Rosario Resources Corp.

Energy — or the lack of it — is a complex, multifaceted problem. It is also "a necessity of life . . . an integral part of the nation's life support system," as the Ford Foundation energy-policy group demonstrated five years ago in "A Time To Choose." Today, that life-support system is endangered as never before. Although political and economic factors must be dealt with in meeting the energy challenge, science and technology will provide many of the data on which eventual solutions will be based. In this special report on energy, SCIENCE NEWS examines some of the possible solutions.

Crude Yet Unconventional

There is a fossil fuel that could cut those long waits at the gas pump and perhaps even stabilize climbing gasoline prices

BY JANET RALOFF

While the Organization of Petroleum Exporting Countries threatens to break our banks with continuing inflationary hikes in the price of the crude oil it exports, the United States is, for the most part, ignoring a vast fossil-fuel resource, much of which could be marketed profitably for well below the cost of imported oil. What's the story? Heavy crude.

Pure and simple, by any other name it's still oil — a natural combination of hydrogen and carbon atoms that, when refined, powers cars, buses, planes, ships, boilers and even electrical generators throughout most of the industrialized world. But while technically petroleum, heavy crude is considered an unconventional form. It takes but a glance to understand why.

Even when cold, conventional crudes pour like motor oil. In contrast, superviscous heavy oils range in consistency from molasses to tar, depending on their makeup and temperature. On cold days, very heavy California crudes could be cut with an ax blade, and then only with difficulty. Needless to say, heavy oils don't gush up well rigs nor do they flow down pipelines unless heated and/or diluted with lighter petroleum derivatives.

Adding to heavy oil's problems is the trouble nearly everybody has in defining it. At a recent international meeting on heavy oil, the Department of Energy's Robert Aitken began his talk on the U.S. policy and outlook for heavy crude by commenting on just that. He said Washington has generally settled on the definition: "all natural hydrocarbon gunk except shale oils. . . ." He admits this "is not elegant enough for many purposes," so the official definition is "oil not included in the U.S. Geological Survey Circular 725 on recoverable resource and reserve estimates." He notes that "[t]his, of course, shifts the burden of describing exactly what we mean to someone else."

Nevertheless, this gunk probably offers

the most immediate — albeit temporary — "cure" to the United States' current oil-supply crisis. Some 500,000 barrels per day of heavy oil is already produced in California. With some compromising of California's rigid environmental controls, another half-million barrels would probably be available almost overnight. And if Congress was as serious about providing incentives to open up new supplies as its rhetoric asserts, changes in oil pricing, refining and taxing policies could unleash another million barrels per day in fairly short order, many experts claim.

For a nation already importing upwards of six million barrels of oil per day, that still falls far short of energy self-sufficiency. But particularly now, with the U.S. economy reeling under the pressures of inflation, an oil shortfall totaling almost one million barrels per day and signs of a developing recession, expanded exploitation of heavy crude oil could buy Washington more time to structure the coherent energy policy it seeks.

According to Richard H. Hertzberg, director of DOE's Division of Fossil Fuel Extraction, heavy oil could stabilize the growing decline in domestic oil production through the year 2000. Since 1970, the amount of oil produced annually has exceeded the discovery of new oil. Heavy oil can offset that decline, Hertzberg told SCIENCE NEWS, but will probably never substantially increase the current domestic-production figures unless major new reservoirs are found.

But some, like Joseph Barnea, organizer of a conference on heavy crude oil and tar sands in Edmonton, Canada, last month, take a more optimistic view. "If the United States should develop a crash program like the Manhattan Project for heavy crude, it could in 10 years — by the end of the '80s — easily produce five million barrels or more of heavy crude per day," Barnea told SCIENCE NEWS. And because the United States is the world's leading importer of petroleum, he added, that could "completely change the world oil picture"

Disappointed at what he feels are conflicting and half-hearted efforts by the government — most notably the White House and top DOE management — to encourage heavy-crude development, he has almost singlehandedly initiated an international campaign to hawk heavy oil's potential. A special fellow at the United Nations Institute for Training and Research (UNITAR), Barnea is probably the nation's leading heavy-crude advocate.

Ironically, Barnea says, it's OPEC's price increases — up 15 percent this month, 42 to 50 percent since January 1 (depending on the exporter) and 1,000 percent above the $1.80 oil at the beginning of this decade — that have enhanced heavy oil's prospects. Not only harder to produce, but also to transport and refine, heavy crude could never compete economically with $2-per-barrel oil. But when the world price jumped to $10 per barrel, Western heavy crudes were in the running. And this month, with OPEC's new "benchmark" at $18 per barrel and two-thirds of its exports at $20 per barrel, domestic heavy crude suddenly offers a cut-rate alternative to OPEC's black gold.

