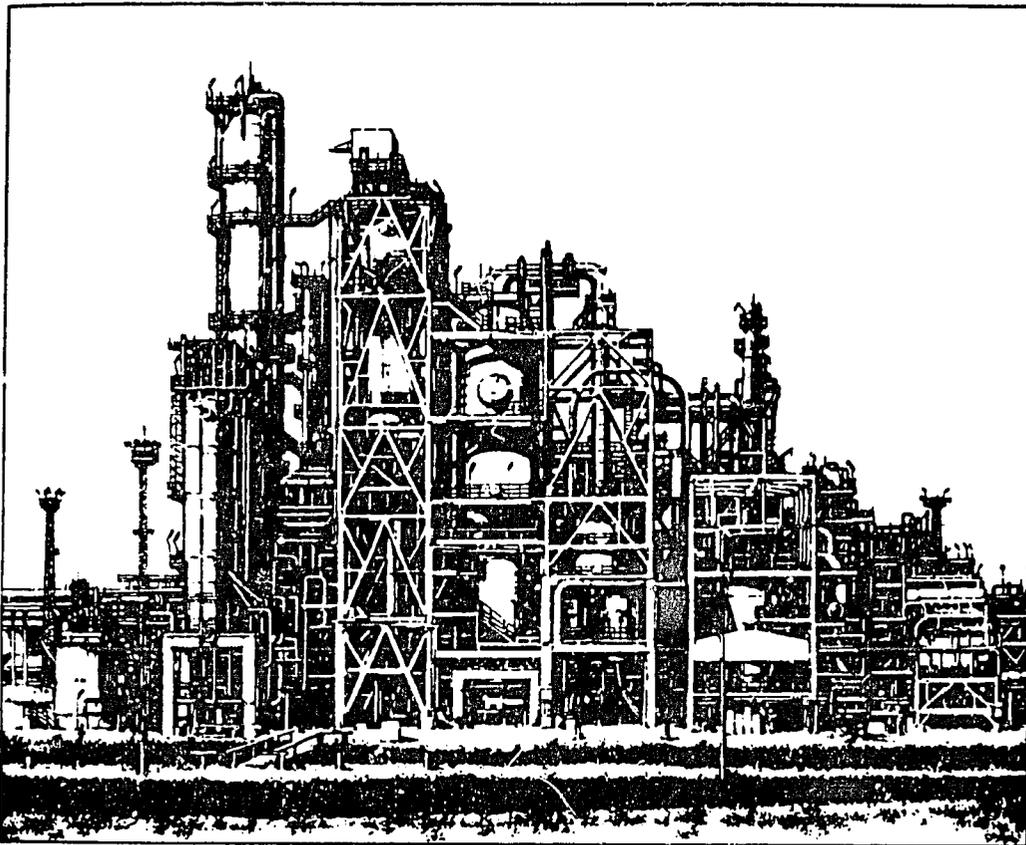


PHASE II FINAL REPORT

HUNGARY'S PETROLEUM REFINERIES:

**A REVIEW OF ENERGY USAGE,
ENVIRONMENTAL AND PROCESSING ISSUES**

AUGUST 1991



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TABLE OF CONTENTS

	<u>Page</u>
1.0 Introduction	1-1
2.0 Summary and Recommendations	2-1
3.0 DKV Refinery - Analysis of Processing Facilities and Operations	3-1
3.1 Description of Processing Facilities	3-1
3.2 Crude Oil Supply	3-1
3.3 Current Refinery Configuration and Processing Capabilities	3-2
3.3.1 Crude Oil Distillation	3-2
3.3.2 Naphtha Fractionating Unit	3-3
3.3.3 Catalytic Reforming Units	3-3
3.3.4 Aromatics Extraction Units	3-3
3.3.5 Maleic Anhydride Unit	3-4
3.3.6 Light Gasoline Isomerization	3-4
3.3.7 Gas Oil Desulfurization Units	3-4
3.3.8 Claus Sulfur Recovery Plants	3-4
3.3.9 Gas Recovery Plant	3-4
3.3.10 Fluid Catalytic Cracking Unit	3-5
3.3.11 HF Alkylation Unit	3-5
3.3.12 Visbreaking Unit	3-5
3.3.13 Lube Oil Manufacturing Block	3-5
3.3.14 Bitumen Unit	3-6
3.3.15 Wax Production Unit	3-6
3.4 Technical Review of Existing Process Technology	3-6
3.5 Energy Efficiency Review of Crude Distillation Units	3-8
3.6 Operating Efficiency of the Catalytic Reformer Complex	3-9
3.7 Current Operating Strategy of the Fluid Catalytic Cracking Unit	3-10
3.8 Operating Efficiency of the Fluid Catalytic Cracker	3-10
3.9 Future Refinery Processing Considerations	3-11
3.9.1 Integration of New CRR Reformer into Processing Scheme	3-11
3.9.2 Impact of New FCC Hydrotreater on Unit Operation	3-11
3.9.3 Analysis of Future Motor Fuel Processing Requirements/Plans	3-12
3.9.4 Analysis of Future Residual Conversion Requirements/Plans	3-13

TABLE OF CONTENTS (CONT'D)

	<u>Page</u>
3.10 Conclusions and Recommendations	3-15
3.10.1 Review of Current Processing Scheme	3-15
3.10.2 Review of Energy and Operating Efficiency	3-15
3.10.3 Feedstock and Process Optimization	3-16
3.10.4 Crude Supply Strategy	3-16
3.10.5 Process Unit Optimization	3-17
3.10.6 Processing Operations and Strategies - Summary Recommendations	3-18
4.0 DKV Refinery - Energy Usage and Conservation	4-1
4.1 Overview of Energy Usage	4-1
4.2 Energy Conservation Efforts of DKV	4-2
4.3 Description of Energy Supply to DKV Refinery	4-3
4.4 Review of Future Energy Supply and Conservation Issues at DKV	4-4
4.4.1 Future Energy Supply: Refinery Cogeneration vs Continuing Purchases from DHV	4-4
4.4.2 Energy Monitoring System (EMS)	4-5
4.4.3 Heat Recovery from Cooling Water	4-7
4.4.4 Improved Burner System at the Atmospheric Vacuum Tower Furnaces	4-7
4.4.5 Other Energy Conservation Opportunities at DKV	4-8
4.4.6 DKV Energy Issues - Summary	4-8
4.5 Recommendations	4-9
4.5.1 Near-Term Suggestions	4-9
4.5.2 Longer-Term Suggestions	4-9
5.0 DKV Refinery - Analysis of Environmental Issues and Solutions	5-1
5.1 Introduction	5-1
5.2 Comparison of Pollution Control in Hungary with the U.S.	5-1
5.3 Summary	5-2
5.4 Discussion of Air Pollution Problems	5-3
5.4.1 Health Problems and Criteria	5-3
5.4.2 Acid Gas Air Pollutants	5-8
5.4.3 Acid Gas Reduction Solutions	5-9

TABLE OF CONTENTS (CONT'D)

	<u>Page</u>
5.4.4 Hydrocarbon Emissions	5-10
5.4.5 Hydrocarbon Reduction Solutions	5-12
5.5 Water Pollution	5-14
5.5.1 Water Pollution Control Requirements	5-14
5.5.2 Water Pollution Solutions	5-17
5.6 Soil and Ground Water Contamination Problems	5-18
5.6.1 Magnitude of the Problem	5-18
5.6.2 Ground Water Standards and Public Health	5-19
5.6.3 DKV's Ground Water Remediation Efforts	5-20
5.6.4 Ground Water Contamination Solutions	5-22
5.7 Solid and Hazardous Wastes	5-23
5.8 Conclusions	5-28
5.9 Recommendations	5-25
5.9.1 Management and Organization	5-25
5.9.2 Air Pollution Control	5-26
5.9.3 Ground Water Control	5-26
5.9.4 Water Pollution	5-27
5.9.5 Environmental Laboratory	5-27
6.0 TIFO Refinery - Analysis of Processing Facilities and Operations	6-1
6.1 Interdependency with Other Facilities	6-1
6.2 Crude Oil Supply and Product Demands	6-2
6.3 Refinery Configuration	6-2
6.3.1 Crude Distillation Unit	6-3
6.3.2 Gas Oil Hydrodesulfurization Unit	6-5
6.3.3 LPG Sweetening	6-6
6.3.4 Claus Sulfur Recovery Unit	6-6
6.4 Gas Processing and Air Pollution Control Problems	6-7
6.5 Future Processing Considerations	6-8
6.6 Summary of Survey Observations	6-10

TABLE OF CONTENTS (CONT'D)

	<u>Page</u>
7.0 TIFO Energy Usage and Conservation	7-1
7.1 Energy Overview	7-1
7.2 Current Status of Energy Conservation Efforts	7-1
7.2.1 Implementation of Previous Energy Audit Recommendations	7-1
7.2.2 Energy Monitoring System	7-2
7.2.3 Power Factor Control	7-2
7.2.4 Steam Conservation	7-2
7.2.5 Other Efforts	7-3
7.3 Review of Current and Future Energy Conservation Issues	7-3
7.3.1 Insulation	7-3
7.3.2 Product Line Tracer Control	7-3
7.3.3 Pump Variable Speed Control	7-4
7.4 TIFO Energy Issues - Summary	7-4
7.5 Recommendations	7-4
7.5.1 Near-Term Suggestions	7-5
7.5.2 Longer-Term Suggestions	7-5
8.0 TIFO Refinery - Analysis of Environmental Issues and Solutions	8-1
8.1 Introduction	8-1
8.2 Comparison of Pollution Control in Hungary with the U.S.	8-1
8.3 Summary of Current Problems	8-2
8.4 Discussion of Air Pollution Issues	8-3
8.4.1 Sulfur Oxides	8-3
8.4.2 Hydrocarbon Emissions	8-4
8.5 Water Pollution	8-7
8.6 Ground Water Considerations and Soil Contamination	8-7
8.7 Conclusions	8-8
8.8 Recommendations	8-9

TABLE OF CONTENTS (CONT'D)

	<u>Page</u>
9.0 Refining Strategic Issues	9-1
9.1 Overview	9-1
9.2 Bottom Line Orientation	9-1
9.3 Competitive Cost Structure	9-1
9.4 Expansion of Product Markets	9-3
9.5 Allocation of Capital to Investment Projects	9-3
9.6 Strategic Planning	9-4
9.7 Organizational Structures	9-5

APPENDICES

Annex A	"Catalytic Routes to Low-Aromatics Diesel Look Promising", OGJ, May 7, 1990
Annex B	Q & A Session on Hydrogen Processing, 1990 NPRA Annual Meetings
Annex C	Comprehensive List of Energy Conservation Projects Implemented by DKV since 1985

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The K & M team would like to thank the staffs at the DKV and TIFO refineries for their hospitality and cooperation in this effort. The results and recommendations included in this report will hopefully justify the time and preparation that our Hungarian hosts and counterparts devoted to our meetings, at the DKV, the visit team was received by Mr. Imre Fekete, Power Supply Manager, who provided information on energy usage and conservation, and also brought in the following staff for energy and environmental discussions.

Mrs. Jolan Danyadi	Head of Department (Energy Management and Control)
Dr. Maria Erdos	Head of Department (Environmental Protection and Water Supply)
Mr. Arpad Kovacs	Head of Electric Division
Mr. Lajos Orsi	Head of Power Supply Division
Dr. Istvan Pasztor	Head of Power Distribution Unit

The co-host at DKV was Dr. Josef Perger who provided information on processing and planning for future facilities. Dr. Perger brought in the following individuals from the Process Engineering, Projects Management and Business Planning Divisions:

Mrs. Iren Hegedus	Leading Process Engineer
Ms. Iren Agostonne Nemeth	Head of Department (Economics)
Mr. Joset Szollosi	Chemical Engineer (Process Division)

Dr. Perger also arranged contacts with:

Mr. Janos Katona	Production Chief Engineer
Mr. Robert Somlai	Production Department

At TIFO, the visit was hosted by Mr. Jozsef Mate, Head of the Energy Department, who provided information on energy and environmental issues. Mr. Istvan Ulrich, Plant Manager and cohost, provided information on processing and facilities planning. Inputs were also provided by a number of other staff members during plant tours and group discussion sessions.

The K & M team would also like to acknowledge the role played by our local Hungarian subcontractor, EGI Contracting/Engineering. Mr. Zoltan Lontay and Mr. Istvan Kovacsics worked with us during our visit acting not only as translators, but also contributing engineering input to our discussions, especially on energy issues. They also have provided follow-up support in arranging details for our visits, as well as obtaining additional information.

1.0 INTRODUCTION

As part of its broader Eastern European Initiative, the U.S. Agency for International Development (USAID) developed a program designed to assist Hungary in improving operating efficiency, energy conservation, and environmental control in its petroleum refinery sector. This program has been carried out in a two-phase effort by K & M Engineering and Consulting Corporation of Washington, D.C.

The first phase consisted of a "characterization study" to develop an understanding of how the Hungarian refinery sector operates, and to collect data on supply, demand, refinery flow schemes, unit operations, energy usage, environmental emissions and overall organizational structure. The results of this effort were published separately in the Phase I report.

The second phase, which is the subject of this report, involved a detailed review of operating and planning issues in processing, energy, and environment. The primary focus of this effort was to identify changes in operating practices and equipment modifications that could be implemented in the near-term to increase the overall operating efficiency of this effort, reduce energy usage, and reduce the level of pollutants from Hungary's two largest operating refineries. In addition, the K & M team was asked to identify areas for potential longer-term capital improvement projects. However, such longer-term projects will require additional feasibility analysis, which was beyond the scope of the current study. Finally, operating and planning issues were also reviewed.

During the Phase II study, the K & M team concentrated its efforts on the following refineries:

- **Dunai Koolajipari Vallalat (DKV)** - situated approximately 30 km south of Budapest at Szazhalombatta on the Danube River. DKV was founded in 1960, with construction beginning in 1961. The first production unit was brought on stream in 1965. Since then, more processing units have been added and currently there are 30 units and a total processing capacity is 8.0 million tons of crude oil per year. DKV is Hungary's largest refinery. In most years, it produces between 70 and 80 percent of the refined products manufactured in the country. Of this amount, about 70-72 percent are white products including motor, jet, and diesel fuels, while 15-18 percent is heavy fuel oil. In addition to producing fuel products, DKV also carries out significant petrochemical activities. Over 300 products from this integrated facility are sold domestically and to 26 different countries.
- **Tiszai Koolajipari Vallalat (TIFO)** - located in the north-eastern part of Hungary at Tiszaujvaros on the Tisza River. TIFO was established in 1973 to provide virgin naphtha to a nearby olefin plant (the Tisza Chemical Works or TVK) and heavy fuel oil to an adjacent power plant (the Tisza Power Station or TEV) to fire an 860 MW oil/gas unit. The original design for TIFO envisioned four processing complexes with a total capacity of 8 million tons per year. However, only the first of these processing complexes was built with a current capacity of 3 million tons per year, or approximately 60,000 barrels per day. The refinery is a low complexity plant with no conversion facilities for converting vacuum gas oil and vacuum residuum to lighter products.

This report has been organized to discuss the processing, energy, and environmental issues in separate sections for each refinery. There is also a final section that discusses overriding refinery business issues that should be considered as Hungary's petroleum refining industry embarks on its transition to a competitive market economy.

2.0 SUMMARY AND RECOMMENDATIONS

The K & M team found the DKV and TIFO refineries to be modern, conventional processing facilities with solid infrastructure for the refining of petroleum. The technical personnel at the refineries appeared to be extremely knowledgeable about petroleum refining and technological trends in the refining industry. Refinery personnel at both DKV and TIFO have been engaged in energy conservation efforts for the past decade, and have already achieved significant reductions in overall energy usage. Environmental regulations in Hungary, and environmental control in general, lag behind similar efforts in the U.S. Most of the environmental problems are at the older DKV facility.

Based on both facilities and people, the Hungarian refineries can be judged to be competitive operations that could survive in a competitive market environment.

This report analyzes key operating and planning issues in processing, energy, and environmental protection at the DKV and TIFO refineries. A fourth area, refinery business issues, is also addressed. Some of the recommendations from each of these areas are highlighted in the following paragraphs. Complete and detailed recommendations are given in the refinery - specific sections of this report. The recommendations highlighted below were selected on the basis of whether or not the U.S. could possibly provide additional assistance, as well as the fact that they addressed issues requiring immediate attention.

The operating and planning issues in processing at DKV and TIFO are primarily a consequence of changes in crude supply and dislocations in the market for refined products.

- Currently, TIFO has no facilities for conversion of vacuum gas oil and residual oil fractions, nor does it have pipeline access to lighter premium crudes. Thus, it has not been able to adjust to a shift in product demand. A decrease in fuel oil demand has resulted in refinery throughput being backed down. In order to increase both the capacity utilization of the existing equipment and profitability of the overall facility, some form of conversion capacity is required. The ability to convert heavy fuel oil to lighter products will provide the refinery with the capability to shift the product output as market conditions change. Providing pipeline access to imported lighter crudes would also increase TIFO's ability to match production to demand.
- Up until 1989, DKV and TIFO ran only Soviet and Hungarian crude. However, with a continuing decline in Soviet oil production, the volume of crude from the USSR is expected to continue to be in short supply for the foreseeable future. Thus, in order to achieve favorable future profits, DKV will need to:
 - value and select the slate of crudes for maximum profits;
 - produce and market the slate of products for maximum profits; and
 - optimize individual unit operations within the context of these given crude and product slates.

To achieve these results requires organizational commitment within the refinery, cooperation of the oil traders purchasing the crudes, and the modeling tools and techniques needed for crude valuation and process unit optimization. (This is clearly an area where additional support could be provided by the U.S.)

This report describes a large number of additional operating unit recommendations, and includes a discussion of future processing options for both DKV and TIFO.

Both DKV and TIFO have made extensive progress in energy conservation over the past decade. There are still some opportunities for additional improvements. DKV could identify and achieve additional energy savings with an expanded and improved energy monitoring system. The dispersed layout of units at DKV will prevent that refinery from ever being in the upper ranks of the most energy efficient refineries; however, the actual energy usage for individual process unit shows DKV to be in the competitive range for refineries of comparable complexity.

Currently, DKV is involved in resolving a major energy supply issue. In the past, DKV has purchased steam and power from the neighboring utility (DHV), but this supply is presently unreliable. Moreover, DKV has been experiencing difficulty in negotiating a continuing supply contract at a favorable rate. As a consequence, DKV is considering building its own cogeneration plant. While the underlying economics in such a case traditionally favor the utility with respect to supplying steam and power to a refinery, such a proposed cogeneration plant may very well be the best option in this case, especially if DHV is unwilling to be more reasonable in contract renegotiations.

The lack of significant progress in the area of environmental control is in direct contrast to the excellent capabilities and overall status of refinery processing operations and energy conservation efforts at both DKV and TIFO. Environmental regulations are much less stringent in Hungary than in the U.S. While both refineries have been working on pollution control problems, a considerable gap still exists between the current situation and future objectives as defined by estimates of future regulatory limits, especially at DKV.

There is a small environmental staff at DKV with some very capable people, but they lack laboratory and test equipment comparable to that found in the U.S. Moreover, they could benefit by a greater awareness and understanding of the full range of environmental control technologies used in the West.

While there are pollution problems in all areas at DKV, several remedial efforts are presently underway which should begin to address these problems, especially in the following areas:

- **Air Pollution Control: SO₂ emissions have been reduced and further reduction will be achieved when the FCC feed hydrotreater comes on stream. Plans and alternatives for controlling hydrocarbon emissions were reviewed and recommendations made.**
- **Soil and Ground Water Contamination: DKV has a severe ground-water contamination problem under large areas of the refinery from leak and spills over the past 25 years of operation. The proposed and partially implemented control solutions consist of a barrier wall and gravity drain. Concern was expressed by the visit team's environmental specialist that these measures would not achieve the desired goal. Other technology options such as investigating vapor stripping were suggested.**

Improved laboratory facilities, testing and monitoring equipment, and modeling tools are recommended in the body of the report, along with suggestions for more extensive monitoring and assessment of environmental quality problems.

3.0 DKV REFINERY-ANALYSIS OF PROCESSING FACILITIES AND OPERATIONS

3.1 Description of Processing Facilities

In 1960 the DKV Refinery was founded and construction was started the following year at a site 30 kilometers south of Budapest on the Danube River. The refinery was started up in 1965, and the number of process units built at the site has now reached thirty. The current capacity of the facility is 8 metric tons/year or 150,000 barrels/day. DKV is the major refinery for Hungary, operating at or near full capacity and producing 70-80% of the refined products manufactured in the country.

The refinery produces three types of products; fuel products, lube oils, and petrochemicals (both intermediates and finished products). A percentage breakdown for the annual production in the various product categories is shown below:

<u>Product</u>	<u>Percentage of Crude Run</u>
Gasolines	27%
Gas Oils	36%
Jet Fuel	4%
Aromatics	4%
Lube Oils	3%
Fuel Oils	18%
Bitumens	5%
Other	3%

DKV products are sold domestically in Hungary through two large domestic distributors, AFOR and VEGYTEK. Exports are managed by the Hungarian foreign trade companies. Products are exported to companies throughout Scandinavia, Western Europe, and the United States. This attests to the fact that DKV products sold throughout the West equal or exceed Western standards of quality.

3.2 Crude Oil Supply

Until very recently, the primary supply of crude oil to the refinery was of Soviet or Hungarian origin. This Soviet export blend crude is transported via the Friendship II pipeline which enters Hungary at the northeastern border with the Soviet Union and via the Friendship I pipeline entering from Czechoslovakia (Figure 3.1). Table 3.1 presents a breakdown of crude sources to the DKV refinery in 1989 and 1990. In 1990, approximately 66.4% of the crude processed at DKV was of Soviet origin. An additional 21% of the crude oil was obtained from domestic Hungarian sources. However, it should be noted that production from the Hungarian fields is declining, and are not expected to serve as a replacement for reduced crude imports from the Soviet Union.

The remaining crude processed in the refinery was purchased from various sources in the Near East and Africa, including Libya, Algeria, Nigeria, and Iraq. Imported crudes from these sources are transported to the refinery via the Adriatic Pipeline. From all indications, it appears that the DKV refinery will require a growing volume of Middle Eastern and African

crudes to replace the diminishing flow of crude from both the Soviet Union and Hungary's domestic fields. Table 3.2 contains a brief comparison of the relative differences in quality between Soviet and African crudes and a Middle Eastern crude. In general, the Soviet crude is much higher in sulfur content and contains a higher percentage of residual material which is of generally lower quality. Residual oil and sulfur content of a specific crude oil have a significant impact on the type of processing equipment required to refine that particular crude.

In 1990, 7.1 million metric tons of crude oil were processed at the DKV refinery. This represents a daily crude oil throughput of approximately 150,000 barrels per day. In addition, approximately 500,000 metric tons of gas field condensates and other purchased feedstocks were processed.

3.3 Current Refinery Configuration and Processing Capabilities

A flow diagram of the current process configuration for DKV is shown in Figure 3.2. Each of the individual units will be described in the following discussion.

3.3.1 Crude Oil Distillation

The initial processing step is crude oil distillation. DKV has three atmospheric-vacuum crude oil distillation complexes. AVU-1 was brought on stream in 1965 and has the capability to process 1.5 million Metric Tons of crude oil annually. This annual capacity equates to an approximate daily run of 30,000 barrels per day. AVU-1 is used primarily for the distillation of Hungarian crude (for lube oil applications) and purchased feedstocks.

AVU-2 was brought on stream in 1968 and is capable of processing up to 2.8 million Metric Tons of crude oil annually (approximately 55,000 barrels per day). This distillation train is used primarily for the processing of Soviet and to a lesser extent, Hungarian crude oils. AVU-3 was brought on stream in 1972 and has the capacity to process up to 3.7 million Metric Tons of crude annually (approximately 74,000 barrels per day). AVU-3 currently provides the flexibility for the processing of various purchased crude oils. Tables 3.3, 3.4 and 3.5 provide a summary of the 1990 feedstock and product breakdown for each crude unit. Table 3.6 provides a summary of the various modes of operation employed for the three crude distillation complexes. At AVU-3, imported as well as Soviet crude are processed in a blocked operation. Blocked operation involves the distillation of a single crude oil one at a time rather than blending the crudes prior to distillation.

Each of the crude units is equipped with a desalter. Also, the fired heaters are equipped with flue gas waste heat recovery capabilities. The recovery of heat from the flue gas is a critical factor in operating the crude unit in an energy efficient manner. Process control is provided in units 1 and 3 by pneumatic and electronic controls. The process control for unit 2 was upgraded to a distributed control system. For AVU-2 and AVU-3, the internals of the respective vacuum columns were replaced during 1983-1984 with Norton structured internals. This is a generally accepted method of increasing vacuum tower capacity as well as providing sharper vacuum gas oil cuts (better quality) for use as catalytic cracking feedstock.

3.3.2 Naphtha Fractionating Unit

Naphtha from the crude distillation complex flows downstream to the naphtha fractionating section. The capacity of the naphtha fractionator is 1.5 million Metric Tons per year (approximately 35,000 BPD). The naphtha fractions are split to provide the following feedstock to the three catalytic reforming units. The boiling ranges of the three naphtha cuts from the fractionator are shown on the next page. Naphtha is fractionated in order to maximize aromatics production and minimize fractionation of reformat.

<u>Fraction</u>	<u>Boiling Range (°C)</u>	<u>Boiling Range (°F)</u>	<u>Disposition</u>
Light Naphtha	70 - 110/115	158 - 275	Reformer Unit #1
Medium Naphtha	105 - 145	212 - 311	Reformer Unit #2
Heavy Naphtha	80 - 180	212 - 356	Reformer Unit #3

3.3.3 Catalytic Reforming Units

The fractions from the naphtha fractionation unit are sent to the three catalytic reforming units. The units are designated as REF-1, REF-2, and REF-3, each with a capacity of 350,000 Metric Tons per year (10,000 BPD). The units are all of the semi-regenerative type and the design of each was based upon Soviet technology. Typically, a refinery of this size would employ one or at most two catalytic reformers. The construction of three catalytic reformers does not represent the most efficient use of capital. However, since the capital has already been employed, the existence of three reformers offers interesting possibilities for overall yield optimization.

The reformer reactors are each loaded with conventional bi-metallic reforming catalysts: REF-1 with Akzo CK-522, REF-2 with Engelhard E-603, and REF-3 with UOP R-62. These catalyst selections are representative of the types of catalysts currently seeing widespread use within the refining industry. A more thorough analysis of the reformer operation will be included in a later section.

3.3.4 Aromatics Extraction Units

The aromatics-rich reformat streams from the three reformers along with benzene-rich pyrolysis gasolines from external sources are sent to aromatics extraction for recovery of high value aromatics. The original technology employed for aromatics separation was based upon the Soviet diethylene-glycol process. The method for aromatics extraction has since been converted to the tetraethylene glycol process licensed from Union Carbide. Each of the aromatics extraction trains has a capacity of 360,000 metric tons per year (10,000 BPD).

Aromatics extraction and recovery consists of two unit operations. The first processing step consists of liquid-liquid extraction which is then followed by distillation for the recovery of high-purity aromatic streams. The products from the aromatics extraction sections include benzene, toluene, ortho-, meta-, and

para-xylene, ethyl-benzene, and raffinates. The meta- and para-xylenes along with the ethyl benzene mixture are further processed in the xylene isomerization unit, with a capacity of 45,000 MT/Year (1250 BPD).

3.3.5 Maleic Anhydride Unit

The initial refinery design called for a portion of the benzene from the aromatics extraction block to be used for the production of 15,000 MT of maleic anhydride on an annual basis. In 1988/1989, the maleic anhydride unit was revamped to a process configuration which accepts butane as feedstock. The purpose of the conversion was to employ a more environmentally friendly feedstock and to divert valuable benzene to other uses.

3.3.6 Light Gasoline Isomerization

A light gasoline isomerization unit was put into service in 1978 for the conversion of normal pentane and hexane to the isoparaffinic form. The capacity of the unit is 150,000 MT/Year (4500 BPD). The unit was revamped in 1988, including the addition of a new reactor for the conversion of Raffinate from Extraction Plant 1 to n-hexane and specialty naphthas. Currently, n-hexanes in the straight run naphtha are not being sent to the isomerization unit. The catalyst technology is based upon precious metal catalysis.

3.3.7 Gas Oil Desulfurization Units

The middle distillate fractions from crude distillation are sent to one of two catalytic hydrotreating (desulfurization) units. GOKM-1, which has a capacity of 700,000 MT/Year (14,000 BPD), was put on-stream in 1971 for the purpose of treating streams for blending into jet fuels. GOKM-2, which has a capacity of 1.2 Million MT/Year (24,000 BPD), was started-up in 1979 for the purpose of desulfurizing diesel fuel streams and FCC gas oils. DKV is planning to add a third reactor to GOKM-2 consisting of a zeolite dewaxing step, which should facilitate the production of diesel fuels with better cold flow pour properties. The sulfur level of the middle distillate products is in the range of 0.15% to 0.5%. Each unit consists of two reactors in series which contain nickel-molybdenum and cobalt-molybdenum catalysts in series. The reactors are designed to operate at pressures up to 57 bar (835 psi).

3.3.8 Claus Sulfur Recovery P

The flow scheme of the DKV refinery includes the incorporation of two Claus sulfur plants for the recovery of elemental sulfur from hydrogen sulfide produced during hydrotreatment. Claus-2 was brought on-stream in 1980 and has a capacity of 10,000 MT/Year. Claus-3 was started up in 1984 and has a sulfur recovery capacity of 16,000 MT/Year. The purity of the sulfur recovered in the Claus process is 99.9% by weight.

3.3.9 Gas Recovery Plant

All gases generated during the distillation of crude oil are collected for transfer to the Central Gas Processing Unit. Fuel gas and liquified petroleum gas (LPG) are separated from any naphtha that would be entrained during the distillation process.

LPG is desulfurized with the use of a molecular sieve process, and then separated into propane, isobutane, and n-butane fractions.

3.3.10 Fluid Catalytic Cracking Unit

In order to achieve conversion of vacuum gas oil to lighter transportation fuels, a Fluid Catalytic Cracking Unit was constructed and brought on-stream in 1984. The unit is a UOP side-by-side design with a capacity of 1.0 Million MT/Year (20,000 BPD). The unit is equipped with a high efficiency regenerator, power recovery, and a Shell 3rd-stage separator. The addition of an electrostatic precipitator is currently under consideration. A review of FCC operating conditions and strategy will be presented in a subsequent section. The FCC complex is state-of-the-art with distributed process control and power recovery capabilities.

3.3.11 HF Alkylation Unit

The olefin-rich C4 hydrocarbon stream from the FCC unit is sent to the alkylation unit for production of high-octane gasoline blending component. The Alkylation unit is of UOP design and employs hydrogen fluoride as the catalyst. The capacity of the unit is 140,000 MT/Year (3500 BPD), and was brought on stream in 1988. Alkylate with a research octane number (RON) of 95 is produced for use as a high octane gasoline blending stock. The propylene from the FCC unit is purified and used for polymer-grade feedstock, rather than sending it to alkylation.

3.3.12 Visbreaking Unit

As a consequence of energy conservation efforts in Hungary, a fourth atmospheric distillation unit was shutdown. This unit was revamped in 1983 to a visbreaker unit based upon the Shell Soaker Technology licensed by Lummus Crest. The capacity of the unit is 740,000 MT/Year (15,000 BPD), with the primary products being low viscosity fuel oil and gas oils. The visbreaker is currently shut-down due to the increased usage of African crude oils and a turnaround on crude unit AVU-2.

3.3.13 Lube Oil Manufacturing Block

The DKV refinery flow scheme includes a lube oil processing section. Most of the lube oil process units were built in the 1960's based on designs for handling Soviet crude. The lube oil facility is now operated primarily with Hungarian crude, which is more paraffinic. The current lube processing configuration may have to be modified in the coming years to provide a more optimum flow scheme for handling the new crudes. The lube oil section consists of the following unit operations:

(1) Propane Deasphalter

The first process in the lube oil processing configuration is the propane deasphalting unit. The propane deasphalter is used to reject the asphaltic portion of the vacuum residual fraction of the crude oil. The deasphalted oil is subjected to further refining and is then available as a blending component for the production of high viscosity lube oil. The asphaltic fraction extracted in the deasphalter serves as the base material for bitumen production. The capacity of the propane deasphalter is 250,000 MT/Year.

(2) Selective Solvent Lube Oil Refining Unit

The light, medium, and heavy paraffin cuts from vacuum distillation as well as deasphalted oil are processed in this unit. Selective Solvent Refining involves the use of liquid-liquid extraction and a solvent to remove components that are gummy and have the tendency to oxidize. The primary products from this unit are raffinates with high viscosity indices. The capacity of the selective solvent refiner is 420,000 MT/Year. The extractions were previously accomplished with phenol until 1988, at which time the unit was revamped to the NMP process licensed by Texaco. Phenol is considered to exhibit harmful effects on both human health and the environment.

(3) Solvent Dewaxing Unit

The raffinate from the selective solvent refiner along with vacuum distillates are dewaxed using a combination of methyl ethyl ketone mixed with toluene. The crystallized slack waxes and petrolatum are separated from low pour point oils on cold vacuum drum filters. These are two solvent dewaxing units, designated MEK-1 and MEK-2, each with a capacity of 150,000 MT/Year.

(4) Lube Oil Hydrofinishing/Blending

Lube oil blending components are produced from the mild hydrogenation and redistillation of dewaxed raffinates. The annual capacity for hydrogenation, redistillation, and blending is 210,000 MT/Year.

3.3.14 Bitumen Unit

The asphaltic fraction recovered from the propane deasphalter is processed into various grades of asphalt at the bitumen unit. The process essentially consists of altering the asphalt properties via an oxidation step which is accomplished by air blowing. The capacity of the bitumen plant is 250,000 MT/Year.

3.3.15 Wax Production Unit

The waxy streams isolated after solvent dewaxing are sent to the paraffin factory for processing into various grades of waxes, including food grade. The unit operations available in this section include the following:

- (1) Redistillation
- (2) Solvent Deoiling
- (3) Sulfuric Acid treatment
- (4) Hydrogenation
- (5) Bleaching
- (6) Deodorization

3.4 Technical Review of Existing Process Technology

Much of the refining technology installed at the DKV refinery is consistent with conventional refining technology employed by companies around the world. The

atmospheric/vacuum distillation systems have been based upon Hungarian and Soviet design. Major developments in the field of crude oil distillation are in the area of column internal design. Distillation column internal advances are openly available through a number of equipment vendors who operate in a competitive environment. DKV has revamped several of its columns in the 1980's with advanced column internals. The naphtha fractionation unit is also based upon an in-house design.

The catalytic reforming reactors were built based upon Soviet design. However, the key component in the use of reforming technology is the catalyst which is employed. The author is very familiar with two of the bi-metallic reforming catalysts used by DKV, Engelhard E-603 and UOP R-62. Both of these catalysts were developed in the United States and represent state-of-the-art offerings by each company. Aromatics extraction technology is based upon the tetra-ethylene process developed by Union Carbide in the U.S.

Xylene isomerization and ortho-xylene recovery processes were developed in East Germany. The maleic anhydride plant was originally designed based upon Soviet technology, but was revamped to make use of process innovations developed by the Scientific Design Company. The isomerization unit was design based upon Soviet and Hungarian process know-how. The gas oil desulfurizers were based upon a Soviet design. However, the catalysts used for the two-stage hydrotreaters are typical examples of catalysts used for this type of application.

The Fluid Catalyst Cracking complex and the HF Alkylation units were both based upon UOP technology. Both of these processing units can be considered state-of-the-art, and in fact the two DKV units are newer than many units installed in the west. This indicates that these units employ all of the design advances and process innovations developed through the mid-1980's.

Much of the lube oil processing technology was purchased from the Soviet Union. However, these processes are primarily based upon physical separation, and the processes employed are typical of those used in lube oil operations.

Although time was not available for spending extended periods out in the plant, a tour of the key processing units was undertaken. The DKV refinery appears to be a modern, conventional petroleum refining operation. The equipment appears to be well maintained and insulation appears to be in good order. One area of opportunity for upgrading technology is in the field of distributed process control. Several of the process units have control systems based upon the Honeywell TDC 2000 and 3000 systems and the Yokogawa distributed control system. This equipment represents state-of-the-art in refinery process control equipment. DKV plans to upgrade process control capabilities as units are revamped and new units are built.

In order to complete a summary review of the technical and operating efficiency of the DKV refinery, data collection and analysis was limited to the three key processing areas highlighted below:

- (1) Crude distillation was chosen as representative of the energy efficiency characteristics of the refinery. Crude distillation contains a number of different types of heat generation and recovery equipment such as fired heaters, exchangers, and heat recovery units.

- (2) Catalytic reforming is one of the key conversion units in the refinery. This process converts relatively low quality, low octane naphtha into high octane gasoline blending components and high value aromatic streams such as benzene.
- (3) Fluid catalytic cracking is a key processing unit for the conversion of gas oil into lower boiling, higher value hydrocarbon fuels.

3.5 Energy Efficiency Review of Crude Distillation Units

Table 3.7 presents an analysis of the usage of steam and various fuels for each of the atmospheric/vacuum crude distillation complexes. The heating value used for the refinery fuel gas was 52 gigajoules per metric ton. This value was in the middle of the range specified by DKV personnel, but is somewhat higher than typical for fuel gas. All of the heating values used for the analysis are specified at the bottom of Table 3.7.

