REFINERY ENERGY PROFILE

"PREPARATION"
TASK 1 REPORT

MASTER

R. W. MAIER

JULY 1977

WORK PERFORMED UNDER CONTRACT NO. EY-77-C-05-5262

GULF RESEARCH & DEVELOPMENT COMPANY
PITTSBURGH, PA.

PREPARED FOR THE

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
DIVISION OF INDUSTRIAL ENERGY CONSERVATION

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I. Summary

Work on Contract EY-77-C-05-5262, "Refinery Energy Profile" was started late in February 1977. The study is being based on Gulf's Alliance Refinery. Task #1 has now been completed and the work is on schedule and within the planned budget. Thus, the first milestone has been reached. This report presents both the background information and a summary of the work accomplished under Task #1. This information together with information in subsequent Task reports will then result in a final report.

Background on the contract is presented in Sections II and III; a discussion of the Alliance Refinery is presented in Section IV and a summary of the work under Task I is presented in Section V. A glossary of terms used for this report is found in the Appendix.

In Task #1, the refinery was separated into 12 processing units, utilities and offsites; or a total of 14 units in all to be studied individually. This was accomplished through studying the various process flow charts, and then confirming the "break-out" of units by "on-site" visits as reasonable for the identification of areas where essential data such as temperature, pressure and flow rates can be measured.

This report has been reviewed and no invention or patentable material was noted.

II. Overall Contract Work

A. Objective

The objective of this effort is the development of a technique for carrying out a refinery energy profile.

B. Technique Development

The effort will consist of five tasks whose purpose is to develop a technique for efficiently conducting energy audits on petroleum refineries. The purpose is not to establish targets for reduction in energy usage, or methods to achieve such reductions; rather, it is to develop a technique for pinpointing those elements in the refinery processes which are large energy consumers and which by being so identified would become areas for energy reduction measures.

C. The Five Tasks

1. Preparation
2. Data Collection
3. Development of Profile Reporting Technique
4. Preparation of Energy Profiles
5. Data Analysis, Recommendations

D. Completion Schedule

The completion schedule for the contract is presented as Figure 1.

FIGURE 1

"REFINERY ENERGY PROFILE" COMPLETION SCHEDULE

Intermittent Effort

Programmatic Milestones

Contract Effective Date
(February 1, 1977)

- (1) Task 1 - Complete Study Limits Generally Established
- (2) Task 2 - Complete Data Gathering
- (3) Task 3 - Complete Profile on First Unit
- (4) Task 4 - Complete Profiles on All Units
- (5) Task 5 - Complete Final Report

	Milestone Complete	Draft Report Issued X
(1)	7/15/77	7/30/77
(2)	4/1/77	4/15/78
(3)	3/1/78	3/15/78
(4)	7/15/78	8/15/78
(5)	10/15/78	10/30/78

As of April 5, 1977

III. General Discussion

A. Petroleum Refining

Crude oil as it is found in nature consists of complex mixtures of compounds containing hydrogen and carbon (hydrocarbons). In the petroleum refining process, useful products, such as gasoline, diesel oils, fuel oils and petrochemicals are manufactured from crude oil which in general is unsuited for direct use.

The various hydrocarbon compounds that are mixed together in crude oil have different boiling points, but apart from the lightest, the differences between the boiling points of neighboring members in the rising scale of molecular weight are so small that they cannot be separated by ordinary distillation. Fortunately, separation of distinct compounds is not usually necessary; through blending, common petroleum products are produced and these consist of mixtures of compounds whose boiling point ranges are not rigorously segregated but overlap instead. For example typical boiling ranges can be: gasoline 90-430°F, kerosene 350-570°F, #2 Heating Oil (Diesel) 380-650°F, Heavy Oils 650°F and above. In practice, however, there are many different grades of each product with different boiling point specifications.

Crude oils vary widely in boiling range and hydrocarbon composition. There are four main types of hydrocarbons present in crude oils: normal paraffins, isoparaffins, cycloparaffins (or naphthenes) and aromatics. Some crude oils such as Pennsylvania, consist largely of n-paraffins. Others, such as Venezuela, can be naphthenic and rich in asphalt. The U.S. Bureau of Mines classifies crude oils as paraffin base, naphthene base, or mixed base by determining the properties of key fractions distilled from the oil.

Petroleum Refining (Cont'd)

There are a number of different processes which are used in refineries to manufacture the various petroleum products. The processes used will depend on the type of crude charged to the refinery and the products to be made. Each refinery will use several of these processes.