Venezuela, the Soviet Union, Canada and the United States — in roughly that order — contain the world's largest known heavy-oil reserves. And the figures are staggering. DOE's (soon to retire) Deputy Secretary John O'Leary has said publicly that if the Western Hemisphere pooled its resources and made the massive investments necessary to scale up heavy-crude production and refining, "it could make us totally independent of the Middle East within 20 years." Politics and cash-flow problems being what they are, no one expects that to happen. But speaking on "The MacNeil/Lehrer Report" earlier this year, O'Leary pointed out that the Venezuelan resource in its Orinoco region alone is "equivalent to all the oil that has ever been found anywhere else in the world. And that's a pretty authenticated number." In all, 65 countries and 30 of 50 U.S. states appear to have heavy-crude deposits.

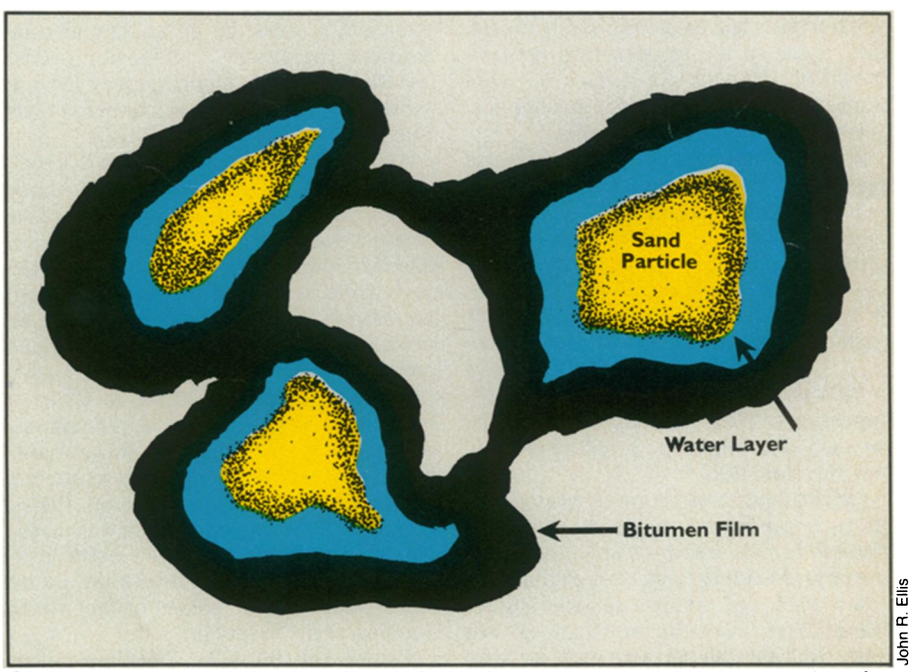
Reports from the Edmonton meeting indicate that Canada has at least 333 billion barrels of recoverable heavy oil and perhaps the most significant heavy-oil deposits in the world. In their paper on the world geographic distribution of heavy oil, Richard F. Meyer of USGS and W. D. Dietzman of DOE estimate reserves of at least 28.5 billion barrels of heavy crude in the United States, of which 2.5 billion should prove recoverable. They say the bulk of the deposits — about 28 billion barrels — is in Utah. And for Venezuela, Meyer and Dietzman estimate deposits totaling more than a trillion barrels of oil in the Orinoco region, more than 100 billion barrels of which may prove recoverable (an amount roughly equal to all the oil ever produced in the United States).

Francisco J. Gutierrez of the University of Central Venezuela, also reporting in Edmonton, suggests that Meyer and Dietzman may even have underestimated his country's deposits by a factor of two or more. Gutierrez, a petroleum engineer, also cited indications of "important accumulations" of heavy crude in Colombia, Ecuador, Bolivia, Chile, the Guianas, Mexico, Cuba and Trinidad. Others described how Europe, Australia, Asia and even the Middle East have their share.

In Africa, only Malagasy's resources — estimated at 1.8 billion barrels in place — appear significant at this time, Meyer and Dietzman report. Last month Malagasy became the first country to take advantage of an offer made at the Edmonton meeting: that any country have samples of its heavy-crude and tar-sand resources assessed free of charge by AOSTRA, an agency of the Canadian province of Alberta (SN: 6/16/79, p. 387).

