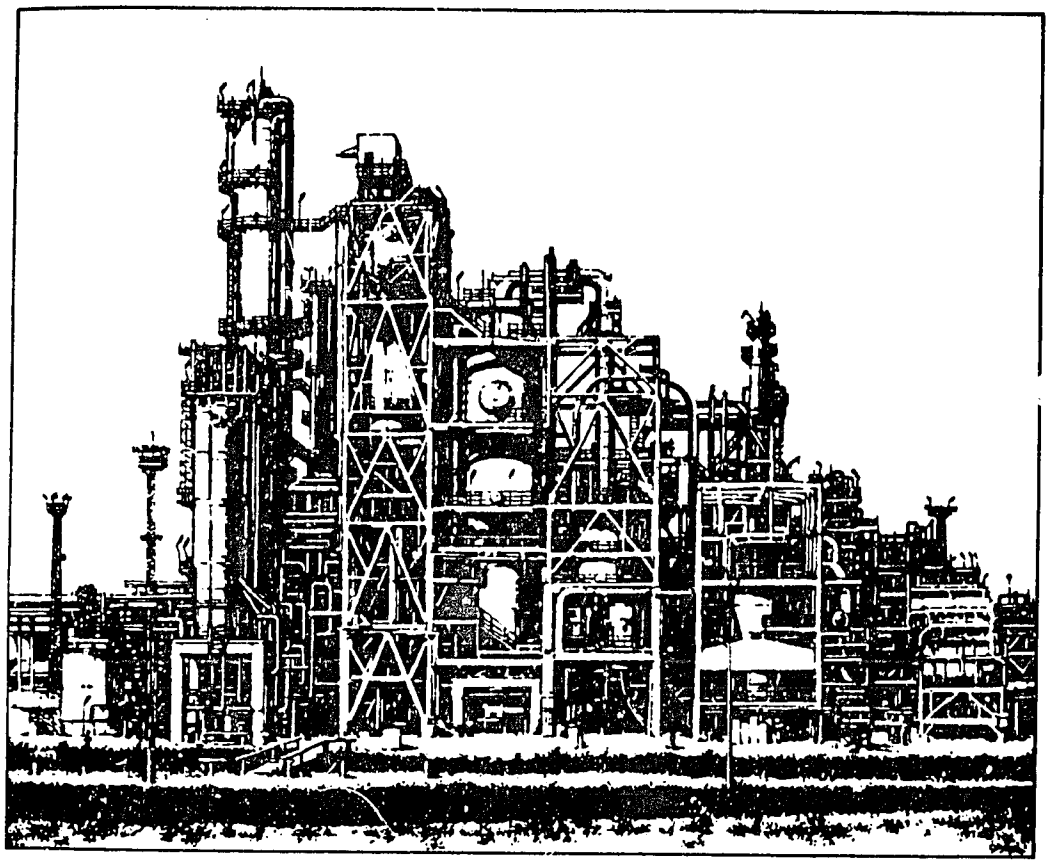
PN-ABK-030

PHASE I FINAL REPORT

A CHARACTERIZATION STUDY OF HUNGARY'S PETROLEUM REFINERY INDUSTRY:

A SECTOR IN TRANSITION

AUGUST 1991



Prepared Under Prime Contract No. EUR-0015-C-00-1007-00
For the

Europe and Near East Bureau of the
U.S. Agency for International Development

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EXECUTIVE SUMMARY

Introduction and Study Objectives

The unprecedented political upheavals that occurred throughout Eastern Europe in 1989, and the recent steps that have been taken toward greater privatization and freer market economies among former members of the Council for Mutual Economic Assistance (CMEA), herald significant changes for the oil and gas industries of the region. Moreover, the recent Persian Gulf crisis has compounded Eastern Europe's problems in obtaining access to sufficient and reliable supplies of crude oil as the Soviet Union continues to reduce exports in the face of dramatically declining production. However, even when Soviet crude is available, new sales are based upon higher international prices in spot markets, and must be paid in convertible currency.

At the same time, emerging market conditions for the product slates from these refineries are no longer conducive to or based upon the needs of a command economy and integrated trading union with other socialist nations. In addition, growing public awareness of the extent of accumulated environmental degradation is likely to bring about more stringent guidelines and regulations as these countries strive to improve overall environmental quality. Finally, as these countries transition to freer market economies, tightened economic conditions will force refinery managers to look for cost savings through more efficient operation of process units and related equipment, and opportunities for additional energy conservation at each refinery.

In a sense then, everything that confronts the manager of a petroleum refinery in Eastern Europe today is in a state of rapid change and flux. His country and economy are moving toward greater privatization and freer markets; his crude oil sources have become less reliable and vastly more expensive; the chemical and physical properties of his crude oil inputs are for the most part dramatically different than what his refinery was designed to process; his product slate is beginning to change and he will soon face increasing external competition; growing public awareness of the need to improve environmental quality will force him to reorder his investment priorities; and tighter operating budgets will force a second look at process unit operating efficiencies and overall energy usage.

In an effort to assist Hungary's petroleum refinery sector during this period of transition and unprecedented change, the U.S. Agency for International Development has developed a near-term program whose initial study effort has the following objectives:

(1) Describe the overall process mix; capabilities, and current operating practices in the Hungarian petroleum sector for use in undertaking possible future work;

(2) Undertake a characterization review of both the Dunai Koolajipari Vallalat (DKV) and Tizai Koolajipair Vallalat (TIFO) refineries;

(3) Identify changes in practice and low-cost modifications to existing refinery equipment that can be implemented in the near-term, and are designed to increase efficiency, conserve energy, and reduce undesirable emissions and effluents; and

(4) Assist the management of both the DKV and TIFO refineries in planning and implementation of the changes identified during the study effort.

This volume addresses the first two objectives, while a companion report will address the third and fourth objectives.

Relevant Background

Historically, Hungary's major international supplier of crude oil and natural gas exports has been the Soviet Union. In 1989, the most recent year for which complete data is available, Hungary imported 60 percent of its 166,000 barrels per day crude oil requirements; fully 90 percent of these volumes came from the Soviet Union. However, as has been widely reported by such diverse sources as the International Energy Agency (IEA), Oil & Gas Journal, and the Wall Street Journal, Soviet exports of crude oil have been cut dramatically. The IEA recently confirmed that 1990 supplies to Hungary from the Soviet Union were expected to reach 130,000 barrels per day, but that a more likely figure is less than 100,000 barrels per day. Indeed, further cuts in Soviet crudes can be anticipated. However, Hungary still remains interested in purchasing Soviet crude oil--even at world prices --since transportation costs are relatively low, and Hungarian refineries were designed to process a narrow slate of crude oils from the Soviet Union.

The Hungarian National Oil and Gas Trust (OKGT) was established in 1957, responsible for managing all activities in Hungary's nationalized oil and gas sector. As such, OKGT is a parastatal organization reporting to the Hungarian Ministry of Industry. At present, the 22 companies of the Trust are divided into three broad groups: 11 vertically-related companies in oil and gas exploration, production, transport, refining, and marketing; 5 independent natural gas suppliers; and 6 companies in background or related industries such as machine manufacturing, pipeline construction, design, and applied research.

However, discussions are currently underway in Budapest regarding how best to reorganize Hungary's refinery sector.

Overview of Hungary's Refinery Sector

In the early 1980's, Hungary had five refineries with a distillation capacity of approximately 14 million tons per year operating at about 65 percent of their capacity. A brief description of the current status of each of these facilities is presented below:

- **Dunai Koolajipari Vallalat (DKV)**

  This major refinery complex is situated approximately 30 km south of Budapest at Szazhalombatta on the Danube River. DKV was founded in 1960, with construction commencing in 1961. The first production unit was brought on stream in 1965. Since then, more than 30 new processing units have been added to achieve a total capacity for processing 10.0 million tons of crude oil per year. However, in the mid-1980's, OKGT shut down one of DKV's four distillation units so that present capacity is at 8.0 million tons per year, or at approximately 150,000 barrels per day. 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 for oil-fired generating capacity. In addition to traditional crude oil refining, 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)**

  This refinery is located in the north-eastern part of Hungary at Leninvaros 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 four oil/gas units with a total capacity of 860 MW. The original design for TIFO envisioned four processing units totalling 8 million tons per year. However, after the first of these units came on stream in 1979, the plan was revised downward to 3 million tons per year, or approximately 60,000 barrels per day. While TIFO is Hungary's second largest refinery, it is presently being under-utilized as a result of Soviet crude oil curtailments. In this regard, OKGT prefers to maximize DKV's capacity first since it is a more complex refinery. In addition, the 860 MW power plant at TEV was only operated at 25 percent capacity last year, limiting the amount of heavy ends that TIFO could sell. Moreover, since TIFO cannot separately supply all of the virgin naphtha needs of the adjacent olefin plant at TVK from existing capacity, TVK is increasingly turning to DKV to provide the bulk of its virgin naphtha requirements. As a result, TIFO was operated at a capacity of 800,000 tons per year in 1989, and only 350,000 tons per year in 1990. Present projections for 1991 have TIFO's processing unit operating at a capacity of about 1.1 million tons for the year.

- **Zala Koolajipari Vallalat (ZKV)**

  This small refinery is situated in the western part of the country at Zalaegerszeg on the Zala River. The ZKV refinery has a capacity of 500,000 tons per year, and is presently being used to process heavy Hungarian crude. It is mainly utilized for asphalt production today.

- **Komaron Koolajipari Vallalat (KKV)**

  This facility is located in northern part of the country at the town of Komaron upstream from the Danube Bend region. It originally had a crude refining capacity of 100,000 - 200,000 tons per year. However, the refinery was closed by OKGT in the mid-1980's, and is now used primarily as a lube oil blending facility utilizing feedstocks provided by DKV.

- **Nyirbogdany Plant**

  This plant has been a TIFO subsidiary since 1976, and is located in the extreme northeastern part of Hungary at Nyirbogdany near the Soviet border. The facility originally had a refinery capacity of 300,000 tons per year, but was shut down in the mid-1980's. Today, it produces various kinds of vasolines, anti-corrosion products, and auxiliary industrial oils from feedstocks provided by TIFO and DKV.

By way of summarizing the current status of Hungary's refinery sector, the following statistical data is provided below for both charge and production capacities:

SUMMARY TABLE 1

1990 CHARGE AND PRODUCTION CAPACITIES OF OPERATIONAL HUNGARIAN REFINERIES

(in barrels per day)

	DKV	TIFO	ZKV	TOTAL
Crude	150,000	60,000	10,000	220,000
Vacuum Distillation	84,000	30,000	6,000	120,000
Thermal Operations	13,300			13,300
Catalytic Cracking	20,000			20,000
Catalytic Reforming	23,000			23,000
Catalytic Hydro-Treating	76,600			76,600
Alkylation	3,300			3,300
Aromatics/Isomerization	9,800			9,800
Lubes	4,000			4,000
Asphalt	6,300		4,500	10,800

SOURCE: OGJ Special, December 31, 1990, Oil & Gas Journal

In addition, the following table indicates in a relative sense how Hungary's overall refinery product slate compares with those of other former CMEA countries.

SUMMARY TABLE 2

OUTPUT OF REFINED PETROLEUM PRODUCTS FOR 1988

(in thousands of barrels per day)

Eastern Europe and USSR	Motor Gasoline	Jet Fuel	Kerosene	Distillate Fuel Oil	Residual Fuel Oil	LPG	Lubricants (inclu. Greases)	Other	Total Output Of Refined Petroleum Products	Refinery Fuel and Losses
Albania	5	0	2	7	12	(*)	(*)	18	44	4
Bulgaria	39	0	5	69	111	3	2	16	247	12
Czeckoslovakia	37	0	9	91	146	5	8	33	328	20
East Germany	111	0	(*)	128	116	10	10	25	400	21
Hungary	38	0	7	65	34	3	4	47	198	8
Poland	66	0	4	105	49	8	10	58	299	11
Romania	128	0	10	139	164	9	11	75	535	28
USSR	1,916	590	224	2,285	3,145	276	157	745	9,337	359
Totals	2,340	590	259	2,889	3,776	313	202	1,018	11,388	463

SOURCE: U.S. Department of Energy, Energy Information Administration, International Energy Annual 1989.

Existing Crude Pipelines

Hungary possesses three crude oil pipelines of sufficient capacity to handle required imports for the foreseeable future. These pipelines include: the Friendship I pipeline from the Soviet Union through Czechoslovakia, entering Hungary from the north, and proceeding directly to DKV; the Friendship II pipeline, direct to TIFO from the Soviet border in the northeast, and then onward to DKV; and the Adriatic pipeline from the Adriatic Sea, up through Yugoslavia and the southwestern part of Hungary with its terminus at DKV. This latter pipeline alone has a capacity of 10 million tons per year.

With respect to apparent deficiencies in this system, lighter imported crudes from Africa and the Middle East cannot presently be transported to TIFO to replace shortfalls in Soviet crude. The Adriatic and Friendship II pipelines are not connected, and the Friendship II pipeline lacks a reverse flow capability.

Crude Purchasing and Product Marketing

Given the nationalized nature and centralized management of Hungary's oil and gas sector over the past forty years, responsibility for purchasing crude oil imports still resides with the Hungarian National Oil and Gas Trust, rather than with the refineries themselves. Indeed, until very recently OKGT made all decisions regarding crude oil imports without any input from refinery managemen and senior operating staff. However, it should be noted that each of the major refineries now has one member on the governmental board that coordinates all crude oil purchases from abroad.

Hungary's refinery products are distributed by Mineral Oils Sales Company (AFOR) and the Chemical Industrial Production Facility Trading Company (VEGYTEK) for the domestic market. Distribution of refined petroleum products to overseas markets is handled by three separate state trading companies. These include: the Hungarian Trading Company for Chemicals (CHEMOLIMPEX), the Hungarian Trading Company of Machines and Equipment for the Chemical Industry (CHEMOKOMPLEX), and the Hungarian Trading Company for Oils and Mining Products (MINERALIMPEX).

Principal Observation and Findings

General Impressions of the Refinery Sector

During Phase I of this assignment, the K&M team formed the following general impressions with respect to the Hungarian petroleum refinery sector:

- The technical and managerial staffs of both the DKV and TIFO refineries are superbly qualified, and knowledgeable about current U.S. and West European technological trends in the refining industry, especially in the areas of energy conservation and process technology.

- In addition, Hungarian refinery personnel have been successfully engaged in aggressive energy conservation efforts for the past decade, and have achieved significant reductions in overall energy usage over this period.

- Overall environmental compliance lags considerably behind recent U.S. and West European efforts in the refinery sector, with most environmental problems being concentrated at the older DKV facility.

- The DKV refinery is considered a modern and complex facility (cracking, lubes, petrochemicals) which is presently being operated at or near capacity; however, this refinery is lacking in additional capacity for conversion of residual materials into lighter transportation fuels, and still has major difficulties in meeting existing environmental guidelines and limits in several key areas.

- On the other hand, based upon a brief analysis of rather limited operating data, it appears that the operating efficiency of DKV's catalytic reformers and FCC units is comparable with similar units found in both Western Europe and the United States.

- Reliability of supply of electricity is a major concern for the DKV refinery.

- The TIFO plant is a modern, low-complexity refinery (distillation, hydrotreating) which is presently being operated at about one-third capacity as a result of serious feedstock and product dislocations.

- TIFO does not presently have facilities for the conversion of vacuum gas oil and residual oil fractions. As a result, while TIFO possesses excellent infrastructure and is well-maintained, it will require major investments for additional conversion capacity to remain competitive in the future, and avoid being bottlenecked by swings in the demand for heavy fuel oils.

- Moreover, TIFO was designed to process a narrow slate of Soviet crudes. In addition, it cannot presently utilize African or Middle Eastern crudes as alternate feedstock sources since the Friendship II pipeline does not possess a reverse flow capability.

- As a final general observation, there is presently insufficient participation by and input from senior refinery technical and managerial staff in the areas of crude oil purchasing and product marketing.

Challenges Facing Refinery Management

Refinery managers in Hungary today are being buffeted by significant changes seemingly beyond their control as the entire country moves from a command economy to one that is more responsive to price signals and bottom line profits. Some of the most serious changes and uncertainties confronting refinery managers at DKV and TIFO include:

- Significant feedstock disruptions brought on by the curtailment of Soviet crude exports and dramatically increased prices;

- Radical swings in the chemical and physical properties of refinery feedstocks as crude oil purchasers scramble to locate more stable supplies of crude.

- Serious product dislocations such as a rapidly deteriorating market for heavy fuel oils as a major fuel source in fossil-fired power plants and factories; in addition, the demand for unleaded motor gasoline appears to be growing steadily in Hungary as a result of having the highest per capita ownership of new automobiles in Eastern Europe;

- Growing public awareness in Hungary of environmental protection issues, especially in communities that are located near major point-source polluters such as petroleum refineries, petrochemical facilities, and fossil-fired power plants;

- Tighter operating and capital improvement budgets resulting from the higher cost of crude inputs, lower profit margins, and the dwindling availability of loans from such traditional sources as Government and the CMEA Development Bank; and

- Growing feeling of frustration and concern over the uncertainties surrounding the future direction of privatization and reorganization efforts in the refinery sector, which has the potential for reopening the whole issue of specific retrofit decisions and investment priorities that have already been approved and incorporated into the current five-year plan.

Impact on Operating Efficiencies

Such changes and uncertainties are beginning to have a detrimental impact on overall operating efficiencies at both refineries.

- For instance, K&M has estimated that the Hungarian refinery sector is presently losing about U.S.50¢ per barrel in overall bottom line profitability as a result of not being able to optimize crude purchases to product yields and slates.

- Similarly, there appears to be a lack of appreciation on the part of both OKGT and the refineries regarding the fragility and vulnerability of their traditional product markets during such a period of transition and change; in this regard, a US5¢ per barrel transportation advantage will never be sufficient to offset the estimated US50¢ per barrel loss due to inefficiencies brought on by rapidly changing crude and product markets.

- With respect to the dramatically increased prices that Hungary has had to pay for crude oil imports during the past two years, the critical question that OKGT should ask in choosing higher priced crude is whether the saving in operating costs plus the added revenue from an improved product slate is more than sufficient to offset the higher cost of the premium crudes that are now being purchased; in this regard, to achieve a favorable profit situation, refinery managers will need to value and select the slate of crude for maximum profit, produce and market the slate of products for maximum profits, and given these crude and product slates, optimize individual processing unit operations accordingly.

- Finally, in as much as TIFO was only operated for about two and one-half months in 1990, and is still being run at less than 40 percent capacity as a result curtailments in Soviet crude deliveries via the Friendship II pipeline, improvements in energy conservation and refinery efficiency are presently academic for this facility.

Status of Energy Conservation Efforts

While specific near and longer-term energy conservation recommendations will be made in the Phase II report, both refineries have already made significant progress in addressing major energy losses, especially in the last five to six years.

- In 1985, under the auspices of the World Bank, Foster Wheeler Iberia conducted in-depth energy audits of both the DKV and TIFO refineries.

- From a preliminary survey encompassing 82 potential areas for achieving energy savings, DKV and the World Bank selected about 40 high priority energy conservation projects, of which approximately one-third of the most cost-effective projects on this list have already been implemented.

- As a result, total energy consumption at DKV has exhibited a marked decline over the past five years, and when compared with U.S. and Western European refineries of similar complexity, DKV's overall energy usage per unit input of crude feed is approximately the same despite the fact that it is physically spread out and dispersed over a relatively large site.

- Similarly, TIFO has also achieved significant energy savings after six years of intensive energy planning and improvements, including the installation of an automated energy monitoring system.

- Finally, ongoing energy conservation efforts are well managed at both refineries, and it would appear that diminishing returns have, for the most part, long since set in regarding any major new undertakings in the area of energy conservation at these two refineries.

Environmental Protection Issues

Environmental regulations are presently much less stringent in Hungary than in the United States. As a result, overall environmental protection has received considerably less attention in Hungary's refinery sector compared to the heightened emphasis placed upon such concerns at similar facilities in both the United States and Western Europe.

- While DKV presently has a very active environmental protection effort underway, serious pollution problems still exist in the areas of air pollution (where the refinery is a major emitter of SO_2, CO, and hydrocarbons such as benzene, toluene, and xylene), production of waste water (where DKV is considerably over the limits for chemical oxygen demand), and soil and groundwater contamination under large areas of the refinery (caused by leaks and spills of hydrocarbons over the past 25 years of operation).

- On the other hand, TIFO is a much newer and less complex refinery whose unit operations reflect more recent advances in pollution control technology.

- As a result, TIFO is not a significant contributor to the serious air quality and other environmental problems which appear widespread in the vicinity of Tiszanvaros.

- Finally, while the environmental staffs at both refineries appear to be very dedicated and capable, they lack laboratory and test equipment comparable to that found at similar U.S. refineries, and also seem somewhat unfamiliar and not fully aware of specific environmental control technologies deployed in U.S. and Western European refineries.

Unsuitability of Coal Substitution

At the request of USAID, K & M undertook a preliminary investigation into the practicality of replacing petroleum hydrocarbon fuels in the refinery furnaces at the DKV refinery with indigenous coal. Such a fuel switch does not appear to be a viable option at the present time for the following reasons:

- Hungary's coal subsector has long suffered from declining production, acute labor shortages, and lengthy lead times for either expanding existing operations or developing new mines.

- Hungary's indigenous coal is also of inferior quality with low calorific values, high ash contents, and fairly high percentages of sulfur.

- Even if capital investment funds were available to construct coal washing/coal preparation plants or coal-slurry pipelines, the refineries would still end up with a higher sulfur fuel replacement, since chemical coal cleaning processes are not yet commercially available.

