COLLABORATIVE TECHNOLOGY DEVELOPMENT

Pooling Resources in the Conventional Oil and Gas Industry

March 1995

Todd Resources

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1.0 PREFACE

This study was commissioned by the "Vice-Presidents Breakfast Club". The Breakfast Club is an informal group of senior executives responsible for production operations who meet informally from time to time to discuss issues of common interest. The group includes 24 companies, representing a cross section of major, intermediate and junior companies.

The study mandate was to assess the interest within the up-stream oil industry of collaboratively supporting pre-competitive research on natural gas production, processing and transportation. The mandate was subsequently expanded to embrace assessing the interest within the industry in collaboratively supporting research in all areas of conventional upstream oil and gas operations excluding heavy oil.

Subject to the industry expressing interest in supporting more collaborative research, a second study phase would proceed. This phase would examine various models under which collaborative research projects might be identified, managed and financed. This phase of the study may also include a recommended model. A third phase would lead to implementation.

The study is based on numerous interviews, the results of a questionnaire sent to a number of oil companies, a review of literature, review of the operation of a number of existing institutions that do collaborative research and the author's personal experience .

As the study proceeded, it became obvious that there was overwhelming support within the 24-company "Breakfast Club" group and with other potential stakeholders, for developing new and better technology for up-stream oil industry operations, performing the research in existing institutions and collaborating in the co-ordination and financing of the research. This observation resulted in a shift in emphasis in the study to identifying a process that would lead to a new model.

I am deeply indebted and grateful to the companies who provided data and executive time. The enthusiastic co-operation and support from the institutions currently doing consortia research reflects their commitment to the concept of collaborative research. Executives at the Alberta Research Council, the University of Calgary and CanMet were very helpful and are keen on the prospect of more collaboration. Bill Svrcek at the University of Calgary needs special thanks for getting this project started.

Murray B. Todd, *P.Eng.*
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2.0 EXECUTIVE SUMMARY

Collaboration in the Canadian Oil industry is not new. The process for auctioning provincial mineral rights leads to multiple owners and subsequent joint operations in virtually every oil and gas field in the country. Unlike the industry in the United States the geography of our industry brings most of the players together in a single location. The industry has a fraternal environment and co-operates in a great many areas.

The industry has supported research consortia such as the Arctic Petroleum Operation Association (APOA), the Canadian Energy Research Institute (CERI), the Computer Modelling Group (CMG), the Center for Engineering Research (C-FER), to name a few, for up to 25 years. Many of the supporters of these research consortia have maintained large in-house research facilities spending most of their research dollars on proprietary research. New technology has found its way into the industry through general application and through the service sector. Government and the universities sponsored a great deal of research, but usually worked on their own without much input from the users.

Today the situation is different. The oil and gas price shocks of the 1980s and 1990s, the entrenched position of the OPEC producers, the realization that dramatic price increases are not in sight and the economic downturn of the 1990s adjusted the thinking of oil companies, governments and universities. It also adjusted the demographics of the industry. The major companies became smaller, focusing their operations on fewer large properties. They retreated from mature marginal operations. This provided the opportunity for the emergence and growth of many junior companies feeding on properties discarded by the majors. Their emergence and growth was partly facilitated by new technology – such as 3D seismic and horizontal drilling – now available to everyone through a differently shaped service industry, a more mobile technical population and the advent of inexpensive high powered computers. With virtually the same technology available to everyone competitors now distinguish themselves in the way they apply technology.

The belt tightening of major companies, governments and universities caused them to reduce their spending on research, and in some cases, abandon their in-house research efforts completely. At the same time there was a growing appreciation for the impact that new technology can have on the business. Horizontal drilling and 3D seismic have made a tremendous impact on Canadian reserve replacement, finding and operating costs. There is a recognition that technology can help to reduce capital and operating costs that were simply accepted as part of the business in the past. There seems to have been a cultural shift on the part of the majors with respect to the proprietary value of upstream research. An executive from a major company said, "...three years ago we felt that all research had proprietary value, improved our competitive position and should be developed in-house and kept secret. We now feel that, with the exception of some speciality areas, technical information moves so fast that we couldn't keep it secret if we wanted to. The real value lies in our ability to creatively apply new technology. And furthermore we can't afford to do the research in-house."

An executive with a junior company also made a revealing comment, "...the big companies are not going to be doing the research and technology development for us any more. We are going to have to step up and do it ourselves."

With the proprietary issue seemingly defused, people readily agree on the benefits of developing new technology collaboratively. By pooling research dollars the contribution of each participant is leveraged. There should be more total dollars for technology development if companies not spending any money now, pick up their share. More brain power is brought to bear on the problems and solutions, the research becomes focused on real needs, and the use of existing research facilities and resources is optimized. There is also the opportunity to involve government and the research performers in the collaborative effort. The question now shifts to defining a model that would bring the stakeholders together.

There is general agreement among the people involved in this study about the principle characteristics of a new collaborative research model. It seems that they are looking for a clearing house – some mechanism to determine the needs of the stakeholders, match these with research providers and co-ordinate the collaboration. The principles include the following:

- involve many participants and a wide cross section of the industry
- erect no new bricks and mortar
- maximize use of existing research facilities
- concentrate on applied research
- deliver value-added results quickly
- ensure voluntary participation
- minimize administration costs
- fund projects through direct stakeholder contributions

In the course of this study several collaborative models were examined. Two models merit a closer look because they come close to fitting the above principles. Both could serve as a starting point in the design of a new collaborative model for the conventional oil industry. The two are the Arctic Petroleum Operators Association and the recently formed Canadian Oil Sands Network for Research and Development (CONRAD).

The APOA was formed in 1970 for the purpose of facilitating collaborative research in the Canadian Arctic. Noteworthy, is the fact that the APOA has been dormant for several years. It was not institutionalized to the extent that it struggled to survive after the need was gone. The APOA included 28 companies. Over the space of 15 years, $65 million was spent on 220 projects. The research was properly documented and now resides in the archives of the Arctic Institute at the University of Calgary. The APOA was a facilitator of research, conducting no in-house research as an institution. APOA members proposed projects, searched for participants and managed the projects. The Association provided overall co-ordination as required, helped with contracts, ensured that projects were properly documented, arranged distribution of reports and served as data custodian.

CONRAD was formed in 1994 after two years of study and design. Members include Syncrude, CanMet, Alberta Oil Sands Technology and Research Authority (AOSTRA), Alberta Research Council, National Research Council, Chevron, Imperial Oil Resources, Shell, Amoco and Suncor. CONRAD has no permanent staff. Its administrative affairs are managed by a secretariat provided temporarily by AOSTRA. Its research is divided into four core areas – in-situ recovery, mining and extraction, upgrading and environment. Universities are members through a special arrangement. Any member may propose a research program and seek participation from other members. Accepted projects are managed by the proposing company. Ownership of the technology is governed by a contract which members sign upon becoming members.

In addition to APOA and CONRAD there is a wealth of information available from existing R&D consortia models both inside and outside the oil industry. There is also the experience of those who have been involved with the formation and attempted formation of consortia groups in the past – a good definition of the "do's and don'ts" and some good processes for moving the project forward.

The time is right for pulling the industry together for the purpose of collaborating on the development of new and better technology. The process for doing this should be sensitive to the fact that there are many prospective stakeholders with diverse backgrounds, needs and interests. Describing research areas, defining projects and managing a new collaborative group will present a new set of challenges. The larger companies have had experience with research and with existing consortia. Junior companies, while perhaps lacking in experience with research will bring a sense of pragmatic optimism and new views on collaboration. To be successful a new conventional upstream technology development consortia must serve the needs of many constituents. All constituents should be offered the opportunity of participating in the design of the new model.

For the prospective stakeholders to get together in the formation of a consortia that would facilitate technology development on the scale envisioned in this study the following ingredients are necessary:

- a collective sense of need on the part of the prospective participants
- a sense of urgency
- broad participation of stakeholders in the process
- a committed champion to keep the project moving
- determination to overcome all obstacles
- a good plan
- some short-term successes to maintain enthusiasm

The process used to design the CONRAD model was call "Road Map". There would be merit in using the same process to design a collaborative technology development model for the conventional production side of the business. It is a hierarchical system which requires stakeholders to step through a systematic process aimed at achieving breakthrough results. The steps include establishing a vision, purpose, beliefs and principles on which a

model would be based. The stakeholders would then go on to define goals and objectives, and a detailed plan with strategies and feedback systems. The last section of this report provides some prompting for this process with a vision, purpose, beliefs and principles, some example goals, objectives and strategies, and some ideas on a model structure.

The recommended next steps include:

1. Present this study to the members of the Vice-Presidents Breakfast Club in order to:
   - obtain feedback
   - obtain approval to proceed with Phase 2 of this study
   - obtain input for the next phase of the study
2. Work with the Management of Technology group, which has common interests with the Breakfast Club in seeing new technology developed.
3. Communicate the results of this study to prospective stakeholders through industry trade associations, industry media and through direct contact.
4. Solicit input from prospective stakeholder groups on the future course of action.
5. Sponsor one or more workshops at the Calgary University Research Park. The purpose of the workshops is to:
   - bring the rest of the industry to the same level of understanding as the Breakfast Club
   - provide an opportunity for research performers – universities, government labs and consortia groups – to describe their capabilities. Some facilities could be toured.
   - familiarize the industry with various collaborative models
   - provide an opportunity for governments to describe their position on research
   - brainstorm needs, obstacles and potential problems
   - develop broad guiding principles to frame a new model
   - decide future action

3.0 THE SITUATION

3.1 A Sense of Urgency

New technology is driven by need, the magnitude of the prize if the technology is successful, and the sense of urgency associated with finding some answers. For example there was a sense of urgency to develop production technology when deep water discoveries needed different approaches to offshore platform design. There was a sense of urgency in the Arctic where the technology did not exist to work safely on the tundra, in the Beaufort and in the high Arctic. There has always been a sense of urgency in the oil sands, where the resource was obvious, but the means to get at it was not available. There was a sense of urgency to safely remove sour gas from Alberta foothills reservoirs before the gas was suitable for market. This sense of urgency has always existed on the exploration and reserve recovery side of the oil industry. It is driven by a production base that is continuously eroding as oil and gas is produced and by vigorous competition to find replacement reserves. A sense of urgency is sometimes created by new rules and regulations.

But on the routine production side of the conventional upstream oil business, there has not been this same sense of need, the definition of a large prize nor the sense of urgency. Technology development has been largely problem driven rather than opportunity driven. It has been driven by a push from inventors and the developers of technology rather than a pull from the users. Operating people are task oriented. When things seems to be running smoothly attention is directed towards those operations with problems. Opportunities to make trouble free operations run better are frequently neglected. We have generally been blessed with relatively high margin operations. Why worry about a well or a plant that is making money? Perhaps this attitude has been created by the fact that, in many cases, operations people have been held accountable for production volumes and unit expenses – not bottom-line profit.

However, the price shocks of the last decade, coupled with the maturing of our oil and gas fields, created a sombre realization that the production of most conventional oil and gas is a marginal business, and that it will get worse before it gets better. Production staff, now usually held accountable for bottom-line results, realize that their competitors are the offshore producers, those who still produce from large, prolific reservoirs. Today, just to ensure survival, there is an urgent need to reduce the cost of finding, developing and producing our oil and natural gas. New and better technology, and proper application of technology is the key to making this happen.

An industry project that illustrates how things get done when people see a need and attach to it a sense of urgency was "DEA 44". DEA 44 was a project initiated by the Drilling Engineers Association in the United States in 1986. Its purpose was to advance the technology of horizontal drilling. It started with a few companies each contributing $35,000. The project grew over three phases, attracted 120 participants and facilitated over $10 million in research. Today horizontal drilling is a routine technology available to everyone and it can be credited with significant additions to the nations oil reserves.

3.2 Adding Value Through Technology

It is difficult to quantify the contribution made by technology to our industry. In some cases it is obvious. It is obvious that the Alberta oil sands would not be in production today in the absence of new technology for mining, extraction and upgrading. Nor would the deeper oil sands in Cold Lake be in production without special technology for drilling, completions, steaming and transportation. Much of Alberta's natural gas would remain in the reservoir had the technology not been developed to safely and efficiently remove hydrogen sulfide. Horizontal drilling technology has had a significant impact on the Canadian oil industry. 3D seismic reduces the frequency of dry holes, and enables us to target wells to undrained parts of the reservoir.

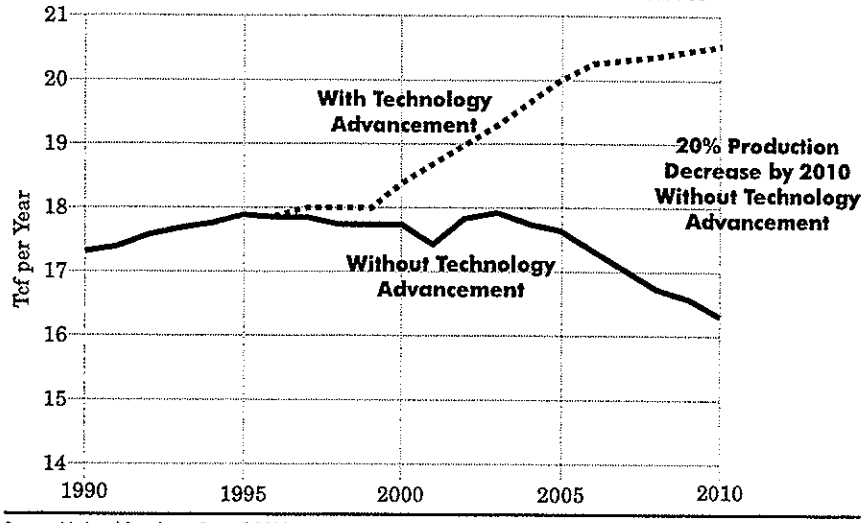
In 1994 producing costs for conventional oil and gas in Canada exceeded $3 billion. Most people would agree that these costs could be reduced through the application of new and better technology. If one could reduce these costs by 5% the savings would amount to $150 million annually. The present value of these savings would be at least $750 million. The impact on oil and gas recovery would be equally as dramatic. A reduction in operating costs extends the life of existing reserves. But more focus on the technology of reservoir management could clearly have an even larger impact on the recovery of the 70% of the oil that would otherwise be left in the ground.

