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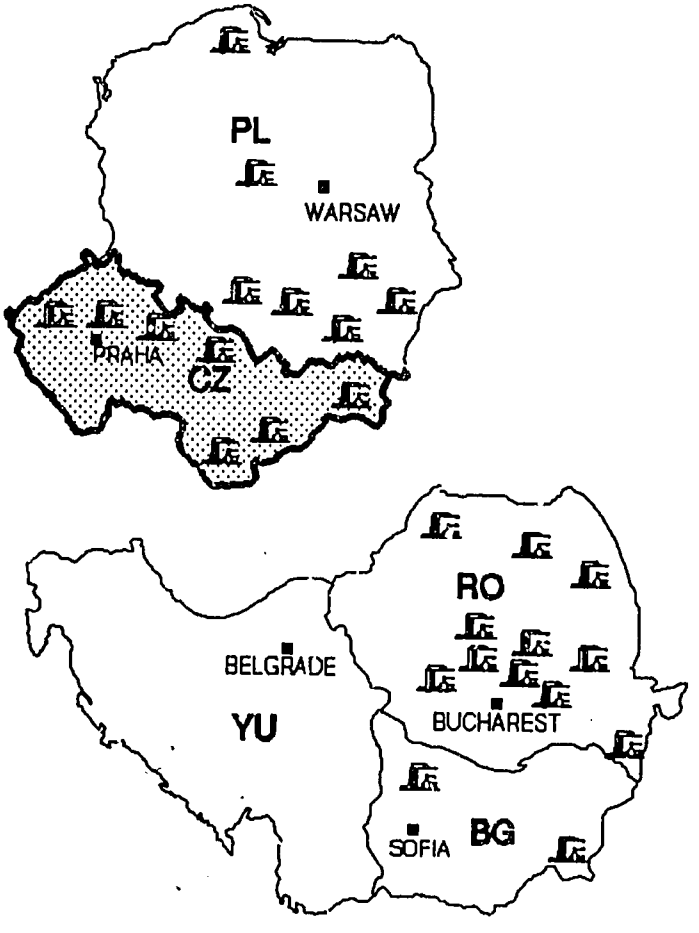
CHARACTERIZATION REPORT
SFR PETROLEUM REFINING SECTOR

A SECTOR OVERVIEW OF:
CAPABILITY, ENERGY CONSUMPTION, ENVIRONMENTAL IMPACT

MAY. 1992



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

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

CHARACTERIZATION REPORT
CZECHO-SLOVAKIAN
PETROLEUM REFINING SECTOR

A SECTOR OVERVIEW OF:
CAPABILITY, ENERGY CONSUMPTION,
ENVIRONMENTAL IMPACT
MAY, 1992

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CHARACTERIZATION OF THE CZECHO-SLOVAKIAN REFINERY INDUSTRY

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EXECUTIVE SUMMARY

Early in the year 1991, the United States Agency for International Development (USAID) retained the Chicago office of Davy McKee Corporation (DMC) to perform a technical study of the seven refineries that constitute the Petroleum Refining Industry of Czechoslovakia (CSFR). The results of the study are presented on two levels: refinery characterization and selected refinery evaluation.

The project started with meetings in early December 1990, between the United States and CSFR energy officials. During the meetings, a plan and schedule were developed for participation by the CSFR in the U.S. Emergency Energy Program. The characterization reports of the CSFR refineries being presented contain the elements agreed upon at these initial meetings.

A refinery characterization report has been produced for each of the seven refineries in the CSFR. Each report provides a technical description of the refinery focusing on the feedstocks, feedstock variability and the yield slate. Data on the physical equipment of each refinery have been gathered with the aim of establishing a refinery data base which may be extended in the future to feed into an optimization program on refinery financial and operational analysis. Utility data supporting the process operation have been made part of the characterization study as has been date on the quantity and quality of effluents.

A map showing the geographical location of the seven individual refineries is presented in Section B of the main body of the report.

In separate evaluation reports, three of the national refineries, Slovnaft, Chemopetrol, and Kaucuk were selected for the study of the potential of achieving substantial improvement in energy efficiency and disposal of solid, liquid, and gaseous effluents - both by reduction in volume and method of handling. Order-of-magnitude capital requirements and return on investment associated with identified opportunities form part of these evaluation reports.

At the outset of the project, teams were organized for both the characterization and evaluation efforts consisting of engineering professionals with many years of experience in their respective engineering disciplines in the design and technical operation of a petroleum refinery. Technical disciplines represented within the team were process, environmental mechanical, electrical, and instrumentation engineering.

The data for preparation of the characterization reports may be considered divided into three stages:

- First, a preliminary, or reconnaissance visit to the CSFR during which a rather detailed questionnaire was furnished to the refinery managers. The questionnaire was designed to acquire most of the data deemed necessary for the preparation of the characterization report. During the visit, host country consultants were engaged to participate in and provide technical assistance for the in-country phases of the work. In addition to such technical assistance, the consultants were able to provide custom and language interpretation to insure mutual understanding. A further goal in the retention of the consultant, who was a Czechoslovakian national, was his ability after involvement in the project, to provide without the expenditure of hard currency, the benefits of all of the refineries in the country as well as the ministerial offices technologies and experience gained from the project. without the expenditure of hard currency.

- The second stage was assembly in Chicago of the DMC team together with the host country consultants for a week of orientation. At the conclusion of the this meeting, the team departed Chicago arriving at the first refinery to be visited, Slovnaft - the largest refinery in the CSFR, on May 20, 1991.

- The third stage of the characterization effort consisted of a visit by the team to all seven refineries within the CSFR. During these visits, the completed questionnaires were received and their contents clarified and amplified in discussions with the refinery operating personnel. The DMC team and DMC program management are very appreciative of the effort and cooperation extended by the personnel of all refineries during the limited visit, subsequent meetings and subsequent contacts for clarification, etc. The dates of each site visit are covered in the description of each refinery.

Currently, the CSFR has seven (7) operating petroleum refineries within the boundaries of the Federal Republic. Most have some downstream processing of crude oil fractions to chemical feeds, intermediate petrochemical feedstocks and downstream petrochemicals, including both bulk and final products. These latter facilities were excluded from the scope of this study, no data was gathered on them, and they were not entered in the refinery visits.

The CHEMOPETROL Refinery is part of a petrochemical complex located approximately 200 kilometers northwest of Prague close to the German border. The original installation of the refinery had a design capacity of 1.7 million tonnes per year, and was built in the early 1960's. The newer section of the refinery has a capacity of 3.3 million tonnes per year, and was constructed in the 1970's. The refinery is currently (mid-1991) capable of processing 5.0 million tonnes (110 500 BPSD) of Russian export blend crude oil. (DMC team visit - 10-14 June 1991)

The PETROCHEMA DUBOVA Refinery is located in middle Slovakia. The refinery was constructed before World War II and it was designed primarily for the production of lube oils. The capacity of this refinery is 120 000 tonnes per year (2 700 BPSD) of domestic crude oil - supplied by railroad. (DMC team visit - 31 May 1991)

The KAUCUK Refinery is part of a petrochemical complex located close to Kralupy, about 25 kilometers north of Prague. This refinery was constructed in stages between 1969 and 1974. The capacity of the refinery is 3.2 million tonnes per year (73 000 BPSD) of mainly Russian export blend crude oil. It is primarily a crude topping type refinery, with no bottoms processing at present. (DMC team visit - 27-31 May 1991)

The KORAMO Refinery is located 60 kilometers from Prague at Kolin. This refinery is fifty years old, and currently produces various grades of lube oils and waxes. The refinery has a processing capacity of 200 000 tonnes per year of crude oil (4 500 BPSD). (DMC team visit - 7 June 1991)

The PARAMO Refinery is located in the town of Pardubice about 100 kilometers from Prague. The refinery is almost one hundred years old and currently produces mainly motor and industrial oils and some asphalt based products. The capacity of the refinery is 1 million tonnes per year of crude oil (22 100 BPSD). (DMC team visit - 5 June 1991)
The SLOVNAFT Refinery is part of a petrochemical complex located adjacent to the Danube River near Bratislava, and built in the 1960's through the 1980's with a major part added in 1968. This refinery is capable of a nominal processing of 6.6 million tonnes per year (146 000 BPSD) of Russian export blend crude oil. The refinery produces a wide range of petroleum products including petrochemical feedstocks and lube oils. (DMC team visit - 20-24 May 1991)

The VOJANY Refinery, located in Eastern Slovakia, was commissioned in 1974. The refinery is closely connected with Slovnaft and has a nominal processing capacity of 2.2 million tonnes per year of crude oil (48 600 BPSD). (DMC team visit - 4 June 1991)

Until 1990, the CSFR received most of its crude oil from the USSR. However, in 1990 the crude oil supply was seriously threatened - partly by the Gulf crisis and partly as a consequence of the internal political changes developing in the USSR.

Due to the changes occurring in the USSR and consequent reduction of crude oil for export along with the internal thrust toward privatization and growth of a free market economy, the CSFR has been forced to seek other sources of crude oil. Contacts with Mexico, Iran, Venezuela and some African countries have been established. Prior to the Gulf crisis, the CSFR also had an arrangement with Iraq for importation of crude oil on a barter basis.

Currently, crude oil supplied by the USSR is transported to the CSFR by a pipeline that enters the country at the eastern border with the USSR. Although the pipeline capacity is 22 million tonnes per year, during 1991 the supply was limited to about half of that. Currently the only other crude oil pipeline route to the CSFR is the Adria Pipeline through Yugoslavia and Hungary. This pipeline, with a total capacity of about 8 million tonnes per year, has to be shared with Yugoslavia and Hungary.

Based on current projections, oil consumption in the CSFR is about 14 to 15 million tonnes per year . If favorable agreements with Yugoslavia and Hungary can be reached, the CSFR could receive as much as 5 million tonnes per year through the Adria Pipeline. The use of this line is currently under negotiation.

In order to ensure an uninterrupted crude oil supply to the three major refineries in the CSFR, several additional pipeline projects are under consideration:

(1) Schwechat (Austria) Slovnaft - a distance of 60 kilometers and a pipeline crude oil capacity of 4 million tonnes per year.

(2) Ingolstadt Kralupy - for supply of crude oil to Chemopetrol, Kaucuk and other refineries.

(3) Wilhelmshaven Litvinov - appears to be an alternate to the Ingolstadt - Kralupy extension.

During 1990, total crude oil processed in the CSFR was approximately 14.5 million tonnes. The refinery products produced from this crude were sufficient to meet the current demand.

The current per capita consumption of gasoline in the CSFR is about 25 percent of that in Western Germany. With the growth of privatization and a free market economy, the domestic demand for both leaded and unleaded gasoline is expected to grow towards the levels in Western Europe. Similarly, demand for other petroleum products, e.g., jet fuels, diesel fuels, and fuel oils, will increase in 1991 and beyond. In addition, a large portion of CSFR petroleum output is used for petrochemicals. The combined ethylene cracking capacity represents about 45% of the current gasoline output.

Tetraethyl lead is still used as an octane booster in most of the gasoline produced as most cars in the country are manufactured to operate on leaded gasoline. A small amount of unleaded gasoline is currently produced for imported cars and tourists. Most Western European countries provide mainly unleaded gasoline for cars, and a small amount of leaded gasoline for older cars and farm machinery. As the CSFR gasoline market approaches the standards and practices of Western Europe, refinery changes toward higher octane levels and the substitution of MTBE for lead can be anticipated.

The diesel fuel produced currently contains a maximum of 0.15 wt% sulfur. Eventually, the accepted sulfur content of diesel fuel all over the world is expected to be below 0.05 wt%. In addition, the aromatic content of both gasoline and diesel fuel products will have to be reduced to meet the expected regulations and specification for sale.

The domestic fuel oil market uses two kinds of oils; light fuel oil (similar to ASTM No. 4) which contains almost 2 wt% sulfur and heavy fuel oil (similar to ASTM No. 6) which contains as much as 3 wt% sulfur. The sulfur content of these fuel oils is much higher than fuel oils normally used in the U.S. As environmental regulations mandate lower sulfur specifications, significant additional hydrodesulfurization capacity will be needed for both diesel and fuel oils.

The refineries are meeting most of the environmental regulations except for air quality under the current regulations in effect in the CSFR which are not so stringent as those in Western Europe or the U.S. Air pollution is a continuing problem wherever the local brown coal is burned in steam boilers operated as part of a refinery and / or petrochemical complex. The high sulfur and ash content of the brown coal generates undesirable levels of sulfur

oxides, nitrogen oxides, and particulate matter (ash) in the emissions. In any event, the refineries are not the only or even the major contributors to the emission problem. For example, Chemopetrol is located at the center of a major brown coal mining area where coal is furnished to six nearby power plants. Current atmospheric emissions from the refinery are almost totally caused by the fired heaters, sulfur plant, incinerators and a proportional or assigned responsibility for those produced by the central power plant firing. As noted above, the sum total of refinery contribution to area pollution is not a major one. It may be concluded that effective atmospheric pollution control is really only required if a site-based approach is required. Conclusion of the plans now in place for environmentally acceptable power plants may warrant a reevaluation of the refinery emission levels.

The characterization report has attempted to include in its scope the more obvious improvement opportunities identified as a result of the team visit. In order to meet future demands for gasoline and other fuels with specifications more in line with those found in western countries, the CSFR will be forced to make changes to its petroleum refineries. Conversion to unleaded motor fuel will require a higher pool octane. Typical processing units required to achieve higher octane are: catalytic reformer, alkylation, fluid catalytic cracking, isomerization, and dehydrogeneration. Increased capacity for the additive MTBE will also be required.

Further study is needed to determine the most economically advantageous processing scheme for vacuum bottoms at Chemopetrol and Slovnaft. At present, part of the vacuum bottoms are converted to road bitumen. At Chemopetrol some hydrogen is produced from the vacuum residue by partial oxidation. Kaucuk does not currently have facilities for processing atmospheric reduced crude. This situation has been under investigation for some time and it is foreseen that the solutions adopted are likely to include the addition of fluid catalytic cracking or hydrocracking.

As concern for the environment grows and wastewater regulations become more severe, additional treatment will be required for the effluent water. In a similar way equipment will be required for reduction of oxides of sulfur and nitrogen in the atmosphere. Chemopetrol has already started planning for the replacement of old power plants with new and environmentally acceptable facilities. Most sulfur plants in the refineries are two-stage Claus type achieving about 95% sulfur recovery. A third stage or tail gas treatment unit is required to achieve about 99% sulfur recovery and thus reduce sulfur discharged to atmosphere from this source. Some liquid and solid waste problems are being addressed.

The middle management of CSFR refineries is well aware of the benefits and general features/aspects of energy saving programs. Several of these are in place and operating. However, the implementation of these programs was stated to generally meet with shortages of financial means and priorities resulting from goals set by top management. For example, process furnace efficiency can be significantly improved and be economically viable by installing an air preheater and more effectively controlling excess air to the burners. Plans for installation of air preheaters on major furnaces together with automatic excess air control have been under annual review for the past five years.

Another example of significant energy savings with potential for reduced environmental impact lies in the concept of returning steam condensate from the process equipment to the boiler. The normal condensate should be discarded only if or when it is contaminated and then only from the contaminating source. This approach is in contrast to the current practice wherein not over 20% of the condensate is actually returned to the boiler and the return systems are not used or properly maintained. A comprehensive study for improved recovery of condensate should include provisions for first class maintenance of steam traps, selective testing of condensate, and diversion of contaminated condensate.

A different type of potential for energy saving, which also has a very definite environmental benefit, may be found in a program to install a secondary sealing system for floating roof type storage tanks. Here the energy loss represented by product loss in venting to atmosphere can be equated to the energy consumed in its production. Conservation of weathered crude components can contribute to refinery output at relatively low specific energy input.

One of the elements to receive attention in the characterization study of refineries in the CSFR is substitution of coal for hydrocarbons directly in the refinery heaters as the source of energy. Such a course of action does not appear viable. Two types of coal are mined within the country, namely a black (coking) coal consumed by the metallurgical industry and brown coal used in power plants and for home heating. Black coal is available in limited quantities (20 million tonnes per year) and brown coal is somewhat more readily available (100 million tonnes per year).

Brown coal is of poor quality with a low heating value and an average sulfur content of about 1.0 to 1.2 wt%. Mining has produced coal of a variable sulfur content with much higher spot values possible. The processing complexes at Kralupy and Litvinov generate power from brown coal while Slovnaft burns heavy fuel oil. Pressure in the populous area around Slovnaft has resulted in partial conversion from fuel oil to natural gas and it is expected that coal will not be accepted even for power generation. It might also be noted that the site plan at Slovnaft would make it extremely difficult to provide for coal and ash handling facilities.

Based on the above discussion concerning sulfur emissions associated with brown coal and the forecast of a diminishing national supply, extension of coal usage for any part of the refinery to process units is not a recommended procedure at this time. Furthermore, substitution of coal for hydrocarbons in a refinery process furnace has not been commercialized.

In the environmental area, middle- and lower-level management, as well as staff personnel at the refineries, are well aware of the opportunities for emissions treatment and operational improvement. However, these opportunities appear to have had a low priority for top management and possibly for the preexisting federal structure at the Ministry level.

A recapitulation of some of the observations made by the visiting team identified for improvement of operations of the petroleum refineries in the CSFR is presented below:

CSFR refineries were designed to process crude oil from the USSR. The age of the equipment in the process units means that they will have to be evaluated technologically and economically with respect to practices at modern refineries in the West. Adaptation to competitive markets and a changed social structure reinforce the necessity for this evaluation.

The physical condition of the plant equipment, plus an absence of mechanical standards, require a large inventory of spare parts to assure continuous operation. This situation has not always been possible due to the financial requirements of inventory management so that on-stream time suffers.

Process control strategy and instrumentation can be modernized with the incorporation of advance control concepts.

The refinery layouts have been spread over too wide an area to achieve economic equipment locations. While it would be difficult or impossible to correct this, careful consideration should be given to site planning for a new unit.

The potential future economic burden of large maintenance and operating staffs caused by factors noted above, could put the refineries at a disadvantage with their Western counterparts. National social programs as they may affect labor practices and thus cost need to be watched closely.

It is to the advantage of each refinery to study and improve safety practices.

In a time of hard currency shortages for the purchase of crude oil on the open market, additional storage capacity should be made available. Suitable instrumentation and equipment is also required for conservation of material during custody transfer and storage.

Acquisition of alternative crude feedstocks will require consideration of their effects on processing units and ancillary facilities. Considerations of effects on capacity, ability to satisfy product specifications, corrosion protection, and removal of unwanted components are typical.

It may be expected that environmental regulations will become ever more stringent. Unleaded gasoline, low sulfur fuel oils, and control of oxides of sulfur and nitrogen in atmospheric emissions are three examples that will need immediate attention.

The information gathered for start of a refinery data base information system (based on the questionnaire in Appendix A) has been compiled on a diskette and is the subject of a separate report.

A. INTRODUCTION

1. OBJECTIVES

The objective of this report is to provide data that will serve as a basis for the modernization and optimization of the economic performance of the petroleum refining industry of CSFR. It addresses the current status of the petroleum refining industry so that recommendations providing low cost economies to improve energy efficiency and environmental control at each refinery can be prepared. Both short and long term improvement possibilities were established and given to the second round team for detailed evaluation. Following the collection of data on operating variables, equipment and refinery impact on the environment, a data base has been organized for use in a linear programming model.

2. SUMMARY OF FIELD ACTIVITIES

In order to carry out the objectives, the following seven refineries of the country were visited by the characterization team consisting of P. Agrawal - Team Leader for CSFR, J. Gallery - Process Engineer and J. Zapletal - Host Country Technical Consultant. The three major refineries, Chemopetrol, Kaucuk, and Slovnaft were also visited by C. Best - Environmental Engineer. In addition, E. Kostelkova provided translation and interpretation services for the Czech and Slovak languages.

Refinery Name	Location	Site Visit Dates
Chemopetrol	Litvinov	10 - 14 June 1991
Dubova	Dubova-Nemecka	31 May 1991
Kaucuk	Kralupy	27 - 31 May 1991
Koramo	Kolin	7 June 1991
Paramo	Pardubice	5 June 1991
Slovnaft	Bratislava	20 - 24 May 1991
Vojany	Vojany	4 June 1991

At three major refineries, Slovnaft, Chemopetrol and Kaucuk, several critical units were identified to perform the evaluation tasks. The selection of units was made in association with individual refinery management. The number of units selected was limited due to schedule constraints. For the evaluation effort, the project team's stay at a specific site was limited to an average of two weeks. In order to utilize the team's time and effort in the most efficient way the current selection appears to be most optimum. In any case, the units selected were the best representation of the operation and were the most critical ones.

The information needed for this characterization report was obtained through the cooperation of the plant personnel in completing a questionnaire. This was followed by meetings and discussions with the DMC team, during visits to the individual refineries. During each visit, a preliminary evaluation of various process units, offsites and utilities was conducted. Particular attention was paid to the following:

a) Feedstocks and their variability
b) Product yields and specifications
c) Operating conditions
d) Mechanical conditions and age of units
e) Utility consumptions
f) Effluent character and quantity
g) Changing environmental restrictions.

Offsites facilities reviewed included:

a) Storages (crude and product)
b) Fire protection
c) Safety
d) Waste treatment
e) Effluent disposal

3. GENERAL DESCRIPTION OF REPORT CONTENTS

This report characterizes the refinery industry in CSFR. There are three major and four smaller refineries in the country. DMC's project team visited all of these refineries and collected data, which is summarized in this report. Seven subsections, covering each refinery, provide as much detail as possible within the program schedule constraints. This report is divided into five main sections:

A. Introduction
B. National Consideration
C. Individual Refinery Data
D. Supporting Tables, Charts, and Figures
E. Appendices

The individual refinery data in section C includes a description of process units, overall material balance, description of utilities and offsites, operating history and experiences, crude oil supply, environmental considerations, immediate and long range opportunities, etc. Where available, a computerized data base was prepared.

4. LIMITATIONS ON USE OF REPORT

This characterization report presents an overview of the refinery industry in CSFR. It points out various opportunities in the areas of energy efficiency, environmental, operational flexibility, and short and long range improvements and expansions. Although some of the recommendations are applicable to the entire refinery industry in the country, most recommendations are refinery specific.

The refinery industry, like other industry in the CSFR, is going through a privatization phase. Prematurely disclosing plans for modernization, upgrade, or organizational changes could have a significant adverse economic affect. Therefore, future project and pending proposals are not summarized in this report, although where appropriate, local refiners could release this information to third parties interested in investing in the refinery.

The information contained herein, while detailed in nature, does not reflect all aspects of refining operations, nor all the variables, both internal and external, that affect past, present and future decision making policy. The reader and user of information contained within this report is directed to contact the individual refinery for further insights, clarifications, and information as is needed.

It should also be noted that the conclusions, however, are the views of the authors and do not represent the official positions of the government of Czechoslovakia. Each of the refineries that was part of this study, has reviewed the report and agreed to its technical context.

5. INTENDED USE FOR DATA BASE PROGRAM

The data base for each refinery includes information supplied on the questionnaire by the refinery personnel. Material and utility balances, and specific information on major equipment items are included.

The data base is presented on a computer diskette in a format compatible with Paradox software. Most linear programming (LP) models take input in spreadsheet form and therefore, this data base may be suitable to be modified in the future to fit an individual LP model. The data base will be a useful tool in planning any modifications to refinery operations, systems, or equipment.

B. NATIONAL CONSIDERATIONS

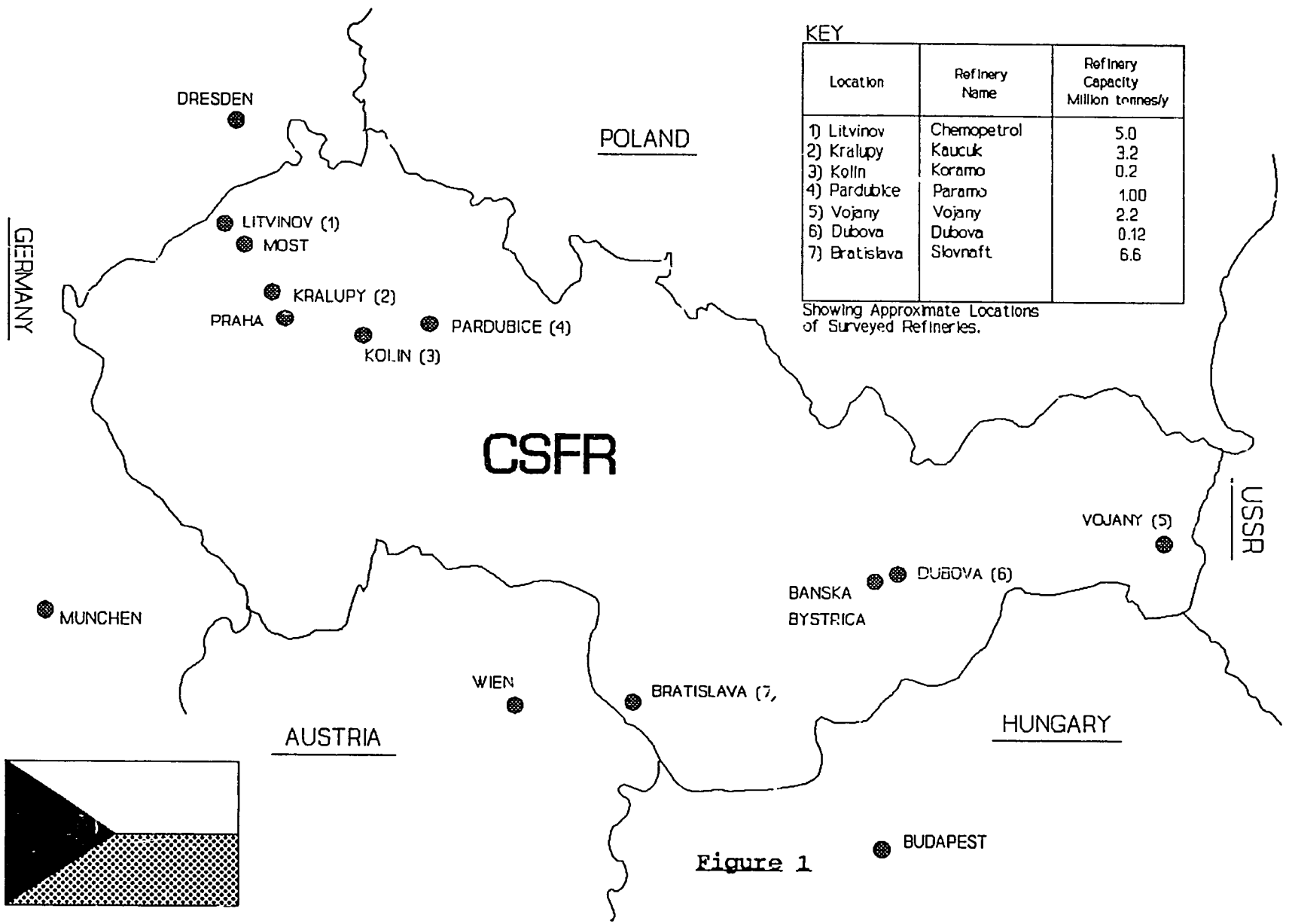
1. OVERVIEW OF THE NATIONAL PETROLEUM REFINING INDUSTRY

1.1. National Petroleum Refineries

There are three major and four minor refineries in the CSFR:

Slovnaft Bratislava:	The largest refinery attached to the petrochemical complex. This refinery is capable of processing 6.6 million tonnes/year of crude oil (146 000 BPSD).
Chemopetrol Litvinov:	The second largest refinery attached to the petrochemical complex. This refinery is capable of processing 5.0 million tonnes/year of crude oil (110 500 BPSD).
Kaucuk Kralupy:	The refinery is attached to a petrochemical complex. This refinery is capable of processing 3.2 million tonnes/year of crude oil (71 000 BPSD).
Slovnaft Vojany:	This refinery is attached, by management, to Slovnaft. It consists of a crude distillation unit only. The capacity of the refinery is 2.2 million tonnes/year of crude oil (48 600 BPSD).
Dubova:	The capacity of this refinery is 120 000 tonnes/year of crude oil (2 700 BPSD).
Paramo:	The refinery has a capacity of 1 million tonnes/year of crude oil (22 100 BPSD).
Koramo:	The refinery has a capacity of 200 000 tonnes/year of crude oil (4 500 BPSD).

A map showing the geographic location of the refineries is shown in Figure 1.



KEY

Location	Refinery Name	Refinery Capacity Million tonnes/y
1) Litvinov	Chemopetrol	5.0
2) Kralupy	Kaucuk	3.2
3) Kolin	Koramo	0.2
4) Pardubice	Paramo	1.00
5) Vojany	Vojany	2.2
6) Dubova	Dubova	0.12
7) Bratislava	Slovnaft	6.6

Showing Approximate Locations of Surveyed Refineries.

Figure 1

1.2. Crude Sourcing

Until 1990, CSFR received most of its crude oil from the USSR. Due to close ties with the USSR, the oil crises experienced by western countries during the early seventies had virtually no affect on these refineries. In 1985, only an 11% reduction in crude oil supply was experienced. In 1990 the crude oil supply was seriously threatened partly by the Gulf crisis and partly by the internal problems of the Soviet Union.

Due to changes in the USSR, the internal thrust toward privatization, and the growth of a free market economy, CSFR is forced to seek other worldwide sources of crude oil. Contacts with Mexico, Iran, Venezuela and some African countries have been established. Prior to the Gulf crisis, CSFR had a mutual agreement with Iraq for importation of crude oil on a barter basis.

Currently, crude oil from the USSR is transported to CSFR by a pipeline that enters the country at the eastern border with USSR. Although the pipeline capacity is 22 million tonnes/y, during 1991 the supply was limited to about half of the capacity. The other source of crude oil is the Adria pipeline through Hungary. This pipeline has a total capacity of about 8 million tonnes/y, which has to be shared with Hungary.

Based on current projections, oil consumption in CSFR is about 14-15 million tonnes/y. If favorable agreement with Hungary can be reached, CSFR could receive as much as 5 million tonnes/y through the Adria pipeline.

In order to ensure an uninterrupted crude oil supply to the three major refineries in CSFR, the following pipeline projects are under consideration:

(1) Schwechat (Austria) - Slovnaft Pipeline: Negotiations are underway with OMV to connect Schwechat and Slovnaft (60 kilometers) with a crude oil and two product pipelines. The crude pipeline may be able to supply up to 4 million tonnes / year.

(2) Ingolstadt - Kralupy Pipeline: Appropriate agreements are in negotiation between TAL and CSFR Ministry for this 350 kilometer long pipeline. This pipeline will enable the supply of crude oil to Chemopetrol, Kaucuk and other refineries.

(3) Wilhelmshaven - Litvinov: Veba-Gelsenkirchen and NWO are negotiating this pipeline with Litvinov. This appears to be an alternate to item 2 above.

1.3. Product Slates

Table B.1.1. below shows the crude input and the product distribution output from the three major refineries in CSFR (in million tonnes/year). The data are for major refinery products only. Light ends, petrochemical feedstocks, lube oils, etc. are not shown. Table B.1.2. lists the gasoline grades produced in CSFR and Table B.1.3. shows the demands of oil products in CSFR for 1989 and 1990.

Table B.1.1. - CSFR Major Refinery Capacities
(million tonnes/year)

	Slovnaft	Chemopetrol	Kaucuk	Total
Crude Input	6.60	5.00	3.20	14.50
Product Output				
Gasoline	0.80	0.55	0.45	1.80
Jet fuel	0.25	0.15	0.17	0.57
Diesel fuel	1.90	1.10	0.84	3.84
Light fuel oil	0.40	0.30	0.14	0.84
Heavy fuel oil	1.40	0.15	1.44	2.99
Bitumen	0.40	0.40	0.00	0.80

Table B.1.2. - CSFR Gasoline Grades Produced

	RON	Lead (g/liter)	Share of Market
Special (regular)	91	0.15	70.7%
Super (premium)	96	0.15	28.6%
Natural (Eurosuper)	95	0.00	0.7%

Table B.1.3. - CSFR Oil Product Demands (million tonnes/year)

Products	1989	1990
Gasoline	1.67	1.64
Jet fuel	0.35	0.35
Diesel fuel	3.53	3.40
Light fuel oil	0.86	0.75
Heavy fuel oil	3.95	3.15
Bitumen	1.00	0.95
Lube oils	0.32	0.30
Petrochemical feeds:		
LPG, naphtha, gas oil	2.44	2.20
Vacuum residue	0.36	0.35
Total demands	14.48	13.09

1.4. Impact on Industry of Changes in Crudes and / or Products

The CSFR product demands for 1989 and 1990 are listed in Section 1.3. Regardless of the source and type of crude oil imported to CSFR, the refining industry in the country will have to continue producing at least the product slate indicated in Section 1.3. (Tables B.1.1 and B.1.3).

The domestic market for both unleaded and super leaded gasolines is expected to grow in 1991 and beyond. Similarly, the demand for diesel fuels and fuel oils will grow as the free market economy becomes more and more prevalent.

It appears that the eastern European refineries, including the ones in CSFR, are designed only for the Russian export crude (around 32 °API gravity). It is also apparent that, to some extent, the equipment does have some additional capacity and / or capability. If the new crude oil is lighter than the Russian Export blend, the light ends sections of the refineries will become loaded accordingly, i.e., the production of gasolines and LPG will increase. This may mean the capacities of the reforming units will be tested. On the other hand, if the imported crude is heavier than the one processed currently, the bottoms or heavy end processing sections of the refineries will be overloaded.

Large western refineries store a one to two month supply of crude oil. This allows crude blending to achieve properties close to that of the design crude. Use of the blended crude permits smooth operation of the refinery. In CSFR, most of the crude oil storage capacities are limited to one week. These storage capacities are not adequate to permit crude blending operations.

Further, western refineries plan operations using a linear programming model and / or a process simulation program. Since computers of reasonable size and cost are currently available in the CSFR to run the software that perform process calculations, it would be advantageous for the refineries of CSFR to acquire both the hardware and software to optimize operations for the expected future variations in crude properties.

1.5. Observation of Markets - Internal and External

The current per capita consumption of gasoline in CSFR is about 25% of that in western Germany. With the growth of privatization and a free market economy in CSFR, gasoline demand can be expected to grow faster than other petroleum products. This will significantly increase the demand on refinery capacity.

The diesel demand in CSFR is about 10% higher than that of western Germany, based on per capita consumption. This should stabilize in the future. Demand for light fuel oil may slightly decrease based on changes in the tax structure. The

estimated future products demands are indicated in table B.1.4. CSFR heavy fuel oil contains a rather high percentage of sulfur. However, this heavy oil can be used in place of high sulfur and low rank brown coal (with sulfur content of 1-1.2 wt%) in power generation.

A large portion of CSFR petroleum output is used for petrochemicals. The combined ethylene capacity represents about 45% of the current gasoline demand.

Table B.1.4. - Estimated Future Product Demands
(million tonnes/year)

Product	1991 - 1992	1995
Gasoline	1.35	1.50 - 1.80
Jet fuel	0.30	0.40 - 0.60
Diesel	2.70	2.50 - 3.20
Light fuel oils	0.60	0.50 - 0.70
Heavy fuel oils	2.70	2.00 - 3.00
Bitumen	0.70	0.60 - 0.70

1.6. Comparisons with International Trends

In CSFR, tetraethyl lead is still used as an octane booster in most of the gasoline produced because most cars in the country are manufactured to operate on leaded gasoline. A small amount of unleaded gasoline is currently produced for imported cars. Most western countries provide mainly unleaded gasoline for cars, and a small amount of leaded gasoline for older cars and farm machinery.

The diesel fuel produced currently contains a maximum of 0.15 wt% sulfur. Eventually, the sulfur content of diesel fuel all over the world is expected to be below 0.05 wt%. In addition, the aromatic contents of both gasolines and diesel fuels will have to be reduced.

The domestic fuel oil market uses two kind of oils: light fuel oil (similar to ASTM No. 4) which contains almost 2 wt% sulfur and heavy fuel oil (similar to ASTM No. 6) which contains as much as 3 wt% sulfur. These sulfur contents are much higher than fuel oils normally used in the U.S.A.

Environmentally, the refineries are meeting the current regulations in most areas, except air quality. However, the current regulations in CSFR are not as stringent as those in Western Europe or the U.S.A. Air pollution is a problem, wherever local brown coal with a high sulfur and ash content is burned in the power plants. The problem exists in terms of SOx, NOx, and particulates (ash). In any case, refineries are not the only contributors to the problem. For instance, Chemopetrol is located in the middle of a major brown coal mining area, with six power plants in the area contributing heavily toward the air pollution problem.

1.7. General Potential and Opportunities for Improvement

In order to meet the future demands of gasoline, and other fuels, with specifications more in line with those found in the Western countries, CSFR will have to upgrade and modernize its refineries.

Such upgrading would necessitate adding processing units to produce high octane unleaded gasolines. Such units are: gasoline reformer for high octane, alkylation, fluid catalytic cracking, isomerization, dehydrogenation, MTBE, and TAME.

To meet the sulfur specifications in the diesel and fuel oils significant additional hydrodesulfurization capacity will be required.

Processing of vacuum bottoms at both Chemopetrol and Slovnaft needs to be further studied. Presently the bottoms are partly converted into road bitumen and, some hydrogen is produced from vacuum residue at Chemopetrol. Kaucuk does not have any processing capability for atmospheric distillation bottoms, this has been investigated and is likely to include fluid catalytic cracking and hydrotreating capabilities.

The lube oil processing plant at Slovnaft needs to be revamped. The plant appears to be rather inefficient in its energy consumption.

Environmentally, to meet the anticipated wastewater regulations, effluent treatment units will have to be added. Equipment for SOx and NOx control will be required. Better particulate emission control from power plants will be required. Chemopetrol has already started planning for the replacement of old power plants with new and environmentally acceptable plants. Most sulfur plants in the refineries are two stage Claus type with about 95% sulfur recovery. A third stage or tail gas treatment unit is required to achieve about 99% sulfur recovery. There are some liquid and solid waste problems, which are being addressed.