Among the more common processes which are used are:

1. Crude Distillation - This is the first processing step in most any refinery and its purpose is to separate the crude oil into the main conventional streams such as gases, gasoline, kerosene/jet A, #2 heating oil/diesel fuel.
2. Coking - In coking, reduced crude is thermally cracked in large coking drums where a coke residue is formed. The drum overhead vapors are processed to produce gas, gasoline, fuel oils, and cracking stock.
3. Fluid Catalytic Cracking (FCC) - This process converts gas oils (petroleum fractions boiling between 650-1050°F) to mainly lower molecular weight products, such as high octane gasoline, fuel oils, LPG, etc. The process utilizes a catalyst and operates at temperatures of about 1000°F and pressures of about 20 psig.
4. Catalytic Reforming - This process is used primarily to upgrade naphthas which have a low octane number to high octane gasoline blending components containing significant quantities of aromatic hydrocarbons. The process uses a catalyst and operates in the range of 850-1000°F and 150-400 psig.

Petroleum Refining (Cont'd)

5. Distillate and Residual Desulfurization - These processes are used to improve the quality of a wide range of petroleum stocks by removal of sulfur, nitrogen and heavy metallic contaminants. The untreated charge stock is heated to temperatures up to 750°F in the presence of hydrogen and passed over a catalytic bed. Gulf-developed processes which are utilized for this purpose are Gulfining and Gulf Hydrodesulfurization (HDS).
6. Alkylation - The process combines propylenes, butylenes and amylenes with isobutane in the presence of strong sulfuric or hydrofluoric acid to produce high octane branched chain hydrocarbons (called alkylate), used for a gasoline blending component.
7. Petrochemical Production - A variety of petrochemicals are made in a refinery. These include ethylene, propylene, benzene, toluene, and xylenes. These are produced from refinery gas streams, naphtha, and gas oils by a variety of processes.

A block flow diagram of a typical U.S. refinery is shown in the attached Figure 2.

FIGURE 2 - A TYPICAL U.S. REFINERY
(Simplified)

B. Energy Consumption in Refineries

The current U.S. refinery thruput is about 14 million barrels/day of crude oil. As mentioned, the type of processing units employed at a given refinery will depend on the crude oil charged and the product demand. It has been estimated that a typical U.S. refinery consumes nearly one barrel of crude for every ten barrels it processes. This amounts to 0.1 barrel or about 600,000 BTU's for every barrel of crude processed. On this basis the refinery industry requires about 1.4 million barrels of crude per day to meet its energy needs. At the current refinery capacity, this is an energy consumption of about 8×10^{12} BTU's/day in the United States. There is general agreement that the potential exists for reducing the consumption of energy in refining by an average of perhaps 15-20% below that used in 1972. At today's rate of thruput, this means a potential savings of some 200,000 barrels of oil per day, or over 1×10^{12} BTU's per day. Thus, the potential for energy saving and reduction of oil consumption as may be identified through Refinery Energy Studies is significant.

IV. The Alliance Refinery

The Alliance Refinery was chosen for the study as a large modern refinery containing the typical processing units discussed in Section III.

The Alliance Refinery is located in Plaquemines Parish, Louisiana, on the West Bank of the Mississippi River, approximately 25 miles below New Orleans. The site occupies approximately 700 acres. It was initially designed to process 160,000 barrels per day of South Louisiana crude supplied by pipeline from both off-shore and on-shore production. Currently, the refinery can process approximately 202,000 barrels of crude per day. A picture of the refinery is shown as Figure 3.

Figure 3
GULF'S ALLIANCE REFINERY

V. Task I - Preparation

The objective of Task #1 was to study the refinery and generally organize the program. It could also be called Preparation. This involved separating the refinery into units that can be studied individually, determining the major energy consuming elements, and determining the types of data to be recorded.

Principal personnel in the Task #1 work were R. W. Maier, W. P. Olivent, and D. L. Brandt from GR&DC and O. L. Hanson and T. G. Golden from Alliance.

A. "Break-out" of Units

After looking at the refinery operation, both from as-built specifications and on-site visits, it was decided that the study could best be carried out by separating the refinery into 14 units, 12 processing units plus utilities and off-sites. These units and their capacities are listed on Figure 4. The list can be referred to as the unit break-out. A Flow diagram for the refinery, on the basis of this "break-out" is shown as Figure 5.

