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ARCTIC & DEEP SEA TECHNOLOGY

Andrew Strilchuk

The Arctic. Our true north strong and free. It's a romantic place of undisturbed beauty where the pioneering spirit runs free -- where tales of adventure can still come true.

There is another vision of the Arctic seen by men like Charles Camsell, Dr. William van Steenburgh and John Sproule. Their vision was a northland of vast mineral resources waiting to be discovered and developed.

Esso Resources has shared this vision of the North, from the drilling of the discovery well at Norman Wells in 1920 right up to the more recent offshore exploration in the Beaufort Sea starting in 1973.

Initially, exploration in the Beaufort Sea was limited to shallow waters. Esso Resources undertook extensive research into ice and its interaction with structures that has allowed our drilling capability to extend to water depths of 20 metres and beyond (Illustration 1).

This has been our tradition of innovation through research and it plays a basic role in Esso Resources' search for new petroleum reserves in the North.

The fundamental aspect of oil and gas exploration is to drill a hole thousands of metres below the surface in search of hydrocarbon-bearing zones. Although this may seem deceptively simple, it presents considerable challenge in difficult environments. Consider this: how do you drill in thick, moving ice? Or how do you drill in 300 metres of water? These challenging questions demanded answers before operations could proceed.

In shallow, ice-free waters, offshore drilling conventionally uses jack-up platforms that consist of a working deck supported on legs extending to the ocean floor. But in ice-covered water, these platform legs would be too fragile to withstand the forces imposed by the crushing ice. We had to find solutions to these problems. We had to meet two crucial design criteria. First, the structure had to be strong enough to withstand the ice forces. Secondly, it had to have sufficient sliding resistance to remain on location.

The first conceptual design for a structure to operate in ice-covered waters was a dredged island -- a concept still used today. However, we didn't expect that islands would be practical in deep water. They were not mobile and they required enormous amounts of dredged fill. So the search continued for a cheaper, re-usable, mobile concept to overcome these limitations.

The monopod was one solution to this design problem. The monopod is a single-legged steel structure that presents a small diameter to the ice. But even though this small surface helps keep ice loads down, the loads exerted by the ice were still large since the monopod had to crush the moving ice (Illustration 2). Since it takes less force to break ice by bending it than by crushing it, a conical section was incorporated into the monopod -- and this was the evolution of the monocone, a refinement of the monopod (Illustration 3).

So again, a series of design questions had to be answered. What are the ice forces on the monocone? Is there an optimum cone angle and what is it? What are the worst ice regimes? What is the frequency of occurrence of the worst ice conditions? What soil characteristics does the structure require? Should there be an ice-melt system to facilitate ice sliding up the cone and breaking?

The first experimental and analytical work to develop answers to some of these questions was done under contract at Arctec Canada Limited, and at Laval University. These small-scale experiments in both saline and synthetic ice were valuable for obtaining preliminary data. But larger-scale tests that simulated conditions as close to full scale as economically possible were needed.

As a result, Esso Resources designed and built a special ice test basin in Calgary in the winter of 1973-74. This facility has been used every year since -- not only to develop design data on conical structures, but also on gravel islands and caisson-retained gravel islands. The ice test basin allows ice sheets, as well as other modelled ice features, to be towed at controlled rates against structures of approximately one-eighth scale. Horizontal and vertical forces are also measured by a computer-based data collection system. Experiments in this unique test basin have helped Esso pioneer the design of monocone structures (Illustration 4).

Even though it was initially envisioned primarily as a mobile exploration drilling platform, the monocone concept is one of the practical alternatives for hydrocarbon production from ice-covered Arctic waters. With mobility a desired criterion, experiments were also done to show that the monocone was not only practical to withstand ice forces but that it could indeed be towed and set down at the desired location. Model experiments at the National Research Council in Ottawa showed the best set-down method was differential ballasting (Illustration 5).

There are other challenges. We have exploration prospects off the East Coast where water depths are greater than 300 metres. In this situation, you simply cannot use bottom-founded drilling platforms. Instead, it becomes necessary to conduct drilling operations from dynamically positioned floating vessels. One of the critical components in such an operation is the marine riser, which connects the well bore with the drill vessel, guides the drill string, and provides a flow path for the drilling fluid.

