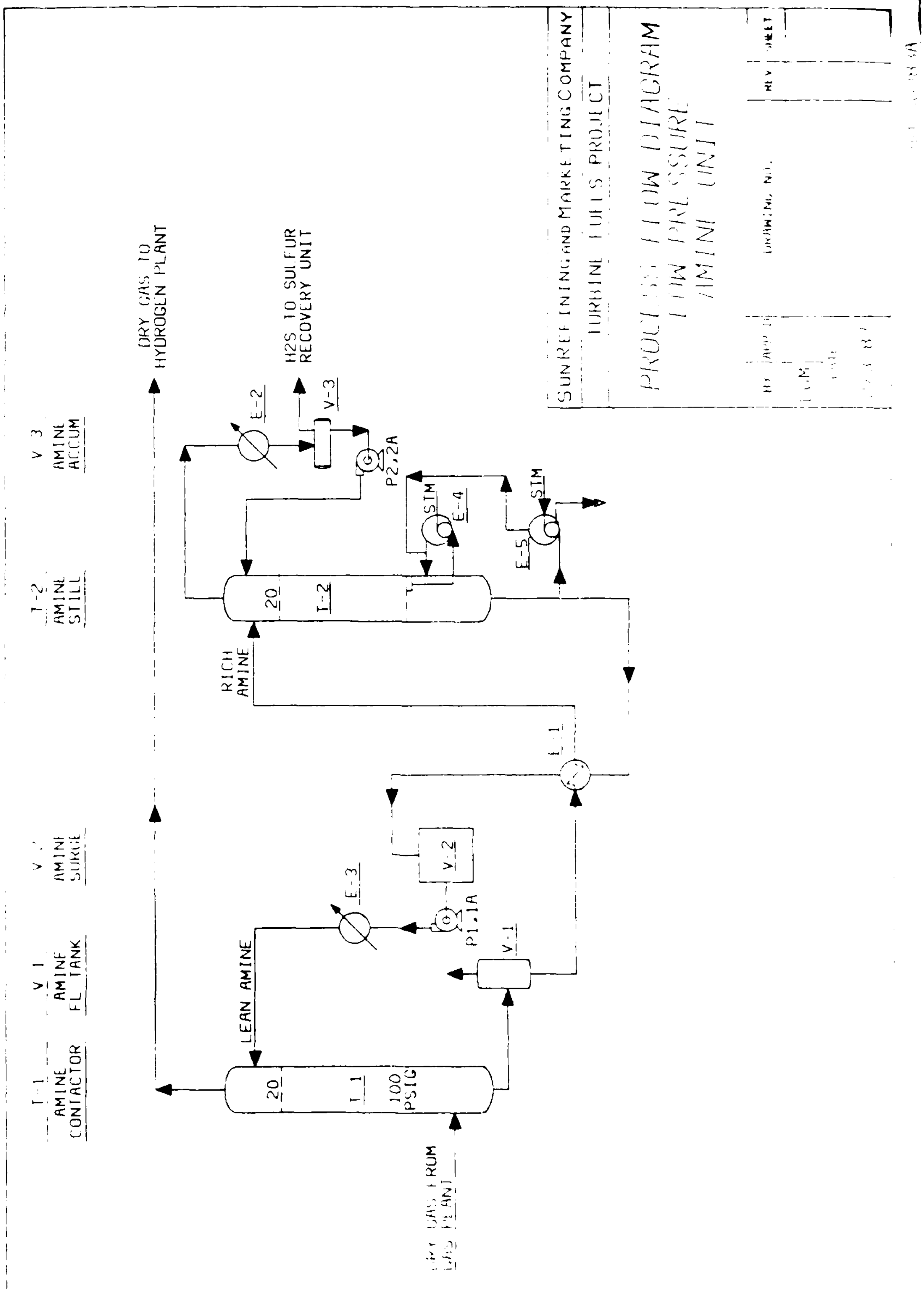
LOCATION:

BY	APP'D	DRAWING NO	REV	SHEET
JRS				4
DATE: 4-…-87				

PROCESS DESIGN SPECIFICATIONS

for the

LOW PRESSURE AMINE UNIT


T-1 AMINE CONTACTOR
V-1 AMINE FL TANK
AMINE SURGE
T-2 AMINE STILL
V-3 AMINE ACCUM
DRY GAS TO HYDROGEN PLANT
H2S TO SULFUR RECOVERY UNIT
LEAN AMINE
RICH AMINE
20
T-1
100 PSIG
T-2
E-2
V-3
P2,2A
STM
E-4
E-5
E-3
P1,1A
V-2
V-1
SUN REFINING AND MARKETING COMPANY
TURBINE FUELS PROJECT
PROCESS FLOW DIAGRAM
LOW PRESSURE
AMINE UNIT
DRAWING NO.
REV
SHEET

LOW PRESSURE AMINE UNIT

Process Description

It is estimated that the combined dry gas from the gas plant plus bypassed lean gas will be about 48.4 million cubic feet per day containing about 1.22 gas volume percent hydrogen sulfide. This gas contains 25 short tons per stream day of sulfur. This must be removed to use this gas for making hydrogen. This is done by scrubbing the gas with 15 wt% monoethanolamine (MEA) in water. The gas is routed at 100°F and 100 psig through the amine absorber. The hydrogen sulfide is absorbed in the MEA. About a 99% removal is possible. The amine to the contactor top tray should be about 5°F above that of the incoming gas to avoid hydrocarbons condensing in the contactor. Condensation causes a "foam over" with amine carry over into the outlet gas.

The lean amine flows down through the 20-tray amine contactor countercurrent to the gas feed. The rich amine from the contactor is flashed to remove entrained hydrocarbons. The flashed amine is preheated by heat exchange and routed to the top of the amine still. Hot water vapor produced by the reboiler removes the hydrogen sulfide and carries it overhead The water vapor is condensed in the overhead condenser and the hydrogen sulfide gas is piped to the sulfur recovery unit.

The stripped amine is cooled by heat exchange and water cooling for recirculation to the contactor.

A drag stream of lean amine is heated to a higher temperature to distill off the amine. Salts and impurities are withdrawn and discarded.

LOW PRESSURE AMINE UNIT

DESIGN BASIS

Feed Gas: 48.4 MMSCFD

Hydrogen Sulfide fed 25 Short Tons/Stream Day

Hydrogen Sulfide recovery 99%

Amine type: 15 wt% MEA (monoethanolamine)

Amine contactor pressure: 100 psig

Amine still bottoms: 235°F

LOW PRESSURE AMINE UNIT

Utilities and Chemicals

Steam

150 psig Steam	1,310 lb/hr
50 psig Steam	12,500 lb/hr
Steam condensate recovered	13,810 lb/hr

Cooling water

Supplied at 85°F, returned at 115°F

Circulation:	720 GPM

Electrical Power (440 and 220 volt)	23 KW

Chemicals

Monoethanolamine (MEA) at 100% concentration:	5 gal/day

LOW PRESSURE AMINE UNIT

List of Major Equipment

Exchangers

E-1	Rich Amine - Lean Amine Exchanger
E-2	Still Condenser
E-3	Lean Amine Cooler
E-4	Still Reboiler
E-5	Still Reclaimer

Towers and Vessels

T-1	Amine Contactor
T-2	Amine Still
V-1	Amine Flash Tank
V-2	Amine Surge Tank
V-3	Amine Accumulator

Pumps

P-1,1A	Lean Amine Pumps
P-2,2A	Still Reflux Pumps

No.	Item	E-1 Shell	E-1 Tube	E-2 Shell	E-2 Tube	E-3 Shell	E-3 Tube	E-4 Shell	E-4 Tube	E-5 Shell	E-5 Tube
1	ITEM NO	E-1		E-2		E-3		E-4		E-5	
2-3	SERVICE	RICH LEAN EXCHANGER		STILL CONDENSER		LEAN AMINE COOLER		STILL REBOILER		STILL RECLAIMER	
4	MANUFACTURER / NO SHELLS		2		1		2		1		1
5	SIZE AND TYPE	20"x20'	AES	18x20	BEU	19"x20	BEU	24x27x20	BKU	30"x1x20	BKU
6	SURFACE / UNIT / SHELL	1800	900	680	680	1525	763	1810	1610	180	180
7		SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE	SHELL	TUBE
8	CONNECTED IN	SERIES	SERIES	—	—						
9	FLUID CIRCULATED	L AMINE	R AMINE	WATER H_2S	WATER	L AMINE	WATER	L AMINE	STEAM	L AMINE	STEAM
10											
11	QUANTITY LBS/HR — LIQUID	79,200	81,283		480 GPM	79.2	240 GPM	91.2	2500	[illegible]	1.31
12	VAPOR MW										
13	FIXED GASES MW			2083 (H2S)							
14	STEAM			720 (H2O)							
15	TOTAL	79.2	81,283	4283		79.2					
16	FLUID VAPORIZED OR CONDENSED							12.2		[illegible]	
17	STEAM CONDENSED			7000					2.5		[illegible]
18	GRAVITY LIQUID (SG)(API) AT °F 60	.99	.98	1.0		[illegible]		.99		.99	
19	VISCOSITY LIQUID AT °F 60	1.1	1.0			[illegible]			[illegible]	[illegible]	[illegible]
20	SPEC HEAT LIQUID BTU/LB °F										
21	LATENT HEAT VAPOR BTU/LB										
22	OPER TEMP °F IN OUT	235-145	105-195	210-[illegible]	35-[illegible]	45-165	[illegible]	235-235	301-301	275-275	339-339
23	OPER PRESSURE PSIG	10	25	10	75	50	75	15	35	5	[illegible]
24	MINIMUM FOULING FACTOR										
25	NUMBER OF PASSES										
26	VELOCITY FT/SEC										
27	PRESSURE DROP PSI	4	5	[illegible]	5	10	10	1	3	1	5
28	HEAT EXCHANGED BTU/HR MM	7.2		7.2		3.6		11.52		1.15	
29	MTD CORRECTED WEIGHTED		30		77				46		6
30	TRANSFER RATE SERVICE CLEAN		133		138				130		150
31	DESIGN PRESSURE PSIG	75	150	75	100	225	100	75	75	[illegible]	250
32	TEST PRESSURE PSIG	110	150		150	340	150	[illegible]	[illegible]		[illegible]
33	DESIGN TEMPERATURE °F	650	650	650	400	650	400	650	400	650	650
34	CORROSION ALLOWANCE	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8
35	CONNECTIONS IN										
36	SIZE STD TYPE OUT										
37	TUBES MAT'L NO	304		8 ADMIRAL			ADMIRAL		304		[illegible]
38	O.D. BWG	3/4"	14	3/4	14	3/4"	14	3/4"	14	3/4	[illegible]
39	LENGTH PITCH	20'	1.0	20'	1.0	20'	1.0		1.0		[illegible]
40	SHELL I.D. O.D.	20"		18"							
41		MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS	MATERIAL	THICKNESS
42	STATIONARY TUBE SHEET										
43	FLOATING TUBE SHEET										
44	CROSS BAFFLES										
45	LONGITUDINAL BAFFLES										
46	TUBE SUPPORTS										
47	SHELL	CS		CS			CS		CS		CS
48	SHELL COVERS										
49	FLOATING HEAD COVER										
50	CHANNEL										
51	CHANNEL COVER										
52	CROSS BAFFLES TYPE SPACING										
53	LONGITUDINAL BAFFLE TYPE										
54	GASKETS										
55	WELDING FLANGES AND NOZZLES										
56	STUDS										
57	WEIGHT EXCHANGER DRY WET										
58	WEIGHT BUNDLE										
59	CODE REQUIREMENTS										
60	SR & XR DRAWING NO										
61	REQUISITION NO										
62	PURCHASE ORDER NO										

NOTES

SR - STRESS RELIEVED
XR - X RAYED

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

HEAT EXCHANGER SCHEDULE

PLANT AIR FORCE
LOW PRESSURE AMINE
PLANT NO UNIT NO

LOCATION

BY	APP'D	DRAWING NO	REV	SHEET
LWS				1
DATE 4/25/77				

Section	Field					
SERVICE	ITEM NO	T-1	T-2	V-1	V-2	V-3
	TITLE	AMINE CONTACTOR	AMINE STILL	AMINE FL TANK	AMINE SURGE	AMINE ACCUM
	SERIAL NO					
	DWG NO — ASSEMBLY					
	DWG NO — DETAILS					
	DWG NO — TRAYS					
	DWG NO — PLATFORMS					
DESIGN	CODE					
	PRESSURE	175	75	125	[illegible]	75
	TEMPERATURE °F	650	650	650	650	650
	CORROSION ALLOWANCE	.125"	.262	.168	.125	.125
	WIND LOADING					
	HYDROSTATIC TEST PRESSURE	265	115	265	—	115
	HAMMER TEST PRESSURE					
	STRESS RELIEVED	YES	YES	YES	YES	YES
	RADIOGRAPHED	SPOT	SPOT	SPOT	SPOT	SPOT
DESCRIPTION	VERTICAL OR HORIZONTAL	V	V	V	V	H
	INSULATION THICKNESS	[illegible]	YES	NO	YES	NO
DIMENSIONAL	O.D. / I.D.	[illegible]	4'	4'[illegible]	10'	30"
	LENGTH SEAM TO SEAM	50	50	10'	20	10'
	LENGTH BASE SECTION					
	HEIGHT OF SKIRT	12'	12'	5'	—	—
	℄ TO BOTTOM OF SUPPORTS					
	TOTAL SHELL THICKNESS	.625"	.375"	.437"	.375	.375
	HEAD THICKNESS	.625	.375	.437"	.375	.375
	SKIRT THICKNESS	.5"	.375	.25		
MH	NO REQ'D	2	2	1	1	
	SIZE	24"	24"	24"	24"	24"
	SERIES & FACING					
LINING	TYPE					
	THICKNESS	NONE	NONE	NONE	NONE	NONE
	LOCATION					
TRAY A	NO TRAYS REQ'D & SPACING	20-24"	20-24"	—	—	—
	TYPE OF TRAY	12 [illegible]	12 CA			—
	NO OF CAPS/TRAY & TYPE	VALVE	VALVE			
	SIZE OF CAPS					
	SIZE OF RISERS					
	TYPE OF DOWNCOMER					
TRAY B	NO TRAYS REQ'D & SPACING					
	TYPE OF TRAY					
MAT'L SPEC	SHELL & HEADS	CS	CS	CS	CS	CS
	SKIRT	CS	CS	CS	CS	CS
	STRUCTURAL MEMBERS	CS	CS	CS	CS	CS
PURCHG DATA	REQUISITION NO					
	PURCHASE ORDER					
	PURCHASED FROM					
	FABRICATOR S/O					
	SHIPPING WEIGHT [illegible]	[illegible]	6,300	3100	2200	1450
	TEST WEIGHT					

NOTES

NO	DATE	REVISION	BY

Sun Refining and Marketing Company

TOWER & VESSEL SCHEDULE

PLANT [illegible] FORCE
Low Pressure Amine
PLANT NO UNIT NO

LOCATION

BY	APPD	DRAWING NO	REV	SHEET
				2
DATE [illegible]				

PUMP ITEM NO			P1,1A		P2,2A						
SERVICE			LOW PRESS AMINE		STILL REFLUX						
OPERATING CONDITIONS											
LIQUID	1		AMINE		WATER						
PUMPING TEMPERATURE	2		140°F		120°F						
SPECIFIC GRAVITY AT P.T.	3		.99		.99						
VISC. SSU, CP, CSTK, AT P.T.	4				.8						
GPM AT P.T.	5		192		18						
SUCTION PRESSURE (PSIG)	6		0		0						
DISCHARGE PRESSURE (PSIG)	7		150		40						
DIFFERENTIAL HEAD (FT)	8		350'		92'						
N.P.S.H. AVAILABLE	9										
RPM	10										
BHP AT RATED GPM	11		28		7						
MAX. B.H.P. FOR INSTALLED IMP.	12		35		10						
PUMP SPECIFICATIONS											
MANUFACTURER	13										
TYPE AND SIZE	14										
STAGES	15										
SUCT. FLG. SIZE RATING FACE	16										
DISCH. FLG. SIZE RATING FACE	17										
NOZZLE ARRGT. SUCTION	18										
NOZZLE ARRGT. DISCHARGE	19										
IMPELLER DIA. REQUIRED	20										
MAX. IMP. DIA. AND HEAD	21										
[illegible]	22										
[illegible] REQUIRED	23										
HYDROSTATIC TEST PRESSURE	24										
THRUST BEARING	25										
RADIAL BEARING	26										
[illegible]	27										
[illegible]	28										
[illegible]	29										
MECHANICAL SEALS MFG	30										
MECHANICAL SEALS TYPE	31										
MECHANICAL SEALS AUX. BOX	32										
WATER COOLED BOX	33										
WATER COOLED BEARING	34										
WATER COOLED PEDESTAL	35										
WEIGHT OF PUMP AND BASE	36										
MATERIAL SPECIFICATIONS											
CASING	37	CS			CS						
CASE WEARING RINGS	38										
STAGE PIECES	39										
BUSHINGS THROAT	40										
BUSHINGS INTERSTAGE	41										
IMPELLER	42	12 CR			12 CR						
IMPELLER WEARING RINGS	43										
SHAFT	44										
SHAFT SLEEVES	45										
GLAND	46										
LANTERN RINGS	47										
BEARING HOUSING	48										
BASE PLATE	49										
GASKETS	50										
SEAL STATIONARY RING	51										
SEAL ROTATING RING	52										
SEAL PACKING	53										
MANUFACTURERS SERIAL NO	54										
PERFORMANCE CURVE	55										
[illegible] NUMBER	56										
[illegible] DRAWING NO	57										

NOTES

NO.	DATE	REVISION	BY

Sun Refining and Marketing Company

CENTRIFUGAL PUMP SCHEDULE

PLANT AIR FORCE

LOW PRESSURE AMINE
PLANT NO UNIT NO

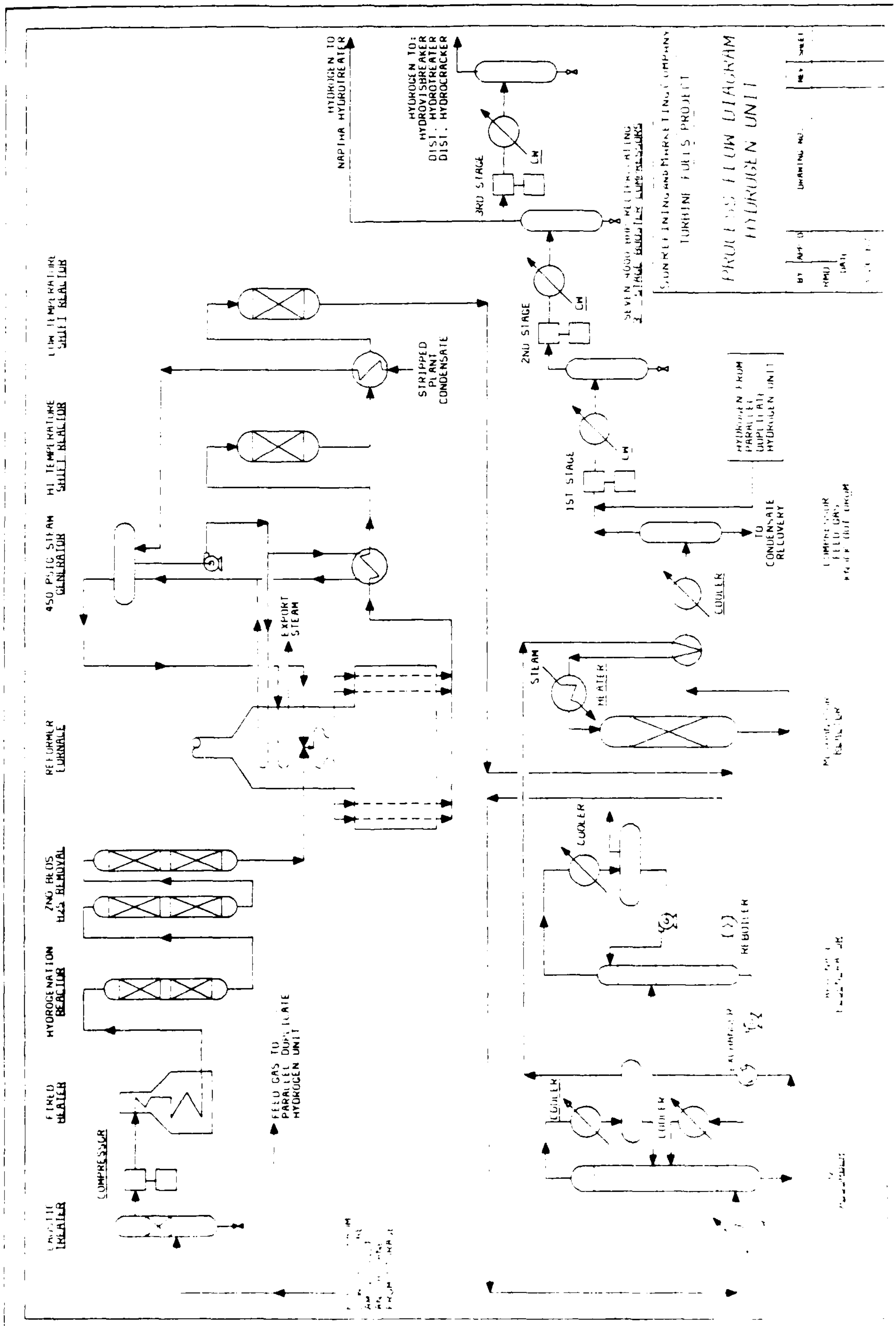
LOCATION

BY	APPD	DRAWING NO	REV	SHEET
LGM				3
DATE 4/15/87				

PROCESS DESIGN SPECIFICATIONS

for the

HYDROGEN PLANT



HYDROGEN TO NAPTHA HYDROTREATER
HYDROGEN TO: HYDROVISBREAKER DIST. HYDROTREATER DIST. HYDROCRACKER
3RD STAGE
CW
2ND STAGE
CW
1ST STAGE
CW
LOW TEMPERATURE SHIFT REACTOR
HI TEMPERATURE SHIFT REACTOR
STRIPPED PLANT CONDENSATE
450 PSIG STEAM GENERATOR
EXPORT STEAM
REFORMER FURNACE
ZNO BEDS H2S REMOVAL
HYDROGENATION REACTOR
FIRED HEATER
COMPRESSOR
CAUSTIC TREATER
FEED GAS TO PARALLEL DUPLICATE HYDROGEN UNIT
TO CONDENSATE RECOVERY
HYDROGEN FROM PARALLEL DUPLICATE HYDROGEN UNIT
COOLER
STEAM
HEATER
COOLER
REBOILER
COOLER
COOLER
SEVEN 4000 HP RECIPROCATING 3 STAGE BOOSTER COMPRESSORS
SUN REFINING AND MARKETING COMPANY
TURBINE FUELS PROJECT
PROCESS FLOW DIAGRAM
HYDROGEN UNIT
DRAWING NO.

