EVALUATION AUDIT REPORT
POLISH PETROLEUM REFINERY
GDANSK, POLAND

A SELECTIVE REFINERY ANALYSIS FOR: OPERATION, ENERGY USE, ENVIRONMENTAL IMPACTS AND IMPROVEMENT OPPORTUNITIES

MAY, 1992

PREPARED BY: DAVY MCKEE CORPORATION, CHICAGO, IL USA

U.S. EMERGENCY ENERGY PROGRAM FOR EASTERN AND CENTRAL EUROPE

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
BUREAU FOR EUROPE
WASHINGTON, D.C. 20523

EVALUATION AUDIT REPORT
POLISH PETROLEUM REFINERY
GDANSK

A SELECTIVE REFINERY ANALYSIS FOR:
OPERATION, ENERGY USE, ENVIRONMENTAL IMPACTS
AND IMPROVEMENT OPPORTUNITIES
MAY, 1992

PREPARED BY: DAVY MCKEE CORPORATION, CHICAGO, IL USA
300 SOUTH RIVERSIDE PLAZA
SUITE 1800
CHICAGO, IL 60606
(312) 669-7000

PROJECT MANAGER:	ARKADIUSZ WALINSKI
LEAD / PROCESS:	WILBUR A. HOLVE
ELECTRICAL:	TADEUSZ P. RASLAWSKI
INSTRUMENTATION:	ALEXANDER I. STEINHAUS
MECHANICAL:	NORRIS A. ROBERTS
LEAD AUTHOR:	ROBERT A. JURISH

U.S. EMERGENCY ENERGY PROGRAM FOR EASTERN AND CENTRAL EUROPE

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
BUREAU FOR EUROPE
OFFICE OF DEVELOPMENT RESOURCES
ENERGY AND INFRASTRUCTURE DIVISION
WASHINGTON, D.C. 20523

USAID CONTRACT EUR-0015-C-00-1011-00

REFINERY EVALUATION AND AUDIT
GDANSK REFINERY WORKS, GDANSK, POLAND

TABLE OF CONTENTS

Davy

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

In 1991, the United States Agency for International Development (USAID), as an element of its Emergency Energy Program for Central and Eastern Europe, retained the Chicago office of Davy McKee Corporation (DMC) to perform a technical study of the seven refineries that constitute the Petroleum Refining Industry of Poland. The results of the study are presented on two levels: refinery characterization and selected refinery evaluation. This report covers the results of an audit and evaluation of the Gdansk Petroleum Refinery in Poland. A separate report covers the characterization of the Polish petroleum refining industry. Also, a separate report covers the structure and use of a computerized data base, which has been prepared from the data in response to a DMC questionnaire issued before the beginning of the field work.

The project started with meetings in early December 1990, between the USAID personnel and Polish Ministry. During the meetings, a plan and schedule were developed for the participation of Poland in the U.S. Emergency Energy Program. This evaluation report on the Gdansk Refinery contains the elements agreed upon at these initial meetings. The goals of the program were to provide a data base for future planning activities in Eastern Europe to improve the viability of the petroleum sector, support the achievement of improved energy consumption efficiency and support alleviation of adverse environmental impact. The study addressed the potential of achieving substantial improvement in energy efficiency and disposal of solid, liquid, and gaseous effluents, both by reduction in volume and method of handling. Order-of-magnitude capital requirements and return on investment associated with identified opportunities form part of these evaluation reports. The Scope of Work, or Terms of Reference for this project may be found in Appendix C of this report.

At the outset of the project, teams were organized for both the characterization and evaluation efforts and consisted of engineering professionals with many years of experience in their respective engineering disciplines in the design and technical operation of a petroleum refinery. Technical disciplines represented within the team were process, environmental, mechanical, electrical, and instrumentation engineering. It should be noted that Gdansk required that DMC sign a Confidentiality Agreement prior to release of information. Further, a similar agreement was executed with UOP of DesPlaines, IL. Each organization required review and approval of a draft report. Such review and approval has occurred.

The steps for acquisition of data for preparation of this evaluation report were divided as follows:

First, there was a preliminary, or reconnaissance visit to Poland during which a rather detailed questionnaire was furnished to the Plock Refinery representative.

The second step of evaluation and audit effort consisted of data collection through meetings with operating managers and engineers of selected process units within the Gdansk Refinery. The DMC Team visited the Gdansk Refinery on 6-8 June, 1991.

During these refinery visits, host country consultants were engaged to participate and provide technical assistance for the in-country phases of the work. In addition to such technical assistance, the consultants were able to provide customs and language interpretation to insure mutual understanding of the material presented. Communication was facilitated by multi-language fluency within the DMC team.

The program for the evaluation process was discussed and agreed upon with the General Director of Gdansk and the refinery management. The in-depth review was confined to the refinery production block and connected off-site facilities. The maintenance system and power plant were reviewed as part of the whole complex. The evaluation was done in close cooperation with refinery management, team members, and refinery personnel reviewing design and process documentation within the context of the following areas:

- energy consumption improvements
- flexibility of the units and impact of crude oil changes
- reduction of environmental impact

Each major processing group in the refining portion of the complex, including the power plant, was reviewed. The process evaluation normally consisted of a meeting with the appropriate process unit manager together with a translator, if necessary, for an initial process flow diagram review. The team mechanical and instrument engineers often attended these reviews to minimize repetitious queries. The DMC team received strong cooperation from the process unit managers.

Following the review sessions, a unit visit generally was conducted to observe directly all equipment items and check temperatures, pressures, and performance.

The Gdansk Refinery is located northeast of the City of Gdansk on the shore of the Baltic Sea. The original refinery was a hydroskimming plant designed to produce gasoline, distillates, and residual fuel oils. It was erected in 1973-75. A year later, construction was started on facilities for lube oil and asphalt production.

The Gdansk Refinery was selected for study because it is one of the principle refineries in Poland. The refinery uses modern western design with electronic instrumentation and employs a high degree of U.S. and European technology. Although this evaluation considers all units of the refinery, the Crude Unit 100, Vacuum Unit 900, and the Gas Oil Hydrotreating Unit were subjected to a more complete review. These three units are considered to be the major factors in the overall refinery energy balance and possible contributions to potential savings. The operational observations for these units and the power plant are presented in this report.

The Port of Gdansk is available for importing crude from the Middle East, the North Sea, and other areas of the world. The refinery also can be supplied with Russian crude via pipeline through a branch from the Friendship pipeline as it passes through Poland on its way to Germany. The capacity of the Gdansk Refinery is 3.2 million tonnes per year (73 000 BPSD).

The petroleum refining industry in Poland, as in the other Eastern European countries, has been predominantly based on a single source of crude oil from the USSR.

The crude oil in the past was supplied at relatively fixed and stable low term prices. Hard currency was not an issue. Products were produced for the domestic market. The primary performance criteria was to satisfy the domestic market, with cost a very secondary consideration. A monopoly distribution and marketing network was developed for gasoline, diesel, and fuel oils. The retail prices were fixed by the state.

Beginning in 1991, supplies of crude oil from the USSR were at international prices payable in convertible currencies. At times, the USSR reduced their deliveries up to 50% of contractual obligations.

Currently, a 70/30 mix of light Iranian and low sulfur Statfjord (Norwegian North Sea Crude) is used and is satisfactory for both lube oil production and for controlling the sulfur content of the crude charge to the refinery at a maximum of 2.0 weight percent. The maximum throughput rate for this blend, at a 42 weight percent residual fuel is approximately 375 tonnes per hour, which is equivalent to 2 952 000 tonnes per year. Recent operations (1990) included a throughput of 2 130 000 tonnes per year, indicating a 72 per cent operational rate. This reflects a declining demand, as reported by the refinery staff, due to competition from lower priced western imports.

The refinery is designed based upon air cooling and electric motor drives. A supplementary cooling system for lower temperature services and trim cooling is also provided.

An important aspect of energy savings in the refinery design is that all heaters in each of the two trains of fuels and lube units are connected to a 120 meter high flue gas stack via breaching through waste heat boilers utilizing induced draft fans.

Energy improvement opportunities are presented individually in Section J. The opportunities are categorized according to magnitude and projected time of achievement and are summarized as follows:

- Reduce product/feed losses by recovering flare gas, installing a crude oil custody transfer system, minimizing tank farm and inter-unit transfer losses, and establishing a committee responsible for hydrocarbon losses.

- Provide training in business management, capital budgeting, and project justification, and provide the operations staff with training and exposure to courses in refining operations.

- Provide access to a refinery/chemical engineering process simulation program, a linear programming model for optimizing refinery operations, and an inventory/maintenance historical database system.

- Reduce motive power losses through impeller trimming and/or consider the use of power recovery turbines in high pressure drop liquid let down service.

- Reduce system heat or steam usage through improved insulation and heater refractory; reduce process stripping steam, minimize heat exchanger fouling; change steam ejectors to a vacuum pump; replace or improve soot blowers; and consider the installation of a hot oil loop in the furfural and propane deasphalting units.

- Increase production through improved on-stream time by reducing corrosion downtime problems.

- Investigate means to improve fractionation through better tray design or application and consider the use of a crude unit pre-flash tower.

- Consider the addition of a visbreaker for vacuum residue and evaluate converting the Ultraformer when retired to pentane/hexane/isomerization/service.

Environmental improvement opportunities are presented individually in Section K. They include:

- Conversion to low nitrogen oxide burners
- Installation of flue gas analyzers
- Installation of emissions monitors
- Study losses of volatile organics
- Provide training through seminars on current Western environmental practices.

Mechanically, the equipment in Gdansk is of Western manufacture and is well maintained. Western standards are used for materials and design. Heat exchangers and oil burner atomizing nozzles are manufactured in Poland to a highly efficient in-house design. The maintenance and repair shops are to be complemented for their excellent accomplishments in maintaining and repairing equipment.

The vessel code in Poland does not allow more than 100,000 hours of operation for pressure vessels. The DMC team suggests that the Polish code and vessel metallurgical design be evaluated in context of possible vessel life extension.

The DMC team further believes that a re-evaluation of the practice of a fixed interval maintenance turn around schedule is in order, with consideration given to past performance of the units. On-stream, non-destructive testing for corrosion would also aid in increasing on-stream time.

Overall, Gdansk is a modern, well run and maintained refinery, and is to be complemented on their fine facility.

A. INTRODUCTION

The Davy McKee Evaluation Team would like to express its gratitude to the management and staff of the Gdansk Refinery for their excellent cooperation and assistance. Special thanks are due also to the following individuals and the entire personnel in their department.

Marek P. Sokolowski	Technical Director
Roman Partykiewicz	Chief of Refinery Energy Department

1. OBJECTIVES

The primary objective of this report is to present opportunities for energy improvement and reduction of emissions for the Gdansk Refinery. A secondary objective is to characterize the modifications for achieving expected benefits in accordance with the magnitude of effort and capital requirements anticipated. Other goals of the study include a consideration of refinery operating flexibility, an evaluation of fuel switching, including the use of coal as a substitute energy supply, and an observation of the plant's general condition and of its maintenance practices for their effect on operations.

The stated USAID objectives of this study are to:

- Identify changes in operating practices and low cost modifications to equipment that can be immediately implemented to increase the efficiency of energy utilization; to conserve energy by avoiding its unjustified use; and to reduce, as far as practical, undesirable gaseous, liquid, and solid effluents.

- Identify, characterize, and recommend more extensive changes in practices, equipment, and modifications to the process units, which appear justifiable but at the same time require further study possibly using inputs that are not yet available.

- Assist the management of each selected refinery in each country, as needed, in implementing the changes identified above through on-the-spot assistance including training sessions for refinery personnel.

This report details the results of the Evaluation and Audit Study. The recommendations of the study to improve energy utilization operations (yields and practices) and environmental conditions are categorized as:

- Immediate minimum cost recommendations: This category covers no cost to low cost modifications to the refinery that will be relatively inexpensive and easy to implement. The refinery can generally implement the recommendations with its internal resources.

- Short term intermediate cost recommendations: This category includes modifications and/or additions to the refinery that will be characterized by costs related to equipment purchases and/or changes to process operating conditions that could be considered significant. Implementation requires outside and appropriate resources.

- Long term substantial cost recommendations: This category characterizes primarily significant modifications to current processing capabilities or installation of additional process units to improve the refiner's competitive refining position into the 21st century. Implementation of this type of recommendation would be potentially expensive and time consuming. Implementation requires outside resources and justification based on changes in crude oil supply and in market conditions.

2. REFINERY SELECTION

The Gdansk Refinery was selected for study because it is one of the principal and most modern refineries in Poland. Although this evaluation considers all units of the refinery, the Crude Unit 100, Vacuum Unit 900, and the Gas Oil Hydrotreating Unit were subjected to a more complete review. These three units are considered to be the major factors in the overall refinery energy balance and possible contributors to potential savings.

3. SUMMARY OF FIELD ACTIVITIES

The Davy McKee Corporation (DMC) evaluation of the Gdansk Refinery took place over a two-week period from 6-18 June 1991. The evaluation team consisted of: T. Raslawski, Electrical; A. Steinhaus, Instrumentation; N. Roberts, Mechanical; A. Lason, a Polish consultant with extensive in-country refinery experience who also provided translation where needed; W. Holve, Refinery Process Engineer; and A. Walinski, Project Manager. The content of this report is enhanced through the insights, experience, and personal knowledge provided by the DMC in-country consultants.

The program for the evaluation was discussed and agreed upon with the General Director of Gdansk and the refinery management. The in-depth review was confined to the refinery production block and connected off-site facilities. The maintenance system and power plant were reviewed as part of the whole complex. The evaluation was done in close cooperation with refinery management, team members, and refinery personnel reviewing design and process documentation within the context of the following areas:

- energy consumption improvements
- flexibility of the units and impact of crude oil changes
- reduction of environmental impact

Potential solutions were discussed and agreement or an understanding was reached with the refinery personnel on the technical aspects of the review.

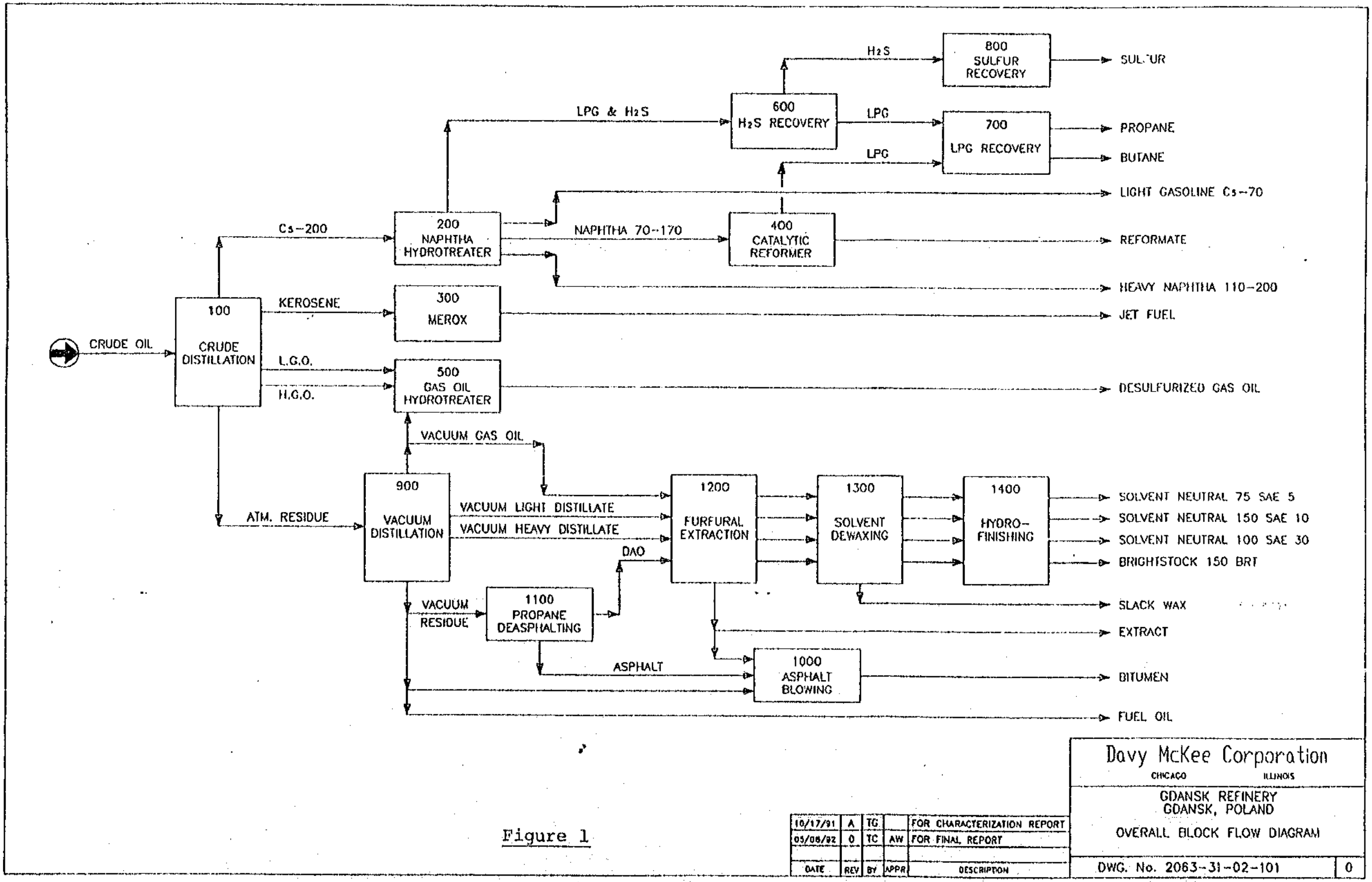
Each major processing group, as shown in the Block Flow Diagram, Figure 1, in the refining portion of the complex including the power plant was reviewed. The process evaluation normally consisted of a meeting with the appropriate process unit manager together with a translator, if necessary, for an initial process flow diagram review. The team mechanical and instrument engineers often attended these reviews to minimize repetitious queries.

The review meetings proceeded successfully overcoming the bilingual interpretations of the review items. The DMC team received strong cooperation from the process unit managers in answering queries or in seeking answers to more complex questions.

Following the review sessions, a unit visit generally was conducted to observe directly all equipment items and check temperatures, pressures, and performance.

4. REFINERY DESCRIPTION

The Gdansk Refinery is located approximately 10 km from the Baltic Sea Coast of Poland. The refinery is modern and combines an automotive fuels and lubricating oil facility designed for Mid-Eastern Kuwait and UAE Zakum crude oils. The facility was constructed between 1972 and 1974 by the Italian firm Snam Progetti. The refinery was constructed in two stages. The hydroskimming fuels section employs US technology licenses for catalytic reforming (Amoco) and hydrodesulfurization (UOP) units. The separate and independent vacuum distillation and lube oil train, based upon licenses from the West German firm Edeleanu, was commissioned in 1976. There is no heat integration between the two major distillation units.



800
SULFUR
RECOVERY
SULFUR
H2S
600
H2S RECOVERY
LPG & H2S
LPG
700
LPG RECOVERY
PROPANE
BUTANE
LIGHT GASOLINE C5-70
C5-200
200
NAPHTHA
HYDROTREATER
NAPHTHA 70-170
400
CATALYTIC
REFORMER
REFORMATE
HEAVY NAPHTHA 110-200
KEROSENE
300
MEROX
JET FUEL
CRUDE OIL
100
CRUDE
DISTILLATION
L.G.O.
H.G.O.
500
GAS OIL
HYDROTREATER
DESULFURIZED GAS OIL
VACUUM GAS OIL
ATM. RESIDUE
900
VACUUM
DISTILLATION
VACUUM LIGHT DISTILLATE
VACUUM HEAVY DISTILLATE
DAO
1200
FURFURAL
EXTRACTION
1300
SOLVENT
DEWAXING
1400
HYDRO-
FINISHING
SOLVENT NEUTRAL 75 SAE 5
SOLVENT NEUTRAL 150 SAE 10
SOLVENT NEUTRAL 100 SAE 30
BRIGHTSTOCK 150 BRT
SLACK WAX
EXTRACT
VACUUM
RESIDUE
1100
PROPANE
DEASPHALTING
ASPHALT
1000
ASPHALT
BLOWING
BITUMEN
FUEL OIL
Davy McKee Corporation
CHICAGO ILLINOIS
GDANSK REFINERY
GDANSK, POLAND
OVERALL BLOCK FLOW DIAGRAM
DWG. No. 2063-31-02-101 0
10/17/91 A TG FOR CHARACTERIZATION REPORT
05/08/92 0 TC AW FOR FINAL REPORT
DATE REV BY APPR DESCRIPTION

Figure 1

The process units and their relationships as shown on the Block Flow Diagram Figure 1, are itemized below:

100	Crude Distillation
200	Naphtha Hydrotreater
300	Kerosene Sweetening (Merox)
400	Catalytic Reforming
500	Gas Oil Hydrodesulfurization
600	H_2S Recovery (MEA, Gas Desulfurization)
700	LPG Recovery
800	Sulfur Recovery - Claus Process
900	Vacuum Distillation
1000	Asphalt Blowing
1100	Propane De-asphalting
1200	Furfural Extraction
1300	Solvent Dewaxing
1400	Lube Oil Hydrofinishing
	Waste Treating Unit
	Water Treating Unit

Crude Unit 100, Vacuum Unit 900, Gas Oil Hydrotreater 500, and the power plant were reviewed in detail. The operational observations for these units are presented in this report. The other units were reviewed briefly and, although not discussed in Section C, some portions of the facilities are mentioned in this report. The energy consumption data in Section B, for example, includes information for units itemized above.

The original refinery design was based on processing the following crudes with an on-stream factor of 328 stream days per year.

TABLE A.1. - CRUDE SUPPLY

Location	Quantity (tonnes/year)
Kuwait	1 340 000
Zakum	1 820 000
Total	**3 160 000**

Currently, a 70/30 mix of light Iranian and low sulfur Statfjord (Norwegian North Sea Crude) is used and is satisfactory for both lube oil production and for controlling the sulfur content of the crude charge to the refinery at a maximum of 2.0 weight percent. The maximum throughput rate for this blend, at a 42 weight percent residual fuel make, is approximately 375 tonnes per hour which is equivalent to 2 952 000 tonnes per year. Recent operations (1990) included a throughput of 2 130 000 tonnes per year indicating a 72 per cent operational rate. This reflects a declining demand, as reported by the refinery staff, due to competition from lower priced western imports.

The refinery is principally based upon air cooling and electric motor drives. A supplementary cooling system for lower temperature services and trim cooling is also provided. The Di-Me Dewaxing propane refrigeration power is supplied by a back pressure steam turbine with the low pressure steam being utilized within the unit for solvent evaporation and heat tracing.

An important aspect of energy savings in the refinery design is that all heaters in each of the two trains of fuels and lube units are connected to the 120 meter high flue gas stack via breaching through waste heat boilers utilizing induced draft fans.

Crude Unit 100, Vacuum Unit 900, and the Gas Oil Hydrotreating Unit 500 were selected for further evaluation, and the results of these studies are described in Section C.

5. TYPES OF ENERGY IMPROVEMENT OPPORTUNITIES

Energy improvement opportunities are presented individually in Section J. The opportunities are categorized according to magnitude and projected time of achievement and are summarized as follows:

- Reduce product/feed losses by recovering flare gas, installing a crude oil custody transfer system, minimizing tank farm and inter-unit transfer losses, and establishing a committee responsible for hydrocarbon losses.

- Provide training in business management, capital budgeting, and project justification, and provide the operations staff with training and exposure to courses in refining operations.

- Provide access to a refinery/chemical engineering process simulation program, a linear programming model for optimizing refinery operations, and an inventory/maintenance historical database system.

- Reduce motive power losses through impeller trimming and/or consider the use of power recovery turbines in high pressure drop liquid let down service.

- Reduce system heat or steam usage through improved insulation and heater refractory; reduce process stripping steam, minimize heat exchanger fouling; change steam ejectors to vacuum pump; replace or improve soot blowers; and consider the installation of a hot oil loop in furfural and PDA units.

- Increase production through improved on-stream time by reducing corrosion downtime problems.

- Investigate means to improve fractionation through better tray design or application and consider the use of a crude unit pre-flash tower.

- Consider the addition of a visbreaker for vacuum residue and evaluate converting the Ultraformer when retired to pentane/hexane/isomerization service.

6. TYPES OF ENVIRONMENTAL IMPROVEMENT OPPORTUNITIES

Environmental improvement opportunities are presented individually in Section K. They include:

- conversion to low nitrogen oxide burners

- installation of flue gas analyzers

- installation of emissions monitors

- study losses of volatile organics

- provide training through seminars on current Western environmental practices.

B. REFINERY ENERGY BALANCE

1. OPERATING UNIT ENERGY USE

To properly undertake an appraisal of the relative energy efficiency of the Gdansk Refinery operations, an effective measure of the performance of typical US refining units was essential. The performance criteria reflects the improvement occasioned by the energy savings programs of recent years. Two published references describe energy consumptions in the US refining industry. The results are based upon surveys and energy audits conducted through the mid 1980s by which time the US refining industry had recorded energy utilization improvements of about 25 percent from the time of the oil crisis in 1972. Progress in energy efficiency still continues but at a reduced rate of 1 to 2 percent per year.

Naturally, the US statistics on refinery unit energy demands were presented in the English system of measurement and volume terms (e.g. BTU/standard US barrel of feed). By convention, European refiners prefer the metric system of measurement and mass terms (e.g. kcal/metric tonne). Consequently, a reasonable conversion to European practice was made by providing typical API gravity values for unit feedstocks. Furthermore, suitable conversions to basic fuel oil equivalence in kilocalories were made for electric power, steam generation or consumption, and cooling water circulation rates. In this manner a table of Refinery Unit Energy Demand criteria was established and used in the assessments of the Polish refiners energy efficiency and performance. These energy demand criteria are presented in Appendix E.

The Gdansk Refinery records all utilities consumption by unit on a monthly basis, which are summarized both quarterly and annually. Similarly, the total feed processed through each unit is documented, thus permitting the specific utilities consumption for each unit to be calculated and compared with the projected design rates. The operating management utilized these statistics as a useful guide to unit energy performance and as a measure of the energy economies achieved in terms of fuel, steam, power, and cooling water consumption.

Furthermore, a consolidated annual energy balance is produced in which all utility flows are converted to Gigajoules (GJ) including the off-sites and powerhouse activities. Unfortunately, this summary fails to include the high pressure steam production as well as the electrical power generation or import so that it is impossible, with the information provided, to effect a complete heat or energy closure for the whole refinery. Nevertheless, full information is provided for the process operations, including the listing of steam production from the process waste heat boilers.

The plant is mainly air-cooled with a supplementary trim cooling water system, and therefore it is not practical to measure the total heat rejection from the refinery as a whole to independently back-check the degree of heat utilization. Similarly, this applies to the lube plant tempered water system which is also air-cooled. Within the limitations noted, the energy information is well presented and accurate.

Due to extensive air cooling, a refinery heat balance closure would not be feasible except through the use of an extensive indirect procedure of measuring and calculating the enthalpy changes in all the relevant process streams. Only under performance test run conditions for individual units could such a program be considered practical.

A compilation of the utilities consumption for each of the refinery units converted to "total energy demand" was made and compared directly with typical US practice. The results are shown in Table B.1.1.

The refinery fuels and lube operations in combination appear to be nearly equivalent to competitive Western practice, although trailing in energy efficiency by approximately 3 percent. Some individual units show more serious deficiencies, which was also well appreciated by the Gdansk operating staff. For example, the atmospheric distillation tower preheat train arrangement has already been improved but still includes at least one questionable service, so it is not surprising that there is a clear indication that some degree of energy improvement should be possible. Further note that the Atmospheric Distillation Unit also includes the Kerosene Merox Operation and that some extent of energy deficiency must be attributed to the present rather low (72%) operating rate.

The Ultraformer indicates a similar deficiency, but planning is already progressing on a new Continuous Catalytic Reforming Unit (UOP CCR).

The gas oil hydrotreater appears to be quite efficient, which is very likely due to charging hot feed to the unit. Additional improvements for this unit are in the planning stages.

In the lube section, only the Di-Me dewaxer shows a considerably higher energy demand than US values. This could be due to the high steam load to the refrigeration compressor, but the exhaust low pressure steam is also utilized for solvent evaporation which should be highly efficient. The other feature may be the intrinsic differences between the Di-Me and MEK-Toluene processing schemes. An additional factor is the quality of the crude oil stock being processed and, perhaps, the lower pour point levels of the finished lube stocks requiring higher refrigeration loads.

In another area of refinery operations, a significant element to refinery energy efficiency is associated with material loss control. An accepted goal of good refinery practice in the US is to contain losses to within the region of 0.5 weight percent. This figure represents unavoidable or unrecoverable losses sustained through process unit upsets, start-up or shutdown flarings, leakage or spillage, "fugitive" emissions from tankage or vents, etc. The refinery operations are aimed at keeping all losses to a bare minimum consistent with the design and condition of equipment.

The comprehensive total energy consumption tables for the Gdansk refinery during the years 1989 and 1990 lists unit feed rates but unfortunately does not indicate the calculated loss rate for the overall refinery operation. However, loss figures were provided for the operation of several major units including the Crude Distillation Unit which recorded loss rates which varied from 0.91 to 1.68 weight percent between 15 January and 30 March, 1991. The Ultraformer mass balance data showed a loss of 0.86 weight percent. This information indicates that important improvements in loss control should be possible at Gdansk with closer attention and greater vigilance in operating practice. Of course, it is also possible that mass balance accounting could be in error because of the lack of suitably calibrated instrumentation. If proved, these losses represent a significant opportunity for energy recovery as well as a direct financial loss. For example, if the crude unit loss could be reduced from an average of 1.25 weight percent down to a more acceptable level of 0.5 weight percent, a recovery of 22 500 tonnes per year of hydrocarbons will result, which is worth about $2 500 000 when valued as fuel oil. DMC recommends undertaking an in-depth review of the refinery mass accounting system with the correction of any deficiencies that may be found.

TABLE B.1.1. - ENERGY EFFICIENCY COMPARISON
Gdansk Refinery Operations 1990 Compared with Typical US Operations

No.	Unit	1990 72% Operating Capacity tonnes/yr	Specific Energy Demands per tonne				Total Energy Demand (kcal/tonne)	Total Energy Demand (Gkcal/yr)	Total Energy Demand (%)	US Specific Energy Demand (kcal/yr)	US Total Energy Demand (Gkcal/yr)
			Fuel (kcal)	Steam (kg)	Elec (kWh)	CW (m^3)					
					FUELS PLANT (1990)						
100	ATM Dist	2127810	152624	40.2	5.0	0.4	193092	410.9	20.2	175000	372.4
200	Naphtha H'treat	554884	178897	4.8	12.6	1.3	213295	118.4	5.8	200000	111.0
300	Kero Merox	68865	0	0.0	0.0	0.0	0	0.0	0.0	10000	0.7
400	Ultraformer	337974	656832	521.2	7.8	5.7	1043830	352.8	17.3	950000	321.1
500	Gas Oil H'treater	421152	130889	3.1	2.4	1.4	139761	58.9	2.9	215000	90.5
600	H_2S Recovery	3055	0	3485	55.98	0.0	2573572	7.9	0.4	3650000	11.2
700	LPG Recovery	45593	0	250.8	44.4	17.1	292380	13.3	0.7	165000	7.5
800	Sulfur Plant	3055	32800	-1075	11.9	35.0	-670140	-2.0	-0.1	-1000000	-3.1
	Fuel Blend'g	1419295	0	34.2	1.8	0	28263	40.1	2.0	20000	28.4
	Total Fuels	4981683					200760	1000.1	49.1	188623	939.7
	% of Crude Run @ 9884000 kcal/tonne (FOE)							4.76			4.47

TABLE B.1.1. - ENERGY EFFICIENCY COMPARISON - continued
Gdansk Refinery Operations 1990 Compared with Typical US Operations

No.	Unit	1990 72% Operating Capacity tonnes/yr	Specific Energy Demands per tonne				Total Energy Demand (kcal/tonne)	Total Energy Demand (Gkcal/yr)	Total Energy Demand (%)	US Specific Energy Demand (kcal/yr)	US Total Energy Demand (Gkcal/yr)
			Fuel (kcal)	Steam (kg)	Elec (kWh)	CW (m^3)					
	LUBE OPERATIONS										
900	Vac Dist	907340	121574	137.7	6.9	9.7	240210	218.0	10.7	250000	226.8
1000	Asphalt (est)	81360	90165	86.6	17.0	0.0	191479	15.6	0.8	100000	8.1
1100	PDA	127479	298560	147.0	31.6	9.5	483000	61.6	3.0	750000	95.6
1200	Furfural	451094	281480	134.8	3.1	8.0	388134	175.1	8.6	525000	236.8
1300	Dewaxing	284998	0	1,593.7	35.1	19.4	1211524	345.3	17.0	950000	270.7
1400	H'Finishing	195508	31050	141.0	4.0	11.1	145884	28.5	1.4	200000	39.1
	Lube Blend'g	195508	0	0.0	0.0	0.0	35400	6.9	0.3	20000	3.9
	Total Lubes	2243287					379315	850.9	41.8	392801	881.2
	% of Crude Run @ 9884000 kcal/tonne (FOE)							4.05			4.19
	Waste Water Treatment							10.0	0.5		10.0
	Misc. Services							175.5	8.6		150.0
	Complete Refinery Operations							2036.5	100.0		1980.8
	% of Crude Run @ 9884000 kcal/tonne (FOE)							9.68			9.42
	Energy Req't - Btu/BBL Crude Feed @ 6000000 Btu/BBL (FOE)							580990.9			565108

2. FUEL SYSTEM

2.1. Fuel Sources

The Gdansk Refinery uses residual bottoms from the atmospheric and vacuum towers for fuel. This fuel is blended with treated gas oil or diesel when the sulfur content is so high that the flue gas would exceed 0.15 volume percent sulfur dioxide. Fuel gas is supplied to various using sites within the refinery. All fuel is processed from the crude supplied to the refinery. The fuel oil used in the refinery is equivalent to approximately 9 percent of the crude oil feedstock. Table B.2.1.1. contains selected fuel properties.

