INTERN EQUIVALENCY AT

THE ENERGY RESOURSES CONSERVATION BOARD

A Report

by

Gerald Collins

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ABSTRACT

The author had seven years' engineering experience before entering the Doctor of Engineering Program and the Internship requirement was waived. This report presents an account of that experience and describes in detail one project which combined technical skills and organizational effectiveness.

The positions held by the author were exploration geophysicist, mining engineer/geologist, and resource allocation engineer. In the first position he designed seismic surveys, interpreted the results, and recommended drilling locations for oil and gas exploration. In the second position he supervised mineral exploration programs, calculated ore reserves, and designed a light-weight drilling rig. As a resource allocation engineer, he analyzed proposals for major petrochemical and fertilizer plants, estimated future production of gas and gas products, and wrote reports for a government agency.

The specific project described involved forecasting the availability of pentanes-plus for benzene manufacture. Several other aspects of the proposal were also analyzed and the author coordinated work with other departments. The author also carried out administrative duties in the processing of the application.

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CHAPTER I

INTRODUCTION

The purpose of this report is to establish that the author's work experience prior to entering the Doctor of Engineering program meets the objectives of the internship. These objectives are:

1. to enable the student to apply his knowledge and training to the solution of a specific practical and relevant problem of particular interest to the organization with which the internship is served, under the supervision of a practicing engineer who will direct him and evaluate his performance; and

2. to enable the student to function in a non-academic environment in a position where he will become aware of the organizational approach to problems in addition to those of traditional engineering design or analysis.

The author is a registered professional engineer in the Province of Alberta, Canada, and has seven years of engineering experience. It is, therefore, reasonable to assume that the above objectives have been satisfied. It remains then to choose specific job assignments which illustrate a combination of technical and organizational skills.

This report is divided into two major sections: a detailed description of the positions held with three different organizations and a more detailed description of the specific job assignment chosen to meet the internship requirement of the Doctor of Engineering degree. That assignment was involved with regulation of the oil and gas industry and the development of the petrochemical industry in Alberta. The author's responsibilities extended beyond technical analysis of the supply of resources to preparation for public hearings and coordination of reports which were submitted to the Provincial Government.

Appendix A is an excerpt from a report written by the author indicating the scope of the projects undertaken while employed by the Energy Resources Conservation Board, a provincial regulatory control and policy agency.

CHAPTER II

ENGINEERING WORK EXPERIENCE

This section contains details of the three positions held after graduation from Nova Scotia Technical College in May 1970. No description is given of the summer experience in surveying for the National Park Service and in analytical laboratory work and computerized maintenance for the Iron Ore Company of Canada.

Amoco Canada Petroleum Company Limited

Upon graduation the author was hired as an exploration geophysicist by Amoco Canada Petroleum Company Limited (Amoco), a subsidiary of Standard Oil Company (Indiana), in Calgary, Alberta. The company's policy for new graduates, who were drawn from varied disciplines, was to have them attend training courses for half days and work with technicians for half days for the first four months of employment. The training courses included local and regional geology, basic geophysical field techniques, computerized processing of digitally recorded seismic data, and petroleum geology. The work with technicians involved routine handling of the field data which was submitted to the computer department. Once the data was printed in an interpretable form, preliminary analyses were performed with the help of a geophysicist who supervised the work. The geophysicist analyzed the seismic data and returned it to the technicians for plotting on maps to facilitate a geological interpretation. From this interpretation he made recommendations regarding additional work or drilling.

After this four month training period the author was assigned to

a group which had responsibility for all geophysical work performed in one area of Alberta. Initial responsibilities included the interpretation of seismic data for mapping subsurface geology. This work involved contour and isopach maps which would indicate potential traps for oil or natural gas. The results of these projects were used for making decisions regarding lease purchases, additional detailed seismic work, or exploratory drilling.

As the author gained experience in interpretation of seismic data, he became more involved in the initial phases of the work. This work was composed of consultation with company geologists to select areas with potential for oil or gas production and designing a seismic survey to explore the area optimally. After an area was selected, several important parameters were analyzed. The first of these was the approximate depth of the geological horizon of interest. Any test wells in the general area or data with the Geological Survey of Canada were used when available. Otherwise, regional trends were used. This information was necessary to decide how long the series of recorders (geophones) would be and how far they would be spaced from the source of the seismic waves.

The second decision necessary was the selection of the source. There are two basic sources: an explosive charge and vibrating source. These sources create a seismic wave in the ground, similar to a sound wave in the air, which is reflected from interfaces between different types of rock. These reflections are recorded digitally on magnetic tape at frequent intervals (on the order of 2 milliseconds) and later translated into the maps of the interfaces. Explosive charges are

detonated at the bottom of a drill hole to provide a single impulse. By arranging several charges in different holes to be simultaneously detonated, the geophysicist can enhance the data by cancelling out some of the reflections which interfere with normal processing or interpretation. A vibrating source, on the other hand, is not an impulse. The waves are generated from a truck which places a large plate in contact with the earth. Hydraulic cylinders transfer the energy to the plate which is caused to vibrate over a set frequency for a specified length of time. For example, the frequency could be set to decrease from 80 cycles per second to 15 cycles per second over 8 seconds. This method of generating a wave is helpful for subsequent data processing because any frequencies outside the range input could be eliminated as noise. The selection of source depends on such parameters as the depth of interest, the complexity of the geology, and often the terrain and near surface geology. Explosive charges are a stronger source and are preferable for complex geology or in areas with loose overburden where the weaker energy from the vibrating source is dissipated. Other factors to be analyzed in source selection are the costs of drilling the shot holes and the ease of moving the particular equipment. The author was involved in surveys using both sources.

After the source was selected, field testing was performed to ascertain the effectiveness of the previously determined parameters for geophone spacing. This involved firing several test holes with different sizes of explosive charge or using different frequencies of vibration. The results were analyzed in the field and, if the quality was acceptable, no changes were made in the recording configuration.

Otherwise, the geophones were spaced differently and further tests run. The data were generally recorded from 24 to 48 groups of geophones with 6 to 12 geophones per group. Such a span would cover about a mile on surface and by moving the source a lesser distance, an overlapping picture of the subsurface could be recorded.

The next phase of the process was reducing the data to a form which was interpretable. The recorded data were in time series form and this could be manipulated mathematically to enhance the important data and suppress the unimportant. The author was not involved in the writing of computer programs for the processing but did select which processes were to be applied to the data. Results from the processing were in the form of vertical sections through the earth. Adjacent sections could be compared to detect any geological changes which occurred between them.

The final result of a seismic survey was a map of the geological surface or thickness of interest. This map would show any anomalous areas which had potential for trapping oil or gas. On the basis of the maps managerial decisions were made. During his two and one-half years with Amoco, the author's recommendations resulted in purchase of significant areas of leases and the drilling of two exploratory wells. Both of these wells were geophysical successes in the sense that the geology conformed to the prediction. They were, however, dry holes with no commercial volumes of hydrocarbons contained in the reservoirs.

Angus G. MacKenzie Mining Consultants

In February 1973 the author left Amoco and joined MacKenzie Mining

Consultants (MacKenzie) in Calgary, Alberta, as a Mining Engineer/ Geologist. MacKenzie performed engineering and supervisory functions for companies which held mineral leases but did not have the staff to evaluate them. In most cases this work was preliminary exploration work to determine if more work was warranted.

At the start of the author's work with MacKenzie, he was initiated into field techniques for mineral exploration by serving on a crew with a senior geologist. The interpretation of results was learned in the office by calculating reserve estimates for one ore body which was in an advanced stage of exploration. The field work ranged from basic exploration such as geochemical, magnetometer, and gravitimeter surveys to core drilling and tunnelling into ore bodies.

Within three months, the author's responsibilities with MacKenzie increased significantly. He was placed in charge of a drilling crew which was to evaluate a limestone deposit on a remote island off the coast of British Columbia. Responsibilities included selecting drilling sites on a topographical map and locating these sites on the ground; supervising the drilling to determine when each hole should be terminated; logging the core for quality of limestone and changes in geology; sampling the core for laboratory analysis; and performing additional surface geological work to determine the extent of the limestone deposit. During a six-week period, the author was on location in the field except for two brief visits to the office, thus all field decisions were his responsibility.

The next phase in the analysis of the property was inspection of the laboratory results and calculation of the ore reserves. In this

instance, the reserves were considered large enough to support a commercial operation for structural limestone but unfortunately the iron content was too high for such a use. The other option for limestone ore bodies is the cement market but because the location was so remote the operation of a cement plant would be uneconomical. Therefore, the project was terminated.

The author was involved in several other similar projects, most of them in remote mountainous or northern areas of Western Canada. The minerals explored for included base metals (copper, lead, and zinc), precious metals (silver and gold), and industrial minerals (limestone and barite). This broad range necessitated a flexible approach to the selection of exploration techniques but one aspect common to all projects was the need to arrange the transportation and communication logistics well in advance. The author learned how to establish wilderness camps and gained a strong appreciation for wildlife and the environment, an understanding which helps in seeing both sides of the views on environmental impacts of major energy projects.

During the winter of 1973-74, exploration in Western Canada was at a low point for two reasons: the winter is not a prime time for exploration and a socialistic provincial government in British Columbia was stifling large companies. Consequently, emphasis was placed on analysis of field work and design projects. During this period, he developed, in response to a request for proposals from the Canadian Government, the conceptual design for a light-weight, highly-mobile diamond drill. This drill was to be used for core drilling in remote and rugged areas. Specifications included the ability to load the

drill in a Twin Otter aircraft and to be able to transport the drill with as few flights as possible. The design proposed consisted of a standard drill which could be mounted on a chassis with flexible tracks. A power take-off from the drill engine would provide power for the tracks to move over rough terrain including swamps and deep snow. In this transportation mode, the drill could also carry its drill pipe or tow a trailer with supplies. The chassis would also provide support when drilling. To move the drill over long distances, the chassis and tracks could be removed and dismantled into parts easily loaded onto a Twin Otter. On the basis of this proposal, MacKenzie was awarded a $30,000 contract in conjunction with a Calgary manufacturer of all-terrain vehicles. The prototype was built and tested after the author left MacKenzie and the author has no knowledge of any commercial production.

Energy Resources Conservation Board

The Alberta Energy Resources Conservation Board (ERCB) is an independent agency of the provincial government which regulates production of oil, gas, and coal, construction of pipelines and electricity transmission lines, the export of natural gas from the province, and the use of gas and gas products within the province as feedstock or fuel for major industries. The ERCB employs about 1500 professional, technical, and clerical staff. The 5-member Board itself is appointed by the government, usually by promotion from within the organization and upon the recommendation of the other members of the Board. The Board consists of four members and a chairman. It is the Board's responsibility

to implement any legislation concerning energy resources and to make recommendations to the Cabinet concerning any applications for projects made pursuant to that legislation. In all but the large projects, the Board's decision is considered final, and the report and recommendations are approved. For large or controversial projects, public hearings are held and the reports include the views of any intervenors who appeared at the hearings. The ERCB could be described as a cross between the Texas Railroad Commission's Oil and Gas Division and the Federal Energy Regulatory Commission of the Department of Energy.

The author joined the ERCB in June 1974 and remained there until June 1977 when he moved to Texas and entered Texas A&M University. His first position at the ERCB was as a gas reservoir engineer. Because of his limited background in reservoir analysis, the author attended training lectures in that area. In his capacity as a gas reservoir engineer, the author was required to calculate the reserves of gas in reservoirs based on pressure, temperature, fluid analysis, and production history. Both volumetric and material balance methods were used. From this analysis and consideration of reservoir parameters, the recoverable reserves were calculated. The ERCB calculated gas reserves for the entire province and published an annual report.