One company, recently interviewed, suggested that they felt their operating costs could be reduced by 20% through improved technology. They equated this to a present value of $100 million for each $100 million of annual operating costs. This same company, an active intermediate, has been active in supporting collaborative research. Their management is committed to improvement through technology and has been able to demonstrate to their satisfaction that there is a correlation between long-term bottom-line performance and corporate spending on technology development.

In 1992, the United States National Petroleum Council estimated the impact of technology on U.S. future gas production and price. The data in Figure 1 indicates that the price of gas at the wellhead in the United States could be reduced by $1.00 per mcf by the year 2010 through technology improvement.

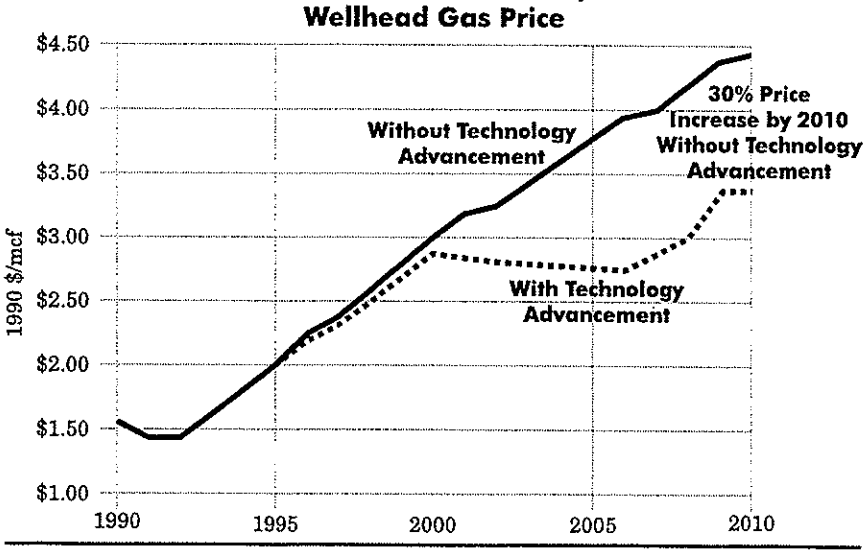
Figure 2 illustrates the impact on reserves and deliverability, indicating that the production decline would be 20% more severe in the absence of technology improvement.

Figure 1
Technology Advancement Impact on Future Natural Gas Domestic Production



Source: National Petroleum Council 1992

Figure 2
Technology Advancement Impact on Wellhead Gas Price



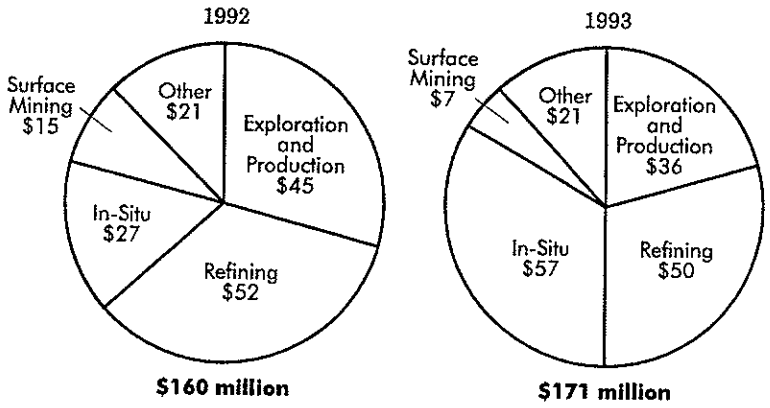
Source: National Petroleum Council 1992

3.3 Our Research Spending

Statistics on total research spending in the conventional oil industry are elusive. Statistics Canada publishes information on "in-house" spending on research by the private sector. Figure 3 shows data from their 1993 report. The 1993 spending, not including heavy oil projects, was $36 million. In the same year Stats Can reports R&D spending on contract research of $141 million, $88 million with parent companies or affiliates outside of the country, and $52 million in Canada (contract research spending is not broken out by industry sector). Considering that the gross industry revenue in 1993 was $17.4 billion and that expenditures on exploration were $1.7 billion, the

spending on exploration and production research seems extraordinarily low. Canada is not known for its propensity to spend money on research and is reputed to be the lowest R&D spender of all industrialized nations. Within Canada, the oil industry ranks 10th when compared with other industries on R&D spending.

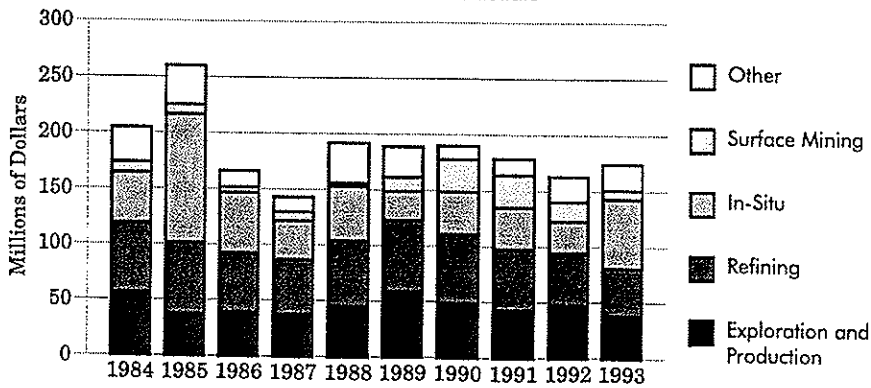
Figure 3
"In-House" R&D Expenditures by Activity
in millions of dollars



Source: Statistics Canada

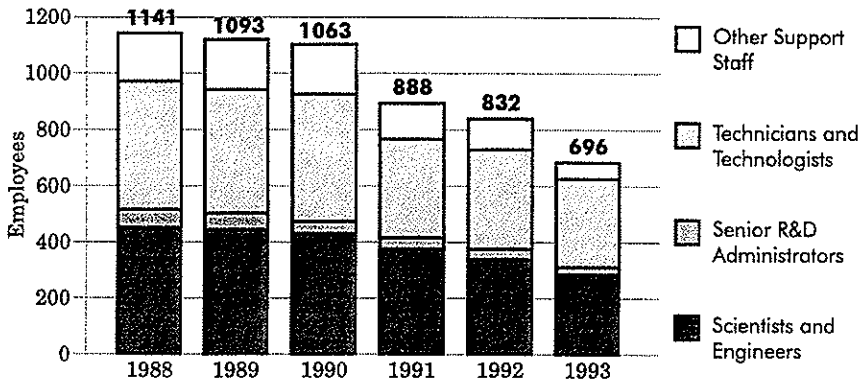
Figure 4 shows the 10 year trend in oil industry R&D expenditures. The trend in the last 5 years is clearly downwards. The downward trend in in-house spending is partially offset by an increase in contract research, which may indicate that more work is done on a collaborative basis. The total dollars spent by the industry on oil industry research (which includes down-stream) has been running about $300 million annually. The percentage of money spent in-house is running about 50%, compared to 75% ten years ago.

Figure 4
"In-House" R&D Expenditures
in millions of dollars



Source: Statistics Canada

Figure 5
R&D Employment
number of employees



Source: Statistics Canada

Figure 5 illustrates the "in-house" R&D employment and indicates a significant drop over the last 6 years.

In reviewing the data for the last 12 years another interesting observation is the number of companies reporting research expenditures. In the mid-eighties the number of companies reporting research expenditures averaged about 30 and peaked at 40. In 1993 18 companies reported research expenditures and the number was only 14 in 1990.

The statistics in the 1980s reported research expenditures as a percentage of sales. In the early eighties this number was about 1.0% declining to 0.6 % in 1988 and 0.7% in 1989, after which this statistic was no longer reported. Research spending for all of industry was about 1.8% of sales in 1988.

While hard numbers are not available to the Alberta observer it is quite clear that the major companies are spending less on research than they previously spent. The statistics suggest that this decrease in spending by the large companies is not compensated for by increased spending on the part of the smaller companies.

3.4 Attitudes Have Changed

In 1985, following the collapse of oil prices, Alberta companies retreated from their traditional research plans. The President of the Calgary Research Authority and the Vice-President of Research at the University of Calgary saw an opportunity to maintain research momentum by encouraging the industry to join forces in order to pool their research resources. They were encouraged by the response from the major companies, as Research Directors from several companies worked together to design a collaborative model. However, after several months of discussions, the endeavour collapsed – apparently because the companies could not agree on any projects on which they were willing to collaborate, excepting a few in the area of safety. Everything else seemed to be viewed as proprietary.

The oil industry has always had a secretive mind-set. Playing things close to the chest provided a competitive advantage in acquiring leases, draining oil

and gas, and competing for capital. Technology was traditionally developed in-house and could be kept in-house. Early research and development provided exploration advantages to those companies who had the technology. Refining and other downstream technologies provided marketing advantages to the developing companies. While the Canadian industry has always collaborated on many things, it has always been intensely competitive and cherished the principle that keeping things secret provides a competitive advantage.

This mind-set was reinforced by Research Directors not wishing to see their programs diluted by turning them over to others.

But attitudes have changed. Part of the change has been brought about by the economy – the realization that something had to change or technology would not advance. Companies today are able to discriminate between the technology that may provide a competitive advantage and technology that is available to everyone. They are able to focus their in-house programs and are willing to work with others on research that provides no proprietary benefit. They recognize that technology changes hands very quickly. High speed desktop computers make complex computations and processes available to the smallest of companies. Most technology is available through the service sector.

Companies distinguish themselves today through the application of technology, not through its ownership. Horizontal drilling technology and 3D seismic technology is provided through the service sector and is available to the entire industry. Some companies have enjoyed tremendous success through creative application of this technology.

Today the large companies no longer have the financial capability to do all of their research in-house. The smaller companies recognize that they will have to be a partner in new technology development. Research dollars must be leveraged. Problems will be identified and solved more quickly if collective thought is brought to bear.

The attitude of government and universities, feeling the same financial crunch as the private sector, is also looking for ways to leverage and focus their research dollars. The existing labs clearly have taken on a customer focus.

That is not to say that the attitude shift is complete. Research still seems to have a philanthropic image. Some people view it as an unnecessary expense, one that can be cut when times are tough. Technology development must be viewed as a high priority item, a part of our day-to-day cost of running the business.

3.5 Bricks and Mortar Not Required

The industry opinion is unanimous in their view that the existing institutions have the basic technology and the facilities to do the necessary research. World class laboratories and qualified researchers are available through government, existing research consortia and private institutions.

4.0 COLLABORATIVE TECHNOLOGY DEVELOPMENT

4.1 The Oil Industry – Natural Collaborators

The Canadian oil industry, while vigorously competitive, collaborates on many things. Fundamental to collaboration within the industry is the proliferation of joint venture operations. The system of auctioning oil and gas leases in Saskatchewan, Alberta and British Columbia, as well as in the federally owned areas, promotes mixed ownership of sub-surface oil and gas pools. Conservation practices and rules require the sharing of basic information and encourage owners to formally work together through unitized operations or otherwise co-operate to manage reservoirs as a single entity. The high cost of operating in frontier areas and the oil sands further encourages partnerships to spread cost and risk. The geography of our business, unlike that in the United States, concentrates activities in a relatively small area. Head offices gravitate to Calgary. The development of downtown Calgary places the corporate offices of oil companies, service companies and the regulatory authorities within walking distance of one another. The university, consortia and private research labs are within a 15 minute drive, while in Edmonton, the University of Alberta, government research facilities, and more private and consortia labs are easily accessed.

The industry jointly sponsors training through the 30 year old Petroleum Industry Training Service. Several trade associations represent the collective interest of oil and gas producers, drilling contractors, and service and supply companies. Professional associations provide a forum for technical exchange, encourage training and identify technical needs. Industry players come together in the community supporting and working with the arts, hospitals, the United Way and other charities. The industry community is large enough to support recreational leagues and social events all over the prairies.

The oil industry relationships, aside from intense competition for leases, and other resources, has a fraternal flavour. The environment could not be better for collaboration on pre-competitive research. The subject has been well discussed by another informal collaborative group – The Management of Technology Interest Group. The focus of this group is the strategic management of technology. It was formed in 1992, and includes Technology Managers from 42 companies, cutting across all sectors of the industry.

It should not come as a surprise to anyone that the industry has been supportive of research consortia for decades. The collaborative research organizations, described in more detail later in this report, have been in existence for as long as 50 years. These groups were usually started through the initiatives of government, industry and the universities working together to identify a specific need. For example the Canadian Energy Research Institute was founded in 1975, by the Governments of Alberta and Canada, the University of Calgary, and several oil companies to undertake objective, independent economic analysis of energy issues. Today with the support of 130 companies, the Government of Canada, four provincial governments, the Northwest Territories and the University of Calgary, CERI effectively provides analysis that helps governments and companies prepare their individual plans and strategies.

The Canadian Oil industry are pioneers in collaboration. This year the Arctic Institute of Canada celebrates its fiftieth anniversary. AINA founded by an act of Parliament in 1945, has collaborated with individuals and industry since its inception and continues to do so today from its location at the University of Calgary. Others, described in more detail in pages following include:

- **Arctic Petroleum Operator Association** – founded in 1970 for the purpose of facilitating collaborative research in the Arctic.
- **Canadian Energy Research Institute** – founded in 1975 to undertake independent economic analysis of energy issues.
- **Centre for Engineering Research** – founded in 1984, specializing in engineering innovations.
- **Computer Modelling Group** – founded in 1977 for the purpose of advancing reservoir simulation software and technology and to train and assist industry users in its application.
- **CONRAD** – founded in 1994 as a multi-stakeholder not-for-profit Alberta corporation for the purpose of improving the competitiveness of oil sands through promoting collaborative technology development.
- **Petroleum Recovery Institute** – founded in 1966 to conduct fundamental research directed toward increasing recovery of oil from Alberta reservoirs.
- **Alberta Sulfur Recovery Institute** – founded in 1964 by 8 companies for the purpose of fostering research in the areas of chemistry and technology of sulfur and its compounds, with particular emphasis on topics of importance to the Western Canadian sulfur and sour gas industry.

4.2 Experience in the United States

Collaborative technology development in the United States on a large scale is relatively new. Collaboration was discouraged by anti-trust laws dating back to 1890. These laws were relaxed in 1984 enabling companies to co-operate on pre-competitive research. The National Co-Operative Research Act was a response to intense competition from Japan where technology was being developed collaboratively. Since that time 267 applications have been filed to form consortia. Consortia exist in the highly competitive micro-electronic field as well as in television, chemicals, bio-technology, materials industry, wood industry and motion pictures.