The management of the CSFR refineries are well aware of the need for benefits of and general features / aspects of energy saving programs and several of these are already in place and operating. However, the implementation of these programs often meets with shortages of funds and priorities set by top management. For example, process furnace efficiency can be significantly improved to an economic payout level by installing an air preheater and more effectively controlling excess air to the burners. Many of the furnaces in CSFR refineries are currently equipped with air preheaters and they have some kind of air control in place. The management of the refineries have plans to install air preheaters on all major furnaces with automatic excess air control, however, in some cases these plans have been reviewed every year for the last five years. Another example of energy saving, is to try to return as much steam condensate as possible to the boiler from steam generated in the processing unit's equipment. This requires a thorough study and maintenance of the various steam traps. Another potential for energy savings is to install a secondary sealing system in floating roof type storage tanks.

CSFR refineries are in the process of revamping the control systems to state-of-the-art distributed control systems. The progress is somewhat slow.

The refinery staffs do not use any software for maintenance planning and their average turnaround cycles are 2 years, which is well below the current turnaround period experienced by U.S. refineries.

Only one of the refineries has access to a LP model. Today the LP models are used by even small independent refineries to plan current and future refinery operations. CSFR refineries also need process simulation programs.

As discussed before, CSFR refineries have very limited crude oil storage capacities. In order to assure blending of various crude oils and to streamline the operation, at least one month storage capacity with proper mixing is recommended.

1.8. Observed General Problems and Trends

The CSFR refineries were designed to process Russian crude oil. The age of the process units means that they will have to be evaluated with respect to practices in the West at modern refineries. Adaptation to competitive markets and a

changed social structure reinforces the necessity for this review. The review of the refineries by the team has revealed some shortcomings in operations and technology due primarily to the following:

1) Shorter run lengths due to equipment conditions and a deficiency of standardization requiring a large inventory of spare parts, a condition not always possible.

2) Process control strategy and instrumentation which could be modernized.

3) Widespread site planning resulting in uneconomical equipment layouts.

4) Large maintenance and operating staffs puts the refineries at a disadvantage with their Western counterparts.

5) Safety practices need improvement.

The middle management and staff personnel at the refineries are well aware of the opportunities for energy and operational improvement. These considerations, however, have had a low priority with top management.

Observations made by the visiting team for improvement of operations in CSFR are:

1) In a time of hard currency shortage for acquiring crude on the world market additional storage capacity is recommended. Instrumentation and equipment will be required for conservation of material during custody transfer and storage.

2) Process units and ancillary equipment will require adaptation to changing crude feedstock properties.

3) Additional processing units and equipment will be required to meet more stringent environmental regulations. Unleaded gasolines, low sulfur fuel oils and air pollution control, in terms of SOx and NOx, are three examples of new regulations.

4) The products will have to be more competitive in terms of quality and specifications.

5) The implementation of computer control systems will have to be expedited. Serious consideration to advanced controls will have to be given.

1.9. Environmental Considerations

In terms of liquid emissions, the Kaucuk Refinery is meeting the current local standards. The Slovnaft Refinery does not meet the BOD limits and the Chemopetrol Refinery does not meet the current limit for oil and ammonia.

The ground water below the Slovnaft Refinery has been sampled and found to be contaminated. A ground water extraction well system has been installed.

The ground water at Kaucuk was tested and not found to be contaminated. The tank areas are lined which prevents oil leaking to the ground water.

The ground water at Chemopetrol has not been investigated because the local deep open pit coal mining has artificially lowered the water table. The direction of the ground water flow is to the open pit mines.

The Chemopetrol Refinery has a serious environmental problem in terms of gaseous emissions, i.e., SOx, NOx and fly ash. However, this plant does not stand alone when considering this problem. The facility is located in the middle of an area of very extensive open pit strip mining of brown coal and numerous power plants. Within a few miles of the plant there are six power plants consuming large quantities of brown coal. These power plants emit much more SO_2 than the 59 000 tonnes/y of SO_2 from two power plants within the Chemopetrol facility. Another source of SO_2 emission is a portion of the sulfur in the crude oil. This SO_2 is from the sulfur plant tail gases. Most process heaters are fired with a mixture of low sulfur refinery gases and natural gas.

The Kaucuk Refinery has reduced the SO_2 emissions by fuel blending, but still are emitting 700 tonnes/y of SO_2. The Slovnaft Refinery is emitting approximately 18 000 tonnes/y SO_2 from burning high sulfur fuel oil. Both of these refineries face finding an alternate low sulfur fuel or installing flue gas desulfurization facilities.

There are also environmental problems, which originate in the refineries and reside in the refineries' products that need to be addressed. Among these are TEL and aromatics in gasolines, and the sulfur content of fuel oils. As product specifications become more in line with Western countries, the refineries will have to be revamped and expanded to produce marketable products that allow for reduction in, or elimination of TEL, aromatics, and sulfur in the products.

Most refineries in CSFR have a long standing history of oily sludge waste problems in terms of organic sludge waste collected in open pits. Chemopetrol has signed an agreement with an Italian company to install incinerators to solve the problems. Oily sludge from both the Kaucuk and Slovnaft refineries are incinerated.

At Chemopetrol, there are two solid waste disposal systems. The first is the power house ash and the second the oily waste. The ash from power plants along with the ash from the solid wastes incinerator and the sludge from the water treatment facilities is conveyed to the ash lagoons. The lagoon is designed for a life of 35 years. The second solid waste disposal system is the rotary kiln incinerator. This system burns waste liquid organic, and tank bottom sludge.

1.10. Fuel Switching

One of the components of this study of refineries in CSFR has been consideration of substituting coal for hydrocarbons as a source of energy. Such a course of action does not appear viable. Two types of coal are mined within the country namely a black (coking) coal consumed by the steel industry and brown coal used in power plants and for home heating. The black coal is available in limited quantities (20 million tonnes/y) and brown coal which is somewhat more common (100 million tonnes/y).

The brown coal is of poor quality with a low heating value and a sulfur content of about 1.0 - 1.2 wt%. Mining experience reveals a variable sulfur content with much higher values possible. The refineries at Kralupy and Litvinov generate power from brown coal while Slovnaft burns heavy fuel oil. Pressure is growing in the populous area around Slovnaft for a fuel change to natural gas and it is expected that coal would not be accepted for even the power generation. It might also be noted that the site plan at Slovnaft would make it extremely difficult to provide for coal and ash handling.

It is concluded that based on sulfur emissions associated with brown coal and the prospect of a diminishing national supply, extension of coal usage for any part of the refinery heat supply is not a recommended procedure at this time. Furthermore, attempts to date to fire coal in a refinery process furnace have been unsuccessful. For a general discussion of the aspects of coal utilization, please see Appendix D.

1.11. Financial Considerations In Refinery Operations and Capital Projects

The objective of this task was to collect data on country financial and accounting practices from a national standpoint. We were to then explore with each refinery, to the extent available, any local variations in cost approach of each improvement opportunity with the view to pragmatically estimating capital and cost savings and evaluating the attractiveness of the opportunity determined.

We briefly reviewed refinery cost accounting and allocation practices to get a better understanding of the composition of the cost data used for project justification purposes. The system in use is similar to that used in the US. The various categories of cost used and the elements contained therein, for a process unit, are as follows:

- Raw Material - All feeds to the unit in question. For example, for diesel fuel product, all gas oil or kerosene from crude units and miscellaneous streams from other refinery facilities.
- Hydrogen - if used, is listed separately.
- Direct Labor - does not include supervision.
- Fuel - refinery gas, natural gas, fuel oil.
- Energy - electricity, steam by pressure level, cooling water, demineralized water, nitrogen, instrument air
- Cost of purchasing - allocated to the unit or product.
- Other direct costs - items such as labor, fringes and social security taxes at 50% of salary.
- Depreciation - straight line basis; equipment at 15 year life; civil and structure buildings - 50 year life.
- Maintenance - material, labor, outside services.
- Other costs covering items of general consumption; paper, pencils, uniforms, etc.
- Overhead allocations - administrative and building maintenance, senior management, area management, engineering, supervision and their fringes.
- Marketing and sales costs.
- Transportation.
- Overhead costs are allocated to individual products on the basis of an overhead to total direct cost ratio.
- Sales and marketing costs are allocated in a similar manner as overhead costs; i.e. total sales cost divided by overhead and direct costs.

Establishing strategic plans, marketing programs and a business plan are viewed by refinery upper level management as essential tasks for the future growth of the refinery industry in the CSFR.

For capital improvement projects planned and executed by the refinery that the DMC team had an opportunity to review, estimating cost techniques were similar to those typically used in the U.S. That is, equipment and installation costs were based on competitive quotes or past historical data. Consideration was given to inflation and contingency allocation appropriate for the scope of work definition. It should be pointed out that this excursion into project estimates practices was not extensive. The foreign exchange component of one major air preheater project (total approximate cost, $600 000) ran about 45% of the total estimated cost.

The cost of utilities (steam, various kinds / types of water, fuel, and electricity) is well developed and understood. Methods used for project justification based on utility savings are well founded. Energy saving project payout times are expected to improve, correspondingly to, but not linearly, as local energy costs increase to meet free market equilibrium. There is a need to bring cost awareness and develop a sense of responsibility for control of cost down to lower level supervisors in the refinery management. Margin maximization can be enhanced by assigning cost accountability, and providing rewards for good performance, down to first line supervisors.

The move to privatization will require performance based on profitability, with the need to focus on understanding, reevaluating and managing costs. The CSFR refineries visited by the DMC team as noted above, have established a sound basis in this respect through a fully featured cost accounting system. This provides them with the ability to measure performance with respect to cost reduction, efficiency improvements and thus profit margin maximization. Establishing operating budgets is a normal practice in the CSFR refineries, along with cost deviation reporting i.e. measuring actual costs against budget values. It is suggested that budget development and attendant responsibility for achievement be delegated downward in the management ranks.

Capital budgeting practices were not examined for any of the three (3) CSFR refineries visited, during the more extended periods by the evaluation and audit team. The feeling received during discussions with refinery engineering staff that this is an area of knowledge offering potential for educational development and training.

The local and national tax situations and government incentives (if any) to enhance project justification did not surface. Tax incentives would fall into the category of credits for reduction of energy consumption, use of non-conventional fuels, environmental improvements, or simply investment credits to induce business investment.

The evaluation reports within this USAID sponsored task, indicat[illegible] approximate payout time for recommended projects. There are many with payouts of less than three (3) years. A more effective and proper analysis for project justification would use discounted cash flow (DCF) or net present value (NPV) methods of financial analysis. Payback methods for capital budgeting purposes use models too simple and naive to detect or identify optimum allocation of funds. The reality of projects is such that cash flows are uneven and not all cash streams inflate at the same rate. DCF and NPV financial models, properly used, take a more realistic view of project economics, which then provides better answers to proper allocation of capital.

Past central planning practices, it is suspected, did not allocate funds on an optimum, best return basis.

With respect to emissions reductions and project justifications, it seems that the penalty (fines) system for pollution does not drive environmental projects to the top of the list for execution and implementation. The system of allocation of capital between new business ventures, new refinery units, maintenance, safety and environmental is in development and the refineries need direction, from both a national policy and refinery implementation point of view.

2. BASIS FOR SPECIFIC EXCLUSIONS

In CSFR, three major refineries and four smaller ones were included in the characterization effort. There is an eighth plant, known as Ostramo, is located at Ostrava which is basically a spent lube oil regeneration facility. This plant was excluded from the report for two reasons. First, Ostrava is a waste treatment and recycling facility which cannot be readily defined as a petroleum refinery, i.e., a plant to process crude oil. Second, the plant is projected to be shut down. Except for this specific facility exclusion no units or sites were excluded that fell within the following definition of petroleum refinery:

> Petroleum refineries and petrochemical manufacturing plants are closely linked both physically and through refinery products that become petrochemical feedstocks. The work shall be confined to petroleum refineries only. For this purpose the refinery shall be defined as comprising all installations that pertain to the receipt of the crude oil through to processing and storage of the refinery's primary products. A

primary product shall be defined as one that has been fully processed so as to be marketable. On-site facilities to blend different gasoline streams, produce, and process them to final specifications are refinery units. Refinery gas and / or liquid streams that are delivered to the other units for further processing, such as to ethylene, ammonia, or aromatic extraction, are to be considered as finished products.

C. INDIVIDUAL REFINERY DATA

1. CHEMOPETROL S.P. - LITVINOV, CSFR

1.1 Summary Description of Refinery

The Chemopetrol Refinery is part of a petrochemical complex located approximately 200 kilometers northwest of Prague close to the German border. The address of the refinery is:

Chemopetrol S.P.
DS 262
436 - 70 Litvinov
CSFR

Telephone: 42 35 294 4477
Telefax: 42 35 4734

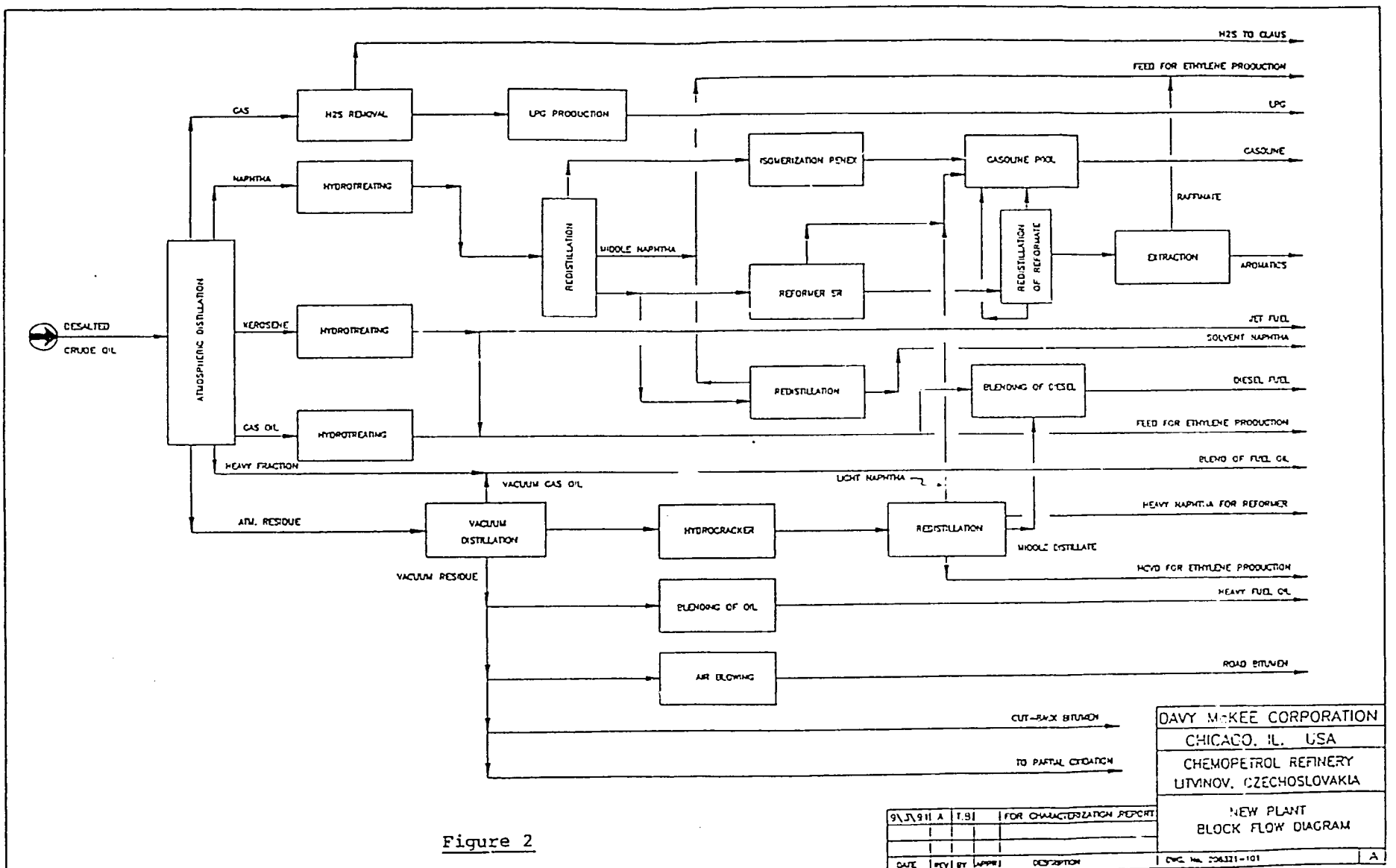
Contact: Milan Vitvar

The refinery consists of two parts. The original refinery has a capacity of 1.7 million tonnes/y, and was built in the early 1960's. The newer part of the refinery has a capacity of 3.3 million tonnes/y, and was built in the 1970's. The total capacity of the refinery is about 5.0 million tonnes/y of Russian export blend crude oil.

The new section of the refinery includes a crude unit, hydrotreaters for naphtha, kerosene (diesel), gas oils, gasoline reformer, LPG recovery, pentane isomerization and blending facilities for gasoline and diesel. Recently a vacuum unit and hydrocracker were added to the new part. The hydrocracker operates at a low conversion (around 40%) to produce feed for the petrochemical plant (Refer to Figure No. 2 for the new plant block flow diagram).

The old section of the refinery includes a crude unit with a preflash tower, vacuum unit, hydrotreaters, a reformer and a hydrocracker. Refer to Figure No. 3 for the old plant block flow diagram.

A portion of the vacuum residue is partially oxidized to produce hydrogen. The remainder of the residue is converted to bitumen.


DESALTED CRUDE OIL
ATMOSPHERIC DISTILLATION
GAS
NAPHTHA
KEROSENE
GAS OIL
HEAVY FRACTION
ATM. RESIDUE
H2S REMOVAL
HYDROTREATING
HYDROTREATING
HYDROTREATING
UPG PRODUCTION
REDISTILLATION
MIDDLE NAPHTHA
ISOMERIZATION PENEX
REFORMER SR
REDISTILLATION
GASOLINE POOL
REDISTILLATION OF REFORMATE
EXTRACTION
BLENDING OF DIESEL
VACUUM GAS OIL
VACUUM DISTILLATION
VACUUM RESIDUE
HYDROCRACKER
REDISTILLATION
LIGHT NAPHTHA
MIDDLE DISTILLATE
BLENDING OF OIL
AIR BLOWING
H2S TO CLAUS
FEED FOR ETHYLENE PRODUCTION
UPG
GASOLINE
RAFFINATE
AROMATICS
JET FUEL
SOLVENT NAPHTHA
DIESEL FUEL
FEED FOR ETHYLENE PRODUCTION
BLEND OF FUEL OIL
HEAVY NAPHTHA FOR REFORMER
HCVD FOR ETHYLENE PRODUCTION
HEAVY FUEL OIL
ROAD BITUMEN
CUT-BACK BITUMEN
TO PARTIAL OXIDATION
DAVY McKEE CORPORATION
CHICAGO, IL. USA
CHEMOPETROL REFINERY
UTVINOV, CZECHOSLOVAKIA
NEW PLANT
BLOCK FLOW DIAGRAM
FOR CHARACTERIZATION REPORT
DATE
REV
BY
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DESCRIPTION
A

Figure 2

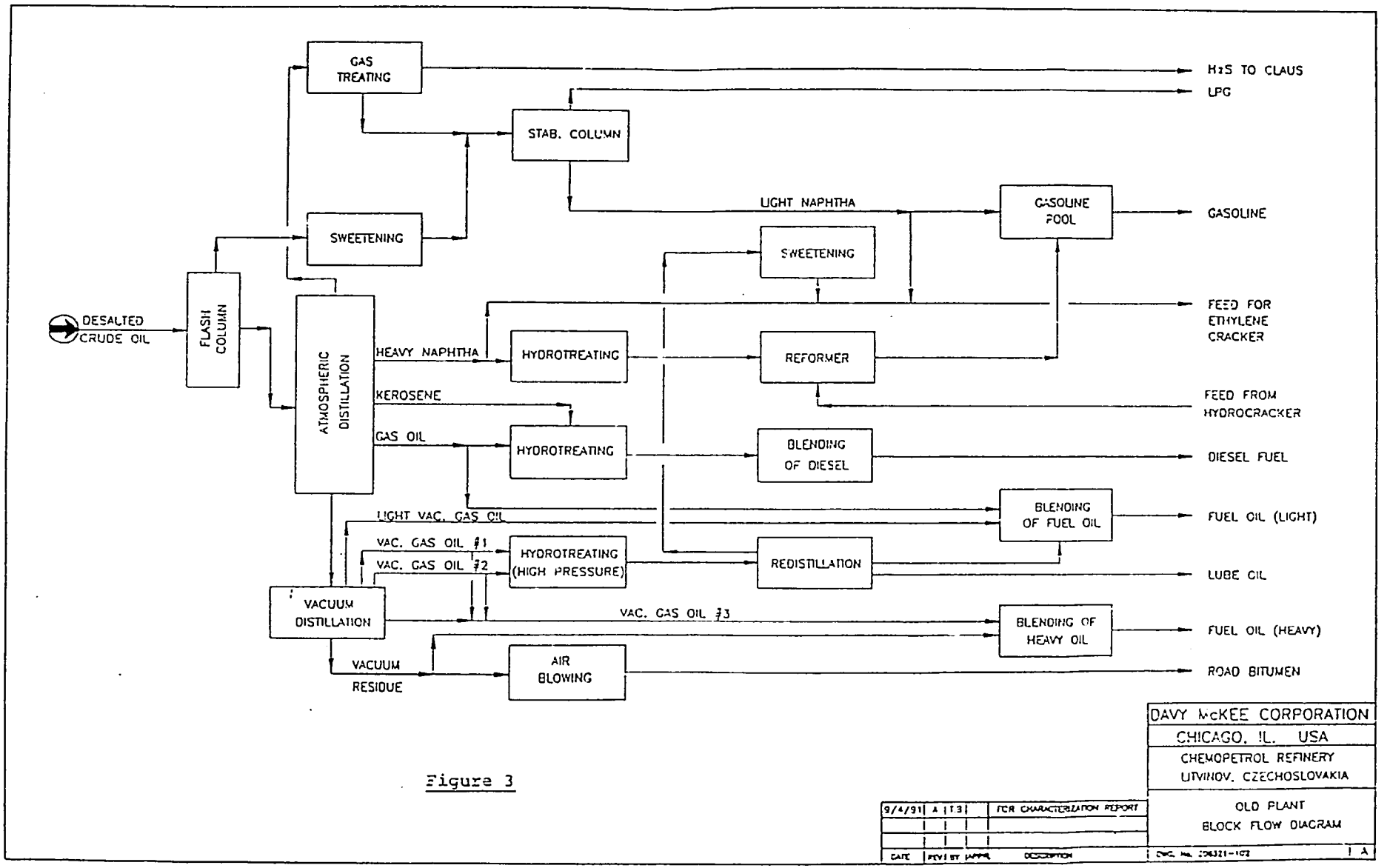
GAS TREATING
H2S TO CLAUS
LPG
STAB. COLUMN
LIGHT NAPHTHA
GASOLINE POOL
GASOLINE
SWEETENING
SWEETENING
FEED FOR ETHYLENE CRACKER
DESALTED CRUDE OIL
FLASH COLUMN
ATMOSPHERIC DISTILLATION
HEAVY NAPHTHA
HYDROTREATING
REFORMER
KEROSENE
FEED FROM HYDROCRACKER
GAS OIL
HYDROTREATING
BLENDING OF DIESEL
DIESEL FUEL
LIGHT VAC. GAS OIL
BLENDING OF FUEL OIL
FUEL OIL (LIGHT)
VAC. GAS OIL #1
VAC. GAS OIL #2
HYDROTREATING (HIGH PRESSURE)
REDISTILLATION
LUBE OIL
VACUUM DISTILLATION
VAC. GAS OIL #3
BLENDING OF HEAVY OIL
FUEL OIL (HEAVY)
VACUUM RESIDUE
AIR BLOWING
ROAD BITUMEN
DAVY McKEE CORPORATION
CHICAGO, IL. USA
CHEMOPETROL REFINERY
UTVINOV, CZECHOSLOVAKIA
OLD PLANT
BLOCK FLOW DIAGRAM
9/4/91 A 1.3 FOR CHARACTERIZATION REPORT
DATE REV BY APPR DESCRIPTION
1 A

Figure 3

Table C.1.1.1. indicates the various units that make up the refinery along with each unit's original start-up date and the contractor. The overall material balance for 1990 is presented in Table C.1.1.2.

TABLE C.1.1.1. - REFINERY UNITS AT LITVINOV

Unit Name	Licensor	Date Licensed	Date Commissioned	Contractor
NEW REFINERY				
Isomerization	UOP	1977	28 June 1983	CHEPOS, IDZ, Brno (CSFR)
Hydrocracker	Unocal	28 June 1984	7 July 1988	Consortium of VOST, Alpine Salzgitter, and Lummus
Bitumen Blowing	PDK Schwedt	1982	1 Nov. 1984	Chemopetrol (refinery maintenance people)
Atmospheric Distillation			1982	Chemoprojekt
Catalytic Reformer			1982	Chemoprojekt
Hydrotreating of Naphtha and Redistillation			1982	Chemoprojekt
Hydrotreating of Kerosene			1982	Chemoprojekt
Hydrotreating of Gas Oil			1982	Chemoprojekt
LPG Production			1983	Chemoprojekt
Vacuum Distillation			1988	Snam Progetti
Solvent Naphtha Production	Domestic Design		1981	Chemoprojekt

TABLE C.1.1.1. - REFINERY UNITS - continued

Unit Name	Licensor	Date Licensed	Date Commissioned	Contractor
OLD REFINERY				
Extraction of Aromatics			1968	Chemoprojekt
Atmospheric Distillation			1967	Chemoprojekt
Vacuum Distillation			1967	Chemoprojekt
Redistillation of Hydrotreated Products	Domestic Design		1942	Refinery design and maintenance
Catalytic Reformer	Domestic Design		1968	Chemont
Heavy Naphtha Hydrotreater			1968	Domestic design office
Kerosene and Gas Oil Hydrotreater			1982	Chemoprojekt
Old Hydrocracker			1942	Domestic Design

Table C.1.1.2 - OVERALL MATERIAL BALANCE 1990

INPUTS	tonnes/y
Crude Oil	4 106 000
Naphtha	370 000
Gas oil	150 000
Tars	125 000
Pyronaphtha	70 000
Total Inputs	4 821 000

OUTPUTS	tonnes/y
Off gases	71 000
LPG	56 000
Gasoline - regular	380 000
Gasoline - premium	172 000
Solvents	50 000
Aromatic plant feeds	85 000
Petrochemical plant feeds	1 340 000
Aviation fuels	72 000
Diesel fuels	1 245 000
Heating oils	535 000
Lube oils base	110 000
Feed to partial oxidation	330 000
Asphalts	330 000
Losses	45 000
Total Outputs	4 821 000

Crude oil distillation unit

There are two crude oil distillation units. The first one is an atmospheric vacuum unit with a 1.7 million tonnes/y capacity. The second one is an atmospheric only with a 3.3 million tonnes/y capacity, and is integrated with the downstream units. Atmospheric residue from this unit feeds the vacuum distillation column within the hydrocracking unit.

Light ends processing

The off gas from both atmospheric distillation units is sweetened (desulfurized) and then split for LPG production. Light naphtha is sweetened and sent to the gasoline pool. Heavy naphtha is hydrotreated and reformed. Kerosene and gas oil cuts are hydrotreated and blended into diesel oil, jet fuel, and fuel oil.

Residual processing units

Vacuum distillates are used for high pressure hydrogenation, blending stock for fuel oil production, and primarily as feed material for the hydrocracking unit.

Part of the vacuum residue is partially oxidized, using Shell's process, to produce hydrogen. The remainder is converted to bitumen using the semiblown process.

Asphalt oxidizers and others

A portion of the vacuum bottoms are air blown and taken off as road bitumen.

Light naphtha isomerization

The new plant has a catalytic "Penex" UOP licensed unit to produce iso-C_5 and C_6 from light naphtha for gasoline blending.

Hydrocracker

The new hydrocracker is licensed from UNOCAL. The unit is designed to process 800 000 tonnes/y of vacuum gas oils at 40% conversion. Alternately, the unit is capable of processing 645 000 tonnes/y of vacuum gas oils at 70% conversion. Currently, the unit is operating at the lower conversion, producing feedstock for the petrochemical plant.

Aromatics extraction

The existing aromatics extraction unit is not considered to be part of the refinery.

Redistillation towers

Several redistillation towers adjust the boiling ranges of the various fractions.

Hydrogen production

The reformer provides hydrogen for the hydrotreaters. The vacuum residue undergoes partial oxidization to produce hydrogen for ammonia production and for use in the hydrocracker.

Sulfur recovery

The refinery is designed to resist the corrosive effects of sulfur in crude and to recover elemental sulfur as a byproduct. A three stage Claus unit (third stage Sulfreen process), with a total efficiency over 99%, receives H_2S from the desulfurization units. The sulfur plant is actually located in the petrochemical complex.

1.2. Utilities, Services, Offsites

Electricity generation and distribution

Most of the electrical power for the complex is generated on site in coal fired power plants. The power plants were commissioned from 1939 to 1965. Sulfur and particulate (ash) emissions are major problems. Plans for new power plants include precipitators and flue gas desulfurizers to reduce these emissions.

The total capacity at present is 325 MW. The power distribution of the complex is at 110 kV and 6 kV. Motors over 100 kW are connected to the 6 kV system. Motors under 100 kW are connected to the 525 V system. Lighting and instrumentation is normally at 220 V. Safety lighting is at 24 V.

The power system is connected to the national grid.

Steam generation and distribution

Steam is furnished by the power plants and is distributed at three levels:

2.60 MPa @ 360 °C
1.80 MPa @ 320 °C
0.25 MPa @ 170 °C

Condensate collection

There are two condensate systems in the Chemopetrol plant. The first one is a pressure system and is pump driven. The second system is a gravity based system. Both systems include pipes, separators, vessels, traps, pumps etc.

Fuel supply

The fuel system consists of refinery gases, natural gas and fuel oil. The compositions are indicated in Tables C.1.2.1 and C.1.2.2.

Table C.1.2.1 - PLANT FUEL GAS

Component	Fuel gas	Natural gas	Mixed gas
	Volume %		
CH_4	10.00	97.80	20.31
C_2	3.80	0.80	14.69
C_3	5.80	0.25	0.65
C_4	1.00	0.10	0.20
C_5	0.20	0.05	1.18
C_6	0.10	-	0.72
H_2	59.49	-	48.09
CO	2.80	-	-
CO_2	12.80	0.20	-
N_2	4.00	0.80	12.51
O_2	0.01	-	0.14
Ar	-	-	1.51
H_2S	-	-	-
Total Sulfur mg/nm^3	-	0.1 - 0.2	-
Heating value, MJ/nm^3	21 000	36 000	25 808

Table C.1.2.2 - PLANT FUEL OIL

Property	Value
Density @ 20°C, kg/m^3	max. 990
Viscosity @ 100°C, mm^2/sec	max. 57
Flash Point, °C	min. 110
Pour Point, °C	+40
Heating Value, kJ/kg	40 500

Raw water supply, treatment, and distribution

The raw water comes from two rivers, the Ohre and the Bilina.

The system includes 4 pump stations. Part of the refinery is supplied by raw (fresh) water, which is used as a make-up source for the cooling water system. The raw water is treated by lime, sedimentation settling and filtration.

Cooling water system

The circulating cooling water system consists of ten cooling towers. Seven are natural draft, hyperbolic types including four with 12 000 cubic meters per hour capacity (each) and three with a 7 000 cubic meters/hour capacity (each). There are also three blocks of forced draft cooling towers of 6 000 cubic meters/hour capacity (each). This gives a total capacity of 87 000 cubic meters per hour. This cooling capacity is used in part of the complex, including the power station and refinery.

There is also a once - through cooling water system for certain areas of the complex.

Fire protection

The fire protection system includes foam, CO_2, Halon, water/steam extinguishers and steam barriers.

Crude oil receiving and product blending and shipment

The refinery does only off - line blending in tanks. See Table C.1.2.3 for transportation modes of feeds and products.

Table C.1.2.3 - FEEDS/PRODUCTS TRANSPORTATION METHODS

Feeds	Transportation
Crude oil	pipeline Druzba
Tars	railway
Naphtha	railway
Gas oil	railway

Products	Transportation
LPG	railway, road trucks
Gasolines	pipeline (75%) railway (25%)
Solvent naphthas	railway
Jet fuel	pipeline (7%) railway (93%)
Diesel Fuel	pipeline (78%) railway (22%)
Fuel oil light	railway
Fuel oil heavy	railway, road-trucks
Fuel oil tar	railway
Lube oil base	railway
Aromatics	railway
Bitumen	railway, road-trucks

Tank farm

All tanks have fixed roofs except those in crude oil service, which have floating roofs. Storage vessels for LPG and solvent naphtha are horizontal cylinders. Tanks of 1 000, 2 000, 3 000 and 5 000 cubic meters capacity are uniformly 10 m high. See Table C.1.2.4 for storage tank capacities.

Table C.1.2.4 - STORAGE CAPACITIES

Service	Size cubic meters
LPG	6 300
Light naphtha	2 000
Raw naphtha	69 000
Gasolines	30 000
Solvents	3 800
Feed for EP	30 000
Isomerate	7 000
Reformate	5 000
Feed for EA	4 000
Aromates	2 300
Jet fuel	7 000
Diesel fuel	60 000
Fuels oil light	4 000
Vacuum gas oil light	4 000
Vacuum gas oils	5 000
HCVD	40 000
Fuel oil heavy	64 000
Tar - fuel oil	4 000
Products of hydrotreating	2 000
Feed for hydrocracker	8 000
Bitumen and feed for PDX	13 500
Crude Oil	90 000

Flares

Several elevated flares, about 60 to 85 meters high and 600 to 800 mm tip diameter, are situated in the refinery.

1.3 Chemicals and Catalyst Use

The refinery uses various catalysts and chemicals for hydrotreating, reforming, water treatment and corrosion inhibition (refer to Table C.1.3.1 and C.1.3.2 for consumptions of chemicals and catalysts).

Table C.1.3.1 - CATALYSTS EMPLOYED CHEMOPETROL REFINERY

Service	Catalyst Used	Supplier/Materials
Isomerization	Penex I-8	UOP
Hydrotreating (naphtha)	Cherox 36-30	Co, Mo, Ni/Al_2O_3
Hydrotreating (kerosene)	Cherox 36-01	Co, Mo/Al_2O_3
Hydrotreating (gas oil)	Cherox 36-06 Cherox 36-01; 36-30	Co, Mo/Al_2O_3 Co, Mo/Al_2O_3;Co,Mo, Ni/Al_2O_3
Reformers	Cherox 39-21	Pt, Re/Al_2O_3,(Cl)
Hydrogenation of lube oil - base	Cherox 34-03	W, Ni/Al_2O_3, SiO_2 (F)
Hydrocracker	HCK HC-16	Nippon Ketjen Union Carbide

Table C.1.3.2 - CHEMICALS AND CATALYSTS CONSUMPTION

Name	Consumption tonnes/month	Comments
Corrosion inhibitors NALCO	1.00	
Corrosion inhibitors PRODECOR	0.15	
Deemulgator SLOVASOL	1.11	
Monoethanolamine	4.40	
NaOH	46.0	
Clay TONSIL	1.36	percolation of aromatics
Diethyleneglycol	4.2	extraction of aromatics
TEL - gasolines	18.5	
TEL - aviation gasolines	1.2	
Antioxidant 4K	0.6	for gasolines and jet fuel
Depressant KEROFLUX	6.3	
K additive	0.25	lubricant for jet fuel
Detergent Shell	1.0	for gasolines
NH_3 - water	8.3	
Catalysts	4.0	reformers and other catalytic needs

Specifications of corrosion inhibitors, gasoline additives, antioxidant, TEL, CCl4 are guaranteed by suppliers.

1.4. Previous 12-month Operating History

1.4.1 Recent Modifications

Chemopetrol is in the process of adding oil/water separators for wastewater treatment. An Italian company has been contracted to install an incinerator to handle the organic liquid waste.

1.4.2 Crude Oil Supply

Chemopetrol is dependent upon the USSR for the bulk of it's crude supply. The crude oil, received from 1989 through 1990, was 99% East Siberian and was delivered through the USSR pipeline. It contained less than 1.0% of other crudes. The total delivery to Chemopetrol for 1990 was 4 106 000 tonnes. The average throughput was 513 tonnes/h.

Soviet crude is relatively light, 32 °API gravity, and it's naphtha cut has sufficient naphthenes to reform to a relatively high octane level. It is a medium sulfur crude, 1.5 wt%, but the refinery is designed to resist the corrosive effects of sulfur and to recover elemental sulfur as a valuable by-product. Desalters treat the incoming crude, reducing the corrosive chloride content to a sustainable level - below 5 ppm. Table C.1.4.1 presents the average crude oil properties; a more extensive list is shown in Table C.1.10.5.

Table C.1.4.1 - BASIC CRUDE OIL PROPERTIES

API Gravity	32.1
Viscosity, Cst	15.1 - 16.5 @ 15°C
Sulfur, wt%	1.8 - 2.1
Watson K	11.94

A sharp decline in the availability of crude oil and a large cost increase resulted from the Gulf War and internal changes in the USSR. This is a weakness that results from depending on only one crude source. USSR's export of foreign crude was reduced during the war and more of USSR's crude was used internally rather than exported.

1.4.3 Operating Experiences

The following is the operating history for the year 1990.

Minimum monthly input:	Minimum input (9/90)	308 670 tonnes
	Maximum input (5/90)	520 560 tonnes
	Monthly average	406 644 tonnes
Shutdowns (planned):	Atmospheric/Vacuum Distillation	12.0 days
	Reformer II	40.0 days
	Hydrocracker	15.3 days

Shutdowns (unplanned):	Hydrocracker / Vacuum Dist.	6.0 days
	Compact block	7.0 days
	Isomerization	4.0 days
		1.0 day
		7.0 days
	Kerosene hydrocracker	8.0 days
	Atmospheric/Vacuum Distillation	42.0 days*

The overall onstream factor for the year 1990 was 0.745.