The consumption of energy at the three AV units based only on fuel usage and process steam is presented below:

<u>Crude Distillation Unit</u>	<u>Process Energy Consumption</u>	
	<u>Gigajoules/MT</u>	<u>BTU/Barrel</u>
AVU-1	0.77	106,369
AVU-2	0.67	91,587
AVU-3	0.66	90,973

Process heat consumption for crude distillation complexes would typically fall into the range of 100,000 to 120,000 BTU/BBL. Crude unit energy usage is dependent upon the side stream processing configuration, the degree of fractionation in the vacuum tower, column internal design, and heat recovery schemes. The energy consumption numbers reported for the three DKV units appear to be very typical compared to those reported by refiners in the west. This conclusion should attest to the fact that DKV personnel have made use of conventional energy conservation methods and up-to-date processing techniques, when capital has been available to do so.

As stated in the introduction section, it is relatively rare for a refinery of this size to have three catalytic reformers included in the processing scheme. Although this scheme does not necessarily represent the most efficient use of previously deployed capital, it offers interesting possibilities for overall optimization.

The current configuration of the reformer complex is outlined in Table 3.8. Light naphtha with a boiling range of 70-135°C (C6-C7) is directed to the #1 reformer, REF-1. A medium naphtha stream with a boiling range of 100-155°C (C7-C8) is fed to the #2 reformer, REF-2. A heavy naphtha stream with a boiling range of 100-180°C (C8-C9) is fed to the #3 reformer. There is considerable overlap among the feedstocks to the three units, which is designed to maximize toluene production.

11

Reforming units #1 and #2 are operated primarily for the production of feedstock for the aromatics extraction block. The molecules contained in the feeds to these two units are precursors for the production of C6 (benzene), C7 (xylenes), and C8 (toluene) aromatics. Reforming unit #3 is operated for the production of high octane gasoline blending components from the heavy naphtha feed.

Key operating conditions for the reformer complex are summarized in Table 3.9. Included in this table are the conditions for the Continuous Catalyst Regeneration (CCR) reformer which is under construction. The operation of the CCR will have a significant impact on the future operating strategy of the reforming complex.

3.6 Operating Efficiency of the Catalytic Reformer Complex

Based on a conventional definition of reformer feedstock quality of N + 2A, the respective feeds to the three units have the following quality:

	<u>N + 2A</u>
Unit #1 -	40.3
Unit #2 -	51.4
Unit #3 -	57.2

The poorest quality feed (40.3) is being fed to the lowest pressure unit (#1). This practice is consistent with conventional strategy for optimization of multiple reformers. Based on annual yield numbers presented in Table 3.10, C5+ reformat and hydrogen yield are presented below:

<u>Reforming Unit</u>	<u>C5+ Reformate (Wt%)</u>	<u>Hydrogen Yield (Wt% on Feed)</u>
REF-1	79-80%	1.3*
REF-2	82-83%	1.7*
REF-3	82-83%	1.5*

*As 100% hydrogen

The C5+ reformat yields for reformer #1 and #2 seem appropriate, but the yield of reformat for unit #3 appears to be somewhat high. The weight % hydrogen yields as reported could not be converted into actual production of hydrogen per barrel of feed since no hydrogen purity values were provided for these streams.

The amount of fuel energy and power consumed in each of the three catalytic reformers is presented below as calculated from the DKV material balance data:

<u>Reforming</u>	<u>REF-1</u>	<u>REF-2</u>	<u>REF-3</u>
Fuel Consumption, MBTU/BBL	203.7	208.7	214.7
Power Consumption, MBTU/BBL	12.2	17.1	19.3
Total Energy Consumption, MBTU/BBL	215.9	225.8	234.0

The levels of fuel energy and electric power consumption are very typical of catalytic reforming units. The reformers are operated with relatively low hydrogen-to-hydrocarbon ratios, which is very favorable for minimizing power consumption for compressor operation. In addition to minimizing gas circulation, reformer optimization is also favored by minimizing pressure consistent with reasonable cycle length.

3.7 Current Operating Strategy of the Fluid Catalytic Cracking Unit

Table 3.11 contains a description of the operating conditions of the fluid catalytic cracking unit (FCC). At the time that we surveyed the unit, the riser outlet temperature was being maintained at 530°C (986°F). The unit is being operated for maximum conversion of feedstock, up to the limits of the available gas compression capacity. The regenerator is typically operated with a dense bed temperature of 680°C (1256°F). The flue gas temperature runs approximately 25-30°C (45-54°F) higher than the dense bed, indicating a carbon monoxide (CO) afterburn condition. In an attempt to control this situation, a combustion promoter is added to allow the unit to operate in essentially a full CO combustion mode. The establishment of a full burn condition has not eliminated the temperature differential, so the current status of air distribution into the catalyst bed should be investigated. The level of carbon on regenerated catalyst is maintained in the range of 0.04 to 0.1 weight%, which is typical for this type of operation. However, previous FCC unit optimization studies generally show that economic optimization often occurs with a carbon-on-catalyst level in the range of 0.1 to 0.15 weight%.

The selection of a cracking catalyst is one of the most critical operating parameters. Personnel at DKV have chosen Precision-60R which is manufactured by Engelhard.

Precision-60R contains a chemically dealuminated zeolite and is formulated to favor the production of relatively high FCC gasoline octane. As with any FCC catalyst of this type, higher gasoline octane comes at the expense of gasoline yield, which is reduced proportionately. With Precision-60R, the loss in gasoline yield results in the production of additional C3 and C4 hydrocarbons, especially olefins which can be used as alkylation feedstock. It was reported that the use of ZSM-5 was attempted but was discontinued because of a shortage of isobutane for alkylation of additional olefins. DKV may want to consider having Engelhard shift the catalyst composition to produce more isobutane relative to olefins. Some amount of ZSM-5 could then be added back in order to maximize the yield of alkylate, if that is an objective.

3.8 Operating Efficiency of the Fluid Catalytic Cracker

Table 3.12 contains a set of annual yields from the catalytic cracking units for 1990. Table 3.13 presents typical values and ranges for the various FCC products. The yields of ethane

and lighter gas and propane/propylene appear very typical. The yield of isobutane to C4 olefins appears relatively low but this should be expected based on the properties of the cracking catalyst. The yield and octane of the FCC gasoline appears reasonable for this catalyst, and good bottoms cracking is indicated by the cycle oil-to-decanted oil ratio. FCC coke yields for gas oil cracking are generally in the range of 4.5 wt% to 5.5 wt%. The annual calculated coke yield of 4.71% by weight represents an average value.

The reported amount of catalyst lost from the unit equals 15% of the fresh catalyst addition rate. Catalyst loss rates which are in the range of 20% to 30% of addition rates are considered typical.

3.9 Future Refinery Processing Considerations

3.9.1 Integration of New CCR Reformer Into Processing Scheme

A UOP design continuous catalyst reformer (CCR) is currently under construction and is slated for start-up in late 1991, with a capacity of 600 MTA (15,000 BPD). The CCR is being added to increase the production of high octane blending components for the production of low-lead and unleaded gasolines. Once the CCR is on-line, one of the semi-regenerative units will be taken out of service as a conventional reformer. DKV is currently studying plans for the conversion of the idled reformer to a trans-alkylation unit for the production of benzene from toluene. Benzene is one of the more valuable products in the DKV product slate.

The feedstock to the CCR will be a blend of light, medium, and heavy naphtha cuts from the naphtha fractionator. The proportion of each naphtha cut expected in the final blend is still to be finalized. The CCR will operate at a final pressure of approximately 7 bars (100 psi). This level of operating pressure would represent the latest design innovations and strategy for reformer optimization. The operation of a CCR will result in better conversion to aromatics, reduce the relative amount of hydrocracking, and increase significantly the amount of hydrogen produced. In order to accommodate the increased demand for naphtha feed to the reforming complex, two of the crude distillation units will have to be revamped.

It is suggested that DKV study the possibility of putting most of the light/medium naphtha to the continuous reformer, and feeding the heavier naphtha fractions to the semi-regen units. This scheme may provide the highest total yield of aromatics for chemical usage via extraction. Also, the yield of reformat diverted to gasoline blending will be higher, with a lower aromatics content, which is favorable for future gasoline reformulation considerations. A detailed series of scheme studies with a catalytic reforming process simulation model would be required to properly analyze this proposed processing scheme.

3.9.2 Impact of New FCC Hydrotreater on Unit Operation

A new hydrotreater is being planned for construction and start-up in 1992. The DESUS technology will be used for the desulfurization of gas oil feedstock to the FCCU. The DESUS process is East German technology which combines hydrotreatment with a mild hydrocracking (MHC) action in the second reactor. It is anticipated that up to 30% conversion of the feed can be achieved in the MHC step. The design operating pressure is 80 bars (1180 psi) which is higher than typical for an FCC feed hydrotreater.

The capacity of the FCC feed hydrotreater will be 1.5 million MTA. It is anticipated that the sulfur content of the FCC feed will be lowered to less than 0.2% to 0.5% by weight, in addition to improving the cold flow properties of the FCC cycle oils. To handle the increased flow of hydrogen sulfide from the gas oil desulfurizer, Claus Unit #4 will add 30,000 MTA of sulfur recovery capacity.

The refinery requirement for hydrogen will increase considerably once the FCC hydrotreater is brought on-stream. The consumption of hydrogen for treating the FCC feed will approach 16,000 MTA which equals 1% of the total feed weight or 600 SCF per barrel. It is anticipated that the increased demand for hydrogen will be met by increased supply from the new CCR reformer.

3.9.3 Analysis of Future Motor Fuel Processing Requirements/Plans

DKV personnel anticipate that additional investment will be required to upgrade facilities for the production of gasolines which meet Western-European standards. In order to meet the phase-down of lead in gasoline, the use of higher-octane gasoline components will have to be increased considerably.

Preliminary technical and economic studies have been completed for advanced processing schemes which incorporate conventional thinking regarding the production of high octane gasoline blending components. The following options were discussed by DKV personnel:

- (1) Addition of a unit for the production of methyl tertiary butyl ether (MTBE) from isobutylene contained in an FCC C4 stream. The raffinate from the MTBE would then be sent to the alkylation unit. It is anticipated that additional FCC capacity would be required to produce the level of isobutylene needed to economically justify the construction of an MTBE unit.
- (2) Addition of a unit for the production of tertiary amyl methyl ether (TAME) from isoamylene in the FCC C5 stream. It is possible that with an addition to alkylation capacity, the C5 raffinate from the TAME unit can also be alkylated.
- (3) Selective hydrogenation would probably be required for treatment of feed to the MTBE unit. Selective hydrogenation results in the conversion of di-olefins to mono-olefins, and isomerization of butene-1 to butene-2. Isomerization to butene-2 boosts the octane of the alkylate which is eventually produced from the C4 raffinate.
- (4) DKV has raised the possibility of reforming the heart-cut from FCC gasoline as a possible consideration for the distant future. Although the mid-cut of FCC gasoline contains the lowest octane quality, the yield loss from reforming this material is significant.
- (5) If additional FCC capacity is added through either revamp or the construction of a second unit, additional isobutane would be required as feedstock for the alkylation of FCC C4 olefins. DKV has identified isomerization of n-butane as a practical source of isobutane.

- (6) DKV has considered the possibility of revamping one of the existing semi-regenerative reformers to incorporate continuous regeneration of a portion of the catalyst. IFP has proposed that this be accomplished through the addition of a last reactor which has the capability for catalyst addition and removal.
- (7) Isomerization of certain light reformat fractions may also be considered in the future.

No additional hydrotreating capacity is required for reducing sulfur levels in gas oils below 0.2% wt. Additional capacity may be required only if sulfur levels have to be reduced to less than 0.05% wt. and as is the trend in the U.S., stringent restrictions on aromatics levels are also introduced.

The processing options being considered are the same as those being considered by refining companies throughout Western Europe and the United States.

Currently, the two highest grades of gasoline (95 and 98 RON) contain 40% or more aromatics by weight. If Western Europe imposes aromatics standards similar to those mandated in the U.S., DKV will need to modify the operation of the existing gasoline production processes along with installation of many of the additional processes outlined in this section.

In 1990, approximately 60,000 MT of unleaded gasoline was produced, which represents approximately 4% of the 1.5 Million MT of gasoline produced. For 1991, the amount of unleaded gasoline production is expected to increase to 100,000 MT, which represents 6.7% of the gasoline pool.

A number of petrochemical applications are being considered in combination with benzene, toluene, and FCC olefin streams. These opportunities, which are listed below, highlight the synergies available when a petroleum refinery is adjacent to a petrochemical complex.

- (1) Conversion of benzene to toluene via transalkylation/disproportionation.
- (2) Alkylation of benzene with FCC ethylene to form ethyl benzene for conversion to styrene.
- (3) Alkylation of benzene with FCC propylene to form styrene and propylene oxide.
- (4) Production of acrylic acid and esters from propylene.
- (5) Recovery and purification of para-xylene.

3.9.4 Analysis of Future Residual Conversion Requirements/Plans

Currently, the residual bottoms from vacuum distillation is processed by one of two methods. The first processing option involves propane deasphalting followed by visbreaking, while the second option involves sending the VTB directly to asphalt production. The primary products from either of these schemes are unconverted heavy hydrocarbons which serve as either heavy fuels or asphalt. There is minimal conversion of the undesirable portion of the crude to lighter materials such as transportation fuels.

For most refineries, conversion of the heaviest fractions of the crude barrel to lighter products can have a tremendous impact on plant profitability. In addition to the economic incentive, the demand for heavy (usually high-sulfur) fuel oils is on the decline. Along with the decline in demand, environmental regulations will ultimately mandate that residual fuels contain much lower sulfur contents than is currently allowed. DKV personnel feel that there will be pressure to reduce fuel oil sulfur from 2 wt% to 1 wt%. Also, Hungary does not wish to be overly dependent on high quality imported crude oils.

DKV management see the obvious advantages and incentives in the conversion of the bottom of the crude barrel. The processing schemes under study were developed while the supply of Soviet export crude was relatively plentiful. Since this is no longer the case, DKV personnel recognize that any future study will have to take into consideration the anticipated quality of crude that the refinery is expected to run.

Three potential processing schemes were discussed with us and are presented below:

- (1) The first scheme involves the use of Residual Oil Supercritical Extraction (ROSE) followed by Residual Oil Cracking. The implementation of resid cracking would either take the form of a revamp of the existing FCC unit or the construction of a new FCC unit specifically designed for heavy oil cracking.
- (2) The second scheme involves the use of delayed coking to remove the heavy carbonaceous material followed by hydrocracking of the coker products.
- (3) The third scheme involves the use of ROSE followed by hydrocracking. The type of hydrocracking identified for this application would be of the ebullated bed type, such as H-Oil.

No decision has been made regarding the selection of a heavy oil conversion scheme because of uncertainties related to crude oil supply and the reorganization of the Hungarian Oil Trust. The use of delayed coking will probably receive no further consideration since there appears to be minimal demand for this product in Hungary. If a processing scheme is selected which involves the addition of substantial amounts of hydrogen, additional hydrogen generation facilities will be required.

Once the range of crude supply options is identified, a number of additional residual conversion technologies should be considered in future scheme studies. These include:

- Flexicoking which is a fluid coking process that has an additional reactor for gasification of the coke to synthesis gas. The net production of coke from this process is less than 1% of the feedstock charged to the fluid coker. Since DKV is integrated with a petrochemical complex, there could be some opportunity for profitable use of a synthesis gas.
- The combination of H-Oil or another ebullated bed hydrocracking process followed by a ROSE unit.

- The combination of fixed bed residual oil desulfurization followed by residual oil catalytic cracking.
- The combination of ebullated bed residual hydrocracking such as H-Oil with residual oil catalytic cracking.
- A variation of the visbreaking process which involves the potential addition of hydrogen and possibly a dispersed catalyst.
- A catalytic hydrocracking process which involves the addition of a dispersed phase catalyst to the oil prior to introduction to the reaction section. Variations of this type of process are just entering the marketplace and include the HDH process developed by the Venezuelans and Microcat-RC developed by Exxon.

DKV personnel were presented with information developed by M. W. Kellogg detailing costs and projected economic benefits for many of the schemes proposed above. As was stated earlier, conversion of the bottom of the barrel can have a tremendous impact on plant profitability. The impact can be either positive or negative. The capital investment per barrel of charge can be very large. The conversion scheme chosen by most US refineries have included delayed coking, and where a market for moderate to high sulfur coke exists, these schemes will generally show the best results. Some of the US refineries who have chosen schemes with more expensive desulfurization are only achieving very low returns. For those with cokers, there is always the concern that the market for high sulfur coke may disappear. To sum up, bottom processing investments involve difficult choices requiring a thorough analysis of crude and product market in addition to cost out alternative processing schemes. For some refiners buying higher priced low sulfur low bottoms crude represents the best scheme.

3.10 Conclusions and Recommendations

3.10.1 Review of Current Processing Scheme

The configuration of the DKV refinery contains a very modern, very conventional series of processing steps. As discussed previously, the refinery is lacking in capacity for conversion of residual materials into lighter transportation fuels. However, there is a section for processing a portion of the vacuum gas oil into lube oils and waxes, which upgrades the entire product mix of the refinery. DKV has outlined a series of steps for upgrading gasoline octane quality and residual conversion capabilities. The addition of the CCR reformer and the DESUS hydrotreating/mild hydrocracking unit should provide additional flexibility and profitability for operation of the refinery.

3.10.2 Review of Energy and Operating Efficiency

Based on analysis of operating data from the crude units, catalytic reformers, and FCC unit, energy consumption for these processes is in-line with typical refining industry levels. Based on an analysis of limited data, it appears that the operating efficiency of the catalytic reformers and the FCC units is typical when compared with similar units in other refineries. With increased technical service and process optimization activity at the refinery, it should be possible to further increase the profitability of key processing units.

3.10.3 Feedstock and Process Optimization

Entering the European refining market presents DKV with both threats and opportunities to its profitability. To achieve a favorable profit situation the refinery needs to:

- value and select the slate of crudes for maximum profit
- produce and market the slate of products for maximum profits
- given crude and product slate, optimize individual unit operations

These three items are, of course, interrelated and can not be dealt with separately. Moreover, in the longer term new process facilities become an additional route to maximizing profits as they can enable the refinery to run lower quality crudes and/or produce higher valued products.

3.10.4 Crude Supply Strategy

In the past two years, DKV has seen a considerable shift in crude supply because of the diminishing availability of Soviet crude. In 1989, Soviet crude accounted for 78.9% of DKV's crude supply (Table 3.1) with domestic crude accounting for the balance. No crudes were purchased on the international market. One year later, the Soviet crude share had dropped to 66.4% and international crudes, mostly high quality African ones, were 15.8% of total crude supply.

The African crudes purchased are premium crudes and are at the top of the price scale on the world market. The principal attributes that give these crudes their high price are low sulfur content and a small fraction of material boiling in the residual fuel range (See Table 3.2). Figure 3.3 show a plot of the price differential between the premium light low sulfur crudes (such as the African crudes frequently also referred to as light sweet) and the Middle East light sour (such as Saudi Lt. which although called light, has twice the amount of residual boiling range material as the African crudes, see Table 3.2).

As shown in Figure 3.3, the sweet-sour crude price differential has been as low as .60\$/bbl and as high as 5.40 \$/bbl. The light sweet crudes have the greater price volatility - when crude was priced at 18 \$/bbl. the price premium for light sweet has been about 10% of the crude price, but when crude dropped to 10-13 \$/bbl. the premium was as low as 5% and when crude prices were 30-40 \$/bbl. as in the case of the single point plotted in August 1991 (the Iraq invasion of Kuwait) the price premium was 17%.

The critical question the refiner faces in choosing a higher priced crude is "Does the saving in operating costs plus the added revenue from an improved product slate more than offset the higher price of crude?" The answer to this question can be quite difficult for different refiners. A refiner with more existing upgrading facilities will see less product improvement using a higher quality crude, a refiner may not have sufficient market opportunities to sell all the higher quality products that could be made with a higher quality crude, and some refiners are in a better position to market lower quality residual fuels, petroleum cokes, asphalts, etc. The refinery which does not optimize its choice of crude given the opportunities and limits of both products market, process configuration and the ability to change operating conditions including catalyst can easily lose 50 \$/bbl and that margin penalty can grow considerably higher when crude prices rise rapidly.

Given the declining availability of Soviet crude, DKV will be meeting their feedstock needs with increasing purchases of international crude. Making the best choices on these feedstock acquisitions may well be one of the most important factors affecting the future profit picture for the refinery. This will require the DKV refinery people to determine the relative values for different types of crude given their equipment and market constraints and then for the oil traders (currently within OKGT) to acquire individual crudes of the types indicated by DKV at the best price and contract terms.

In the past when DKV ran a nearly constant crude slate of Soviet and domestic crude, the refinery did not need to determine the relative value of the many potential crudes available for purchase on the international market. Doing crude valuation requires three things:

- Methodology (valuation techniques and people experienced in using those techniques)
- Data (crude assays, process unit data - feeds, operating conditions, catalyst)
- Tools (crude assay program, unit process correlations, refinery optimization model)

DKV has a decent starting point for developing a crude valuation capability. They have been using LP refinery optimization models to analyze operations and facility investments and they have a very capable economics and process engineering staff with the ability to develop the tools, apply and gain experience in crude valuation methodology.

DKV is a difficult refinery for doing crude evaluation because:

- It is a complex refinery
- It is a multi-train refinery - crudes can be segregated through different processing unit chains
- It has both a lube plant and petrochemical facilities
- The extent of change in production of higher valued products which could be successfully marketed is not well defined.

To carry out a crude evaluation DKV needs to acquire and improve both data and tools. They need a data base of international crude assays done on a consistent basis and an assay program which will calculate AVU yields and properties for user specified cut points which match refining operations. The assay program should also synthesize distillation of a user defined crude blend. Process unit correlations for the major refinery units are needed to calculate the yields for intermediate streams from new crudes or crude blends. In addition to crude valuation, the process unit correlations are needed for normal process optimization studies. Finally, when the refinery modeling system grows to include data bases, correlations, assay program, it may outgrow the capabilities of the current modeling software and LP matrix generation tools. Some of the commercially available refinery modeling systems or matrix generation systems should be considered. Information of some of these system has been provided to DKV.

3.10.5 Process Unit Optimization

In our discussions with DKV personnel, we learned that the engineers do not have access to process models on-site in areas such as catalytic reforming, fluid catalytic cracking, and hydrotreating. Although, a number of petroleum refining

process models are available at the technical institute, it appears that these empirical models are based primarily on data from the open literature. Most of the good process models with which we are familiar were developed from extensive databases of pilot plant and commercial operation. Although the Hungarian process models have been updated to reflect actual commercial experience, the scope of change in feedstock quality and operating conditions were probably too narrow to allow accurate predictions outside of narrow range.

In addition to the lack of good process models, DKV personnel also appear to lack access to ongoing technical support in the form of catalyst and feedstock evaluation services. As indicated in a previous section, no operating parameter has more impact upon the success of catalytic refining processes than the selection of a catalyst. This type of technical assistance requires a number of tools including bench-scale and pilot plant evaluation facilities.

Finally, in order to facilitate the completion of scheme studies for refinery additions in areas such as residual conversion, it is necessary to have access to accurate technical information regarding the performance of the various processes under consideration. This requires open communication with the licensing companies regarding the capabilities of their respective technologies. The licensing companies often maintain techniques for evaluating the performance of each process and predicting yields based on feedstock differences. Access to this type of information is absolutely critical when evaluating new processing possibilities.

In conclusion, the US could provide technical assistance to DKV in the form of commercial process models in the areas of crude distillation, catalytic reforming, fluid catalytic cracking, and hydrotreating, along with training in the use of these models. In addition, it also would be useful to set up a program to transfer technical licensing information from the west to our friends in Hungary to provide them with better tools for performing future scheme studies.

3.10.6 Processing Operations and Strategies - Summary Recommendations

The DKV refinery contains modern, conventional processing facilities and solid infrastructure for the refining of petroleum. The technical personnel that we met were very knowledgeable about petroleum refining and about technological trends in the refining industry. DKV personnel have employed conventional methods of energy conservation where practical, so only minimal impact can be made in this area.

The areas in which the US could provide useful additional assistance to DKV are the following:

- (1) **Crude Oil Valuation** - provide DKV with additional consultation and tools to develop the ability to determine the "relative" values of available crudes based upon current and anticipated future processing configurations and product market demands.

- (2) **Process Optimization** - assist DKV in obtaining the tools necessary to facilitate economic optimization of existing process operations. Appropriate tools would include:
- Commercially available process simulation models
 - Process monitoring and data collection devices.
 - Training in various areas of model tuning, process simulation, and process optimization.
- (3) **Access To Capital** - work with DKV to locate sources of funds with which to finance future projects in areas such as reformulated gasoline and residual conversion. The Hungarians have already proceeded with a number of joint venture possibilities, which indicates their preference for this type of arrangement.

Table 3.1

DKV Refinery

Crude Oil Slate - 1990

	<u>Tons</u>	<u>Weight %</u>
Soviet Crude	4,714,528	66.38%
Algyoi Crude (Hungary)	1,263,880	17.79%
Szanki Crude (Hungary)	83,929	1.18%
Alfoldi/Vasut Crude (Hungary)	128,980	1.81%
Sirtica Crude (Libya)	150,471	2.12%
Brega Crude (Libya)	155,711	2.19%
Sahara Blend Crude (Algeria)	344,297	4.85%
Bonny Light Crude (Nigeria)	133,190	1.88%
Iraqi Crude	128,030	1.80%
	<u>7,103,106</u>	<u>100.00%</u>

Table 3.2**Comparison of Soviet and African Crudes****Crude Characteristics**

<u>Crude</u>	<u>Soviet Export</u>	<u>Brega</u>	<u>Sirtica</u>	<u>Bonny Light</u>
API Gravity	32.5	40.0	41.3	34.7
Specific Gravity: g/cc	0.863	0.825	0.819	—
Sulfur: Wt%	1.38	0.23	0.45	0.16
Viscosity: Cst @ 20°C	11.5	—	—	—
Viscosity: SUV, Sec. @ 77°F	—	42.1	38.3	—

Residue (Atmospheric)

Range: 350°C+				
Yield: Vol% Crude	44.9%	33.75%	27.17%	30.87%
Gravity: g/cc	0.952	0.921	0.945	0.943
Sulfur: Wt%	2.20	0.47	1.10	0.30%
Conradson Carbon: Wt%	5.1	4.61	6.38	3.88
Vanadium: PPM	60	2.4	12	1.9
Nickel: PPM	20	9.4	28	15

Residue (Vacuum)

Range: 545°C+				
Yield: Vol% Crude	16.99%	8.71%	10.91%	5.36%
Gravity: g/cc	1.0	0.998	0.997	1.011
Sulfur: Wt%	2.70	0.73	1.71	0.42
Conradson Carbon: Wt%	12.5	15.7	16.0	15.4

Table 3.3
1990 Material Balance
Crude Distillation Unit AVU-1

<u>Feed</u>	<u>Tons</u>	<u>WT%</u>	
Soviet Crude	21,620	1.77%	
Hungarian Crude	975,697	80.09%	
Condensate Liquids	237,301	18.12%	
Heavy Gasoline	201	0.02%	
Other	46	—	
	<hr/>		
	1,218,832	100.0%	
<u>Product Streams</u>			
Gas	200	0.02%	
Flare Gas	200	0.02%	
Stabilizer Gas	916	0.08%	
Liquid Gas	8,413	0.69%	
Light Gasoline	102,337	8.42%	
Medium Gasoline	253,190	20.78%	
Heavy Gasoline	12,569	1.03%	
Test Gasoline	49,061	4.03%	
White Gasoline	13,379	1.10%	
Jet A-1	1,884	0.15%	
Distillate Oil	454,829	37.33%	
Lube Oil Streams	210,976	25.79%	
Resid	103,247	8.47%	
		<hr/>	
		99.43%	
		0.57%	Loss
		<hr/>	
		100.00%	Total

Table 3.4

1990 Material Balance

Crude Distillation Unit AVU-2

<u>Feed</u>	<u>Tons</u>	<u>WT%</u>	
Soviet Crude	1,713,172	65.66%	
Hungarian Crude	795,580	30.5%	
Condensate Liquids	42,231	1.62%	
	<hr/>	<hr/>	
	2,608,985	100.00%	
 <u>Cuts</u>			
Fuel Gas	715	0.03%	
Stabilizer Gas	2,310	0.09%	
Liquid Gas	33,205	1.27%	
Light Gasoline	126,706	4.86%	
Medium Gasoline	104,002	3.99%	
Heavy Gasoline	296,589	11.37%	
Test Gasoline	4,913	0.19%	
Petroleum	94,145	3.61%	
Jet A-1	138,252	5.30%	
R. T. Petroleum	—	0.0%	
Light Gas Oil	86,016	3.30%	
Heavy Gas Oil	83,037	3.18%	
Vacuum Gas Oil	190,067	7.29%	
Gas Oil Alt.	298,562	11.44%	
Lube Oil Streams	660,026	25.30%	
Resid	474,873	18.20%	
	<hr/>	<hr/>	
	2,593,418	99.40%	
	15,567	0.60%	Loss
		<hr/>	
		100.00%	Total

76

Table 3.5
1990 Material Balance
Crude Distillation Unit AVU-3

<u>Crude Oil Feed</u>	<u>Tons</u>	<u>Wt%</u>
Soviet Crude	2,590,065	72.53%
Hungarian Crude	60,179	1.68%
Sirtica Crude	150,471	4.21%
Brega Crude	155,711	4.36%
Sahara Blend Crude	344,297	9.64%
Bonny Light Crude	133,190	3.73%
Iraqi Crude	128,030	3.58%
Condensate Liquids	9,454	0.27%
	<hr/> 3,571,397	<hr/> 100.00%
<u>Product Streams</u>		
Fuel Gas	1,275	0.04%
Stabilizer Gas	4,090	0.11%
Liquid Gas	48,234	1.35%
Light Gasoline	251,663	7.05%
Medium Gasoline	160,621	4.50%
Heavy Gasoline	319,257	8.94%
Jet Fuel A-1	265,307	7.43%
Gas Oils	1,033,136	28.92%
Lube Oil Streams	626,652	17.54%
Residual Oil	838,467	23.48%
Vesztseg	22,695	0.64%
	<hr/> 3,571,397	<hr/> 100.00%

27

Table 3.6
Analysis of Crude Distillation Complex
Modes of Operation

<u>Unit</u>	<u>Mode</u>	<u>Primary Feedstock</u>	<u>Unit-Days</u>
AVU-1	1	Soviet Crude	5.6
AVU-1	60	Hungarian Crude	293.4
AVU-2	1	Soviet Crude	285.8
AVU-2	60	Hungarian Crude	72.3
AVU-3	1	Soviet Crude	266.1
AVU-3	59	Iraqi Crude	12.0
AVU-3	60	Hungarian Crude	6.5
AVU-3	73	Sirtica Crude	15.0
AVU-3	75	Brega Crude	13.5
AVU-3	77	Sahara Blend Crude	40.0
AVU-3	79	Bonny Light Crude	11.8

Table 3.7

Analysis Of Crude Distillation Complex

Energy Usage

Unit	<u>AVU-1</u>	<u>AVU-2</u>	<u>AVU-3</u>
Feed: MTA	1,218,832	2,608,925	3,571,397
Feed: BBL/Year	8,934,038	19,123,860	26,178,340
<u>Natural Gas Usage</u>⁽¹⁾			
Usage, MTA	2,578	3,119	6,331
Heating Value, GJ	110,854	134,117	272,233
Heating Value, BTU	105 x 10⁹	127 x 10⁹	258 x 10⁹
<u>Fuel Gas Usage</u>⁽²⁾			
Usage, MTA	11,802	13,291	28,746
Heating Value, GJ	625,506	701,764	1,517,790
Heating Value, BTU	593 x 10⁹	665 x 10⁹	1,439 x 10⁹
<u>Fuel Oil Usage</u>⁽³⁾			
Usage, MTA	3,603	21,685	17,507
Heating Value, GJ	147,723	889,085	717,787
Heating Value, BTU	148 x 10⁹	889 x 10⁹	718 x 10⁹
<u>Process Steam Usage</u>⁽⁴⁾			
Usage, MTA	56,497	107,767	133,136
Heating Value, GJ	172,316	328,690	406,065
Heating Value, BTU	162 x 10⁹	312 x 10⁹	385 x 10⁹
<u>Total Energy Usage</u>			
Gigajoules/Ton	0.866	0.787	0.816
BTU/BBL	112,930	104,260	107,070

(1) Heating Value of 43 Gigajoules/Ton
 (2) Average Heating Value of 53 Gigajoules/Ton
 (3) Heating Value of 41 Gigajoules/Ton
 (4) Average Extracted Heating Value of 3.05 GJ/Ton

29

Table 3.8
Catalytic Reforming Complex
Feedstock and Product Properties

Unit	<u>REF-1</u>	<u>REF-2</u>	<u>REF-3</u>
<u>Feedstock Quality:</u>	Light Naphtha	Medium Naphtha	Heavy Naphtha
Boiling Range: °C	70 - 110/115	105 - 145	80 - 180
Boiling Range: °F	158 - 275	212 - 311	212 - 356
Composition:			
Paraffins, Wt%	64.8%	59.89%	56.74%
Olefins, Wt%	0.0%	0.27%	0.0%
Naphthenes, Wt%	30.12%	28.33%	29.30%
Aromatics, Wt%	5.08%	11.51%	13.96%
Specific Gravity	0.705	0.740	0.75
<u>Product Quality:</u>			
Composition:			
Paraffins, Wt%	64.7%	59.89%	56.34%
Olefins, Wt%	0.1%	0.27%	0.4%
Naphthenes, Wt%	2.46%	1.18%	2.47%
Aromatics, Wt%	42.92%	65.11%	61.71%

30

Table 3.9
Catalytic Reforming Complex
Operating Conditions

Unit	REF-1	REF-2	REF-3	REF-4⁽¹⁾
Capacity: MT/Day BBL/Day	1,050	1,050	1,050	1,800
Design	Semi-Regen	Semi-Regen	Semi-Regen	CCR
Catalyst	Akzo CK-522	Engelhard E-603	UOP R-62	UOP R-34
Maximum Severity: RON	84	96	96	100
Operating Severity: RON	80	92	95	(1)
Outlet Pressure: Final Reactor, Bars Final Reactor, PSI	19-21 295	22 325	25 370	6.8 100
Space Velocity: LHSV	1.8	1.8	1.6	1.5
Hydrogen-To-Hydrocarbon: Mole Ratio	3.5	4.5	4.0 - 5.0	3.2
Objective:	Aromatics	Aromatics	Gasoline	Gasoline

⁽¹⁾ Design conditions. Unit currently under construction.