One of the most publicized consortia is the Microelectronics and Computer Technology Corporation with 75 members, 400 employees and an annual budget of $55 million. The United States Gas Research Institute (GRI) was one consortia formed well before the change in anti-trust laws. It facilitates research in natural gas production, transportation and natural gas use, has 250 employees and a $200 million budget. Funding is obtained through a surcharge collected by pipelines. GRI does not conduct any research of its own, but is responsible for managing research contracted to outside labs.

Extensive literature exists documenting successes and failures and describing many models.

4.3 Benefits of Collaborative Technology Development

The literature documents the merits (and some problems) with research that is carried out collaboratively. Following is a list of benefits for collaborative research. This list was partly sourced from the Proceedings of the Seminar on R&D Consortia held at Banff in 1994.

- leveraging of each contributors research dollars
- multiple participants may make more funds available for research
- collaboration reduces duplication
- sharing of skills may provide synergies between organizations
- provides a technology transfer mechanism to convey technology to users
- facilitates lateral thinking
- the project selection process forces strategic thinking
- results improve the competitiveness of the industry and individual company prosperity
- amplifies the value of the organizations resources
- permits more effective use of facilities
- provides a vehicle to integrate the effort of university labs, government labs and the private sector
- matches the innovation strengths of small companies with resources of large companies
- accelerates the development of technology
- makes organizations more technology conscious
- provides a means for organizations to influence safety, regulatory or performance standards which may emerge from the results of consortium based technology development
- provides a means for small companies to participate in technology development
- facilitates companies documentation of R&D costs for tax purposes
- motivates researchers to work on the right things

5.0 DEVELOPING A NEW MODEL

5.1 The Process

A cultural shift is required to facilitate wide-scale collaborative technology development in the conventional oil and gas industry. Stakeholders must learn to view technology development as an investment, not a cost. They must recognize that shareholder value can be added through the application of new and better technology. They must agree that new technology will be developed faster and more efficiently if all stakeholders – research providers, governments and industry – work together. They should all contribute resources and focus on common needs and problems. They must accept that proprietary ownership of technology has little value. Technology is available to everyone – the creative application of technology is the key to adding value.

The requirements to bring about change in a multi-stakeholder group include the following:

- a collective sense of need on the part of the prospective participants
- a sense of urgency
- broad participation of stakeholders in the process
- a committed champion to keep the project moving
- identification of problems and barriers
- a determination to overcome all obstacles
- a good plan
- some short-term successes to maintain enthusiasm

Interviews with large and small producers, and the results of the questionnaire suggests there is a sense of need and a sense of urgency. Among this group one can likely find one or more determined champions.

5.2 Models to Build On – A Starting Point

The industry has a great deal of experience with collaborating on technology development. In designing a new model one can choose an existing model or models that come close to satisfying the needs and modify it as required. There are two models that closely fit the principles. One is the Arctic Petroleum Operators Association and the other is CONRAD. Attractive features of these consortia include:

- both facilitate collaboration, but neither do research on their own
- both are stakeholder driven with projects being generated and managed by users
- stakeholder funding is self determined in accordance with willingness to participate in joint projects
- neither promote the survival of the institution for its own sake
- the APOA ceased to exist after the needs were satisfied
- the APOA was successful – it survived for 16 years, sponsored over 200 research projects, issued 380 reports and facilitated $65 million in collaborative research spending

- the APOA provided input data for proprietary research subsequently done by participating companies
- the APOA provided a forum to bring together stakeholders who were sometimes adversarial to search for solutions together
- CONRAD is similar to APOA
- CONRAD is a recently conceived model, put together after a great deal of study
- the structure of CONRAD has already been agreed to by a number of stakeholders who might also be participants in a new conventional technology development model

There will be other models outside the oil industry that may be worthwhile reviewing. One could save a lot of time in designing a new model by studying how others have dealt with similar problems.

Assuming there is agreement that the APOA and CONRAD models present a good starting point, one should look at the situation differences to design a model that would work for conventional oil and gas production. Some differences are:

- APOA and CONRAD had relatively few participants. The new model could potentially have many diverse participants (i.e. large multi-nationals, intermediate and junior oil companies, manufacturers, transportation and construction companies, the service sector, and many research providers).
- APOA and CONRAD focus on big problems and the focus is relatively narrow. ***The New Model,*** cutting across the entire upstream industry, could find itself dealing with a multitude of projects with little relationship between them. Selecting projects will be difficult.
- There was a sense of urgency and a sense of need among Arctic and Heavy Oil operators, making it easier to sell the idea of research. Conventional producers may not have this sense of urgency or need.
- Both in the Arctic and in Heavy Oil the operating companies generally apply new technology directly. New technology in the conventional producing sector of the business will likely be delivered through the service and supply sector.
- Research in the Arctic and in Heavy Oil has been a blend of applied research and basic research. Research in conventional production operations tends to be oriented towards applied research and problem solving.

While these differences may present problems, they are not insurmountable obstacles to the formation and operation of the new model.

5.3 The Road Map Model

The Road Map Model is a conceptual framework. It is useful when there is a commitment to jointly describing a plan to deal with a complex problem. It tends to simplify the complexities and provides a framework that enables participants to work through the problems, issues and alternatives in a systematic way. This is the model that was used by the participants in the design of CONRAD.

The process is hierarchical starting with the description of a vision to which the participants aspire. It then requires the definition of a purpose, followed by a statement of beliefs and principles. Goals which are long range and qualitative are established. The goals are supported by shorter term quantitative objectives which leads to the development of a full-blown plan including strategies, tactics and feedback systems.

5.4 A Sample Plan –

Vision, Purpose, Beliefs, Principles and Goals

In this section of this report the Road Map model is used to describe what the vision, purpose, beliefs, principles and goals of prospective stakeholders in a new model might be. These ideas are offered for illustrative purposes. Hopefully these thoughts might also stimulate discussion and move the process along faster than otherwise might have occurred.

The new model should be driven by a vision.

The vision might be:

"For the Canadian conventional oil and gas industry – including the transportation and service and supply sector – to be regarded as reliable, competitive and progressive, and recognized as a world-wide leader in the development and application of new technology."

The stakeholders should be united by a purpose.

The purpose could be:

"To facilitate the collaborative development of new technology that would improve the safety, reliability, recovery efficiency, cost of operation, exploration effectiveness and overall competitiveness of the Canadian conventional oil and gas industry."

The vision and purpose should be based on beliefs.

The beliefs of the stakeholders might include:

- the belief that the Canadian oil and gas industry has the capability to develop and use leading edge technology
- the belief that the application of new and better technology can:
  - reduce finding, operating and development costs
  - improve the safety and environmental security of the industry
  - improve oil and gas recovery
  - improve the overall competitiveness of the industry
- the belief that research facilities and human resources are in place in Canada to develop the necessary technology

- the belief that the most effective and efficient way to carry out pre-competitive technology development is through a sharing of expertise and resources by all stakeholders – government, research providers, producers, transporters, the service and supply sector, and manufacturing
- the belief that individual companies will benefit from an industry that is technically on the leading edge
- the belief that competitors can and should work together to develop new and better pre-competive technology

The Principles on which the new model will be designed might include:

- broad participation will be encouraged
- governments and academia should be included as stakeholders
- participation should be voluntary
- the structure and operation should compliment the operation of existing consortia
- fixed costs, i.e. administrative costs, should be minimized
- activities will be focused on problem solving and applied research
- intellectual property will be owned by project sponsors
- projects will be funded by project participants and costs equitably allocated
- participants will be encouraged to be long-term members

The stakeholders will work towards their vision by establishing several goals. The goals will be broadly stated, will be long-term in their orientation and will be consistent with the beliefs and principles.

Example goals might include:

- to reduce lifting costs by reducing the consumption of energy
- to reduce the environmental impact of the conventional oil and gas industry by reducing emissions to the atmosphere

Objectives, more quantitative in scope, should accompany each goal.

Example objectives to support the example goals stated above might include:

- to decrease lifting costs by reducing the cost of handling produced water by x% by 1998.
- to decrease the volume of sour gas released from block sulfur to the atmosphere by y% by the year 2000

In the detail plan one would develop strategies and tactics. It is this exercise that would lead to identifying specific research projects that would advance the technology of the business.

6.0 A SAMPLE MODEL FOR DISCUSSION PURPOSES

To stimulate discussion, the principle features of a new model are described. Using this format and approach the prospective stakeholders can design a structure that suits their needs. The structure presented is intended to be consistent with the principles previously described.

Description

The new consortia model is intended to promote collaboration among all stakeholders in the Canadian conventional oil and gas producing industry for the development of new and better technology. The new consortia will serve as a clearing house endeavouring to identify technology needs, bring the users with common needs together, help describe research projects that would address needs through improved technology, help select research providers to do the research and communicate results to stakeholders.

Membership

Conventional oil and gas companies, service and supply companies, oil and gas transportation companies.

Research providers including universities, research consortia and private research companies.

Members will join for a three year period.

Members agree to participate in a minimum of two technology development projects each year and agree to share in managing projects from time to time.

Membership Fees

Regular members pay a joining fee to provide start-up capital. Fees will vary from $1,000 to $10,000 depending on company size and ability to pay.

Annual fees would vary from $1,000 to $5,000.

Universities would have a special class of membership and fees would be nominal.

Research providers fees would be somewhere between special members and full members.

Governance

Board of Governors representative of the diversity of stakeholders, i.e. representatives from large, intermediate and small oil companies, service and manufacturing sector, transportation, universities, research providers and government.

Majority of Board to come from technology users.

Board of Governors determines policy and provides overall direction.

Technical Service Areas (TSA), representing logical division of research area, would have responsibility for establishing goals and objectives in their area and ensuring that projects are identified and pursued.

Technical Service Areas might include: production operations, corrosion, plants, pipelines and gathering systems, drilling and completions, enhanced recovery, exploration, and, safety and environment.

Sub-groups within TSAs would look at more specific areas and projects. For example production operations might include artificial lift, stimulation, surface facilities and water handling.

Project Selection:

Any member could propose a project in any Technical Service Area or sub-area. The TSA would determine the suitability of that project on the basis of how it would impact the goals and objectives of the TSA.

Project Financing

Projects would be financed by those members agreeing to participate. Generic financing formulas would be developed. The formulas should take into consideration the benefits that would flow to participants from new technology and their ability to pay.

Project Management

Ideally projects would be managed by one of the sponsoring stakeholders. However, the stakeholders could elect to have the project managed by the secretariat.

Ownership of Data

Project sponsors would have ownership of technical data. Other members could buy into a project and then have access to data.

Administration

A secretariat would be in charge of networking and would provide administrative service. Service would include assistance in identifying and polling prospective participants, coaching of stakeholders in the identification and description of projects, assistance in preparing requests for proposals to research providers, assistance in analyzing proposals, project management if required, assistance in project documentation, distribution of reports, management of communication and feedback systems, and serving as custodian of data. They would maintain an active list of prospective technology users and technology providers, and serve as an agent between these constituents.

The organization would require at least one senior person with a good general knowledge of the industry, interest in research and technology and a knowledge of research providers.

Initially this person might be seconded for one or two years from one of the stakeholders.

Administrative support, including office space, might be provided by one of the industry associations (like CAPP), or by one of the existing industry R&D consortia groups.

7.0 WHERE DO WE GO FROM HERE?

1. Present this study to the members of the Vice-Presidents Breakfast Club in order to:
   - obtain feedback
   - obtain approval to proceed with Phase 2 of this study
   - obtain input for the next phase of the study
2. Work with the Management of Technology group, which has common interests with the Breakfast Club in seeing new technology developed.
3. Communicate the results of this study to prospective stakeholders through industry trade associations, industry media and through direct contact.
4. Solicit input from prospective stakeholder groups on the future course of action.
5. Sponsor one or more workshops at the Calgary University Research Park. The purpose of the workshops is to:
   - bring the rest of the industry to the same level of understanding as the Breakfast Club
   - provide an opportunity for research performers – universities, government labs and consortia groups – to describe their capabilities. Some facilities could be toured.
   - familiarize the industry with various collaborative models
   - provide an opportunity for governments to describe their position on research
   - brainstorm needs, obstacles and potential problems
   - develop broad guiding principles to frame a new model
   - decide future action

Existing Consortia – Models that Work

The following pages summarize the key characteristics of several technology consortia. The consortia selected for inclusion in this report provide the reader with a variety of funding and governance mechanisms. Some of the consortia do in-house research while others contract out all research. Some include governments as partners and some include universities. Some are large and some are small. One consortia, the Arctic Petroleum Operators Association, is dormant, its purpose having been fulfilled.

Alberta Sulphur Research Ltd. – ASR

Description

Not-for-profit corporation founded in 1964 by 8 companies for the purpose of fostering research in the areas of technology and chemistry of sulfur and its compounds with particular emphasis on topics of importance to the Western Canadian sulfur and sour gas industry.

Membership

28 in total, comprised of a majority of the sour natural gas producers, engineering companies, sulphur processing and marketing companies. Some foreign members.

Governance

12 person Board of Directors including 9 outside directors, all from industry.

Funding

Revenue derived about 40% from membership fees, balance from contract work and other sources. Three levels of membership dependant on corporate size and volume of sulphur produced. Three year commitment required. Current year budget is approximately $1 million.

Membership Fees

Three levels (as above) annual cost $27,500, $20,000, or $13,000.

Staff

5 - 20 researchers

Research Mandate

Varies as directed by members. Generally look at global sulfur sphere – "downhole to end product", including environmental. Example: production and processing of high H_2S containing natural gas, sulfur deposition in pipelines, and in the reservoir, corrosion, reduction of gaseous emissions. Program as described by ASL "...covers all aspects of the sulfur system from "where nature put it, to where man uses it." Current program includes topics such as phenomena associated with sour gas reservoir depletion and re-injection of acid gas, degassing of sulfur and related measurement technologies, removal of lower level H_2S from gas streams and trapping of fugitive H_2S in enclosed spaces, thermal decomposition of H_2S, corrosion enhancement by free elemental sulfur, compilation of regulations related to sulfur, development of a course on the chemistry of sour gas and sulfur from the reservoir, to production, to handling solid sulphur.