Additional duties in this capacity were to calculate the maximum deliverability of single wells and whole fields based on pressure drawdown tests, to forecast the production of liquids such as propane and butane from the gas, and to set allowables for gas wells in which there was water influx.

The author was transferred to the Resource Allocation Section

within the Gas Department after nine months of employment. In this position he reported directly to the assistant manager, Don Pearson, who was a professional engineer. This section was established to administer Section 42 of the Oil and Gas Conservation Act and the Gas Resources Preservation Act, both statutes of the Province of Alberta. The ERCB was given the authority to require any company which used gas or gas products (ethane, propane, etc.) as an industrial fuel or feedstock to apply for an industrial development permit. This legislation took effect in 1974 and exempted facilities which were in existence or were in design or construction phases. Under the Gas Resources Preservation Act, the ERCB regulated the export of gas from the province basing its decisions on the ability of the proved reserves of gas to meet Alberta's projected needs for a 30-year period from the date of the application. All companies wishing to export gas were required to obtain a gas removal permit.

The author was involved with the first applications for industrial development permits and it was necessary to establish standard procedures for handling the applications. The following procedure was accepted for these early applications:

1. the application was reviewed by the author and other staff members in the economics department for compliance with the legislation;
2. if there were any deficiencies the applicant was requested to supply more information;
3. when the application was essentially complete, a public hearing date was set;
4. the hearing was advertised and a deadline for any interventions for or against the project was established;

5. the application and any interventions were then analyzed further by the author and others and questions were prepared for legal counsel to ask at the hearing;

6. the application was heard before three Board members; and

7. all information was incorporated into a report which was approved by the Board and submitted to the Cabinet.

The author was involved with all aspects of these applications from technical analysis to report writing and arranging details of meetings within the organization. This required coordination between three departments and the members of the Board in addition to post-hearing consultations with the applicants.

The author was first involved with applications for permits to use natural gas as a feedstock and fuel for the production of ammonia and urea which would be used as fertilizers. The primary tests which these projects (and all others) were required to meet were that they be in the public interest having regard to: 1) the efficient use without waste of gas or gas products and 2) the present and future availability of hydrocarbons in Alberta. Other considerations in the public interest were the possible use of alternative feedstocks, the degree of resource upgrading within Alberta, and the economic impact on the province. Items of lesser importance to the Board, but possibly more important to other agencies of the government, were the prices to be paid for the natural gas, the applicant's marketing and financing plans, the manpower requirements, and the environmental impact. The author's main responsibility on these projects was analysis of the present and future availability of hydrocarbons, one of the major tests for the

projects.

Every three years, the ERCB forecasted the 30-year requirements for natural gas within Alberta. These requirements were then provided for before any gas was authorized for export from the province. In its forecasts, the ERCB included volumes of gas for future industries such as fertilizer plants. Consequently, if the total number of such plants did not exceed what the ERCB had projected, the future availability of gas was assured and it was no impediment to the project. If, however, the proposed project would increase the gas requirements in any category, it was necessary to revise the forecast and recompare it with the projected availability of gas. This also required a new calculation of the gas surplus, described below.

The author also worked on the applications covering development of a petrochemical industry in the province. These applications requested the use of ethane as a feedstock for ethylene manufacture and further upgrading to polyethylene and polyvinyl chloride. There were, prior to these applications, only minor uses of ethane in the province and the author was required to calculate the reserves of ethane contained in the natural gas in the province and the availability of that ethane at processing plants in sufficient quantities to justify its extraction. The total ethane available was then compared with the requirements over the life of the project. In this case, the ethane forecast was high enough to justify approval of the projects.

Another major project which the author completed was an analysis of the availability of pentanes-plus, a natural gas by-product, which two competing consortiums wished to use as feedstock in a benzene

manufacturing plant. This project is described in detail in the next section of this report.

The other responsibility which the author had as resource allocation engineer was the calculation of the gas surplus to Alberta's needs. This was necessary each time an application was received under the Gas Resources Preservation Act for removal of gas from the province. The ERCB had established a procedure which considered the proved reserves, a portion of reserves expected to be discovered in the future, and the projected provincial requirements. The volume of gas already under contract for export was subtracted from the total available and the remainder was considered surplus. This volume was compared with that requested in the application to determine if a permit would be granted. The method for handling the applications was similar to that for industrial development permits outlined above if the request was for a large volume or a long term. For minor requests or amendments to existing permits, the public hearing stage was eliminated if there were no interventions when the application was advertised.

During the last two years of his employment with the ERCB, the author worked eighty per cent on industrial development permits and twenty per cent on gas removal permits. The industrial development permits covered such chemicals as benzene, methanol, ethanol amines and glycols, vinyl acetate, ethylene and its derivatives, and nitrogen fertilizers. Work in both of these areas required monitoring of the permits to determine if the applicants were fulfilling certain clauses. For the industrial development permits these were generally conditions or deadlines which the permit-holder was required to meet. For gas

removal permits, the holders were restricted to daily, annual, and permit-life maximum volumes and actual volumes were reported to the ERCB. The volumes were monitored by the author in conjunction with the accounting department. Because of emergency situations outside of the province, during the winter of 1976-77, two companies were granted exemptions to these restrictions.

The author supervised the work of two junior engineers and two technicians during the last two years in this position. His work required consultation with other departments within the organization including the legal and economics departments. The author attended two in-house supervisory courses during his employment with the ERCB. In addition, the technical requirements of the position entailed a knowledge of the methods of producing, transporting, and upgrading gas and gas products. In summary, the position was at the level which would be expected of an engineer with five to eight years of experience and included supervisory and organizational tasks in addition to technical assignments.

CHAPTER III

INTERNSHIP EQUIVALENCY

Background

The position with the ERCB has been chosen to demonstrate that the author has met the objectives of the internship as stated in the Introduction. The particular project selected is the analysis of the availability of pentanes-plus for benzene manufacture in the province of Alberta. A discussion of the other aspects of the project that the author was involved in is also included. At the time the author was employed in the Resource Allocation Section of the Gas Department and was supervised by Don Pearson, the Assistant Manager. The author was directly responsible for one junior engineer and two technicians at that time.

The benzene project was somewhat more complicated than the other projects because two competing projects filed applications to use the same feedstock for the same purpose over the same period. The Petrochemicals Alberta Project (Petalta) was composed of four companies: Alberta Energy Company, Hudson's Bay Oil and Gas, Mitsubishi Petrochemical Company Limited, and Mitsubishi Corporation. Their application requested a permit to use 47,200 barrels of pentanes-plus per day to produce benzene and by-products over a 20-year period. The competing group included Alberta Gas Trunk Line Company Limited, Dow Chemical of Canada Limited, and Alberta Gas Chemicals Limited. This group will be referred to as Trunk Line, et al. Their application requested a permit to use 37,500 barrels of select pentanes-plus per

day to produce benzene, motor fuels, and other by-products over a 20-year period.

The similarities between the projects are obvious. The difficulties arise after the forecast of pentanes-plus is analyzed and the conclusion is that, at best, there is only enough feedstock for one project. The discussion of that forecast is presented below with a section of the final report included here as Appendix A.

The Availability of Pentanes-Plus

Pentanes-plus is a by-product of natural gas and is quite often called condensate. It is extracted from the natural gas at the wellhead or in the field before the gas is transported to the consumer by pipeline. Consequently, pentanes-plus is generally not available in large volumes or at one central location. Some of the pentanes-plus produced in Alberta is injected into crude oil pipelines and is not available as a segregated product. Some of the remainder is used as a buffer between crude oil and propane which are transported by pipeline to distant markers. Additionally, a small refinery in Alberta had contracts to use 6,000 barrels of pentanes-plus per day. The problem of availability, therefore, involved much more than the physical production of pentanes-plus.

The first step in determining the availability was a forecast of the production and, because pentanes-plus is a by-product of gas, a forecast of gas production was essential. Gas was divided into two categories: proved reserves and future reserves. The forecast from proved reserves was based on all the information which the Board had

including reserves estimates, production history, deliverability projections from companies who owned or had contracted for gas, and the restrictions due to the size or location of gas processing plants. For solution gas production, the forecast was based on projected oil production and the gas-oil ratio. The production of pentanes-plus from each field or area was based on representative analyses of the gas. In cases where the composition of the gas was expected to change over the life of the reservoir, the pentanes-plus production was based on the changing composition or on expected recovery during cycling schemes. These cycling schemes were implemented in reservoirs where condensation with lower pressures would reduce liquid recovery. In all instances, pentanes-plus recovery was based on historical plant efficiencies.

From this forecast of pentanes-plus production for fields or areas, a forecast for each pipeline system was made to determine the areas where the feedstock would be available. A table showing the forecast for these pipelines is included in Appendix A.

For production from future discoveries of natural gas, the author made some assumptions based on recent history and on the estimated ultimate reserves of gas to be discovered. After the assumptions were made regarding discoveries, further estimates of production rates were necessary. A simplifying assumption that gas would be produced from old reserves before new was made. As the new reserves became necessary to meet requirements, it was assumed that production would occur at a rate which would give a 20-year life. Because the recent trend in discoveries had been toward drier gas, the yield of pentanes-plus was reduced from an average of 20 barrels per million cubic feet to 15

barrels. By multiplying this yield by the forecast of gas production, an estimate was obtained for the pentanes-plus to be recovered from future reserves. The total forecast was the sum of the production from proved and future reserves. These curves are plotted on Figure 6-1 in Appendix A. That figure also compares the production forecasts submitted by the two competing projects. The severe decline in the production forecasts indicates the importance of this aspect of the analysis.

After the forecasts were finalized, the existing requirements for pentanes-plus were calculated. Three basic requirements were identified. An existing refinery within Alberta used pentanes-plus for gasoline manufacture. Pipeline companies used pentanes-plus to separate different products such as crude oil and propane. Other pipelines used the feedstock as a blending agent for heavy crude oils to reduce viscosity and make transportation easier. These latter two uses were not considered to be essential. The pentanes-plus not used in these categories was normally mixed with crude oil or natural gas liquids.

Figures 6-2 and 6-3 are included in Appendix A to indicate the availability of feedstock for the proposed projects. The conclusion is that neither project would have sufficient feedstock available for the 20-year term. However, both groups did state at the hearing that they could switch to alternative feedstocks later in the plant life if pentanes-plus was not available. Based on this conclusion the ERCB had to decide which of the projects would be better for the province based on other aspects such as economic impact and potential for additional

upgrading.

Other Aspects of the Project

In addition to the above technical analysis, the author was in charge of many of the details associated with processing the application and preparing the report. The application was handled according to the procedure outlined in Chapter II and a public hearing was held for each application. The author prepared most of the questions for legal counsel to ask and was present at the hearings to give technical support. After the hearings, the author was given responsibility for the major section of the report described above and for the following minor sections:

1. the description of each proposal and the interventions received;
2. alternative feedstocks;
3. ownership and control of the projects, and opportunities for Albertans to participate;
4. economic viability and financing;
5. required government support;
6. location and environmental impact; and
7. miscellaneous matters.

These sections of the report, though minor in the decision, did give the author the opportunity to examine the full scope of a major petrochemical project.

Some administrative duties were also delegated to the author. He was responsible for monitoring progress on the report and for scheduling meetings with the other departments involved and the members of the

Board. He was also in charge of the final manuscript and coordinated all typing, drafting, printing, press releases, and distribution. The approval of the Board members who had presided at the hearing was required before these last tasks were completed.

Summary

The objectives of the internship or its equivalent are to enable the student to apply his knowledge to a specific problem and also to enable him to function effectively in a non-academic environment. The project described above meets these objectives with ease. The author was required to use all of his technical skills and experience and was called upon to be innovative in the forecast of pentanes-plus production. He was also in a situation where coordination across departmental lines was essential. This aspect of the project and also the analysis of the minor aspects of the proposals required the author to expand his focus and look at the overall merits of the proposals. The additional administrative duties gave the author an appreciation of the office support staff necessary for a technical organization.