Table 3.10

Catalytic Reforming Units

Reformats and Hydrogen Yields

Reforming Unit #1

<u>Product</u>	<u>Tons</u>	<u>Weight %</u>
Aromatics Extraction #1 Feed	229,998	60.82
Aromatics Extraction #2 Feed	56,095	14.83
Hydrogen	19,912	5.27
Othe.	<u>72,127</u>	<u>19.08</u>
Total Of All Parts	378,132	100.00%

Reforming Unit #2

<u>Product</u>	<u>Tons</u>	<u>Weight %</u>
Aromatics Extraction #1 Feed	34,382	9.80
Aromatics Extraction #2 Feed	226,646	64.60
Hydrogen	11,231	3.20
Low Sulfur Specialty Naphtha	3,410	0.97
Reformat - 92	3,320	0.95
Reformat - 94	19,736	5.63
Other	<u>52,112</u>	<u>14.85</u>
Total Of All Parts	350,837	100.00%

Reforming Unit #3

<u>Product</u>	<u>Tons</u>	<u>Weight %</u>
Aromatics Extraction #2 Feed	37,312	10.85
Hydrogen	20,737	6.03
Low Sulfur Specialty Naphtha	4,126	1.20
Reformat - 92	11,275	3.28
Reformat - 94	214,635	62.40
Reformat	21,933	6.38
Other	<u>33,960</u>	<u>9.86</u>
Total Of All Parts	343,978	100.00%

230

Table 3.11

Fluid Catalytic Cracking

Unit Operating Conditions

Unit Design:	UOP Side-By-Side	
Capacity:	MT/Day	3,450
	3BL/Day	24,000
Regenerator Temperatures:		
	Dense Bed	680°C/1256°F
	Flue Gas	705°C/1300°F
Catalyst-To-Oil Ratio:	6.5 - 8.0	
Feed Preheat Temperature:	530°C/986°F	
Flue Gas Analysis: Mole %		
	Carbon Dioxide	16.9
	Carbon Monoxide	0.0 ⁽¹⁾
	Oxygen	2.0 - 3.0
Catalyst Factors:		
Carbon On Regenerated Catalyst, Wt%	0.04 - 0.1 Wt%	
Catalyst Type	Engelhard Precision-60R	
Nickel On Catalyst, PPM	240	
Vanadium On Catalyst, PPM	650	
Fresh Addition Rate: MT/DAY	1.4	
Catalyst Losses: MT/DAY	0.2	

⁽¹⁾ **Combustion Promoter Is Used**

77

Table 3.12

1990 Material Balance

DKV - Catalytic Cracker

<u>Feedstocks</u>	<u>Metric Tons</u>	<u>Weight %</u>
TIFO Gas Oil Feedstock	76,274	6.34
Gas Oil Feedstock	1,093,772	90.88
Visbreaker Gasoline	33,486	2.78
	<hr/>	<hr/>
	1,203,532	100.00
 <u>Product Streams</u>		
Fuel Gas (Ethylene And Lighter)	51,350	4.27
Propane	16,506	1.37
Propylene	56,312	4.68
C4 Hydrocarbon Stream	117,683	9.78
Hydrogen Sulfide	8,372	0.70
FCC Gasoline	605,577	50.32
Light Cycle Oil	187,256	15.56
Heavy Fuel Oil (Decanted Oil)	94,938	7.89
Coke	56,692	4.71
	<hr/>	<hr/>
	1,194,686	99.26
Unaccounted	8,846	0.74
	<hr/>	<hr/>
	1,203,532	100.00%

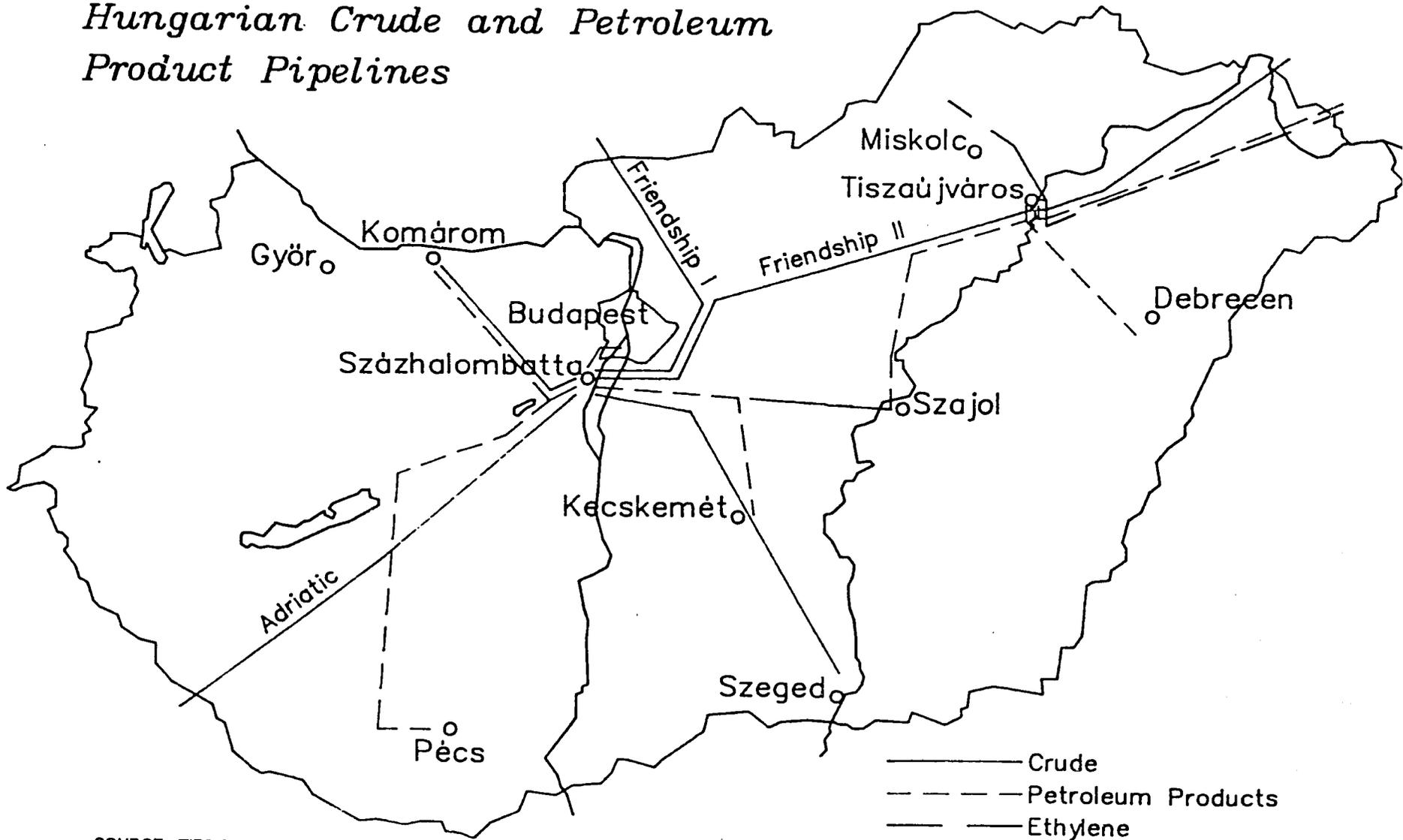
Table 3.13
Fluid Catalytic Cracking Unit
Results of Recent Yield Surveys

<u>Light Gas Yield</u>	<u>Wt% Yield</u>
Hydrogen	0.03
Methane	1.30
Ethane	1.09
Ethylene	<u>0.93</u>
	3.35
<u>C3 Yields</u>	<u>Wt% Yield</u>
Propane	1.2 - 1.6
Propylene	4.0 - 5.0
<u>C4 Yields</u>	<u>Wt% Yield</u>
n-Butane	7 - 1.5
Isobutane	2.9 - 3.5
C4 Olefins	<u>6.2</u>
	10.3%
<u>Fuels</u>	<u>Wt% Yield</u>
Gasoline	50
Light Cycle Oil	15 - 20
Decanted Oil	6 - 8
Coke Yield	4.0 - 6.0
Gasoline Octanes:	
RON	92.5
MON	81.5

35

FIGURE 3.1

Hungarian Crude and Petroleum Product Pipelines

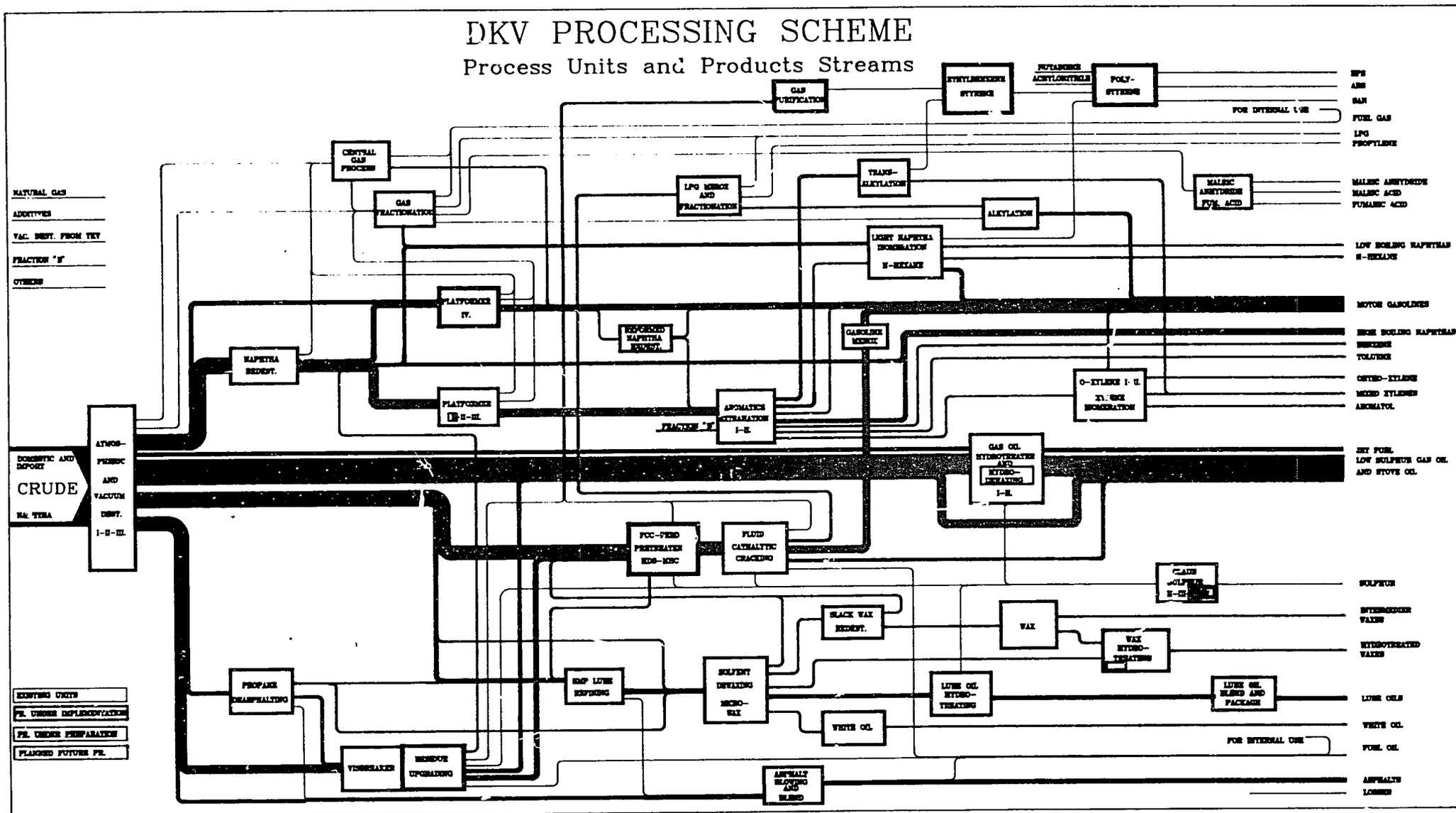


SOURCE: TIFO Briefing Materials

FIGURE 3.2

DKV PROCESSING SCHEME

Process Units and Products Streams

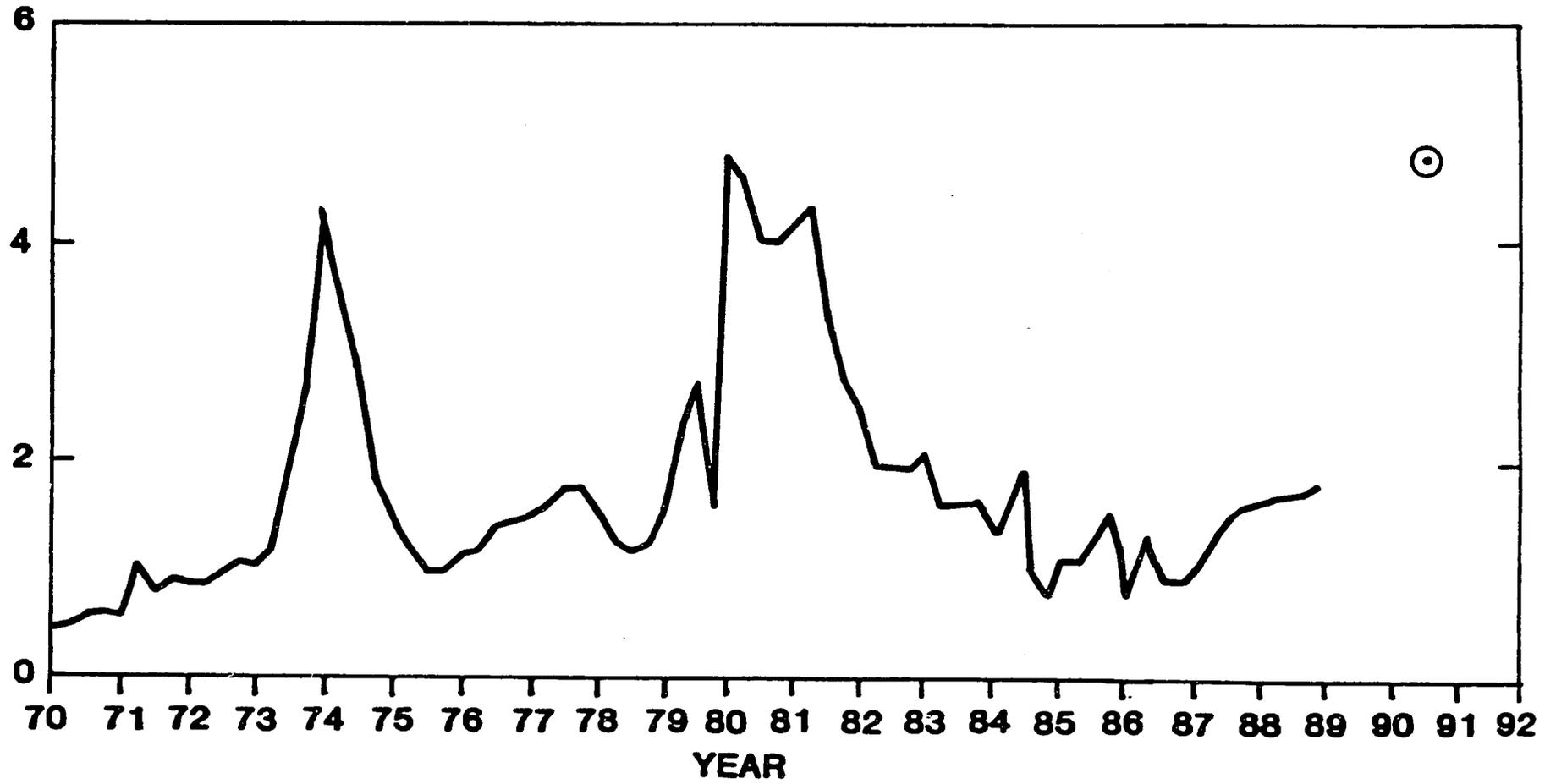


SOURCE: DKV Refinery

FIGURE 3.3

SWEET - SOUR CRUDE PRICE DIFFERENTIAL .

\$/BBL



23

4.0 DKV REFINERY-ENERGY USAGE AND CONSERVATION

4.1 Overview of Energy Usage

The energy needs of the DKV Refinery are met using purchased steam and electricity and the combustion of refinery gases and liquids and purchased natural gas. The steam and electricity are purchased from a large electricity generating plant, Danube Power Station (DHV), located only 5 km from the refinery.

In 1990 energy usage in the refinery was:

284,000 metric tons of fuel
 3,457,000 metric tons of steam
 429,000 Mwh of electricity

Total refinery charges in 1990 was approximately 7,440,000 metric tons of which 7,103,000 tons were crude. It was estimated that 69% of the steam consumed is purchased, with the balance being produced within the refinery. The energy requirement per unit of crude input to the refinery is as follows:

Fuels: 00.0384 mt fuel/mt of crude feed
 Purchased steam: 00.341 mt steam/mt of crude feed
 Power: 57.97 kwh/mt of crude feed

Figure 4.1 shows how these energy inputs are consumed in the refinery (this energy balance is based on 1989 data).

It is useful to put the energy inputs on a common energy unit basis and compare total energy input per unit of crude input with data for other refineries. The following conversion factors are used:

Fuel = 6,278,000 Btu/Bbl (at 6.66 Bbl/mt) = 41,871,420 Btu/mt
 Steam = 2,644,800 Btu/mt
 Electricity = 10,000,000 Btu/kwh

Based on these conversion factors and also assuming 7.4 bbl of crude feed per metric ton (mt), the energy usage per unit input of crude feed are:

	Thousand kJ/mt	Thousand Btu/mt	Thousand Btu/bbl
Fuel	1,695.3	1,606.9	217.2
Steam	951.5	901.9	121.9
Electricity	<u>611.6</u>	<u>579.7</u>	<u>78.3</u>
	3,258.4	3,088.5	417.4

In the table below DKV's energy consumption is compared with data for U.S. refineries of varying complexity. This is not an exactly one-to-one comparison. The U.S. data is for 1983 and it is also for fuels refineries, i.e. petrochemical unit operations have been excluded. Data from a paper presented by Solomon Associates at a 1990 meeting of the National Petroleum Refiners Association (NPRA) is presented in Figure 4.2 which shows

the declining energy consumption trends of refineries in various countries.

ENERGY USE AT DKV COMPARED TO U.S. REFINERIES

COMPLEXITY GROUP	1	2	3	4	5	6	DKV
Refineries in Group	11	12	16	11	10	11	
Average Capacity (MB/D)	47	58	85	120	175	375	162
Average Complexity	6.2	8.5	9.9	11.6	12.2	10.4	11

ENERGY CONSUMPTION (thousand BTu/bbl)

Fuel	311	335	355	370	409	433	217
Purchase Steam							122
Power	<u>45</u>	<u>70</u>	<u>44</u>	<u>63</u>	<u>65</u>	<u>39</u>	<u>78</u>
TOTAL	356	405	399	433	474	472	417

Data Source: "U.S. Fuels performance Analysis For 1983"
- Solomon Associates, Inc.

Despite the differences in the DKV and Solomon data it can be said that DKV was approximately in line with the average for a facility of its complexity when compared with the 1983 data. If we assume that those averages have moved about 10% since 1983, then DKV would be slightly above average in energy usage.

4.2 Energy Conservation Efforts of DKV

The DKV Refinery has been engaged in an energy conservation effort for almost a decade. A key element in the planning of that effort was a detailed study performed by Foster Wheeler Iberia and completed in 1985. In this study, Foster Wheeler Iberia identified 82 potential areas to achieve improved energy efficiency. Since 1985 the refinery has worked on implementing the higher priority items on the implementation list. To date, about two-thirds of the projects have been implemented. Examples of the types of projects which have been done are the following:

- Preheating of AVU feed - product streams from AVU used to preheat feed.
- Preheater efficiency improved with installation of improved furnace burners.
- Steam generator installed for waste heat recovery at Reformer Unit No. 1 heater.
- Air preheater installed at the heaters of the Gas Fractionation Unit for heat recovery.
- Incinerator for waste material and use of waste heat.
- Isomerization unit uses product heat for preheating.
- Storage tank insulated to reduce heat loss.
- Improved heating of buildings (used condensate).

- Organized collection of water from steam traps.
- Motor speed regulation.
- Heat exchanger optimization.

A more comprehensive list of projects, including those arising from the Foster Wheeler study and also those initiated by the refinery staff, is given in Appendix C.

Considering that DKV has been working on energy conservation for a decade it is not surprising that a personal tour of the plant did not disclose significant visible energy losses. No steam leakage could be seen from leaky steam traps or pipes. Pipes were all insulated. Metering of utilities was just adequate and could be improved.

Heat recovery is used extensively throughout the refinery. Some fired units were fired without good control and could be improved. Energy management systems are outdated, consisting of basic monitoring with manual control.

General maintenance of facility systems appears to be good.

4.3 Description of Energy Supply to DKV Refinery

Steam is supplied to the refinery from the DHV power station through 3 pipes of 600 mm diameter. Total summer steam consumption is approximately 300 t/hr with approximately 200 t/hr being imported from DHV. In winter the total consumption rises to 410 - 420 t/hr with about 300 t/hr being purchased. The pressure of the purchased steam is about 17 bars absolute. Because part of the refinery need is for lower pressure steam, the pressure of a portion of the incoming steam is reduced across two steam turbines after it enters the refinery. The two turbine can produce a maximum of 6 MW. One of the two is generally shut down in the summer.

The electric needs of 429,000 MWh of power are fulfilled in entirety from purchases from the DHV Power Station. Power is delivered from DHV via a 120 kV line and is transformed to 6 kV at the refinery's receiving station for distribution throughout the plant. DKV has experienced problems with power interruptions. Power has been cut a total of 10 times a year. The longest outage (in the past 14 years) lasted 13 minutes.

There are three types of fuels used in the refinery: Light hydrocarbon refinery gases, 0.8% S liquid fuel, and purchased natural gas. The 0.8% fuel is produced from the residual fraction from low sulfur crudes charged and the heavier products from the FCC unit. Recent prices for refinery fuels are shown below:

DKV ENERGY PRICES (Forint/Giga Joule)

	1985	1986	1987	1988*	1989	1990	1991
Steam	157.3	163.9	160.9	179.3	184.0	189.1	256.6
Power	383.5	430.7	483.2	547.4	577.1	800.0	1,054.0
Fuel Gas	133.5	113.2	100.5	108.8	123.3	175.3	267.4
Fuel Oil*	160.8	147.5	113.5	122.3	129.3	183.8	296.8
Natural Gas	100.9	153.1	158.8	150.3	143.5	222.6	356.4

*Before July 1, 1988 prices are for 2% S fuel oil, after July 1988 for 1% S fuel oil.

41

The prices have risen significantly in the past two years, the percentage increases from 1989 to 1991 have been:

	%
Steam	39.5
Power	82.6
Fuel Gas	116.8
Fuel Oil	129.5
Natural Gas	148.4

The refinery is also projecting energy prices to increase again next year as shown below:

	Gj/Unit ton or MWh	Btu/Unit Pound or KWh	1991 Ft/Gj	(\$/MMBtu*)	1992 Ft/Gj	% Increase 1991-1992
Steam	3.05	1,312	256.6	(3.73)	346.0	34.8
Power	3.6	3,412	1,054.0	(15.31)**	1,423.0	35.0
Fuel Gas	43	18,472	267.4	(3.89)	279.0	4.4
Fuel Oil	41	17,632	296.8	(4.31)	296.0	0.4
Natural Gas	43	18,492	356.4	(5.17)	477.00	33.8

*Calculated at 172.6 Ft/\$

**5.3 ¢/Kwh

Steam and power costs are projected to increase more than refinery gas and fuel oil in 1992 but as was seen above these costs have experienced the least increase from 1989 to 1991.

4.4 Review of Current and Future Energy Conservation Issues

Future energy supply and conservation issues were discussed in detail with refinery staff members. These included both short and longer term issues. Also where appropriate inspection visits were made to view the areas affected. In the following sections these issues are discussed:

4.4.1 Future Energy Supply: Refinery Cogeneration vs Continuing Purchases from DHV

Concerns about the reliability of the power supply and difficulties in negotiating future favorable steam and power price contracts with DHV, has prompted DKV to develop a study for a cogeneration facility at the refinery. The proposed refinery cogeneration facility would consist of the installation of (3) gas driven turbine generator sets which would provide electrical energy and simultaneously produce steam through (3) waste heat boilers. Steam from the waste heat boilers would be utilized further to drive a tandem arrangement of two steam turbines coupled to yet another generator. Exhaust steam from each of the steam turbines would be fed into the existing main steam headers for use as process heat.

40

The study concluded that the costs associated with the construction of an in-house cogeneration system were significantly less than for purchasing electrical/steam energy from the DHV power plant. A major portion of the savings came from the estimates by which the projected energy costs from the power plant were calculated.

The DHV utility is in the process of replacing their older generation facilities which have historically provided steam and power to DKV with a new gas turbine system. Basically a future price negotiation is being conducted with both DKV and DHV both doing calculations for cogeneration of power and steam for the refinery. Since both cases assume natural gas as fuel gas, it would be expected that DHV would show a lower cost of electricity because of the economy of scale of a larger unit and use of some existing facilities. But that does not turn out to be the case. DHV appears to assume a large reserve capacity for generating the refinery electricity meaning a higher capital component of unit electricity generating cost than in the refinery's own cogeneration case.

Fundamentally a utility located in such proximity to the refinery should be able to provide power and steam to the refinery more cheaply than the refinery is able to achieve by self-generation. For the utility the refinery is a large customer and probably also has a more level demand than most of its customers. These conditions should enable the utility and refinery to negotiate a rate agreement that satisfies the intent of both parties. Clearly the refinery must continue pursuing its own cogeneration project in case success is not achieved in negotiating with DHV.

If the power plant continues to supply electrical/steam energy to the refinery, side issues include the installation of two parallel supply electrical feeders for improved reliability and the dedication of one turbine/generator unit for refinery service. A new low pressure steam line to meet increasing steam demands would also be required.

4.4.2 Energy Monitoring System (EMS)

At the present time, electrical power is monitored via a computer system located in the electrical control room. Various consumptions and demand are monitored on a continuous basis. Since excursions beyond contracted demands and consumption results in significant penalties, electricity is carefully controlled by manual means. The present electrical monitoring system was installed about eight years ago and monitors consumption of thirty-five operating units. There is a need to have the system expanded to new units that are or will be brought on line.

Presently, the monitoring is, for the most part, instantaneous for the units. As electrical usage is monitored within a predetermined efficiency range, excursions beyond this range are investigated and corrected by making mechanical adjustments to the unit. These adjustments are determined by quality control personnel consistent with feedstock characteristics.

On the electrical feeder system, power consumption is monitored on an analog indicator and a pointer indicator when allowable limits are exceeded. If power consumption or demand exceeds predetermined values for longer than fifteen minutes, an alarm sounds. Correction is usually accomplished by tripping electrical operating equipment (motors, etc.) or by shutting down an entire operating unit. The system appears adequate but lacks continuous recording capability.

To achieve a more desirable monitoring system would require the installation of sensors at each location or unit desired to be monitored. Under existing monitoring, only 70% of steam usage can be monitored. It is desirable that shutdown of steam service to a particular facility be accomplished on a manual basis after management has decided on a course of action. It is also desirable to operate steam valves, breakers, etc., remotely because of the great distances between operating units. United States technology has been developed to enable remote operation of control stations over existing low voltage power circuits. This would greatly reduce installation costs.

Factors to consider when expanding the EMS are:

- Installation of Sensors
- Which computer system to use (e.g. upgrade existing or purchase new)
- Installation of sensory conduits and line.

In-house plant estimates on potential energy savings fall in the 7% to 10% range. An advantage of an EMS is that it is anticipated that the system would motivate unit operators to be more attentive to energy usage and challenge them to compete for optimal utilization of energy. The existing system could be expanded to include both steam and electrical usage. Since there are severe penalties for exceeding energy demand or consumption, it appears desirable to monitor energy usage to the various eleven operating units for improved energy control purposes. One major advantage of such a monitoring system is to record trends in consumption. This not only gives control over usage penalties, but enables operators to detect inefficiencies within a system so that corrective action can be taken.

In summation, expansion of the existing electrical monitoring system is a sound concept and should be expanded to include steam energy monitoring.

The goal of the new system would be to:

- (1) Detect and record steam energy trends.
- (2) Alert operators to shutdown devices to avoid penalties.
- (3) Control to be accomplished manually by operators.

The system should monitor total steam usage at the headers as it enters the plant and at each operating unit. The estimated steam energy savings of over 5% appears reasonable but is largely dependent on operator cooperation.

4.4.3 Heat Recovery of Cooling Water

Typical of most industrial operating units, vast amounts of low temperature (low grade) heat is unused in the cooling water process. This low grade heat is difficult to recover because the differential temperature between the two heat exchange media is usually not great enough to justify the expense of capital equipment.

A technology previously used in the United States consisted of a water source heat pump. This is basically a compression refrigeration plant consisting of an evaporator (to absorb heat), a compressor (to return the refrigerant to a usable form), a condenser (to release heat) and an expansion valve (to allow the refrigerant to expand in order to have the ability to absorb heat). Coefficients of performance between two and five are generally expected. This means that for every unit of electrical energy input to the system, two to five units could be returned as usable heat.

Approximately seven years ago, Westinghouse Corporation developed a high efficiency unit that took heat from low temperature sources such as a large volume of cooling water and converted the heat to low pressure steam. Once a use for the steam is determined, an economic evaluation of the system can be made. Unfortunately, recent contacts with Westinghouse have indicated that the division utilizing this technology was discontinued and have of any American Company presently engaged in similar technology is unknown.

Based on this highly efficient energy conversion, it may be worthwhile to pursue whether any organizations are promoting or marketing the technology. DKV's inherent need for steam and the abundance of waste heat available make this refinery a candidate for the utilization of heat pump technology.

4.4.4 Improved Burner System at the Atmospheric Vacuum Tower Furnaces

There are two types of furnaces at the DKV Refinery. One type has burners that receive combustion air from the atmosphere without any assistance of controlled forced air fans. The second type utilizes controlled forced air supplied by fans.

There are three atmospheric - vacuum units at DKV and one of these - an older unit not having forced air supply was inspected. This unit has not been revamped and it is considered a candidate for improvement. Monitoring of combustion efficiency is largely through oxygen and temperature measurements of the flue gas. For the unit inspected, oxygen content in the flue gases were between 4% to 5% with temperatures of about 350°C. An efficient furnace would be expected to run at an oxygen level of 2% to 3% and at a temperature of 210°C. No air preheaters are installed on the unit observed. From the data presented above, it appears that significant savings could be achieved from the installation of controlled air burner system on this furnace.

Coupled with this system should be a complete monitoring recording system that prints out the necessary operating parameters to enable more efficient operation. This monitoring, at a minimum, should include the ratio of fuel and combustion air, flue gas temperature and carbon dioxide temperature at the stack. From this data, operations of the individual furnaces can be arranged to operate the most efficient units on a ranking basis. At present, this ranking can be achieved through portable

instrumentation. It is possible to determine the required thermal efficiencies to furnish spot check information, to gain immediate savings until the automated system is installed. This ranking can be accomplished once the operating data from the portable instrumentation is received.

4.4.5 Other Energy Conservation Opportunities at DKV

From our discussion with refinery energy staff personnel, the following items were identified as potential candidates for improvement or installation.

- Improved heat recovery on atm/vac. distillation units can result in greater energy efficiency.
- Variable speed controllers on motors can save electrical energy.
- Tracer line control on product lines when heat energy is not needed would save steam energy.
- An infrared or similar type portable "gun" could be used throughout the facility on lines, vessels, etc. to locate thermal hot spots where insulation is needed.
- Replacement of steam driven sectors with vacuum pumps.
- Renewal of refractory lining in the heaters of Solvent Lube Refining Unit.

4.4.6 DKV Energy Issues - Summary

Energy Supply

Conventional wisdom normally indicates that with the physical layout of the power plant being in such close proximity to the refinery, that cogeneration at the refinery would not be the economical alternative. However, if the negotiation of attractive rates cannot be achieved, cogeneration at the refinery appears to be the only economical alternative.

- **Energy Conservation**

The DKV Refinery has made significant progress over the years in energy conservation. The previous Foster Wheeler study and recommendations were instrumental in achieving this goal. The energy situation is well under control by refinery management and it is apparent that they continually strive to make additional improvements as economics and technology permit. Refinery management has identified areas where energy management is deficient and are trying to overcome the obstacles which make implementation difficult.

4.5 **Recommendations**

The foregoing narrative of this report details various situations that either need improvement or have become energy issues. This section presents a summary of recommendations resulting from these findings.

4.5.1 **Near-Term Suggestions**

- Proposed Cogeneration Plant - It is recommended that better terms for energy costs be negotiated with the DMV power plant before implementing a cogeneration project.
- Establish links of communication between refineries to exchange energy technologies and experience.
- Operating data for atmospheric vacuum distillation units should be obtained so that programmed sequential operations can be determined for the burners and units.
- Install automatic tracer line shut off control on insulated product lines where product can maintain heat of system.
- Purchase and use an infrared portable heat detection "gun" to locate insulation weak spots and other heat loss areas.
- Insulate pipes, heat exchangers, and areas where heat loss is excessive. Check quality of insulation with heat gun.
- Replace steam driven ejectors with electric driven vacuum pumps.

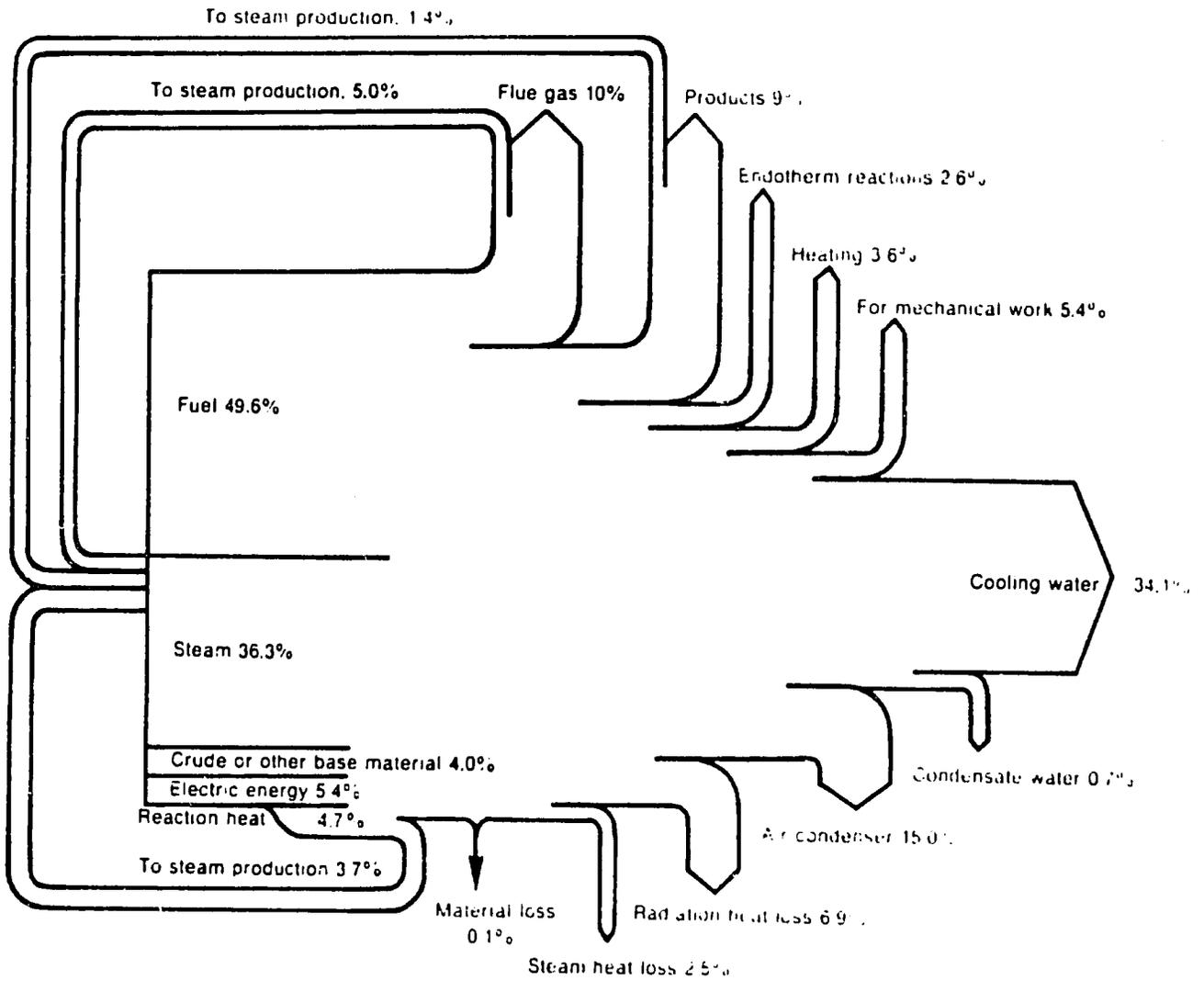
4.5.2 **Longer-Term Suggestions (Over 6 Months)**

- Investigate the economics of the installation of additional heat recovery system on atmospheric -vacuum distillation units.
- Consider DC variable speed control on motor driven pumps.

- **Upgrade or install a new energy monitoring system. At a minimum, the system should monitor and record steam and electrical consumption and demand. Communicate with TIFO on details of a successful system.**
- **Further investigate ways to extract usable heat from cooling water. Investigation into previous Westinghouse technology would be a good start.**
- **Further attempt to negotiate better energy rates from the DHV power plant to avoid capital outlay for a cogeneration system.**
- **Consider the business opportunities for receiving and incinerating outside waste streams in the existing incinerator. The income can subsidize energy conservation projects and recovered heat could save other purchased energies.**
- **Evaluate the economics and advantages of an improved electrical power factor and install capacitors for correction if justified.**

FIGURE 4.1

ENERGY UTILIZATION AT THE DKV REFINERY, 1989

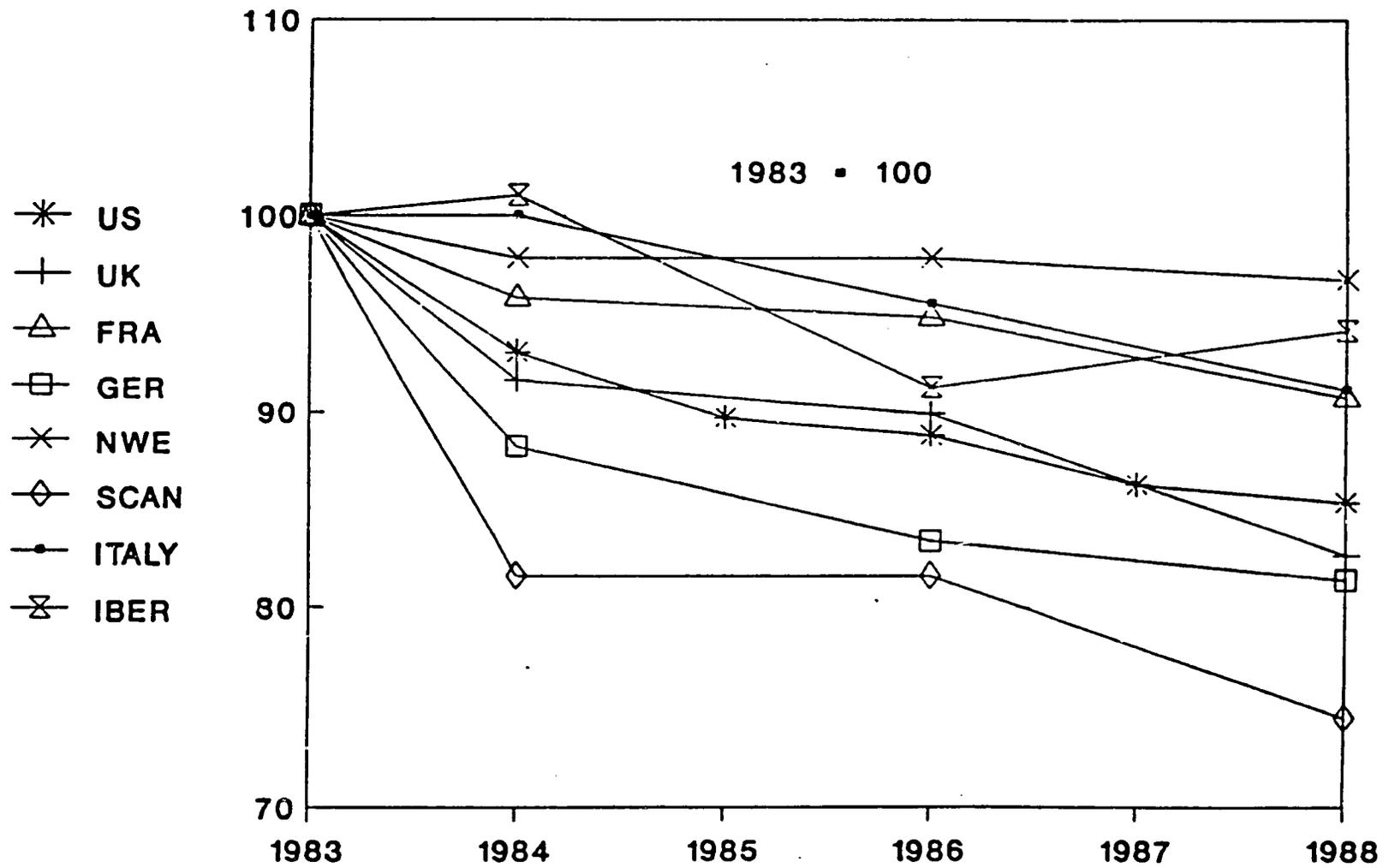


SOURCE: DKV Informational Brochure

49

FIGURE 4.2

ENERGY CONSUMPTION INDEX TREND



5.0 DKV REFINERY-ANALYSIS OF ENVIRONMENTAL ISSUES AND SOLUTIONS

5.1 Introduction

The Dunai Kislajipari Vallat (Danube Refinery or DKV) is situated on 710 hectares (approximately 1,750 acres) and is between the towns of Szazhalombatta, Tokol, Ercsi Rackeresztur, and Mvasar. These towns lie several hundred meters to several thousand meters distant from the refinery. The refinery is about 30km south of Budapest.