Although high-pressure integrity of the riser is not required, it must withstand the lateral forces of waves, currents, and vessel motion (Illustration 6). It must also withstand the operating tension placed on the riser by the vessel to counteract the weight of the riser and the drilling fluids it contains. The design of the riser must consider the effects of fatigue as well as overstress because the loads resulting from waves, currents, and vessel motions are cyclical. If a very severe storm is forecast in which the vessel could have difficulty holding position, drilling would stop, the well would be secured, and the riser would be pulled aboard until the storm had passed. However, when drilling in very deep water, it may be impractical or impossible to pull and stow all of the riser each time a severe storm is imminent.

In order to prepare for this situation, Esso Resources is developing designs that make use of an intermediate, buoyant, subsea disconnect platform between the ocean floor and the drilling vessel. In the event of a severe storm, the riser section above the disconnect platform would be retrieved onto the vessel. The section below would be supported vertically by the buoyant platform (Illustration 7). Once the storm was over, the reconnection would be achieved using standard techniques.

Of course, a drilling riser for very deep waters must be much stronger than those in common use today. Thus, Esso Resources conducted a detailed analysis of riser dynamics to develop the specifications for construction of a high-strength riser. This strong riser is now used as our back-up unit for our East Coast drilling operations.

It was the explorer Stefansson who said, "The explorer is the poet of action and the exploring is the poetry of deeds."

If that's so, then we at Esso Resources are fortunate to be a part of this lyrical moment in the development of the Arctic frontier. We foresaw the problems of today and solved them yesterday. Today, we are solving the problems of the future.