- As a result, DKV would be compounding an already serious SO_2 emission problem.

Need for New Evaluative Criteria

In light of declining domestic production of petroleum, rapidly rising prices for imported crude oils from non-Soviet sources, reduced profits, and dwindling sources of traditional financing for refinery expansions and improvements, OKGT, DKV, and TIFO now face the problem of how to use their limited investment resources most efficiently during this austere period of transition.

- Under the Government's traditional framework for managing and controlling its parastatal enterprises, OKGT has had only limited and at times unclear degree of autonomy, particularly in the area of investment decisions.

- Such decisions are oftentimes subject to the approval of multiple government bodies, thus making it difficult for OKGT to develop appropriate and consistent internal criteria for the allocation of investment funds, especially among competing activities.

- Moreover, to the extent that evaluative criteria exist for the rank-ordering of investment decisions, they tend to be quite general; for instance, the three principal criteria employed by DKV for ranking potential investment decisions in their bottoms - up planning process include: need, overall cost, and availability of investment funds.

- While such criteria may still be suitable for ranking potential improvements in the area of energy conservation at a given refinery, for instance, more rigorous criteria need to be developed in the future to assist OKGT in making such difficult choices as whether bringing DKV into overall environmental compliance is more important than restoring TIFO's overall competitiveness through the addition of a new facility for the conversion of vacuum gas oil and residual oil fractions to lighter products, or vice versa.

Fruitful Areas for U.S. Assistance

There are several areas in which the Hungarian refinery sector either still needs or could successfully profit by additional assistance from such U.S. agencies as AID and TDP. A summary of suggested areas or activities is listed below for consideration and possible inclusion in planned follow-on assistance efforts:

- Immediate help on environmental protection matters, including consultation on alternative solutions and technical approaches, modeling assistance, software programs, monitoring equipment, and related training in Hungary.

- Reverse trade missions to U.S. refineries of similar complexity, as well as to U.S. refinery equipment suppliers and firms specializing in environmental retrofits and upgrades.

- Training program for senior and mid-level management at DKV and TIFO with a focus on the commercial aspects of strategic planning, crude valuation, and feedstock selection designed to optimize refinery operations and profits.

- Executive development program in the United States for senior managerial and technical staff at both OKGT and the refineries.

- Feasibility study assistance to DKV for evaluating the proposed cogeneration option versus continued steam and electricity purchases from DHV.

- Financial planning and cost benefit analysis assistance to OKGT in the area of prioritizing facility investment decisions.

I. INTRODUCTION

A. Refinery Sectors in Transition

The unprecedented political upheavals that occurred throughout Eastern Europe in 1989, and the recent steps that have been taken toward greater privatization and freer market economies among former members of the Council for Mutual Economic Assistance (CMEA), herald significant changes for the oil and gas industries of the region. Moreover, the recent Persian Gulf crisis has compounded Eastern Europe's problems in obtaining access to sufficient and reliable supplies of crude oil as the Soviet Union continues to reduce exports in the face of dramatically declining production.

Even when Soviet crude oil is available to these countries, state oil trading and importing organizations in Eastern Europe are beginning to face tougher commercial attitudes from their former major supplier. The days of barter deals based on industrial products for crude oil are rapidly disappearing, as are internal crude pricing formulas which were kept well below world market levels and based upon costs of production that failed to take into account opportunity costs and return on capital. In their place are sales based upon international crude oil prices which must be paid in convertible currency.

In response, most Eastern European nations have been forced to look elsewhere for larger volumes of crude oil --either to members of the Organization of Petroleum Exporting countries or even selected Western producers. However, most existing refineries in former CMEA member states were designed to process a narrow slate of crude oils supplied from the Soviet Union. Typically, these crudes are much higher in sulfur content and contain a higher percentage of residual materials and heavy metals than do African and Middle East crudes currently available in the spot market. Unfortunately, these lighter premium crudes are considerably more expensive, and possess vastly different physical and chemical properties than do Soviet crude oils which can have a major impact on overall refinery operating efficiencies.

At the same time, emerging market conditions for the product slates from these refineries are no longer conducive to or based upon the principles and needs of a command economy and integrated economic trading union with other socialist nations. In the past, the petroleum refinery sectors of these countries had the luxury of selling to a captive domestic marketplace or supplying finished product for barter arrangements without having to worry about external competition and changing market conditions. In addition, the expected growth of automobile ownership in these new market economies will at the very minimum require updating of refining operations and marketing strategies.

Moreover, growing public awareness of the extent of environmental degradation that has occurred over the past forty years will likely bring about more stringent guidelines and regulations as these countries strive to improve overall environmental quality. Such a trend could force significant changes in existing refinery operating procedures, as well as the ranking of planned plant and equipment expenditures.

Finally, as these countries transition to freer market economies, tightened economic conditions will force refinery managers to look for cost savings through more efficient operation of process units and related equipment, and opportunities for additional energy conservation at each refinery.

In a sense then, everything that confronts the manager of a petroleum refinery in Eastern Europe today is in a state of rapid change and flux. His country and economy are moving toward greater privatization and freer markets; his crude oil sources have become less reliable and vastly more expensive; the chemical and physical properties of his crude oil inputs are for the most part dramatically different than what his refinery was designed to process; his product slate is beginning to change and he will soon face increasing external competition; growing public awareness of the need to improve environmental quality will force him to reorder his investment priorities; and tighter operating budgets will force a second look at process unit operating efficiencies and overall energy usage.

Some of the complexities of the management task confronting responsible authorities in the petroleum refining sector of these Eastern European countries is illustrated in Figure 1. In most of these countries, refinery managers have responsibility for or influence over only what happens inside of the box entitled Petroleum Refining. Crude oil supply and crude oil allocation decisions are made elsewhere with little or no input from refinery managers. Similarly, marketing management and product marketing decisions are made by others.

To successfully weather the transitional period now underway in the petroleum sectors of these countries, refinery managers are going to have to expand their management horizons both upstream and downstream, and responsible governmental authorities in these countries should permit greater participation by refinery managers in appropriate crude oil purchasing, as well as downstream product marketing and distribution organizations.

B. Objectives of the U.S. Assistance Program

As part of the Administration's Eastern European Initiative, the U.S. Agency for International Development (USAID) and the U.S. Trade and Development Program (TDP) have developed an in-depth strategy to assist Hungary in improving efficiency and energy conservation in its petroleum refinery sector. In this regard, USAID is responsible for focusing on nearer-term assistance activities that have the potential for more immediate improvements in overall operational efficiency and energy conservation, while TDP intends to concentrate its planning services on one or more of the most promising longer-term project opportunities that come out of the work to be performed under this assignment.

Accordingly, the intended objectives of the USAID- sponsored work in Hungary's petroleum refinery sector are as follow:

- Describe the overall process mix, capabilities, and current operating practices in the Hungarian petroleum sector for use in undertaking possible future work;
- Undertake a characterization review of both the DKV and TIFO refineries;
- Identify changes in practice and low-cost modifications to existing refinery equipment that can be implemented in the near-term, and are designed to increase efficiency, conserve energy, and reduce undesirable emissions and effluents; and
- Assist the management of both the DKV and TIFO refineries in planning and implementation of the changes identified during the study effort.

As a follow-up to this nearer-term assistance effort, TDP is making available a planning service grant to OKGT of approximately US$510,000 to conduct feasibility studies of a project-specific nature in Hungary's refinery sector.

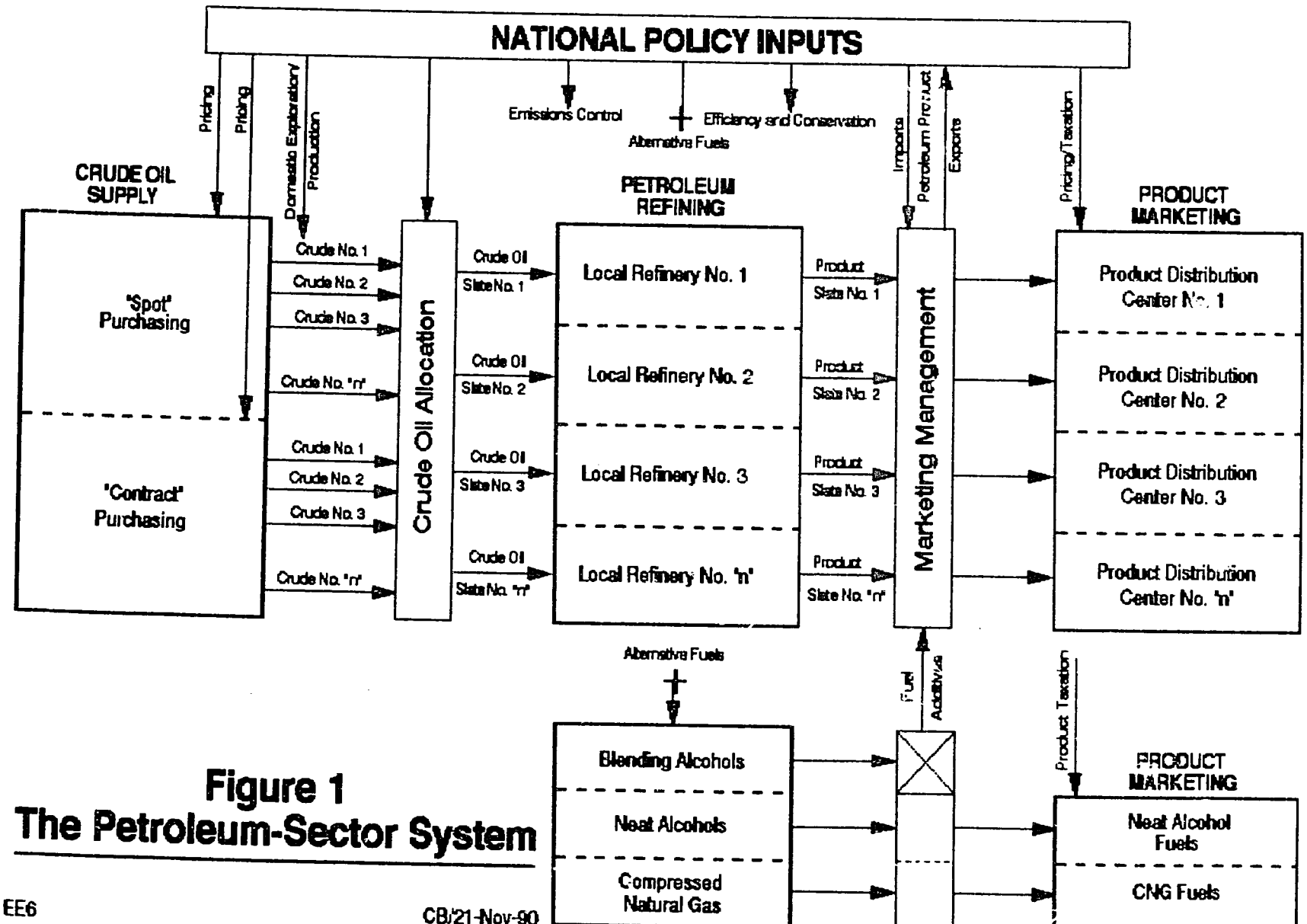


Figure 1
The Petroleum-Sector System

C. Overall Approach and Deliverables

K & M Engineering and Consulting Corporation (K & M) under subcontract to RCG/Hagler Bailly Inc. was selected by USAID to provide consulting services in the area of petroleum refinery efficiency improvement and energy conservation in Hungary. In undertaking this assignment, K & M followed a two-phased approach as described below.

The first phase consisted of a four week effort, including a 10-day visit to Hungary by a senior two-man team, to undertake a Phase I refinery sector reconnaissance and refinery characterization study effort. Specific assignments during this phase consisted of the following tasks: (1) working closely with the U.S. Trade and Development Program to coordinate near-term and longer-term planning activities; (2) collecting data on the overall financial structure of Hungary's refinery sector including privatization goals from appropriate Hungarian governmental sources; (3) performing a characterization study of Hungary's petroleum refinery sector including flow diagrams for major refineries; and (4) commenting on the practicality of fuel switching at the DKV refinery.

In carrying out these tasks, the K & M team met with the following organizations:

- U.S. Trade and Development Program (TDP)
- American Embassy Budapest
- Hungarian Ministry of Industry and Trade
- Hungarian National Oil and Gas Trust (OKGT)
- Hungarian Institute for Energetics (EGI)
- Dunai Koolajipari Vallalat (DKV) Refinery
- Tizai Koolajipair Vallalat (TIFO) Refinery

The results of these discussions and the data collected during the 10-day visit form the basis of this Phase I Report.

The second phase will consist of a five week effort, including a 3-week visit to Hungary by a four-man technical team, to conduct a more detailed evaluation of both the DKV and TIFO refineries from the perspective of improving overall operating efficiencies, energy balances, and environmental quality in the near-term. It is expected that specific tasking assignments will include: (1) making housekeeping observations designed to detect opportunities for improving overall operating and maintenance practices; (2) undertaking an update of energy conservation management practices; (3) analyzing major process unit operating conditions to determine if these refineries are still achieving an optimum product slates based on changing crude inputs and dramatically increased prices; and (4) surveying solid, liquid, and gaseous effluents at both the DKV and TIFO refineries.

The analytical results findings, and recommendations from this 3-week working visit will be published as a separate Phase II companion report with special emphasis on implementation activities and strategies for successfully transitioning to a market economy.

II. BACKGROUND

A. Energy Use in the Hungarian Economy

Despite its modest energy resource base, Hungary's economy is relatively energy intensive. In particular, during the 1970's energy demand grew rapidly resulting from the development of energy-intensive manufacturing which utilized energy as a factor input at well below its economic cost. This resulting demand was met through expanded energy imports from the Soviet Union coupled with a major increase in energy project investments accounting for 15 percent of all Hungarian investments over the past fifteen years. To better understand the magnitude of this commitment in resources, such expenditures amounted to approximately half of all investments in industrial plant and equipment, and fully two-thirds of all investments financed on-budget by the Government over this same period of time.

More recently, the Government's policy has shifted towards more effective energy conservation and demand management, including higher prices for most types and categories of energy. As a result of such policies, energy demand began to slow in the early 1980's, declining from 17 percent per year between 1975 and 1980 to around 6 percent per year between 1980 and 1985. Even more progress was achieved between 1985 and 1987 when total energy consumption grew by only 2.2 percent per year.

Despite such progress, energy consumption in Hungary is still relatively high. According to World Bank figures, in 1987 gross energy consumption in Hungary was approximately 13,450 petajoules (or 33.5 MM Toe), corresponding to an energy consumption of 1.63 Toe per US$1,000 GNP. While such a consumption level is lower than comparable CMEA countries (for instance, Poland is at 1.76 Toe per US$1,000 GNP), this level is still considerably higher than such industrialized countries as Belgium and the Federal Republic of Germany where comparable energy consumption is at 0.53 and 0.42 respectively.

B. Hungary's Limited Energy Resource Base

Hungary's energy resource base is quite limited, and the domestic production of fuels is expected to decline slightly throughout the 1990's. Such a projected decline is largely attributable to uneconomically high costs associated with mining marginal coal reserves, as well as a declining rate of new oil and gas discoveries.

Domestic energy resources consist mainly of coal, oil, and natural gas. Coal reserves include 210 MM Toe of black coal, 275 MM Toe of brown coal, and 230 MMToe of lignite. Production of black and brown coal totalled 16.7 million tons in 1987; however, production is expected to decline in the future since much of Hungary's coal reserves are uneconomic to produce at current international energy prices.

Proven recoverable reserves of hydrocarbons are about 27 MMToe for crude oil and 135 billion cubic meters or 108 MMToe for natural gas. Domestic production of crude oil, gas liquids, and 2 LPG totalled 2.7 MMToe in 1987, which was only sufficient to meet 30 percent of domestic liquid hydrocarbon requirements. For the same year, domestic natural gas production totalled 7.0 billion cubic meters, which was sufficient to meet about 58 percent of domestic gas requirements. However, both oil and gas production are expected to fall in the 1990's.

According to World Bank and selected international oil company sources, Hungary's oil and natural gas producing regions are considered to be well explored. Moreover, no new very large fields are expected to be found in Hungary. Since proven reserves are being depleted at a faster rate than new reserves are likely to be discovered, Hungary's oil and natural gas production is expected to decline somewhat over the next ten years.

In this regard, the Oil & Gas Journal predicts that Hungary should be able to sustain 30,000 to 40,000 barrels per day for the rest of the decade, down from an average production of slightly over 40,000 barrels per day for the past twenty years.

C. Role of Energy Imports and Exports

Even given the high level of energy sector investments during the past fifteen years, Hungary has had to rely on imports to meet a large share of its energy requirements. For instance, in 1987 net imports accounted for approximately 48 percent of total domestic primary energy consumption.

Historically, Hungary's major international supplier of crude oil and natural gas exports has been the Soviet Union. In 1989, the most recent year for which complete data is available, Hungary imported 60 percent of its 166,000 barrels per day crude oil requirements; fully 90 percent of these volumes came from the Soviet Union. However, as has been widely reported by such diverse sources as the International Energy Agency (IEA), Oil & Gas Journal, and the Wall Street Journal, Soviet exports of crude oil have been cut dramatically. The IEA recently confirmed that 1990 supplies to Hungary from the Soviet Union were expected to reach 130,000 barrels per day, but that a more likely figure is less than 100,000 barrels per day. Hungarian Ministry of Industry sources also confirmed this trend stating that 6.5 million tons per year were purchased from the Soviet Union in 1989, but that only 4.5 million tons per year were made available to Hungary in 1990.

Indeed, further cuts in Soviet crude exports can be anticipated. For instance, in March 1991, Soviet President Gorbachev announced that his country was further cutting oil exports in half. While a cut in Soviet exports was not unexpected, some analysts and oil market watchers appeared surprised at how deeply and quickly the Soviets are slashing their sales to traditional foreign markets.

Hungary remains interested in buying Soviet oil even at world prices since transportation costs are relatively low, and Hungarian refineries were designed to run on Soviet crude oil. However, continued Soviet supplies in sufficient volumes may not be available at any price. Consequently, Hungary attempted to enter into crude oil agreements with Iraq (which still owes it $160 million) and Kuwait just prior to the Gulf War. More recently, owing to a lack of availability of crude oil supply from the Soviet Union, Hungary has been forced to enter the spot market leading to purchases from Libya and Algeria. In addition, current discussions are presently underway with Nigeria for additional purchases of Bonny Light.

From an overall crude oil supply perspective, Hungarian energy planners are left with few viable options. They can continue to seek new crude sources (albeit at spot market prices payable in hard currency); they can design an emergency crude oil allocation plan; and they can revisit the whole issue of demand management and energy conservation. In any event, time is running short for effective action.

Turning finally to the export side of the equation, about one-fourth of Hungary's crude oil imports are refined for export. However, due to the shortfall in Soviet deliveries coupled with

an overall increase in domestic consumption of finished products, exports are off significantly. The most recent monthly data available shows that exports from Hungary of finished product averaged about 85,000 barrels per day in both January and February of 1990, compared to an average for all of 1989 of 160,000 barrels per day. A decline in exports of this magnitude will result in a financial loss to Hungary of about $100 million over the course of a full year.

D. Relevant Energy Sector Institutions

Hungary's energy sector is under the jurisdiction of the Ministry of Industry. Under this government ministry, the main energy supply institutions are:

- **The Hungarian National Oil and Gas Trust (OKGT)**– comprised of 22 companies and one subsidiary whose activities encompass the entire range of oil and gas exploration and production, refining, transport, storage, and retail distribution of refined products.

- **The National Power Company (MVMT)**– responsible for 97 percent of the country's electric power generation and distribution.

- **The Mining Association** –made up of all seven independent regional coal and lignite mining companies, plus one mining equipment supply company.

- **Various Municipalities** –involved in district heat supply systems.

The Hungarian National Oil and Gas Trust was established in 1957 as the parastatal entity responsible for all activities in Hungary's nationalized oil and gas sector. At present, the 22 companies of the Trust are divided into three broad groups: 11 vertically -related companies in oil and gas exploration, production, transport, refining, and marketing; 5 independent natural gas suppliers; and 6 companies in background or related industries such as machine manufacturing, pipeline construction, design, and applied research.

According to the World Bank, OKGT has built up a solid track record in exploration, production, pipelines, refining, and distribution. Its staff is well educated and highly trained. In early 1989, the Trust had a total of 46,350 employees with total assets worth approximately US$2.5 billion.

With the recent changes brought about by the dissolution of CMEA and the Warsaw Pact, and Hungary's desire to foster greater use of market mechanisms and pricing incentives throughout its economy, more and more talk is heard about the eventual restructuring of OKGT, including possible foreign equity participation in the refinery sector. In this regard, the K & M team was told that the CO_2, LPG, and natural gas producer companies would soon be removed from OKGT's jurisdiction. Moreover, extensive discussions were underway while the team was in Budapest regarding how best to reorganize Hungary's refinery sector. Two such approaches under active discussion at the time were: an integrated production refinery joint venture comprised of the two largest refineries still within the OKGT framework of companies with provisions for minority ownership and participation by overseas partners; and two separate and independent refinery operations with greater autonomy from OKGT. Of these two options, the former seemed to have more policy level support within government. In any event, quite a bit of turmoil seemed apparent at the refinery management and operating levels as a result of uncertainties regarding future directions, investment decisions, and ultimate reporting relationships.