Although the author does not necessarily approve of government regulation to the extent described here, he is grateful for the opportunity he had to expand his professional experience at the ERCB.

APPENDIX A

6 MATTERS OF PARTICULAR IMPORTANCE TO THE BOARD IN ITS APPRAISAL OF THE APPLICATIONS

6.1 AVAILABILITY OF PENTANES-PLUS AND ALTERNATIVE FEEDSTOCKS

6.11 Pentanes-Plus

6.111 Views of Petalta

The Petalta project would utilize some 47 200 barrels per day of pentanes-plus commencing in the fourth quarter of 1979. To demonstrate the availability of this feedstock, Petalta submitted a forecast of pentanes-plus production which was prepared by James A. Lewis Engineering Co. Ltd. The study forecast pentanes-plus production from proved gas reserves on the basis of a review of submissions made by operators, an independent study made by Hudson's Bay Oil and Gas Company Limited, and published studies of the Board. The forecast production from proved reserves is shown in column 2 of Table 6-1.

The Petalta study also included a forecast of pentanes-plus production from future gas reserves and was based on an initial projected growth rate for gas reserves of 2.6 Tcf per year declining in later years such that the total growth between 1976 and 1997 would be 27.6 Tcf. The future gas reserves were assumed to be produced at the rate of one MMcf/d for each 7.3 Bcf of reserves of marketable gas and to yield 14.6 barrels of pentanes-plus per MMcf of marketable gas. The forecast pentanes-plus production from future gas reserves is shown in column 3 of Table 6-1.

The forecast total production of pentanes-plus, shown in column 4 of Table 6-1, was adjusted by Petalta to reflect the segregated pentanes-plus which would be available in the Edmonton area. The adjustment was made by subtracting volumes of pentanes-plus which are blended in crude oil or natural gas liquids and volumes which are not

available at Edmonton due to geographical constraints. Petalta also made an adjustment for volumes which are blended with heavy crude oil being removed from the province. The resulting supply of pentanes-plus in the Edmonton area is shown in column 5 of Table 6-1 and amounts to 80 000 barrels per day in 1980, 65 000 barrels per day in 1990 and 46 000 barrels per day in the year 2000.

The pentanes-plus production forecast as submitted by Petalta is shown in Figure 6-1 compared to other available forecasts. The total production is shown as well as production from only the proved reserves.

In reply to questions at the hearing, Petalta said that, if the quality of pentanes-plus was lower than assumed, its requirements would be greater if it wished to produce the same volume of benzene.

6.112 Views of Interveners upon the Petalta Application

Dome, as a result of questions at the hearing, submitted a forecast of pentanes-plus production. Dome's forecast was based on the application of a recovery ratio of pentanes-plus from gas to a projection of total natural gas production. As such it was not possible to distinguish between production from proved reserves and from future reserves as forecast by Dome. With respect to recovery ratios, Dome projected both a high and a low case. The high case reflected a decline from a current level of 21 barrels per MMcf of raw gas to 17 barrels per MMcf by 1990. For the low case, the recovery ratio was projected to decline to 10 barrels per MMcf by 1990.

The pentanes-plus production as forecast by Dome for both the high and the low case is shown in Table 6-2 and Figure 6-1.

None of the other interveners submitted a supply or requirements forecast for pentanes-plus. Dome and Amoco expressed concerns regarding the continuity of the supply of pentanes-plus which they require as a buffering material for the movement of natural gas liquids from the province in the Interprovincial crude oil pipeline. At the hearing

Amoco said that other materials such as naphtha, synthetic crude oil, diesel oil, or unleaded gasoline could technically be used as buffering material but the economics of their use had not been appraised. Dome said that the liquid by-products from the proposed plant would be suitable as a buffering material if they were available at the same price as pentanes-plus. Chevron stated that its requirement of 13 500 barrels per day of pentanes-plus at its Burnaby refinery should continue to be satisfied should the Petalta project proceed. Gulf submitted that Petalta's requirements could be understated because the quality of the available pentanes-plus may not be as good as Petalta assumed. Gulf also raised questions about the quality of the pentanes-plus to be produced from future discoveries of gas.

6.113 Views of Trunk Line et al

Trunk Line et al would use some 37 500 barrels per day of pentanes-plus in its project commencing in the second quarter of 1980. Trunk Line et al stated that it had asked the Alberta Petroleum Marketing Commission for a forecast of the blends and quantities of pentanes-plus which would be gathered into Edmonton. It had not received such a forecast so had accepted the Board's forecast of pentanes-plus supply as submitted to the National Energy Board in April 1975. It also submitted an analysis comparing the supply and requirements of pentanes-plus produced in Alberta over the period 1976 to 1994. The requirements considered were those of the Trunk Line et al proposed benzene project, blending requirements for upgrading heavy crude oil streams, refinery demands in Canada, volumes currently mixed in the field with crude oil, and exports. The study showed a deficit of pentanes-plus after 1981 if all requirements are considered. The study concluded that the proposed project of Trunk Line et al would require diversion of pentanes-plus destined to satisfy refinery demands elsewhere in Canada, or the gathering of those quantities of pentanes-plus now mixed with crude oil streams. The conclusion was strengthened when an allowance was made for the pentanes-plus not available in the Edmonton area due to geographical constraints.

Since the production so projected by Trunk Line et al was taken

from an earlier Board forecast and presents no new work, it has not been included in Figure 6-1 which shows a comparison of production estimates.

Trunk Line et al, in reply to questions, said that, if the pentanes-plus quality was not as good as it assumed, then its requirements would be greater and it would attempt to purchase alternative feedstocks to supplement the pentanes-plus supply.

6.114 Views of the Interveners upon the Trunk Line et al Application

None of the interveners submitted projections of the supply and requirements of pentanes-plus within Alberta. However, several of them stated that traditional purchasers of pentanes-plus should have the opportunity to compete for available supplies. These traditional purchasers include refinery operators beyond Alberta borders and those who utilize pentanes-plus as a buffering material for removing propane and butanes from the province. Gulf submitted the same views regarding the quality of pentanes-plus as discussed in section 6.112. In addition, Gulf stated at the hearing that the application did not establish the future availability of pentanes-plus because the applicant was still awaiting a reply from the Alberta Petroleum Marketing Commission.

6.115 Views of the Board

In assessing the availability of pentanes-plus to meet the needs of the proposed benzene projects, the Board believes that it is appropriate to evaluate the availability on a year-by-year basis. Consequently, the Board has made a new assessment of the supply of pentanes-plus for the period 1977 to 2000. The assessment includes a forecast of the supply of pentanes-plus from proved and future reserves of gas.

From Proved Reserves

The Board's forecast of pentanes-plus production from proved reserves is based on the projected production and processing of natural gas from proved remaining recoverable reserves at December 31, 1975. In preparing its estimate, the Board had regard for gas deliverability schedules submitted by owners and by gas purchasers operating in Alberta,

the productive capacity of existing reserves, gas processing facilities in existence or approved by the Board as of December 31, 1975, plant operating histories, and owners' submissions and progress reports for gas cycling schemes.

The gas producing rates for each field or area were obtained from the latest gas deliverability and production schedules made available to the Board by various permittees who are authorized to remove gas from Alberta, from operators in the major pools, and from deliverability schedules developed by the Board. The forecast of solution gas production was based on expected crude oil production and gas-oil ratio behaviour for the pools involved.

The composition of gas produced from each pool was based on a representative analysis. Where changes in composition are expected to occur due to retrograde condensation or other effects, the composition of the gas to be produced was based on reservoir fluid studies. In reservoirs where gas cycling schemes designed to curtail retrograde losses are in operation the production forecast reflects the Board's estimate of how pentanes-plus recovery will be affected by cycling.

Plant recovery efficiencies were based on plant history and submissions presented to the Board in support of gas processing applications under section 38 of The Oil and Gas Conservation Act. In most instances the pentanes-plus recovery factors approach 100 per cent.

The small volumes of condensate recovered from field separator facilities were assumed to occur in the same proportion to total pentanes-plus production as current operating experience indicates.

The forecasts of pentanes-plus production from each pool for the period 1977 to 2000 inclusive were combined to provide individual gas plant forecasts which were arranged according to pipeline systems as shown in Tables A-2 to A-21 of Appendix A. Only those plants with pentanes-plus production of 1 000 barrels per day or greater are identified individually in the tables. The remaining plants are classified as "other facilities".

A summary of the production forecasts for plants served by each pipeline system is also presented in Table A-1 of Appendix A. The table shows the Board's forecast of total pentanes-plus production from proved

remaining recoverable reserves as of December 31, 1975.

From Future Reserves

The Board's forecast production from future gas reserves has been based on an analysis of the pentanes-plus growth pattern in the proved initial reserves of marketable gas. Since the production forecast from proved reserves reflects reserves as of December 31, 1975, the production from future reserves includes reserves growth during 1976. Since the proposed use of pentanes-plus is within Alberta, the Board has decided to recognize, in its projections, the reserve growth anticipated over the full period being analysed rather than a limited period as is its practice when dealing with applications to remove gas or propane from the province.

In the case of a gas or propane removal application the Board calculates the number of years of reserves growth which it will recognize. The number of years is dependent upon the percentage of the ultimate recoverable reserves of gas which has been discovered to date and the reserves growth is based on the long-term trend. This calculation recognizes a block of future reserves which may reasonably be relied on. The future reserves calculated for the purpose of this report represent the total reserves which the Board expects to be developed over the forecast period and, therefore, are considerably larger than those calculated in a gas surplus calculation.

The annual growth in proved initial reserves of marketable gas has averaged some 2.5 Tcf for many years, and, given favourable incentives, especially as they affect the net revenue to the producer, growth at this rate may be expected for the next year or so, following which some decline is inevitable. The Board estimates that the increase in proved initial reserves of marketable gas would be some 2.5 Tcf per year in 1976 and 1977 and subsequently decline annually to some 0.6 Tcf in 1995. The Board has projected this growth rate to be consistent with its estimate of the ultimate recoverable gas reserves of the province of 110 Tcf.

Gas production from these new reserves was projected at the rate necessary to meet a share of Alberta's future requirements plus new removal permits which the Board estimates may be issued in the future.

In determining the volume of future gas which would be produced to meet Alberta's requirements, the Board has assumed that all currently proved gas reserves would first be produced at the maximum possible rate and only then would future reserves be used to meet Alberta's requirements. The Board recognizes that this is an arbitrary assumption and actual production would not occur in this manner. With respect to production to meet new removal permits, the Board has assumed that the 30-year protection policy will continue in future. The Board assumed that certain volumes of gas would be authorized for removal in future in stages until a surplus no longer exists. The production to meet these new permits was assumed at a rate of one MMcf/d for each 7.3 Bcf of marketable reserves of gas for a period of 10 years, subsequently declining at a rate of 10 per cent annually. The assumptions regarding production to meet Alberta's requirements and future removal permits have the effect of limiting considerably the production of gas from future reserves.

The forecast of pentanes-plus production from growth of gas reserves was then established from the gas production forecast by applying an assumed pentanes-plus yield of 15 barrels per MMcf of marketable gas over the entire period of the forecast. The recovery ratio is a judgement estimate based on the fact that for all proved reserves the ratio is currently some 20 barrels per MMcf and on the expectation that future reserves will contain less liquids than reserves developed to date.

A summary of the pentanes-plus production from future reserves is presented, on an annual basis for the period 1977 to 2000 inclusive, in Table A-22 of Appendix A. The results of the Board's forecast have been smoothed but, in general, reflect the actual calculations to the nearest 1 000 barrels per day.