The refinery, is located adjacent to a power generation station. The refinery does not generate its own electricity or steam, but buys them from the power plant. The proximity of the power plant to the refinery, while good economically, makes the pollution control problems for both substantially more difficult.

The plant environmental staff is aware of many of the refinery's environmental problems, and is assisting refinery management in the process of arranging financing for the construction a number of production enhancements and some environmental projects. The environmental projects will help bring the facility closer to compliance with existing air, and water quality regulations. The facility has prepared a summary document¹ which discusses the some of the environmental impacts of their existing operations and environmental benefits attained from the planned improvements. In the US, similar documents are often prepared to assist in the issuance of corporate bonds to finance pollution control projects.

5.2 Comparison of Pollution Control in Hungary with the U.S.

The United States has over twenty years of legislative history in the control of air, water, and land pollution. As a result, there is a substantial body of air and water quality standards which define environmental problems. Hungary does not have the same legislative history or standards.

In Hungary, the air pollution control regulations are approximately at the same point as U.S. regulations were before 1975. The Hungarian equivalent of the comprehensive Clean Air Act does not exist. The numerical air pollution standards which do exist are so high that the affected communities experience chronic and acute health problems which may be directly attributed to the exposure to chemicals. U.S. occupational health medical data suggests that continued exposure to the compounds such as benzene, toluene, and other hydrocarbons may cause acute problems which include shortness of breath, decreased pulmonary function, persistent bronchial infections and altered blood enzyme levels. There is a preponderance of statistical evidence which links long term exposure to low levels of hydrocarbons exposure to such diseases as cancer, leukemia, and emphysema, but conclusive medical evidence has not yet been developed. In those instances where Hungarian air pollution control standards exist, they are generally much less stringent than comparable U.S. health based standards. While Hungarian air pollution standards may not be directly applicable to equivalent air pollution standards, or to NIOSH standards, some

¹Proposition for Discharging Environment Protection Related Responsibilities, prepared by the DKV plant in May, 1990

indicative comparisons can be made. For example, the current U.S. NIOSH (National Institute of Occupational Safety and Health) Standards for Benzene concentration in the workplace environment are 0.031 milligrams per cubic meter based upon an eight hour weighted average exposure. Various states are in the process of establishing ambient air concentrations which limit the measured ambient air standard on a 24 hour basis to 1/10 to 1/100 of the time weighted average. The NIOSH Standard is already more than 25 times more protective of human health than its Hungarian equivalent. Other NIOSH standards on toluene and xylene are higher than the equivalent Hungarian "protected" values. The individual state standards are more protective than the Hungarian Standards.

In U.S. refineries the principal sources of hydrocarbon emissions are from leaks in valves, fittings and flanges. The U.S. refineries have been highly regulated and their environmental management staffs are experienced and comfortable in dealing with the complex U.S. environmental control laws. The DKV refinery understands some of the impacts of their air emissions but they do not have the experience in dealing with many of the complex public health problems which occur when people are exposed to several pollutants at the same time.

5.3 Summary

The DKV refinery has a major impact upon the environment of the community. The refinery is a substantial emitter of hydrocarbons, sulfur dioxide, carbon monoxide, and various acid gasses. The refinery acknowledges, that they may be adversely affecting the environment and health of the surrounding communities, principally in the towns of Szazhalombatta, Tokol, and Ercsi which are in closest proximity to the refinery.

To state that the refinery has major air emissions of CO, HC's, and SO₂ and may be the largest regional contributor of these pollutants misses the principal point. The power plant next to the refinery is also a major contributor to air pollution. Its emissions may be approximately the same total tonnage of pollutants as those from the refinery. The refinery and the power plant both emit sulfur oxides, but the power plant also emits substantial quantities of respirable particulates which can deposit directly in the lungs, irritating them and worsening other air pollution related health effects. The combination of hydrocarbons, sulfur oxides, nitrogen oxides, and fine particulates is a very unhealthy air quality situation for the local communities.

Another source of air pollution in the communities is automotive air pollution. The Trabant, a small, under-powered, vehicle of East German design has a two cycle engine and it is often blamed for a substantial amount of air pollution. The automobile air pollution is most noticeable in the larger cities, particularly Budapest. The magnitude of the automobile air pollution is beyond the scope of this report and could not be evaluated.

The community air pollution control and public health problems cannot be addressed by implementing controls on just one emission source. The refinery and the power plant must act in concert to improve the air quality in the community. Long term health improvement in the communities may also require actions from the Ministry of the Environment to reduce automotive and other air pollution sources as well.

The refinery is not using the latest technology to control water pollution. The refinery's waste water treatment system is not currently meeting its extremely generous water quality limits for discharge to the Danube River. While DKV management has recognized the need for upgrading the water pollution control system and may have already ordered



the aerators needed to convert the existing waste water treatment lagoons to aerobic treatment basins, the need for in-plant controls which will reduce the toxicity of the waste-water appears not to have been recognized. Without good in-plant monitoring and control systems on the process waste-water discharges and pretreatment of the waste prior to discharging it into the aeration basins, refinery personnel may have great difficulty in successfully operating the waste water treatment plant when it is constructed.

The ground-water contamination in the refinery is extensive. Over the years, a number of leaks and spills have caused large areas of the ground to be contaminated. At several locations within the refinery the depth of free product (gasoline or other product which floats on the top of the groundwater) is well over 2 meters. The plant has installed over 320 wells in an effort to investigate and correct the groundwater contamination problem. To date, well over 1,000 m³ of free product have been recovered by pumping it from the groundwater.

Additional ground-water protection efforts by the plant management include authorizing the construction of several thousand meters of internal drainage trench and cutoff wall around the refinery. This barrier and drainage system is between 5 and 10 meters deep, and is designed to collect and recover much of the free product and prevent the movement of water off the refinery site. However, the DKV plan may not be as effective as one would hope. There is a body of emerging evidence from the U.S. sources which indicates that the presence of dissolved gasoline in the water may act as a desiccant to the bentonite-cement wall and cause it to crack and allow contaminated water to penetrate the wall. If the contaminants go beyond the barrier wall they will contaminate local wells.

Current U.S. drinking water quality standards permit no more than 5 micrograms of benzene in any water to be used for drinking. The current Hungarian Ministry of the Environment standards are substantially above that level and may not be as protective of human health as U.S. standards. The barrier wall may or may not be as effective as has been planned for the protection of drinking water wells in the neighborhood around the plant.

The solid and hazardous wastes generated by the plant are adequately treated in their on-site incinerator. This incinerator has additional capacity and should be able to adequately handle future plant needs.

The DKV refinery management places great emphasis on production and less emphasis on environmental protection. The environmental control staff is very professional, but it has neither the necessary equipment nor the manpower to adequately serve the needs of a modern refinery.

5.4 Discussion Of Air Pollution Problems

5.4.1 Health Problems and Criteria

The DKV refinery management has identified several air pollution related health problems in the local community. The proximity of the town of Szazholmbatta and Ercsi to the refinery and the power plant and the relatively high levels of hydrocarbons and sulfur dioxide air pollutants have caused public concern in Szazholmbatta. A public health investigation was undertaken to determine the relative health of the citizens of the towns closest to the refinery.

According to the report entitled, "Proposition for Discharging Environment Protection Related Responsibilities," prepared by the DKV plant in May, 1990:

"It was at Szazhalombatta that various health surveys had been made. Society Medical Institute of University of Medical Sciences, in cooperation with the local health authorities (KÖZAL) and the united health institutes of Szazhalombatta have made environmental - epidemiological surveys amongst the adult population of Szazhalombatta governing factors as follows.

Has the air pollution any deleterious effect on the health of adult population, if so, what kind?

Can that effect be detected through an increase in the frequency of some chronic diseases?

Does it cause detectable changes in the respiratory functions, circulatory, hematological, and immunologic parameters of adults?

The survey was divided along classical epidemiological lines to consider those working in Szazhalombatta and living elsewhere, and those working elsewhere and living in Szazhalombatta. The findings were evaluated by Dr. Tibor Pauka, the UMS Society Medical Institute and the results were announced on May 22, 1990. The findings of the medical survey team were as follows:

"Szazhalombatta population is sicker than anywhere else."

In terms of tumor diseases and infant mortality or frequency of premature deliveries, the data are not worse at Szazhalombatta than in the regions used as a basis for comparison,

However, chronic diseases of respiratory organs occurred at almost a double frequency. In addition, higher values were found within each assessment group amongst those living somewhere else, but working at Szazholmbatta.

For late fetus mortality also a double frequency was recorded, and the number of indications to changes in blood count and the anemia frequency for women was also found higher"

Another report by Dr. Margit Kohami, a Public Health official in Pest County, surveyed the children in Szazholmbatta and found a number of problems which primarily relate to decreased respiratory function, a high state of stress in the children's immune system, and degradation of the cilium activity of the upper respiratory mucous membrane.²

The medical findings clearly indicate that air pollution in and around Szazhalombatta and Ercsi have been causing health problems. The air pollution problems in Ercsi have not been directly measured, but are inferred from the measured air pollution problems in Ercsi, which are discussed below.

The DKV refinery is violating the Hungarian air pollution standards 24 hour maximum air quality standards for a number of pollutants. The Hungarian air quality values for benzene in "Protected" areas in Hungary is 0.8 milligrams per cubic meter of air. The maximum air quality values for three principal hydrocarbons were established as follows:

Benzene	0.800 mg/M³ = 0.25 ppm/24 hour average
Toluene	0.600 mg/M³ = 0.16 ppm/24 hour average
Xylene	0.200 mg/M³ = 0.046 ppm/24 hour average

During 1989, in Szazholmbatta, the benzene and xylene standards were for was exceeded once each, and the toluene standard was exceeded four times. Average air quality data for the town of Tork appears to be worse than that for Szazhalmbotta. The data presented for Ercsi show only about 2/3 of the instances of numeric air quality exceedences when compared to those at Szazhalombatta and about 1/2 of those values for Tork.

The only comparable air pollution standards in the US are for benzene. Benzene has been identified by US health officials as a potent carcinogen. The maximum allowable benzene concentration as specified by NIOSH is 0.1 ppm for an 8 hour Time Weighted Average (TWA). The 0.1 ppm is equivalent to 0.031 milligrams per cubic meter. Many US states are establishing an applicable ambient air concentration standard between 0.1 and 0.01 of the 8 hour TWA. These concentrations are allowable at the property line of the facility emitting the benzene.

²Proposition for Discharging Environment Protection Related Responsibilities, Dunai Kilitajipari Vallat, (Danube Refinery), Szazhalombatta Hungary, May, 1990., Pages 16-22.

Toluene and xylene have not been identified as carcinogens in the US, and the equivalent U.S. exposure standards for 8 hour time weighted average are: toluene - 200 ppm = 750 mg/M³, and xylene - 100 ppm = 435 mg/M³.

The DKV report acknowledges that the refinery does need to control sulfur dioxide and nitrous oxide emissions, but there is no data available on the Hungarian ambient air quality standards for these pollutants in the DKV "Proposition" report³.

Relevant US National Ambient Air Quality Standards have been established for the following air pollutants:

POLLUTANT	AMBIENT AIR QUALITY STANDARD
Sulfur Dioxide	3 hour average once per year- 1300 micrograms/m ³ , maximum 24 hour average 365 micrograms/m ³ , annual arithmetic average for the entire year 80 micrograms/m ³
Nitrous Oxides	Annual Average 100 micrograms/m ³
Carbon Monoxide	One hour maximum 40 milligrams/m ³ Eight Hour average 10 milli-grams/m ³
Lead	Three month average 1.5 micrograms/m ³
Ozone	Two hour maximum concentration once per year 0.012 ppm, or 235 micrograms /m ³

The U.S. Environmental Protection Agency has determined that almost all hydrocarbons except methane produce ozone; and ozone is a major lung irritant. The U.S. EPA air protection policy limits all types of hydrocarbon emissions except methane. The U.S. air pollution control strategy has a substantially different control strategy and focus than the Hungarian air pollution control strategy.

One other difference between U.S. and Hungarian air control strategies which emerged in the discussions with DKV's environmental staff was in the way that the Hungarian Ministry of the Environment is choosing to regulate all pollutants emitted. The Hungarian regulations governing the refinery limit the amount of discharge based upon stack height and number of stacks within the area. The United States abandoned this control strategy as unworkable in the mid-1970's. Some of the Ministry of the Environment air pollution control emission limits are shown below. In the following table, the first number is the number of stacks at the facility of a particular height range and the second number is the emission limit from each stack per pollutant.

³Op.Cit. footnote 2

**NUMBER OF STACKS AND LIMITING
DISCHARGES IN KG PER HOUR PER STACK FOR SELECTED STACK HEIGHTS**

<u>Contaminant</u>	<u>10-20m</u>	<u>20-35m</u>	<u>35-50m</u>	<u>50-60m</u>	<u>80-100m</u>	<u>100-120m</u>
SO₂	2/0.018	17/0.3176	19/2.21	7/17.143		1/360
CO	4/3.0	17/10.588	19/73.684	7/571.428	1/8000	1/12000
NO_x	4/0.051	17/0.317	19/2.210	7/9.714		1/360
Particulates	1/0.24	13/0.277	12/2.333	4/20.0		1/240

The refinery estimates its emissions, or has the local air pollution control agency make an annual estimate of the emissions. Without test data to substantiate the emission estimates, there will be some inaccuracies in the figures. For example, the plant estimates that it currently emits 4,251 tons of sulfur dioxide annually. In some of K & M's trial mass balance calculations for sulfur emissions from the Claus and the FCC units, we calculated the sulfur dioxide emissions to be over 5500 tons per year. K & M does not know how the plant estimates of annual sulfur dioxide emissions were developed, and we do not challenge the accuracy of DKV's estimates. We do point out that the plant number are also estimates which may be inaccurate.

Current Hungarian air pollution control regulations are not strictly enforced. The DKV refinery is exceeding current sulfur dioxide and other air emission limits. Our discussion with the plant environmental staff indicated that the only current air pollution regulation which the Ministry of the Environment had issued required the installation of sampling ports on several stacks within the refinery. The production department in the refinery could make these installations at almost any time, but have decided to wait about two years for the next plant shutdown to make the installation. The Ministry of the Environment is apparently satisfied with the delay in installing the sampling ports.

The refinery has had a number of its stacks tested, but did not have the equipment for testing the stack gasses themselves. The refinery personnel were generally not familiar with stack testing procedures or methods. From this, it can be inferred that the Hungarian government has placed a lower priority on stack testing as a means of compliance. (By comparison, US refinery environmental staffs would be particularly familiar with almost all aspects of stack testing and air pollution control modeling because the refinery's air pollution control program had attained a great deal of importance in the operation of the refinery.) This is not a criticism of the refinery or the environmental staff, but it is a comment on the fact that the Ministry of the Environment has not been effective in enforcing their own regulations.

5.4.2 Acid Gas Air Pollutants

The principal acid gas air pollutants are sulfur dioxide and nitrous oxides, and ozone. Ozone is not referenced as an air pollutant standard in Hungary. Nitrous oxides are formed when combustion takes place in air. The nitrogen in air combines with oxygen in the combustion reaction and produces nitrous oxides. Nitrous oxides are acidic and lung irritants. The principal sulfur dioxide sources within the refinery are burning of fuels containing sulfur, the Claus reactors, and the oxidation of sulfur from the cokes and catalyst regeneration of the FCC.

In the Claus reactor, the $H_2S - SO_2$ combustion generates sulfur and water. The water hydrolyzes some of the sulfur converting it back into SO_2 . The Claus units at the plant have a capacity of about 26 kilotons per year. These sulfur units are about 96% efficient, but release about 1,040 tons of sulfur (2,080 tons of sulfur dioxide) into the atmosphere per year.

The sulfur dioxide emissions from the refinery FCC flue gas stream are estimated to be between 2,000 and 3,000 metric tons per year. The refinery's planned installation of an FCC feed hydrotreater may reduce the sulfur emissions from the refinery by about 90% -95%, and should reduce the refinery's sulfur dioxide emissions by over 2,000 metric tons per year. The installation of the new Claus unit will reduce the refinery's contribution to sulfur dioxide air pollution by over half. The refinery has made some progress in reducing total sulfur dioxide emissions. Between 1987 and 1989 the refinery has cut its sulfur dioxide emissions almost in half—down to 4251 tons per year.

By comparison, U.S. refineries are required to meet relatively stringent sulfur dioxide emissions. The emission from the Claus unit cannot exceed 250 parts per million SO_2 by volume where there is an incinerator following the Claus unit or 300 ppm SO_2 and 50ppm H_2S where there is not. Moreover, SO_2 regulations in the additionally regulate the FCC units in the following manner: 1) reduce SO_2 emissions from the FCC to 50 ppm or by 90%; 2) maintain SO_2 emissions from the coke burn off to less than 9.8 kg SO_2 per 1000 kg- without controls; 3) process fresh feed in the FCC with a sulfur content of no greater than 0.30 percent sulfur by weight. These regulations have been in place since the mid- 1970's in the U.S., and they have made a substantial reduction in air pollution from refinery sources.

One other major source of acidic air pollutants within the plant is the Maleic Anhydride (MAN) Unit. The MAN unit is emitting approximately 460 kilograms of carbon monoxide CO, and almost 700 kilograms of miscellaneous organic contaminants and acid gasses per hour. We infer from comments in the DKV "Proposition" report that the MAN tail gas emission is so highly acidic and is produced in such great quantity that it is rapidly corroding the steel on nearby process units and creating a maintenance problem. A tail gas Incineration system proposed by the refinery will reduce carbon monoxide levels in the in the community. The DKV environmental capital report does not discuss the community health effects of carbon monoxide or of the acid gases which they release. Carbon monoxide is poisonous because it reacts with haemoglobin in the blood replacing the oxygen there. The other acid gasses emitted are

primarily lung irritants, but the effect of long term exposure on humans is not known.

The refinery has begun alkaline scrubbing to neutralize the acid from the tail gas. The refinery soon found that it was consuming over 800 metric tons of expensive sodium hydroxide annually. Moreover, the neutralized tail gas solution dramatically increased the amount of Chemical Oxygen Demand (COD)⁴ substances discharged to their waste water treatment plant. Since the waste-water treatment plant is already over the permitted discharge limits, the only thing the neutralization accomplished was the swapping of an air problem for a water problem, at substantially increased operating costs.

The Danube is planning to build a tail gas incinerator for the treatment of the Maleic Anhydride gas stream. The incinerator construction should begin sometime in 1992, and when completed, should reduce the CO emissions from the refinery by a substantial amount, probably on the order of 2,600 metric tons per year. The amount of acids emitted should also be reduced by about 4,000 metric tons per year. Both of these reductions will substantially reduce the total emissions from the plant, and will help to improve area-wide air quality.

5.4.3 Acid Gas Reduction Solutions

The refinery acknowledges that they are exceeding local sulfur dioxide air pollution limits. The plant's plan to install a Claus sulfur unit along with the Fluid Catalytic Cracker upgrade will substantially reduce the amount of sulfur dioxide the plant emits to the air. The Claus unit may reduce the sulfur dioxide emissions by more than 2,000 tons. Other sulfur reduction solutions include the addition of additional stages to the existing Claus process units or the installation of SCOT, SuperClaus, or other equivalent technology, and the installation of an alkaline scrubber as a final source of control for sulfur removal. Increasing the number of stages on a Claus unit to four will increase overall sulfur recovery to 99%. Based upon U.S. experience, the installation of additional process removal stages to the Claus unit should decrease the tailgas concentration to less than 250 ppm. We have included references on the installation of improvements to a Claus process in an separate submittal to the refinery.

The acid tail gas incinerator which the refinery is planning to install on the Maleic Anhydride unit will significantly reduce the amount of acid gasses and carbon monoxide released to the atmosphere and should help reduce the costs of plant operations.

⁴Chemical Oxygen Demand is determined by oxidation of waste-water with a permanganate solution. This reaction theoretically measures the amount of oxygen consuming substances in the waste-water. In practice, however, it has been proven to be subject to a number of interferences from aqueous salts. The purpose of the test is to determine how much oxygen will be consumed in the aquatic environment such as a river from the discharge of wastes containing organic substances.

The plant needs to take an active role in determining what its own emissions are through testing. As part of the information exchange which accompanied this visit, K & M has made arrangements to send DKV a copy of appropriate air pollution control regulations and various appropriate models so that they can make their own evaluations of the impact of their air pollution emissions. The refinery needs ambient air quality measurement equipment, stack testing equipment and assistance in setting up and using air quality models to identify which sources of air pollution are creating significant problems and or violating air quality regulations.

The refinery is not the sole cause of air quality problems in the area. The power plant must also assume a substantial portion of the responsibilities for the emission of sulfur dioxides and particulates. The power plant is believed to be the major contributor of particulates in the community air, and after the installation of the new Claus unit at the refinery, the power plant may also be the largest area source of sulfur dioxide as well. The air problems in the community cannot be addressed solely by the refinery, but control efforts by the refinery can make substantial improvements in the region's air quality.

5.4.4 Hydrocarbon Emissions

DKV loses over 2,500 metric tons of hydrocarbons per year from their volatile petroleum storage tanks⁵. Plant personnel estimate that the actual number may be as high as 4,000 tons from this source⁶. While this estimate includes emissions from a number of process sources, it does not include losses from leaking valves, fittings, pump seals, and the waste-water treatment system. The actual emissions from all the hydrocarbon sources are substantially higher than the plant even knows or suspects.

The principal production units which are responsible for the majority of the hydrocarbon emissions in the plant may include the fluid catalytic cracker, the atmospheric vacuum distillation condensers and compressors, the hydrotreaters and reformer units. Other large sources include the filling station or loading racks, the tank storages, and the waste water treatment system. Potentially, almost every production unit within the refinery is an hydrocarbon air emission source.

As with the emission of sulfur oxides, the refinery does not really have the equipment which will permit it to measure its own air losses. It is currently relying on internal estimates from various production departments to determine losses. If U.S. experience in manufacturing and chemical process

⁵Source: Discussions with plant personnel and "Proposition Report", Op. Cit, Section 2 page 9.

⁶The estimated total emissions from DKV is 12,746 tons annually- a figure believed to be somewhat low. Based upon a plant estimate of the hydrocarbon emissions as representing just above 21% of the total, the plant published figures calculate almost 4600 tons per year of hydrocarbons.

Industries is relevant, the production departments estimates of their losses are probably low.

The refinery has a number of fixed roof storage tanks. According to DKV's own estimates, the fixed roof tanks may account for as much as 2,500 tons per year of hydrocarbon losses. The refinery uses an emission calculation method recommended by API (the American Petroleum Institute). This calculation method has wide acceptance and is believed reasonably accurate.

The refinery is considering installation of floating roof tanks for the products which have a high vapor pressure. The installation of floating roofs in existing tanks requires substantial reconstruction of the tank, and is quite expensive. Other alternatives, including the installation of vapor chillers and carbon adsorbers for hydrocarbon recovery may be equally cost effective.

The non-controlled vapor emissions from fugitive sources within the refinery can be substantial. Leaks at flanges, pump seals, valves, and other sources can add up to over a thousand tons of hydrocarbon emitted annually from a refinery the size of DKV. Presently, DKV has no way to determine these losses, and they are not in their current emission estimates.

The waste water treatment system is another source of hydrocarbons emissions. According to data from the U.S. Environmental Protection Agency, each in plant drain emits about 0.032 kg of hydrocarbons per hour per drain. The EPA currently estimates that a refinery similar to DKV could have as many as 1000 drains. By simple calculation, the refinery could lose about 32 kg/hour of hydrocarbons. On an annual basis these losses could amount to about 200 metric tons.

Direct evaporation from the surface of the API separator (the first step in refinery's waste water treatment process) could account for daily losses of approximately 1,122 kg of hydrocarbons- on a yearly basis this loss is about 409 metric tons.⁷ Another estimate by the API puts the losses from the separator between 68 and 256 kilograms of hydrocarbon released per 1,000 kg of crude oil processed. Using the most conservative API value, the VOC emissions would amount to another 544 metric tons per year. Either way, the losses from having an uncovered API separator are substantial.

Most U.S. refineries use a dissolved air flotation (DAF) system for pretreatment of the waste-waters and removal of the oils before they are discharged to the biological waste-water treatment system. Since DKV does not have anything which is comparable to DAF systems at this time, one could come close to estimating emissions losses from the existing waste-water treatment lagoons by doubling the emissions estimates from the API separators. Using this technique we estimate that the evaporation from the lagoons could account for another 800-1,088 metric tons of hydrocarbons emitted annually.

⁷VOC (Volatile Organic Hydrocarbon) Emissions from Petroleum Refinery Waste-water Systems-- Background information for Proposed Standards, USEPA Office of Air Quality Planning and Standards, Research Triangle Park, N.C., February, 1985. Publication Number EPA-450/3/85-001a.

Another large emission source for the refinery is the filling station. Most U.S. facilities load tank cars and tank trucks from the bottom, transport the materials in vapor tight containers, and recover the vapor from the tanks into which the product is delivered. The losses from a filling station can exceed the emissions of the storage tank losses. The DKV environmental staff is aware of the magnitude of the filling station emission losses, but the emissions are not quantified in their annual estimates.

There are a number of air emission sources for hydrocarbons within DKV which have not been considered by the refinery or by the Ministry of the Environment. These unidentified sources may represent losses which are as great as the identified losses from the storage tanks.

5.4.5 Hydrocarbon Reduction Solutions

There are a number of ways to reduce the hydrocarbon emissions from DKV. One way is the installation of floating roof covers on the high volatility product storage tanks. This represents a great expense, and lost time for use of the tanks during the installation of the floating roof in the tank. The proposed installation of floating roofs on the volatile product tanks will not eliminate the emissions from the tanks but will substantially reduce the emissions. The installation of a floating roof will reduce the hydrocarbon losses from a single tank by 90% or more.⁸

In a refinery there is often the danger of fire. To help reduce the danger from fire the vapor space above the tank is sometimes filled with an inert gas. The inert gas is often nitrogen or carbon dioxide. Nitrogen is very expensive, and carbon dioxide is often more popular because it can be generated by a small internal combustion engine where the exhaust gases are sent through a water trap and then out to the tanks. A major northeastern U.S. chemical plant uses this technique to reduce the fire potential in its acetone storage tanks, and acetone is as volatile and flammable as gasoline. That facility also uses a cold carbon adsorber system to reduce their air emissions. A similar system could reduce fire hazards and hydrocarbon emissions at DKV.

One of the most common hydrocarbon capture technologies in use by U.S. bulk plant filling stations is the chiller/condenser system. The air which contains hydrocarbon vapor is cooled down to -70° C to recover all the hydrocarbons. The capture efficiency of these units is quite high. The average vapor recovery efficiency for this type of equipment is on the order

⁸The DKV Refinery estimates that the installation of internal floating roofs on the refinery tanks will reduce the hydrocarbon emissions by 90%.

of 99.8%.⁹ If DKV installed a number of individual chiller/vapor recovery units on all the tankage within the plant, they could recover about 2,500 * 0.998 = 2,495 tons of product per year which is now emitted to the atmosphere. This recovery could be achieved with or without the installation of the carbon dioxide blanketing of the tanks.

If the refinery wishes to reduce the size of the compressor system which may be required for the vapor recovery, it could install a floating roof gas receiver tank. In the U.S., these tanks are still used to equalize supply at natural gas pipeline pumping stations and to feed many chemical processes. Installation of this type of balancing system could balance the receiving and shipping loads and permit the installation of a smaller compressor system. Another potential advantage of a chiller/vapor recovery system is that it can also be used to recover vapor which will be generated from the cleanup of the contaminated soil at the plant.

Another classical and time proven technique for reducing hydrocarbon emissions is to flare them. The installation of a steam fed flare with appropriate instrumentation can easily reduce the hydrocarbons to carbon dioxide and water. The only drawback of the flare is that the hydrocarbons are unrecoverable when burned.

The refinery needs equipment which will allow it to conduct a quick and representative survey of the vapor emissions from the various sources without having to rely on conventional analytical techniques. The use of a flame ionization or photolization detector (PID or FID) would meet this requirement. The PID will detect hydrocarbons, except methane, the FID will detect all hydrocarbons including methane. These instruments are used in the U.S. to conduct fugitive emission surveys. The FID can be equipped with a hydrocarbon gas trap (activated charcoal filter) which will allow it to discriminate between methane and non-methane hydrocarbons. Both instruments are highly portable and both can be used to make the type of hydrocarbon surveys which DKV will require if it is to reduce its hydrocarbon losses. As will be discussed below, the PID and FID are also useful in locating leaks from pipelines and detecting the concentrations of hydrocarbons in the soils.

DKV's environmental laboratory needs substantial improvements. The laboratory is not presently equipped to perform complex analyses; the personnel have had training on some of the types of equipment which the laboratory will need. The laboratory needs stack testing equipment, ambient air monitoring equipment, gas chromatography analyzers, an atomic adsorption unit, and a gas chromatograph/mass spectrograph. With these equipment items and the budget and training to use them effectively, the environmental laboratory can be a full partner in helping the refinery plan and execute environmental programs.

⁹Source: Performance test Data, Star Enterprise Terminals, Norfolk Virginia, Richmond, Virginia, and Doraville, Georgia. The 99.8 percent is an average figure based on independent performance tests conducted by an outside agency.

5.5 Water Pollution

5.5.1 Water Pollution-Control Requirements

The DKV refinery discharges approximately 50,000 m³ of waste-water to the Danube River every day. The Ministry of the Environment limits the discharges of the refinery to the following maximum parameters:¹⁰

<u>Parameter</u>	<u>Numerical Limit Limit (mg/l)</u>	<u>Annual Averaged DKV's Water Discharge (mg/l)</u>
Oil	10	22
Chemical Oxygen Demand	150	198
pH	5-10 Standard Units	7.7 Standard Units
Phenols	3.0	1.4
Sulfate (SO ₃)	5.0	1.4

The plant regularly exceeds its water quality discharge limits on oil and Chemical Oxygen Demand (COD). Both of these substances consume oxygen in the Danube and can be harmful to aquatic life. The COD test is seldom used in the US because it is subject to a number of interferences from various types of salts. The U.S. practice measures the oxygen demand using the 5-Day BOD test, or BOD5.

The Hungarian water quality discharge limits for the Danube are extremely generous by comparison to those imposed upon a typical US refinery. The U.S. environmental regulations for existing and new technologies cover a wide variety of processes and sizes of installations. Pollution discharge limits used by U.S. plants are summarized below. The regulated effluent quantities are specified in terms of mass units discharged per metric ton of petroleum refined. Almost all U.S. industries have water pollution standards which related to plant production. Effluent standards are independent of concentration because the U.S. EPA wanted to encourage treatment of water pollutants rather than the attainment of water pollution limits by dilution.¹¹

¹⁰Note that all parameters are measured by Hungarian test methods which in some cases are not as sensitive as those used in the US. For example, the Hungarian Oil and Grease test method is equivalent to a simple solvent extraction which while still found in Standard Methods, has extremely poor reproducibility.

¹¹USEPA Development Document for Effluent Limitation and Guidelines in the Petroleum Refining Industry, Point Source Category, USEPA, Washington, D.C. Publication Number EPA/440/1-82-014, 1982.

64

PARAMETER	PERCENTAGE REMOVAL OR EFFLUENT VALUE
Conventional Pollutants, which include Biochemical Oxygen Demand, Oil and Grease, and Total Suspended Solids	85% minimum pollution removal based upon Influent to facility. Approximate values of BOD and COD are calculated by complex formulas which use size factors and process factors. Monthly average discharge values for BOD5 be as high as 60 kg/1,000 m ³ feedstock; similar values for TSS and Oil and Grease are 30 and 12 kg/1,000 m ³ feedstock respectively.
Non Conventional Pollutants, which include COD, Ammonia, Total Organic Carbon, and Phenols	Minimum of 74 % reduction is required, stream standards will also apply for protection of aquatic life from chronic exposure to ammonia and phenols. Process and size factors may allow COD quantities discharged up to 220 kg/1,000 m ³ of feedstock. Discharge limits for phenols and ammonia can be as high as 0.25 and 4.0 kg/1,000 m ³ feedstock respectively.

OTHER REPRESENTATIVE NUMERICAL DISCHARGE LIMITS

Arsenic	0.01	micrograms/liter
Cadmium	0.25	micrograms/liter
Lead	5.15	micrograms/liter
Mercury	0.88	micrograms/liter
Chromium ⁺³	107.9	micrograms/liter
Chromium ⁺⁶	7.73	micrograms/liter
Benzene	2.3	micrograms/liter
Toluene	10.1	micrograms/liter

In the above table, the data base was established between 1974 and 1982, and it does not reflect additional changes in treatment technology which have been developed since that time. Also, the comparison to U.S. refineries may be somewhat difficult because most U.S. refineries have installed an effective pretreatment system above and beyond the API separators before the wastes are permitted to flow into the biological waste-water treatment system. While one could find COD levels in a refinery effluent as high as several hundred milligrams per liter, it would be the exception rather than the rule. Most of the individual states would insist that the discharge from the refinery not violate the minimum oxygen and other water quality standards in the receiving stream even when drought conditions persist.

67

One reason for the high levels of COD in the DKV plant effluent is that the plant is neutralizing its Maleic Anhydride tailgas and discharging the organic acids and other chemicals to its existing waste water treatment system. In its environmental report, the refinery indicated that the COD of the MAN tailgas contained approximately 30,000 milligrams of COD per liter. This is an extremely strong source and its elimination might help bring the COD in the plant back down closer to its current permit values. This one source is not, however, the largest or only source of COD in the plant effluent.

Almost any petroleum compound is slightly soluble in water. The dissolved component is quite difficult to remove by conventional waste-water treatment systems contained at the plant. In some instances the material can be adsorbed on to activated carbon or it can be treated biologically to remove the organic materials.

Principal waste-water pollution contributors within the refinery include the desalters, the FCC, the condensers on the atmospheric distillation units, tank and product de-watering and cleaning, and almost any other source which uses cooling water or steam. These units all transfer their waste materials, contaminated cooling water dissolved and or suspended or emulsified levels of hydrocarbons.

The wastes which are discharged from the various plant units flow into the industrial wastes sewer system. (The plant has a separate collection and waste treatment system for sewage, but it is not considered here because of its limited capacity and influence.) The plant has two separate sewer systems and two waste water treatment systems operating in parallel. Discussions with the DKV environmental staff indicated that they do not have a good water balance for the various plant processes, nor do they really have any data on the quantities of water or wastes generated by each production unit. Without this type of information, the plant cannot accurately determine the waste loads or toxicity of process operations within the plant.

The Danube refinery is planning to install aerators into their waste water treatment lagoons to convert the plant into a secondary waste water treatment system. From our investigation of the refinery, there is little or no information about the loads or toxicity of the individual process units, and sparse understanding by management of the substantial effort which will be required to make the waste-water treatment system work as designed.

When we inspected them, DKV's API separators were not working at peak efficiency. The API separators do not have the required vertical baffles, and much short-circuiting of the flow was evident. This short-circuiting decreases the separator efficiency. An additional evidence of the poor performance of the separator was obtained by inspection of the waste water treatment lagoons.

One of the waste-water treatment lagoons was out of service for repairs during our visit. We observed the maintenance staff in the process of removing about a half meter of oils and tars from the bottom of the lagoon. If the separators had been working as intended, the quantity of sludge would have been much less. Additional evidence of the poor performance of the API separators was

evidenced by the layer of free oils which was observed on the surface of the active lagoon. The observed oily layer was several centimeters thick near the outlet end of the lagoon, and may have been as low as 0.5 cm thick on the inlet end of the lagoon.