III. OVERVIEW OF THE HUNGARIAN REFINERY SECTOR

A. Brief Description of Refinery Facilities

In the early 1980's, Hungary had five refineries with a distillation capacity of approximatel 14.0 million tons per year operating at about 65 percent of their capacity. The location c these units is illustrated in Figure 2. A brief description of each facility is presented below

- **Dunai Koolajipari Vallalat (DKV)**

  This major refinery complex is situated approximately 30 km south of Budapest a Szazhalombatta on the Danube River. DKV was founded in 1960, with constructio commencing in 1961. The first production unit was brought on stream in 1965. Sinc then, more than 30 new processing units have been added to achieve a total capacit for processing 10.0 million tons of crude oil per year. However, in the mid-1980's OKGT shut down one of DKV's four distillation units so that present capacity is at 8. million tons per year, or at approximately 150,000 barrels per day. DKV is Hungary' largest refinery. In most years, it produces between 70 and 80 percent of the refine products manufactured in the country. Of this amount, about 70-72 percent are whit products including motor, jet, and diesel fuels, while 15-18 percent is heavy fuel o for oil-fired generating capacity. In addition to traditional crude oil refining, DKV als carries out significant petrochemical activities. Over 300 products from this integrate facility are sold domestically and to 26 different countries.

- **Tiszai Koolajipari Vallalat (TIFO)**

  This refinery is located in the north-eastern part of Hungary at Leninvaros on the Tisz River. TIFO was established in 1973 to provide virgin naphtha to a nearby olefin plan (the Tisza Chemical Works or TVK) and heavy fuel oil to an adjacent power plant (th Tisza Power Station or TEV) to fire four oil/gas units with a total capacity of 860 MW The original design for TIFO envisioned four processing units totalling 8 million ton per year. However, after the first of these units came on stream in 1979, the plan wa revised downward to 3 million tons per year, or approximately 60,000 barrels per day While TIFO is Hungary's second largest refinery, it is presently being under-utilize as a result of Soviet crude oil curtailments. In this regard, OKGT prefers to maximiz DKV's capacity first since it is a more complex refinery. In addition, the 860 MW power plant at TEV was only operated at 25 percent capacity last year, limiting th amount of heavy ends that TIFO could sell. Moreover, since TIFO cannot separatel supply all of the virgin naphtha needs of the adjacent olefin plant at TVK from existin capacity, TVK is increasingly turning to DKV to provide the bulk of its virgin naphth requirements. As a result, TIFO was operated at a capacity of 800,000 tons per yea in 1989, and only 350,000 tons per year in 1990. Present projections for 1991 hav TIFO's processing unit operating at a capacity of about 1.1 million tons for the year.

- **Zala Koolajipari Vallalat (ZKV)**

  This small refinery is situated in the western part of the country at Zalaegerszeg on the Zala River. The ZKV refinery has a capacity of 500,000 tons per year, and is presently being used to process heavy Hungarian crude. It is mainly utilized for asphal production today.

- **Komaron Koolajipari Vallalat (KKV)**

  This facility is located in northern part of the country at the town of Komaron upstream from the Danube Bend region. It originally had a crude refining capacity of 100,000 - 200,000 tons per year. However, the refinery was closed by OKGT in the mid-1980's, and is now used primarily as a lube oil blending facility utilizing feedstocks provided by DKV.

- **Nyirbogdany Plant**

  This plant has been a TIFO subsidiary since 1976, and is located in the extreme northeastern part of Hungary at Nyirbogdany near the Soviet border. The facility originally had a refinery capacity of 300,000 tons per year, but was shut down in the mid-1980's. Today, it produces various kinds of vasolines, anti-corrosion products, and auxiliary industrial oils from feedstocks provided by TIFO and DKV.

By way of summarizing the current status of Hungary's refinery sector, the following statistical data is provided in Table 1 below for both charge and production capacities:

TABLE 1

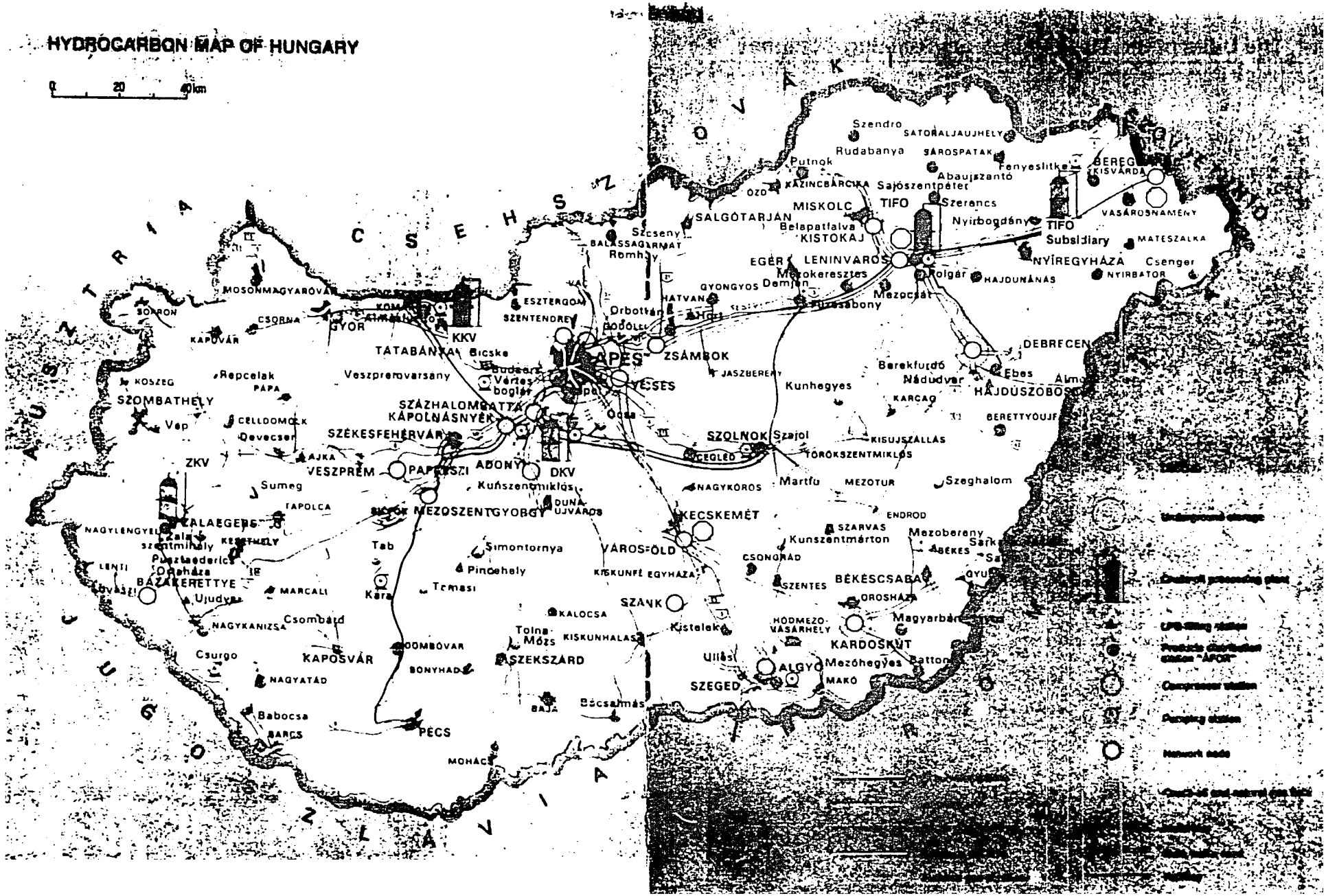
1990 CHARGE AND PRODUCTION CAPACITIES OF OPERATIONAL HUNGARIAN REFINERIES

(in barrels per day)

	DKV	TIFO	ZKV	TOTAL
Crude	150,000	60,000	10,000	220,000
Vacuum Distillation	84,000	30,000	6,000	120,000
Thermal Operations	13,300			13,300
Catalytic Cracking	20,000			20,000
Catalytic Reforming	23,000			23,000
Catalytic Hydro-Treating	76,600			76,600
Alkylation	3,300			3,300
Aromatics/Isomerization	9,800			9,800
Lubes	4,000			4,000
Asphalt	6,300		4,500	10,800

SOURCE: OGJ Special, December 31, 1990, Oil & Gas Journal

FIGURE 2



SOURCE: TIFO Informational Brochure

Finally, the information presented in Table 2 below indicates where the Hungarian refinery sector stands relative to other former CMEA member countries from the perspective of overall output of refined petroleum products:

TABLE 2

OUTPUT OF REFINED PETROLEUM PRODUCTS FOR 1988

(In thousands of barrels per day)

Eastern Europe and USSR	Motor Gasoline	Jet Fuel	Kerosene	Distillate Fuel Oil	Residual Fuel Oil	LPG	Lubricante (inclu. Greases)	Other	Total Output Of Refined Petroleum Products	Refinery Fuel and Losses
Albania	5	0	2	7	12	(*)	(*)	18	44	4
Bulgaria	39	0	5	69	111	3	2	16	247	12
Czeckoslovakia	37	0	9	91	146	5	8	33	328	20
East Germany	111	0	(*)	128	116	10	10	25	400	21
Hungary	38	3	3.5	65	34	3	4	47	198	8
Poland	66	0	4	105	49	8	10	58	299	11
Romania	128	0	10	139	164	9	11	75	535	28
USSR	1,916	590	224	2,285	3,145	276	157	745	9,337	359
Totals	2,340	590	259	2,889	3,776	313	202	1,018	11,388	463

SOURCE: U.S. Department of Energy, Energy Information Administration, International Energy Annual 1989

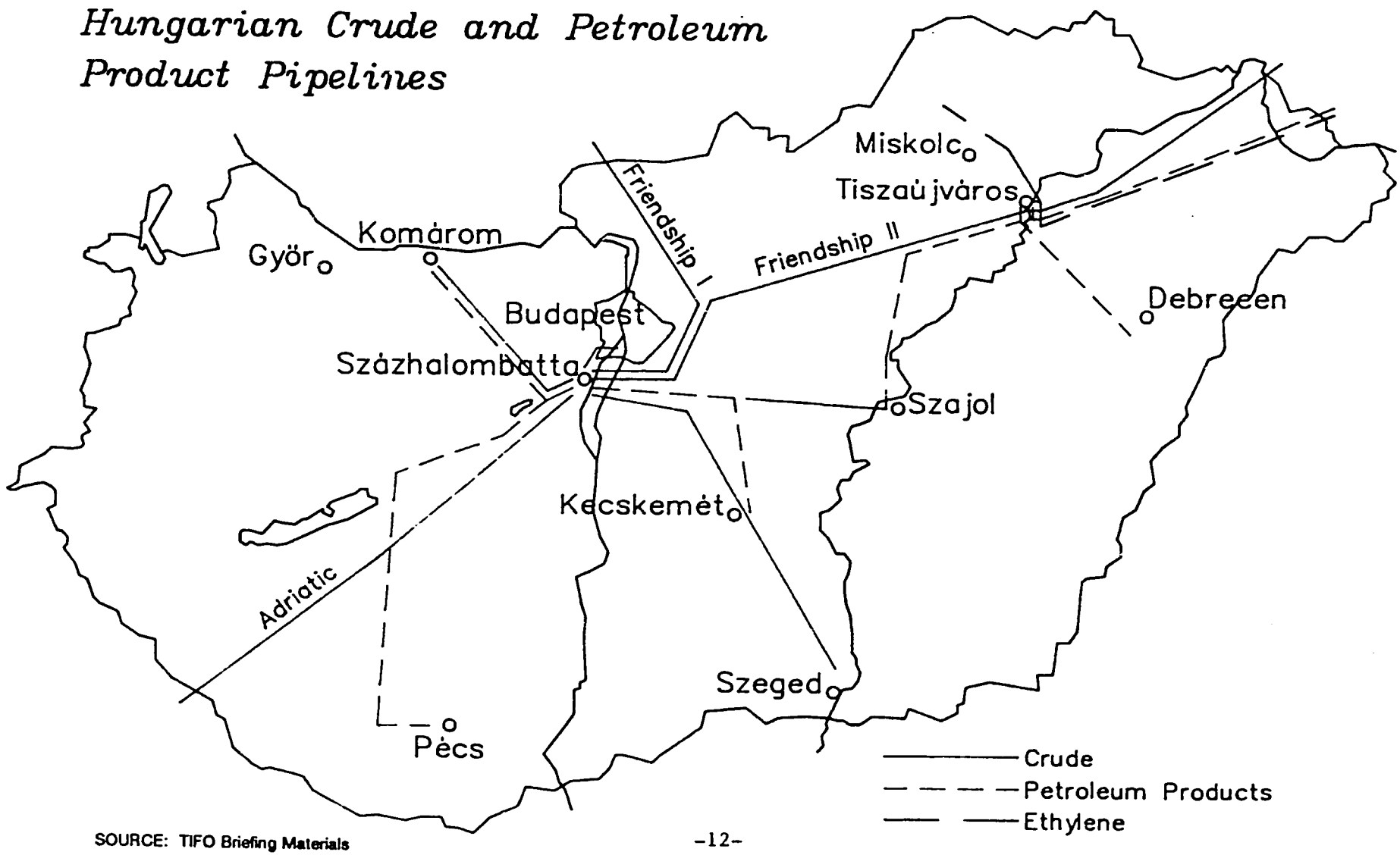
B. Crude and Petroleum Product Pipelines

Hungary possesses three crude oil pipelines of sufficient capacity to handle required imports for the foreseeable future. These pipelines include: the Friendship I pipeline from the Soviet Union through Czechoslovakia, entering Hungary from the north, and proceeding directly to DKV; the Friendship II pipeline, direct to TIFO from the Soviet border in the northeast, and then onward to DKV; and the Adriatic pipeline from the Adriatic Sea, up through Yugoslavia and the southwestern part of Hungary, with its terminus at DKV. This latter pipeline alone has a capacity of 10 million tons per year. See Figure 3 for a schematic illustration of Hungary's existing crude oil and petroleum product pipelines.

With respect to apparent deficiencies in this system, officials at TIFO told the K & M team that given the uncertainty over continued crude oil exports from the Soviet Union, they would like to see a pumping system installed so that imported crude flowing up the Adriatic pipeline could be transported all the way to TIFO from Szazhalombatta via the Friendship II pipeline. This pipeline upgrade would have the added benefit of connecting DKV's and TIFO's extensive on-site tank storage.

The majority of petroleum products from Hungary's two largest refineries are dispatched via pipelines, with the remainder being transported by rail, canal, and public roads. Both DKV and TIFO have extensive rail transport loading facilities and switchyards. The largest of these pipeline connections are highlighted in Table 3.

FIGURE 3



SOURCE: TIFO Briefing Materials

TABLE 3

MAJOR HUNGARIAN PRODUCT PIPELINES

Route	Diameter (mm)	Length (km)	Capacity (kt/yr)
DKV - Szajol	150	112.8	475
DKV - TIFO	300	237.1	1,950
DKV - Pecs	200/300	189.4	1,080
DKV - KKV	200/150	87.6	460
DKV - KKV	200/300/400	87.6	2,100
DKV - Ferihegy	150/200/400	46.2	750

SOURCE: DKV Information Brochure

C. Responsibility for Purchasing Crude Oil Imports

Given the nationalized nature and centralized management of Hungary's oil and gas sector over the past forty years, responsibility for purchasing crude oil imports still resides with the Hungarian National Oil and Gas Trust, rather than with the refineries themselves. Indeed, until very recently, OKGT made all decisions regarding crude oil imports without any input from refinery management and senior operating staff. However, it should be noted that each of the major refineries now has one member on the governmental board that coordinates all crude oil purchases from abroad.

With respect to actual procurement activities, the bulk of Hungarian crude oil imports are arranged through the Hungarian Trading Company for Oils and Mining Products (MINERALIMPEX), with the remainder being purchased through its authorized representatives.

D. Product Slate Dispatch and Marketing

In principle, the sale of refined petroleum products and management of dispatching falls under the purview of the Production Chief Engineer and Product Marketing Divisions at both DKV and TIFO.

However, in actual practice, these products are distributed by Mineral Oils Sales Company (AFOR) and the Chemical Industrial Production Facility Trading Company (VEGYTEK) for the domestic market. Distribution of refined petroleum products to overseas markets is handled by three separate state trading companies. These include: the Hungarian Trading Company for Chemicals (CHEMOLIMPEX), the Hungarian Trading Company of Machines and Equipment for the Chemical Industry (CHEMOKOMPLEX), and MINERALIMPEX.

IV. THE DKV REFINERY

A. Historical Development, Product Mix, and Storage

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 this site has reached thirty. The current capacity of the facility is 8 million tons per year or 150,000 barrels per day. DKV is the major refinery for Hungary, operating at or near full capacity producing between 70 and 80 percent of the refined products manufactured in the country.

The process technologies found at DKV are a blend of East and West with some specific adaptations made by the Hungarians. Most of the early units were of Soviet design; however, the HF alkylation unit, the FCC unit, and the new reforming unit under construction are all UOP technology units. The catalyst employed in the various units indicates a strong awareness on the part of the Hungarians of recent developments in catalyst technology. A description of specific processing units at the DKV refinery is contained in Section C below.

Like many U.S. refineries, the DKV refinery has grown in stages, and has multiple processing trains from each stage of growth. For instance, there are 3 atmospheric/vacuum distillation units, 3 refinery units, 2 sulfur recover units, and 2 gas oil hydrotreaters. These multiple processing trains permit the refinery to segregate the processing of crudes of different quality (based on S content, those attractive for lube oil production, etc.).

The refinery produces three types of products; fuel products, lube oils, and petrochemicals (both intermediaries and finished products). On a tons of capacity basis, most of the refinery capacity is geared toward production of primary fuels products which account for about 85 percent of the total product. The lube and petrochemical products are, however, high value-added products, and thus have an importance beyond that indicated by the relative tons of product produced. A percentage breakdown for the annual production in the various product categories is shown in the Table 4 below:

TABLE 4

DKV PRODUCT SLATE FOR 1990

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

SOURCE: DKV Information Brochure

With respect to overall storage for receiving crudes by pipeline and for storing semi-finished and finished products, DKV has an overall tank storage capacity approaching 2 million cubic meters with tanks ranging in size from 500-40,000 cubic meters. It should be noted that a portion of the storage tanks can be switched from crude to oil products service and vice versa. Details on this storage capacity are presented in Table 5 below:

TABLE 5

DKV STORAGE CAPACITY ON SITE

Material Category	Storage Capacity (m^3)
Crude Oil	380,000
Liquid Gas	18,250
Aromatics	38,000
Gasolines	498,000
Jet Fuel	60,000
Gas Oil	310,000
Fuel Oil	474,000
Bitumen	16,800
Lube Oil	96,200
Semi-finished Product	92,900
Other	10,500
Total Storage Capacity	1,994,650

SOURCE: DKV Informational Brochure

B. 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 primarily 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. Table 6 presents a breakdown of crude sources to the DKV refinery for both 1989 and 1990. In 1990, approximately 66.4 percent of the crude processed at DKV was of Soviet origin. An additional 21 percent of the crude oil was obtained from domestic Hungarian sources. However, it should be noted that the Hungarian fields are being rapidly depleted, and are not expected to serve as a replacement for reduced crude imports from the Soviet Union.

The remaining crude processed at DKV 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 stream of Middle Eastern and African crudes to replace the diminishing flow of crude from both the Soviet Union and Hungary's domestic fields. Table 7 contains a brief comparison of the relative differences in quality between Soviet and African crudes and a Middle Eastern crude. In general, Soviet crude is much higher in sulfur content, contains a higher percentage of residual material, and is generally lower of quality. Residual oil and sulfur content of a specific crude oil can have a significant impact on the type of processing equipment required to refine a given crude oil input.

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

TABLE 6

DKV CRUDE SUPPLY, 1989 AND 1990

	Tons	Weight %
Crude Slate - 1989		
Soviet Crude	5,629,600	78.86
Hungarian Crude	1,509,400	21.14
Totals	7,139,000	100.00
Crude Slate - 1990		
Soviet Crude	4,714,528	66.38
Algyol 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
Totals	7,103,106	100.00

Source: DKV Refinery

TABLE 7

COMPARISON OF SOVIET, AFRICAN, AND MIDDLE EAST CRUDES

Crude Characteristics	Soviet Export (USSR)	Brega Crude (Libya)	Sirtica Crude (Libya)	Bonny Light (Nigeria)	Saudi Light (Saudi Arabia)
API Gravity	32.5	40.0	41.3	34.7	34.0
Specific Gravity: g/cc	0.863	0.825	0.819	--	--
Sulfur: Wt%	1.38	0.23	0.45	0.16	1.84
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	40.97
Gravity: g/cc	0.952	0.921	0.945	0.943	0.961
Sulfur: Wt%	2.20	0.47	1.10	0.30	3.20
Conradson Carbon: Wt%	5.1	4.61	6.38	3.88	8.90
Vanadium: PPM	60	2.4	12	1.9	37.00
Nickel: PPM	20	9.4	28	15	10
Residue (Vacuum)					
Range: 545°C+					
Yield: Vol% Crude	16.99	8.71	10.91	5.36	16.36
Gravity: g/cc	1.0	0.998	0.997	1.011	1.002
Sulfur: Wt%	2.70	0.73	1.71	0.42	4.20
Conradson Carbon: Wt%	12.5	15.7	16.0	15.4	20.70

SOURCE: DKV Refinery

C. Current Refinery Configuration and Processing Capabilities

A listing of all plants and units found at the DKV refiners as well as their location within the refinery site are illustrated in Figure 4. In addition, a flow diagram of the current process configuration for DKV is illustrated in Figure 5. Each of the individual units is described below:

- **Crude Oil Distillation and Processing Units**

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 processing 1.5 million tons of crude oil per year. 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 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 tons of crude annually (approximately 74,000 barrels per day). AVU-3 currently provides DKF with the additional flexibility for processing various imported crude oils beyond those from the Soviet Union. Imported as well as Soviet crude are processed at AVU-3 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.