Total Production and Comparison With Other Forecasts

The Board's forecast of the total production of pentanes-plus from proved remaining recoverable reserves as of December 31, 1975 and from the expected reserves growth is summarized in columns 2 and 3 respectively of Table 6-3. As shown in column 4 of the table the total production of pentanes-plus is forecast to peak in the next few years at some 140 000

barrels per day, then to decline over the forecast period even with the expected growth in gas reserves. The forecast production is some 60 000 barrels per day by 1990 and less than 30 000 barrels per day by the year 2000. These data are also shown graphically in Figure 6-1.

The Board recognizes that long-term forecasts such as those summarized in Figure 6-1 are subject to uncertainty and consequently it has shown its forecast production rates as broken lines after the year 1985 in this and subsequent figures. Most of the uncertainty is due to the fact that the pentanes-plus forecast is based on a forecast of gas production. The gas forecast is dependent upon many variables such as the rate of development of existing reserves, exploration levels and gas discoveries within the province, the effect which industrialization within Alberta will have on gas consumption, the timing of gas deliveries from frontier areas to markets otherwise supplied from Alberta, and the authorization of new removal permits. An additional uncertainty relates to the assumptions respecting the pentanes-plus content of future gas reserves.

A review of Figure 6-1 indicates that the Board's pentanes-plus production forecast is lower than those submitted by Petalta and by Dome. The Petalta forecast (prepared by James A. Lewis Engineering Co. Ltd.) from proved reserves compares closely with the Board forecast although it is considerably higher for the first 2 or 3 years. However, the Petalta forecast of pentanes-plus production from future reserves is much higher than is the Board's. The major reason for the difference is that the Petalta forecast assumes all new gas reserves, upon development, would be immediately placed on production at a rate of one MMcf/d for each 7.3 Bcf of reserves while the Board forecast visualizes a much lower rate of production. As mentioned earlier, the Board forecasts production from future gas reserves only as needed to meet Alberta's requirements or new removal permits which the Board's projections suggest would be possible under existing policy and procedures respecting protection for Alberta's future requirements and the related surplus calculations. One assumption adopted in the Board's approach to projecting production from future reserves is that such reserves would be produced only after all currently proved reserves have been produced at their maximum rate. Many

of the currently proved reserves in small pools that are thus projected as being produced to meet Alberta's requirements have a pentanes-plus content lower than the 15 barrels per MMcf assumed for future reserves. To the extent that the Board's assumption does not hold true, and future reserves rather than small currently proved reserves are utilized to meet Alberta's requirements, the pentanes-plus production from future reserves would be greater than as forecast by the Board.

To test the sensitivity of the forecast to this assumption, the Board made another projection of the manner in which gas reserves could be produced to meet Alberta's requirements. It was assumed that future reserves of gas containing 15 barrels of pentanes-plus per MMcf were produced before the small currently proved reserves which contain 3 to 5 barrels per MMcf. The net effect was an increase of approximately 5 000 barrels per day of production and consequently even under those circumstances, the Board's forecast would remain much lower than that submitted by Petalta.

The Dome forecast did not separate the production of gas from proved and future reserves and thus a comparison on that basis with the Board's forecast is not possible. An analysis of the data supporting the Dome forecast indicates that the marketable gas production forecast by Dome is in good agreement, until the mid-1980's, with the total production forecast by the Board. Thereafter the Board forecasts a steeper decline in the gas production rate. The major difference in the pentanes-plus production forecast is in the recovery ratios used. For its high case, Dome used for all of its projected gas production the equivalent of some 25 barrels of pentanes-plus per MMcf of marketable gas, declining to some 21 barrels per MMcf. The Board used an actual forecast for proved reserves which results in an average recovery ratio of 22 barrels per MMcf of marketable gas in 1977 and a declining recovery ratio thereafter. The average recovery ratio in the Board's forecast from proved reserves declines because forecasts were made for individual plants, and production from those fields with high recovery ratios is declining more rapidly than that from the leaner fields and consequently the average recovery ratio is declining. For future reserves the Board used a recovery ratio of 15 barrels per MMcf. It recognizes that in recent

years the new discoveries and additions to existing gas reserves have contained less than 15 barrels of pentanes-plus per MMcf but believes that is due to the impact of reserves developed in the shallow formations in south-eastern Alberta. In the long term the Board believes the pentanes-plus content of future gas reserves will be higher than that of the reserves discovered in the recent past. Dome, for its low case, used a recovery ratio of some 24 barrels per MMcf declining to about 12 barrels per MMcf. The low recovery ratio projected by Dome for the later years coupled with the fact that the gas production forecasts are similar results in the Dome low forecast being similar to the Board's by 1990.

General Requirements for Pentanes-Plus

All of the pentanes-plus currently being produced in Alberta is being marketed. Average production during 1976 was 130 000 barrels per day. Additionally, pentanes-plus production is expected to decline in the 1980's and 1990's. This raises the question of whether any or all of the existing markets for Alberta's pentanes-plus should be provided for prior to considering its availability as a feedstock to a benzene industry. The Board notes that several of the interveners contended that certain existing markets should continue to be served.

The Board considers that the current uses can be generally categorized as follows (estimated daily consumption during 1976 is shown in parentheses):

(a) refinery requirements within Alberta (6 500 bbl/d),

(b) volumes mixed with crude oil in the field (this is not a use for pentanes-plus in the normal sense but it is necessary in order to market economically production from certain areas) (21 500 bbl/d),

(c) volumes blended with heavy crude oil for upgrading and transportation purposes (5 800 bbl/d),

(d) volumes used as a buffer in shipping natural gas liquids by pipeline (13 900 bbl/d),[1]

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1 Currently all marketed in the United States after separation at Sarnia.

(e) direct refinery requirements elsewhere in Canada (37 000 bbl/d), and

(f) exports to the United States for use as a refinery feedstock (44 000 bbl/d).

In determining whether the above uses should be given priority over the manufacture of benzene in Alberta, the Board has had regard for the reference in the industrial development permit legislation to the Alberta public interest. It has also had regard for the Alberta Government's stated policy of encouraging the maximum upgrading of Alberta's resources within the province as opposed to shipping them to extraprovincial markets in an unprocessed form.

The Board believes that existing refinery requirements for pentanes-plus within Alberta should be provided for prior to reserving product for benzene manufacturing. Such requirements are exempt from the industrial development permit legislation and thus it might be said that permits are deemed to exist for the utilization of pentanes-plus in Alberta refineries to the extent that it was used during the 12-month period ending March 31, 1976. The refinery at Bowden is the only one in this category.

With respect to volumes of pentanes-plus which are mixed with crude oil in the field, the Board recognizes that to the extent that the mixing is necessary for the economic marketing of the product, it is a use which must be provided for. In the Board's view, a considerable portion of the pentanes-plus currently mixed with crude oil could be transported to the Edmonton area in a segregated state if it were definitely needed for an Alberta-based industry, although there would be a related incremental cost. The Board believes that the same is true with respect to certain volumes of pentanes-plus which are currently not available in the Edmonton area due to their remote location. The latter is not a use of pentanes-plus but the Board finds it convenient for assessment purposes to combine such volumes with those volumes mixed with oil, and to categorize them separately as (a) volumes definitely unavailable under any foreseeable circumstances and (b) volumes which possibly could be available if the need were great enough. The definitely unavailable pentanes-plus must be subtracted from production

prior to providing volumes for manufacturing benzene. For simplicity the Board has assumed that none of the pentanes-plus available from future reserves would be mixed with crude oil streams or would be geographically unavailable. The volume of future reserves that would not be available would, in any event, likely be small and would have little impact on the available supply.

The Board recognizes that the pentanes-plus currently blended with heavy crude oil is an integral part of the marketing process and thus is in the Alberta public interest. The Board believes it possible that over the next several years facilities for further upgrading of heavy oil will be built in Alberta, possibly in connection with oil sands developments, and that the current blending requirement for pentanes-plus could be virtually eliminated. Additionally, there exists the possibility of using certain other products to mix with heavy oil if the value of the pentanes-plus within Alberta is great enough. For these reasons, the Board believes that beyond the next several years, a reservation of pentanes-plus for mixing with heavy crude oil need not be made.

With respect to the pentanes-plus which is used as a buffer to move natural gas liquids by pipeline, the Board believes that, if necessary and given proper economic incentives, other refinery products such as naphtha or possibly a synthetic crude oil might serve as a buffer. Also, all of the pentanes-plus currently used for that purpose is exported and the Board questions whether such export is in the Alberta public interest when compared with the possibility of further upgrading the pentanes-plus in Alberta. Moreover, the controls respecting export of crude oil and equivalents which are expected to be imposed by the National Energy Board could effectively terminate the use of pentanes-plus as a buffering material unless a market could be found in the Sarnia area. Accordingly, the Board will not in its study reserve pentanes-plus for buffering of natural gas liquids.

The Board believes that use of Alberta pentanes-plus as refinery feedstock elsewhere in Canada would not be more in the Alberta public interest than would the upgrading within the province. (For more detail

on this matter see section 6.5 of this report). With respect to refinery requirements for the pentanes-plus in the United States, the Board expects that such exports will be phased out by the National Energy Board within the next 5 or so years. In any case, such use would not rate precedent over an Alberta-based petrochemical project. Consequently, the Board does not consider that extraprovincial refinery requirements for pentanes-plus have a priority over its use in Alberta to manufacture benzene.

Conclusions

The availability of pentanes-plus to the proposed benzene projects is summarized in Figures 6-2 and 6-3. The figures are similar except that the first deals with the Petalta project while the second relates to the proposal of Trunk Line et al. The figures show, by the red lines, the production as forecast by the Board from proved reserves alone and also in total. These have been taken from Table 6-3 and Figure 6-1. The requirements are shown on Figures 6-2 and 6-3 parallel to the abscissa and, moving from bottom to top, in the sequence of the priorities which the Board places on them.

Existing refinery requirements in Alberta are estimated at 6 000 barrels per day throughout the period of the study and are for the Shell refinery at Bowden. This requirement is also shown, along with all other estimated requirements, in columns 5 to 11 of Table 6-3. The pentanes-plus which definitely could not be made available due to mixing with crude oil or geographical constraints, amounts to some 3 700 barrels per day in 1977 and is estimated to decline to about 1 700 barrels per day by the year 2000. This is made up of relatively small volumes in many fields which are identified in Table A-23 of Appendix A. The volumes that are mixed with crude oil are so mixed in order that they may be marketed. The geographically constrained volumes are too small and too far from Edmonton to be moved there economically. The above mentioned are the only two uses given absolute priority over the proposed projects; the Petalta requirement of 47 200 barrels per day in one case and the Trunk Line et al requirement of 37 500 barrels per day in the other case are shown next in sequence.

The next entries show volumes of pentanes-plus which are not currently available as a segregated stream in the Edmonton area but

which the Board estimates could be made available if the need was essential. These volumes include those which are currently mixed with natural gas liquids. In certain instances the movement to the Edmonton area would have to be by truck and in other cases new pipelines or separation facilities might be required. The extra costs associated with transporting pentanes-plus from certain sources could be as much as $.50 to $1.00 per barrel. The volume in this category currently amounts to some 40 000 barrels per day but is estimated to be only some 7 000 to 9 000 barrels per day by the late 1990's. The fields with production in this category are listed in Table A-24 of Appendix A. The Board has assumed that the pentanes-plus production from the Edson area, which is currently transported directly from the province, could be made available in the Edmonton area.