*Due to shortage of crude oil supply.

1.4.4 Impact of Crude Oil Changes

It appears Chemopetrol is capable of processing a wide range of crudes. It produces, with the present crude, a full line of saleable products in addition to supplying feedstock for the petrochemical plant.

In contrast to Western practices where typically the refinery is designed to handle a range of crudes, the CSFR refineries are designed specifically for Russian export crude oil only (around 32 °API). However, the Chemopetrol equipment does have some additional capacity. The refinery is constructed to withstand crudes that have up to 1.9 wt% sulfur.

One way to evaluate an existing crude unit for a new crude or a crude blend is to simulate the unit for the existing operation and establish the capacities and bottlenecks. Then the new crude feedstock is simulated to find the operating conditions, product rates, pumparound duties, flash zone conditions, crude heater duty, crude column tray loadings and capacities of the downstream equipment. All this is done by using sophisticated process simulation software and appropriate high speed computers. It is rather important to select proper thermodynamic and physical properties to perform the simulation.

1.4.5 Impact of Product Market Changes

Currently the refinery production is oriented toward the domestic market. As the free market economy becomes prevalent, foreign products will be competing in the domestic market. This means that the refinery must take the necessary steps to produce products at a competitive price.

Eventually, leaded gasolines will be discontinued and the aromatic content of gasoline will have to be reduced. The refinery will require modifications to adjust to these changes.

1.4.6 Impact of Legislation and Social Changes

Currently, the impact of legislative and social changes toward a market - oriented economy is being evaluated. These changes are expected to profoundly change the mode of operation of the refinery.

It is fair to predict that within the next few years, based on the present environmental restrictions in other countries, tetraethyl lead will no longer be legislatively acceptable as a gasoline additive in CSFR. Also, the aromatics content, especially of benzene in gasoline, will be limited by legislation. This will dictate the need for additional processing units, such as a CCR reformer, an alkylation unit and a butane isomerization plant.

1.5 Environmental Considerations

1.5.1 Quality of Local Environment

The plant appears to be meeting the current regulations for liquid emissions. There are no apparent groundwater pollution problems. The treated wastewaters and overflow water from the ash lagoon are tested on a regular basis and are meeting the quality standards for discharge into the river.

The plant does have a serious environmental problem in terms of gaseous emissions, i.e., SO_2 and fly ash. However, this plant is not the sole contributor to the problem in the area. The facility is located in the middle of a very extensive open pit, brown coal strip mining operation and numerous power plants. Within a few miles of the plant are six power plants, each consuming large quantities of brown coal. These power plants emit many times more SO_2 than the 59 000 tonnes/y emitted by the two power plants within the Chemopetrol facility.

1.5.2 Current Emission Controls

Plant personnel are aware of the requirements and regulations for liquid, gaseous, and solid effluents, and are operating near the design capabilities of the equipment.

The wastewater from various sources in the refinery, along with the sewage from both the plant and the city of Litvinov, are treated in a central treatment plant. The effluent wastewater is within all the current standards except for oil content.

Several oil/water separators are being installed and construction of a lagoon with a twenty day retention time has started. A chemical sewage treatment facility is also under construction. Currently, treated water is discharged into the Bilina River. After the installation of the above mentioned equipment and systems is complete, most of the treated water will be recycled to the plant.

An Italian company has been contracted to install an incinerator to deal with the organic liquid waste collected in open pits.

Air quality is a major pollution problem. The refinery has two power plants which burn local brown coal, containing more than 1 wt% sulfur. These power plants emit about 59 000 tonnes of SO_2 each year. The brown coal also contains a high amount of ash, and the electrostatic precipitators (ESP) currently in operation, are not able to meet the level of 100 mg dust/standard cubic meters of flue gas.

There are two solid waste disposal systems. The ash from the power plants, along with solid wastes and sludges from various water treatment facilities, are conveyed to ash lagoons, designed with a 35 year life. The second solid waste disposal system is a rotary kiln incinerator. This system burns waste liquid organic and tank bottom sludge.

1.6 Refinery Specific Potential and Opportunities for Improvement

Efficiency of furnaces

New crude and reformer heaters are operating around 80% energy efficiency. Installation of air preheaters and automatic control of combustion air should raise the efficiency to 90+%. The refinery has conducted an economic analysis showing a 2 year payback. Air preheaters could also be considered for the furnaces in old crude and vacuum units.

Further, the redistillation heaters (B1, B3, B4, C, D) could be modified with dual firing (oil and gas) burners. This will improve energy economy, and increase operational flexibility.

Reformer feed/effluent exchanger

The efficiency and capacity of the new reformer can be improved by replacing existing shell and tube exchangers with a single vertical shell and tube exchanger or a welded plate type exchanger.

In-line gasoline blending

Currently, Chemopetrol conducts gasoline blending operations batchwise. The use of a more efficient in-line blending system is recommended. In addition, an octane analyzer and control system to optimize octane blending is recommended. The system can achieve blending to within 0.1 octane.

Vacuum units

The vacuum tower of the atmospheric-vacuum distillation unit is being considered for revamping by replacing the internals with structured packing. This change will increase capacity, reduce pressure drop and improve product separation.

Amine acid gas removal units

All the amine units in the refinery are operating with 15 wt% MEA solution. Today, most MEA units operate with around 30 wt% solution. However, in order to control degradation of the solution, a large activated carbon filter and reclaim unit is required. The higher solution concentration should cut the energy consumption in half.

Secondary sealing of tanks

Secondary sealing of tanks will improve the recovery of products currently lost to the atmosphere.

Computer software and hardware

The refinery can use both process simulation and LP model software and computers to run the programs. They can also use a maintenance planning and spare parts inventory program.

Steam condensate return to the boiler

Currently, only a portion of the steam condensate is returned to the boiler. A proper steam trap selection and maintenance program, along with a condensate return and polishing system, will improve the efficiency of the steam system.

New pipelines

A decision to link the Chemopetrol and Kaucuk refineries with Ingolstadt in Germany and the TAL oil pipeline would represent an uninterrupted supply of the crude oil.

Chemopetrol also has tentative plans to extend the products network to Leipzig and the petrochemical complexes in eastern Germany and supply southern Poland.

New power plants

Chemopetrol has plans in place to construct new, environmentally acceptable, power plants. These coal - fired plants will be equipped with filters for fly ash control and flue gas desulfurizers for SOx and NOx control.

Reformulation of future gasolines

Currently, the leaded gasolines produced contain 0.15 mg TEL/liter. Eventually, the lead will be phased out and the aromatic contents of gasoline will be reduced.

Chemopetrol is already planning a high octane reformer (with CCR) and will, in the future, need a combination of MTBE and alkylation units.

Bottoms processing

Currently, part of the bottoms from the vacuum units is partially oxidized in a Shell partial oxidization unit (built in 1968) producing hydrogen. The other part of the bottoms is converted into asphalt (bitumen). It is safe to say that refinery flexibility, growth, choice of feedstock (crudes), and processing throughput all are limited at some point by the bottom of the barrel disposal or processing capabilities. Typically it is also here that a refinery's contribution to environmental degradation by its products is concentrated both in heavy metals and sulfur. Chemopetrol almost surely must consider bottom of the barrel processing, if it is to maintain its ability to produce petrochemical feedstock.

Some bottoms processing options include:

- Sending the bottoms to another site / refinery for further processing, probably at "distress prices."
- Burning the bottoms in boilers and desulfurizing the flue gas.
- Installing another partial oxidation unit with clean up, and considering generation of power and steam.
- Installing residue hydrotreating to remove sulfur and metals and adding an FCC/RCC unit.
- Installing thermal cracking or visbreaking to further process bottom of the barrel.

Chemopetrol is planning a new oxygen plant. The capacity needed for the plant will be influenced by the options selected from the above list.

Environmental impact reduction

To control air pollution caused by SOx, NOx and fly ash emissions, Chemopetrol will need:

- Filters (better than ESP) for fly ash control
- Flue gas desulfurization units
- Burner revamps to provide for NOx control at all furnaces.

1.7 Refinery Specific Problems and Trends

A portion of the vacuum residue is converted into bitumen. However, the bitumen market is uncertain and limited as to volume of uses. The refinery is studying various possibilities for alternative processing of the vacuum residue.

1.8 Methodology of Data Collection

The Davy McKee (DMC) questionnaire was completed by the refinery to the extent they were able / willing. The answers in the questionnaire were the subject of the questions and in some part formed the basis for the material in this report. The DMC team visited the refinery in June 1991, and reviewed the information in the questionnaire.

1.9 Evaluation of Results Achieved by/for Data Base

A computerized data base was prepared based on pertinent data provided by the refinery and is the subject of a separate report.

1.10 Supporting Plant Data

The following tables indicate the properties of crude oils and products:

C.1.10.1	Crude Oil Properties, 1990
C.1.10.2	LPG (Liquified Petroleum Gas) Specifications
C.1.10.3	Gasoline Specifications
C.1.10.4	Jet Fuel (Aviation Fuel) Specifications
C.1.10.5	Diesel Fuel Specifications
C.1.10.6	Fuel Oil Specifications
C.1.10.7	Road Bitumen Specifications
C.1.10.8	Solvent Naphtha Specifications
C.1.10.9	Vacuum Bottoms Properties
C.1.10.10	Tar (Feed)

Table C.1.10.1 - CRUDE OIL PROPERTIES, 1990

Property	Quarter			
	I	II	III	IV
Crude Oil				
Gravity, °API	32.6	32.4	32.5	31.1
Sulfur, wt%	1.51	1.58	1.57	1.8
Pour Point, °F	-1	-4	-8	-8
Viscosity, cs at 15 °C	15.1	15.5	15.8	16.5
Conradson Carbon, wt%	3.9	3.8	3.7	4.1
Asphaltenes, wt%	1.6	1.7	1.2	2.5
Metals, (Ni + Va) ppm	60	55	56	64
Gasoline, C_5-405 °F (C5-207 °C)				
Yield, wt%	24.2	27.0	23.0	22.9
Sulfur, wt%	0.063	0.058	0.061	0.072
Octane, F-1, 3 ml TEL			cca 65	
Light Gas Oil, 405 - 650 °F (207 - 344 °C)				
Yield, wt%	23.2	23.5	24.1	25.0
Gravity, °API	37.0	36.6	36.7	36.3
Sulfur, wt%	0.83	0.87	0.86	1.05
Pour Point, °F	-1	-1	-4	-3
Heavy Gas Oil, 650 - 1000 °F (344 - 538 °C)				
Yield, wt%	29.1	24.3	28.5	25.0
Gravity, °API	22.5	22.6	22.9	22.9
Sulfur, wt%	1.88	1.85	1.84	2.11
Viscosity, cs at 100 °C	7.8	7.6	7.3	7.2
Wax Content, wt%	7.8	7.6	7.5	7.0
Residuum, 1000+ °F				
Yield, wt%	23.4	25.5	22.5	26.0
Gravity, °API	7.2	6.8	6.5	7.3
Sulfur, wt%	3.35	3.25	3.17	3.13
Viscosity, cs at 135 °C	160	162	170	178.5

Table C.1.10.2 - LPG (Liquified Petroleum Gas) SPECIFICATIONS

Composition	Propane	Butane	LPG
Vapor Pressure at 100 °F (MPa)	1.44	0.48	1.26
Volatile Residue (ppm)	8.9	12.7	19.6
Butane and Heavier (wt% max)	0.6	97.4	40.0
Pentane and Heavier (wt% max)	0.03	3.1	0.7
Residual Matter	moisture and higher hydrocarbons		
Corrosion, Copperstrip (max)	-	-	-
Total Sulfur (ppmw)	2.0	11.7	1.8
Moisture Content	-	-	-
Free Water Content	-	-	-
Bottled at Refinery?	yes	yes	yes

Table C.1.10.3 - GASOLINE SPECIFICATIONS

Type	91 C Regular	95 C Premium	95 D Natural Lead Free
Density @ 20°C (kg/m^3)	736	742	748
Octane Number			
RON	92	96.5	96
MON	85.5	87.5	86
Distillation Volume			
IBP	36	36	36
10%	49	48	47
50%	87	89	90
90%	166	165	177
EP	205	206	213
Distillation Residue (wt%)	1	1	1
RVP kPa	40 - 70	40 - 70	40 - 70
Sulfur Content (wt%)	0.01	0.01	0.01
MTBE Content (vol%)	-	-	-
TEL Content (g/liter)	0.13	0.13	-

Table C.1.10.4 - JET FUEL (Aviation Fuel) SPECIFICATIONS

Type	RT
Density @ 20°C, kg/m³	788
Distillation, Volume IBP 10% 50% 90% 98% EP	 152 168 188 214 228 239
Distillation Residue (wt%)	1
Viscosity (mm²/sec)	1.49
Aniline Point (vol%)	15.6
Freeze Point (°C)	-61.5
Flash Point (°C)	41
Total Sulfur (wt%)	0.01
Mercaptan (wt%)	<0.01
Aromatic Content (vol%)	15.6
Doctor Test	negative
Smoke Point (mm)	24.7
Gum (mg/100 ml)	1.0
Net Heat of Combustion	-
Acidity (mg KOH/100 cm³)	0.57

Table C.1.10 - DIESEL FUEL SPECIFICATIONS

Type	Winter '90 NM22	Summer '90 NM4
Density @ 20 °C (kg/m³)	830	835
Distillation Volume %/°C		
IBP	170	170
10%	175	180
50%		
90%		
95%		
98%		350
EP	350	
Viscosity (mm²/sec at 20°C)	3.88	4.56
Pour Point (°C)	-32	-15
Flash Point (°C)	77	79
Sulfur Content (ppmw)	0.1	0.12
Carbon Residue (wt%)	0.01	0.01
Ash (wt%)	0.01	0.01
Water and Sediment (vol%)	none	none
Corrosion, Copper Strip	IA	IA
Cetane Number (min)	50	50
Filterability (°C)	-19	-5
Acidity (mg KOH/g)	0.01	0.01

Table C.1.10.6 - FUEL OIL SPECIFICATIONS

Type	Heavy	Light
Density @ 20 °C (kg/m^3)	961	886
Distillation Volume 10% 90%	-	-
Viscosity (mm^2/s)	46 (1)	11 (2)
Flash Point (PM °C)	212	105
Pour Point (°C)	13	0/-15 (3)
Sulfur (wt%)	2.4	1.3
Carbon Residue % (on 10% bottoms) CONRADSON	8	< 0.1
Ash (wt%)	-	0.01
Corrosion, Copper Strip	-	-

(1) 100°C
(2) 40°C
(3) summer/winter

Table C.1.10.7 - ROAD BITUMEN SPECIFICATIONS

Quality	AP-80	A-200
Penetration @ 25 °C	85.60	186
Soft point, °C	46.41	39
Brittle point, °C	-19.76	-19
Ductility @ 25 °C	100	100
Asphaltene content,%	11.73	8.2
Density @ 20 °C, kg/m^3	-	1022

Table C.1.10.8 - SOLVENT NAPHTHA SPECIFICATIONS

Solvent Naphtha 140/200	
Density @ 20°C, kg/m^3	770
IBP, °C	142
98% vol. °C	183
Flash-point, °C	30
Aromatic content, wt%	14.2
Doc-test	neg.

Table C.1.10.9 - VACUUM BOTTOMS PROPERTIES

Property	Value
ASTM 1160, °C	
Beginning	280
5% vol.	353
10%	386
20%	425
30%	454
40%	483
50%	515
60%	546
End: 61% obj.	550
UOP K	11.94

Table C.1.10.10 - TAR (FEED)

Property	Value
Density @ 20 °C, kg/m^3	990
Flash point, °C	30
Pour point, °C	+10
Sulfur, wt %	0.30

C. INDIVIDUAL REFINERY DATA

2. PETROCHEMA DUBOVA, S.P. - BANSKA BYSTRICA, CSFR

2.1 Description of Refinery

The Dubova Refinery is located in middle Slovakia in a deep valley of the River Hron, about 25 kilometers east of the town of Banska Bystrica. The address of the refinery is:

Petrochema Dubova s.p.
97697 Nemecka nad Hronom
Okres Banska Bystrica

Telephone: (0867) 92201-6
Telex: 070273 Petro Dubova

Contact: Ing. Matas

The refinery was built before World War II for the production of lube oils, using sulfuric acid and clay treatment. It is the oldest crude oil processing installation in Slovakia. The refinery is not connected to the crude oil pipeline system and crude oil is supplied by railroad. Crude oil is processed here mainly because the refinery is capable of producing certain specialized products. In addition to the crude, the refinery also processes some imported distillates and raffinates from other CSFR refineries.

Refer to the Block Flow Diagram, Figure No. 4, for the overall processing scheme. The historical data of all the refinery units are shown in Table C.2.1.1.

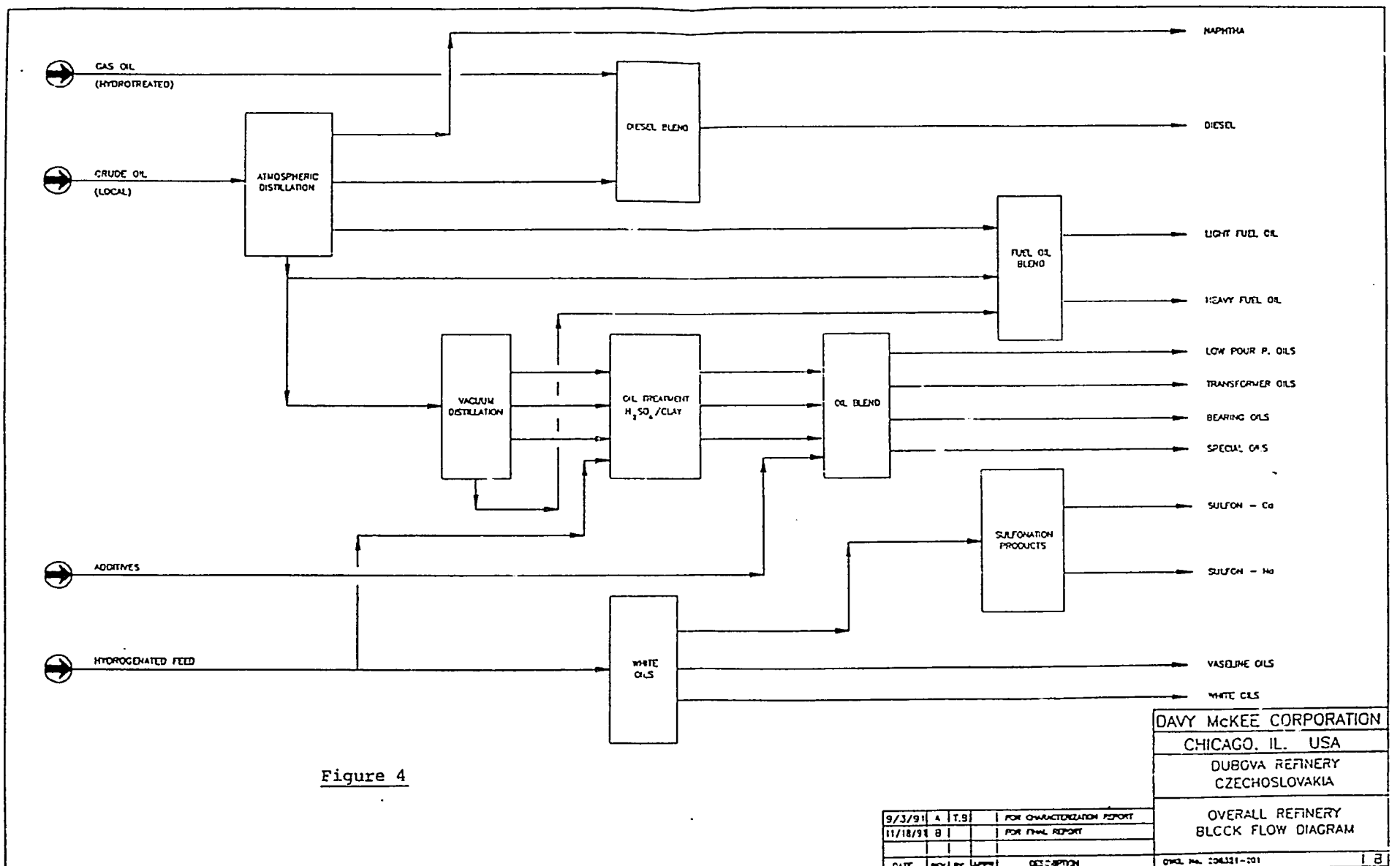

Figure 4

DATE	REV	BY	APPR	DESCRIPTION
9/3/91	A	T.S		FOR CHARACTERIZATION REPORT
11/18/91	B			FOR FINAL REPORT

DAVY McKEE CORPORATION
CHICAGO, IL. USA
DUBOVA REFINERY
CZECHOSLOVAKIA
OVERALL REFINERY BLOCK FLOW DIAGRAM
DWG. No. 204321-201 | B

Table C.2.1.1 - REFINERY UNITS

UNIT	START OF CONSTRUCTION	START OF OPERATION	REVAMPS AND COMMENTS
Oil Treatment	1937	1939	Sulfuric acid treatment
Special Chemicals	1946	1947	1951/52 - capacity increased
Hot Clay Treatment	1948	1949	
Old White Oils	1949	1952	
Atmospheric Vacuum Distillation	1953	1955	1986 - Capacity increased from 60 000 to 90 000 tonnes/year
Continuous White Oils and Sulfonates	1971	1975	Balestra license (Italy)
Alkyl-aryl Sulfonates (AAS)	1969	1972	1987/88 - Capacity increase from 8 000 to 12 000 tonnes/year 1990/91 - Capacity increase to 15 000 tonnes/year
Waste Incinerator I	1973	1974	
Waste Water Treatment	1977	1981	Mechanical and chemical stage
Overbased Sulfonates	1986	1991	Lube oil additives
Waste Incinerator II	1987	1989	
Waste Water Treatment	1987	1991	Biological stage
Steam Boilers	1935	1938	1960/63 - Replacement of the old coal fired boilers by fuel oil 1970/72 - Two boilers added and capacity increased 1988/91 - Fuel / gas burners installed

Description of processing units

The crude oil processing equipment is old and presently produces a wide variety of products in small quantities, mainly for the domestic market. In addition to typical refinery products, the refinery produces white oil, additives, detergents, and many other specialized products.

The processes used are mainly out of date and environmentally not very acceptable (acid/clay treatment, sulfurization, chlorination, Friedel-Crafts alkylation).

Crude oil processing is realized in small-capacity, atmospheric and vacuum units using the distillation equipment followed by hot clay treatment of the oils. Different vacuum distillates (from the naphthenic crude) are treated with sulfuric acid (H_2SO_4) and clay.

The continuous production of white oils began after 1975, and was based on hydrogenated oils from Slovnaft and Chemopetrol using the Italian Balaestra process and equipment. The sulfonate by-products are used as detergents and additives.

AAS (alkyl-arylsulfonates) production is based on alkyl chlorination and alkylation of benzene using Friedel-Crafts catalysts.

Alkylbenzenesulfonate production, based originally on a narrow kerosene cut (alkyl), was introduced for detergent production. Now straight chain alkanes from a Molex unit are used.

In the past, waste materials (sludge) were dumped and these deposits represent an economical and technical burden. Currently, the waste materials are incinerated, but flue gas from the incinerator produces more than 80% of the refinery's total sulfur dioxide emissions.

Overall refinery material balance

The Dubova Refinery processes two types of crude oils - N (naphthenic) and PP (half paraffinic). The total capacity of the refinery is 120 000 tonnes of crude oil per year (see Table C.2.1.2). During 1990, the refinery processed 91 000 tonnes of crude oil (see Table C.2.1.3).

Table C.2.1.2 - DESIGN CAPACITY MATERIAL BALANCE

PP Crude	tonnes/year
Input	120 000
Output-low sulfur fuel oil case	
Gasoline	7 200
Gas oil	59 400
Vacuum distillates	2 880
Fuel oil	49 200
Loss	1 320
Output-light fuel oil case	
Gasoline	7 320
Gas Oil	61 200
Vacuum distillates	31 320
Fuel oil	18 840
Loss	1 320
Total Output	120 000

N Crude	
Input	120 000
Output-middle distillate case	
Gasoline	6 000
Gas oil	36 000
Vacuum distillates	36 000
Fuel oil	40 680
Loss	1 320
Total Output	120 000

Table C.2.1.3 - OVERALL MATERIAL BALANCE 1990

Inputs	tonnes/year
Crude Oil	91 000
Total Inputs	91 000

Outputs	tonnes/year
Gasoline	5 187
Gas oil	39 585
Vacuum distillates	17 745
Fuel oil	27 482
Losses	1 001
Total Outputs	91 000

2.2 Utilities, Services, Offsites

Steam system

Steam is produced in four oil - fired boilers and two waste material incinerators. The steam is produced at 1.6 MPa, and 320 °C.

In 1991, the supply of natural gas will be increased and partially allocated for steam boiler fuel. Steam is used within the refinery at two pressure levels; 1.1 MPa and 0.6 MPa.

Cooling water system

The gasoline overhead condensers are continuously cooled using fresh water from the River Hron. The circulating system consists of 3 cooling towers with forced draft fans and pumps rated at 3 200 liter/sec each. The water from the gasoline condensers is returned to the circulating system, and excess water in the circulating system is released into the sewer.

Table C.2.10.4 describes the water system's conditions and Table 2.10.5 contains data provided on the water analyses.

Natural gas

A connection to the natural gas pipeline provides gas for the complex. About 6 million cubic meters of natural gas/y was used mainly in the crude oil distillation units and in AAS production. In 1991, the consumption of natural gas will be expanded to partially fuel the 3 boilers. These units are furnished with combined burners for gas and fuel oil.

The composition of natural gas is as follows:

Component	CO_2	N_2	C_1	C_2	C_3	C_4
Vol %	0.2	0.5	95.0	2.2	0.8	0.4

Instrument air

Air is compressed and dried to produce instrument air. The header pressure of the system is 0.4 MPa and the dewpoint is -40 °C.

Electricity

Electrical power is imported from Slovenske Energeticke Za'vody (general supplier). A line of 11 kV voltage is transformed to 0.4 kV. Individual supply 380/220 V is made by means of cables. The power supply is reliable.

Storage, blending and transport

There are adequate storage facilities for feed and product materials.

Blending is done in tanks or agitated vessels. The blending capacity for different materials is as follows:

Lube Oils OD3, PD4, OD8, OD10, OD16	3.75	tonnes/h
Lube Oil OD20	0.2083	tonnes/h
Diesel fuel	4.0	tonnes/h
Light fuel oil	4.5	tonnes/h
Heavy fuel oil	2.083	tonnes/h

The railroad is the major means of transportation. The refinery's existing loading and unloading facilities are conventional.

Maintenance facilities

A major part of the equipment is old and worn out, and there is a corresponding demand for maintenance and difficulties with spare part procurement. Also, the processes used in the refinery involve the use of corrosive chemicals. The turnaround cycle time of the crude oil processing units is only 6 months. Only about 50% of the maintenance work is done by refinery maintenance people.

Fire protection equipment

The refinery has a fire-fighting group and the necessary equipment. Seven people work in this area per shift. Basic equipment includes 5 trucks, each with foam-producing capability.

2.3 Catalysts and Chemicals

Aluminum chloride is used as a catalyst for the AAS alkylation unit. No other data on the consumption of catalysts or chemicals were made available.

2.4 Previous 12-month Operating History

The operation during 1990 was limited to 76% of capacity.

2.4.1 Recent Modifications

Major recent modifications are oriented toward increasing the processing capabilities of marketable products while minimizing the impact on the environment. A new biological water treatment unit was commissioned in 1991.

AAS production has been expanded from 12 000 to 15 000 tonnes per year. Also, production facilities for base sulfonates (a lube oil additive) were added.

2.4.2 Crude Oil Supply

The Dubova Refinery processes only domestic crude. The total production of domestic crude is small and declining. There are two types of crude: N (naphthenic) and PP (half paraffinic), both low in sulfur (0.15%). Crude oil is brought to the refinery by railroad. Section 2.10 contains more detailed information on the properties of PP and N crude and some products.

2.4.3 Operating Experiences

During 1990, the plant operated at 76% of capacity.

2.4.4 Impact of Crude Oil Changes

The refinery has been processing only domestic crude oils.

2.4.5 Impact of Product Marketing Changes

Changing market conditions in CSFR represent a serious problem for the refinery, which produces products with no competitive market value.

2.4.6 Impact of Legislation and Social Changes

It is anticipated that more stringent environmental regulations will be imposed in the future. Pressure from the competitive market may necessitate changes in product slate and reduction in refinery staff.

2.5 Environmental Considerations

The refinery is meeting the current environmental regulations.

2.5.1 Quality of Local Environment

Current environmental aspects present one of the most difficult problem areas for the refinery, and some existing factors complicate the solution:

- The refinery is located in a deep valley in an attractive mountain area.

- The River Hron is a small river and cannot tolerate more pollution.
- Sludge deposits from past production have to be removed.

There are two sludge deposits outside the refinery:

Predajna I with about 100 000 cubic meters of semi-solid sludge

Predajna II with about 60 000 cubic meters of sludge containing:

15 000 cubic meters of acidic emulsion layer
15 000 cubic meters of sour water (H_2SO_4 solution)
20 000 cubic meters semi-solid sludge

There are four sludge deposits inside the refinery:

Deposit A	15 000 cubic meters sour water and sludge
Deposit B	8 000 cubic meters semi-solid sludge
Deposit C	4 500 cubic meters semi-solid sludge
Deposit D	8 000 cubic meters (1000 cubic meters emulsion layer + 8 000 cubic meters semi-solid sludge)

In addition, there is about 10 000 cubic meters of sediment from water treatment units (dry substance content is about 20 - 30%). Finding an economical solution for liquidating the old deposits is very important for the refinery. The start of the biological stage of the water treatment unit should reduce river pollution.

Air pollution conditions are primarily due to sulfur dioxide from the flue gas though there are contributions from hydrocarbon evaporation and other chemical leakage. Sulfur dioxide emissions are being reduced by using low sulfur fuel oil and by increasing the natural gas portion of the refinery fuel. Most of the sulfur dioxide is generated from sludge incineration.

The total SO_2 emission is estimated to be approximately 1 350 tonnes per year.

2.5.2 Current Emissions Controls

Water treatment unit

The wastewater treatment unit consists of mechanical and chemical stages. The design capacity of the unit is 78 liter/sec (2 144 500 cubic meters/year). The current level of purification is not sufficient, and a new

biological stage is under construction and is scheduled for commissioning in the near future. The capacity of the water treatment unit compared to the plant size is high because:

- there is a variable load of very contaminated rain water from all the sludge deposits that has to be collected, brought to the plant and purified to prevent environmental contaminating overflow
- all cooling water added and released from the cycle goes through the water treatment unit.

All water treatment analytical data will change when the biological stage treatment unit is completed and commissioned.

Waste Disposal

All waste materials are now incinerated in two existing incinerators. The capacity of each unit is sufficient to incinerate waste materials from the standard process. Depositing waste materials is no longer allowed. If the incineration units fail, the refinery has to be shut down.

Sulfuric acid treatment of oils has been used here for a very long time, and the acidic sludges were previously deposited both inside and outside the refinery. Although incineration units for sludges and oily clay have been built, there are still environmental problems with the existing production. These are in addition to the problems posed by the earlier deposits of waste products. To begin to solve these problems, the water treatment system was expanded and a biological stage is now under construction.

Increased pressure from local authorities to reduce the environmental impact of the refinery has stopped the depositing of sludge. Incineration units for waste products were constructed. Correspondingly, a wastewater treatment unit was built and expanded. Environmental pressure to reduce pollution of any type and also to clean-up old waste deposit fields is expected to continue.

2.6 Refinery Specific Potential and Opportunities for Improvement

From the brief analysis of the operation of the refinery, the following recommendations should be considered:

1) Meter the steam used in individual units and fix the accountability for its consumption.

2) Evaluate the possibility of separating the once through cooling water and returning it through a guard separator into the river, but retaining provisions for switching to the full treatment plant if contamination is detected.

3) Regularly measure the flue gas composition and adjust combustion conditions (air) to bring the excess air to an acceptable level.

4) Evaluate alternatives for ultimate disposal / destruction of the existing sludge deposits taking into account economical and financial possibilities (even with outside support).

5) Evaluate the technical and economical possibilities of reducing sulfur dioxide emissions from sludge incinerating units.

2.7 Refinery Specific Problems and Trends

The Dubova Refinery is closely connected with the processing of local, partly naphthenic crude. The crude oil processing equipment is old and worn, but the refinery continues to be the unique producer of many different specialty products in small quantities. The processes used are mainly out-of-date, of low capacities, oriented for the domestic market, and environmentally unfriendly. Demand for some of the products is diminishing and new products will have to be developed and marketed.

Out of country purchasing (maybe later) to acquire replacement for, some or most of the product line deserves serious consideration and evaluation. Possibilities exist for savings and energy conservation. The reasons for this are listed below:

- Most of the steam used in units is not measured and just distributed following previous practices.

- All water introduced to the plant leaves the plant through the water treatment units with no separation of cooling water and contaminated wastewater.

- There is a very short cycle of shutdown for overall maintenance (6 months) in continuously running units.

Major problems at the refinery are connected with existing sludge deposits from past continuous production of heavily contaminated wastewater, the incineration of sludge from the oil treatment unit (acid/clay) and white oils production which represents more than 80% of the total site sulfur dioxide emission.

2.8 Methodology of Data Collection

The Davy McKee (DMC) questionnaire was sent to the refinery in May 1991. During the early part of June, the DMC consultant met with the refinery manager to review the results of the questionnaire.

2.9 Evaluation of Results Achieved by/for the Data Base

The data collected through the questionnaire and personal meetings was included in a computerized data base and is the subject of a separate report.

2.10 Supporting Plant Data

As referred to and indicated in the block flow diagram, a variety of products and feed materials are used in the refinery. The following tables present typical feed and product specifications for the Dubova Refinery.

C.2.10.1 Crude Oil Properties
C.2.10.2 Imported Feeds and Blending Stocks
C.2.10.3 Lubricating Oils
C.2.10.4 Water Systems Conditions
C.2.10.5 Water Analyses

Table C.2.10.1 - CRUDE OIL PROPERTIES

Crude Name Source (Country)	PP Crude	N Crude
Crude Oil		
Density (kg/cubic meters)	845 - 875	890 - 925
Sulfur (wt%)	0.13 - 0.16	0.11 - 0.13
Pour Point (°C)	0 - (-)4	-40
Viscosity (cs at 20°C)	73 - 20/20	20 - 65/20
Conradson Carob (wt%)	n/a	n/a
Asphaltenes and Resins (vol%)	n/a	n/a
Metals (Ni + Va, PPM)	n/a	n/a
Gasoline (C5 - 207°C)		
Yield (vol%)	6	5
Sulfur (wt%)	0.05	0.05
Octane (F-1, 3 ml TEL)	N	N
Light Gas Oil (180 - 370°C)		
Yield (vol%)	50	27 -35
Density kg/cubic meters	830 -850	845 - 895
Sulfur content (wt%)	0.07 - 0.09	0.07 - 0.09
Pour Point (°C)	-14	-40
Residuum, 370°C+		
Yield (vol%)	43	67
Gravity (kg/cubic meters)	880 - 890	890 - 900
Sulfur (wt%)	0.15 - 0.25	0.15 - 0.25
Viscosity (cSt at 210°F)	7.5 - 15/100	39 - 55/40

Table C.2.10.2 - IMPORTED FEEDS AND BLENDING STOCKS

Type		Diesel 35A	VL-21	Spent Trafo	R-68	720-N	R-931	R-935	R-950	Pseudo Rafin
Density at 20°C, kg/cubic meters		805-815	P86	900	922-928	880	860	865	-	950
Flash Point, °C	min	55	145	135	190	140	180	212	220	230
Pour Point, °C	max	-40	-45	-40	-20	-50	-12	-12	-8	-10
Viscosity at 20°C, mm²/sec		-	22-30	41.3	-	25	-	-	-	-
Viscosity at 50°C, mm²/sec		-	-	-	38-45	-	16-20	26-34	61.6-22	280
Avid mr, mg KOH/g	max	-	0.15	-	0.05	-	-	-	-	-
Viscosity Index	min	-	-	-	40	95	90	90	80	15-30
Ash Content	max	-	-	-	-	-	-	-	-	-
Color ASTM	max	-	1.5	-	3	-	2	2	5	-
Carow, wt%	max		20	-	-	8	-	-	-	-
Sulfur Content, wt%	max	0.32	-	-	-	0.2	0.4	0.6	-	-

Table C.2.10.3 - LUBRICATING OILS

Type Gravity	OD-3	OD-4	OD-8	OD-16
Composition (wt)	N			
Density at 20°C (kg/cubic meters)	940	945	950	960
Kinematic Viscosity (cs at 40°C)	39 - 55	62 - 77	120 - 152	189 - 216
Viscosity index	-	-	-	-
Pour point (°C)	-32	-20	-18	-10
Flash point (°C)	130	130	160	160
Carbon residue (Ramsbottom, wt%)	-	-	-	-
Sulfur (% wt)	-	-	-	-
Asphaltenes (% wt)	0.2	0.3	0.2	0.5
Ash content at 775°C (% wt)	-	-	-	-
Neutralizing number (mg KOH/g) i.k.	1.2	1.2	1.2	1.0

Table C.2.10.4 - WATER SYSTEMS CONDITIONS

Description	Refinery Raw Water Supply	Once-Through Cooling Water	Circulating Cooling Water
Source	Hron	Hron	-
Supply Temperature (°C)	10	10	30 - 50
Supply Pressure (MPa) at battery limits at grade	-	0.6	0.6
Return Pressure (MPa) at battery limits at grade	-	-	-
Exchanger Inlet Water Temperature (°C)	-	10	30 - 50
Exchanger Outlet Water Temperature (°C) - max	-	50	60
Exchanger Water Side Design Temp. (°C)	-	-	-
Exchanger Water Side Design Pressure (MPa)	-	-	-
Fouling Resistance	-	-	-

Table C.2.10.5 - WATER ANALYSIS

Description	Refinery Raw Water Supply	Once-Through Cooling Water	Treated Boiler Feedwater
pH			8.5 - 9.5
Total Hardness as $CaCO_3$(mval/liter)	1.84	1.84	0.03
Calcium as $CaCO_3$ (mval/liter)	1.26	1.26	
Magnesium as $CaCO_3$ (mval/liter)	0.58	0.58	
"P" Alkalinity as $CaCO_3$ (ppm)	-	-	-
Sulfate as SO_4 (ppm)	-	-	
Chloride as Cl (mval/liter)	0.39	0.39	
Silica as SiO_2 (ppm)			
Iron as Fe (mg/liter)	0.18	0.18	
Total Dissolved Solids (ppm)			
Total Suspended Solids (mg/liter)	19.2	19.2	0.2
Turbidity (ppm)			
Conductivity (ms/cm)	187	187	

C. INDIVIDUAL REFINERY DATA

3. KAUCUK REFINERY WORKS - KRALUPY, CSFR

3.1 Summary Description of Refinery

Kaucuk Kralupy is a refining and petrochemical complex. In addition to the refinery, there are petrochemical production facilities (butadiene, styrene, SBR, polystyrene, ABS and MTBE) based on raw materials received from Litvinov via pipelines. Only the refinery is reviewed in this characterization report.