Program Planning

Technical advisory, a committee drawn from membership, advise the Research Director. Planning committee includes board members and does long range planning.

Communications

Quarterly Bulletin, twice yearly half day chalk talks, response to direct inquiry, reports and publications.

Other

Operates under a contract with the university. Serve as a contact point between industry and academia. Provide graduate student opportunities. Do some instructing. Research reports: all available to public, excepting contract work.

Arctic Petroleum Operators Association – APOA

Founded

1970 for the purpose of facilitating collaborative research in the Arctic. The association did no research themselves. Activities came to a near standstill when oil prices collapsed. The APOA was merged into the Canadian Petroleum Association's (CPA) Frontier Division in 1986 and has been dormant since that time. *(See Applendix II)*

Location

Calgary

Background

Significant leasing of Arctic onshore and offshore exploration permits occurred in the 1960's. Research was needed to help operators design facilities for exploration and development and to provide data required to secure drilling licenses. 28 Companies came together in the APOA, recognizing the merit of pursuing this research collaboratively. The federal government agreed to credit the cost of this research against individual work commitments in return for the companies agreeing to release the information to the public after 5 years.

Membership

28 Companies

Membership Fees

Membership fees were nominal, projects were financed on a user-pay basis with the cost being divided among the companies that elected to participate.

Budget

Association costs were minimal because the association had no responsibility for conceiving or managing projects. APOA had no permanent employees. One employee worked part time when there was an exceptionally large number of projects.

Governance

The association had an executive elected annually. Committees were organized by research area. There was one part-time director for the first few years. A consultant co-ordinated activities, ensured the research was properly documented, managed distribution of the reports to the public and served as custodian of the reports.

Project Selection

Members submitted projects to the APOA for review by the appropriate committee. Included in the proposed project was a detailed description, a budget cost and a deadline by which other companies could participate. The projects would sometimes be modified to meet the needs of all parties. If the project was subscribed, one of the companies was appointed operator and assumed management responsibility for the project. The operator would bill participants for their share of the work, keep them informed on progress and distribute final reports.

APPENDIX I

Project Management

The individual projects were managed by one of the participating companies – usually the company which proposed the project.

Projects Undertaken

In the first 8 years of operation 129 projects at cost of $24 million were carried out under the APOA umbrella. In 1977, a particularly active year, 25 projects were undertaken at a cost of $5.4 million. APOA wound down in the mid 1980s shortly after the National Energy Program (NEP) was introduced. The NEP included a provision called the Environmental Sciences Revolving Fund which forced companies owning Arctic leases to make a contribution to the government which was spent by the government on research. APOA became dormant thereafter and was folded into CPA in 1986. In total there were over 200 projects completed for a cost of $65 million. In excess of 380 study reports were generated and are on file at the Arctic Institute at the University of Calgary. Individual companies did additional proprietary research using APOA research as a foundation.

The research was directed at obtaining engineering and environmental data and preparing feasibility studies to adapt established operating techniques and design new equipment to meet unique operating conditions in the Arctic. There was a wide range of projects including such things as ice mechanics and behaviour, ice island design, Arctic clothing, Arctic vehicles, oil spill behaviour and clean up (both onshore and offshore), delineation of Beaufort Sea ocean currents, investigation of the sea floor, interaction of moving ice with man made structures, and a host of environmental projects.

Staff

None, except for a part time person for the first several years. Administrative support was provided by a consultant.

Communications

A monthly publication, The APOA Review, was started in 1978. All projects were properly documented and reports provided to participating companies and the government. All reports became public within 5 years or sooner if the participants agreed. The APOA paid for the microfiche of all reports and distributed copies to a number of libraries and research institutions. Other recipients were able to purchase reports for the cost of reproduction.

The APOA sponsored numerous workshops and seminars.

Services Provided by APOA

A model agreement for joint venture projects
A formula for participation
Administrative support publication, report distribution, data custodian
A modest structure which brought people together to discuss needs
An interface with government
Help with research documentation

Canadian Energy Research Institute – CERI

Description

Founded in 1975 as a not-for-profit corporation by the Government of Canada, Province of Alberta, University of Calgary and the Private Energy Research Association (the industry sponsors). Its mission was to undertake objective, independent economic analysis of energy issues and studies of the economic and environmental impacts of energy and related policies on Canada. It is located at the University Research Park in Calgary.

Membership

Private Energy Research Association (PERA) includes 130 companies. Other sponsors include: Government of Canada, Governments of Alberta, Saskatchewan, British Columbia, Ontario, and the NWT and the University of Calgary.

Governance

26 member Board of Directors including 8 from PERA, 2 members at large (currently from industry), 3 from University of Calgary, remainder from several governments

Funding

Membership Fees: PERA members annual fee varies from $1500 to $10,000 depending on size. Government sponsors provide grants of varying amounts. PERA provides one half of core funding.

Current year budget -about $2 million. Approximately one half from core funding, one half from conferences, sale of reports, and other income.

Staff

21 people

Research Programs

Since 1988, completed research includes studies of Canadian and world crude oil markets, industrial energy demand, electric power planning, continental natural gas market developments, coal/bitumen co-processing, alternative fuels, emissions permit trading, and oil and natural gas finding and replacement costs.

Recent Projects

Demand-Side Management for Natural Gas: Regulation and Implementation, Containing Iraq: World Oil Market Projections, 1993-2008, Natural Gas in Canada and the United States — From Wellhead to Burner-Tip, Expanding U.S. Markets for Canadian Crude Oil, Saskatchewan's Potential for EOR and Horizontal Drilling Volume I and II, and Survey of Canadian Natural Gas Deliverability.

Program Planning

The Board of Directors determine structure and scope of research programs. Individual projects have advisory committees. Also use research forums in each commodity/topic area for input on research topics. Every new project has an advisory committee.

Communications

Host several conferences and workshops, publish journal "Geopolitics of Energy," numerous studies and reports, research forums.

Other

All publications are available to the public. CERI does no contract research. Administrative stages of the research process include: approval of research proposals and related budgets by the Board of Directors, management and direction of research by senior staff, review of draft reports by Advisory.

Canadian Oil Sands Network for Research and Development – CONRAD

Description

CONRAD was founded in 1994 as a multi-stakeholder not-for-profit Alberta corporation for the purpose of improving the competitiveness of oil sands through promoting collaborative technology development. While there has always been a measure of co-operation among researchers, it was recognized that technological breakthroughs were required if the industry were to remain a competitive producer of synthetic crude oil and that breakthroughs were most likely to be achieved if the talent and resources of all stakeholders were pooled.

Co-operation among the stakeholders was facilitated by the Alberta Chamber of Resources. Over a two year period a model design emerged and CONRAD was incorporated on October 31, 1994. CONRAD, as an institution, does no research of its own. Its purpose is to provide structure and a vehicle for participants to contribute and share. It was designed to bring together the performers of research and the users of research and promotes optimum use of resources by the Government of Canada, the Province of Alberta, Crown corporations, the universities, private research consortia, and the private sector.

Membership

Government agencies – Alberta Oil Sands Technology and Research Authority (AOSTRA), CanMet, the National Research Council, University of Calgary, University of Alberta, Chevron, Imperial Oil, Shell Canada, Suncor and Amoco.

A Network Co-ordinating Council with representatives from members is the governing body. They determine policy and provide leadership.

There are four Technical Planning Groups (TPA) – Environment, In-situ Recovery, Upgrading, and Mining and Extraction. Each TPG has a Board-like structure with representatives from participating members. The TPGs establish objectives, co-ordinate activities, evaluate in-house research contributed by members and monitor progress.

Research providers, such as universities, have a special class of membership.

A secretariat provides administrative support.

Funding

Members contribute cash or in-kind research to become members of a TPG portfolio. There are two classes of membership depending on the level of contribution. Contributions, when reaching $75,000, provide access to the member for all research in the TPG. Lesser contributors receive data only for the projects to which they contribute. Membership is by portfolio (i.e. TPG). A company may participate in any of the four portfolios.

Research providers such as universities are not required to fund projects

Administrative costs, cover the secretariat, and are minimal.

Staff

No permanent staff. Secretariat duties are currently provided by one of the members.

Research Programs

The four Portfolio areas – environment, in-situ recovery, upgrading, and mining and extraction – are managed independently.

Center for Engineering Research – C-FER

Description

C-FER was founded in 1984 as a not-for-profit Alberta corporation. It is a consortia of government, academia and industry. C-FER has specialized facilities at the Edmonton Research Park and specializes in engineering innovations.

Membership

18 – includes oil, service, manufacturing, and pipeline companies. Stakeholders also include Government of Canada, Government of Alberta, and University of Alberta.

Governance

15 person Board of Directors, 11 from industry. Board includes representation from University of Alberta, Government of Canada and Government of Alberta. Committees include Research and Policy, Membership and Networking.

Funding

Since 1984, approximately $50 million has been invested in C-FER, including $19 million in capital expenditures. Industry has contributed 66%, the federal and provincial governments 17% each. The bulk of the government contribution has been in capital investment. Currently C-FER receives no government grants. During 1984 - 1994 revenue sources were:

Government grants –	$ 5.0 million
Core funding – (membership fees and Devonian Foundation)	$11.5 million
Contract research and engineering –	$15.5 million

The current year budget is $4.3 million.

Members pay annual fees based on company size. Funding structure is under review. Membership fees are currently being revised.

Staff

46 people, including 37 engineers, scientists and technologists

Core Competencies

- Structural and mechanical systems engineering
- Reliability engineering
- Engineering software development
- Technology transfer

Products

- Analysis testing and assessment of structural and mechanical systems
- Development and feasibility demonstration of structural and mechanical systems

- Probabilistic risk assessment of engineering structures, plants and processes
- Development of software and decision-support tools to optimize design
- Operation of engineering systems

Program Planning

Research Strategy Committee identifies and prioritizes key R&D needs. Technical Committees select proposals for detailed development.

Current Activities

Include 44 contract projects, 23 core research projects. Projects include progressive cavity pump study, produced sand utilization, numerous downhole tubular projects, sucker-rod behaviour, heavy oil production, sand management, horizontal wells, down-hole oil/water separation, production software, permafrost interaction and numerous pipeline studies.

Communications

Numerous published reports and studies, sponsors workshops, network through Technical Committees

The Computer Modelling Group – CMG

Description

Founded in 1977 by Energy departments of the Alberta and Federal government for the purpose of advancing reservoir simulation software and technology, and to train and assist industry users in its application. The organization was changed in 1979 to industry sponsorship. It is a not-for-profit corporation and is located at the University Research Park in Calgary.

Membership

100 oil companies, consultants, research centres and governments from 30 countries.

Governance

13 - 15 person Board of Directors from member companies plus executive. 4 person Executive committee.

Funding

About one half from membership fees, the rest from contract work and other sources.

Companies pay a joining fee of $75,000 which buys all computer software. Additional $35,000 for software installation, annual fee of $30,000. 5 year commitment required.

The current year budget is about $4 million.

Staff

35

Principal Activities

Reservoir simulation programs, technology transfer, training courses and advisory services, specialized software for oil and gas and environmental applications.

Program Planning

Technical Advisory Committee with one representative from each member. Provide an advisory function. Meet annually to review CMG's research and development plans, status, and quality, and to critique these items, and to provide comments, suggestions, or recommendations to CMG and to report impressions to the directors.

Communications

Annual technical symposium lasting 4 - 5 days, on or off-site training for member companies, newsletters, technical reports and publications.

Gas Research Institute – GRI

Description

Founded in 1976 by American Gas Association and Interstate Natural Gas Association of America. Their mission is to discover, develop and deploy technologies and information that measurably benefit gas customers and the industry.

GRI has no research labs. They contract to private research labs, universities, manufacturing companies and other organizations. They are located in Chicago, Illinois.

Membership

41 Interstate pipeline companies, 154 gas distribution companies, 56 municipal utility members, 36 Independent producer members, 19 major producers, and 23 associate members (foreign governments or countries).

Funding

GRI is funded by a surcharge on pipeline tariffs. There is a volumetric and a demand surcharge approved by the Federal Energy Regulatory Commission (FERC). Also raise about $100 million by manufacturers, government agencies, and others co-funding specific projects.

The current year budget is $200 million.

Staff

250

Governance

24 person Board of Directors from various stakeholder groups

Several advisory bodies, research co-ordination council, industry technical advisory committee, municipal gas system advisory committee

Research Programs

Four program areas: gas supply (the upstream business), end use (the consumer), gas operations (generally transportation and storage) and cross-cutting research (environment and safety). Gas supply is about one quarter of the budget, gas operations is about one eighth. Budget also includes basic research for about one tenth.

Objective of the gas supply program is to increase deliverability and to decrease drilling and completion costs by 20% below those projected for the year 2000, in the absence of technology advances. Current programs supported in gas supply area include well stimulation, drilling technologies, gas supply models, well logging, measurement of reservoir properties, reservoir management, gas dehydration and gas processing.

Environmental programs include site restoration, air quality, emissions monitoring.

Communications:

Quarterly news magazine, special interest publications, brochures, technical reports, news releases, special workshops and seminars, trade shows.

The Institute for Chemical Science and Technology – ICST

Description

ICST is a not-for-profit corporation founded in 1985 for the purpose of sponsoring collaborative research at Canadian universities. It is located at Sarnia Ontario. Its mission is to sponsor world class relevant research, generate new ideas and unique technology, enhance the growth of Canadian chemical, petroleum and related industries, and utilize the combined skills and resources of industry, universities and government.

Membership

21 members, including 6 industry members and 15 universities.

Governance

16 person Board of Directors, meets twice per year, 13 person management committee, meets 4 times per year, 14 person Scientific Advisory Committee – meets 5-6 times per year.

Funding

33% member fees, 17% Industry Canada grant, 50% Federal and Provincial grant.

Members fees are paid annually and vary from $100,000 to $25,000 depending on size as determined by sales. Also encourage small companies to join through fee based on percentage of sales. Universities pay flat fee of $10,000.

Current year budget is $1.3 million. 35% from member fees, 20% from DRIE, 37% from NSERC/URIF and balance from other sources.

Staff

Not Available. Administration expenditures average 12% of total expenditures.

Research Area

Petrochemical. Four Project Areas – Environmental, Industrial Catalysis, Polymers, and Separations. In 1993 involved in 37 research projects at 18 universities.

Program Planning

Request proposals from Universities for research projects. Receive 70 - 100 per year. Short list developed by Project Teams and recommended program developed. Final approval by Scientific Advisory Committee. Apply for matching grants. Process from start to implementation takes about 12 months.