The next entries show those volumes which might be required for blending with heavy crude oil. Since the Board believes this need may disappear over the next few years and prior to a critical supply period for the proposed projects, it has shown this requirement to have a lower priority than the benzene plants. Due to the uncertainty as to when such requirements might end the Board has shown them for illustrative purposes through to 1995 and has made them proportional to its forecast of heavy oil shipments. Facilities for upgrading the heavy crude oil, which may be built in the future, would reduce these requirements. The final entries are the estimated requirements for buffering of natural gas liquids in pipelines. These requirements do not include those volumes which are commingled with the liquids. Again the requirements are shown until 1995 even though the Board believes substitute buffering products could be available if required earlier.

In keeping with the earlier statement that the Board would not consider extraprovincial refinery requirements as having a priority over benzene manufacturing requirements, the figures do not reflect such usage.

The initial and most apparent conclusion that can be drawn from Figures 6-2 and 6-3 is that insufficient pentanes-plus will be available in Alberta to supply feedstock to more than one benzene project. Indeed, the figures show that, only if the use of pentanes-plus as a natural gas liquids buffer and for blending with heavy oil is discontinued, and if a significant portion of the pentanes-plus not now available in the Edmonton

area is made available in future, would there be sufficient feedstock for even one of the proposed projects. As mentioned previously, the Board believes that the use of pentanes-plus as a buffer and for blending purposes can be phased out and that increased volumes can be made available in segregated form in the Edmonton area. It notes, accepting the Board's production and other forecasts as accurate, that none of the usages need be curtailed prior to 1982 or 1983 and the cutbacks could be spread over a period of at least 10 years.

Figure 6-2 shows that if the availability of pentanes-plus to the Petalta project was maximized the required volume of 47 200 barrels per day would be available only until about 1992 which is some 7 years short of the requested 20-year period. It should be noted that Petalta stated it could scale down the size of its proposed project to as small as 35 000 barrels per day and still operate economically. Such a reduction in size would extend by some 3 years the time period over which adequate volumes of pentanes-plus would be available. Figure 6-3 shows that the 37 500 barrel per day requirement of Trunk Line et al would be available for some 13 years or until 1995. These assessments assume that the production of pentanes-plus will be essentially as forecast by the Board. Earlier in this section the Board noted the great uncertainty in production forecasts as far as 15 to 20 years into the future, particularly with respect to future reserves. The Board has noted earlier that one facet of its forecast, the assumption that future reserves will be produced only after maximizing production from proved reserves, could have a material effect on the results. This was estimated to be as high as 5 000 barrels per day. Due to this and the many other uncertainties, the Board believes that the conclusions drawn directly from Figures 6-2 and 6-3 must be tempered with general judgement.

Both applicants indicated that the pentanes-plus feedstock to the proposed facilities could be replaced over a time period, in part or in total by alternative feedstocks derived from crude oil or synthetic crude oil on the plant site, or obtained from a refinery. These alternatives, coupled with the detailed assessment indicating availability of feedstock for 12 to 15 years and with the uncertainty of the long-term forecast, lead the Board to conclude that although there are reasons for concern respecting

feedstock supplies, such reasons are not sufficient to require the denial of the applications. The applicants, however, must recognize that a shortage of feedstock may occur.

The Board agrees with Gulf that, depending on the quality of the pentanes-plus, the volumes required by the applicants could be significantly higher. The necessary detailed information is not available for the Board to make a useful estimate respecting this matter. If the quality of the available pentanes-plus were lower than that assumed by the applicants, the effect would be to advance the date when either applicant would have to supplement its feedstock supply. However, given the likely declining supplies of pentanes-plus, the Board concludes that any permit issued should specify a particular volume of pentanes-plus which would be reserved for the benzene plant rather than approve the use of an uncertain volume of pentanes-plus which might be required to produce a given amount of benzene. Flexibility could be provided so that, during any period when pentanes-plus was available, additional volumes could be used over and above the reserved volume.

Summary

In summary, the Board is satisfied that it would not be appropriate to deny both applications due to lack of pentanes-plus. On the other hand, adequate feedstock will be available for only one of the proposed projects. There may be an incremental cost necessary to ensure the availability of enough segregated pentanes-plus in the Edmonton area. The prospect of declining pentanes-plus supply is such that any approved project should provide for the likely conversion to other feedstocks in a manner which would minimize the economic impact of the conversion on the project. The likelihood of a tight supply situation also suggests that any permit issued should specify a particular volume of pentanes-plus which would be reserved for the approved project. In that the Trunk Line et al project is planned on a smaller scale and would use less pentanes-plus, it has an advantage over the Petalta project as far as feedstock availability is concerned. It is evident, however, that this advantage would diminish if the Petalta proposal were scaled down to the extent that it indicated would be feasible.

6.12 Alternative Feedstocks

6.121 Views of Petalta

While Petalta considered pentanes-plus to be, at present, the only economic feedstock for large-scale production of benzene in Alberta, it acknowledged that pentanes-plus may have to be supplemented by other feedstocks before expiry of the requested 20-year term. It agreed that the C_6 - C_8 naphtha fraction of Alberta crude oil is similar in quality to the corresponding fraction of pentanes-plus and that the latter could therefore be augmented by purchasing naphtha from refiners or installing crude oil fractionation, treating and blending equipment at the proposed plant and extracting the naphtha fraction there.

Petalta contended that, while synthetic crude oil currently produced from Athabasca tar sands yielded a C_6 - C_8 naphtha with a lower aromatics potential than crude oil naphtha or pentanes-plus, this fraction could, if necessary, also be used to supplement pentanes-plus.

Petalta said it had held some discussions with refiners in the Edmonton area and found that naphtha would, at this time, not be available to the proposed plant.

In reply to questions, Petalta stated that benzene could not be economically manufactured in Alberta from coal because no suitable commercial technology exists now and none is expected to emerge before the late 1980's.

6.122 Views of Trunk Line et al

Trunk Line et al also acknowledged that intermediate refinery fractions obtained from crude oil or synthetic crude oil could be used as feedstock for benzene production, but contended that the use of crude oil would be premature and not feasible at this time. With respect to naphtha or reformate, preliminary discussions with refiners had shown that these could probably be made available to the proposed project, although volumes were uncertain.

6.123 Views of the Interveners

Gulf contended that oil refineries in the Edmonton area could produce up to 147 million gal of benzene per year (9 590 barrels per day) from crude oil at a lower capital investment than the proposed projects, and could do so without the difficulties Gulf could foresee for the applicants of securing a supply of pentanes-plus for twenty years. There would then also be no co-production of low value by-products. Gulf indicated it could produce 52.5 million gal per year (3 425 barrels per day) from its Edmonton refinery if benzene demand justified it.

Gulf also expressed the view that Trunk Line et al's plan to use crude oil as a supplementary feedstock would involve significantly higher capital investments and operating costs.

6.124 Views of the Board

The Board agrees that coal is not now an economic feedstock for the manufacture of benzene, and recognizes that the bulk of current benzene production comes from integrated refinery operations based on crude oil. It also notes Gulf's argument that benzene volumes similar to those which the applicants propose to manufacture from pentanes-plus could be produced from crude oil at Edmonton refineries. However, the Board does not have before it details of a scheme or schemes to make benzene at refineries and cannot therefore assess the relative advantages of the two approaches. It only has before it proposals to make benzene from pentanes-plus and, bearing in mind its conclusions respecting the availability of pentanes-plus (see section 6.115), it considers it inappropriate to deny the applications solely because of interveners' statements respecting benzene manufacture at refineries. The Board recognizes that it may be economically feasible and in the public interest to produce benzene at refineries and believes that in the future benzene may be manufactured at both refineries and pentanes-plus based plants.

The Board notes that both applicants could use a suitable fraction of crude oil or synthetic crude oil to supplement pentanes-plus when

this becomes necessary for maintenance of an economic level of production over the life of the proposed plants. As indicated in section 6.115, the Board believes that the future diminishing supply of pentanes-plus indicates the need for flexibility to convert to other feedstocks. To the extent that a supplemental feedstock is required, the benefit to the province could be increased or decreased, depending on plant modifications and the price of the supplement versus the price of pentanes-plus.

With respect to alternative feedstocks, the Board sees no distinction between the two proposals.

6-20

TABLE 6-1 PRODUCTION AND AVAILABILITY OF PENTANES-PLUS AS ESTIMATED BY PETALTA, Barrels Per Day

1	2	3	4	5
YEAR	PRODUCTION FROM PROVED RESERVES[a]	PRODUCTION FROM FUTURE RESERVES[a]	TOTAL PRODUCTION[a]	SEGREGATED SUPPLY AVAILABLE IN EDMONTON AREA[b]
1977	160 000	-	160 000	-
1978	154 000	-	154 000	-
1979	143 000	6 000	149 000	-
1980	132 000	11 000	143 000	80 000
1981	122 000	15 000	137 000	-
1982	108 000	20 000	128 000	-
1983	95 000	24 000	119 000	-
1984	87 000	27 000	114 000	-
1985	78 000	31 000	109 000	63 000
1986	71 000	35 000	106 000	-
1987	65 000	38 000	103 000	-
1988	59 000	41 000	100 000	-
1989	54 000	44 000	98 000	-
1990	50 000	46 000	96 000	65 000
1991	46 000	47 000	93 000	-
1992	42 000	48 000	90 000	-
1993	39 000	48 000	87 000	-
1994	35 000	49 000	84 000	-
1995	32 000	49 000	81 000	55 000
1996	30 000	48 000	78 000	-
1997	27 000	48 000	75 000	-
1998	25 000	47 000	72 000	-
1999	23 000	46 000	69 000	-
2000	21 000	44 000	65 000	46 000

[a] Taken from Figure 2 of the application, page 24.

[b] Taken from Table 6 of the application, page 25. (Estimated on five-year intervals).

TABLE 6-2 PRODUCTION OF MARKETABLE GAS AND PENTANES-PLUS AS ESTIMATED BY DOME

1	2	3	4
YEAR	MARKETABLE GAS PRODUCTION, Bcf	PENTANES-PLUS PRODUCTION, Barrels Per Day HIGH CASE	LOW CASE
1977	2 217	154 700	144 200
1978	2 339	160 900	146 700
1979	2 480	168 100	149 700
1980	2 572	171 700	148 300
1981	2 618	173 000	144 800
1982	2 696	175 400	142 700
1983	2 650	169 800	134 000
1984	2 600	163 900	125 400
1985	2 550	158 200	116 100
1986	2 450	149 500	105 700
1987	2 350	141 100	95 900
1988	2 225	133 700	85 600
1989	2 110	123 100	76 100
1990	2 000	114 600	67 400

TABLE 6-3 SUPPLY AND REQUIREMENTS OF ALBERTA PENTANES-PLUS AS ESTIMATED BY THE BOARD, Barrels Per Day

1	2	3	4	5	6
YEAR	AVAILABLE FROM PROVED GAS RESERVES[a]	AVAILABLE FROM FUTURE GAS RESERVES	TOTAL AVAILABLE	EXISTING REFINERY REQUIREMENTS WITHIN ALBERTA	DEFINITELY UNAVAILABLE[b]
1977	138 100	-	138 100	6 000	3 740
1978	136 100	4 050	140 150	6 000	3 740
1979	133 500	6 450	139 950	6 000	3 710
1980	122 460	13 200	135 660	6 000	3 520
1981	113 010	13 200	126 210	6 000	3 320
1982	97 330	13 200	110 530	6 000	3 130
1983	85 510	13 200	98 710	6 000	2 950
1984	77 030	13 200	90 230	6 000	2 720
1985	69 460	15 000	84 460	6 000	2 620
1986	63 110	15 900	79 010	6 000	2 410
1987	56 870	16 950	73 820	6 000	2 320
1988	52 270	17 550	69 820	6 000	2 300
1989	47 680	17 700	65 380	6 000	2 240
1990	44 710	16 650	61 360	6 000	2 390
1991	41 480	16 500	57 980	6 000	2 250
1992	38 250	17 550	55 800	6 000	2 110
1993	35 450	18 000	53 450	6 000	2 060
1994	32 510	18 450	50 960	6 000	2 010
1995	29 960	13 950	43 910	6 000	1 930
1996	28 000	10 050	38 050	6 000	1 850
1997	26 180	9 000	35 180	6 000	1 760
1998	24 430	7 950	32 430	6 000	1 710
1999	22 390	7 500	29 890	6 000	1 690
2000	20 640	7 200	27 840	6 000	1 660

[a] Proved reserves as of December 31, 1975.