HYDROGEN PLANTS

Catalytic Steam Reforming of Hydrocarbons

PROCESS DESCRIPTION

The overall hydrogen production requirement for the refinery conversion processes is 160 MMSCFD of 95% purity hydrogen. This has been divided into two duplicate 80 MMSCFD hydrogen plants since this is approaching the maximum shop-fabricated equipment size. Also, the conversion processes - hydrovisbreaking, naphtha hydrotreating, distillate hydrocracking, and hydrocracking - can be kept on-stream if one hydrogen unit fails.

The feed to the units is amine-treated dry gas plus vaporized butane. These gases are caustic washed to remove residual hydrogen sulfide.

The feed gas is then compressed from 100 psig to 400 psig and preheated with a fired furnace to about 700°F. The preheated gas is then mixed with hydrogen and passed over cobalt-moly catalyst, which saturates olefins and converts any organic sulfur compounds to saturated hydrocarbons plus hydrogen sulfide.

The feed gas is then routed through two zinc oxide beds in series, which remove the small amount of hydrogen sulfide formed from organic sulfur compounds. The feed gas is then mixed with preheated steam and is fed to the reformer furnace to produce hydrogen plus carbon monoxide and carbon dioxide. The zinc oxide is converted to zinc sulfide. The zinc oxide is replaced periodically.

The reformer furnace contains vertical tubes with an inside diameter of approximately six inches packed with catalyst. The feed gas enters through the convection section after being premixed with superheated

steam. The steam is waste steam produced in the process which has also been preheated in the furnace convection section. The steam and hydrocarbon gas flow down over the catalyst in the radiant tubes where the conversion to hydrogen, carbon dioxide, carbon monoxide, and water vapor takes place. The converted gases leave the furnace at about 1525°F and are cooled to 650°F in the waste heat steam generator.

The gases are then routed through a high temperature (750°F) catalytic shift converter followed by a low temperature (400°F) catalytic shift converter. These catalytic reactors convert the carbon monoxide to carbon dioxide. The carbon dioxide is then absorbed in a regenerative potassium carbonate solution and thus removed from the process.

The carbon dioxide absorber tower operates at about 200°F and 300 psig. The rich solution is stripped of the absorbed carbon dioxide in a reboiled regenerative tower. The carbon dioxide is vented to the atmosphere. The scrubbed gas is now about 95% hydrogen but still contains some carbon dioxide and carbon monoxide, which are next removed by a catalytic methanator.

The catalytic methanator reacts carbon oxides with hydrogen to form methane plus water vapor. This removes the carbon monoxide which is hydrocracker catalyst poison. The methanator operates at about 500°F and about 300 psig.

The purified hydrogen product is then cooled and compressed from 240 psig to 2445 psig with electrically driven reciprocating compressors for use in the Hydrovisbreaker, Distillate Hydrotreater, and Distillate Hydrocracker Units. A portion of the hydrogen is removed at 1190 psig for use in the Naphtha Hydrotreater Unit.

HYDROGEN PLANT

DESIGN BASIS

Two (2) duplicate units

Feed (combined total for both units):

Refinery Dry Gas	48.42 MMSCFD	(containing 23.64 MMSCFD Hydrogen)
Vaporized Butane	1158 BPSD	
Steam consumed	146,000 lb/hr	

Steam export (estimated) 0 - 50,000 lb/hr

The detailed steam balance within the unit was estimated from similar units. A detailed hydrogen plant design was not developed.

Total Hydrogen Product (95% purity): 160 MMSCFH

Hydrogen Required by the Hydroprocessing Plants

Naphtha Hydrotreater	9.0	MMSCFD
Hydrovisbreaker	40.0	
Distillate Hydrotreater	55.0	
Distillate Hydrocracker	52.0	
Internal use at Hydrogen Plt.	4.0	
Total	160.0	MMSCFD

HYDROGEN PLANT

Utilities, Chemicals, and Catalyst

Combined Requirements for both 80,000 MMSCFD plants

Export Steam Generated (450 psig):	0 - 50,000 lb/hr
Cooling water circulated	38,720 GPM
Electrical power	
Excluding product booster compressors	2,700 KW
Product booster compressors	19,206 KW
Total	21,906 KW
Process water	838 GPM
Fuel (from refinery butane and naphtha products)	

Butane	917.5 MMBTU/HR	= 5,743 BPSD
Naphtha	371.5 MMBTU/HR	= 2,111 BPSD

Raw Materials

Caustic Soda	1000 lb/day
Zinc Oxide	4.2 lb/day
Cobalt Moly Desulfurization Catalyst	61.2 lb/day
Reforming Catalyst	86.4 lb/day
High Temperature Shift Catalyst	252 lb/day
Low Temperature Shift Catalyst	288 lb/day
Potassium Carbonate	1120 lb/day
Methanation Catalyst	33 lb/day

HYDROGEN PLANT

Major Equipment

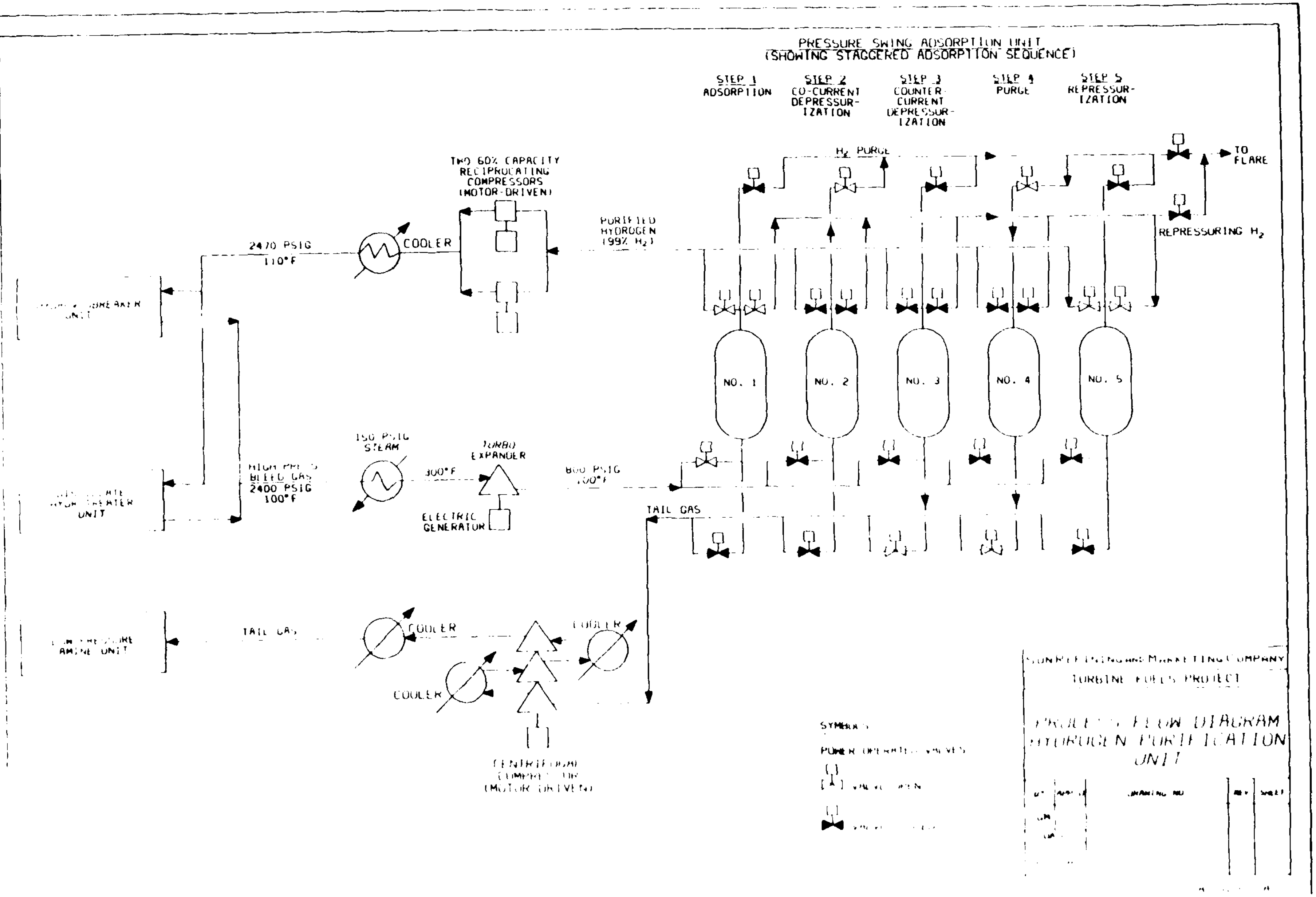
The hydrogen plant capital and utility requirements were based on data taken from Stanford Research Institute reports and from Sun Company hydrogen plant designs. Therefore, no detailed design or major equipment list was developed.

Additionally, no royalty is involved in purchasing the hydrogen plants.

PROCESS DESIGN SPECIFICATIONS

for the

HYDROGEN PURIFICATION UNIT



PRESSURE SWING ADSORPTION UNIT
(SHOWING STAGGERED ADSORPTION SEQUENCE)
STEP 1 ADSORPTION
STEP 2 CO-CURRENT DEPRESSUR-IZATION
STEP 3 COUNTER-CURRENT DEPRESSUR-IZATION
STEP 4 PURGE
STEP 5 REPRESSUR-IZATION
H_2 PURGE
TO FLARE
REPRESSURING H_2
NO. 1
NO. 2
NO. 3
NO. 4
NO. 5
TWO 60% CAPACITY RECIPROCATING COMPRESSORS (MOTOR-DRIVEN)
PURIFIED HYDROGEN (99% H_2)
COOLER
2470 PSIG 110°F
150 PSIG STEAM
TURBO EXPANDER
300°F
800 PSIG 100°F
ELECTRIC GENERATOR
2400 PSIG 100°F
UNIT
TAIL GAS
AMINE UNIT
CENTRIFUGAL
(MOTOR DRIVEN)
SYMBOLS
TURBINE FUELS PROJECT
UNIT

HYDROGEN PURIFICATION UNIT

Pressure Swing Absorption plus Recompression

Process Description

In hydroprocessing oil refineries hydrogen of 95 mole percent purity or higher is injected into the reactors. In the reaction methane and other light hydrocarbons are produced as byproducts. These are absorbed into the liquid product and removed from the system. In addition in hydrovisbreaking a bleed of the high pressure hydrogen recycle is required to maintain hydrogen purity (and hydrogen partial pressure) in the recycled gas system.

Recovering hydrogen from the high pressure bleed gas by use of pressure swing absorption is an economic method to reduce the size of the hydrogen production plant. This process developed by Union Carbide has been demonstrated world-wide in over 240 commercial units, and is available royalty-free.

Shown in the attached process flow diagram, it was found desirable to recover hydrogen from the distillate hydrotreater as well as the hydrovisbreaker. These bleed gases are combined at a pressure of 2400 psig and a temperature of 100°F. They must be reduced in pressure from 2400 psig to 800 psig for Pressure Swing Absorption (PSA) processing. A turbo-expander is used to recover valuable energy. Preheating ahead of expansion is required to obtain an expander outlet temperature of 100°F.

Hydrocarbons are absorbed on a molecular sieve in the PSA unit. The high purity hydrogen passes through the PSA, is recompressed and reused in the hydrotreater and hydrovisbreaker units. The PSA system is installed as a 5-vessel unit. While one vessel is absorbing hydrocarbons, four vessels are undergoing staged regeneration. A cycle is arranged so one vessel in a unit is always onstream.

Normal practice is to install two or more 5-vessel units in parallel depending on the capacity required. The cyclic sequence of a 5-vessel unit is:

Vessel Number	Operating Status	Process Description
1	On stream	Absorption of hydrocarbons. Upflow feed.
2	Off line	Depressuring - top vent - venting hydrogen to repressure vessel No. 5, followed by purge hydrogen to vessel No. 4.
3	Off line	Final Depressuring - bottom vent - venting absorbed hydrocarbon gases to tail gas at 0 psig and 110°F.
4	Off line	Purge hydrogen from vessel No. 2 into top of vessel. The purge sweeps hydrocarbon gases out bottom vent to tail gas at 0 psig and 110°F.
5	Off line	High purity, medium pressure hydrogen from vessel No. 2 is injected into the vessel followed by high pressure pure hydrogen. This repressures vessel No. 5, which then goes on stream as vessel No. 1 goes off line.

The cycle continues controlled automatically.

The hydrogen product at 99 mole percent purity is compressed from 800 psig to 2475 psig, cooled to 110°F and returned to the Hydrovisbreaker and Distillate Hydrotreating Unit.

The tail gas is compressed from 0 psig to 165 psig, cooled and routed to the low pressure amine unit for removal of hydrogen sulfide.

HYDROGEN PURIFICATION UNIT

DESIGN BASIS

Purification Process: Polybed Pressure Swing Absorption Unit

	Feed Gas (1)	Hydrogen Product Gas (2)	Fuel Gas (3)
Flow Rate, MMSCFD	96.5	75.0	21.5
Pressure, psig	800	790	2
Temperature, °F	100	110	110
Composition, mol%			
Hydrogen	87.85	99 minimum	49.1
Methane	9.36	1 maximum	38.4
Ethane	1.54	-	6.9
Propylene	0.05	-	0.2
Propane	0.69	-	3.1
Butane	0.29	-	1.3
Pentane	0.18	-	0.8
Water	0.04	-	0.2
Totals	100.00	100	100.0

Notes:

(1) Feed gas enters the area at 2475 psig and 110°F. It is preheated to 300°F then expanded to 800 psig and 100°F.

(2) Hydrogen product gas is compressed from 790 psig to 2470 psig and cooled to 110°F.

(3) Fuel gas is compressed from 0 psig to 165 psig and cooled to 110°F.

HYDROGEN PURIFICATION UNIT

Utility and Chemical Requirements

Steam Used: 150 psig to Feed Gas Preheater 19,200 lb/hr

Instrument Air: 3500 SCFH at 100 psig

Electrical Power:

Power used by hydrogen compressors (Two 4000 BHP motors)	7026 BHP
Power used by fuel gas compressor	3750 BHP
Total power required for compressors	10,776 BHP
Power generated by Turbo-Expander	9,714 BHP
Net power required for compressors	1,062 BHP
Power for instrumentation, lighting, etc.	10 KW

Cooling Water

Supply temperature: 85°F
Return temperature: 105°F

Hydrogen Compressor Inter- and Aftercoolers	1,348 GPM
Fuel Gas Compressor Inter- and Aftercoolers	319 GPM
Total	1,667 GPM

HYDROGEN PURIFICATION UNIT

Major Equipment

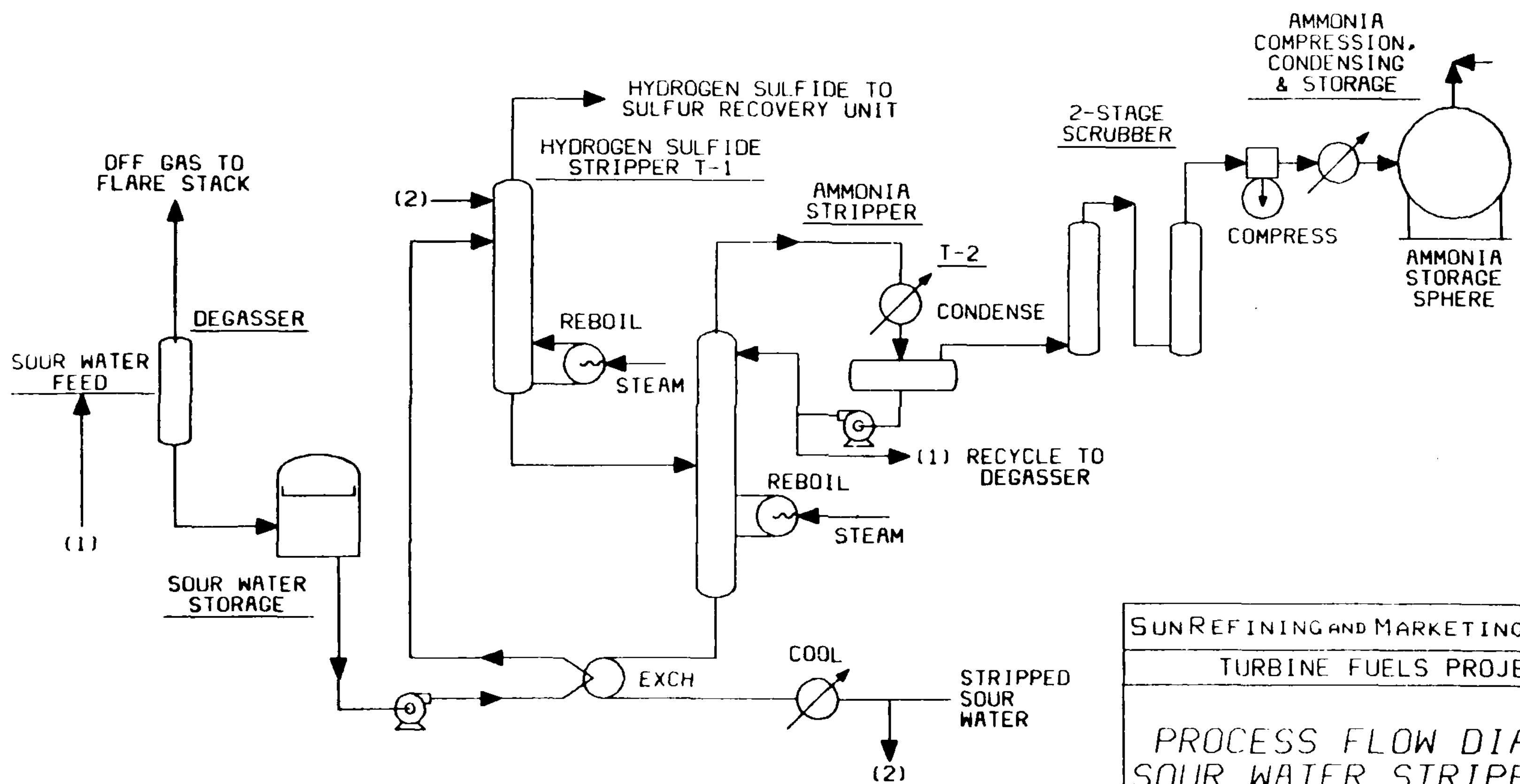
Because a package price for the Polybed Pressure Swing Adsorption Unit was obtained from Union Carbide, it was unnecessary to specify the equipment in detail. However, the turbo-expander feeding the unit and the compressor systems for the hydrogen product and tail gas were specified separately. The Hydrogen and Fuel Gas Compressor systems were priced by Dresser (equipment supplier). Sun estimated the horsepower and price of the Turbo-Expander.

Additionally, Union Carbide advised that the life of the molecular sieves in the pressure swing adsorption unit is sufficiently long that a replacement batch is not required. Their plant price included the cost of the molecular sieves. There is no royalty charge.

PROCESS DESIGN SPECIFICATIONS

for the

SOUR WATER STRIPPER AND AMMONIA PLANT



(1) RECYCLE RESIDUAL H_2S IN NH_3 AND WATER TO DEGASSER
(2) RECYCLE STRIPPED SOUR WATER TO WASH RESIDUAL NH_3 FROM H_2S

SUN REFINING AND MARKETING COMPANY				
TURBINE FUELS PROJECT				
PROCESS FLOW DIAGRAM SOUR WATER STRIPPING & AMMONIA RECOVERY UNIT				
BY	APP'D	DRAWING NO.	REV	SHEET
LGM				
DATE				
4/8/87				

SOUR WATER STRIPPER AND AMMONIA RECOVERY PLANT

PROCESS DESCRIPTION

Approximately 1750 GPM of sour water is recovered from the hydroprocessing units. This is largely wash water used to eliminate condenser and cooler fouling in the reactor recycle loops. Extensive investigations in the petroleum industry show that the ammonium hydrosulfide concentration in water must be held to 2 wt% or less to eliminate equipment fouling. It is estimated that up to 100 short tons/day of ammonia and 143 short tons/day of hydrogen sulfide will be contained in the water.

The ammonia combines with an equal molar volume of hydrogen sulfide in the sour water. The above quantities occur at 49% nitrogen conversion to ammonia in the Hydrovisbreaker which was used as maximum design conversion.

Two stage sour water stripping is required to recover the ammonia separately from the hydrogen sulfide. Typically, caustic is added and the ammonia is steam stripped off. The alkaline water is then neutralized with acid and the hydrogen sulfide is steam stripped off. The resulting stripped sour water contains appreciable salts and is a disposal problem.

Two-stage stripping, separating ammonia from hydrogen sulfide is highly desirable for proper operation of the sulfur recovery unit. Also the ammonia has a worthwhile product value.

Chevron Research Company has developed a licensed process (WWT Process) which does not require the addition of caustic and acid to separately recover the ammonia and hydrogen sulfide by steam stripping. This permits re-using the stripped water for hydroprocessing injection, crude unit desalting water, and other process uses. A drag stream must be routed to disposal via waste water treating to oxidize the phenols and a small residual ammonia and hydrogen sulfide content.

The WWT Process is included in this plant since it reduces water usage and water disposal. The process consists of four main process steps:

1. Degassing and feed storage
2. Acid gas (H_2S) steam stripping
3. Ammonia steam stripping
4. Ammonia purification and liquefaction

The sour water feed to the plant is combined with a recycle stream from the ammonia stripper, cooled and fed to a degasser where dissolved hydrogen, methane, and other light hydrocarbons are removed. The recycle stream is rich in ammonia, which helps keep acid gases in solution in the degasser. Thus, the release of acid gas and possible air pollution are minimized. The degassed sour water is pumped to an off-plot storage tank which serves to dampen flow rate and composition changes. It also provides the opportunity to remove entrained oil and solids.

From the feed tank the degassed sour water feed is pumped to the WWT unit, where it is heated by feed-bottoms exchange and fed to the acid gas or hydrogen sulfide stripper. This stripper is a steam-reboiled distillation column. The hydrogen sulfide, which is stripped overhead, is of high purity - an excellent feed for a sulfur or sulfuric acid plant. It contains negligible ammonia, less than 50 ppm, and very little hydrocarbon since the plant feed has been degassed. However, it does contain any carbon dioxide that is present in the feed. The hydrogen sulfide is available at about 20 psig and 100°F and will be saturated with water vapor.