Like many developing nations with potentially significant heavy-oil deposits, Malagasy has lacked the money and technology to exploit its resource and therefore imports 100 percent of the oil it uses. Barnea hopes the airing and sharing of information on the occurrence of heavy oil and the availability of suitable extraction and processing technologies will help turn this situation around.

And that, he says, is the reason he



John R. Ellis

Oil does not occur in underground pools. Instead it surrounds individual grains of sand or coats the surfaces of porous rocks in a thin film. The goal is to bring up the oil with as little sand and rock as possible. Breaking the especially tough grip with which heavy oils cling to their host media generally requires heat and other means. Deposits where oils occur in a near-solid state — tar sands — offer the biggest challenge.

pushed UNITAR, together with DOE and the Alberta government, to sponsor the Edmonton heavy-crude conference. Though the Western Hemisphere may be (relatively speaking) awash in heavy crude, there are also substantial deposits elsewhere. And by spurring nations — especially developing nations — to identify and develop their own resources, it may be possible to break OPEC's debilitating stranglehold on much of the oil-importing world.

Despite the large number of known heavy-oil deposits, Barnea cautions that one must not rely on current finds as a gauge of how much is out there. Claiming that heavy oil has been found almost exclusively by accident in the search for more desirable light crude, he asks, "How much more might be found if we consciously looked for it?" Petroleum geologists are only now beginning to characterize geology specific to heavy crudes, he says.

Oil is never found where it was formed. Over geologic time it migrates upward from great depths where pressures are high. Usually riding atop a shifting water table, oil makes its way through permeable rock and sand; contrary to popular belief, underground petroleum reservoirs are not lakes of oil, but oil-soaked sand and rock. As the pressure decreases in its ascent, migrating petroleum will begin to lose its lighter constituents. They bubble out, like carbonation from an opened can of beer or soda pop. Generally, the closer to the surface it's found, the heavier the oil.

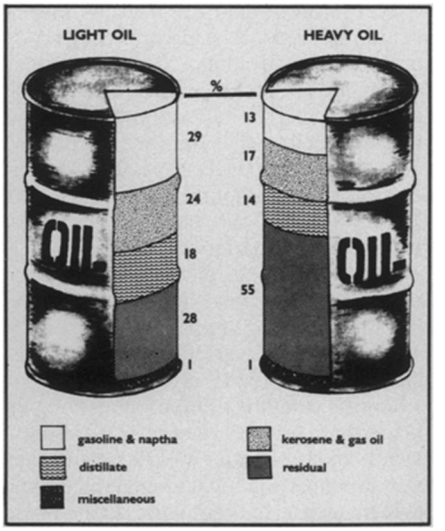
It's a change in petroleum's normal carbon-to-hydrogen ratio that makes heavy oil heavy. Carbon is 12 times heavier than hydrogen. Dissipation of light, hydrogen-rich fractions leaves carbon-rich gunk behind. Some of the heaviest and earliest-known oil deposits are surface outcroppings. The La Brea tar pits and biblical references to pitch are examples.

But while the presence of heavy crude has been acknowledged for millennia, realization of its potential as a fuel is a comparatively modern development. And research on special technologies to produce and process heavy crudes didn't get underway in earnest until after World War II.

The fruits of those efforts — many ripening only now — are as important to heavy crude's prospects as is its newfound economic workability. The Edmonton meeting served as a forum for the proposal of many new technologies.

For instance, overcoming heavy oil's viscosity presents a major challenge because many oils are nearly solid within the reservoir. Thinning them enough that they flow toward well pumps has generally required heat. Injection of steam or hot water to heat the oil and rock or sand reservoirs is done commercially today, although air pollutants associated with production of that steam or hot water have forced the closing of several wells in California within the past year.

The borehole steam generator under development at Sandia Laboratories in Albuquerque, N.M., may offer one solution to that pollution. To counter heat losses to the borehole in steam injected thousands of feet to the oil, the usual 20-foot by 40-foot surface boiler is replaced with a small combustion chamber built into the 7-inch borehole of an injection well. Fuel pumped down the well is atomised, mixed with air and ignited by a spark plug. Resulting combustion gases are then mixed with water, flashing it to steam. It is expected that the 700° F exiting steam and gases will be sufficient to heat the oil as they migrate through the reservoir depositing their exhaust pollutants along the way. Several versions of the concept will undergo tests this year.