A summary of unit-days of operation in 1990 for various primary feedstocks by unit is shown in Table 8 below:

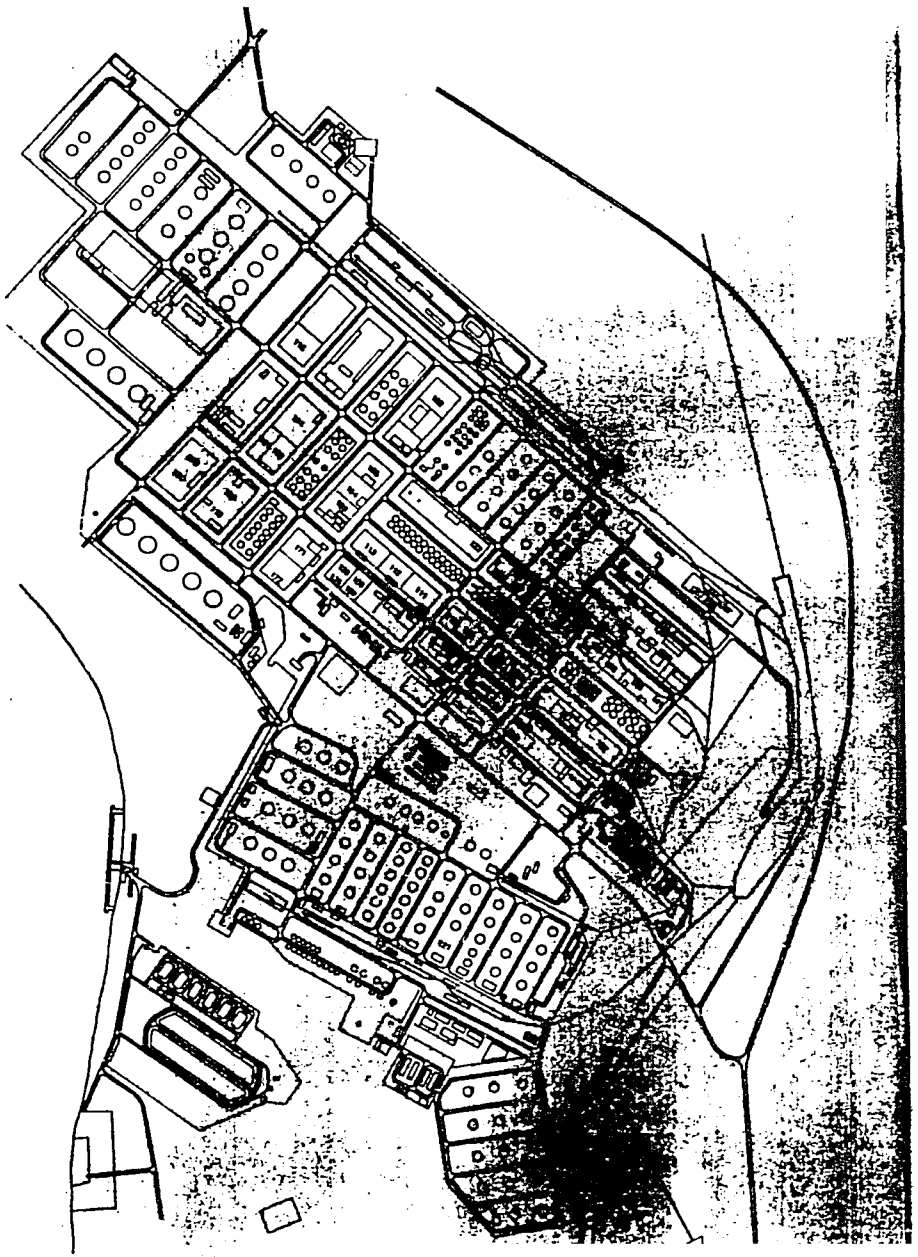
TABLE 8

DKV UNIT-DAYS OF OPERATION FOR VARIOUS FEEDSTOCKS, 1990

Distillation Unit	Primary Feedstock	Unit-Days
AVU-1	Soviet Crude	5.6
AVU-1	Hungarian Crude	293.4
AVU-2	Soviet Crude	285.8
AVU-2	Hungarian Crude	72.3
AVU-3	Soviet Crude	266.1
AVU-3	Iraqi Crude	12.0
AVU-3	Hungarian Crude	6.5
AVU-3	Sirtica Crude	15.0
AVU-3	Brega Crude	13.5
AVU-3	Sahara Blend Crude	40.0
AVU-3	Bonny Light Crude	11.8

SOURCE: DKV Refinery

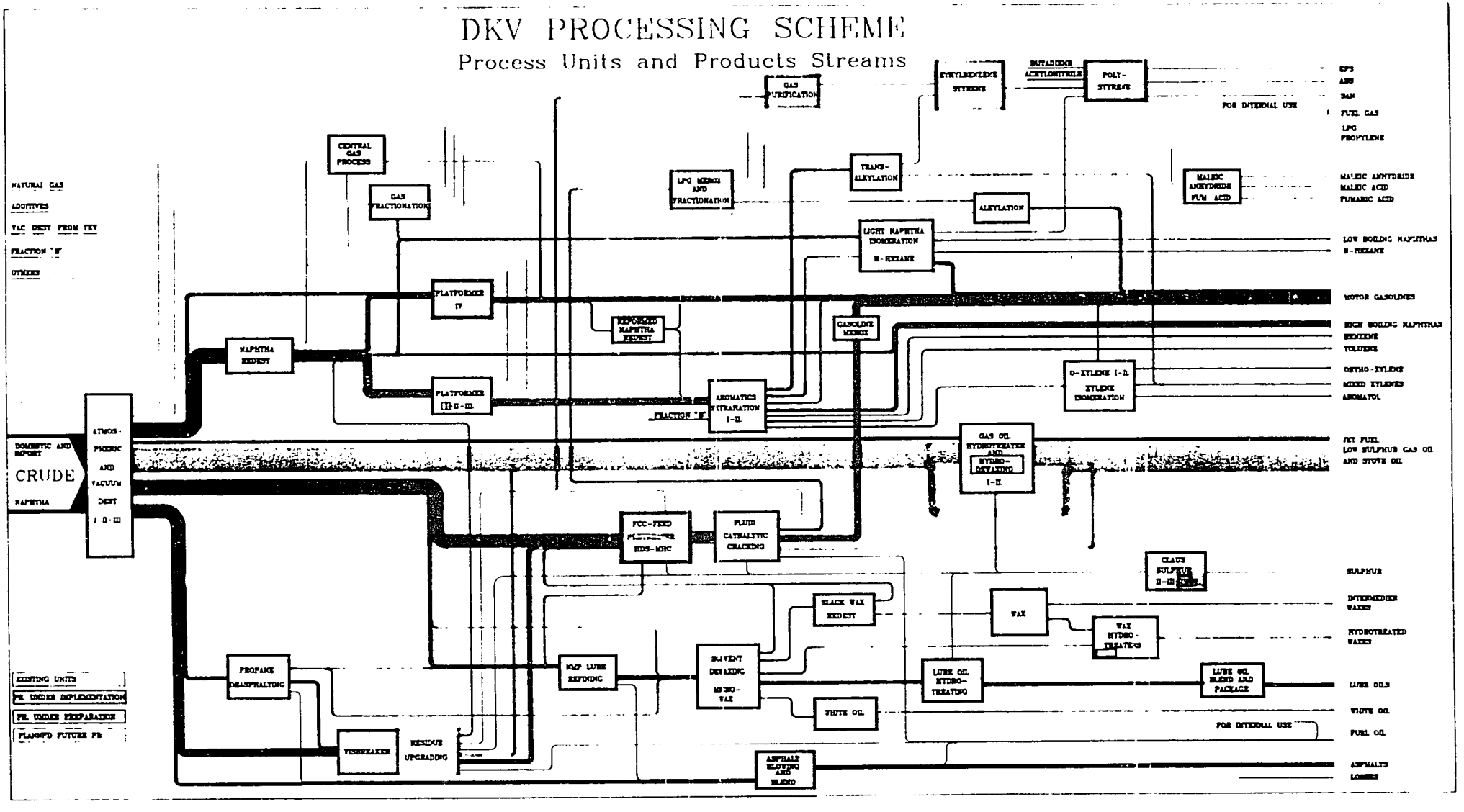
FIGURE 4



Explanation of codes used on the company location map

Code	*Description/name of plants*
111	ATMOSPHERIC AND VACUUM DISTILLATION, UNIT 2.
112	GASOLINE REFORMING PLANT 1.
113	GAS OIL DESULPHURIZATION UNIT 1.
114	DEPENTANIZING UNIT
115	LIGHT GASOLINE ISOMERIZATION UNIT
116	GAS OIL DESULPHURIZATION PLANT 2.
121	ATMOSPHERIC AND VACUUM DISTILLATION, UNIT 1.
122	PROPANE DEASPHALTING UNIT
123	LUBE OIL REFINING UNIT
124	SOLVENT DEWAXING AND MICROCRYSTALLINE WAX DEOILING UNIT 1.
125	SOLVENT DEWAXING AND MICROCRYSTALLINE WAX DEOILING UNIT 2.
126	LUBE OIL HYDROFINING AND MICROCRYSTALLINE PARAFFINE HYDROGENATING UNIT
131	PARAFFIN AND MODIFIED PARAFFIN MANUFACTURING PLANT
132	BITUMEN MANUFACTURING PLANT
133	SLACK WAX–PETROLATE REDISTILLATION UNIT
135	AROMATICS EXTRACTION UNIT 1.
136	AROMATICS EXTRACTION UNIT 2.
137	SULPHUR RECOVERY PLANT 2 AND ACID TAR REMOVING UNIT
138	MICROCRYSTALLINE WAX, CONTACT REFINING AND MODIFIED PARAFFIN MANUFACTURING UNIT
141	LUBE OIL BLENDING UNIT
151	ATMOSPHERIC AND VACUUM DISTILLATION UNIT 3.
152	NAPHTHA FRACTIONATING UNIT
153	NAPHTHA REFORMING PLANT 2.
154	NAPHTHA REFORMING PLANT 3.
156	GAS FRACTIONATING PLANT
157	ORTHOXYLENE PLANT
164	XYLENE ISOMERIZATION AND ORTHOXYLENE PLANT 2.
161	LIGHT GASOLINE SWEETENING UNIT
162	MALEICANHYDRIDE UNIT
171	VISBREAKER UNIT
172	CENTRAL GAS PROCESSING PLANT
178	HF ALKYLATION PLANT
185	FLARE UNIT 1–2.
221	GASOLINE BLENDING AND ETHYLATING PLANT
232	RAILWAY LOADER NO. 232
235	RIVER LOADER/UNLOADER STATION NO. 235
256	LIQUID GAS AREA NO. 256
257	LIQUID GAS AREA NO. 257
443	INDUSTRIAL WASTE INCINERATOR
800	CATALYTIC CRACKING PLANT
820	SULPHUR RECOVERY UNIT 3

FIGURE 5



SOURCE: DKV Refinery

In addition, a one-year material balance for DKV's crude processing complex is for 1990 presented in Table 9 below:

TABLE 9

ONE-YEAR MATERIAL BALANCE FOR DKV'S
CRUDE PROCESSING COMPLEX, 1990

(in thousands of tons per year)

Crude Oil Feed	Tons Per Year (1,000's)	Percentages by Weight
Soviet Crude	4,324	58%
Hungarian Crude	1,832	25%
Sirtica Crude	150	2%
Brega Crude	156	2%
Sahara Blend Crude	344	5%
Bonny Light Crude	133	2%
Iraqi Crude	128	2%
Condensate Liquids	288	4%
		100%
Product Streams		
Fuel Gas	2	--
Stabilizer Gas	7	--
Liquid Gas	89	1%
Light Gasoline	482	7%
Medium Gasoline	518	8%
Heavy Gasoline	629	9%
Test Gasoline	54	1%
White Gasoline	13	--
Petroleum	94	1%
Jet Fuel A-1	405	5%
Distillate Oil	455	6%
Gas Oils	1,691	23%
Lube Oil Streams	1,498	20%
Residual Oil	1,416	19%
Vesztseg	23	--
		100%

SOURCE: Derived from Raw Data Provided by DKV.

A summary of unit-days of operation in 1990 for various primary feedstocks by unit is presented in Table 8 below. In addition, a one-year material balance for DKV's crude processing complex for 1990 is presented in Table 9.

Finally, 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 the period 1983-1984 with Norton structured internals. Such a retrofit is a generally accepted method for increasing vacuum tower capacity while at the same time providing sharper vacuum gas oil cuts (better quality) for use as feedstock in the fluid catalytic cracking unit.

- **Naphtha Fractionating Units**

Naphtha from the crude distillation complex flows downstream to the naphtha fractionating section. The capacity of the naphtha fractionator is 1.5 million tons per year (approximately 35,000 barrels per day). The naphtha fractions are split to provide light naphtha to reformer unit number 1, medium naphtha to reformer unit number 2, and heavy naphtha to reformer unit number 3. Naphtha is fractionated in order to maximize aromatics production and minimize fractionation of reformat.

- **Catalytic Naphtha 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 tons per year (10,000 barrels per day). These 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 only 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 in the future.

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 throughout the refining industry worldwide.

- **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 tons per year (10,000 barrels per day).

Aromatics extraction and recovery consists of two unit operations. The first processing step consists of liquid-liquid extraction which is then followed up 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 long with the ethyl benzene mixture are further processed in the xylene isomerization unit, with a capacity of 45,000 tons per year (1,250 barrels per day).

- **Xylene Isomerization Unit**

This relatively new unit was brought on stream in 1985, and has a capacity of 45,000 tons per year. Products produced from this unit include both high purity orther-xylene and C7 overhead product.

- **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 tons of maleic anhydride on an annual basis. During the period 1988-1989, the maleic anhydride unit was revamped to a process configuration which accepts butane as a feedstock. The purpose of the conversion was to employ a more environmentally friendly feedstock and to divert valuable benzene to other uses.

- **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 tons per year (4,500 barrels per day. The unit was revamped in 1988, including the addition of a new reactor for the conversion of raffinate from extraction plant number 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.

- **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 tons per year (14,000 barrels per day), was put on stream in 1971 for the purpose of treating streams for gas oil hydro-desulfurization. Jet fuel production was introduced in 1985, and this unit has operated in both these production modes since that time. GOKM-2, which has a capacity of 1.2 million tons per year (24,000 barrels per day), 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 percent to 0.5 percent. 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 pounds per square inch).

- **Claus Sulfur Recovery Plants**

  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 tons per year. Claus-3 was started up in 1984, and has a sulfur recovery capacity of 16,000 tons per year. The purity of the sulfur recovered in the Claus process is 99.9 percent by weight.

- **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.

- **Fluid Catalytic Cracking Unit**

  In order to achieve conversion of vacuum gas oil to lighter transportation fuels, a fluid catalytic cracking (FCC) 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 tons per year (20,000 barrels per day). 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.

- **Hydrogen Fluoride 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 tons per year (3,500 barrels per day), with start-up occurring 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 then sending it too alkylation.

- **Visbreaking Unit**

  As a consequence of an earlier energy conservation campaign 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 tons per year (15,000 barrels per day), 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.

- **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 tons per 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 tons per 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. The are two solvent dewaxing units, designated MEK-1 and MEK-2, each with a capacity of 150,000 tons per 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 metric tons per year.

- **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 tons per year.

- **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 redistillation, solvent deoiling, and sulfuric acid treatment.

In addition to these operational units, a UOP design continuous catalyst reformer (CRR) is presently under construction, and is scheduled for start-up in late 1991. This unit will have capacity of 600 tons per year (or 15,000 barrels per day), and is being added to increase the production of high octane blending components for the production of low-lead and unleaded gasolines.

Finally, a new FCC hydrotreater is being planned for construction and start-up in 1992. A DESUS design technology will be employed for the desulfurization of gas oil feedstock to the FCC unit. This process is of East German origin, and combines hydrotreatment with a mild hydrocracking function in the second reactor. The capacity of this unit will be 1.5 millions tons per year. It is expected that as a result, the sulfur content of FCC feed will be lowered to between 0.2 and 0.5 percent by weight. The addition of this unit to the processing complex will both increase the flow of hydrogen sulfide from the gas oil desulfurizer and increase the consumption of hydrogen for treating the FCC feed. Accordingly, Claus unit number 4 will be added to increase sulfur recovery by another 30,000 tons per year, and it is anticipated that the new CRR reformer will produce sufficient additional hydrogen to meet these enhanced requirements.

D. <u>Overview of Energy Usage</u>

The energy needs of the DKV refinery are met using purchased steam and electricity from an adjacent power plant, as well as natural gas from the gas pipeline grid. In addition, DKV also utilizes some of its own refinery gases and liquids. Both steam and electricity are purchased from the largest electricity generating facility in Hungary, the 1,800 MW Danube Power Station (DHV), located only 5 km from the refinery.

In 1990, overall energy usage at the DKV refinery was:

284,000 tons of fuel
3,657,000 tons of steam
429,000 Mwh of electricity (with a peak load of approximately 63 MW)

Crude charge in 1990 was approximately 7,400,000 tons. It is estimated that 69 percent of the steam consumed is purchased, with the balance being produced within the refinery. As reported to the K & M team, the energy requirement per unit of crude input to the DKV 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 6 shows how these energy inputs are utilized and consumed in the refinery. This energy utilization diagram is based on 1989 data.

It is useful to put the refinery's energy inputs on a common energy unit basis for use in comparing total energy consumption with other refineries. In this regard, the following conversion factors were 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

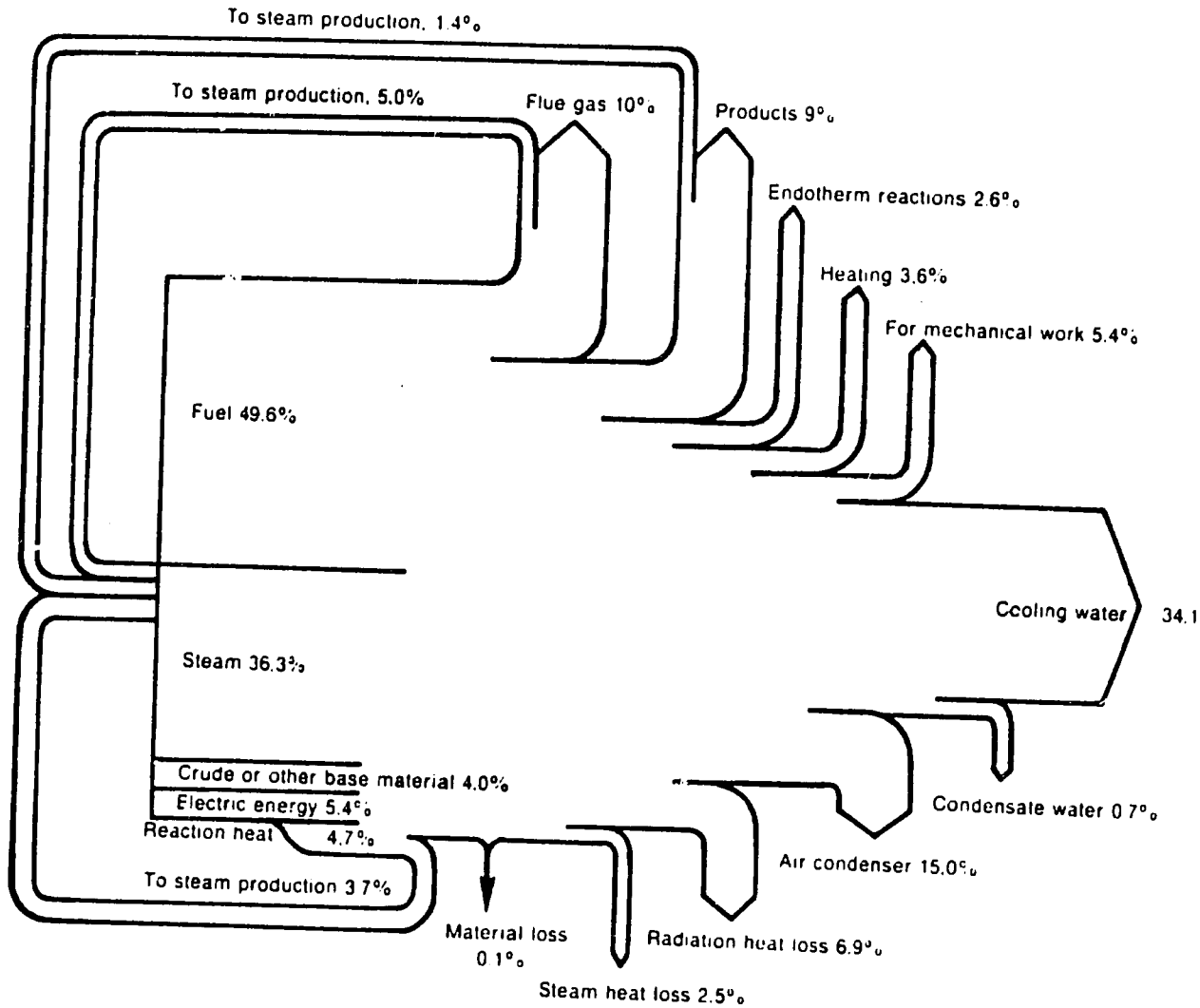
Assuming 7.4 barrels of crude feed per metric ton (mt) and utilizing the above conversion factors, the overall energy usage per unit input of crude feed at the DKV refinery is:

	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	611.6	579.7	78.3
	3,258.4	3,088.5	417.4

These figures for overall energy usage per unit input of crude feed at DKV are compared in Table 10 with similar data for several groups of U.S. refineries of varying complexity. Caution must be exercised in interpreting this data since U.S. refinery data is based on fuel refineries (i.e. petrochemical unit operations have been excluded), and all U.S. data is from 1983 while DKV data is from 1989.