The refinery is located within a complex adjacent to the Vltava River, not far from Kralupy, a city of about 20 000 people, located about 25 km north of Prague. The address of the refinery is:

Kaucuk S.P.
278-52 Kralupy NAD.VLT
CSFR

Telephone: (0205) 23663
Telefax: (0205) 23566
Telex: 132 343

Contact: Ing. Jiri Tlusty

The Kaucuk Refinery was built as a hydroskimming refinery between 1969 and 1974, when sufficient amounts of crude oil from the USSR were available. The rated capacity of the refinery is 3.2 million tonnes/y. Figure 5 shows the processing units in the refinery.

A fully integrated distillation unit (atmospheric only) supplies the downstream units with feed materials without cooling and day storage. In an emergency, it is possible to cool and store some products. The distillation unit also includes a crude oil desalting stage and a naphtha rerun column. The history of various units is indicated in Table C.3.1.1 and typical yield patterns are shown in Table C.3.1.2. The overall material balance for 1990 is shown in Table C.3.1.3.

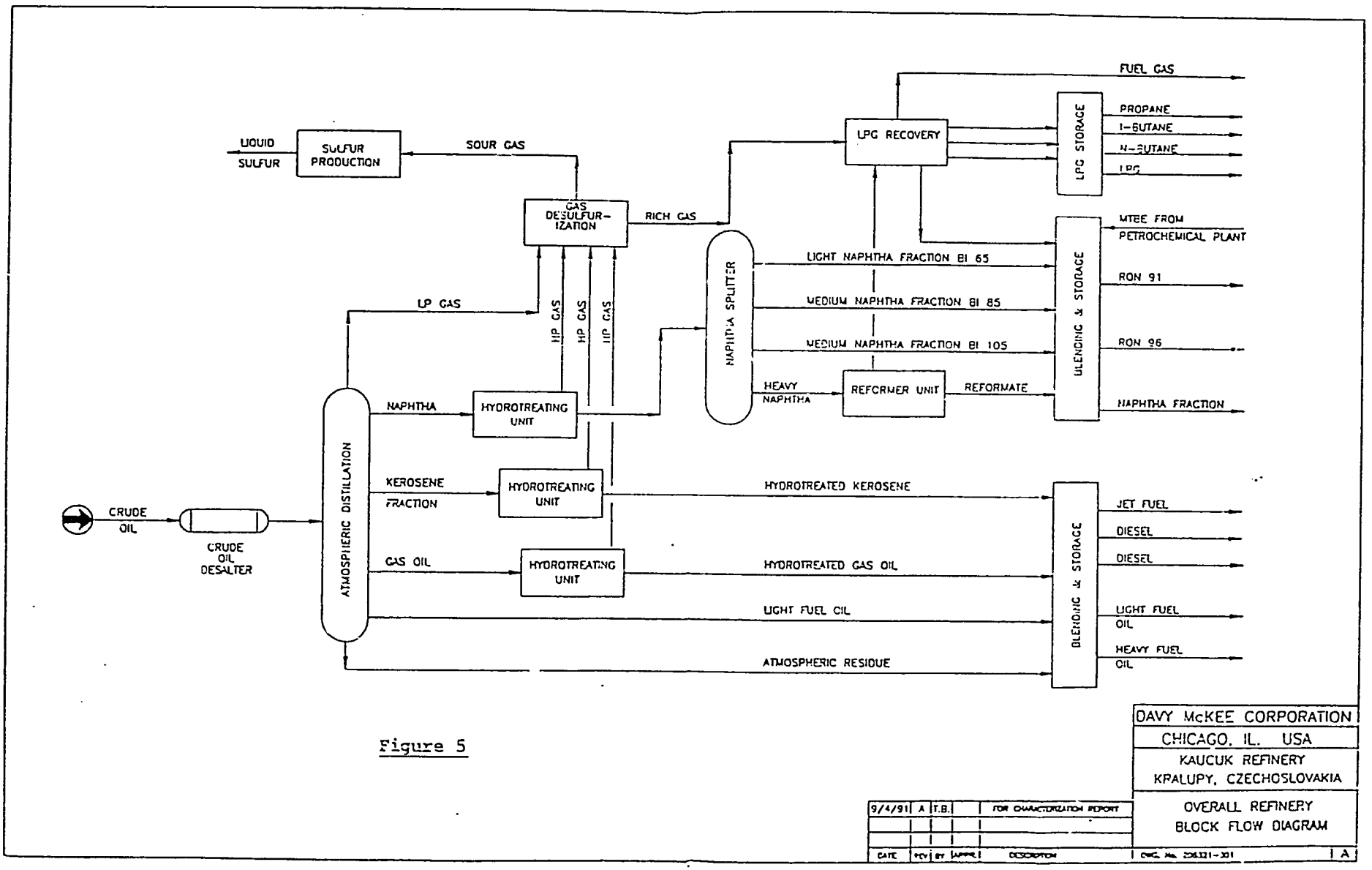
LIQUID SULFUR
SULFUR PRODUCTION
SOUR GAS
GAS DESULFUR-IZATION
RICH GAS
LPG RECOVERY
FUEL GAS
LPG STORAGE
PROPANE
I-BUTANE
N-BUTANE
LPG
MTBE FROM PETROCHEMICAL PLANT
RON 91
RON 96
NAPHTHA FRACTION
BLENDING & STORAGE
NAPHTHA SPLITTER
LIGHT NAPHTHA FRACTION BI 65
MEDIUM NAPHTHA FRACTION BI 85
MEDIUM NAPHTHA FRACTION BI 105
HEAVY NAPHTHA
REFORMER UNIT
REFORMATE
LP GAS
HP GAS
HP GAS
HP GAS
NAPHTHA
HYDROTREATING UNIT
KEROSENE FRACTION
HYDROTREATING UNIT
HYDROTREATED KEROSENE
GAS OIL
HYDROTREATING UNIT
HYDROTREATED GAS OIL
LIGHT FUEL OIL
ATMOSPHERIC RESIDUE
ATMOSPHERIC DISTILLATION
CRUDE OIL
CRUDE OIL DESALTER
BLENDING & STORAGE
JET FUEL
DIESEL
DIESEL
LIGHT FUEL OIL
HEAVY FUEL OIL
DAVY McKEE CORPORATION
CHICAGO, IL. USA
KAUCUK REFINERY
KRALUPY, CZECHOSLOVAKIA
OVERALL REFINERY BLOCK FLOW DIAGRAM
9/4/91 A T.B. FOR CHARACTERIZATION REPORT
DATE REV BY APPR. DESCRIPTION
DWG. No. 206321-301
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Figure 5

Table C.3.1.1 - PROCESSING UNITS

Unit	Capacity tonnes/year	Startup
Crude Oil Distillation	3 270 000	1974
Naphtha HDS Unit	624 000	1975
Kerosene HDS Unit	344 000	1975
Gas Oil HDS Unit	830 000	1975
Cat. Reformer Unit	330 000	1975
LPG Unit	122 000	1975
Claus Unit	8 000	1975

Table C.3.1.2 - REFINERY PRODUCT YIELDS

Product	Yield in wt%
Naphtha	17.8
Kerosene	9.0
Gas oil	23.5
Light fuel oil	6.0
Heavy fuel oil	43.5
Gas	0.2
Total	100.0

Table C.3.1.3 - OVERALL MATERIAL BALANCE 1990

Inputs	tonnes/year
Crude Oil	2 456 500
MTBE	25 800
C_4 Fraction (1)	22 000
Total Feeds	2 504 300

Outputs	tonnes/year
Gasoline BA91C	261 300
Gasoline BA95C	102 470
Naphtha	46 800
Diesel NM4	344 600
Diesel NM22	275 100
Diesel NM30	-
Gas Oil Hydrotreated	20 600
Jet Fuel	123 000
Light Fuel Oil	155 600
Heavy Fuel Oil	1 034 200
LPG	79 500
Sulfur	4 800
Fuel Gas	17 800
Fuel Oil	23 504
Losses	15 026
Total Products	2 504 300

(1) C_4 fraction after the MTBE production

Light ends processing

Sour gases from the refinery are collected and desulfurized using DEA.

Sweet gases are mixed with the LPG stream from the reformer unit and sent to the gas separation plant. Compressed gases are washed using hexane as a solvent. Lighter components, including ethane, are separated in a gaseous form and sent to the refinery fuel gas system. Propane, butane, and pentane are selectively desorbed and solvent is recycled. If necessary, normal and iso-butane can be separated. Individual components are partly remixed for a commercial specification or sold directly.

Table C.3.1.3 shows typical yields of light products in the overall yearly balance. Table C.3.1.4 shows the typical stream composition of C_1 through C_6.

Table C.3.1.4 - STREAM COMPOSITIONS

Component % Vol	Fuel Gas	C_3	C_4	C_5	i-C_4	n-C_4	Solvent
H_2	30.0	-	-	-	-	-	-
C_1	26.7	-	-	-	-	-	traces
C_2	36.6	-	-	-	-	-	0.1
C_3	0.6	47.2	-	-	traces	-	traces
i-C_4	-	20.9	10.7	traces	99.3	6.4	-
n-C_4	0.1	37.9	87.6	0.8	0.7	92.2	0.2
i-C_5	3.0	traces	1.6	33.3	traces	1.3	11.9
n-C_5	2.2	-	0.1	23.8	-	0.1	10.3
C_6+	3	-	-	42.1	-	-	77.5

Residual processing units

Currently, there are no atmospheric residue processing units in the refinery. When the refinery was constructed, it was assumed there would be a continuous, large supply of crude oil from the USSR. Therefore, bottoms processing was not necessary. Now the supply of crude oil from the USSR is limited, and atmospheric bottoms processing is necessary. Several bottoms processing schemes are being evaluated.

Light and heavy naphtha processing

Raw naphtha from the distillation column is hydrodesulfurized, stabilized and rerun into individual cuts. In addition to the naphtha feed, 3 - 4 tonnes/h of C_4 is introduced (C_4 fraction after the butadiene extraction and MTBE production) to be saturated. A major portion from the bottom of the rerun column is heavy naphtha. It is fed to the catalytic reformer unit for upgrading to increase the octane. Liquid product from the reformer unit is the high octane number component of a gasoline pool. The overhead fraction from the naphtha rerun column (naphtha 65) is used as a light component in the gasoline pool, medium fraction (naphtha 85) is partly used for gasoline production and partly sold as a feed for steam cracking. MTBE is also a part of the gasoline pool. Isomerization of light naphtha is being evaluated. The amount and quality of gasoline produced is indicated in Tables C.3.1.3. and Table C.3.10.2. Naphtha quality is listed in Table C.3.10.3.

Distillate processing

Kerosene and gas oil are hydrotreated to remove sulfur. Medium pressure hydrodesulfurization is used. Kerosene is used for jet fuel production and the rest is sent to the diesel pool. The major portion of hydrotreated gas oil is used for diesel production; a smaller part is sold directly. The quantity and quality of jet and diesel fuel are presented in Tables C.3.1.3 and 3.10.8.

Gas oil conversion

The Kaucuk Refinery does not have a vacuum distillation unit.

Hydrogen production

No special hydrogen production exists in the refinery. The major part of the hydrogen for the HDS units is produced as a by-product in the catalytic reformer unit. There is high pressure hydrogen storage for the startup of the reformer unit. A small amount of hydrogen from styrene production (dehydrogenation of ethylbenzene) may be purified and used within the refinery.

Sulfur recovery

The average sulfur content of Russian crude is 1.5 - 1.6 wt%. The majority of the sulfur is concentrated in heavy fuel oil and sold with the product. The white products are hydrodesulfurized and this sulfur, in the form of H_2S, is converted to elemental sulfur in the Claus unit in the refinery. The 1990 production of sulfur was 4 800 tonnes as shown in Table C.3.1.2. This represents only about 12.6% of the sulfur introduced with the crude oil.

Refinery process control

The refinery is computer controlled from a single control room.

3.2 Utilities, Services, Offsites

Electricity generation and distribution

A power station inside the Kaucuk complex supplies electricity for the refinery. In the main station there are four 125 tonnes/h coal fired boilers producing 9.6 MPa steam, superheated to 540 °C. Two generators of 30 MW each produce electricity for the whole complex; even though one generator can support the facility. The system is connected to the national grid.

Power from the generators is 6 kV and this voltage is used for plant distribution. Electrical power distribution in the refinery units is as follows:

6 000 volts	Incoming distribution voltage is used to power refinery motors of 160 kW and up.
380 volts	Powers motors below 160 kW and supplies power to the desalter.
220 volts	Normal refinery lighting.
24 volts	Safety lighting.

Steam generation and distribution/condensate collection

Process steam for the whole complex is supplied from:

- The power station: 4 boilers @ 125 tonnes/h - coal fired
- Two small boilers: @ 25 tonnes/h each 1.6 MPa 230 °C - gas or oil fired
- Local process waste heat boilers

Steam is produced from waste heat in the following locations:

• Reformer heater	1.6 MPa	240 °C	7.50 tonnes/h
• Reformer heater	0.6 MPa	190 °C	4.28 tonnes/h
• Gas oil and Kero HDS	0.6 MPa	190 °C	9.00 tonnes/h
• Claus Unit	0.6 MPa	190 °C	1.00 tonnes/h

In the power station, steam is extracted from turbines at 1 MPa and 0.25 MPa and sent to the process steam system. Primary condensate is returned to the primary cycle.

Part of the condensate collected is used in a crude oil desalting unit in combination with the fresh softened water from the power station as boiler feed water for the wasteheat steam production mentioned above.

Fuel supply, nature and sourcing

Steam and power production in the main power station is based on coal firing. All refinery furnaces are now gas fired (combined oil/gas burners). Fuel gas is a mixture of refinery gas (40%) and natural gas (60%) from the pipeline connected to the national grid. The heating value of this mixture is 54 GJ/tonne. The composition of individual components is shown in Table C.3.2.1 below.

Table C.3.2.1 - COMPOSITION OF FUEL GASES

Component	Refinery Gas (vol%)	Natural Gas (vol%)
H_2S	0.01	15 ppm
CO_2	-	0.25
N_2	-	0.85
H_2	70.00	-
C_1	14.39	97.66
C_2	13.50	0.90
C_3	1.10	0.30
C_4	-	-
i-C_4	0.40	-
n-C_4	0.40	-
C_5	0.20	0.02
C_6	-	0.02

Cooling towers

The refinery has its own cooling water system. There is a separate cooling tower with a natural air draft and a 3 000 cubic meters/h capacity. The average temperature difference is 6 to 8 °C. There are no special problems with corrosion or fouling of coolers. During the summer, the water from the cooling tower is too warm for the condensers in the gas separation plant, and on warm days some raw water is mixed with cooling water to achieve the desired temperature.

Fresh water supply

Fresh water is supplied from the Vltava River. The refinery has a recycled cooling water system, and water from the river is used as makeup water to replace evaporation losses and blowdown. Fresh water for the refinery is supplied from the central pumping station because the rest of the complex uses a once-through cooling water system.

Water treatment and distribution

Only makeup water for the recycle cooling system of the refinery is filtered. The fire water is stored in one of the stages of the biological wastewater treatment unit. It is connected to pumps and the fire water distribution system.

Crude oil supply

Crude oil is supplied by the pipeline. Within the refinery, there are 6 crude storage tanks (31 000 cubic meters each). Mixers in each tank prevent basic sediment and water (BS&W) from settling. Low pressure pumps feed the distillation unit. There is a tank farm sufficient for storage of semi and final products, including LPG.

Product blending and shipment

Two electronic in-line blenders made by Jiskoot (Great Britain) are controlled from a local board along with an Enraf Nonius meter and Minelect tank gauging system. The first blender is used for combining 5 streams to obtain product gasoline. The second blender mixes 2 streams for diesel.

Products are shipped via:

- Product pipeline 175 cubic meters/hour
- Railway tanks 400 cubic meters/hour
- Tank cars 100 cubic meters/hour

There is an automatic, computer-controlled, filling station for railway tank cars.

Flare, blowdown, dropout system

The refinery has its own flare system with a separator drum. Liquid hydrocarbons are separated and returned to the process. There is a standard elevated flare system with no return of hydrocarbon vapors.

3.3 Chemicals and Catalyst

Catalysts are used in the refinery in hydrodesulfurization units, catalytic reformers and the Claus unit. Catalyst usage is noted in Table C.3.3.1.

Table C.3.3.1 - CATALYST USAGE

Service	Catalyst (Supplier)
Naphtha Hydrotreater	KF 124 (Akzo Ketjen)
Reformer unit	CK522 (Akzo)
Kerosene Hydrotreater	S444T (Shell)
Gas oil Hydrotreater	S444T (Shell)
Claus unit	S201 alumina (Kaiser Chemicals) CR catalyst (Rhone Poulenc)

3.4 Previous 12-Month History

The overall material balance for 1990 is shown in Table C.3.1.3. The reduction of crude oil supplied from the USSR and the economic changes in CSFR had the greatest impact on the 1990 data. This, and the fact that Kaucuk is a hydroskimming refinery and produces heavy fuel oil, make Chemopetrol and Slovnaft preferred sites for the now limited crude supply. Both of these refineries have hydrocracking units and can convert the available crude oil into more valuable products.

3.4.1 Recent Modifications

When the catalytic reformer was modified it resulted in increased capacity, improved heat exchange and lower furnace duty. An old IBM 1800 computer was replaced by a distributed control system (DCS) to improve the process control. Other energy saving projects are under consideration.

3.4.2 Crude Oil Supply

Practically all crude oil processed in the Kaucuk Refinery is from the USSR. Small amounts of Middle East crude have been added and mixed with the Russian crude. Detailed properties of the Russian crude oil are in Section D.

Sources and supply network

Until recently, only Russian crude oil was available. During the last year, the crude oil supply was reduced and other resources are being evaluated, including alternative resources for crude and new transport possibilities.

In addition to the crude pipeline from the USSR, the ADRIA pipeline from the Adriatic Sea (Omisaj) via Yugoslavia, Hungary and southern Slovakia connects with the Russian pipeline. CSFR participated financially in the construction of this pipeline, and the original agreement enabled CSFR to use 5 million tonnes/y capacity. This agreement has not been in effect for a long time and has expired.

The Hungarians have similar concerns about supply problems with Russian crude for their refineries. It may be possible to transport about 5 million tonnes/y of crude via the ADRIA pipeline to CSFR.

Other alternatives include:

- The extension of the pipeline from the Schwechat Refinery to Slovnaft (about 60 km). The bottleneck of this solution is the relatively low spare capacity in this pipeline (max. 4.0 million tonnes/y).

- Ingolstadt - Kralupy pipeline connecting TAL pipeline to Litvinov or Kralupy. The distance is longer (about 350 km from Kralupy), but it may be a possible solution.

3.4.3 Operating Experiences

The refinery was designed for Russian crude, and since the startup, only Russian crude has been processed. The refinery was designed and built in one integrated, compact block of units without day tanks and only final products are cooled down and stored.

Off-site units and utility supplies are very reliable and contribute to the fact that unexpected shutdowns are infrequent and turn-around cycles are extended beyond what is typical for CSFR.

Irregular crude supply was the major problem experienced in the last year.

3.4.4 Impact of Changing Crudes

The refinery has no practical experience with processing different crudes, however small amounts of different crudes have been added and diluted in the Russian oil. Over the last few months the sulfur content of the Russian crude (1.8-1.9 wt%) has increased. This higher sulfur content has increased the sulfur in distillates and residual products. The major problem with the fuel oil quality, especially with the heavy fuel oil that has more than 3 wt% sulfur, is that it exceeds specifications. The refinery is very vulnerable because it has no vacuum distillation or residue processing capabilities.

Due to the lack of experience with other crudes, suitable simulation software could be used to help predict process conditions and identify equipment bottlenecks caused by the new feedstock. Although some potential crudes have been selected and analyzed using refinery simulation software, additional sophisticated simulation software is required to study frequent changes in the crude supply.

Since there is no direct experience with processing different crude oil, it may be possible to set some limits within the mixed or alternative crude that will obviate negative consequences for the refinery, but these limits are not yet proven or defined.

3.4.5 Impact of Product Market Changes

Refinery production is preferably oriented to the domestic market. In the past, some excess products have been exported. Recently, due to crude oil reductions, some products (gasoline, for example) have been imported. In the near future, it is reasonable to expect stronger competition, even in the domestic market, for at least some products. This means that the refinery should take precautions in order to achieve a profit at competitive prices. The Kaucuk Refinery has the advantage of integrated, economical production and its proximity to a major market (Prague). This advantage will be more valuable after down-stream units for atmospheric residue processing are completed.

3.4.6 Impact of Legislation and Social Changes

The subject of legislation and social changes toward a market oriented economy is expected to profoundly change the mode of operation for the refinery. The most important step, the privatization of the company, is under evaluation.

The economic impact of free market conditions will result in more careful processing and quality improvements. Environmental restrictions (lead and benzene content in gasoline, SOx, NOx emissions, wastewater quality, etc.) may require additional refinery equipment modifications. Similarly, crude oil changes and crude oil pricing may also require equipment modifications. The most crucial problem facing the refinery is to find an economical way to process atmospheric residue.

Each of the above factors affect the refinery and have to be evaluated soon.

3.5 Environmental Considerations

3.5.1 Quality of Local Environment

Environmental restrictions (lead and benzene in gasoline, SOx and NOx emissions and wastewater quality) may require modifications to refinery equipment to amplify the present product slate.

The liquid wastes from the refinery appear to meet the current regulations and standards. During 1990, treated wastewater was continuously sent to the Vltava River. There are no apparent groundwater problems. Currently, the refinery is meeting the local air pollution control regulations. As the national policy for use of high sulfur coal and the release of NOx is established, the refinery will have to upgrade its control systems.

Solid wastes include ashes from the rotary kiln incinerator and the brown coal fired boilers. These ashes are combined and deposited at an approved offsite landfill.

3.5.2 Current Emissions Control

The refinery has a typical wastewater treatment plant, including separators, flocculation chemical feed system, and biological treatment. The oil losses at the API separator are well controlled. The treated water discharged to the river meets the current regulatory levels in terms of BOD, COD, chlorides, sulfates, oil (extract) and suspended solids.

The power plant boilers are burning brown coal, with over 1 wt% sulfur and high ash content. The flue gas passes through the electrostatic precipitators (ESP). There is no SOx or NOx control. The boilers emit 18000 tonnes of SO_2/year. The Claus sulfur plant has an efficiency of about 95%, and about 640 tonnes/year sulfur is emitted with the tail gas.

The solid wastes from the various water treatment plants consist of API sludge, water softener and waste activated sludge. These solids, along with the storage tank bottom sludge, are incinerated in a rotary kiln. Other solid wastes, such as scrap plastics, fibers, papers, etc., are also incinerated. The bottom ash from the incinerators is combined with the ash from the boilers and transported to a landfill lined with impervious material.

3.6 Refinery Specific Potential and Opportunities for Improvement

Computer software and hardware

Kaucuk has personal computers (PC's) capable of running simulation programs. The computers can also run LP model software.

Kaucuk could also use a PC based maintenance planning and spare parts inventory program.

Efficiency of furnaces

The crude and reformer heaters are operating below 80% combustion efficiency. Installation of air preheaters and automatic control of combustion air should improve the efficiency to 90+%.

Reformer feed/effluent exchanger

Replacing existing shell and tube exchangers with a single vertical shell and tube exchanger will improve the efficiency and capacity of the reformer unit.

In-line gasoline blending

An octane analysis and control system to optimize octane blending calculations is recommended. The system could achieve continuous blending within 0.1 octane.

Secondary sealing of tanks

Secondary sealing of floating roof type tanks will save products lost to the atmosphere and reduce hydrocarbon emissions.

Steam condensate return to the boiler

Currently, only part of the steam condensate from the process units is returned to the boiler. A proper steam trap selection and maintenance program along with a condensate return and polishing system will improve the efficiency of the steam system.

Bottoms processing

Kaucuk does not have any bottoms processing, i.e., atmospheric residue is not processed. On the other hand, residue is sold as fuel oil (with about 2.5 wt% sulfur).

To integrate this refinery, it is recommended that one of the following options be considered:

1) Add a vacuum unit and hydroprocess the vacuum gas oils before charging into an FCC unit. Increase the capacities of the naphtha hydrotreater and reformer. Consider a CCR. Also, increase the capacity of the diesel hydrotreater. Bottoms from the vacuum unit could either be converted into bitumen, or partially oxidized for producing hydrogen or methanol.

2) The bottoms from the crude unit could be hydrodesulfurized directly and demetalized before being charged into an FCC/RCC unit. This option does not require a vacuum unit. However, other units, mentioned in option (1), will have to be revamped or added.

3) Add a vacuum unit and a hydrocracker. Increase the capacities of the reformer and hydrotreaters. Add a hydrogen plant based on natural gas or vacuum bottoms, or convert vacuum bottoms to bitumen.

4) Add thermal cracking to either option 1) or 3) above.

5) The bottoms from the vacuum unit could also be fired in the boilers or furnaces. However, this will require flue gas desulfurization.

Reformulation of gasoline

Currently, the gasolines produced contain less than 0.15 g TEL/liter. Eventually, the lead will be phased out and the benzene content will be reduced. In order to accomplish this, Kaucuk will need a high octane reformer and maybe a combination of isomerization and alkylation units to support the MTBE unit.

Environmental impact reduction

To control air pollution due to SOx, NOx and fly ash, Kaucuk will need:

1) Tail gas treatment units for the Claus sulfur recovery plant
2) Filters (better than ESP) for fly ash control
3) Flue gas desulfurization units
4) Better burners for NOx control

New pipeline

A major crude oil supply development was a decision to link the Chempetrol and Kaucuk refineries with Ingolstadt in Germany and the TAL oil pipeline.

3.7 Refinery Specific Problems and Trends

A major problem is the need for the refinery to adapt to competitive markets and changing social and economic conditions. Specific problems and concerns involved in adapting to these changing conditions are constantly being sought. Many of these problems and possible solutions are discussed in Section 3.6. Further detailed feasibility evaluations are needed. Priorities will have to be established based on a consideration of the financial possibilities.

3.8 Methodology of Data Collection

A questionnaire, completed by refinery personnel, furnished the basis for most of the data in this report. The rest was obtained by the Davy McKee team during a site visit to the refinery.

3.9 Evaluation of Results Achieved by / for Data Base

Data from the questionnaire and the site visit to the refinery are the subject of a separate report and have been applied to the formation of a computerized data base.

3.10 Supporting Plant Data

Product specifications and properties are indicated in the following tables:

C.3.10.1	LPG (LIQUEFIED PETROLEUM GASES)
C.3.10.2	GASOLINES
C.3.10.3	NAPHTHA FOR STEAM CRACKING
C.3.10.4	JET FUELS
C.3.10.5	DIESEL FUELS
C.3.10.6	FUEL OILS

Table C.3.10.1 - LPG (LIQUEFIED PETROLEUM GASES)

Component	Propane-Butane Mixture		n-Butane	i-Butane
	Summer	Winter		
C_2 + inerts % volume	7	7	5	-
C_3 min. % volume	30	55	max. 6	-
C_4 % volume	30 - 60	15 - 42	min. 90	-
i-C_4 % volume	-	-	-	min. 96
C_5 max. % volume	3	2	5	(C_3+C_5) max. at 4
H_2S max. ppm	0.2	0.2	0.2	-
Total sulfur max. ppm	200	200	200	2
Olefin content % volume	-	-	-	max. 0.05

Table C.3.10.2 - GASOLINES

GRADE	91C	95C
Density at 20 °C kg/cubic meters	710 - 750	710 - 750
Octane No Research	91	96
Octane No Motor	82	85
Lead Content max. g Pb/c	0.15	0.15
Distillation:		
10% at °C max. summer	65	65
winter	60	-
50% at °C summer	95 - 115	80 - 115
winter	75 - 110	75 - 110
90% at °C (max.)	180	180
EP °C (max.)	215	215
Distil. resid (max.) % vol.	2	2
RVP kPa summer	40 - 70	40 - 80
winter	50 - 90	-
Sulfur content (max.) %wt	0.05	0.05
Benzene content (max.) %wt	5	-
MTBE content (max.) %wt	10	10

Table C.3.10.3 - NAPHTHA FOR STEAM CRACKING

Density at 15 °C kg/cubic meters	650 - 710
Lead content max. ppb	50
Distillation	
IBP min. °C	35
50% vol. max. °C	85
EP max. °C	130
Sulfur content max. ppm	400
Aromatics content max. %wt	7
Olefin content max. %wt	1

Table C.3.10.4 - JET FUELS

Property	Value
Density at 20 °C kg/cubic meters (min.)	775
Distillation:	
IBP min. °C	135
10% max. °C	185
50% max. °C	220
90% max. °C	260
95% °C	-
98% max. °C	275
EP °C	-
Distill. residue % vol.	2.01
Viscosity at 20 °C mm^2/sec min	1.3
Viscosity at -40 °C mm^2/sec max	10.0
Pour Point °C	-60
Flash point P-M °C min.	38
Acid No. mg KOH/100 ml	0.4 - 0.7
Iodine No g/100 g	0.5
Aromatics content max. % wt.	20
Sulfur content max. % wt.	0.1
Sulfur mercaptans max. % wt.	0.001
Doctor Test	negative
Smoke Point min., mm	25
Calorific value kJ/kg	42 800

Table C.3.10.5 - DIESEL FUELS

Property	NM-4B	NM-22B	NM-30B
Density at 20 C kg/cubic meters	810 - 850	850 - 835	800 - 830
Cetane No min.	45	42	40
Distillation			
IBP °C	-	-	-
to 170 °C max. vol%	15	15	15
to 350 °C min. vol%	90	90	-
to 370 °C min. vol%	97	97	-
Viscosity at 20 °C mm^2/sec	2.5 - 6.0	2.5 - 6.0	2.3 - 5.0
Cloud point max. °C	-4	-22	-30
Flash point P-M °C	60	56	56
Sulfur max. % wt.	0.15	0.15	0.15
Acid No. mg KOH/g	0.1	0.1	0.1
Calorific value kJ/kg	42 500	-	-

Table C.3.10.6 - FUEL OILS

Property		Light	Heavy
Density at 20 °C kg/m^3		900	960
Viscosity at 40 °C mm^2/sec		max. 18	-
at 100 °C mm^2/sec		-	max. 57
Flash point min. °C		66	140
Pour Point °C	summer	+10	+40
	winter	-5	-
Sulfur content max. % wt.		2	3
Water content max. % wt.		0.5	1.0

C. INDIVIDUAL REFINERY DATA

4. KORAMO REFINERY WORKS - KOLIN, CSFR

4.1 Summary Description of Refinery

This is a very small refinery, located some 60 kilometers from Prague at Kolin. It primarily produces lubricating oils for the domestic market and exportation. The atmospheric and two vacuum towers provide a portion of the feed for the lube plant. The rest comes as partially processed petroleum products having defined, agreed upon properties from Chemopetrol by railroad.

The refinery address is:

Koramo, S.P.
280 70 Kolin
CSFR

Telephone:	42 321 515
Telefax:	42 321 255 05
Telex:	0134201
Contact:	Ing. Vilem Gruml Manager Marketing and Development

The rated capacity of the refinery is 200 000 tonnes/y of throughput. Figure 6 shows the processing units in the refinery. A material balance of inputs and products is presented in Table C.4.1.1 and a list of products, showing international equivalents, is shown in Table C.4.10.2.

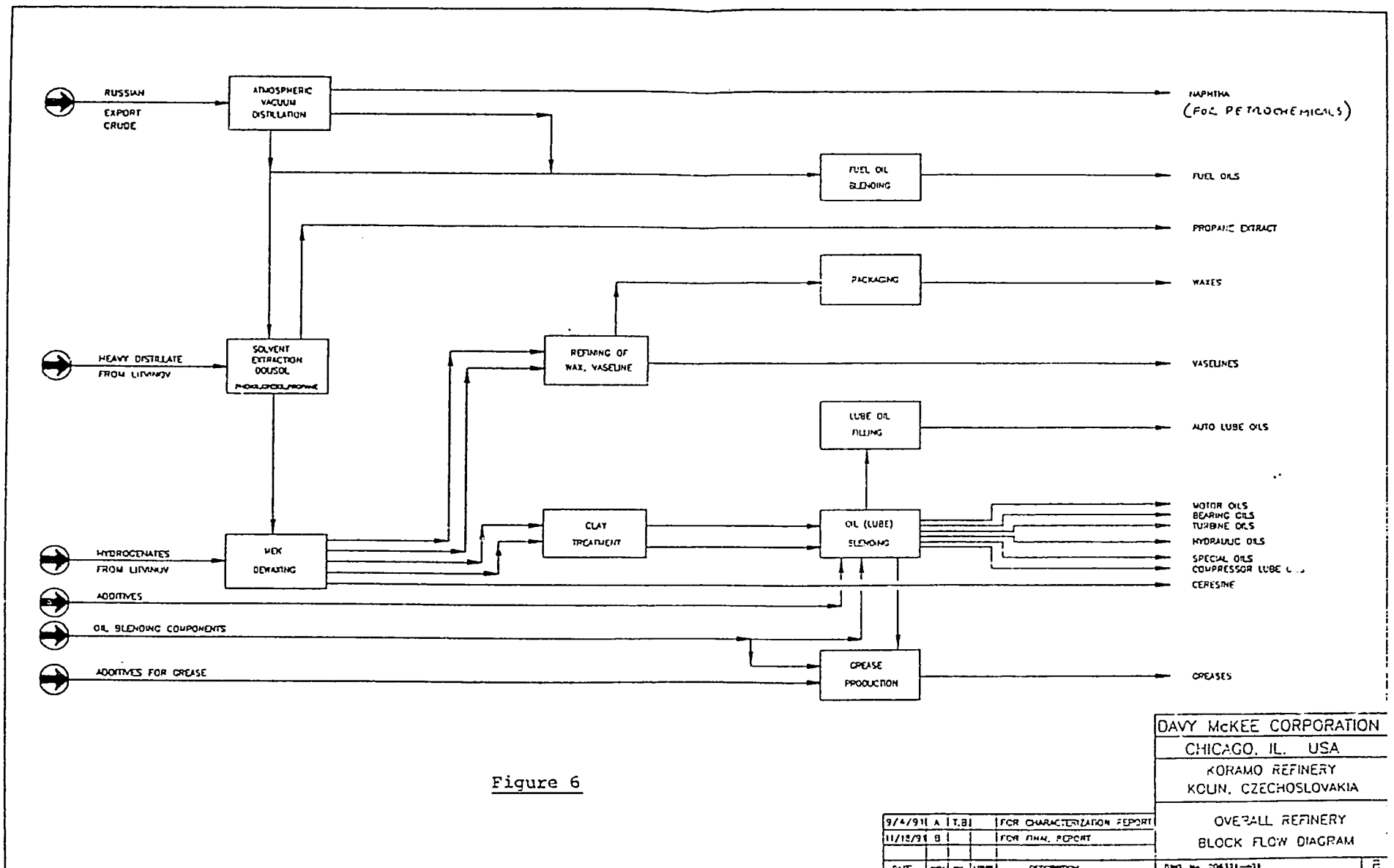
RUSSIAN
EXPORT
CRUDE
ATMOSPHERIC
VACUUM
DISTILLATION
NAPHTHA
(FOR PETROCHEMICALS)
FUEL OIL
BLENDING
FUEL OILS
PROPANE EXTRACT
PACKAGING
WAXES
HEAVY DISTILLATE
FROM LITVINOV
SOLVENT
EXTRACTION
DOUSOL
REFINING OF
WAX, VASELINE
VASELINES
LUBE OIL
FILLING
AUTO LUBE OILS
HYDROGENATES
FROM LITVINOV
MEK
DEWAXING
CLAY
TREATMENT
OIL (LUBE)
BLENDING
MOTOR OILS
BEARING OILS
TURBINE OILS
HYDRAULIC OILS
SPECIAL OILS
COMPRESSOR LUBE
CERESINE
ADDITIVES
OIL BLENDING COMPONENTS
ADDITIVES FOR GREASE
GREASE
PRODUCTION
GREASES
DAVY McKEE CORPORATION
CHICAGO, IL. USA
KORAMO REFINERY
KOLIN, CZECHOSLOVAKIA
OVERALL REFINERY
BLOCK FLOW DIAGRAM
9/4/91 A T.B. FOR CHARACTERIZATION REPORT
11/15/91 B FOR FINAL REPORT
DATE REV BY APPR DESCRIPTION

Figure 6

Table C.4.1.1 - MATERIAL BALANCE OF RECENT OPERATIONS

Inputs	tonnes/year	
Crude oil from USSR	150 000	
Feedstock from Chemopetrol	120 000	
Other feedstocks and additives	45 000	
Total Inputs	315 000	

Outputs	tonnes/year	% of CSFR market
Lube oils	100 000	30
Engine oils	40 000	25
Hydraulic oils	30 000	68
Turbine oils	10 000	94
Bearing oils	10 000	24
Special oils	10 000	10
Wax, ceresine, vaseline	12 000	90
Greases	3 000	30
Fuel oils	70 000	2
Naphtha for Petrolchemicals	30 000	1
Total Outputs[1]	315 000	

[1]No losses were reported.