TABLE B.2.1.1. - PROPERTIES OF REFINERY FUELS

Refinery Fuel	Heating Value (GJ/tonne)	Sulfur (wt%)	Viscosity cs@80° C	Flash Point Min °C	Ash Max wt%
Fuel Gas	51.18	---	---	---	---
Fuel Oil	41.2	3.0	122	110	0.2

2.2. Fuel Distribution

The liquid fuel is heated after blending and pumped to the user unit in insulated lines. Gaseous fuel is scrubbed and piped to the user units. The fuel gas system is steam traced and provided with a local liquid knockout drum. Table B.2.2.1. illustrates the fuel distribution system within the refinery.

TABLE B.2.2.1. - REFINERY FUEL DISTRIBUTION SYSTEM

Unit Number	Unit Description	Connection to	
		Fuel Oil	Fuel Gas
100	Atmospheric Distillation	X	X
200	Light Distillate HDS	X	X
400	Catalytic Reforming	X	X
500	Gas Oil HDS	X	X
800	Claus Unit	---	X
900	Vacuum Distillation	X	X
1000	Bitumen Blowing & Blending	X	X
1100	Propane Deasphalting	X	X
1200	Furfural Extraction	X	X
1400	Lube Oil Hydrofinishing	X	X
3500	Flare	---	X
3700	Fuel Oil Blending for Power Station & Process Units	X	
---	Waste Water Treatment	---	X
---	Power Station	X	X
---	Laboratory	---	X

2.3. Fuel Users

Power House

The power boilers use pressure atomizing liquid nozzles. The firing rate is controlled by the fuel pressure at the nozzle. No steam is used to aid atomization.
One power boiler is used on stream while a standby boiler is kept ready by steam heating so that it may immediately be placed into service if needed.

Process Heaters

The process heaters use the same blended liquid fuel as does the power house.

Sludge Incinerator

Fuel gas is burned in the fluidized bed sludge incinerator at a usage rate of 400 Nm^3/h.

Sulfur Recovery Furnace

The Claus unit furnace uses fuel gas in varying amounts to oxidize the hydrogen sulfide. Highly concentrated hydrogen sulfide requires less fuel gas.

Rotary Kiln

As of June 1991, the Gdansk Refinery has a rotary kiln under construction. This kiln will process the hydrocarbon contaminated soil found in abandoned settling ponds of the waste treatment unit. The kiln will be fired using fuel gas.

3. STEAM SYSTEM

3.1. Steam Generation

High pressure steam at 7.5 MPa is supplied by two boilers in tandem delivering 40 to 160 tonnes per hour depending upon demand with a third boiler in reserve. In addition, steam at lower pressures is recovered from process steam generators and flue gas waste heat boilers in the process area of the plant.

3.2. Steam Levels

The steam pressure levels utilized in the Gdansk Refinery are:

7.5 MPa for high pressure turbine generator
2.0 MPa for process turbine drives and heating
0.6 MPa for process heating, stripping, and utilities

3.3. Steam Users

The high pressure steam is used for electric generation. The lower pressure levels are used for turbine drives, process heating and stripping and utility services as noted above. It was stated that condensate return to the power house averaged 40 percent of the refinery steam usage.

4. ELECTRIC POWER SYSTEM

4.1. Electricity Sources and Generation

The refinery is fed with electric power from two sources:

- national power system
- refinery central heating station.

The central heating station is equipped with two turbogenerators (made in France) that drive generators rated at 6 kV, 18.8 MVA each. A tabulation is included in Appendix F showing the distribution of purchased and plant generated electrical power.

4.2. Electric Distribution System

The electrical system at Gdansk Refinery is very stable and reliable. During the past two years, the refinery has not experienced a power outage.

The power supplied to the Gdansk Refinery is from the national power system by the Utility Power Company. Power comes from three independent feeders at 110 kV on overhead lines: Port, Blonie 1, and Blonie 2. Each 110 kV overhead line is suitable to feed two transformers at any time. Two lines provide power, the third is spare. Switching system is at 110 kV and can feed any transformer from any of the three lines.

Three main transformers rated 20 MVA, 110 kV primary and 6 kV secondary provide medium voltage to Gdansk Refinery for 6 kV drives and power distribution to 31 local substations. Two main transformers are always in operation, the third is a spare. The operating transformers are working at 50% load. One transformer at 100% load can feed the Gdansk Refinery. The spare transformer is de-energized. Once a month, for period of 24 hours, the spare transformer is energized for tests.

For power factor correction, two capacitor banks, at 900 KVAr each, are employed on the 6 kV system. The capacitor banks are connected to the system only when local generators (G1 and G2) are not in operation. At the level of 380 VAC, a system total of 5 040 KVAr (capacitors) are employed for power factor correction (capacitor banks are from 60 KVAr to 240 KVAr). As observed on 11 June 1991 at 11:45 am, the average power factor was 0.92. The refinery is not paying the Utility Power Company a low power penalty fee.

The central grid grounding system, with a resistance of less than 5 ohms (Polish code required maximum is 5 ohms), is checked every six years. The lightning system is checked every year during February and March and repairs are completed by 15 April which is typically the beginning of the lightning season in Poland.

Equipment, devices, and instruments are well maintained and in very good condition. Secondary protection instruments and small compressors, which operate the vacuum switches, are of non-domestic manufacture (BBC, Brown Boveri, Landis and Gyr). All other equipment and devices are domestic (Polish).

4.3. Electric Power Users

Power at the 6 kV level is distributed between the main substation GPZ-6kV and unit substations as listed:

Unit Substation	Unit/Facility Served
S1-6kV	Distillation ATM/VAC, Merox & Naphtha HDS
S2-6kV	Reforming, gas oil HDS, hydrogen sulfide Rec, LPG recovery Claus, sulfur loading and lube oil hydrofinishing
S3-6kV	Propane deasphalting, furfural extraction, cool water system, Di-Me
S4-6kV	Crude TK farm, flare, loading, slope pumps, LPG pumps
S5-6kV	Waste water treatment and Gestra
S6-6kV	Water treatment (demineral condition), nitrogen and Administration Building
S7-6kV	Power plant
S8-6kV	Product tanks
S9-6kV	Water intake/Water supply to refinery
S10-6kV	Asphalt blowing, intermediate tanks, product tanks, and loading

22

All feeders are three conductor, aluminum, underground (direct buried) and manufactured in Poland. All 56 transformers are 6kV to 0.4kV, between 400 KVA and 1600 KVA, are oil-cooled, and made in Poland (Elta-Lodz). No leaking spots of oil were observed at the transformers. Feeders to power distribution panels and motor control centers are connected by aluminum bus, short runs, or aluminum cables. The power distribution panels and motor control centers were manufactured in Poland. All of the above mentioned equipment was observed to be in good condition and well maintained.

All of the power feeders between the motor control centers and the motors are four conductor aluminum cables, three phases plus ground. Feeder cables are routed in cable trays.

Most of the motors, approximately 98%, were imported from Germany, England, France, and Italy. Only 2% of the motors were manufactured in Poland. All motors are single or two speed with across the line starting. There are no variable speed type drives in the plant. Most process drives are controlled locally (start/stop). Others are controlled both locally and from the unit control rooms. All push button stations were manufactured in Poland. The motors, equipment, and devices observed are suitable for their location (NEMA classification) and are in good condition.

Lighting

Lighting level is adequate and per code requirements at the process areas, tank farms, roads, and buildings. However, there is over design in a number of fixtures and some fixtures are on continuously during the night. This situation could be improved by installing additional local switches, then the operators could turn them on as required.

The majority of the lighting is incandescent. The remainder consists of mercury, fluorescent, and low pressure sodium. The supply lighting voltage level is 220 VAC. Poor lighting levels predominate in the process control rooms and compressor rooms due to burned-out fluorescent tubes, missing tubes, and other malfunctions. Emergency lighting in the power house operates at a 220 VDC from two sets of batteries with 200 Ah capacity. Emergency lighting in the process areas operates at 110 VDC and is fed from batteries with a 150 Ah capacity.

Buildings and electrical rooms

Poor construction and/or material has led to cracks in buildings and leaking roofs, which is evident at substation S1. Electrical rooms (substations, MCC) are not heated and are only ventilated by forced air (fans). Electrical rooms and cable tunnels are oversized with a lot of unused space. All electrical rooms are clean, and spare equipment is well kept and organized.

Further information on the electrical system can be found in F.3.8 and Appendix D.

5. COOLING WATER SYSTEM

5.1. Water Source

The cooling water for the Gdansk Refinery is pumped from an intake located 9.3 kilometers upstream from the salt water mouth of the Vistula River on the Motlawa River. The intake reservoir's normal level is approximately 20 centimeters above mean sea level. Any unusually high tide in the Gdansk Bay presents an unwanted risk of intaking salt water.

The first stage pumps are located in a pumphouse with the suction level normally below the intake level, but there are times when the river flow is low and the bay tide is also low so that the pumping prime must be established with vacuum pumps. This requires that the pump seals be capable of vacuum as well as pressure. The five intake pumps each have a capacity of 1230 cubic meters per hour. The river water usage permit limits the intake to the extent that only two pumps (2460 cubic meters per hour) are run simultaneously.

The first-stage pumps discharge to a holding reservoir with a capacity of 650 000 cubic meters capacity. On 7 June 1991 the holding reservoir level was 1.5 meters below sea level.

The second stage pumps deliver the water to the refinery through two separate buried pipe lines running a distance of approximately 16 kilometers. There are six main pumps, rated at 576 cubic meters per hour each. Normal usage limits the flow rate, by permit, to 478 cubic meters per hour. Emergency usage such as fire water supply allows full capacity of both pipelines until the reservoir is dry.

5.2. Water Treating

Raw water is received in the powerhouse where it is treated in the following order:

- Decarbonization
- Settling tank
- Lime, iron sulfate, and flocculent injection
- Settling, sludge decanting, and skimming
- Sand filter

The water out of the sand filters goes to the cooling tower and to further treating for boiler feed water. The sludge is dehydrated and sold as agricultural fertilizer. The boiler feed water is demineralized, and ammonia is added prior to the boiler injection. The cooling tower water is injected with a corrosion inhibitor, and a chlorine biocide is used periodically.

5.3. Cooling Towers

The cooling tower structure is constructed of reinforced concrete and is composed of six cells. The surface plates are plastic packing. There are no wood parts. Fastening parts are carbon steel with a rustproof coating.

The five 470 kW pumps are each capable of 2 300 cubic meters per hour. Two pumps are normally in service.

The induction fans, each rated at 130 kW, are fixed pitch and manually set. The motors are single speed and non reversing. For winter operation the fans are stopped and the hot return water is directed to a distributor located below the structured packing. The quality of the cooling water observed on 7 June 1991 was very good with no apparent hydrocarbon inclusions.

There is the likelihood that during most of the year more water than is actually necessary is circulated, as the operators seldom trim cooling water flows for changing conditions or throughput capacities. However, it is also expected that any savings in adjusting cooling water flows would prove to be quite marginal.

6. AIR COOLERS

The majority of air coolers were fitted with a manually adjustable blade pitch propellers. Consequently, there is the likelihood that at less than design throughput and air temperatures, more fan horsepower would be expended than actually necessary to meet process requirements. It is the plant's practice to shut down fans as appropriate in multi-fan units during favorable atmospheric temperatures or during rainstorms in order to prevent process upsets, since air cooler efficiency increases greatly in the rain.

6.1. Crude Unit 100

Air fan units condense the overhead naphtha vapors which amounts to 25% of the feed. The blade pitch is automatically adjusted by the temperature out controller. The fan unit receives flow at 90 kPa gauge and 130 to 133°C.

6.2. Hydrotreater Unit 200

Air fan units are used similar to the application in the crude unit. The blade pitch is set automatically. The cooler consists of four sections with belt driven fans. A high pressure separator addition could eliminate this fan unit.

6.3. Stabilizer

An air fan unit cools and partially condenses LPG. Final cooling and condensation is provided by a trim shell-and-tube heat exchanger using cooling water.

6.4. Gas Oil Hydrotreater Unit 500

A fan unit condenses the reactor outlet flow at 240°C. Hydrogen gas is co-mingled with the outlet flow. This unit could be eliminated with the installation of a low pressure steam generator. See energy saving opportunities in Section J.

6.5. Vacuum Distillation Tower Unit 900

A fan unit is used in summer operation to cool the top pump-around reflux stream. In the winter the power plant raw water is heated for treatment from 5°C to 30°C. This heat load also could be used to evaporate the propane in the deasphalting unit. Fan unit 900E12 A-D could be eliminated. See energy saving opportunities in Section J.

6.6. Propane Deasphalting

The heaters in the propane deasphalting unit can be replaced by a hot oil pumparound system to evaporate the propane. See energy saving opportunities in Section J regarding the use of a single higher efficiency heater to replace multiple smaller heating duties.

6.7. Furfural Extraction Unit

Three air coolers are used to advantage where energy recovery would be difficult. Unit E12 has exhibited a tendency to foul. The pressure drop on this unit is logged carefully. The unit operator decides when to bypass the flow and install a spare tube assembly. The heaters also could be replaced by a hot oil system.

6.8. Di-Me Dewaxing Unit

Air cooler unit 13-EA23 condenses the de-waxing solvent. Relevant exchanger process data follows:

Heat load	11 250 000 Kcal/hr
Dichloro-ethane/methyl chloride	16 800 kg/hr
Hydrocarbons	10 700 kg/hr
Inlet Temperature	130°C
Exit Temperature	50°C

The air cooler has insufficient surface for hot summer operation and has control difficulty in winter operation. The unit is being considered for replacement by a shell-tube water cooled condenser.

7. ENERGY RECOVERY SYSTEMS

7.1. Power Plant

Ljungstrom type air preheaters are used on all the boilers. The surface plates have exhibited excess draft loss from corrosion caused by high sulfur content in the flue gas.

Soot blowers are installed in the power boilers. The blowers are not used because the air preheaters draft loss would be increased by the soot trapped in the corroded plates. Consequently the achievable superheat temperature is deteriorating.

Feed water and condensate heat exchangers are used to enhance energy recovery. The blowdown is exercised twice a day and is used to heat water in winter and heat boiler feed in the summer.

The generating turbine drivers have extraction for medium pressure process steam and exhaust into the low pressure process steam header.

7.2. Fired Process Heaters

The process heaters are connected with insulated breechings that collect the flue gas. The waste heat recovery steam generator receives the flue gas from this system and exhausts it to a common chimney. During June 1991, the waste heat boiler was not in service and was being repaired due to corrosion caused by the high sulfur content of the flue gas.

C. REFINERY FLEXIBILITY

1. OVERVIEW

The overall refinery and its potential for alternate modes of operation were reviewed. Three process units -- Crude Unit No. 100, Vacuum Unit No. 900, and Gas Oil Hydrotreating Unit No. 500 -- were chosen for a separate energy savings study. The flexibility of the refinery in general and the three process units in particular are presented in this section.

2. CRUDE UNIT NO. 100

2.1. Process Flow Diagram

The process flow diagram is shown in Figure 2.

2.2. Feedstock

The crude unit currently runs 70/30 Light Iranian/Statfjord blend crude at about a 70 percent capacity level based upon the design vapor loading of the tower. Any future selections of crude feed will be restricted by the necessity to control the sulfur content for environmental reasons and the clear necessity to control vacuum distillate quality level, essential for successful lube oil production. Crude properties are shown in the Characterization Report which is part of Appendix A in this document.

2.3. Unit Flexibility

The refinery was originally designed to operate at 328 stream-days per year and process 3 160 000 tonnes per year of a 60/40 weight percent split of Zakum/Kuwait crudes. The current charge of a 70/30 weight percent light Iranian/low sulfur Statfjord crude oil is reported to result in a medium throughput rate of 2 952 000 tonnes per year. Operations in 1990 were at 2 130 000 tonnes per year or a 72% operational factor.

There is no apparent difficulty in operational flexibility consistent with maximum vapor loading criteria as the crude tower is equipped with valve trays. This permits operating levels as low as 30 to 40 percent but at rapidly decreasing specific energy efficiencies.

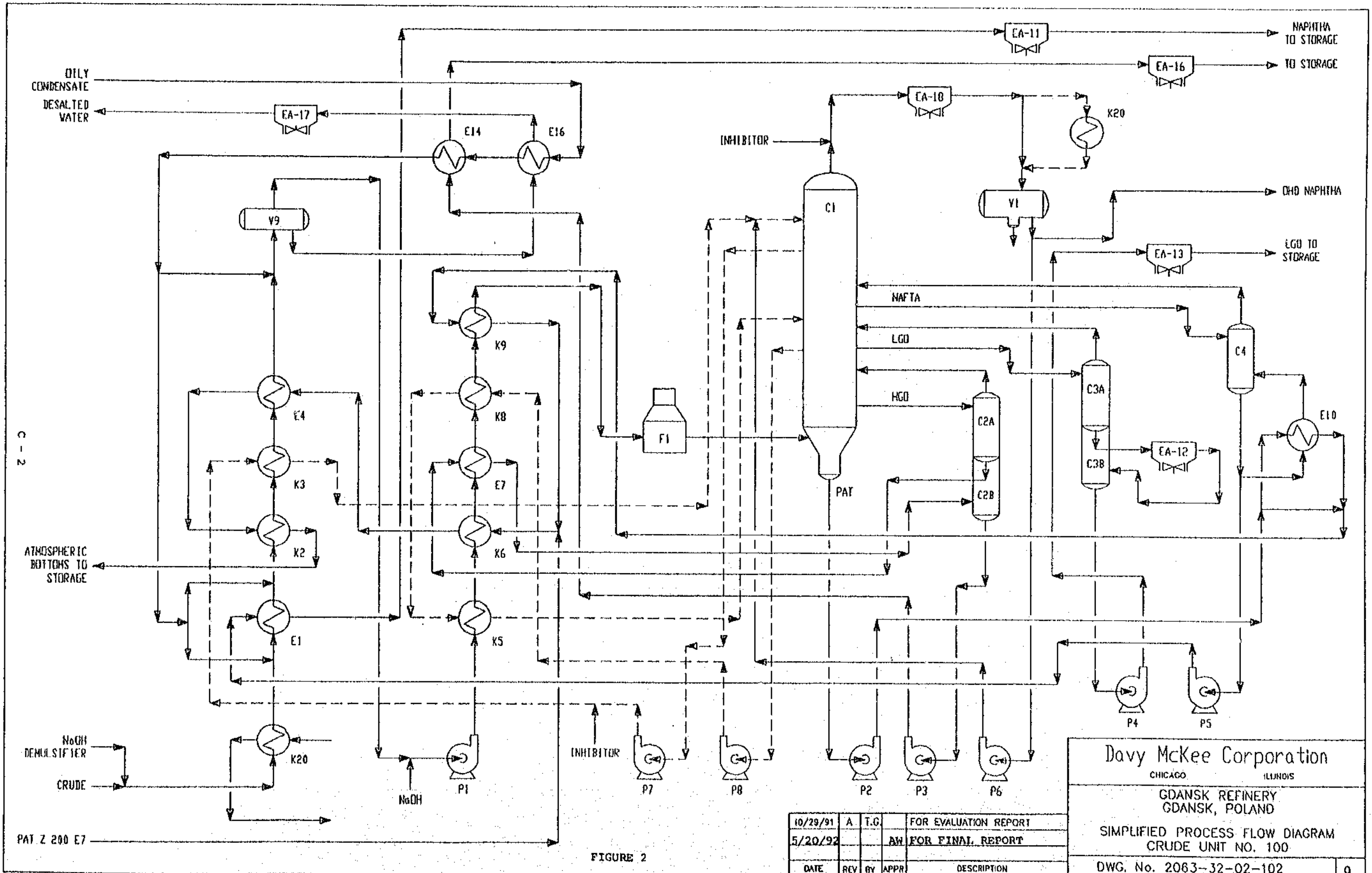


FIGURE 2

C - 2

SECTION C

30

2.4. Operational Sensitivity

The total output of this refinery is devoted to fuels and lube products. None of the intermediate or final product streams are diverted to petrochemical operations. Variation in crude composition must be consistent with the design criteria and equipment capacity limitations for the atmospheric bottoms based on Kuwait crude and the distillate fractions based upon Zakum crude.

2.5. Product Specifications

The IBP/heavy gasoline fraction is rerun and split following hydrotreating. The gas oil streams are blended into diesel oil products. Consequently, the only significant specifications to be met and controlled at the crude unit are the kerosene/light gas oil flash point, the boiling ranges of kerosene and light/heavy gas oils, and the color/pour point of the heavy gas oil. In addition, an important operating parameter is the viscosity of the atmospheric bottoms which is used as a guide for producing satisfactory lube fractions.

2.6. Unit Yields

UNIT YIELDS
70/30 wt% Light Iranian/Statfjord Feed

Description	Wt%
Refinery Gas	0.2
IBP - Heavy Gasoline	25.0
Kerosene	4.0
Light Gas Oil	17.0
Heavy Gas Oil	12.0
Atmospheric Bottoms	41.0
Loss	0.8
TOTAL	100.0

2.7. Unit Modification Potential

The IBP-heavy gasoline fraction is hydrotreated and then fractionated for LPG recovery, reformer feed, and a small heavy gasoline bottoms stream. This approach simplifies the process scheme for the removal and control of sulfur compounds in the light ends. However, it does entail revaporizing essentially the full atmospheric tower overhead fraction, thus incurring an additional energy burden. A potential savings could result if a closer cut could be made and the heavy gasoline avoided. However, the injection of nitrogen containing corrosion inhibitor, which is a platinum reforming catalyst poison, would have to be reconsidered.

31

In addition, it appears that a more effective split and degree of over-flash between the atmospheric and vacuum tower operations could be found, since the atmospheric heater outlet temperature is 10-15°C lower than the Kuwait design figure of 360°C. A detailed engineering study of these points would be useful.

Desalting water from the vacuum tower jet hot well is injected into the crude unit feed at 3 to 5 weight percent. Electric desalting is carried out with added Petrolite demulsifiers at a rather low 110-120°C. A 1.0 percent reduction in the desalting water rate would improve the desalting temperature by approximately 1.5°C, which is equivalent to approximately 250 000 kcal/h resulting in a savings of about 200 tonnes of fuel oil per year.

The crude preheat train should be re-examined by expert "Pinch" technology analysis to determine if a more efficient exchanger arrangement would be economically feasible. A locally conducted "Pinch" study has already been carried out with inconclusive results. However, as the crude unit is the major refinery energy consumer (20.2 percent), there could be significant opportunities for improvement. The refinery already has made savings by a partial heat recovery from the tower overhead stream. Additional possibilities are likely to exist to increase preheat and provide a higher temperature to the heater with resultant fuel oil savings.

The "Pinch" analysis also could be extended to review the opportunities offered by installing a preflash tower to remove the light ends and reformer feed fractions.

Although the vacuum unit is located at some distance (approximately 300 meters from the crude unit), the technical and economic feasibility and justification of recovering heat, which is now rejected to the cooling water by the vacuum gas oil fractions should be closely examined in light of present and future energy costs.

The heat exchanger preheat train fouling trends should be more closely monitored, particularly with the TDC-3000 control system now fully commissioned. This offers the potential for optimizing cleaning schedules for energy saving economies.

The crude feed booster pump, P-1, head can be considered excessive, since the control valve pressure drop to the heater, F-1, approximates 0.7 MPa at 72 percent operating capacity. Pump impeller trimming could be a simple expedient, although retrofitting the electronic frequency/variable speed control to the motor should be considered.

The atmospheric bottoms stripping steam rate of 3.5 weight percent appears excessive. A simulation study in conjunction with the heater overflash and required product qualities might allow a reduction in steam usage to a more efficient 1.5 to 2.0 weight percent. Savings would be projected at about 1.7 tonnes of steam per hour.

The refinery is generally arranged on spacious plot plans. The plot layout will permit comfortable access for safe construction under tight supervision during normal operations. The downtime for required inter-connections could be minimized and completed during a normally scheduled turn-around period. For example, if the installation of additional heat exchangers or preflash tower is shown to be technically and economically viable, few difficulties should exist for any reasonable expansion.

2.8. Capacity Increase Potential

The potential for increasing the crude tower throughput exists through the device of changing from valve trays to structured packings at the limiting region(s) of vapor/liquid traffic in the tower. However, operating and engineering studies would be required to closely pinpoint these bottlenecks for the existing crude blend and for a range of potential future crude selections.

The practical capacity increase to be achieved by this method could be expected to be limited to about 120 percent of the original flooding rate for the tower. In this regard, it is inherently assumed that an improved preheat train would have provisions for sufficient heat savings so that the heater design duty would not be exceeded at a 120 percent throughput rate. It is further assumed that the pumps are not fitted with the maximum impeller size so the 40 percent increase in equipment pressure drop could be accommodated and not exceed the motor power rating.

2.9. Operating Practices

The operators are to be congratulated for maintaining the fired heater flue gas oxygen content within a region of 3 to 5 volume percent with fuel oil firing. Manual adjustments are based on periodic readings with a Kent analyzer.

Atomizing steam at the burners has been reduced from an original 0.6 kilogram steam to a current 0.2 to 0.3 kilogram steam per kilogram fuel oil. However, improved and more efficient burners would be welcomed, particularly of the low nitrogen oxide type.

A difficult problem to resolve in energy saving terms is the present inefficiency of the steam soot blowers in the heater convection/superheater banks. These banks are washed down and cleaned during the bi-annual turn-around period.

Another energy saving modification for which the operators are to be commended is the recovery of the crude tower overhead flash gas under pressure control to special low pressure heater burners. In the original design, these flash gases were routed to the flare.

2.10. Replacement/Shutdown Observations

At this time there is no reason to consider replacement or shutdown of this unit.

3. VACUUM UNIT NO. 900

3.1. Process Flow Diagram

The process flow diagram for this unit is shown in Figure 3.

3.2. Feedstock

The vacuum unit normally receives feed directly from the crude unit at about 100°C following heat exchange. In the event of upsets or abnormal variations in quality, feed can be received directly from storage with a steady composition and at a similar temperature. The design capacity rating is as follows:

Kuwait	44 wt% vaporization	460 tonnes/hr
Zakum	62 wt% vaporization	370 tonnes/hr

Running the current 70/30 Light Iranian and Statfjord blend at 58 weight percent vaporization was stated to have a probable throughput rating of 375 tonnes per hour. A throughout rating of 395 tonnes per hour should be possible.

3.3. Unit Flexibility

As with the crude tower, acceptable operations should be experienced consistent with the vapor loadings cited above in Section C.3.2. as long as the vacuum residue flow does not exceed the Kuwait design figure of about 115 tonnes per hour. The nine meter diameter vacuum tower is equipped with 28 two-pass bubble cap trays. There are problems with fractionation efficiency. Possible causes of the uneven vapor distribution and liquid overflow in the risers include

34

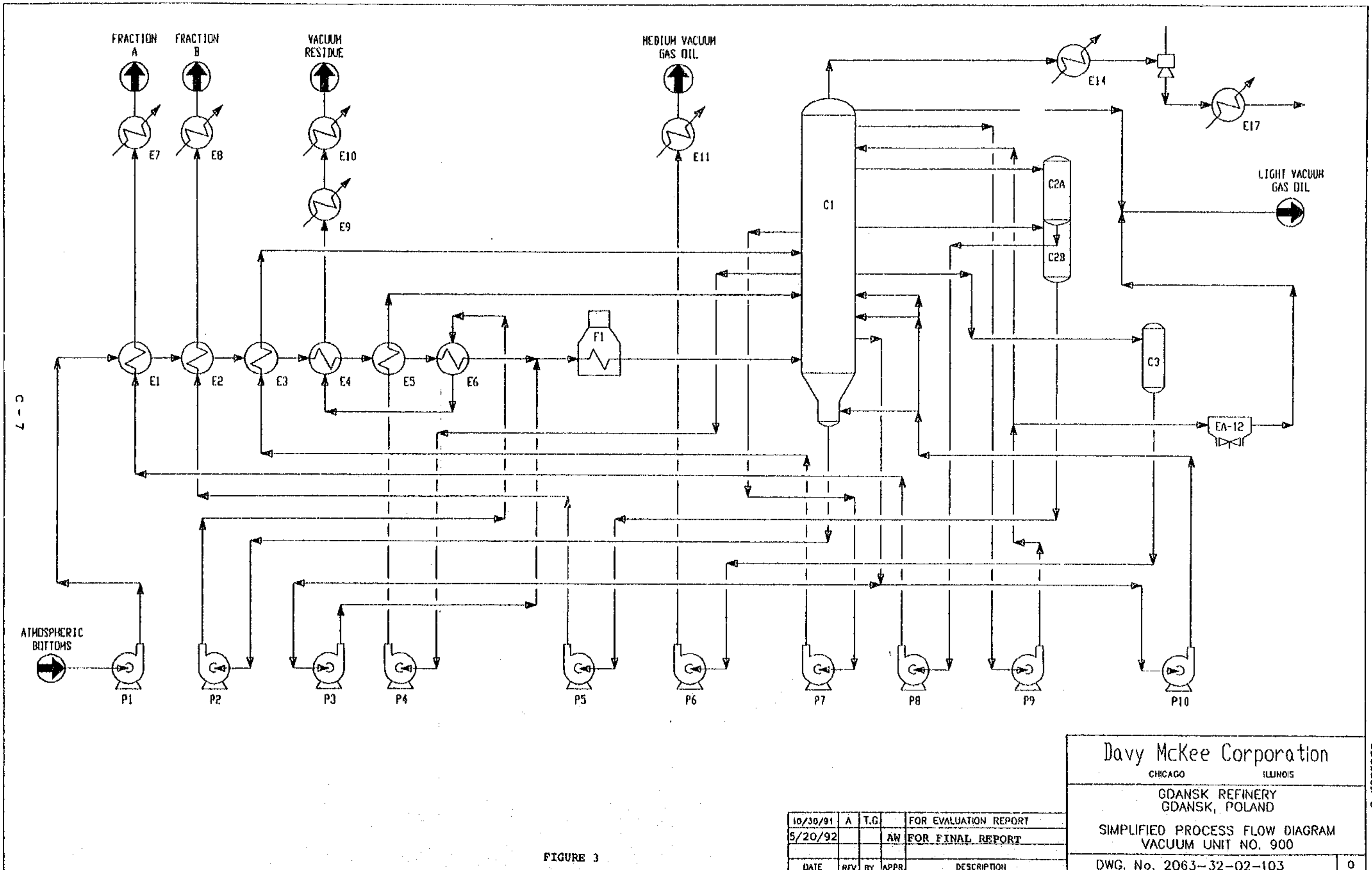

FRACTION A
FRACTION B
VACUUM RESIDUE
MEDIUM VACUUM GAS OIL
LIGHT VACUUM GAS OIL
ATMOSPHERIC BOTTOMS
E1
E2
E3
E4
E5
E6
E7
E8
E9
E10
E11
E14
E17
EA-12
F1
C1
C2A
C2B
C3
P1
P2
P3
P4
P5
P6
P7
P8
P9
P10
Davy McKee Corporation
CHICAGO ILLINOIS
GDANSK REFINERY
GDANSK, POLAND
SIMPLIFIED PROCESS FLOW DIAGRAM
VACUUM UNIT NO. 900
DWG. No. 2063-32-02-103
0
10/30/91 A T.G FOR EVALUATION REPORT
5/20/92 AW FOR FINAL REPORT
DATE REV BY APPR. DESCRIPTION

FIGURE 3

excessive tray leakage or high hydraulic gradients across the trays. Although four-pass trays should have been specified, a thorough tray design analysis is required to determine the exact cause. Meanwhile, the refinery plans to replace some trays with structured packing to observe any resultant operational changes. Improved fractionation performance would permit the possible elimination of some trays allowing a higher vacuum level and some steam saving at the vacuum jets.

3.4. Operational Sensitivity

Within the design capacity ranges cited in Section C.3.3., no problems are expected. As with all vacuum heaters, a peak temperature is reached in the heater coil dependent upon the degree of vaporization, the pressure drop, and the point and rate of steam injection. Furthermore, lubricating oil stocks are sensitive to the peak temperature level where incipient cracking can cause quality degradation and Gdansk operations are near the accepted maximum. Therefore, care must be exercised when throughput rates approach or exceed the design capacity of the unit.

Other major variables, such as the atmospheric cut point of the feed and side stream pump around rates, are subject to overall refinery optimization techniques consistent with achieving the vacuum gas oil qualities for the required lube oil operations and satisfactory base stock specifications.

3.5. Product Specifications

The significant variable in the vacuum tower side steam product specifications for lube oil production is in maintaining the proper viscosity levels, which, in turn, are dependent upon the feed stock source. Since this is a sensitive parameter, a viscosity analyzer is helpful. Another important property is the color level of the lowest side stream, since this is very sensitive to any asphaltene entrainment caused by poor tray or demisting pad performance or by inadequate reflux levels below the draw off tray for washing the flash zone vapors. Table C.3.5.1. illustrates vacuum unit product characteristics as a function of varying crude feed composition.