[b] Mixed with crude oil or geographically unavailable.

[c] Commencing October 1, 1979.

[d] Commencing April 1, 1980.

[e] Currently mixed with crude oil or natural gas liquids or geographically unavailable.

[f] Not estimated for the period from 1996 - 2000.

7	8	9	10	11
REQUIREMENTS OF PROPOSED PETALTA PROJECT	REQUIREMENTS OF PROPOSED TRUNK LINE ET AL PROJECT	POSSIBLY AVAILABLE[e]	FOR BLENDING WITH HEAVY CRUDE	FOR BUFFER FOR NATURAL GAS LIQUIDS
-	-	39 690	3 500	15 000
-	-	38 780	6 500	15 000
42 480[c]	-	38 800	8 000	15 000
47 200	37 500[d]	36 440	8 500	15 000
47 200	37 500	34 370	9 500	15 000
47 200	37 500	31 830	10 000	15 000
47 200	37 500	28 750	10 000	15 000
47 200	37 500	26 380	10 500	15 000
47 200	37 500	23 990	11 500	15 000
47 200	37 500	21 490	12 000	15 000
47 200	37 500	19 030	12 000	15 000
47 200	37 500	17 490	12 000	15 000
47 200	37 500	16 020	12 000	15 000
47 200	37 500	15 120	8 000	15 000
47 200	37 500	13 870	8 000	12 000
47 200	37 500	12 670	8 000	12 000
47 200	37 500	11 800	7 500	12 000
47 200	37 500	10 610	7 500	12 000
47 200	37 500	9 650	7 000	5 000
47 200	37 500	9 170	-[f]	-[f]
47 200	37 500	8 490	-	-
47 200	37 500	7 960	-	-
47 200	37 500	7 390	-	-
47 200	37 500	6 580	-	-

6-25

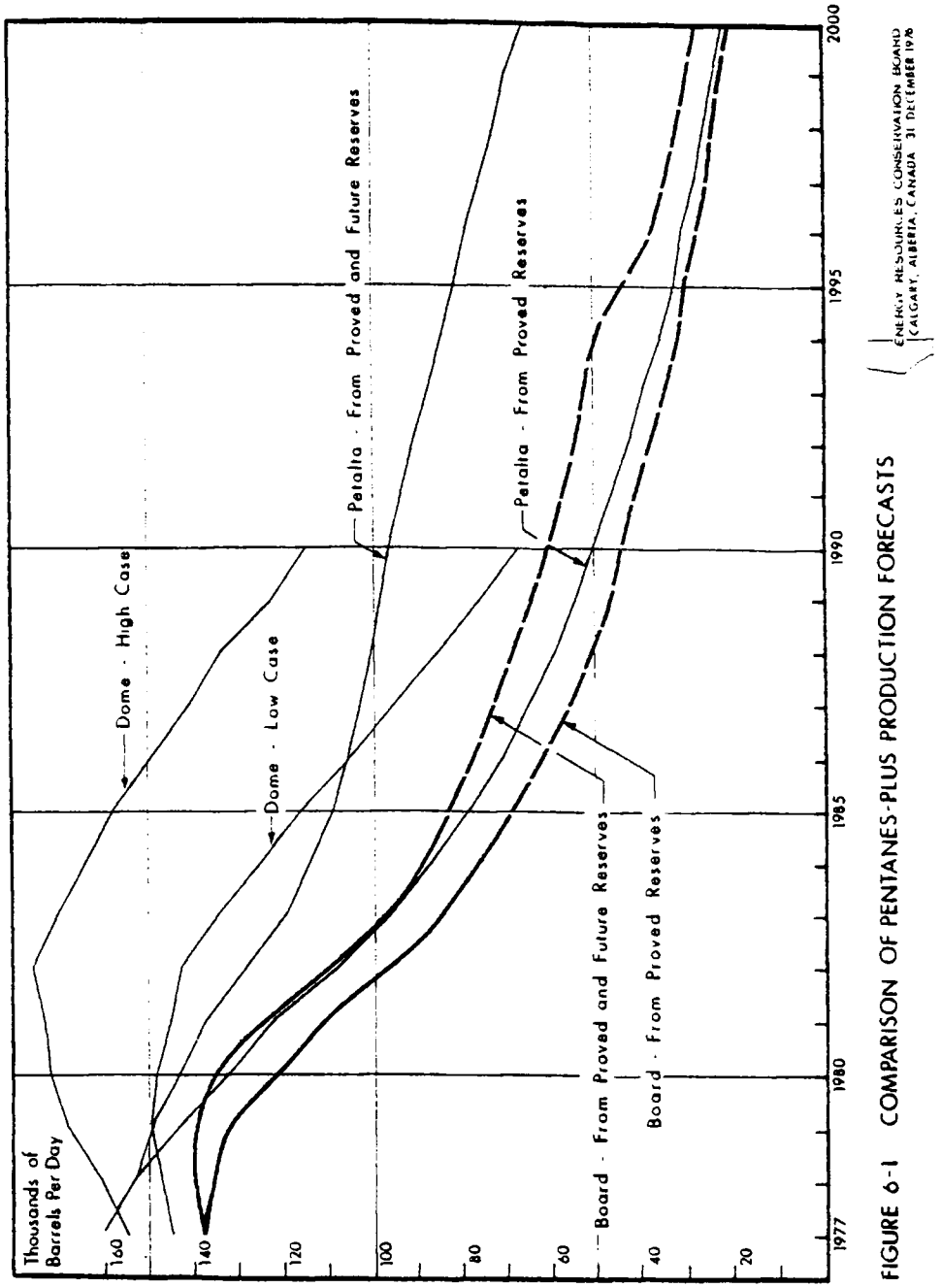

FIGURE 6-1 COMPARISON OF PENTANES-PLUS PRODUCTION FORECASTS

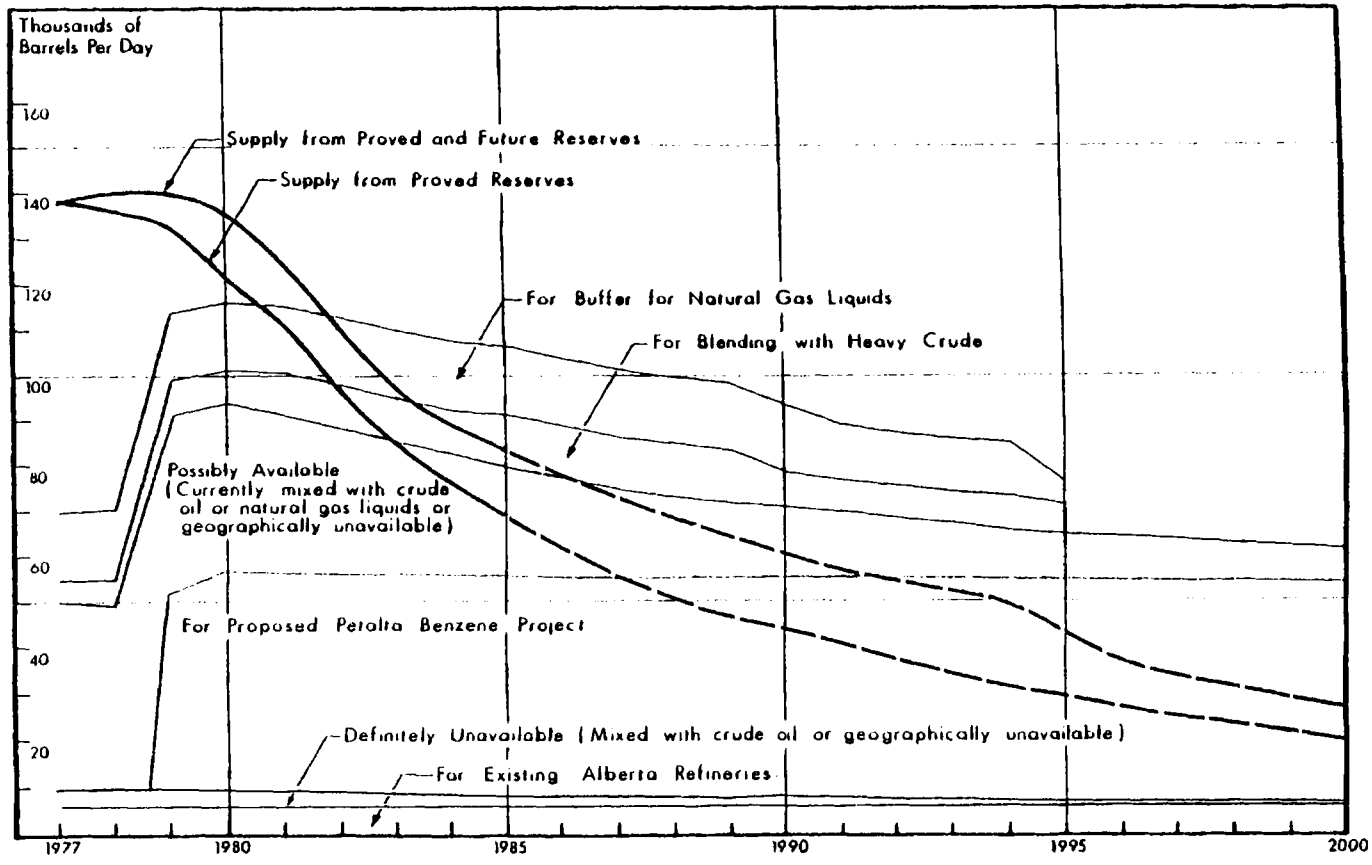

FIGURE 6-2 PETALTA REQUIREMENTS RELATIVE TO THE SUPPLY AND REQUIREMENTS OF ALBERTA PENTANES-PLUS (BOARD ESTIMATED)