Table C.4.1.2 - UNIT CAPACITIES

Unit Capacities	tonnes/y
Atmospheric and vacuum crude distillation	250 000
Solvent extraction (Duosol)	80 000
Solvent dewaxing/MEK	120 000
Clay treatment	120 000
Blending of lube oils	120 000
Bottle and tin filling, packing	10 000
Wax and vaseline clay's treating	12 000
Wax chilling and packing	12 000
Grease plant	4 000
Fuel oil blending	70 000

4.2 Utilities, Services, Offsites

Water

The fresh water supply, 100 cubic meters/hour, comes from artisan wells. Wastewater is discharged into the nearby Labe River. It is understood that the effluent does not currently meet all the environmental standards and biological treatment is being added.

Electric power

The plant powerhouse uses natural gas for fuel and produces 1 MW of power.

Steam

The powerhouse can produce, by letdown turbines, as much as 550 000 tonnes/year of steam.

Process heaters

Fired heaters are all equipped with combination type burners: natural gas and fuel oil.

4.3 Chemicals and Catalysts Use

Phenol, cresol, methylethylketone (MEK), clay and lube oil additives are imported. No catalytic processes are employed.

4.4 Previous 12-month Operating History

150 000 tonnes of crude oil was processed in 1990, and the refinery operated at approximately 60% of capacity.

4.4.1 Recent Modifications

Additional effluent treatment is being installed including biological treatment ponds. Additional equipment to further distill the hydrocracked material received from Chemopetrol is planned.

4.4.2 Crude Oil Supply

The crude supply is mostly from the USSR, but the pipeline may contain other crudes in small amounts. Hydrocracked lube distillates are received by tankcar from Chemopetrol.

4.4.3 Operating Experiences

During 1990, the plant operated at 60% of its capacity due to reduced feedstock supply.

4.4.4 Impact of Crude Oil Changes

Based on current planning, in the future, this refinery may no longer receive or process crude oils. The waste lube oils may be treated along with hydrotreated material received from Chemopetrol.

4.4.5 Impact of Product Market Changes

Koramo plans to modernize the blending and packaging plant and install additional equipment to bring its products more in line with international standards. The refinery already manufactures some materials that meet the standards of major companies, including Esso, Shell, Mobil and others. Planned improvements are directionally correct. Whether the refinery can be competitive is yet to be determined.

4.4.6 Impact of Legislation and Social Changes

Pressure from a competitive marketplace may result in changes in product slate and reduction in refinery staff. In the future, stricter environmental regulations may lead to modifications.

4.5 Environmental Considerations

It appears that the refinery is not meeting the current environmental regulations in terms of treated wastewater. A biological treatment system is planned to meet these requirements.

4.6 Refinery Specific Potential and Opportunities for Improvement

The refinery staff would like to accomplish the following:

1) Modernize the blending and packaging plant.
2) Add a waste lube oil refining facility.
3) Improve the quality of hydrogenates received from Chemopetrol prior to using them at Koramo. This can be achieved by redistilling.
4) Add a biological treatment system in the wastewater treatment plant.

4.7 Refinery Specific Problems and Trends

No refinery specific problems or trends were noticed or recognized.

4.8 Methodology of Data Collection

The Davy McKee (DMC) questionnaire was sent to the refinery in May 1991. During the early part of June, the DMC team met with the refinery manager to review the results of the questionnaire.

4.9 Evaluation of Results Achieved by/for the Data Base

The data collected through the questionnaire and personal meeting were included in the computerized data base, and is the subject of a separate report.

4.10 Supporting Plant Data

The specifications for various products from KORAMO are indicated in the following tables:

C.4.10.1	ASSORTED PRODUCTS FROM KORAMO
C.4.10.2	HYDRAULIC OILS
C.4.10.3	TURBINE OILS
C.4.10.4	COLD SERVICE LUBRICATING OILS
C.4.10.5	ENGINE OILS
C.4.10.6	WAXES AND VASELINES
C.4.10.7	LUBRICATING GREASES

Table C.4.10.1 - ASSORTED PRODUCTS FROM KORAMO

LUBRICATING OILS			
Hydraulic Oils			
OH-HM	32* 37* 46 68 100*	Shell TELLUS Oils	32 37 46 68 100
OH-HV	32* 46 68*	Shell TELLUS Oils T	32 46 68
Turbine Oils			
OT-TB	32 46 68*	Shell TURBO Oils T	32 46 68
Refrigerator Oils			
ONF	46 68	Shell CLAVUS Oils G	46 68
Base Oils			
SAE 10 (W)/80 SAE 10 (W)/105 SAE 20/90 SAE 50/87			
Engine Oils			
Mogul SUPER SAE	15 W/30 (SD/CB) 15 W/40 (SD/CB) 15 W/50 (SD/CB)	Shell X-100 Motor Oils	15 W/30 15 W/40 15 W/50
Mogul SUPER Stabil SAE 15 W/40 (SF/CC)		Shell SUPER PLUS Motor Oil Castrol GTX Mobil Oil SUPER	15 W/40 15 W/40 15 W/40
SAE 15 W/40 - G (SG/CD)*		Shell HELIX Motor Oil Castrol GTX - 3	15 W/40 15 W/40
SAE 15 W/40 - D(SF/CE)* (10 W/40)		Shell RIMULA X Oil	15 W/40

Table C.4.10.1 (cont'd)

PARAFFIN WAXES, CERESINE, VASELINES	
Paraffin R 50/54 Paraffin R 58/62 Ceresine Z 60/65 Yellow pharmaceutical vaseline Contact vaseline	(1)
LUBRICATING GREASES	
Automotive Greases	
PM - LA 2	Mobilgrease MP
Industrial Greases	
PM - LV 2-3 PM - LV 2 EP PM - Molyka G	Mobilux 2,3 Mobilux EP 2

(1) Koramo plans to manufacture these oils after 1992.

Table C.4.10.2 - HYDRAULIC OILS

Property	Type			
	OH-HM 32	OH-HM 46	OH-HM 68	OH-HM 100
ISO viscosity grade	32	46	68	100
Kinematic Viscosity at 40 °C (mm^2/sec)	28.8 - 35.2	41.4 - 50.6	61.2 - 74.8	90 - 110
Dynamic Viscosity at -10 °C (MPa/sec)	-	-	2500	-
at -20 °C	2500	5000	-	-
Viscosity Index min.	105	105	105	105
Pour Point (°C) max	-40	-30	-28	-24
Flash Point (°C) min.	-	190	200	230
Deemulsibility after 40 minutes (cm^3) min.	40-37-3	40-37-3	40-37-3	40-37-3
Foam tendency/stability (max) at 25°C (cm^3)	40/0	40/0	40/0	40/0
at 95°C (cm^3)	40/0	40/0	40/0	40/0
at 25°C after 95°C (cm^3)	30/0	30/0	30/0	30/0

Table C.4.10.3 - TURBINE OILS

Property	Type		
	TB-32	TB-46	TB-68
ISO Viscosity grade	32	46	68
Kinematic Viscosity at 40°C (mm^2/sec)	28.8 - 35.2	41.4 - 50.6	61.2 - 74.8
Viscosity Index min.	90	90	95
Pour Point (°C) max.	-10	-8	-12
Flash Point (°C) min.	180	185	200
Deemulsification Number max	150	150	150

Table C.4.10.4 - COLD SERVICE LUBRICATING OILS

Property	Type	
	ONF-46	ONF-68
ISO Viscosity Grade	46	68
Kinematic Viscosity at 40°C (mm^2/sec)	36	52
Viscosity Index min.	85	90
Pour Point (°C) max.	-35	-35
Flash Point (°C) min.	180	195
Floc forming tendency (°C) max.	-35	-35
Phillip test / 96 hour	pass	pass
Foam tendency/stability (cm^3) max. at 25 °C	100/0	100/0
at 95 °C	50/0	50/0
at 25°C after 95°C	100/0	100/0

Table C.4.10.5 - ENGINE OILS

Property	Type		
	SAE 15W/30	SAE 15/40	SAE 15W/50
Kinematic viscosity at 100 °C (mm^2/sec)	min 11.0	min 13.8	16.5 - 17.5
Dynamic viscosity at -15 °C (MPa/sec)	max 3 500	max 3 500	max 3 500
Viscosity index	min 140	min 150	min 160
Pour point (°C)	max -30	max -30	max -30
Flash point (°C)	min 210	min 210	min 210
Color ISO	max 4.5	max 4.5	max 4.5
TBN (mg KOH / g)	min 4.0	min 4.0	min 4.0
HTHSV (150 °C,10^6/sec) (MPa/sec)	min 3.5	min 3.5	min 3.5
Noack volatility (wt%)	max 15	max 15	max 15

Table C.4.10.6 - WAXES AND VASELINES

Property	Type				
	Paraffin 50 / 54	Paraffin 58 / 62	Ceresine 65 / 70	Yellow Pharmaceutical Vaseline	Contact Vaseline
Congealing Point °C	50 / 54	58 / 62	65 / 70	37 - 56	-
Dyn. Viscosity at 60°C MPa/min	-	-	-	16	-
Oil Content wt% max	1.8	1.8	-	-	-
Mechanic Impurities wt% max	0.005	0.005	0.02	-	-
Sulfated Ash wt%	-	-	-	0.1	-
Ash Content wt% max	0.02	0.02	0.02	-	0.2
Drop Point °C min. 50	-	-	-	-	50
Penetration at 25°C 10 cm^{-1} max	-	-	30	-	240-300
Total Acid Number mg KOH /g max	-	-	-	-	0.05

Table C.4.10.7 - LUBRICATING GREASES

Property	Type			
	LA 2 Grease	LV 2-3 Grease	LV 2-EP Grease	Molyka G Grease
Dropping Point (ASTM D 566), °C	min 180	min 185	min 185	min 170
Penetration, worked at 25 °C (ASTM D 217)	250 - 290	230 - 270	240 - 280	-
Dynamic anti-rust test (DIN 51 802)	0.0 - 0.1	0.0	0.0	-
Extreme-pressure properties (ASTM D 2596), weld load, kg	min 254	-	-	-
Oxidation stability at 100 °C/100 h, ΔMPa (ASTM 1264)	max 0.04	-	max 0.05	-
Water Washout test/80 °C (ASTM 1264), %	max 15	-	-	-
Base oil viscosity at 100 °C, mm^2/sec	ca 12	-	-	-
SHELL ROLL Stability test, change of penetration (ASTM D 1403), %	-	max 20	max 15	-
Base oil viscosity at 40 °C, mm^2/sec	-	ca 50	ca 50	-
NLGI consistency number	-	-	-	2-3
Solid contents of lubricant, %	-	-	-	6

C. INDIVIDUAL REFINERY DATA

5. PARAMO REFINERY WORKS - PARDUBICE, CSFR

5.1 Summary Description of Refinery

The refinery is located in the town of Pardubice about 100 kilometers from Prague. It is about one hundred years old, but some modernization is underway. The plant specializes in the production of motor and industrial oils, plus pitch and asphalt based products. Production is based totally on processing imported crude from the USSR.

The address of the refinery is

Paramo Refinery Works
53006 Pardubice
CSFR

Telephone: 42 40 30848
Telefax: 42 40 30848
Telex: 196229

Contact: Ing. Josef Dolezal

See Block Flow Diagram, Figure 7 for the overall processing scheme for the facility. The plant has a capacity of 1.0 million tonnes/year. Table C.5.1. shows the material balance for the year 1990.

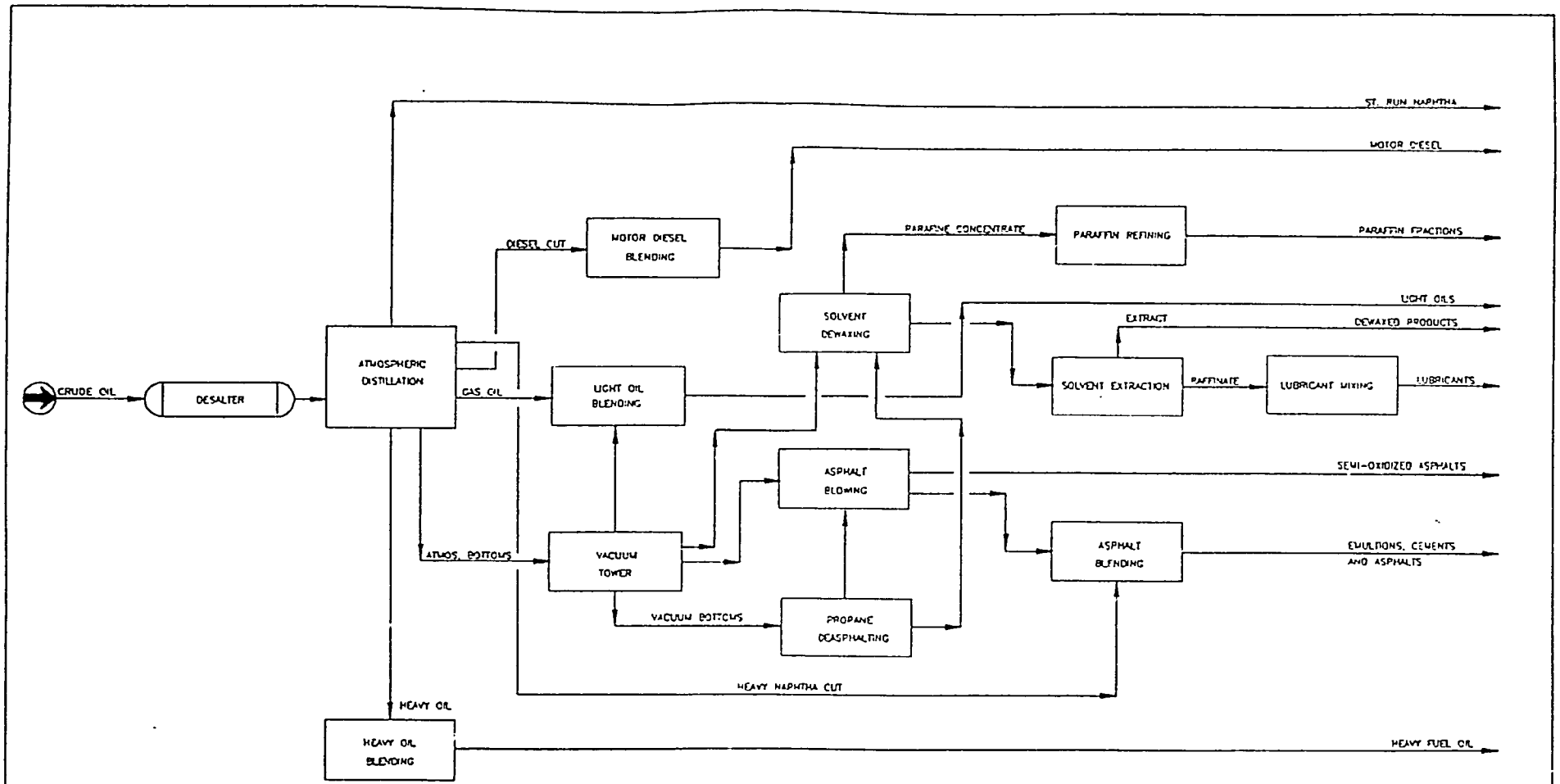

Figure 7

2/4/91	A	T.B		FOR CHARACTERIZATION REPORT	DAVY McKEE CORPORATION CHICAGO, IL. USA PARAMO S.P. REFINERY PAREDUBICE, CZECHOSLOVAKIA OVERALL REFINERY BLOCK FLOW DIAGRAM
11/18/91	B			FOR FINAL REPORT	
DATE	REV	BY	APPR	DESCRIPTION	DWG. No. 204321-501 | B

Table C.5.1 - MATERIAL BALANCE 1990

	Tonnes/year
Crude input[1]	526 000
Outputs	Tonnes/year
Diesel Fuel	1 000 000
Fuel Oils	180 000
Motor Oils	22 000
Hydraulic Oils	9 000
Industrial Oils	10 000
Asphalts (semi-brown)	40 000
Industrial Asphalts	70 000
Special Asphalts	95 000
Total[2]	526 000

(1) Crude oil and various blending stocks are included
(2) No losses were reported

Table C.5.2 - PROCESSING UNIT CAPACITIES

	Tonnes/year
Atmospheric distillation unit	1 000 000
Vacuum unit	280 000
Dewaxing	80 000
Selective refining	35 000
Propane deasphalting	35 000
Air Blowing[1]	100 000
Asphalt emulsions	30 000
Mastic asphalts	7 000
Modified asphalts	20 000

(1) This capacity is for the continuous unit. The capacity of the batch unit is 90 000 tonnes/year.

Crude distillation unit

Crude oil is desalted and fed into the atmospheric tower. A Straight run naphtha cut is exported for feed to a petrochemical plant and also sold as a solvent.

Light ends

The off gases, along with fuel oil, are used for firing the heaters.

Heavy naphtha and other side products

A heavier naphtha cut, 140 to 200 °C, is used as cutter stock for asphalt paints. two side cuts are motor diesel and gas oil.

Residual processing

Atmospheric tower residue is divided. One part is sent to the vacuum tower and the other part is used for heavy oil blending.

The vacuum tower produces as side cuts a light oil blend stock, feed for the solvent dewaxer, and material for asphalt blowing. The bottoms go to a propane deasphalting unit.

After the solvent MEK - toluene dewaxing unit, selective refining with cresol produces special lube oil components.

5.2 Utilities, Services, Offsites

Electrical power

Part of the electricity demand, 2 300 MWh/y, is produced in the plant and 1 500 MW is imported from an offsite power station.

Steam

The power plant supplies steam for the refinery.

Water supply

Industrial water consumption, 160 cubic meters/hour, is obtained from wells.

Waste treatment

The refinery is facing some ground water contamination problems.

Plant & instrument air

the air compressors are reciprocating machines with a 6500 cubic meters/hour capacity. They furnish oil free air for instrument use. The dew point is below -27°C and the discharge pressure is from 4.2 to 5.2 bar.

refrigeration systems

An ammonia system, installed in 1965, operates at -30°C. With this system the temperatures of process streams can be reduced to -15°C.

Inert gas

Nitrogen is obtained from an oxygen separation plant with a 5 730 cubic meters/hour capacity. Oxygen production is 4 800 cubic meters/hour.

5.3 Chemical and Catalyst Use

Most of the lube oil specialized solvents and lube oil additives used in product formulation are imported. No catalysts are employed.

5.4 Previous 12-month Operating History

The plant was not in operation during the survey. During 1990, the refinery was operating at about 53% of capacity due to reduced feedstock supply.

5.4.1 Recent Modifications

The wastewater treatment unit is being modernized with the installation of a dissolved air flotation unit (DAF) following the oil / water separators.

The instrumentation is currently being upgraded.

5.4.2 Crude Oil Supply

The crude oil supply has been Russian Export Blend. The properties of the crude oil can in found in Section D of this report.

5.4.3 Operating Experiences

During 1990, the plant operated at about 50% of capacity due to a lack of crude oil.

5.4.4 Impact of Crude Oil Changes

The refinery was designed to operate on only one type of crude oil. The impact of crude oil changes will have to be studied.

5.4.5 Impact of Product Market Changes

With the development of a free market economy in the CSFR, most products will have to compete with imports.

5.4.6 Impact of Legislation and Social Changes

The pressure from the competitive market may result in changes in product slate and reduction in refinery staff. stricter environmental regulations will require additional equipment.

5.5 Environmental Considerations

5.5.1 Quality of Local Environment

The refinery appears to be meeting current environmental regulations, although some groundwater contamination exists.

5.5.2 Current Emissions Control

5.6 Refinery Specific Potential and Opportunities for Improvement

Optimization studies are underway to minimize energy consumption in crude/vacuum units.

5.7 Refinery Specific Problems and Trends

No specific problems or trends were noticed.

5.8 Methodology of Data Collection

The Davy McKee (DMC) questionnaire was sent to the refinery in May 1991. during the early part of june, the DMC team met with the refinery manager to review the results of the questionnaire.

5.9 Evaluation of Results Achieved by/for the Data Base

The data collected through the questionnaire and personnel meeting was included in the computerized data base.

5.10 Supporting Plant Data

The specifications of various products are indicated in the following tables:

C.5.10.1 HYDRAULIC OILS
C.5.10.2 ENGINE LUBE OILS

Table C.5.10.1 - HYDRAULIC OILS

Property	Type		
	OH-HV 32	OH-HV	OH-HV 68
ISO viscosity grade	32	46	68
Kinematic viscosity (mm^2/sec) at 40 °C	28.8 - 35.2	41.4 - 50.6	61.2 - 74.8
Dynamic viscosity (MPa/sec) at -10 °C	-	-	-
at -20 °C	1 360	3 300	-
Viscosity index min	165	165	165
Pour point (°C) max	-40	-36	-36
Flash point (°C) min	165	180	200
Deemulsibility after 40 minutes (cm^3) min	40-37-3	40-37-3	40-37-3
Foam tendency/stability (max) at 25 °C (cm^3)	50/0	30/0	30/0
at 95 °C (cm^3)	50/0	30/0	30/0
at 25 °C after 95 °C (cm^3)	50/0	30/0	30/0

Table C.5.10.2 - ENGINE LUBE OILS

Property	Type	
	M6ADS III	M7ADS III
Viscosity at 100 oC (mm2/sec)	12.5 - 14.5	14.5 - 15.7
Viscosity index	90	125
Flash point (oC)	224	210
Pour point (oC)	-25	-30
TBN (mg KOH/g)	12	10
Ash content (wt%)	min 1.4	(inf) 1.30
Water content (wt%)	0	0
Conradson-Ash (wt%)	0.8	0.8

C. INDIVIDUAL REFINERY DATA

6. SLOVNAFT REFINERY AND PETROCHEMICAL COMPANY - BRATISLAVA, CSFR

Address:

Slovnaft s.p. Bratislava
Vlcie Hrdlo
82412 Bratislava
CSFR

Telephone: (42-7) 283 635
Telefax: (42-7) 246 829

Contact: Mr. Boris Nikolov

6.1 Summary Description of Refinery

Slovnaft s.p. Bratislava is a refinery and petrochemical complex. For this characterization effort, only the refinery was selected, although it is closely integrated with the rest of the complex. The refinery is located adjacent to the Danube River, close to Bratislava, about 20 kilometers from the Austrian border.

The rated processing capacity of Slovnaft refinery is 6.6 million tonnes/y of the USSR export blend crude oil. Figure 8 shows the processing units in the refinery. Table C.6.1.1 indicates the various units that make up the refinery along with each unit's original start-up date and the contractor. Table C.6.1.2 lists the overall material balance for the refinery during 1990. Tables C.6.10.1 - C.6.10.10 indicate the feeds to and product slates from the refinery. Following is a description of the major process units in the refinery.

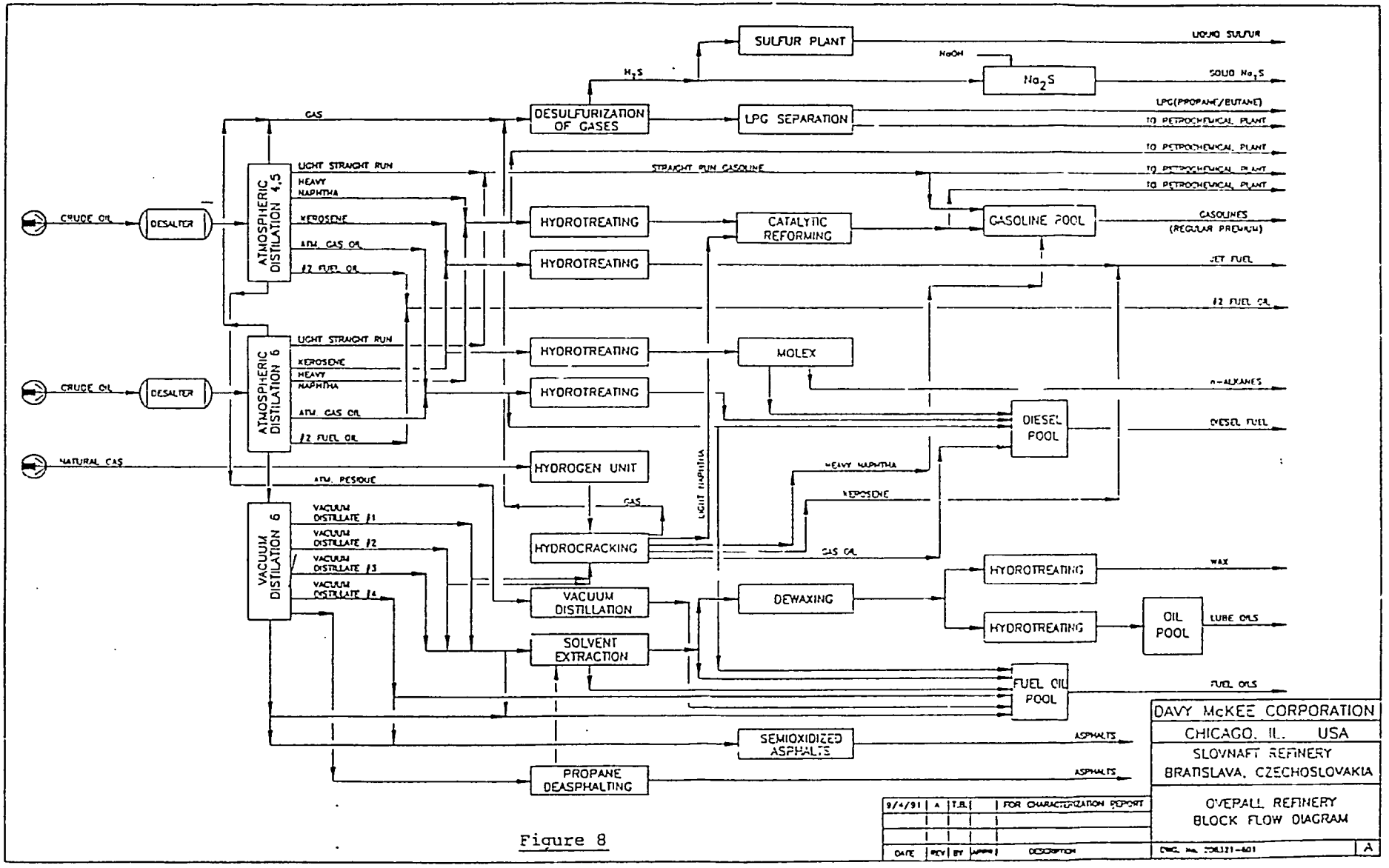
CRUDE OIL
DESALTER
CRUDE OIL
DESALTER
NATURAL GAS
ATMOSPHERIC DISTILLATION 4,5
ATMOSPHERIC DISTILLATION 6
VACUUM DISTILLATION 6
GAS
LIGHT STRAIGHT RUN
HEAVY NAPHTHA
KEROSENE
ATM. GAS OIL
#2 FUEL OIL
LIGHT STRAIGHT RUN
KEROSENE
HEAVY NAPHTHA
ATM. GAS OIL
#2 FUEL OIL
ATM. RESIDUE
VACUUM DISTILLATE #1
VACUUM DISTILLATE #2
VACUUM DISTILLATE #3
VACUUM DISTILLATE #4
DESULFURIZATION OF GASES
H_2S
SULFUR PLANT
NaOH
Na_2S
LIQUID SULFUR
SOLID Na_2S
LPG SEPARATION
LPG(PROPANE/BUTANE)
TO PETROCHEMICAL PLANT
TO PETROCHEMICAL PLANT
TO PETROCHEMICAL PLANT
TO PETROCHEMICAL PLANT
STRAIGHT RUN GASOLINE
HYDROTREATING
HYDROTREATING
HYDROTREATING
HYDROTREATING
HYDROGEN UNIT
HYDROCRACKING
VACUUM DISTILLATION
SOLVENT EXTRACTION
PROPANE DEASPHALTING
CATALYTIC REFORMING
MOLEX
DEWAXING
SEMIOXIDIZED ASPHALTS
GASOLINE POOL
DIESEL POOL
FUEL OIL POOL
OIL POOL
HYDROTREATING
HYDROTREATING
GAS
LIGHT NAPHTHA
HEAVY NAPHTHA
KEROSENE
GAS OIL
GASOLINES (REGULAR PREMIUM)
JET FUEL
#2 FUEL OIL
n-ALKANES
DIESEL FUEL
WAX
LUBE OILS
FUEL OILS
ASPHALTS
ASPHALTS
DAVY McKEE CORPORATION
CHICAGO, IL. USA
SLOVNAFT REFINERY
BRATISLAVA, CZECHOSLOVAKIA
OVERALL REFINERY BLOCK FLOW DIAGRAM
9/4/91 A T.B. FOR CHARACTERIZATION REPORT
DATE REV BY APPR DESCRIPTION
A

Figure 8

Table C.6.1.1 - REFINERY UNITS

UNIT	Start-up Date	Contractor
Atmospheric Distillation #4	1963	Kralovopolska Stojirna Brno
Atmospheric Distillation #5	1967	Kralovopolska Stojirna Brno
Atm. and Vacuum Distillation #6	1971	Kralovopolska Stojirna Brno
Catalytic Reformer #3	1969	Kralovopolska Stojirna Brno
Catalytic Reformer #4	1973	Kralovopolska Stojirna Brno
Redistillation of Heavy Gasoline	1972	Kralovopolska Stojirna Brno
Aromatic Extraction	1972	Linde, Ger.
Aromatic Solvent Plant	1963	Kralovopolska Stojirna Brno
Pyrolysis gasoline redistillation	1971	Kralovopolska Stojirna Brno
Hydrotreater #1 Gas Oil	1963	Kralovopolska Stojirna Brno
Hydrotreater #2 Gas Oil	1964	Kralovopolska Stojirna Brno
Hydrotreater #3 Jet Fuels	1964	Kralovopolska Stojirna Brno
Hydrotreater #4 BTX Fraction	1964	Kralovopolska Stojirna Brno
Hydrotreater #5 Gas Oil	1969	Kralovopolska Stojirna Brno
Hydrotreater #6 Kerosene	1974	Kralovopolska Stojirna Brno
n-Alkanes (Molex)	1980	Chisso, Japan
Hydrocracker	1991	Snam Progetti
Gasoline and Diesel Pool	1957	Kralovopolska Stojirna Brno
Fuel Oil Pool	1957	Kralovopolska Stojirna Brno
Gas Desulfurization #1	1963	Kralovopolska Stojirna Brno
Gas Desulfurization #2	1982	Kralovopolska Stojirna Brno
LPG Plant #1	1963	Kralovopolska Stojirna Brno
LPG Plant #2	1974	Kralovopolska Stojirna Brno
Sulfur Plant	1983	Kralovopolska Stojirna Brno
Sodium Sulfide Plant	1970	Kralovopolska Stojirna Brno
Solvent Extraction #1	1961	Kralovopolska Stojirna Brno
Solvent Extraction #2	1970	Kralovopolska Stojirna Brno
Dewaxing Unit #2	1964	Kralovopolska Stojirna Brno
Dewaxing Unit #3	1989	USSR
Oil and Wax Hydrotreater	1964	Kralovopolska Stojirna Brno
Semioxidation Asphalts	1987	Slovnaft
Propane Deasphalting	1963	Kralovopolska Stojirna Brno

Crude distillation units

There are three crude oil distillation units. Each crude unit has a crude desalter that reduces the salt content to under 5 ppm to reduce corrosion of the equipment. Two of the crude units are atmospheric distillation only, while the third is a combined atmospheric/vacuum unit. The vacuum distillate constitutes the lube oil stock. There is also a vacuum tower to process the atmospheric residual (partly) from the atmospheric towers. This vacuum tower provides feed to the hydrocracking unit.

The furnaces of the atmospheric vacuum distillation unit have flue gas/combustion air heat exchangers.

Light ends processing

Sour gases from the tops of the crude towers and from the HDS units are collected and desulfurized using MEA treating. There are two lines for gas desulfurization. Sweet gas is mixed with LPG streams from the reformer units and sent to the gas separation plant. There are also two lines for gas separation. Compressed gases are washed, using a C_5 cut as an absorbing medium. Lighter components, including ethane, are separated in a gaseous form and sent to the refinery fuel gas system. Propane, butane and pentane are selectively desorbed. Individual components are then mixed to produce a controlled composition commercial product (LPG). The remainder of the recovered gases are used as feed for the steam cracker. The absorption medium is recycled.

Light and heavy naphtha processing

Naphtha is used partly as a feed to the ethylene plant and partly for gasoline production. For the gasoline production, straight run naphtha is hydrotreated and rerun to remove light ends. Bottoms product from this rerun column is sent to the reformer unit to increase the octane number. Liquid product from the reformer is the high octane component of the gasoline pool. Two principle grades of gasoline are produced: a 91 octane grade leaded with 0.15 cubic centimeters TEL/liter and a 95 octane grade, also leaded, with 0.15 cubic centimeters TEL/liter. A small amount of 95 octane lead free gasoline is also produced. The quality of the gasoline is indicated in Table 6.10.6.

Distillate processing

Kerosene and gas oil are hydrotreated to remove sulfur. Standard medium pressure hydrodesulfurization is used. Kerosene is used for jet fuel production and as feed to a Molex unit for the production of straight chain alkanes C_{10}'s - C_{13}'s and C_{14}'s - C_{18}'s. The kerosene remaining is blended into the diesel pool. In all cases it is possible to meet product specifications.

The quality of the diesel pool is improved by the gas oil from the hydrocracking unit, as it is practically free of sulfur.

No. 2 fuel oil is the next heavier fraction and goes off directly as product fuel oil.

Vacuum distillates

The total capacity of the vacuum distillation units is about 2.5 million tonnes/y of atmospheric bottoms. The average yield of vacuum residue is 42.3%. Vacuum distillates are used for lube oil production (380 300 tonnes/y), for hydrocracking and finally any remaining is sent to fuel oil blending.

Vacuum distillates from AVD-6 are the preferred feed for the lube oils production. Part of the distillates is furfural extracted to increase the viscosity index or directly dewaxed. Excess of these distillates over that needed to meet lube oil production schedules is sent to the hydrocracking unit for fuel oil production and as cutterstock in semi-blowing of bitumen. Vacuum bottoms is partly used in bitumen production and partly blended in the fuel oil pool.

Another vacuum distillation unit feeds the hydrocracking unit. That vacuum residue is handled solely by being blended in the fuel oil pool.

Lube oil processing

Vacuum distillates are extracted with furfural in rotating disc extractors, where the low viscosity index portion is dissolved. The solvent from the refined product and extract is recovered by distillation and recycled. There are two units of 70 000 tonnes/y and 200 000 tonnes/y feed capacity. The product yields vary between 50 to 60%, depending on the viscosity index desired in the product. The extract is mainly directed to fuel oil blending.

Dewaxing units

There are three dewaxing units in the refinery. No. 2 has a capacity of 120 000 tonnes/y and No. 3 has a capacity of 150 000 tonnes/y. Dewaxing unit No. 1 was permanently shut down after the startup of the No. 3 unit.

Dewaxing Unit No. 2 uses a mixture of acetone and toluene as the solvent. Ammonia is used as a cooling agent. The pour point of dewaxed oil is about -12 °C. No deoiled solid paraffins are produced.

Dewaxing Unit No. 3 was designed by and equipment supplied from the USSR. The unit was put into operation during July 1990. This unit was designed for very low pour point oil production - namely for transformer oil production. A methylethylketone (MEK) and toluene mixture is used as a solvent. Propylene is used as a cooling medium in the first stage and ethylene in the second stage of cooling. The equipment is not standardized and therefore requires a large inventory of spare parts.

The design pour point of the dewaxed oil is -45 °C. CSFR consumption of transformer oil is about 13 000 tonnes/y and there is no clear opportunity to export low pour point oils.

To run the unit for the normal lube oil production (pour point of dewaxed oil is about -15°C) causes trouble in some parts of the filtration section and in the cooling system.

Lube oil and paraffin hydrofinishing unit

After dewaxing, the oils are hydrofinished in a medium pressure process over Co - Mo catalyst. There are two lines with a total capacity of about 130 000 tonnes/y and 1 line for paraffin hydrofinishing with a capacity of about 20 000 tonnes/y.

Blending unit

Different kinds of lube oil products are blended batchwise in tanks with agitators. An adequate quantity of components and additives is mixed together and the mixture is analyzed.

Hydrogen production

Sufficient quantity of hydrogen for the hydrotreating units is produced within the refinery from the heavy naphtha reformer. There is hydrogen production within the two ethylene plants in the complex and in a natural gas steam reforming plant that produces hydrogen for the hydrocracking unit.

Sulfur recovery

Sulfur is removed from the LPG in various hydrotreating units. H_2S is burned catalytically to produce elemental sulfur in the Claus unit. There are two lines of 12 000 tonnes/y sulfur each. One of these lines has been modified to be able to burn H_2S with some NH_3 content from the hydrocracking unit. The total efficiency of the two stage Claus unit is 94 - 96% sulfur removal. The remainder of the sulfur is emitted in the tail gas.