FIGURE 6

ENERGY UTILIZATION AT THE DKV REFINERY, 1989



SOURCE: DKV Informational Brochure

TABLE 10

ENERGY CONSUMPTION AT DKV COMPARED TO U.S. REFINERIES
(in thousands of Btu per barrel)

Complexity Group	A	B	C	D	E	F	DKV
Refineries in Group	11	12	16	11	10	11	1
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							
Fuels	311	335	355	370	409	433	217
Purchased Steam							122
Power	45	70	44	63	65	39	78
Total (thousand Btu/bbl)	356	405	399	433	474	472	417

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

Despite those differences in the DKV and Solomon data, it can be said that DKV was roughly in line with, or perhaps even slightly more energy efficient than the average U.S. facility of comparable complexity in 1983. However, if we assume that the average energy efficiency for U.S. refineries has continued to improve by about 10 percent since 1983, then DKV may be a bit less energy efficient on average than the current U.S. refineries of comparable complexity.

E. Energy Supplies and Prices to the 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 tons per hour with approximately 200 tons per hour being imported from DHV. In winter total consumption rises to 410 to 420 tons per hour with about 300 tons per hour being purchased. The pressure of the purchased steam is about 17 bar absolute. Because part of the refinery need is for lower pressure steam, the pressure for a portion of the incoming steam is reduced across two steam turbines after it enters the refinery. These two turbines can produce a maximum of 6 MW; however, one of the two is generally shut down during the summer months.

With the exception of this small fraction of electricity being generated within the refinery, the bulk of DKV's power needs of 429,000 MWh are purchased from DHV. Electricity 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 significant problems with power interruptions which have been averaging ten times a year for the past five years. The longest outage in 1990 was for 13 minutes causing benzene to overflow at the facility throughout the outage.

There are three types of fuels used in the refinery: light hydrocarbon refinery gases, 0.8 percent sulfur liquid fuel, and purchased natural gas. The 0.8 percent fuel is produced from the residual fraction from the low sulfur crudes charge, as well as heavier products from the FCC unit. A breakdown of percentage utilization in both 1985 and 1990, for each of these fuels is presented in Figure 7.

In addition, energy prices for the past nine years are shown in Table 11 for steam, electricity, fuel gas, fuel oil, and natural gas.

TABLE 11

ENERGY PRICES PAID BY DKV, 1985-1991

(in Hungarian Forints per 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 percent S fuel oil; after July 1, 1988 prices are for 1 percent S fuel oil.

Energy prices have risen significant the past two years as reflected below by percentage increases from 1989 to 1991:

		Percentage Increase (1989-1990)
Steam	=	39.5
Power	=	82.6
Fuel Gas	=	116.8
Fuel Oil	=	129.5
Natural Gas	=	148.4

The DKV refinery is projecting that energy prices will increase again next year as shown in Table 12 below:

TABLE 12

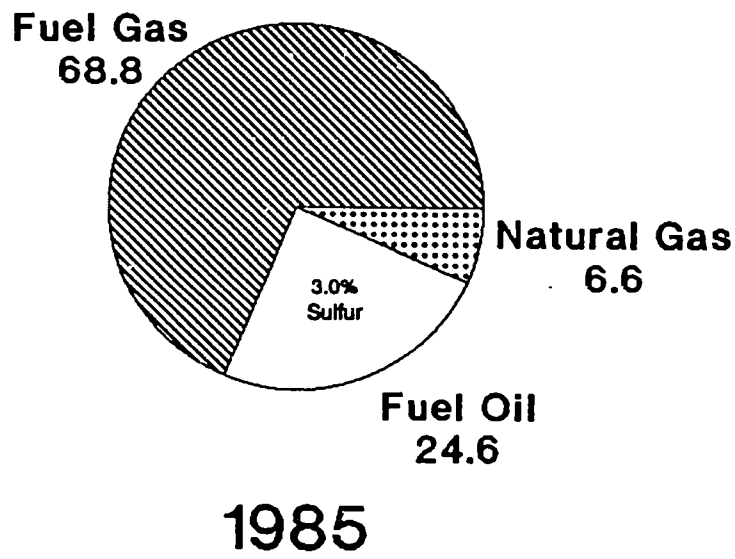
PROJECTED 1992 ENERGY PRICES FOR DKV

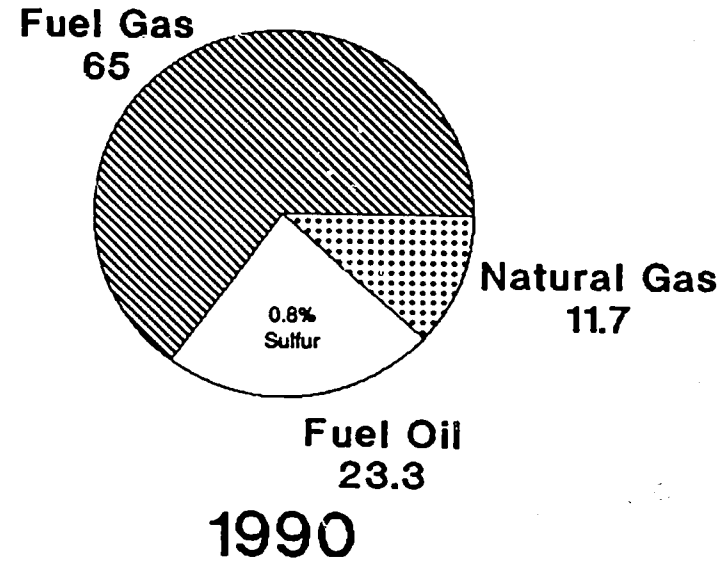
	Gj/Unit ton on MWh	Btu/Unit Pound or kWh	1991 Ft/Gj	($/MMBtu*)	1992 Ft/Gj	% Increase 1991-1992
Steam	3.05	1,312	256.6	(3.73)	346.0	34.8
Power	3.6	3,412	1,054.0	(15.31)**	1,423.0	35.0
Fuel Gas	43	18,472	267.4	(3.89)	279.0	4.4
Fuel Oil	41	17,632	296.8	(4.31)	298.0	0.4
Natural Gas	43	18,492	356.4	(5.17)	477.00	33.8

*Calculated at 172.6 Ft/$
**5.3 ¢/kWh

FIGURE 7

FUELS UTILIZATION AT DKV
IN 1985 AND 1990





FUELS BREAKDOWN BY PERCENT.
Source: DKV Refinery

F. Status of Energy Conservation Efforts

The DKV Refinery has been engaged in an intensive and well planned energy conservation effort since the mid-1980's. A key element in the planning of that effort was a detailed study funded by the World Bank and performed by Foster Wheelers Iberia. This study effort was completed in 1985, and identified 82 potential areas for achieving improved energy efficiency. From this preliminary survey, DKV and the World Bank selected about 40 high priority energy conservation projects for possible implementation utilizing funds from a World Bank loan. To date, about one-third of the most cost-effective projects from this list have already been implemented. Examples of the types of projects which have already been completed include:

- Preheating of AVU feed (the product streams from the AVU are being used to preheat feed).
- Improving preheater efficiency with installation of improved furnace burners.
- Preheating of excess air in the notary furnaces.
- Employing flue gas heat recovery.
- Incineration waste materials to produce makeup steam.
- Utilizing product heat from the isomerization unit for preheating.
- Insulation of storage tanks to reduce heat losses.
- Heating buildings with condensate instead of steam and organizing collection of water from steam traps.
- Installing continuous speed controls for electric motors.
- Optimization of heat exchangers throughout the refinery.

A more comprehensive list of energy conservation projects that have been implemented since 1985, including those arising from the Foster Wheeler Iberia study as well as those initiated by DKV's excellent energy management staff, is presented in Appendix A.

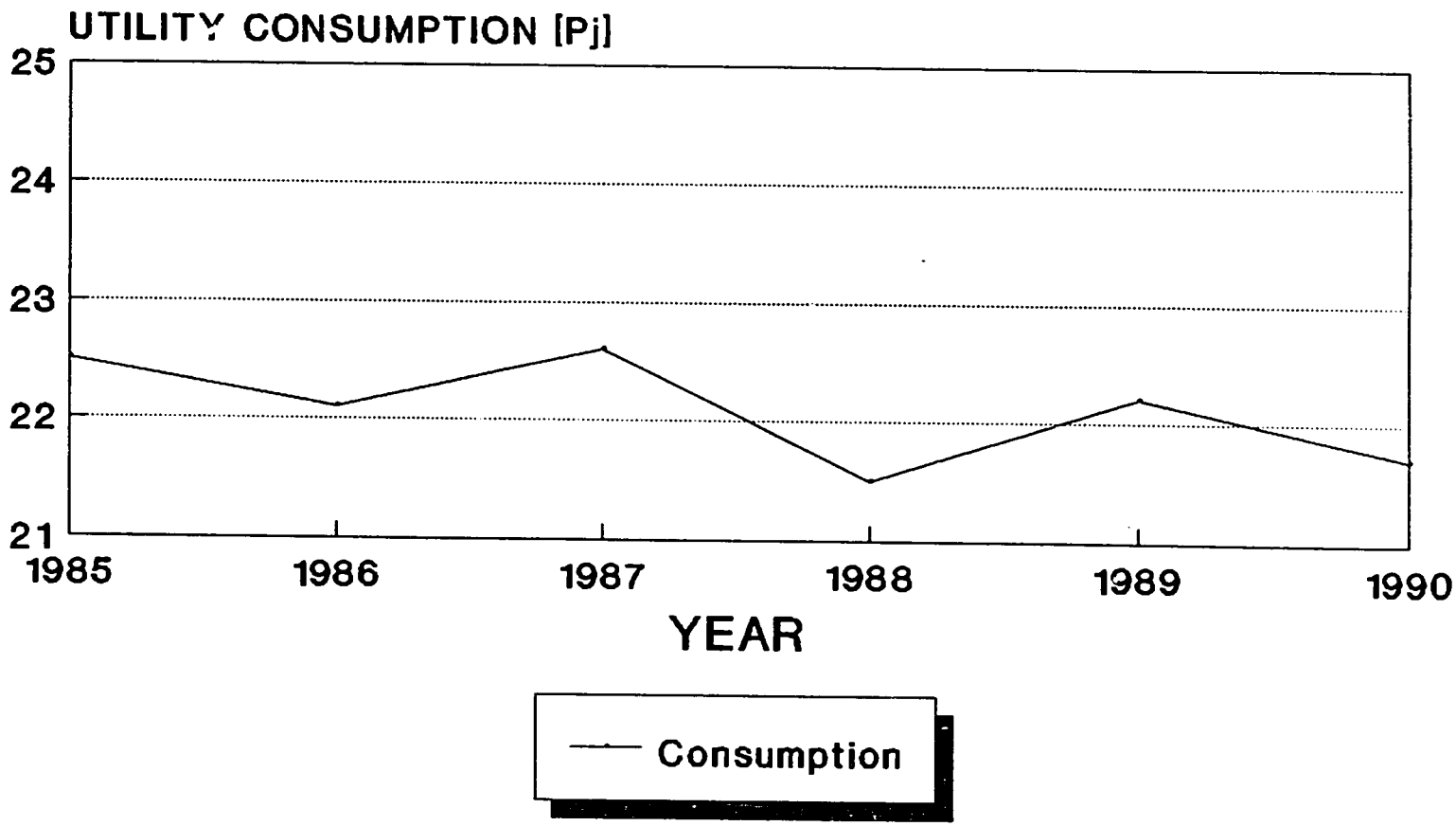
Considering that DKV has been working on energy conservation for almost a decade, it is not surprising that a personal tour of the plant did not disclose significant visible energy losses. No steam leakage could be seen from leaky steam traps or pipes. All pipes were well insulated. However, metering of utilities was just adequate, and could be improved. Just how successful this program has been over the past 5 to 6 years is illustrated in Figure 8 which shows a declining trend in energy utilization at the DKV refinery over this same period.

In discussing the future direction of their energy conservation efforts, the DKV refinery staff indicated that there was a need to re-examine the list of implementation projects from the Foster Wheeler Iberia study that had not been done, and to re-evaluate the potential benefits in light of current crude oil costs as there has been considerable change since 1984-1985 when the original evaluations were made. There are, in all probability, additional areas that may have been recognized by the refinery staff, and that might also be identified by a subsequent K & M team visit, and need to be added to an updated energy conservation project list. Ultimately, the pace and scope of the refinery energy conservation effort will be determined as energy conservation projects are viewed in the context of overall refinery investment needs.

However, after identifying potential energy saving projects, establishing project costs, and ranking these energy conservation projects, such projects must then be viewed along with other potential projects that compete for scarce manpower and money resources. Clearly, the refinery should allocate its limited manpower and capital investment budget to achieving the greatest overall improvement in competitive position (i.e. bottom line profitability).

FIGURE 8

DKV ENERGY UTILIZATION
DECLINING TREND, 1985-1990



UTILITY CONSUMPTION IN PETA JOULES
Source: DKV Refinery

Interestingly, it may not be possible for DKV to achieve a high rank in the refining industry based on achieving one of the lowest levels of energy usage per ton of refinery simply because the refinery is fairly complex and too spread out.

DKV is above average in refinery complexity when compared with both European and U.S. refineries where complexity is a measure of the number and type of units used to process the individual crude component stream after they are separated in the primary distillation unit upon entering the refinery. The size of individual refinery processing is less than optimal, and in a number of instances, DKV has 2 or 3 small units rather than a single larger unit which could be more economical from the stand point of operating efficiency and maintenance costs. However, these smaller multiple units do give DKV an advantage in running different crudes, and in directing the most appropriate crudes to lube and petrochemical processing. Lastly, the refinery has a very dispersed layout which insures greater energy losses as intermediate and products streams are moved between the many processing units and to blending and storage operations.

Thus, it would appear on the surface that diminishing returns with respect to additional energy conservation projects and investments have for the most part long since set in for the DKV refinery, and that other areas of potential capital investments and improvements may yield higher benefits and returns. However, that is not to say that potential energy conservation projects of a high priority do not remain to be considered in the future.

G. Progress Toward Environmental Compliance

The DKV Refinery presently has a very active environmental protection effort underway. The staff dealing with environmental pollution problems is part of the Energy Management and Chief Energetic Organization. They deal with environmental pollution problems in the following areas:

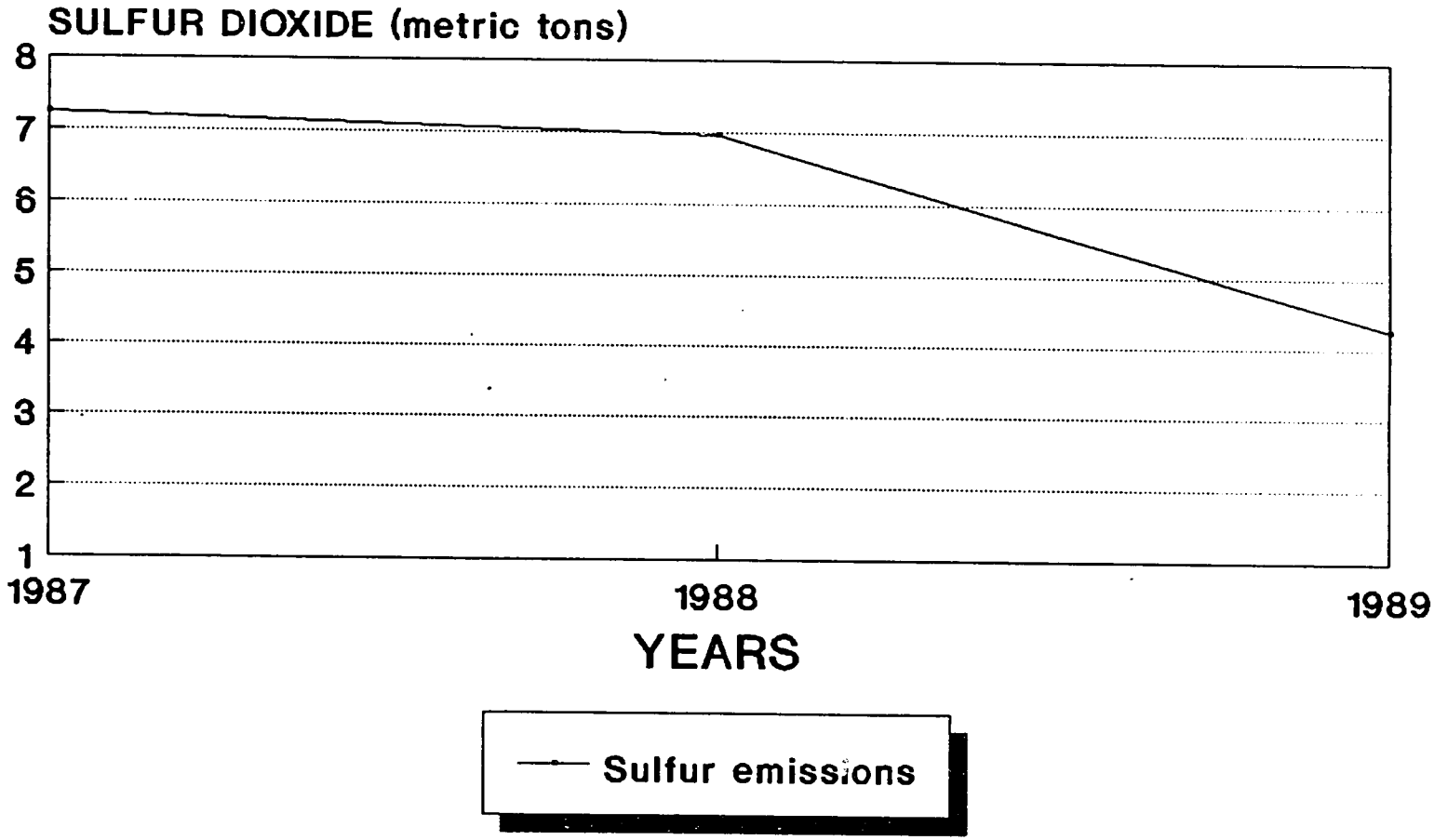
- Air pollution
- Production of waste water
- Soil and ground water contamination
- Production of solid wastes

Recent progress has been made in reducing pollution from the refinery. As can be seen in Figure 9, SO_2 emissions have declined considerably; however, they are still significantly above permissible levels under Hungary's current environmental laws. In addition, the sulfur and lead content of engine fuels, lube oils, and fuel oil have also been reduced. The sulfur content of the products marketed by DKV in 1989 was only 56 percent of what it had been in 1984, and lead content had been reduced by one-third over the same period.

Waste water from the refinery is discharged into the river. It is treated chemically first, but there is currently no biological clean-up system at DKV. In the past, oil content in the water has exceeded authorized levels, and the chemical oxygen content has also exceeded authorized levels. The oil content of the water has been falling as illustrated in Figure 10, and is expected to be under the allowable limit this year. There is discussion of purchasing a biological treatment system. Such a system is intended to reduce both oil and the chemical oxygen content of the waste water.

FIGURE 9

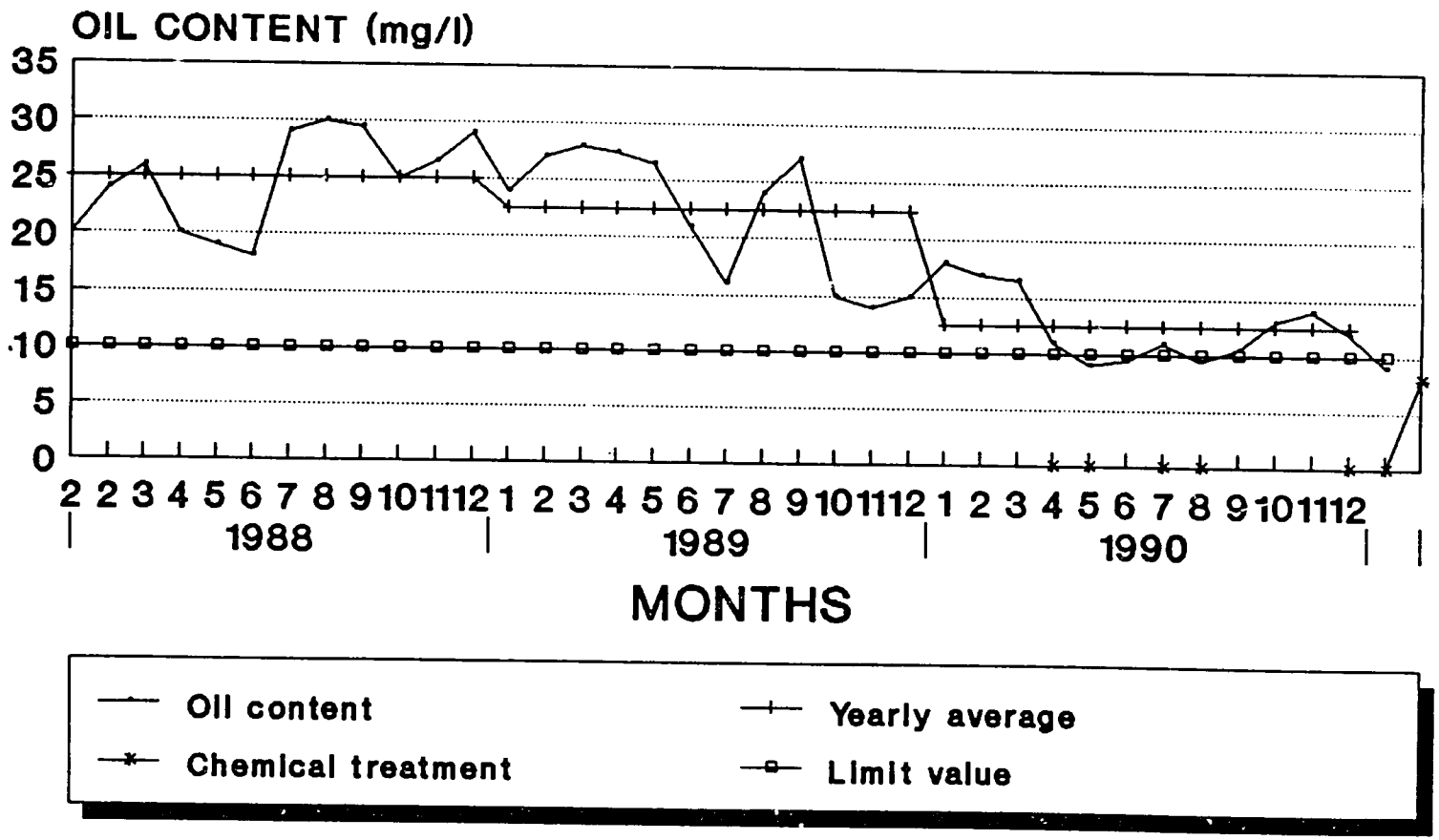
PROGRESS IN REDUCTION OF SULFUR DIOXIDE EMISSIONS



Source: DKV Refinery

FIGURE 10

DECLINE OF OIL
IN WATER DISCHARGES AT DKV



Source: DKV Refineries

Approximately 60 percent of the waste with high oil content is treated in the plant. Oil is reclaimed with a three-phased slurry centrifuge. The remainder of the waste is burned in incinerators. There is also a search underway for new ways and commercial opportunities within Hungary to reclaim valuable material from waste. Two successful examples over the past year include high paraffin containing clays and aluminum oxide from HF alkylation processing for sale to the aluminum industry.