Figure 4

BREAK-OUT OF UNITS

<u>Unit No.</u>	<u>Name</u>	<u>Capacity, BPSD</u>
AVU-191	Atmospheric & Vacuum Unit	202,000
NU-291	Naphfining Unit	42,000
GU-292	Gulfining Unit	22,000
GU-293	Gulfining Unit	16,000
AU-491	Alkylation Unit	35,000*
SRU-591	Sulfur Unit and Tail Gas Treater	43 LT/D*
DCU-891	Delayed Coking Unit	16,000
FCCU-1291	Fluid Catalytic Cracking Unit	78,000
CRU-1391	Catalytic Reforming Unit	37,500
AEU-1791	Aromatics Extraction Unit	22,500
THDU-1792	Thermal Hydro-Dealkylation Unit	6,300
SGU-7991	Saturate Gas Unit	-
	Utilities	-
	Offsites	-

* Capacity based on product rate.

FIGURE 5. ALLIANCE REFINERY FLOW DIAGRAM

B. Major Energy Consuming Elements

The flow charts for the units were studied to determine the major energy elements involved and the type of data required for a detailed profile. These are summarized in Figure 6. At this early point it is not yet possible to know how much of this data is available with currently installed instrumentation or how much can reasonably be obtained with specially installed instrumentation or even if all of this information will be required in the technique to be developed; but that, of course, is a primary consideration in the objective of the study and will be determined as the work progresses.

It has now been determined that the first unit to be studied in detail will be the crude unit. As a follow-up to the general data requirements shown in Figure 6, a list of major energy elements for the crude unit (AVU 191) was prepared as Figure 7, with design energy values.

C. Operating History

It was found that a considerable amount of operating data is available from unit log sheets, particularly flow, temperature, and pressure information. It is now planned that this log sheet information will be compared to the detailed data gathered under Task #2 to determine its reliability and potential usefulness in preparing energy profiles.

It was also found that much information on charge rates, unit yields, and fuel usage are available from daily operating reports; and total electric power consumption from monthly utility billings. Recent studies by the refinery provided some information on steam consumption. Evaluation of this information indicated it can be useful in preparing energy profiles, but just how much and in what manner it will be utilized will become clearer as the overall refinery profile is prepared under Task #4.

Figure 6

Type of Data Required on
Major Energy Elements for Detailed Energy Profile

Item	Type Data								Other
	Type Energy Calculation	Type Stream	Flow ⁽⁴⁾	Anal- ysis ⁽³⁾	Temp Out	Temp In	Press. Out.	Press. In	
(Furnaces & Boilers)	Input	Fuel	X	X		X			
"	Output ⁽¹⁾	H.C.	X	X	X	X	X ⁽²⁾	X ⁽²⁾	For each stream
"	Output ⁽¹⁾	Steam	X		X	X	X	X	
"	Loss	Stack Gas		X	X				Air temp and humidity
"	Radiation Loss	-							Configuration with respective Area & Temp; Air temp & Vel.
Motors	Input	Power							(Amp, volts, power factor) on Watts, Mfr Eff ⁽¹⁾
"	Output ⁽¹⁾	Fluid	X	X	X	X	X	X	Mfr Eff on Driven Equip, for example, pump
Turbines	Input	Steam	X		X	X	X	X	Mfr Eff ⁽¹⁾
"	Output ⁽¹⁾	Fluid	X	X	X	X	X	X	Mfr Eff ⁽¹⁾
Reactors	Heat of Reaction	H.C.	X	X	X	X	X ⁽²⁾	X ⁽²⁾	
"	Rad. Loss	-							Configuration with respective Area & Temp; Air Temp & Vel.
Regenerators	Input	Air/Coke	X			X		X	Velocity ⁽¹⁾
"	Output	Flue Gas		X	X		X		Velocity ⁽¹⁾
"	Radiation Loss	-							Configuration with respective Area & Temp.; Air Temp & Vel.
Power Recovery	Input	Fluid	X	X		X		X	Mfr Eff ⁽¹⁾ on Expander, turbine
"	Output	Fluid	X	X	X	X	X	X	" " Driven Equip,
"	Output	Power							(Volt. amp., P.F.) or watts, Mfr Eff ⁽¹⁾
Steam Reboilers	Input ⁽¹⁾	Steam	X		X	X	X ⁽¹⁾	X ⁽¹⁾	
"	Output ⁽¹⁾	H.C.	X	X	X	X	X ⁽¹⁾	X ⁽¹⁾	
Coolers-Water	Loss ⁽¹⁾	H.C.	X	X	X	X	X ⁽²⁾	X ⁽²⁾	
"	Loss	Water	X		X	X			
Coolers-Air	Loss	H.C.	X	X	X	X	X ⁽²⁾	X ⁽²⁾	
Exchangers ⁽¹⁾	Transferred	Fluid 1	X	X	X	X	X ⁽²⁾	X ⁽²⁾	
" ⁽¹⁾	" ⁽¹⁾	Fluid 2	X	X	X	X	X ⁽²⁾	X ⁽²⁾	
" ⁽¹⁾	Rad. Loss	-							Surface Area & Temp., Air Temp & Vel.
(Misc systems such as Mixers, Dryers)	Input	Fluid	X	X		X	X ⁽²⁾	X ⁽²⁾	For each stream for Import Energy
"	Output	Fluid	X	X	X		X ⁽²⁾	X ⁽²⁾	For each stream for Export Energy
"	Input	Process Steam	X			X		X	Quality if not superheated
"	Power Input	"							(Volt, amp. P F) or Watts, Mfr Eff ⁽¹⁾
"	Output	"							(Volt, amp. P F) or Watts, Mfr Eff ⁽¹⁾
"	Input	Fuel	X	X		X			
"	Loss	Fluid	X	X	X		X ⁽²⁾		
"	Radiation Loss	-							Configuration with respective Area & Temp; Air Temp & Vel.
"	Loss	Fluid	X	X	X		X		Heating Value for H.C.