Illustration 1

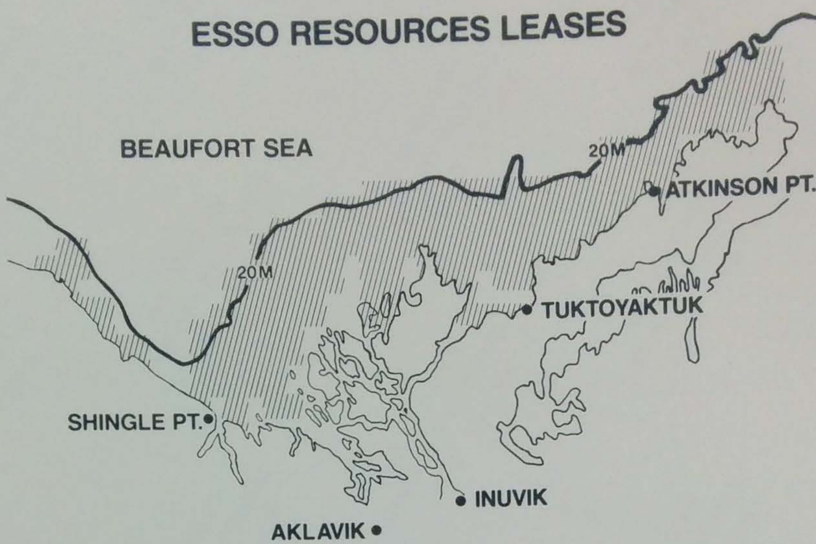


Illustration 2

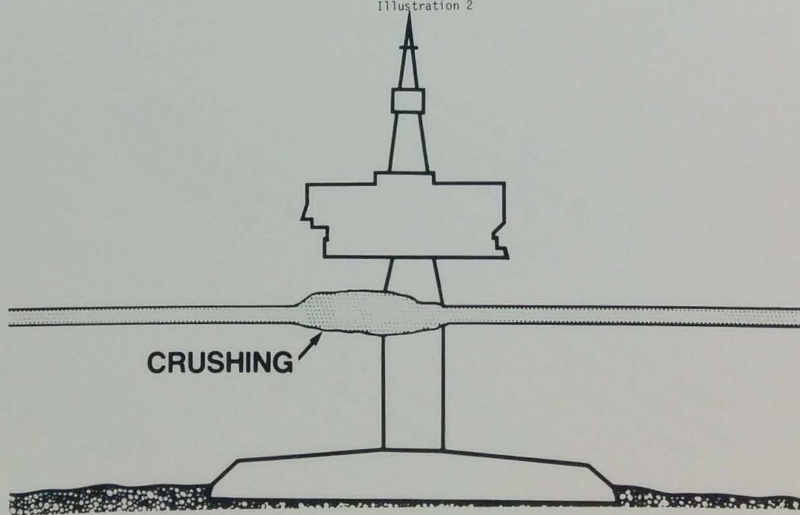


Illustration 3

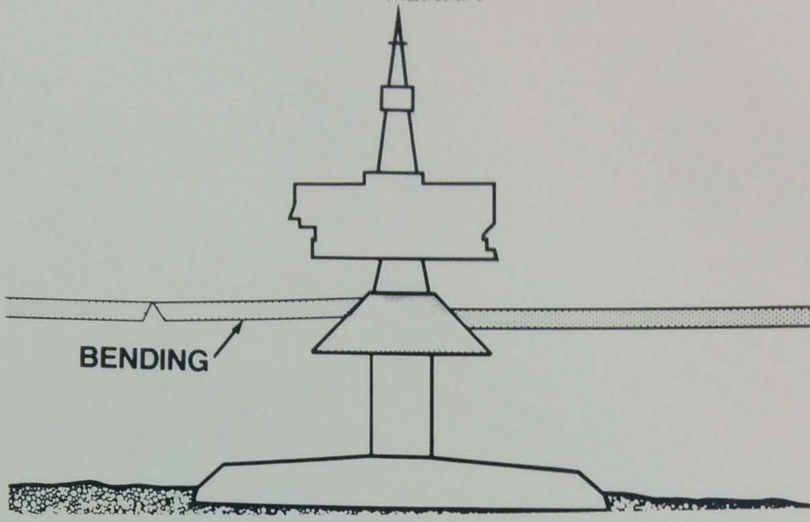
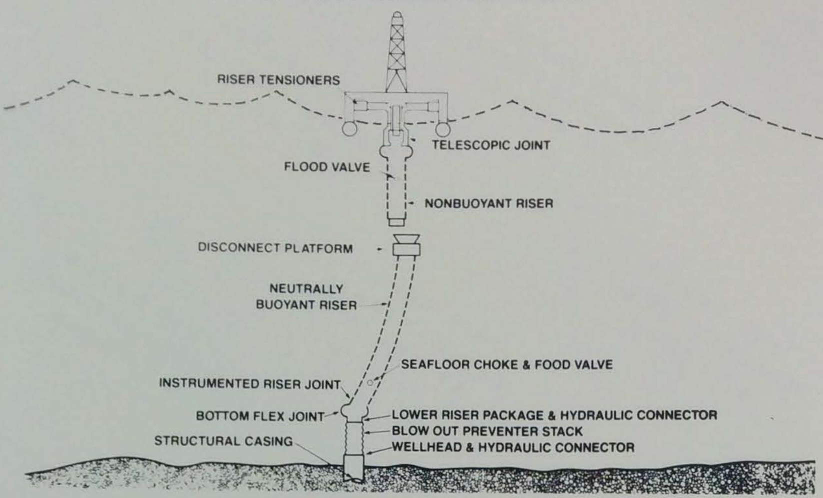


Illustration 4

Illustration 7

ORPHAN BLOCK DRILLING RISER SYSTEM



DISCUSSION ON

ARCTIC AND DEEP SEA TECHNOLOGY

WHAT IS THE ECONOMIC LIMIT FOR BUILDING AN ARTIFICIAL ISLAND IN THE BEAUFORT SEA?

The economic limit right now is 20 m water depth.

THE INDICATIONS ARE THAT THE NEW DISCOVERIES OFF NEWFOUNDLAND ARE STILL FAR FROM ECONOMIC. WOULD A HIGHER PRICE FOR OIL OFFSET ALL OF THE CAPITAL INVESTMENT?

I guess it's a question of whether you're talking about the price that exists today or your perception of what prices might be five or 10 years from now when it's in full production. Areas like the Beaufort and the east coast offshore are beginning to show favorable economics by the time that they can be put into production, but certainly not at today's domestic price for light crude oils.