Communication

Research reports, publications, annual technology day.

Other

Service Provided by ICST – written reports, technology day presentations, seminar/sit visits by project teams, company-organized seminars, transfer of leads by project team member, contract laboratories, network with universities and provide focus for government research dollars.

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Guiding Principles

All core research carried out at universities, all members have access to all research results, each member free to translate research results into technology solutions for its own use.

Petroleum Recovery Institute – PRI

Description

A not-for-profit corporation founded in 1966 by Alberta Government, University of Calgary and oil industry to conduct fundamental research directed toward increasing recovery of oil from Alberta reservoirs. It is located at the University Research Park in Calgary. Has modern facilities including MRI equipment.

Membership

19 oil companies, 8 foreign national oil companies or governments.

Governance

11 directors from industry, plus ex-official members from ERCB, Alberta Research Council, Alberta Energy and Natural Resources, AOSTRA, University of Calgary, and University of Alberta.

Funding

Through membership fees, contract research and grants. Fees: currently $15,000 annual fixed fee plus one and a half cents per cubic meter of oil produced.

Current year budget is approximately $3 million – about one half from member fees, one quarter from contract research, and remainder from grants and other sources.

Staff

40

Research Area

Recent realignment reduced number of projects and placed emphasis on reservoir science and focused on practical and economic new processes. Established four research areas:

1. Improved water-flood recovery from heterogeneous limestones
2. Improved water-flood recovery from heterogeneous sandstones
3. Improved heavy oil recovery from unconsolidated sands
4. Water coning abatement in gas production.

Reports to members detailed in annual report include 8 projects of Sweep Improvement, and 2 projects on Productivity Improvement Technology.

Program Planning Board responsible to select from and approve the major research areas and associated research projects based on business priorities. Technical Advisory Committees and Sub Committees provide project suggestions. Sub-Committees include Gas Flooding, Heavy Oil, Productivity Improvement Technology, Sweep Improvement, and Magnetic Resonance Imaging User's Group.

APPENDIX I

Communications

Numerous technical papers, studies and publications, co-sponsored horizontal well conference, sponsored a text book, 7 workshops on: Horizontal Wells, Water Coning Abatement, Formation Damage, EOR Evaluation, Economic Considerations in EOR Process Selection, Water Coning in Gas Wells, and Diagnostic Analysis of Sucker Rod Beam Pumping Well Performance, quarterly news publication called "Partners". Network through a large in Technical Advisory Committee and Sub-Committees.

FEBRUARY 1978
Volume 1 No. 1

APPENDIX II

A.P.O.A. Review

ARCTIC PETROLEUM OPERATORS' ASSOCIATION

MESSAGE FROM JOHN HNATIUK, APOA Past Chairman Gulf Oil Canada Limited

I am pleased to welcome our readers to the first edition of the "APOA Review". We are planning to establish this newsletter as a quarterly publication to provide information about the work that APOA has done in the past as well as its current activities. We anticipate that it will form an important part of our overall APOA Information Program through which public awareness and understanding of the petroleum industry's joint research efforts in Canada's Arctic will be better understood.

Each of APOA's projects is funded by a group of member companies who subscribe a portion of the cost and obtain the results of the work. In almost all cases, a report of the project has been prepared giving detailed results of the research. While these reports are available initially only to those member companies providing support for the project, they are later released to the general public. In some cases, the participants have agreed upon immediate releases. In others, the reports are released after a protected period of up to five years.

Although these reports, when released, are available to the public through the government and some libraries, we realize that many people find it inconvenient to gain access to them or are not even aware of their existence. We hope that the summaries of the reports we shall be publishing in the "Review" will bring APOA's work to the attention of many more people with a direct involvement in Northern development and environmental issues, as well as to those with a broad interest in these matters.

I hope you will enjoy the "Review" and I shall welcome your comments on it and the material it contains.

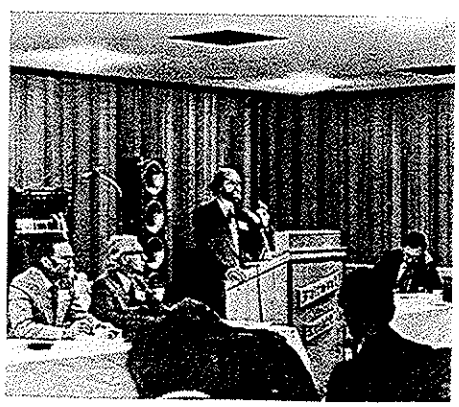
John Hnatiuk

APOA UNDERTAKES WIDE VARIETY OF STUDIES

Since the Arctic Petroleum Operators' Association was established in 1970, the Association has completed, underway, or proposed 129 projects for a total cost of over $24 million. A non-profit association of 28 petroleum companies operating in the Arctic, APOA promotes joint research in the Arctic and provides liaison between industry, government and universities on Arctic research related to petroleum development.

During 1977, for example, the Association undertook or proposed 25 projects at a cost of $5.4 million. Eight of these centred on the Eastern Arctic and were undertaken in Davis Strait to satisfy environmental guide lines of the Department of Indian and Northern Affairs. Much work was already underway or completed in the Davis Strait area prior to the announcement of the Eastern Arctic Marine Environmental Study program in late 1977.

Continued on page 2



S. L. Ross speaks at APOA Environmental Workshop, 1977.

1977 APOA Environmental Workshop, general sessions.

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A.P.O.A. Review

ARCTIC PETROLEUM OPERATORS' ASSOCIATION

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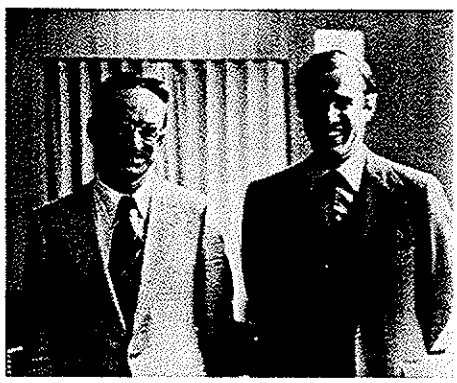
Continued from page 1

In other areas of the Arctic, recent studies have included tests to ignite oil under ice and on water pools under Arctic springtime conditions. An extensive shoreline study was carried out of the Southern Beaufort Sea during the summer of 1977. Other ice studies will be continuing throughout 1978.

A review of the types of studies which APOA has sponsored in the past seven years is given in the article on page 5, "Arctic Petroleum Research in an Historical Perspective."

BILL BERNARD ELECTED APOA CHAIRMAN AT ANNUAL MEETING

At APOA's Annual Meeting held January 13, 1978 in Calgary, W. F. (Bill) Bernard was elected chairman for 1978. Mr. Bernard is Engineering Manager of Dome Petroleum's subsidiary, Canadian Marine Drilling Ltd. Other members of the Board of Directors for 1978 are: Tom Beck, Aquitaine; Bob Currie, Panarctic; Gordon Jones, Petro-Canada; John Hnatiuk, Gulf Oil Canada; Ed Kustin, Hudson's Bay Oil and Gas; and Stan Mackay, Imperial Oil. Secretary-Treasurer is Al Burroughs of Dome/Canmar.



John Hnatiuk, past chairman and Bill Bernard new APOA chairman at APOA Annual Meeting, January, 1978.

In addition to the regular business and reports on the various subcommittees' work, the meeting was advised that the APOA Environmental Workshop will be held from April 12 - 14, 1978 at Fairmont, B.C. This workshop is an annual event co-sponsored by the Canadian Petroleum Association and APOA. It brings together representatives of industry, government, universities, northerners and representatives of special interest groups and the media to discuss issues of mutual interest and concern in the Arctic and share results of recent research work.

The theme for the 1978 Workshop will be "Offshore Resources". Proceedings of the Workshop are published and are available to participants and to interested members of the public for a small fee.

EDITORIAL

As editor of the "APOA Review", I would like to welcome our new readers. I know there is a deluge of material written today about the Arctic and environmental matters. Despite this, we hope that the "APOA Review" may provide a means whereby much of the valuable information about the Northern environment as it relates to the petroleum industry's activities will be widely disseminated for the first time. We hope, as well, that the publication will arouse an increased interest and awareness of the extensive work which has been and will continue to be done by industry in this area.

This and each of the forthcoming editions of the "APOA Review" will feature summaries of a number of APOA reports. At first we shall be concentrating on many of the earlier studies dating back to the early 1970's. A. E. Pallister's article outlines the history of development of these early northern studies and relates them to possible future activities. Information about more recent APOA projects will be included. As well, we shall describe current activities of the APOA.

The "Review" will be published quarterly, and will, we hope, reach a distribution of 5,000 in the near future. In addition to individual mailings, we shall be providing a number of copies to municipal offices and other organizations in northern communities. Anyone interested may be placed on the direct mailing list

free of charge. If you know of individuals or groups who might wish to receive the "Review", please send us names and addresses.

Some of the material from each issue of the "Review" will be translated to Inuktitut, the language of the Inuit of Eastern Arctic where it is the prevailing form of both verbal and written communication. This abstract will be sent out after each issue in a separate mailing. Anyone wishing to receive this publication should send in the coupon found in this issue.

Your ideas and critiques are welcomed. Letters to the Editor will be appreciated along with suggested material and pictures for future issues.

Mary Collins
Editor

STUDY LOOKS AT ARCTIC VEHICLES

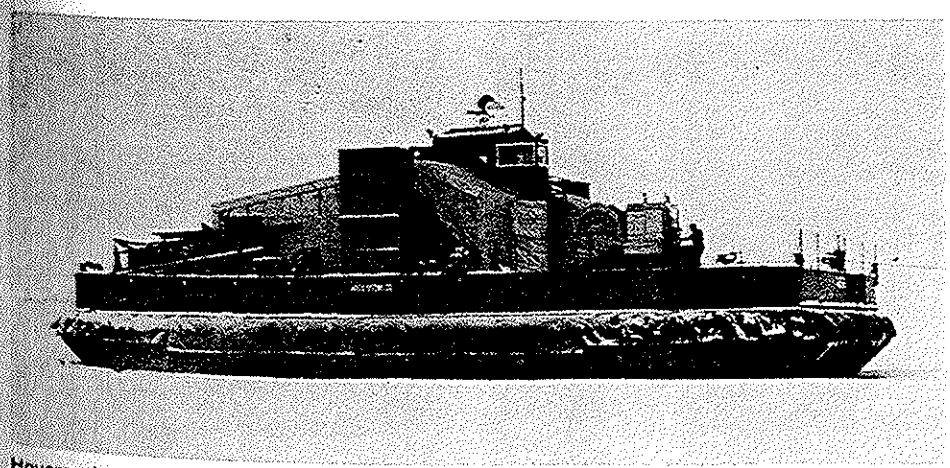
Project Title: —
Cross-Country Vehicle Study
Report Title: —
Preliminary Arctic Engineering Study of Surface Transport Vehicles
Project No.: — 7
Project Cost: — $6,671.
Report Date: — December, 1970

The petroleum industry in the Arctic is not obtaining the reliability and performance from vehicles in the Arctic which would be possible with more stringent performance requirements imposed on manufacturers, concluded a report prepared for APOA in one of its early projects conducted in 1970. The report, prepared by J. E. Rymes Engineering Ltd., included an in-depth review of much of the vehicular equipment then in use or planned for seismic and geophysical operations in the low Arctic, especially in the vicinity of the Mackenzie Delta.

In undertaking the review, the engineering consultants looked not only at the vehicles themselves but also took into consideration the climate and terrain of the Arctic, the reliability and maintenance of equipment and the impact of Arctic operations regulations.

Because of the particular environmental conditions in the north, it is necessary to develop vehicles that will not damage the tundra or cause melting of the permafrost. The harsh winter climate also necessitates certain adaptions to vehicles to ensure that they can keep operating and be maintained despite the low temperatures.

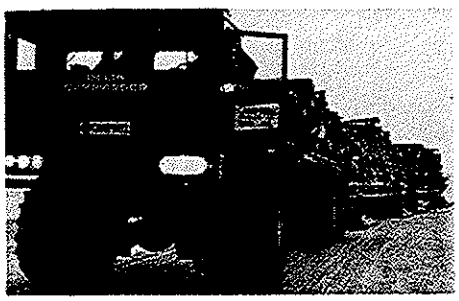
Several classifications of vehicles were reviewed: tracked vehicles, wheeled vehicles, hovercraft, and special equipment. The consultants observed that vehicles existing at the time were not capable of meeting all the desired requirements. Special designs were required to meet the rigorous land-use conditions. Consequently, it was found that a total vehicle mobility for every function was lacking, although there are a variety of vehicles used, with varying capabilities.



Hovercraft used in Arctic winter operations.

In addition, many vehicles were sent to the Arctic without preparation or testing. Many manufacturers, even with Arctic experience, were sending vehicles into the Arctic and learned from experience rather than considering basic environmental parameters first. This was described as "wearing out the customer" and was not an uncommon practice in the early geophysical operations.

The fundamental reason that was described was the short lead time often given to equipment and vehicle operators to provide their services to the industry. With insufficient time, these operators were often compelled to take the "first and cheapest vehicles available" and hope that the job could be done without too much trouble. The competitive nature of the manufacturing sector and of the development of new designs often results in a failure of manufacturers to standardize major replacement components of their vehicles. Given the difficulties of logistics in the North such standardization would ideally alleviate some of the service problems being encountered and reduce the cost of operations, the report concluded.



Delta Commander hauling across the winter snow roads.

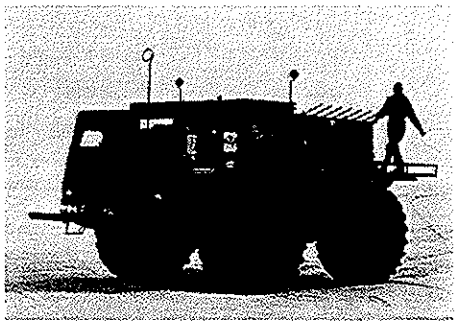
One of the major shortcomings isolated was the lack of detailed vehicle and equipment specifications. The report observed that "when it comes to purchasing vehicles and equipment, it is most revealing that the petroleum industry at large should be so openminded, when

Continued on page 4

Continued from page 3

their reputation is one of meticulous detail to attention. We are not aware of any other industry, where vehicles and equipment form such an important role in their operations, that would tolerate this policy."