Notes:

- (1) Possible additional data for alternate calculation or cross check.
- (2) Required if a vapor phase is present.
- (3) ASTM distillation, Lt. ends analysis, and API gravity for liquids. Component Vol. % for vapors.
- (4) Where flow measurements cannot be made directly, additional information will be required.

Figure 7

AVU 191 MAJOR ENERGY ELEMENTS WITH DESIGN ⁽⁹⁾ ENERGY VALUES

Item No.	Service	Consumed ⁽¹⁾ (MM BTU/HR)	Transferred ⁽²⁾ (MM BTU/HR)	Rejected ⁽³⁾⁽⁷⁾ (MM BTU/HR)
<u>Furnaces</u>				
H-1	Atmospheric Charge	561	491	70
H-2	Vacuum Charge	<u>236</u>	<u>201</u>	<u>35</u>
	Subtotals	797	692	105
<u>Electric Motor Drivers</u> ⁽⁴⁾				
LM-1 A,B	Raw Crude Pump	1.6	1.5	0.1
LM-2 A,B	Desalted Crude Pump	2.7	2.6	0.1
LM-3 A,B	Top Pumparound Pump	0.4	0.4	(8)
LM-4	HFO Pumparound Pump	0.5	0.5	(8)
LM-6 A,B	HFO Product Pump	0.3	0.3	(8)
LM-8 A	Atm. Frac. Btms Pump	0.6	0.6	(8)
LM-10 A,B	S.R. Debut. Charge	0.6	0.6	(8)
LM-11 A,B	#2HO Product Pump	0.3	0.3	(8)
LM-12 A	Vacuum Recycle Pump	0.2	0.2	(8)
LM-13	Vacuum Residue Pump	0.3	0.3	(8)
LM-14 A,B	HVGO Prod. Pump	1.4	1.4	0.1
LM-15 A,B	LVGO Prod. Pump	0.5	0.5	(8)
LM-23 A,B	Desalter F.W. Pump	0.3	0.3	(8)
KM-4 A,V	Atm. Frac. O.H. Fan	0.6	0.6	(8)
	Misc. Motors (19)	<u>1.1</u>	<u>1.1</u>	<u>0.1</u>
	Subtotals	11.5	10.9	0.6
<u>Steam Turbine Drivers</u> ⁽⁴⁾				
LN-8 B	Atmos. Frac. Bot. Pump	0.6	0.6	(8)
LN-12 B	Vacuum Recycle Pump	0.3	0.3	(8)
LN-20 B	Boiler Circulation Pump	<u>0.1</u>	<u>0.1</u>	<u>(8)</u>
	Subtotals	1.0	1.0	(8)
<u>Water Coolers & Condensers</u>				
X-11	Crude Frac. OH Trim			32.4
X-13	LFO Prod. Cooler			6.0
X-14	HFO Prod. Cooler			8.0
X-15	LVGO PA Cooler			31.4
X-18	1st Stage InterCond.			6.5
X-19	2nd Stage InterCond.			6.0
X-20	3rd Stage InterCond.			<u>4.6</u>
	Subtotals	0	0	94.9
<u>Air Coolers & Condensers</u>				
X-7 A,B	HFO Prod. Cooler			21.0
X-8	HFO P.A. Cooler			12.3
X-9	HVGO P.A. Cooler			24.7
X-10 A-K	Crude Fract. OH Cond.			151.1
X-12 A,B	LFO Prod. Cooler			37.6
X-100	Desalter Water Effl. Cooler			<u>16.5</u>
	Subtotals	0	0	263.2

