# CHEMISTRY FOR TAR SANDS DEVELOPMENT

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I would like to suggest some possible research projects that would be of benefit to the oil sand industry as a whole. The Research Department of my company is fully occupied with efforts to ensure that the plant currently under construction (and scheduled to start production in March 1978) will operate satisfactorily. This takes us into studies of the geology of the formation, especially hydrogeology; extraction; tailings management; analytical research; and upgrading. Naturally we are acutely aware of the costs of oil sand development. And we are often reminded that knowledge specifically for application to the high cost areas of oil sands development has never been acquired.

Total investment in the Syncrude project for obtaining synthetic crude oil from the tar sands of northern Alberta will be $2.048 billion for initial production of 105M bbld/d. Construction is more than 60% complete (Feb. 1977). Aside from hot water extraction procedures that we have developed independently, our technology has been adapted from practices followed in established industries. Considering the investment required this is not a good route to follow in the long run. Oil sands is capable of being such a big industry that research effort devoted to its particular problems is overdue. Syncrude alone will have one of the world's biggest mines removing 92 MM tons tar sand and 45 MM tons overburden per year. Our utilities plant is designed for 260 MW. Yet in spite of scale and the rising price of conventional crude, oil sand economics are still marginal. Research deliberately devoted to oil sands problems could lead to new equipment and process steps that would improve the economic outlook for the development of oil sand. Mining and extraction will be employed for working the top 200 feet or so of the deposit but deeper oil sand will have to be processed <u>in-situ</u> and this will require the acquisition of more knowledge to keep operations at acceptable costs.

A comparison of some statistics for the mining and <u>in-situ</u> plants looks like this. In both schemes the scale is large.

| | MINING | IN-SITU |
|---|---|---|
| Area (acres) | 8,000 | >16,000 |
| Production BPD | 125,000 | 125,000 (at 50% recovery) |
| Steam used lb/hr | 4,500,000 | 7,500,000 injected (1) |
| Major mining equipment | 4 X 80 cu yard draglines | 8000 wells (2 acre spacing) |
| | 4 bucket wheel reclaimers | Oil gathering system |
| | >35,000 feet of conveyor belt | Steam distribution system |

In each of the two schemes upgrading of the isolated bitumen is needed to yield liquid hydrocarbon products.

Setting aside the question of what on this continent we should do to conserve energy, the fact remains that there is an urgent real demand for hydrocarbon fuels as conventional crude dwindles. It is also a fact that the oil sands of northern Alberta are a huge deposit of bituminous matter from which, by suitable treatment, fuel-grade hydrocarbons can be derived. Obviously mining tar sand and then manufacturing crude therefrom is more expensive than establishing land-based wells in accessible regions, and it is because costs of obtaining conventional crude have increased as less-accessible supplies have to be tapped that synthetic crude from oil sands has now become economically feasible.

If oil sands is to become the viable source of hydrocarbons that its extent and proximity to the Canadian market suggest that it can be, new solutions must be found to unacceptably expensive steps in the process. Otherwise, for new reasons, oil sand will remain what it has been for 200 years -- a known but unworkable bituminous deposit.

Areas of high cost cannot be dealt with solely by chemical invention. I am increasingly aware of our need in the Syncrude Research Department, for expertise in disciplines other than chemistry and chemical engineering. Because oil research is traditionally staffed by people with chemical training, we tend to concentrate on those problems that lend themselves to laboratory or pilot scale inquiry. In fact investment breaks down to:

| | |
|---|---|
| Mining | 34% |
| Extraction, Froth Treatment and Diluent Recovery | 12% |
| Upgrading | 30% |
| Offplots | 24% |
| | 100% |

It can be, and is, argued that mining is not our province but the responsibility of the mining industry. But the punitive cost of oil sand mining is in danger of blocking oil sands development. Ultimately such high cost must be attributed to failure to recognize the need for research.