TABLE C.3.5.1. - TYPICAL PROPERTIES OF VACUUM DISTILLATION PRODUCTS

Feedstock Blending Proportions - wt%					
Iranian Light	53%	80%	74%	70%	68%
Osberg	20%	20%	20%	---	2%
German	27%	---	6%	---	---
Statfjord	---	---	---	30%	30%
Vacuum Gas Oil					
viscosity CS at 100°C	2.72	2.81	2.85	2.65	2.73
flash point °C	---	162	---	152	154
Vacuum Light Distillate					
viscosity CS at 100°C	5.29	5.48	5.56	5.41	5.43
flash point °C	213	205	202	208	214
coke, wt%	---	---	---	0.00 7	0.021
distillation					
5% °C	365	384	395	368	375
50% °C	407	427	440	415	408
95% °C	487	497	496	474	473
Vacuum Heavy Distillate					
viscosity CS at 100°C	13.60	14.00	14.5 9	13.9 6	13.73
flash point °C	257	258	252	260	264
coke, wt%	0.31	0.36	0.35	0.25	0.31
distillation					
5% °C	409	435	422	405	418
50% °C	468	484	466	458	469
95% °C	548	635	585	548	557
Vacuum Residue					
penetration	275	---	230	360	330

3.6. Unit Yields

Table C.3.6.1. illustrate variations in vacuum product yield as a function of crude feedstock compositions.

TABLE C.3.6.1. - TYPICAL VACUUM UNIT YIELD

Crude Feed	Weight Percent of Crude					
Iranian Light	53	70	80	74	70	68
Oseberg	20	5	20	20	-	2
German	27	-	-	6	-	-
Statfjord	-	25	-	-	30	30
Products	**Product Yield as Wt% of Crude Feed**					
Atm. Residue (feed)	43.26	37.02	40.54	39.22	39.10	40.16
Vacuum Gas Oil	3.14	2.49	2.87	2.43	2.48	2.68
Vacuum Lt. Distillate	7.93	6.81	7.17	6.62	6.88	7.91
Vacuum Hvy. Distillate	12.33	10.27	11.17	10.56	10.73	11.62
Slop	6.61	0	0	0	0	0
Vacuum Residue	27.36	17.3	19.19	19.46	18.65	17.79

The light vacuum gas oil cut is normally sent to the gas oil hydrotreater for desulfurization and blending into the diesel oil pool, although a small quantity may be extracted and dewaxed for specialty lube oil applications. Also, in the winter, this stream may be dewaxed for specially low pour point diesel oil specifications.

A portion of the vacuum residue serves as feed to the propane deasphalting (PDA) unit, another portion is sent to asphalt blowing for bitumen production based upon sales requirements. The remaining quantity is delivered to fuel oil blending for internal refinery and power house needs or for external sales.

38

It has been noted that the atmospheric bottoms are fully heat exchanged with incoming crude feed instead of being sent hot to the vacuum tower heater. This occurs since the crude unit was commissioned with the remaining fuel units in advance of the construction of the vacuum tower and lube processing units. Due to this historical development, the vacuum tower was equipped with its own preheat train instead of being arranged as an integrated combination crude/vacuum unit. Although this approach involved considerable expense, as additional heat exchanger surface and pumping power are needed, it possesses an advantage in terms of flexibility and independence of operations. Also, as previously mentioned, the quality of the vacuum distillate fractions is more readily controlled when divorced from variations in crude tower operations.

3.7. Unit Modification Potential

Opportunities observed for potential energy savings are listed below for further review or implementation.

The vacuum unit feed pump (P.1) head, similar to the crude feed pump, necessitates an excessive control valve pressure drop of over 0.6 MPa. Here also it is proposed either to trim the impeller or to consider installation of a variable frequency drive (VFD) for the motor.

The stripping steam rate to the vacuum tower bottoms at 4.3 weight percent seems to be at least twice the expected normal amount in similar operations. It is understood that the operations staff has already devoted considerable efforts to decreasing this stripping steam rate but the residue and deasphalted oil quality has suffered. Further simulation studies are suggested in conjunction with an evaluation of the degree of over flash and the bottoms pump around wash stream together with a lower pump around through E-5 to determine if any excess of heavy distillate is being rejected to the residue and then revaporized and recycled by the high stripping steam rate.

The vacuum tower top pump around circuit, operating at 125 tonnes per hour from approximately 125 to 55°C, is currently air cooled. A portion of this waste heat can be usefully employed to provide preheat for propane/deasphalted oil evaporation in the adjacent propane deasphalting unit. A preliminary conservative energy savings estimate based on sensible heat recovery only at the proposed propane/deasphalted oil rates of 58/14 tonnes per hour at an inlet temperature of 64°C indicates a major savings of 3 500 000 kilocalories per hour. Gdansk is presently working on this energy saving scheme.

The tempered water system (60 - 85°C) serving the lube train is currently air cooled. The level of this waste heat rejection is quite sufficient to be useful in raising the incoming raw water temperature up to 25 - 27°C before treatment and deionization during the winter and spring periods. Plans are advancing to incorporate this energy saving arrangement in the near future.

The Gdansk refinery intends a major conversion from the multiple heater services in the lube train propane deasphalting and furfural units to a hot oil system employing a single high efficiency heater with low nitrogen oxide burners. The energy improvement of this conversion is very difficult to predict before more thorough engineering studies are done because of the changes that will result to the existing flue gas waste heat boiler steam output. However, a 5 percent increase in heater efficiency would alone result in projected savings of about 1 000 000 kilocalories per hour at the present operating levels.

The vacuum tower heater suffers from hot spots that are apparently due to the minimal thickness of its fire brick, which may also have been poorly applied. DMC personnel provided advice and references regarding more modern refractory materials and installation techniques.

3.8. Capacity Increase Potential

Precisely the same comments made in respect to the crude tower in Section C.2.8. also apply to any increase in throughput at the vacuum tower. However, there is a question in respect to the hydraulic stability of the existing 2-pass bubble cap trays that could lead to declining fractionation efficiency as the liquid head on the trays increase at higher capacity.

3.9. Operating Practices

The excess oxygen at the vacuum unit heater is manually adjusted within the range of 3 to 5 volume percent with periodic oxygen analyzer readings. The operators are to be commended for their diligence.

Atomizing steam at the burners has been reduced from an original 0.6 kilogram steam to a current 0.2 to 0.3 kilogram steam per kilogram fuel oil. However, improved and more efficient burners would be welcomed, particularly of the low nitrogen oxide type.

A difficult problem to resolve in energy saving terms is the present inefficiency of the steam soot blowers in the heater convection/superheater banks. These banks are washed down and cleaned during the bi-annual turn-around period.

There is one area of concern, however, related to the energy economy program. Currently, considerable downtime and maintenance expense is experienced due to the effects of corrosion in the flue gas waste heat boilers, and Ljungstrom air preheaters at the power house.

For example, it was noted that the lube train flue gas waste heat boiler was inoperative since June 1990 due to a complete overhaul and retubing expected to be completed by September 1991. This represents a considerable recoverable energy loss over an extended period but the investment cost effectiveness should also be scrutinized for technical optimization balanced with economic practicability.

Never-the-less, despite this energy loss, the Gdansk lube train energy demand during 1990 was about 3.5 percent less than would be expected in similar US operations.

3.10. Replacement/Shutdown Observations

There is no need at this time to consider replacement or shutdown of this unit.

4. GAS OIL HYDROTREATER UNIT NO. 500

4.1. Process Flow Diagram

A process flow diagram for this unit is shown in Figure 4.

4.2. Feedstock

The light, heavy, and vacuum gas oils are normally received for processing directly from the crude and vacuum units at 175°C for processing. Alternatively, feed from tankage may be included.

The design capacity rating of the gas oil hydrotreater is 60 tonnes per hour and a 70 tonnes per hour maximum throughput has been established. When charging the currently selected light 70/30 blend of Light Iranian/Statfjord crudes at the anticipated crude unit rate of 375 tonnes per hour, the light, heavy, and vacuum gas oil fractions will total 35.5 weight percent on crude or 133.1 tonnes per hour. This is 190 percent or nearly twice the installed desulfurization capacity. Presently, at the reduced 72 percent operating capacity of the plant, some 96 tonnes per hour of gas oils are available for processing so that over 30 percent

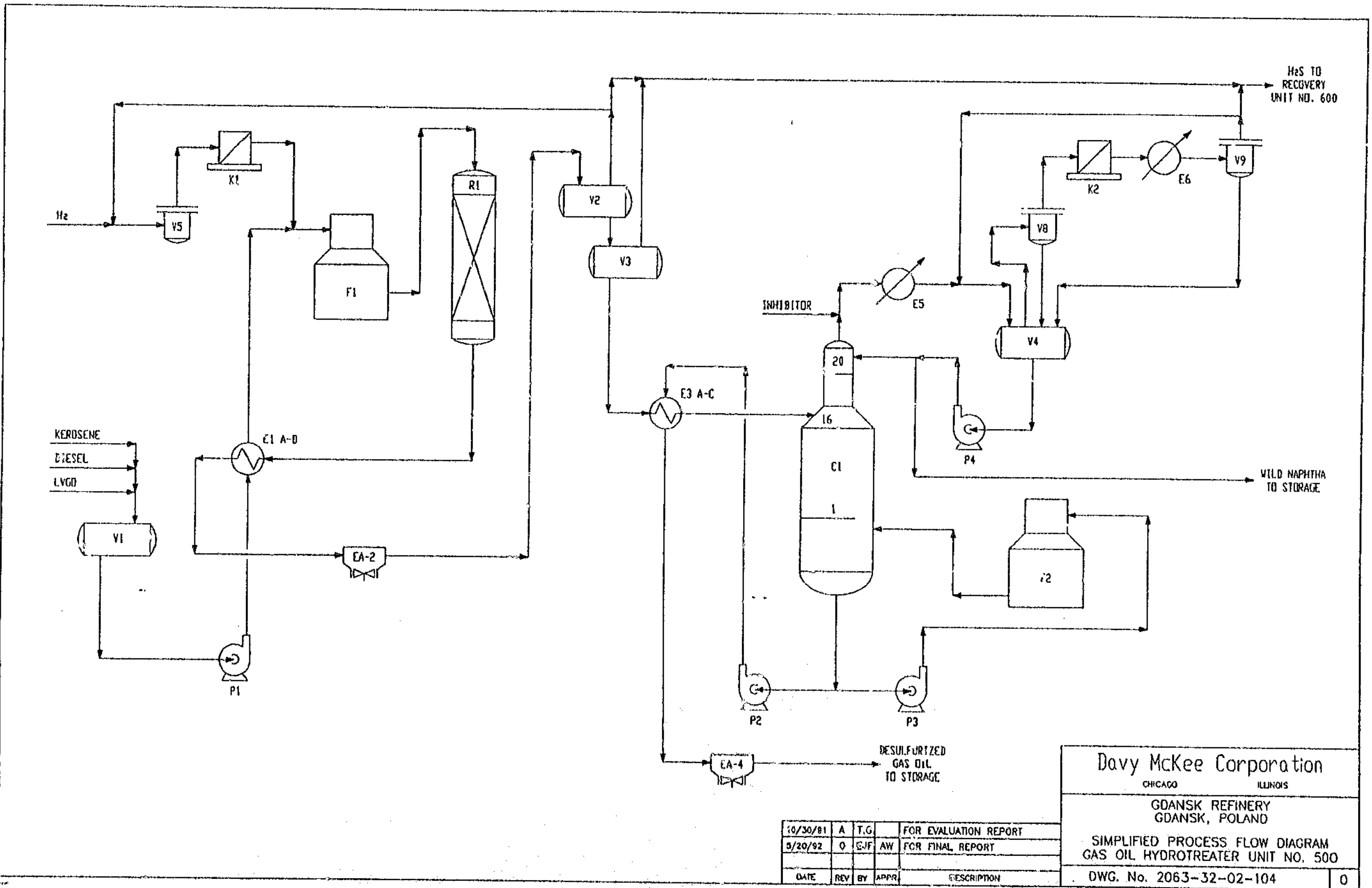

H2 TO RECOVERY UNIT NO. 600
H2
V5
K1
F1
R1
V2
V3
KEROSENE
DIESEL
LVGO
V1
E1 A-D
EA-2
P1
E3 A-C
INHIBITOR
E5
20
16
C1
1
V4
P4
V8
K2
E6
V9
WILD NAPHTHA TO STORAGE
F2
P2
P3
EA-4
DESULFURIZED GAS OIL TO STORAGE
Davy McKee Corporation
CHICAGO ILLINOIS
GDANSK REFINERY
GDANSK, POLAND
SIMPLIFIED PROCESS FLOW DIAGRAM
GAS OIL HYDROTREATER UNIT NO. 500
DWG. No. 2063-32-02-104
0
10/30/81 A T.G. FOR EVALUATION REPORT
5/20/92 0 SJF AW FOR FINAL REPORT
DATE REV BY APPR DESCRIPTION

FIGURE 4

must be bypassed and back blended to specifications. Therefore, there is a necessity for selecting a controlled lower sulfur feedstock for effective operations aside from the sulfur emissions environmental concerns derived from fuel oil firing. An expanded gas oil hydrotreating capacity could become imperative for increased operating flexibility, for crude selections, and for product specifications in the future.

4.3. Unit Flexibility

As indicated, the capacity of the gas oil hydrotreater is limited when processing light crude oil feeds, so that the unit must be operated near its hydraulic operating limits for the reactor and other major equipment. Sufficient hydrogen rich gas is available from the Ultraformer, so that once through hydrogen treating is practiced at 70 percent sulfur conversion for these low sulfur stocks. However, recycle compression is installed and available for emergency use.

Although diesel product specifications of 0.3 weight percent sulfur can still be achieved even when bypassing a significant portion of the lighter gas oil blending stocks, increased desulfurization capacity would be desirable, since sulfur levels in fuels are expected to become more restrictive in the future. Also, a broader selection of crude feed stocks could be possible and economically attractive with larger hydrotreating facilities.

4.4. Operational Sensitivity

Desulfurization processes incorporate catalysts that are very robust and stable assuming an assured supply of hydrogen rich gas. Gdansk has replaced the original catalyst with a Polish manufactured catalyst that is considered to be equivalent in performance, and there is no reason to question this change.

The degree of desulfurization depends on the feed stock quality, reactor space velocity, temperature, hydrogen partial pressure and contact rate with the hydrogen rich gas. With the exception of the space or velocity reactor volume consideration, previously discussed in terms of capacity and flexibility, the remaining factors are within convenient control of the operating staff for achieving the required results without difficulty.

The associated stripping tower C-1 is provided with a fired reboiler in order to provide direct control and adjustment of the product flash point and initial boiling point specifications.

4.5. Product Specifications

The current degree of desulfurization from 0.65 weight percent in the gas oil feed to 0.2 weight percent in the product stream, a 70 percent conversion, is adequate for meeting the diesel pool blend specification of 0.3 weight percent. It should be noted however, that lower sulfur crude feed stocks have been selected for the Gdansk refinery operations.

4.6. Unit Yields

UNIT YIELDS

Description	wt%
H_2S	0.45
Off Gas/Gasoline	0.70
Hydrotreated Gas Oil Prod.	98.85
TOTAL	100.00

4.7. Unit Modification Potential

Although only a small amount of hydrocracking occurs in the desulfurization process, a considerable amount of energy is required due to the heating of the reactor feed followed by cooling and condensation of the reaction products for effective gas separation. Subsequently, the gas oils must be reheated at high temperature levels for stripping of the lighter components and the product cooled once again to final storage temperature. This energy inefficiency cannot be avoided in a single flash system as employed at Gdansk, but can be minimized by conversion to a two-stage hot and cold flash arrangement.

The Gdansk staff proposes a novel approach to accomplish this conversion. Preliminary calculations and investment cost studies at the Plock Research Center indicate a six month pay back period, but this prediction cannot be verified until the proper engineering studies are conducted.

Aside from the production of LP steam from the reactor effluent and bottoms stabilizer, a special feature of the scheme is the concept of utilizing the hot separator flash gas from V-2 after cooling as motive gas through the jet, J-1, to educt otherwise wasted light gases from the flare leader. Gdansk estimates indicate some 400 cubic meters per hour resulting from equipment leakages via safety valve seats could be recoverable. The hot liquid condensate from V-2 would then pass to the stabilizer as feed without the further loss of energy by further cooling.

A suggested alternative proposal is to investigate the possibility of introducing a hydraulic turbine to depressure the stabilizer feed stream over a 2.5 MPa pressure drop.

The Gdansk staff is innovative and discussed the possibility of ducting hot air from air cooler air fins to the heaters. However, this was considered to be impractical both technically and economically.

Serious consideration should be given to creating an "economic" evaluation group able to utilize a financial model based on Polish accounting methods and tax laws. This group should be equipped with modern software for professionally exploring, identifying, and implementing the most appropriate cost effective energy saving schemes.

A further recommended extension to this suggestion would be the acquisition of suitable PC mounted refinery linear program (LP) software for the commercial optimization of the whole refinery operation. This tool could be used to undertake optimized cut point evaluations and product blending requirements, and to explore future feedstock acquisitions or the effects of changing feed or product pricing.

4.8. Capacity Increase Potential

The maximum throughput of this unit has already been established at 70 tonnes per hour. Therefore, any expansion needs will have to be satisfied by the installation of new capacity. If an expansion is necessary, it is believed that the new Continuous Catalytic Reforming Unit (CCR) will provide sufficient hydrogen rich gas for satisfactory operations.

4.9. Operating Practices

The operators again were conscientious in maintaining low excess oxygen values in the heater flue gases with reported efficiencies of 75% for these relatively small fired duties.

4.10. Replacement/Shutdown Observations

As noted above under Section C.4.8 the possible replacement of the gas oil hydrotreater may have to be considered if additional desulfurization capacity is required. Linear Programming optimization studies would be the most helpful in this analysis.

5. PLANT LIMITATIONS

5.1. Unit Capacities

Comments on the flexibility and the capacities of the units reviewed are contained in Sections C.1. through C.4. with the most notable comment being the capacity limitation of the Gas Oil Hydrotreater Unit No. 500.

5.2. Product Requirements

The refinery is able to meet all specifications for the products that are prescribed by the Polish standards. This is partly due to the judicious selection of the feed crude blend of relatively low sulfur content to meet the allowable sulfur emission permit. This element may prove to be restrictive to maximizing profitability in future years and warrants thoughtful and timely forward planning.

5.3. Fuel System

With the exception of controlling the sulfur content of the fuel oil to meet emission standards no limitation in the fuel gas or fuel oil systems was reported.

5.4. Steam System

No limitations noted.

5.5. Electric Power System

No limitations noted.

5.6. Tankage

At maximum crude throughput, the refinery has 36 days of crude storage available.

46

5.7. Other Limitations

Currently the Gdansk Refinery does not use crude oil from the USSR. Crude oil is pumped into the refinery's receiving tanks either directly from tankers arriving at the Gdansk port, or from "PERN", a state owned company which has a tank farm of its own. It is not clear what measurements and procedures of crude transfer were in force between the tankers delivering the crude and "PERN" and between "PERN" and the Gdansk Refinery. The general situation, however is clear: there are no custody transfer installations between "PERN" and the Gdansk Refinery. However, each transfer of crude to the Gdansk Refinery is attended by a representative of "PERN" who has his own portable instruments for determining the level in the receiving tank, temperature and determines the amount of water in the crude. It was said that the accuracy of the transfer is within ± 0.5% (U.S. practice is ± 0.1%) and thus far the Gdansk Refinery has not had any problems with transfer of the crude. However, considering ongoing changes in the economic climate in Poland, it is suggested that the refinery should carefully analyze the situation of its present custody transfer and accounting. Needed to be considered are the price of custody transfer equipment, its calibration, and maintenance, the possible loss of hard currency due to inadequate accuracy of measurements of incoming crude and likely increases in the price of crude.

A modern custody transfer installation is expensive. Depending on the required maximum flow of the measured crude, it should have several positive displacement meters or turbine meters with the related pipe runs and valving, crude oil filtering and a sampling system with intermittent or on-line monitoring of bottoms, sludge and water in the crude and measurements of temperature and density.

Also, in order to calibrate flow meters on a regular basis, the custody transfer installation would need either a stationary meter prover, or else be designed such that a transportable meter prover would have access to all of the meters.

47

HEAT CONSERVATION

1. HEAT TRANSFER PRACTICES

The Gdansk Refinery maintains excellent statistical records for the utilities consumption of individual processing units and the refinery as a whole. As described in Section B.1., the utilities energy consumptions for the units and overall refinery in terms of "Total Energy Demands" compare with typical US practices. The Gdansk Refinery energy demands are approximately 2.8 percent greater than the US refinery average.

The atmospheric distillation, gas oil hydrotreating, and vacuum distillation (Unit Nos. 100, 500, and 900) were selected for a more detailed review of operating conditions. The energy demands for these units are presented in Table D.1.1. and are compared with typical US requirements. (Also refer to Appendix E for the basis of the US Energy Demand utility data.)

TABLE D.1.1. - ENERGY DEMANDS

	Unit	Gdansk Specific Energy Demand (kcal/tonne)	US Specific Energy Demand (kcal/tonne)	Gdansk/US (%)
100	Crude	193 092	175 000	110.3
500	Gas Oil Hydrotreating	139 761	215 000	65.0
900	Vacuum Distillation	240 210	250 000	96.1

The energy demands compare favorably with US performance, although the Gas Oil Hydrotreater energy demand is relatively low. However, this unit only accounts for 2.9 percent of the total refinery energy requirements so any variance will be of nominal importance. Units with high energy requirements such as the Ultraformer and Di-Me Dewaxing are less energy efficient than expected when compared with US counterparts.

These results should not be viewed as especially surprising. The Gdansk Refinery began operations only 15 years ago, uses modern Western design, and employs a high degree of US and European technology.

2. HEAT UNIT BALANCES

2.1. Crude Unit 100

Some of the observed energy consumption overrun for this unit can be accounted for by the fact that the Merox Unit 300 utilities are billed to the Gdansk atmospheric distillation operations.

2.2. Gas Oil Hydrotreating Unit 500

The Gdansk practice of feeding hot gas oils to hydrotreatment could account for much of the refinery's advantage over average US practice.

2.3. Vacuum Distillation Unit 900

The vacuum distillation results are comparable to US practice. Differences may be due to variations in feedstock gravities, depth of vaporization, etc.

3. HEAT TRANSFER EQUIPMENT ANALYSIS

3.1. Fired Heaters

As noted in Section C.2.9., the fired heaters utilize fuel oil. The excess oxygen has been controlled in the 3 to 5 per cent range. The stacks from process heaters are manifolded for heat recovery (waste heat boilers).

3.2. Heat Exchange Trains

The crude unit is a major energy consumer at the refinery. "Pinch" technology analysis should be applied for possible improvement in energy consumption by the fired heater. The refinery does not log heat exchanger train pressure drops or temperature.

Constant monitoring of the preheat train for exchanger fouling can contribute to energy saving at crude pump drives as well as at the fired heater.

3.3. Waste Heat Recovery

Heat recovery from the combined flue gases of the process heaters as practiced in Gdansk is a constructive step in conservation of energy.

3.4. Economics of Increasing Surface Areas

Based on DMC experience, poor heat transfer rates are more often attributed to poor design characteristics of individual exchanger with respect to fluid velocities, baffle pitches or cuts, etc. It is possible that a more fundamental analysis of heat exchanger train arrangement will be fruitful and this study should incorporate exchanger design considerations. At a design capacity of 3.16 million tonnes per year, an increase in crude heat exchanger efficiency of 1°C is worth $19 000 per year in fuel oil savings (see Appendix D for the calculation basis).

4. STEAM SYSTEM

4.1. Steam Balance and Utilization

A summary description of the steam system is in Section B.3. The steam balance is automatically maintained by the generation of sufficient 7.5 MPa steam for let down through the turbogenerator with extraction to the 2.0 MPa system and backpressuring into the 0.6 MPa system to meet its demand. In an emergency, desuperheated let down from higher pressure levels is possible. The variation in power is compensated for by changing the imported power from the national grid to meet plant requirements. During the winter period, the Gdansk Refinery power house furnishes power to the national grid.

Energy saving projects should have negligible effect upon steam balance concerns except for a possible reduction of demand.

4.2. Selection of Pressure Levels

Section B.3. defines the steam pressure levels and paragraph D.4.1. describes the interrelationship for maintaining a steam balance.

4.3. Condensate System

There are four condensate collection stations located throughout the refinery and a fifth unit located in the water treatment station. Intermediate tank data is shown in Table D.4.3.1.

TABLE D.4.3.1. - CONDENSATE TANK DATA

Tag Number	Quantity	Size (m^3)	Operating Parameters	
			Pressure (MPa)	Temperature (°C)
S-2,3,4	3	400.0	atm	---
V-2	1	13.4	atm	100
V-3	1	6.6	0.35	125
V-4	1	15.7	atm	100
V-2A,B,C	3	33.9	0.4	15

The condensate is cooled to less than 70°C and the average daily output varies between 1 200 to 1 800 cubic meters. Allowable contaminants are:

organic chlorides	< 0.5 ppm
hydrocarbons	< 4.0 ppm
permanganate value	< 2.0 mg oxygen/liter

The condensate is collected in the main station and pumped from the receiver to a deaerator system at the water treatment plant where it is processed into the boiler feedwater system. A 4 ppm hydrocarbon "hi-alarm" is in place before the filter system.

As stated in Section B, 40 percent of the refinery steam is returned to the power house as condensate. The remaining condensate is used as process water in the desalter.

4.4. Insulation

Some breaks in insulation were observed. Replacing the insulation would save energy.

4.5. Potential Effect of Energy Saving Projects to Steam Balance

Recovering heat as steam will lead to a fuel savings and normally will have a beneficial effect on steam balance.

5. HEAT REJECTION SYSTEMS

5.1. Cooling Water System

The cooling tower exit temperature is maintained at 17°C to 23°C. The maximum differential temperature across the cooling tower is 10°C. Makeup is normally 1.5 percent of the circulating rate and a bypass filter is used for 3 percent of circulation.

A description of the cooling water system is included in Section B.5.3.

5.2. Air Coolers

Section B.6. describes applications of air coolers for possible energy saving. Section F.3.2. addresses the maintenance of air coolers. Section F.3.9. discusses corrosion problems with air cooler 1300 EA23.

5.3. Equipment, Piping, and Steam Heat Losses

Mechanical observations concerning specific units are presented in Sections C and F. In general, the insulation thickness is appropriate for thermal containment at the temperature levels protected.

5.4. Recovery Systems

Mechanical observations concerning specific units are presented in Sections C and F.

5.5. Tracing and Temperature Maintenance Systems

In spite of the severe winter conditions in this region, no serious problems with temperature maintenance and freeze protection in the process plant were reported.

6. USE OF HOT OIL LOOPS

The balance of advantages and disadvantages must be considered when a loop with circulating hot oil is to be provided to furnish heat to several users. The furnace serving as the heat source can be designed for high efficiency and low nitrogen oxides emissions. There is an advantage to operating one furnace instead of several. This also applies to the steam system used to recover heat from the flue gas. On the other hand, heat losses could be high in the oil circulating loop if there are long pipe runs for widely scattered users. There can also be some loss of flexibility of operation.

The Gdansk Refinery has evaluated use of a hot oil system for propane deasphating and furfural with expectation of savings in the area of $78 000 per year by improved heater efficiency. The energy is expected to be provided with a low level of nitrogen oxide emissions as well.

E. MECHANICAL DRIVE SYSTEMS

1. COMPRESSORS/FANS

The Gas Oil Hydrotreating Unit No. 500 has a hydrogen centrifugal compressor which is driven by a 1.6 MW steam turbine. There is no spare for this service. The Reforming Unit No. 400 has a hydrogen reciprocating compressor driven by a 700 kW electric motor; 6000 V, 3 phase, and 50 Hz. The motor was drawing 76 amp when observed on 12 June 1991. All other compressors are smaller and are electric motor driven.

2. SPECIAL PUMPS

The critical pumps are electric motor driven. The boiler feed pumps are mounted outside the powerhouse. The electrical distribution system is designed for high reliability. There are no steam driven pumps. The boiler feed pumps were manufactured by K.S.B. Germany.

3. ELECTRIC MOTORS

Most of the electric motors in the Gdansk Refinery originated in Italy.

4. STEAM TURBINES

The two generator turbine drivers in the powerhouse are of French manufacture.

5. SPECIAL EQUIPMENT

There are steam ejectors on the crude vacuum towers to provide vacuum. However, no observations were made nor inputs received with respect to operation of these units.

F. MAINTENANCE/MECHANICAL OBSERVATIONS

1. OVERALL IMPRESSIONS

The mechanical equipment in the Gdansk Refinery was manufactured in Western Europe and the United States (or their European licensee companies). For example, pumps are Worthington, relief valves are Consolidated, and manual valves are Italian.

The equipment is well maintained. Hand valves and steam traps are repaired on a rotation basis. Every piece of equipment is tested prior to returning it to service. The maintenance and repair shops have the capability to make replacement parts for all the equipment. Relief valves are disassembled; replacement parts are made; then the valves are reassembled and tested. In Western practice, relief valves would mostly be returned to the original supplier or an authorized repair facility.

Some of the original mechanical equipment specified by Snam Progetti has been replaced with locally designed equipment. Heat exchangers and oil burner atomizing nozzles are manufactured in Poland to a highly efficient in-house design. Western standards are used for materials and design.

2. UNIT REVIEW

The mechanical equipment of Crude Unit No. 100, Vacuum Unit No. 900, and the Gas Oil Hydrotreating Unit was discussed in the review meetings and inspected during the site visit. All units were well maintained. The unit managers responsible for maintenance deserve a compliment. Some units exhibited steam leaks, but the leaks were not excessive or frequent. The units were free of inoperative pieces and control rooms were free of waste paper, debris, and removed instruments.

3. EQUIPMENT CONDITION SUMMARY

3.1. Fired Heaters and Boilers

The atomizing nozzles of the process fired equipment have a fouling problem because of the residual fuel oil used. Periodically, the nozzles need to be removed and bench cleaned. The steam power boilers were being reworked. The Ljungstrom air preheaters showed excessive pressure drop due to corrosion. Accumulation of soot from the generator tubes aggravated this pressure drop and consequently the soot blowers are not being used. As a result, the achievable superheat temperature is gradually falling due to the fouling build-up.

All of the major fired heaters in the Gdansk refinery have flue gas breechings to a common steam generator for waste heat recovery. The combustion air for fired heaters is not preheated. The air/fuel ratio is manually adjusted for minimum oxygen content in the flue gas without smoke formation.

At the time of inspection, the waste heat boiler was out of service due to repairs.

A typical fired heater operation is illustrated in Table F.3.1.

TABLE F.3.1. - TYPICAL FIRED HEATER DATA
GAS OIL HYDROTREATER FURNACE

Unit No.	Duty Gcal/h	Eff. %	Flue Gas Temp. °C	Permissable Pressure kg/cm^2	Heat Transfer Surface		Max. Temp °C	Number of Passes		Number of Tubes	
					rad m^2	conv m^2		rad	conv	rad	conv
F-1	4.2	75	470	38.7	105	11.9	510	2	2	28	8
F-2	3.8	75	470	5.9	84	8.9	455	2	4	32	8

3.2. Heat Exchangers

The heat transfer equipment in the Gdansk Refinery uses TEMA Standards for design, fabrication, and materials. There are few applications where the fouling is extremely high. An example of the refinery's handling of these applications is that an extra tube bundle that must be kept available for E12 in the furfural extraction unit. The differential pressure and flow are closely observed. The operator decides when to change the tube bundle. This task requires approximately two days to complete during which time the exchanger is by-passed.

Air coolers

Some of the air cooling fans at the Gdansk refinery are equipped with variable pitch blades. The blade pitch being controlled by the product outlet temperature.

The operation of heat transfer and recovery equipment incorporates a record of equipment pressure difference and flow rate. The operators use this information to assess fouling as it progresses. The operators can arrange for cleaning or bundle replacement if excessive fouling is detected prior to normal turnaround.

3.3. Vessels

The vessel code in Poland does not allow more than 100 000 hours of operation for pressure vessels. There are many applications where this limit is too restrictive. For example, in the Reformer Unit 400, the reactor vessels contain hydrogen and are cycled each 12 hours of operation. Temperatures between 500°C and 900°C occur during regeneration. US practice uses the ASME Boiler and Pressure Vessel Code Section VIII, Division 2 for cyclic service life assessment. British 5500 code has similar rules. It would be an advantage for Poland's Vessels Authority to adopt some of the modern codes that would allow greater utilization of capital investments. Before a vessels' life could be extended, the metallurgical design basis for that vessel would have to be thoroughly investigated in the context of code requirements.

3.4. Rotating Equipment

The refinery pumps were primarily manufactured by Worthington. Double John Crane seals are utilized. LPG service uses a steam injected seal to prevent auto-refrigeration. Table F.3.4.1. illustrates typical pump operating conditions.

The pumps generally exhibited no vibration or seal leaks and showed signs of good original assembly and sustained maintenance.

The centrifugal compressor and its turbine drive were also excellently maintained. Reciprocating compressor 400-MK3 was operating without enough volume in the pulsation damper. A check valve in the discharge line was slamming and vibrating. The pressure indicator was broken; the needle had fallen off due to excessive cyclic pressuring.

TABLE F.3.4.1. - TYPICAL PUMP OPERATION

Pump	Suction Pressure (KPa)	Discharge Pressure (MPa)	Flow Rate		Approximate Efficiency (per cent)
			tonnes/hr	amperes	
P1A	800	2.70	300	24A @ 6kV	51.8
P2A	120	2.05	120	17.5A @ 6kV	38.32
P5A	95	1.18	19.5	61A @ 380V	29.36

3.5. Steam System

The system pressures are:

7.5 MPa	510°C	
2.0 MPa	340°C	Superheated
2.0 MPa	230°C	Saturated
0.6 MPa	180°C	Superheated

The 7.5 MPa steam pressure is produced by flashing and desuperheating the drum pressure steam. The 7.5 MPa superheated steam is used to generate turbo-electric power from the two turbogenerators. However, the 2.0 MPa and 0.6 MPa steam is used primarily for processing. Only one power generating turbine is run during the summer, but both units operate during the winter when the steam load is high.