Fast traveling and gas guzzling add up to a high demand for the lighter fractions of the crude-oil barrel — gasoline, kerosene and naptha. Without upgrading, heavy crude produces mostly the thicker home-heating (distillate) and bunker (residual) oils.

Carmel Energy Inc. in Houston is developing a related concept called Vapor Therm. Superheated combustion gases produced above ground are pumped down a well to stimulate and heat the oil. Initial tests have shown as much as a 10-fold increase in the quantity of oil that can be produced from a given well, and surface emissions are virtually eliminated.

The IIT Research Institute in Chicago has proposed a more exotic process: inserting tubular conductors down boreholes and then applying radio-frequency energy to electrically heat the oil. Petro-Canada, a Canadian oil company, is investigating a similar process — electric *pre*heating of oil. This would be followed by more conventional steam or hot-water flooding of the reservoir.

On the refining side, there are an increasing number of approaches to upgrading heavy crude — altering its carbon-to-hydrogen ratio so that it resembles conventional, light crude in the products that can be made from it. An approach that drew much attention in Edmonton tackles what have probably been the most undesirable aspects of domestic heavy oils — their high sulfur content and heavy-metals contaminants.

Unless removed, sulfur makes crudes unattractive as fuel stocks. And heavy metals damage traditional refining catalysts. UOP, Inc., in Des Plaines, Ill., is working on a process to inexpensively clean up the crude. Tested on Venezuelan and Canadian oils with particularly high sulfur and metal levels, UOP's Aurabon process removed up to 38 percent of the sulfur, up to 27 percent of the nitrogen and fully 98 percent of the vanadium. The firm also reported that ways to recover the vanadium and nickel as salable byproducts have been developed.

"Heavy oil in its natural state is just garbage to the refiner," explains Fred Hallmark, a petroleum-reservoir engineer for the state of California. "He hates it. It's hard for him to make anything out of it that he can sell." But with these cleaning and upgrading processes, it's possible to engineer a "supercrude" that will match the quality of the best Arabian light crudes, he told SCIENCE NEWS. And he added that current cost estimates indicate these upgraded substitutes can be marketed at a profit for $18 to $20 per barrel.

But what's so frustrating, Barnea complains, is that now that OPEC prices have made heavy crude economical, now that the technology is there and now that a market for the product exists, counterforces in Washington are erasing heavy crude's economic advantages. He points to three main obstacles: oil-price controls, insufficient heavy-crude refining capacity and the pending windfall-profits tax.

Oil price controls were designed to keep inexpensively produced domestic petroleum from increasing in price at the same inflationary rates as oil on the world market. The controlled rate was unrelated to actual production costs. But since heavy oils are so viscous, few deposits produce much oil without heating.

"When you're injecting steam," explains Hallmark, "you're generally burning 25 to 30 percent of the oil that you produce to make that steam — roughly one of every three barrels you produce." Then the oil must be treated to keep its viscosity low enough to flow down pipelines. "It means producing heavy oil is very energy intensive *and* cost intensive," he says.

But to date no action has been taken other than introduction of a measure to speed decontrol of projects receiving DOE certification of the fact that they use expensive "tertiary" recovery processes — such as reservoir heating. Several California heavy-oil producers have applied for such certification; half of the state's heavy oil is produced by thermal recovery.

Refiners, too, complain about price controls — on their products, such as gasoline. They claim they don't get the profit mar-

Continued on page 56

. . . Rad Waste

uble minerals are found that are naturally, inexorably bound to radioactive elements. The mineral pollucite, for example, naturally binds cesium; monazite holds plutonium; feldspar snares strontium. By matching the wastes with a mixture of the appropriate minerals, the most insoluble solid forms possible can be made. Preliminary tests of the stability of ceramics look good, but critics warn against problems such as radiation damage and subsequent weakening of the crystalline structure.

In addition, such ceramic-bound wastes might be most stable in rock types other than salt, and that combination more stable than glass in salt. Many critics, including Luth, the NAS and the USGS, favor more research on basalts and granites (both formed from molten rock), tuffs (solidified volcanic ash) and shales (muds that become rock by high temperature and pressure) as geologic hosts. Though all these rocks fracture, which can allow the entrance of water, all, in varying degrees, absorb radioactive elements; salt does not. This ability to retard the dispersion of radioactive elements, therefore, may outweigh salt's advantages. Moreover, a ceramic waste form could be adapted to enhance a rock type's natural properties. "Best fit" might be the ultimate disposal solution: "[T]ailor our garbage to suit the needs of the geologic host," says Luth.