HOW BIG IS YOUR GROUP?

The section totals something like 17 persons. Of these, about nine or 10 are professionals and of those, three are working in Arctic research.

ARE THERE ANY OTHER THINGS THAT THEY'RE WORKING ON BESIDES THE PLATFORM THAT YOU'VE BEEN TALKING ABOUT?

One person works on the ice test facility at Calgary. During the winter, we will be running a program on the forces associated with the generation of rubble fields around the islands. We will also conduct a field study of the rubble fields around the artificial island in the Beaufort Sea as well. There's another person researching soil conditions and we're studying surface currents and monitoring ice conditions.

HOW DO YOU FIND A FLOATING PIPE UNDER THE SURFACE OF THE OCEAN AFTER A STORM?

Beacons are placed on the sea floor in the vicinity of the well and the vessel uses these to position itself over the hole accurately. We use television cameras to find the actual wellhead. Once that is done, the vessel maintains its position until we make the reconnection.

DO DEEP-SEA DRILLING RIGS HAVE ENOUGH MANEUVERABILITY TO AVOID ICEBERGS?

In a situation where an iceberg is approaching the vessel, an attempt is made first of all to tow it out of a collision path. If the iceberg is too large to tow, we would have to disconnect from the well, move off location and re-establish a connection after it has passed.

IS THE RISER FLEXIBLE ENOUGH THAT YOU COULD MOVE SEVERAL HUNDRED METRES TO ONE SIDE RATHER THAN DISCONNECT?

No. While we're connected to the wellhead, the riser angle has to be kept within something like five or six degrees at all times.

LOOKING INTO THE SUN

John Bichard

At an increasing rate for the past two hundred years, we have been consuming the sun's energy that has been stored in the form of fossil fuels. These non-renewable fossil fuels are now becoming more expensive to find and recover. Moreover, their supply is not infinite.

As our population continues to grow and demand more energy, these non-renewable resources will become seriously depleted. We will have to start to learn to live more on our natural daily income of energy and much less on stored energy from the past.

Hence, renewables -- such as direct solar energy, biomass, wind, and tides -- are important options in energy for the future. They also present minimal environmental problems.

We assume that with higher future costs of non-renewable energy, consumers will start to use solar energy more. Therefore, by the end of this century, renewable resources should become a significant energy source.

Generally, the current economics for applications of renewables are not competitive with fossil fuels today. Cost reductions from innovations in design and in material can improve the economics, but it will need technical breakthroughs or substantial government subsidies to make renewable applications economically practical in the near future.

Imperial, as an energy company, has accepted this challenge and opportunity to help Canada use more renewable energy. Our total budget this year is $1.4 million -- probably one of the largest independently financed renewable energy research efforts in Canada.

Currently we are following developments in all renewable energy areas.

Imperial is interested in three aspects of solar energy application: First, conservation, through the use of high-quality insulating products like those currently being marketed by Building Products of Canada Limited, a subsidiary of Imperial Oil. Insulation is probably the most cost-effective method of conserving energy in existing buildings.

Second, we are interested in passive building designs that capture heat in winter and reject heat in summer. Passive design principles are essentially the same as those used in making efficient solar collectors.

Third, since 1978 we have been looking into active systems that can use solar energy for preheating hot water and for supplemental space heating to meet both commercial and residential energy needs in Canada. Active solar-systems research constitutes about 60 percent of our total budget which includes both in-house research and demonstration projects. It is this research into active systems that I would like to discuss in detail.

Our overall objective here is to obtain hands-on experience of the technology. In practical research terms, our goal is to define the optimum combinations of solar collectors and heat storage systems for Canada.

Canadian weather conditions are therefore critical in designing these systems. We receive lower average radiation, as measured by atmospheric environmental services on a horizontal surface, than the southern United States (Illustration 1). This is due to the more oblique angle of the sun in the northern Canadian latitudes. However, it is possible to maximize the amount of radiation obtained and the energy collected by tilting the solar collector to track the sun.