5.5.2. Water Pollution - Solutions

We believe that the proposed waste water treatment plant upgrading may not accomplish its intended purpose. The refinery does not have adequate information on the amount and kind of waste materials which are being discharged to the waste water treatment plant. The process discharge sources have not been identified, and alternative measures which could lead to substantial savings and ease of operation have not been implemented.

The refinery needs to improve, upgrade, and optimize the performance of its API separators as a first step in controlling their water pollutants. The separator performance is marginal to poor, and thorough rehabilitation should be considered.

The chemical regimen of polymer treatment and flocculants currently being used needs to be re-examined and adjusted to further increase the performance of the existing equipment. The refinery has made a substantial amount of progress in reducing the concentration of oils in the effluent stream to below 10 mg/l. From the overall appearance of the waste-water treatment system, much of the oil removal is taking place in the final basins rather than in the API separators. When the aeration system is installed in these basins, the improvements in effluent due to settling will be lost.

The DKV refinery needs to conduct a thorough waste water and waste load study. This study should, preferably be performed before the waste water treatment plant improvements are constructed. The environmental staff needs the training and the equipment to properly conduct this survey.

The refinery environmental staff needs a gas chromatograph/mass spectrograph, a gas chromatograph, an atomic adsorption analyzer with graphite furnace capabilities or an inductively coupled plasma arc analyzer (ICAP), and the training to use these items. The environmental laboratory currently consists of a wet chemistry laboratory capable of only the most elementary analyses. With environmental standards becoming more stringent, the refinery will be calling on the environmental laboratory more and more to perform sensitive trace chemical analyses which cannot be performed in the production laboratory because of the nature of the chemicals in use and the status of the laboratory.

The environmental laboratory and staff need a number of composite waste-water sampling devices and a portable water flow meter. The samplers may be portable or fixed, but they need to be installed downstream from principal operating units within the Danube Refinery. At least one sampler should be located downstream of each major process unit or processing area. The portable flow measurement equipment should be either the Gurley type or the equivalent Marsh-McBirney unit which is electronic. In order to conduct the

survey in a timely fashion, the plant may require two or more flowmeters. The equipment can be purchased or rented.

When the plant has these equipment items the environmental staff and laboratory should be assigned the responsibility for conducting a comprehensive waste survey and developing a pollution control baseline characterizing the range of variability in each of the waste-water discharges from each of the various processes. This survey should be done on an around the clock basis for each operating shift.

The proposed sampling campaign will dramatically increase the environmental laboratory's workload and require it to function around the clock. The benefits from the program will enable the plant to accurately assess the performance and decrease product losses to various product units. Other refineries and chemical plants which have performed similar surveys found that product losses to the waste-water plant will decrease by up to 20% as a result of conducting the survey. The survey itself will also generate a list of suggestions for process modifications and other ways to decrease losses to the plant sewers. When implemented, these suggestions can materially improve plant productivity.¹²

The increased capabilities of the refinery's environmental laboratory will also help DKV to solve some of its ground-water contamination problems.

5.6 Soil and Ground Water Contamination Problems

5.6.1 Magnitude of the Problem

The DKV refinery has a very large and serious ground-water contamination problem under large areas of the facility. Old leaking pipes, spills, losses from the sewers, leaks from tanks, and a lack of care regarding the handling of products have all permitted substantial quantities of petroleum products to leak into the ground, contaminating it and the groundwater.

We learned that the refinery has recovered over 1000 m³ (264,000 gallons) of gasoline during the past year alone by gravity drains at the ground-water table. In spots within the plant, the depth of free product floating on top of the ground water is several meters. Data from 1990 indicated that in the southwest corner of the plant, one storage area had a free product depth which totaled over 4 meters.

¹²Allied Chemical conducted such a survey at their SouthPoint, Ohio chemical plant back in 1977. The facility at that time consisted of an ammonia plant, melamine, urea, and urea formaldehyde plants. The plant employed about 3000 people total. The survey was conducted within a six week period on a 24 hour basis with the existing environmental sampling team of 8 technicians supplemented with approximately 20 other process engineers. The survey included mass balances around the equipment operating units and generated process improvements which increased the overall throughput of several processes by about 12% and reduced losses to the sewer by over 25%.

An analysis of a recent spill in the United States indicates the magnitude and kind of problems which DKV may be having. The subject spill was 113 cubic meters of gasoline. Approximately 62 % of the spilled material will exist in a recoverable form as free product. Thirty-two percent (32%) of the gasoline was adsorbed on to the soil particles, and was difficult or impossible to recover by gravity drainage. The balance of the gasoline, estimated at between 1% and 5% of the total, was dissolved in the ground-water. For this 113.55 m³ (30,000 gallon) spill the free phase contaminated about 5,435 m³ of soil and the gasoline absorbed in the soil contaminated about 114,800 cubic meters, and the dissolved gasoline in the ground-water contaminated approximately 734,720 m³.¹³

For this particular spill the amount of soil contaminated by the spill was about 6 times the spill volume, and the volume of the groundwater contaminated was about 6470 times the spill volume. While these ratios on the amount of contamination may vary from soil to soil, the largest problems of contamination will be the soil and the ground-water; it is precisely those areas which the current DKV cleanup efforts do not address.

The DKV refinery has retained a geologic consulting firm and a academic geological consultant to help them with their contamination problems. The consulting firm installed almost 350 ground-water recovery and monitoring wells. The refinery, at the instigation of their consultant and the consulting firm, is building an extensive ground-water contamination migration barrier around the perimeter of the refinery. To this end, the plant is spending about 12,000 Forints per meter (approximately \$ 50.38 per linear foot) to construct a bentonite clay-cement barrier wall which is impermeable to the passage of ground-water, and a surface drainage system which will collect the free product material which is floating on top of the water-table. While we commend the refinery's efforts, we question the cost effectiveness of the proposed solutions.

Unfortunately, the barrier wall, despite its expense will do little to control the long term migration of pollution, nor will it be protective of the groundwater or of human health.

5.6.2 Ground Water Standards and Public Health

The Hungarian Ministry of the Environment has established ground-water protection standards. Regulation L 09 sets forth drinking water physical and chemical criteria. While the regulations are quite specific to the geology of the country, they are quite generous with respect to some pollutants, and more stringent than US standards on other pollutants. The Hungarian government generally follows the 1971 World Health Organization Drinking Water Standards. These standards are less protective than current U.S. standards in such areas as nitrate and sulfate and benzene. The Hungarian drinking water regulations are specific only to potable water sources.

¹³Wilson, S.B. and Brown, R.A., "In-Situ Bioreclamation: A Cost Effective Technology to remediate subsurface Organic Contamination," Ground Water Monitoring Review, Vol 9, No. 1, 1989 - original estimates of volumes provided in English Units.

Recently revised (1988) U.S. Drinking Water Standards have established a level of protection for organic chemicals. These values include a limitation on benzene in groundwater at 5 micrograms per liter (0.005 mg/l). While these are national standards, various states have established action levels which are protective of their groundwater. Of these states, Florida is among the most protective because it has a surface water aquifer which is sometimes just a few feet below the surface, and which is an important source of drinking water throughout the state. A brief summary of cleanup standards for Florida's ground-water is shown below:

State of Florida - Groundwater Cleanup Standards¹³

Benzene	1 ug/l
1,2, Dichloroethane	3 ug/l
1,2, Dibromomethane	0.02 ug/l
Total Volatile Organic Analytes	50 ug/l
Lead	50 ug/l
MTBE	50 ug/l

State of Florida - Kerosene Analytical Group

Benzene	1 ug/l
1,2, Dichloromethane	0.02 ug/l
Total Volatile Organic Analytes	50 ug/l
Polynuclear Aromatic Hydrocarbons -	Detection limits on methods
Total Napthalene	100 ug/l
Lead	50 ug/l
MTBE	50 ug/l
Total Petroleum Hydrocarbons	5 mg/l

Note that all values except Total Petroleum Hydrocarbons are expressed in micrograms.¹⁴

The greatest concern about the particular solution which DKV has selected to contain and recover petroleum is that it may not be sufficiently protective of public health, and that it will also not succeed in accomplishing the desired end result.

5.6.3 DKV's Ground Water Remediation Efforts

We are concerned about DKV's hydrocarbon remediation efforts for several reasons. The first reason is the cost effectiveness of the solution. The second is the effectiveness of the proposed solution. The third is the length of time required to achieve the desired end results. The following technical considerations are brought up because they may affect the current groundwater cleanup efforts which DKV is conducting.

¹⁴Source: State of Florida, Ground Water Protection Standards.

10

- The proposed barrier wall and the recovery trench at DKV will recover only about 60- 62% of the spilled material. The ground-water collection system cannot remove or recover the 25-30% of the material which has been adsorbed on the soil. Moreover, the recovery system does nothing to treat the largest physical component, the groundwater which contains dissolved gasoline and oils.
- Research in the United States has indicated that specific remediation measures are needed to remove the oil and hydrocarbons from the soil. The process of water washing the soil was found to be unacceptable, as it was demonstrated that even for a sand, the easiest soil to cleanse, over 500 pore volumes of water¹⁵ did not efficiently or effectively remove significant levels of contamination from the contaminated sands used in the experiments. On mixed soils which contain clays, the amount of water which will be required will be substantially greater because the clays have small particle sizes and are able to adsorb proportionally greater quantities of petroleum.
- The proposed solution will do little or nothing to remove, remediate, or treat the dissolved petroleum in the ground-water.
- With the existing trench system, it appears to be unavoidable that concentrated hydrocarbons will contact the barrier wall, and that layers of free product will also contact the clay aquaclude beneath the site. The presence of free product in the soil will cause the clays in the barrier wall and the aquaclude to desiccate and crack. These cracks will allow hydrocarbon penetration about 1,000 times faster than could be calculated when only water permeation is considered.
- The petroleum in the ground-water is smeared through the soil column by the rising and falling groundwater table. As such, it will provide a continual source of re-contamination for the ground-water as the water table rises and falls. The existing solutions under development by the plant will do little to solve this problem. The plant will be collecting and treating the ground-water for years at a very high long term cost.
- There are a number of mass transport considerations and literature references which suggest that the presence of free product on the surface of the ground-water and the saturation of the ground-water may lead to diffusive penetration of the aquaclude which may contaminate deeper aquifers if any are present.¹⁶

¹⁵One pore volume of soil is equal to about 25-40 percent of the total volume of the soil, or exactly equal to the space between the soil particles.

¹⁶The issue relates to the ability of the materials to be adsorbed on clays, their oil-water partitioning coefficient and diffusion and advective considerations involving Fick's second Law. A discussion of the issue can be found in USEPA's "Transport and Fate of Contaminants in the Subsurface," Publication Number EPA/625/4-89-019.

71

- **The ground-water remediation efforts at DKV are expensive, and they have committed to a long term program which may not be as effective as could be hoped. There are more rapid, more effective solutions for recovery of the material from the ground-water at a substantially lower total cost.**
- **Vapor stripping of the soil is rapidly finding acceptance within the US. The vapor stripping volatilizes the petroleum in the soil moving it into the vapor phase. The rate of product removal is between 10 and 500 times greater than the removal of gasoline and product by pump and treat or gravity methods. If the plant needs to recover some of the product, it can either condense the material or it can use it directly to fuel supplement.**

5.6.4 Ground Water Contamination Solutions

DKV is very aware of the problems and possible solutions regarding the treatment of ground-water and the recovery of the free product in the ground. The solutions currently being implemented are expensive and may not be protective of the environment in the long term. DKV needs to develop some expertise of its own in handling and treating ground-water contamination problems. In order to accomplish this, the facility will need to augment their environmental staff with equipment, money, and personnel and assign them the responsibility for investigation and development of alternatives which will provide faster treatment of the soil and better recovery of the material spilled.

The DKV refinery should consider the vapor phase extraction of hydrocarbons from the ground-water. The vapor phase extraction of the soil is a simple technique and can remove the free product levels in the soil down to a trace or less within a matter of days to months. The recovered vapor can be condensed and recovered as product, or it can be burned as an supplementary source of energy.

The refinery should line the waste-treatment lagoons. The lining will stop the leaching of oils from the sediments and sludges in the lagoons into the ground. Current U.S. practice and policies for waste treatment and disposal lagoons require the lining of waste treatment lagoons.

The DKV refinery also needs to develop a comprehensive flow model of the refinery ground-water and vadose zone systems. The terrain is complex and the ground-water flows are equally so. The refinery needs to develop a comprehensive model of the ground-water regimen which is supported by computer modeling studies. This computer model will be a tool which will enable effective management of their ground-water problems, control costs, and develop effective recovery programs.

As an example of the types of information which can be obtained from elemental ground-water and computer modeling is shown in the appendix to this report. In that example, an arbitrary set of coordinates in the extreme southwest corner of the DKV refinery was selected with the axes of the grid parallel to the principal roadways in the refinery. When the grid was established, the approximate coordinates of the ground-water monitoring wells

were determined by scaling them from a small map. The thickness of the free product levels in meters was obtained from a June, 1990 well survey. The survey data was plotted using SURFER, a computer aided graphics package. The results show the approximate contours of the free product in meters over that section of the plant. The results show areas where the concentrations are the highest, and provide a realistic picture of the status of the contaminant levels. This type of information can be used to guide the recovery work.

As was mentioned above, a Flame Ionization Detector or Photo Ionization Detector (FID or PID) can be used to survey suspect spill and leak sites and develop a rapid quantification of the amount of ground contamination. The surveys are routinely conducted in the U.S. at the site of spills and leaks from underground storage tanks. The surveys, when supported with limited hydrogeologic investigation have proven economical and accurate. Information about this equipment is being transmitted to the refinery separately from this report.

The refinery should consider developing methods for the treatment of the dissolved hydrocarbons in groundwater. The contaminated groundwater can be recovered by placing it in the biological treatment facility or it can be recovered by direct air or steam stripping. Biological methods of soil remediation can also be used to treat the groundwater. Biological methods of treatment are proving to be the most cost effective of all methods because they are the only methods capable of lowering the contamination levels in the ground without resorting to incineration.

5.7 Solid and Hazardous Wastes

The DKV refinery generates approximately 50,000 metric tons of hazardous wastes per year. About 60% of the facility's hazardous waste is recycled or reclaimed through use of the on-site rotary kiln incinerator. The incinerator has an annual capacity of approximately 290 GigaJoules per year, and it uses plant fuels which are supplemented with trash from the surrounding community.

During a typical year, the hazardous wastes generated by the facility are approximately as shown below:

<u>Waste Description</u>	<u>Approximate Percentage Breakdown</u>
Oily Sludges	63.3%
Tank Bottoms	16.1%
Incinerator Slag and Ash	8.0%
Centrifuged Sludge from API Separator Bottoms	3.7%
Acid Tars High in Sulfur	2.6%
Miscellaneous Paraffins	2.5%
Other Wastes Contaminated with Oils (including contaminated clothes, filter sands, and other materials)	3.8%

13

The refinery is required to test most of its hazardous wastes. The hazardous waste testing program costs approximately 30,000 Huf (or about \$ 4,132) for each waste stream. The testing program appears to be adequate as it includes analyses for heavy metals, organic compounds, and includes an long term bioassay which must consider the effects of the substances in the waste on fish, algae and wildlife.

Many of the oily sludges which are generated at the waste water treatment lagoons, particularly those materials which have oil contents between 10% and 15% are often re-refined. The tank bottoms generally have a very high heating value and must be diluted before destruction. The refinery does have some problems with the handling of specific waste streams such as the acid tars, which are very corrosive and must be handled carefully to avoid worker exposures.

5.8 Conclusions

The Dunal Killajipari Vallat has a number of significant environmental problems which all appear to be serious and expensive to correct. By far the most serious problems are associated with air pollution because they already are making an impact on the health of the local communities, and that impact has been documented by qualified medical personnel. The other problems -- massive groundwater contamination and a waste-water treatment problem are not immediately threatening to the public health over the short term. If forced to choose between placing emphasis on either of the latter two problems, the ground water contamination problem will have the longest term and greatest cost impacts. The refinery's environmental control priorities and efforts should be placed on air pollution control, ground-water control, and water pollution control.

Many of the air pollution control problems in the area surrounding the refinery cannot be solved without the cooperation of the adjacent power plant. Specifically, the problems of sulfur dioxide control and particulates within the community must be addressed by the refinery and the power generation plant working together.

The refinery management needs to consider the fact that the refinery emits over 4,000 tons per year of sulfur oxides, and over 2,500 tons per year of hydrocarbons. The amount of sulfur dioxide released by the refinery will be substantially reduced when the new Claus unit is installed as the FCC unit is upgraded. The total reduction in sulfur dioxide emissions may be between 2000 and 3000 tons per year. Additional improvements can still be made by adding additional stages to the existing Claus units and adding alkaline scrubbing for the Claus tail gas. Some of the best control technology can produce tail gas from the Claus unit which is on the order of 200- 250 parts per million by volume. The refinery can achieve significant reductions in sulfur dioxide by implementing careful selection of technology and alkaline scrubbing.

The hydrocarbon issues were thoroughly discussed above and alternatives to the installation of floating roofs on the various product tanks was also discussed. The refinery needs to consider the potential use of chiller/condenser systems carefully, as they may be useful not only in the recovery of hydrocarbons from tanks, but may also be used to recover free product from the ground.

If the refinery elects to utilize vapor stripping for recovery of hydrocarbons from the ground and combine it with vapor condensation, it is likely that the ultimate quantity of material recovered will be well into the hundreds of thousands of cubic meters. The vapor

recovered can either be condensed and recovered as free product or it can be used as a supplemental fuel at various locations in the refinery.

The environmental regulations within Hungary will increase significantly over the next few years. The refinery needs to act now and in a decisive manner to upgrade its environmental control staff's capabilities, laboratory facilities, and modeling tools, and develop a proactive rather than a reactive policy toward environmental matters.

Based upon observations of the environmental activity in the United States over the last twenty-five years, the only way in which the DKV refinery can develop an effective proactive environmental control program is to lead the Ministry of the Environment on technical issues, rather than wait for the Ministry to make the decisions for them. The major U.S. companies which have a pro-active environmental policy in the U.S. are also some of the most consistently profitable industries.

The DKV needs to coordinate environmental planning with environmental measurements and develop a revolving capital budget for environmental affairs which is reviewed and revised about every 6 months. The budget process should be coordinated with a periodic bi-yearly meeting with the Ministry of the Environment and should consider the new regulations which are in the planning stages. Where the refinery has adapted the latest in control technology, that technology should be recommended to the ministry for adoption by others.

The DKV refinery's existing environmental staff is qualified to handle the tasks of conducting the necessary surveys and making the needed measurements if they receive adequate manpower and capital from the refinery. In fact, the refinery's environmental staff are among the more qualified environmental personnel we have encountered, even when compared to U.S. refineries.

5.9 Recommendations

The following recommendations need to be implemented in order to allow the DKV refinery to develop an more effective environmental control program and solve some of its existing environmental problems.

5.9.1 Management and Organization

- The environmental staff director should be enlarged, provided with an improved laboratory and test facilities and computer modeling tools necessary to serve a modern refinery.
- The environmental director and staff should be charged with the responsibility of developing an environmental master plan which addresses the existing status of the refinery with regard to proposed environmental standards and an implementation plan to address the capital needs and timing of improvements.
- The environmental staff should be given the responsibility and manpower and equipment necessary to conduct a plant-wide survey and make actual measurements to determine the plant emissions into the air and into the water and into the ground.

5.9.2 Air Pollution Control

- **The refinery needs to install the necessary sampling ports on existing process equipment.**
- **The refinery needs to obtain stack testing and ambient air monitoring equipment to enable them to make actual emission determinations on the various sources throughout the facility.**
- **The refinery needs to consult with the nearby power plant to establish an air monitoring program which includes particulates, sulfur oxides, and other appropriate gasses including hydrocarbons**
- **The refinery needs to obtain and use an acceptable long and short term air quality models. (K & M is making arrangements to obtain the models for DKV.) DKV needs to obtain necessary meteorological data and run these models on a computer.**
- **DKV needs to review and refine its sulfur emission estimates with regard to the current emission levels and the impact of proposed improvements, the addition of the new Claus plant, and the upgrading of the FCC.**
- **DKV needs to reconsider the control strategies for the reduction of hydrocarbons from the storage tanks. Inert gas blanketing of the vapor space above the petroleum storage tanks should be considered. Vapor space condensation systems should be implemented in lieu of installation of the floating roofs to reduce total hydrocarbon emissions from the facility.**
- **DKV should implement a fugitive emission control program to reduce the volatile losses of hydrocarbons from such sources as leaking valves and fittings, pump seals, piping flanges, the refinery sewer system, the waste water treatment lagoons, and the API separators.**

5.9.3 Groundwater Control

- **The refinery needs to develop its own in-house hydro-geology and geologic capabilities with regard to the recovery of petroleum from groundwater.**
- **The refinery needs to investigate and implement vapor stripping techniques for the treatment of contaminated soils.**
- **The refinery needs to acquire and utilize groundwater transport and vadose zone transport computer models to optimize the recovery of gasoline and other contaminants which it can remove from the ground.**
- **The refinery needs to acquire either a Photoionization Detector or a Flame Ionization Detector to investigate the leaking pipelines around the plant.**
- **DKV needs to acquire a portable gas chromatograph and use it to begin conducting vapor surveys to detect the extent and direction of the petroleum contaminant plumes now beneath substantial portions of the plant.**

- **DKV should develop a comprehensive spill control and cleanup policy to insure that leaks and spills, when they occur, are quickly cleaned up.**

5.9.4 Water Pollution

- **The performance of the chemical treatment regimen and the API separators needs to be optimized to increase oil recoveries.**
- **The API separators need to be rehabilitated.**
- **The API separators will ultimately need to be covered to reduce hydrocarbon air pollution arising from them.**
- **The refinery should perform a detailed waste and water balance on the plant to support the upgrading of the waste-water lagoons.**
- **The refinery needs to purchase or acquire portable flow metering equipment and waste water sampling equipment.**
- **DKV needs to begin work on a pretreatment plant to remove substantial quantities of oil from the wastes before they are sent to the waste-water treatment lagoons.**
- **DKV should line the waste treatment basins with an impermeable membrane liner to reduce the flow of contaminated waste-water through the sides of the basin into the ground.**
- **DKV needs to implement long term continuous monitoring of the waste water effluent to accurately assess and reduce the aquatic toxicity of the effluent.**

5.9.5 Environmental Laboratory

- **The environmental laboratory needs to be upgraded with substantial amounts of new analytical equipment and training for the personnel. The equipment should include 1) a Gas Chromatograph, 2) a Gas Chromatograph/Mass Spectrograph, 3) a Atomic Adsorption Analyzer with graphite furnace capabilities or an Inductively Coupled Plasma Analyzer.**
- **The environmental laboratory should receive additional personnel and facilities necessary to house and utilize the equipment recommended above.**

TABLE 5.1

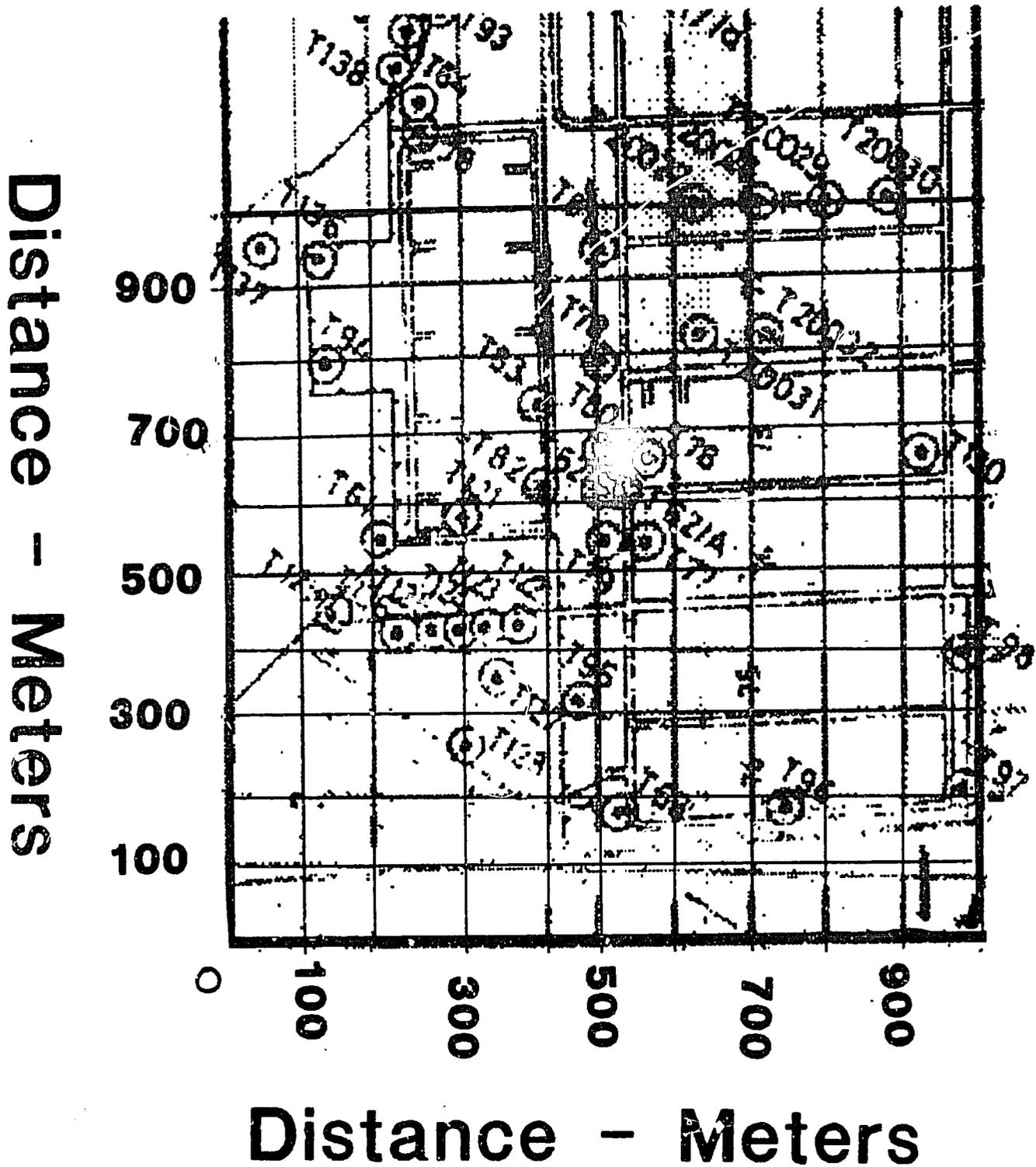
FREE PRODUCT THICKNESS AT DKV - JUNE 1990

	A	B	C	D	E
1	DKV Groundwater Monitoring Data- June, 1990				
2	location	X value	Y value	Depth	Product
3		meters	meters	M	Depth, M
4					
5	61	550	210	12.08	0.05
6	62	550	510	7.45	2.78
7	62A	550	610	7.45	0
8	63	520	180	19.43	0
9	76	580	670	2.43	4.32
10	77	560	560	6.41	1.09
11	78	500	800	8.51	0.21
12	79	550	550	6.8	1.19
13	80	500	680	7.49	1.23
14	81	500	930	7.08	0.89
15	82	390	600	8.84	1.7
16	83	390	730	9.05	0
17	94	120	800	8.32	0
18	95	470	320	17.73	0
19	96	730	190	22.82	0
20	97	980	200	13.78	0
21	98	980	400	10.44	2.02
22	121	300	550	6.51	0
23	122	370	440	16.4	0.1
24	123	320	440	14.95	0
25	124	290	440	14.98	0
26	125	260	440	14.9	0
27	127	340	360	16.14	0
28	128	300	260	16.05	0
29	129	130	460	13.98	0
30	130	920	570	6.2	0
31	136	110	940	13.21	0
32	137	50	950	11.81	0
33	20027	520	1000	5.81	0.21
34	20028	700	1000	6.09	0.03
35	20029	800	1000	6.19	0.01
36	20030	890	1000	6.41	0
37	20031	630	820	6.03	0
38	20032	710	820	6.26	0.02



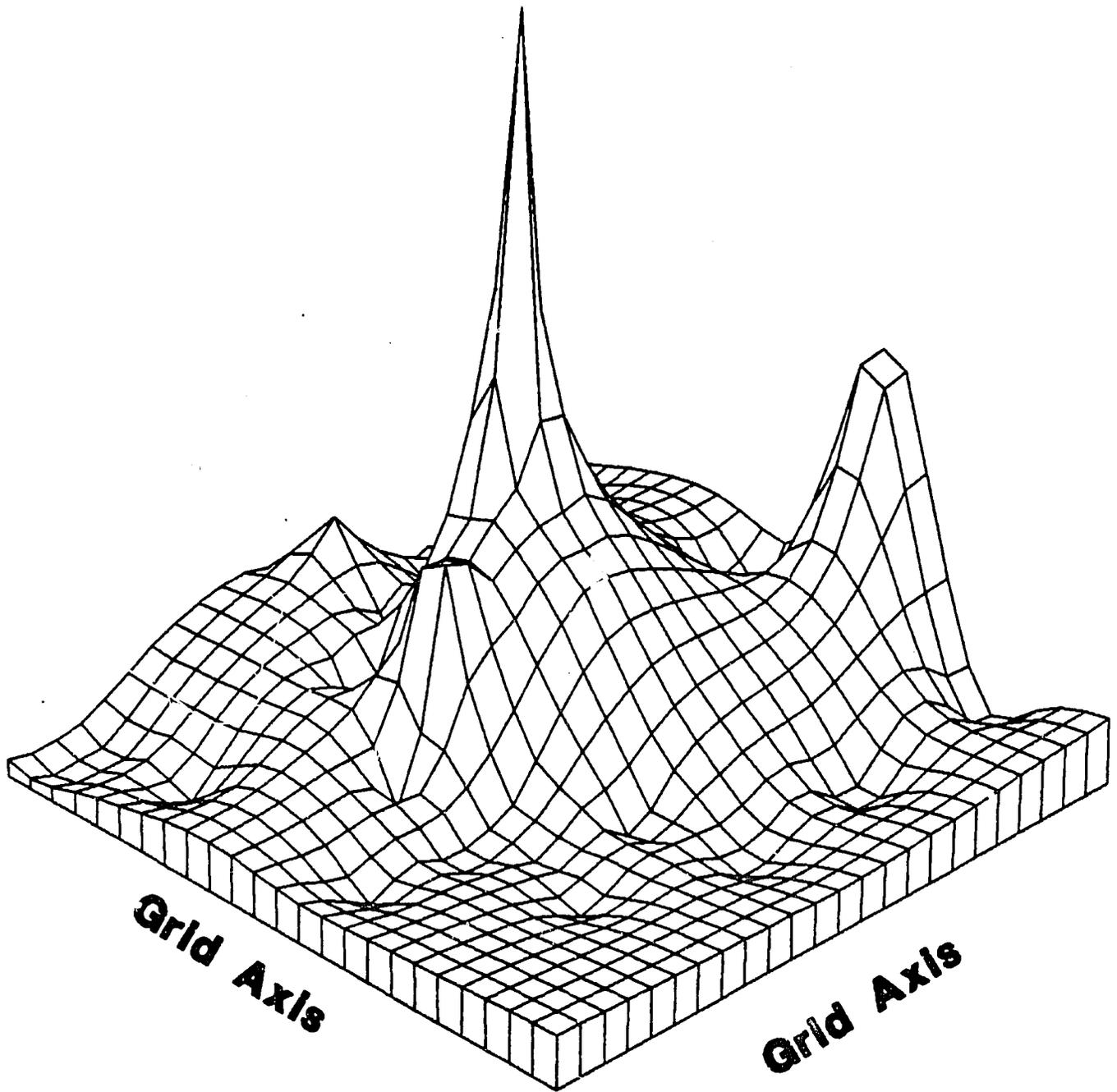
FIGURE 5.1

Grid Map of Monitoring Wells



79

Topographic Map of Ground-Water Contamination -- S.W. Corner of DKV Refinery



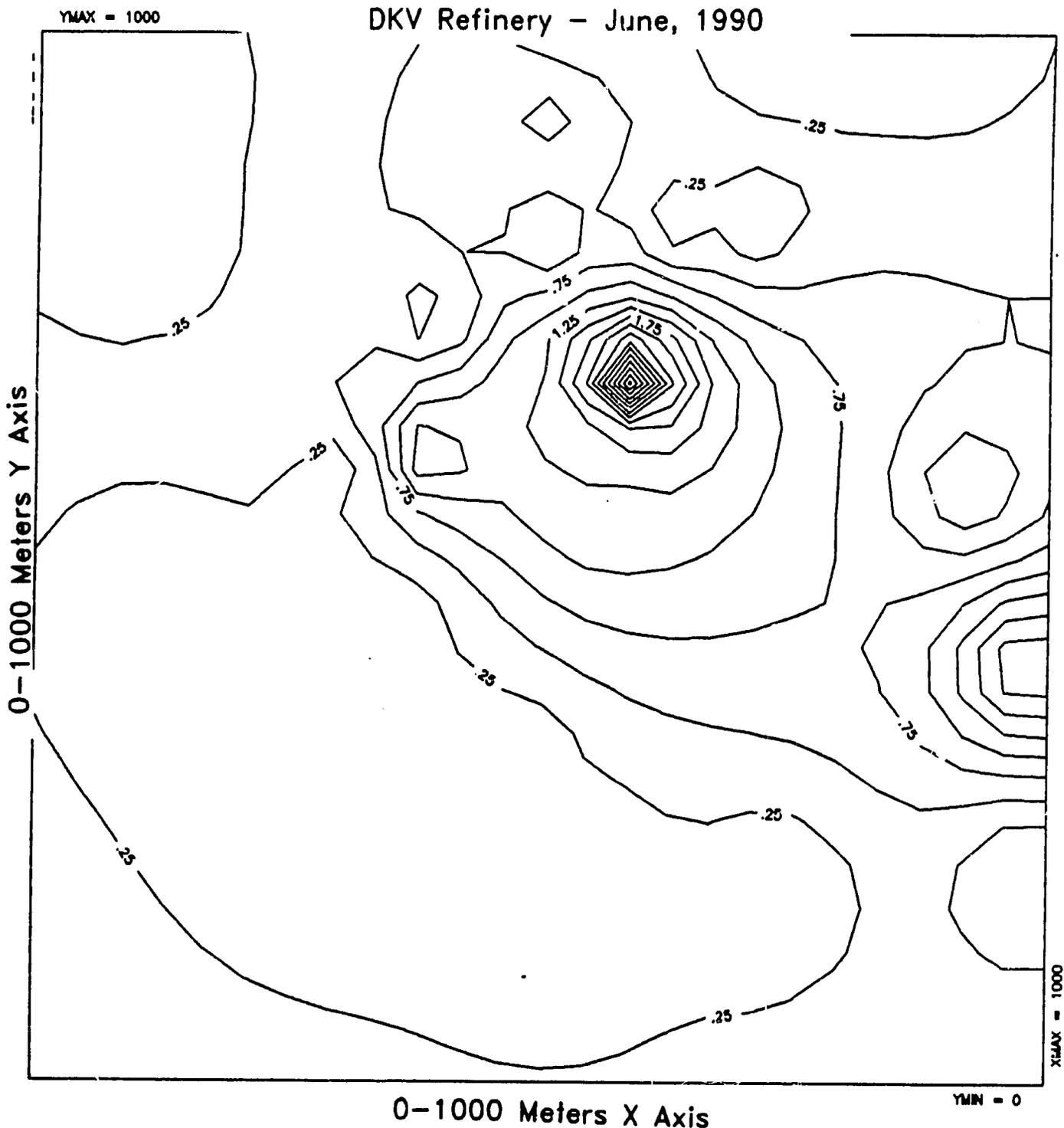
80

FIGURE 5.3

Topographic Map

Free Product Petroleum Depths

DKV Refinery - June, 1990



6.0 TIFO REFINERY-ANALYSIS OF PROCESSING FACILITIES AND OPERATIONS

6.1 Interdependency with Other Facilities

The Tisza Petroleum Refining Company (TIFO) Refinery is located in the northeast corner of Hungary, near the town of Tiszajvaros approximately 50 miles from the Soviet border. Processing of crude was initiated at the refinery in 1979, to achieve the following set of objectives:

- (1) To supply virgin naphtha to the adjoining Tisza Chemical Works (TVK) as a feedstock for cracking to olefins.
- (2) To supply motor gasoline to the northeast section of Hungary. The gasoline product is composed of hydrocarbon components from both the refinery and petrochemical works.
- (3) To supply fuel oil to the adjacent Tisza Power Station (TEV) for power generation.

Currently, the operation of the petroleum refinery is closely integrated with the operation of the petrochemical works and the power plant as illustrated in Figure 6.1. The TIFO refinery provides the following petroleum fractions to the petrochemical and power generation operations.

- (1) Virgin naphtha for steam cracking at TVK.
- (2) Hydrotreated atmospheric gas oil for steam cracking at TVK.

The TIFO refinery is also dependent upon both the chemical works and power plant for various utilities and hydrocarbon fractions as outlined below.

Utilities

- Steam from the TEV power station
- Filtered and pretreated water from the TEV power station (Boiler feed).
- Electricity from the TEV power station.
- Hydrogen from the TVK chemical works.
- Nitrogen from the TVK chemical works.
- Drinking water the TVK chemical works.