Finally, the solid and hazardous wastes generated by the refinery are adequately treated in their on-site incinerator. This incinerator has additional capacity, and should be sufficient to address all disposal needs for the foreseeable future.

Despite such favorable downward trends and overall progress in reducing effluents and wastes, and the extremely positive attitudes on the part of DKV's staff from top management all the way down to junior operating personnel regarding a desire to clean-up their refinery, DKV still has significant environmental problems and could profit from immediate near-term assistance from appropriate U.S. agencies and consultants.

H. Remaining Environmental Protection Problems

The most significant environmental protection problem that DKV presently has is an air pollution problem. The refinery is major emittor of sulfur dioxide, carbon monoxide, and hydrocarbons (such as benzene, tolerene and xylene). The most troublesome acid gas air pollutant from the DKV refinery is SO_2. Sulfur dioxide emissions from the refinery FCC Flue gas stream alone are estimated to be between 2,000 and 3,000 tons per year. In this regard, DKV is in the process of installing a new Claus unit along with an FCC unit upgrade which is expected to reduce SO_2 emissions from that source by 90 to 95 percent. However, DKV is located adjacent to Hungary's largest fossil-fired power plant which is also a major point source polluter of sulfur dioxide. While such close proximity makes imminently good sense from the perspective of nearly availability of steam and electricity, such a co-siting makes the pollution control problems of both plants substantially more difficult from an overall environmental compliance perspective for the surrounding region.

At present, the refinery has no way of accurately determining or estimating the precise level of its emissions into the atmosphere, nor evaluating the effect of these emissions on local communities. The only estimates available for such emissions appear to have been either derived from process materials balance calculations by the refinery staff, or estimated by various Hungarian government agencies and institutes dealing with environmental matters. In any event, these estimates reveal that DKV is still significantly over the current environmental compliance limits for gaseous wastes. A comparison of total quantities of gaseous emissions versus amount over the limit for DKV in 1990 is presented in Table 13 below:

TABLE 13

COMPARISON OF QUANTITIES AND TONS OVER COMPLIANCE FOR DKV GASEOUS WASTES, 1990

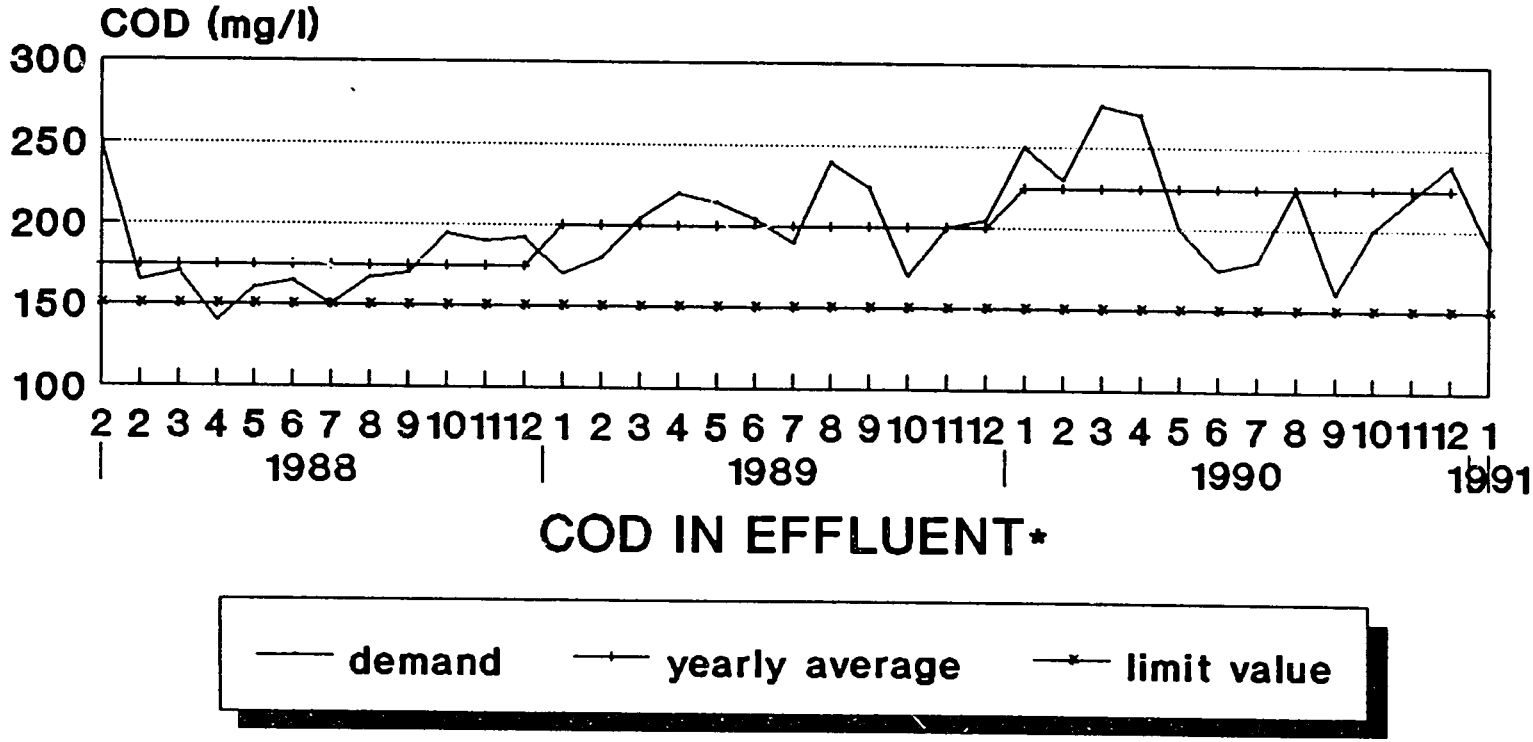
Selected Gaseous Wastes	Total Quantity of Emission (tons)	Total Quantity Over the Limit (tons)	Projected Reduction of the quantity over the Limit in Year 1991 (tons)
SO_2	4251	2630	453
H_2S	623	607	218
NO_x	93	16	10
CO	4565	-	-
dust	456	167	107
HCl	1	-	-
in-butan	2757	-	-
TOTAL	12746	3420	

Source: DKV Refinery.

With respect to water pollution from the refinery, DKV's waste water treatment system is still not meeting its extremely lenient water quality limits for discharge into the Danube River. Presently, DKV only slightly exceeds permissible pollution levels for oil in the water effluent stream. On the other hand, the refinery is considerably over limits for Chemical Oxygen Demand (COD) as illustrated in Figure 11. In fact, the amount that it exceeds this limit is increasing over time. As a result, DKV intends to install aerators, as well as construct a new waste water treatment plant. While aerators needed to convert the existing waste water treatment lagoons to aerobic treatment basins may have already been ordered at the time this report is published, refinery management has not yet recognized the need for in-plant controls designed to reduce the toxicity of the waste-water. 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, DKV may still have great difficulty in successfully bringing its new waste water treatment plant now under construction to within prescribed limits.

FIGURE 11

RECENT INCREASES IN OVERALL CHEMICAL OXYGEN DEMAND OF DKV EFFLUENT STREAMS



*(measured at the endpoint of the sewage - handling system)
Source: DKV Refinery

Contamination of soils with hydrocarbons and migration into the water table under the DKV refinery is becoming a major area of concern regarding the overall environmental protection of the refinery. Indeed, groundwater contamination in particular is especially bad at DKV. 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 (i.e. - gasoline or other product which floats on top of the groundwater) is well over 2 meters. To address this growing problem, DKV has installed over 320 wells in an effort to investigate and correct this groundwater contamination problem. Indeed, to date, well over 1,000 cubic meters of free product have been recovered by pumping it from the groundwater.

Additional groundwater protection efforts by DKV include the construction of several thousand meters of internal drainage trenching and a cut-off wall around the refinery. This barrier and drainage system is between 5 to 10 meters deep, and is designed to collect and recover much of the remaining free product, as well as prevent the movement of water off the perimeter of the refinery site. However, this plan may not be as effective as originally envisioned. There is a growing body of literature and emerging evidence from U.S. sources which indicate that the presence of dissolved gasoline in the water may act as a desiccant to the bentonite - cement wall, and cause it to crack thereby allowing contaminated water to penetrate the wall. If contaminants go beyond the barrier wall, they will most certainly contaminate local wells.

V. THE TIFO REFINERY

A. Interdependency, Design Capacity, and Storage

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

- To supply virgin naphtha to the adjoining Tisza Chemical Works (TVK) as a feedstock for cracking to olefins.
- 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.
- 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. The close proximity of these facilities is illustrated in Figure 12. The TIFO refinery provides the following petroleum fractions to the petrochemical and power generation operations.

- Virgin naphtha for steam cracking at TVK.
- Hydrotreated atmospheric gas oil for steam cracking at TVK.

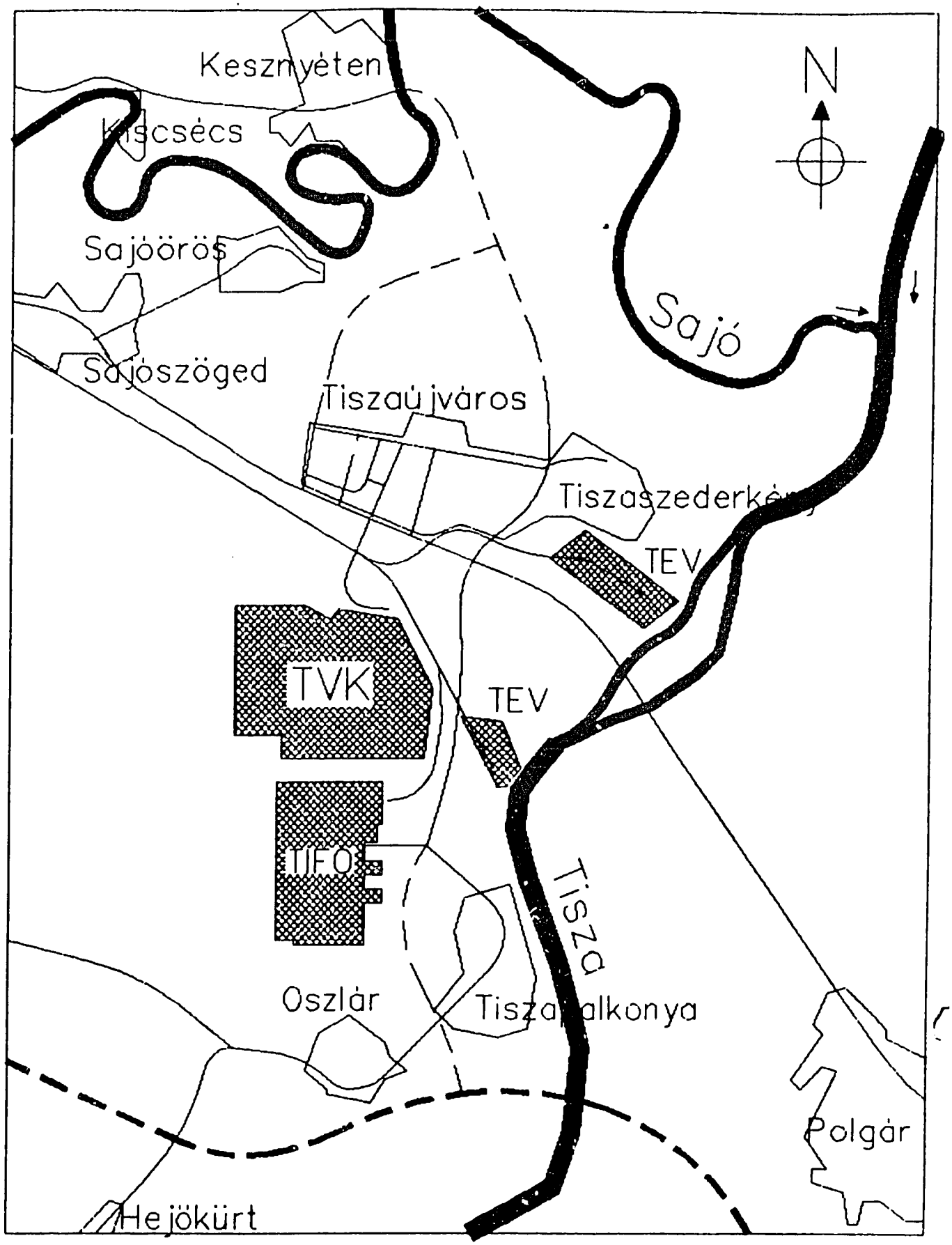
The TIFO refinery is also dependent upon both the chemical works and power plant for various utilities and hydrocarbon fractions as illustrated in Figure 13 and outlined below:

Utilities Inputs

- 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.

FIGURE 12

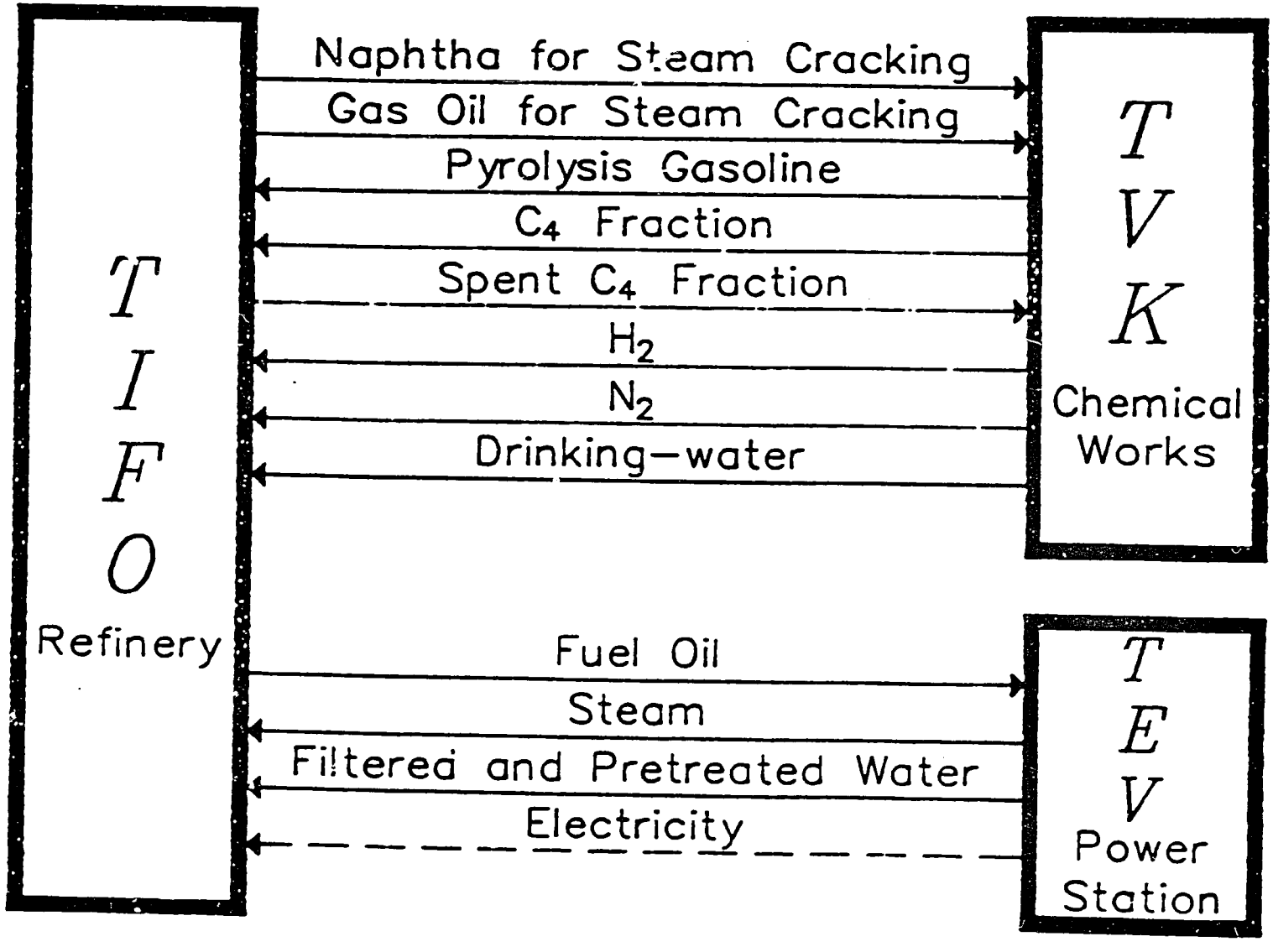
LOCATION OF MAJOR REFINING, CHEMICAL AND POWER FACILITIES IN THE VICINITY OF TISZAUJAROS



SOURCE: TIFO Briefing Materials

FIGURE 13

INTERDEPENDENCE OF MAJOR INDUSTRIAL FACILITIES IN THE VICINITY OF TISZAUJAROS



SOURCE: TIFO Briefing Materials

Hydrocarbon Fractions Supply

- 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.

The original design for the TIFO Refinery envisioned an 8 million tons per year crude processing facility which would include 4 processing complexes. Only the first of these complexes was built. The design capacity of existing units is listed both in metric tons per year and in approximate barrels (42 gallon) per day in Table 14 below:

TABLE 14

DESIGN CAPACITIES OF TIFO PROCESSING UNITS

Unit	Design Capacity (Thousand MT/Yr)	Design Capacity (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
Isobutylene	3.2	80

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

Source: TIFO Refinery.

The crude distillation complex units were completed in 1979, and two additional units were added at the site in 1982. The methyl tertiary butyl ether or (MTBT) unit and the isobutylene plant. A discussion of specific processing units is contained in Section C below.

While only the first processing block at TIFO was built to process 3 million tons per year, the product movement and storage facilities were developed in anticipation of a full 8 million tons per year operation. Most of the product moves from TIFO by pipelines to TVK and TEV. There are also product lines between DKV and TIFO. Product can also be shipped from the refinery by rail and track. On site storage capacity volumes for the TIFO refinery are presented in Table 15.

TABLE 15

TIFO STORAGE CAPACITY ON SITE
(in thousands of cubic meters)

Material Category	Storage Capacity (thousand meters^3)
Crude	240
Fuel Oils	400
Diesel and Heating Oils	265
Naphtha and Gasoline	100
Methanol	5
LPG, MTBE and C_4 Fractions	9
Total Storage Capacity	1,019

Source: TIFO Briefing Materials.

B. Continuing Low Operating Levels and Conditions

The operating levels in the crude complex of TIFO have been at a low level of capacity utilization for the past ten years. While the design capacity is 3 million tons per year, the refinery has mostly operated in the area of 1 million tons per year; however last year it was operated well below that level in the neighborhood of 350,000 tons per year. The anticipated level for 1991 is 1.1 million tons per year. The refinery has been constrained on both the product demand and crude supply sides, and is currently operating at a capacity utilization rate of 50 to 55 percent on a daily basis, and only about 30 percent on an annual basis when shutdowns are factored in.

With respect to diminishing product demand, the primary customer for TIFO fuel oil is the TEV power plant. This facility consists of an older 220 MW coal-fired plant and a newer 860 MW oil-fired generating facility built in 4 blocks. However, only one of these 4 oil/gas-fired units is currently being operated since Hungary is still purchasing significant amounts of electricity on a take or pay basis from the Soviet Union rather than operating these units. In addition, factories in the region also burn fuel oil from TIFO, but have had to reduce purchases significantly as demand for the various products they produce for the Soviet Union has declined. As a result, production and energy consumption are off in these factories by 25 percent or more.