Table C.6.1.2 - MATERIAL BALANCE 1990

INPUTS	tonnes/y	TOTAL tonnes/y
Crude Oil	6 190 472	
Imported Blending Stocks		
Naphtha from USSR	164 623	
Naphtha from other sources	13 333	
LPG from Kralupy	22 164	
Aromatics from Litvinov	1 138	
Nonparaffins from Koramo	667	
Nonparaffinic Oil from Koramo	1 503	
Mixed Xylenes from Litvinov	8 376	
	211 804	
MTBE	15 602	
TEL	207	
	15809	
TOTAL INPUTS		6 418 085
OUTPUTS		
Gaseous Products		
LPG	47 336	
Propane - Butane	1 820	
i-butane	2 931	
n-butane	1 305	
	53 392	
Regular Gasoline		
BA 91C	327 004	
Premium Gasoline		
BA 96C	159 231	
BA 95D	2 131	
	161362	
Solvents		
Nonaromatic Solvents	29 081	
Technical Naphtha	17 643	
	46 724	

Table C.6.1.2 (cont'd.)

OUTPUTS (cont'd.)	tonnes/y	TOTAL tonnes/y
Feed to the Aromatic Complex		
BTX from Refinery	174 455	
BTX from Hydrocracker	119 160	
	293 615	
Feed to the Petrochemical Complex		
Gas	130 174	
Naphtha	586 873	
	717 047	
Aviation Fuels		
PL-6	118 092	
Kerosene		
PS-2	23 891	
Diesel Fuels		
Diesel fuel	1 625 114	
Diesel EX	337	
Component for MN 35	4 797	
	1 630 248	
Heating Oils	357	
Industrial Fuels		
VOTL	322 627	
VONS PH	38 069	
VOTM	1 673 171	
Oxidized Products	138 513	
	2 172 380	
Lube Oils		
Heavy Oils + Raffinate	143 685	
Paraffins	2 667	
Greases		
Heavy Greases	8 102	
PEKOL	114	
	8 216	
Asphalt		
Primary Asphalt	32 381	
Oxidation Products + Road Asphalt	328 372	
	360 753	

Table C.6.1.2 (cont'd.)

OUTPUTS (cont'd.)	tonnes/y	TOTAL tonnes/y
Coke	0	
Sulfur Products		
Sodium Sulfide 25%	5 051	
Sodium Sulfide Scale	6 300	
Sodium Hydrosulfide	1 029	
Sulfur	8 773	
(Neglect in Balance)	21 153	
Alkanes		
n-alkanes C10 - C13	28 018	
n-alkanes C14 - C18	2 917	
	30 935	
Naphtha for Pyrolysis	41 225	
TOTAL PRODUCTS (1)		6 152 746

CLOSURE = 95.9%

Note (1) Fuel consumption and losses are not included.

6.2 Utilities, Services and Offsites

Electricity and steam generation and distribution

There are four (4) turbogenerators at Slovnaft (29 MW, 24 MW and two 25 MW machines). Steam is extracted from the turbines at 3.5 Mpa, 1.2 MPa and 0.6 MPa levels in quantities needed to supply the plant. The remaining steam is condensed through turbines to complete the steam balance.

About 50% of the power is produced inside the plant, the rest is supplemented from the national grid.

Condensate collection

Only a fraction of the steam condensate is returned to the boilers (waste heat boiler).

Fuel supply

Part of the plant fuel gas is imported as natural gas containing 96 - 98% methane. The rest of the fuel is off gases from the refinery units.

Fresh water supply

The facility obtains plant water from the Danube River. The water supply pump station is rated at 22 420 m^3/h. This supplies the once-through cooling water, makeup for the cooling towers, feedwater for the boilers and various service water uses. Drinking water is supplied by the city of Bratislava. Untreated water is used for once-through cooling water, fire water and general washdown.

Cooling water system

Cooling water is basically once-through. There are a few local cooling towers for individual units. Within the refinery, there is a forced draft cooling tower and cooling water circuit for the dewaxing units.

Crude oil receiving

Crude oil, known as Russian Export blend, is delivered by pipeline and is about 99% East Siberian in origin.

Product blending and shipping

All product blending is done in tankage. Gasoline and diesel fuels are shipped mainly by pipeline. Heavier products are shipped by railcars and trucks.

Tank farm

Crude Oil:	12 @ 20 000 cubic meters with 12 days operating capacity
Product/intermediate:	126 varying in size up to 10 000 cubic meters

The crude oil and lighter product tanks have floating roofs; others are fixed roof tanks. In the future, the plant plans to replace the crude oil storage tanks with 50 000 cubic meters tanks.

Flares

Elevated flares are used.

Fire protection

The fire protection, process water intake and wastewater are combined, therefore, the following applies to both the oil refinery and the petro-chemical complex. The refinery and petro-chemical complex has a fire protection system that consists of water ponds, pump house, Danube river water intake and a pipe distribution loop. The fire water pond serves a dual function. It is the final aerated lagoon after the activated sludge waste water treatment, as well as the fire water pond. The pond is 186 meters wide by 6 meters deep and holds approximately 117 850 cubic meters of water (18 622 000 gallons). It was reported that the system was recently upgraded.

6.3 Chemicals and Catalysts Use

The majority of catalyst usage is within the hydrotreating, hydrofinishing and reforming units. Most of the catalysts are imported.

6.4 Previous 12 Month Operating History

In 1990, the refinery was not fully loaded because it lacked crude oil, as indicated in the overall material balance information presented in Section 6.1.

6.4.1 Recent Modifications

The major factor that modified refinery production was the startup of the hydrocracking unit. Existing plants have been modified primarily to reduce energy consumption (air preheat, hot separator in HDS) and to improve product quality. Dewaxing Unit No. 3 was put into operation in the lube oil train.

Sourcing and pricing

Since 1 January 1991 a free market pricing system has been in effect. This system does not, however, apply to the refinery product prices which are still under control. Product prices have been following crude oil prices and are approaching world market prices.

6.4.2 Crude Oil Supply

Crude oil, processed in the Slovnaft Refinery during 1989 - 1990, was 99% East Siberian (USSR) and delivered via the pipeline. Less than 1.0% of other crudes were used. Delivery varied, but the average for the period was 774 tonnes/h.

In addition to the crude pipeline from the USSR, the ADRIA pipeline from the Adriatic Sea via Yugoslavia and Hungary is connected to the Russian pipeline. CSFR participated financially in the construction of this pipeline, but it has not been used by the CSFR in a very long time, and the contract has since expired. The Hungarians have similar problems with the supply of Russian crude, and have chosen to use the ADRIA pipeline for their own supply. The ADRIA Pipeline could potentially transport 3 - 4 million tonnes/y of crude to the CSFR.

Other alternatives being considered are the extension of the pipeline from the Schwechat Refinery to Slovnaft (about 60 km), and a pipeline (about 360 km) from the TAL pipeline in Germany to Litvinov and Kralupy.

Crude oil characterization / properties

The Slovnaft Refinery was designed to process Russian crude oil. Russian crude is relatively light, 32 °API gravity, and the naphtha cut has sufficient naphthenes to reform to a relatively high octane level. It is also considered to be a medium sulfur crude, 1.5 wt%, although the sulfur content has risen this year to 1.9 wt%. The Slovnaft Refinery has been designed to resist the corrosive effects of sulfur, and the plant also has the facilities to recover elemental sulfur and to produce sodium sulfide (Na_2S) as a valuable by-product. Desalters treat the incoming crude to reduce the corrosive chloride content to an acceptable level. See Sections 6.10. and D for the crude oil properties characterization curves.

API Gravity	32.1 °API
Viscosity, Cst	5.4 - 5.9 @ 50 °C
Sulfur, wt%	1.5
Watson K	11.91

6.4.3 Operating experiences

The refinery is offsite and the utility facilities experience frequent shutdowns; the on-stream factor for the year was 0.91. The operating staff is skilled and the technicians are on a good level, although compared to western practices, the refinery appears overstaffed.

There are some problems with spare parts. Some of the equipment is old and spare parts are no longer produced. Also some of the equipment has been supplied from western countries and there are problems in procuring spare parts in a timely manner.

The power station, located in the plant, supplies about 50% of the required electric power. It is backed up by the national grid. Overall, electric power is very dependable. Only two outages (both of short duration) were experienced due to power failures in 1990.

Some 760 hours (one month) of operating time were lost last year due to lack of crude supply and turnarounds. The Gulf War resulted in a sharp decline in the amount of crude available and a large price increase. This weakness is a result of being dependent on one crude source. USSR had its supply of foreign crude reduced during the war and used more of its own production internally instead of exporting it.

6.4.4 Impact of Crude Oil Changes

The refinery is designed to process mainly Russian Export Blend crude oil. The refinery is capable of producing a full product slate at its full capacity of 6.5 million tonnes/y. The refinery is flexible and has eliminated the need to import naphtha from the USSR. Materials used in the construction of the refinery are capable of handling crude oil with as much as 1.9 wt% sulfur. Slovnaft is considering future processing of crude oils from Iran, Syria and Saudi Arabia.

In the U.S., most crude units are designed to process three types of crude oils. These are light, medium and heavy, ranging in gravity from 40 - 50, 30 - 40 and 20 - 30 °API. The crude oil properties which determine the product slate are: gravity (density), characterization (UOP or Watson K) and the slope of the crude distillation curve. The gravity and slope of the crude distillation curve determine the number of products that can be obtained from a given crude. The other crude oil properties affecting the refinery configuration and design are salt, naphthenic acid, sulfur and metals (Ni + Va) content. The sulfur and sometimes naphthenic acids content affect the metallurgy of refinery equipment.

As mentioned before, Slovnaft crude units are designed to process only the Russian export crude (around 32 °API gravity). It is also apparent that, to some extent, the equipment does have additional capacity/capability.

The best way to evaluate an existing crude unit when considering a new crude oil or a blend of crude oils as a feedstock, is to simulate the unit using existing operating conditions. This is done to establish capacities, limitations and bottlenecks. Then through further simulation with a new feedstock, the operating conditions, production rates, pumparound duties, flash zone conditions, crude heater duty, crude column tray loadings and capacities of the downstream equipment are determined. All this is done by using sophisticated process simulation software and appropriate high speed computers.

6.4.5 Impact of Product Market Changes

Refinery production is oriented to the domestic market. Some excess products have been exported. Recently, due to crude oil reduction, some products (gasoline) have been imported. In the near future, it is reasonable to expect stronger competition even in the domestic market (at least with some products). For the refinery, this means that the ability to produce competitive products at competitive prices and still make a profit will become very important.

6.4.6 Impact of Legislation and Social Changes

The impact of legislation and social changes, presumably toward a market oriented system, is expected to profoundly change the mode of operation for the refinery. It is safe to predict that within the next few years, based on the present environmental restrictions in other countries, tetraethyl lead in the CSFR will no longer be acceptable as a gasoline additive and that the aromatics content in gasoline will be strictly limited. The tolerances for sulfur in the fuel oils and diesel will also be reduced and the tail gas from the Claus unit will require further treatment. This will dictate the need for other processing units at Slovnaft, such as a CCR reformer, an alkylation unit and a butane isomerization / MTBE plant to produce the present gasoline grades without the additive values of the TEL and aromatics. Each of these factors will affect the refinery and must be solved soon.

6.5 Environmental Considerations

6.5.1 Quality of Local Environment

The Slovnaft Refinery is located adjacent to Bratislava near the confluence of the Danube River and the Little Danube River. The river water receives numerous discharges of industrial waste as evidenced by the chemical and biological composition. The water must be treated before any use other than once-through cooling.

The ground water is quite high in dissolved salts (500 to 1000 ppm) which is typical for Eastern Europe. The well water is normally softened and chlorinated before use.

The topography in the area of the city and plant is flat, consisting of old flood plains of the Danube River. The land a few kilometers away from the river bed is comprised of rolling hills. The hills are 200 - 700 meters in height. This topography causes the refinery and other industries located along the river to raise air pollution levels along the flat lands following the river bed. The industries currently have no, or few, control systems for SOx, NOx, VOC's and particulate matter.

6.5.2 Current Emissions Controls

Gaseous effluents

Combustible gaseous emissions are being released to the atmosphere from storage tanks, process units (leaks), API separators and water treatment units. A major part of the gaseous emissions are flue gases from different furnaces, three incinerators, power station boilers containing SO_2, NOx, and particulate matter.

Liquid effluents

The refinery has three water discharges: two are cooling and storm water outlets to the Little Danube River. Both pass through API type oil/water separators. The third effluent is from the combined wastewater treatment plant, which is discharged to the Danube River. The design and actual quality of treated wastewater is as follows:

Table C.6.5.1 - TREATED WASTEWATER QUALITY

ITEM	DESIGN	ACTUAL
pH	6.5 - 8.5	7.98
TSS (mg/liter)	<30	15.9
BOD_5 (mg/liter)	<20	28.7
Phenol (mg/liter)	<0.1	0.054
PO^3 (mg/liter)	--	2.64
Flow (cubic meters/h)	3 600	1 350

Solid waste

Solid wastes are generated from water treatment, sludge incineration and the various processes in the form of spent catalysts, molecular sieves and drying bed materials. The spent catalysts are reprocessed to recover metal and the rest of the materials are dumped. Ash from two solid waste incinerators is dumped into a dry concrete lined pit. Ash from the multihearth incinerator is pumped to a concrete storage tank.

Sulfur management

Based on the 1990 production and Soviet crude oil analysis of 1.5 wt% sulfur, the refinery received 85 604 tonnes of sulfur. Of this amount, 11 231 tonnes (13%) were recovered in the Claus Unit, 65 365 (76%) tonnes were shipped offsite in various products and 9008 tonnes (11%) were released to the atmosphere.

Volatile organic compounds (VOC) management

The only observed VOC management program is the use of floating covers in 39 storage tanks.

Heavy metals management

The potential sources of heavy metals were: sludge materials from wastewater treatment and bottom materials from crude oil distillation. Burning or incineration of these materials produces ash or dust containing heavy metals. This ash and materials containing leachable metals are currently stored in a large concrete lined pit.

General health and safety

The major effort in general employee safety has been the emphasis on fire prevention, ventilation of confined areas before entering and teaching proper burning or cutting methods.

6.6 Refinery Specific Potential and Opportunities for Improvement

Short Term Improvements:

Steam trap maintenance and condensate return to boiler

Slovnaft has in place a program for steam trap evaluation and maintenance. They have to seriously implement the program and maximize the condensate returned to the boiler.

Computer software and hardware

Slovnaft needs a sophisticated process simulation program.

Slovnaft is in the process of acquiring PIMS, an LP model marketed by Bechtel.

Slovnaft can use a PC based maintenance planning and spare parts inventory program.

Improvement of efficiency of furnaces

For AD#4 (Atmospheric Distillation #4) and AD#5 furnaces, the calculated combustion efficiencies are around 70 - 75%. Better flue gas analysis and combustion air control, in addition to an air preheater, are recommended. Flue gas from the #6 AVD furnace contains about 8 - 9% oxygen, which is rather high.

Similarly, all furnaces in the lube oil processing plant require better flue gas analysis and air control.

Hydrodesulfurizer #6 (HDS #6)

Slovnaft plans to install a hot flash drum in HDS #6. This is a sound idea, as the hot flash drum will improve the energy efficiency.

Reformer feed / effluent exchanger

The efficiency and capacity of the reformer can be improved by replacing the existing shell and tube exchangers with a single vertical shell and tube exchanger or a welded plate type exchanger.

In-line gasoline blending

Currently, Slovnaft conducts gasoline blending operations batchwise. A more efficient in-line blending system is recommended.

In-line lube oil blending plant

Slovnaft is planning to market its products throughout Europe. The refinery will definitely need an in line lube oil blending facility.

#6 AVD (Atmospheric and Vacuum Distillation Unit)

The vacuum gas oil cuts from the vacuum unit overlap and thus are not of good quality. These cuts are the feed to the lube oil plant. It is recommended that the internals in the vacuum column be replaced with structured (Sulzer or Norton) packing. This will result in a lower pressure drop and better separation.

Amine acid gas removal

All the amine units in the refinery are operating with 15 wt% MEA solution. Today, most MEA units operate with around 30 wt% solution. However, in order to control degradation of the solution, a large activated carbon filter and reclaim unit is required. The higher solution concentration should reduce the energy consumption by one half.

Secondary sealing of tanks

The secondary sealing of floating roof type storage tanks will save products lost to the atmosphere.

Long Term Capital Improvements:

Lube oil processing

There are two very old furfural units. In most modern refineries, the furfural has been replaced with NMP. However, given the cost of importing NMP and the fact that furfural is available in-country, and the ease of operating furfural units the decision to change should be evaluated closely.

The No. 3 Dewaxing Unit was designed to produce transformer oils (w/ -45 °C pour point) for the lube oil blending. A revamped unit for base oils would result in considerably higher energy efficiency.

Sulfur plant

Slovnaft needs tail gas treatment units in the existing sulfur plant for improving efficiency to 99% and also for environmental reasons. A third sulfur plant may be needed to cover the increased capacity.

Vacuum bottoms processing

Some of the options for vacuum bottoms processing are as follows:

1) Incinerate in the boilers and treat the flue gas for SO_2 removal.

2) Thermal cracking or visbreaking.

3) Partially oxidize to produce synthesis gas which can be converted to hydrogen, methanol, ammonia or gasoline.

Gasoline reformulation

Slovnaft is negotiating an MTBE and alkylation project with OMV in Austria. The project also includes pipelines for crude oil and products.

6.7 Refinery Specific Problems and Trends

The refinery needs to adapt to competitive markets and changing social and economic conditions. Refinery management is aware of these problems and is continuously seeking solutions. Many of the specific problem areas are discussed in Section C.6.6 where possible solutions are specified. Further detailed evaluations are recommended. Priorities will have to be established based on financial realities.

6.8 Methodology of Data Collection

This report describes refinery operations and lube oil sections as of June 1991. It does not cover the petrochemical section, but details the production of raw materials employed in the petrochemical section. A questionnaire, sent to the refinery before the team's visit, furnished the basis for much of the data gathered by the Davy McKee team during their stay at the refinery.

6.9 Evaluation of Results Achieved by/for Data Base

Data gathered in the field, pertinent parts of which are the subject of a separate report, have been applied to the formation of a computerized data base.

6 10 Supporting Plant Data

Product specifications are indicated in the following tables:

C.6.10.1	LPG (LIQUIFIED PETROLEUM GASES)
C.6.10.2	GASOLINES
C.6.10.3	JET FUEL (AVIATION FUEL)
C.6.10.4	DIESEL FUEL
C.6.10.5	FUEL OIL
C.6.10.6	LUBE OIL

Table C.6.10.1 - LPG (LIQUIFIED PETROLEUM GASES)

Composition	Propane	Butane	LPG
Vapor Pressure at 100°F (MPa)	95.0	0.2	30/55
Volatile Residue (ppm)	5.0	-	7.0
Butane and Heavier (LV% - max.)	5.0	97.4	60/40
Pentane and Heavier (LV % - max.)	-	1.0	3.0
Residual Matter	moisture and higher hydrocarbons		
Corrosion, Copperstrip (max)	-	-	-
Total Sulfur (ppmw)	30.0	200.0	200.0

Table C.6.10.2 - GASOLINES

Type	91C Regular	96C Premium	95D Natural
Density @ 20°C, kg/cubic meters	736	742	748
Octane Number			
RON	91	96	95
MON	82	87	85
Distillation Volume			
10%	65	65	65
50%	115	80 - 115	110 - 115
90%	180	180	180
EP	215	215	215
Distillation Residue (wt%)	2	2	2
RVP (at 38 °C, kPa)	40 - 70	40 - 70	40 - 70
Sulfur Content (wt%)	0.01	0.01	0.01
MTBE Content (vol%)[1]	10	10	-
TEL Content (g/liter)	0.15	0.15	-

[1]MTBE is supplied by Kaucuk

Table C.6.10.3 - JET FUEL (AVIATION FUEL)

Type	
Density @ 20°C, kg/cubic meters	788
Distillation Volume IBP 10% 50% 90% EP	 135 °C 180 °C 225 °C 270 °C 280 °C
Viscosity (mm^2/s) 20 °C	2
Crystallization Point (°C)	-55
Flash Point (°C)	38
Smoke Point (mm)	23
Net Heat of Combustion (kJ/kg)	42 800
Acidity (mg KOH/100 cubic centimeters)	0.50

Table C.6.10.4 - DIESEL FUEL

Type	Winter MN 22B	Summer MN 4B
Density at 20°C (kg/cubic meters)	855 - 835	810 - 850
Distillation Volume IBP °C 50% °C EP °C	 175 - 205 - 355	 175 - 215 260 360
Viscosity @ 20°C (mm^2/sec)	2.3 - 5.0	2.3 - 5.0
Pour Point (°C)	-22	-4
Flash Point (°C)	56	60
Sulfur Content (ppmw)	0.15	0.15
Carbon Residue (wt%)	0.01	0.01
Ash (wt%)	0.01	0.01
Water and Sediment (vol%)	none	none
Cetane Number (min)	42	45
Filterability	-15	0
Acidity (mg KOH/g)	0.01	0.01

Table C.6.10.5 - FUEL OIL

Type	Heavy	Light
Gravity @ 20 °C (kg/cubic meters)	961	886
Distillation Volume % vol at 350 °C	-	20
Viscosity (mm^2/sec)	57 at 100 °C	2.5 - 12.6 at 50 °C
Flash Point (°C)	140	66
Pour Point (°C)	13	0/-5
Sulfur (wt%)	3.0	2.0
Carbon Residue (wt%) CONRADSON	15	0.5
Ash (wt%)	-	0.002

Table C.6.10.6 - TYPICAL QUALITY OF LUBE OILS PRODUCED

Type	MD Motor Oils			Motor Oils	
	M7AD SAE10W40	M3AD SAE10W30	M6AD SAE30	M6A	M9A
Viscosity at 100 °C, mm²/sec	14.5 - 17	10 - 12	12 - 13.5	10 - 12	13 - 15
Viscosity Index	170	150	90	85	80
Pour Point, °C	-30	-30	-25	-25	-10
Flash Point, °C	210	205	225	220	225
Ash, wt%	-	0.40	0.45	-	-
Color ASTM max.	4.5	2.5	6.0	6.5	8.0
Viscosity at -18 °C, MPa/sec	3 000	4 000	-	-	-
Carbon Resid. minus ash, wt% (max)	0.3	0.2	0.4	0.3	0.4
Oxidation Test (CSN 656335)	-	-	-	-	-
Increase of Viscosity at 50 °C, %	5	10	15	15	15
Increase of Carbon resid., %	0.3	0.4	0.6	0.9	1.0
Reaction of Water Extract	Neutral or Alkaline			Neutral or Alkaline	
Viscosity at 20 °C, mm²/sec	-	-	-	-	-
Viscosity at 50 °C, mm²/sec	-	-	-	-	-
Acid No., mg KOH / g	-	-	-	-	-

Table C.6.10.6. (cont)

Type	Bearing Oils					Compressor Oils		
	B1	B2	B4	B5	B7	K-8	K-12	K-18
Viscosity Index at 100 °C, mm^2/sec	-	-	-	-	-	11	15	19
Viscosity Index	-	-	-	-	-	80	80	80
Pour Point, °C	0	0	0	0	0	-12	-8	-8
Flash Point, °C	135	150	170	175	180	230	240	260
Ash, wt%	-	-	-	-	-	0.02	0.02	0.02
Color ASTM max.	-	-	-	-	-	7	8	8
Viscosity at -18 °C, MPa/sec	-	-	-	-	-	-	-	-
Carbon Resid. minus ash, wt% (max)	-	-	-	-	-	-	-	-
Oxidation Test (CSN 656335)	-	-	-	-	-	-	-	-
Increase of Viscosity at 50 °C, %	-	-	-	-	-	20	20	15
Increase of Carbon resid., %	-	-	-	-	-	-	-	-
Reaction of Water Extract	-	-	-	-	-	Neutral		
Viscosity at 20 °C, mm^2/sec	-	-	-	-	-	-	-	-
Viscosity at 50 °C, mm^2/sec	-	16-22	30-35	45-53	60-75	76	114	175
Acid No., mg KOH/g								

C. INDIVIDUAL REFINERY DATA

7. SLOVNAFT (VOJANY) - VOJANY, CSFR

Vojany is a village in Eastern Slovakia about 15 km from the Russian border. The Vojany refinery is a small plant connected by management to Slovnaft. The day-to-day operation is controlled by Slovnaft, even to the extent of crude oil supply and product distribution. The crude processing was down most of 1991.

The address of the refinery is:

Slovnaft, N.P. Bratislava
076 72 Zavod Vojany
CSFR

Telephone: 2681 - 3
Telex: 77460

Contact: Pavol Polacko

7.1 Summary Description of Refinery

In 1960 a power station was erected (2 x 200 MW) designed for using Russian coal. In 1970 the power station was expanded (Vojany II). During the construction phase, fuel for Vojany II was changed from coal to fuel oil. Since the consumption of fuel oil was quite high (1350 tonnes/day), and the crude pipeline is quite close, an atmospheric distillation unit was built to produce enough fuel for Vojany II and to cover the demand in Eastern Slovakia. The crude distillation unit (2.2 million tonnes/y of crude) was built adjacent to the power stations. The unit was placed into operation in 1974.

The refinery consists of an atmospheric tower and storage units for intermediates, end products and loading facilities. Fuel oil for Vojany II is pumped and the products are transported by railway. The distribution of products is as follows:

Customer	Product	Application
Slovnaft	LPG	Separation
Novaky	Light naphtha	Pyrolysis
Slovnaft	Heavy naphtha	Reforming
Local Consumption	Kerosene	Remixing with HDS oil (diesel quality)
Slovnaft	Gas oil	HDS treatment (to be returned to Vojany)
Local consumption	Light fuel oil	Fuel material
Vojany & Local	Heavy fuel oil	Fuel material

Besides the atmospheric tower, a unit was built to dehydrogenate n-alkanes to n-alkenes. This is a semi plant unit with a capacity of 8 000 tonnes/y. The process was developed in the Research Institute (VURUP) in Bratislava. The n-alkane feed was to be imported from Slovnaft, Bratislava from the Molex unit (UOP). The dehydrogenation unit has not been fully commissioned to date. The unit is used part time to purify n-alkanes as a solvent for a peroxide catalyst employed in high pressure polyethylene production at Slovnaft and in Russia.

Refer to Figure 9 for the overall refinery configuration. For properties and specifications of feed and products, refer to data in the Slovnaft report (Section C.6).

The overall material balance for the year 1990 is:

Input	Tonnes/y
Crude oil	574 579
Output	
Low pressure gas (used as fuel)	1 875
LPG	1 668
Light naphtha	34 651
Heavy naphtha	72 241
Kero + gas oil	44 617
Light fuel oil	56 346
Heavy fuel oil	256 160
Losses	4 201
Total output	574 579

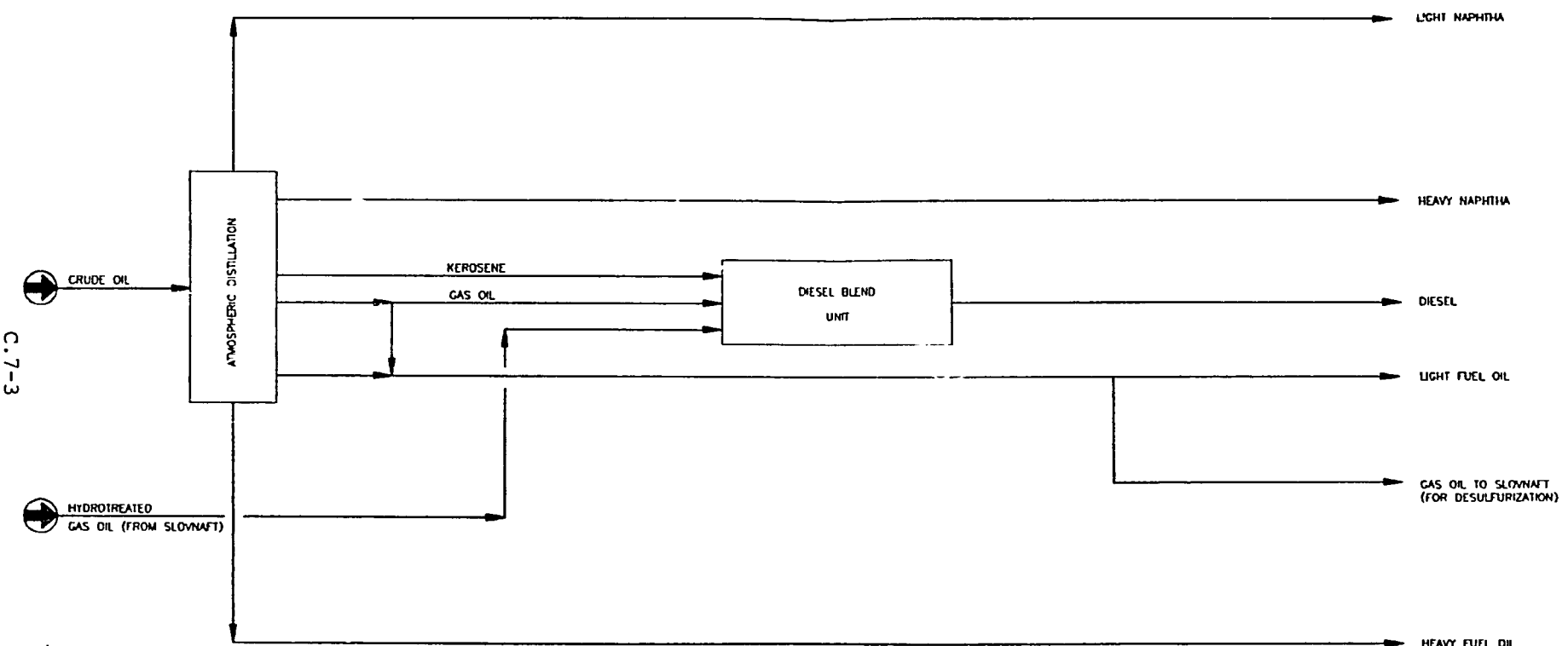

Figure 9

DATE	REV	BY	APPR	DESCRIPTION
9\3\91	A	T.B		FOR CHARACTERIZATION REPORT
11/18/91	B			FOR FINAL REPORT

DAVY McKEE CORPORATION
CHICAGO, IL. USA
VOJANY REFINERY
CZECHOSLOVAKIA

OVERALL REFINERY
BLOCK FLOW DIAGRAM

DWG. No. 206321-701 B

7.2 Utilities, Services, Offsites

Electrical power supply and distribution

Electric power to the refinery is supplied by the power plant at Vojany. During 1990, the total electric power consumption was 147 260 MJ (256.3 kJ/tonne of crude oil).

Steam generation and distribution

Steam is supplied to the refinery from the power plant at Vojany. The steam is available at two levels (1.2 and 0.6 MPa).

Total steam consumption in the refinery during 1990 was 42 861 tonnes (0.07466 tonnes/tonne of crude oil).

Cooling water system

A circulating cooling water system is used. The makeup water is supplied from the power plant.

Fuel system

Light gases and heavy fuel oil from the refinery are used as fuel. Total fuel consumption during the year 1990 was 271.4 TJ (472.4 MJ/tonne of crude oil).

Tank farm

Crude Oil	3 x 20 000 cubic meters
Light Naphtha	1 x 10 000 cubic meters
Heavy Naphtha	1 x 10 000 cubic meters
Diesel	1 x 20 000 cubic meters
Fuel Oil	1 x 60 000 cubic meters

Loading facilities

Loading facilities include an automatic computer controlled system to the rail cars.

Waste treatment

Waste water treatment includes both chemical and biological systems, with 100% spare capacity. The spare capacity was installed to treat waste water from the new dehydrogenation unit.

Incineration is used to burn storage tank bottoms.

Fire protection

A fire protection system is in place. No particular description was provided.

7.3 Chemicals and Catalysts

No catalysts are used.

7.4 Previous 12-month Operating History

The distillation unit was partly shutdown during the year due to a reduced supply of crude. The amount of crude oil processed is shown in Section 7.4.2.

7.4.1 Recent Modifications

A dehydrogenation unit is planned to be added, and represents a major modification to the refinery. In addition, this modification prompted an increase to the waste treatment facilities.

7.4.2 Crude Oil Supply

In 1990 the crude oil supply to the Vojany refinery went through drastic reductions. The refinery was shut down completely for almost four months. The following table shows the amount of crude oil processed on a monthly basis for 1990:

Month	Tonnes processed
January	59 649
February	0
March	105 805
April	146 680
May	134 778
June	0
July	0
August	40 286
September	0
October	250
November	87 042
December	30 369
Total for 1990	574 759

7.5 Environmental Considerations

Water treatment has both chemical and biological stages with 100% spare capacity. It was intended to handle wastewater from the n-alkanes dehydrogenation.

A system of wells around the refinery are checked for the presence of hydrocarbons by a gathering system.

7.6 Refinery Specific Potential and Opportunities for Improvement

This refinery is very dependent on Slovnaft. For example, products from Vojany are hydrotreated at Slovnaft and then returned to Vojany for distribution.

7.7 Refinery Specific Problems and Trends

This refinery, just like the CSFR refinery industry as a whole, is facing all the aspects and concerns of a free market economy. The products produced at this refinery will have to compete in terms of value and quality.

7.8 Methodology of Data Collection

The Davy McKee (DMC) questionnaire was sent to the refinery in May 1991. During the early part of June, the DMC team met with the refinery manager to review the results of the questionnaire.

7.9 Evaluation of Results Achieved by / for the Data Base

The data collected through the questionnaire and personnel meeting was not sufficient to produce a complete data base.

7.10 Supporting Plant Data

No supporting plant data was provided.