The hydrogen sulfide stripper bottoms, containing all the ammonia in the feed and some hydrogen sulfide, is fed directly to the ammonia stripper, which is a steam-reboiled refluxed distillation column. In this column, essentially all the ammonia and hydrogen sulfide are removed from the water, which leaves as the column bottoms stream. After exchanging heat with the hydrogen sulfide stripper feed, this stripped waster is cooled and sent off-plot for reuse or

treating. The stripped water contains less than 50 ppm of free ammonia and less than 10 ppm of free hydrogen sulfide. The stripped water will also contain traces of phenols and salts which entered with the feed. If the feed contains acidic compounds that "fix" ammonia, the fixed ammonia can be released and then stripped off.

The ammonia and hydrogen sulfide stripped from the water in the ammonia stripper are passed through an overhead condenser and are partially condensed. The liquid is used as column reflux, with a portion being recycled to the degasser and off-plot feed tank.

For production of anhydrous ammonia, the gas is passed through a two-stage scrubbing system to remove hydrogen sulfide and is then liquified to produce the anhydrous ammonia. The hydrogen sulfide content of the ammonia is typically less than 5 ppm.

The ammonia is compressed to 225 psia and condensed with cooling water. The ammonia product liquid is stored in a 42 foot diameter sphere which will hold 700 short tons (7 days of production).

SOUR WATER STRIPPER AND AMMONIA PLANT
DESIGN BASIS

Feed: Maximum design

1750 GPM Sour Water at 100°F and 130 psig containing:

Ammonia	100.4 Short tons/stream day
Hydrogen sulfide	142.6 Short tons/stream day

Trace amounts of phenols, chloride, and salts

A pH of 8.5 to 9.0 is expected due to an excess of ammonia.

Hydrogen Sulfide Product

Hydrogen sulfide vapor containing 100 wt ppm ammonia, saturated with water vapor. The product is available at 20 psig and 100°F. This is feed to the Sulfur Recovery Unit.

Ammonia Product

Liquid ammonia (anhydrous) containing 5 wt ppm hydrogen sulfide and
0.4 wt ppm of water.

Stripped Water

The water will contain 50 wt ppm of ammonia (maximum) and 10 wt ppm of hydrogen sulfide (maximum). Small amounts of phenols, chlorides, and salts will be present.

SOUR WATER STRIPPER AND AMMONIA PLANT
UTILITY AND CHEMICAL REQUIREMENTS

Utilities

150 psig Steam used:	90,000 lb/hr
50 psig Steam used:	118,000 lb/hr
Steam condensate recovered:	208,000 lb/hr
Cold condensate used:	26,000 lb/hr
Electrical power used (440 and 220 Volt)	980 KW
Cooling water circulated	1,720 GPM
Supplied at 85°F	
Returned at 100°F	

Chemicals and catalyst None

SOUR WATER STRIPPER AND AMMONIA PLANT
MAJOR EQUIPMENT

Because this is a licensed process, a detailed design and equipment list were not developed. These would be supplied by Chevron Research when needed.

Royalty cost basis

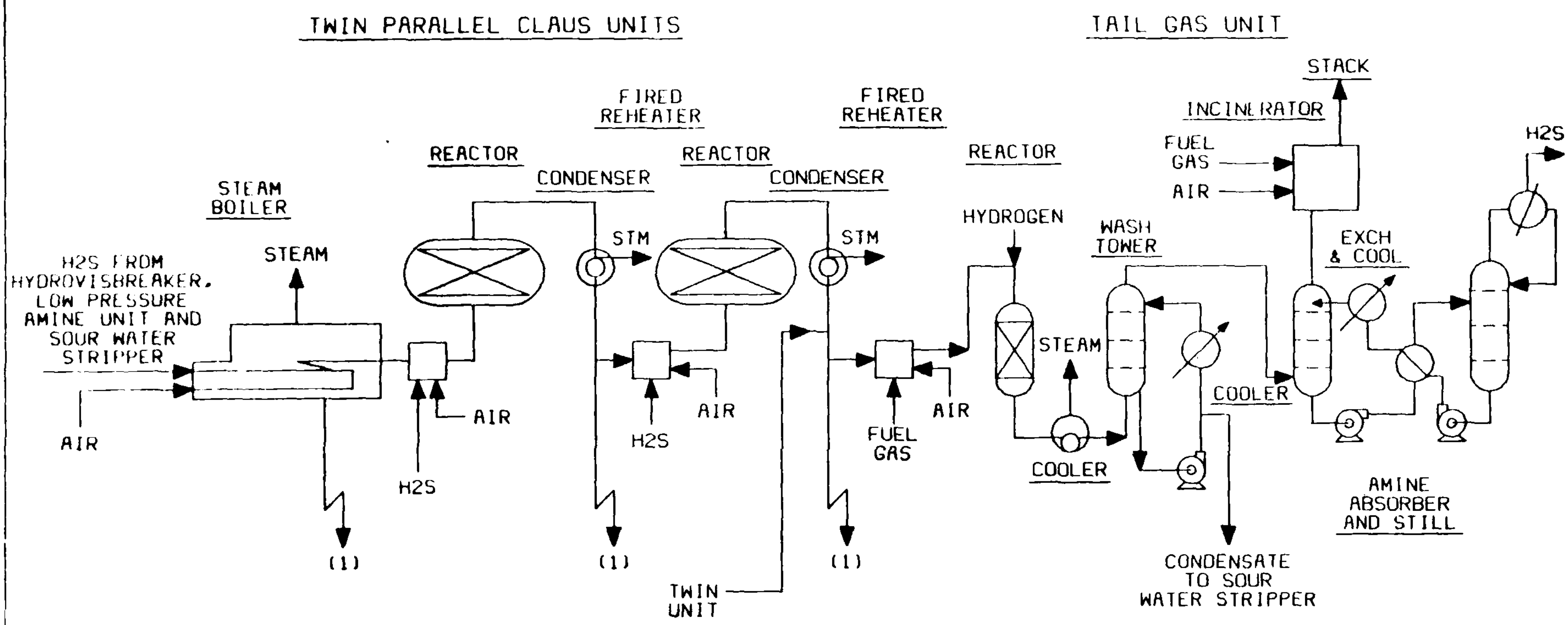
Fixed royalty - $400,000 paid over 2 years

Running royalty - 87,500 per year (This would vary slightly with actual H_2S and ammonia recovery.)

PROCESS DESIGN SPECIFICATIONS

for the

SULFUR RECOVERY UNIT



(1) MOLTEN SULFUR DRAINS TO PIT

SUN REFINING AND MARKETING COMPANY				
TURBINE FUELS PROJECT				
PROCESS FLOW DIAGRAM SULFUR RECOVERY UNIT				
BY	APP'D	DRAWING NO.	REV	SHEET
LCM				
DATE				
4/7/87				

SULFUR RECOVERY UNIT

including a
Claus Unit and Tail Gas Unit

Process Description

The Claus process is the most widely used method to recover sulfur from hydrogen sulfide (H_2S). Conversion is achieved by combustion of one-third of the hydrogen sulfide to sulfur dioxide (SO_2). Since the reaction is exothermic, it is carried out in a waste heat steam generator using air for combustion. The H_2S and SO_2 then react over a catalyst to form sulfur and water vapor. Since the conversion is incomplete the gases are cooled, the sulfur is condensed out, and the reheated gases are fed to a second stage reactor. The gases are again cooled indirectly by low pressure steam generation, and the sulfur is condensed out. The Claus reaction takes place at about 220°C (428°F) and 3 to 8 psig. Alumina or bauxite is the normal catalyst for both reactors.

Since some hydrocarbon carryover and other problems with sulfur plants tend to plug the catalyst, it is normal practice to install two 100% capacity units to ensure 100% onstream time.

The twin units are followed by a single tail gas unit to ensure about 99.8% total hydrogen sulfide removal. The tail gas unit reheats the tail gas and introduces hydrogen as a reducing gas to convert all the sulfur compounds in the tail gas to hydrogen sulfide. The tail gas is then cooled, and the hydrogen sulfide is scrubbed out with amine. The amine is recycled to a still to strip out and recover the hydrogen sulfide. The conversion of sulfur compounds plus hydrogen to hydrogen sulfide takes place in a reactor containing a cobalt/molybdenum catalyst at about 300°C (572°F) and essentially atmospheric pressure.

The off-gas remaining after the tail gas has been scrubbed by amine is routed to a direct fired incinerator to combust any residual hydrogen sulfide or hydrocarbon gases.

These incinerated gases are then dispersed from a stack. The percentage sulfur removal from the tail gas can be maintained at 99.8% of the H_2S in. However, good instrumental control and maintenance of the unit is necessary.

SULFUR RECOVERY UNIT

Design Basis

Feed:	Sulfur Equivalent
Hydrogen sulfide from amine units	87.9 short tons/day
Hydrogen sulfide from sour water stripper	77.3 short tons/day
Total	165.2 short tons/day

The unit must be designed for a major amount of the hydrogen sulfide (about 86%) coming from the Sour Water Stripper when the Hydrovisbreaker operates at maximum nitrogen conversion. This is because the resulting ammonia in the Hydrovisbreaker wash water will absorb most of the hydrogen sulfide. At that time the Hydrovisbreaker amine unit duty will be light.

Product: Molten Sulfur 165 short tons/day = 330,000 lb/day

Two parallel Claus sulfur plants each designed for 165 short tons/day of sulfur production followed by one BSR/MDEA or Scott Tail Gas Unit plus an incinerator and stack.

SULFUR RECOVERY UNIT

Utilities and Chemical Requirement

Utilities Produced

Excess 600 psig Steam at 600°F	8,400 lb/hr
Excess 50 psig Steam	28,900 lb/hr
Excess condensate produced	37,300 lb/hr

Utilities Required

Electrical power	192 KW
Cooling water circulation	3,390 GPM
Treated boiler feed water	45,841 lb/hr
Natural gas	21.4 MMBTU/hr

Catalyst and chemical cost — $32,430 per year

Includes: alumina Claus catalyst
Co-Mo tail gas catalyst
and alkanolamine

SULFUR RECOVERY UNIT

Major Equipment

A packaged price was obtained for both the Claus units and the tail gas unit from Ralph M. Parsons Company, a builder of many sulfur plants. Consequently it was unnecessary to develop a detailed process design or major equipment list.

There is no royalty on the Claus units, but there is a royalty on the tail gas unit. The royalty on the BSR/MDEA tail gas unit would be:

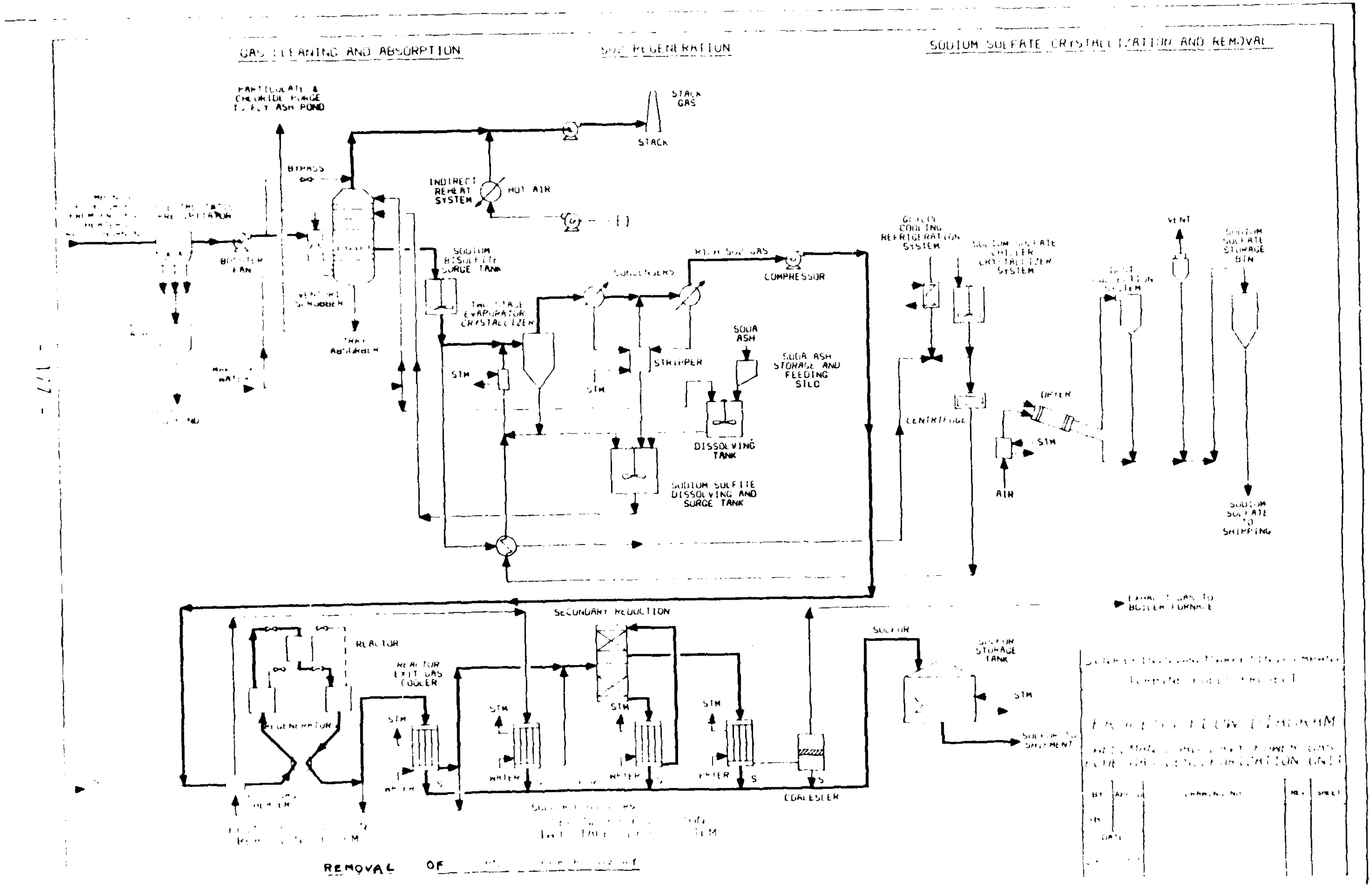
Tail Gas Unit Royalty, Ralph M. Parsons Co.
for 165 tons/day sulfur production:

$172,000 distributed as:	25% upon signing the license
	25% upon start of construction
	25% upon mechanical construction
	25% after performance guarantee is met

PROCESS DESIGN SPECIFICATIONS

for the

FLUE GAS DESULFURIZATION UNIT


GAS CLEANING AND ABSORPTION
SO2 REGENERATION
SODIUM SULFATE CRYSTALLIZATION AND REMOVAL
PARTICULATE & CHLORIDE PURGE TO FLY ASH POND
STACK GAS
STACK
BYPASS
INDIRECT REHEAT SYSTEM
HOT AIR
BOOSTER FAN
VENTURI SCRUBBER
TRAY ABSORBER
SODIUM BISULFITE SURGE TANK
TWO STAGE EVAPORATOR CRYSTALLIZER
CONDENSERS
RICH SO2 GAS
COMPRESSOR
STRIPPER
STM
SODA ASH
SODA ASH STORAGE AND FEEDING SILO
DISSOLVING TANK
SODIUM SULFITE DISSOLVING AND SURGE TANK
GLYCOL COOLING REFRIGERATION SYSTEM
SODIUM SULFATE CHILLER CRYSTALLIZER SYSTEM
CENTRIFUGE
DRYER
AIR
VENT
SODIUM SULFATE STORAGE BIN
SODIUM SULFATE TO SHIPPING
EXHAUST GAS TO BOILER FURNACE
SECONDARY REDUCTION
REACTOR
REACTOR EXIT GAS COOLER
REGENERATOR
WATER
COALESCER
SULFUR
SULFUR STORAGE TANK
SULFUR TO SHIPMENT
FLOW DIAGRAM
DRAWING NO.
REMOVAL OF

Flue Gas Desulfurization Unit

Process Description

The vacuum residuum produced from hydrovisbreaking will contain 1.34 weight percent sulfur based on the pilot plant data. There will be 4839 BPSD of this residuum produced. At maximum firing rate on the feed heaters and the boiler, 3862 BPSD of this residuum will be used as fuel. This will be send an excessive amount of sulfur dioxide to the atmosphere (19.7 tons per day), unless stack gas scrubbing is installed. This fuel will also contain 612 lb/hr of molybdenum sulfide (MoS) derived from the Hydrovisbreaker coke-suppressing additive, which will become fly ash after fuel combustion. This must be removed by an electrostatic precipitator (ESP) ahead of the stack gas scrubber.

Ths Wellman-Lord stack gas scrubbing process was selected since this process has more proven commercial operation than any other regenerative process. Since it is a regenerative process it recovers sulfur and eliminates a large spent treating agent disposal problem which non-regenerative processes have. Also the make-up treating agent (soda ash) is a common low cost chemical.

Information from the Stanford Research Institute was used to develop the following information. A detailed design was not developed for the San Ardo crude stack gas scrubber.

A process flow diagram of the Wellman-Lord sulfite scrubbing process for removing SO_2 from flue gases is attached. The scrubbing liquor is regenerated for recycling and the liberated rich SO_2 gas stream is reduced to sulfur by methane using a proprietary process of Allied Chemical Corporation.

The flue gas enters the system at 450°F and is cooled to 200°F by exchanging heat with the effluent flue gas. The flue gas enters the

electrostatic precipitator where 99.5 to 99.8 wt% of the fly ash is removed and then proceeds through a booster fan to the scrubber system. The gas enters a venturi prescrubber at 200°F where the gas is humidified and cooled to about 130-135°F with a recirculating aqueous stream which also removes 95 to 99% of the SO_3 and chlorides in the flue gas as hydrochloric and sulfuric acids. Any remaining particulate in the gas is substantially removed in this step. The removal of chlorides in this step keeps chlorides in the subsequent sulfite scrubbing at a very low level, thus reducing the potential occurrence of stress corrosion. Make-up process water is added at this point to the bottom of the absorber to replace water lost by vaporization in humidifying and cooling the gas and water removed in the purge stream from the venturi scrubber. This aqueous purge stream containing solids and acids collected by the venturi scrubber are pumped to an ash disposal pond where an alkaline reaction with the ash neutralizes the acidic constituents. The stream may alternately be neutralized with an excess of slaked lime slurry if necessary before disposal in the ash pond. The saturation of the flue gas in the venturi prescrubber system prevents the evaporation of any significant amounts of waster in the SO_2 scrubber itself.

The flue gas enters the bottom of the absorber almost saturated with water, and then passes through a chevron type demister to catch carryover of any entrained recycle wash solution into the main body of the absorber. The cooled humidified flue gas enters the scrubber through chimney type distributors where it flows upwasrd through three valve trays. The lean sodium sulfite solution enters at the top of the scrubber and flows downward counter-currently to the rising flue gas from tray to tray, removing over 90% of the SO_2 and forming sodium bisulfite in the liquor. The sodium sulfite solution has the capacity to absorb SO_2 up to about 60 g/liter. The superficial gas velocity through the absorber is about 10 fps. Rich scrubber solution is collected on the bottom tray and flows to a surge tank of a capacity to allow the regenerator circuit to be shut down for up to 24 hours without halting scrubber operation.

Oxidation of the sodium sulfite in the scrubber solution occurs by reaction with the oxygen in the flue gas and inactive sodium sulfate is formed. About 8 to 10% of the sulfur absorbed from the flue gas is converted to Na_2SO_4 by typical levels of excess oxygen in the flue gas. To keep this level of unreactive salt from building up to undesirable levels and causing crystallization in the scrubber, a purge of about 15% of the rich scrubber liquor is withdrawn from treatment to separate Na_2SO_4 from the system and return the active solution to the scrubber. The warm purge stream is first cooled by exchange with cold returning scrubber solution and then cooled further to about 30-32°F in a chiller-crystallizer. A mixture of sodium sulfate and sodium sulfite crystallizes out which is separated from the liquor in a centrifuge at about 40% solids. With controlled crystallization, Na_2SO_4 precipitates in a much greater proportion than the other sodium compounds. The solids are dried in a rotary drum with indirectly steam-heated air. The product is a crystalline mixture of Na_2SO_4 (70%) and Na_2SO_3 (30%) with very small amounts of thiosulfates, pyrosulfites and chlorides. This solid can be disposed of by sale as a salt cake mixture to a kraft paper mill. An ethylene glycol refrigeration system is used for cooling in the crystallization system.

The SO_2 regeneration system consists of a double effect, forced circulation evaporator-crystallizer, with low pressure exhaust steam as the source of heat. Other equipment includes condensers, a condensate stripper and a sodium sulfite dissolving tank. Sodium sulfite is regenerated from sodium bisulfite plus the evolution of SO_2 by reversing the absorption reaction by the addition of heat.

The rich scrubber liquor combined with the liquor from the Na_2SO_4 centrifuges is split between the two evaporator effects, about 55% to effect I and about 45% to effect II. The liquor in the first effect is heated with exhaust steam in an external recirculation heat exchanger and operates at about 200°F under a small vacuum. The vapor from the first effect is used to similarly heat the second effect which operates at about 170°F and a higher vacuum. Water vapor and SO_2 exit overhead from each evaporator effect and are

partially condensed to remove most of the water and concentrate the SO_2. Also, in each effect primarily sodium sulfite crystallizes out to a 45% solids concentration in the recirculating liquor as a slurry. A bleed stream of this slurry is withdrawn to a dissolving tank where the Na_2SO_3 is dissolved with recycled condensate from the evaporator condensers. The regeneration reaction in the evaporators is limited by the equilibrium concentration of sulfite ion in solution. Since Na_2SO_3 is less soluble than $NaHSO_3$, the crystallization of sulfite continuously removes it from the equilibrium allowing the regeneration reaction to proceed to substantial completion. Several hundred ppm of dissolved SO_2 is present in the condensate and this is stripped with steam to drive the SO_2 overhead. The Na_2SO_3 slurry is dissolved in a dump tank with stripped condensate and water in a sodium carbonate solution added as sodium makeup to the system to replace that lost in the solid Na_2SO_4 purge. The resulting solution is recycled to the scrubber as lean absorbent medium. The resulting SO_2 exiting the regeneration system contains about 5 to 10% water and is compressed and transferred to the SO_2 reduction section.

Reducing gas (natural gas) is added in a correct proportion to the rich gas stream, and this gas mixture is then passed through a feed gas heater where its temperature is raised above the dew point of the sulfur formed in the primary reduction system. The principle function of the catalytic reduction reaction is to form over 40% of the total recovered sulfur plus an amount of H_2S to attain an H_2S/SO_2 ratio in the gas stream to approximate the stoichiometric ratio of 2:1 required for the Claus reaction.