The consultants recommended the development of specification standards for vehicles and related equipment to operate in the Arctic, the establishment of reliability records for various vehicles, the undertaking of more winter-testing, the standardization of such support items as fuel and lubricants, preparation of windchill charts for vehicle drivers, consideration of electric vehicles and 24-volt electrical systems, provision of additional heaters in vehicles, requiring escape hatches as standard equipment, and sealing of all cabs and engine components.



Vehicle used for Arctic Seismic.

BEAUFORT SEA ICE AND CURRENTS MEASURED IN EARLY STUDIES

Project Title: — Sea Ice Survey — Properties and Movement of Ice and Current Measurements

Report Title: — Beaufort Sea — Ice Movement and Current Survey, 1970

Project No.: — 2

Project Cost: — $378,265

Report Date: — November, 1970

The project was carried out in two parts. The first dealt with sampling of sea ice at 15 sites across the Mackenzie Delta. These tests were designed to sample ice strength and thus included specific tests of ice thickness, snow cover, salinity, temperature, the structure of crystals in the ice and strength of ice on a small scale.

During the 4th week of March, 1970, it was found that the average ice thickness was 61" and snow cover was 4". The saline or salt content of the ice was found to be low, probably because of the influence of the fresh water from the Mackenzie River.

It was determined that the small scale strength values of the ice were typical of sea ice with a low salt content. The tensile strength was indicated at 100 pounds per square inch. That is, it would take a one-hundred-pound, one-square-inch weight to break or bend the ice below.

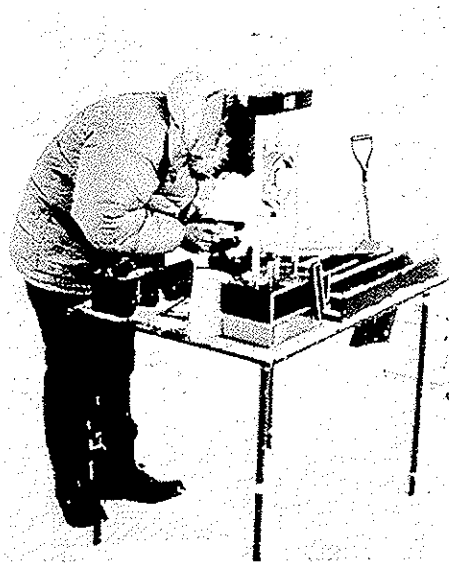
In the second part of the project, ocean current and ice movement sensors were installed in the spring of 1970 in several locations in the Beaufort Sea, operating for about two months. Measurement of ice thickness and water depth were also made.

Currents were measured at five locations where water depths ranged from 23 - 128 feet. Either smooth ice or rough ice was present at all locations. The maximum speed of the water just under the ice was from 0.1 to 1.1 knots, the latter being rather high and perhaps resulting from the presence and movement of large marine mammals in the area. The average speed of the water near the surface ranged from 0.10 to 0.35 knots. At the bottom of the sea, the maximum speeds ranged from 0.05 to 0.5 knots, with an average range from 0.06 to 0.08 knots.

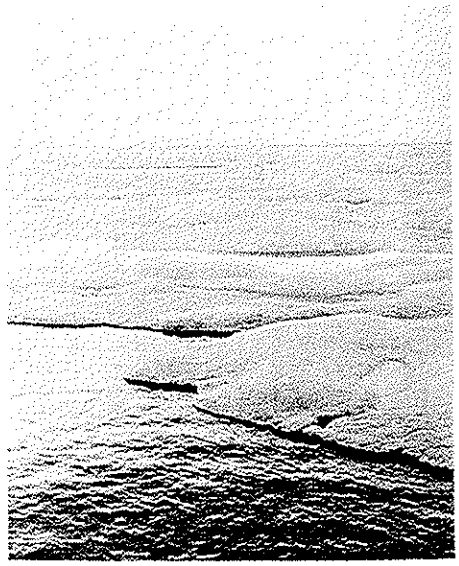
Ice movements were also measured and showed wide variation. At one location, for example, ice was found to move 14 to 24 feet in a six-hour period. This occurred where there were high winds and where there was space for the ice to move.

The ice thickness measurements showed that ice thickness increased considerably during the period from March to May. Increases as great as 18" occurred on one location where the ice had been 4'8" in March and had thickened to 6'2" by May. There were other increases from 4'10" to 6' and from 5' to 5'8". This rapid growth propably occurred as a result of the extremely cold temperatures present in the region at that particular time.

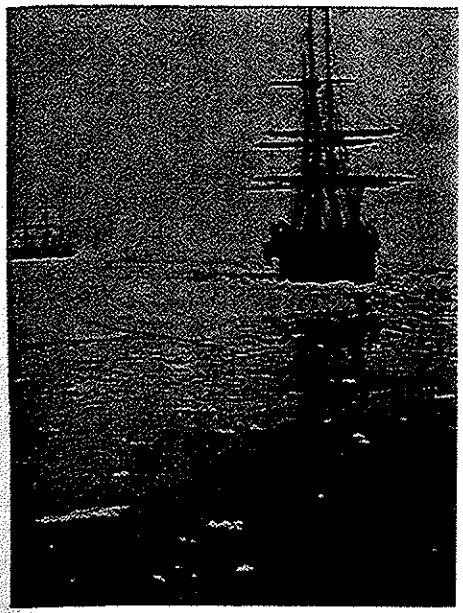
From these early ice tests, further tests took place in future years. They were all important in assisting the petroleum companies to design equipment and systems to operate in the Arctic effectively, with minimum possibility of damage to either equipment or the environment.



Equipment used to test ice strength in Beaufort Sea. Ken Croasdale



Ice in the Beaufort Sea.



Whalers "Diana" and "Nova Zembia", Dexerity Harbour Baffin Land, 1899 — vessels used in Captain Peary's voyages of Arctic explorations.
Glenbow-Alberta Institute

ARCTIC PETROLEUM RESEARCH IN AN HISTORICAL PERSPECTIVE

by A. E. Pallister
Pallister Resource Management Ltd.
Calgary, Alberta

HIGHLIGHTS OF THE HISTORY OF THE EXPLORATION FOR PETROLEUM IN THE CANADIAN ARCTIC

Man's First Explorations

Exploration of the North American Arctic began perhaps as far back as 40,000 years ago during the Ice Age when hunters moved northward to an ice-free region of northern Asia, crossed the land bridge which is now the Bering Strait and migrated southward on the North American continent.

About 5,000 years ago, with the warming of the Arctic climate following the Ice Age, northern people who had established the early Denbigh culture in the northwest of the continent gradually ventured eastward to occupy the coastal regions of the polar seas in what is today included in Alaska, the Canadian Arctic and Greenland.

As a result of future changes in climate, a series of north-south migrations of animals and their hunters took place into the interior Arctic regions. The Eskimo culture developed during these migrations with the original Denbigh and the later Dorset cultures being replaced by the Thule-Inuit people who have lived on the barren lands and along the North American and Greenland coasts for almost 3,000 years.

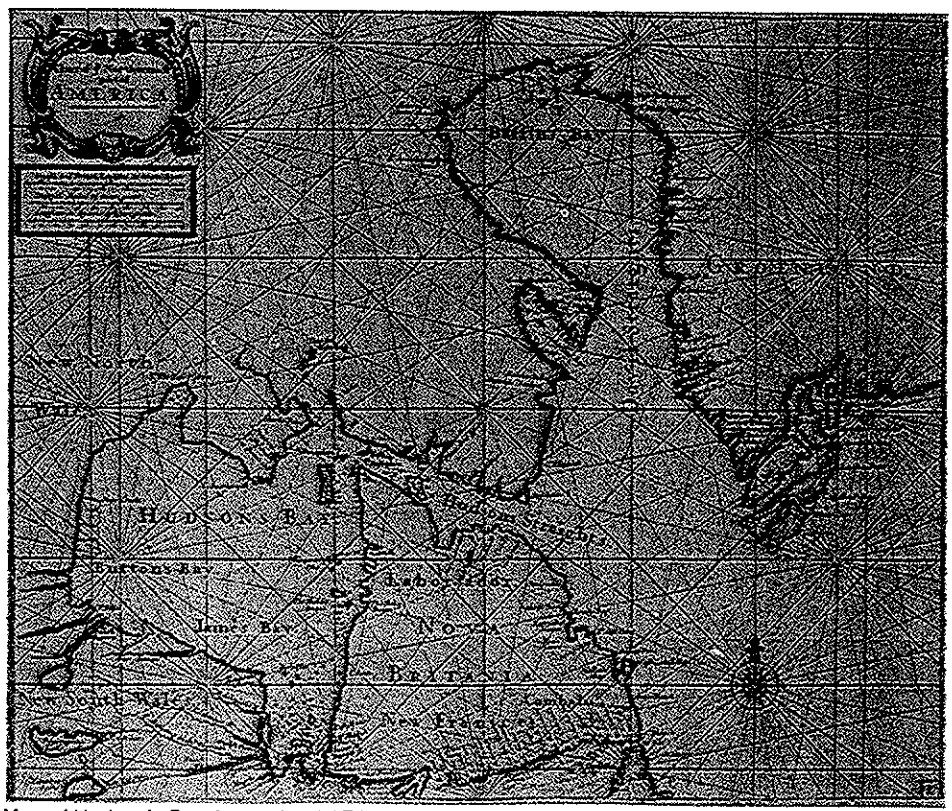
European Excursions

Although Leif Ericsson landed from the east almost 1,000 years ago on what is now known as Baffin Island, Europeans are comparative latecomers to this area and their early visits were not sustained. It was 500 years after Ericsson's landing that Europeans first seriously speculated about a sea route westward from Europe to Asia across the top of the globe. Explorations for a passage were initiated in the early 1500's, but it was nearly 100 years later that the Bay, named after Baffin, was entered by Europeans. Another 200 years passed before Parry's ships, the "Hecla" and "Griper" followed up the previous sighting of Lancaster Sound by sailing westward to reach Melville Island. That was only 160 years ago.

The continuous sea route from the Atlantic to the Pacific was not linked for another 30 years when M'Clure who, having entered from the west, was beset on Banks Island and completed the passage by foot. The route was not actually navigated by a vessel for yet another 50 years — in the early years of this century.

During these explorations, knowledge of not only the geography but some fundamental geology of the region was acquired. While much of the early scientific "research" was directed towards finding surface mineral deposits, particularly native copper, gold and iron, observations which lead to speculation of the structural and sedimentary nature of the subsurface also emerged.

Reverend Haughton, for example, published the first geological map of the Arctic Islands in 1859 from



Map of Hudson's Bay Area, about 1700. Glenbow-Alberta Institute

collections made during the Franklin Search Explorations. Geological reports in the eastern Arctic came from the ocean voyages of Nares and in the western Arctic from M'Clintock's expeditions in the nineteenth century.

Canadian Expeditions

The Geological Survey of Canada, established in 1841 with a staff of two and an annual budget of $6,000, pioneered in the description of the natural resources in the Canadian Arctic. The "Survey" commenced

Crew of the Hudson's Bay Company schooner "Fort MacPherson", King William Island, 1925.
Glenbow-Alberta Institute

northern expeditions in 1875 to northern Hudson Bay and Labrador. Geological field trips by land to the Yukon and to the Arctic coast of the Northwest Territories were made in the late 1800's. By 1904, entering by sea, survey parties gathered geological information from the Arctic Islands. In addition to its scientific mission, the expedition established formal possession for Canada of the eastern Arctic Islands.

The Canadian Arctic Expedition to the western Arctic and western Arctic Islands during 1913-18 under the command of Stefansson included scientific staff from the Geological Survey. An Arctic Biological Committee subsequently worked for seven years in preparing the sixteen-volume report of this mission. These volumes, prepared by seventy-three specialists in geography, mammals, birds, botany, fish, marine biology, hydrography, Eskimo culture and technology, archaeology and geology, are (in scope) not unlike those of the Beaufort Sea Environmental Program which took place sixty years later. The Stefansson expedition mapped for the first time and laid claim for Canada several of the ice-locked islands in the northwest of the archipelago.

Early Petroleum Prospects

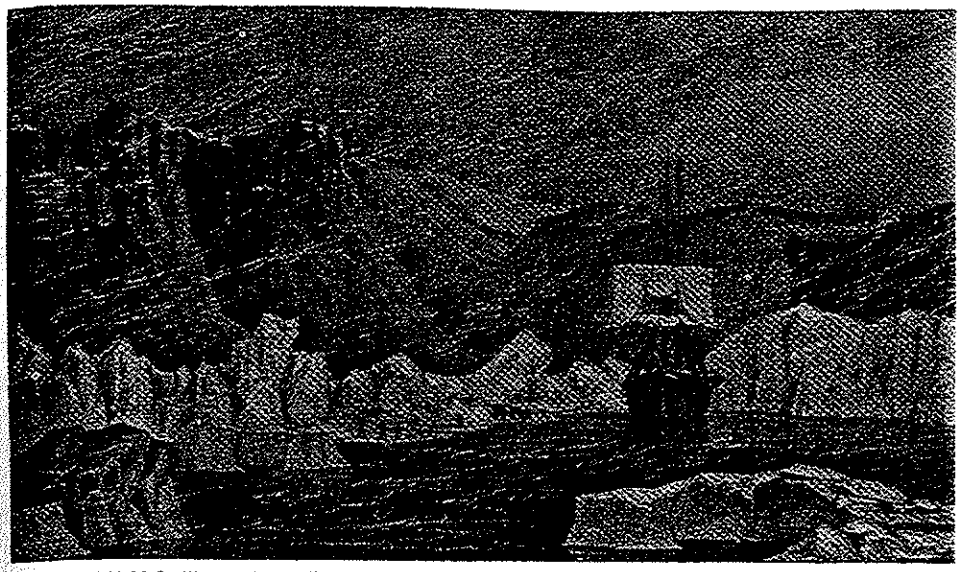
It was not until 1955, however, that a comprehensive geological mission of the High Arctic took place under "Operation Franklin." This operation included geological field parties, air photo reconnaissance and airborne geophysical surveys and resulted in the description of a number of sedimentary basins with potential for oil and gas reservoirs. Industry's interest in the possibility of oil accumulation in the Arctic Islands and the western Arctic was heightened by these findings. At that time, major oil discoveries had been made in central Alberta and Saskatchewan and oil exploration had extended into the northern parts of the provinces and into the southern Northwest Territories and Yukon.