D. SUPPORTING TABLES, CHARTS AND FIGURES

TBP curves for Russian crude oil

Figure 10 - Temperature vs. Yield
Figure 11 - Temperature vs. Density
Figure 12 - Temperature vs. Sulfur Content
Figure 13 - Temperature vs. Viscosity
Figure 14 - Chromatographic Analysis of C_6 - 100 °C EP

Figure 10 - Temperature vs. Yield

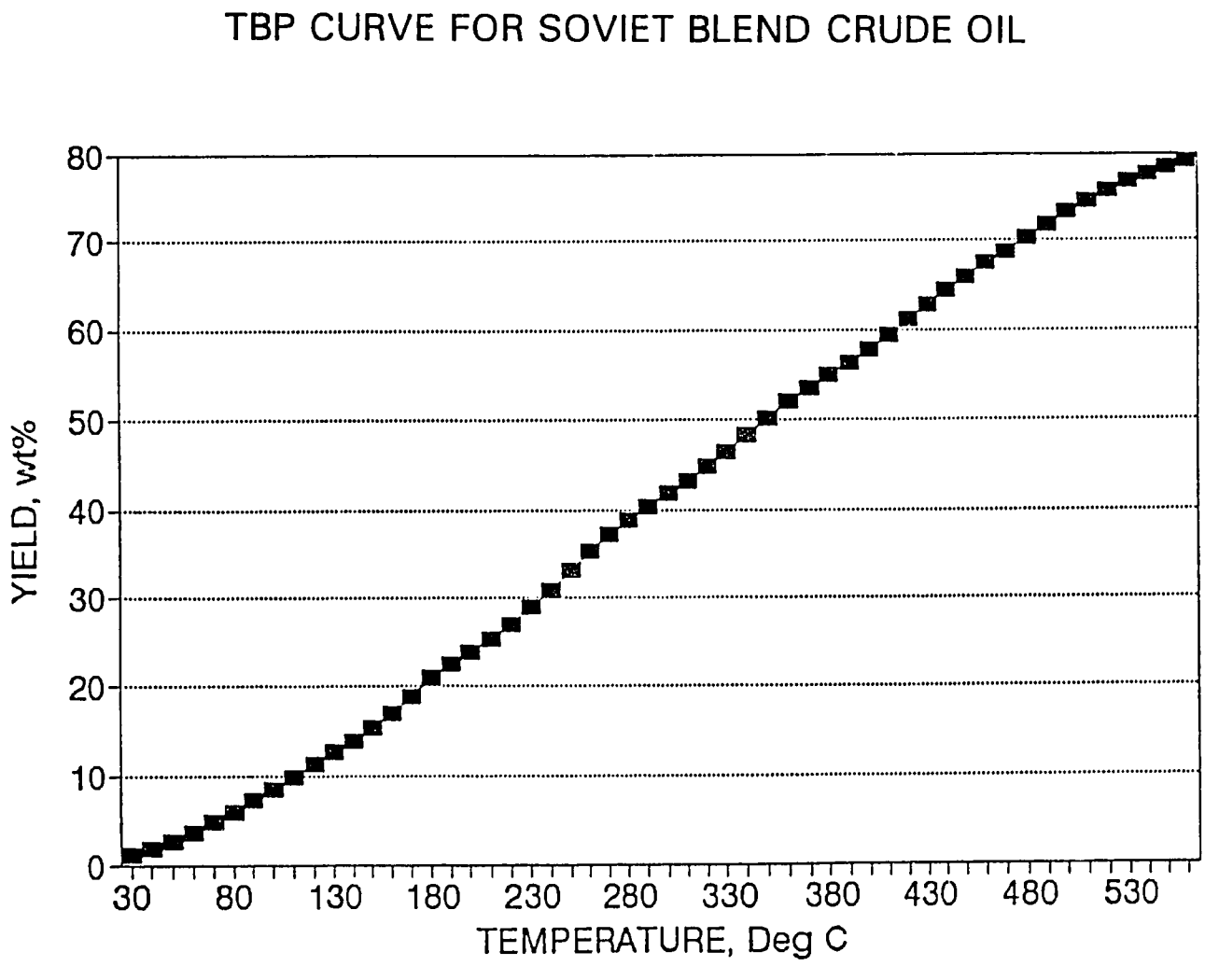

Figure 11 - Temperature vs. Density

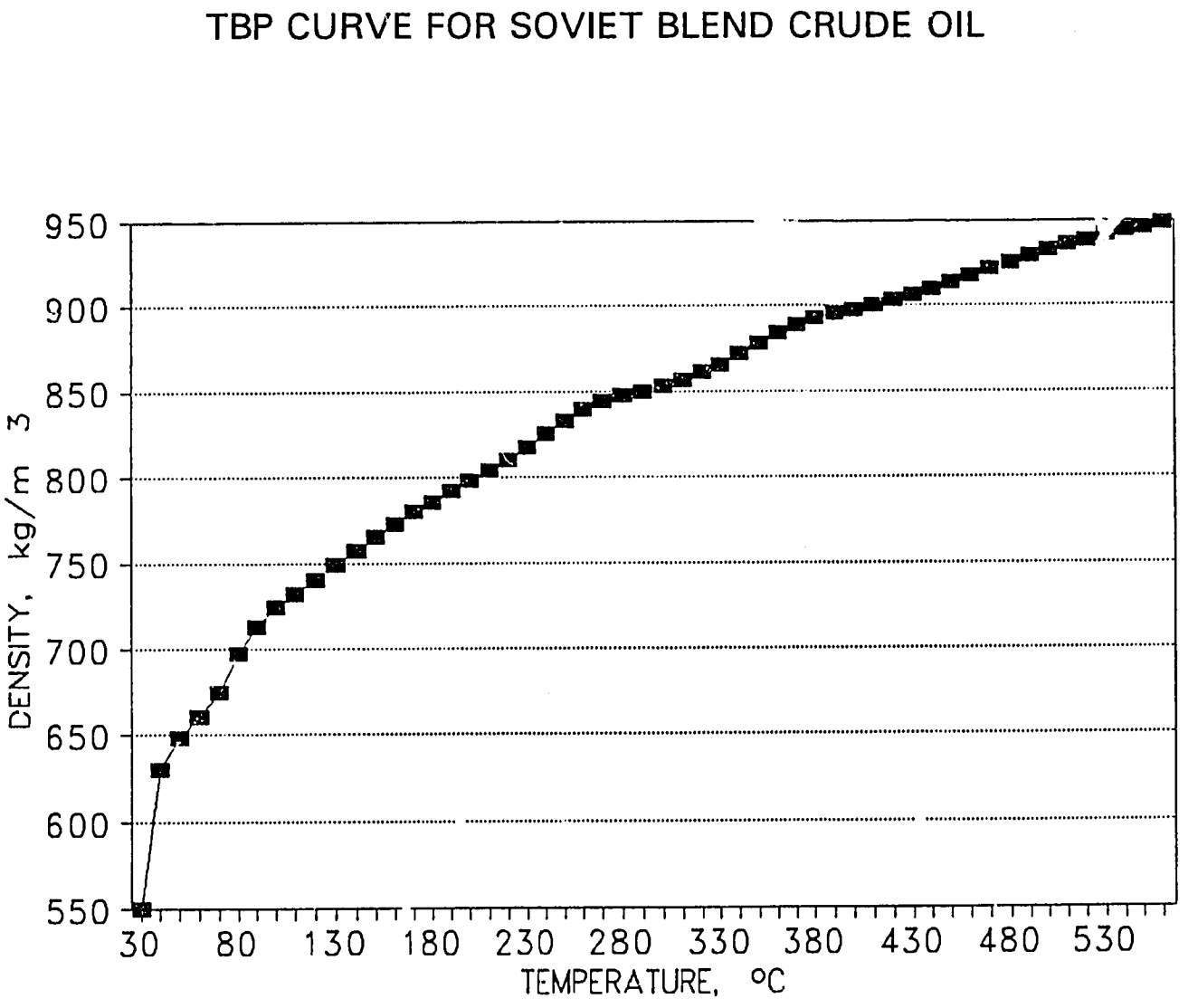

Figure 12 - Temperature vs. Sulfur Content

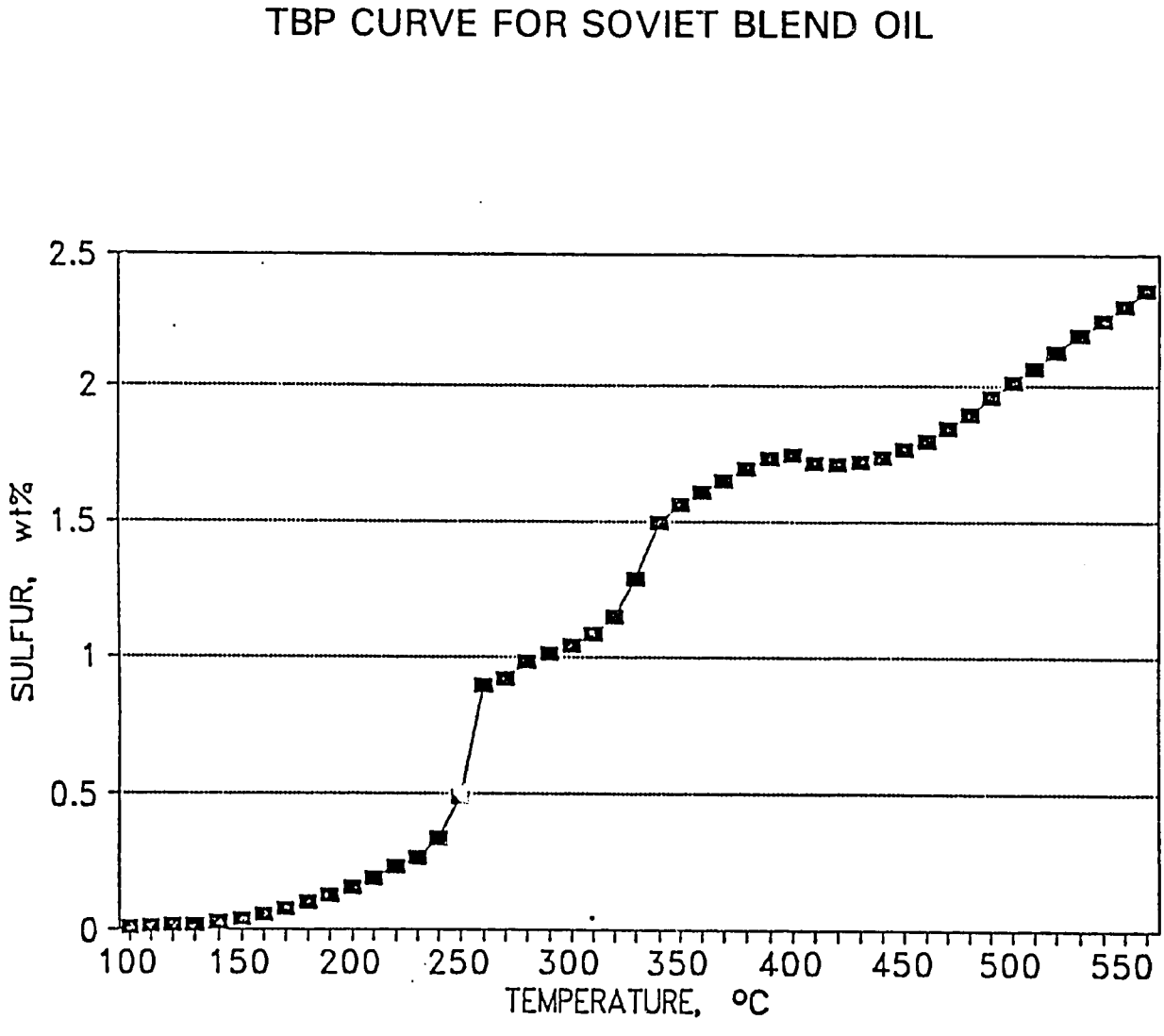

Figure 13 - Temperature vs. Viscosity 20 Deg C

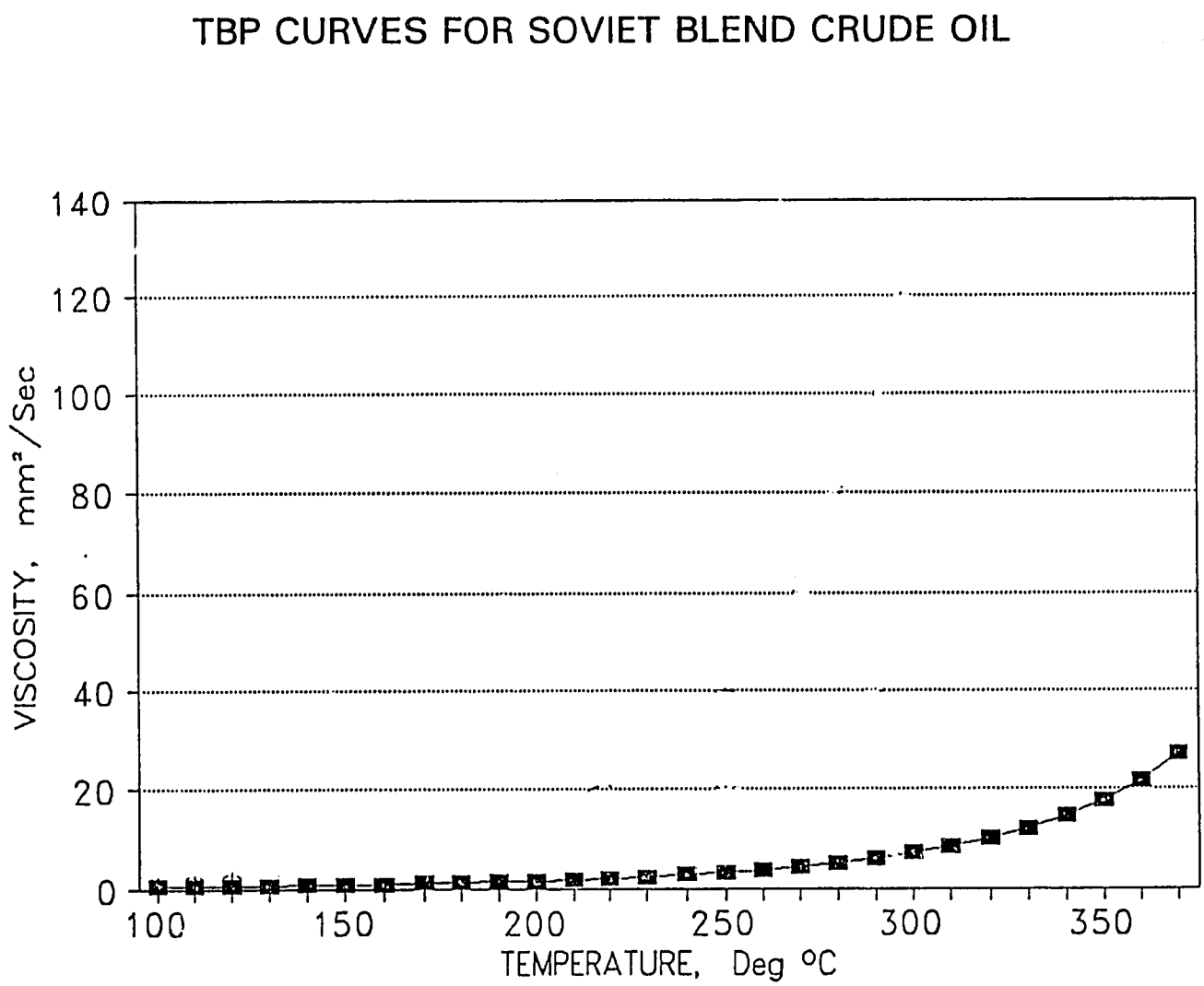

Figure 14 - Chromatographic Analysis of C_5 to 100 °C EP

Component	wt%
i-C_5	9.40
n-C_5	14.65
2.2 + 2.3 diMC_4 + CyC_5	2.24
2MC_5	8.84
3MC_5	5.70
n-C_6	14.54
McyC_5	7.05
Benzene	0.89
CyC_6	4.25
diMcyC_5	10.51
i-C_7	6.15
n-C_7	8.61
McyC_6	4.47
Toluene	1.12
higher	1.57
TOTAL	99.99

APPENDIX A

REFINERY CHARACTERIZATION QUESTIONNAIRE

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2.	Refinery Configuration (including Material Balances)	4
3.	Properties and Specifications of Feeds and Products.	7
4.	Refinery Process Units	14
5.	Utility Information	14
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8.	Environmental Aspects	27
9.	Miscellaneous Information (Battery Limit Conditions)	41
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LIST OF TABLES AND FIGURES

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FIGURES

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2.2	Generic BFD (Intergrated Refinery)	6

Davy McKee

1. GENERAL

1.1 NAME AND LOCATION

Name: _____
Location: _____
_____
_____

1.2 CORRESPONDENCE

Correspondence relating to this project shall be directed as follows:

To the Refiner:

Name: _____
Address: _____
_____
_____
Attention: _____
Telephone No: _____ Telex No.: _____
Ext.: _____ TWX: _____
Telecopier No.: _____
Telecopier Model: _____
(Does it receive not attended? Yes / No Hours_____)

To Davy McKee

Name: DAVY MCKEE CORPORATION
Address: 300 S. Riverside Plaza
Suite 1800
Chicago, Illinois 60606 USA
Attention: _____
Telephone No: (312) 669-7000 Telex No.: 190146
Ext.: 7031 TWX: N/A
Telecopier No.: (312) 902-1236
Telecopier Model: Cannon 705
(Does it receive not attended? Yes / No Hours: 24 hours)

Davy McKee

1.3. SCOPE OF FACILITIES

(Provide a general overall description including infrastructure)

1.4 SYSTEM OF MEASUREMENT

Indicate from the following, the units being followed by the refinery. (By circling selection for each of the following condition or property).

	ENGLISH	MKS	SI
Temperature	°F	°C	°C
Pressure	psi	kg/cm²	kPa
Mass	lb	kg	kg
Length	ft-in	m-mm	m-mm
Relative Density	Spec Gravity T°F/60°F	Spec Gravity T°C/15°C	Spec Gravity T°C/15°C
Absolute Density	°API or lb/gal at 60°F	kg/m³ at 15°C	kg/m³ at 15°C
Flowing Density	lb/ft³	kg/m³	kg/m³
Flowing Quantities			
Mass	lb/hr	kg/h	kg/h
Vapor	ft³/sec	m³/h	m³/h
Liquid	U.S. gal/min	m³/h	m³/h
Standard Quantities			
Vapor	10^6 std ft³/day at 60°F	normal m³/h at 0°C	std m³/h at 15°C
Liquid	bpd at 60°F	std m³/h at 15°C	m³/h at 15°C
Enthalpy	Btu/lb	kcal/kg	kJ/kg
Heat Rate	10^6 Btu/hr	10^6 kcal/hr	MW

It will be assumed that all data provided by refinery will be in the above units, unless noted otherwise.

1.5 SITE INFORMATION

1.5.1 Climatic Data

Winterizing provisions are based on _____ °_____.

Direction of prevailing wind is from _____.

1.5.2 Unit Elevation

Indicate elevation of refinery site above sea level _____.

(Average Barometric Pressure _____.)

Design Dry Bulb Temperature is _____°_____.

Design Wet Bulb Temperature is _____°_____.

2.0 REFINERY CONFIGURATION

2.1. REFINERY BLOCK FLOW DIAGRAM

Provide a Block Flow Diagram similar to Figures 2.1 or 2.2.

Figure 2.1 is a generic Block Flow Diagram for a very simple refinery, with the exception of a TOPPING UNIT or a LUBE OIL REFINERY.

Figure 2.2 is a generic Block Flow Diagram for a fully integrated refinery. This figure is only for reference, not many refineries consist of that many units.

The Desalter is not shown on the Block Flow Diagram. However, it should be shown if it exists.

2.2 Provide a list of the Refinery utilities and off-site facilities. (The Block Flow Diagrams in section 2.1 show only the process units.)

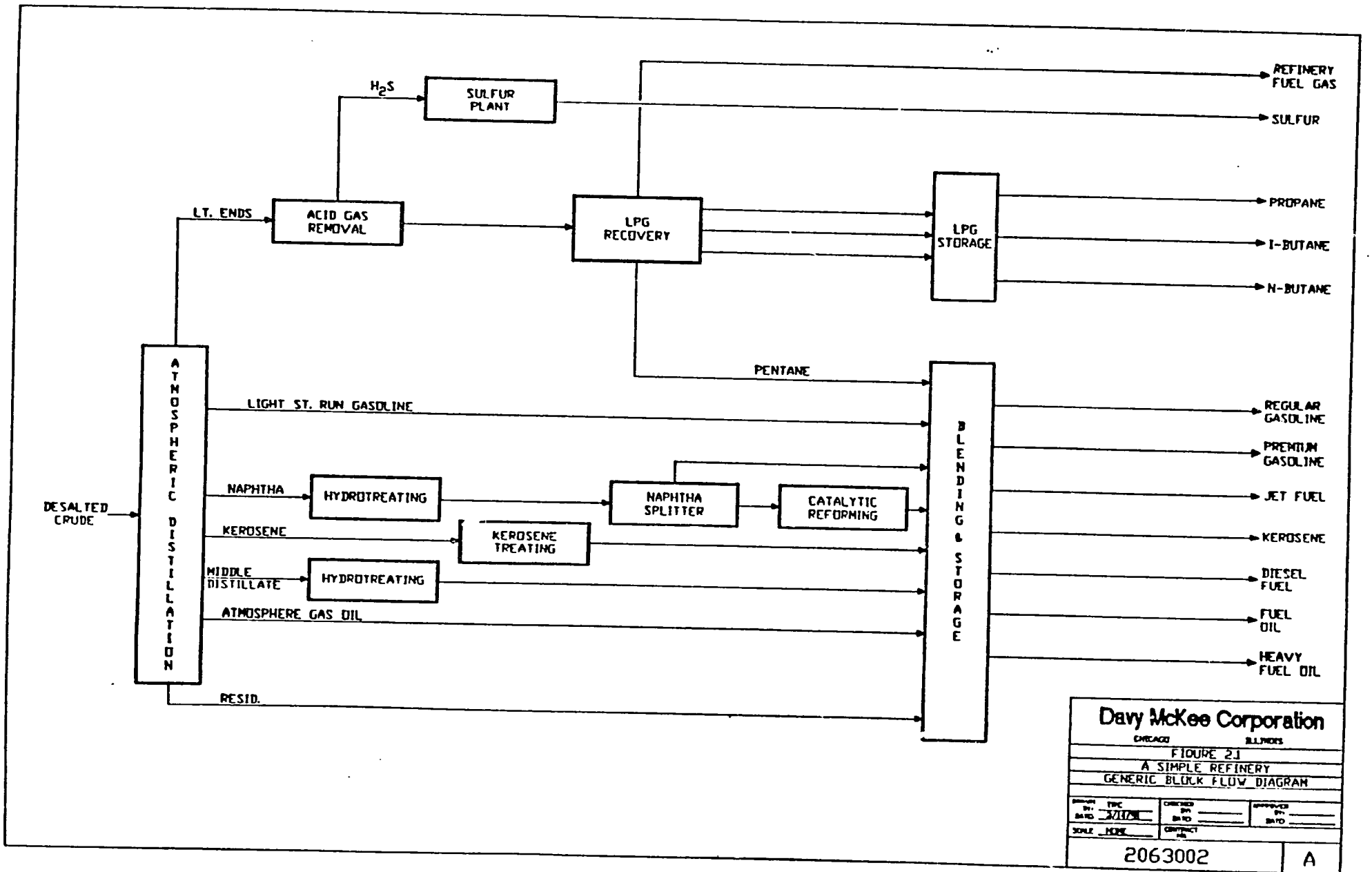
2.3 OVERALL MATERIAL BALANCE

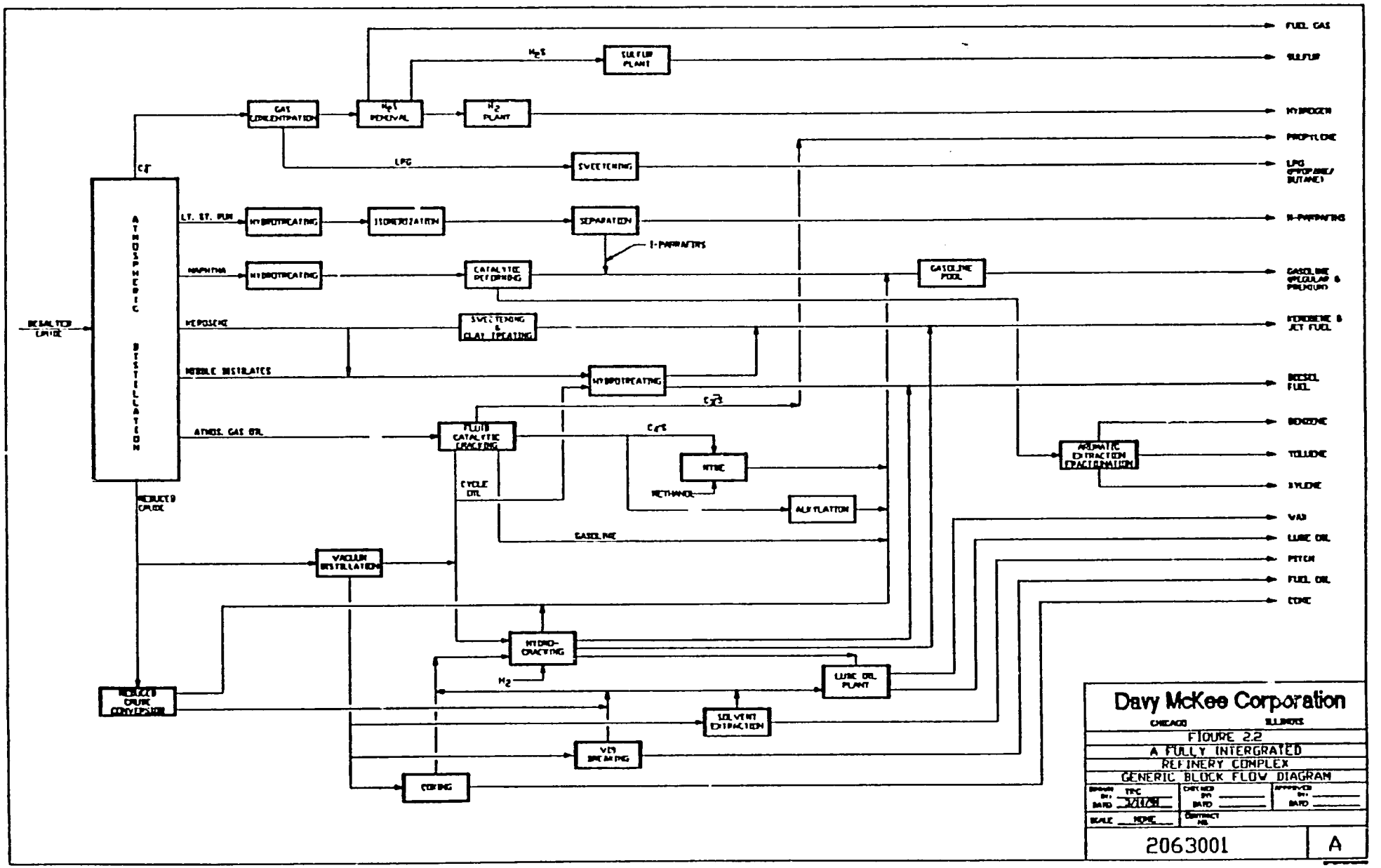
Crude oil throughput:
Imported Blending Stocks:

Products:

LPG:
Regular Gasoline:
Premium Gasoline:
Solvents:
Feeds to Aromatic Complex:
Feeds to Petrochemical Complex:
Aviation Fuels:
Diesel Fuels:
Heating Oils:
Lube Oils:
Greases:
Asphalts:
Industrial Fuels:
Coke:
Etc.:

2.3.1 Provide the names and monthly (average) consumption quantities of various chemicals (treating, process, corrosion inhibitors, etc.) and catalysts. Include gasoline additives such as MTBE, TEL, etc., and additives for lube oils.


DESALTED CRUDE
ATMOSPHERIC DISTILLATION
LT. ENDS
ACID GAS REMOVAL
H_2S
SULFUR PLANT
LPG RECOVERY
LPG STORAGE
REFINERY FUEL GAS
SULFUR
PROPANE
I-BUTANE
N-BUTANE
PENTANE
LIGHT ST. RUN GASOLINE
NAPHTHA
HYDROTREATING
NAPHTHA SPLITTER
CATALYTIC REFORMING
KEROSENE
KEROSENE TREATING
MIDDLE DISTILLATE
HYDROTREATING
ATMOSPHERE GAS OIL
RESID.
BLENDING & STORAGE
REGULAR GASOLINE
PREMIUM GASOLINE
JET FUEL
KEROSENE
DIESEL FUEL
FUEL OIL
HEAVY FUEL OIL
Davy McKee Corporation
CHICAGO ILLINOIS
FIGURE 2.1
A SIMPLE REFINERY
GENERIC BLOCK FLOW DIAGRAM
SCALE NONE
2063002
A



Davy McKee Corporation
CHICAGO ILLINOIS

FIGURE 2.2
A FULLY INTERGRATED
REFINERY COMPLEX
GENERIC BLOCK FLOW DIAGRAM

DRAWN BY: TPC DATE: 3/10/78
CHECKED BY: DATE:
APPROVED BY: DATE:
SCALE: NONE
CONTRACT NO.

2063001 A

3.0 PROPERTIES AND SPECIFICATIONS OF FEEDS AND PRODUCTS

3.1 Feeds to Refinery

3.1.1 For Crude Oil (or oils) processed, provide properties for each of the crude oils processed as indicated in Table 3-1.

In addition to Table 3-2, the following would be required (for each crude oil) to perform analysis of atmospheric crude distillation:

1. TBP Curve, with mid-volume plots of gravity, viscosity, and sulfur.
2. Light ends analysis up through hexanes.
3. Characterization factor (UOP or Watson k) for whole crude.
4. For vacuum unit (if it exists), provide vacuum distillation (D-1160) for residua.

TABLE 3-1 CRUDE OIL PROPERTIES

Crude Name Source (Country)				
Crude Inspection				
Gravity, °API				
Sulfur, Wt. %				
Pour Point, °F				
Viscosity, cs at 130°F				
Conradson Carob, Wt. %				
Asphaltenes & Resins, Vol. %				
Metals, Ni + Va, PPM				
Gasoline, C-405°F (C5-207°C)				
Yield, Vol. %				
Sulfur, Wt. %				
Octane, F-1, 3 ml TEL				
Light Gas Oil, 405-650°F (207-344°C)				
Yield, Vol. %				
Gravity, °API				
Sulfur, Wt. %				
Pour Point, °F				
Characterization Factor				
Heavy Gas Oil, 650-1000°F (344-538°C)				
Yield, Vol. %				
Gravity, °API				
Sulfur, Wt. %				
Viscosity, cs at 130°F				
Wax Content, Wt. %				
Characterization Factor				
Residuum 1000°F PLUS				
Yield, Vol. %				
Gravity, °API				
Sulfur, Wt. %				
Viscosity, cs at 210°F				
Viscosity Index of Dewaxed Lubricating Oil				

3.1.2 Properties and Specifications of Feeds other than Crude Oil

Provide properties of following (if available, also provide the source):

a. Fuels (oil, gas, or coal)

b. Inert gas (Nitrogen)

c. Treating chemicals (for water, steam, cooling tower, wastewater, etc.)

d. Corrosion inhibitors

e. Other chemicals used in the processing (e.g., Caustic, Sulfuric Acid, Carbon Tetrachloride, Sufiding Agents, Amines, etc.)

f. Catalysts (specify source and specification)

g. Gasoline additives, e.g, MTBE and TEL., etc.

h. Lube oil additives

3.2 PROPERTIES AND SPECIFICATION OF PRODUCTS

Indicate the following properties of various products:

LPG (LIQUEFIED PETROLEIUM GASES) TABLE 3-2

Composition	PROPANE	BUTANE	LPG
Vapor Pressure at 100°F			
Volatile Residue,			
Butane and Heavier, LV % (Max)			
Pentane and Heavier, LV% (Max)			
Residual Matter			
Corrosion, Copperstrip, Max.			
Total Sulfur, ppmw			
Moisture Content			
Free Water Content			
If Bottled at Refinery?	YES/NO	YES/NO	YES/NO

GASOLINES TABLE 3-3

TYPE GRAVITY	REGULAR	PREMIUM
Octane Number RON MON		
Distillation, Volume 10% 50% 90% EP		
Distillation Residue, % Wt.		
RVP		
Sulfure Content, % Wt.		
MTBE Content, % Vol.		
TEL Content (if any)		

JET FUELS (AVIATION FUEL) TABLE 3-4

TYPE GRAVITY		
Distillation, Volume IBP 10% 50% 90% EP		
Distillation Residue, % Wt.		
Viscosity		
Aniline Point		
Freeze Point		
Flash Point		
Total Sulfur, Wt. %		
Mercaptan, Wt. %		
Aromatic Content, Vol. %		
Doctor Test		
Smoke Point		
Gum mg/100 ml		
Net Heat of Combustion		

DIESEL FUELS TABLE 3-5

TYPE GRAVITY		
Distillation, Volume IBP 10% 50% 90% EP		
Viscosity		
Pour Point		
Flash Point		
Sulfur Content, ppmw		
Carbon Residue		
Ash		
Water and Sediment, % Vol.		
Corrosion, Copper Strip		
Cetane Number, Min.		

FUELS OILS TABLE 3-6

TYPE GRAVITY		
Distillation, Volume 10% 90%		
Viscosity		
Flash Point		
Pour Point		
Sulfur, % Wt.		
Carbon Residue %		
(on 10% bottoms)		
Ash, % Wt.		
Corrosion, Copper Strip		

3.2.6 Provide properties and specifications of any other product from the refinery, such as, sulfur, lube oils, pitch, greases, coke, asphalts, road oils, tars, solvents, petrochemicals and aromatic feed stocks produced in the refinery, etc.

4.0 REFINERY PROCESS UNITS

See LP Data Base in Appendix.

5.0 UTILITY INFORMATION

5.1 Steam System (and Hot Oil System, if it exists)

Provide details of on-site steam generation, i.e., type of boiler (gas, oil, or coal fired).

Provide Boiler Capacity and steam quality.

Provide details of Boiler Blowdown disposition.

5.1.1 Systems may be identified in general terms such as High Pressure, Medium Pressure, Low Pressure, etc., or as nominal pressure levels such as 600 PSIG, 150 PSIG, etc.

Minimum steam pressures and temperatures are the lowest pressures and temperatures which may be expected at any point in the area header.

Normal steam pressures and temperatures are the pressures and temperatures which may be expected at any point in the area header.

Maximum steam pressures and temperatures are the highest pressures and temperatures which may be expected at any point in the area header.

Design pressures and temperatures are the conditions specified for the mechanical design of piping and equipment.

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STEAM SYSTEM TABLE 5-1

System Identification	Pressure				Temperature			
	Min.	Norm.	Max.	Design	Min.	Norm.	Max.	Design

5.1.2 Condensate Systems

If there are more than one condensate systems, describe each separately.

The typical condensate system may contain a drum or receiver, anywhere in the refinery.

The condensate is pumped from the receiver to a polishing system at the boiler plant.

5.1.3 Hot Oil System

Provide details of Hot Oil System (or belt), if used in the refinery.

Provide specifications of the hot oil used.

5.2 WATER SYSTEM

5.2.1 Is raw water used directly as cooling tower make-up water? YES/NO

5.2.2 Describe the treatment of raw water for the following uses and provide generical names of chemicals used:
(1) potable water,
(2) water used for purposes other than BFW and cooling tower.

5.2.3 Boiler Feed Water (BFW)

Provide the following information about the chemical treating used in steam generators and corrosion control treatment for steam and condensate systems.

WATER TREATMENT TABLE 5-2

System Identification	Method of Feeding And Location of Feed Point	Chemicals Used

5.2.4 Cooling Water System(s)

Describe the Cooling water system. If more, then one, describe each system and identify the units it serves. For each system, provide the following:

If it is a once through type system, provide the source of the cooling water. Provide the type of treatment and chemicals used.

If it a closed cooling water system, provide the type and number of cooling towers. Identify the generic names of chemicals used for treatment.

Provide the destination of the cooling tower blowdown.

Provide the capacity of the cooling water pumps and indicate number of operating and spare pumps. Indicate, if any, steam turbine driven pump is installed.

5.2.5 Provide following information on water system

WATER SYSTEMS TABLE 5-3

DESCRIPTION	REFINERY RAW WATER SUPPLY	ONCE-THROUGH COOLING WATER	CIRCULATING COOLING WATER	TREATED BOILER FEEDWATER
Source				
Supply Temperature, ° _____				
Supply Pressure, _____ At battery Limits at Grade				
Return Pressure, _____ At battery Limits at Grade				
Exchanger Inlet Water Temperataure, ° _____				
Exchanger Outlet Water Temperataure, ° _____ (Max)				
Exchanger Water Side Design Temperataure, ° _____				
Exchanger Water Side Design Pressure, _____				
Fouling Resistance _____				

WATER ANALYSIS TABLE 5-4

DESCRIPTION	REFINERY RAW WATER SUPPLY	ONCE-THROUGH COOLING WATER	TREATED BOILER FEEDWATER
pH			
Total Hardness as CaCO3, PPM			
Calcium as CaCO3, PPM			
Magnesium as CaCO3, PPM			
"P" Alkalinity as CaCO3, PPM			
Sulfate as SO4, PPM			
Chloride as Cl, PPM			
Silica as SiO2, PPM			
Iron as Fe, PPM			
Total Dissolved Solids, PPM			
Suspended Solids, PPM			
Turbidity, PPM			
Conductivity, MicroMHOS/CM			

5.3 REFINERY FUEL SYSTEM

Provide a description of the refinery fuel system. Indicate the amount and type of fuel being imported into the refinery.

5.3.1 Coal as Fuel
If coal (or coals) is used as a fuel, provide complete analysis and net heating value. Describe current coal receiving, storage, handling and preparation systems. Indicate if coal is the primary or supplemental fuel.

5.3.2 Liquid Fuels
If liquid fuels, such as, LPG, Naphtha, Fuel Oils, etc., are used as fuels, provide descriptions of the systems. The system may include receiving, storage, pumping and distribution.

5.3.3 Fuel Gas
Provide a description of the fuel gas system, i.e,, fuel gas drum, operating conditions and distribution.

Indicate the properties of pilot gas if not supplied from the refinery fuel gas header, (i.e., imported into the refinery).

A. Is the existing fuel gas system steam traced? YES / NO

B. Is the existing fuel gas system provided with local liquid knockout drum? YES / NO

5.4 ELECTRICAL POWER

Describe the on-site power generation, i.e., type of turbo-generato and its driver.

If power is imported, indicate the source.
Describe the overall electrical system, including stepdown, distribution, load shedding, reliability, etc.

Provide information on emergency generator.

Provide the following information relating to the electrical power system:

ELECTRICAL POWER TABLE 5-6

SERVICE	HORSEPOWER RANGE		NAME PLATE VOLTAGE	PHASE	FREQUENCY (HERTZ-Hz)
	FROM	TO			
MOTORS					
INSTRUMENTS					
LIGHTING					

FUEL GAS DATA TABLE 5-5

PROPERTY	SOURCE	
	REFINERY	IMPORTED
Composition (Volume %)		
H2S		
H20		
CO		
CO2		
O2		
N2		
H2		
C1		
C2=		
C2		
C3=		
C3		
C4=		
C4		
iC4		
nC4		
C5=		
iC5		
nC5		
C6+		
TOTAL	100%	100%

5.5 PLANT AND INSTRUMENT AIR

Provide the capacity and type of air compressors, coolers and driers. Indicate the sparing policy.

Does system furnish oil free air? YES / NO

Indicate dew point for instrument air; ___°_____.

Indicate system header pressure; _____.

5.6 REFRIGERATION SYSTEM

Provide the type and capacity of the refrigeration system, if any.

Indicate the refrigerant used.

5.7 INERT GAS SYSTEM

Indicate the source of inert gas and its quality.

If on-site inert gas generation is available, provide details of the equipment, capacity, etc.

6.0 OFF-SITE FACILITIES

The refinery off-site facilities normally include the following:

6.1 Flare and Blowdown Systems.
Provide size (Tip Diameter) and height of flare stack (or stacks), drums and header sizes.

Provide the size of the condensate return system including pump, hydrocarbon knockout drum, etc.

Provide sizes of ground flares, if any.

6.2 Flue Gas Treatment (if any).
Provide description and capacity of the unit. If it is a licensed unit, provide the name of licensor.

6.3 Waste Disposal.
Provide description of waste disposal in terms of solids, liquid and gaseous streams.

If coal is used as fuel, describe treatment and disposition of ash.

6.4 STORAGE, BLENDING AND TRANSFER

6.4.1 Provide storage capacities for all feeds into the refinery. Major feeds to the refinery are crude oils from various sources. In addition, refinery may have feeds in terms of treating chemicals, catalysts, corrosion inhibitors, inert gases, methanol, MTBE, fuel oil, fuel gas, solvents, etc.

6.4.2 Provide storage capacities of all products, including all intermediate storage. Products from an integrated refinery may include: LPG, gasolines, kerosene, jet fuel, diesel fuel, aromatic, lube oils, fuel oils, etc.

6.4.3 Besides capacities, provide the size and type of storage vessels and tanks. For example, LPG storage could be in bullets, spheres or atmospheric (refrigerated) tanks, gasoline could be in fixed or floating roof tanks.

6.4.4 Provide description and capacities of various blending units, i.e., gasoline, fuel oil, etc.

6.4.5 Indicate the mode of transportation for feeds and products, i.e., pipeline, truck, or railroad.

6.5 Fire Protection Equipment

Provide details of fire protection equipment.

7.0 OPERATING COST DATA

Provide estimated variable costs of the following: (Note 1)

Electrical Power

Fuel

Raw Water

Treating Chemicals (Boilers, Cooling Water etc.)

Catalysts

Steam

Cooling Water

Additives for Gasolines

Additives for Lube Oils

Crude Oils

Products

Other Chemicals

Etc.

NOTE 1: At least some cost data, in appropriate units, is required in order to conduct any techno-economic evaluation.