The preheated SO_2 and natural gas mixture enters the primary reduction reactor through a four-way flow reversing valve and is further preheated as it flows upward through a packed bed heat regenerator prior to entering the catalytic reactor A bypass arrangement may be included in the design to keep a constant temperature on the gases entering the reactor by continuously bypassing a small quantity of cool gas mixture around the up-flow heat regenerator The heat of reaction in this step is exothermic and is balanced throughout the system A proprietary catalyst, developed by Allied Chemical,

AD-A190 120 TURBINE FUELS FROM TAR SANDS BITUMEN AND HEAVY OIL 3/3
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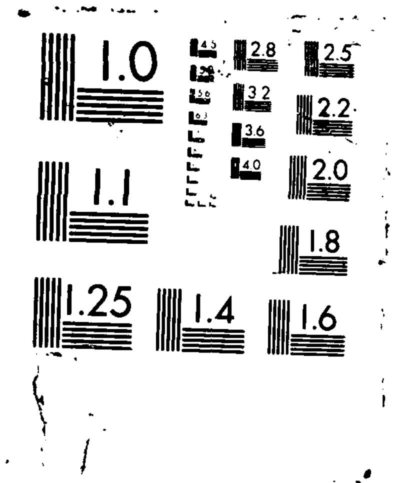
UNCLASSIFIED SEP 87 AFWAL-TR-87-2043-VOL-2 F/G 21/4 NL


1.0
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remains stable at temperatures up to 2000°F and operates generally at a temperature above 1500°F. The main gas flow passes downward through a second heat regenerator yielding its heat to the packing before leaving the system through the four-way reversing valve. A heat balance can be maintained in the system by bypassing a small flow of the reactor hot gases around the heat regenerator and remixing with the main stream after the four-way valve before entering the gas cooler/sulfur condenser. The heat regenerators raise the temperature of the incoming gases so that the SO_2/natural gas reaction is initiated. The heating and cooling cycles of the two regenerators are periodically reversed by use of the four-way valve.

A portion of the reactor heat is used to heat the entering SO_2/natural gas mixture in an exchanger. The exit gases from the reactor may be too hot and too corrosive for the metal exchanger, so they are tempered by mixing with a portion of gases exiting the gas cooler/sulfur condenser before introduction into the feed gas heat exchanger.

Elemental sulfur formed in the primary reduction step is condensed in two shell-and-tube steam generating condensers. At this stage the condensed sulfur represents somewhat over 40% of the total sulfur recovered. The combined gas stream from the two condensers enters the first stasge of a Claus conversion system where more sulfur is formed. The gases emerge at about 750-800°F. The gas is cooled in a steam generating condenser condensing more sulfur. Further conversion of H_2S and SO_2 to sulfur and water occurs in the second stage Claus reactor at about 550-600°F with the sulfur condensed again in another steam generator. The remaining gases proceed to a coalescer containing mesh screens which remove liquid sulfur entrained in the gas. Molten sulfur from all the condensers is collected in a sulfur holding pit and transferred to sulfur storage at the Sulfur Recovery Unit.

Residual H_2S in the exiting gases from the system are exhausted to the boiler firebox where oxidation to SO_2 occurs which recycles through the stack gas scrubber.

The desulfurized flue gas leaving the absorber is demisted of entrained droplets by a water wash across a chevron demister and then reheated in the heat exchanger. The reheated flue gas exits the stack at 380°F, which eliminates any water vapor plume.

FLUE GAS DESULFURIZATION UNIT

Design Basis

The flue gas is derived from the firing of residual fuel with 1.34 wt% sulfur content, fired at a maximum rate of 3862 BPSD with 30% excess air.

Maximum flue gas to electrostatic precipitator:	1,089,882 lb/hr @ 450°F
Fly ash removed in electrostatic precipitator:	612 lb/hr
Flue gas to absorber containing 1500 ppm SO_2:	1,089,270 lb/hr
Flue gas from absorber containing 150 ppm SO_2:	1,087,796 lb/hr
Sulfur recovered:	8.1 tons/day

FLUE GAS DESULFURIZATION UNIT

Utilities and Chemicals

450 psig Steam Used	10,000 lb/hr	(1)
Total power required	2,200 KW	(2)
Natural Gas	128,200 SCFD	
Makeup process water	100 GPM	(3)
Cooling water circulated	2,400 GPM	
Soda Ash makeup	221 lb/hr	
Purge sodium sulfate/sodium sulfite (for sale)	285 lb/hr	

Notes: (1) Approximate, when the flue gas heat exchanger is used

(2) Approximate from SRI data

(3) Includes 3% makeup of cooling water circulated

FLUE GAS DESULFURIZATION UNIT

Major Equipment

Stanford Research Institute (SRI) information was used to develop capital and operating requirements. No detailed design was obtained since the design would be done by an engineering company (Davy Powergas) that sells the process and design.

Some adjustments were necessary to scale the SRI case to our unit size. Also their case was based on 300°F flue gas from a power boiler with extensive flue gas economizer heat exchange. Our entering flue gas temperature is 450°F which made a gas-to-gas heat exchanger necessary. This cools the inlet gas to 200°F and reheats the exit flue gas to 380°F. Reheating of scrubbed flue gas is necessary to prevent condensation of a stack plume near the ground. The heat exchange eliminates hot air injection into the stack proposed by SRI.

PROCESS DESIGN SPECIFICATIONS

for

TANKAGE

TANKAGE DESIGN BASIS

All tankage specifications were based on refinery flow rates that were calculated for the production of JP-4 turbine fuel. The economic basis established by the U.S. Air Force included the following inventory specifications:

Crude inventory:	21 days storage capacity
	14 days inventory
Product inventory:	14 days storage capacity
	7 days inventory

INTERMEDIATE PRODUCTS

Although separate tankage for intermediate refinery products was excluded purposely from the design basis at the direction of the U.S. Air Force, a plan was developed for their potential emergency storage. The plan designates part of the crude oil tank allotment as alternate emergency storage for intermediate products. Each intermediate stream that needs storage capacity is assigned to a tank, which is available for optional crude storage also. Since the design basis allowed for 21 days of crude storage capacity, but only required an inventory of 14 days, the extra seven days of inventory capacity could easily be put into this alternate service, especially if the refinery were supplied by pipeline.

The basis for sizing the intermediate tankage is a capacity of 3.5 days at half the normal flow rate.

Intermediate tankage is provided for the stabilized liquid feedstocks for each of the hydroprocessing units in the event of a downstream unit shutdown. This includes the feedstock for the Hydrovisbreaker, Naphtha Hydrotreater, Distillate Hydrotreater, and the combined Distillate Hydrocracker and Main Fractionator.

The basis for sizing intermediate tankage assumes that in the event of an emergency shutdown at one of the units, the production rate at upstream units would be cut in half. Consequently, the stabilized feedstock to the affected unit would be stored at half its normal production rate for up to 3.5 days.

JP-4 VERSUS JP-8 OPERATIONS

Because refinery operations upstream of the Distillate Hydrocracker and Main Fractionator are identical for both the JP-4 and JP-8 operations, the crude and intermediate tankage requirements are the same for both modes of operation.

However, in switching from JP-4 to JP-8 operations, the rate of naphtha production will increase. During JP-4 production the Dehexanizer bottoms, which boils nominally in the range of 120°-275°F, is added to the JP-4 product. But this material boils below the acceptable range for JP-8 turbine fuel, so during JP-8 production, the Dehexanizer is shutdown and the 120°-275°F distillate is routed to naphtha storage. Consequently, the naphtha storage tanks are specified to satisfy storage requirements for the JP-8 operations.

HYDROVISBREAKER VACUUM RESIDUUM

The pilot plant sample of Hydrovisbreaker vacuum tower bottoms, which represents the refinery Residuum product, did not blend with normal cutter stocks to a lower viscosity because it was of such a high-boiling nature. Therefore it is stored at 400-450°F to maintain it in a fluid state for use principally as furnace fuel oil for the process heaters and refinery boiler furnace.

BUTANE STORAGE

Since all butane is consumed as either feedstock for the Hydrogen Plant or as fuel for the Hydrogen Plant reformer furnace, the product storage capacity was somewhat arbitrarily reduced from 14 days to 3.5 days.

TANKAGE SPECIFICATIONS

Crude Oil Tankage

Number of tanks:	5
Operating temperature:	150°F
Diameter:	142 ft.
Height:	56 ft.
Volume:	157,956 BBL per tank (789,779 BBL total)
Roof:	Covered floater
Other features:	Heated and insulated
Crude oil storage capacity:	15.29 days at 51653 BPD at 150°F

Intermediate Hot Tankage

In addition to the stream designations listed below, these "hot" intermediate storage tanks are to be considered as optional storage capacity for Crude Oil.

Tank designations:

1. Hydrovisbreaker feed (crude unit vacuum residuum)
2. Distillate Hydrotreater feed
3. Distillate Hydrotreater Depropanizer bottoms (Dist. Hydrocracker Feed)

Number of tanks:	3
Operating temperature:	200°F (or 150°F if crude oil storage)
Operating pressure:	atmospheric
Diameter:	100 ft.
Height:	56 ft.
Volume (per tank):	439,823 cu.ft. = 78,336 BBL
Volume total (3 tanks):	1,319,469 cu.ft. = 235,008 BBL
Roof:	Covered floater
Other features:	Heated and insulated
Crude oil capacity:	(at 51653 BPD crude at 150°F)
	1 tank: 1.52 days
	3 tanks: 4.55 days

TANKAGE SPECIFICATIONS
(continued)

Intermediate Cold Tankage

In addition to the stream designations listed below, these "cold" intermediate storage tanks are to be considered as optional storage capacity for Crude Oil.

Tank designations:

1. Naphtha Hydrotreater Feed
2. Naphtha Hydrotreater Stripper Bottoms

Number of tanks:	2
Operating temperature:	100°F (or 150°F if crude oil storage)
Operating pressure:	atmospheric
Diameter:	82 ft.
Height:	32 ft.
Volume (per tank):	168,993 cu.ft. = 30,099 BBL
Volume total (2 tanks):	337,986 cu.ft. = 60,198 BBL
Roof:	Covered floater
Other features:	Heated and insulated for optional crude use
Crude oil capacity:	(at 51653 BPD crude at 150°F) 0.58 days for 1 tank 1.16 days for 2 tanks

Note on Intermediate tank sizing:

Each tank exceeds the minimum storage requirement for the intermediate products listed above, which consisted of 3.5 days storage at half-flow rate of intermediate product. The tanks were sized larger to satisfy the overall crude oil storage capacity of 21-days.

Summary of Crude Oil Storage Capacity

Basis: Crude oil at 51653 BPD at 150°F storage (50,000 Std. BPD)

Tankage	Capacity
Crude oil tanks (5):	789,779 BBL (15.29 days crude)
Hot intermediate tanks (3):	235,008 BBL (4.55 days crude)
Cold intermediate tanks (2):	60,198 BBL (1.16 days crude)

Total crude tankage: 1,084,985 BBL (21.00 days crude)

TANKAGE SPECIFICATIONS
(continued)

Product Tankage

Butane Product sphere

Number of spheres:	1
Operating pressure:	50 psig
Operating temperature:	100°F
Design pressure:	75 psig
Design temperature:	650°F (carbon steel)
Diameter:	65 ft.
Volume:	143,793 cu.ft. = 25,611 BBL
Shell thickness:	1.250 in. (includes 0.182" corrosion allowance)
Sphere weight:	678,610 lb.

Note that all butane product will be consumed consumed as either hydrogen plant feedstock or hydrogen plant fuel.

Naphtha Product tankage

Number of tanks:	1
Operating temperature:	100°F
Operating pressure:	atmospheric
Diameter:	114 ft.
Height:	56 ft.
Volume (per tank):	571,594 cu.ft. = 101,805 BBL
Roof:	Covered floater

Jet Fuel Product tankage

Number of tanks:	4
Operating temperature:	100°F
Operating pressure:	atmospheric
Diameter:	143 ft.
Height:	56 ft.
Volume (per tank):	899,394 cu.ft. = 160,188 BBL
Roof:	Covered floater

Residuum Product tankage

Number of tanks:	1
Operating temperature:	450°F
Operating pressure:	atmospheric
Diameter:	81 ft.
Height:	32 ft.
Volume:	164,896 cu.ft. = 29,369 BBL
Roof:	Cone roof
Other features:	Heated and insulated

TANKAGE SPECIFICATIONS
(continued)

Sulfur Product storage (14 days total storage capacity)

Sulfur pit:

Location:	Below grade, under the sulfur recovery unit
Rectangular dimensions:	20'long x 20'wide x 8'deep
Storage capacity:	3200 cu.ft. = 570 BBL
Construction material:	Either concrete or steel, lined with common brick in acid-proof cement
Pit cover:	Carbon steel plate
Operating temperature:	260 - 280°F
Pit heating:	75 psig steam coils

Sulfur Product tankage:

Number of tanks:	1
Operating temperature:	260 - 280°F
Operating pressure:	atmospheric
Tank diameter:	57 ft.
Tank height:	16 ft.
Head of sulfur at base:	12.4 psi max.
Volume:	40828 cu.ft. = 7272 BBL
Roof:	Cone roof
Tank heating:	75 psig steam coils (25 sq.ft. heating surface per sq.ft. of tank wall and roof)
Other:	Insulate entire outer shell and roof

Ammonia product storage sphere

Number of vessels:	1
Type vessel:	Sphere
Operating temperature:	100°F
Operating pressure:	200 - 210 psig
Design temperature:	650°F (carbon steel)
Design pressure:	225 psig
Diameter:	42 ft.
Volume:	39,000 cu.ft.
Shell thickness:	2.25 in.
Total weight:	510,000 lb.
Storage capacity:	7 days of ammonia production

APPENDIX

CAPITAL COST ESTIMATE

TURBINE FUEL REFINERY
CAPITAL COST ESTIMATE
BASIS

The accompanying capital cost estimate for the Turbine Fuel Refinery is based upon the following:

1. The location of the refinery is Salt Lake City, Utah.

2. Mechanical completion occurs during the fourth quarter of 1985.

3. Estimates for the following onsite plants are based on specified equipment lists and flow diagrams:

   a. Crude Unit
   b. Hydrovisbreaker
   c. Naphtha Hydrotreater
   d. Distillate Hydrotreater
   e. Distillate Hydrocracker
   f. Gas Plant
   g. Low Pressure Amine Unit

4. Estimates for the following onsites plants were factored from historical plant costs, with the exception of specified compressor systems for the Hydrogen Plant and Hydrogen Purification Unit:

   a. Hydrogen Plant
   b. Hydrogen Purification Unit
   c. Sour Water Stripper and Ammonia Plant
   d. Sulfur Recovery Unit
   e. Flue Gas Desulfurization Unit

5. Tankage estimates were based on specified tank sizes.

6. The cost of off-sites excluding tankage was assumed to be 45% of the total installed on-site cost estimate.

7. All work is to be accomplished in a standard work week with no overtime.

8. This estimate is for economic evaluation and comparison only.

9. Capitalized spare parts are included as one percent of major equipment cost.

10. In general, royalties, catalysts and chemicals are not included in this estimate. However, the initial loading of molecular sieves for the Hydrogen Purification Unit are included in the cost.

11. Offsites have been estimated as 45% of the total onsite installed costs at the request of the U.S. Air Force.

TURBINE FUEL REFINERY
CAPITAL COST SUMMARY

ONSITES	Installed Cost [1]
Crude Unit	$ 19,968,000
Hydrovisbreaker Unit	168,119,000
Naphtha Hydrotreater Unit	24,154,000
Distillate Hydrotreater Unit	140,183,000
Distillate Hydrocracker Unit	94,724,000
Gas Plant	9,380,000
Hydrogen Plant	99,075,000
Hydrogen Purification Unit	60,915,000
Low Pressure Amine Unit	3,079,000
Sour Water Stripper and Ammonia Plant	33,091,000
Sulfur Recovery Unit	37,119,000
Flue Gas Desulfurization Unit	54,328,000
Total Onsites	$ 744,135,000

OFFSITES	
Tankage	$ 45,061,000
Other: Specified by U.S. Air Force as 45% of onsite costs	334,861,000
SPARE PARTS	1,498,000
ROUND UP TO NEAREST MILLION DOLLARS	445,000

TOTAL REFINERY INSTALLED COST	$ 1,126,000,000

[1] Based on 4th Quarter 1985 prices, Salt Lake City, Utah location

Factored Estimate Worksheet Summary

	Crude Unit	Naphtha Hydrotreater	Hydrovisbreaker	Distillate Hydrotreater	Distillate Hydrocracker	Gas Plant
Total Major Equipment	$11,833,400	$14,427,600	$100,607,500	$84,576,800	$56,649,100	$5,684,100
Instruments	2,058,000	2,375,200	16,344,400	12,941,600	9,245,600	840,400
Insulation	-	-	-	-	-	-
Rounding	(400)	200	100	(400)	300	500
Total Direct Installed Cost	13,890,000	16,803,000	116,952,000	97,518,000	65,895,000	6,525,000
Home Office Costs	2,084,000	2,520,000	17,543,000	14,628,000	9,884,000	979,000
Subtotal	15,974,000	19,323,000	134,495,000	112,146,000	75,779,000	7,504,000
Contingency	3,994,000	4,831,000	33,624,000	28,037,000	18,945,000	1,876,000
Total Installed Costs	19,968,000	24,154,000	168,119,000	140,183,000	94,724,000	9,380,000

	Hydrogen Plant	Hydrogen Purification Plant	Stack Gas Scrubbing and Collecting Unit	Low Pressure Amine Unit	Sour Water Stripper and Ammonia Plant	Sulfur Recovery Unit
Total Major Equipment	$52,705,000	$32,685,900	$31,276,800	$1,864,000	$18,993,500	$22,132,800
Instruments	16,216,800	9,689,600	6,516,000	278,400	4,026,800	3,688,800
Insulation	-	-	-	-	-	-
Rounding	200	500	200	(400)	(300)	400
Total Direct Installed Cost	68,922,000	42,376,000	37,793,000	2,142,000	23,020,000	25,822,000
Home Office Costs	10,338,000	6,356,000	5,669,000	321,000	3,453,000	3,873,000
Subtotal	79,260,000	48,732,000	43,462,000	2,463,000	26,473,000	29,695,000
Contingency	19,815,000	12,183,000	10,866,000	616,000	6,618,000	7,424,000
Total Installed Costs	99,075,000	60,915,000	54,328,000	3,079,000	33,091,000	37,119,000

	Total Onsites	Offsites excl. tankage	Tankage			Total Refinery Capital Cost
Total Major Equipment	$433,435,500	-	$22,822,600			$456,258,100
Instruments	84,221,600	-	5,753,600			89,975,200
Insulation	-	-	2,770,800			2,770,800
Rounding	900	-	-			900
Total Direct Installed Cost	517,658,000	-	31,347,000			549,005,000
Home Office Costs	77,648,000	-	4,702,000			82,350,000
Subtotal	595,306,000	-	36,049,000			631,355,000
Contingency	148,829,000	-	9,012,000			157,841,000
Total Installed Costs	744,135,000	334,861,000	45,061,000			1,124,057,000
Spare Parts (1% of $149,756,600 material cost of total major equipment)				1,498,000		
Roundup to nearest million dollars						445,000
Refinery Total Installed Cost						1,126,000,000

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
CRUDE UNIT
ESTIMATE NO: 7263
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
	ESTIMATE SUMMARY										
270P	TOWERS	1					358,400				$1,433,600
300R	REACTORS										
320A	AIR COOLED HEAT EXCHANGERS	1					37,000				$160,200
320S	SHELL & TUBE HEAT EXCHANGERS	14					742,700				$2,844,600
370H	FIRED HEATERS	2					1,198,500				$2,696,600
400T	TANKS										
400V	VESSELS	7					656,700				$2,646,400
450C	COMPRESSORS										
450P	PUMPS	16					427,000				$2,028,500
480	MISC. EQUIPMENT										
	CROLL REYNOLDS STM JET SYS	1					10,000				$22,500
	UNION CARBIDE H.P.U.										
	W-L/DP/ACP/SRI SYSTEMS										
	ELEC. PRECIP. & FLY ASH COLL. SYS										
	CHEVRON W.W.T PROCESS SYS.										
	RALPH. M. PARSONS CO. SYSTEM										
A	TOTAL MAJOR EQUIPMENT	41					3,430,300			3.45	$11,832,400
600	INSTRUMENTS	15 % M.E.					514,500			4.00	$2,058,000
620	INSULATION										
	ROUNDING										($400)
A+B	TOTAL DIRECT INSTALLED COST										$13,890,000
	HOME OFFICE COSTS	15 % D.I.C.									$2,084,000
800	CATALYST & CHEMICALS										
	SUB TOTAL										$15,974,000
	CONTINGENCY	25 %									$3,994,000
	ROYALTIES										
	TOTAL INSTALLED COST	4/Q/85									$19,968,000
	ESCALATION	% /YR. FOR YEAR									
	TOTAL INSTALLED COST	4/Q/85									$19,968,000

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
CRUDE UNIT

ESTIMATE NO: 7263
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BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
270P	T1 VACUUM TOWER 650 F FULL VAC. 12.5' X 63' CS/CS W/SKIRT 122,000# SOURCE: HOOTER	1	300,000	3 %	15,600	358,400	358,400	4.00	4.00	4.00	$1,433,600
	TRAYS: VALVE TYPE ALLOY QTY 30 SOURCE: NUTTER		32,800								
320A	E12 RECYCLE CLR. 350 F 50 PSIG 1 - 12' X 20' BAY CS SOURCE: HAPPY	1	34,000	3 %	2,000	37,000	37,000	4.10	5.00	4.33	$160,200
320S	E1 CIRC REFLUX-DESALT FD. AES 450 F 450 PSIG 7,600 SF CS/CS SOURCE: WESTERN	2	72,200	3 %	2,900	77,300	154,600	3.50	4.80	3.83	$592,100
	E2 FLASH TWR OH COND AJS 450 F 450 PSIG 6,000 SF CS/CS SOURCE: WESTERN	1	57,000	3 %	2,300	61,000	61,000	3.50	4.80	3.83	$233,600
	E3 FLASH TWR PREHTR #1 AJS 450 F 450 PSIG 2,200 SF CS/CS SOURCE: WESTERN	1	24,200	3 %	1,000	25,900	25,900	3.50	4.80	3.83	$99,200
	E4 FLASH TWR PREHTR #2 AES 550F 450 PSIG 1,940 SF CS/CS SOURCE: WESTERN	1	21,350	3 %	900	22,900	22,900	3.50	4.80	3.83	$87,700
	E5 FLASH TWR PREHTR #3 AJS 625F 450 PSIG 5,000 SF CS/CS SOURCE: WESTERN	1	47,500	3 %	1,900	50,800	50,800	3.50	4.80	3.83	$194,600
	E6 FLASH TWR PREHTR #4 AES 625F 400 PSIG 6,750 SF CS/5CR SOURCE: WESTERN	2	105,000	3 %	4,200	112,400	224,800	3.50	4.80	3.83	$861,000
	E7 CIRC REFLUX TRIM CLR AES 300F 75 PSIG 760 SF CS/ADMIRALTY SOURCE: WESTERN	1	21,500	3 %	900	23,000	23,000	3.50	4.80	3.83	$88,100
	E8 NAPTHA PROD CLR AES 300F 75 PSIG 2,400 SF CS/ADMIRALTY SOURCE: WESTERN	1	43,200	3 %	1,700	46,200	46,200	3.50	4.80	3.83	$176,900
	E9 VAC TWR OH COND AES 300F -10 TO+75 PSIG 2,000 SF CS/ADMIRALTY SOURCE: WESTERN	1	36,000	3 %	1,400	38,500	38,500	3.50	4.80	3.83	$147,500
	E10 FRESH - SALT WTR EXCH AES 350F 600 PSIG 880 SF CS/CS SOURCE: WESTERN	2	24,750	3 %	1,000	26,500	53,000	3.50	4.80	3.83	$203,000
	E11 DESASTER EFF WTR CLR AES 300F 400 PSIG 1,400 SF CS/ADMIRALTY SOURCE: WESTERN	1	39,200	3 %	1,600	42,000	42,000	3.50	4.80	3.83	$160,900
370H	H1 FLASH TWR FEED 99.2 MM BTU/HR H2 FLASH TWR FEED 46.2 MM BTU/HR SOURCE: BOURNE	1 1	1,115,000	3 %	50,000	1,198,500	1,198,500	2.00	3.00	2.25	$2,696,600