Deionized boiler feed water is processed from the intake water source at the Motlava River. Approximately 60 percent of the process steam condensate is not returned to the power plant. The oily condensate is used in the desalter for process water. All equipment appeared to be well maintained except for the problems with flue gas corrosion at the boiler Ljungstorm air preheaters.

3.6. Piping and Valves

The piping on Unit 400 in the cyclic temperature use showed need of expansion allowance. The valves in the service exhibited internal leakage. This unit is scheduled to be dismantled when a new continuous catalytic reformer is built although conversion to pentane/hexane/isomerization should be investigated first.

3.7. Instrumentation

From the beginning, the Gdansk Refinery was equipped with electronic instrumentation. The instrumentation is an intrinsically safe type. The basic line is Honeywell "Vutronik." Process connected switches are mostly of US design and are in explosion-proof case. The refinery has already started to convert to a Distributed Control System (DCS). A Honeywell TDC-3000 system is installed and operating.

Unlike many other types of imported equipment that are sometimes difficult to maintain due to spare parts supply problems, the refinery uses the services of a Honeywell maintained warehouse (located on the refinery premises), that stocks all necessary spare parts. Consequently, the refinery does not lose time in obtaining the spare parts nor does it incur the cost of stocking the spare parts in its own warehouse.

Refinery personnel received their initial training and continue to receive additional training from Honeywell. The staff is already quite experienced in configuring and programming the TDC-3000 and can now continue this activity with minimal outside assistance.

The Crude Distillation Unit No. 100, Naphtha Hydrotreater Unit No. 200, and Merox Unit No. 300 have already been converted to TDC-3000 control. This system receives temperature measurements directly from process connected thermocouples from Units 100 through 800 and Unit 3700. Currently three operator stations are employed. The DCS controls 90 control loops (with redundancy), 100 indication and recording loops, and over 800 temperature measurement points.

Parts from old panel-mounted instruments, which were disconnected when the TDC-3000 was introduced, are cannibalized as needed, and used as spares for units not yet converted to the TDC-3000. Field transmitters are gradually being replaced with the most recent generation of regular electronic transmitters. Rosemount licensed transmitters built in Poland are being supplied. Smart transmitters will be used for services that require higher accuracy. The choice of manufacturer for smart transmitters has not yet been finalized.

The Gdansk Refinery has a time schedule for the conversion to DCS and computerization. By the end of 1991 the Gas Oil Hydrotreater Unit 500, H_2S Recovery Unit 600, LPG Recovery Unit 700, and Sulfur Recovery Unit 800 will be transferred to the TDC-3000. The Catalytic Reformer Unit 400 will be transferred to the TDC-3000 in 1992. All temperature measurements from Vacuum Distillation Unit 900, Propane Deasphalting Unit 1100, Furfural Extraction Unit 1200, Solvent Dewaxing Unit 1300, and Hydrofinishing Unit 1400 will be transferred to the DCS in 1991. The control of Asphalt Blowing Unit 1000 is currently, and in the future, will be by Siemens "Simatic". The total transfer to TDC-3000 (including the power house) is planned for 1995 completion. At the same time, the main control rooms (the plan is to have two) will be modernized. The rooms will be air conditioned and pressurized.

Originally, data logging and mass balances were accomplished by two Honeywell "Vupack" H-716 computers. One of these computers (mass balance calculations) was scheduled to be replaced in June 1991 by a desk-top, IBM compatible, 386 computer, incorporated into the overall communication highway and communicating through the Xenix system. An H-716 computer receives pressure, temperature, and flow signals from all of the above process units (with the exception of Unit 100), as well as from the power house and storage tanks used for data acquisition. Soon, it will have a communication link with the new computers.

A separate computer is used exclusively to process the data from a network of air quality monitoring stations. A workstation dedicated to accounting and other administrative tasks is also planned and will be incorporated into the plant communication loop.

Advance Controls

With the implementation of distributed control system (DCS) on their process units, the opportunity for a greatly increased use of advance controls and stratagems dawned for US refineries. It became apparent to many of these refineries that the increased profits from advance controls would quickly payout on analog instrumented process units, the costs of a DCS and the advance controls. One US major decided (in the early 1980s) to convert all its refinery process controls to DCS; their experience was that it normally took four to twelve months of the new control's operations to recover the DCS/Advance control costs for almost all units.

With the implementation of DCS, the following unit advance controls should be considered:

- Crude Units

  - Decoupling the side draws - This control allows the board operator to increase/decrease a product draw (changing that product's IBP and EBP) without upsetting the other product sidedraws.

  - Cutpoint calculation - This control replaces an expensive high maintenance analyzer. Calculating and inferring boiling point measurements such as 95 percent point from tower measurements. This measurement can then be used for tower control.

- Pumparound control - This control looks at the pumparound flows, temperature, energy use and heat transfer. It determines the economics of increasing or decreasing pumparound to increase or decrease product flow.

- Reformer Units

    - Reactor optimization - Controls reactor temperatures to optimize the catalyst life versus octane number output.

    - Prefractionator control - Sharpens fractionation so as to minimize catalyst poisoning heavy ends and non-reactable light components in the reactor feed, thereby increasing the reformer's octane barrel output.

- Hydrogen Desulfurizers

    - Hydrogen control - Ratio hydrogen to feed to smooth flow, enhance the desulfurization reaction and extend catalyst life.

- Furnace/Heaters

    - Furnace air control - Regulate the combustion air to minimize excess air and prevent smoke formation.

When starting an advance control project, a process audit covering those areas that the advance controls will impact needs to be made. This audit should show all pertinent data such as flows, process condition, energy usage, product quality and stream values. This establishes the baseline. Three to four months after implementation of the advance controls, a final process audit needs to be taken. This audit collects the same data that was taken for the starting audit. With the data from the two audits, a final report can be issued showing the actual savings versus the estimated savings and reasons for any differences. Besides establishing credibility for the project estimate and payouts, it also provides the feedback necessary to improve future savings estimating.

Ideal members of this final audit team are the advance control engineer, the process unit operations engineer, and one of the consulting engineers, if used. With the high degree of savings seen on advance control projects, there is usually a push for their rapid implementation. This push, plus a lack of available experience, makes it prudent to hire outside expertise, i.e. a consultant. This is an opportunity to upgrade the facilities staff expertise. A staff advance control engineer should be assigned to work with and monitor the consultant. On later projects, this will allow more (or sometimes all) of the same type of work to be done in-house.

Having already installed the TDC-3000 on three units, the refinery is looking for a consulting firm to develop process optimization strategies and algorithms which would permit introduction of advance controls. However, efficient process optimization controls would also require a substantial increase in the accuracy of some measurements, especially flow, and the introduction of additional dedicated on-line analyzers. The problems of process optimization controls and increasing the accuracy of flow measurements and adding the on-line analyzers were addressed by the Gdansk Refinery in general, but no practical steps have yet been taken.

The Gdansk Refinery instrumentation and computerization department is well trained and motivated to accomplish the task of converting the refinery's instrumentation to the most modern levels.

It is, however, suggested that more attention also be given to the problem of intra-plant communications and to the implementation of fixed and remotely controlled field closed circuit television, starting with a camera watching the flare. These two components would coordinate the highly advanced process control of the units and permit observation and improved control of field personnel and of the most important pieces of equipment.

Control valves

The Gdansk refinery is equipped primarily with Masoneilan valves. Many of them are imported. However, Poland has a license agreement with Masoneilan, and a significant number of control valves have been manufactured in Poland. There are also many Fisher valves - particularly the specialty valves (i.e. high pressure, high temperature). Most of the control valves in the power plant are Fisher valves.

Most of the valves are in good to moderate working condition. Only a few of them leaked at the flanged connections. Sometimes, there are problems with the valve's tight shut-off but usually the refinery is able to repair the valves.

Currently, about 90 percent of all control valves are equipped with positioners. With the introduction of DCS, some control loops, with the valves that do not have positioners show excessive hysteresis and dead band (over 3 percent). Wherever higher accuracy is required, the related control valves will be refurbished with the positioners.

Power house instrumentation

The power house instrumentation is not modernized. The boiler's design operating conditions are 7.5 MPa @ 510°C. Actual operating conditions are 7.2-7.4 MPa @480°C. The lower than design pressure and temperature are due to the fact that the boiler's tubing and superheaters are not in good operating condition. This, in turn, makes it necessary to disable the attemperators. The boilers are equipped with modern oxygen analyzers (Kent). The readings show low excess oxygen (2.6 to 2.7 percent).

During the visit, two boilers and one turbine were in operation. The pressure drop between the steam header and the turbine inlet at 120 tonnes per hour, read from the pressure gauge at the turbine panel and header pressure gauge (readings on the panel mounted instruments were judged to be even more uncertain) was approximately 0.06 MPa. This is extremely high.

Although it is possible that the accuracy of the gauges was not satisfactory and the actual pressure drop was much lower, the following should be noted. Analysis of the original calculations for the flow nozzles found that the line between the header and the turbine has an internal diameter of 230.18 mm. With two boilers supplying maximum steam of 160 tonnes per hour, the steam velocity will be about 50 meters per second which is high. Also, the minimum diameter pipe results in high differential pressure in the flow nozzles. Therefore, the total losses in the long run become relatively high.

The power plant control room is equipped with the original panel mounted instruments. The accuracy of these instruments and associated controls, as well as the accuracy of the instrument readings, is much lower than is achievable with more modern instruments. There is no automatic data logging, and the readings are manually entered into the shift journal twice every shift. With the low accuracy of the readings and the manual logging, it is very difficult to analyze the long term changes in the efficiency of the boiler operation.

The boiler level transmitter is connected directly to the boiler drum; there is no constant head chamber. It was not clear whether the boiler level measurements are compensated for boiler pressure. It was also not clear how the reduced temperature is accounted for in the boiler steam flow measurements. If the steam flow measurements are not compensated for temperature and pressure, the accuracy of these measurements would be reduced by 5 percent due to the lower steam temperature. Assuming the flow nozzle error is 2 percent and the accuracy of the transmitter is 1.5 percent, the resulting accuracy may be low by as much as 6 percent. Accounting for the fact that the flow nozzle has worked for about 15 years, in a pipe where steam velocity is high and erosion likely, it is reasonable to assume that the current accuracy of the nozzle is much less than 2 percent. Also the flow transmitter connection has long tubing which might reduce the accuracy even further. As a result, it is possible the overall error of the steam flow measurements could be even higher. It is therefore suggested that the refinery conduct a boiler audit.

Suggestions for further analysis

1. It was reported that the boiler feed water valves on the boilers are air failure closed. The recommended practice in the US is to clamp the valve in the position it was in prior to the air supply failure, and have a dedicated alarm for air failure to that valve.

2. There are no vibration or bearing temperature measurements and no alarms on the air fan. Availability of these signals in the control room might help avoid a costly shut down.

3. There are no oil level, bearing temperature measurements and/or alarms on the Ljungstrom air preheater. Availability of these signals in the control room might help to avoid costly shut downs.

4. It was reported that skin thermocouples are not used to monitor temperatures on the boiler tubes. This type of measurement might be quite useful.

5. Oxygen analyzers are calibrated once a year. In order to maintain stability and accuracy, it is suggested that the analyzers be calibrated more often.

3.8. Electrical Equipment

The two steam turbines drive generators produce 15 MW each at 6 kV. During the summer only one generator is in operation, producing energy for internal use only. In winter, two generators are in operation. At this time the refinery is selling energy to the Utility Power Company.

Generators (see Table APP.F.1 in Appendix F.

Jeumont Schneider
Electromechanical Division
59460 Jeumont, France

The generator section of the power plant building was designed and constructed by a French contractor. The remaining section of the building, with its three boilers, was constructed by a German firm. The main load at 6 kV level at power plant is:

3 induced draft fans	800KW
4 water supply pumps	780KW
2 air compressors	600KW

The main control panel and the local control panels at generators and the boilers are French. All others are domestic.

The electrical equipment is in good condition and has been well maintained. Further details pertaining to the electrical system can be found in Appendix F.

3.9. Corrosion

The dewaxing unit air cooler, 1300EA-23, which condenses water and a mixture of dichloroethane with methylene chloride (Di-Me), exhibits corrosion. The tubes are ASTM A179 carbon steel with aluminum fins. A spare tube assembly is kept ready for installation and the maintenance shop re-tubes the spent assembly. This air cooled unit exhibits control difficulties in winter and has inadequate surface area during extremely hot summer conditions. A study of materials resistant to the water and Di-Me combination is recommended. It is anticipated that titanium is a likely choice. Coupons of metallurgical samples should be subjected to the stream for evaluation before final selection. A water cooled condenser using the results of the metallurgical sample study should be designed to replace this air cooled unit.

3.10. Insulation Condition

External insulation at Gdansk is mineral wool with aluminum jacketing. This appears to be adequate. Valves, pumps and flanges were bare. It is recommended that where feasible, the bare components be covered. It is acknowledged that some units in very high temperature and hydrogen service require bare flanged joints to minimize bolt expansion and for leak detection and fire quenching respectively.

Internal insulation in some applications with better materials, or better assembly of materials, is desirable. For example: the vacuum tower heater's external walls are bare steel. Insulation consists of internal fire brick and refractory. The metal temperature exhibited on 14 June 1991 was 55-60°C with ambient temperature at 19°C. This resulted in a heat loss of 6 percent to 8 percent of the heater duty. It is recommended that a study of more effective refractory and ceramic wool insulation be made specifically for this heater.

4. MAINTENANCE

4.1. Policies

The time between turnarounds (TAR) at Gdansk is a fixed interval without regard to past performance of the units. A history of items replaced and failures between turnarounds would be an advantage in an effort to increase operating time between turnarounds. Also, on stream non-destructive testing for corrosion and the use of corrosion coupons would help provide for longer TAR intervals and/or increased safety.

4.2. History

Information regarding the maintenance history of the Gdansk Refinery was not received.

4.3. Current Practices

The maintenance and repair shops at Gdansk deserve a compliment for the excellent accomplishment of a difficult task of manufacturing and repairing the various pieces of equipment without access to Western manufacturers. The machine shop equipment, such as drill press, milling machines, and lathe, are not computer controlled. The accuracy of the work depends on the skill of the machinist. For example, a large heat exchanger tube sheet was being drilled one hole at a time with the holes being manually located. Numerically controlled machine tools would greatly enhance the repair shop's operation productivity and quality.

G. ENERGY LOSS MONITORING SYSTEM

The Gdansk Refinery incorporates a comprehensive system of process stream and utility metering. The system is not fully implemented on an individual unit or major equipment basis. As mentioned, decreasing the losses reported for operations is desirable. If a Loss Control Committee is set up as expected, its responsibilities could be extended to Energy Auditing. Accuracy and adequacy of the metering will be an essential aspect for loss control so utility metering should be checked and reconfirmed at the same time.

Also desirable is an extension of reliable oxygen analyzers to measure the oxygen in furnace/heater flue gas. An in-situ type oxygen analyzer such as the Zirtek with a measuring cell placed in the firebox should provide the accuracy and reliability needed. It also will provide high and low oxygen and temperature alarms as well as a reliable signal for an advance control furnace control and monitoring system.

Gdansk is gathering data from the process units and storing the information in the refinery computer system. The measurements for a reliable energy-use database are currently in the system or easily added. The essential need is to extract this data from the system in a meaningful timely manner. The database can then be used to identify problem energy uses and losses and significant energy trends. Programs could then be established to minimize losses.

Energy-use monitoring should allow charging the process units, on some calendar basis, for their various energy usages. Accountability for the efficient usage of the refinery energy then needs to be established, then goals to reduce energy use can be set and monitored.

Gdansk has implemented a TDC-3000 distributed control system (DCS) in the Fuels Block and is currently extending this system to the rest of the refinery. When implemented, the control system will be on a par with what is rapidly becoming the standard in Western refineries. This will then allow real time tracking of energy usage and with the implementation of advance controls to raise product quality and minimize the energy per tonne of crude processed. What remains is the programming of the system to yield helpful guides and documentation such as the performance of heat exchangers and their fouling trends so as to be able to optimize cleaning schedules etc. with positive cost-benefit returns.

In summary, the data obtained and equipment installed can be used to identify energy loss problems, energy use charges and energy usage trends and also be available for energy minimization advance controls.

The refinery is now managing energy loss through a variety of approaches. First, and most importantly, management has established an energy management group, whose purpose is to seek out and implement energy saving opportunities. These activities may generate projects that range from re-arrangement of the crude heat exchange train to changing reactor operating conditions and outlet temperature, yet maintaining yields and throughput, thus saving fired fuel usage.

Several state-of-the-art fixed combustion gas oxygen analyzers are installed at Gdansk but it is believed that a useful addition would be portable instruments for periodic checking of in-line instruments and also for minimizing the need for Orsat sampling. The operating staff appears conscientious in utilizing analyzer data for adjusting burners.

A difficulty in implementing energy saving projects is availability of funds, not opportunities or solutions to problems. Capital budgeting practices may need review. The desirable change in the operating staffs attitude in adjusting burners is an example of the type of staff motivation problems that must be extended to all areas of energy efficiency.

This is not to leave the impression that all is perfect. Further work remains to be done. The Gdansk Engineering Staff were very sensitive to energy recovery and are to be complimented. However, energy efficiency is and will be a continuing problem, so no let-up in effort is possible. The application of motivation techniques, such as setting objectives with mutual agreement between management and staff, accountability, ownership, rewards and ability of the staff to control the variables affecting their objectives, need to be implemented. In summary, much good work has been done by the Gdansk staff to reduce energy consumption. Their continued efforts will be needed to ensure future success.

FUEL SWITCHING/UTILIZATION

1. REFINERY FUEL SYSTEM

Refer to Section B.2. for information on the refinery fuel system.

2. GENERAL REVIEW OF POTENTIAL REFINERY USE FOR COAL

The availability of native coal makes a review of coal as an energy source of interest to the national economy. A study on the use of coal as an adjunct or substitute for hydrocarbon fuel streams is, therefore, included in this evaluation.

The refining of crude petroleum in the USA typically requires 380 000 Btu per barrel (crude feed) of fired fuel. Heat is provided by burning a variety of fuels in directly fired heaters. Generally the fuels are a collection of effluent streams from the various operations around the refinery complex in both gaseous and liquid forms.

Coal is frequently used in industry as a fuel source. Generally, it is used on large capacity boiler units. There are significant base investment and operating costs and activities associated with feed and ash handling equipment, sulfur removal, etc. that can be charged out over large installations but prove too inhibitive in the economics of small units.

There are many ways of utilizing coal as a fuel. Probably the most applicable to the situation at hand is discussed below. The first two, direct coal firing and coal gasification, are discussed in some detail. Several others, such as coal liquefaction, coal-oil mixtures, coal fired gas turbines, are touched upon briefly.

Coal usage in existing refinery process heaters would most likely be restricted to one of the methods in which a product fuel can be produced in one location and piped to the various users. Plot space in the vicinity of the existing furnaces along with safety considerations typically does not allow for coal and ash storage and handling facilities within the refinery processing area. Also existing equipment is not designed for the particulate loading experienced in the flue gas with coal firing. In addition, any required sulfur removal equipment would have to deal with flue gas clean-up on an individual process heater basis if there were not a central coal processing facility.

The entire refinery energy and equipment picture dictates whether coal could be incorporated into the refinery as a acceptable energy source. If a new process heater or utility boiler would be needed and the fuel balance allows for another fuel source, then the use of coal may be justified and the new coal technologies would be worth looking at. If the residual fuel picture changes because of modifications to the refinery, coal usage may be justified.

2.1. Direct Coal Firing

Coal usage is not simple anymore. Gone are the days of stoking the fire by shovelful of run-of-mine coal and just letting it burn. Coal may need to go through physical cleaning, sizing and drying just to get it to the furnace. Burners are specially designed to achieve optimum efficiency and low nitrogen oxides emissions. Additives are injected to reduce ash sticking to heater tube walls, reduce sulfur dioxide in the flue gas, etc. Flue gas may be subjected to further treatment such as wet scrubbing to reduce sulfur dioxide to tighter levels of environmental acceptance.

Traveling grate burners bring the coal automatically to the burning chamber where the coal is combusted. Coal with a moisture content much above 30 percent must be dried before burning, so lignite/brown coals would most likely need pre-combustion drying. Hot under grate air can be used for this purpose. Ash builds up on the grate until it drops into a hopper. The ash is later removed from the hopper. However sulfur must typically be dealt with after combustion if removing sulfur oxides are necessary. The cost of sulfur dioxide removal equipment significantly adds to the cost of a unit.

Modern direct coal burning systems include atmospheric and pressurized fluidized bed combustion (AFBC and PFBC) units that provide for gas burning, clean-up and heat recovery all in one unit. Limestone is used as part of the fluidizing medium and the calcium present in it reacts with the sulfur dioxide before it is able to escape from the combustion chamber. The result is a non-toxic disposable by-product.

FBC technology is applicable to a wide variety of fuels including a wide range of coals, residual oil, petroleum coke, etc. AFBC technology for boilers is available commercially from a large number of licensors while PFBC technology is still considered to be in the development stages. The application of FBC technology to a process heater may be possible, but it would require extensive pilot test runs and special considerations in equipment design.

2.2. Coal Gasification

Coal gasification has been utilized for a long time and there are several companies (Texaco, Lurgi, IGT, KRW, etc.) that have commercialized processes. The product from the gasification (hydrogen, carbon monoxide, carbon dioxide, and others) can be used as a chemical feedstock or a fuel gas. To produce a fuel gas of medium range heating value (9.3 to 18.6 MJ/cubic meters or 250 to 500 Btu/SCF) suitable for burning in a process heater, oxygen must be used in the gasification. Because of the reducing conditions present in the gasifiers, most of the sulfur in the coal is converted to hydrogen sulfide. Hydrogen sulfide can be removed reliably from the gas stream by a number of available processes. In addition, it can further be turned into elemental sulfur.

Development work is being done for in-situ desulfurization in a fluidized bed coal gasifier. This process is much the same as the PFBC except that the product is a gas with a heating value instead of combustion product gases. It is also similar to the FBC technology in that it can utilize a wide variety of fuels, such as the sour residual oil produced within the refinery.

Fuel gas produced in this way can be piped into a plant fuel header and used anywhere around the facility. The attractiveness of this option is that the coal usage would be in one central location while the fuel users could be in many different locations.

Another possible use of the gas produced via gasification could be as a fuel to a gas turbine. The gas turbine could be used to generate electricity or to provide a direct large capacity mechanical drive, such as a compressor. The thermal efficiency of a gas turbine is typically raised by using the turbine exhaust gas to raise steam in a waste heat boiler. This is the co-generation process.

2.3. Other Technologies

Coal Liquefaction

Production of liquid fuels from coal can be either indirect or direct. In indirect liquefaction, the synthesis gas produced in a gasification step is further reacted to produce a readily burnable fuel (i.e., via the Fischer Tropsch process to naphtha, diesel and waxes or via syngas to methanol to gasoline). Since the gasification product would be an adequate fuel for the heaters on the refinery, there would be no need to go beyond that step to liquid fuels.

Direct liquefaction producing a No. 2 type fuel oil would be more applicable to the fuel needs in the refinery. Several processes have been developed in the US since the 1960s including H-Coal, SRC-I, Exxon Donor Solvent, and SRC-II. The high cost and inefficiency associated with these processes led to the cutback of further development of the technologies as they stood. The early processes have been modified and further developed by the United States Department of Energy (US DOE) and industrial partners into two-stage liquefaction processes. These processes are still not available on a large commercial scale. Estimates are that the cost of a barrel of oil produced by coal liquefaction using such methods might approach $25 per barrel by the late 1990s.

Coal Oil/Water Mixtures

The use of coal slurried with oil or water to produce a usable fuel is also the subject of numerous studies and optimizations. There are even annual conferences on "Coal & Slurry Technology" sponsored by the Coal & Slurry Technology Association and the US DOE's Pittsburgh Energy Technology Center (PETC). Coal water mixtures can be prepared with up to 70 percent solids, while current technologies and pilot plant results show coal oil mixtures are limited to 30 to 50 percent solids. Coal-oil mixtures could be prepared in one location and pumped around the plant to the various process heaters; however, emissions in terms of sulfur dioxide, nitrogen oxides and particulates would be a problem at each furnace.

Coal-Fired Gas Turbines

Direct coal-fired gas turbines are being developed and improved by General Electric, Westinghouse, United Technologies, and others. In the refinery, the use of gas turbines are likely be restricted to electricity generation. Solids and impurities deposition on blades and casings would likely require frequent cleaning and duplication of equipment would be required to even out loads. Environmental control requirements would also likely limit the application of this technology to high quality coals.

The use of coal as an energy source for a power plant near the Gdansk Refinery was studied a few years ago. Based on this study, no action is being considered for the change from fuel oil to coal primarily due to:

- high sulfur and ash content of coal emissions
- added cost for coal and ash handling
- freight cost to bring in coal by rail
- disposal of high sulfur ash

Even fluidized bed combustion for diminution of the flue gas sulfur dioxide would only affect one of the objectives above.

Fuel Cells

The combination of coal gasification and emerging fuel cell technology presents an attractive high efficiency electrical and heat energy generation possibility. current projections, based on work sponsored by the US DOE, indicate an efficiency between 45 and 55 percent in converting hydrocarbons directly to electricity. The hydrogen and carbon monoxide rich fuel from coal gasification is suited to fuel cell use, with carbon dioxide used in the cathode side of the cell.

Of the four major fuel cell technologies, two are worthy of mention here: phosphoric acid and molten carbonate. Phosphoric acid fuel cells are at a more advanced state; however, they operate in the range of 200°C compared to molten carbonate cells at 650°C.

The molten carbonate fuel cell is best suited for use with coal gasification in applications where good quality heat is needed. The exhaust gas temperature of 650°C is useful in the generation of high quality steam for process purposes. The use of bottoming cycles further enhances the system.

Overall efficiencies, including electrical and recovery of exhaust gas heat to generate steam are in the order of 80 percent. The US DOE is sponsoring sub-megawatt tests of commercial sized units; these tests are scheduled for the 1993 calendar year.

While the technology is not ready for commercial use, it is potentially attractive and should be watched closely.

3. COAL AT THE GDANSK REFINERY

3.1. Availability and Characteristics of Coal

Coal is not used at the refinery.

3.2. Potential for Use

Modification to equipment and/or the space required for coal handling, flue gas desulfurization, etc., will require a major capital investment that is unlikely to occur.

3.3. Economics of Use

The availability and attractive price of natural gas and the ease of use within refinery fired heaters, coupled with the high capital cost required for coal utilization, leads to the observation that new coal burning furnaces are not an attractive alternative for the Gdansk Refinery.

Davy

References and Bibliography

Feldkirchner, Harlan. (Conversation 11 July 1991); Institute of Gas Technology, Chicago, Illinois, USA.

Stauffer, Chris (conversation 11 July 1991); Process Sales Company (representative for Pyropower Corp.), Houston, Texas, USA.

Scowden, James (conversation 15 July); Detroit Stoker, Monroe, Michigan, USA.

Ekmann, James M. (conversation 15 July 1991); Coal Combustion Division, United States Department of Energy, Pittsburgh Energy Technology Center (PETC), Pittsburgh, Pennsylvania, USA.

Vander Molen, Robert H. (conversation 19 July 1991); Combustion Power Company, Menlo Park, California, USA.

Dellefield, Randy (conversation 19 July 1991); United States Department of Energy, Morgantown Energy Technology Center (METC), Morgantown, West Virginia, USA.

Podolski, Walter F. (conversation 19 July 1991); Chemical Technology Division, Argonne National Laboratory, Argonne, Illinois, USA.

Engineering & Economics Research, Inc., Hagler, Bailly & Co.,Inc., PEI Associates Inc., Spaite, Paul W. ;"Emerging Clean Coal Technologies"; Noyes Data Corporation; Park Ridge, New Jersey, USA; 1986.

Cooper, Bernard R. and Ellingson, William A.; "The Science and Technology of Coal and Coal Utilization"; Plenum Press, New York; 1984.

Lord, Norman W., Ouellette, Robert P., Farah, Oscar G., Cheremisinoff, Paul N.; "Coal-Oil Mixture Technology"; Ann Arbor Science Publishers; 1982.

McGurl, Gilbert V.; "Two-Stage Liquefaction of Coal"; PETC Review, PETC; Issue 1, March 1990.

I. REFINERY EMISSIONS

1. SUMMARY OF ENVIRONMENTAL SURVEY

The Gdansk Refinery is subject to semi-annual inspections of atmospheric emissions by local (non-refinery) authorities with particular reference to hydrogen sulfide and sulfur dioxide. Permissible limits have been established for eight sources of vapor emissions. These are shown in Table I.1.2.1.

1.1. Refinery Sulfur Balance

During 1990 the Gdansk Refinery processed crudes from Iraq (Kirkuk), Iran, USSR, and Germany. The composite sulfur quantity entering with the crude is estimated to be about 34 000 tonnes per year. The crude rate for 1990 was 2 127 900 tonnes or about 67 percent of capacity.

The major part of the sulfur passes from the refinery via three routes. These are through the sulfur plant, the fuel oil, and the bitumen product.

1.2. Air Emissions

Flue gas enters the atmosphere from eight sources at the refinery and is reported to be the combustion products of 180 000 tonnes per year of fuel oil containing three percent sulfur. Conversion to sulfur dioxide results in 10 800 tonnes per year. Emission of sulfur dioxide at this level exceeds the permissible 8 603 tonnes per year shown in Table I.1.2.1. However, the fuel oil is cut back (blended) with desufurized gas oil or diesel in order to meet permit sulfur dioxide levels. Local authorities randomly sample each of the eight stacks twice a year, and not necessarily at the same time. A nominal fee is paid for pollution (amount unknown) with a ten times fee penalty, should atmospheric emission exceed permit values. The refinery has not been found in violation of its permit.

TABLE I.1.2.1. - ALLOWABLE STACK EMISSIONS, 1991

Stack Emissions	Quantity (kg/hr)	Quantity (tonnes/yr)
Power House		
Particulate	67	587
SO_2	556	4 871
NO_x	230	635
Lube Oil Heaters		
Particulate	49	429
SO_2	370	3 241
H_2S	2	17.5
NO_x	246	679
Low Flare		
SO_2	10	87.6
H_2S	0.04	0.35
NO_x	3	8.3
High Flare		
SO_2	10	87.6
H_2S	0.04	0.35
NO_x	3	8.3
Sulfur Plant	-	-
Fluidized Bed Incinerator		
SO_2	18	157.7
NO_x	1	2.8
Bitumen Oxidation Furnace		
SO_2	2	17.5
H_2S	0.02	0.19
	2	
Heating Oil Furnace		
SO_2	16	140.2
Total SO_2 Basis: 365 days per year	-	8 603

1.3. Water Quality

The refinery raw water is supplied by the river as described in Section B.5. The sequence of treatment for preparing boiler feedwater is also described in B.5.2. Table I.1.3.1. presents the average analysis of raw water, cooling water, and boiler feedwater.

Potable water is obtained from wells.

TABLE I.1.3.1. - WATER ANALYSIS, 1990

Description	Refinery Raw Water Supply	Cooling Water	Treated Boiler Feedwater *
pH	8.18	7.95	9.20
Total hardness as $CaCO_3$, ppm	256	274	-
Calcium as $CaCO_3$, ppm	-	189	-
Magnesium as $CaCO_3$, ppm	-	85	-
"P" Alkalinity as $CaCO_3$, ppm	1.5	1.5	0.05
Sulfate as SO_4, ppm	-	176	-
Chloride as Cl, ppm	71	132	-
Silica as SiO_2, ppm	10.5	-	0.023
Iron as Fe, ppm	0.25	0.08	-
Total Dissolved Solids, ppm	-	761	-
Suspended Solids, ppm	-	-	-
Turbidity, ppm	-	-	-
Conductivity, microMHOS/CM	515	-	6.6
Supply Temperature, °C	0.5-26		60-70

*After treatment with NH_4OH

1.4. Solid Waste Disposal

A new incinerator is being built to dispose of solids that accumulate in a waste water lagoon.

1.5. Impact of Maintenance Practices in Generating Emissions

Selection of crude oil with low sulfur content as feedstock is more significant in terms of lowering sulfur emissions than the present maintenance practices.

1.6. Evaporation Losses

Although time did not permit a thorough investigation of the tank farm and a determination of potential hydrocarbon savings, recommendations proposed in Section J include:

- forming a Material Control Committee to identify possibilities for reducing hydrocarbon losses
- acquiring a hydrocarbon analyzer for detection of leakage

1.7. Loss of Products to Solvents

Loss of products to solvents will be negligible as the only solvents, furfural and Di-Me, are recycled within their respective units. However, there will be a marginal loss of furfural, in particular, in the reject water from the unit following steam stripping.

2. HANDLING OF MATERIALS

The refinery practice in handling materials such as tetra-ethyl lead, heavy metals, acids, and tars was not reviewed. Therefore, the following sub-sections are not addressed:

- 2.1. Tetraethyl lead (TEL)
- 2.2. Aromatics
- 2.3. Solvents
- 2.4. Halogenated Hydrocarbons
- 2.5. Heavy Metals
- 2.6. Sulfur
- 2.7. H_2SO_4, HF
- 2.8. Combustion Products
- 2.9. Tars

3. MEASUREMENT OF EMISSIONS

The Gdansk Refinery is facing significant changes in the requirements for continuous emissions monitoring. The refinery has permits to operate eight sources of pollution. The refinery faces the task of selecting the instruments and methods for monitoring which would comply with government regulations and would be reliable and affordable. Considering the fact that flue gas analyzers are both expensive and high maintenance instruments, alternative methods of monitoring will need to be analyzed and negotiated with the authorities before the final method of monitoring is established. Until such time, the existing monitoring systems will stay in place.