Cloud cover presents additional problems. In Sarnia, frequent cloud cover results in an average of about 50 percent direct and 50 percent diffuse annual radiations. In the southern United States, the comparable figures are perhaps 80 percent direct and 20 percent diffuse radiations. Flat-plate collectors that capture both direct and diffuse radiation are a better fit for Canada than concentrators, which collect only direct radiation. Flat-plate collectors are therefore our prime interest, especially the designs that minimize heat loss.

Further, we recognized early in our original assessment of existing solar technology that systems using flat-plate liquid collectors and water storage were the most developed for application to water heating and also offered some scope for near-term, competitive product development.

Initially, our approach has been to concentrate our research effort on the shorter-term, lower-risk, systems that use liquid as a collector and water for storage, to gain experience of actual operation.

In order to achieve this research objective, Imperial has set up a number of facilities to evaluate both collectors and complete systems.

An outdoor research facility is used to test liquid prototype collectors and to compare them with commercially available products (Illustration 2). This liquid-collector facility produces either reference efficiency data needed to certify collectors or simultaneous comparison of any two collectors in a fixed or sun-tracking mode.

The temperature control and pumping capabilities in this facility are such that we can obtain a wide range of fluid flow rates and extremes in fluid temperature where the largest scatter in data is experienced by others. Sophisticated and precise methods are used for both controlling and measuring key parameters of collector performance.

We also have a four-collector project on a locker/wash-up building in the Sarnia refinery that supplies more than 50 percent of the hot water needs of the workers in this area. Recently, after a year of operations, we converted this demonstration project into a research facility to expand our testing capabilities. Our current interest here is to look at collector performance as a function of tilt angle and demand for hot water.

Another facility is a project that preheats water to wash trucks in Imperial's marketing terminal in Toronto. Forty solar collectors are arranged in eight arrays representing five Canadian manufacturers to meet 50 to 60 percent of the demand for heated water. Collector durability is a critical factor as the economics are based on a life cycle of 20 years. Durability is one of the performance criteria monitored at this facility.

We are currently planning a fifth facility that will operate with 16 collectors on the roof of the new 33-storey Esso Resources building in Calgary. It will be an array of four different types of flat-plate and vacuum-tube collectors in vertical configuration with reflectors to enhance energy collection.

These facilities will let us assess performance under specific Canadian environmental conditions. They will allow us to look not only at the key parameters of the collector designs but also at some key parameters of systems design.

It is this type of extensive technical data that is needed for us to be able to design appropriate solar heating systems for Canada with any degree of confidence and guarantee performance over the economic service life of the system.

In our assessment of solar technology, we found that air-collector technology is not as well developed as liquid-collector technology. Air collectors, however, are a better fit for supplemental space heating applications, since most houses in Canada use forced-air heating.

We are therefore setting up an indoor simulator of environmental conditions to screen novel ideas for design and for material substitutions -- plastics, for example -- using air mini-collectors (Illustration 3). The goal of this experimental research, which is supported by computer modelling, is to develop effective air collectors for the Canadian climate.

There is enough solar energy radiant on a Canadian building to meet all heating needs on a year-round basis if we had a means of storing excess summer energy for winter use (Illustration 4).

Hence, efficient heat storage is a key development in making the application of solar systems economically practical in Canada since availability doesn't match demand.

Conventionally, water is used in hot-water heating systems for storing sensible heat on a short-term basis.

Rocks are generally used with air, and stratification is desirable in that the air returning to the collectors will be at a lower temperature and this maximizes the collector's efficiency (Illustration 5).

An alternative method we are actively studying is to store heat in chemicals. Chemicals that undergo a phase change involving high heats of transition, for example, could be used. Heat is stored in these chemicals at a constant transition temperature -- a big advantage over sensible heat storage. Therefore, the chemical selected determines the operating temperature. But many of the simple systems that would be economically competitive with water do not work too well.