PROJECT: TURBINE FUELS PROJECT
CRUDE UNIT
ESTIMATE NO: 7263
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
400V	V1 RECYCLE SURGE DRUM 350 F 50 PSIG 7.5' X 16' CS/CS W/SADDLES 9,700# SOURCE: BUFFALO	1	12,500	3 %	1,725	14,600	14,600	4.00	4.10	4.03	$58,800
	V2 DESALTER 350 F 350 PSIG 12' X 52' CS/CS W/SADDLES 175,000# SOURCE: BUFFALO	2	154,000	3 %	30,500	189,100	378,200	4.00	4.10	4.03	$1,524,100
	V3 FLASH TWR 625 F 50 PSIG 9' X 25' CS/CS W/SKIRT 24,000# SOURCE: BUFFALO	1	52,500	3 %	4,700	58,800	58,800	4.00	4.10	4.03	$237,000
	V4 VAC TWR OH REC 250 F 50 PSIG 3.5' X 6' CS/CS W/SADDLES 1,600# SOURCE: BUFFALO	1	4,000	3 %	350	4,500	4,500	4.00	4.10	4.03	$18,100
	V5 FEED SURGE TANK 300 F 50 PSIG 16' X 65' CS/CS W/SKIRT 106,000# SOURCE: BUFFALO	1	167,500	3 %	17,300	189,800	189,800	4.00	4.10	4.03	$764,900
	V6 STEAM DRUM 400 F 200 PSIG 5' X 10' CS/CS W/SADDLES 6,200# SOURCE: BUFFALO	1	9,500	3 %	1,000	10,800	10,800	4.00	4.10	4.03	$43,500
450P	P1 CRUDE CYCLE FEED CS/12CR HOR 2310 GPM DISCH 350 PSIG DELTA 350 PSI-885' PUMP TEMP 175 F @ 0.91 SG MOTOR HP 725 @ 3600 RPM SOURCE: UNITED	2	63,000	3 %	1,000	65,900	131,800	4.00	7.00	4.75	$626,100
	P2 RECLE DIL'T CS/12CR HOR 600 GPM DISCH 45 PSIG DELTA 45 PSI - 135' PUMP TEMP 250 F @ 0.77 SG MOTOR HP 35 @ 3600 RPM SOURCE: UNITED	2	10,950	3 %	220	11,500	23,000	4.00	7.00	4.75	$109,300
	P3 VAC TWR FEED CS/12CR HOR 1940 GPM DISCH 173 PSIG DELTA 165 PSI - 470' PUMP TEMP 572 F @ 0.81 SG MOTOR HP 310 @ 3600 RPM SOURCE: UNITED	2	32,300	3 %	450	33,700	67,400	4.00	7.00	4.75	$320,200
	P4 CIRC REFLUX CS/12CR HOR 28.3 GPM DISCH 85 PSIG DELTA 80 PSI - 233' PUMP TEMP 368 F @ 0.79 SG MOTOR HP 130 @ 3600 RPM SOURCE: UNITED	2	21,300	3 %	350	22,300	44,600	4.00	7.00	4.75	$211,900
	P5 RED'D CRUDE CS/12CR HOR 1600 GPM DISCH 115 PSIG DELTA 122 PSI - 338' PUMP TEMP 595 F @ 0.83 SG MOTOR HP 205 @ 3600 RPM SOURCE: UNITED	2	28,000	3 %	450	29,300	58,600	4.00	7.00	4.75	$278,400
	P6 VAC TWR OH C CS/12CR HOR 28.3 GPM DISCH 70 PSIG DELTA 70 PSI - 192' PUMP TEMP 105 F @ 0.84 SG MOTOR HP 2.6 @ 3600 RPM SOURCE: UNITED	2	8,000	3 %	150	8,400	16,800	4.00	7.00	4.75	$79,800

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
CRUDE UNIT

ESTIMATE NO: 7263
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
	P7 DES W.W. BSTR CS/12CR HOR 150 GPM DISCH 355 PSIG DELTA 75 PSI - 188' PUMP TEMP 300 F @ 0.92 SG MOTOR HP 14.6 @ 3600 RPM SOURCE: UNITED	2	8,400	3 %	150	8,800	17,600	4.00	7.00	4.75	$83,600
	P8 DES W.W. FEED CS/12CR HOR 150 GPM DISCH 335 PSIG DELTA 335 PSI - 786' PUMP TEMP 140 F @ 0.98 SG MOTOR HP 53 @ 3600 RPM SOURCE: UNITED	2	32,200	3 %	450	33,600	67,200	4.00	7.00	4.75	$319,200
480	STEAM JET VACUUM SYS 665 GPM FLOW SOURCE: CROLL REYNOLDS	1	9,500	3 %	200	10,000	10,000	2.00	3.00	2.25	$22,500

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
NAPTHA HYDROTREATER
ESTIMATE NO: 7269
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
	ESTIMATE SUMMARY										
270P	TOWERS	2					319,400				$1,277,600
300R	REACTORS	1					603,900				$2,415,600
320A	AIR COOLED HEAT EXCHANGERS	3					307,600				$1,331,900
320S	SHELL & TUBE HEAT EXCHANGERS	14					1,195,500				$4,578,800
370H	FIRED HEATERS	3					475,900				$951,800
400T	TANKS										
400V	VESSELS	9					263,700				$1,062,700
450C	COMPRESSORS	1					365,200				$777,900
450P	PUMPS	16					427,600				$2,031,300
480	MISC. EQUIPMENT CROLL REYNOLDS STM JET SYS UNION CARBIDE H.P.U. W-L/DP/ACP/SRI SYSTEMS ELEC. PRECIP. & FLY ASH COLL. SYS CHEVRON W.W.T PROCESS SYS. RALPH M. PARSONS CO. SYSTEM										
A	TOTAL MAJOR EQUIPMENT	49					3,958,800			3.64	$14,427,600
600	INSTRUMENTS	15 % M.E.					593,800			4.00	$2,375,200
620	INSULATION										
	ROUNDING										$200
A+B	TOTAL DIRECT INSTALLED COST										$16,803,000
	HOME OFFICE COSTS	15 % D.I.C.									$2,520,000
800	CATALYST & CHEMICALS										
	SUB TOTAL										$19,323,000
	CONTINGENCY	25 %									$4,831,000
	ROYALTIES										
	TOTAL INSTALLED COST	4/0/85									$24,154,000
	ESCALATION		% /YR. FOR		YEAR						
	TOTAL INSTALLED COST	4/0/85									$24,154,000

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
NAPTHA HYDROTREATER
ESTIMATE NO: 7269
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
270P	T1 FEED SPLITTER 650 F 75 PSIG 9' X 74' CS/CS W/SKIRT 68,000# SOURCE: NOOTER	1	142,400	3 %	11,400	182,100	182,100	4.00	4.00	4.00	$728,400
	TRAYS: VALVE TYPE ALLOY QTY 30 SOURCE: NUTTER		24,000								
	T2 STRIPPER 650 F 200 PSIG 6' X 56' CS/CS W/SKIRT 50,000# SOURCE: NOOTER	1	110,400	3 %	6,600	137,300	137,300	4.00	4.00	4.00	$549,200
	TRAYS: VALVE TYPE ALLOY QTY 36 SOURCE: NUTTER		17,000								
300R	R1 NAPTHA HTR REACTOR 775 F 1815PSIG 8.5' X 22'2.25CR W/O'LAY 185,400# SOURCE: NOOTER PACKED BEDS QTY 2 SOURCE:	1	556,200	3 %	31,000	603,900	603,900	4.00	4.00	4.00	$2,415,600
320A	E2 SPLITTER COND. 650 F 75 PSIG 1 - 12' X 36' BAY CS SOURCE: HAPPY	1	60,700	3 %		62,500	62,500	4.10	5.00	4.33	$270,600
	E6 R1 EFFLUENT A/C 650 F 1630 PSIG 2 - 18' X 40' BAYS 410 SS SOURCE: HAPPY	1	186,360	3 %		192,000	192,000	4.10	5.00	4.33	$831,400
	E8 STRIPPER COND. 650 F 200 PSIG 1 - 12' X 36' BAY CS SOURCE: HAPPY	1	51,600	3 %		53,100	53,100	4.10	5.00	4.33	$229,900
320S	E1 FEED BOTTOMS AES 650 F 150 PSIG 1120 SF CS/CS SOURCE: HUGHES ANDERSON	3	15,000	3 %		15,500	46,500	3.50	4.80	3.83	$178,100
	E3 R1 EFF NA CLR AES 850 F 1395 PSIG 1440 SF 1CR O'LAY / 347 SOURCE: HUGHES ANDERSON	3	197,400	3 %		203,300	609,900	3.50	4.80	3.83	$2,335,900
	E4 R1 EFF NAPTHA AES 650 F 1440 PSIG 1100 SF 1CR O'LAY / 347 SOURCE: HUGHES ANDERSON	2	150,500	3 %		155,000	310,000	3.50	4.80	3.83	$1,187,300
	E5 R1 EFF STM GEN AKT 650F 1315 PSIG 1250 SF CS/CS SOURCE: WESTERN	1	52,000	3 %		53,600	53,600	3.50	4.80	3.83	$205,300
	E7 STRIP'R FD BTMS AES 650F 300 PSIG 1764 SF CS/CS SOURCE: WESTERN	5	34,050	3 %		35,100	175,500	3.50	4.80	3.83	$672,200

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
NAPTHA HYDROTREATER
ESTIMATE NO: 7269 BY: J.T.HARLAN
JOB NO: 848768 FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
370H	H1 SPLITTER REBOILER 40.6 MM BTU/HR SOURCE BORN:	1	157,000	3 %		161,700	161,700	2.00	2.00	2.00	$323,400
	H2 RECYCLE GAS HTR 28.34 MM BTU/HR SOURCE BORN:	1	155,000	3 %		159,700	159,700	2.00	2.00	2.00	$319,400
	H3 STRIPPER REBOILER 18.85 MM BTU/HR SOURCE BORN:	1	150,000	3 %		154,500	154,500	2.00	2.00	2.00	$309,000
400V	V1 FEED DRUM 650 F 40 PSIG 10' X 32' CS/CS W/SKIRT 24,500# SOURCE: BUFFALO	1	35,500	3 %	4,800	41,400	41,400	4.00	4.10	4.03	$166,800
	V2 SPLITTER SEPARATOR 650 F 50 PSIG 8' X 16' CS/CS W/SADDLES 8,200# SOURCE: BUFFALO	1	14,000	3 %	1,700	16,100	16,100	4.00	4.10	4.03	$64,900
	V3 COMP. K O DRUM 300 F 1650 PSIG 3' X 10' CS/CS W/SKIRT 12,000# SOURCE: NOOTER	1	18,000	3 %	2,100	20,600	20,600	4.00	4.10	4.03	$83,000
	V4 HI PRESS SEP 300 F 1650 PSIG 5.5' X 18' CS/CS W/SKIRT 51,000# SOURCE: NOOTER	1	76,500	3 %	8,550	87,300	87,300	4.00	4.10	4.03	$351,800
	V5 LOW PRESS SEP 300 F 175 PSIG 8' X 25' CS/CS W/SADDLES 28,000# SOURCE: BUFFALO	1	30,600	3 %	4,600	36,100	36,100	4.00	4.10	4.03	$145,500
	V6 STRIPPER REC'R 650 F 200 PSIG 5' X 20' CS/CS W/SADDLES 10,000# SOURCE: BUFFALO	1	17,060	3 %	2,300	19,900	19,900	4.00	4.10	4.03	$80,200
	V7 STEAM DRUM 650 F 200 PSIG 5' X 15' CS/CS W/SADDLES 8,000# SOURCE: BUFFALO	1	14,000	3 %	1,900	16,300	16,300	4.00	4.10	4.03	$65,700
	V8 STEAM DRUM 650 F 200 PSIG 4' X 12' CS/CS W/SADDLES 4,500# SOURCE: BUFFALO	1	12,500	3 %	1,000	13,900	13,900	4.00	4.10	4.03	$56,000
	V9 STEAM DRUM 650 F 200 PSIG 4' X 8' CS/CS W/SADDLES 2,900# SOURCE: BUFFALO	1	11,000	3 %	800	12,100	12,100	4.00	4.10	4.03	$48,800

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
NAPTHA HYDROTREATER
ESTIMATE NO: 7269
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
450C	K1 RECYCLE COMP. CENT. 800 BHP 54,293 SCFM @ 1.38 K & 7?? MOLE WT SUCT. 108 F @ 1190 PSIA DISCH. 126 F @ 1325 PSIA SPARES: SOURCE: I R	1	340,000 15,000	3 %		350,200	365,200	2.00	2.50	2.13	$777,900
450P	P1 FEED PUMP CS/12CR HOR 387 GPM DISCH 60 PSIG DELTA 60 PSI - 180' PUMP TEMP 332 F @ 0.5 SG MOTOR HP 25 @ 3600 RPM SOURCE: UNITED	2	12,200	3 %		12,600	25,200	4.00	7.00	4.75	$119,700
	P2 SPLT'R BTMS 12CR/12CR HOR 265 GPM DISCH 100 PSIG DELTA 92 PSI - 308' PUMP TEMP 594 F @ 0.69 SG MOTOR HP 25 @ 3600 RPM SOURCE: UNITED	2	17,400	3 %		17,900	35,800	4.00	7.00	4.75	$170,100
	P3 REBLR PUMP 12CR/12CR HOR 1000 GPM DISCH 70 PSIG DELTA 62 PSI - 208' PUMP TEMP 574 F @ 0.69 SG MOTOR HP 70 @ 3600 RPM SOURCE: UNITED	2	21,600	3 %		22,200	44,400	4.00	7.00	4.75	$210,900
	P4 SPLTR REF 12CR/12CR HOR 211 GPM DISCH 68 PSIG DELTA 68 PSI - 204' PUMP TEMP 259 F @ 0.77 SG MOTOR HP 20 @ 3600 RPM SOURCE: UNITED	2	11,600	3 %		11,900	23,800	4.00	7.00	4.75	$113,100
	P5 REACTOR FEED CS/12CR HOR 541 GPM DISCH 1370PSIG DELTA 1370PSI - 4187' PUMP TEMP 150 F @ 0.75 SG MOTOR HP 700 @ 3600 RPM SOURCE: UNITED	2	102,700	3 %		105,800	211,600	4.00	7.00	4.75	$1,005,100
	P6 STRIPPER CHG CS/12CR HOR 327 GPM DISCH 270 PSIG DELTA 120 PSI - 360' PUMP TEMP 116 F @ 0.80 SG MOTOR HP 75 @ 3600 RPM SOURCE: UNITED	2	14,000	3 %		14,400	28,800	4.00	7.00	4.75	$136,800
	P7 STRPR REBLR CS/12CR HOR 886 GPM DISCH 243 PSIG DELTA 78 PSI - 313' PUMP TEMP 445 F @ 0.56 SG MOTOR HP 75 @ 3600 RPM SOURCE: UNITED	2	17,400	3 %		17,900	35,800	4.00	7.00	4.75	$170,100
	P8 STRPR REFLX CS/12CR HOR 105 GPM DISCH 211 PSIG DELTA 61 PSI - 270' PUMP TEMP 114 F @ 0.52 SG MOTOR HP 10 @ 3600 RPM SOURCE: UNITED	2	10,780	3 %		11,100	22,200	4.00	7.00	4.75	$105,500

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
HYDROVISBREAKER
ESTIMATE NO: 7273
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
	ESTIMATE SUMMARY										
270P	TOWERS	4					1,619,200				$6,476,800
300R	REACTORS	3					9,360,000				$37,440,000
320A	AIR COOLED HEAT EXCHANGERS	1					114,400				$495,400
320S	SHELL & TUBE HEAT EXCHANGERS	26					5,053,500				$19,354,800
370H	FIRED HEATERS	3					2,756,000				$5,512,000
400T	TANKS	3					353,800				$707,600
400V	VESSELS	13					4,354,700				$17,264,600
450C	COMPRESSORS	3					1,466,400				$3,123,400
450P	PUMPS	32					2,146,800				$10,197,600
480	MISC. EQUIPMENT										
	CROLL REYNOLDS STM JET SYS	1					15,700				$35,300
	UNION CARBIDE H.P.U.										
	W-L/DP/ACP/SRI SYSTEMS										
	ELEC. PRECIP. & FLY ASH COLL. SYS										
	CHEVRON W.W.T PROCESS SYS.										
	RALPH M. PARSONS CO. SYSTEM										
A	TOTAL MAJOR EQUIPMENT	89					27,240,500			3.69	$100,607,500
600	INSTRUMENTS	15	% M.E.				4,086,100			4.00	$16,344,400
620	INSULATION										
	ROUNDING										$100
A+B	TOTAL DIRECT INSTALLED COST										$116,952,000
	HOME OFFICE COSTS	15	% D.I.C.								$17,543,000
800	CATALYST & CHEMICALS										
	SUB TOTAL										$134,495,000
	CONTINGENCY	25 %									$33,624,000
	ROYALTIES										
	TOTAL INSTALLED COST	4/0/85									$168,119,000
	ESCALATION		% /YR. FOR		YEAR						
	TOTAL INSTALLED COST	4/0/85									$168,119,000

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
HYDROVISBREAKER
ESTIMATE NO: 7273
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
270P	T1 AMINE ABSORBER 650 F 2,700 PSIG 5.5' X 50' CS/CS W/SKIRT 285,000# SOURCE:	1	920,000	3 %	9,400	977,000	977,000	4.00	4.00	4.00	$3,908,000
	TRAYS: VALVE TYPE 12CR QTY 20 SOURCE:		20,000								
	T2 AMINE STILL 650 F 75 PSIG 6.5' X 50' CS/CS W/SKIRT 17,000# SOURCE:	1	46,200	3 %	700	68,300	68,300	4.00	4.00	4.00	$273,200
	TRAYS: VALVE TYPE 12CR QTY 20 SOURCE:		20,000								
	T3 ATMOSPHERIC TWR 650 F 75 PSIG 8/26/10' X 44/6.5/12' CS/CS WITH SKIRT 50,000# SOURCE: NOOTER	1	244,000	3 %	2,800	286,100	286,100	4.00	4.00	4.00	$1,144,400
	TRAYS: VALVE TYPE 12CR QTY 32 SOURCE: EST.		32,000								
	T4 VACUUM TOWER 750 F FULL VACUUM 20/10' X 20/12' CS/CS W/SKIRT 95000# SOURCE: NOOTER	1	265,000	3 %	2,800	287,800	287,800	4.00	4.00	4.00	$1,151,200
	TRAYS: VALVE TYPE 12CR QTY 12 SOURCE: EST.		12,000								
300R	HYDRO-VIS REACTORS 850 F 2805 PSIG 10' X 43'2.25CR W/O'LAY 838,100# SOURCE:C.B.I. SUPPORT GRIDS QTY 2 SOURCE:C.B.I.	3	3,000,000	3 %	30,000	3,120,000	9,360,000	4.00	4.00	4.00	$37,440,000
320A	E16 VAC BTMS A/C 650 F 150 PSIG 1 - 12' X 40' BAY CS/5CR SOURCE: HOFFMAN	1	110,000	3 %	1,100	114,400	114,400	4.10	5.00	4.33	$495,400
320S	E1 R FEED EFF. AEU 950 F 2740 PSIG 6100 SF 5 CR W/347 OL/347 TUBES SOURCE: EFCO	2	350,000	3 %	3,500	364,000	728,000	3.50	4.80	3.83	$2,788,200
	E2 R EFF RECYCLE GAS AEU 800 F 2855 PSIG 2621 SF2.25CR W/347 OL/347TUBES SOURCE: EFCO	1	200,000	3 %	2,000	208,000	208,000	3.50	4.80	3.83	$796,600
	E3 R EFF 450# STM GEN AKU 700 F 2730 PSIG 2236 SF CS /347 TUBES SOURCE: EFCO	1	235,000	3 %	2,400	244,500	244,500	3.50	4.80	3.83	$936,400
	E4 HOT SEPR VAP 150#STM GEN AKU 700F 2740 PSIG 7944 SF CS/347 TUBES SOURCE: EFCO	1	450,000	3 %	4,500	468,000	468,000	3.50	4.80	3.83	$1,792,400
	E5 HOT SEPR VAP 50# STM GEN AKU 650F 2710 PSIG 5556 SF CS/347 TUBES SOURCE: EFCO	1	350,000	3 %	3,500	364,000	364,000	3.50	4.80	3.83	$1,394,100
	E6 HOT SEPR VAP RECYCLE GAS AEU 650F 2880 PSIG 3915 SF2.25CR/347 TUBES SOURCE: EFCO	3	275,000	3 %	2,800	286,100	858,300	3.50	4.80	3.83	$3,287,300
	E7 HOT SEPR VAP COOL WATER AEU 650F 2690 PSIG 5556 SF CS/MONEL TUBES SOURCE: EST.	2	314,000	3 %	3,100	326,500	653,000	3.50	4.80	3.83	$2,501,000