4. REVIEW OF SPECIFIC RECOMMENDATIONS

There may be no need to install a continuous sulfur dioxide analyzer to monitor sulfur dioxide content in a flue gas of a boiler or a process heater. It may be sufficient to regularly determine sulfur concentration in the fired fuel using a portable instrument, measure and total the fuel flow, and continuously measure the oxygen level in the flue gas. Based on these data the amount of sulfur dioxide per unit of energy can be calculated as well as the total amount of sulfur dioxide released to the atmosphere during a certain period of time.

The nitrogen oxides components become a problem if and when the combustion temperature exceeds a certain threshold. This implies that the process of combustion should be carefully adjusted to reduce the amount of nitrogen oxides and the temperature in the boiler or heater should be accurately measured and maintained below a certain limit.

Consequently, the cost of continuous emission monitoring systems (CEMS) and their maintenance may be significantly reduced if the refinery can positively prove that the combustors are run in a consistently well regulated combustion mode, and all the related measurements are accurate and either made on regular basis (sulfur content in the fired oil), or continuously (oxygen in the flue gas and combustion temperature).

Since the success of any emission monitoring program is critically dependent on experience, it is recommended that the Refinery acquire a portable integrated system for flue gas analysis and short term monitoring. Such a system will measure sulfur dioxide, nitrogen oxides, carbon monoxide, carbon dioxide, temperature, stack draft, and efficiency. It also will test the smoke. This system would permit the refinery to develop initial skills in monitoring. Even more important is that in using this portable system the refinery would be able to accomplish a detailed emissions audit of all their sources, such as boilers and heaters and obtain important data on emissions before the first stationary CEMS is started up. The total quantitative picture of major emission components produced by the refinery pollution sources would permit the refinery to develop a first round comprehensive program of pollution reduction methods which might significantly reduce air pollution through better control of combustion and better maintenance of equipment.

High Flare Monitoring

The Gdansk Refinery has a problem monitoring flow in the flare header to the high flare. Monitoring this stream which relates directly to emission release from the flare is a problem which has not been entirely solved in the US. Television monitoring is a widely used practice in the US. Further study is suggested for Gdansk in the area of measurement and control of the flare header flow.

J. ENERGY EFFICIENCY IMPROVEMENTS

1. IMMEDIATE OPPORTUNITIES

Institute a "Material Control Committee" responsible for identifying and reducing hydrocarbon losses to more acceptable levels.

Use a variable frequency drive on a trial basis in a high pressure drop control valve service to reduce excessive pump power needs.

Alternatively, trim the impellers on the pumps that deliver excessively high heads to reduce control valve losses.

Test the reduction of stripping steam rates to the atmospheric and vacuum tower bottoms together with increased bottom side stream off-takes. This should have very little effect on product quality.

Commission a study for minimizing waste heat boiler tube corrosion problems that lead to long term losses when the boilers are out of service.

Consider a short term test, decreasing the desalter water application while using an improved demulsifier at the same time. The aim is to minimize water injection without affecting salt reduction.

Investigate the economics of using power recovering turbines in high pressure drop liquid let down service in the gas oil hydrotreater.

Insulate bare piping, fittings, pumps, etc., where service temperature exceeds 65°C. However, the flanged joints in the hydrogen service must be left bare for safety reasons.

Implement an effective eductor or compressor system for recovering waste gas leakage to the flare header.

Commission an examination and study of the vacuum heater refractory insulation for an optimum correction of hot spots.

Commission an expert tray design analysis to determine the cause of poor fractionation and provide alternatives for minimum cost correction of the problems.

Develop a heat exchanger monitoring system, that will follow fouling trends and measure the effectiveness of performance to optimize cleaning schedules.

Acquire low cost refinery simulation software to improve in-house studies for evaluating energy recovery projects.

Acquire suitable linear programming (LP) software for performing refinery operations optimization studies.

Acquire or develop a maintenance control program for all process equipment.

Arrange for the training of a qualified staff member in the techniques and use of "pinch" technology.

Study the potential benefits of a preflash system before the crude tower using process simulation and "pinch" technology.

Arrange for qualified staff to attend short "professional advancement" courses on fired heaters, advanced control systems, environmental and loss control etc. as appropriate.

Acquire a portable flue gas analyzer to aid in heater control improvements.

Acquire a non-contact industrial thermometer to aid in monitoring hot spots for maintenance correction and energy savings.

Evaluate the possibility of converting to a high/low pressure flash system for the Gas Oil Hydrotreater. Conduct a similar review for the Naphtha Hydrotreater unit.

2. MEDIUM TERM OPPORTUNITIES

Evaluate the replacement of the existing rotors in the Ljungstrom air preheaters with the corrosion resistant rotors.

Bypass the air cooler in the vacuum unit top pump-around and extend it to the raw water heating service during the winter and/or to PDA unit propane evaporation duties.

Commission a detailed study for converting the Di-Me air condenser to a titanium tubed water cooled condenser to control the current severe corrosion difficulties and the high air fin bundle replacement costs and to provide additional cooling and better temperature control.

Commission a study/evaluation to determine the best implementation of an advance control scheme and instrumentation for process operation optimization.

Consider the merits of a crude receiving custody transfer installation.

Commission a study of the strategy and instrumentation necessary for tank farm management to minimize loss of crude oil and products.

Commission a study for inter-unit product transfers and their accounting to help control oil loss.

Arrange for appropriate staff to attend short term business management courses to get an introduction to Western practices, methods, and techniques.

Investigate the repair or replacement of the power boilers soot blowing systems.

Study the addition of a vacuum pump to replace the steam vacuum jets in the normal operation of the vacuum unit.

3. LONG TERM OPPORTUNITIES

Study the conversion of direct fired heaters in PDA and furfural services to a high efficiency hot oil system with a cost/benefit analysis.

Commission a study for visbreaking vacuum residue to a lower viscosity fuel oil with the recovery of lighter products.

Commission a study for the conversion of the ultraformer (when retired from service) to pentane/hexane isomerization service. Amoco has done this.

Commission a study to evaluate the refinery needs for modern analytical equipment in the central laboratory to aid in energy and product improvements.

Procure numerical control units for the maintenance shop and write programs for time consuming tasks such as tube sheet drilling.

J. Energy Efficiency Improvement

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Institute a "Material Control Committee" responsible for carefully examining all aspects of hydrocarbon movements and processing to satisfactorily help close the mass balance for all operations and identify the points of all losses. Control and minimize losses through a practical loss prevention strategy and monitor the results on a continuing basis.	Negligible, considered to be a normal extension of Refinery Management and operational responsibilities.	At 3 000 000 tonnes/year capacity and $150/tonne crude value $45 000 per 0.01% decrease in refinery losses reported

J. Energy Efficiency Improvement

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Test the performance and effectiveness of variable speed drives on selected high pressure drop pump circuits using variable frequency control. Select situation(s) where the control valve pressure drop approximates 30% of the total pump head at normal flows which would rise to 50% or more at a reduced 85% capacity rate or less. Note: Suggest a crude unit feed pump trial and if the experience is satisfactory extend the procedure to other appropriate applications. Material cost information: Allen-Bradley Chicago 2 July 1991	<u>50kw:</u> Material = $9 000 Installed = $11 500 (@1.25 Factor) <u>200kw</u> Material = $31 000 Installed = $38 750	Power cost use = $0.06/kwh <u>50kW</u> @30% cv loss = 15 kw x 24 x 330 x 0.05 = $7 128/year Payout = $11,500/7128 = 1.61 years 50 kW @ 50% cv loss Payout = 0.97 years <u>200kw Pump</u> @30% cv loss Payout = 1.36 years @50% cv loss Payout = 0.82 year

J. Energy Efficiency Improvement

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Trim selected pump impellers where excessive control valve pressure drop is observed to a minimum 0.1 MPa pressure drop at design flow rate. If the total head can be reduced 10% the energy savings will be significant. Note: Crude and vacuum unit feed pumps are the best candidates.	Approximately 40 man hours or $500 per impeller	Power cost use = $0.06/kwh 50kw 5 x 24 x 330 x $0.06/kwh = $2376/year Payout = 0.21 years = 11 weeks 200kw Pump 20 x 24 x 330 x $0.06 = $9 504/year Payout = 0.0526 years = 2.7 weeks

J. Energy Efficiency Improvement

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Consider a short term task of reducing the stripping steam rate to the atmospheric bottoms from 3.5% to approximately 2.0% Investigate the degree of overflash and/or offtake of the atmospheric gas oil. The objective is to reduce the steam injection rate without significantly affecting the product quality. Expected savings up to 1.7 tonnes/hour steam. Note: Similar test also applicable to the vacuum tower.	Negligible but allow $5 000 for increased laboratory testing	LP Steam: $6.61/tonne Value = 1.7 x $6.61 x 24 x 330 = $151 295/year Payout = 0.033 years = 1.7 weeks

J. **Energy Efficiency Improvement**

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Commission a study to lessen corrosion effects in the fuels and lube plant waste heat boilers that result in approximately a 12 month period of downtime for retubing. Loss of LP steam is approximately 100 tonnes/day.	LP Steam $6.61/tonne $6.61 x 100 x 330 = $218 130 year/unit	Indeterminate depending upon study results and recommendations.

J. <u>Energy Efficiency Improvement</u>

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Consider a short term test program, for a step wise decrease in desalting water, together with laboratory advice on optimum/economic selection of demulsifier agents. Note: A 1.0% decrease from the current 5.0% water injection rate for a crude run of 270 tonnes/hour will save approximately 2 700 x (110-20) = 243 000 kcal/hour	Negligible, but budget $5000 for extra lab work and engineer's time	Fuel: $113.15/tonne @ 9.5 x 10^6 kcal/tonne A 1.0% decrease 243 000/(9.5 x 10^6) x 113.15 = $2.89/hr x 24 x 330 = $22 923/year Payout = 0.22 years = 11.3 weeks

J. **Energy Efficiency Improvement**

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-off
Investigate the economic feasibility for an effective power recovery from the high pressure liquid let-down in the gas oil hydrotreater. Flow: 70 m^3/hour at 25 bar op Theo kW = 70/.227 x (25 x 14.5)/1713 x 0.75 = 48.9 kW Assume 70% efficiency = 34.2 kw	Budget Hold until suitable machine for the service can be identified.	Power: $0.06/kWh Savings: 34.2 x 0.06 x 24 x 330 $16 250/year Payout: Hold

J. **Energy Efficiency Improvement**

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Insulate bare pumps, valves, piping etc. and jackets with aluminum jacketed insulation where process temperature exceeds 65°C.	Approximately 50 items at 1.0 m^2 each Installed cost at $210/$m^2$ = $10 500	At average process temperature = 150°C heat loss with 3 m/sec wind approximately 3200 kcal/m^2 = 160 000 kcal/hour Fuel: $113.15/tonne @9500 kcal/kg Savings: .160 X 113.15 x 24 x 3309.50 = $15 093/year Payout: = .7 years

J. Energy Efficiency Improvement

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Implement an effective eductor or compressor system to recover an estimated 400 nm^3/hr of flare gas leakage or spillage that is currently wasted. At an estimated MW = 16 and LHV = 12 000 kcal/kg savings are projected at: $400/22.4 \times 16 \times 12\ 000 = 3.43 \times 10^6$ kcal/hour	Budget: $50 000 for eductor system if found feasible for G.O hydrotreater 2-stage flash revamp or $250 000 for a compressor, surge tank and controls to fuel gas system.	Fuel: $113.15/tonne @9 500 kcal/kg Savings: 3.43/9.50 x 113.15 x 24 x 330 = $323 557/year Payout: 0.15 - 0.77 years

J. **Energy Efficiency Improvement**

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Commission a detailed examination and study for determining the heat losses sustained in the vacuum heater due to poor, inadequate or improper installation of insulation and firebrick. Costs for renewing, in accordance with modern practice to be established. Maximum temp (convection section) = 110°C Average temperature assume 70°C Predicted heat loss (ambient) 225 btu/Hour ft^2 Wind factor average 4.0 m/s = 2 Total surface 12.4 x 5 x 20.4 m = 7 600 ft^2 Heat loss expected: 3 420 000 btu/hour = 0.86 x 10^6 kcal/hour	Undetermined until study is completed	Fuel: $113.15/tonne Total loss: 0.86/9.5 x $113.15 x 24 x 330 = $81 125/year Assume 75% reduction is possible Net loss: $60 800/year

J. **Energy Efficiency Improvement**

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Commission an expert tray design analysis for the vacuum tower operations with present crude mix vapor/liquid loadings and determine the cost of any improvements that may be recommended. Objective: Improved product quality and possibly reduced stripping steam Note: Structured packing in critical zones is being considered.	Budget $ 5 000 to $10 000	Undetermined

J. **Energy Efficiency Improvement**

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Investigate the potential for the gradual replacement of existing heater burners with high efficiency low NO_x burners Objective: Improved air/fuel control Decreased NO_x emissions as more strict environmental regulations are enforced To be implemented upon positive cost/benefit results or when environmental concerns dictate.	Budget $5000 for study undetermined until study completed in respect to implementation	To be established by study

J. **Energy Efficiency Improvement**

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Develop and institute a heat exchanger train temperature and pressure monitoring program to detect fouling rates so as to optimize anti-foulant injection and/or cleaning periods. Note: Can be incorporated into the expanding TDC-3000 system	Minimal	Undetermined but an improvement upon existing practice

J. **Energy Efficiency Improvement**

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Action: Sponsor a study to evaluate process engineering simulation programs, including a heat exchanger network pinch analysis. Benefit: Provide an ability to simulate and/or calculate complex refinery chemical engineering operations. To simulate crude and vacuum columns with different crude oils; to simulate and optimize operating conditions, to use high speed computer calculations of unit operations so as to quickly understand and solve operating problems. Supplier of Simulation: "Hysim" - Hyprotech, Chem Share, Aspen Sim-Sci or equivalent. Supplier of Study: Engineering design firm of appropriate background. John Brown/Davy McKee would be pleased to be considered for this program.	Study Cost- $110000	Immediate

J. **Energy Efficiency Improvement**

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Acquire a suitable refinery linear program (LP) software, such as "PIMS", to enable the reliable modelling of the refinery and eventually the total complex. When completed (allow 6 months) the model will permit a systematic approach to optimizing operations with regard to feedstock/processing costs and product marketing realities. As experience is gained, the model can be utilized to study, analyze and identify: 1) areas of existing deficiencies 2) means of maximizing product profitability 3) optimum modernization possibilities.	Budget: Software: $50 000 Staff: 2 man years assumed, total cost estimated at $100 000	Undetermined, but at 3 million tonnes per year crude throughput at $150 tonnes $450 million/year $100 000 represents 0.022% of crude cost. Experience indicates average improvements of 10% in operational profitability can be achieved using LP techniques

J. **Energy Efficiency Improvement**

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Develop or acquire a maintenance history program or a more sophisticated history, scheduling, spare part catalogs/inventory repair method work order, etc. program to monitor and initiate a more effective preventive maintenance system for process equipment. Objective: To better track equipment problems and devise strategies to reduce down time and the expense of equipment failures	Budget: Minimal to $50 000	Undetermined but established as a cost effective procedure in modern maintenance operations.

J. **Energy Efficiency Improvement**

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Arrange for the attendance at a Linhoff- March "Pinch" technology training seminar at a European location for a qualified engineer fluent in English. The aim will be to assess existing heat exchange networks for improvements to higher energy efficiency and to pass on the instruction received to other staff members.	5 day course approximately $2 500	Undetermined but nearly immediate upon the first improvement implemented

J. **Energy Efficiency Improvement**

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Allied with the "Pinch" technology training experience, commission an engineering/cost study for evaluating the merits of installing a preflash tower before the crude distillation tower. This could also involve consideration of an alternative to hydrotreating the total overhead naphtha stream and the light end refractionation scheme.	Budget: $5 000 - $10 000	Undetermined but the objective is more effective crude preheat system, recovery of heat from product stream, and minimizing refractionation of light ends

J. **Energy Efficiency Improvement**

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Arrange for suitably qualified staff with appropriate language capabilities to attend short refresher courses in "Professional Advancement" such as those conducted at the Amsterdam RAI by qualified US/European instructors. Subject to availability, courses could include: Fired heaters Advanced control systems Environmental and loss control Engineering computing Refinery management Product quality control Project estimating, etc. Objectives: To introduce participants to state of the art techniques, methodologies and practices in their specialties. Also to provide an important contact with Western colleagues.	Budget: Allow $2 500 per course. Suggest an initial trial of 5 courses for evaluation of benefits	Undetermined, but would expect a pay off in one year through improved competence and awareness.

J. **Energy Efficiency Improvement**

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Action: Portable flue gas analyzer to measure, record, and monitor NO_x (or NO), SO_2 (or SO_x), CO, CO_2, O_2, flue gas temperature, flue gas particulates. Benefits: Expedite air pollution sources audit, expedite improvements of combustion efficiency, and verify operation of stationary flu gas analyzer Supplier: American Gauge Corp. (available through RAECO)	$6 000 $12 000 (advanced model)	Undetermined

J. Energy Efficiency Improvement

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Action: Purchase a non-contact industrial thermometer, such as a model 514L Thermo Hunter pro Benefit: Allows maintenance crew to measure surface temperature and determine hot spots for energy audits and trouble shooting surveys, thereby leading to energy savings through installation of additional insulation. Supplier: Capintee Instruments, Inc. Alternative: Infra-Red Photo Scanner for "Before and After" documentation purposes.	$1 500	Less than one year

J. **Energy Efficiency Improvements**

2. Medium Term Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Replace Ljungstrom air preheater plates with stainless steel, or equal corrosion resistant plates in the two power boilers. Reference: Tel contact with Ljungstrom	Budget: Carbon steel $100 000 each 36 month life Stainless steel $250,000 each 240 month life Installation cost: $20 000 each (estimated)	Based on 240 month term carbon steel: Units 240/36 x 2 x $100 000 = $1 333 333 Installation costs: 240/36 x 2 x $20 000 = $266 660 Total expenses = $1 600 000 Stainless Steel Units = 2 x 250 000 = $500 000 Installation cost 2 x $20 000 Total expense = $540 000 Savings 1 060/20 years = $53 000/year in favor of stainless steel **Note:** This simple analysis excludes: 1. Financial Discounting 2. Energy losses

J. Energy Efficiency Improvement

2. Medium Term Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Bypass the air cooler in the vacuum unit top pump- around circuit and extend to: 1) Raw water preheating during the winter 5-30°C x 210.0 m^3/hour = 5 250 000 Replaces LP steam kcal/hour estimated exchanger surface - 2200 ft^2 2) PDA C_3 evaporation estimated duty recovery potential = 3 500 000 reduce fired fuel demand 75% estimated kcal/hour exchanger surface = 5 000 ft^2	REF "Richardson" heat exchangers use: 1. \$25/ft^2 FAB x 2.5 = installed total = \$137 500 2. \$25/ft^2 FAB x 2.5 = installed total = \$312 500	LP stm = \$6.61/tonne Use: 625 kcal/kg condensing duty 1) $\frac{5\ 250\ 000}{625 \times 1000} \times 6.61$ = \$55.52/hour x 24 x 330 = \$439 750/yr Payout = 0.313 years Fuel = \$113.15/tonne 2) $\frac{3500\ 000 \times \$113.15}{9500 \times 1000 \times 0.75}$ = \$55.58/hour x 24 x 330 = \$440 213/yr Payout = 0.71 years

J. **Energy Efficiency Improvement**

2. Medium Term Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Commission a detailed study and corrosion tests for replacing the air fin Di-Me condenser which is suffering severe chloride corrosion (3 year life) with a titanium tubed water cooled condenser. Evaluate the material suitability and costs. Preliminary indications for verification are: air fin bundle replacement cost = $177 000 Life 3 years Titanium condenser installed = $500 000 Life (estimated) 15 years Note: The considerable space saving would also be useful.	$59 000/year $33 000/year	Indicated simple savings: approximately $25 000/year

J. **Energy Efficiency Improvement**

2. Medium Term Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Continuous emissions monitoring CO, SO_2, NO_x, CO_2 or O_2 and capacity Suppliers: Lear Siegler, Anarad, Rosemont	Up to $100 000 per source, depending on the updated National rules and regulations	Depending on regulations and penalties

J. **Energy Efficiency Improvement**

2. Medium Term Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Action: Commission a study to determine the best implementation of advanced control instrumentation and schema for optimizing process operation. Benefit: Results in improved energy efficiency and product consistency any yield.	$250 000	To be evaluated

J. **Energy Efficiency Improvement**

2. Medium Term Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Action: Purchase portable air analyzer model "Scentoscreen" Benefit: Measures total hydrocarbons and volatile and semi- volatile organic compounds such as gasoline, benzene, toluene, ethyl benzene, xylene, C_1 - C_6, etc. components in air and in water samples. Will permit the audit of hydrocarbon leakages in cooling water and condensate return systems, leakages in tank-farms and air pollution. Supplier: Sentex Technology, Inc.	Under $12 000	Less than 1 to 2 years

J. **Energy Efficiency Improvement**

2. Medium Term Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Custody Transfer installation (crude receiving) transportable meter prover with trailer (No truck). Suppliers: Xelix, Brooks, or Daniels	$200 000 to about $350 000	Undetermined

J. **Energy Efficiency Improvement**

2. Medium Term Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Action: Attendance at education/training seminar related to US practices of continuous emissions monitoring and related instrumentation. Benefit: Result will be improvements in current practices of continuous emissions monitoring and savings due to purchasing proper instrumentation.	Sending US instructor to the refinery $5 000	Undetermined

J. **Energy Efficiency Improvements**

2. Medium Term Opportunities — Gdansk Refinery

Description	Cost	Pay-Off
Action: Commission a study to evaluate the best strategies and instrumentation for tank farm management Benefit: Elimination of unnecessary losses of crude and oil products	Undetermined	Undetermined

J. **Energy Efficiency Improvement**

2. Medium Term Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Action: Commission a study to evaluate the best strategy and instrumentation for inter-unit product transfer and accounting there of. This study should account for any pending organizational changes in the refinery. Benefit: Reduction of unnecessary losses of products.	Undetermined	Undetermined

J. **Energy Efficiency Improvement**

2. Medium Term Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Arrange for appropriate qualified staff to attend a short term course in Business Management at an approved or certified institution in the USA or Europe. Objective: To acquaint East European managers with modern business practices, methods, and techniques and to provide the opportunities for useful contacts and bonds with their Western counterparts.	Budget: Assume 2 to 3 month courses and 3 to 5 participants over a two year period at $10 000/month $60 000 to $150 000 (estimated)	Undetermined, but should contribute to and improve refinery organization, efficiency and potentially its profitability

J. **Energy Efficiency Improvement**

3. Long Term Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Replace existing individual heater services in the propane deasphalting unit (2 off) and furfural unit (2 off) with a single hot oil heater and circulation system rated for 315°C Total duty 1990 (use 70% capacity level) PDA 127 479 tpy x 298 600 kcal FO/t = 38 060 x 10^6 kcal/year Furfural 451 094 tpy x 281 500 kcal FO/t = 126 974 x 10^6 kcal/year Total fired duty = 165 034 x 10^6 kcal/year 24 330 0.7 = design at 29.8 x 10^6 kcal/hour expect to achieve a 5% efficiency increase Savings = 0.05 x 38 060 x 10^6/0.7 = 11 788 x 10^6 kcal/year FO at 9 500 000 kcal/tonne = 1 241 tonne/year Recommended more detailed Engineering study to establish proper feasibility parameters and costs.	Expected $1 000 000+	Fuel oil = $113.15/tonne Savings = 1 241 x $113.15 = $140 400/year at 5% efficiency improvement Would need 10-15% improvement for viability by this initial assessment

J. **Energy Efficiency Improvement**

3. Long Term Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Commission a study regarding visbreaking vacuum residue for viscosity reduction leading to decreased fuel oil heating for firing and/or improved steam atomization and firing efficiency plus recovery of valuable lighter products.	Budget $25 000	Undetermined

J. **Energy Efficiency Improvement**

3. Long Term Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Commission a study to evaluate the impact of converting the spare catalytic reformer to C_5/C_6 isomerization Note: 1) This study is not required until the new reformer is contracted or the ultraformer is retired from service. Amoco has done this and might be a source of information. 2) An LP program would be extremely helpful for this analysis.	Budget $25 000	Uncertain but could lead to product quality improvements or decrease in TEL additions

J. **Energy Efficiency Improvement**

3. Long Term Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Action: Commission a study to evaluate the refinery needs for modern analytical equipment for the Central Laboratory and modern on-line analyzers. Benefit: Results in improved energy efficiency and product yield and consistency.	$25 000	Undetermined

K. ENVIRONMENTAL EMISSIONS REDUCTIONS

1. IMMEDIATE OPPORTUNITIES AND IMPLEMENTATION ACHIEVED

- Investigate the economics of gradually converting to high efficiency, low nitrogen oxide burners. If found to be feasible, this will result in improved air/fuel control and reduced nitrogen oxide emissions.

- The energy saving recommendations in Section J to install an effective eductor or compressor system in a flare gas recovery system will also result in reduced emissions.

- Acquire a portable volatile organic analyzer to allow the plant to identify areas of product loss. Data accumulated from a volatile organic compounds survey of the entire refinery will allow for a logical plan of organic emission reduction.

- Establish a hydrocarbon material controi committee to identify possibilities for deducing emission losses.

2. MEDIUM TERM OPPORTUNITIES

Install pumps and pipeline to recover water from waste treatment outfall and direct this to the cooling water systems. This eliminates a requirement for cooling water make-up from the Vistula River which is limited by agreement with the water use authority.

- Attendance at training seminar related to US practices of continuous emissions monitoring and related instruments.

- Acquire continuous emissions monitoring analyzer for environmental control.

K. ENVIRONMENTAL EMISSIONS REDUCTION RECOMMENDATIONS

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Investigate the potential for the gradual replacement of existing heater burners with high efficiency low NO_x burners Objective: Improved air/fuel control Decreased NO_x emissions as more strict environmental regulations are enforced To be implemented upon positive cost/benefit results or when environmental concerns dictate.	Budget $15 000 for study, benefit undetermined until study completed in respect to implementation	To be established by study

K. ENVIRONMENTAL EMISSIONS REDUCTION RECOMMENDATIONS

1. Immediate Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Action: Purchase portable air analyzer model "Scentoscreen". Benefit: Measures total hydrocarbons and volatile organic compounds (VOC) such as gasoline, benzene, toluene, ethyl benzene, xylene, C_1 - C_6, etc., components in air which are lost to the atmosphere. Data accumulated from a VOC survey of the entire refinery will allow for a logical plan of reduction. Supplier: Sentex Technology, Inc.	Under $12 000	Less than 1 to 2 years

K. ENVIRONMENTAL EMISSIONS REDUCTION RECOMMENDATIONS

2. Medium Term Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Action: Attendance at education/training seminar on US practices of continuous emissions monitoring and related instrumentation Benefit: Improvement in current practices of continuous emissions monitoring and savings due to purchasing proper instrumentation.	Sending US instructor to the refinery $10 000 - $15 000	Undetermined

K. ENVIRONMENTAL EMISSIONS REDUCTION RECOMMENDATIONS

2. Medium Term Opportunities

Gdansk Refinery

Description	Cost	Pay-Off
Continuous emissions monitoring CO, SO_2, NO_x, CO_2 and O_2 Suppliers: Lear Siegler, Anarad, Rosemont	Up to $100 000 per source, depending on the updated National rules and regulations	Depending on regulations and penalties

APPENDIX A - EXTRACT FROM CHARACTERIZATION REPORT

2. GDANSK REFINERY WORKS - GDANSK, POLAND

Address:	Gdanskie Zaklady Rafineryjne 80-718 Gdansk ul. Elblaska 135 Poland
Telephone:	388100
Telex:	0512278
Contact:	Marek Sokolowski Technical Director

2.1. Summary Description of Refinery

The refinery is located north east of the city of Gdansk. The original refinery was a hydroskimming plant designed to produce gasoline, distillates, and residual fuel oils. It was erected in 1973-1975. A year later construction was started on facilities for lube oils and asphalts production.

The Port of Gdansk is available for importing crudes from the Middle East, the North Sea, and other areas of the world. It handles ships up to 150 000 tonnes and is limited by the water depth of the shipping lanes through Skagerrak and Kattegat in the North Sea. The refinery also can be supplied with Russian crude via pipeline through a branch from the Friendship Pipeline as it passes through Poland on its way to Germany.

The lube and hydroskimming facilities are integrated from the standpoint of flow and stack gas heat utilization. Facilities are provided for cooling the products from the hydroskimming units to rundown temperature. This permits the independent operation of the fuel oil block while the lube facilities are shut down. The processing scheme and selection of processes was done by Bipronaft which also arranged for purchase of the licenses. The basic design was done by Snam Progetti and the detailed design was done by Bipronaft together with other specialized engineering companies for civil and other work.

The Gdansk refinery design capacity is 3 160 000 tonnes per year with an on-stream factor of 328 days assuming the following crude to be processed:

Kuwait Crude	1 340 000 tonnes/year
Zakum Crude	1 820 000 tonnes/year

The refinery supplies slack wax to the southern refineries for further processing to finished waxes. In most cases, this consists of clay treating for color improvement. Considerable shipping and handling costs could probably be saved if the wax were finished in the Gdansk refinery.

The block flow diagram of the refinery is shown in Figure No. 3. Table C.2.1.1 shows the process units within the refinery. Table C.2.1.2. shows production-case overall material balance for the refinery using the following crudes: Russian, Kirkuk, Iranian Light, Oseberg, and German.

Table C.2.1.1 - Refinery Units

Units	Date Operational	Design Capacity (tonnes/year)
Atmospheric Distillation	1974	3 130 000
Kerosene Sweetening (Merox)	1974	27 400
HDS & Splitting Light Distillates	1974	876 300
Catalytic Reforming	1974	413 000
H_2S Recovery (MEA)	1974	103 300
Sulfur Recovery - Claus Process	1974	4 243
Gas Oil Hydrodesulfurization	1974	531 000
LPG Recovery	1974	58 400
Vacuum Distillation	1976	1 267 600
Bitumen Blowing & Blending	1976	174 700
Propane Deasphalting	1976	289 200
Lube Oil Hydrofinishing	1976	1 400 000
Furfural Extraction	1976	515 800
DI-ME Dewaxing	1976	348 400

The units are conventional except that the flue gas ducts from the furnaces are integrated for heat recovery and heat exchange is provided for the operation of the fuels block of the refinery while the lube block is shut down. The lube block can also be operated independently of the fuels block, except that no hydrogen is available when the catalytic reformer is shut down. Naphtha storage is provided so that the reformer may be operated when the balance of the fuel refinery is shut down.