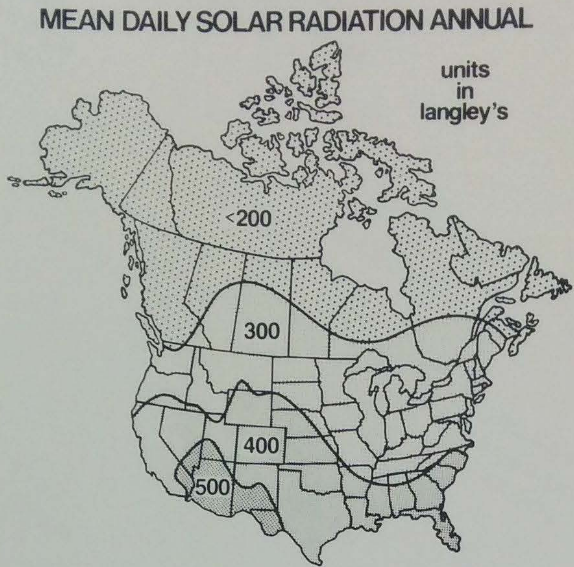
We are actively searching for suitable additives that will simultaneously overcome the problems of supercooling, physical separation of the system, and crystal size control. Such additives would facilitate repeated cycling to store and extract heat smoothly. Our results are promising. However, we have not yet attained the ideal system that would be encapsulated and used either in passive building designs or active storage.

We are also evaluating simple chemical exchanges for commercial applications, such as an immiscible oil-salt hydrate system that has an efficiency of over 90 percent for short-term storage of both low and high temperature heat (Illustration 6). Other chemical systems, such as chemical heat pumps and chemical reactions, are being scoped for higher temperature heat storage.

As for annual heat storage, we are currently exploring the application of absorbents that have the advantage of storage at ambient temperatures without heat loss.

Practical success in applying solar energy depends on mating past knowledge and basic principles with new materials and innovative ideas. Although we are newcomers to solar-energy technology, we at Imperial Research believe we have the resources and approach to address the problems that need to be solved to make solar energy applications economically practical in Canada. As researchers we are looking hard for technical breakthroughs that will accelerate the development of solar energy.

Illustration 1



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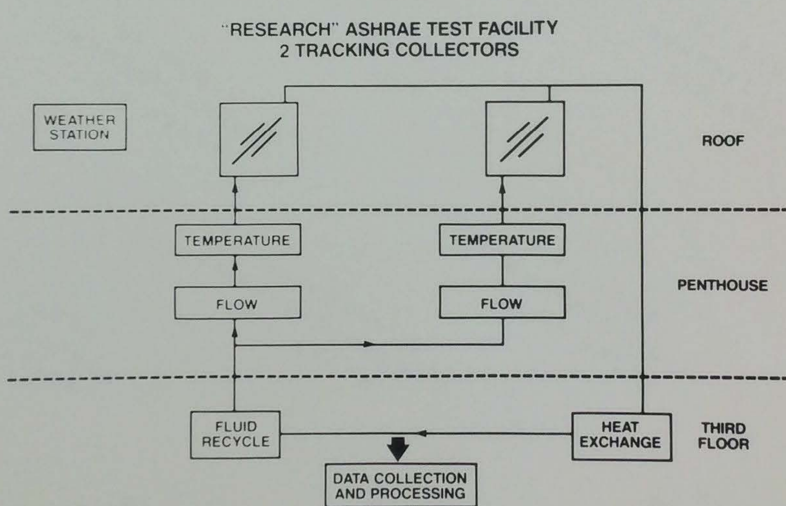

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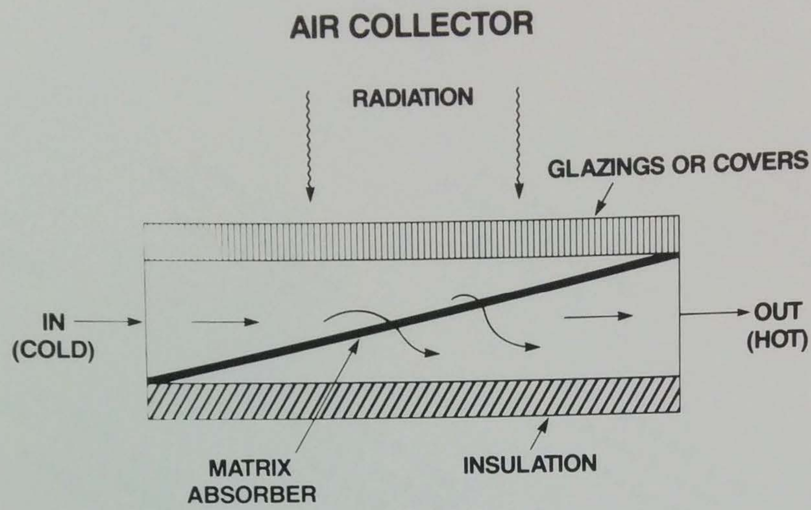