SUN REFINING AND MARKETING CO P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
HYDROVISBREAKER
ESTIMATE NO: 7273
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
	E5A HOT LP SEP [illegible] AKU650F 175 PSIG 1084 SF [illegible] TUBES SOURCE: EST.	1	17,000	3 %	200	17,700	17,700	3.50	4.80	3.83	$67,800
	E5B HOT LP SEP GAS [illegible] AEU 650F 175 PSIG [illegible] SF [illegible] TUBES SOURCE: EST	1	55,000	3 %	600	57,300	57,300	3.50	4.80	3.83	$219,500
	E9 AMINE [illegible] 2750 PSIG 2257 SF [illegible] TUBES SOURCE: EST.	2	180,000	3 %	1,800	187,200	374,400	3.50	4.80	3.83	$1,434,000
	E10 AMINE S[illegible] 75 PSIG [illegible] SF [illegible] 60 TUBES SOURCE: EST	1	136,000	3 %	1,400	141,500	141,500	3.50	4.80	3.83	$541,900
	E10A LEAN AMINE [illegible] 2750 PSIG [illegible] SF 316 [illegible] 60 TUBES SOURCE: EST	2	152,000	3 %	1,500	158,100	316,200	3.50	4.80	3.83	$1,211,000
	E11 AMINE ST[illegible] 75 PSIG 4524 SF [illegible] TUBES SOURCE: EST	1	339,300	3 %	3,400	352,900	352,900	3.50	4.80	3.83	$1,351,600
	E11A AMINE REG[illegible] 200 PSIG 450 SF 316 [illegible] TUBES SOURCE: EST,	1	45,000	3 %	500	46,900	46,900	3.50	4.80	3.83	$179,600
	E12A ATM TWR OH [illegible] 650F 100 PSIG 2560 SF [illegible] SOURCE: EST.	1	31,000	3 %	300	32,200	32,200	3.50	4.80	3.83	$123,300
	E12B ATM TWR [illegible] 150 PSIG 3330 SF [illegible] TUBES SOURCE: EST,	2	47,000	3 %	500	48,900	97,800	3.50	4.80	3.83	$374,600
	E13 ATM TWR P[illegible] 150 PSIG 1695 SF [illegible] TUBES SOURCE: EST,	1	21,200	3 %	200	22,000	22,000	3.50	4.80	3.83	$84,300
	E14 VAC TWR PA [illegible] 650F 100 PSIG 5012 SF [illegible] SOURCE: EST.	1	52,000	3 %	500	54,100	54,100	3.50	4.80	3.83	$207,200
	E15 VAC TWR PA B [illegible] 150 PSIG 1010 SF [illegible] SOURCE: EST.	1	16,000	3 %	200	16,700	16,700	3.50	4.80	3.83	$64,000

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
HYDROVISBREAKER
ESTIMATE NO: 7273
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
370H	H1 RECYCLE GAS HTR 110.1 MM BTU/HR SOURCE: EST.	1	1,800,000	3 %	18,000	1,872,000	1,872,000	2.00	2.00	2.00	$3,744,000
	H2 ATM TWR FEED HTR 101.0 MM BTU/HR SOURCE: EST.	1	500,000	3 %	5,000	520,000	520,000	2.00	2.00	2.00	$1,040,000
	H3 VAC TWR FEED HTR 61.0 MM BTU/HR SOURCE: EST.	1	350,000	3 %	3,500	364,000	364,000	2.00	2.00	2.00	$728,000
400T	TK 1 CRUDE RESIN HOR 12' X 50' W/SAD DES 650 F 30 PSIG CS W/SS OLAY SOURCE; BUFFALO	1	150,000	3 %	1,500	156,000	156,000	2.00	2.00	2.00	$312,000
	TK 2 ADDITIVE TANK 20' DIA X 16' H. DES 150 F ATMOSPHERIC CONE BOTTOM FIXED ROOF SOURCE: BUFFALO	2	95,000	3 %	1,000	98,900	197,800	2.00	2.00	2.00	$395,600
400V	V1 HOT HP SEP 650 F 2715 PSIG 9' X 20' 1.25CR W/SDLS 371,300# SOURCE: EST.	1	1,370,000	3 %	13,700	1,424,800	1,424,800	3.50	4.80	3.83	$5,457,000
	V2 HOT LP SEP. 650 F 200 PSIG 7' X 26' CS/CS W/SDLS 21,500# SOURCE: BUFFALO	1	50,000	3 %	500	52,000	52,000	4.00	4.10	4.03	$209,600
	V2A COOLED HT SEP VAP 500 F 200 PSIG 3' X 9' CS/CS W/SDLS 4,000# SOURCE: BUFFALO	1	6,250	3 %	100	6,500	6,500	4.00	4.10	4.03	$26,200
	V3 COLD HI-PRESS SEP 650 F 2680 PSIG 8' X 24' CSW/347 OL W/SDLS 324,200# SOURCE: EST.	1	1,195,000	3 %	12,000	1,242,900	1,242,900	4.00	4.10	4.03	$5,008,900
	V4 COLD LP SEP 650 F 200 PSIG 7' X 24' CS/CS W/SDLS 20,000# SOURCE: BUFFALO	1	31,000	3 %	300	32,200	32,200	4.00	4.10	4.03	$129,800
	V5 COMP K.O. DRUM 650 F 2670 PSIG 4.5' X 10' CS/CS W/SKIRT 49,000# SOURCE: EST.	1	180,500	3 %	18,100	204,000	204,000	4.00	4.10	4.03	$822,100
	V6 AMINE ACCUM 650 F 75 PSIG 3' X 15' SA516-70 W/SDLS 1,750# SOURCE: EST.	1	8,000	3 %	800	9,000	9,000	4.00	4.10	4.03	$36,300
	V7 AMINE FLASH DRUM 650 F 200 PSIG 5' X 20' SA516-70 W/SDLS 10,000# SOURCE: EST.	1	37,000	3 %	3,700	41,800	41,800	4.00	4.10	4.03	$168,500
	V8 ATMOS TWR ACCUM 650 F 75 PSIG 6' X 24' CS W/SDLS 12,000# SOURCE: BUFFALO	1	1,195,000	3 %	12,000	1,242,900	1,242,900	4.00	4.10	4.03	$5,008,900
	V9 150# STM DRUM H-1 650 F 300 PSIG 6' X 15' CS/CS W/SDLS 11,000# SOURCE: BUFFALO	1	24,000	3 %	200	24,900	24,900	4.00	4.10	4.03	$100,300
	V10 150# STM DRUM H-2 650 F 200 PSIG 5' X 15' CS/CS W/SDLS 7,000# SOURCE: BUFFALO	1	15,300	3 %	1,500	17,300	17,300	4.00	4.10	4.03	$69,[illegible]

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
HYDROVISBREAKER
ESTIMATE NO: 7273
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
	V11 150# STM DRUM H-3 650 F 200 PSIG 4.5' X 12' CS/CS W/SDLS 5,400# SOURCE: BUFFALO	1	11,900	3 %	1,200	13,500	13,500	4.00	4.10	4.03	$54,400
	V12 AMINE SURGE TANK 650 F 75 PSIG 10' X 25' SA516-70 W/SDLS 10,500# SOURCE: EST.	1	38,000	3 %	3,800	42,900	42,900	4.00	4.10	4.03	$172,900
450C	K1 RECYCLE COMP. CENT. 1395 BHP 159,396 SCFM @ 1.37 K & ??? MOLE WT SUCT. 125 F @ 2440 PSIA DISCH. 131 F @ 2620 PSIA SPARES:ROTOR SOURCE: EST.	1	850,000	3 %	8,500	884,000	884,000	2.00	2.50	2.13	$1,882,900
	K2 ATMOS TWR OFF-GAS COMP. 50 BHP 537 SCFM @ 1.159 K & ??? MOLE WT SUCT. 100 F @ 34.7 PSIA DISCH. 237 F @ 164.7 PSIA SPARES: SOURCE: EST.	2	280,000	3 %	2,800	291,200	582,400	2.00	2.50	2.13	$1,240,500
450P	P1 FEED PUMP CS/12CR HOR 1444 GPM DISCH 2700 PSIG DELTA 2695 PSI-7123' PUMP TEMP 514 F @ 0.894 SG MOTOR HP 3500 @ 3560 RPM SOURCE: UNITED	2	360,000	3 %	3,600	374,400	748,800	4.00	7.00	4.75	$3,556,800
	P2 ADD & MIX CS/12CR HOR 100 GPM DISCH 30 PSIG DELTA 30 PSI - 88' PUMP TEMP 90 F @ 0.79 SG MOTOR HP 5 @ 3560 RPM SOURCE: UNITED	2	10,200	3 %	100	10,600	21,200	4.00	7.00	4.75	$100,700
	P3,4,5 REA MIX 12CR/12CR H 14280 GPM DISCH 2515 PSIG DELTA 5 PSI - 16' PUMP TEMP 850 F @ 0.74 SG MOTOR HP 100 @ 3600 RPM SOURCE:	6	75,600	3 %	800	78,700	472,200	4.00	7.00	4.75	$2,243,000
	P6 ATMOS TWR PA CS/12CR HOR 495 GPM DISCH 79 PSIG DELTA 46 PSI-152' PUMP TEMP 515 F @ 0.878 SG MOTOR HP 30 @ 3560 RPM SOURCE: UNITED	2	15,050	3 %	200	15,700	31,400	4.00	7.00	4.75	$149,200
	P7 LEAN AMINE CS/12CR HOR 440 GPM DISCH 2480 PSIG DELTA 2480 PSI-5787' PUMP TEMP 145 F @ 0.99 SG MOTOR HP 1100 @ 3560 RPM SOURCE:	2	295,000	3 %	3,000	306,900	613,800	4.00	7.00	4.75	$2,915,600

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
HYDROVISBREAKER
ESTIMATE NO: 7273
JOB NO: 848768

BY: J.T.HARLAM
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
	P8 AMINE STILL RFX CS/12CR H 40 GPM DISCH 50 PSIG DELTA 50 PSI - 117' PUMP TEMP 105 F @ 0.99 SG MOTOR HP 4 @ 3600 RPM SOURCE:	2	5,000	3 %	100	5,300	10,600	4.00	7.00	4.75	$50,400
	P9 ATMOS TWR OH CS/12CR H 519 GPM DISCH 76 PSIG DELTA 66 PSI - 204' PUMP TEMP 100 F @ 0.751 SG MOTOR HP 40 @ 3600 RPM SOURCE: UNITED	2	14,070	3 %	100	14,600	29,200	4.00	7.00	4.75	$138,700
	P10 ATMOS TWR BTMS CS/12CR H 895 GPM DISCH 77 PSIG DELTA 78 PSI - 224' PUMP TEMP 619 F @ 0.806 SG MOTOR HP 75 @ 3600 RPM SOURCE: UNITED	2	19,320	3 %	200	20,100	40,200	4.00	7.00	4.75	$191,000
	P11 ATMOS TWR DIST CS/12CR H 274 GPM DISCH 67 PSIG DELTA 44 PSI - 146' PUMP TEMP 543 F @ 0.694 SG MOTOR HP 15 @ 3600 RPM SOURCE: UNITED	2	14,630	3 %	100	15,200	30,400	4.00	7.00	4.75	$144,400
	P12 VAC TWR DIST CS/12CR H 564 GPM DISCH 67 PSIG DELTA 81 PSI - 227' PUMP TEMP 542 F @ 0.824 SG MOTOR HP 50 @ 3600 RPM SOURCE: UNITED	2	16,330	3 %	200	17,000	34,000	4.00	7.00	4.75	$161,500
	P13 VAC TWR PA CS/12CR H 792 GPM DISCH 51 PSIG DELTA 66 PSI - 185' PUMP TEMP 542 F @ 0.824 SG MOTOR HP 50 @ 3600 RPM SOURCE: UNITED	2	17,400	3 %	200	18,100	36,200	4.00	7.00	4.75	$172,000
	P14 VAC TWR BTMS CS/12CR H 187 GPM DISCH 133 PSIG DELTA 47 PSI - 377' PUMP TEMP 631 F @ 0.901 SG MOTOR HP 40 @ 3600 RPM SOURCE: UNITED	2	17,070	3 %	200	17,800	35,600	4.00	7.00	4.75	$169,100
	P15 VAC TWR OH WAT CS/12CR H 31 GPM DISCH 56 PSIG DELTA 70 PSI - 163' PUMP TEMP 100 F @ 0.99 SG MOTOR HP 5 @ 3600 RPM SOURCE: UNITED	2	10,000	3 %	100	10,400	20,800	4.00	7.00	4.75	$98,800
	P16 VAC TWR OH DIS CS/12CR H 106GPM DISCH 56 PSIG DELTA 70 PSI - 180' PUMP TEMP 100 F @ 0.902 SG MOTOR HP 15 @ 3600 RPM SOURCE: UNITED	2	10,780	3 %	100	11,200	22,400	4.00	7.00	4.75	$106,400
480	STEAM JET VACUUM SYS 665 GPM FLOW SOURCE: CROLL REYNOLDS	1	15,000	3 %	200	15,700	15,700	2.00	3.00	2.25	$35,300

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
DISTILLATE HYDROTREATER
ESTIMATE NO: 7281
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
	ESTIMATE SUMMARY										
270P	TOWERS	1					93,500				$374,000
300R	REACTORS	3					12,792,000				$51,168,000
320A	AIR COOLED HEAT EXCHANGERS	1					124,800				$540,400
320S	SHELL & TUBE HEAT EXCHANGERS	16					5,772,400				$22,108,400
370H	FIRED HEATERS										
400T	TANKS										
400V	VESSELS	7					991,100				$3,983,100
450C	COMPRESSORS	1					811,200				$1,727,900
450P	PUMPS	6					984,200				$4,675,000
480	MISC. EQUIPMENT CROLL REYNOLDS STM JET SYS UNION CARBIDE H.P.U. W-L/DP/ACP/SRI SYSTEMS ELEC. PRECIP. & FLY ASH COLL. SYS CHEVRON W.W.T PROCESS SYS. RALPH M. PARSONS CO. SYSTEM										
A	TOTAL MAJOR EQUIPMENT	35					21,569,200			3.92	$84,576,800
600	INSTRUMENTS	15 % M.E.					3,235,400			4.00	$12,941,600
620	INSULATION										
	ROUNDING										($400)
A+B	TOTAL DIRECT INSTALLED COST										$97,518,000
	HOME OFFICE COSTS	15 % D.I.C.									$14,628,000
800	CATALYST & CHEMICALS										
	SUB TOTAL										$112,146,000
	CONTINGENCY	25 %									$28,037,000
	ROYALTIES										
	TOTAL INSTALLED COST	4/0/85									$140,183,000
	ESCALATION		% /YR. FOR		YEAR						
	TOTAL INSTALLED COST	4/0/85									$140,183,000

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
DISTILLATE HYDROTREATER
ESTIMATE NO: 7281
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
270P	T1 FEED STRIPPER 650 F 200 PSIG 5.5' X 42' CS/CS W/SKIRT 24,600# SOURCE: BRIGHTON	1	85,000	3 %	900	93,500	93,500	4.00	4.00	4.00	$374,000
	TRAYS: VALVE TYPE 12CR QTY 16 SOURCE: BRIGHTON		5,000								
300R	DIST HTR REACTORS 850 F 2805 PSIG 10' X 68'2.25CR W/O'LAY 1,138,820# SOURCE:C.B.I. SUPPORT GRIDS QTY 2 SOURCE:C.B.I.	3	4,100,000	3 %	41,000	4,264,000	12,792,000	4.00	4.00	4.00	$51,168,000
320A	E6 EFF. COOLER. 300 F 2710 PSIG 1 - 18' X 40' BAY CS SOURCE:	1	120,000	3 %	1,200	124,800	124,800	4.10	5.00	4.33	$540,400
320S	E1 R FEED EFF. BEU 700 F 2750 PSIG 7945 SF 2.25CR W/347 OL/347 SOURCE: HTE	2	1,900,000	3 %	19,000	1,976,000	3,952,000	3.50	4.80	3.83	$15,136,200
	E2 R EFF 450# STM GEN BKU 700 F 2740 PSIG 7950 SF CS/347 SOURCE: HTE	1	172,200	3 %	1,700	179,100	179,100	3.50	4.80	3.83	$686,000
	E3 RECY EFF EX BEU 550 F 2720 PSIG 4223 SF 2.25CR W/347 OL/347 SOURCE: HTE	1	1,055,700	3 %	10,600	1,098,000	1,098,000	3.50	4.80	3.83	$4,205,300
	E4 R EFF 50# STM GEN BKU 550F 2720 PSIG 7460 SF CS/347 SOURCE: HTE	1	80,800	3 %	800	84,000	84,000	3.50	4.80	3.83	$321,700
	E5 #1 RECYCLE EFF EX BEU 400F 2715 PSIG 2170 SF CS/347 SOURCE: HTE	2	27,800	3 %	300	28,900	57,800	3.50	4.80	3.83	$221,400
	E7 EFF TRIM CLR BED 300F 2690 PSIG 6600 SF CS/MONEL SOURCE: HTE	1	84,500	3 %	800	87,800	87,800	3.50	4.80	3.83	$336,300
	E8 STRIPPER OH COND AEU 400F 115 PSIG 865 SF CS/ADM SOURCE: HTE	1	11,100	3 %	100	11,500	11,500	3.50	4.80	3.83	$44,000
	E9 STRIPPER FD BOTTOMS AES 650F 320 PSIG 4190 SF CS/CS SOURCE: HTE	6	45,400	3 %	500	47,300	283,800	3.50	4.80	3.83	$1,087,000
	E10 STRIPPER FD PREHTR BEU 650F 500 PSIG 1632 SF CS/CS SOURCE: HTE	1	17,700	3 %	200	18,400	18,400	3.50	4.80	3.83	$70,500

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
DISTILLATE HYDROTREATER
ESTIMATE NO: 7281
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
400V	V1 FEED TANK 650 F 30 PSIG 12' X 50' CS/CS W/LEGS 52,000# SOURCE: BUFFALO	1	53,000	3 %	500	55,100	55,100	3.50	4.80	3.83	$211,000
	V2 HI-PRESSURE SEP. 650 F 2685 PSIG 8' X 24' CS/CS W/LEGS 320,000# SOURCE: C.B.I.	1	730,000	3 %	7,300	759,200	759,200	4.00	4.10	4.03	$3,059,600
	V3 LO-PRESSURE SEP. 650 F 200 PSIG 8' X 24' CS/CS W/LEGS 27,000# SOURCE: BUFFALO	1	29,000	3 %	300	30,200	30,200	4.00	4.10	4.03	$121,700
	V4 COMP. SUCT. KO 650 F 2670 PSIG 3.5' X 10' CS/CS W/SKIRT 57,000# SOURCE: C.B.I.	1	130,800	3 %	1,300	136,000	136,000	4.00	4.10	4.03	$548,100
	V5 STRIPPER ACCUM. 650 F 200 PSIG 4' X 10' CS/CS W/LEGS 3,300# SOURCE: BUFFALO	1	3,000	3 %	300	3,400	3,400	4.00	4.10	4.03	$13,700
	V6 STEAM DRUM 650 F 200 PSIG 4.5' X 10' CS/CS W/LEGS 4,500# SOURCE: BUFFALO	1	4,200	3 %	400	4,700	4,700	4.00	4.10	4.03	$18,900
	V7 STEAM DRUM 650 F 200 PSIG 3.5' X 8' CS/CS W/LEGS 2,500# SOURCE: BUFFALO	1	2,200	3 %	200	2,500	2,500	4.00	4.10	4.03	$10,100
450C	K1 RECYCLE COMP. CENT. ??? BHP 106,439 SCFM @ 1.393 K & ??? MOLE WT SUCT. 123 F @ 2450 PSIA DISCH. 136 F @ 2650 PSIA SPARES:ROTOR,CPLG,SHAFT SOURCE:	1	780,000	3 %	7,800	811,200	811,200	2.00	2.50	2.13	$1,727,900
450P	P1 FEED PUMP CS/12CR HOR 1165 GPM DISCH 2650 PSIG DELTA 2650 PSI-7918' PUMP TEMP 470 F @ 0.795 SG MOTOR HP 3000 @ ???? RPM SOURCE:	2	440,000	3 %	4,400	457,600	915,200	4.00	7.00	4.75	$4,347,200
	P2 STRIP'R FD. CS/12CR HOR 1008 GPM DISCH 235 PSIG DELTA 96 PSI - 255' PUMP TEMP 165 F @ 0.847 SG MOTOR HP 200 @ 3600 RPM SOURCE:	2	30,700	3 %	300	31,900	63,800	4.00	7.00	4.75	$303,100
	P3 STRPR REFLX CS/12CR HOR 30 GPM DISCH 200 PSIG DELTA 55 PSI - 199' PUMP TEMP 110 F @ 0.64 SG MOTOR HP 3 @ 3600 RPM SOURCE:	2	2,500	3 %		2,600	5,200	4.00	7.00	4.75	$24,700

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
DISTILLATE HYDROCRACKER
ESTIMATE NO: 7285
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
	ESTIMATE SUMMARY										
270P	TOWERS	4					767,100				$3,068,400
300R	REACTORS	1					3,120,000				$12,480,000
320A	AIR COOLED HEAT EXCHANGERS	3					457,600				$1,981,400
320S	SHELL & TUBE HEAT EXCHANGERS	24					6,542,200				$25,056,600
370H	FIRED HEATERS	2					1,716,000				$3,432,000
400T	TANKS										
400V	VESSELS	7					1,101,300				$4,438,200
450C	COMPRESSORS	1					728,000				$1,550,600
450P	PUMPS	18					977,200				4,641,900
480	MISC. EQUIPMENT CROLL REYNOLDS STM JET SYS UNION CARBIDE H.P.U. W-L/DP/ACP/SRI SYSTEMS ELEC. PRECIP. & FLY ASH COLL. SYS CHEVRON W.W.T PROCESS SYS. RALPH M. PARSONS CO. SYSTEM										
A	TOTAL MAJOR EQUIPMENT	60					15,409,400			3.68	$56,649,100
600	INSTRUMENTS	15 % M.E.					2,311,400			4.00	$9,245,600
620	INSULATION										
	ROUNDING										$300
A+B	TOTAL DIRECT INSTALLED COST										$65,895,000
	HOME OFFICE COSTS	15 % D.I.C.									$9,884,000
800	CATALYST & CHEMICALS										
	SUB TOTAL										$75,779,000
	CONTINGENCY	25 %									$18,945,000
	ROYALTIES										
	TOTAL INSTALLED COST	4/0/85									$94,724,000
	ESCALATION	% /YR. FOR			YEAR						
	TOTAL INSTALLED COST	4/0/85									$94,724,000