Such a tailor-made approach may be a long way off; DOE and its predecessors have carried only minimal projects in alternative host rocks and waste forms. But according to some observers, the recent scientific criticism seems to be taking. Of importance, the recent 14-agency review group report represents an acknowledgement of past program inadequacies. DOE has begun to broaden some programs; funding has been stepped up for studies in basalt and tuffs, and an increase of $10 million has been allocated for alternative waste forms in 1980. In addition, an "Earth Science Technical Plan" — a joint project of the USGS and DOE — will "develop a program of research and development to resolve the remaining earth-science problems" of geologic disposal, according to a January draft report. And combined with political threats that may stall or kill WIPP and nix the 1985 goal for a commercial repository (see p. 38), such actions may allow the undernourished alternative programs to fatten up. Despite the apparent progress, some critics are reluctant to release their fingers from DOE's throat. Says Terry Lash, attorney for the Natural Resources Defense Council: "There's some progress, but so little, you can't take hope from it." Others are more optimistic. Former critic Luth says, "They still have to get their cards in order and their homework done [on HLW]....But now I can see a light at the end of the tunnel. Three to five years ago, all I could see was a big black hole." □

. . . Crude

gins necessary to make capital-intensive investments for plant changes. And those changes are necessary to adapt a plant from refining light, clean crudes to the more complicated processing of dirtier and heavier crudes. As a result, a shortfall of light crudes can force refiners to run at partial capacity regardless of how much heavy oil is available.

Exemption from the proposed windfall-profits tax is advocated by almost all heavy-oil supporters. The tax would virtually wipe out any advantage decontrol could offer, particularly for thermal-recovery projects, they charge.

But things are looking up. For instance:

- In his energy address on Monday, President Jimmy Carter called for the immediate decontrol of heavy oil (p. 38).
- Two last-minute changes prior to House passage of the Moorhead bill (SN: 6/30/79, p. 421) — which offers $2 billion in subsidies for government purchases of synthetic fuels — amended the definition of synfuels to include heavy oils.
- In response to popular demand, Barnea has announced plans for a second international heavy crude and tar sands conference. The United States has offered to host it, probably some time after the next presidential election, he says.
- On the recommendation of a working group at the Edmonton meeting, UNITAR will consider establishing a heavy-crude and tar-sands information center. Its first project would be publication of an international "who's who" in heavy oils. According to Barnea, the Alberta government has already pledged that if UNITAR goes through with the venture, it will immediately make available $10,000.

While doing research in connection with planning the Edmonton meeting, Barnea asked an oil company executive for data on the occurrence of heavy crude in the United States. He recalls being surprised when he was told, "Look, we're all hunting around to get leases on heavy crude and you want us to give you that? You won't get it from any company." Subsequent inquiries proved the oil man right. They've got the message, Barnea says. "I think the coming task now is to bring that message to Washington." □

. . . Helium

austerity measure. Since helium production was then about seven times the demand, this left the four government contractors with no market. They began releasing the helium to the atmosphere and filed suits against the government.

Private companies have their reservations about HR 2620. Long-term government contracts have been canceled in the past, and the 25-year contracts suggested under HR 2620 may not be long-term enough for a helium market to have developed from the new technologies. The government's large helium store represents a potential threat to future markets. Recent court decisions have raised the possibility that helium extractors may have to pay natural gas producers and landowners for part of its value.

Sometime before fall, HR 2620 will be reported in the House and may pass there, according to Michael Kitzmiller, counsel to the Subcommittee on Energy and Power. Kitzmiller refuses to speculate on the bill's changes, adding, "Every year somebody introduces a bill that would rehabilitate the helium program and every year it doesn't happen. But there is a lot of enthusiasm for the bill in the Senate."

BOM Helium Division chief Ray Munnerlyn disagrees: "It's our impression from hearing the testimony that HR 2620 has very little support outside the subcommittee."

The situation of helium reserves today has been compared to that of natural gas between 1930 and 1960. During that period the United States flared or vented about 119 trillion cubic feet (Tcf) of natural gas, regarding it merely as a byproduct of petroleum production. 119 Tcf equals 58 percent of proven U.S. reserves as of 1977. Had this waste been prevented, the United States would be in a better energy situation today. Will future generations view helium in the same manner?

"You've spent a billion dollars so far on fusion," says Charles Laverick, a consultant formerly with Argonne National Laboratory and an insistent presence at helium policy gatherings. "You'll have spent $20 billion on fusion by the time you get it and, if things continue as they've been going, you'll have no helium." □