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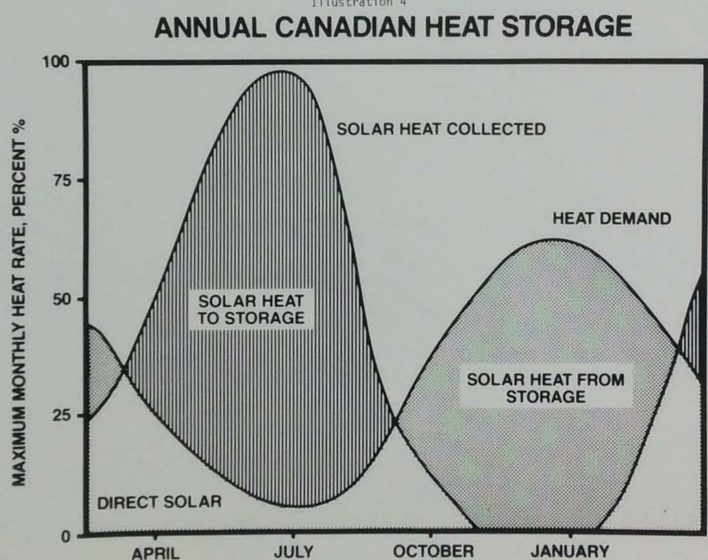


Illustration 5

STRATIFICATION

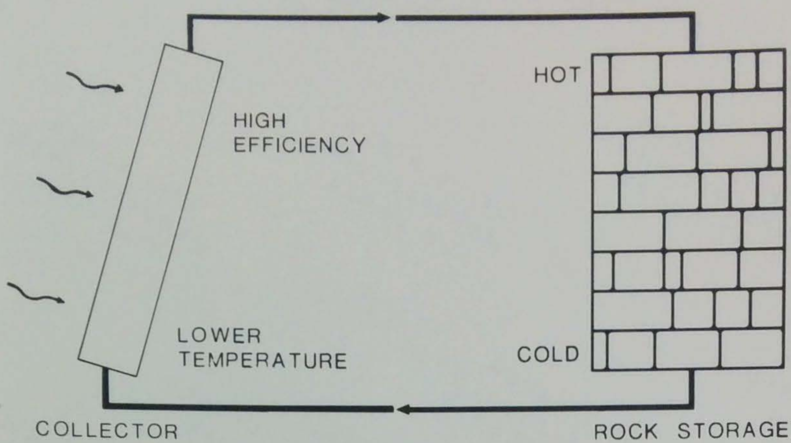
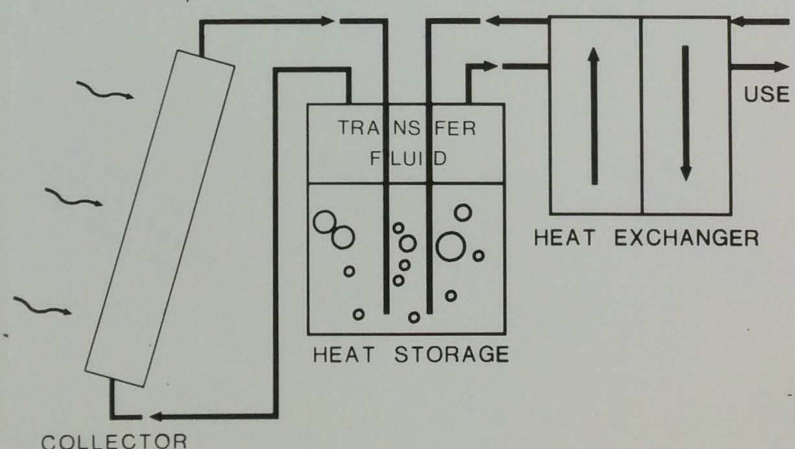


Illustration 6

HEAT STORAGE EXCHANGER



DISCUSSION ON
LOOKING INTO THE SUN

HOW DO YOU MAKE CHOICES AMONG COLLECTORS?