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
DISTILLATE HYDROCRACKER
ESTIMATE NO: 7285
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
270P	T1 PREFRACTIONATOR 650 F 200 PSIG 8.5&10'X32&42' CS/CS W/SK 114,000# SOURCE: BRIGHTON	1	156,000	3 %	1,600	178,300	178,300	4.00	4.00	4.00	$713,200
	TRAYS: VALVE TYPE 12CR QTY 16&16 SOURCE: BRIGHTON		16,000								
	T2 MAIN FRACTIONATOR 650 F 41 PSIG 11&12.5&20&10'X24&84&42&30' CS/CS W/SKIRT 190,000# SOURCE: BRIGHTON	1	395,000	3 %	4,000	480,900	480,900	4.00	4.00	4.00	$1,923,600
	TRAYS: VAL TYPE 12CR QTY 10&36&18&8 SOURCE: BRIGHTON		70,000								
	T3 DEHEXANIZER 650 F 50 PSIG 6&8'X30&24' CS/CS W/SK 25,000# SOURCE: BRIGHTON	1	87,000	3 %	900	95,500	95,500	4.00	4.00	4.00	$382,000
	TRAYS: VALVE TYPE 12CR QTY 13&7 SOURCE: BRIGHTON		5,000								
	S1 MN.FRAC. STRIPPER 650 F 100 PSIG 5'X 23' CS/CS W/SK 9,600# SOURCE: BRIGHTON	1	11,000	3 %	100	12,400	12,400	4.00	4.00	4.00	$49,600
	TRAYS: VALVE TYPE 12CR QTY 8 SOURCE: BRIGHTON		1,000								
300R	HYDROCR'R REACTORS 850 F 2805 PSIG 8' X 80'2.25CR 840,000# SOURCE: CBI SUPPORT GRIDS QTY 4 SOURCE:CBI	1	3,000,000	3 %	30,000	3,120,000	3,120,000	4.00	4.00	4.00	$12,480,000
320A	E11 MN FRAC PA CLR. 650 F 75 PSIG 1 - 12' X 40' BAY CS SOURCE: YUBA	1	120,000	3 %	1,200	124,800	124,800	4.10	5.00	4.33	$540,400
	E15 MN FRAC TURB FUEL CLR. 650 F 100 2 - 16' X 36' BAY CS SOURCE:	2	160,000	3 %	1,600	166,400	332,800	4.10	5.00	4.33	$1,441,000
320S	E1 R FEED EFF. BEU 800 F 2720 PSIG 5500 SF 5CR 1/2MO/347 SOURCE: HTE QUOTE	3	1,333,000	3 %	13,300	1,386,300	4,158,900	3.50	4 80	3.83	$15,928,600
	E2 #1 H TO EFF. EX. BEU 700 F 2740 PSIG 1700 SF 1CR 1/2 MO /347 SOURCE: HTE QUOTE	2	425,000	3 %	4,300	442,100	884,200	3.50	4.80	3.83	$3,386,500
	E3 450# STM GEN BKU 650 F 2585 PSIG 3000 SF CS/CS SOURCE: HTE QUOTE	1	65,000	3 %	700	67,700	67,700	3.50	4.80	3.83	$259,300
	E4 #2 H TO EFF. EX. BEU 650 F 2775 PSIG 1230 SF CS/CS SOURCE: HTE QUOTE	1	139,000	3 %	1,400	144,600	144,600	3.50	4.80	3.83	$553,800
	E5 MN FRAC FD EX. BEU 2575 PSIG 2750 SF CS/CS SOURCE: HTE QUOTE	2	49,000	3 %	500	51,000	102,000	3.50	4.80	3.83	$390,700
	E6 LP FL TO EFF EX. BEU 2565 PSIG 6050 SF CS/CS SOURCE: HTE QUOTE	4	96,500	3 %	1,000	100,400	401,600	3.50	4.80	3.83	$1,538,100

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
DISTILLATE HYDROCRACKER
ESTIMATE NO: 7285
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
	E7 RX EFF CLR BEU 650F 2545 PSIG 7190 SF CS/ADMIRALTY SOURCE: HTE QUOTE	2	138,000	3 %	1,400	143,500	287,000	3.50	4.80	3.83	$1,099,200
	E8 PREFRAC COND BEU 400F 200 PSIG 3750 SF CS/ADMIRALTY SOURCE: HTE QUOTE	1	48,000	3 %	500	49,900	49,900	3.50	4.80	3.83	$191,100
	E9 PREFRAC REBLR BKU 650F 500 PSIG 5400 SF CS/CS SOURCE: HTE QUOTE	2	58,500	3 %	600	60,900	121,800	3.50	4.80	3.83	$466,500
	E10 MN FRAC OHD COND BEU 650F 100 PSIG 4345 SF CS/ADMIRALTY SOURCE: HTE QUOTE	2	57,500	3 %	600	59,800	119,600	3.50	4.80	3.83	$458,100
	E12 DEHEX OHD COND BEU 650F 100 PSIG 4900 SF CS/ADMIRALTY SOURCE: HTE QUOTE	2	61,000	3 %	600	63,400	126,800	3.50	4.80	3.83	$485,600
	E13 DEHEX REBLR BKU 650F 200 PSIG 1526 SF CS/CS SOURCE: HTE QUOTE	1	26,500	3 %	300	27,600	27,600	3.50	4.80	3.83	$105,700
	E14 DEHEX BTM CLR BEU 650F 100 PSIG 3900 SF CS/ADMIRALTY SOURCE: HTE QUOTE	1	48,500	3 %	500	50,500	50,500	3.50	4.80	3.83	$193,400
370H	H1 RECYCLE GAS HTR 13.28 MM BTU/HR SOURCE SELAS	1	250,000	3 %	2,500	260,000	260,000	2.00	2.00	2.00	$520,000
	H2 MAIN FRAC REBLR 157.27 MM BTU/HR SOURCE SELAS	1	1,400,000	3 %	14,000	1,456,000	1,456,000	2.00	2.00	2.00	$2,912,000
400V	V1 FEED TANK 650 F 175 PSIG 12' X 50' CS/CS W/LEGS 96,000# SOURCE: CBI	1	150,000	3 %	1,500	156,000	156,000	4.00	4.10	4.03	$628,700
	V2 HI-PRESSURE SEP. 650 F 2530 PSIG 8' X 24' CS/CS W/LEGS 340,000# SOURCE: CBI	1	780,000	3 %	7,800	811,200	811,200	4.00	4.10	4.03	$3,269,100
	V3 LO-PRESSURE SEP. 650 F 200 PSIG 8' X 24' CS/CS W/LEGS 27,000# SOURCE: BUFFALO	1	28,800	3 %	300	30,000	30,000	4.00	4.10	4.03	$120,900
	V4 COMP. SUCT. KO 650 F 2530 PSIG 3' X 10' CS/CS W/SKIRT 25,000# SOURCE: CBI	1	55,000	3 %	600	57,300	57,300	4.00	4.10	4.03	$230,900
	V5 PREFRAC. ACCUM. 650 F 200 PSIG 8' X 24' CS/CS W/LEGS 27,000# SOURCE: BUFFALO	1	28,800	3 %	300	30,000	30,000	4.00	4.10	4.03	$120,900
	V6 MAIN FRAC ACCUM 650 F 70 PSIG 8' X 24' CS/CS W/SDLS 11,600# SOURCE: BUFFALO	1	10,000	3 %	100	10,400	10,400	4.00	4.10	4.03	$41,900
	V7 DEHEX. ACCUM 650 F 40 PSIG 5' X 17.5' CS/CS W/SDLS 5,500# SOURCE: BUFFALO	1	6,100	3 %	100	6,400	6,400	4.00	4.10	4.03	$25,800

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
DISTILLATE HYDROCRACKER
ESTIMATE NO: 7285
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
450C	K1 RECYCLE COMP. CENT. 1133 BHP 91,939 SCFM @ 1.37 K & 4.0 MOLE WT SUCT. 110 F @ 2305 PSIA DISCH. 125 F @ 2535 PSIA SPARES:ROTOR,CPLG,SHAFT SOURCE: IR	1	700,000	3 %	7,000	728,000	728,000	2.00	2.50	2.13	$1,550,600
450P	P1 PREFR FD CS/12CR HOR 1686 GPM DISCH 255 PSIG DELTA 105 PSI-33' PUMP TEMP 110 F @ 0.733 SG MOTOR HP 150 @ ???? RPM SOURCE: UNITED	2	23,000	3 %	200	23,900	47,800	4.00	7.00	4.75	$227,100
	P2 PREFR REF CS/12CR HOR 906 GPM DISCH 208 PSIG DELTA 63 PSI - 288' PUMP TEMP 167 F @ 0.505 SG MOTOR HP 50 @ ???? RPM SOURCE: UNITED	2	15,300	3 %	200	16,000	32,000	4.00	7.00	4.75	$152,000
	P3 MN FR REF&PR CS/12CR HOR 1064 GPM DISCH 114 PSIG DELTA 109 PSI - 370' PUMP TEMP 154 F @ 0.68 SG MOTOR HP 100 @ ???? RPM SOURCE: UNITED	2	21,100	3 %	200	21,900	43,800	4.00	7.00	4.75	$208,100
	P4 MN FR PA CS/12CR HOR 860 GPM DISCH 53 PSIG DELTA 40 PSI-138' PUMP TEMP 339 F @ 0.670 SG MOTOR HP 30 @ ???? RPM SOURCE: UNITED	2	16,900	3 %	200	17,600	35,200	4.00	7.00	4.75	$167,200
	P5 MN FR REBOIL CS/12CR HOR 5799 GPM DISCH 115 PSIG DELTA 100 PSI - 345' PUMP TEMP 598 F @ 0.670 SG MOTOR HP 500 @ ???? RPM SOURCE: UNITED	2	54,300	3 %	500	56,400	112,800	4.00	7.00	4.75	$535,800
	P6 RX FEED CS/12CR HOR 1833 GPM DISCH 2640 PSIG DELTA 2625 PSI -4320' PUMP TEMP 588 F @ 0.68 SG MOTOR HP 2000 @ ???? RPM SOURCE: UNITED	2	294,400	3 %	2,900	306,100	612,200	4.00	7.00	4.75	$2,908,000
	P7 TURB FUEL CS/12CR HOR 971 GPM DISCH 80 PSIG DELTA 63 PSI-214' PUMP TEMP 322 F @ 0.680 SG MOTOR HP 60 @ ???? RPM SOURCE: UNITED	2	19,300	3 %	200	20,100	40,200	4.00	7.00	4.75	$191,000
	P8 DEHX OH R&P CS/12CR HOR 385 GPM DISCH 55 PSIG DELTA 40 PSI - 145' PUMP TEMP 112 F @ 0.6355 SG MOTOR HP 15 @ ???? RPM SOURCE: UNITED	2	11,200	3 %	100	11,600	23,200	4.00	7.00	4.75	$110,200
	P9 DEHX BTMS PR CS/12CR HOR 712 GPM DISCH 60 PSIG DELTA 40 PSI - 140' PUMP TEMP 242 F @ 0.660 SG MOTOR HP 30 @ ???? RPM SOURCE: UNITED	2	14,500	3 %	100	15,000	30,000	4.00	7.00	4.75	$142,500

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
GAS PLANT

ESTIMATE NO: 7286
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
	ESTIMATE SUMMARY										
270P	TOWERS	3					626,300				$2,505,200
300R	REACTORS										
320A	AIR COOLED HEAT EXCHANGERS										
320S	SHELL & TUBE HEAT EXCHANGERS	11					499,300				$1,912,200
370H	FIRED HEATERS										
400T	TANKS										
400V	VESSELS	4					57,100				$230,100
450C	COMPRESSORS										
450P	PUMPS	14					218,200				$1,036,600
480	MISC. EQUIPMENT CROLL REYNOLDS STM JET SYS UNION CARBIDE H.P.U. W-L/DP/ACP/SRI SYSTEMS ELEC. PRECIP. & FLY ASH COLL. SYS CHEVRON W.W.T PROCESS SYS. RALPH M. PARSONS CO. SYSTEM										
A	TOTAL MAJOR EQUIPMENT	32					1,400,900			4.06	$5,684,100
600	INSTRUMENTS	15 % M.E.					210,100			4.00	$840,400
620	INSULATION										
	ROUNDING										$500
A+B	TOTAL DIRECT INSTALLED COST										$6,525,000
	HOME OFFICE COSTS	15 % D.I.C.									$979,000
800	CATALYST & CHEMICALS										
	SUB TOTAL										$7,504,000
	CONTINGENCY	25 %									$1,876,000
	ROYALTIES										
	TOTAL INSTALLED COST	4/0/85									$9,380,000
	ESCALATION		% /YR. FOR		YEAR						
	TOTAL INSTALLED COST	4/0/85									$9,380,000

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
GAS PLANT
ESTIMATE NO: 7286
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
270P	T1 ABSORBER STRIPPER 650 F 166 PSIG 6'&9'X50&57' CS/CS W/SK 94,437# SOURCE: BRIGHTON	1	225,000	3 %	2,300	261,100	261,100	4.00	4.00	4.00	$1,044,400
	TRAYS: VALVE TYPE 12CR QTY 22&20 SOURCE: BRIGHTON		27,000								
	T2 DEBUTANIZER 650 F 130 PSIG 8.5' X 98' CS/CS W/SKIRT 79,236# SOURCE: BRIGHTON	1	292,000	3 %	2,900	327,700	327,700	4.00	4.00	4.00	$1,310,800
	TRAYS: VAL TYPE 12CR QTY 43 SOURCE: BRIGHTON		24,000								
	T3 DEBUT SIDE STRIP'R 650 F 128PSIG 3.5'X 24' CS/CS W/SK 6,507# SOURCE: BRIGHTON	1	35,000	3 %	400	37,500	37,500	4.00	4.00	4.00	$150,000
	TRAYS: VALVE TYPE 12CR QTY 9 SOURCE: BRIGHTON		1,000								
320S	E1 ABS'R OH COND BEU 400 F 156 PSIG 3341 SF CS / ADMIRALTY SOURCE: HTE QUOTE	1	38,000	3 %	400	39,500	39,500	3.50	4.80	3.83	$151,300
	E2 ABS'R INTERCLR BEU 400 F 164 PSIG 5830 SF CS / ADMIRALTY SOURCE: HTE QUOTE	2	79,000	3 %	800	82,200	164,400	3.50	4.80	3.83	$629,700
	E3 STRIPPER INTERHEATER BEU 650 F 165 PSIG 1607 SF CS/CS SOURCE: HTE QUOTE	1	17,500	3 %	200	18,200	18,200	3.50	4.80	3.83	$69,700
	E4 STRIPPER REBOILER BKU 650 F 166 PSIG 2639 SF CS/CS SOURCE: HTE QUOTE	1	31,000	3 %	300	32,200	32,200	3.50	4.80	3.83	$123,300
	E5 DEBUT FEED/BOTTOMS BEU 140 PSIG 6297 SF CS/CS SOURCE: HTE QUOTE	1	40,000	3 %	400	41,600	41,600	3.50	4.80	3.83	$159,300
	E6 DEBUT OH COND. BEU 120 PSIG 6889 SF CS/ ADMIRALTY SOURCE: HTE QUOTE	1	66,500	3 %	700	69,200	69,200	3.50	4.80	3.83	$265,000
	E7 DEBUT OH PROD COND BEU 400F 2545 PSIG 2109 SF CS / ADMIRALITY SOURCE: HTE QUOTE	1	27,000	3 %	300	28,100	28,100	3.50	4.80	3.83	$107,600
	E8 DEBUT SIDE STRIP REBLR BKU 650 F 128 PSIG 465 SF CS/CS SOURCE: HTE QUOTE	1	13,500	3 %	100	14,000	14,000	3.50	4.80	3.83	$53,600
	E9 DEBUT REBLR BKU 650F 500 PSIG 4121 SF CS/CS SOURCE: HTE QUOTE	1	36,000	3 %	400	37,500	37,500	3.50	4.80	3.83	$143,600
	E10 LEAN OIL CLR BEU 400F 115 PSIG 4947 SF CS/ADMIRALTY SOURCE: HTE QUOTE	1	52,500	3 %	500	54,600	54,600	3.50	4.80	3.83	$209,100

SUN REFINING AND MARKETING CO.　　P. E. T. S.　FACTORED ESTIMATE WORKSHEET　　DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
GAS PLANT
ESTIMATE NO: 7286　　BY: J.T.HARLAN
JOB NC: 848768　　FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
400V	V1 ABS'R OH ACCUM 650 F 150 PSIG 6.5' X 21' CS/CS W/SDLS 13,000# SOURCE: BUFFALO	1	11,200	3 %	100	11,600	11,600	4.00	4.10	4.03	$46,700
	V2 INTERCOOLER SEP. 650 F 162 PSIG 9' X 20' CS/CS W/SDLS 26,000# SOURCE: BUFFALO	1	28,600	3 %	300	29,800	29,800	4.00	4.10	4.03	$120,100
	V3 DEBUT REFLUX ACC 650 F 115 PSIG 7' X 17' CS/CS W/SDLS 10,500# SOURCE: BUFFALO	1	10,000	3 %	100	10,400	10,400	4.00	4.10	4.03	$41,900
	V3 DEBUT OH PROD ACC 650 F 110 PSIG 5' X 12' CS/CS W/SDLS 4,500# SOURCE: BUFFALO	1	5,000	3 %	100	5,300	5,300	4.00	4.10	4.03	$21,400
450P	P1 ABSORB REFLUX CS/12CR HOR 717 GPM DISCH 204 PSIG DELTA 77 PSI-233' PUMP TEMP 100 F @ 0.7315 SG MOTOR HP 60 @ ???? RPM SOURCE: UNITED	2	19,300	3 %	200	20,100	40,200	4.00	7.00	4.75	$191,000
	P2 STRIP REFLUX CS/12CR HOR 1297 GPM DISCH 193 PSIG DELTA 56 PSI - 195' PUMP TEMP 100 F @ 0.622 SG MOTOR HP 73 @ ???? RPM SOURCE: UNITED	2	17,100	3 %	200	17,800	35,600	4.00	7.00	4.75	$169,100
	P3 STRIP'R BTMS CS/12CR HOR 1187 GPM DISCH 158 PSIG DELTA 15 PSI - 60' PUMP TEMP 278 F @ 0.5789 SG MOTOR HP 15 @ ???? RPM SOURCE: UNITED	2	11,200	3 %	100	11,600	23,200	4.00	7.00	4.75	$110,200
	P4 DEBUT REFLUX CS/12CR HOR 738 GPM DISCH 154 PSIG DELTA 61 PSI-273' PUMP TEMP 135 F @ 0.5170 SG MOTOR HP 45 @ ???? RPM SOURCE: UNITED	2	15,300	3 %	200	16,000	32,000	4.00	7.00	4.75	$152,000
	P5 BUTANE PROD. CS/12CR HOR 252 GPM DISCH 205 PSIG DELTA 117 PSI - 521' PUMP TEMP 127 F @ 0.5188 SG MOTOR HP 30 @ ???? RPM SOURCE: UNITED	2	16,900	3 %	200	17,600	35,200	4.00	7.00	4.75	$167,200
	P6 DEBUT BTMS CS/12CR HOR 882 GPM DISCH 206 PSIG DELTA 98 PSI - 406' PUMP TEMP 411 F @ 0.5607 SG MOTOR HP 100 @ ???? RPM SOURCE: UNITED	2	21,100	3 %	200	21,900	43,800	4.00	7.00	4.75	$208,100
	P7 LEAN OIL M.U. CS/12CR HOR 36 GPM DISCH 154 PSIG DELTA 91 PSI - 316' PUMP TEMP 250 F @ 0.6643 SG MOTOR HP 5 @ ???? RPM SOURCE: UNITED	2	4,000	3 %		4,100	8,200	4.00	7.00	4.75	$39,000

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE: 16-Mar-87

PROJECT: TURBINE FUELS PROJECT
HYDROGEN PRODUCTION PLANTS - TWO @ 80 MMSCFD EACH
ESTIMATE NO: 7287
JOB NO: 848768

BY: J.T.KAPLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
	ESTIMATE SUMMARY										
270P	TOWERS						756,000			1.95	$1,474,000
300R	REACTORS						2,142,000			1.95	$4,177,000
320A	AIR COOLED HEAT EXCHANGERS										
320S	SHELL & TUBE HEAT EXCHANGERS						4,686,000			1.95	$9,138,000
370H	FIRED HEATERS						10,800,000			1.95	$21,060,000
400T	TANKS										
400V	VESSELS						921,000			1.95	$1,796,000
450C	COMPRESSORS						7,480,000			1.95	$14,586,000
450P	PUMPS						243,000			1.95	$474,000
480	MISC. EQUIPMENT CROLL REYNOLDS STM JET SYS UNION CARBIDE H.P.U. W-L/DP/ACP/SRI SYSTEMS ELEC. PRECIP. & FLY ASH COLL. SYS CHEVRON W.W.T PROCESS SYS. RALPH M. PARSONS CO. SYSTEM										
A	TOTAL MAJOR EQUIPMENT						27,028,000			1.95	$52,705,000
600	INSTRUMENTS	15 % M.E.					4,054,200			4.00	$16,216,800
620	INSULATION										
	ROUNDING										$200
A+B	TOTAL DIRECT INSTALLED COST										$68,922,000
	HOME OFFICE COSTS	15 % D.I.C.									$10,338,000
800	CATALYST & CHEMICALS										
	SUB TOTAL										$79,260,000
	CONTINGENCY	25 %									$19,815,000
	ROYALTIES										
	TOTAL INSTALLED COST	4/0/85									$99,075,000
	ESCALATION	% /YR. FOR		YEAR							
	TOTAL INSTALLED COST	4/0/85									$99,075,000

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
HYDROGEN PURIFICATION UNIT
ESTIMATE NO: 7288
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	LOW	FACTOR HIGH	USED	INSTALLED COST
	ESTIMATE SUMMARY										
270P	TOWERS										
300R	REACTORS										
320A	AIR COOLED HEAT EXCHANGERS										
320S	SHELL & TUBE HEAT EXCHANGERS	4					127,000				$486,400
370H	FIRED HEATERS										
400T	TANKS										
400V	VESSELS										
450C	COMPRESSORS	1					10,949,800				$23,323,100
450P	PUMPS										
480	MISC. EQUIPMENT CROLL REYNOLDS STM JET SYS UNION CARBIDE H.P.U. W-L/DP/ACP/SRI SYSTEMS ELEC. PRECIP. & FLY ASH COLL. SYS CHEVRON W.W.T PROCESS SYS. RALPH M. PARSONS CO. SYSTEM	1					5,072,200				$8,876,400
A	TOTAL MAJOR EQUIPMENT	6					16,149,000			2.02	$32,685,900
600	INSTRUMENTS	15 % M.E.					2,422,400			4.00	$9,689,600
620	INSULATION										
	ROUNDING										$500
A+B	TOTAL DIRECT INSTALLED COST										$42,376,000
	HOME OFFICE COSTS	15 % D.I.C.									$6,356,000
800	CATALYST & CHEMICALS										
	SUB TOTAL										$48,732,000
	CONTINGENCY	25 %									$12,183,000
	ROYALTIES										
	TOTAL INSTALLED COST	4/Q/85									$60,915,000
	ESCALATION		% /YR. FOR		YEAR						
	TOTAL INSTALLED COST	4/Q/85									$60,915,000