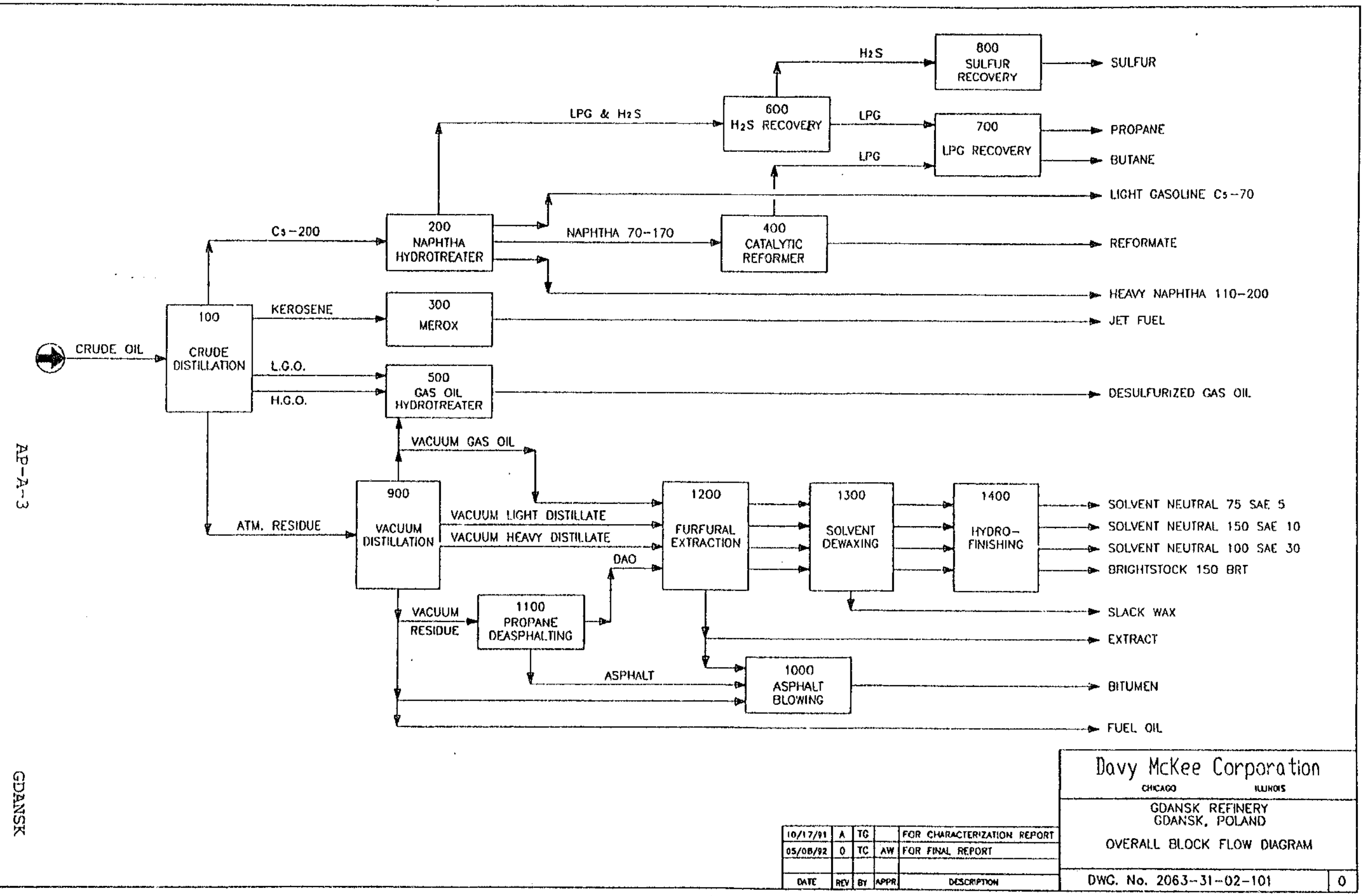

CRUDE OIL
100
CRUDE DISTILLATION
C5-200
KEROSENE
L.G.O.
H.G.O.
ATM. RESIDUE
200
NAPHTHA HYDROTREATER
300
MEROX
500
GAS OIL HYDROTREATER
LPG & H2S
NAPHTHA 70-170
600
H2S RECOVERY
H2S
LPG
LPG
800
SULFUR RECOVERY
700
LPG RECOVERY
400
CATALYTIC REFORMER
SULFUR
PROPANE
BUTANE
LIGHT GASOLINE C5-70
REFORMATE
HEAVY NAPHTHA 110-200
JET FUEL
DESULFURIZED GAS OIL
VACUUM GAS OIL
900
VACUUM DISTILLATION
VACUUM LIGHT DISTILLATE
VACUUM HEAVY DISTILLATE
DAO
VACUUM RESIDUE
1100
PROPANE DEASPHALTING
ASPHALT
1200
FURFURAL EXTRACTION
1300
SOLVENT DEWAXING
1400
HYDRO-FINISHING
1000
ASPHALT BLOWING
SOLVENT NEUTRAL 75 SAE 5
SOLVENT NEUTRAL 150 SAE 10
SOLVENT NEUTRAL 100 SAE 30
BRIGHTSTOCK 150 BRT
SLACK WAX
EXTRACT
BITUMEN
FUEL OIL
10/17/91 A TG FOR CHARACTERIZATION REPORT
05/08/92 0 TC AW FOR FINAL REPORT
DATE REV BY APPR DESCRIPTION
Davy McKee Corporation
CHICAGO ILLINOIS
GDANSK REFINERY
GDANSK, POLAND
OVERALL BLOCK FLOW DIAGRAM
DWG. No. 2063-31-02-101 0

FIGURE 3

Table C.2.1.2.
Material Balance - 1990

Input	Tonnes/year
USSR crude	483 017
Kirkuk crude	589 878
Iranian crude	841 941
Oseberg crude	185 605
German crude	25 059
Slops	44 967
TOTAL	2 170 467
Outputs *	**Tonnes/year**
Propane	11 534
Butane	27 999
Light Gasoline	75 276
Reformate	295 431
Heavy Naphtha	37 363
Jet Fuel	68 862
Desulfurized - Gas Oil	397 301
Solvents	169 698
Slack wax	45 561
Extracts	207 651
Bitumen	65 948
Fuel Oil	354 939
Sulfur	2 765
losses	25 644
Misc. small volume products; fuel, slops, etc.	384 495
TOTAL	2 170 467

* Outputs shown are for major streams only.

2.2. Utilities, Services, Off-sites

Electricity Generation and Distribution

Power is supplied to the Gdanzk refinery from an external network by 110kV overhead lines. Each line has the capacity to feed two transformers.

Three main transformers, 20MVA, 110 Kv primary and 6kV secondary, provide medium voltage to the refinery for its 6 Kv drives and power distribution to 31 local substations. Two main transformers are always in operation and a third transformer is used as a spare. Currently, transformers are working at 50 percent load. One transformer at 100 percent load can satisfy the refinery power requirements.

Steam Generation and Distribution

There are three fuel-oil fired boilers for steam generation. Each boiler has a capacity of 160 tonnes per hour and a minimum rate of 32 tonnes per hour. Information on the steam system is summarized in Table C.2.2.1.

Table C.2.2.1.
Steam System

Stream Pressure	Pressure (MPa)				Temperature (°C)			
	Min	Norm	Max	Design	Min	Norm	Max	Design
High	7.0	7.5	8.4	7.5	480	510	515	510
Medium	1.8	2.0	2.1	2.0	330	340	360	340
Medium	1.8	2.0	2.1	2.0	230	240	260	240
Low	0.40	0.45	0.73	0.50	170	200	220	180

Condensate Collection

Condensate is collected and returned to the boiler feed water system.

Fuel Supply

The fuel for the refinery is refinery gas plus fuel oil with a low sulfur content. This mix permits the refinery to meet the total sulfur emission specification. If additional gas becomes available, a higher sulfur fuel oil could be used.

Diesel fuel is used during start up. An LPG vaporizer maintains gas pressure on the fuel gas system for pilot lights and other uses. The fuel gas used in the refinery is by-product gas from the refinery. Propane is used to maintain pressure on the fuel gas system. The diesel and fuel oil properties are given in Section C.2.9, Tables C.2.9.5 and C.2.9.6, respectively.

Fresh Water Supply

Raw water intake is located on the Motlawa River and has a capacity of 400 cubic meters per hour. An analysis of the raw water supply is provided in Section C.2.9.1, Table C.2.9.1.1.

Raw water treatment includes coagulation, decarbonization, and filtration on a sand and carbon bed. This water supplies make-up water for the cooling water system (50 to 60 cubic meters per hour) and the boiler feed water system.

Drinking water is supplied from underground wells. The capacity of the wells is 780 cubic meters per day.

Water Treatment and Distribution

Water for the boiler feedwater system is demineralized and deaerated. Hydrazine is added as needed. The characteristics of the treated water are:

conductivity	< 0.3 microS/cm
SiO_2 content	< 0.02 mg/l
pH	6.5 - 7.5
O_2 content	< 0.02 mg/l

Part of the deaerated water supplies waste heat recovery boilers installed on flue gases from the process furnaces. The balance of the water supplies three steam boilers. An analysis of the treated boiler feedwater is provided in Section 2.9.1., Table C.2.9.1.1.

Cooling Towers

There are six cooling water towers with forced circulation of 4500 cubic meters per hour. It is a closed circulation network with a capacity of 5500 cubic meters. The network also includes sidestream filters, chlorine, inhibitor, and bio-active compounds feeding the system.

130

Inert Gas

Inert gas is produced by propane burning. The characteristics of the inert gas are:

O_2 content	0.1 % vol.
pressure	0.7 MPa
temperature	ambient

Compressed Air

Compressed air is supplied by two air compressors each with a 4930 Nm^3/h capacity, and 2 reciprocating compressors each with a 1930 m^3/h capacity. The characteristics of the compressed air are:

pressure	0.9 MPa
temperature	ambient
dew point	- 5°C

Crude Oil Receiving

Crude is supplied to the refinery via the crude terminal at Gdansk port or through the pipeline from the Plock area.

Product Blending and Shipment

Products are shipped by railroad cars and tank trucks, see Table C.2.2.2.

Table C.2.2.2
Product Shipping Facilities

Product	Shipping Method	Quantity (tonnes/year)
LPG	Rail cars	85 700
Gasolines	Rail cars	1 300 000
Diesel Oil	Rail cars	120 000
Bitumen	Rail cars	200 000
Slack wax	Rail cars	30 000
Gasoline and Gas Oils	Trucks	1 680 000
Sulfur	Trucks	6 000
Bitumen	Trucks	150 000

Tank Farm

The storage capacity for the refinery is summarized in Table C.2.2.3.

Table C.2.2.3.
Storage Tanks

Tank	Capacity
Crude	400 000 m^3
Slop	64 000 m^3
LPG	11 500 m^3
Gasolines	141 500 m^3
Jet	15 000 m^3
Diesel Oil	100 000 m^3
Fuel Oil	50 000 m^3
Lube Oils and Bitumen	234 000 m^3

Flares, Blowdown, and Dropout Systems

Process off-gases are collected and sent to a 60-meter flare. The flue gases from the process furnaces are collected and sent, without cleaning, to a 120-meter stack. Also, flue gases from the utility plant are sent, without cleaning, to a 160-meter stack.

Fire Protection

The fire protection system includes a fire fighting water network with hydrants and monitors, alarm system-control panel, and a control board with room fire detectors.

The fire brigade is fully staffed and equipped with standard fire fighting equipment including a foam system installed in the storage tank farm.

Automation and Control

There are two independently operated main control rooms. One control room is for the fuel block and one is for the lube block. There are several small local control rooms for specific units such as the fuels blending plant, finished lubricating oil blending plant, and the filling stations.

There are two main computers of the H716 type. They are used for the data acquisition, storage and management to execute mass balances, prepare daily production reports, and perform administrative work.

A Distributive Control System for process control is being introduced. Currently, temperature readings are taken for three plant units by a TDC 3000 Honeywell. The system includes a PC AT 80386 and currently mass balances are calculated. The plan for connecting other units to the TDC 3000 has been developed.

2.3. Chemicals and Catalyst Use

Table C.2.3.1.
Chemicals and Catalysts

Unit	Chemical	Quantity
Crude	caustic	0.01 kg/tonne
Furfural	furfural	1.0 kg/tonne
Di-Me	$C_2H_4Cl_2$ CH_3Cl	0.5 kg/tonne 1.0
Hydrofinishing Lube Oils Gasoline	 DEA CoMo catalyst ceramic balls CoMo catalyst ceramic balls	 0.03 kg/tonne 0.035 0.001 0.01 0.00155
Gas Oil Blending	Z-20 Z-35 Z-40 Il-country Il-export	0.15 kg/tonne 0.53 1.27 0.08 0.3
Asphalt Blowing	tribasic sodium phosphate PP-1 catalyst	0.0015 kg/tonne 0.009
Catalytic Reforming	AK20 Polish	0.01 kg/tonne 0.04
Boiler Feedwater	hydrazine phosphate	0.38 g/tonne 0.8
Potable Water	chlorine	3.5 g/tonne
Raw Water	chlorine	5.0 g/tonne
Decarbonated Water	chlorine lime $FeSO_4$	38.0 g/tonne 170.0 70.0
Service Water	chlorine	2.0 g/tonne
Waste Water	urea WALCO	1.0 35.0

134

2.4. Previous 12 Month Operating History

A summary of operations by month during the year 1990 is shown in Section 2.1., Table C.2.1.2. The crude unit was shut down during part of May and all of June for the bi-annual turnaround. In general, the units were scheduled to operate at rates which permit steady operation, rather than higher rates on a start-stop basis.

During the 12-month period, the tax structure and the government price structure made it cheaper to import gasoline, diesel, some lubes, and other products than to purchase them from Gdansk. Ships bunkers, which can be purchased from other ports at a lower cost, did not provide a significant market for Gdansk. Therefore, the refinery was operated below capacity. In addition, the deasphalter was shut down during the last 12 months due to a decreased market for bright stock produced from deasphalted oil,

During the previous 12 months the refinery started to build a service station chain and is negotiating for the direct sale of jet fuel.

2.4.1. Recent Modifications

A system was installed for using low pressure gas from the crude tower in the heater. Special low pressure burners were installed. Over a three year period, these measures have reduced fuel consumption by over 25 percent.

2.4.2. Crude Oil Supply

Crude can be supplied to the refinery either by sea tankers via the crude terminal at Gdansk North Port or by the pipeline connected to the Friendship pipeline from the USSR.

To meet sulfur specifications on fuel oil, it will be necessary to reduce the sulfur content of crude, to install facilities to reduce the sulfur content of fuel oil components, or to reduce the ratio of high sulfur components to low sulfur components in the fuel. The current choice is to replace part of the high sulfur crude with enough low sulfur crude to met sulfur specifications. The crude mix will consist of 30 percent low sulfur North Sea and 70 percent Iranian Light Crude.

2.4.3. Operating Experience

There were no unusual operating experiences on the fuel side of the refinery during the last 12 months. There was a planned maintenance shutdown. After 15 years operation, 33 tubes were replaced in the radiant section and one half of the tubes were replaced in the convection section of the atmospheric furnace. No tubes were replaced in the vacuum furnace. In 1988, new tubes were installed in the naphtha and heavy gas oil hydrotreaters.

One outstanding event was the development of a computer program for monitoring operations and for scheduling operations using Lotus 1-2-3. The Lotus program as developed contains almost all the data requirements for a linear program to optimize the refinery.

2.4.4. Impact of Crude Oil Change

Incorporation of low sulfur North Sea Brent crude into the blend will reduce the sulfur content of the residual fuel oil. It will also reduce the quantity of the residual since the 550 °C + on the Brent crude is about half that of 1990 crude runs and only one-third that of the design crude mix. Assuming that refinery operations will be limited by light products sales, as they have been, the refinery will run 5 to 10 percent less crude than is currently run. The hydroprocessing units and other units down stream of the crude unit will process roughly the same amount of feed on all light products sales limiting basis; however; the sulfur content of the feeds and products will be less. The reformer feed will have a naphthene plus aromatics content which is significantly higher than the design mix or the current mix; this means that at the same operating conditions, the yields of reformate and hydrogen will be higher and the octane of the reformate will be higher.

If the refinery is able to find a larger market for its products than in the past, it may be possible that the refinery could run short of downstream capacity. With a crude such as Brent (0.37 wt% sulfur), it might be sufficient to caustic wash Brent diesel and kerosene and use the hydroprocessing capacity for other services if blocked out operating is used. Blocked operation on high sulfur and low sulfur crudes might be attractive. With lower sulfur feeds to the hydroprocessing units, lower sulfur products could be produced; alternatively, a higher charge rate might be possible. The capacity for the various scenarios should be determined.

With the new crude mix, the quality of the reformate could improve enough so that future octane requirements could be met by blending MTBE from the Plock Refinery. The future gasolines will probably require that there will be some oxygenates content in any case.

All of the various possibilities should be included in a linear program designed to optimize operations.

2.4.5. Impact of Product Market Changes

The refinery plans to develop 28 retail stations within a 100 km radius of the refinery. The first four are scheduled to be build in 1991. The refinery plans to fund these stations from its own revenues. Currently, a small shop that sells the refinery's finished motor lubricating oils is located at the refinery's headquarters.

It is anticipated that there will be a significant increase in road building which will result in increased asphalt sales. This will favorably impact refinery economics and make it possible to use the residue from high sulfur crudes for asphalt. The result should be that processing of lower cost, heavy high sulfur crudes will be more attractive.

For the export market, lower sulfur distillate products will probably be required. If lower sulfur crudes are processed, it should be possible to supply these products.

The TEL content of Gdansk gasoline is now too high for the export market. It is probable that in the future, unleaded gasoline will be required for both the Polish and export markets. A scenario could develop in which unleaded gasoline would be sold only in population centers.

Increased tourism should have a favorable impact on gasoline demand. Gasoline specifications are discussed in C.2.4.4 and C.2.4.6.

2.4.6. Impact of Legislation and Social Changes

It is anticipated that the tax structure will be changed so that it will not favor the import of products over the products from the Polish refineries. This will have a favorable effect on refinery economics and tend to increase crude runs.

Free market prices could replace the current low state-dictated prices for heating apartments and public buildings. The laws could require that much lower sulfur fuels be burned in high population density areas such as Warsaw. Gas imports could replace part of the residual fuel oil market.

Rail transport is now subsidized by the government. Slack wax derived from Gdansk is now shipped to the small southern Polish refineries for finishing. The slack wax from deasphalted oil is only clay treated for color improvement; this could be done at Gdansk. These shipments by rail could be reduced.

It is possible that legislation will be enacted requiring some oxygenate content of gasolines (MTBE or alcohols). Export sales to European countries will probably require oxygenate content. This could impact decisions regarding reforming capacity.

2.5. Environmental Considerations

2.5.1. Quality of Local Environment

Until 1994, the refinery will be permitted to emit up to 6 400 tonnes per year of SO_2. In 1990 SO_2, emissions were 9000 tonnes. The use of 30 percent low sulfur North Sea crude in the mix will permit Gdansk to meet this emission specification. If more natural gas becomes available, the emissions could be reduced even more.

2.5.2. Current Emissions Control

NO_x is controlled by firing conditions. The refinery does not have coal burning utilities or processes which emit particulates. There is no problem with CO.

Flows to the flare should be monitored and flare flow reduced to a minimum. The refinery has proposed a flare gas recovery system. A pitot tube could be used to give an indication of the flare flow.

In addition to low sulfur content gases, about 180 000 tonnes per year of fuel oil of 3.0 percent sulfur content have been burned in recent years in the power plant. The sulfur content of fuel oil products and the liquid fuel used in the refinery will be controlled by blending low sulfur crudes from the North Sea with the higher sulfur crudes from the Middle East. The sulfur emission will be reduced in proportion to the reduction in sulfur content of the liquid fuel.

The refinery has two API separators and is installing a third separator to improve the quality of waste water. The waste water is flocculated, settled, mixed with the sanitary effluent, aerated, and sent to a large (40 000 cubic meters) stabilization basin. The overflow from this basis meets Polish standards.

The solids from the separator following the flocculation step are high in iron due to the $FeSO_4$ used as the flocculating agent. The solids are dewatered to 40 percent solids and sent to a Lurgi fluidized bed incinerator. The remaining solids, containing 40 percent iron, are used in land fill. Markets for the solids are be developed.

The sludge from boiler feedwater treating is sold for agricultural purposes.

2.6. Refinery Specific Potential and Opportunities for Improvement

Linear programming studies should be made to determine the most economic route to meet future octane requirements. Alternates are to install a CCR reformer, use MTBE or alcohols, install C_5 and/or C_6 isomerization, or to use combinations of these steps. Sale of virgin naphtha would eliminate low octane material from the gasoline pool and improve the pool octane.

A study should be made to determine if paraffin production at Gdansk (rather than the smaller refineries where it is done now) from the available slack waxes would be profitable.

If bright stock can not be sold, as was the case in the last 12 months, consideration should be given to hydroprocessing the deasphalted oil. By hydrodesulfurizing the deasphalted oil and blending the low sulfur product to the residual pool, residual fuel sulfur content would be reduced. This would make it possible to use lower cost, higher sulfur content fuels. Possibly, the deasphalted unit could be revamped for super critical operation with C_4 or C_5 solvent to reduce the residual quantity and for higher throughput.

2.7. Refinery Specific Problems and Trends

The major current problems for the refinery relate to meeting the changing (no lead) gasoline octane requirement and reducing the sulfur content of products. These have been discussed in the preceding sections.

2.8. Reference to Data Base

The information contained in the questionnaire has been formatted into a computerized data base, which is the subject of a separate report.

2.9. Supporting Plant Data

Table C.2.9.1.	Water Analysis - 1990
Table C.2.9.2.	Utilities Consumption - 1990
Table C.2.9.3.	Characteristics of Crude Oils
Table C.2.9.4.	Atmospheric Distillation Design Capacity
Table C.2.9.5.	Diesel Fuel Properties
Table C.2.9.6.	Gasoline Properties
Table C.2.9.7.	Fuel Oil Properties
Table C.2.9.8.	LPG Properties
Table C.2.9.9.	Harbor Characteristics

Table C.2.9.1.
Water Analysis - 1990

Description	Raw Water Supply	Semi-Open Cooling Water	Treated Boiler Feedwater
pH	8.18	7.95	9.20
total hardness as $CaCO_3$, PPM	256	274	---
calcium as $CaCO_3$, PPM	---	189	---
magnesium as $CaCO_3$, PPM	---	85	---
P alkalinity as $CaCO_3$, PPM	1.5	1.5	0.05
sulfate as SO_4, PPM	---	176	---
chloride as Cl, PPM	7.1	132	---
silica as CiO_2, PPM	10.5	---	0.02
iron as Fe, PPM	0.25	0.08	---
total dissolved solids, PPM	---	761	---
suspended solids, PPM	---	---	---
turbidity, PPM	---	---	---
conductivity, microMHOS/CM	515	---	6.6

Table C.2.9.2.
Utilities Consumption - 1990

Unit	Unit Feed (tonnes)	Fuel Oil (tonnes)	Fuel Gas (tonnes)	Diesel Oil (tonnes)	Propane (tonnes)	LPS (tonnes)
crude distillation	2127810.0	21348.0	8999.1			74430.0
naphtha recovery	554883.7	7591.0	1871.2			
catalytic reformer	337974.1	11816.6	8291.8			12637.0
gas oil hydrotreater	421152.9	2600.3	2330.2			
H_2S recovery	61074.7					10650.0
LPG recovery	45592.5					11434.0
sulfur recovery	3054.6		168.6			
vacuum distillation	907339.7	8562.1	1650.5			29749.0
asphalt blowing	113.0	1389.9	851.0			23905.0
propane deasphalt.	127479.2		3114.8		294.0	16602.0
furfural extraction	451093.5	11263.3	1224.8			46356.0
solvent dewaxing	284998.1				101.0	249325.0
hydro finishing	195508.3		429.8			12045.0
lube oil						
fuel gas						99715.5
inert gas						41716.0
waste water treat.			733.0		1339.0	
power plant		86296.0		240.0		
others						204262.0
TOTAL		150867.1	29666.8	240.0	1734.0	832826.5

Table C.2.9.2. - continued
Utilities Consumption - 1990

Unit	MPS (tonnes)	SHHP (tonnes)	Cooling Water (tonnes)	Electric Power (kWh)	Energy Cons. (Gj)
crude distillation	1139		822754	10721208	1639893.0
naphtha recovery	2665		740353	6995640	446613.7
catalytic reformer	4062	159449	1735082	2634535	1481229.6
gas oil hydrotreater	1314		594882	1028038	238926.8
H_2S recovery					29873.3
LPG recovery			781823	2025317	39978.0
sulfur recovery				1386551	1391.0
vacuum distillation	100182		9103406	5616235	840236.0
asphalt blowing	462			5404279	190413.2
propane deasphalt.	1342		1111410	2936357	240425.8
furfural extraction	16201		3705470	1766568	716758.1
solvent dewaxing	3793	252448	6010068	10985537	1543307.8
hydro finishing	15563		2270829	775845	105819.0
lube oil				2723535	289506.7
fuel gas				2205642	124953.7
inert gas				1289490	66718.2
waste water treat.				771478	41695.6
power plant				16044374	3638768.2
others	42351	12923			734725.8
TOTAL	199075	424820	26876076	75310629	12423761.4

192

**Table C.2.9.3.
Characteristics of Crude Oils**

Crude Oil/Characteristics	USSR Crudes	Arabian Light	Iranian Light	Brent Blend
Density 15°C, Kg/m^3 (API)	860 (32.9)	859 (33.1)	855 (34.0)	835 (37.9)
Sulfur, wt %	1.45	1.74	1.47	0.37
Water, wt %	0.23	0.12	0.14	0.36
Chlorides, MgNaCl/kg	15	108	66	24
IBP, °C	45	59	45	38
Yields: under 80° wt %	7.28	4.92	7.68	8.8
80-150°C	10.50	10.44	10.84	13.5
150-180°C	5.05	5.34	5.32	5.1
180-200°C	3.30	3.31	3.21	3.4
200-350°C	25.42	27.01	24.52	26.8
350-520°C	23.75	27.31	28.01	25.7
520-550°C	3.12	4.13	3.25	5.9
Residue above 550°C	21.88	17.54	17.17	10.8
Viscosity @ 20°C, mm^2/sec.	9.34	10.70	9.72	6.14
Pourpoint, °C		<-30	-42	-9
Conradson Carbon wt %	3.74	4.53	3.97	2.0
Metals (V+Ni), ppm	49	17	53	8
Asphaltenes, wt %	1.71	1.12	1.14	0.62
Paraffins, wt % (Freezing point, °C)	2.57 (53)	2.4 (56)	2.94 (52)	- (-)
Acid Number, MgKOH/g	0.06	0.01	0.09	0.06
Aromatics + Naphthene A+N/ZA+N in Free 80-150°C, wt %	39.4/47.4	27.7/39.6	39.4/52.2	57.3/74.6
Sulfur in Vacuum Residue, wt %	2.80	4.23	3.54	1.13
Metals Content (V+Ni) wt %	206	78	302	41
Paraffin Content in wt % (Freezing Pt., °C) wt %	3.18 (58)	1.31 (60)	2.82 (60)	—

Table C.2.9.4.
Atmospheric Distillation Design Capacity

Crude	Yearly Capacity	Daily Rate
Kuwait Crude	10,910 tonne/year 12,560 m^3/day	454.6 tonne/day 523.3 m^3/day
Zakum Crude	8,870 tonne/year 10,760 m^3/day	369.6 tonne/day 448.3 m^3/day

Table C.2.9.5.
Diesel Fuel Properties

Characteristics	Winter	Summer
Distillation, volume 50% max 90% max	 280 350	 290 350
Viscosity 20 °C	2.4-6.0	2.8-8.0
Flash Point °C min.	40	40
Setting Point, °C	-20	-5
Sulfur Content, ppm	6 000	6 000
Carbon Residue, %wt. max	0.2	0.2
Ash, %wt max	0.01	0.01
Water and Sedimet, %vol	0	0
Cetane Number, min	45	45

Table C.2.9.6.
Gasoline Properties

Characteristics	Regular	Premium
Octane Number RON MON	 86 80	 94 84
Distillation, volume 10% max 50% max 90% max EP max	 70 125 185 215	 70 120 185 215
Distillation Residue % vol max	1.5	1.5
RVP, KPa	winter 50-80 summer 40-70	winter 50-80 summer 40-70
Sulfur Content, wt% max	0.15	0.15
MTBE Content %vol	---	---
TEL Content Pb/ℓ	0.56	0.30

Table C.2.9.7.
Fuel Oil Properties

Characteristics	Grade III
Distillation, volume 10% max 90% max	 --- ---
Viscosity, 80°C max	122
Flash Point °C min	110
Setting Point, °C	+25
Sulfur, wt%	3.0
Carbon Residue, %wt. max	---
Ash, %wt max	0.2

Table C.2.9.8.
LPG (Liquefied Petroleum Gases) Properties

Characteristics	Propane	Butane	LPG
Vapor Pressure @158 F	3 040	1 080	2 550
Butane and Heavier %wt max	10	---	---
Pentane and Heavier %wt max	---	1	1
Residual Matter	---	---	---
Total Sulfur, ppmw	50	50	50
Free Water Content	---	---	---

146

Table C.2.9.9.
Harbor Characteristics

The Port of Gdansk serves the refinery. Local weather conditions permit harbor operations for about 300 service-days per year.

The harbor can accommodate crude tankers up to 135 000 tonnes/DWT and product tankers up to 60 000 tonnes/DWT. The harbor facilities can service ships up to a length of 300 meters with a beam of 50 meters and a draught of 15 meters. There are conventional berthing on jetty for refinery on and off loading. Six pipelines serve the refinery from the berth having the following pumping rates:

R1	Crude oil	10 000
R2	Gasoline	2 500
R3	Jet	1 000
R4	Circulating	1 000
R5	Gas oil	2 000
R6	Fuel oil Insulated	1 000

There are no viscosity limits to the pumping although viscosity affects pumping rates. The ambient working temperatures vary from -16°C to +30°C. There is no interference with dry loading/unloading.

ABBREVIATIONS

°API	deg API (gravity of oil fractions, defined by API)
°C	degree Celsius
°F	degree Fahrenheit
%	per cent
/	per (e.g., tonnes/day)
A	ampere
ACFM	actual cubic feet per minute
AFBC	Atmospheric Fluidized Bed Combustion
API	American Petroleum Institute
ASTM	American Society of Testing Materials
BACT	best available control technology
BFW	boiler feed water
BOD	biological oxygen demand
BPCD	barrels per calendar day
BPSD	barrels per stream day
BS&W	Basic, Sediment and Water
BTX	benzene toluene xylene
Btu	British thermal units
C.F.	characterization factor
CCR	continuous catalyst regeneration
COD	chemical oxygen demand
CV	calorific value (heat of combustion)
DCS	distributed control system
DEA	Diethanolamine
EP	end point
EPA	Environmental Protection Agency (U.S.)
FBP	final boiling point
FCC	fluid catalytic cracking
FGD	flue gas desulfurization
FOE	fuel oil equivalent
G	giga(10^9)
GCV	gross calorific value
GJ	giga joules
HC	hydrocarbons
HDS	hydrodesulfurization
HP	high pressure
Hg	mercury
Hz	hertz

158

IBP	initial boiling point
IGT	Institute of Gas Technology
ISBL	inside battery limit
J	joule
KRW	Kellogg Rust Westinghouse
LHSV	Liquid Hourly Space Velocity
LP	linear programming/low pressure
Lube	Lubricating
M	mega(10^6)
MEA	Monoethanolamine
MEK	methyl ethyl ketone
MHC	mild hydrocracking
MON	motor octane number
MPa	Megapascal, a unit of pressure
MSW	municipal solid waste
MTBE	methyl tertiary butyl ether
MVA	mega volts ampere
MVAR	mega voltampere reactive
MW	mega watts
NAAQS	National Ambient Air Quality Standards
NCV	net calorific value
NO_x	Oxides of Nitrogen
NPDES	National Pollutant Discharge Elimination System
OSBL	outside battery limit
OVA	Organic Vapor Analyzer
PFBC	Pressurized Fluidized Bed Combustion
PONA	Paraffins, Olefins, Naphthanes and Aromatics
Pa	pascal, a unit of pressure
RCC	reduced crude conversion
RON	research octane number
RTD	Resistance Temperature Detector
RVP	Reid Vapor Pressure
S.R.	Straight Run
SCFD	standard cubic feet per day
SCFH	standard cubic feet per hour
SCFM	standard cubic feet per minute
SG	specific gravity
SO_x	Oxides of sulfur
SRC	solvent refined coal
T	tera (10^{12})
TBP	true boiling point
TDS	total dissolved solids
TEFC	totally enclosed fan cooled
TEL	tetraethyl lead
TOC	total organic carbon
TSS	Total Suspended Solids

UOP K	UOP Characterization Factor
V	volt
VOC	volatile organic compound
WWTP	wastewater treatment plant
WATSON K	Watson Characterization Factor
XP	explosion proof
atm	atmosphere or atmospheres
bar	bar
cP	centipoise
cSt	centistokes
cal	calorie
cm	centimeters
cps	cycles per second
day	day
ft^3	cubic feet
ft	feet or foot
g	gram
gal	gallons
gpm	gallons per minute
h	hour
hp	horse power
in	inch or inches
k	kilo
kA	kiloamperes
kPa	kilo pascal, a unit of pressure
kV	kilovolts
kWh	kilowatt hour
kcal	kilo calories
kcal	kilo calories
kg	kilogram
kg/cm^2	kilogram per square centimeter
lb	pound or pounds
liter	liter or litre
m	meter or metre
max.	maximum
mg	milligram
mi	mile
million	million(10^6)
min	minute
min.	minimum
mm	millimeters
mol	mole
n	normal
ohm	ohm
pH	pH, a measure of acidity or strength of a base.
percent	percent(or %)

160

phase	phase (electrical)
ppm	parts per million
ppmv	parts per million (volume)
ppmw	parts per million (weight)
ppb	parts per billion
psi	pounds per square inch
psia	pounds per square inch absolute
psig	pounds per square inch gauge
ptb	pounds per thousand barrels of oil
rpm	revolutions per minute
sec	seconds
tonne	metric ton
tonnes	metric tons
vol	volume
wt	weight
y	year

USAID

TERMS OF REFERENCE

DESCRIPTION/SPECIFICATIONS/WORK STATEMENT

Component #2: A PETROLEUM REFINERY EFFICIENCY IMPROVEMENT ENERGY CONSERVATION PROGRAM

1. BACKGROUND

The petroleum sectors of Bulgaria, Czechoslovakia, Poland, Romania, and Yugoslavia (as well as that of Hungary) are emerging from a 40-year period of centrally-planned crude supplies and centrally-controlled markets. Practically all of the petroleum refineries in these six countries were built, or modernized, during this period.

Among the five countries, it appears that Bulgaria has three separate refineries having an aggregate throughput of 300,000 B/D; Czechoslovakia has seven aggregating 455,000 B/D; Poland nine with an aggregate throughput of 385,000 B/D; Romania thirteen aggregating 617,000 B/D; and Yugoslavia seven with an aggregate capacity of 609,135 B/D. Now, these refineries face changing circumstances.

First, it is likely that the existing refineries were designed to process a narrow slate of crude oils supplied from the USSR. Now, crude supply options have broadened so that supplies can be bought on the world market through spot and contract purchases. The USSR appears to be phasing out as a primary crude supplier to these countries. Accordingly, potential future crude oil slates can have a much broader range of physical and chemical characteristics than has heretofore been the case.

Second, market conditions for the refinery product slates have been based on the principles of a centrally-planned national economy. Expectations, because of the shift to democratic pluralism in these countries, are for a higher standard of living for the populations, for a greater awareness of the need for environmental protection, and for shifts in refinery-product slates that will occur because of these. The capabilities of the mix of processing units in the refineries in each country to adjust simultaneously to changing crude slates and product slates will be brought into question.

Third, greater public awareness of preserving environmental quality and of the environmental deterioration that has occurred during the past forty years are likely to force major changes in refinery design and operating practices to reduce noxious gaseous, liquid, and solid waste emissions. This awareness is likely to emphasize production of unleaded gasolines and alcohol additives, and perhaps also the exploration of neat alcohol and compressed natural gas alternatives. At the same time, changes in refinery operations will be demanded to reduce noxious emissions to the extent practical.