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8.0 ENVIRONMENTAL SURVEY

Emergency Energy Program for East & Central Europe
Davy McKee Job No, 2063

I. WATER SUPPLY

A. Process Water.

1. Source:_____

_____

2. Capacity:_____L/M

3. Chemical Quality- as used:

TEST	Units	TEST	Units
TDS	_____	OIL/GREASE	_____
TSS	_____	PHENOL	_____
COD	_____	AMMONIA	_____
BOD	_____	CHROMIUM	_____
TOC	_____	ZINC	_____
pH	_____	SULFITES	_____
Fe	_____	HARDNESS	_____

4. Pretreatment before use:
   a. pH control. _____
   b. Settling. _____
   c. Flocculation/Sedimentation. _____
   d. Filtration. _____
   e. Other. _____

B. Drinking Water.

If a different source than (I-A) above, complete same information as requested in (I-A-1) through (I-A-4-e).

1. Source:_____

_____

2. Capacity:_____L/M

3. Chemical Quality- as used:

TEST	Units	TEST	Units
TDS	_____	OIL/GREASE	_____
TSS	_____	PHENOL	_____
COD	_____	AMMONIA	_____
BOD	_____	CHROMIUM	_____
TOC	_____	ZINC	_____
pH	_____	SULFATES	_____
Fe	_____	HARDNESS	_____

4. Pretreatment before use:

a. pH control. _____
b. Settling. _____
c. Flocculation/Sedimentation. _____
d. Filtration. _____
e. Other. _____
_____

C. Cooling Tower Water:

1. Source of water _____
2. If same as (I-A) or (I-B) above:
   a. Once through. _____
   b. Cooling tower loop. _____

3. Additional pretreatment other than (I-A-4) or (I-B-4)? Define. _____
_____

4. Recycle water treatment:
   a. Corrosion control. _____
   b. Biocides. _____
   c. TDS of recycle/blowdown _____

5. Recycle rate _____ L/M

6. Make-up rate _____ L/M

7. Blowdown rate _____ L/M

8. Blowdown discharge to: _____

D. Boiler Feed Water.

1. Source: _____
_____

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2. BFW Treatment:

   a. Softening: Resin_____ Lime_____
   b. R.O._____
   c. Ion Exchange. _____
   d. Waste heat distillation._____

3. Water Treatment Chemicals:

   a. H_2SO_4 _____
   b. HCl _____
   c. NaOH _____
   d. Na_2SO_3 _____
   e. H_2NNH_2 _____
   f. Phosphates _____
   g. Other _____

4. Regenerant discharge: _____L/cycle_____cycles/day

   To:_____

5. Blowdown discharge rate:_____L/M_____To

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II. STORM WATER

A. Tank Storage Areas.

1. Tank areas diked to prevent the spread of oil leaks?
   Yes_____ No_____

2. Capacity of the diked area verses the capacity of largest tank?
   1:1 1:1.1 1:1.25 other _____

3. Inside of dike: earth: concrete: plastic liner.

4. Method of removing the trapped oil/water?_____
   _____

5. Oil skimming provided? Yes _____ No _____

B. Process Area.

1. Area curbed to prevent rain water run on? Yes ___ No ___

2. Disposition of the rain water falling on the process area?_____
   _____

3. Are the following leaks/drains contained?

   a. Pump seals: Yes __ No __
   b. Valve stems: Yes __ No __
   c. Flanges: Yes __ No __
   d. Sample line drains: Yes __ No __
   e. Tank overflow lines: Yes __ No __
   f. Pump casing drains: Yes __ No __
   g. Control valve drains: Yes __ No __
   h. Heat exchangers: Yes __ No __

C. Roadways, Parking Lots & Roof Drains.

1. Are these rain water flows separated from A & B above?
   Yes __ No __

2. If No above, could they be separated at a reasonable cost?
   Yes __ No __

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D. Stormwater Treatment. Define for each system.

1. No treatment. _____

2. (A), (B), (C) above treated? (circle which).

3. Treatment.

   a. Lagoon with oil skimming. _____
   b. Biological treatment._____
   c. Held for Plant make-up water._____
   d. Other - define on separate page._____

4. Chemical quality of outlet water.

   a. TSS_____
   b. TDS _____
   c. Fats/Oils/Grease _____
   d. BOD _____
   e. COD _____
   f. pH _____
   g. Discharged to _____

III. ON-SITE WATER SYSTEMS

A. Attach a sites plan showing the locations and routing of the following:

1. Roof drain sewers.
2. Roadway and Parking lot sewers.
3. Open area catch basins and sewers.
4. Storage tank area drains and sewers.
5. BS&W drain/sewers.
6. Process water drain/oily sewers.
7. Process area stormwater sewers.
8. Sour water piping and sewers.
9. Wastewater treatment units.
10. Solid waste storage/disposal sites.
11. Water supply.
12. Barometric condenser drains.

B. Attach block flow diagrams of any wastewater treatment systems on any of the above sewers or combinations of sewers. Show-

1. Pump stations.
2. Equalization basins.
3. Flow control devices.
4. Chemical additions.
5. Oil skimming.
6. Settled solids removal.
7. Air/steam stripping.
8. Aeration area for chemical oxidation.
9. Biological treatment BOD/COD.

10. Effluent equalization.

11. Points of water discharge to off-site.

12. Sample locations.

    a. Flow rates.
    b. Chemical quality. (I-A-3)

13. Any current recycle system.

14. Any recycle system being considered.

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IV. WASTEWATER TREATMENT

A. For each major unit shown on the block flow diagrams (III-B) give the critical data:

1. Volume. _____

2. Length, width & liquid depth. _____

3. Pump rates. _____

4. Water quality in/out. (I-A-3) _____

5. Chemicals added. _____

6. Method of sludge disposal. _____

   a. Quantity. _____cu. m.
   b. Frequency. _____

7. Method of skimmed oil disposal. _____

8. Design flow rates. _____

9. Energy consumed at each unit. _____

B. Provide process flow diagrams showing the typical Chemical Engineering parameters.(If available)

V. NOISE LEVEL

During the Characterization, Evaluation and the Environmental visits, those areas for observed excessive noise levels will be noted. no field measurements are to be made at this time. If simplified and economical method of control is evident to the Team, this will be noted as defined. If the excessive noise is due to a complex of sources, this will be noted for potential future study.

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VI. SOLID WASTE

A. Crude tankage silt.

1. Quantity and frequency of removal. _____

2. Method of disposal. _____

B. Atm./Vacuum still bottoms.

1. How used? _____

2. How disposed? _____

C. FCC fines/spent catalyst.

1. How collected? _____

2. How disposed? _____

3. Quantity? _____

D. Spent caustic.

1. Quantity? _____

2. How disposed? _____

E. Water treatment sludge.

1. Quantity? _____

2. How disposed? _____

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F. Oil/water separator.

1. Quantity of oil and how disposed? _____

2. Quantity of sludge and how disposed? _____

G. Wastewater treatment sludge.

1. Quantity? _____

2. How disposed? _____

H. Boiler system.

1. Fly ash quantity and how disposed? _____

2. Bottom ash quantity and how disposed? _____

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VII AIR POLLUTION

A. Benzene:

Benzene has been defined as a carcinogenic substance. If the Evaluation Team suspects the presence of Benzene, a MSA benzene tube tester will be used. The tube tester will only confirm the presence of 2 - 150 ppmv at the time of sampling. Those areas suspect and tested shall be noted and the results recorded. Before control systems can be designed, an in depth study must be conducted.

B. Storage tanks:

1. Crude: (Vapor pressure) _____

a. Covered _____ Uncovered _____
b. Capacity _____cu.m
i. Diameter _____ m
ii. Height _____ m
c. Number _____
d. Vent control:
i. None. _____
ii. Conservation valve. _____
iii. Carbon adsorption. _____
iv. Flare system. _____

2. Light ends: (Vapor pressure) _____

a. Covered _____ Uncovered _____
b. Capacity _____cu.m
i. Diameter _____ m
ii. Height _____ m
c. Number _____
d. Vent control:
i. Conservation valve. _____
ii. Carbon adsorption. _____
iii. Flare system. _____
iv. Other _____ Define _____

3. Middle Distillate: (Vapor Pressure) _____

a. Covered _____ Uncovered _____
b. Capacity _____cu.m
i. Diameter _____ m
ii. Height _____ m
c. Number _____

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d. Vent control:
   i. Conservation valve. _____
   ii. Carbon adsorption. _____
   iii. Flare system. _____
   iv. Other _____ Define _____

4. Resid: (Vapor Pressure) _____

   a. Covered _____ Uncovered _____
   b. Capacity _____ cu.m
      i. Diameter _____ m
      ii. Height _____ m
   c. Number _____

   d. Vent control:
      i. Conservation valve. _____
      ii. Carbon adsorption. _____
      iii. Flare system. _____
      iv. Other _____ Define _____

C. Heaters (complete for each heater & boiler):

1. Unit number. _____

2. Fuel. _____

3. Fuel composition - attach a copy.

   a. J/gm _____ HHV
   b. Sulfur content. _____%
   c. Ash content. _____%
   d. Moisture content. _____%

4. Firing rate. _____ Kg/Stream Hr.

5. Pollution control:

   a. Particulate:
      i. Type. _____
      ii. Efficiency. _____%
   b. Sulfur:
      i. Type. _____
      ii. Efficiency. _____%
   c. NO_x
      i. Type. _____
      ii. Efficiency. _____%
   d. CO:
      i. Type. _____
      ii. Efficiency. _____%

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D. Sulfur recovery:

1. Yes _____ No _____

2. If yes, recovery: _____%

$$\frac{\text{Total S Recovered}}{\text{Total S to refinery}}$$

3. Process name: _____

E. NO_x & SO_x

MSA sample tube testers are provided to the Evaluation Team. The NO_x level is 0.5 - 50 ppmv and the SO_x level is 1-150 ppmv. These tubes will only confirm the presence of the pollutant at the time of sampling. Before any design can be performed, a detailed sampling program must be completed.

F. Process losses.

1. Define the flows to the flare._____

2. Define the type of flare._____

3. Flare burning control. _____

4. Frequency of "sniffing" the valve stems, flanges, pump & compressor seals,and the pressure control valves?_____

5. Define other hydrocarbon vent losses not routed to carbon adsorber or the flare. _____

6. Estimate the number of each of the following:

a. All process streams:

i. Open ended valves. _____

ii. Process drains. _____

-20

b. Gas streams:

i. Open ended valves. _____

ii. Process drains. _____

c. Light liquid & gas/liquid:

i. Open ended valves. _____

ii. Process drains. _____

d. Heavy liquids:

i. Open ended valves. _____

ii. Process drains. _____

e. Hydrogen stream:

i. Pipe line valves. _____

ii. Compressor seals. _____

G. Fuel Costs at the refinery:

a. Fuel gas: _____
b. Natural gas: _____
c. LNG: _____
d. LPG: _____
e. Brown coal: _____
f. Soft coal: _____

H. Solid fuels:

Collect a copy of a "typical" ultimate fuel analysis.

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9.0 MISCELLANEOUS INFORMATION

9.1 Battery Limit Requirements

9.1.1 Indicate the following battery limit information for streams, including hydrocarbon and chemicals, entering the refinery.

INCOMING STREAM	SOURCE	PRESSURE ____	TEMP ____

9.1.2 Indicate the following battery limit information for outgoing streams:

OUTGOING LIQUID STREAM	DESTINATION	DESTINATION PRESSURE ___	DESTINATION TEMP. ___

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10.0 INSTRUMENTATION

Describe the refinery instrumentation in general. Provide a listing of the symbols used to indicate controls in Piping and Instrument Diagrams.

10.1 General Control Concept/Philosophy

10.1.1	Is Refinery control Centralized?	Yes	No
10.1.2	Does Refinery have both centralized control and unit centralized control?	Yes	No
10.1.3	Does refinery only have control at the unit level?	Yes	No
10.1.4	Is control at the unit all local?	Yes	No

10.2 Instrument Type

10.2.1 Control Room Type

1.	Pneumatic?	Yes	No
2.	Electronic?	Yes	No
3.	Distributed Control?	Yes	No
4.	PLC?	Yes	No
5.	Main Frame Computer?	Yes	No
6.	CRT Based?	Yes	No
7.	Panel Mounted Based?	Yes	No

10.2.2 Field Instrumentation Type

1.	Pneumatic?	Yes	No
2.	Electronic?	Yes	No

11.0 MECHANICAL EQUIPMENT INFORMATION

See Data Base for Physical Characteristics in Appendix.

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APPENDIX

A. Refinery Organization Chart

B. Overall Refinery Plot Plan

C. Summary of Last 12 Months Operation

D. Spare Parts Policy and Description of Curren Maintenance Facilities

E. Loss Analysis

F. LP Data Base

G. Physical Characteristic of Refinery

APPENDIX B. GENERAL REVIEW OF COAL USE IN REFINERY SERVICE

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

Heat is provided by burning a variety of fuels in directly fired heaters. Generally in a chemical processing plant, the fuels are a collection of effluent streams from the various operations around the refinery complex in both gaseous and liquid forms, plus various types of imported fuel to balance but the heat requirements.

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

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

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

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

APPB.1. Direct Coal Firing

Coal usage is not a simple thing anymore. Gone are the days of stoking the fire by shovelful of run-of-mine coal and just letting it burn. Coal may need to go through physical cleaning, sizing and drying just to get it to the furnace. Burners are specially designed to achieve optimum efficiency and low NOx emissions. Additives are injected to reduce ash sticking to heater tube walls, reduce SO_2 in the flue gas, etc. Flue gas may be subjected to further treatment such as wet scrubbing to reduce SO_2 to meet the more stringent levels of environmental acceptance.

Traveling grate burners bring the coal automatically to the burning chamber where the coal is combusted. Coal with a moisture content much above 30% must be dried before burning, so lignite / brown coals would most likely need pre-combustion drying. Hot under grate air can be used for improved efficiency. Ash builds up on the grate until it drops into a hopper and the ash is later removed from the hopper. If sulfur becomes a problem it is typically dealt with after combustion in the form of sulfur oxides. Add on SO_2 removal equipment adds significant cost to a unit.

Modern direct coal burning systems include atmospheric and pressurized fluidized bed combustion (AFBC and PFBC) units that provide for gas burning, clean-up and heat recovery all in one unit. Limestone is used as part of the fluidizing medium and the calcium present in it reacts with the SO_2 before it is able to escape from the combustion chamber. The result is a non-toxic disposable by-product.

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

APPB.2. Coal Gasification

Coal gasification has been utilized for a long time and there are several companies (Texaco, Lurgi, IGT, KRW, etc.) that have commercialized processes. The product from the gasification (H_2, CO, CO_2, + others) can be used as a chemical feedstock or a fuel gas. To produce a fuel gas of medium range heating value (9.3 - 18.6 MJ/m^3 or 250 - 500 Btu / SCF) suitable for burning in a process heater, oxygen must be used in the gasification. Because of the reducing conditions present in the gasifiers, most of the sulfur in the coal is converted to H_2S. H_2S can be removed from the gas stream by a number of available processes. In addition, it can further be turned into elemental sulfur.

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

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

Another possible use of the gas produced via gasification could be as a fuel to a gas turbine. The gas turbine could be used to generate electricity or to provide power for a compressor. The thermal efficiency of a gas turbine is typically raised by using the turbine exhaust gas to raise steam in a waste heat boiler, in a co-generating system.

Given the availability of coal in Czechoslovakia, coal gasification technology should be watched closely and given full consideration at such time that energy economics dictate its use.. The selection of the proper technology to best fit the local brown coal characteristics should be kept in mind. In-country technical experts, we understand, are very well aware of the various technologies and are keeping abreast of current developments. Initial investment cost is high and although a project may be justified from a DCF or NPV basis, a shortage of hard currency may delay or defer action.

The cheapest source of fuel at this time is Russian natural gas. Alternate sources of fuel will not come to fruition until it is economical to do so.

APPB.3. Other Technologies

Coal liquefaction

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

Direct liquefaction producing a No. 2 type fuel oil would be more applicable to the fuel needs in the refinery. Several processes have been developed since the 1960's including H-Coal, SRC-I, Exxon Donor Solvent, SRC-II, etc. (in the U.S.). The high cost and inefficiency associated with these processes led to the cutback

of further development of the technologies as they stood. The early processes have been modified and further developed by the United States Department of Energy (U.S. DOE) and industrial partners into two-stage liquefaction processes. These processes are still not available on a large commercial scale. Estimates are that the cost of a barrel of oil produced by coal liquefaction using such methods might approach $25/barrel by the late-1990's.

Coal oil / water mixtures

The use of coal slurried with oil or water to produce a usable fuel is also the subject of numerous studies and optimizations. There are even annual conferences on "Coal & Slurry Technology" sponsored by the Coal & Slurry Technology Association and the U.S. DOE's Pittsburgh Energy Technology Center (PETC). Coal water mixtures can be prepared with up to 70% solids, while current technologies and pilot plant results show coal oil mixtures are limited to 30 - 50% solids. Coal-oil mixtures could be prepared in one location and pumped around the plant to the various process heaters, however, emissions in terms of SO_2, NOx and particulates would be a problem at each furnace.

Coal-fired gas turbines

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

Fuel cells

The combination of coal gasification and emerging fuel cell technology presents an attractive high efficiency electronic and heat energy generation possibility. Current projections, based on work sponsored by the US Department of Energy, indicate an efficiency between 45 and 55% in converting hydrocarbons directly to electricity. The H_2 and CO rich fuel from coal gasification is suited to fuel cell use, with CO_2 used in the cathode side of the cell.

Of the four major fuel cell technologies, two are worthy of mention here, phosphoric acid and molten carbonate. Phosphoric acid fuel cells are at a more advanced state, howeve they operate in the range of 400 °F compared to molten carbonate cells at 1 200 °F.

The molten carbonate fuel cell is best suited for use with coal gasification in applications where there is need for good quality heat. The exhaust gas

temperature of 1 200 °F is useful in the generation of high quality steam for process purposes. The use of bottoming cycles further enhances the system. Overall efficiencies, electrical and utilization of exhaust gas to generate steam, are in the order of 80%. The Department of Energy is sponsoring sub-megawatt tests of commercial sized units; these tests are scheduled for the 1993 calendar year.

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

3. COAL IN THE CSFR REFINERIES

3.1 Availability and Characteristics of Coal

Coal is available and used to generate electricity and steam in the central power stations at several of the CSFR refineries.

Two types of coal analyses are as shown in table H.3.1.

Table H.3.1 - Typical Czechoslovak Coal Analysis

Component	At Kralupy	At Chemopetrol (Litvinov)
C	33.3	29.3
H_2	3.8	3.3
Combustible Ash	1.0	-
N_2	0.5	0.4
O_2	10.7	10.5
Total Sulfur	1.1	1.0
H_2O	27.0	24.3
Ash	23.7	31.2

The heating value of the coal at Chemopetrol is reported to be 10.82 GJ/tonne with an August, 1991 delivered cost of 260 Kcs/tonne ($8.67/tonne @ $30/Kcs). Energy inflation is expected to drive this cost upward in the near future.

3.2 Potential for Use

It is reported that only a 30 year supply of coal is left in Czechoslovakia. The country is building nuclear power stations for future electrical needs. The coal reserve will be used to feed existing power stations, not refineries. Therefore, at this point in time the potential for new coal use is extremely low. Refinery fuel fired equipment can easily use natural gas or fuel oil. Modification for coal use reflects a major capital investment that is unlikely to occur.

3.3 Economics of Use

High sulfur fuel oil is a product that does not have much demand, especially in the summer. Its use as a refinery fuel is a convenient way to utilize the material. Switching existing fuel oil furnaces to coal would present an over supply of fuel oil. The availability and current price of natural gas at about $3.00/1 000 ft^3, coupled with a high capital investment required to utilize coal leads to the observation that new coal burning facilities are not an attractive alternative for the CSFR refineries.

It should also be noted that new coal burning facilities in the CSFR would not be allowed by environmental authorities, unless their desulfurization and particulate removal were especially efficient.

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APPENDIX C. GLOSSARY OF REFINERY TERMS

ENGLISH	CZECH
absorber	absorbční kolona
accumulator	sběrná nádrž
additives	přísady,aditiva
admission valve	sací ventil
after cooler	dochlazovač
air pressure switch	hlídač tlaku vzduchu
air valve	odvzdušňovací ventil
alternate current	střídavý proud
amine corrosion	aminové praskání
amine wash	aminová výpírka
ammonia	čpavek
aniline point	anilinový bod
annular furnace (heater)	kruhová pec
asphalts	asfalty
atmospheric distillation (crude d.)	atmosferická destilace ropy
aviation fuels	letecké pohonné hmoty
balance measurements	bilanční měření
ball valve	kulový ventil
battery	akumulátor
belt filter	pásový filtr
bleeder	pojistný ventil
blender	směšovací kohout
blending	míchání
block flow diagram	blokové schema
blow-down	odkal, spodní odtok vody (z kotle)
blower	dmychadlo
blow-down	odluh
board	panel
boiler	kotel
boiler fittings	armatura kotle
boiler plant	kotelna
boiler trial	provozní zkouska kotle
boot	kalník
bottom of column	pata kolony, spodek
breaking point	bod lámavosti
bubble cap trays	kloboučková patra
bubble-cup column	kloboučková kolona
burner	hořák
cable tray	kabelová lávka
capacitors, condensers	kondensátory

ENGLISH	CZECH
catalyst	katalyzátor
cell	cela, kobka
centrifugal pump	odstředivé čerpadlo
charge pumps	nástřiková čerpadla
check valve	zpětný ventil
chemical sewer	kanalizace odpadních vod
chemicals	chemikálie
chimney	komín
chimney pot	komínový nástavec
check valve	zpětný ventil
cladding	výstelka, vyložení, vyplátování
claus unit	jednotka na zpracování S
clay	hlinka
cocurrent flow	souproud
coil	vlásenka
coke	koks
coking	koksování
column	kolona
combustible S	spalitelná S
compressor	kompresor
concrete lining	betonová vyzdívka
conduit	kabelový kanál
consumption	spotřeba
control valve	regulační ventil
cooling water	chladicí voda
corrosion inhibitors	protikorozní inhibitory
corrosion, copper strip	koroze na měděném plíšku
countercurrent flow	protiproud
counterflow	protiproud
cracks	praskliny
crude oil / desalted crude	(surová) ropa / odsolená ropa
crude unit	destilační jednotka
current	tok, elektrický proud
cutoff cock / valve	uzavírací kohout / ventil
data logging system	sběrný systém dat
desalted crude	odsolená ropa
desalter	odsolovač
dewaxing unit	parafínka
diesel fuel	nafta
diked area	nádržové dvory
direct burial	kabel uložení přímo do země
direct current (DC)	stejnosměrný proud
distillation	destilace

ENGLISH	CZECH
distribution centre	rozvodna
distribution substation	rozvodna (ne hlavni)
distributor	rozdělovač
double mechanical seal	dvojitá mechanická ucpávka
drain valve	odkalovací ventil
drainage / sewerage	kanalizace
drop point	bod skápnutí
drum	nádrž
ducts	potrubí, kanály pro el.rozvod
eductor	eduktor
ejector	ejektor
elbow	koleno
emergency	nouzová situace
emergency lighting	nouzové osvětlení
encrustation	inkrustace
energy conservation	úspora energie
enthalpy	entalpie
excite	budit
expansion	intensifikace
extractor	extrakční kolona
feed	nástřik, vstup suroviny
feed forward	dopředná regulace
feeder	přívod, napáječ
feeds to aromatic complex	surovina pro aromatický komplex
feeds to refinery	surovina pro rafinerii
fired heater	pec
firing rate	spotřeba paliva
flange	příruba
flange gasket	těsnění do příub
flare	fléra
flash point	bod vzplanutí
float type	plovákový typ
floating roof	plovoucí střecha
flowing quantities	množství při nestandartních podmínkách
flue gases	spaliny
foaming agent	pěnidlo
freezing point	bod tuhnutí
fuel	palivo
fuel gas	topný plyn
fuel oil	topné oleje
furnace	pec
gas desulphurization	odsírění plynu
gas manifold	kouřovod

ENGLISH	CZECH
gas phase	plynná fáze
gasoline	benzín
gasoline additives	přísady do benzínu
gate valve	šoupě
gauge	kalibr
gear pump	zubové čerpadlo
greases	mazací tuky,
ground rods	uzemňovací tyče
grounding system	uzemnění
hard hat	helma
heat exchanger train	výměníková řada
heat exchangers	výměníky tepla
heat output	tepelný výkon
heat rate	tepelný tok
heat tracing system	ohřevný systém, otápění
heater suction	tah pece
heating oils	topné oleje
hydrocracker	hydrokrak
hydrotreatment	hydrogenace
ignition burner (torch)	zapalovací hořák
in-line	v trubkách
incinerator	spalovna
indication	signalizace
industrial fuels	prúmyslová paliva
injection pump	dávkovací čerpadlo
instrumentation	přístrojové vybavení
invertor	střídač
jet fuel	letecké palivo
kerosine	petrolej
kiln	pec
lack of feed	nedostatek suroviny
leaks	netěsnosti
light ends distillation	plyny z destilace
light/heavy gas oil	lehký/těžký plynový olej
liquefied petroleum gases(LPG)	zkapalněné uhlovodikové plyny
liquid ring pump	vodokružná vývěva
loading	plnění
loop	smyčka
lube oil train	olejářská linka
manhole	průlez
mass	hmotnost
material and heat balance	materiálová a tepelná balance
material balances	materiálové bilance

ENGLISH	CZECH
measurement devices	měřicí zařízení
mechanical seal	mechanická ucpávka
moisture content	obsah vlhkosti
molex unit	molexová jednotka, molekulová síta
motor control center(cabinet type)	motorový rozvaděč (skříňový typ)
motor control centre	rozvodna
motor drive valve	servo-ventil
naphtha	benzín(mimo automobilového)
naphtha splitter	benzínová redestilační kolona
nozzle	hrdlo, tryska
nuts and bolts	matky a šrouby
octane number	oktanové číslo
off-gases	odplyny (odpad-plyny)
off-site facilities	přidavná zařízení
oil separator	separátor
oil skimming	shrabování ropných látek
one line diagram	liniový diagram
operation costs	provozní náklady
orifice (meter)	clona
orifice plate	clonový kotouč
outlet	výstup
overexcited motor	přebuzený motor
overflow	přepad
overhead condensor	hlavový kondensátor/k.hlavových par
packed column	náplňová kolona
packing	náplň
particulates	pevné částice
pilot	stabilizační hořák
piston	pístový
pitch	zbytek z kolony
plated	oplátováno
pneumatic control	pneumatické řízení
poles	poly
positioner	posicionér
positive displacement meter(oval)	oválové měřidlo
power plant	elektrárna
preflash	předfleš
pressure above atmospheric	přetlak
pressure below atmospheric	podtlak
pressure fan	výtlačný ventilátor
pressure transmitters	tlakové vysílače
process	zpracování
process unit	procesní jednotka

ENGLISH	CZECH
properties	vlastnosti
pulsation dampner	náraznik (u kompresoru)
pumparound	cirkulační reflux
purge	proplach, pročištěni(kvůli hořlavinám)
purging	profukování
push button control	tlačitkové ovládání
push button stations	tlačitkove stanice
pyrolysis	pyrolýza
rain water	dešťová voda
reboiler	reboiler
rectifier	usměrňovač
rectify	rektifikovat
refinery	rafinerie
reflux	reflux (zpětný tok)
reflux drum	refluxní nádrž
register	zapisovač
removal of NOX	odstranění oxidu N
residua	zbytky
resistance temperature detectors(RTD)	odporový teploměr
safety valve	pojišťovací ventil
screwed	sešroubované
scrubber	pračka, vypírání nečistot
seal	ucpávka, těsnění
sheet	plášť
shell	plášť (výměníku)
shut-down	odstavení
simulation program	simulační program
sleeve	rukáv kolony
slop	znečištěná vrstva oleje, vody
sludge	kaly
sodium sulphide	Na2S
solution	roztok
solvent	rozpouštědlo
sour water stripper	stripr kyselých vod
spray cooler	sprchový chladič
spray tower	sprchová kolona (absorbér)
spread of oil leaks	kontaminace ropnými látkami
stack	komín
stack damper	komínova klapka
stack gas	spaliny
start up	najíždění
steam	pára
steam superheater	parní přehřívák

ENGLISH	CZECH
steel sheet	ocelový pancíř
stem	dřík ventilu
storage tanks	skladovací nádrže
storming water	přívalová voda
straight-way valve	přímý ventil
stripped	stripovaný
stripper	stripovací kolona
structured packing	výplň (orientovaná)
submersible pump	ponorné čerpadlo
suction head	sací výška čerpadla
sulphur plant	výrobna síry
surge drum	vyrovnávací nádoba
sweetening	čištění
switch gear	vypínač
synchronized motor	synchronizovaný motor
tail gases	koncové plyny
tandum seal	dvojitá ucpávka
tank farm	tankoviště
tank storage area	tankoviště, skladovací prostory
tars	dehty
thermocouple	termočlánek
to design sth. for	(dimenzovat něco na),projektovat
top of the column	hlava kolony
topping plant	destilační jednotka
tower	věž, destilační kolona
tracing (steam/electric)	otápění (parní/elektrické)
transformer	transformátor
trap	lapač
trapped oil / water	zachycené ropné látky / voda
tray	patro
treating	úprava
trim cooler	dochlazovač
tubes	trubky
two stage unit	2stupňová jednotka
vacuum gas oil	vakuový plynový olej
valves	ventily, uzavírací armatury
vent	odvzdušňovací ventil
vessel	nádoba, nádrž
viscosity	viskosita
voltage	napětí
waste heat recovery boiler	parní přehřívák
welded	svařené
winterising provisions	zimní opatření

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ENGLISH	CZECH
yield	vytěžek

ABBREVIATIONS

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

GJ	giga joules
HC	hydrocarbons
HDS	hydrodesulfurization
HP	high pressure
Hg	mercury
Hz	hertz
IBP	initial boiling point
IGT	Institute of Gas Technology
ISBL	inside battery limit
J	joule
KRW	Kellogg Rust Westinghouse
LHSV	Liquid Hourly Space Velocity
LP	linear programming/low pressure
Lube	Lubricating
M	mega(10^6)
MEA	Monoethanolamine
MEK	methyl ethyl ketone
MHC	mild hydrocracking
MON	motor octane number
MPa	Megapascal, a unit of pressure
MSW	municipal solid waste
MTBE	methyl tertiary butyl ether
MVA	mega volts ampere
MVAR	mega voltampere reactive
MW	mega watts
NAAQS	National Ambient Air Quality Standards
NCV	net calorific value
NO_x	Oxides of Nitrogen
NPDES	National Pollutant Discharge Elimination System
OSBL	outside battery limit
OVA	Organic Vapor Analyzer
PFBC	Pressurized Fluidized Bed Combustion
PONA	Paraffins, Olefins, Naphthanes and Aromatics
Pa	pascal, a unit of pressure
RCC	reduced crude conversion
RON	research octane number
RTD	Resistance Temperature Detector
RVP	Reid Vapor Pressure
S.R.	Straight Run
SCFD	standard cubic feet per day

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SCFH	standard cubic feet per hour
SCFM	standard cubic feet per minute
SG	specific gravity
SO_x	Oxides of sulfur
SRC	solvent refined coal
T	tera (10^{12})
TBP	true boiling point
TDS	total dissolved solids
TEFC	totally enclosed fan cooled
TEL	tetraethyl lead
TOC	total organic carbon
TSS	Total Suspended Solids
UOP K	UOP Characterization Factor
V	volt
VOC	volatile organic compound
WWTP	wastewater treatment plant
WATSON K	Watson Characterization Factor
XP	explosion proof
atm	atmosphere or atmospheres
bar	bar
cP	centipoise
cSt	centistokes
cal	calorie
cm	centimeters
cps	cycles per second
day	day
ft^3	cubic feet
ft	feet or foot
g	gram
gal	gallons
gpm	gallons per minute
h	hour
hp	horse power
in	inch or inches
k	kilo
kA	kilcamperes
kPa	kilo pascal, a unit of pressure
kV	kilovolts
kWh	kilowatt hour
kcal	kilo calories

kcal	kilo calories
kg	kilogram
kg/cm^2	kilogram per square centimeter
lb	pound or pounds
liter	liter or litre
m	meter or metre
max.	maximum
mg	milligram
mi	mile
million	million(10^6)
min	minute
min.	minimum
mm	millimeters
mol	mole
n	normal
ohm	ohm
pH	pH, a measure of acidity or strength of a base.
percent	percent(or %)
phase	phase (electrical)
ppm	parts per million
ppmv	parts per million (volume)
ppmw	parts per million (weight)
ppb	parts per billion
psi	pounds per square inch
psia	pounds per square inch absolute
psig	pounds per square inch gauge
ptb	pounds per thousand barrels of oil
rpm	revolutions per minute
sec	seconds
tonne	metric ton
tonnes	metric tons
vol	volume
wt	weight
y	year

USAID

TERMS OF REFERENCE

DESCRIPTION/SPECIFICATIONS/WORK STATEMENT

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

1. BACKGROUND

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

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

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

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

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

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

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

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

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

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

2. GOAL AND OBJECTIVES

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

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

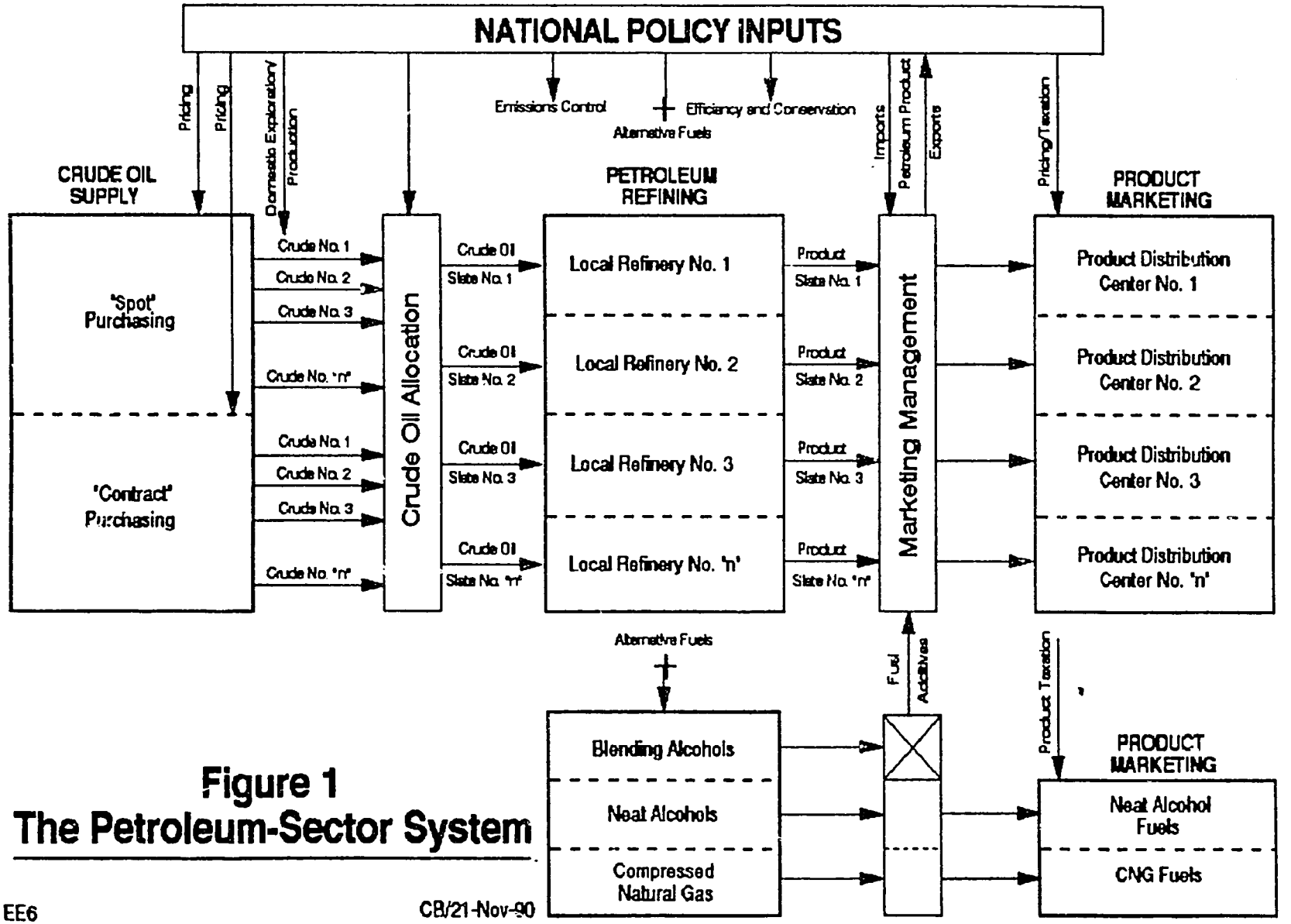

Figure 1
The Petroleum-Sector System

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

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

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

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

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

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

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

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

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3. APPROACH

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

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

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

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

Petroleum refineries and petrochemical manufacturing plants are closely linked both physically and through refinery products that become petrochemical feedstocks. The work shall be confined to petroleum refineries only. For this purpose the refinery shall be defined as comprising all

installations that pertain to the receipt of the crude oil through to processing and storage of the refinery's primary products. A primary product shall be defined as one that has been fully processed so as to be marketable. On-site facilities to blend different gasoline streams, produce, and process them to final specifications are refinery units. Refinery gas and/or liquid streams that are delivered to other units for further processing, such as to ethylene, ammonia, or aromatic extraction, are to be considered as finished products.

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

4. TASKS

The following tasks are foreseen for the work.

a. Refinery Characterization

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

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

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

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

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

b. Refinery Financial Structure

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

c. Selection of the Refineries

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

d. Refinery Housekeeping

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

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

2) incrementally insulating excessively hot surfaces,

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

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

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

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

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

e. Heat Conservation

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

f. Process Unit Operating Conditions

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

g. Refinery Energy Balance

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

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

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

h. Fuel Switching

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

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

i. Refinery Emissions

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

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j. Data Evaluation

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