It is worth noting, however, that oil seeping to the surface near Fort Norman on the Mackenzie River, had been observed long before. An oil well was drilled there in 1920 and completed in 1923 with a production rate of 12 barrels per day. This was 25 years before the discovery of oil at Leduc, Alberta — an event which set off the huge growth of the Canadian petroleum industry. Seven more wells were drilled in the Northwest Territories before 1924. Following a fifteen-year period of no further development, another 93 were drilled during World War II to extend the Norman Wells fields. During the 1950's, 70 exploration wells were drilled in the southern Northwest Territories as exploration from the western provinces spread northward. Natural gas was discovered in 1955 at Rabbit Lake, near Hay River. A gas field was established at Pointed Mountain near the Yukon/B.C. boundary in 1967 and went on production in 1972 through a pipeline joining the gas fields in northeastern British Columbia.

The first exploratory well in the Arctic Islands of the Northwest Territories was drilled in 1961 on Melville Island at Winter Harbour, near the site where Parry had wintered 142 years earlier. Only four more Island wells were drilled during the remainder of the 1960's; then, with the discovery of gas at Drake Point on Melville Island in 1969, the pace of drilling increased. More than 20 exploratory and delineation wells were drilled annually in the years following. There have been a number of oil and gas discoveries in the Island, but production has not commenced as yet.

After four years of geophysical exploration, the first well was drilled in the Yukon Territory in 1957 and was followed during the 1960's with an average of four wells per year. Gas was discovered in 1960 at Chance in the Eagle Plain and in 1964 at Beaver River, an extension of a nearby field discovered in B.C. in 1959. Beaver River began production in 1971, but no further development has taken place in the more northern regions of the Yukon.

In summary, in the whole of the Yukon and Northwest Territories, after an early start in 1920, about 100 wells were drilled during the



Position of H.M.S. "Investigator" on the 20th of September, 1851 from the book "The Discovery of the North-West Passage" by Captain R. M'Clure, published by M. G. Hurtig Ltd., Edmonton.

following 30 years, mostly at Norman Wells. The 1950's saw another 70 wells drilled, and during the 1960's, the exploration companies increased their activity somewhat in sinking 260 more holes in the search for northern hydrocarbons.

During the 1950's, a total of $40 million was spent with annual expenditures increasing gradually from $1 million to $17 million. During the 1960's, expenditures were more than 7 times higher, increasing to almost $90 million per year, with a total of almost $300 million spent during the decade.

A comparison of expenditures by the petroleum industry in northern and southern Canada from 1950 - 70 is given below.

Expenditures by the Petroleum Industry in Northern and Southern Canada
1950 - 1970

(in millions)

	Northern	Southern
Exploration ...	$300	$ 5,730
Development .	18	3,940
Operating Costs	10	2,380
Royalties	2	1,450
TOTAL	$330	$13,500

The Seventies

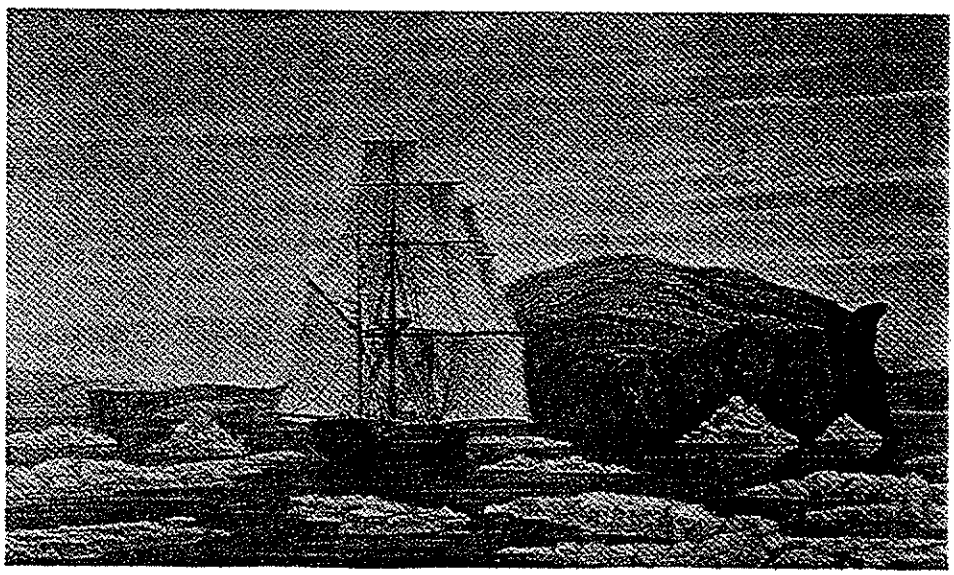
At the beginning of the 1970's, 360 exploratory and 70 development wells had been drilled North of 60°. By comparison, in western Canada 22,000 exploratory wells had been drilled — more that 1,100 of them prior to the Leduc discovery. Additionally, 34,000 development wells were in place.

The discovery of the 12-billion-barrel oil field on the Alaskan north slope in 1968 generated renewed interest in the petroleum potential of the Canadian Arctic. Canada lands under permit doubled to over 400 million acres in 1969. A large increase in exploration activity in the Canadian Arctic followed quickly. In 1970, expenditures for the one year were equivalent to the full period, 1964 - 67.

Oil companies now have some 250 million acres under permit from the Federal Government North of 60°, a decrease from the 460 million acres under permit in 1971. This is about 30% of the 800 million acres of petroleum lands in all of Canada under exploration or in production.

During the first 7 years of the 70's, expenditures in the two Territories totalled more than $1,700 million, with the rate now running at almost $300 million each year. In 1976, 26% of expenditures were for geophysical surveys, 63% for exploratory drilling, 6% for development, 2% for operating costs and 2% for royalty payments. Expenditures in 1978 are expected to exceed the total amount spent during the entire 50-year period, 1920 to 1970.

During 1976, 27 wells with an average depth of 10,000 feet were drilled in the Territories. Seven of these were development wells outlining fields previously discovered. By comparison, more than 5,600 wells were drilled in southern Canada during that year — 2,400 exploratory and 3,200 development.



Discovery of Princess Royal Island from the book "The Discovery of the North-West Passage" by Captain R. M'Clure, published by M. G. Hurtig Ltd., Edmonton.

Exploratory drilling activity in the North is now only 1% of the Canadian total, although geophysical activity in the North is about 30% of the total activity in Canada.

Expenditures in Canada for geophysical surveys and exploration for new oil and gas reserves in 1976 were more than $800 million, of which a third ($282 million) was invested North of 60°. In 1976, expenditures by the Canadian petroleum industry, including development and operating costs, were $3,100 million. When payments for royalties are added, industry expenditures reached $5,400 million. These figures exclude expenditures on pipelines, refineries, oil sands plants, etc.

Oil and Gas Production

Total oil production North of 60°, has been over 20 million barrels — all from Norman Wells. This is less than 0.2% of the total 8,400 million barrels produced to date in all of Canada. Production of gas from the southern Yukon and Northwest Territories has totalled 0.2 trillion cu. ft., 85% of it produced during the past 5 years. This is 0.5% of the 40 trillion cubic feet produced in all of Canada to date.

At the present time, annual production from the Northwest Territories is less than 1 million of the almost 500 million barrels of oil and less than 0.04 trillion of the 3 trillion cubic feet gas production — about 0.2% and 1.3%, respectively, of total Canadian production.

Other oil and gas discoveries which have been made in the Yukon, Arctic Islands and the Mackenzie Delta await the establishment of transportation facilities before production can commence.

Potential Resources

The area North of 60° is particularly important with respect to potential oil and gas resources for Canada. Proved reserves in southern Canada are about 7,800 million barrels of oil and 53 trillion cubic feet of gas. Numerous discoveries of natural gas have been made in the Mackenzie Delta and Arctic Islands, and the reserve estimates are significant when compared to the above mentioned proved reserves in southern Canada.

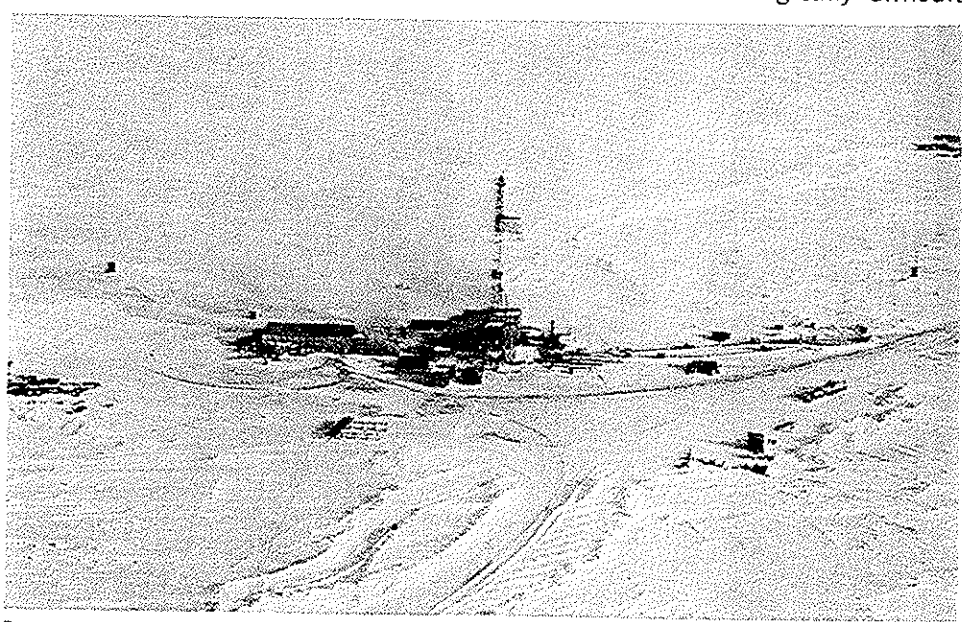
It has been estimated[1] from subsurface information obtained from the 700 northern exploratory wells that have been drilled to date that there could be an additional "undiscovered" volume of some 6,000 million to 24,000 million barrels of recoverable oil. Of the total Canadian undiscovered oil potential, estimated to fall in the range of 17,000 million to 35,000 million barrels, some one-quarter to one-half could be found North of 60°. These comparative figures are for "conventional oil" and do not include the western Canadian oil sands potential.

Similar estimates have been made for natural gas. The estimated undiscovered potential North of 60° falls in a wide range from 65 to 230 trillion cubic feet. In all Canada, the estimated undiscovered potential gas resource is from 170 to 320 trillion cubic feet. Future gas discoveries North of 60° might represent, on average, roughly half of the Canadian total.

These estimates of northern undiscovered potential resources do not include oil or gas that may be discovered in "inaccessible" offshore areas. A lack of knowledge of the exact nature of the sediments in geologic basins which have not yet been penetrated by the drill, together with limits of present technology to produce in areas of permanently ice-covered and/or very deep water make such estimates extremely speculative at this time. The addition of these potentials will add very significant amounts to the northern resource base.

In viewing the estimates of potential, great caution should be exercised. Their accuracy is very limited. Firstly, the well density per acre in the North is very low. Only 700 exploratory wells exist over a region of 700,000 square miles of sedimentary basin, a density of 1 well per 1,000 square miles. By comparison, estimates of remaining resources in western Canada are based on information from 34,000 exploratory wells in a 200,000 square-mile sedimentary area, or a density of 1 well per 6 square miles. Secondly, the cost of exploring for, producing and transporting oil and gas from distant and technologically difficult

[1]The estimates of undiscovered potential have been derived from a 1976 publication of the Federal Department of Energy, Mines and Resources. Proved reserves are from the 1976 report of the Reserves Committee published by the Canadian Petroleum Association.



Panarctic Tenneco et al W. Hecla N-52. Offshore Melville Island. World's first gas well to be drilled from floating ice platform. Well drilled in 400 feet of water encountered gas at the 2,695 foot level on March 31, 1974.
Panarctic Oils Limited

areas is very different than in the established areas. So, although stating ranges of estimates of future potential is important, it is equally important to recognize the uncertainty of the volumes which might become commercially available. Research during continued exploration will play a large role in refining these qualified estimates.

Canadian Consumption

In order to fully appreciate the foregoing potential resources, proved reserves, and production statistics, it is important to look at their relationship to the Canadian consumption of oil and natural gas. In 1976, Canadians used 617 million barrels of oil and 1.4 trillion cubic feet of gas. Taking a medium estimate of potential reserves at 15,000 million barrels of oil and 150 trillion cubic feet of gas, places the undiscovered potential in northern resources in perspective. When compared to the remaining proved supplies and the consumption rate in southern Canada, the importance of northern exploration and research becomes obvious.

The basic conclusion is that the northern region of Canada is an area whose potential could be very high but for which data is yet very limited. Considering some future cost and technology unknowns, the extent to which the oil and gas industry might grow in the North remains speculative at this time.

APOA Research

In 1970, the petroleum industry formed a new organization to coordinate northern research project — The Arctic Petroleum Operators' Association. Although some oil companies had been operating in the Arctic for several years, it had become clear that more research would be needed to provide information for an expanded level of activity in the 70's and that projects should be done cooperatively to avoid repetition and undue cost. Since that time, this research has been directed towards obtaining engineering and environmental data and preparing feasibility studies to adapt established operating techniques and design new equipment to meet unique operating conditions in the Arctic. Over the past eight years, 129 separate projects have been carried out at a cost of $24 million. During 1977, 25 projects were undertaken or proposed at a cost of $5.4 million.

The first studies were conducted in the offshore western Canadian Arctic. They included measurements of the properties of sea ice, delineation of Beaufort Sea ocean currents and investigations of the nature of the sea floor. These projects led to the construction of temporary artificial islands in the shallow offshore waters. Further studies have investigated the feasibility of designing permanent bottom-founded structures capable of withstanding the forces of ice pack movements in deeper waters. Much of the initial work was also directed towards the design of vehicles which could operate on land in the vicinity of the Mackenzie Delta and the Anderson Plains with minimal disturbance to the tundra and temperature changes to the underlying permafrost. Progressively, studies were undertaken to gather wildlife data and assess potential environmental impacts. Research results led to the establishment of special drilling guidelines to prevent possible pollution. Subsequently, an emphasis was placed on devising methods for containing, detecting and cleaning up oil should an accident occur. As time went on, studies focussed on conditions in the eastern Arctic. Results have been applied to operations in the Arctic Islands and form a base for future offshore drilling in Lancaster Sound, Baffin Bay and Davis Strait.