Finally, tightened economic conditions will force refinery managements to improve operations through introducing more efficient internal utilization of energy and through implementing opportunities for energy conservation. These improvements will have to occur while anticipating changing crude and product conditions and with an inventory of processing units in the refineries that in all likelihood has a limited flexibility to adapt to changes. The roles for alternative fuels could emerge here also.

Compounding the problem of managing change are shortages of foreign exchange, increases in foreign exchange demands because of purchase of crude oil supplies on the open market at now greatly increased price levels, and demands on investment capital that will be generated by the political and economic changes in these countries. Foreign investment by international oil companies in petroleum-sector investment opportunities could bring needed foreign exchange and could potentially lead to new refinery construction at strategic locations and the scrapping of some existing refineries.

The complexity of the relationships within the petroleum sector system is somewhat illustrated in Figure 1 of this Appendix.

Obviously, managing the process of change will take some time. The inputs for analysis are not yet completely available. Economic benefits will depend on national policies, formed or as yet unformed. The current crude supply and pricing picture is an unstable one. Foreign investor interest in the five countries probably varies among the countries and perhaps is not yet well focused on the petroleum sector.

Nevertheless, a start in an analysis to improve the situation can be made provided the focus of initial efforts is on a rationalization of the petroleum-system situation in each of the five countries. Rationalization intends (a) efficient, effective, and environmentally-acceptable improvement in the production of petroleum products to serve current domestic markets, (b) adaptation of current operating practices to serve emerging domestic markets from expected, cost-attractive, crude-oil slates, and (c) identification of the improvements in terms of consistency with the privatization policies in each of the five countries.

2. GOAL AND OBJECTIVES

Accordingly, the generic goal of the work is to begin a process that ultimately can lead to such rationalization of the petroleum sectors in each of the five countries. The end results for the work at this time are

a. an organized data base comprising available data and information relevant to producing inputs for later use by others (when sufficient data and information for the

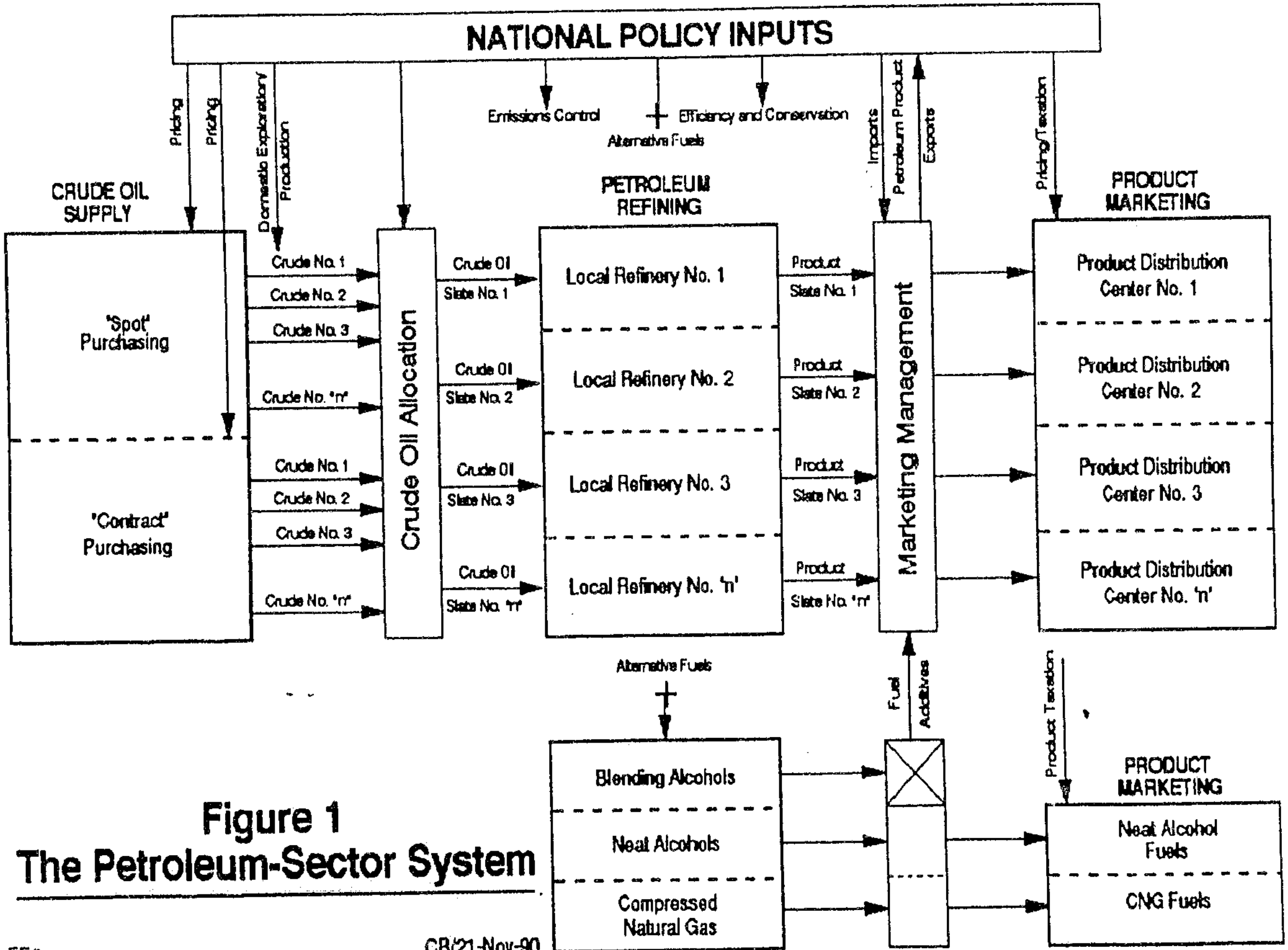


Figure 1
The Petroleum-Sector System

EE6

CB/21-Nov-90

various components of the petroleum system, such as is shown in Figure 1, become available) in a commercial linear programming model to optimize the petroleum system in each country,

b. low-cost improvements in the energy efficiency and environmental impact of selected refineries producing the current product slates that have been implemented during the course of the Contractor's work, and

c. the identification of further improvements which can only be implemented at a later time by others through making a significant investment that needs to be justified.

Accordingly, the objectives of the work focus on the five countries and are

a. for the refinery sector in each country and to the extent that relevant information is available, to describe the process mix in each refinery, the technical capabilities, and current operating practices in a form that (1) provides a data base for undertaking further and future work by others aimed at optimizing the petroleum system in each country and (2) more specifically for the present, enables at least qualitative judgments to be made of effects of changing crude-oil slates on refinery product slates;

b. for a sample of two refineries each in Czechoslovakia, Poland, and Yugoslavia and one refinery each in Bulgaria and Romania, to identify changes in operating practices and low-cost modifications to equipment that can be immediately implemented to increase the efficiency of energy utilization, to conserve energy by avoiding unjustified use, and to reduce as far as practical undesirable gaseous, liquid, and solid effluents;

c. for the same refinery selection in each country, to identify, characterize, and recommend more-extensive changes in practices and equipment and modifications to the process units, which appear justifiable but at the same time require further study possibly with inputs that may not yet be available; and

d. to assist the management of each refinery selected in each country, as needed, in the implementation of the changes identified in b. above through on-the-spot assistance (including training sessions for refinery personnel).

3. APPROACH

This work statement is intended to be generic and applicable in each of the five countries. The intent is to undertake the work with two separate teams of specialized personnel operating in parallel. One team will undertake the work in three countries sequentially and the other in the two remaining countries sequentially. The two teams will be supported as appropriate by a home-office team. The work of the three teams will be coordinated by a program director.

In order to permit pragmatic planning for efficient accomplishment of the work, the first activity will be a reconnaisance in the five countries, probably lasting five weeks, during which needed technical and administrative inputs will be developed and needed local support arranged for. In order to gauge the effectiveness of the work, the final activity will be return visits to the five countries, probably over a two week period when the final reports have been submitted, for the purpose of discussing the results and answering questions that may arise.

The expectations are that considerable data and information will be collected for the countries and for the operating oil refineries. Also, expectations are that this data base, aside from the needs of the Contractor's work program and even after the completion of his work, can provide continuing inputs to other efforts aimed at improving operations in the non-refinery components of the petroleum-sector system (see Figure 1) or to follow-on efforts aimed at implementing the longer-term improvement opportunities identified in the work. Therefore, data and information collection is to be computer oriented with programs organized to be user-friendly and documented accordingly in the Contractor's final reports.

Furthermore, in the identification of improvement opportunities relevant to achieving the objectives of the work, expectations are that benefit/cost estimates will be prepared and/or evaluations performed as far as practical. Estimates and calculations will, with little doubt, require assumptions to fill in for a lack of data. Therefore, estimate preparation and evaluation of opportunities is also to be computer-oriented and user-friendly with programs designed to permit asking "what if" questions, with documentation incorporated in the Contractor's final reports.

Petroleum refineries and petrochemical manufacturing plants are closely linked both physically and through refinery products that become petrochemical feedstocks. The work shall be confined to petroleum refineries only. For this purpose the refinery shall be defined as comprising all installations that pertain to the receipt of the crude oil through to processing and storage of the refinery's primary products. A primary product shall be defined as one that has been fully processed so as to be marketable. On-site facilities to blend different gasoline streams, produce, and process them to final specifications are refinery units. Refinery gas and/or liquid streams that are delivered to other units for further processing, such as to ethylene, ammonia, or aromatic extraction, are to be considered as finished products.

Equipment purchases (both for test work and for permanent installation) needed for the implementation of short-term improvements shall be defined and justified. A brief report shall be submitted for A.I.D. approval before committing to purchase.

4. TASKS

The following tasks are foreseen for the work.

a. Refinery Characterization

The work is technically oriented. It involves preparing for each refinery in each country, a block flow diagram showing the processing units and the support facilities between receipt of the crude oil slate and the dispatch of the product slate to market. The depth of detail for this characterization will provide

1) a description as far as practical of the capability of each processing unit in terms of feedstocks and feedstock variability and product yields and specifications; of the operating conditions, age, mechanical condition of the processing units; of the consumption of utilities (electricity, water, catalysts, chemicals, etc.); and of the quantities and characteristics of the effluents.

2) a description as far as practical of the support facilities in terms of crude and product storage capacity, fire protection and personnel safety provisions, and methods for segregation, collection, treatment, and disposal of solid, liquid, and gaseous effluents.

3) a written operating history of a refinery for the previous 12-month period emphasizing crude-oil receipts and specifications, product slates produced, unusual operating experiences, routine maintenance performed, and emergencies encountered during operations.

4) a description of the method of electricity supply, whether entirely purchased, self-generated, or a combination of both; and a technical description of the design and operation of the power house (if any) in terms of energy balance and heat rate.

b. Refinery Financial Structure

The objective in this task will be to collect data on local practices from the refinery management and/or from other appropriate sources that can be evaluated to establish the basis whereby the cost of each improvement opportunity can be pragmatically estimated and attractiveness of the opportunity determined. The expectation is that attractiveness will be based in part on (a) the magnitude of the capital requirement, including the foreign exchange component, and (b) the period of time within which the cost of the improvement can be recovered through savings in operating costs achieved. Attractiveness shall refer also to quantification (if practical) of benefits from reduced emissions of objectionable effluents. No need exists to relate emissions for compliance with any existing standards.

c. Selection of the Refineries

The refineries to be subjected to more detailed study, in order to meet Objectives b, c, and d above, shall be selected during the reconnaisance period by mutual agreement between the Contractor and the host-government agency concerned. For Contractor's guidance, the main criterion for selection should be based on achieving a maximum efficiency/environmental improvement impact for a minimum effort and cost in a minimum time frame. However, the selection shall be subject to A.I.D. concurrence.

d. Refinery Housekeeping

For each country and for each selected refinery, the work involves observation over a period of time of the refinery operations in order to detect opportunities to improve operating and maintenance practices, such as by

1) eliminating the presence of leaky valve-stems and steam traps,

2) incrementally insulating excessively hot surfaces,

3) avoiding poor combustion conditions (high oxygen content in chimney gases because of excessive excess air beyond combustion needs and/or leaky furnace settings),

4) avoiding excessive carbon monoxide in chimney gases (poor combustion, inadequate mixing of fuel and air),

5) increasing the frequency with which heat transfer surfaces are cleaned of fouling deposits,

6) reviewing whether rotating machinery is adequately maintained in terms of lubrication and condition of bearings, and

7) reviewing whether plant instrumentation is adequate and/or well-enough maintained to provide accurate readings of operating conditions and is appropriately configured to permit efficient operation.

e. Heat Conservation

The work involves observations over a period of time to evaluate the adequacy of provisions to recover heat that otherwise is wasted. The best example is a lack of airheaters to recover heat from hot chimney gases in refinery furnace equipment. Another example is the design of feedstock preheat heat exchanger trains and the opportunity to introduce an additional heat exchanger that can be justified now because of higher energy prices.

f. Process Unit Operating Conditions

The work involves analyzing the operating conditions and control systems installed for each processing unit in a selected refinery in order to determine whether these are appropriate for the products from the feedstock. This analysis can be particularly significant if current feedstocks and/or product slates have changed from the conditions on which the original design of the processing unit was based.

g. Refinery Energy Balance

The work involves analysis of the flows of energy among the different processing units comprising each selected refinery as well as within the processing units themselves in order to identify opportunities for energy-efficiency improvement in the short term and long term.

The analysis should attempt to provide a data base to assist others to foresee the longer term opportunities for a more efficient energy balance through review of the market demand, future crude oil supplies, and the design and applicability of the processing units themselves. Ultimately, the product of such analysis by others could be decisions to abandon certain units, modify others, or add new units, all providing for greater thermal efficiency.

Accordingly, the Contractor shall attempt to foresee as far as practical the prospect that such future analysis could invalidate the benefits perceived for an identified long-term opportunity from a presumption that a substantial remaining useful life for the process unit exists.

h. Fuel Switching

For each selected refinery, the work shall include comment and expert opinion on the practicality of replacing petroleum hydrocarbon fuels with indigenous coal. Refinery furnaces have in the past been fired with coal. Fuel switching to coal to save on oil imports could be a viable option. However, the Contractor shall focus on a different technical option for coal utilization, in order to reduce investment, by considering high fuel-density, coal/water slurry fuels as a direct replacement for fuel oil with minimum retrofit. Sootblowers could handle the higher ash content.

Consideration of such an option should be limited to assessing its practicality in terms of coal supply and characteristics, the state-of-the-art of fuel formulation, and adaptability to existing combustion equipment.

i. Refinery Emissions

For each selected refinery, the work involves preparing a survey of all solid, liquid, and gaseous refinery effluents in terms of sourcing, probable quantities, and chemical analyses, and suggesting practices to be employed in the refinery for control to reduce such emissions that reflect experiences elsewhere where emission control laws are in effect. There is no need to relate this task to showing compliance of emissions with standards that may be established by the World Bank or the U.S. Environmental Protection Agency.

160

j. Data Evaluation

The work involves computer-oriented organization of the data and information collected, evaluation of the data and information, compiling cost estimates, performing financial calculations, ranking opportunities in terms of the adopted criteria, and preparing final reports to meet the objectives of the work.

APPENDIX D - ELECTRICAL

1. TABLE AP-D.1. - GENERATOR CHARACTERISTICS

Type	SAT 110.5-160-4
Manufacturing number	153 786
Output (kVA)	18 800
Voltage (volts)	6 000
Current (A)	1 809
Frequency (Hz)	50
Power factor	0.8
Number of phases	3
Number of poles	4
Speed	1 500
Overspeed (rpm)	1 800

2. ENERGY PRICING AND BILLINGS

Energy prices charged to the refinery by the state owned Utility Power Company (12 June 1991) are as follows:

- Annual charges for agreed upon price paid on monthly basis — 150 ZL/kW
- Monthly energy agreement — 16.2 MW
- Monthly payment for calculated energy — 22,500ZL/kW
- Monthly payment for excess calculated energy over agreed energy — 125 000 ZL/kW
- Cost for used active power in peak demand — 325 ZL/kWh
- Cost for used active power during day time — 200 ZL/kWh
- Cost for used active power during night time — 113 ZL/kWh
- Cost for reactive power during day time — 75 ZL/KVArH
  and peak demand during night time — 50 ZL/KVArH
- Cost for maintenance energy meters — 95,000 ZL/month

Energy prices charged to the Utility Power Co. by Gdansk Refinery:

Present		Proposed from 28 May 1991
205 ZL/kWH	during peak time period	256 ZL/kWH
95 ZL/kWH	day time	120 ZL/kWH
45 ZL/kWH	night time	56 ZL/kWH

Exploration of purchased/sale energy between refinery and Utility Power Company.

Before April 1990

Example:

Energy required by refinery - 16 MW
Energy production by refinery generator - 15 MW
Used own energy - 7 MW
Sale energy to Utility Power Co. - 8 MW
Purchased energy from Utility Power Co. - 9 MW
Purchased energy from UPC - 325 ZL/kWh
Sale energy to UPC - 256 ZL/kWh
Refinery paid for 9 MW x 325 ZL/kWh
Refinery collect for 8 MW x 256 ZL/kWh

AFTER APRIL 1990

Refinery purchased balance meters mfg. by Landis & Gyr in Switzerland and installed at Refinery. Balance meters ($50 000) which recorded balance: (energy purchased minus energy sale)
Using above example: 9-8 = 1 x 325 ZL/kWh
Refinery annual saving = $400 000

TABLE AP-D.2 - ANNUAL ELECTRICAL ENERGY CONSUMPTION
JUNE 1990 THROUGH MAY 1991

Equipment/Units			MWh	MVArh
Generators	Production	Generator TG1	57 191	24 966
		Generator TG2	23 973	11 561
		TOTAL (TG1 + TG2)	81 164	36 527
Main Transformers	Used	Transformer T1	23 865	7 941
		Transformer T2	444	69
		Transformers T3	42 171	13 141
		TOTAL (T1 + T2 + T3)	6 648	21 151
	Sale	Transformer T1	22 463	5 575
		Transformer T2	357	96
		Transfomer T3	6 836	2 501
		TOTAL (T1 + T2 + T3)	29 673	8 172
Substation 1	unit 100, 200, 300 900 *		27 036	12 518
Substation 2	unit 400, 500, 600, 700, 800, 850, 1400*		7 365	3 436
Substation 3	unit 1100, 1200, 1250, 1300*		17 157	6 643
Substation 4	unit 1800, 3500, 4000, 5100, 7700, p.18, p.24, p.br, p.sl, CPN*		4 413	1 691
Substation 5	unit 5100 GESTRA*		3 188	611
Substation 6	unit 2700, 2750, 2900, 2930, 3200 Central Administration*		15 800	8 783
Substation 7	unit EC (power plant)*		20 512	13 931
Substation 8	unit 2000 p.20 CPN*		2 540	1 176
Substation 9	Water Intake*		1 167	96
Substation 10	unit 1000, 1500, 1900, 2000, 2050, 3700, 4000, GPBP, Dz.W*		8 844	3 571

* See Table App.F.2.a, for a description of unit numbers.

TABLE AP-D.3
ELECTRICAL ENERGY CONSUMPTION (MWh)
GDANSK REFINERY
SECOND QUARTER OF 1990

ITEM NO.	DESCRIPTION	APRIL 1990	MAY 1990	JUNE 1990	TOTAL PER QUARTER
1	Energy Production by plant generators	7 388	4 273	0	11 661
2	Purchased energy from Utility Power Co. (T1,T2,T3)	2 702	3 113	1 979	7 793
3*	Purchased energy from Utility Power Co. for railroad transport only	70	54	33	157
4*	Purchased energy from Utility Power co. for pump station at sea port	0	0	3	3
5	Sale energy to Utility Power Co.	0	0	0	0
6	Sale energy to contractors at refinery	100	71	61	632
	TOTAL (1+2+3+4)-(5+6)	10 060	7 369	1 953	19 382
7	Steam (for heating only)(GJ) sale to contractors at refinery	10 041	6 808	2 560	19 409

* Separate source (15 kV) and meters (no connection with refinery distribution system)

TABLE AP-D.4
ELECTRICAL ENERGY CONSUMPTION (MWh)
GDANSK REFINERY
THIRD QUARTER OF 1990

ITEM NO.	DESCRIPTION	JULY 1990	AUG 1990	SEPT 1990	TOTAL PER QUARTER
1	Energy Production by plant generators	0	3 640	6 891	10 531
2	Purchased energy from Utility Power Co. (T1,T2,T3)	8 471	7 110	4 014	19 595
3*	Purchased energy from Utility Power Co. for railroad transport only	42	60	73	175
4*	Purchased energy from Utility Power co. for pump station at sea port	3	7	8	18
5	Sale energy to Utility Power Co.	0	0	0	0
6	Sale energy to contractors at refinery	61	67	90	218
	TOTAL (1+2+3+4)-(5+6)	8 455	10 750	10 896	30 101
7	Steam (for heating only)(GJ) sale to contractors at refinery	4 878	5 219	4 450	14 547

* Separate source (15 kV) and meters (no connection with refinery distribution system)

TABLE AP-D.5
ELECTRICAL ENERGY CONSUMPTION (MWh)
GDANSK REFINERY
FOURTH QUARTER OF 1990

ITEM NO.	DESCRIPTION	OCT 1990	NOV 1990	DEC 1990	TOTAL PER QUARTER
1	Energy Production by plant generators	1 990	7 612	10 345	24 964
2	Purchased energy from Utility Power Co. (T1,T2,T3)	4 439	3 277	1 318	9 034
3*	Purchased energy from Utility Power Co. for railroad transport only	108	126	138	372
4*	Purchased energy from Utility Power co. for pump station at sea port	0	0	25	25
5	Sale energy to Utility Power Co.	0	0	0	0
6	Sale energy to contractors at refinery	152	161	136	449
	TOTAL (1+2+3+4)-(5+6)	11 402	10 854	11 690	33 946
7	Steam (for heating only)(GJ) sale to contractors at refinery	8 011	9 238	12 229	29 478

* Separate source (15 kV) and meters (no connection with refinery distribution system)

TABLE AP-D-6
ELECTRICAL ENERGY CONSUMPTION (MWh)
GDANSK REFINERY
FIRST QUARTER OF 1991

ITEM NO.	DESCRIPTION	JAN 1991	FEB 1991	MAR 1991	TOTAL PER QUARTER
1	Energy Production by plant generators	10 408	9 910	9 947	30 355
2	Purchased energy from Utility Power Co. (T1,T2,T3)	1 136	312	443	1 891
3*	Purchased energy from Utility Power Co. for railroad transport only	154	147	114	415
4*	Purchased energy from Utility Power co. for pump station at sea port	0	13	2	15
5	Sale energy to Utility Power Co.	0	0	0	0
6	Sale energy to contractors at refinery	212	190	133	535
	TOTAL (1+2+3+4)-(5+6)	11 576	10 192	10 373	32 141
7	Steam (for heating only)(GJ) sale to contractors at refinery	13 766	14 846	12 922	41 534

* Separate source (15 kV) and meters (no connection with refinery distribution system)

TABLE AP-D.7 - AREA DESIGNATION

Area	Designation
100	Atmospheric Crude Distillation
200	Naphtha Hydrotreating
300	Kerosene Sweetening (Merox)
400	Catalytic Reforming
500	Gas Oil Hydrodesulfurization
600	H_2S Recovery (MEA) [gas desulfurization]
700	LPG Recovery
800	Sulfur Recovery - Claus Process
850	Sulfur Loading
1400	Lube Oil Hydrofinishing
1100	Propane deasphalting
1200	Furfural Extraction
1250	Cooling Water System at 1200
1300	Di-Me Dewaxing
1800	Crude Oil Tanks (Tank Farm)
3500	Flare
4000	Loading Station (4000-Railway; 4100-Tankcars)
5100	Four Slop Pumps (waste)
7700	LPG Pump Station
p. 18	Crude Pump Station
p. 24	LPG Pump Station
p. br	Loading Arm
p. sl	Slope Pump Station
CPN	Central Distributing Company
INST 1500	Waste Water Treatment

Table AP-D.7 - AREA DESIGNATION - continued

GESTRA	Outside Contractors (other companies)
2700	Demineralized water to Power Station
2750	Condensate Collecting
2900	Primary Treating
2930	Demineralization
3000	Cooling Water Tower
3200	Nitrogen Unit (Inert Gas Plant)
Cent. Admn.	Administration
INST EC	Power Station
3100	Air Compressors
INST 2000	Product Tanks
p. 20	Product Pump Station
I°	Pump Station (from Moteawa River to Reservoir)
II°	Pump Station (from Reservoir to Refinery)
1000	Asphalt Blowing & Blending
1500	Lube Oils Units
1900	Temporary Oil Storage Tanks
2050	Gasoline Loading
3700	Fuel Oil Blending for power Station & Process unit)
4000	Asphalt Loading (Rail & Road)
GPBP	Outside Contractors
Dz W	Maintenance Shop

APPENDIX E

REFINERY ENERGY BALANCE AND "ENERGY DEMAND" CRITERIA

To properly undertake an appraisal of the energy efficiency of Eastern European refinery operations, it was apparent that some standard measure of the performance of typical modern US refinery installations was essential. A literature search revealed two documents describing typical energy consumptions in the US refining industry based upon surveys and energy audits as follows:

> R.V. Elshout, Barnard and Bunk Engineers and Constructors Inc., Pasadena, California, Hydrocarbon Processing, July 1982, Pg. 109.
>
> R.O. Pelham and R.D. Moriarty, Profimatics, Inc., Thousand Oaks, California, Hydrocarbon Processing, July 1985, Pg. 51.

The 1982 article lists typical utility requirements for a range of common refinery processing units, whereas the 1985 article analyzes the thermodynamic elements of energy usage for a typical 80 000 BPSD fuels refinery. These two references assessed US refinery energy performance from 1972 through the early 1980s. This is the period during which the US refining industry had recorded energy utilization improvements of about 25 percent.

By convention, the English system of measurements (Barrels, API, BTU's, etc.) is still preferred by US refineries whereas mass and the metric or System International units (grams, metric tons, specific gravity, joules, kilocalories, etc.) are commonly used in Europe. Therefore, it is necessary to establish equivalent values between the two methods of measurement so that equitable comparisons can be made. The typical US refinery unit energy demands provided by Elshout have therefore been transformed from American to European practice as shown in the following Tables 1-3 by the provision of typical API gravities (where appropriate) for the unit feedstocks.

Direct and positive comparison of total energy demands between similar unit operations is still not possible; however, due to the individual refiner's selection of electric or motive steam for the provision of mechanical power and also to the selection of cooling water or air as the sink for rejected heat. Consequently, suitable conversions to the basic fuel oil energy source were required and are shown in Table 4 in both the European and American usages. It is believed that our selected efficiency factors of 80% for steam generation; 35% for power generation; and 60% for combined pump with motor driver are reasonable or conservative in deriving the selected conversion to fuel oil equivalence to obtain a common, simple, and effective measure of total energy demand.

171

In a further attempt to extend and update the validity of these data, the most recent publication of refinery unit licensors' information (Refiner's Notebook - "Hydrocarbon Processing," November 1990) was selected to reflect technical and economic trends, together with other available information, to supplement lube oil energy demands. A consolidated listing of the results is shown in Tables 5 to 13.

Finally, Table 14 attempts a reconciliation of the "Unit Total Energy Requirements" chosen from the above-cited development and based upon Elshout, with the overall typical fuels refinery energy usage reported in the Profimatics survey. The predicted results of 378 455 versus 380 000 BTU/BBL required by the "reasonably efficient fuels refinery" cited in the Profimatics example provides reasonable assurance for the general validity of the methodology even though it is claimed that improvements are continuing at the rate of 1 to 2% per year.

For convenience, Table 15 summarizes the "Refinery Unit Energy Demand Criteria" selected as best representing expected and obtainable refinery practice under current technical knowledge and economic pressures. These values were used for the overall assessment of the Eastern European energy efficiency of refinery operations.

In conclusion, it is well to recognize that in these selected energy demands, the potential for a further 15 to 20 percent reduction in energy usage could be technically/economically feasible by prudent retrofitting in an existing plant but more likely in applying modern design techniques to future energy efficient installations where proper long term economic criteria are both encouraged and applied.

TABLE AP-E.1
USA
TYPICAL REFINERY UTILITY USAGE
****
PER 1000 BPSD CAPACITY EXCEPT AS NOTED

	TYPICAL °API	FUEL FIRED M BTU/H	18 °F DELTA T CW GPM	POWER KWH/H	STEAM LB/H	SURFACE AREA SQ FT
CRUDE DISTILLATION	25.0	2500	375	10	333	1200
	40.0	3330	500	13	250	1000
VAC DISTILLATION	16.0	2100	410	15	1250	2000
VISBREAKER	9.0	8000	240	15	1250	
THERMAL CRACKER	9.0	20000	2000	31	1900	
DELAYED COKER	9.0	9120	830	50	1450	
FLUID COKER (1)	9.0	-250	830	175	-3300	
PROPANE DEASPHALTING	9.0	15200	1000	40	2100	
HYDROTREATING NAPHTHA (2)	45.0	2750	150	50	700	900
GAS OIL	25.0	3500	250	60	700	
CAT REFORMING (90 RON)	45.0	16000	550	150	1800	
CAT CRACKING FCC (3&4)	20.0	800	800	275	650	
TCC	20.0	2000	800	225	-650	
HYDROCRACKING (5)	20.0	8000	750	200	600	2100
CAT POLYMERIZATION	110.0		350	160	8000	
SULFUR PLANT (10 TPD TONNE/DAY)		1500		45	-2800	
MEA UNIT (10 TPD S TONNE/DAY)			220	12.5	4200	
H2 PLANT(10 MM SCFD)(6&7)		200	200	1400	1800	

(1) INCLUDES AIR BLOWER FOR AVERAGE 15% PRODUCTION COKE BURNING
(2) COMPRESSOR POWER COULD BE SUPPLIED FROM ASSOCIATED CAT REFORMER
(3) POWER INCLUDES REGENERATOR BLOWER BUT NO CREDIT FOR LETDOWN TURBINE
(4) NO CREDIT FOR CO BOILER WASTE HEAT RECOVERY
(5) POWER EXCLUSIVE OF H2 MAKE-UP COMPRESSOR
(6) FUEL INCLUDES FEED - STEAM METHANE REFORMING
(7) POWER INCLUDES BOOSTER COMPRESSOR TO 1750 PSIG
(8) REF: HYDROCARBON PROCESSING JULY, 1982, PG 109

TABLE AP--E.2
USA
TYPICAL REFINERY UTILITY USAGE (1)
****
PER 1.0 BBL CAPACITY EXCEPT AS NOTED

	TYPICAL °API	FUEL FIRED BTU	18 °F DELTA T CW US GAL	POWER KWH	STEAM LB	INTERCHANGE SURFACE SQ FT
CRUDE DISTILLATION	25.0	60000	540	0.24	7.992	28.8
	40.0	79920	720	0.312	6	24.0
VAC DISTILLATION	16.0	50400	590.4	0.36	30	48.0
VISBREAKER	9.0	192000	345.6	0.36	30	
THERMAL CRACKER	9.0	480000	2880	0.744	45.6	
DELAYED COKER	9.0	218880	1195.2	1.2	34.8	
0	9.0	-6000	1195.2	4.2	-79.2	
PROPANE DEASPHALTING	0.0	364800	1440	0.96	50.4	
0	45.0	66000	216	1.2	16.8	21.6
GAS OIL	25.0	84000	360	1.44	16.8	
CAT REFORMING (90 RON)	45.0	384000	792	3.6	43.2	
0	20.0	248846	1152	6.6	15.6	
TCC	20.0	277646	1152	5.4	-15.6	
0	20.0	192000	1080	4.8	14.4	50.4
CAT POLYMERIZATION	110.0	0	504	3.8	192.0	
SULFUR PLANT (1.0 TONNE S)		3600000		108.0	-6720.0	
MEA UNIT (1.0 TONNE S)			31680	30.0	10080.0	
H2 PLANT (1000 SCF)(7&8)		480	28.8	3.4	4.3	

(1) REF: HYDROCARBON PROCESSING JULY, 1982, PG 109
(2) INCLUDES AIR BLOWER FOR AVERAGE 15% PRODUCTION C N COKE BURNING
(3) COMPRESSOR POWER COULD BE SUPPLIED FROM ASSOCIATED CAT REFORMER
(4) NOTE: POWER INCLUDES REGENERATOR BLOWER BUT NO CREDIT FOR LETDO
(5) NOTE: 5 W% COKE BURNING INCLUDED BUT NO CREDIT FOR CO BOILER WA
(6) POWER EXCLUSIVE OF H2 MAKE-UP COMPRESSOR
(7) FUEL INCLUDES FEED - STEAM METHANE REFORMING
(8) POWER INCLUDES BOOSTER COMPRESSOR TO 120 BARG

TABLE AP-E.3
USA
TYPICAL REFINERY UTILITY USAGE (1)
****
PER 1.0 TONNE CAPACITY EXCEPT AS NOTED

	TYPICAL SP GR	FUEL FIRED KCAL	10 °C DELTA T CW M3	POWER KWH	EXCH STEAM KG	SURFACE M2
CRUDE DISTILLATION	0.9042	105264	14.2	1.67	25.3	18.6
	0.8251	153650	20.8	2.38	20.8	17.0
VAC DISTILLATION	0.9593	83337	14.6	2.36	89.4	29.3
VISBREAKER	1.0071	302407	8.2	2.25	85.1	
THERMAL CRACKER	1.0071	756017	27.2	33.77	-44.3	
DELAYED COKER	1.0071	344744	28.3	7.50	98.7	
FLUID COKER (2)	1.0071	-9450	28.3	26.26	-224.7	
PROPANE DEASPHALTING	1.0760	537768	31.9	5.62	133.8	
HYDROTREATING NAPHTHA (3)	0.8017	130588	6.4	9.43	59.9	15.8
GAS OIL	0.9042	147369	9.5	10.03	53.1	
CAT REFORMING (90 RON)	0.8017	759784	23.5	28.28	154.0	
CAT CRACKING FCC (4&5)	0.9340	422627	29.4	44.50	47.7	
TCC	0.9340	471539	29.4	36.41	-47.7	
HYDROCRACKING (6)	0.9340	326083	27.5	32.36	44.1	31.6
CAT POLYMERIZATION	0.5859		20.5	41.27	936.3	
SULFUR PL ANT (1.0 TONNE S)		999295		119.02	-3360.0	
MEA UNIT (1.0 TONNE S)			132.0	33.06	5040.0	
H2 PLANT (1000 NM3) (7&8)		4038	3.6	112.22	65.5	