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
HYDROGEN PURIFICATION UNIT
ESTIMATE NO: 7288
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
480	HYDROGEN PURIF. UNIT - UNION CARBIDE GAS RATE 74.9 MMSCFD HYDROGEN PRODUCT PURITY 99.0 % FEED GAS HYDROGEN RECOVERY 87.5 % PLANT FEED PRESSURE 800 PSIG TOTAL 147.4 LT/D	1	4,785,000	5 %	47,900	5,072,200	5,072,200	1.50	2.50	1.75	$8,876,400
320S	E1 EXP FD PREHTR BEU 650 F 2640 PSIG 1,200 SF CS/CS SOURCE:	1	26,500	5 %	300	28,100	28,100	3.50	4.80	3.83	$107,600
	E2 HYD. COMP. AFTERCLR BEU 400 F 2725 PSIG 1,872 SF CS/ADMIRALTY SOURCE:	1	46,800	5 %	500	49,600	49,600	3.50	4.80	3.83	$190,000
	E3 BLEED GAS COMP INTERCLR BEU 400 F 100 PSIG 1,083 SF CS/ADMIRALTY SOURCE:	1	16,500	5 %	200	17,500	17,500	3.50	4.80	3.83	$67,000
	E4 BLEED GAS COMP AFTERCLR BEU 400 F 190 PSIG 1,962 SF CS/ADMIRALTY SOURCE:	1	30,000	5 %	300	31,800	31,800	3.50	4.80	3.83	$121,800
450C	GAS EXPANSION AND COMPRESSION UNIT CONSISTING OF THE FOLLOWING COMPRESSORS AND MOTOR:										
	K1 TURBOEXPANDER 9714 BHP 96.459MMSCFD @ 1.37K & 4.371MOLE WT. SUCT 300 F @ 2395 PSIG DISCH 108 F @ 800 PSIG	1	6,000,000	5 %	60,000	6,360,000	6,360,000	2.00	2.50	2.13	$13,546,800
	K2 HYDROGEN COMPRESSOR 3513 BHP 51996 SCFM @ 1.287K & 2.156MOLE WT. SUCT 110 F @ 750 PSIG DISCH 340 F @ 2475 PSIG	2	1,000,000	5 %	10,000	1,060,000	2,120,000	2.00	2.50	2.13	$4,515,600
	K3 BLEED GAS COMPRESSOR 3750 BHP T FIRST STAGE 2550 BHP 14989 SCFM @ 1.285K & 12.053MOLE WT. SUCT 110 F @ 0 PSIG DISCH 255 F @ 37 PSIG SECOND STAGE 2589 BHP 14989 SCFM @ 1.285K & 12.053MOLE WT. SUCT 110 F @ 32 PSIG DISCH 310 F @ 165 PSIG	1	2,330,000	5 %	23,300	2,469,800	2,469,800	2.00	2.50	2.13	$5,260,7[illegible]

SOURCE: K2 & K3 I.R. - K1 EST.

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
TANKAGE

ESTIMATE NO: 7289
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
	ESTIMATE SUMMARY										
270P	TOWERS										
300R	REACTORS										
320A	AIR COOLED HEAT EXCHANGERS										
320S	SHELL & TUBE HEAT EXCHANGERS										
370H	FIRED HEATERS										
400T	TANKS	18					9,589,300				$22,822,600
400V	VESSELS										
450C	COMPRESSORS										
450P	PUMPS										
480	SPECIALIZED EQUIPMENT CROLL REYNOLDS STM JET SYS UNION CARBIDE H.P.U. W-L/DP/ACP/SRI SYSTEMS ELEC. PRECIP. & FLY ASH COLL. SYS CHEVRON W.W.T PROCESS SYS. RALPH M. PARSON CO. SYSTEM										
A	TOTAL MAJOR EQUIPMENT	18					9,589,300			2.38	$22,822,600
600	INSTRUMENTS	15 % M.E.					1,438,400			4.00	$5,753,600
620	INSULATION		254,300 SQ.FT.			2.83	719,700			3.85	$2,770,800
	ROUNDING										
A+B	TOTAL DIRECT INSTALLED COST										$31,347,000
	HOME OFFICE COSTS	15 % D.I.C.									$4,702,000
800	CATALYST & CHEMICALS										
	SUB TOTAL										$36,049,000
	CONTINGENCY	25 %									$9,012,000
	ROYALTIES										
	TOTAL INSTALLED COST	4/Q/85									$45,061,000
	ESCALATION		% /YR. FOR		YEAR						
	TOTAL INSTALLED COST	4/Q/85									$45,061,000

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
TANKAGE

ESTIMATE NO: 7289
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
400	CRUDE TANKAGE OPER. TEMP. 150 F DIA. 142' HT. 56' ROOF=COV'D.FLOATER HEATED&INSULATED VOL. 157,956 BBLS.	5	631,864	5 %	15,800	679,300	3,396,500	2.00	3.50	2.38	$8,083,700
	INTERMEDIATE HOT TANKAGE OPER. TEMP. 200 F (150 F CRUDE STOR) DIA. 100' HT. 56' ROOF=COV'D.FLOATER HEATED&INSULATED VOL. 439,823 CU FT.	3	362,695	5 %	9,100	389,900	1,169,700	2.00	3.50	2.38	$2,783,900
	INTERMEDIATE COLD TANKAGE OPER. TEMP. 100 F (150 F CRUDE STOR) DIA. 82' HT. 32' ROOF=COV'D.FLOATER HEATED & INSULATED VOL. 30,099 BBLS.	2	245,306	5 %	6,100	263,700	527,400	2.00	3.50	2.38	$1,255,200
	BUTANE PRODUCT SPHERE OPERATING PRESS. 50 PSIG @ 100 F DESIGN PRESS. 75 PSIG @ 650 F DIA. 65' VOL. 25,611 BBLS. SHELL THK. 1.250" WT. 678,610 LBS.	1	566,475	5 %	5,700	600,500	600,500	2.00	3.50	2.38	$1,429,200
	AMMONIA STORAGE SPHERE OPERATING PRESS. 200 PSIG @ 100 F DESIGN PRESS. 225 PSIG @ 650 F DIA. 42' VOL. 39,000 CU FT SHELL THK. 2.250" WT. 510,000 LBS.	1	380,000	5 %	3,800	402,800	402,800	2.00	3.50	2.38	$958,700
	NAPTHA PRODUCT TANKAGE OPER. TEMP. 100 F DIA. 114' HT. 56' ROOF=COV'D.FLOATER VOLUME 101,805 BBLS.	1	545,675	5 %	5,500	578,500	578,500	2.00	3.50	2.38	$1,376,800
	JET FUEL PRODUCT TANKAGE OPER. TEMP. 100 F DIA. 143' HT. 56' ROOF=COV'D.FLOATER VOLUME 160,188 BBLS.	4	640,752	5 %	6,400	679,200	2,716,800	2.00	3.50	2.38	$6,466,000
	RESIDUUM PRODUCT TANKAGE OPER. TEMP. 450 F DIA. 81' HT. 32' ROOF=CONE ROOF HEATED&INSULATED VOL. 29,369 BBLS.	1	185,900	5 %	1,900	197,100	197,100	2.00	3.50	2.38	$469,100

SUN REFINING AND MARKETING CO.   P. E. T. S. FACTORED ESTIMATE WORKSHEET   DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
STACK GAS SCRUBBING AND COLLECTING UNIT
ESTIMATE NO: 7291   BY: J.T.HARLAN
JOB NO: 848768   FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
	ESTIMATE SUMMARY										
270P	TOWERS										
300R	REACTORS										
320A	AIR COOLED HEAT EXCHANGERS										
320S	SHELL & TUBE HEAT EXCHANGERS										
370H	FIRED HEATERS										
400T	TANKS										
400V	VESSELS										
450C	COMPRESSORS										
450P	PUMPS										
480	SPECIALIZED EQUIPMENT										
	CROLL REYNOLDS STM JET SYS										
	UNION CARBIDE H.P.U.										
	W-L/DP/ACP/SRI SYSTEMS	10					7,843,900				$22,590,700
	ELEC. PRECIP. & FLY ASH COLL. SYS	2					3,016,000				$8,686,100
	CHEVRON W.W.T PROCESS SYS.										
	RALPH M. PARSONS CO. SYSTEM										
A	TOTAL MAJOR EQUIPMENT	12					10,859,900			2.88	$31,276,800
600	INSTRUMENTS	15 % M.E.					1,629,000			4.00	$6,516,000
620	INSULATION										
	ROUNDING										$200
A+B	TOTAL DIRECT INSTALLED COST										$37,793,000
	HOME OFFICE COSTS	15 % D.I.C.									$5,669,000
800	CATALYST & CHEMICALS										
	SUB TOTAL										$43,462,000
	CONTINGENCY	25 %									$10,866,000
	ROYALTIES										
	TOTAL INSTALLED COST	4/Q/85									$54,328,000
	ESCALATION		% /YR. FOR		YEAR						
	TOTAL INSTALLED COST	4/Q/85									$54,328,000

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
STACK GAS SCRUBBING AND COLLECTING UNIT
ESTIMATE NO: 7291
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
480	RAW MATERIAL STORAGE HANDLING AND PREPARATION COMPLETE. (ELEVATOR BINS, FEEDER, TANK AGITATION, AND PUMPS)	1	110,700	3 %	2,800	116,800	116,800	2.50	4.00	2.88	$336,400
	FLUE GAS COOLING (VENTURIS)	1	1,584,400	3 %	15,800	1,647,700	1,647,700	2.50	4.00	2.88	$4,745,400
	SO2 SCRUBBER SYSTEM (TRAY SCRUBBERS, DEMISTERS, TANKS, AGITATORS PUMPS)	1	2,918,500	3 %	29,200	3,035,300	3,035,300	2.50	4.00	2.88	$8,741,700
	CHLORIDES AND SOLIDS PURGE SYSTEM (TANKS AND PUMPS)	1	11,500	3 %	100	11,900	11,900	2.50	4.00	2.88	$34,300
	STACK GAS REHEAT SYSTEM	1	525,500	3 %	5,300	546,600	546,600	2.50	4.00	2.88	$1,574,200
	SO2 REGENERATION SYSTEM (EVAPORATOR-CRYSTALLIZERS, HEATER, CONDENSERS, STRIPPERS, COMPRESSORS, TANKS, AGITATORS AND PUMPS)	1	679,000	3 %	6,800	706,200	706,200	2.50	4.00	2.88	$2,033,900
	SO2 REDUCTION SYSTEM	1	654,000	3 %	6,500	680,100	680,100	2.50	4.00	2.88	$1,958,700
	SULFUR STORAGE (PIT AND STORAGE TANK, PUMPS AND HEATERS)	1	75,500	3 %	800	78,600	78,600	2.50	4.00	2.88	$226,400
	SODIUM SULFATE PURGE SYSTEM (CHILLER CRYSTALLIZER, CENTRIFUGE, ROTARY DRYER, TANKS, PUMPS, CONVEYING EQUIPMENT, BIN, AND LOADOUT)	1	314,500	3 %	3,100	327,000	327,000	2.50	4.00	2.88	$941,800
	BOOSTER AND ID FANS	1	667,000	3 %	6,700	693,700	693,700	2.50	4.00	2.88	$1,997,900
	SOURCE FOR THE ABOVE IS: WELLMAN-LORD/DAVY POWERGAS/ ALLIED CHEMICAL PROCESS/SRI										
	ELECTROSTATIC PRECIPITATOR	1	2,500,000	3 %	25,000	2,600,000	2,600,000	2.50	4.00	2.88	$7,488,000
	FLY ASH COLLECTION AND REMOVAL SYSTEM CONSISTING OF:	1	400,000	3 %	4,000	416,000	416,000	2.50	4.00	2.88	$1,198,100
	SILO 12' DIA X 35'		80,000								
	SILO UNLOADING ROOM 12' DIA X 15'		20,000								
	BOTTOM STORAGE HOPPER 15'X15'X15'		40,000								
	CONVEYOR SYSTEM		260,000								
	SOURCE: UNITED CONVEYOR										

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
LOW PRESSURE AMINE PLANT
ESTIMATE NO: 7292
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
	ESTIMATE SUMMARY										
270P	TOWERS	2					211,700				846,800
300R	REACTORS										
320A	AIR COOLED HEAT EXCHANGERS										
320S	SHELL & TUBE HEAT EXCHANGERS	7					179,000				685,500
370H	FIRED HEATERS										
400T	TANKS										
400V	VESSELS	3					22,400				90,300
450C	COMPRESSORS										
450P	PUMPS	4					50,800				241,400
480	MISC. EQUIPMENT CROLL REYNOLDS STM JET SYS UNION CARBIDE H.P.U. W-L/DP/ACP/SRI SYSTEMS ELEC. PRECIP. & FLY ASH COLL. SYS CHEVRON W.W.T PROCESS SYS. RALPH M. PARSONS CO. SYSTEM										
A	TOTAL MAJOR EQUIPMENT	16					463,900			4.02	$1,864,000
600	INSTRUMENTS	15 % M.E.					69,600			4.00	$278,400
620	INSULATION										
	ROUNDING										($400)
A+B	TOTAL DIRECT INSTALLED COST										$2,142,000
	HOME OFFICE COSTS	15 % D.I.C.									$321,000
800	CATALYST & CHEMICALS										
	SUB TOTAL										$2,463,000
	CONTINGENCY	25 %									$616,000
	ROYALTIES										
	TOTAL INSTALLED COST	4/0/85									$3,079,000
	ESCALATION		% /YR. FOR		YEAR						
	TOTAL INSTALLED COST	4/0/85									$3,079,000

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
LOW PRESSURE AMINE PLANT
ESTIMATE NO: 7292
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
270P	T1 AMINE CONTACTOR 650 F 175 PSIG 6.5'X50' CS/CS W/SK 30,000# SOURCE: BRIGHTON	1	136,500	3 %	1,400	147,400	147,400	4.00	4.00	4.00	$589,600
	TRAYS: VALVE TYPE 12CR QTY 20 SOURCE: BRIGHTON		5,400								
	T2 STILL 650 F 75 PSIG 4' X 50' CS/CS W/SKIRT 11,000# SOURCE: BRIGHTON	1	59,300	3 %	600	64,300	64,300	4.00	4.00	4.00	$257,200
	TRAYS: VAL TYPE 12CR QTY 20 SOURCE: BRIGHTON		2,600								
320S	E1 LEAN/RICH EXCH AES 650 F 100 PSIG 900 SF CS / 304 SS SOURCE: ESTIMATED	2	22,000	3 %	200	22,900	45,800	3.50	4.80	3.83	$175,400
	E2 STILL COND BEU 400 F 75 PSIG 680 SF CS /BIMETAL ADMIRALTY/CS SOURCE: ESTIMATED	1	24,500	3 %	200	25,400	25,400	3.50	~~4.80~~	~~3.83~~	~~$97,300~~
	E3 LEAN AMINE CLR BEU 400 F 175 PSIG 762 SF CS /BIMETAL ADMIRALITY/CS SOURCE: ESTIMATED	2	26,500	3 %	300	27,600	55,200	3.50	4.80	3.83	$211,400
	E4 STILL REBOILER BKU 650 F 175 PSIG 1810 SF CS/304 SS SOURCE: ESTIMATED	1	43,400	3 %	400	45,100	45,100	3.50	4.80	3.83	$172,700
	E5 AMINE RECLAIMER BKU 200 PSIG 180 SF CS/18-8 SOURCE: ESTIMATED	1	7,200	3 %	100	7,500	7,500	3.50	4.80	3.83	$28,700
400V	V1 FLASH TANK 650 F 175 PSIG 3.5' X 10' CS/CS W/LEGS 2,500# SOURCE: ESTIMATED	1	3,500	3 %		3,600	3,600	4.00	4.10	4.03	$14,500
	V2 SURGE TANK 650 F 0 PSIG 10' X 20' CS/CS W/LEGS 12,200# SOURCE: ESTIMATED	1	15,500	3 %	200	16,200	16,200	4.00	4.10	4.03	$65,300
	V3 REFLUX TANK 650 F 75 PSIG 2.5' X 10' CS/CS W/SDLS 1,450# SOURCE: ESTIMATED	1	2,500	3 %		2,600	2,600	4.00	4.10	4.03	$10,500
450P	P1 LEAN AMINE CS/12CR HOR 192 GPM DISCH 150 PSIG DELTA 150 PSI-35' PUMP TEMP 140 F @ 0.99 SG MOTOR HP 35 @ ???? RPM SOURCE: ESTIMATED	2	19,300	3 %	200	20,100	40,200	4.00	7.00	4.75	$191,000
	P2 STILL REFLUX CS/12CR HOR 18 GPM DISCH 40 PSIG DELTA 40 PSI - 95' PUMP TEMP 120 F @ 0.99 SG MOTOR HP 1 @ ???? RPM SOURCE: ESTIMATED	2	5,000	3 %	100	5,300	10,600	4.00	7.00	4.75	$50,400

SUN REFINING AND MARKETING CO.   P. E. T. S.   FACTORED ESTIMATE WORKSHEET   DATE:16 Mar 87

PROJECT: TURBINE FUELS PROJECT
SOUR WATER STRIPPER AND AMMONIA PLANT
ESTIMATE NO: 7293
JOB NO. 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
	ESTIMATE SUMMARY										
200P	TOWERS										
300R	REACTORS										
300A	AIR COOLED HEAT EXCHANGERS										
300S	SHELL & TUBE HEAT EXCHANGERS										
370H	FIRED HEATERS										
400T	TANKS	1					669,100				$1,592,500
400V	VESSELS										
450C	COMPRESSORS										
450P	PUMPS										
450	SPECIALIZED EQUIPMENT CROLL REYNOLDS STM JET STS UNION CARBIDE H.P.U. W/C DP ACP/SRI SYSTEMS ELEC. PRECIP. & FLY ASH COLL. SYS CHEVRON W.W.T. PROCESS SYSTEM RALPH M. PARSONS CO. SYSTEM	1					6,042,000				$17,401,000
A	TOTAL MAJOR EQUIPMENT	1					6,711,100			2.83	$18,993,500
600	INSTRUMENTS	15 % M.E.					1,006,700			4.00	$4,026,800
620	INSULATION										
	ROUNDING										($300)
A+B	TOTAL DIRECT INSTALLED COST										$23,020,000
	HOME OFFICE COSTS	15 % D.I.C.									$3,453,000
800	CATALYST & CHEMICALS										
	SUB TOTAL										$26,473,000
	CONTINGENCY	25 %									$6,618,000
	ROYALTIES										
	TOTAL INSTALLED COST	4/Q/85									$33,091,000
	ESCALATION		% /YR. FOR		YEAR						
	TOTAL INSTALLED COST	4/Q/85									$33,091,000

SUN REFINING AND MARKETING CO.   P. E. T. S. FACTORED ESTIMATE WORKSHEET   DATE: 16-Mar-87

PROJECT: TURBINE FUELS PROJECT
SOUR WATER STRIPPER AND AMMONIA PLANT
ESTIMATE NO: 7293   BY: J.T.HARLAN
JOB NO: 848768   FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
480	ANHYDROUS AMMONIA RECOVERY SYSTEM W.W.T. PLANT PRODUCTS AMMONIA 100.4 ST/D HYDROGEN SULFIDE 142.6 ST/D STRIPPED WATER 1,747 GPM @ 140 F	1	5,700,000	5 %	57,000	6,042,000	6,042,000	2.50	4.00	2.88	$17,401,000
440T	SOUR WATER FEED TANK OPER. TEMP. 100 F DIA. 140' HT. 48' ROOF=COV'D.FLOATER VOLUME 120,000 BBLS.	1	631,200	5 %	6,300	669,100	669,100	2.00	3.50	2.38	$1,592,500

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
SULFUR RECOVERY UNIT
ESTIMATE NO: 7294
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
	ESTIMATE SUMMARY										
270P	TOWERS										
300R	REACTORS										
320A	AIR COOLED HEAT EXCHANGERS										
320S	SHELL & TUBE HEAT EXCHANGERS										
370H	FIRED HEATERS										
400T	TANKS										
400V	VESSELS										
450C	COMPRESSORS										
450P	PUMPS										
480	SPECIALIZED EQUIPMENT CROLL REYNOLDS STM JET STS UNION CARBIDE H.P.U. W-L/DP/ACP/SRI SYSTEMS ELEC. PRECIP. & FLY ASH COLL. SYS CHEVRON W.W.T. PROCESS SYSTEM RALPH M. PARSONS CO. SYSTEM	1					6,148,000				$22,132,800
A	TOTAL MAJOR EQUIPMENT						6,148,000			3.60	$22,132,800
600	INSTRUMENTS	15 % M.E.					922,200			4.00	$3,688,800
620	INSULATION										
	ROUNDING										$400
A+B	TOTAL DIRECT INSTALLED COST										$25,822,000
	HOME OFFICE COSTS	15 % D.I.C.									$3,873,000
800	CATALYST & CHEMICALS										
	SUB TOTAL										$29,695,000
	CONTINGENCY	25 %									$7,424,000
	ROYALTIES										
	TOTAL INSTALLED COST	4/0/85									$37,119,000
	ESCALATION		% /YR. FOR		YEAR						
	TOTAL INSTALLED COST	4/0/85									$37,119,000

SUN REFINING AND MARKETING CO. P. E. T. S. FACTORED ESTIMATE WORKSHEET DATE:16-Mar-87

PROJECT: TURBINE FUELS PROJECT
SULFUR RECOVERY UNIT
ESTIMATE NO: 7294
JOB NO: 848768

BY: J.T.HARLAN
FOR: L. MAGILL

COST CODE	DESCRIPTION	QTY	QUOTE	DESIGN ALLOW.	FREIGHT	UNIT COST	MATERIAL COST	FACTOR LOW	FACTOR HIGH	FACTOR USED	INSTALLED COST
480	SULFUR RECOVERY UNIT S.R.U. PLANT FEED AMINE ACID GAS 78.6 LT/D S.W.S. ACID GAS 68.8 LT/D TOTAL 147.4 LT/D	1	5,800,000	5 %	58,000	6,148,000	6,148,000	2.50	4.00	3.60	$22,132,800

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