Hydrocarbon Fractions (See Figure 6.1)

- Stream of C4 hydrocarbon from steam cracking from TVK for production of Methyl Tertiary Butyl Ether (MTBE). The unreacted C4 raffinate is returned to the chemical works.
- Pyrolysis gasoline for use in motor gasoline blending.

92

6.2 Crude Oil Supply and Product Demands

The primary supply of crude oil to the refinery is of Soviet origin. This Soviet export blend crude is transported via the Friendship II pipeline which enters Hungary at its northeast border with the Soviet Union. The TIFO refinery has access only to crudes that can be transported via the Friendship II pipeline which can also be used to move crude west to the DKV refinery. However, the Friendship II pipeline is not connected to the Adriatic pipeline which supplies non-Soviet crude to DKV.

Because of declining crude production in the Soviet Union, the supply of Soviet export crude to TIFO has been restricted. In addition, factories which operate on fuel oil from TIFO have seen their production curtailed by 25% or more due to a reduction in demand for various products in the Soviet Union. To further complicate this issue, Hungary purchases electricity from the Soviet Union for foreign exchange. The cost of this electricity (\$0.06/Kwh) exceeds the available cost of electricity generated in Hungary (\$0.045 - \$0.05/Kwh) by 20% to 33%. The curtailed power generation capacity in Hungary could be operated with fuel oil from TIFO.

Due to the diminished demand for fuel oil, the TIFO refinery with its current configuration could not process more crude oil even if it was available. The demand for fuel oil is the bottleneck for the refinery. As a result, the refinery is currently operating at a capacity utilization rate of 50% to 55% on a daily basis and 30% on an annual basis when shutdowns are taken into account.

The TVK chemical plant is the primary consumer of TIFO naphtha and part of the gas oil production. TVK was originally designed to use naphtha in their crackers for olefin production but recently two cracking furnaces have been adopted to accept an atmospheric gas oil feed. The current feedstock requirement for TEV is shown below:

Chemical naphtha	600-700 million tons/yr
Atmospheric gas oil	300-400 million tons/yr

The naphtha feed stock requirement can be met with contributions from both TIFO and DKV. DKV can supply 300-400 millions tons/yr of naphtha for TVK by pipeline.

It is well recognized that optimum operating efficiency cannot be achieved at the current low capacity utilization rate of 30%. In light of this situation, a detailed survey of unit operations and energy efficiency would not accurately reflect the efficiency potential of the refinery. Therefore, the study at TIFO consisted of a review of the current operational status of each processing unit along with discussion of problems and solutions identified by TIFO personnel. In addition, detailed discussions were held pertaining to the current and future processing requirements of the refinery.

6.3 Refinery Configuration

The original design for the TIFO Refinery envisions an 8 million MT/yr crude processing facility which would include 4 processing complexes. Only the first of these complexes has been built. The design capacity of each is listed on the following page both in metric tons per year and in approximate barrels (42 gallon) per day.

<u>Unit</u>	<u>Design Capacity</u> (Thousand MT/Yr)	<u>Design Capacity</u> (Barrels/Day)
Atmospheric Crude Distillation	3,000	60,000
Vacuum Crude Distillation	1,600	27,700
Atmospheric Gas Oil Desulfurizer	700	14,400
Merox Treating	150	3,500 **
LPG Sweetening	50	NA
Sulfur Recovery	7	22 T/D
MTBE	30	750

** Merox is currently shut down because of low mercaptan levels.

The crude distillation complex units were completed in 1979, two additional units have been added at the site. The methyl tertiary butyl ether (MTBE) unit was constructed and a 3,000 t/yr isobutylene unit in 1987.

6.3.1 Crude Distillation Unit

The crude distillation complex includes both atmospheric and vacuum distillation. The atmospheric tower contains 50 valve trays and operates well. The cuts from the atmospheric portion of the distillation unit are listed below along with the disposition of these streams.

<u>Fraction</u>	<u>Disposition</u>
Isopentane	Motor Gasoline Blending
Naphtha	Steam Cracking at TVK
Kerosene	Diesel Fuel/Light Gas Oil for Steam Cracking
Atmospheric Gas Oil	Desulfurization To: 1. Gas Oil For Steam Cracking 2. Sale as FCC Feedstock

The vacuum tower contains 25 bubble cap trays and provides the following cuts:

<u>Fraction</u>	<u>Disposition</u>
Vacuum Gas Oil	Sold as FCC Feedstock - Possible Desulfurization Sold as High Sulfur/Low Viscosity Fuel Oil
Vacuum Tower Bottoms	Sold as High Sulfur/High Viscosity Fuel Oil

A one-year material balance for the crude processing complex at TIFO is presented below, as well as illustrated schematically in Figure 6.2.

**One-Year Material Balance for
TIFO's Crude Processing Complex**

<u>Feedstocks</u>	<u>Thousand Metric Tons</u>
Crude Oil	1500
Imported High-Sulfur Fuel Oil	300
Hydrogen	3
 <u>Products</u>	
Motor Gasoline Components	15
Naphtha for Steam Cracking	290
Diesel Oil/Gas Oil for Steam Cracking	550
FCC Feedstock	140
High-Sulfur Low-Viscosity Fuel Oil	170
High Sulfur High-Viscosity Fuel Oil	610
Sulfur	4

TIFO personnel have identified a number of projects for improving the operational and energy efficiency of the crude distillation complex. The current configuration does not include a pre-flash tower before the atmospheric tower. No detailed study was presented for this proposed modification but it is believed that the economics would be favorable. Also, TIFO is currently studying the possibility of revamping the vacuum tower to remove the bubble cap trays and replace them with a structured packing. The purpose for the project would be to increase the yield of vacuum gas oil and potentially reduce energy consumption. It has been estimated that the investment will be recovered within one year of operation.

In general, the control system for the crude complex uses older generation electronic controllers. This control equipment is quickly becoming obsolete as spare parts become more difficult to obtain. The control system for the crude distillation section should be upgraded with modern technology. With the installation of advanced control equipment, the operators will be able to make sharper cuts off of the towers. This will enhance recovery of product fractions to the optimum boiling range, improve product quality, and result in enhanced energy efficiency.

Note: Evaluation of a control system upgrade for the crude complex is one area where additional assistance can be provided on a short-term basis.

6.3.2 Gas Oil Hydrodesulfurization Unit

The atmospheric gas oil from the crude unit flows to a desulfurization unit. In addition, some portion of the vacuum gas oil can also be diverted to the desulfurization unit. There are two reactors in the HDS section of this unit. The first reactor contains Shell 424 (Nickel-Molybdenum) catalyst and the second reactor contains a Soviet (Cobalt-Molybdenum) catalyst. The unit operates at an operating pressure up to 50 bars (approximately 750 psia) with a hydrogen partial pressure of 40 to 42 bars (600 to 630 psia). The purity of the hydrogen received from the chemical works has a purity in the range of 87% to 90%. Approximately 90% desulfurization of the gas oil is achieved, which results in a product containing 0.1 to 0.15% sulfur.

The question was raised whether the existing equipment can be configured to provide saturation of aromatics in gas oil. The gas oil currently contains 26% to 28% aromatics by weight. Saturation of the aromatics content to less than 10% by weight would lower the level of aromatics in the pyrolysis fuel oil. At the operating pressure of the gas-oil hydrotreater, some saturation of poly-aromatics to mono-aromatics will occur, although overall aromatics reduction will be minimal. Several references are attached.

The burners in the HDS feed furnace were recently changed to achieve better energy efficiency. TIFO personnel have also identified that they should install an air preheater for this furnace to further improve energy efficiency. However, no money is available for this project at this time. TIFO personnel also mentioned that one option for future consideration would be the installation of a hot separator.

TIFO also mentioned filtering problems in the MEA/DEA system, and have identified a potential solution to this problem with the use of filter technology provided by Pall.

6.3.3 LPG Sweetening

The refinery contains a 50,000 metric ton per year capacity for the desulfurization of propane and butane. In this process flow, the light naphtha from the bottom of the stabilizer tower is transferred to a redistillation tower. At this tower, the isopentane is driven overhead for recovery as a gasoline blending component. Consideration is being given to changing the internals from trays to structured

packing. It has been estimated that with the changeover to structured packing, the number of theoretical plates would be increased from 27 to 52. This would enhance the purity of the isopentane being recovered and reduce the RVP of this component by virtue of better light ends removal.

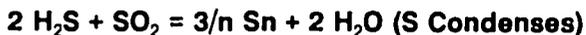
Note: No comment can be provided regarding the economic attractiveness of revamping the tower without close examination of data from the current operation and the design calculations.

6.3.4 Claus Sulfur Recovery Unit

The TIFO refinery operates a 7,000 metric ton per year Claus unit which recovers gas phase sulfur generated during the desulfurization of gas oil. The TIFO unit consists of two catalytic stages. A conventional Claus unit consists of a thermal stage followed by two or three catalytic stages. In the thermal stage, one-third of the hydrogen sulfide gas is oxidized to sulfur dioxide. The reaction is shown below:



The remaining portion of the hydrogen sulfide gas reacts with the sulfur dioxide to form elemental sulfur in the catalytic stages. This reaction is shown below:



Sulfur recovery in a two-stage Claus plant is typically in the range of 90% to 96%. Higher recoveries cannot be achieved because of equilibrium considerations, water dilution of the reaction mix, and difficulty in achieving the correct 2:1 stoichiometric ratio of H_2S to SO_2 . As a result, the tail gas from the TIFO sulfur recovery unit often contains either unreacted SO_2 or H_2S . When sulfur dioxide is emitted from the stack, it condenses with moisture in the air to form sulfurous acid.

TIFO personnel believe that environmental control considerations will require that sulfur emissions be significantly reduced, and have proposed two schemes to accomplish this.

The first scheme involves the installation of a sulfur dioxide analyzer on the tail gas stream to provide feedback to an air flowrate control valve. This would keep the relative amounts of H_2S and SO_2 in close balance and minimize the amount of SO_2 vented to the stack. However, for a number of reasons cited above, it will be difficult to eliminate all SO_2 emissions from the tail gas stack.

The second scheme involves the addition of a Superclaus stage to the sulfur recovery unit. Superclaus involves direct reaction of H_2S with oxygen to form elemental sulfur directly. Minimal sulfur dioxide is formed during this process. This technology can be applied in existing sulfur recovery plants by adding the new catalyst to the last Claus reactor or to a new third stage.

After further review of the situation, a number of analyzer and additional process options have been identified. A number of refiners in the U.S. successfully use tail gas analyzers to feedback to the air control valve. A number of SO_2 and H_2S analyzers are currently being used, and a listing of these is shown below.

- **Western Research Model 700 Analyzer**
- **DuPont Model 460 Analyzer**
- **DuPont Model 462 Analyzer**
- **Anarad Model 930 Analyzer**
- **Thermal Electron Model 40 Pulsed Fluorescent Analyzer**

In addition to the use of an advanced control scheme, or the use of an additional reaction section, there are a number of other post recovery treatments that may be worthwhile to explore. These include:

- **Beavon Sulfur Recovery/MDEA Process for SO₂ recovery from tail gas.**
- **SCOT Process for sulfur recovery from tail gas.**
- **Modop Process for SO₂ recovery from tail gas.**
- **Solinox Process for SO₂ recovery from tail gas.**

In addition, there are numerous options for the removal of excess H₂S from a tail gas stream if the unit is operated in an oxygen-starved mode.

Note: There are a large number of U.S. technologies that could be used to solve the problem. This is an area which will provide opportunities for both short-term improvement (purchase and install an analyzer) and long-term improvement (addition of a treatment section). A fairly detailed study would be required to complete a survey of existing technology and to develop comparison economics.

6.4 Gas Processing and Air Pollution Control Problems

In addition to reduction of SO₂ in the sulfur plant tail gas, there are a number of other gas processing emission concerns which need to be addressed in the near future.

The tail gas from the vacuum tower is of poor quality and TIFO would like to burn this in the atmospheric tower heater. However, this material contains a large amount of H₂S. If MEA scrubbing will be used to remove the H₂S from the combustion gas, what will be the impact of oxygen on the amine solution.

Many of the process heaters are fired with natural gas, so that sulfur dioxide emissions are typically not a problem.

One problem area is the emission of hydrocarbon vapors which are carried to the wastewater treatment plant in emulsion with the water. The problem of emulsion primarily occurs when fuel oil and slop oil must be added to the desalting process. Since the plant does not have the option to bypass the desalter with these streams, oil is often carried over to the wastewater treatment plant. TIFO personnel have proposed the installation of a roof on the wastewater treatment plant along with condensation and recovery of the

process vent. The emulsion problem is further discussed in the environmental section of this report.

6.5 Future Processing Considerations

Currently, TIFO has no facilities for the conversion of vacuum gas oil and residual oil fraction, nor does it have pipeline access to lighter crudes. Thus it has not been able to adjust to a shift in product demand. A decrease in fuel oil demand has resulted in refinery throughput being backed down. In order to increase both the capacity utilization (crude run) of the existing equipment and profitability of the overall facility, some form of conversion capacity is required. The ability to convert heavy fuel oil to lighter products will provide refinery personnel with the capability to shift the product output as market conditions fluctuate. This flexibility in the refinery processing scheme will provide TIFO management with many options that did not previously exist.

TIFO has proposed the construction of a hydrocracking unit for the processing of vacuum gas oil. This material is currently being sent to DKV as FCC feedstock after hydrotreating or sold as fuel oil. Typically, vacuum gas oil commands a much higher value if it can be converted to lighter products such as gasoline and diesel fuel. In the case of the TIFO refinery, there is an additional option available for increasing product value. The hydrocracker configuration under consideration would yield a hydrogen-rich gas oil which would make an excellent feedstock for steam cracking. At the current time, TIFO management believes that TVK would like to acquire additional high quality feedstock. Therefore, it is projected that the hydrocracked gas oil would have a value similar to that of gasoline. Under this scenario, the installation of a hydrocracker at the TIFO refinery would represent an excellent addition to the current processing scheme. If hydrogen of 87% to 90% purity from the chemical which to be used were recommended considering from the of hydrogen purification in the development of a project scope.

TIFO has received a licensing proposal for the Unicracking hydrocracker technology developed by Unocal corporation. Three capacity options have been considered and are listed below:

- 500,000 Metric Tons/Year (10,000 BPD)
- 650,000 Metric Tons/Year (13,000 BPD)
- 800,000 Metric Tons/Year (16,000 BPD)

The construction cost for the 650,000 Metric Tons/Year case was estimated at \$60 Million U.S. Dollars.

A second area of opportunity for increasing refinery flexibility would be in the processing of heavy high-sulfur fuel oil. The current sulfur level of the heavy fuel oil is in the range of 2.7% to 3.0% by weight. It is anticipated that future demand will be for heavy fuel oil with a sulfur content of approximately 1.0% by weight. TIFO management has proposed the installation of a fixed-bed catalytic unit to hydrotreat the residual bottoms from the vacuum tower.

Although residual oil desulfurization can meet the desired objective of sulfur reduction, only minimal conversion to lighter products can be achieved with this technology. This does not increase the flexibility of the refinery, or provide the refinery with options in the event that the demand for residual fuels drops off considerably nor does it mean the refinery would be producing the product slate that maximize return of investment.

We discussed a number of additional alternatives for processing of the residual fraction including delayed coking and visbreaking. TIFO has surveyed the marketplace and does not anticipate that there would be any appreciable demand for petroleum coke, which is typically used in the fabrication of carbon anodes for aluminum production. We suggested that it may be reasonable to consider the Exxon Flexicoking process as an alternative to delayed coking. Flexicoking is a fluid coking process with an optional stage for gasification of the coke to produce a synthesis gas. Since the refinery is so closely integrated with the operation of the chemical works, it is possible that some demand could be created for such a synthesis gas.

Visbreaking is another option that was mentioned. Conventional visbreaking yields a fuel oil of lower viscosity and tends to concentrate the sulfur in the heaviest portion of the visbreaker product. However, once again, there is minimal conversion of the fuel oil to lighter, higher-value products. In this case, there are recent developments of the visbreaking concept which involve the addition of hydrogen pressure and possibly a dispersed catalyst. This technology is currently offered by IFP, which is a French company. There are similar technologies under development by other companies.

Finally, one emerging trend for the treatment of residual oils would be the installation of an ebullated bed hydrotreater such as LC-Fining or H-Oil as an alternative to fixed bed hydrotreating. An ebullated bed hydrotreater can be run at a much higher severity which results in the conversion of residual oil to lighter products. It is also possible that an ebullated bed unit could be designed larger in order to accept the vacuum gas oil being proposed for processing in a hydrocracker. Although ebullated bed processing is more capital-intensive than fixed bed hydrocracking, the potential combination of two units into one may provide a significant economic advantage.

In summary, in an open market economic environment, TIFO management should consider whether they should even be in the business of producing residual fuel oil. Any one of a number of available conversion technologies may provide sufficient economic incentive for at least considering alternative scenarios. It is our recommendation that a much more detailed process study should be completed prior to selecting a processing strategy for the residual fuel.

A final opportunity for additional processing flexibility would be in the installation of units for the production of environmentally-acceptable gasoline blending components. A number of options are highlighted below:

- Isomerization of a C4/C5/C6 stream for production of isobutane for alkylation feedstock and isopentane/isohexane for high octane gasoline blending components.
- Alkylation of C4 raffinate from MTBE production with the isobutane produced during the isomerization step proposed above.
- Selective hydrogenation and etherification of a C5 olefin stream from the TKV petrochemical works.

These are all conventional processing steps for gasoline reformulation which are widely used in conventional petroleum refineries or are currently under study for the 1990's.

TIFO currently blends gasoline from internal isopentane and MTBE, along with pyrolysis gasoline from TKV, and other purchased components. To produce the quality of gasoline necessary for environmental protection, TIFO will need access to more high quality gasoline blending components such as those that have been proposed above.

6.6 Summary of Survey Observations

The entire survey team toured the general lay-out of the refinery and then separated for a closer look at the areas of individual interest. The processing equipment at the TIFO refinery is modern conventional equipment, representative of equipment used in the West to achieve similar purposes. The processing equipment appears to be well-insulated and well-maintained. The personnel who we worked with were very knowledgeable and possessed strong technical skills. Technical personnel had access to a great deal (but not all) of the technical information which is available in the U.S. The infrastructure of the plant appears to be modern and well-maintained.

In summary, TIFO possesses good infrastructure and conventional processing equipment. The refinery is operated by strong technical management. The primary concerns for this refinery are twofold. First, TIFO is in need of conversion capacity so that the refinery will not be bottlenecked by the swings in demand for heavy fuel oils. Just like every other refinery in the world, TIFO will require significant investment capital to remain competitive. It is our opinion that TIFO personnel do not have the most sophisticated tools available for the evaluation of the various investment alternatives. These tools would include computer-based process simulation models, linear programs for refinery-wide simulation, and access to licensing information from the West.

The second pressing issue is one of crude oil availability. In 1989, 6.5 million metric tons of Soviet crude oil was imported into Hungary. For 1990, the volume of imported Soviet crude dropped to 4.5 million tons. No projections were made available to us for 1991, but recent news reports indicate that Soviet exports of crude oil for 1992 will probably be reduced by 30% to 50%. Alternative sources of crude oil must be secured for the Hungarian refining complex (TIFO/DKV) in order to insure the long-term viability of this industrial sector. For TIFO it would be possible to add pumping capacity and reverse the direction of flow of the Friendship II line between Szazhalombatta and TIFO and thus provide access to crudes coming to Szazhalombatta via the Adriatic line.

In the longer term, TIFO offers an opportunity for growth for the Hungarian refining industry. When the refinery was built it was envisioned to contain 4 processing complexes with a capacity of 8 million tons/year. Only the first of the four complexes were built at the current 3 million tons/year, but most of the support facilities (tanks, product movement, etc.) for 8 million tons/year were installed. The existence of these support facilities would mean a lower investment cost for additional throughput capacity at TIFO vs other sites. The key to pursuing this opportunity is finding and expanding markets in Hungary and in neighboring countries.

FIGURE 6.1

INTERDEPENDENCE OF MAJOR INDUSTRIAL FACILITIES
IN THE VICINITY OF TISZAUJAROS

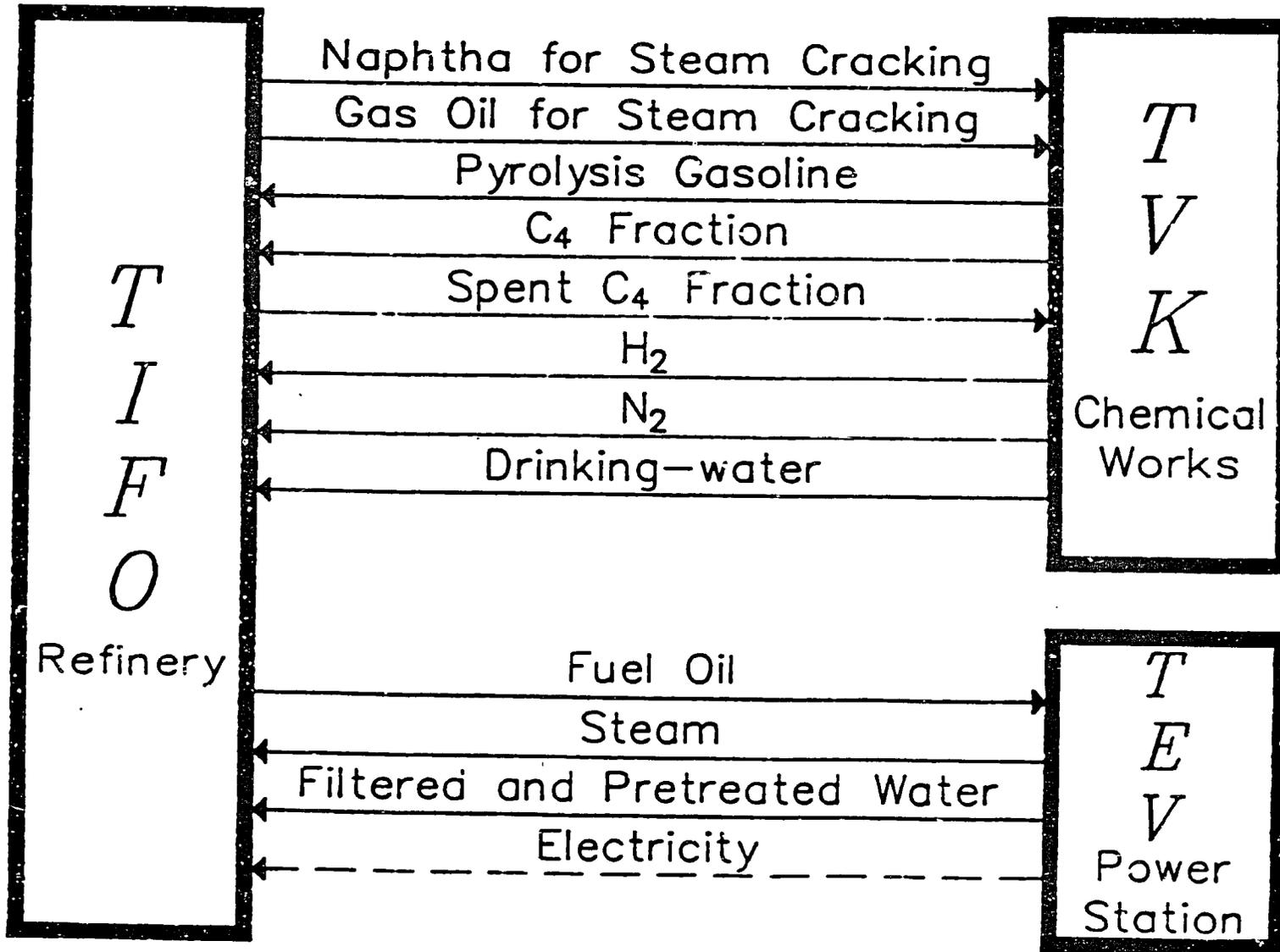
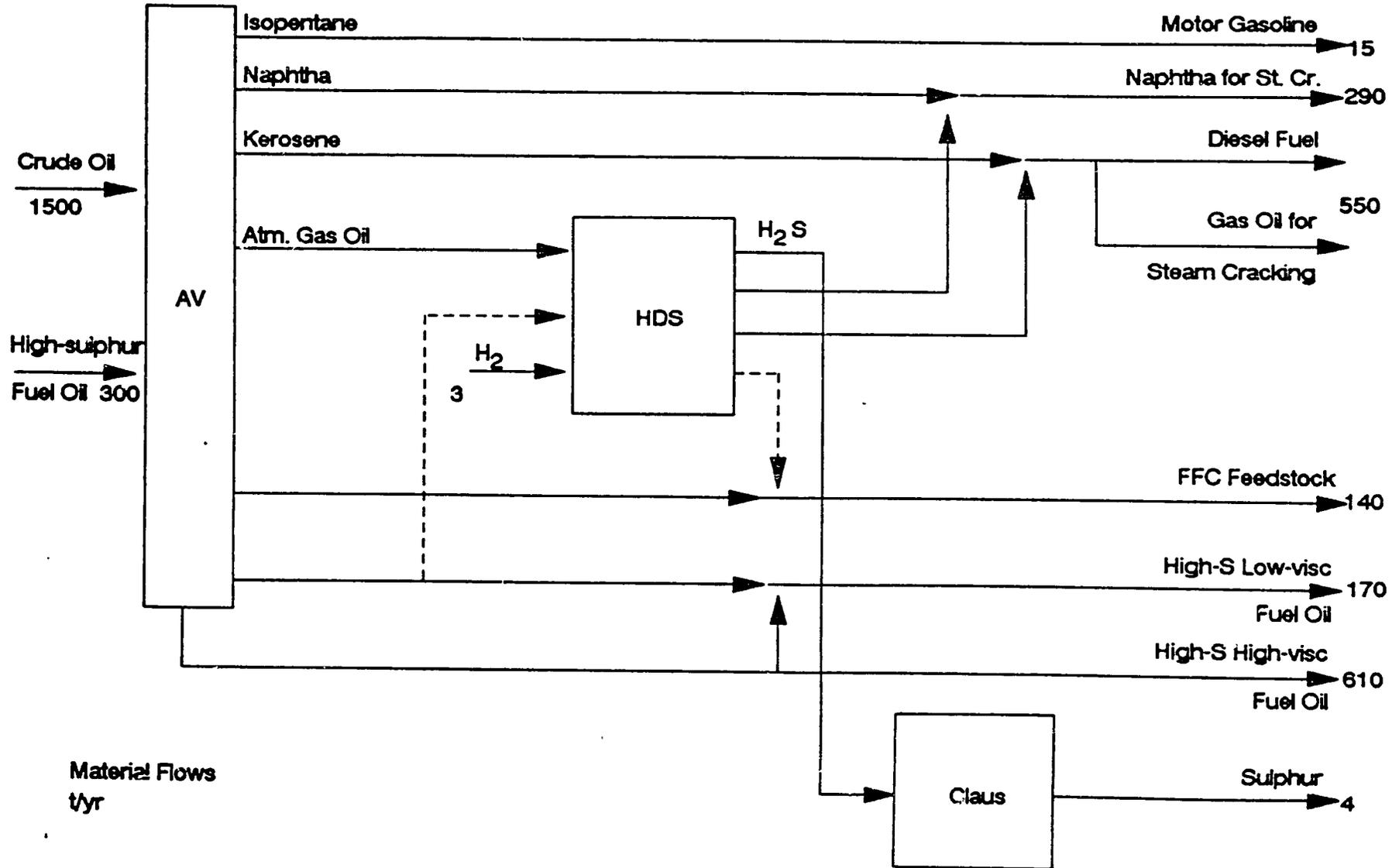


FIGURE 6.2

**MATERIAL BALANCE AND FLOWS
FOR TIFO'S CRUDE PROCESSING COMPLEX, 1990**



Material Flows
t/yr

SOURCE: TIFO Briefing Materials

7.0 TIFO Energy Use and Conservation

7.1 Energy Overview

Like the DKV refinery, TIFO is also served by an adjacent power plant (TEV). In the past energy prices for steam and power have been set and controlled by the government. Steam and electrical energy are delivered from the power plant to the refinery. The refinery contracts with the utility both consumption and demand commitments for steam and electricity and if limits are exceeded, severe penalties are applied. Natural gas is also purchased from an outside source.

Annual energy consumption for the TIFO Refinery is given in Table 7.1. During the last couple of years the throughput rate to the refinery has varied considerably and, as would be expected, the energy consumption per unit of refining feed input increases as feed rate decreases. As can be seen in Table 7.2, when crude input is increased from 210 t/hr (37.3 thousand bbl/d) to 312 t/hr., energy use per ton of crude change decreased from 132.5 mbtu/bbl. to 114.3 mbtu/bbl.

7.2 Current Status of Energy Conservation Efforts

7.2.1 Implementation of Previous Energy Audit Recommendations

Foster Wheeler Iberia performed an extensive energy conservation study at TIFO several years ago. TIFO officials indicated that all recommendations were evaluated for economic pay back and then implemented based on the economic conclusions. Practically all projects were implemented. Efforts were concentrated in the following three general areas:

- **Heat Exchange Optimization**
- **Modern Burner Systems, particularly at the gas oil desulfurization plant**
- **Improved monitoring**

One example included the recovery of waste heat to increase crude oil temperatures entering the system. Another example involved the installation of a heat recovery boiler in their waste incinerator. In addition, flue gases from (3) atmospheric - vacuum distillation units were sent to another heat recovery boiler to generate usable steam.

Steam tracers on "cold" product and water lines were converted to more efficient electric elements and this project remains in progress. Thicker, more efficient insulation replaced insulation where economical.

7.2.2 Energy Monitoring System

An efficient and effective computerized Energy Monitoring System is in place and is being used by operating personnel. Each operating unit is monitored on a daily basis and provides a printout of energy usage for review by the energy department. The printout shows consumptions throughout the twenty-four hour daily period with peaks for both electricity and steam. From this data, coefficients of performance are recorded along with electrical power factors. Power factors at the TIFO refinery were stated at 1.0 (unity). This unusually high but desirable power factor was reportedly achieved through the installation of capacitors.

Both electrical and steam consumption data are accumulated from the first day of each month. In this way, trends can be established and irregularities can be compared with planned consumptions. Appropriate corrective action is taken as needed. Other monitored utilities include natural gas, process gas, boiler feed water, compressed air, nitrogen, soft water and other industrial waters. Separate printouts are provided for each operating unit. The system has been in operation since mid 1988 and appears to meet the satisfaction of management. As mentioned, follow up corrective actions are not automated and must be implemented based on sound management decisions. In this regard, follow up activity response is sometimes slow and improvement can be realized in this area.

In summation, the TIFO energy monitoring system performs effectively and meets expectations of plant personnel. A schematic of the TIFO EMS is shown in the Appendix.

7.2.3 Power Factor Control

Electrical power factor at the TIFO refinery is reported to be near 1.0 (unity). This has been accomplished through the use of capacitors.

7.2.4 Steam Conservation

In general, the TIFO refinery had taken many steps to conserve steam heat losses. For instance, a tour of the facility did not uncover significant heat losses from steam lines, leaky steam traps or areas where large amounts of steam energy was lost. Heated tanks and pipelines were insulated. However, the dollar value of heat losses from tanks and pipelines was estimated at \$208,000/yr. and \$834,000/yr. respectively.

The stretched out physical nature of the plant layout contributes to the amount of heat loss incurred.

7.2.5 Other Efforts

The TIFO refinery has implemented the following procedures in the past to minimize energy usage throughout the plant.

- Refinery by-product and waste gases have been diverted to fired heaters instead of flaring.
- Heat exchange systems between crude oil and product streams have been optimized to recover more heat.
- The majority of conservation items recommended by Foster Wheeler Iberia were implemented.

7.3 Review of Current and Future Energy Conservation Issues

7.3.1 Insulation

Insulation on some pipelines and heated equipment has deteriorated or is not at optimal thickness considering present costs of energy. A program is already underway to replace insulation on a ranking based on the economics of the situation. Since it is physically impossible to examine the integrity of covered insulation, an infrared heat detection device can be used to pinpoint "hot spots" and other deficient areas. In addition, it would be desirable to utilize preformed or removable insulation jackets on valves and heat exchanger heads. In this way, maintenance activity on equipment can be performed at less cost and at the same time expedite reinsulating. Information regarding removable insulation blankets can be seen in the appendix.

7.3.2 Product Line Tracer Control

Many product lines are steam tracer controlled to maintain temperatures of the product in the fluid state. Once the product begins flowing, the inherent heat of the product negates the need for additional external heat from the tracers. The tracers through remain in the "on" mode and excess heat flows into the system.

It would be desirable to have an automatic shut off control installed on the steam tracer system. Although the system would need to be designed, present technology exists to allow a sensor to sense product line temperatures and send a signal to a controller which would in turn shut off the supply steam valve. In this way, steam is not called for when the product line temperature is at satisfactory levels. Design of a system needs to consider the effects of "flashing" when a cold tracer system reactivates and feeds cold condensate into a hot condensate return header.

96

7.3.3 Pump Variable Speed Control

Throughout the refinery, the many pumps used to transport product, etc. operate at inefficient levels due to variable loads. Motors are usually sized to accommodate maximum load conditions and therefore consume excessive electrical power when loads are low.

DC adjustable speed drive devices control the electrical input to motors to vary the speed of the motor/pump set. Such a system can save energy but the economics and associated pay back must be determined for specific cases. Disadvantages of such systems include possible electrical noise that may be imposed to the electrical grid and subsequent low power factors that are incurred from these systems. In some cases, a derating of the motor becomes necessary. These factors necessitate careful and competent design before undergoing conversion to variable drive. International manufacturers of DC adjustable speed drive systems include:

- (1) Siemens Energy & Automation, Inc.
- (2) ASEA Brown Boveri
- (3) CEGELEC Automation, Inc.

7.4 TIFO Energy Issues - Summary

TIFO is very much in tune with the value of energy saving methodologies and has done much in the last ten years to minimize energy usage. Significant staffing and effort is spent on energy matters. The TIFO staff has been diligent in energy conservation matters. The refinery has an excellent energy monitoring system and keeps abreast of developments in the energy conservation field.

Some areas that need further investigation for additional energy savings are:

- Improved insulation
- Product line tracer control
- Variable speed pump control
- Improved methods to detect heat loss through infrared detection.

7.5 Recommendations

The foregoing narrative of this report details various situations that need improvement or have become energy issues. Following is a summary of recommendations resulting from these findings.

7.5.1

Near-Term Suggestions

- **Establish links of communication between refineries to exchange energy technologies and experience.**
- **Install automatic tracer line shut off control on insulated product lines where product can maintain heat of system.**
- **Purchase and use an infrared portable heat detection "gun" to locate insulation weak spots and other heat loss areas.**
- **Using heat detection gun above, insulated pipes, heat exchangers in areas where heat loss is excessive.**
- **Replace steam driven ejectors with electric driven vacuum pumps.**

7.5.2

Longer-Term Suggestions (Over 6 months)

- **Consider DC variable speed control on motor driven pumps. Contact potential vendors in the body of this report.**
- **Further investigate ways to extract usable heat from cooling water. Investigation into previous Westinghouse technology would be a good start.**

8.0 TIFO Refinery - Analysis of Environmental Issues and Solutions

8.1 Introduction

The TIFO refinery is situated in a chemical and power generating complex on the Tisza River. The surrounding communities are predominantly rural, except for the "factory town" of Leninvaros (now Tiszauvaros) which was created at the same time the refinery was built. Most of the workers in the refinery reside in Tiszaujvaros which lies approximately 5 kilometers to the northeast of the refinery, chemical, and power generating facilities.

The environment around the refinery is influenced by the air polluting discharges from the neighboring chemical and power plants and by the community use of high sulfur soft coal. As a result, a number of the environmental problems which were observed in Tiszaujvaros could not be addressed by visiting the refinery alone. The environmental problems in the community must be viewed and approached in a holistic fashion, considering all of the various sources of contamination, and it is our current belief that the refinery may not be a major contributor to the environmental problems in the community.

In the refinery visit, we identified one or more potential air pollution problems, but were unable to ascertain their magnitude or severity. From the refinery visit, and the brief time spent in Tiszaujvaros, we can infer that there may be groundwater contamination problems and water pollution control problems which may be present in the community environment, but which are not related to any activities at the refinery. We observed and experienced a community-wide air pollution control problem, and believe that there may be an impact on community health due to these air pollution problems.

8.2 Comparison of Pollution Control in Hungary with the U.S.

The United States has over twenty years of legislative history in the control of air, water, and land pollution. As a result, there is a substantial body of air and water quality standards which define environmental problems. Hungary does not have the same legislative history or standards.

In Hungary, the air pollution control regulations are approximately at the same point as U.S. regulations were before 1975. The Hungarian equivalent of the comprehensive Clean Air Act does not exist. The numerical air pollution standards which do exist are so high that the affected communities experience acute health problems such as shortness of breath, decreased pulmonary function, persistent bronchial infections and altered blood enzyme levels long before they observe chronic effects such as cancer, leukemia, and emphysema.

In those instances where Hungarian air pollution control standards exist, they are generally much less stringent than comparable U.S. health based standards. For example, the current U.S. NIOSH (National Institute of Occupational Safety and Health) Standards for benzene concentration in the workplace environment are 0.031 milligrams per cubic meter based upon an eight hour weighted average exposure. Various states are in the process of establishing ambient air concentrations which limit the measured ambient air standard on a 24 hour basis to 1/10 to 1/100 of the time weighted average. The NIOSH Standard is already more than 25 times more protective of human health than its Hungarian equivalent. Other NIOSH standards on toluene and xylene are higher than the equivalent Hungarian "protected" values. The individual state standards are more protective than the Hungarian Standards.