ENERGY RESOURCES CONSERVATION BOARD
CALGARY, ALBERTA, CANADA 31 DECEMBER 1976

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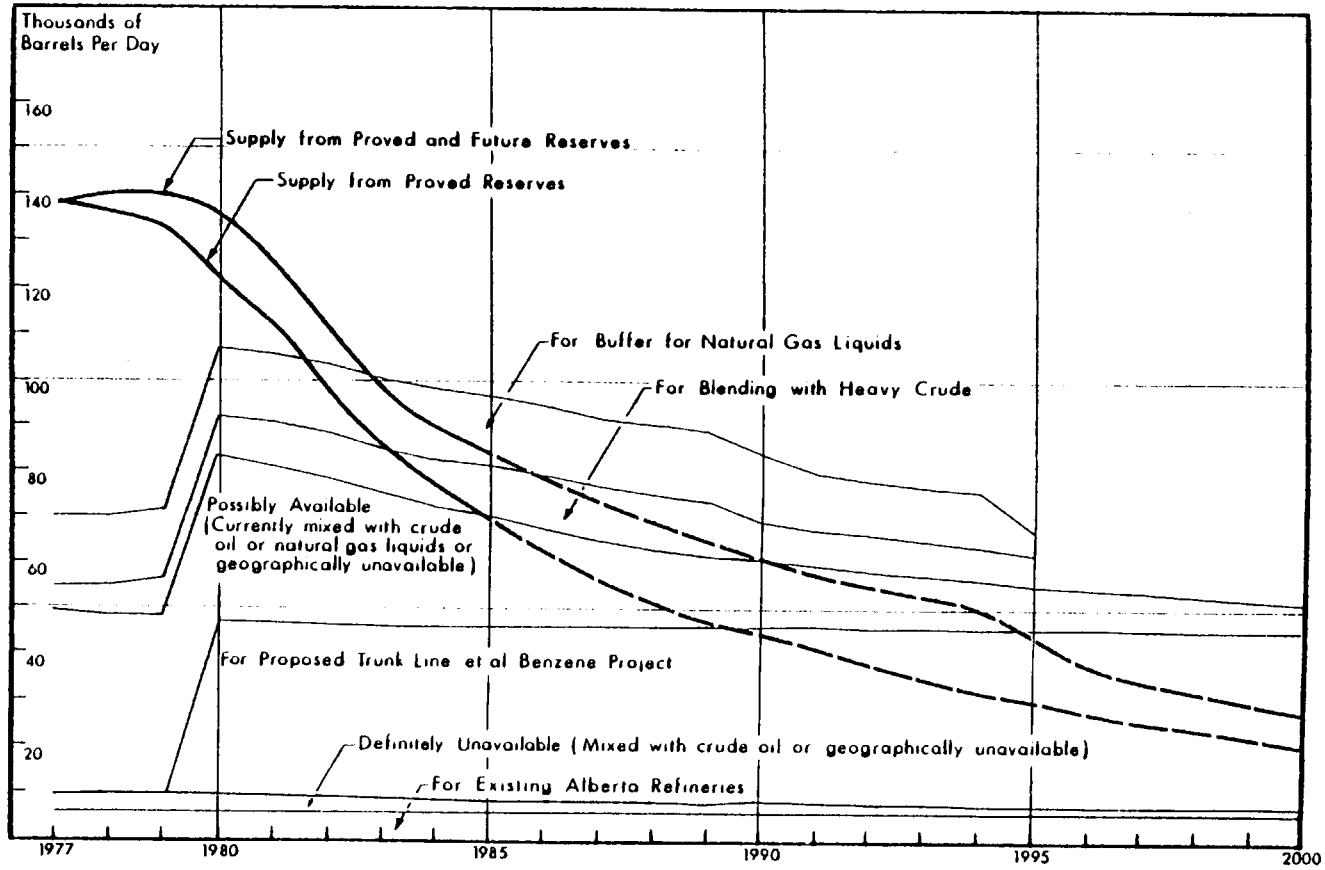

FIGURE 6-3 TRUNK LINE ET AL REQUIREMENTS RELATIVE TO THE SUPPLY AND REQUIREMENTS OF ALBERTA PENTANE-PLUS (BOARD ESTIMATED)

ENERGY RESOURCES CONSERVATION BOARD
CALGARY, ALBERTA, CANADA · 31 DECEMBER 1976

APPENDIX A AVAILABILITY OF PENTANES-PLUS

This appendix presents the details of the forecast of production of pentanes-plus from proved reserves and from future reserves. The gas plants and fields from which pentanes-plus is not currently available at Edmonton in a segregated form are also tabulated. These plants and fields are placed in two categories: those from which, in the Board's judgement, pentanes-plus will be definitely unavailable under any foreseeable circumstances and those from which pentanes-plus could possibly be made available given adequate demand.

Table A-1 is a summary of the forecast of the total pentanes-plus production from proved reserves as of 31 December 1975. The production is tabulated for the years 1977 to 2000 according to the pipeline system which transports the pentanes-plus.

Tables A-2 to A-21 show the forecast of production of pentanes-plus by pipeline system. Only those plants which have pentanes-plus production in excess of 1 000 barrels per day are listed individually. The remainder are grouped under the heading "others".

Table A-22 shows the expected production of marketable gas and pentanes-plus from future reserves of gas. This forecast is based on the Board's estimate of production of gas necessary to meet Alberta's requirements and also new removal permits which the Board believes may be issued.

Table A-23 is a list of the plants and fields from which pentanes-plus production is currently blended to crude oil or geographically isolated from Edmonton and which the Board believes will definitely not be available in a segregated form at Edmonton over the forecast period. Table A-24 lists the plants from which production is currently not available at Edmonton but which the Board believes could possibly be segregated and/or transported to Edmonton if sufficient need existed. These volumes are currently blended with crude oil streams or natural gas liquids or shipped directly out of the province.

TABLE A-1 SUMMARY BY PIPELINE SYSTEM OF [illegible] PRODUCTION FROM PROVED RESERVES AS OF DECEMBER 31, 1976, [illegible]

PIPELINE SYSTEM	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
BOW RIVER PIPELINE	2 950	[illegible] 980	3 110	3 090	3 050	[illegible]	[illegible] 950	[illegible] 900	2 860	[illegible] 800	[illegible]	[illegible]	1 650	1 430	1 [illegible]
BONNIE GLEN PIPELINE	810	810	810	770	730	690	650	580	570	560	520	530	550	300	250
CO-ED PIPELINE	13 020	1[illegible] 720	1[illegible] 550	11 770	10 900	10 [illegible]	8 170	6 710	4 9[illegible]0	3 860	3 070	2 390	[illegible] 060	1 780	1 590
KEMONA PIPELINE	16 160	16 340	16 360	16 060	1[illegible] 450	1[illegible] 380	10 760	8 810	7 520	6 500	5 860	5 130	4 580	3 710	3 170
FEDERATED	110	100	110	100	100	100	80	70	60	60	20	20	20	-	
FT. SASKATCHEWAN	2 530	2 380	2 200	1 800	1 500	1 300	900	800	600	600	600	500	500	500	400
GIBSON	1 150	1 200	1 230	1 140	1 070	990	830	670	560	430	330	260	220	160	130
GULF	2 760	2 500	2 360	2 140	2 010	1 820	1 590	1 410	1 260	1 110	1 000	890	790	710	650
IMPERIAL-ELLERSLIE	430	460	550	430	430	400	350	310	280	200	120	70	50	50	50
IMPERIAL-LEDUC	4 580	5 050	4 800	4 500	6 400	6 300	5 600	5 130	4 100	3 400	2 580	2 000	1 640	1 430	1 3[illegible]0
IMPERIAL-REDWATER	360	300	250	200	180	130	100	70	40	20	20	10	10	10	10
MURPHY	70	70	70	70	70	70	60	60	60	60	50	40	40	30	30
PEACE RIVER	50 520	47 550	44 020	37 630	31 840	25 570	18 520	14 680	12 330	10 760	9 340	8 010	6 930	6 250	5 200
PEMBINA PIPELINE	3 970	4 240	4 580	4 220	4 130	3 810	3 360	2 850	2 290	1 780	1 090	830	620	470	370
RAINBOW PIPELINE	460	490	970	920	870	820	750	690	660	500	380	280	200	150	110
RANGELAND PIPELINE	17 530	16 970	16 780	15 560	14 670	13 490	10 380	7 150	4 360	3 700	4 250	1 650	1 210	2 550	1 930
RIMBEY PIPELINE	9 040	9 520	9 990	9 980	7 960	5 210	2 550	1 310	770	470	310	210	80	70	70
TEXACO EXPLORATION	5 070	5 430	5 670	5 560	5 250	4 840	1 920	3 200	2 680	2 150	1 930	1 710	1 500	1 300	1 100
VALLEY PIPELINE	3 590	3 790	4 020	3 990	3 930	3 860	3 740	3 580	3 270	2 650	2 280	1 960	1 690	1 470	1 260
TRUCK & TANK CAR	2 990	3 100	2 880	2 530	2 350	2 210	2 100	2 110	2 140	2 450	2 260	2 140	1 970	1 810	1 720
TOTAL	138 100	136 100	133 500	122 460	113 010	97 130	77 030	63 110	52 270	44 710	38 250	32 510	28 000	24 380	20 640

TABLE A-2 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR BOW RIVER PIPELINE, Barrels per day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
EMPRESS (PACIFIC)	2 160	2 240	2 350	2 350	2 350	2 350	2 350	2 350	2 350	2 350	2 080	1 720	1 410	1 220	1 100
OTHERS*	790	740	760	740	700	670	600	550	510	450	360	320	240	210	190
TOTAL	2 950	2 980	3 110	3 090	3 050	3 020	2 950	2 900	2 860	2 800	2 440	2 040	1 650	1 430	1 290

* Includes facilities in the Bantry, Bassano, Cessford, Commorsville, Countess, Enchant, Hanna, Huxley, Little Bow, Provost, Stanmore, Wayne-Rosedale (PanCanadian), and Wintering Hills Fields, and field condensate.

TABLE A-3 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR BONNIE GLEN PIPELINE, Barrels per day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
PEMBINA (GOLIAD)	810	810	810	770	730	690	640	580	520	460	420	380	340	300	220

TABLE A-4 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR CO-ED PIPELINE, Barrels per Day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
ALBERTA NATURAL GAS	1 410	1 490	1 560	1 560	1 560	1 560	1 560	1 310	650	470	310	0	0	0	0
EMPRESS (DOME)	1 720	1 800	1 750	1 750	1 750	1 650	1 250	960	520	90	0	0	0	0	0
QUIRK CREEK	1 000	930	900	830	770	710	610	520	440	380	320	270	240	200	170
STRACHAN - RAM RIVER	1 500	1 440	1 400	1 300	1 140	1 060	850	690	560	470	380	340	220	170	160
STRACHAN (GULF)	4 620	4 360	4 140	3 750	3 350	3 030	2 490	2 020	1 660	1 340	1 080	860	720	580	470
RICINUS	2 080	2 030	2 050	1 980	1 850	1 660	980	840	800	780	760	730	710	690	670
OTHERS*	690	670	640	600	570	550	430	370	320	270	220	190	170	140	120
TOTAL	13 020	12 720	12 440	11 770	10 990	10 220	8 170	6 710	4 950	3 800	3 070	2 390	2 060	1 780	1 590

* Includes facilities in the Ferrier (Seafort), Pembina Keystone (Texaco), and Phoenix Fields and the reprocessing plant at Edmonton.

TABLE A-5 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR CREMONA PIPELINE, Barrels per day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
CARSTAIRS	4 340	4 260	4 190	3 950	3 710	3 370	2 530	1 790	1 270	900	640	450	320	-	-
CROSSFIELD	1 810	1 730	1 590	1 390	1 230	1 090	820	620	440	330	260	200	150	100	30
HARMATTAN	6 110	6 480	6 700	6 500	6 460	4 100	3 630	3 440	3 260	3 130	3 050	2 800	2 550	2 300	2 060
LONEPINE CREEK	1 420	1 490	1 540	1 480	1 450	1 390	1 280	1 100	920	770	650	540	450	380	220
OTHERS*	2 480	2 480	2 840	2 740	2 630	2 530	2 200	1 860	1 590	1 430	1 260	1 190	1 010	930	860
	16 160	16 440	16 860	16 060	15 480	12 480	10 460	8 810	7 480	6 560	5 860	5 120	4 480	3 710	3 170

* Includes facilities in the Burnt Timber, Crossfield East, and Olds Fields and field condensate.

TABLE A-6 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR FEDERATED PIPELINES LTD., Barrels per day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
OTHERS*	110	100	110	100	100	100	80	70	60	60	20	20	20	-	-

* Includes facilities in the Judy Creek (Great Plains) and Virginia Hills Fields.

TABLE A-7 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR FORT SASKATCHEWAN, Barrels per day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
FORT SASKATCHEWAN	2 530	2 380	2 200	1 800	1 500	1 300	900	800	600	600	600	500	500	500	400

TABLE A-8 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR GIBSON PETROLEUM COMPANY LIMITED, Barrels per day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
OTHERS*	1 150	1 200	1 230	1 140	1 070	990	840	670	560	480	330	260	220	160	130

* Includes facilities in the Acheson, Corbett Creek, Ferrybank, Okotoks, Paddle River, Three Hills, Wilson Creek, and Worsley Fields.