Figure 7 (page 2 of 3)

Item No.	Service	Consumed ⁽¹⁾ (MM BTU/HR)	Transferred ⁽²⁾ (MM BTU/HR)	Rejected ^{(3) (7)} (MM BTU/HR)
<u>Heat Exchangers</u>				
X-1 A-D	TPA/Crude		100.0	
X-2 A-D	HFO Prod/Crude		81.0	
X-3 A-D	HFO PA/Crude		47.1	
X-4 A,B	Atm. G.O./Crude		23.5	
X-5 A-F	Vac. Res/Crude		51.4	
X-6 A-F	HVGO PA/Crude		<u>100.0</u>	
	Subtotals	<u>0</u>	403.0	<u>0</u>
<u>Process & Misc.</u>				
V-3	Atmospheric Twr	27.1	27.1	
V-5	Side Strippers	30.7	30.7	
U-1,2,3	Ejectors	31.0	31.0	
	Miscellaneous	<u>2.5</u>		<u>2.5</u>
	Subtotals	91.3	88.8	2.5
<u>Import⁽⁵⁾</u>				
	Crude Charge	To be calculated later		
	Process Slop			
	Sour Water			
	Clarified River Water			
	Fuel Gas			
	THD-1792 Hvy. polymers			
<u>Export & Products⁽⁶⁾</u>				
	Sour Water	To be calculated later		
	Gas to SGU 7991			
	Naphtha to SGU 7991			
	HFO Products			
	HFO PA to SGU-7991			
	LFO Products			
	AGO Products			
	#2HO Products			
	HVGO Products			
	Vac TWR Btms			
	Subtotals	<u>0.0</u>		<u>0.0</u>
	Grand Total ⁽⁷⁾	901	1196+	466

Notes:

1. LHV of fuel burned + electrical power used + enthalpy change in steam used.
2. Heat is transferred from one medium to another.
3. Rejection to atmosphere directly or via heat transfer with air or water.
4. Driver efficiency assumed at 95%.
5. Sensible heat in streams to unit shall be determined relative to convenient enthalpy reference temp.
6. Sensible heat in streams from unit shall be determined relative to convenient enthalpy reference temp.
7. Radiation losses not included except on furnaces.
8. Less than 0.1 MM BTU/Hr.
9. Design for AVU-191 is 160,000 BPSD.

APPENDIX

Glossary of Terms and Abbreviations

<u>Term</u>	<u>Definition</u>
AGO	Atmospheric Gas Oil
API	American Petroleum Institute
ASTM	American Society for Testing Materials
BFW	Boiler Feed Water
BPSD	Barrels per Stream Day
BTU	British Thermal Unit
Comp.	Compressor or Component or Composition
Cut	A Petroleum Fraction of a Particular Gravity
Eff.	Efficiency
Effl.	Effluent
F.G.	Fuel Gas - A mixture of Light Hydrocarbon Vapors
Fluid	Any Liquid, Vapor, Solids, or mixture of, that will flow
Frac.	Fractionator - Used for Separating Petroleum into Fractions with different gravities.
FW	Feed Water - generally boiler feed water
Gas	A vapor - generally hydrocarbon
Gen.	Generator
GO	Gas Oil
GR&DC	Gulf Research & Development Company
HC	Hydrocarbon - a petroleum liquid and/or vapor
HFO	Heavy Furnace Oil
#2HO	#2 Heating Oil
HVGO	Heavy Vacuum Gas Oil
LFO	Light Furnace Oil

Appendix (Cont'd)

LHV	Lower Heating Value
LPG	Liquified Petroleum Gas
LT/D	Long Tons per Day (Long Ton = 2240 Pounds)
LVGO	Light Vacuum Gas Oil
Mfr	Manufacturer
Misc	Miscellaneous
MM	Million
OH	Overhead - generally the top vapor stream of a tower
PA	Pumparound
PF	Power Factor
Pres.	Pressure
Prod.	Product - a final stream of a unit operation
Rad.	Radiation heat loss - also generally includes convective loss to air
Res.	Residue
SR	Straight Run
Temp.	Temperature
Tower	A cylindrical, vertical vessel
TPA	Top Pumparound
Vac.	Vacuum - a pressure less than atmospheric
Vol.	Volume