If you buy a collector, buy a well made collector. The reason is that with a cheap, lightweight collector you need a much larger area. The problem with the economics of solar collectors on a domestic hot water heating system is that installation costs are so high -- almost half the cost -- and as you would really like to cut your installation costs, you're going the wrong way in going to a cheap collector.

HOW, GENERALLY, DO CANADIAN COLLECTORS COMPARE WITH AMERICAN MAKES?

From our testing, we find that collectors fall into three categories: (1) well made, well designed, high performance collectors; (2) general intermediate collectors, and many of the Canadian collectors are in this area; and (3) cheap, plastic, lightweight collectors. Some of the cheap lightweight collectors can give you the same contribution as the higher performance collectors, whereas the intermediate ones are not quite as good. You have to look at this on its contribution to performance on a yearly basis, using a computer simulation. And using these simulations, you have to make certain assumptions about the use of the hot water.

WOULD YOU RECOMMEND PEOPLE INSTALLING SOLAR HEATING FACILITIES FOR HOUSING, POOLS, HOT WATER, WHATEVER? ARE THEY ECONOMIC?

No. Not at this time. To be economic on a 20-year life cycle, you really have to halve the current cost, which probably runs between $2500 and $3000 for our domestic hot water systems.

THEY'VE BEEN USING SOLAR HEATING FOR THEIR WATER IN ISRAEL FOR A VERY LONG TIME. IS IT ECONOMICAL THERE?

I think they have far more sun and, therefore, it is justified. They have a reflector-type there that has a very good absorber design. It's light in weight and is made with plastic. It's one of the more ideally designed reflectors for that sort of environment.

WHAT ABOUT THE VACUUM-TUBE TYPE COLLECTOR, THE SO-CALLED SECOND-GENERATION COLLECTOR?

The vacuum tube falls in the middle between concentrators that make steam for enhanced oil recovery or for some commercial operations and flat-plate collectors, which are probably a better fit for diffuse radiation. Vacuum tubes will give you higher temperatures and that could be an advantage if you wanted to go to total space conditioning. The stagnation temperatures can go as high as 600°F and as long as you get above 170°F -- forgive me, I'm not metricated -- you can use this for cooling and so it can serve several purposes.

Certainly in the regeneration of absorbents, etc., this sort of collector could probably have a role to play.

THE COMMENTS WE HAVE HEARD SO FAR ARE WHAT I WOULD CALL COTTAGE INDUSTRY ENERGY GENERATION. WHAT ABOUT LARGE-SCALE OPERATION?

Well, large-scale operations are generally handled by power towers or banks of concentrators. For instance, Southern California Power Company are looking at towers for making steam to generate electricity and this appears to have some economy of scale. However, they have a lot of direct radiation, as I have pointed out, whereas if you applied the same kind of technology in certain places in Canada you wouldn't get very far. In terms of concentrators, you're limited to the areas in Canada where you have quite a lot of sunshine days.

IF YOU MADE FLAT-PLATE COLLECTORS IN VERY LARGE QUANTITIES WOULDN'T THEIR PRICE COME DOWN FROM THE $2500 TO $3000 YOU MENTIONED?

In a solar system, almost 50 percent of the costs are for installation. You can make improvements in collectors and produce them on a mass scale, but the advantages of reduced cost are not sufficient for you to be in business. We really need a breakthrough -- a new approach to this type of technology.

IS IMPERIAL DOING ALL ITS RESEARCH IN SOLAR ENERGY INDEPENDENTLY OR DO YOU HAVE CONTRACTS WITH UNIVERSITIES OR OTHER COMPANIES?

We do most of the work ourselves but in the case of the Calgary facility that we're putting on top of the Esso Resources Building, we are working with the University of Calgary on the type of monitoring equipment to install.