As an example, my company will spend about $80 million dollars on conveyors, and an as yet unknown amount on their maintenance. These conveyors will handle a material so harsh that it would be difficult to artificially formulate a worse composition for this mode of conveying, and working at temperatures ranging from -50°F to +100°F. For the benefit of tar sand development as a whole, several millions of dollars would be well spent on conveyor materials research and other uses of rubber or rubber substitute. The reason why this has not been done, I think, is that an oil sand industry is only now emerging, and approaches to the conveyor supplying industry have so far been made in a piece-meal fashion. Such a large army of construction workers is needed to build an oil sands plant that one plant has to be completed before another can be started. Hence through lack of concerted investigation each plant is doomed to be equipped with conveyor that may be less than fully appropriate. The same reasoning applies to other features of oil sands technology.

## Steam

The piece-meal approach needs to be corrected even in chemical questions. Of the 600 billion barrels crude oil equivalent present in the Athabasca deposit, only 20 billion barrels can be recovered by a process involving a mining step. This is the preferred scheme where possible due to high recovery of around 93%. For the rest we must resort to *in-situ* methods (so far 50% recovery at best), which have as their common feature that they involve heating the deposit to render the bitumen fluid. Some proposed *in-situ* processes utilize steam which in turn calls for large quantities of water of sufficient purity to be used as boiler feed. Purifying water for boiler feed in electrical power generation is more demanding because not only will silica be deposited as scale, but some forms of silica will be volatile under the high pressures and high temperatures in modern boilers, only thereafter to be deposited downstream on such delicate equipment as turbine blades. Oil sands steam usage differs from that in conventional power generation because the steam is used and then allowed to escape: except in the utilities plant, no condensate is returned. Clearly for ourselves and for other developers inexpensive ways of producing copious supplies of purified water would be an important development.

Raw water of the Athabasca region contains soluble organic acids of high molecular weight and much dissolved silica in the form of silicic acids. Strongly basic ion exchange resins may be used to remove silica but if such resins are exposed to the dissolved organics, they foul irreversibly -- that is, they cannot be regenerated by simple caustic treatment. It is then necessary to add another resin system to guard the highly basic resin and to regenerate that. Besides introducing further capital expense, this brings operating complexity because the water eluted from the guard resin must be carefully monitored before it is advanced to the basic resin.

One answer to the resin-fouling problem lies in the use of ozone, for degradation of the large organic molecules. At Syncrude Research we have adjusted the molecular weight of the organics to the desired value by use of as little as 5 ppm ozone and success was demonstrated in a six-day experimental run where no noticeable resin fouling was observed (2).

Ozone is helpful, but if we go back a step we see that the problem is not so much in the water as in the resin. There is nothing inately harmful in contacting organic molecules with resins, but only contacting organic molecules with resins whose pore structure encourages too strong an affinity. In short, the resins available to use have been manufactured without Athabasca region water in mind and contain cavities that readily occlude the humic and fulvic acids with which we are plagued. Athabasca water needs tailor-made resins or some novel treatment.

Reliability

The very scale on which Syncrude will operate constitutes a risk and a challenge. Unlike the conventional oil industry where the risk is in locating the oil, with us it is the reliability of the equipment. A new science of equipment reliability will have to be developed.

Syncrude has a train of 41 plants. If each of these were to operate at 99% reliability the total system could be depended upon to operate for only 66% of the time. At the high investment required it is uneconomical simply to have duplicate pieces of equipment. What we need is reliability engineering -- that is,some means for informing us of the health of equipment before such equipment fails. I understand that large computers will now diagnose failure of certain of their own components. Using a network of probes and monitors attached to equipment, this diagnostic practice needs to be extended to large mechanical systems.

Synthetic crude is more corrosive than its conventional counterpart. Stainless steel is not a good material from which process equipment should be fabricated because of its poor heat transfer properties. New alloys for synthetic crude would justify research effort.

I have already referred to a need in the tar sand industry for new conveyor belt material. It should be strong, resist abrasion, work at a demanding range of temperatures, resist attack by hydrocarbons, and release tar sand or at least not suffer when release agents are applied. Steam distribution systems are made expensive because expansion joints have to be let into the system. If in-situ recovery were to be employed over an area of 25 square miles this would be an enormous source of cost. There is an incentive to invent expansionless piping (possibly from ceramic or glass?).