Similarly, the TVK chemical plant is the primary consumer of TIFO naphtha and part of the TIFO gas oil production. Although TVK was originally designed to use naphtha in its crackers for olefin production, more recently two cracking furnaces have been adopted to accept an atmospheric gas oil feed. The current feedstock requirements for TVK are reflected below:

Chemical Naphtha:	600-700 thousand tons per year
Atmospheric gas oil:	300-400 thousand tons per year

Moreover, this naphtha feed stock requirement can be met with contributions from both TIFO and DKV. For instance, DKV can supply 300 - 400 thousand tons per year of naphtha for TVK by product pipeline.

In the case of crude supply restrictions, the primary supply of crude oil to the refinery is of Soviet origin, and its availability has been curtailed considerably by the Soviets over the past couple of years. When it is available, this Soviet export blend crude is transported via the Friendship II pipeline which enters Hungary at the northeast border with the Soviet Union. The TIFO refinery only has access to crudes that can be transported via the Friendship II pipeline, which ultimately terminates at the DKV refinery at Szazhalombatta. Friendship II is not presently connected to the Adraiatic pipeline which also supplies crude to DKV; and in any case, crude oil flows cannot presently be reversed in the Friendship II pipeline. Thus, there is no way for TIFO to receive imported international crudes via the Adriatic pipeline to offset declining Soviet exports. It would be possible, however, to add pumping capacity to and reverse the direction of flow of the Friendship II line between Szazhalombatta and TIFO, and thus provide TIFO with access to crudes coming to Szazhalombatta via the Adriatic pipeline.

C. Current Refinery Configuration and Processing Capabilities

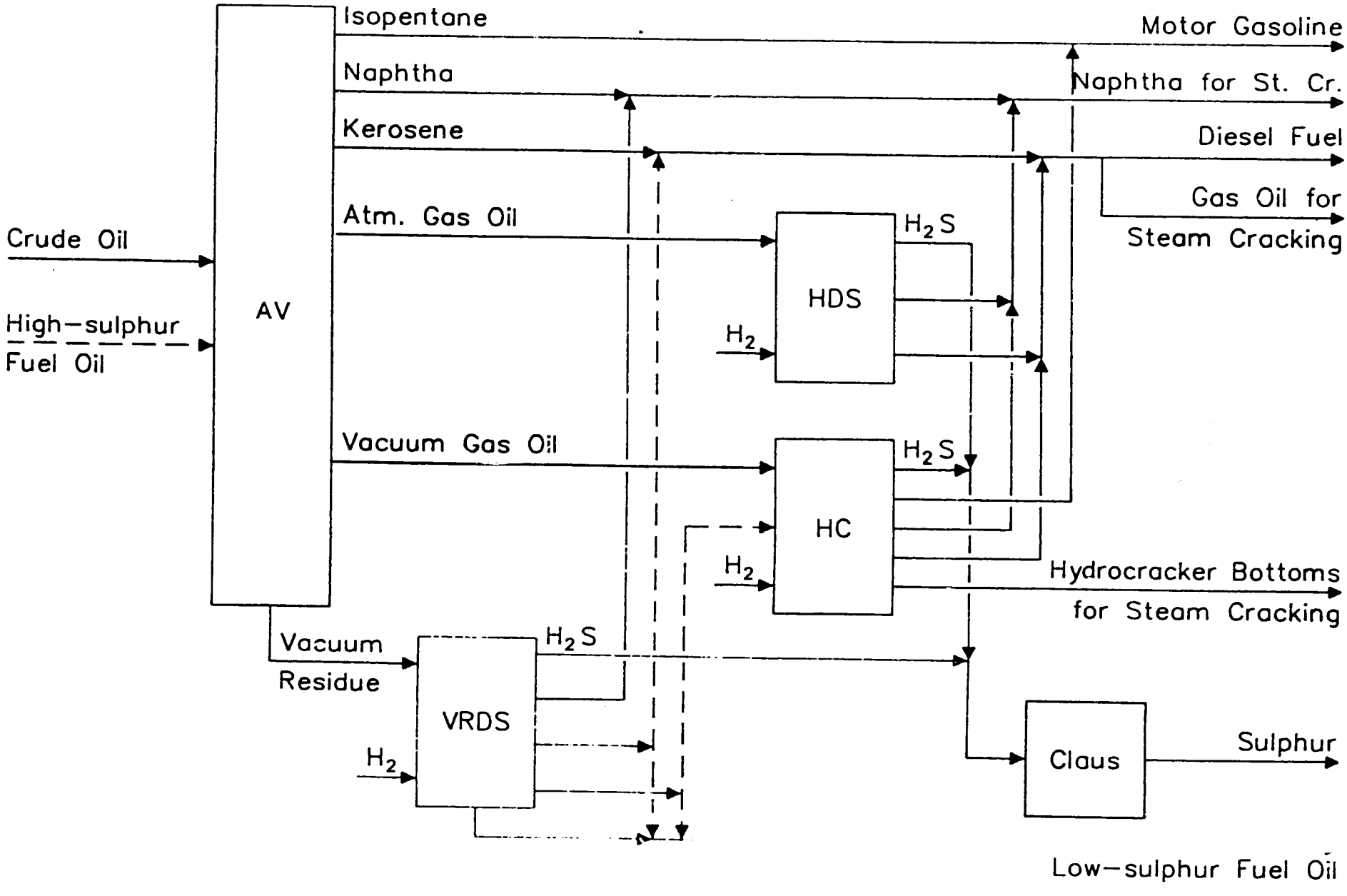
A flow diagram of the current process configuration is illustrated in Figure 14. Each of the major individual units and plants is described below:

- **Crude Distillation Unit**

  The crude distillation complex includes both atmospheric and vacuum distillation. The atmospheric tower contains 50 valve trays and operates well. In addition, the vacuum tower contains 25 bubble cap trays.

FIGURE 14

FLOW DIAGRAM OF THE CURRENT PROCESS CONFIGURATION OF TIFO



SOURCE: TIFO Briefing Materials

The material balance and flows for the crude processing complex at the TIFO refinery are shown on Figure 15, as well as summarized in Table 16 below.

TABLE 16

ONE-YEAR MATERIAL BALANCE FOR TIFO's
CRUDE PROCESSING COMPLEX, 1990
(in thousands of tons per year)

Feedstocks	Tons per Year (1,000's)	Percentage by Weight
Crude Oil	1,500	83%
Imported High-Sulfur Fuel Oil	300	17%
Hydrogen	3	–
		100%
Products		
Motor Gasoline Components	15	–%
Naphtha for Steam Cracking	290	16%
Diesel Oil/Gas Oil for Steam Cracking	550	31%
FCC Feedstock	140	8%
High-Sulfur Low-Viscosity Fuel Oil	170	10%
High Sulfur High-Viscosity Fuel Oil	610	35%
Sulfur	4	–
		100%

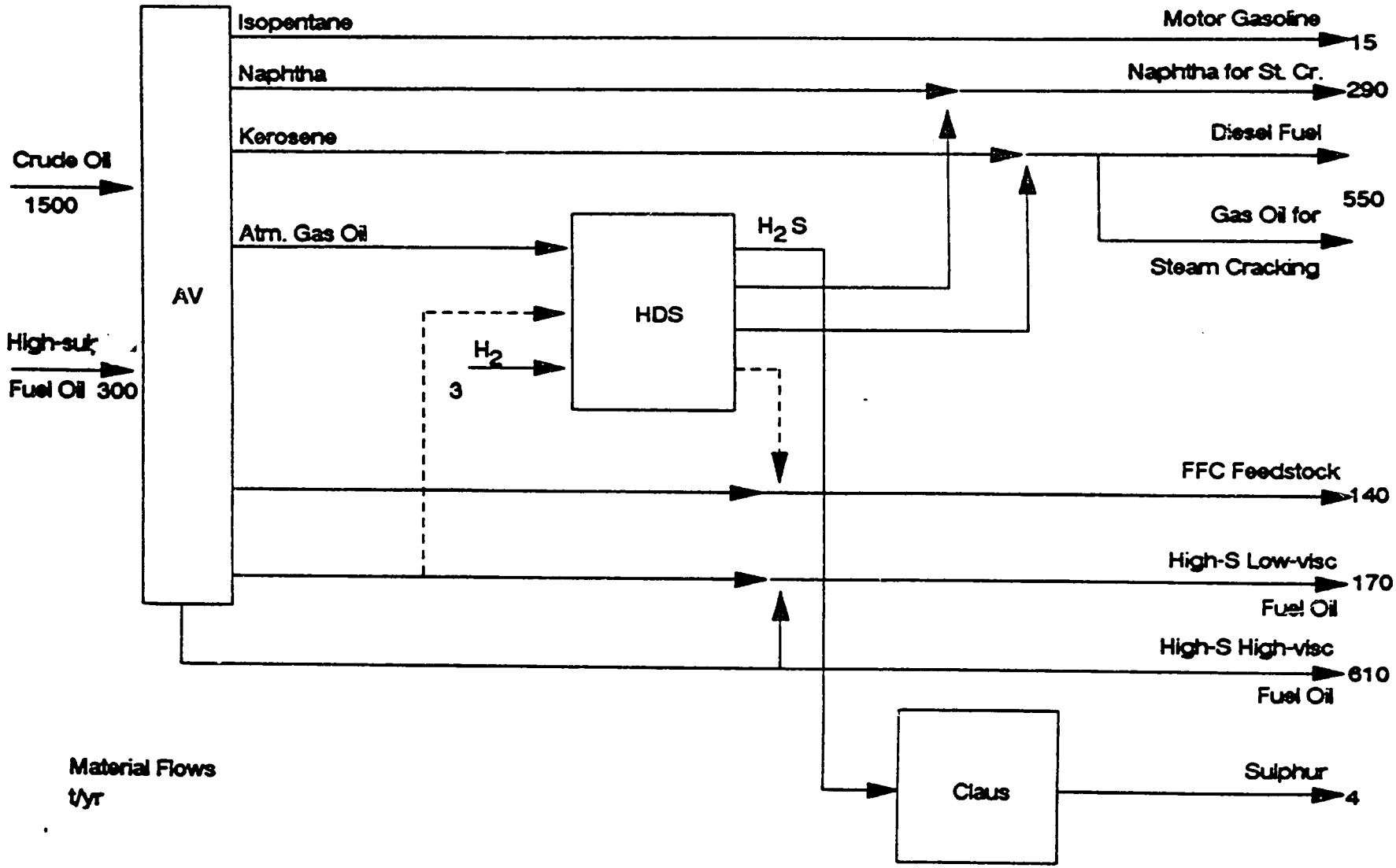
Source: TIFO Briefing Materials.

Gas Oil Hydro-desulfurization 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 bar (approximately 750 psia) with a hydrogen partial pressure of 40 to 42 bar (600 to 630 psia). The purity of the hydrogen received from the chemical works has a purity in the range of 87 percent to 90 percent. Approximately 90 percent desulfurization of the gas oil is achieved, which results in a product containing 0.1 to 0.15 percent sulfur.

FIGURE 15

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



SOURCE: TIFO Briefing Materials

- **LPG Sweetening**

  The refinery contains a 50,000 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.

- **Claus Sulfur Recovery Unit**

  The TIFO refinery operates a 7,000 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 stage.In the thermal stage, one-third of the hydrogen sulfide gas is oxidized to sulfur dioxide. The remaining portion of the hydrogen sulfide gas reacts with the sulfur dioxide to form elemental sulfur in the catalytic stages.

  Sulfur recovery in a two-stage Claus plant is typically in the range of 90 percent to 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.

- **MTBE and Isobutylene Unit**

  A 30,000 ton per year methyl test-butyl ether (MBTE) plant has been in operation at TIFO since 1982. In this plant, MBTE is produced from raw C_4 fraction feed obtained from the adjacent olefin plant at TEV, as well as imported methanol. MTBE is the most valuable component of unleaded motor fuels, and is sold primarily in the export market.

  A 3,000 ton per year high purity (99.9 percent by weight) isobutylene plant is associated with the MTBE unit to produce product through the catalytic cracking of MTBE.

A material balance for these two units is presented below in Table 17.

TABLE 17

ONE-YEAR MATERIAL BALANCE FOR THE
MTBE AND ISOBUTENE UNITS AT TIFO, 1990

(in thousands of tons per year)

Feedstocks	Tons per Year (1,000's)
C_4 fraction	80
Methanol	9
Products	
MTBE	26
Isobutene	3
Spent C_4 fraction	59

Source: TIFO Briefing Materials.

D. Changing Product Demands and Processing Requirements

Ever since the first process unit was brought on stream in 1979, TIFO has endeavored to find ways to increase the proportion of more valuable products in its product slate by increasing the yields of its white products, and thereby contributing greater profits; however, declining demands for TIFO's product slate (especially residual fuel oil for power generation at TEV and changing requirements at the TVK chemical works) have proceeded at a pace that far outstrips any increase in white product yields and associated profits. Accordingly, TIFO has begun to look at potential opportunities for producing new products for possible sale to both TEV and TVK. Already included in the development strategy of the TIFO refinery are the following possibilities: (1) introducing a bottom of barrel process to produce the additional feedstocks that will be required at TVK's upgraded olefin plant, (2) exploring the feasibility of heavy residue firing at TEV, and (3) undertaking the further processing of the C_4 and C_5 fractions from TEV's olefin plant to produce special petrochemical products.

At present, TIFO has no facilities for conversion of vacuum gas oil and residual oil fraction, nor does it have pipeline access to lighter crudes. Thus, it has not be 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 such a scenario, the installation of a hydrocracker at the TIFO refinery would represent an excellent addition to the current processing scheme.

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 percent by weight. It is anticipated that future demand will be for heavy fuel oil with a sulfur content of approximately 1.0 percent 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. Accordingly, this process neither increases TIFO's flexibility by providing the refinery with options in the event that the demand for residual fuels drops off further, nor does it necessarily mean the refinery would be producing the product slate that maximizes return on investment.

A number of additional alternatives exist for processing of TIFO's 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. It may also 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 for processing residual fraction. 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.

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.

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. In this regard, 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 upgraded environmental protection, TIFO will need access to more high quality gasoline blending components such as those that have been listed above.

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.

A summary of annual energy consumption at the TIFO refinery for a typical year is presented in Table 18. Steam purchases by TIFO from TEV in 1990 totalled about 231,000 tons, but only 200,000 tons will in all probability be required in 1991 as a result of planned expansions in self-generated steam capacity.

During the last couple of years, the through put rate to the refinery has varied considerably creating an immediate impact or change in overall energy consumption per unit of refining feed input as illustrated in Table 19. When crude oil through puts are decreased and feed rates are reduced from 312 to 210 tons per hour, for example, the usage of electricity, steam, and fuel increases dramatically.

F. Status of Energy Conservation Efforts

TIFO is a modern refinery comprised of conventional processing equipment representative of similar components used in the West to achieve comparable results and purposes. The refinery processing equipment, along with its associated infrastructure, appears to be well-insulated and well-maintained. Refinery personnel are extremely knowledgeable, and possess strong technical skills.

Despite the fact that TIFO has been operated at a very low utilization rate over the past couple of years, the refinery and its staff appear very much interested in and committed to finding additional energy savings at TIFO.

TABLE 18

ANNUAL ENERGY CONSUMPTION AT THE TIFO REFINERY FOR A TYPICAL YEAR

	Crude Processing 1,500,000 t of crude oil	Complex: 300,000 t of imported fuel oil	MTBE and isobutylene unit	Storage and dispatching	Energy supply and others	Totals
Electricity, MWh	24,000	8,400	2,250	5,400	13,600	53,650
Steam, t	75,000	42,000	54,000	102,500	44,000	317,500
- purchased	--	10,500	54,000	102,500	24,000	191,000
- self-generated	75,000	31,500	--	--	20,000	126,500
Fuel, tFOE	27,000	9,000	470	1,500	1,000	38,970
- purchased natural gas	20,400	7,808	470	1,500	1,000	31,170
- self-produced fuel gas	6,600	1,200	--	--	--	7,800

Source: TIFO Refinery.

TABLE 19

TIFO REFINERY CRUDE PROCESSING COMPLEX REQUIREMENTS AS A FUNCTION OF TYPE OF FEED AND FEEDRATE

	CRUDE		CRUDE		FUEL OIL		COPROCESSING CRUDE AND FUEL OIL	
Feed Rate	210 t/hr	37.3 mb/d	312 t/hr	55.4 mb/d	92 t/hr	16.3 mb/d	250 = t/hr	50.4 mb/d
Electricity	18.8 kw/t	25.4 mbtu/b	16.0 kw/t	21.6 mbtu/b	28.0 kw/t	37.8 mbtu/b	17.2 kw/t	23.2 mbtu/b
Purchased Steam	20.0 kg/t	7.2 mbtu/b	0.0 kg/t	0.0 mbtu/b	35.0 kg/t	12.5 mbtu/b	8.0 kg/t	2.9 mbtu/b
Fuel (FOE)								
Refinery gas	5.0 kg/t	25.7 mbtu/b	4.4 kg/t	22.7 mbtu/b	4.0 kg/t	20.6 mbtu/b	4.6 kg/t	23.7 mbtu/b
Natural gas	14.4 kg/t	74.1 mbtu/b	13.6 kg/t	70.0 mbtu/b	26.0 kg/t	133.9 mbtu/b	13.9 kg/t	71.6 mbtu/b
Total	19.4 kg/t	99.9 mbtu/b	18.0 kg/t	92.7 mbtu/b	30.0 kg/t	154.5 mbtu/b	18.5 kg/t	95.3 mbtu/b
Total Energy Requirements		132.5 mbtu/b		114.3 mbtu/b		204.8 mbtu/b		121.4 mbtu/b

Source: TIFO Refinery.

TIFO has already accomplished a great deal in this area as a result of implementing many of the recommendations contained in the 1985 Foster Wheeler Iberia energy audits study. Subsequent implementation efforts have been concentrated in the following areas:

- Optimization of heat exchangers
- Installation of crude pre-heater trains
- Installation of more energy efficient burner systems in the HDS unit
- Implementation of an automated computerized energy monitoring system
- Alternation of the EPD cut in the crude column, and minimization of overall operating pressures in the process unit
- Installation of a steam generator in the waste incinerator
- Diversion of refinery by product and waste gases to fire heaters instead of flaring

In addition, in late 1990 and early 1991, TIFO had a follow-up energy consumption audit performed by Credit Suisse, First Boston, and McKinsey and Associates so that TIFO would be able to compare its overall operations and energy usage to that of similar West European refineries. No information was available for review from this most recent audit.

F. Minor Contributor to Regional Environmental Problems

Since the TIFO refinery was built in 1979, its unit operations reflect relatively recent advances in pollution control technology. As a consequence, the refinery is not a significant contributor to the serious air quality and other environmental problems which appear widespread at Tiszanvaros. The environment around the refinery is adversely influenced by the significant air pollution discharges from the neighboring chemical and power plants, as well as the community use of high sulfur soft coal for home heating. In addition, TIFO's management has paid close attention to potential problem areas with respect to water pollution and solid waste management. As a result, environmental problems in the TIFO refinery are considered minor overall.

The environmental problems that do exist at the TIFO refinery appear to be caused primarily by process air emissions, since many storage tanks utilize floating roofs and process heaters are fired with natural gas. The principal air pollutants, as identified by the refinery staff, include sulfur oxides and hydrocarbons.

Sulfur oxides are emitted from the Claus and Vacuum Tower Tailgas Units. TIFO staff appeared quite interested in learning more specific information about the utilization of mono ethanol amine (MEA) for scrubbing the vacuum tower tailgas stream for H_2S, as well as its capture and recycle. Presently, this stream is fed directly into an incinerator and the H_2S is converted into SO_2. However, sulfur oxide emissions from the TIFO refinery may not be significant when compared with other air emission sources nearby. On one side of TIFO is a 1,080 MW power plant facility, of which 220 MW is coal-fired. The team was told that this plant utilizes essentially the same high sulfur coal as the villages do for home heating. This plant is not equipped with flue gas desulfurization units. On the other side of the refinery is an agricultural chemicals complex whose single stack continuously discharges a bright yellow plume which could be nitrogen oxide, sulfur dioxide, or both. Detailed air emission information was unavailable to the team for both TEV and TKV.

A number of hydrocarbon emission points exist within the DKV refinery, but many are already controlled to levels which are acceptable in the United States. The principal contributor of hydrocarbon emissions appears to be fugitive losses or leaks from such specific sources as valves, flanges, pump seals, and fittings, as well as evaporation from condenser water in the Vacuum Distillation Unit and the waste water treatment facility.

With respect to water pollution, the TIFO refinery's waste water treatment facility is quite advanced, and provides substantial residence time and opportunity for the discharge materials to biodegrade before reaching the Tisza River. This system includes biologic treatment, clarification and filtration. The effluent from TIFO's waste water treatment plant is relatively low in chemical oxygen demand with average COD values of 66 milligrams per liter and a low of 32 milligrams per liter over the past several years. Moreover, Oil concentrations in the discharge water have been showing a continuous decrease from 1983 to 1990, and are presently at less than 3 milligrams per liter. The refinery is presently within compliance levels for the Tisza River.

Regarding ground water and soil contamination, refinery personnel appeared sensitive to many of the causes which generate soil contamination and ground water problems. In most refineries, the loading racks and filling pipes are a major source of spills which can contaminate the soil and ground water. Accordingly, the filling station area is lined with stone and clay, monitoring wells have been drilled, and a leakage collection system has been installed. If a spill occurs, the stone and soil are immediately replaced.

In summary, at current production levels, the TIFO refinery is not believed to be a significant contributor of sulfur dioxide or hydrocarbon emissions to the environment. Moreover, its waste water treatment system is in excellent operating condition, and provides treatment comparable to current levels required for new plants in the United States.