TABLE A-9 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR GULF ALBERTA PIPELINE, Barrels per day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
NEVIS	1 970	1 730	1 560	1 340	1 230	1 040	820	650	500	380	290	220	170	130	110
OTHERS*	790	770	800	800	780	780	770	760	760	730	710	670	620	580	540
TOTAL	2 760	2 500	2 360	2 140	2 010	1 820	1 590	1 410	1 260	1 110	1 000	890	790	710	650

* Includes facilities in the Carbon, Elnora, Chigwell, Ghost Pine, Bussar, Mikwan, Parflesh, Penhold, Twining, Wayne-Rosedale (Tenneco), and Wood River Fields, and field condensate.

TABLE A-10 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR THE IMPERIAL PIPELINE COMPANY, LIMITED - ELLERSLIE, Barrels per day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
OTHERS*	430	460	450	430	430	400	350	310	280	200	120	70	50	50	50

* Includes facilities in the Golden Spike, Holmberg, and Morinville Fields (assuming blowdown of the Golden Spike gas cap commencing in 1981) and field condensate.

TABLE A-11 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR THE IMPERIAL PIPELINE COMPANY, LIMITED - LEDUC, Barrels per day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
JUDY CREEK	4 220	4 670	4 400	4 100	4 000	3 900	3 200	2 900	2 400	1 900	1 600	1 400	1 200	1 060	1 000
OTHERS*	360	380	400	400	2 400	2 400	2 400	2 250	1 700	1 200	900	600	440	370	330
TOTAL	4 580	5 050	4 800	4 500	6 400	6 300	5 600	5 150	4 100	3 100	2 500	2 000	1 640	1 430	1 330

* Includes facilities in the Leduc-Woodbend Field (assumes blowdown of the gas cap commencing in 1981) and field condensate.

TABLE A-12 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR THE IMPERIAL PIPELINE COMPANY, LIMITED - REDWATER, Barrels per day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
REDWATER	360	300	250	200	180	130	100	70	40	20	20	10	10	10	10

TABLE A-13 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR MURPHY OIL COMPANY LTD., Barrels per day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
OTHERS*	70	70	70	70	70	70	60	60	60	60	50	40	40	30	30

* Includes facilities in the Princess and Retlaw Fields.

TABLE A-14 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR PEACE RIVER OIL PIPE LINE CO. LTD., Barrels per day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
CARSON CREEK	1 550	1 630	1 650	1 600	1 490	1 430	1 400	1 350	1 070	690	480	280	130	60	50
DUNVEGAN	1 280	1 340	1 410	1 410	1 340	1 210	970	780	630	510	410	330	270	220	180
KAYBOB	2 410	2 330	2 240	2 010	1 770	1 520	1 100	770	510	340	240	180	80	70	60
KAYBOB SOUTH	40 090	37 550	34 400	28 800	24 100	18 700	13 300	10 500	9 100	8 400	7 600	6 700	6 000	5 500	4 550
WINDFALL	3 350	3 140	2 800	2 400	1 800	1 450	650	350	200	100	0	0	0	0	0
OTHERS*	1 840	1 560	1 520	1 410	1 340	1 260	1 100	930	820	720	610	520	450	400	360
TOTAL	50 520	47 550	44 020	37 630	31 840	25 570	18 520	14 680	12 330	10 760	9 340	8 010	6 930	6 250	5 200

* Includes facilities in the Alexander, Gold Creek, Greencourt, Simonette, Sturgeon Lake South, and Whitecourt Fields and field condensate.

TABLE A-15 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR PEMBINA PIPELINE, Barrels per day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
BRAZEAU RIVER	2 430	2 520	2 660	2 580	2 390	2 240	2 040	1 790	1 400	1 020	750	550	400	290	220
MINNEHIK - BUCK LAKE	1 280	1 420	1 510	1 350	1 450	1 290	1 030	830	680	570	180	140	100	80	60
OTHERS*	260	300	290	290	290	280	270	230	210	190	160	140	120	100	90
TOTAL	3 970	4 240	4 480	4 220	4 130	3 810	3 340	2 850	2 290	1 780	1 090	830	620	470	370

* Includes facilities in the Bigoray, Peco, and Willesden Green Fields and field condensate.

TABLE A-16 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR RAINBOW PIPE LINE COMPANY, LTD., Barrels per day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
OTHERS*	460	490	970	920	870	820	750	690	660	500	360	280	200	150	110

* Includes facilities in the Nitsue and Nipisi Fields and field condensate.

TABLE A-17 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR RANGELAND PIPE LINE, Barrels per day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
CAROLINE	1 090	1 140	1 200	1 200	1 200	1 180	980	740	560	430	330	250	190	140	100
FERRIER	1 360	1 410	1 460	1 450	1 440	1 320	930	660	470	330	240	160	110	80	0
GILBY	1 060	1 130	1 210	1 170	1 070	940	670	500	370	250	210	180	140	120	100
PINCHER CREEK	1 600	1 400	1 230	1 020	850	710	50	0	0	0	0	0	0	0	0
SYLVAN LAKE	1 270	1 270	1 370	1 280	1 330	1 230	890	530	410	340	280	230	190	160	140
WATERTON	9 460	8 840	8 460	7 640	7 070	6 550	5 680	3 890	2 880	2 850	2 800	2 520	2 450	2 210	1 540
WIMBORNE	1 070	1 120	1 180	1 180	1 180	1 080	790	580	420	300	220	160	120	80	0
OTHERS*	620	660	670	620	530	480	390	310	250	200	170	150	110	60	60
TOTAL	17 530	16 970	16 780	15 560	14 670	13 490	10 380	7 150	5 360	4 700	4 250	3 650	3 210	2 850	1 940

* Includes facilities in the Innisfail, Joffre, and Medicine River Fields and field condensate.

TABLE A-18 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR RIMBEY PIPELINE, Barrels per day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
HOMEGLEN RIMBEY	9 040	9 520	9 990	9 980	7 960	5 210	2 550	1 310	770	470	310	210	80	70	70

TABLE A-19 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR TEXACO EXPLORATION CANADA LTD., Barrels per day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
BONNIE GLEN	4 800	5 150	5 400	5 300	5 000	4 600	3 700	3 000	2 500	2 000	1 800	1 600	1 410	1 230	1 050
OTHERS*	270	280	270	260	250	240	220	200	180	150	130	110	90	70	50
TOTAL	5 070	5 430	5 670	5 560	5 250	4 840	3 920	3 200	2 680	2 150	1 930	1 710	1 500	1 300	1 100

* Includes facilities in the Pembina Field.

TABLE A-20 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR VALLEY PIPELINE, Barrels per day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
JUMPING POUND	2 450	2 620	2 810	2 840	2 830	2 840	2 810	2 760	2 610	2 340	2 010	1 730	1 490	1 290	1 110
OTHERS*	1 140	1 170	1 210	1 160	1 100	1 020	910	820	660	510	270	230	200	180	150
TOTAL	3 590	3 790	4 020	3 990	3 930	3 860	3 740	3 580	3 270	2 850	2 280	1 960	1 690	1 470	1 260

* Includes facilities in the Turner Valley and Wildcat Hills Fields.

TABLE A-21 SUMMARY OF FORECAST OF PENTANES-PLUS PRODUCTION FROM PROVED REMAINING RECOVERABLE RESERVES AS OF DECEMBER 31, 1975 FOR MOVEMENTS BY TRUCK & TANK CAR, Barrels per day

PLANT	1977	1978	1979	1980	1981	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000
EDSON	2 410	2 350	2 120	1 820	1 650	1 490	1 220	1 020	830	680	560	460	380	310	250
OTHERS*	580	750	760	710	700	720	880	1 090	1 310	1 770	1 700	1 680	1 590	1 500	1 470
TOTAL	2 990	3 100	2 880	2 530	2 350	2 210	2 100	2 110	2 140	2 450	2 260	2 140	1 970	1 810	1 720

* Includes facilities in the Boundary Lake South, Equity, Rockyford, Sedalia, Swalwell, and Waskahigan Fields, field condensate, and proved reserves which are not now connected.

A-14

TABLE A-22 PRODUCTION OF MARKETABLE GAS AND PENTANES-PLUS FROM FUTURE RESERVES OF GAS

1	2	3
YEAR	MARKETABLE GAS PRODUCTION, MMcf/d	PENTANES-PLUS PRODUCTION* Barrels per day
1977	-	-
1978	270	4 050
1979	430	6 450
1980	880	13 200
1981	880	13 200
1982	880	13 200
1983	880	13 200
1984	880	13 200
1985	1 000	15 000
1986	1 060	15 900
1987	1 130	16 950
1988	1 170	17 550
1989	1 180	17 700
1990	1 110	16 650
1991	1 100	16 500
1992	1 170	17 550
1993	1 200	18 000
1994	1 230	18 450
1995	930	13 950
1996	670	10 050
1997	600	9 000
1998	530	7 950
1999	500	7 500
2000	480	7 200

* Based on a recovery ratio of 15 barrels per MMcf.

TABLE A-23 PLANTS OR FIELDS FROM WHICH PENTANES-PLUS PRODUCTION WOULD BE DEFINITELY UNAVAILABLE IN SEGREGATED FORM IN THE EDMONTON AREA

Blended to Crude Oil

Bantry
Bassano
Cessford
Connorsville
Countess
Enchant
Hanna
Huxley
Little Bow
Provost
Stanmore
Wayne-Rosedale (PanCanadian)
Wintering Hills
Judy Creek (Great Plains)
Virginia Hills
Corbett Creek
Carbon
Elnora
Chigwell
Parflesh
Penhold
Wayne-Rosedale (Tenneco)
Princess
Retlaw
Alexander
Cherhill
Bigoray
Peco
Joffre
Medicine River Compressor Station
Field Condensate for several pipelines

Geographically Isolated

Worsley

A-16

TABLE A-24 PLANTS OR FIELDS FROM WHICH PENTANES-PLUS PRODUCTION MIGHT POSSIBLY BE AVAILABLE IN SEGREGATED FORM IN THE EDMONTON AREA

Mixed with Crude Oil or Natural Gas Liquids

Burnt Timber
Acheson
Ferrybank
Okotoks
Paddle River
Three Hills
Wilson Creek
Ghost Pine-Drumheller-Rowley
Hussar
Mikwan
Nevis
Twining
Golden Spike
Holmberg
Morinville
Redwater
Dunvegan
Gold Creek
Greencourt
Kaybob
Simonette
Sturgeon Lake South
Whitecourt
Brazeau River
Minnehik-Buck Lake
Willesden Green
Innisfail
Wimborne
Bonnie Glen
Mitsue
Nipisi
Alberta Natural Gas
Quirk Creek
Strachan-Ram River
Ricinus
Ferrier (Seafort)
Pembina Keystone (Texaco)
Phoenix
Edmonton Liquid Gas

Geographically Isolated

Empress-Dome
Empress-Pacific
Pincher Creek
Waterton

VITA

Gerald Collins

Mr. Collins was born on January 24, 1949, in Leicestershire, England. His wife is the former Mardi Mitchell. His parents are Martin and Eva Collins of Hare Bay, Newfoundland, Canada.

Mr. Collins graduated from Brown Memorial High School with Honors Matriculation. He received a Bachelor of Engineering in Mining Engineering degree from Nova Scotia Technical College, Halifax, Nova Scotia, Canada, in 1970.

Mr. Collins served as an exploration geophysicist for Amoco Canada Petroleum Company Limited, as a mining engineer for MacKenzie Mining Consultants, and as a resource allocation engineer for the Energy Resources Conservation Board. All three positions were in Calgary, Alberta, Canada. He is a registered professional engineer in the Province of Alberta.

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