Upgrading

This is the operating by which the bitumen is coverted to synthetic crude, suitable for treatment in a convention oil refinery. Bitumen is first "cracked" and distilled above 900°F to yield light and heavy gas oils.

The assumption is that because 50% of bitumen is in the boiling range of conventional residuum, bitumen should be treated by residuum upgrading. With available technology this is correct. Nevertheless, about 25% of the energy available to the tar sand is lost in upgrading. We subject the bitumen to high temperature to crack the heavier molecules and to remove the carbon with a view to increasing the hydrogen/carbon ratio of the product. Unfortunately, side reactions are quite prominent and encourage production of

- olefins -- which have to be saturated at a later stage
- gases -- which consist of hydrogen and light hydrocarbons rich in hydrogen and constitute a serious loss of hydrogen from the reactive mixture, notwithstanding the fact that coking is intended to correct an alleged hydrogen deficiency.

Paraffins have a hydrogen/carbon ratio of approximately 2, benzene has 1.0. So in fact, bitumen, at a hydrogen/carbon ratio of around 1.5 is not deficient in hydrogen. It is coking that makes it so. It would appear that during coking, hydrogen migrates to give one by-product so starved of hydrogen that it must be rejected as a coke, and another, so rich in hydrogen that it is lost as refinery gas. Granted these are only side reactions, but serious in absolute terms. We will produce 800,000 tons per year of a coke of hydrogen/carbon ratio 0.3 and of low economic value, which started off as a constituent of useful hydrocarbons. Olefin production is so serious that in the subsequent hydrodesulfurization sixty percent of the hydrogen consumed is used merely to hydrogenate these olefins. We will use 35 MM cubic feet of natural gas per day to produce hydrogen. Both hydrogen migration and olefin production appear to be a function of temperature and hence a lower temperature cracking process is needed for oil sands upgrading.

Lewis acid catalysts, homogeneous with the mixture to be hydrocracked (3) (eg. fused zinc chloride) hold promise, but efficient catalyst recovery would be needed for economic reasons. Bed catalysts are at a disadvantage because of poisoning brought about by the metal content of the bitumen itself, and its ash content. The de-metalizing step, possibly using manganese nodules would probably solve this. Another possible application for catalytic action would be a reforming step. Although large volumes of hydrogen are needed to hydrogenate bitumen during hydrocracking, much of this could be regenerated by re-forming simultaneously with the creation of a valuable product, high in aromatics. Alternatively, it has been suggested that sulphur is evenly distributed along the length of the large molecules and that merely removing this sulphur from bitumen by hydrodesulfurization would bring about a ten-fold reduction in hydrocarbon molecular weight (4). If so, we are throwing away a great natural advantage that bitumen presents.

Although fluid coking followed by hydrodesulphurization is adequate for residuum in conventional crude, direct application to oil sands bitumen is really only a stop gap. As we move toward bitumen as a major hydrocarbon raw material, side reactions, which are a decided nuisance in the treatment of conventional residuum, will become a serious source of waste. The Catalytic Cracker (developed as recently as the early fourties) was brought into use to cope with two new problems: expanded market for hydrocarbons of gasoline boiling range; and the increased use of heavier oil as refinery feedstock. Bitumen may be seen as the next step towards even heavier oil and the time seems ripe for the development of a brand new residuum conversion process.

Canada is fortunate in that as conventional crude supplies are depleted we have an intermediate source of hydrocarbons in the form of oil sands bitumen from which our liquid hydrocarbon needs can be satisfied. Other nations have to go directly to uncongenial hydrocarbon sources such as coal and oil shale. Oil sand poses technical and scientific problems but these are capable of being handled by Canadian research resources. I am sometimes asked what will be the future of the Syncrude Research Department once the first plant is operating and debottlenedked. My reply is that by that time we will have clear ideas about what the research problems of oil sands really are. The deposit contains about 600 million barrels. Whether we convert it from a deposit to a resource will depend on whether we correctly choose new directions as a result of the initial experience we are gaining now.

References

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