VI. FUEL SWITCHING AND CAPTIVE POWER

A. Practicality of Fuel Switching

As part of this assignment, USAID requested that K & M explore a very preliminary fashion the practicality of replacing petroleum hydrocarbon fuels at DKV with indigenous coal. Briefly, as stated in K&M's scope of work from USAID: "Refinery furnaces have in the past been fired with coal. Fuel switching to coal to save on oil imports could be a viable option. However, a different technical option for coal utilization should be included, in order to reduce investment, by considering high fuel density, coal-water slurry fuels as a direct replacement for fuel oil with minimum retrofit. Sootblowers could handle the higher ash content."

K & M has reviewed the practicality of switching to indigenous coal for firing refinery furnaces at DKV from several different perspectives, and found this notion to be lacking in several key respects including:

- While the concept of fuel switching was of interest to DKV, Hungary's coal subsector has long suffered from such problems as declining production (since much of the present reserves are uneconomic to produce at current international energy prices), lack of mining infrastructure (especially in the area of coal cleaning and coal preparation), growing labor constraints (the mining industry is increasingly having difficulty recruiting workers despite offering the highest industrial wages), and extremely long lead times (for developing new mines).

- Hungary's indigenous coal is also of inferior quality. Most coal mined in Hungary is either lignite or brown coal. Moreover, Hungary's sub-bituminous coals that are suitable for combustion in power plants are typically of lower rank (with low calorific values, high ash contents, and fairly high percentages of sulfur). Even if capital investment funds were available to construct coal washing/coal preparation plants or coal-slurry pipelines, only pyritic sulfur would be removed by such methods. The only way to remove elemental sulfur from coal prior to combustion is by chemical cleaning, and chemical coal preparation techniques are not yet commercially available.

- Use of any fuel other than natural gas to replace fuel oil will further compound DKV's already considerable air pollution problems. Since overall environmental compliance is currently DKV's most pressing problem, why compound it further?

- Burning indigenous coal in DKV's refinery furnaces would be more expensive than continuing to switch to natural gas as has been occurring over the past five years. (Use of fuel oil as a fuel source is down slightly at DKV from 24.6 percent by volume in 1985 to 23.3 percent in 1990, while natural gas usage is up from 6.6 percent in 1985 to 11.7 percent in 1990). Combustion of natural gas will not contribute additional SO_2 emissions to the atmosphere as will the burning of coal. In any cases, the combustion of Hungarian coal in any form (whether solid or coal-water mixture from a coal slurry pipeline) will require the installation of expensive scrubbers. On the other hand, Soviet and Hungarian natural gas supplies are still relatively cheap, and their combustion does not require expensive environmental retrofits since there will be no sulfur dioxide to remove from the flue gases.

Finally, one alternative to both gas and coal may be the greater utilization of DKV's residual fraction to its refinery furnaces or in a new captive power plant at DKV. However, such an option would need to be carefully evaluated in a detailed feasibility study, possibly with funding assistance from TDP or USAID.

B. Refinery Cogeneration vs Continued Power Purchases

Concerns about the reliability of power supply, and difficulties in negotiating future favorable steam and power price contracts with DHV, have prompted DKV to develop a cogeneration option for the refinery. The proposed refinery cogeneration facility would consist a combined cycle power plant in the range of 90-120 MW in total generating capacity. One possible configuration would include 3x25MW of gas turbines to be fueled by natural gas and distillate oil, 3x90 ton per hour heat recovery steam generators, and one double extraction steam turbine capable of generating approximately 35MW of electricity. Exhaust steam from this new steam turbine would be fed into the existing main steam headers for use as process heat.

A preliminary analysis performed by the Hungarian Institute for Energetics (EGI) 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 basis by which the projected energy costs from the power plant were calculated.

The utility (DHV) is in the process of replacing its older generation facilities (which have historically provided steam and power to DKV) with a new gas turbine power plant totalling about 140MW in capacity. Basically, the future price negotiation will be conducted with both DKV and DHV having done calculations for their own cogeneration scheme for producing power and steam for the refinery. Since both approaches assume natural gas as the fuel source, the conventional wisdom is that DHV will show a lower cost of electricity generation because of the economies of scale of its larger units, as well as the availability and common use of existing facilities and infrastructure. However, this may not necessarily prove to be the case since DHV assumes a large reserve capacity for generating electricity for the refinery, meaning a higher capital component of unit electricity generating cost than in the refinery's own cogeneration case.

Fundamentally, a utility located in such close 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 exhibits a more level demand load than most of its customers. These conditions should enable the utility and refinery to negotiate a new rate agreement that satisfies the intent of both parties. Clearly though, the refinery must continue pursuing its own cogeneration project in case success is not achieved with DHV at the negotiating table.

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 emergency refinery service. A new low pressure steam line to meet increasing steam demands would also be required in the event that a new purchase agreement can e arranged between DKV and DHV.

Another alternative suggested by the K & M team was to oversize the combined cycle power plant, and sell the surplus electricity to Austria to cover debt servicing. Such an approach would also lead itself to either a joint venture arrangement with an outside equity partner, or else as a separate stand-alone build-own-operate (BOO) or build-own-transfer (BOT) project concept.

VII. PROJECT FINANCING AND INVESTMENT DECISIONS

A. The OKGT Hydrocarbon Investment Program

Over the period 1989-1992, OKGT expects to invest a total of approximately US$1,075 million in Hungary's oil and gas sector, of which about US$218 million will be for imported capital equipment. Planned investments by budgetary component for the oil and gas sector are presented in Table 20 below, based upon the most recent five-year plan that the K & M team was able to review:

TABLE 20

APPROVED OIL AND GAS INVESTMENTS, 1988 - 1992

(in billions of 1988 Hungarian Forints)

Component	1988	1989	1990	1991	1992
Exploration and Drilling Equipment	2.17	1.22	.68	1.37	1.11
Development	3.81	5.09	4.96	5.75	4.16
Pipeline Construction	1.22	2.13	1.27	2.18	2.36
Petroleum Refining	1.75	2.49	3.78	4.68	2.49
Underground Gas Storage	.93	1.23	.68	.99	1.72
Carbon Dioxide Production	.13	.35	.09	.14	.05
Storage Transportation	.35	.26	.23	.36	.37
Lube Oil Production	.14	.15	.15	.50	.50
Other	.04	.06	.04	.10	.10
Total	10.54	12.98	11.88	16.07	12.86

Source: The World Bank.

B. Financing in the Oil and Gas Sector

Until the mid-1980's, OKGT's investment programs were financed primarily by central government loans. More recently, direct contributions from government have all but disappeared as a possible source of project financing in the oil and gas sector.

Major sources of financing for OKGT projects in the past have included: commercial banks, World Bank, CMEA Development Bank, government loans, some municipal sources, and OKGT's own profit. The planned distribution of project financing sources from OKGT's 1988-1992 financing plan is presented in Table 21.

TABLE 21

DISTRIBUTION OF OKGT FINANCING SOURCES, 1988 - 1992

(In millions of 1988 Hungarian forints)

Source	1988	1989	1990	1991	1992
Commercial Bank	911	1,340	2,080	4,785	4,467
World Bank	1,807	1,709	1,888	1,010	580
Own Resources (Profit, Depreciation, Misc. Development Funds)	7,790	10,200	7,669	10,712	9,213
State Loans	747	—	—	—	—
Municipal Sources	498	—	—	—	—
CMEA Development Bank	—	500	1,000	900	—
Total	11,753	13,749	12,637	17,407	14,260

Source: The World Bank.

However, two major external events have occurred recently which have the potential for causing serious disruptions to this approved financing plan. First, the CMEA Development Bank may no longer be a viable source of funds for Hungary's hydrocarbon sector now that the Warsaw Pact has been disbanded; and second, the dramatically increased bill for crude oil purchases from Africa and the Middle East at premium prices will soon deplete profits included under the Own Resources Account.

Such a shortfall in the availability of funds for overall project financing is likely to be felt most immediately and acutely in the petroleum refinery investments area. For instance, in 1990 when Soviet crude was more readily available and before the Soviets raised their prices to world market levels, DKV generated a profit of approximately 4 billion Hungarian forints. Of this amount transferred to OKGT, DKV only received about 1 billion Hungarian forints back for capital equipment expansion projects designed primarily to improve process unit operating efficiencies, energy usage, and environmental quality. With a bill for crude oil imports that has at least doubled in the last year, will OKGT still be able to support a 1 billion Hungarian forint per year investment program at the DKV refinery?

If the answer to this question is no, then both DKV and TIFO will increasingly be turning to international joint venture partners for planned product unit expansions, or alternatively, to minority ownership of Hungarian refinery operations by overseas investors.

C. Governmental Oversight and Review

OKGT is presently organized as a government trust reporting primarily to the Ministry of Industry. As such, OKGT has only a limited and at times unclear degree of autonomy, especially with respect to decisions regarding major capital investments. In the recent past, all investments in the refinery sector were subject to approval of the Ministry of Industry, and were accompanied with complicated capital flows between the central government and OKGT. In addition, OKGT must also coordinate with other government ministries for all related aspects of the project finance and investment decision-making process, including foreign exchange allocations, planning, and detailed financing plans. Moreover, everything is presently in a state of transition. As a result, it has bee difficult for OKGT to develop

appropriate and consistent internal criteria for the allocation of investment funds between different refineries and among competing activities and needs.

Despite recent political changes, OKGT is still responsible for working within annual and five-year plans whose preparation is initiated at the company level (or at DKV and TIFO in the case of the refinery sector). Submissions are consolidated at OKGT headquarters, modified as required, and finally reviewed and approved by appropriate government planning agencies. In 1989, for instance, of the planned capital improvement projects for all 22 companies and one subsidiary that comprise OKGT's core business operations, fully 70 percent of these planned investments required specific authorization from Government.

In particular, large investments such as a refinery upgrade or pipeline expansion require prior planning authorization and fiscal approval by Government before they can be undertaken.

D. Decision-making Process for Project-Specific Investments

At both the DKV and TIFO refineries, three different expansion levels are prepared annually in a detailed bottoms-up planning process for review by the Board of Directors of OKGT. Each refinery is represented on this board by its General Director, who has an equal vote with other board members in the review process. Each specific project that is proposed requires a majority decision by this body. Decisions do not have to be unanimous. If a proposed project is rejected, the decision cannot be revisited for at least one year.

Projects that survive this initial bottoms-up planning process are incorporated into the three different expansion levels, and reviewed not only by appropriate governmental agencies, but also by the workers at each of the refineries.

With respect to actual implementation of the final approved investment plan for the current year, weekly conference meetings are generally held at each refinery and chaired by the General Director to review the status and progress of each capital equipment expansion project.

E. Ranking Criteria for Potential Investments and Improvements

Only three general criteria are utilized today in preparing a proposed investment plan for both the annual and current five-year plan. These include: (1) need as justified by the refineries; (2) cost; and (3) availability of investment funds. More specific ranking criteria do not currently exist, but in all probability will come into greater play in the future as the notion of profits in a Western sense begins to play larger role in the commercial operation of the refinery sector.

VIII. SUMMARY OF OBSERVATIONS AND FINDINGS

A. Overall Impressions of the Hungarian Refinery Sector

During Phase I of this assignment, the K&M team formed the following general impressions with respect to the Hungarian petroleum refinery sector:

- The technical and managerial staffs of both the DKV and TIFO refineries are superbly qualified, and knowledgeable about current U.S. and West European technological trends in the refining industry, especially in the areas of energy conservation and process technology.

- In addition, Hungarian refinery personnel have been successfully engaged in aggressive energy conservation efforts for the past decade, and have achieved significant reductions in overall energy usage over this period.

- Overall environmental compilance lags considerably behind recent U.S. and West European efforts in the refinery sector, with most environmental problems being concentrated at the older DKV facility.

- The DKV refinery is considered a modern and complex facility (cracking, lubes, petrochemicals) which is presently being operated at or near capacity; however, this refinery is lacking in additional capacity for conversion of residual materials into lighter transportation fuels, and still has major difficulties in meeting existing environmental guidelines and limits in several key areas.

- On the other hand, based upon a brief analysis of rather limited operating data, it appears that the operating efficiency of DKV's catalytic reformers and FCC units is comparable with similar units found in both Western Europe and the United States.

- Reliability of supply of electricity is a major concern for the DKV refinery.

- The TIFO plant is a modern, low-complexity refinery (distillation, hydrotreating) which is presently being operated at about one-third capacity as a result of serious feedstock and product dislocations.

- TIFO does not presently have facilities for the conversion of vacuum gas oil and residual oil fractions. As a result, while TIFO possesses excellent infrastructure and is well-maintained, it will require major investments for additional conversion capacity to remain competitive in the future, and avoid being bottlenecked by swings in the demand for heavy fuel oils.

- Moreover, TIFO was designed to process a narrow slate of Soviet crudes. In addition, it cannot presently utilize African or Middle Eastern crudes as alternate feedstock sources since the Friendship II pipeline does not possess a reverse flow capability.

- As a final general observation, there is presently insufficient participation by and input from senior refinery technical and managerial staff in the areas of crude oil purchasing and product marketing.

B. Unprecedented Change and Uncertainty

Refinery managers in Hungary today are being buffeted by significant changes seemingly beyond their control as the entire country moves from a command economy to one that is more responsive to price signals and bottom line profits. Some of the most serious changes and uncertainties confronting refinery managers at DKV and TIFO include:

- Significant feedstock disruptions brought on by curtailment of Soviet crude exports and dramatically increased prices;

- Radical swings in the chemical and physical properties of refinery feedstocks as crude oil purchasers scramble to locate more stable supplies of crude.

- Serious product dislocations such as a rapidly deteriorating market for heavy fuel oils as a major fuel source in fossil-fired power plants and factories; in addition, the demand for unleaded motor gasoline appears to be growing steadily in Hungary as a result of having the highest per capita ownership of new automobiles in Eastern Europe;

- Growing public awareness in Hungary of environmental protection issues, especially in communities that are located near major point-source polluters such as petroleum refineries, petrochemical facilities, and fossil-fired power plants;

- Tighter operating and capital improvement budgets resulting from the higher cost of crude inputs, lower profit margins, and the dwindling availability of loans from such traditional sources as Government and the CMEA Development Bank; and

- Growing feeling of frustration and concern over the uncertainties surrounding the future direction of privatization and reorganization efforts in the refinery sector, which has the potential for reopening the whole issue of specific retrofit decisions and investment priorities that have already been approved and incorporated into the current five-year plan.

C. Impact on Operating Efficiencies

Such changes and uncertainties are beginning to have a detrimental impact on overall operating efficiencies at both refineries.

- For instance, K&M has estimated that the Hungarian refinery sector is presently losing about U.S.50¢ per barrel in overall bottom line profitability as a result of not being able to optimize crude purchases to product yields and slates.

- Similarly, there appears to be a lack of appreciation on the part of both OKGT and the refineries regarding the fragility and vulnerability of their traditional product markets during such a period of transition and change; in this regard, a US5¢ per barrel transportation advantage will never be sufficient to offset the estimated US50¢ per barrel loss due to inefficiencies brought on by rapidly changing crude and product markets.

- With respect to the dramatically increased prices that Hungary has had to pay for crude oil imports during the past two years, the critical question that OKGT should ask in choosing higher priced crude is whether the saving in operating costs plus the added revenue from an improved product slate is more than sufficient to offset the

higher cost of the premium crudes that are now being purchased; in this regard, to achieve a favorable profit situation, refinery managers will need to value and select the slate of crude for maximum profit, produce and market the slate of products for maximum profits, and given these crude and product slates, optimize individual processing unit operations accordingly.

- Finally, in as much as TIFO was only operated for about two and one-half months in 1990, and is still being run at less than 40 percent capacity as a result curtailments in Soviet crude deliveries via the Friendship II pipeline, improvements in energy conservation and refinery efficiency are presently academic for this facility.

D. Status of Energy Conservation Efforts

While specific near and longer-term energy conservation recommendations will be made in the Phase II report, both refineries have already made significant progress in addressing major energy losses, especially in the last five to six years.

- In 1985, under the auspices of the World Bank, Foster Wheeler Iberia conducted in-depth energy audits of both the DKV and TIFO refineries.

- From a preliminary survey encompassing 82 potential areas for achieving energy savings, DKV and the World Bank selected about 40 high priority energy conservation projects, of which approximately one-third of the most cost-effective projects on this list have already been implemented.

- As a result, total energy consumption at DKV has exhibited a marked decline over the past five years, and when compared with U.S. and Western European refineries of similar complexity, DKV's overall energy usage per unit input of crude feed is approximately the same despite the fact that it is physically spread out and dispersed over a relatively large site.

- Similarly, TIFO has also achieved significant energy savings after six years of intensive energy planning and improvements, including the installation of an automated energy monitoring system.

- Finally, ongoing energy conservation efforts are well managed at both refineries, and it would appear that diminishing returns have, for the most part, long since set in regarding any major new undertakings in the area of energy conservation at these two refineries.

E. Environmental Protection Issues

Environmental regulations are presently much less stringent in Hungary than in the United States. As a result, overall environmental protection has received considerably less attention in Hungary's refinery sector compared to the heightened emphasis placed upon such concerns at similar facilities in both the United States and Western Europe.

- While DKV presently has a very active environmental protection effort underway, serious pollution problems still exist in the areas of air pollution (where the refinery is a major emitter of SO_2, CO, and hydrocarbons such as benzene, toluene, and xylene), production of waste water (where DKV is considerably over the limits for chemical oxygen demand), and soil and groundwater contamination under large areas of the refinery (caused by leaks and spills of hydrocarbons over the past 25 years of operation).

- On the other hand, TIFO is a much never and less complex refinery whose unit operations reflect more recent advances in pollution control technology.

- As a result, TIFO is not a significant contributor to the serious air quality and other environmental problems which appear widespread in the vicinity of Tiszanvaros.

- Finally, while the environmental staffs at both refineries appear to be very dedicated and capable, they lack laboratory and test equipment comparable to that found at similar U.S. refineries, and also seem somewhat unfamiliar and not fully aware of specific environmental control technologies deployed in U.S. and Western European refineries.

F. Unsuitability of Coal Substitution

K & M undertook a preliminary investigation into the practicality of replacing petroleum hydrocarbon fuels in the refinery furnaces at the DKV refinery with indigenous coal. Such a fuel switch does not appear to be a viable option at the present time for the following reasons:

- Hungary's coal subsector has long suffered from declining production, acute labor shortages, and lengthy lead times for either expanding existing operations or developing new mines.

- Hungary's indigenous coal is also of inferior quality with low calorific values, high ash contents, and fairly high percentages of sulfur.

- Even if capital investment funds were available to construct coal washing/coal preparation plants or coal-slurry pipelines, the refineries would still end up with a higher sulfur fuel replacement, since chemical coal cleaning processes are not yet commercially available.

- As a result, DKV would be compounding an already serious SO_2 emission problem.

G. Need for New Evaluative Criteria

In light of declining domestic production of petroleum, rapidly rising prices for imported crude oils from non-Soviet sources, reduced profits, and dwindling sources of traditional financing for refinery expansions and improvements, OKGT, DKV, and TIFO now face the problem of how to use their limited investment resources most efficiently during this austere period of transition.

- Under the Government's traditional framework for managing and controlling its parastatal enterprises, OKGT has had only a limited and at times unclear degree of autonomy, particularly in the area of investment decisions.

- Such decisions are oftentimes subject to the approval of multiple government bodies, thus making it difficult for OKGT to develop appropriate and consistent internal criteria for the allocation of investment funds, especially among competing activities.

- Moreover, to the extent that evaluative criteria exist for the rank-ordering of investment decisions, they tend to be quite general; for instance, the three principal criteria employed by DKV for ranking potential investment decisions in their bottoms - up planning process include: need, overall cost, and availability of investment funds.

- While such criteria may still be suitable for ranking potential improvements in the area of energy conservation at a given refinery, for instance, more rigorous criteria need to be developed in the future to assist OKGT in making such difficult choices as whether bringing DKV into overall environmental compliance is more important than restoring TIFO's overall competitiveness through the addition of a new facility for the conversion of vacuum gas oil and residual oil fractions to lighter products, or vice versa.

H. Fruitful Areas for U.S. Assistance

There are several areas in which the Hungarian refinery sector either still needs or could successfully profit by additional assistance from such U.S. agencies as AID and TDP. A summary of suggested areas or activities is listed below for consideration and possible inclusion in planned follow-on assistance efforts:

- Immediate help on environmental protection matters, including consultation on alternative solutions and technical approaches, modeling assistance, software programs, monitoring equipment, and related training in Hungary.

- Reverse trade missions to U.S. refineries of similar complexity, as well as to U.S. refinery equipment suppliers and firms specializing in environmental retrofits and upgrades.

- Training program for senior and mid-level management at DKV and TIFO with a focus on the commercial aspects of strategic planning, crude valuation, and feedstock selection designed to optimize refinery operations and profits.

- Executive development program in the United States for senior managerial and technical staff at both OKGT and the refineries.

- Feasibility study assistance to DKV for evaluating the proposed cogeneration option versus continued steam and electricity purchases from DHV.

- Financial planning and cost benefit analysis assistance to OKGT in the area of prioritizing facility investment decisions.

APPENDIX A

COMPREHENSIVE LIST OF ENERGY CONSERVATION PROJECTS IMPLEMENTED BY DKV SINCE 1985

I. Engineering Projects Without Capital Investment Requirements

	Savings 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 Orthor-Xylen 1 & Xylene-Isomerizaton 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

	Savings 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
TOTAL	989,472 GJ

C. **Heat Recovery from Products Streams**

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
TOTAL	506,676 GJ