In U.S. refineries, the principal sources of hydrocarbon emissions are from leaks in valves, fittings and flanges. The U.S. refineries have been highly regulated and their environmental management staffs are experienced and comfortable in dealing with the complex U.S. environmental control laws. The DKV refinery understands some of the impacts of their air emissions but they do not have the experience in dealing with many of the complex public health problems which occur when people are exposed to several pollutants at the same time.

At the time of our inspection of the TIFO refinery, the facility was operating at about 50% capacity on a daily basis, and about 30% capacity on an annual basis. At those production levels, the emissions from the refinery may not be a significant air pollution source for the community.

6.3 Summary of Current Problems

The TIFO refinery is not a significant environmental contributor to the air quality and other environmental problems which may be present in Tiszaujvaros. As far as could be ascertained, the plant does not perceive the existence of community wide air quality problems, and does not have the monitoring and air emission data which could help to determine the air quality in the community. This is also believed true for the nearby chemical plant and power plant.

Aside from a community wide air pollution problem, the TIFO refinery does not have many other environmental management problems. The plant is relatively new, (approximately 10 years old), and the management has paid attention to the potential problem areas of water pollution and solid waste management. As a result, environmental problems in the refinery are minor.

What environmental problems do exist at the TIFO refinery appear to be caused by process air emissions. The principal emission sources which the refinery identified arise from the desulfurization of fuel and its conversion to sulfur, and emissions from hydrocarbons at various points throughout the plant. The principal gasses released were SO₂, H₂S, and hydrocarbons.

The refinery has no environmental control staff, but relies on the technical manager's staff to interpret and implement environmental policy. Over the long term, this arrangement will not serve the plant management well as the technical staff will have divided responsibilities. Environmental analyses are performed in the chemistry laboratory and not a separate laboratory facility.

The plant management did not identify any water pollution control problems relating to discharges to the Tisza River. The refinery has an extensive waste water treatment plant which is followed by a series of lakes. This system provides substantial residence time and opportunity for the discharge materials to biodegrade before they reach the Tisza River. The refinery is consistently meeting or exceeding water quality discharge limits.

The refinery discussed a problem with oil emulsions arising from the desalting of crude oil. During our visit, we identified specific equipment items and technology which can be used to help control that problem. The suggestions offered included consideration of belt skimmers for recovery of free oil on the surface of the water, and dissolved air flotation units which may be used to remove oil emulsions, and reduce the overall costs of water treatment. Manufacturer's equipment brochures are being sent to the refinery in a separate package.

8.4 Discussion of Air Pollution Issues

Within the refinery, sulfur oxides and hydrocarbon are the principal air pollutants emitted. Both pollutants are emitted from several process sources.

8.4.1 Sulfur Oxides

Sulfur oxides are emitted from the Claus and Vacuum Tower Tailgas units. The Claus converter has two catalytic stages, and the implied sulfur recovery efficiency of the unit is believed to be on the order of 90-96% or better. In the United States, Claus and SuperClaus sulfur recovery units are required to recover more than 99% of the total sulfur sent to the facility. The tailgas stream from the Claus units in the US units runs about 250 ppmv (parts per million by volume).

The plant requested specific information about the utilization of Mono Ethanol Amine (MEA) for the scrubbing of the vacuum tower tailgas stream for H₂S and its capture and recycle. Currently, this stream is fed directly into an incinerator and the hydrogen sulfide is covered to sulfur dioxide. We have included information on the utilization of MEA and other information on upgrading the Claus process in another separate transmittal.

The sulfur oxide emissions from the plant may not be significant when compared with other air emission sources nearby. The development of enforceable sulfur oxide emission regulations do not appear to be a priority item with the Environmental Ministry, as the plant management was unaware of the emission limits and air quality standards. The surrounding country side is predominantly rural, but most of the residents burn a high ash- high sulfur coal for home heating. At times, on the trips to and from the refinery we could smell and feel the shortness of breath which accompanies high sulfur emissions from the surrounding communities before we entered these towns.

On one side of the TIFO refinery is a coal-burning electricity generating plant. This plant uses the same high sulfur coal as the villages, and it does not have any air sulfur oxide pollution control equipment. On the other side of the refinery, closer to Tiszaujvaros is an agricultural chemicals complex. This chemical facility has a single stack which is visible from the town and which continuously discharges a bright yellow plume which could be nitrous oxides (NO_x) or Sulfur Dioxide (SO₂). Refinery personnel did not have much information about the agri-chemicals complex, and time did not permit a site visit to the facility.

The refinery is not the only generator of sulfur dioxide compounds in the area. Any attempt at air pollution control must be made on a community wide basis and must include the other community sources including other industrial facilities. The nature, complexity, and number of area air pollution sources are so great that control of a single source (such as the refinery) may not be sufficient in achieving a significant reduction of the SO₂ levels within the community.

At current reduced levels of production, the refinery does not appear to be a significant contributor of sulfur oxide emissions in the area. However, if the refinery resumes production at original levels, and even though it reduces the sulfur content in the fuels it produces, the refinery may again become a major sulfur dioxide emission source.

The long term solutions for the lowering of sulfur dioxide emissions from the refinery include significant upgrading of the instrumentation and control systems and replacement of the tail gas analyzer on the Claus unit. A second alternative includes the addition of a Superclaus process unit to the existing Claus plant or the addition of a third Claus stage plus control and scrubbing equipment to the existing equipment. The installation of the controls and analyzer will help the refinery to achieve better sulfur control with their existing equipment, but will do little to improve the overall capture efficiency of the process. The installation of process modifications such as the SuperClaus process or the SCOT process, can achieve sulfur recoveries consistently in excess of 99%.

The potential installation of an MEA adsorption system to remove H₂S from the tailgas of the Vacuum Distillation Unit has been discussed above.

8.4.2

Hydrocarbon Emissions

There are a number of hydrocarbon emission points within the refinery, but many of them are already controlled to levels which are comparable to those found in the U.S. The principal losses appear to be fugitive losses which are associated with operation and maintenance practices, and losses to the cooling and waste-water facilities in the plant.

In a typical refinery, as is the case in TIFO, many of the light hydrocarbon tanks represent a potentially significant source of air emissions from the refinery. The principal losses from these tanks are evaporation from the surface of the hydrocarbons within the tanks. The losses fall into two categories - breathing losses and working losses. Breathing losses represent the emissions from a tank due to the diurnal variation in temperature of the air above the liquid in the tank. Working losses represent the emissions from the vapor space above the fluid but below the roof which are displaced when the tank is filled. One of the best control technologies for these type of losses is the installation of floating roof tanks which eliminate the vapor space between the roof and the liquid. TIFO has this type of control technology on their light hydrocarbon storage tanks.

1072

The installation of floating roof tanks can eliminate well over 80% of the potential emissions from the refinery storage. Additional improvements and modifications are possible by installation of internal seal tank cover seals, control of vents and vacuum breakers and installation of gasketing around tank opening and hatchways.

In the future, TIFO can provide an additional reduction of hydrocarbons from their light hydrocarbon storage tanks by installing double seals on the floating roof covers and by gasketing the hatchways and access doors. At this time we do not believe it necessary for the refinery to take these actions as they would provide little reduction in total hydrocarbon emission for the cost of the installations. Fugitive emission controls and waste-water treatment equipment controls should be emphasized first.

According to a recent U.S. EPA survey, refineries have a large number of fugitive emission sources. The principal sources of fugitive emission losses are leaks from valves, flanges, pump seals and fittings; evaporation from the waste water treatment plant equipment; and losses from loading racks and fill pipes. These sources may release several thousand tons of hydrocarbons annually. Other fugitive hydrocarbon emission losses at TIFO may include secondary losses from the condenser water in the Vacuum Distillation Unit, and evaporation of hydrocarbons from the water treatment facilities.

The principal waste water treatment fugitive air emission is attributed to the crude-water emulsion tank. The plant estimates that the desalting system waste water flow contains between 1.5% and 2.0% crude oil. The emulsion is placed into a large (10,000 m³) open-topped tank where it is allowed to gravity separate. Some of the crude oil evaporates from the tank.

In our brief inspection of the refinery, we were shown the emulsion holding tank. The open topped tank which we viewed was about 1/2 full of crude and water. It was estimated that approximately 2 meters of water was beneath about 4-5 meters of oil. Both of these were on top of a sludge layer which was estimated to be about 1-2 meters thick.

We did not discuss the problems or emissions which may be associated with the vacuum distillation equipment.

- **Potential Solutions - Crude Oil Desalting**

Several potential solutions for the removal and elimination of the crude oil emulsion problem were discussed with the refinery. The solutions proposed included 1) better chemical treatment of the crude desalting water by using highly charged, high molecular weight cationic polymers to promote coagulation of the oils; 2) potential separation of the water-oil emulsion by more conventional chemical means using flotation, pH adjustment, and flotation/precipitation; and 3) direct evaporation of the water in the emulsion by utilization of a wiped face, falling film evaporator.

All the potential solutions were discussed with plant personnel. Solutions number one and two both will incur some increased chemical costs for water treatment. Although the relatively small quantity of the emulsion should provide a marginal capital cost increase. The implementation of solution number three will require the installation of a thin film evaporator similar to those manufactured by Luwa, Niro Atomizer, and others. Depending upon the boiling temperature of some of the crude oils, this solution may not be technically feasible. The temperatures required may exceed the operating ranges of the heat transfer fluids which would be needed in the evaporators.

Dissolved air flotation or electrolytic (water dissociation by electrical current) flotation systems may help break the emulsion stream. Research into this area is clearly needed, and the plant should try several different treatment technologies and proposed solutions to determine which one is most appropriate for direct use.

Covering of the crude-emulsion water storage tank would also help to reduce the total hydrocarbon emissions.

Potential Solutions - Vacuum Distillation Unit

One significant hydrocarbon source at TIFO is associated with the use of the vacuum distillation unit. The vacuum distillation of hot crude oils entrains vapor which contaminates the steam used to create the vacuum. When the steam is quenched, this water and vapor condense in the barometric leg which is carried down and into the waste water treatment system. The water from the waste water treatment system carries as much as 200- 500 mg/l of total oil, and of that almost all of the oil is volatile. For the TIFO refinery, assuming the waste water flow to be approximately 80m³ per hour, and an applied load of between 350-800 kilograms of hydrocarbon lost to the atmosphere per day.

Potential Solutions - Loading Rack/ Filling Stations

The loading rack or filling station for the tank cars may also be a significant source of hydrocarbon emissions. We were not able to quantify this source, but believe that the loading of bulk fuel tanks is conducted from the top rather than by use of submerged fill pipes, and the filling station probably does not use vapor recovery techniques to collect the vapors generated when the tank cars and trucks are filled. Because the refinery is currently operating at a reduced capacity, these emissions are relatively small.

Potential Solutions - Improved Maintenance

Other hydrocarbon reduction techniques which may be applied to the TIFO refinery include the control of fugitive losses from leaks and drips from pipelines and process equipment. The

10/1

periodic testing of the packing glands on pumps, flanges, valves, and pipe joints, and rapid repair of leaking fittings can reduce the amount of hydrocarbons lost to the atmosphere. The magnitude of these fugitive losses at TIFO refinery could not be quantified without additional study and an physical inventory of the number of valves, fitting, etc., and their condition. Comparisons with similarly sized U.S. refinery suggests that the fugitive emissions losses may represent several hundred tons of hydrocarbons per year.

8.5 Water Pollution

The TIFO refinery has an excellent waste water treatment plant. The waste-water treatment system includes biologic treatment clarification and filtration. These processes are followed by a series of waste water treatment lagoons, which finally discharge the water to the Tisza River. The effluent from the refinery is relatively low in Chemical Oxygen Demand (COD values range from annual averages of 66 mg/l to as low as 32 mg/l); oil concentration in the discharge water average less than 3 mg/l, and between 1983 and 1990, the overall trend of the pollution discharges showed a continuous decrease. We were unable to ascertain whether or not the COD and oil decreases were due to better operation of the refinery or acclimatization of the local biological population to the materials in the effluent stream.

In support of our observation that the water discharge from the refinery is one which represents good treatment technology, a summary of U.S. New Source Performance Standards is shown below:

Performance Standards for New Sources Source: U.S. EPA 1982

Daily Maximum Mass discharge (kg/1000 m ³ of production throughput)		30 Day daily Average Mass discharge (kg/1000 m ³ of production throughput)
Biochemical Oxygen Demand	11.8	6.3
Suspended Solids	8.3	4.9
Oil and Grease	3.6	1.9
Phenolic Compounds (Total)	0.088	0.043
Ammonia as N	2.8	1.3
Sulfide	0.076	0.035

The refinery is not presently exceeding water quality standards on the Tisza River.

There is little which can be done or said to improve a well run operation, and from what we observed, the waste water treatment system at the TIFO refinery is operating satisfactorily.

8.6 Ground Water Considerations and Soil Contamination

Refinery personnel are sensitive to many of the causes which generate soil contamination and ground-water problems. In most refineries, the loading rack or filling station is the principal source for many spills which contaminate the soil and ground-water.

According to TIFO personnel, the filling station is lined with stone and clay. The area has a leachate collection system and monitoring wells which are monitored on a weekly basis. When a spill occurs, the stone and soil is replaced.

The plant has the capability to treat small amounts of soil biologically. There was no information available about the long term disposal of contaminated soil, hazardous or other wastes, or the status of potential contamination due to leaks from pipelines within the plant.

The plant did not share any information on the status of ground-water contamination which may have occurred from leaks, spills, and discharges from process piping. Considering the age of the facility, just about 10 years, and the excellent condition of the physical plant, it is not unreasonable to assume that the reason for the lack of information about groundwater contamination is because the plant has not been able to identify any particular problems or concerns.

We were told that all the surrounding villages are on public water supply, and that the supply in the immediate vicinity of the refinery were on public water supplies. The source of the public water is believed to be the Tisza River.

8.7 Conclusions

Based upon our interviews we make the following conclusions about the environmental status of the TIFO refinery:

- The air pollution problems in the community surrounding the TIFO refinery are complex. There are a number of significant industrial pollution sources of hydrocarbons, sulfur dioxide, particulates, and possibly nitrous oxides. The surrounding communities also contribute to the air pollution problems by burning low heating value- high sulfur content coal.
- At current production levels, which are about 30% - 50% of refinery maximum capacity, the refinery is not believed to be a significant contributor of sulfur dioxide or of hydrocarbons to the environment. The situation will change as the refinery adds new equipment and processes which will increase its throughput.
- The refinery staff is aware of several aspects of environmental control needs in the community as they directly pertain to plant processing considerations.
- The refinery is actively considering process improvements which will reduce sulfur dioxide emissions from the Claus process and an adsorption system which will increase overall sulfur removal efficiency in the plant to in excess of 99%.
- The refinery's waste water treatment system is quite advanced and provides excellent treatment of the current plant wastes. The treatment provided is comparable to current levels required for new plants in the United States.

106

8.8 Recommendations

- **The refinery should develop an separate environmental staff and move that staff out of the production department into its own department with clearly developed responsibilities and assignments. The responsibilities and assignments of this group should include the development of programs and achievable goals which anticipate the environmental requirements which will be placed upon the refinery, and which will assist the refinery to develop programs which are beneficial for the workers and for the community as a whole.**
- **The newly formed environmental protection staff should assemble an information framework about environmental emissions from the facility and become a repository for test and modeling information.**
- **The refinery should undertake an emission inventory to determine the concentration and flow rates of all process vents and stacks.**
- **The refinery environmental committee should meet with the local power plant and the chemical plant management to develop an air survey of emissions from the various points within each of those facilities.**
- **The refinery should lead a joint effort with the cooperation of the power plant, and the chemical plant to develop and implementing a community wide air pollution monitoring network and control program. Such a program should be supported by computer modelling and ambient air monitoring to calibrate the model.**
- **The refinery should consider developing an after-coking process and selling low sulfur coke to the community to replace low-energy, high sulfur fuels which are burned in the homes.**
- **The refinery should call in specialists to assist them with developing a treatment technology which will successfully remove the emulsified oils from the desalting waters. The objective of the program should be to develop a specific waste stream which will break the emulsion and leave a clear effluent which can be successfully treated in the waste water treatment plant without causing disruptions in the plant operations.**
- **The refinery should begin developing a ground-water monitoring and protection strategy before the plant starts developing leaks in pipelines. A protection and monitoring strategy which employed vapor survey techniques could locate leaks and pipeline breaks very quickly and inexpensively.**
- **The refinery should develop a valve and fitting maintenance and control program to detect vapor leaks and fitting losses before they become serious problems. This can be accomplished by the purchase and use of an photoionization detector which will directly determine the leakage from valves and fittings.**
- **The refinery should begin long term studies of water pollution impacts on the Tisza River to enable them to be in a position to determine what effect their discharge to the river is having on the fish and the overall environment.**

107

9.0 REFINING STRATEGIC ISSUES

9.1 Overview

The previous sections have dealt with specific energy, processing, and environmental issues at the DKV and TIFO refineries. This final section will attempt to address the urgent and most pressing refining business issues that the Hungarian refiners face today. Many of these issues are arising or intensifying as the Hungarian refining industry makes the transition to a competitive market environment. While refining strategic planning was not the primary focus of our consultancy effort, nevertheless this issue appeared to be of high interest to senior managerial and technical staff at both refineries. Thus, we have chosen to briefly address what we believe to be the most important issues that must be faced by the Hungarian refining industry in making a successful transition to a competitive market economy.

9.2 Bottom Line Orientation

A sense that the company has to achieve a positive profit margin to survive needs to permeate the entire organization. Technical issues and economic issues are usually not separate items that can be dealt with by separate groups in separate efforts—they are usually intertwined and need to be handled together. One of the most important attributes of a firm with a bottom line orientation is the ability to recognize profit improvement opportunities. As an example, refiners in the US in the early 1970's paid little attention to the cost of carrying crude and product inventories, of course, at that time crude was selling for \$3/Bbl. By the late 1970's crude was selling for \$35/Bbl and interest rates were 15%. Some companies recognized that by reducing average inventory levels they could reduce working capital cost and add \$5.25 to the profit line for every barrel of inventory reduction. It literally took years for other companies to recognize this opportunity for improved bottom line performance.

9.3 Competitive Cost Structure

Analyzing competitive cost structure consists of looking at the elements of costs for the company to produce a unit of product and comparing those costs for the company vs estimates for competitors as illustrated on the following page.

COMPETTIVE COST OF PRODUCTS (Ft/Ton)

	Company	Competitor A	Competitor B	Competitor C
Product Revenue	+			
Product Costs				
Feedstock	-			
Energy	-			
Catalyst & Chemicals	-			
Operating Labor	-			
Maintenance Labor	-			
Maintenance Materials	-			
Admin. and Other	-			
	_____	_____	_____	_____
Gross Margin				
Capital Charges	-			
Net Margin				

The purpose of such a comparison is to help the company focus on those areas where their costs are higher than some or all of their competitors and attempt to find cost reduction opportunities. That does not mean that the company should ignore those cost areas where they already appear to be competitive as these may also be opportunities for further improvement.

Comparing competitive cost structure for refineries is not a simple matter because of the variations in product mix and complexity. Comparing a low complexity refinery such as TIFO with DKV, a high complexity refinery, will probably not be too informative. DKV should have a significantly higher gross margin to support the higher investment in place but the differences in complexity are so great that a line by line comparison would probably bear few meaningful conclusions.

While we did not review unit cost data for either DKV or TIFO, we would anticipate that in DKV's case feedstock costs would be an area for potential improvement and both refineries might make improvements in product revenue by seeking to produce and market a more profitable product mix (although in TIFO's case that improvement may be a long term versus a short term issue). Energy costs have been addressed by both refineries as was discussed in detail previously. TIFO and DKV both have large labor forces when compared with United States and Western European refineries but those relatively higher staffing figures are more than offset by the lower wages in Hungary.

It was encouraging to see the extent to which refinery staff were thinking in terms of competitive cost structures. DKV has had some consulting work done for them to get some evaluation of the competitiveness of their costs. We also left with them some results of a competitive cost study done for United States refineries to illustrate an analytical approach. Some additional consulting support could be beneficial in improving the understanding the capabilities of the refinery staff in this area.

9.4 Expansion of Product Markets

Expansion of product market volumes could be an important element in increasing utilization and improving the viability of operations at TIFO. Increasing product sales volumes would certainly entail significant increases in the volume of product exports. One of the TIFO staff expressed doubts about significant increases in export sales of refinery products from Hungary. He also felt that Hungary would not experience competition from product imports since the Hungarian refineries owned and controlled the pipeline delivery system.

We would recommend that increasing exports of Hungarian refined products be analyzed and explored. While the control of the product distribution infrastructure offers a degree of economic advantage to both Hungary and its neighbors it may not be a large enough cost barrier to protect those countries from imports from their neighbors. In fact geographical sections of neighboring countries may represent attractive opportunities for imports/exports. In a competitive market place it is important to identify opportunities before your competitor recognizes the threat to his market. The analysis of export opportunities will also improve the assessment of vulnerability to threat of imports into the Hungarian market.

Earlier in this report, we discussed that a future manufacturing strategy should consider type of crudes purchased as an option to residual conversion facilities. Product slate and product markets should also be components of a future manufacturing strategy. The refinery can try to find markets for high sulfur residual fuel and petroleum as alternatives to conversion of these materials. The refineries need to explore sales of heavy high sulfur material versus conversion within the refinery. Exploring product markets means examining potential price versus volume relationships. It may be more economical for potential product purchasers to deal with the negative qualities of these materials rather than by additional refinery processing.

9.5 Allocation of Capital to Investment Projects

Entering competitive refinery markets will cause the Hungarians to experience the up and down swings in profitability that the refining industry experiences. It will also heighten their awareness that the allocation of current profits to future capital projects must be done with great care to achieve favorable future profit results. Monies for capital projects is limited and priority rankings for the use of investment must be developed. The basis for those rankings need to reflect the changes that the Hungarian refining industry is experiencing.

One of the situations that sometimes causes difficulty in ranking process project is having to simultaneously deal with process projects designed to increase revenues and profits and environmental projects that generate no added revenues but do protect against some potential future liability. In the United States there are two reasons for environmental projects expenditures. The first is that the expenditure is made to meet compliance standards to stay in business. Secondly, there is an environmental investment made to protect the public against potential hazards to their health. This type of project can be compared in economic terms by estimating possible liability costs to redress health damages which the members of the public might succeed in obtaining through litigation and estimating the probability of number, timing and level of possible litigation awards.

Finally, there is the pro-active approach of improving pollution control before regulations are put in place. The company can take the position of indicating potential health hazards and correcting them in a very public way and conspicuously promoting the legislation of new pollution standards. The rationale is two-fold, first to get "sensible" regulations and second to derive the benefit of a positive company image which will benefit the company in product sales and making legislators inclined to trust company prepared position statements. Here again there are economic benefits for doing the right thing - those benefits do, however, require a more subjective and complex approach to translate to dollar benefits for comparison with projects that produce more or better products.

In summary all of the capital projects of a company need to be viewed together and to assure that the company's scarce capital is used to its best advantage to insure the future health, growth and profitability of the company.

9.6 Strategic Planning

All of the above items mentioned are part of the strategic management of a company. A strategic planning effort by a company consists of the chief executive with his top management team setting aside specific blocks of time each year to assess:

- Where are we?
- Where do we want to take the company in the future?
- And how do we get there?

Part of the process is also monitoring how the company is doing in carrying out past planning goals and the effectiveness of implementation steps.

Instituting a formal planning process represents a commitment by top management to allow some time away from the specific day-to-day problems, when they can step back and look at the larger long term picture. The company staff develops analyses for the top management team to address the three questions stated above, such as:

- Where are we?
 - competitive performance vs others in industry
 - identify prominent trends which have been affecting company
 - emerging threats to company businesses, opportunities
 - comparison to past goals and projections
 - company's strength and weaknesses
- Where do we want to be?
 - outlook for industry
 - what should be focus for goals
 - what do we want to fix?
 - how do we want to change?
- How do we getting there?
 - capital improvements
 - operating strategies, cost reductions, marketing strategic, etc.
 - organizational

9.7 Organizational Structures

During discussions with refinery personnel on processing, energy, and environment, there was considerable discourse about the future organizational fate of DKV, TIFO and OKGT. There was speculation that there might be separate competing companies or that they might be combined together. It was not the objective of the K & M visit team to assess the best organizational structure for the future refinery industry in Hungary; however, part of the effort was intended to lend support to any privatization efforts that may be underway, so a few comments of limited scope are appropriate.

Clearly, there is no single type of business organization that is required for success in the petroleum business. A variety of organizations succeed in the free market economics of the world. There include integrated companies, independent refiners/marketers, independent refiners, and independent marketers. And within those types, organizational structures which sometimes are geographical, sometimes functional, sometimes centralized, sometimes decentralized, and sometimes individual units are operated as distinct profit centers or alternatively as integrated operations. While there is considerable ongoing argument about which of these organizational structures is best suited, the predominant view is that private business ownership is preferable to state ownership. In the past decade, several State-owned petroleum businesses have been privatized, and the results have been uniformly positive.

Privatization of refining in Hungary could be by outright acquisition by a private international or European petroleum company, or it could be by creation of a private Hungarian company through the sale of stock in the company. In the case of outright acquisition, the concern would be to assess the value of the business to insure that the price at which it was sold was reasonable. The second possibility perhaps seems the more interesting for a country emerging into a free market economy. It would seem desirable for those businesses which can operate on their own as Hungarian businesses should do so. Development of business leadership and self-confidence will occur to a greater degree in an independent business, as compared with being a subsidiary of a foreign company which would almost certainly fill top management positions with foreign personnel.

Based on our visits to DKV and TIFO, the K & M team feels that an independent Hungarian refining company could survive and prosper in a competitive market environment. As has been described earlier, the manufacturing facilities have modern up-to-date units using current technology, the operating cost is in the competitive range, and perhaps most critically, K & M believes the refinery staffs could function successfully in a competitive market environment. This opinion is based on our observations of their ability to deal with change. They are now dealing with major changes in crude supply, product market demand patterns (i.e., the market for bottom of the barrel products), and costs of purchased energy. In all of these cases, they have demonstrated the ability to recognize not only the broader issues, but also detailed technical problems, including alternative solutions to deal with such problems and issues. However, as indicated earlier, in cases such as crude valuation and crude supply strategy, the refinery could benefit from outside consulting support. Use of consulting support should not be taken as an indication of inability. Both DKV and TIFO understand the problems they face. Rather, consulting support would give them the added benefit of others' past experience, and help speed up the process of determining which of the many options is the best solution or approach to this particular problem.

On the last day of the team's visit, we were told that the new organizational structure would combine the refineries with the petroleum operations in OKGT. If this is indeed the case, then we would offer two management development suggestions. The first involves the transfer of a few selected management personnel between the two refineries and the "headquarters" groups at OKGT. Such a swap or exchange would help to broaden the experience of managers either moving into the refineries or coming from a refinery into OKGT. It would also add to the overall cohesiveness of the total organization. Finally, it would provide more advancement opportunities for top-performing staff members.

The second suggestion deals with the usefulness of formal executive development programs. The refinery staffs have already demonstrated their capacity to acquire technology expertise from the larger base of activity in the international community. Now they need to accomplish a similar effort in building and acquiring expertise on the "business side" of refining. While much will be accomplished by dealing with day-to-day problems, there is also something to be gained from contact with other business managers as well as the instructional programs of business schools. Most U.S. universities with MBA programs offer four to six week executive development programs for business managers. The learning experience comes both from organized instruction and contact with other business managers.

Several copies of a descriptive brochure of the management development program at Carnegie Mellon University (CMU) have already been sent to DKV and TIFO under separate cover. While this program is not geared to a specific industry, it can be tailored for senior and mid-level oil company managers. For instance, at any given time, there are generally 3-6 oil company people in attendance at each session. CMU always has attendees from non-English speaking countries, and helps with language problems. However, much of the value of the program comes from exchanges with other participants so a moderate English capability is desirable. From our visits at the refineries, there are clearly a number of managers with adequate English skills to benefit from such a program.

Finally, in conjunction with attending such a program, extended working visits could also be arranged with U.S. oil companies to see how they operate in a competitive free market economy.

APPENDICES

Catalytic routes to low-aromatics diesel look promising

Arthur J. Suchanek
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Producing low-aromatics diesel fuel may be accomplished catalytically rather than through large capital investment.

Pilot-plant test results show that some catalyst types and catalyst systems such as various combinations of nickel-molybdenum (NiMo) and nickel-tungsten (NiW) on alumina in the presence of sulfur; noble metal on alumina for low-sulfur feeds; and noble metal on zeolite for moderate sulfur feeds can achieve the proposed tougher specifications on diesel aromatics at minimum capital investment.

For the past several years, we have been hearing that highway diesel sulfur levels may be reduced to as low as 0.05 wt % and aromatics to as low as 10 vol % across the

U.S. In fact, some areas of California already market diesel fuels that meet these very strict regulations.

For the refining industry, the reduction of sulfur and aromatics will be expensive. Numerous studies have already been done or are being done. Results of those studies indicate that very high levels of capital expenditures will be necessary to reduce sulfur and aromatics in diesel fuel.

The potential for increased costs of diesel production make it necessary to determine both the technical and economical means of reducing sulfur and aromatics in diesel fuels.

Criterion concluded earlier that use of a high activity aromatics catalyst system under a particularly severe test case assessed (i.e., feed, operating conditions, product goals) that a great deal of capital would most

likely be needed to achieve the proposed aromatics specifications.¹

This article carries that analysis a step further in light of some novel catalyst systems. There are many approaches that will allow refiners to solve the aromatics reduction problem catalytically, rather than being forced to spend major capital.

Technical overview

Technically, at a given pressure level and adequate hydrogen treat-gas rate, sulfur removal is directly related to the amount of catalyst in the reactor and temperature.

High activity cobalt molybdenum (CoMo) catalysts achieve required sulfur levels with total pressure as low as 500 psig.

Aromatic reduction, however, is on the other side of the toughness curve compared to sulfur reduction. Whether by saturation or hydrocracking, aromatic reduction is strongly dependent on some tough rules of nature.

Pressure, catalyst type, and an understanding of the interaction of these variables on chemistry and thermodynamic equilibria are necessary to determine how best to handle the aromatics present in the refiner's available diesel-blending streams. Then, by knowing the product specifications, stream properties, limits of existing equipment, and available technical approaches, a sound economic solution to aromatic reduction can be selected.

We will discuss the chemistry of the diesel boiling range materials, identify some problem streams to the refiner, and cite ways that we, as a catalyst company, can economically help reduce aromatics and improve the quality of future diesel fuels.

However, the future aromatic specifications have not yet been pinpointed and, in fact, are still being discussed.

The chemistry

The boiling range of diesel-blending components gener-

Based on a paper presented at the National Petroleum Refiners Association annual meeting, San Antonio, Mar. 25-27.

Diesel aromatic structures

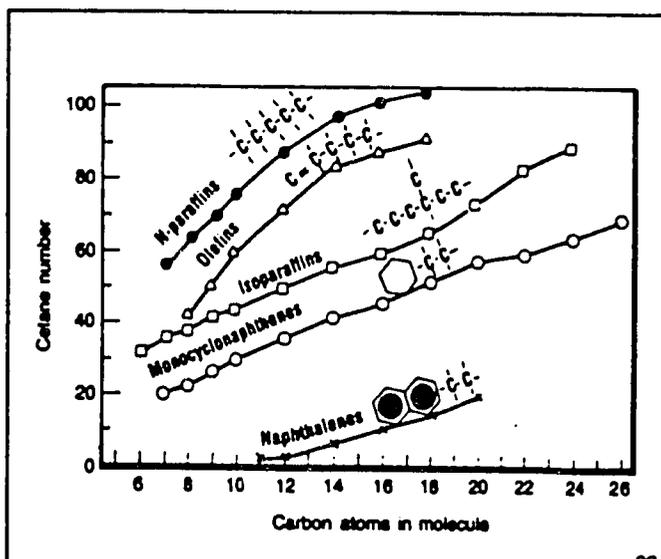
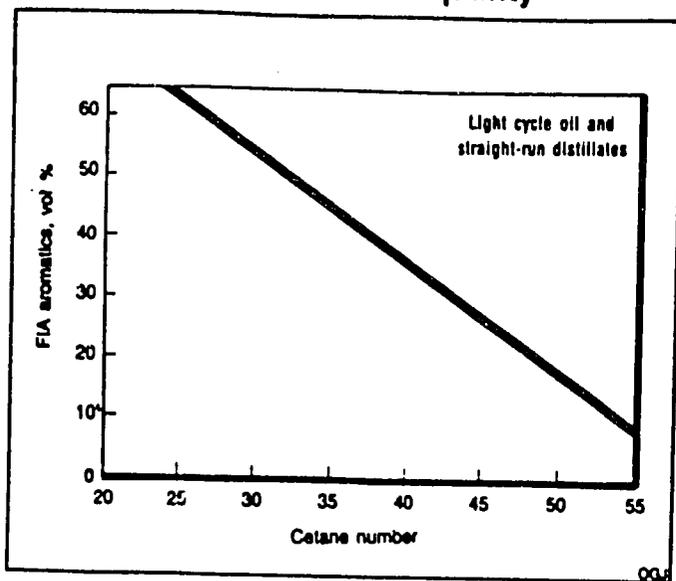


Fig 1

High aromatics vs. cetane quality



ally falls between 400 and 680° F., with plus or minus some front or back end. The molecular structure is generally in the C₁₂-C₂₅ or so range and is comprised of aromatics, naphthenes, iso and n-paraffins, olefins, or molecular combinations of them all. But because of the very wide array of streams available for blending into the ultimate fuel, the proportion of the various molecules varies widely.

In a discussion of aromatics reduction one also needs to associate aromatic content and cetane number because cetane number is the accepted measure of diesel quality.

Cetane quality is highly dependent on the paraffinicity of molecular structures, whether they are straight-chain or alkyl attachments to rings. Therefore, a stream which is mostly aromatic rings with few or no alkyl side chains would be a low cetane quality material, and a highly paraffinic stream would be high in cetane quality.

An FCC cycle oil fits the former description quite well and, because it is highly aromatic, it is also very hydrogen deficient. Naphthene molecules, which are saturated aromatics, have a somewhat higher cetane potential, but still not overwhelming.

For years, the author has used a "molecular thought pattern" to look at diesel boiling range or any other boiling range streams (Fig. 1).

By studying Fig. 1, much

can be seen about the chemical nature of diesel fuels. Note the highly condensed aromatic structures with the very low cetane quality.

If the refiner simply saturates the aromatic rings, then the resulting product reaches a 40-41 cetane number level and one immediately wonders if aromatics saturation of cycle oils is advisable. Past work has shown that it would take high pressure, and possibly two-stage processing, to saturate 60% or more of the aromatics.¹

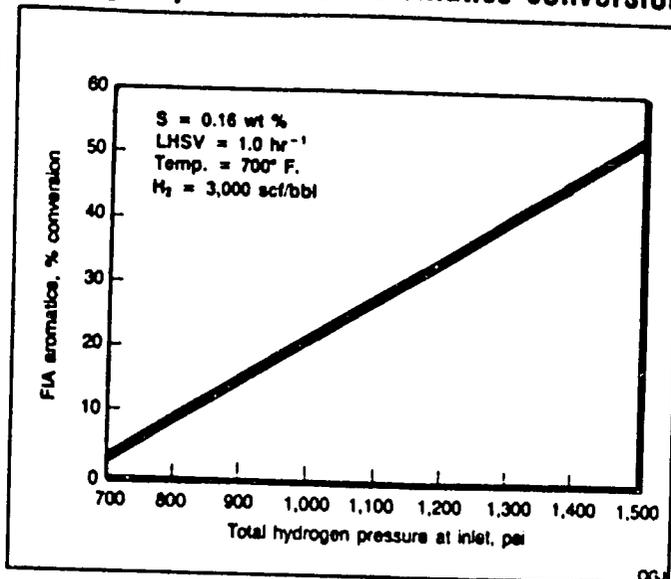
At this point in the decision analysis, the refiner would then be forced to seriously consider a hydrocracker with the same or marginally higher investment. A cycle oil hydrocracker, for instance, would produce not only good quality diesel, but also high quality jet fuel.

Another consideration for highly aromatic cycle oils would be blending the cycle oil with virgin straight run, thus improving the cetane potential via dilution with better molecules. Subsequent processing of the stream to low sulfur with accompanying marginal aromatic conversion would then be achieved at lower severity. Thus, understanding the chemistry can hopefully lead the refiner to solid economic choices for diesel component upgrading.

Cetane/aromatics

There is a somewhat confusing relationship between

Hydrogen pressure vs. aromatics conversion



cetane number, cetane index, fluorescent indicator adsorption (FIA) aromatics, and aromatics measured by many other techniques. Cetane quality measurements, resulting in either cetane number or cetane index, and aromatics analysis by any means, should be complementary, but they are not. Therefore, we manage with what we have while understanding the drawbacks of each method.

While technically studying finite incremental changes in aromatic hydroprocessing, it is important to watch the trail of aromatics removal or saturation as it progresses from multi-ring molecular structures to mono-ring structures, and finally to naphthene. It is equally important to also watch the alkyl or naphthenic appendages as they directly affect the cetane number of the product.