(1) REF: HYDROCARBON PROCESSING JULY, 1982, PG 109
(2) INCLUDES AIR BLOWER FOR AVERAGE 15% PRODUCTION COKE BURNING
(3) COMPRESSOR POWER COULD BE SUPPLIED FROM ASSOCIATED CAT REFORMER
(4) NOTE: POWER INCLUDES REGENERATOR BLOWER BUT NO CREDIT FOR LETDO
(5) NOTE: 5 W% COKE BURNING INCLUDED BUT NO CREDIT FOR CO BOILER WA
(6) POWER EXCLUSIVE OF H2 MAKE-UP COMPRESSOR
(7) FUEL INCLUDES FEED - STEAM METHANE REFORMING
(8) POWER INCLUDES BOOSTER COMPRESSOR TO 120 BARG

TABLE AP-E.4
USA
TYPICAL REFINERY TOTAL ENERGY USAGE (1)

PER 1.0 TONNE CAPACITY EXCEPT AS NOTED

	TYPICAL SP GR	FUEL FIRED KCAL	10 °C DELTA T CW KCAL	POWER KW	STEAM KCAL	TOTAL ENERGY KCAL/T	SAY TOTAL ENERGY M KCAL/T	SAY TOTAL ENERGY MBTU/Bbl
CRUDE DISTILLATION	0.9042	105264	8532	4012	17697	135505	135	77.2
	0.8251	153650	12467	5715	14545	186377	185	96.9
VAC DISTILLATION	0.9593	83337	8786	5672	62547	160341	160	97.0
VISBREAKER	1.0071	302407	4908	5402	59578	372296	370	236.4
THERMAL CRACKER	1.0071	756017	16341	81037	-30981	822415	820	522.2
DELAYED COKER	1.0071	344744	16951	18008	69111	448814	450	285.0
FLUID COKER (2)	1.0071	-9450	16951	63029	-157287	-86757	-85	-55.1
PROPANE DEASPHALTING	1.0760	537768	19118	13484	93680	664050	665	450.5
HYDROTREATING NAPHTHA (3)	0.8017	130588	3849	22623	41913	198972	200	100.6
GAS OIL	0.9142	147369	5688	24071	37163	214292	215	123.5
CAT REFORMING (90 RON)	0.8017	759784	14113	67868	107775	949540	950	479.9
CAT CRACKING FCC (4&5)	0.9340	422627	17621	106800	33406	580454	580	341.8
TCC	0.9340	471539	17621	87382	-33406	543136	545	319.8
HYDROCRACKING (6)	0.9340	326083	16520	77673	30837	4511112	450	2656.3
CAT POLYMERIZATION	0.5859	0	12289	99052	655404	766745	765	283.2
SULFUR PL ANT (1.0 TONNE S)		999295	0	285638	-2352000	-1067067	-1070	-1070
MEA UNIT (1.0 TONNE S)		0	79200	79344	3528000	3686544	3700	3700
H2 PLANT (1000 NM3)(7&8)		4038	2182	269331	45825	321376	320	320

(1) REF: HYDROCARBON PROCESSING JULY, 1982, PG 109
(2) INCLUDES AIR BLOWER FOR AVERAGE 15% PRODUCTION COKE BURNING
(3) COMPRESSOR POWER COULD BE SUPPLIED FROM ASSOCIATED CAT REFORMER
(4) NOTE: POWER INCLUDES REGENERATOR BLOWER BUT NO CREDIT FOR LETDOWN TURBINE
(5) NOTE: 5 W% COKE BURNING INCLUDED BUT NO CREDIT FOR CO BOILER WASTE HEAT RECOVERY
(6) POWER EXCLUSIVE OF H2 MAKE-UP COMPRESSOR
(7) FUEL INCLUDES FEED - STEAM METHANE REFORMING
(8) POWER INCLUDES BOOSTER COMPRESSOR TO 120 BARG

ENERGY CONVERSION FACTORS TO FUEL OIL EQUIVALENTS::

CW, M3/H: USE 4.41*75/2284*0.6 = 0.24 KWH/H * 2400 = 579 KCAL - - SA
STEAM, KG/H: USE 540 KCAL/KG @ 80% EFF = 675 KCAL/KG - S - SA
POWER, KWH: USE 860.5 KCAL/KWH @ 35 % EFF = 2459 KCAL - S - SA

TABLE AP-E.5

TYPICAL REFINERY UTILITY USAGE

PER 1.0 BBL CAPACITY EXCEPT AS NOTED

UNIT	REF HDBK 1990*	TYPICAL °API	FIRED BTU	CW US GAL	POWER KWH	STEAM LB
CRUDE DISTILLATION	TECHNIP LO 4TWR	34.0	40000	68	1.10	6.0
	* TECHNIP HI 4TWR	34.0	60000	90	1.50	12.0
	H PROC JULY '82 Hy	25.0	60000	540	0.24	8.0
	H PROC JULY '82 Lt	40.0	79920	720	0.31	6.0
CRUDE/VAC DISTILLATION	* GDANSK	32.0		20	0.60	24.0
	* FW LO RANGE	8.7	80000	20	0.60	24.0
	FW HI RANGE	8.7	120000			
	PLOCK LO RANGE 1&2	32.5				
	PLOCK HI RANGE 3&4	32.5				
VAC DISTILLATIN	* SHELL – LUBES	22.0		590	0.36	30.0
	H PROC JULY '82	16.0	50400			
	GDANSK	20.0				
VAC FLASHER						
LT ENDS FRACT'N (USE)						
LPG		130.0		260	0.30	40.0
NAPHTHA SPLITTING		50.0		450	0.30	70.0
H'TREATING – NAPHTHAS	H PROC JULY '82	45.0	66000	216	1.20	16.8
	GDANSK	45.0				
– GAS OILS	H PROC JULY '82	25.0	84000	360	1.44	16.8
	PLOCK	26.0				
	GDANSK	26.0				
– RESIDS	* IFP – RESID	15.0	52500	285	8.50	74.0
	* CHEVRON					
REFORMING	* CHEVRON + HT	48.0	285000	160	0.70	-40.0
	* ENGELHARD-100 RON	48.0	250000	40	2.00	
	* IFP -102 RON	48.0	65000		1.00	-12.5
	H PROC JULY '82	45.0	384000	792	3.60	43.2
	PLOCK + HT (AVG)	48.0				
	GDANSK	45.0				

TABLE AP-E.6

TYPICAL REFINERY UTILITY USAGE

PER 1.0 BBL CAPACITY EXCEPT AS NOTED

UNIT	REF HDBK 1990	TYPICAL °API	FUEL FIRED BTU	18 °F DELTA T CW US GAL	POWER KW/H	STEAM LB
FCCU	MW KELLOGG	20.0	229646	0	0.90	-100.0
	H PROC JULY '82	20.0	248846	1152	6.60	15.6
	PLOCK I	20.0				
	PLOCK II	20.0				
TCCU	H PROC JULY '82	20.0	277646	1152	5.40	-15.6
ALKYLATION – PRODUCT	STRATCO H2SO4	50.0		2050	13.50	180.0
	PLOCK	50.0				
CAT POLYMERIZATION	H PROC JULY '82	110.0		504	3.84	192.0
PROPANE DEASPHALTING	IFP	12.0	23750		1.40	7.0
	KERR-McGEE	12.0	95000	0	2.00	12.0
	* FW CRACKED	12.0	89000	0	2.00	60.0
	H PROC JULY '82	9.0	364800	1440	0.96	50.4
LUBES – PDA	FW LUBE	12.0	86000	415	2.10	115.0
	SHELL	12.0				
	GDANSK	15.0				
– FURFURAL/NMP	SHELL	25.0				
	* EXXON NMP – 103 VI	25.0	202000	200	1.40	54.3
	PLOCK	25.0				
	GDANSK	25.0				
– DEWAXING	SHELL MEK	27.0				
	PLOCK ACETONE/BENZE	27.0				
	GDANSK DI-ME	27.0				
– H'FINISHING	SHELL	27.0				
	PLOCK	27.0				
	GDANSK	27.0				
GREASE – PER TONNE STRATCO						

TABLE AP-E.7

TYPICAL REFINERY UTILITY USAGE

PER 1.0 BBL CAPACITY EXCEPT AS NOTED

UNIT	REF HDBK 1990*	TYPICAL °API	FUEL FIRED BTU	18 °F DELTA T CW US GAL.	POWER KWH	STEAM LB
H'CRACKING	* LUMMUS/OXY/AMOCO	12.4	56100	64	8.40	-35.5
		4.7	69800	164	16.50	-97.0
	* CHEVRON	23.0	143000	330	7.00	-50.0
	* IFP	21.5	40000		2.80	12.5
	* LINDE	21.5	50000	190	1.50	
	* UNOCAL/UOP	8.4	135000		10.00	
	H PROC JULY '82	20.0	192000	1080	4.80	14.4
THERMAL CRACKER	H PROC JULY '82	20.0	48000	1152	5.40	-15.6
VISBREAKING	* LUMMUS - 356'FFEED	8.2	75000	270	0.50	45.0
	* IFP	15.0	22800	0	1.90	10.6
	H PROC JULY '82	9.0	192000	346	0.36	30.0
COKING	* LUMMUS - DELAYED	7.4	145000	180	3.90	20.0
	* EXXON - FLEXI	3.1		400	13.00	-100.0
	* FW	2.6	120000	36	3.60	-40.0
	H PROC JULY '82 DEL	9.0	218880	1195	1.20	34.8
	H PROC JULY '82 FL	9.0	-6000	1195	4.20	-79.2
COKE CALCINING-PER TONNE	* GKT - W GERMANY					
ASPHALT BLOWING	* SNAM - 80/100 PEN	5.9	89335		0.81	6.57
	- 40/50 PEN	5.1	57659		2.73	30.75
	PLOCK	8.0				
	GDANSK	8.0				
MTBE - PRODUCT	CD TECH	45.4		1860	1.00	296.0
	* PHILLIPS	45.4		1870	1.10	224.0
MEA (1.0 TONNES)	* H PROC JULY '82			31680	30.00	10080.0
	GDANSK					
SULFUR PLANT (1.0 TONNE S)	* H PROC JULY '82		3600000		108.00	-6720.0
	PLOCK					
	GDANSK					
H2 PLANT (1000 SCF)(6&7)			480	29	3.36	4.3

TABLE AP-E.8

TYPICAL REFINERY UTILITY USAGE

PER 1.0 TONNE CAPACITY EXCEPT AS NOTED

UNIT		REF HDBK 1990	TYPICAL SP GR	FUEL FIRED KCAL	10 °C DELTA T CW M3	POWER KWH	STEAM KG
CRUDE DISTILLATION		TECHNIP LO 4TWR	0.8550	74212	1.9	8.10	20.1
	*	TECHNIP HI 4TWR	0.8550	111317	2.5	11.05	40.1
		H PROC JULY '82 Hy	0.9042	105264	14.2	1.67	25.3
		H PROC JULY '82 Lt	0.8251	153650	20.8	2.38	20.8
		GDANSK	0.8654	153000	0.4	5.00	40.2
CRUDE/VAC DISTILLATION		FW LO RANGE	1.0096	125734	0.5	3.74	67.9
	*	FW HI RANGE	1.0093	188601	0.5	3.74	67.9
		PLOCK LO RANGE 1&	0.8628	180380	8	4.80	56.0
		PLOCK HI RANGE 3&4	0.8628	205580	8	8.20	139.0
VAC DISTILLATION	*	SHELL – LUBES	0.9218	174000	14.2	3.40	131.0
		H PROC JULY '82	0.9593	83337	14.6	2.36	89.4
		GDANSK	0.9340	122000	9.7	6.90	138.0
VAC FLASHER			0.0000	0			
LT ENDS FRACT'N (USE)							
LPG			0.5411	0	11.4	3.49	211.2
NAPHTHA SPLITTING			0.7796	0	13.7	2.42	256.5
HYDROTREATING							
– NAPHTHAS		H PROC JULY '82	0.8017	130588	6.4	9.43	59.9
		GDANSK	0.8017	178000	1.3	12.60	4.8
– GAS OILS		H PROC JULY '82	0.9042	147369	9.5	10.03	53.1
		PLOCK	0.8984	61000	14.0	14.00	55.6
		GDANSK	0.8984	131000	1.4	2.40	3.1
– RESID	*	IFP – RESID	0.9659	86221	7.0	55.42	218.9
	*	CHEVRON	0.0000	0	0.0	0.00	0.0
REFORMING	*	CHEVRON + HT	0.7883	573487	4.8	5.59	-145.0
	*	ENGELHARD-100 RON	0.7883	503058	1.2	15.98	0.0
	*	IFP -102 RON	0.7883	130795	0.0	7.99	-45.3
		H PROC JULY '82	0.8017	759784	23.5	28.28	154.0
		PLOCK + HT (AVG)	0.7883	760000	15.0	42.00	138.8
		GDANSK	0.8017	657000	5.7	7.80	521.2

TABLE AP-E.9

TYPICAL REFINERY UTILITY USAGE

****

PER 1.0 TONNE CAPACITY EXCEPT AS NOTED

UNIT	REF HDBK 1990*	TYPICAL SP GR	FUEL FIRED KCAL	10 °C DELTA T CW M3	POWER KWH	STEAM KG
FCCU	MW KELLOGG	0.9340	390019	0.0	6.07	-305.9
	H PROC JULY '82	0.9340	422627	29.4	44.50	47.7
	PLOCK I	0.9340	601930	32.0	62.00	55.6
	PLOCK II	0.9340	808770	17.0	28.00	74.1
TCCU	H PROC JULY '82	0.9340	471539	29.4	36.41	-47.7
ALKYLATION - PRODUCT	STRATCO H2SO4	0.7796	0	62.6	109.05	659.7
	PLOCK	0.7796	385680	116.0	41.00	130.0
CAT POLYMERIZATION	H PROC JULY '82	0.5859	0	20.5	41.27	936.3
PROPANE DEASPHALTING	IFP	0.9861	38206	0.0	8.94	20.3
	KERR-McGEE	0.9861	152823	0.0	12.77	34.8
	* FW CRACKED	0.9861	143171	0.0	12.77	173.9
	H PROC JULY '82	1.0071	574573	34.0	6.00	143.0
LUBES - PDA	FW LUBE	0.9861	138345	10.0	13.41	333.2
	SHELL	0.9861	550000	26.3	10.90	268.0
	GDANSK	0.9659	298600	9.5	31.60	117.0
- FURFURAL/NMP	SHELL	0.9042	414000	27.9	9.90	137.0
	[illegible] NMP - 103 VI	0.9042	354389	5.3	0.00	171.6
	PLOCK	0.9042	453860	30.0	20.00	333.3
	GDANSK	0.9042	281500	8.0	3.13	134.8
- DEWAXING	SHELL MEK	0.8927	440	36.1	27.40	1233.0
	PLOCK ACETONE/BENZE	0.8927	0	49.0	110.00	1463.0
	GDANSK DI-ME	0.8927	0	19.4	35.13	1593.7
- HYDROFINISHING	SHELL	0.8927	150000	4.1	9.20	106.0
	PLOCK	0.8927	152400	25.0	8.50	148.1
	GDANSK	0.8927	150000	11.1	3.95	141.0
GREASE - PER TONNE	STRATCO	0.0000	545000	660.0	81.50	0.0

TABLE AP-E.10

TYPICAL REFINERY UTILITY USAGE

PER 1.0 TONNE CAPACITY EXCEPT AS NOTED

UNIT	REF HDBK 1990	TYPICAL SP GR	FUEL FIRED KCAL	10 °C DELTA T CW M3	POWER KWH	STEAM KG
H'CRACKING	* LUMMUS/OXY/AMOCO	0.9833	90498	1.6	5.80	-103.2
		1.0389	106573	3.8	100.02	-266.8
	* CHEVRON	0.9159	247673	8.6	48.13	-156.0
	* IFP	0.9248	68607	0.0	19.07	36.6
	* LINDE	0.9248	85758	4.9	10.21	0.0
	* UNOCAL/UOP	1.0114	211722	0.0	62.26	0.0
	H PROC JULY '82	0.9340	326083	27.5	32.36	44.1
THERMAL CRACKER	H PROC JULY '82	0.9340	81521	29.4	36.41	-47.7
VISBREAKING	* LUMMUS - 356'FFEED	1.0129	117455	6.3	3.11	126.9
	* IFP	0.9659	37455	0.0	12.29	31.4
	H PROC JULY '82	1.0071	302083	8.2	2.25	85.1
COKING	* LUMMUS - DELAYED	1.0187	225779	4.2	24.11	56.1
	* EXXON - FLEXI	1.0513	0	9.1	77.87	271.8
	* FW	1.0255	180395	0.8	21.49	-108.3
	H PROC JULY '82 DEL	1.0071	344744	28.3	7.50	98.7
	H PROC JULY '82 FL	1.0071	-9450	28.3	26.26	-224.7
COKE CALCINING-PER TONNE*	GKT - W GERMANY	0.0000	270000		54.00	1950.0
ASPHALT BLOWING	* SNAM - 80/100 PEN	1.0300	55000	0.0	4.00	20.0
	- 40/50 PEN	1.0360	65000	0.0	10.00	20.0
	PLOCK	1.0143	139700	0.0	5.00	18.5
	GDANSK	1.0143	90165	0.0	16.95	86.6
MTBE - PRODUCT	CD TECH	0.7999	0	55.4	7.87	1057.3
	* PHILLIPS	0.7999	0	55.7	8.66	800.1
MEA UNIT (1.0 TONNE S)	H PROC JULY '82	0.0000	0	132.0	33.06	5040.0
	GDANSK	0.0000	0	0.0	0.00	6292.0
						-3360
SULFUR PLANT (1.0 TONNE S)	H PROC JULY '82	0.0000	999295	0.0	119.02	-5181.0
	PLOCK	0.0000	1397000	0.0	68.00	-1075.0
	GDANSK	0.0000	33	35.0	11.90	-1075.0
H2 PLANT (1000 NM3)(6&7)		0.0000	4038	4.1	112.22	65.5

TABLE AP-E.11

TYPICAL REFINERY TOTAL ENERGY USAGE

PER 1.0 TONNE CAPACITY EXCEPT AS NOTED

UNIT		REF HDBK 1990	TYPICAL SP GR	FUEL FIRED KCAL	10 °C DELTA T CW KCAL	POWER KCAL	TOTAL STEAM KCAL	ENERGY KCAL/T	SAY USE TOTAL ENERGY M KCAL/T	SAY USE TOTAL ENERGY M KCAL/T
CRUDE DISTILLATION		TECHNIP LO 4TWR	0.8550	74212	1136	19445	14036	108829	110	58.7
	•	TECHNIP HI 4TWR	0.8550	111317	1504	26516	28072	167409	170	90.2
		H PROC JULY '82 Hy	0.9042	105264	8532	4012	17697	135505	135	77.2
		H PROC JULY '82 Lt	0.8251	153650	12467	5715	14545	186377	185	96.9
		GDANSK	0.8654	153000	240	12000	28140	193380	195	105.5
CRUDE/VAC DISTILLATION		FW LO RANGE	1.0093	125734	283	8985	47561	182563	185	116.2
	•	FW HI RANGE	1.0093	188601	283	8985	47561	245430	245	156.2
		PLOCK LO RANGE 1&2	0.8628	180380	4800	11520	39200	235900	235	128.3
		PLOCK HI RANGE 3&4	0.8628	205580	4500	19680	97300	327060	325	177.9
VAC DISTILLATION	•	SHELL – LUBES	0.9218	174000	8520	8160	91700	282380	280	164.1
		H PROC JULY '82	0.9593	83337	8786	5672	62547	160341	160	97
		GDANSK	0.9340	122000	5820	16560	96600	240980	240	141.9
VAC FLASHER			0.0000	0	0	0	0	0		
LT ENDS FRACT'N (USE)			0.0000	0	0	0	0	0		
LPG			0.5411	0	6864	8379	147850	163094	165	55.6
NAPHTHA SPLITTING			0.7796	0	8246	5816	179583	193645	195	95.2
H'TREATING – NAPHTHAS		H PROC JULY '82	0.8017	130588	3849	22623	41913	198972	200	100.6
		GDANSK	0.8017	178000	780	30240	3360	212380	210	107.3
– GAS OILS		H PROC JULY '82	0.9042	147369	5688	24071	37163	214292	215	122.1
		PLOCK	0.8984	61000	8400	33600	38920	141920	140	80.4
		GDANSK	0.8984	131000	840	5760	2170	139770	140	79.2
– RESIDS	•	IFP – RESID	0.9659	86221	4215	133006	153236	376678	375	229.4
	•	CHEVRON	0.0000	0	0	0	0	0		
REFORMING	•	CHEVRON + HT	0.7883	573487	2900	13421	-101488	488319	490	242.7
	•	ENGELHARD–100 RON	0.7883	503058	725	38345	0	542128	540	269.4
	•	IFP –102 RON	0.7883	130795	0	19173	-31715	118253	120	58.8
		H PROC JULY '82	0.8017	759784	14113	67868	107775	949540	950	479.9
		PLOSK + HT (AVG)	0.7883	760000	9000	100800	97160	966960	965	480.6
		GDANSK	0.8017	657000	3420	18720	364840	1043680	1045	527.7

TABLE AP-E.12

TYPICAL REFINERY TOTAL ENERGY USAGE

PER 1.0 TONNE CAPACITY EXCEPT AS NOTED

UNIT	REF HDBK 1990	TYPICAL SP GR	FUEL FIRED KCAL	10 °C DELTA T CW KCAL	POWER KCAL	STEAM KCAL	TOTAL ENERGY KCAL/T	SAY TOTAL ENERGY M KCAL/T	SAY TOTAL ENERGY M BTU/Bbl
FCCU	MW KELLOGG	0.9340	390019	0	14564	-214143	190440	190	112.1
	H PROC JULY '82	0.9340	422627	17621	106800	33406	580454	580	341.8
	PLOCK I	0.9340	601930	19200	148800	38920	808850	810	476.3
	PLOCK II	0.9340	808770	10200	67200	51870	938040	940	552.3
TCCU	H PROC JULY '82	0.9340	471539	17621	87382	-33406	543136	545	319.8
ALKYLATION - PRODUCT	STRATCO H2SO4	0.7796	0	37566	261713	461785	761064	760	374.1
	PLOCK	0.7796	385680	69600	98400	91000	644680	645	316.9
CAT POLYMERIZATION	H PROC JULY '82	0.5859	0	12289	99052	655404	766745	765	283.2
PROPANE DEASPHALTING	IFP	0.9861	38206	0	21458	14198	73862	75	45.9
	KERR-McGEE	0.9861	152823	0	30655	24340	207818	210	129.2
	* FW CRACKED	0.9861	143171	0	30655	121701	295527	295	183.7
	H PROC JULY '82	1.0071	574573	20427	14407	100092	709499	710	450.5
LUBES - PDA	FW LUBE	0.9861	137345	6013	32187	233260	408805	410	254.1
	SHELL	0.9861	550000	15780	26160	187600	779540	780	484.6
	GDANSK	0.9659	298600	5700	75840	102900	483040	485	294.1
- FURFURAL/NMP	SHELL	0.9042	414000	16740	23760	95900	550400	550	313.8
	* EXXON NMP - 103 VI	0.9042	354389	3160	23402	120117	501068	500	285.6
	PLOCK	0.9042	453860	18000	48000	233310	753170	755	429.3
	GDANSK	0.9042	281500	4782	7512	94360	388154	390	221.3
- DEWAXING	SHELL MEK	0.8927	440	21660	65760	863100	950960	950	535.2
	PLOCK ACETONE/BENZE	0.8927	0	29400	26400	1024100	1079900	1320	607.8
	GDANSK DI-ME	0.8927	0	11622	84312	1115590	1211524	1210	681.8
- H'FINISHING	SHELL	0.8927	150000	2460	22080	74200	248740	250	140.0
	PLOCK	0.8927	152400	15000	20400	103670	291470	290	164.0
	GDANSK	0.8927	150000	6654	9480	98700	264834	265	149.0
GREASE - PER TONNE	STRATCO	0.0000	545000	396000	1956000	0	1136600	1135	

TABLE AP-E.13

TYPICAL REFINERY TOTAL ENERGY USAGE

PER 1.0 TONNE CAPACITY EXCEPT AS NOTED

UNIT	REF HDBK 1990	TYPICAL SP GR	FUEL FIRED KCAL	10 °C DELTA T CW KCAL	POWER KCAL	STEAM KCAL	TOTAL ENERGY KCAL/T
H'CRACKING	• LUMMUS/OXY/AMOCO	0.9833	90498	933	129109	-72207	148333
		1.0389	106573	2255	240036	-186741	162123
	• CHEVRON	0.9159	247673	5148	115516	-109192	259145
	• IFP	0.9248	68607	0	45758	27033	141398
	• LINDE	0.9248	85758	2935	24513	0	113206
	• UNOCAL/UOP	1.0114	211722	0	149428	0	361150
	H PROC JULY '82	0.9340	326083	16520	77673	30837	451113
THERMAL CRACKER	H PROC JULY '82	0.9340	81521	17621	87382	-33406	153118
VISBREAKING	• LUMMUS - 356'FFEED	1.0129	117455	3808	7461	88859	217583
	• IFP	0.9659	37444	0	29731	21950	89125
	H PROC JULY '82	1.0071	302407	4908	5402	59578	372295
COKING	• LUMMUS - DELAYED	1.0187	225779	2524	57861	39267	325431
	• EXXON - FLEXI	1.0513	0	5436	186898	-190255	2079
	• FW	1.0552	180395	487	51564	-75819	156627
	H PROC JULY '82 DEL	1.0071	344744	16951	18008	69111	448814
	H PROC JULY '82 FL	1.0071	-9450	16951	63029	-157287	-86757
COKE CALCINING-PER TONNE*	GKT - W GERMANY	0.0000	270000	0	129600	1365000	1764600
ASPHALT BLOWING	• SNAM - 80/100 PEN	1.0300	55000	0	9600	14000	78600
	- 40/50 PEN	1.0360	65000	0	24000	14000	103000
	PLOCK	1.0143	139700	0	12000	12950	164650
	GDANSK	1.0143	90165	0	40682	60634	191481
MTBE - PRODUCT	CD TECH	0.7999	0	33220	18895	740134	792249
	• PHILLIPS	0.7999	0	33399	20784	560102	614285
MEA UNIT (1.0 TONNE S)	H PROC JULY '82	0.0000	0	79200	79344	352800	511344
	GDANSK	0.0000	0	0	0	4404400	4404400
SULFUR PLANT (1.0 TONNE S)*	H PROC JULY '82	0.0000	999295	0	285638	0	1284933
	PLOCK	0.0000	1397000	0	163200	0	1560200
	GDANSK	0.0000	33	21000	28560	-752500	-702907
H2 PLANT (1000 NM3)(6&7)		0.0000	4038	2468	269331	45825	321662

TABLE AP-E.14

USA

TYPICAL REFINERY TOTAL ENERGY USAGE

****

COMPARISON OF TYPICAL REFINERY UNIT TOTAL ENERGY REQUIREMENTS
AGAINST A REASONABLY EFFICIENT 80 000 BPSD USA FUELS REFINERY
(ENERGY REQUIREMENT = 380 000 BTU/BBL CRUDE FEED)

REF: PELHAM & MORIARTY, PROFIMATICS INC, HYDROCARBON PROCESSING, JULY 1985 Pg 51 - TABLE 1

UNIT		CAPACITY BPSD	TOTAL ENERGY DEMAND Btu/BbL	CALC'D TOTAL ENERGY DEMAND M Btu/D	REPORTED TOTAL ENERGY DEMAND M Btu/D	TOTAL ENERGY DEMAND %
CRUDE/VAC UNIT		80000	133700	10696.0		35.3
LT ENDS FRACTINATION	SAY	1000	56300	56.3		0.2
NAPHTHA HDS		16000	101100	1617.6		5.3
CATALYTIC REFORMER		16000	480200	7683.2		25.4
ALKYLATION UNIT		5500	368600	2027.3		6.7
FCC UNIT		24000	341500	8196.0		27.1
TOTAL PROCESS UNITS			378455	30276.4		100.0
TOTAL REFINERY PREDICTED			378455	30276.4		
TOTAL REFINERY REPORTED		80000	380000		30400.0	
TOTAL CRUDE FEED @ 6.0 MM BTU/BbL				480000.0	480000.0	
ENERGY EFFICIENCY - % ON CRUDE				6.31	6.33	

NOTE: THE CLOSE CORRESPONDENCE OF THESE RESULTS APPEARS TO JUSTIFY THE GENERAL VALIDITY OF THE 'TOTAL ENERGY DEMAND' FACTORS IN REPRESENTING REASONABLE ENERGY EFFICIENCIES IN A MODERN REFINERY CONTEXT.

HOWEVER, IT SHOULD NOT BE OVERLOOKED THAT THE CONCLUSIONS OF THIS PAPER WITH THERMODYNAMIC AND PRACTICAL CONSIDERATIONS OF REFINERY ENERGY LOSSES WAS TO SUGGEST THAT GIVEN THE CURRENT REFINERY CONFIGURATIONS AND TECHNOLOGIES, CONCEIVABLE FURTHER IMPROVEMENTS COULD APPROXIMATE 23 PERCENT.

TABLE AP-E.15

USA

TYPICAL REFINERY UNIT ENERGY USAGE

****

SELECTED SPECIFIC ENERGY DEMANDS

UNIT	BASIS FEED/ PRODUCT	FEEDSTOCK °API	FEEDSTOCK Sp Gr	SPECIFIC ENERGY DEMAND KCAL/T	SPECIFIC ENERGY DEMAND BTU/BBL
DISTILLATION				*10^3	*10^3
ATMOSPHERIC	FEED	25.0	0.9042	135	77.0
ATMOSPHERIC	FEED	40.0	0.8251	185	96.2
ATMOSPHERIC/VACUUM LUBES	FEED	32.0	0.8654	305	166.4
ATMOSPHERIC/VACUUM FLASH	FEED	32.0	0.8654	245	133.7
VACUUM – FUELS	FEED	16.0	0.9593	160	96.8
LPG	FEED	130.0	0.5411	165	56.3
NAPHTHA SPLITTING	FEED	50.0	0.7796	195	95.8
FCC GAS PLANT	FEED		0.0000		
CRACKING					
FCC	FEED	20.0	0.9340	580	341.5
TCC	FEED	20.0	0.9340	545	320.9
VISBREAKING	FEED	9.0	1.0071	350	222.2
DELAYED COKING	FEED	9.0	1.0071	450	285.7
FLUID COKING	FEED	9.0	1.0071	–85	–54.0
FLEXI COKING	FEED		0.0000		
HYDROTREATING					
NAPHTHA	FEED	45.0	0.8017	200	101.1
GAS OIL	FEED	25.0	0.9042	215	122.6
RESID	FEED		0.0000		
HYDROCRACKING					
GAS OILS	FEED	20.0	0.9340	400	235.5
RESID	FEED		0.0000		

TABLE 15 – CONTINUED

USA

TYPICAL REFINERY UNIT ENERGY USAGE

****

SELECTED SPECIFIC ENERGY DEMANDS

UNIT	BASIS FEED/ PRODUCT	FEEDSTOCK °API	FEEDSTOCK Sp Gr		SPECIFIC ENERGY DEMAND KCAL/T	SPECIFIC ENERGY DEMAND BTU/BBL
LUBES						
VACUUM – LUBES	FEED	22.0	0.9218		[illegible] 0	446.2
PDA – LUBES	FEED	12.0	0.9861		250	145.3
FURFURAL/NMP	FEED	25.0	0.9042		525	299.3
DEWAXING – MEK/DI-ME	FEED	27.0	0.8927		950	534.7
H'FINISHING	FEED	27.0	0.8927		200	112.6
BLENDING	PRODUCT	27.0	0.8927	USE	30	16.9
REFORMING	FEED	45.0	0.8017		950	480.2
TREATING						
MEROX	FEED	35.0	0.8498	USE	20	10.7
PDA – FUELS	FEED	9.0	1.0071		250	158.7
AMINE	PRODUCT		PER TONNE		3650	3650.0
SULFUR PLANT	PRODUCT		PER TONNE		-1000	-1000.0
HYDROGEN PLANT	PRODUCT		1000 NM3		320	320.0
GENERAL						
ALKYLATION	PRODUCT	50.0	0.7796		750	368.6
POLYMERIZATION	FEED	110.0	0.5859		750	277.0
OLIGOMERIZATION	PRODUCT	50.0	0.7796		200	98.3
MTBE	PRODUCT	45.0	0.8017		700	353.8
GREASE	PRODUCT		PER TONNE		1150	1150.0
COKE CALCINING	PRODUCT		PER TONNE		1750	1750.0
ASPHALT BLOWING	FEED		PER TONNE		100	100.0
BLENDING – FUELS	FEED	35.0	0.8498		20	10.7