As the projects were completed, it became possible to correlate the inter-relationships of the exploration operations at the working surface — whether it be tundra, delta or offshore ice-infested waters — with the biological, botanical and atmospheric conditions and with the objective of employing techniques which are safe to workers and to the environment.

The results of the APOA research and that carried out by individual companies were soon utilized in geophysical and exploration drilling operations and a number of new Arctic technologies have evolved. Arctic petroleum technology is now capable to traverse the Arctic terrain without irreparably damaging the surface, to drill in the Beaufort Sea from man-made islands and from ships, to conduct seismic surveys over ice, to drill from strengthened ice between the Arctic Islands, and to deploy

Panarctic Bent Horn F-72A on Cameron Island drilled in October 1975. The well is established as the first possible commercial oil discovery in the High Arctic. Panarctic Oils Limited

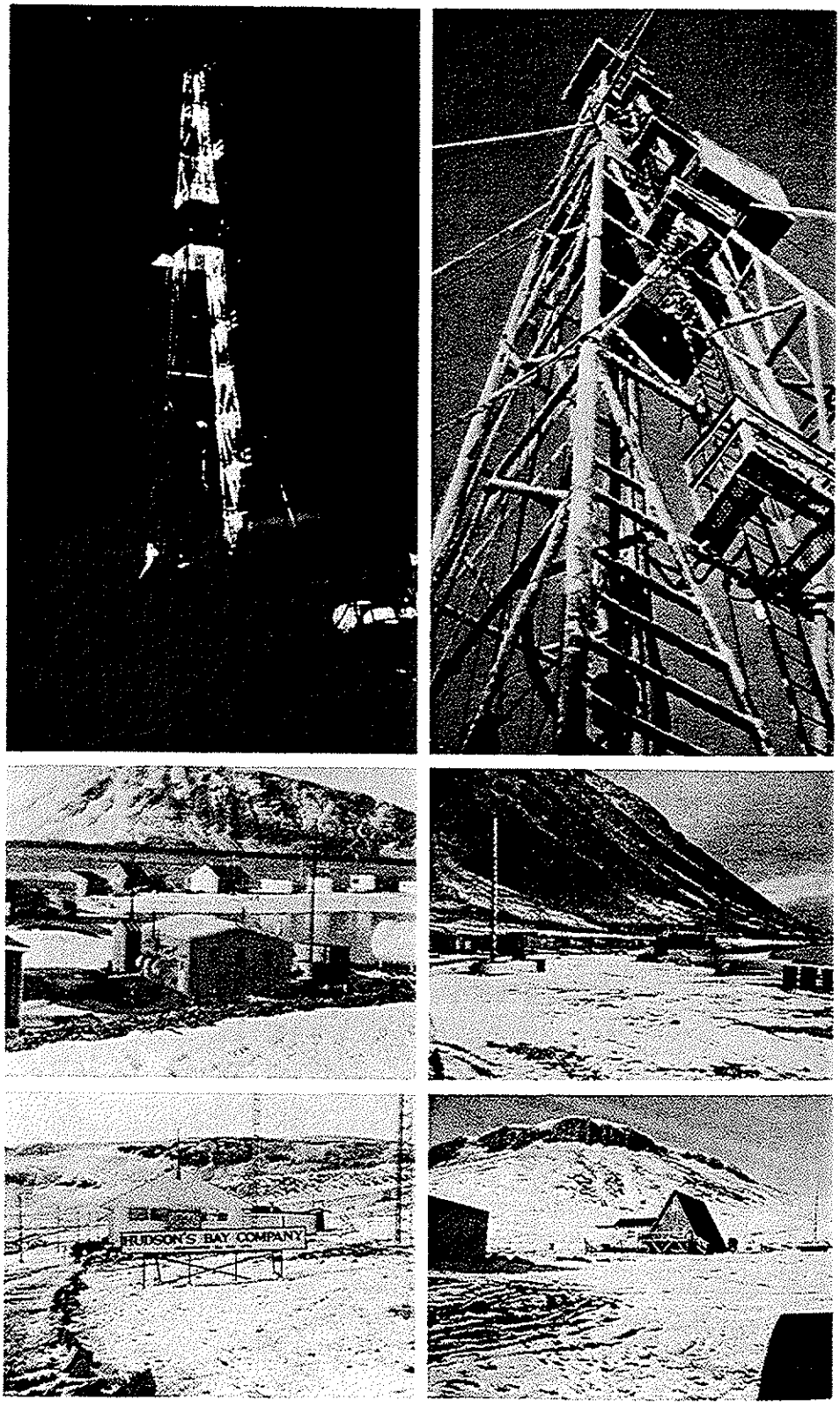
oilspill containment and cleanup equipment designed to Arctic standards. The principal application of research has been to improve ways of conducting geophysical surveys and exploration drilling. But, many of the techniques provide solutions only during specified seasons. That is, operations are often still limited to a prime season dictated by local conditions. In some activities, the prime season is the summer open-water period. In others, it is during the winter stable-ice, frozen-land-surface period. The high cost of Arctic exploration can be reduced materially by extending these short operating periods. As oil and gas reservoirs of a commercial size are discovered, means of producing and transporting oil and gas year-round will be an important objective.

Near-term research by the APOA and individual member companies is expected to be directed to extending presently limited operating seasons and to the drilling in yet undrilled areas. For example, methods need to be developed to drill in the inter-Arctic Islands offshore in areas of ice shift, in the deep, iceberg-frequented waters of Baffin Bay and Davis Strait, and within land-fast ice from ships. In the longer-term, when offshore fields are developed, systems to bring oil and gas to shore — safe from the impact of ice-sour and subsea permafrost — will need to be installed. The knowledge gained from the APOA research programs serves as a base for continued research by the petroleum industry which would lead to the development of permanent production installations and transportation systems.

The findings of each APOA research project are the property of those companies which have financed and participated in the particular study. The project reports are also submitted to the Department of Northern and Indian Affairs upon completion. The studies are released from priority status 5 years after their completion. At this time, 36 reports have been released from temporary confidential status and are being progressively summarized in the "APOA Review". At least another 15 will be available during 1978.

Anyone wishing to purchase micorfiche copies of the studies may do so (See page 12).

For further information about any of the studies, write to the APOA Information Service, P.O. Box 1281, Postal Station M, Calgary, Alberta, Canada T2P 2J2.



Top row pictures of the High Arctic — Dome et al Winter Harbour, first well drilled in the Arctic Islands.
Middle row: Grise Fjord, N.W.T. in the Arctic Islands.
Bottom row: Arctic Bay, N.W.T.

BOOKSHELF ITEMS

The following items may be of interest to readers wishing further information about northern research. Where possible, a source has been provided from which the items can be obtained. Items marked * are available from the APOA Information Service.

Amaria, P. J., Bruneau, A. A. and Lapp P. A. (eds.), **Arctic Systems**, proceedings of Arctic Systems Conference held at Memorial University, August 18-22, 1975, Plenum Press, N.Y.

Arctic Petroleum Operators Association and the Canadian Petroleum Association, **Proceedings of the Sixth Arctic Environmental Workshop**, Fairmont, B.C., April 1977, Available as Publication EE6 from the Institute for Environmental Studies at the University of Toronto, Toronto M5S 1A4.

Beaufort Sea Environmental Program: [1]Oil Spill Countermeasures. **The Beaufort Sea and the Search for Oil**, by S. L. Ross, W. J. Logan, Wade Rowland. Edited by A. R. Milne.

[1]Birds and Marine Mammals, **The Beaufort Sea and the Search for Oil**, by Donald A. Blood. Edited by Brian D. Smiley.

Both above available from the Institute of Ocean Sciences, Sidney, British Columbia.

Croasdale, K. R., "Crushing Strength of Ice" in **The Coast and Shelf of the Beaufort Sea**, pp. 377-399, published by The Arctic Institute of North America, December 1974.

Energy, Mines and Resources Canada, **Polar Continental Shelf Projects**, titles and abstracts of Scientific Papers supported by PCSP, no. 1, 1974.

Environmental Protection Service, **Spill Technology Newsletter**, v. 1 (1) to v. 2 (3) available from Environment Canada.

Indian and Northern Affairs, "North of 60, Oil and Gas Monthy Activities".

NORCOR Engineering and Research Limited, **Probable Behavior and Fate of a Winter Oil Spill in the Beaufort Sea**, report to Research and Development Division, Department of Fisheries and the Environment, Report EPS4-EC-77-5, August, 1977.

*O'Rourke, J. C., "Environmental Research for Arctic Marine Operations" presented to the 11th Congress of the Canadian Meteorological Society, June 1977, Winnipeg.

*Pallister, A. E., "The Canadian Oil Industry's Scientific Activities in the Arctic Offshore" presentation to Oil-Environment — 1977, an International Symposium, Recovery of Oiled Northern Marine Environments, Oct. 13, 1977, Halifax, N.S.

Wells, G. C., "The Canadian Arctic, A Future Source of Oil and Gas" presentation to the 17th Annual Institute on Petroleum Exploration and Economics, March 1977.

The following are papers presented to the Fourth International Conference on Port and Ocean Engineering under Arctic Conditions Conference (POAC 77) Memorial University Sept. 26-30, 1977:

Crosdale, K. R., "Ice Engineering for Offshore Petroleum Exploration in Canada".

Steltner, H. A. R., "Transportation of Personnel, Instruments and Equipment on First Year Sea Ice for Oceanographic Survey and Research Purposes".

McLeod, W. R. and Hodder, D. T., "An Examination of Long Term Ice Forecast and Periodicities of the Beaufort Sea".

Brown, R. J., Palmer, A. C. and Kenny, J. P., "Construction of Pipelines Between the Canadian Arctic Islands".

Member Companies of the APOA

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Sun Oil Company Limited
Tenneco Oil of Canada Ltd.
Texaco Exploration Canada Ltd.
Total Petroleum (North America) Ltd.
Union Oil Company of Canada Limited

APOA REPORTS AVAILABLE

Reports on the following APOA projects are available. Microfiche copies can be obtained from Oil and Gas Geology Section, Oil and Minerals Division, Department of Indian and Northern Affairs, 112 - 11th Avenue S.E., Calgary, Alberta T2G 0X5 (403) 231-5631. The charges depend upon the length of the report. Anyone interested in reading a copy in Calgary, may contact the APOA Information Service at (403) 266-5074. Copies may also be read at the library of Arctic Institute of North America, University Library Tower, 2920 - 24th Avenue N.W., Calgary.

* A summary of the report has been published in "The APOA Review"

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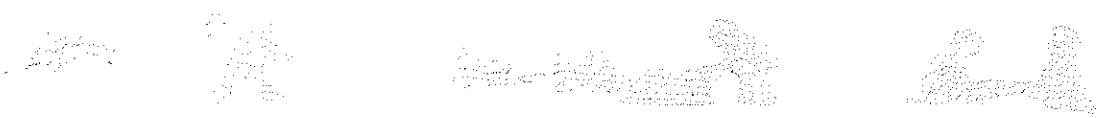

MEMORANDUM OF ASSOCIATION
OF
CANADIAN OIL SANDS NETWORK FOR RESEARCH AND DEVELOPMENT

1. In this Memorandum, unless the context otherwise requires, expressions defined in the *Companies Act* R.S.A. 1980 c. C-20 or any amendment thereto shall have the meaning so defined, and in addition;

(a) "Company" means Canadian Oil Sands Network for Research and Development;

(b) "meeting of the Members" means any duly constituted meeting of the Members;

(c) "Member" means any member of the Company of any type;

(d) "membership" means a membership in the Company;

(e) "Memorandum" means the Memorandum of Association of the Company; and

(f) "Network Coordinating Council" means the governing body of the Company as described in the Articles of Association of the Company.

2. The name of the Company is Canadian Oil Sands Network for Research and Development.

3. The objects for which the Company is established are to promote, engage in, carry on and conduct:

(a) the promotion of collaboration among researchers to accelerate the development of technology relating to oil sands and heavy oil;

(b) research into the technological methods required for the efficient and economic recovery and processing of crude bitumen and other oil sands products from oil sands deposits;

(c) research into the technological methods required for the efficient and economic recovery of crude oil through the use of enhanced recovery methods;

(d) research into the technological methods required for the efficient and economic processing of crude oil;

(e) research into the technological methods required to ensure an acceptable quality of the environment during and after such recovery and processing operations;

(f) research into the technological methods required to alleviate problems impeding the development of production capacity to meet the demand for synthetic crude oil and crude oil products derived from crude oil; and

(g) any activity or matter that the Network Coordinating Council considers necessary, convenient or desirable to attain any of its other objects.

These objects shall not be interpreted as restricted by reference to each other, or by the Company's name. If there is any ambiguity, this clause shall always be interpreted so as to widen and not to restrict the objects and powers of the Company.

4. The liability of the Members is limited.

5. Every Member of the Company undertakes to contribute to the assets of the Company in the event of its being wound up while he is a Member, or within one year afterwards, for payment of the debts and liabilities of the Company contracted before he ceases

to be a Member, and the costs, charges, and expenses of winding-up, and for the adjustment of the rights of the contributories among themselves, such amount as may be required, not exceeding $1.00.

6. The Company is formed for the purpose of promoting research and development of technology relating to heavy oil and oil sands and for the objects set out in this Memorandum and not for the object of acquisition of gain, and it is the intention of the undersigned to apply the profits, if any, or any other income of the Company in promoting its objects. The payment of any dividend or any income of the Company to the Members, or any of them, is hereby prohibited.

7. Upon dissolution of the Company, the property of the Company shall be converted into cash and the amount thereof distributed firstly in payment of all outstanding debts and liabilities and the balance shall be distributed to similar organizations, companies or groups in Canada with objects similar to those of the Company as determined by a majority of the Members at a meeting of the Members.

We, the several persons whose names and addresses are subscribed, are desirous of being formed into a company in pursuance of this Memorandum of Association.

Dated at Edmonton, Alberta this 3rd day of October, 1994.

3807 - 118 street
Edmonton, AB
T6J 1W9

Witness — 9945 - 108 st, Edmonton, AB T5K 2G6

Witness — Bill McKeown

11626 - 75 Avenue
Edmonton, AB
T6G 0J2

Witness