To help follow this trail, we must spend a little more time discussing aromatics analysis. In an NPRA paper last year, Richard Nash discussed aromatics analysis and cited the following derived equation for relating FIA aromatics analysis and UV mono-aromatics analysis for the particular feed in his study:¹

$$\text{FIA aromatics} = 4.7(\text{mono-aromatics}) - 11.6$$

While we use various sophisticated analytical deter-

minations in research and development work, the FIA trail best fits the logic flow of this article. This is necessary because the FIA analysis, even with all of its problems, is still solidly entrenched as the accepted test for diesel aromatics and, by correlation, cetane quality.

Fig. 2 illustrates a generalized correlation of cetane number vs. FIA aromatics content for a refinery mixture.² Our thanks to George Unzelman for this relation.

While not meant to be precise, this relation aids in the overall thought pattern for understanding the means to reduce aromatics in diesel fuels.

Another interesting technical paper has been presented by Syncrude Canada Ltd., relating cetane quality to its fluid coker-based operation on bitumen feed.³

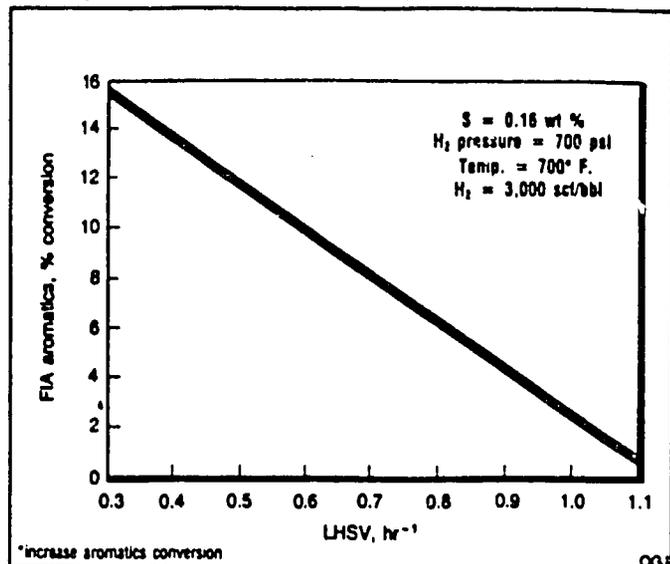
Today's diesel

Looking at the worldwide quality of diesel today, quite a large variation in its molecular makeup is evident. Most of the U.S. diesel meets a specification minimum cetane number of 40.

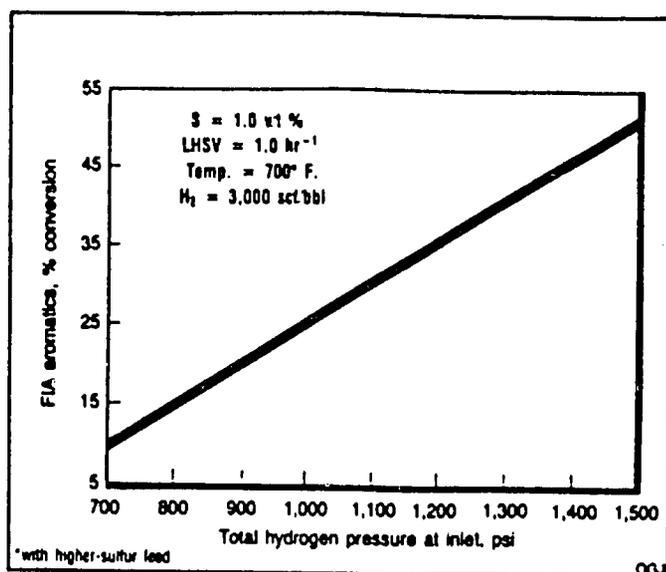
However, in the European Economic Community (EEC), the cetane number is in the high forties and refiners there meet this without any problems. The reason for this discrepancy can be correlated to U.S. conversion capacity.

It has been stated many times that U.S. cetane quality

Low pressure, more catalyst*



Better aromatics conversion*



Diesel boiling range refinery streams

Table 1

	Virgin distillate*	Blend of virgin & cokert	FCC cycle oil§	Hydrotreated blend,†	Mild hydrocracked product	Hydrocracked product
Gravity, °API	33	31	21.3	27	32	36.0
Sulfur, wt %	0.5	0.5	0.89	0.16	0.01	<0.001
Nitrogen, wt %	0.01	0.03	0.06	0.015	0.02	<0.001
Bromine No.	0	5	7	—	—	—
FIA Aromatics, vol %	35	40	71	58	25	20
Dist. D88						
IP	420	400	320	355	400	400
10%	485	480	442	487	415	415
50%	535	530	531	551	470	470
90%	625	630	655	651	560	560
EP	680	680	700	688	660	660
Cetane number	44	40	20's	38.5	40	43

*Alaskan North Slope crude. †California refinery blend. §Based on Maya crude max., Coker, cycle, straight-run max.

is directly related to consumption of gasoline and, thus, the high dependence on FCC and coking units.⁴ As a result, FCC cycle oils and coker gas oils constitute a high proportion of the streams available for ultimate blending into diesel fuels.

The technical problems have been compounded even further by making diesel molecules even tougher and more difficult to treat by processing at high contact times and high temperatures in U.S. heavy-oil upgrading processes. Fundamentally then, the streams available for hydroprocessing and ultimate blending into diesel can be characterized as low in hydrogen and high in sulfur, nitrogen, and aromatics.

Refinery streams

Table 1 illustrates six streams that a refiner will

consider for ultimate hydro-treatment and blending into the diesel pool.

The molecular thought pattern can be used to determine how to best bend, reshape, or break the molecules to meet the overall objective of improving diesel quality. And then, with interpolation and extrapolation, the correct catalytic and/or process route can, it is hoped, become evident.

A point to reiterate here is that a major aim of the technical approach is to determine catalysts or technologies which can help the refiner fit existing refinery equipment, with added investment recommended only as absolutely needed. This subject has been covered in a previous publication.⁵

Catalytic approaches

For the streams of interest,

there are various catalysts that can be used in varying ways to achieve overall reduction in diesel fuel aromatics. Each catalyst has, however, restrictions on where and how it can be used. Table 2 shows Criterion Catalyst Co. catalysts and their areas of application.

Generally, NiMo catalysts, such as C-411 and C-424, are used for contaminant heteroatom (N,S,O) removal, but they also saturate some aromatics. The effectiveness of NiMo catalysts is highly dependent upon the system hydrogen pressure.

While it is true that hydrocracking is the ultimate sledgehammer for aromatics reduction of diesel boiling range streams, the reality is that these units carry a high investment cost. For most streams, a catalyst system that would achieve moderate

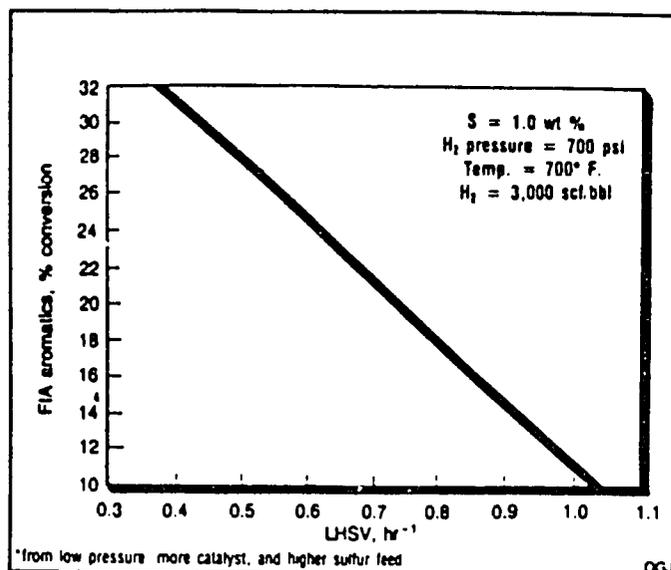
aromatics saturation should suffice.

The catalyst used should be strong, not only for aromatic saturation, but also for hydrodesulfurization (HDS) and hydrodenitrification (HDN). An NiW on alumina catalyst can fit this job description quite well.

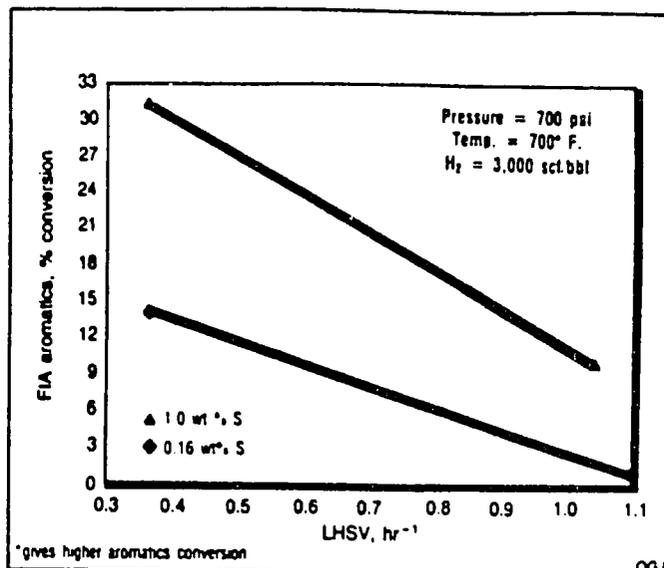
Still, in many situations hydrocracking is desirable and must be considered for refining systems laden with aromatics (particularly for FCC cycle oil). There are many operating hydrocrackers achieving high yields of jet and diesel from FCC cycle oils. Several NiMo first-stage catalysts, as well as second-stage zeolite-based hydrocracking catalysts, are available for this type of processing operation. Table 2 cites some information on these hydrocracking catalysts.

Finally, noble metal cata-

Better conversion*



Higher feed reactivity*



Catalysts used in testing

Table 2

Identification	Description	Service
424/411	Ni/Mo alumina	Hydrotreating Cat. feed hydrotreating First-stage HC
354	NiW/alumina	Hydrotreating aromatics saturation Lube hydrocracking
614	Pt/Silica alumina	Aromatics saturation
704A	Noble metal/zeolite	Aromatics saturation
703	NiW/zeolite	Hydrocracking; max diesel
753	NiW/zeolite	Hydrocracking; max gasoline

lysts are well known to be very high in activity for saturation of aromatics, but conventional wisdom teaches us they are easily poisoned by sulfur and nitrogen. For example, noble-metal on silica-alumina catalyst is excellent for diesel range streams of very low sulfur—less than 10 ppm.

More exciting, however, is a new noble metal on zeolite catalyst (704A). This catalyst represents a significant improvement in sulfur and nitrogen tolerance to about 1,200 ppm and 200 ppm, respectively.

Processing logic

Straight-run streams or blends of straight-run with coker and FCC cycle oils are presently treated to sulfur specifications of 0.05-0.2 wt % in units with at least 500-600 psig total pressures and liquid hourly space velocities (LHSV's) of at least 1.0 hr⁻¹, but most likely 3.0 hr⁻¹ or higher. It would be nice if the

product from this normal hydrotreater could be further hydrogenated to reduce its aromatic content.

It would be even nicer if it could be done in the same hydrogen circuit. Better yet, the ultimate would be single-stage processing in the same hydrogen loop, which certainly should be an economically attractive route.

The problem with this scenario is that high pressures (approximately 1,500 psi H₂) are needed to achieve significant aromatic reduction via saturation to greater than 60-65%. Last year's Criterion paper showed that a 60% aromatic stream could be reduced to the 10-20% aromatics range with two-stage processing.

However, units such as this are not usually available and would carry a high investment cost. The capital cost for the saturation unit would probably be similar to the investment for a hydrocracker, yet a hydrocracker

would net higher value products.

Thus, as mentioned, high-level aromatic saturation of high aromatic content streams is probably not the optimum means of cetane improvement of diesel fuel. The FCC cycle oil and hydro-treated blend cited in Table 1 are examples that fit this situation. Overall, the refiner would like to determine what can be done in an existing refinery reaction system or hydrogen loop before considering high investment approaches.

Aromatics saturation tests

Pilot studies were conducted on three feedstocks to define aromatics reduction via saturation:

- 0.16% sulfur, 58% aromatics
- 1% sulfur, 58% aromatics
- 0.5% sulfur, 40% aromatics

These studies used vary-

ing LHSV and pressures ranging from 700-1,500 psi hydrogen. This approach views reducing LHSV at lower constant pressure as a refiner would achieve by adding parallel or series reactors to an existing reactor system.

The catalyst system used in our studies is a stacked-bed system with the proportion of various catalysts somewhat optimized to achieve the highest saturation activity with minimal reactor fill cost. The term "somewhat optimized" means that pilot studies and commercial evaluations are not yet complete.

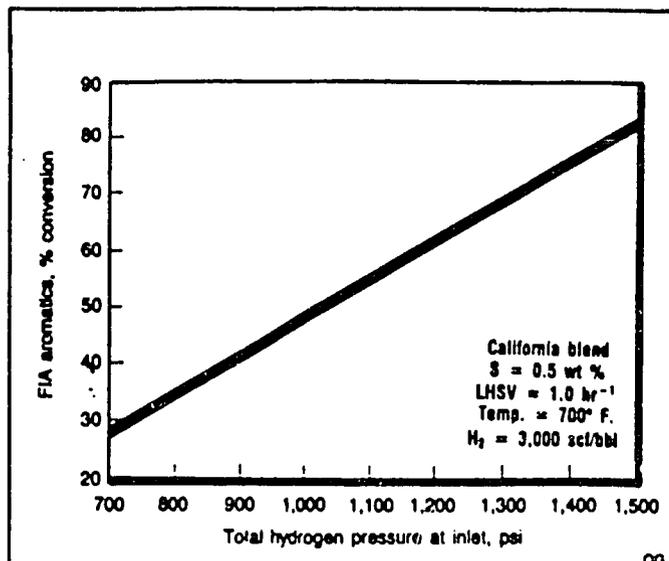
In processing a feedstock defined in Table 1 as a hydro-treated blend of FCC cycle oil, coker gas oil, and straight-run distillate, this diesel boiling range material was doped by adding sulfur back to the 0.16 wt % level, nearly typical for units operating today.

The studies were done at 700° F. reactor temperature; 700, 1,100, and 1,500 psi partial pressure, and at LHSV's that varied between 0.4 and 1.0 hr⁻¹ at the lowest (700 psi) pressure. Fig. 3 shows, as expected, that at constant throughput (LHSV), the pressure increase from 700 to 1,500 psi increases aromatic relative conversion from the 0-5% range to 50-55%.

Fig. 4, for the same feedstock, shows that at the lower hydrogen pressure of 700

118

Aromatics reduction on an actual feed



psi, increased catalyst volume via LHSV reduction to 0.3-0.4 hr⁻¹ increases the FIA aromatic conversion to the 15% range. The key observation here is that low-pressure processing can achieve reasonable aromatics reduction by using increased catalyst volume within the existing hydrotreater reactor system.

One might envision this as first-stage processing to a normal sulfur level product, and then a slip stream processed in the same hydrogen loop at low throughput for incremental aromatics reduction. Hydrogen circulation could be separate or cascaded.

The preceding scheme covers processing of an already hydrotreated refinery blend, thus the scheme is two-stage overall. Single-stage processing with both heteroatom contaminant removal and aromatic satur-

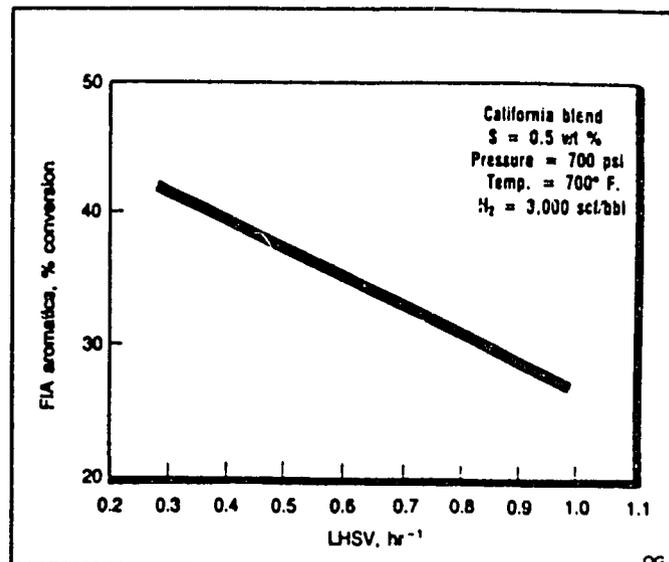
tion at the same time would obviously be more desirable cost-wise. Therefore, the feedstock was further doped to a higher 1.0 wt % sulfur level.

This is where the results get interesting. The study pattern was the same, initially scouting hydrogen pressure between 700 and 1,500 psi. Fig. 5 shows similar performance at the higher pressure levels for the higher sulfur feed.

However, about 10% FIA relative reduction was found at the low 700 psi pressure, compared to less than 5% for the low-sulfur stock. As shown in Fig. 6, as LHSV was decreased at 700 psi, the performance improved even further, and 31% relative FIA reduction was obtained at 0.36 hr⁻¹ LHSV, compared to 15% with the low-sulfur feed.

The difference in the reactivity of the two feeds is high-

Conversion at low pressure, low LHSV



lighted in Fig. 7. Surprisingly, the catalyst system performance improved with higher feed sulfur at low pressure and low throughput.

For further verification of the applicability of single-stage processing, we conducted an identical study of an actual refinery blend, also defined in Table 1. This feed is a California refinery blend of virgin and coker distillates containing 0.5 wt % sulfur and 40 vol % aromatics.

Figs. 8 and 9 show even more dramatic results because greater than 80% FIA aromatics relative conversion was achieved at 1,500 psi and 1.0 hr⁻¹ LHSV, and more than 40% FIA aromatics reduction was obtained at 700 psi and 0.3 LHSV.

Ongoing temperature optimization studies at the same pressure and space velocity conditions are showing increases in FIA aromatics conversion to the 55% range. In addition, we have further confirmed the FIA aromatics conversion with results from other analysis techniques.

Therefore, for this California blend the operation at 700 psi hydrogen pressure and 0.3 hr⁻¹ LHSV will have reduced the FIA aromatics to less than 20% and increased its cetane number to the high 40's. These are interesting data that point to a high probability of low investment cost solution to diesel aromatics reduction.

The studies are continuing

with the aging of the catalyst system and the gathering of more data on the effects of operating variables.

Hydrocracked and mild hydrocracked products

There are two streams produced in some plants which contain low levels of contaminants or virtually no contaminants. Hydrocracking yields diesel boiling range products which contain virtually no significant heteroatom contami-

The author...



Suchanek

Arthur J. Suchanek is manager of technical services for Criterion Catalyst Co. L.P. in Houston. He has nearly 30 years' experience in the refining and petrochemical industries. His background includes all facets of refining, but mainly in the areas of hydroprocessing and bottom-of-the-barrel upgrading. Suchanek was a member of the 1984 NPRA Q&A panel, he is a member of the NPRA screening committee, and he has authored or co-authored 12 technical papers.

Table 3

Noble metal/zeolite catalyst testing on diesel streams

Feed	30-35	30-35
Gravity, °API	0-10	1,200
Sulfur, ppm wt	0-10	200
Nitrogen, ppm wt	30	40
FIA aromatics, vol %		
Required operating conditions		
H ₂ pressure, psi	600	1,500
Temperature, °F.	500-600	675
LHSV, hr ⁻¹	3-4	1.0
% aromatic reduction	>95	>85
% liquid yield, above 300° F.	>95	>90

Q & A SESSION ON HYDROGEN PROCESSING 1990 NPRA ANNUAL MEETINGS

MORGAN:

I agree with the previous comments. We have found that trying to beef up the line supports has not been very effective, nor have changes in process variables. In most cases where vibration was caused by instable fluid flow, we have had to change piping diameter or routing.

QUESTION 15:

What is your experience with alonized tubes in hydrotreater heaters?

RATERMAN:

Mobil currently does not have any experience with alonized tubes in hydrotreater service. We do, however, use 9-chrome alonized tubes in several of our delayed coker heaters with good success in reducing oxidation and internal coking problems. We guess that one could alonize tubes for corrosion reasons, but we find that 321 or 347 stainless steel in hydrotreater heater service is quite acceptable.

CHARLES S. MCCOY (McCoy Consultants):

The use of alonized tubes in hydrotreater heaters is effective if you have a reactor plugging problem because of iron sulfide scale. The alonizing does reduce corrosion and does reduce the bed plugging problem. But my own feeling is you should not bet your life on it. Base the corrosion allowance and expected corrosion rate on the assumption that there are bare spots in the alonizing.

STEWART L. GRIEST (Alon Processing Company):

Information on this topic is available in paper No. 128, presented at Corrosion 1974 in Chicago, entitled "Corrosion Rates for H₂S at Elevated Temperatures and Refinery HDS Processes," by J. D. McCoy, available through the National Association of Corrosion Engineers in Houston.

LANCE FRANZ (Koch Refining Company):

We have used 9-chrome alonized tubes in hydrotreater service with good results. Our operating conditions are not unusual.

Secondly, there is an excellent reference book on this and other material selection matters. It is a book by the NACE, titled, "Process Industries Corrosion Theory and Practice". In the book there is a section, "Petroleum Refining Corrosion", by Gutzeit from Amoco which in 20 pages does an excellent job of covering material selection, both for high temperature corrosion and low temperature corrosion like some of the topics we have talked about earlier today.

In addition, the NACE book has an excellent bibliography for somebody who wants to dig deeper into some of these subjects.

QUESTION 16:

Does anyone use a cartridge-type feed filter in gas oil HDS service that will operate successfully above 400 °F? What types of filters are available and what is the upper temperature limit for each?

SCHAUB:

We do not know of a cartridge filter for this service. The Ronningen-Petter backwash filters can be used at tempera-

tures of up to 650 °F with the proper choice of materials. Perhaps the questioner has something like this and wants to change it out. If you are willing to be a partner in some developmental work, it may be interesting to see some of the sintered-metal filters or the etched-disc filters that are now being used on FCC slurry. Gas oil HDS service should be an easier application.

Process**QUESTION 17:**

What advances in hydrotreating technology are being pursued to saturate aromatics at low pressures (i.e., below 1,000 psig)? What modifications can be added to a low pressure light cycle oil treater (approximately 700 psig total pressure) operating for a target sulfur of 0.05 weight percent, that will enable the unit to reduce aromatics from 70 volume percent to below a level of 20 percent?

BRANHAM:

Many people are working on catalyst for light cycle oil hydration. However, the most effective present means to saturate light cycle oil is high pressure, precious metal treating. It is very doubtful that a 700 psig total pressure unit will be appropriate for 70% aromatic reduction, even at very low space velocities. I would refer you to an article by Criterion Catalyst that appeared in the May 7, 1990, issue of the "Oil and Gas Journal," for a discussion about some of the catalytic alternatives that could be considered.

RATERMAN:

Mobil currently does not have any specific operating experience with saturating aromatics at low pressure. We are, however, pursuing options such as those reported in the Criterion paper in the "Oil and Gas Journal" of April 29, 1989.

As to the second part of this question, we do not believe that going from 70 to 20 vol % aromatics will be feasible without using as active a catalyst as possible in addition to increasing reactor volume or reducing the capacity of the unit to achieve the lowest possible reactor temperature.

This will be required since thermal dynamics favor aromatic saturation at low reactor temperatures and high hydrogen partial pressures, while reaction rates are favored by temperatures and catalyst activity or volume. At 700 psi the additional catalyst will allow operation at the lowest possible reactor temperature for maximum aromatic saturation at the highest possible reaction rate. Even so, 20 vol % aromatics may not be possible.

SCHAUB:

We agree. At the present time only the high operating pressure could assure saturation of aromatics.

TIEMAN:

We think that possibly the existing hydrotreater could be modified to satisfy the immediate requirement for lower diesel sulfur contents and then it could be possible later on to add an aromatic saturation stage and use the hydrotreater as a pretreatment portion for noble metal catalyst

type. We are looking at two stage processes at low pressure for that application.

WILSON:

We have run quite a few tests on this using conventional nickel molybdenum or cobalt molybdenum hydrotreating catalyst. We found that high hydrogen partial pressures on the order of 1,500 to 1,900 psig, as well as low liquid space velocities, are required for deep aromatic saturation. We also found that nickel molybdenum type catalyst show a definite advantage over cobalt molybdenum. Only additional catalyst volume will enable the unit to achieve ultra low levels of aromatics.

As a test, at a hydrogen partial pressure of 500 psig and a space velocity of 2, we found that 45% of the di-aromatics and tri-aromatics were saturated to mono-aromatics for a light cycle oil feed. However, total aromatics content of the light cycle oil was reduced only 2.5 vol %. More details on these data and the results of this test were published in 1990 at the NPRA Annual Meeting, in Paper AM-90-19.

ARTHUR J. SUCHANEK (Criterion Catalyst Company L.P.):

Yes, we are aggressively pursuing low pressure options for removal of aromatics as well as the deep desulfurization. The paper we presented in the spring clearly showed that we can do this with Criterion Catalyst at low pressure by adding catalyst volume. As a matter of fact some of the work that we are pursuing now is showing that we can go as high as 40% aromatics reduction at 600 psi. We have a catalyst system that is being developed with our Zeolyst brothers in which we are currently wrapping pipes around a process that will enable at 700 or 750 psi to be able to really get to levels of the 20 to 30% aromatics with the type of feedstock we are talking about here. It is our main objective to try to minimize the amount of investment cost that the refiner will have to incur. If you are going to put in high pressure equipment, it seems that one should seriously be considering hydrocrackers as opposed to aromatic saturation. This will provide much more economic value for you.

DONALD B. ACKELSON (Unocal Corporation):

At pressure levels below 1,000 psig we prefer a two-stage approach, the first stage being used to hydrotreat to low nitrogen levels, and the second to saturate aromatics over a noble metal catalyst. Using this approach we have reduced cycle oil aromatic levels from around 70 to 5% or less. At 700 psig, a cycle oil hydrotreater will saturate some poly aromatics to mono aromatics but will not likely reduce total aromatics to any great extent. Again, the most likely successful approach would be to use the hydrotreater as a nitrogen removal step prior to a noble metal catalyst.

OSCAR A. ALDAMA (Coastal Refining & Marketing, Inc.):

I have a question for the Criterion representative. What kind of liquid hour space velocities will you have to have?

ARTHUR J. SUCHANEK (Criterion Catalyst Company L.P.):

When you are talking about the all alumina system, we are looking at pressures, as I mentioned in the paper, at 700

psi with space velocities between 0.3 and 0.5. When you look at the zeolite system, we have an active zeolite that can function very well with higher sulfur and nitrogen than you are normally used to seeing. So the levels would be fairly high in the second stage. The first stage would be set to be able to get the nitrogen and sulfur to the levels that are required for the second stage. It is feedstock dependent, obviously.

JOHN A. LYNCH (Petrogistics, Inc.):

I know there has been a lot of investigation in pursuit of dearomatization of light cycle oil. But there may possibly be an opportunity for a number of refiners to consider the aromatics extraction of that stream. Since 1970, the dinuclear aromatic content of light cycle oil has doubled. It has gone from roughly the 20 to 25% range up to about presently 50%. Back in the late 1960s, Sun actually had a unit in Toledo, Ohio, for recovery of naphthalene and dinuclear aromatics out of that stream. I believe that unit is now being dismantled. Marathon at Detroit also had a unit, known as Redex and Simex. At the time, there really was not a big incentive to go after the naphthalene molecule via light cycle oil extraction. But I think the time has come for naphthalene extraction from LCO, when you are facing the alternative dearomatization capital costs and operating costs. You can not solve everybody's problems with extraction, but I believe there are a number of refiners that can take the chemical opportunities associated with that naphthalene molecule and put it in the chemical marketplace versus the fuel.

G. ED ADDISON (ARI Technologies, Inc.):

What happened to the thought that what the EPA really wanted was to remove the tri-cyclic and di-cyclic aromatics from diesel. Does not the EPA give credit for that? Could I have comments from the panel and audience?

WILSON:

I am not so sure that the EPA differentiates between di- and tri-aromatics and mono-aromatics. If anybody has some information on that, I would certainly like to know about it.

CHARLES S. MCCOY (McCoy Consultants):

The EPA insists on looking at total aromatics when talking about aromatics reduction in diesel, while most of us believe that mono-aromatics are essentially harmless. It is the di-, tri-, and poly-aromatics that are creating problems.

G. ED ADDISON (ARI Technologies, Inc.):

It just seems so obvious. What you have in mono-cyclic aromatics are materials that are going to be burned. When you find a benzoid coming out of an exhaust, you probably have the remnants of a di-aromatic or tri-aromatic that did not quite make it to the oxidation stage. They tend to increase entropy but not sufficiently to complete the combustion process. I think the single rings have a much better chance.

HIGGINS:

I can agree with the statement that EPA concentrated on total aromatics as opposed to aromatic species. In their

Regulatory Impact Analysis, EPA stated that the available data on diesel fuel aromatics species were limited and the analyses of the effect of aromatic species on emissions "should be considered preliminary."

The EPA backed off the 20% maximum aromatics specification because, based on the proposal by the joint oil-diesel manufacturers, the diesel manufacturers felt that they did not need the 20% aromatics to meet the specified 1994 particulate emission levels. Also, EPA concluded that the reduction in emissions achieved by reducing fuel aromatics would not be cost effective.

ARTHUR J. SUCHANEK (Criterion Catalyst Company L.P.):

I am going to add a little bit to that. The work that we have been doing is not just centered on FIA aromatics, although the papers that we have presented have presented it that way because that is what people are used to looking at. What is really happening is that the tri-aromatics and the di-aromatics are saturating down to the mono-aromatics. We are also reducing the mono-aromatics significantly with the catalytic systems that we are talking about, but it is very critical to understand that even in low pressure desulfurization, and with high catalyst volumes, to be able to get aromatic saturation at the same time, there is a very good probability that the aromatics coming out of that system will be predominantly mono-aromatics.

QUESTION 18:

What special efforts have been made to increase the purity of recycle gas other than H₂S removal?

KENNEDY:

We increase the purity of our recycle gas streams in our hydrotreaters by doing three things. We recontact our excess catalytic reformer offgas in our naphtha hydrotreater products separator. We process a portion of our catalytic reformer offgas in our PSA system. And we maintain a purge stream on each of our hydrotreaters.

RATERMAN:

In our hydrocracker designs, we rely on the DEA scrubbing system and recycle gas purge between 5 and 15% of the makeup gas rate to maintain recycle gas hydrogen purity. The purge gas rate is dependent upon the degree of conversion in the hydrocracker and is usually cascaded to a low pressure hydrotreater. Another method that is used to improve hydrogen purity is a high pressure naphtha adsorber. This is usually used downstream of the H₂S removal step to selectively remove methane and other light hydrocarbons.

SCHAUB:

We would also look at a naphtha sponge absorber to reduce the concentration of C₃'s and C₄'s in the hydrogen recycle. The recycle stream would be enriched in hydrogen concentration. The extent of the purification, or the benefits, would differ for every unit. Economic justification might be questionable. We would have to look at it very closely before recommending it.

LOUIS SCOTTI (ABB Lummus Crest Inc.):

We have developed a patented low pressure recycle gas purification system using a PSA system. This system has been developed as part of an improved LC Finer product recovery system design and it is in commercial operation at Syncrude's plant.

QUESTION 19:

What parameters are commonly considered to set the gas/feed oil ratio at reactor inlets for naphtha, diesel, and vacuum gas oil desulfurizers?

WILSON:

The optimum hydrogen to oil ratio for any hydrotreater depends on the type of feed, system configuration, and the operating mode of the unit. However, as a general rule, we like to use a 3 to 1 ratio of hydrogen to oil versus hydrogen consumption at the reactor outlet. Thus, if you consume 100 standard cubic feet hydrogen per barrel of feed, you should have 300 standard cubic feet per barrel at the outlet, or in other words 400 standard cubic feet per barrel at the inlet. The goal here is to insure adequate hydrogen partial pressure throughout the reactor bed, limiting any chance of localized hydrogen starvation. This will affect the percent hydrodesulfurization and especially the percent hydrodenitritication and the catalyst stability if you do have low hydrogen areas.

For easy service, such as straight-run naphthas, this ratio can be reduced to 2-to-1 or so. While for more difficult services, in particular, those with a high percentage of cracked feedstocks, we would prefer to see something more towards 4-to-1. Of course the higher hydrogen-to-oil ratios can improve the catalyst activity by reducing the H₂S partial pressure, but they also decrease the unit activity by reducing the residence time for the vaporized hydrocarbons.

Thus, one needs to find an optimum for each unit, balancing unit capabilities with the desired cycle length. Hydrogen-to-oil ratios for hydrocrackers tend to be dictated by heat release and other factors as well as the hydrogen consumption.

RATERMAN:

There are numerous requirements which contribute to setting the hydrogen-to-oil ratios at the inlet of the reactor. The most obvious factor is the need to maintain excess hydrogen through the reactor to account for the chemical consumption. Other factors include acting as a heat sink to limit the temperature rise or drop across the reactor due to the heat of reaction or to insure the proper hydrogen partial pressure for catalyst aging or fouling reasons.

In addition to the above, liquid distribution and holdup considerations may also set hydrogen recycle requirements as well as the particular need to have an all vapor phase present throughout the reactor. In general, for a new distillate hydrotreater, we would recommend a minimum recycle rate that is 4 times the chemical consumption. Heavier feeds will require higher recycle rates. For more general information concerning the general hydrogen partial pressures and the recycle gas requirements of various units, we refer you to an article by Art Suchanek, in the December 17, 1984, issue of the "Oil and Gas Journal."

APPENDIX C

**COMPREHENSIVE LIST OF ENERGY CONSERVATION
PROJECTS IMPLEMENTED BY DKV SINCE 1985**

**Engineering Projects Without Capital
Investment Requirements**

	<u>Savings</u>
	GJ/Year
Utilization of heat content of heavy gas oil for BFW pre-heating in certain modes of operation in Topping Unit AV-3.	76,739
Realization of simultaneous production of n-hexane, special boiling point (SBP) naphthas and isopentane-rich gasoline blending component in Light Naphthas Isomerization Unit with elimination of stabilizer system.	303,439
Replacement of steam with dark cut as heating medium for reboiling stripper column used for adjustment of kerosene flash point in Topping Unit AV-2.	24,371
Utilization of remaining heat content of dark cut after heat exchange for generating 3 barge steam	30,800
Implementation of a side cut system for the preflash column in Topping Unit AV-3 to produce a naphtha cut in acceptable quality for downstream processing and sending it directly to the Naphtha Redestillation (Gasoline Fractionation) Unit	82,000
Increase of steam production by modifying one steam generator coil for alternate use of atmospheric or vacuum residue as heating medium and by increasing the size BFW feed nozzle and line.	28,790
Reduction of steam consumption in FCC Unit by optimizing main column bottoms (MCB) recirculation system and changing catalyst type from DA 250 to NOVA-D.	75,628
Reduction of steam consumption in Gas Oil Hydrodesulphurization Unit GOK-2 by changing heat tracing systems from steam to condensate supply and by the modification of the 10 barge steam system.	22,322

Savings

GJ/Year

Reduction of steam consumption in Aromatics Complex by eliminating intermediate storage (with accompanying cooling & re-heating losses) and sending product streams directly to downstream processing between Reformer 1 & Aromatics Extraction 1, Reformer 2 & Aromatics Extraction 2 and Ortho-Xylenes & Xylene-Isomerization Units. Reduction of steam and fuel consumption also by implementing direct links between repeated extraction and distillation operations.

174,325

Reduction of steam consumption by installing automatic heating control systems actuated by electric regulators for subcontractor buildings and temporary construction site facilities.

14,486

Reduction of fuel consumption in Gas Oil Hydro-desulphurization Unit GOK-2 by installing up-to-date VEIKI Model OGX burners for heater.

12,640

TOTAL

845,540 GJ

II. Energy Conservation Projects Implemented with Capital Investments

A. Reduction of Hydrocarbon Losses

Hydrocarbons recovery by three-phase sludge centrifuge at waste water treatment plant.

570,520

Flare gas recovery

590,903

TOTAL

1,161,423 GJ

B. Heat Recovery from Flue Gases

Installation of heat recovery system for steam generation for heaters in Topping Unit AV-3.

242,537

Installation of heat recovery system for steam generation for heaters in Topping Unit AV-2.

140,584

	<u>Savings</u>
	GJ/Year
Heat recovery from Bitumen Plant tail gases for steam generation.	74,638
Installation of heat recovery system for steam generation for heater in Reformer-1 Unit.	86,356
Installation of heat recovery system for air -preheating and burner modernization for heaters in Naphtha Redestillation unit.	97,733
Reduction of fuel consumption by heat recovery from flue gases and burner modernization for heater in Gas Oil Hydro-desulphurization Unit GOK-1	61,824
Installation of heat recovery system for air pre-heating and burner modernization for heaters in Reformer-1/2 Units.	137,400
Installation of heat recovery system for steam generation in Waste Incinerator Plant.	140,400
	<hr/>
TOTAL	989,472 GJ
 C. <u>Heat Recovery from Products Streams</u>	
Reduction of fuel/steam/power consumptions in Gas Oil Hydro-desulphurization Units GOK-1/2 by recycle gas pre-heating, heat recovery from hydrotreated product & optimization of heat exchanger system (with steam generation stopped, however)	11,376
Reduction of fuel/steam consumptions in Topping Units AV-1/2/3 by optimization of heat exchanger systems & condensate pre-heating.	439,200
Reduction of steam consumption in Wax Plant by optimization of heat exchanger system.	56,100
	<hr/>
TOTAL	506,676 GJ