



Retorting trials at the Division of Fuel Technology.

Footnote that big import bill will adversely affect the nation's balance of payments, and a smaller domestic supply will reduce government royalties and lower economic activity in production areas (particularly in Victoria). Barring further discoveries, the gap between local production and needs will continue to widen.

Yet, Australia has abundant deposits of coal, oil shale, and natural gas. At current rates of consumption, our known reserves of coal will last more than 2000 years, and known natural gas reservoirs will keep us supplied for more than a century. Oil shale deposits in eastern Queensland alone contain 28 000 million barrels of oil — about 15 times our currently recoverable petroleum reserves.

Can alternative fuels bridge the widening gap between supply and demand for oil? A small part of the breach can be filled by substituting natural gas and liquefied petroleum gas in some cases, but liquid fuel is what our transport system craves. Alternative liquid fuels could indeed meet all our needs if — and this still remains the big question mark — the cost could be reduced.

When Arabian crude oil can be pumped from the ground for \$1–2 per barrel, there's no way that synthetic oil can compete. However, a market price for crude of \$20 per barrel is not far short of a level where synthetic alternatives begin to look attractive.

Research over the past decade has led to improved production efficiencies, virtually halving the projected cost of synthetics. Exxon now believes it can produce oil from coal and oil shale for about \$US30 per barrel, and Southern Pacific Petroleum calculates that it can achieve a commercially acceptable return from mining richer portions of the Stuart oil-shale deposit in Queensland and selling the oil for \$US28 per barrel.

Fill 'er up... on shale oil?

Synfuels have become unfashionable. A decade ago, scientists were enthusiastically predicting we'd be running our vehicles on synthetic liquid fuels made from coal, oil shale, natural gas, and biomass. Today, with low prices for abundant crude, those predictions have faded into the background.

But they're right, of course. It's just that the time frame has shifted 10 years or so into the future.

Australia is already suffering a decline in its self-sufficiency in crude oil.

In 1984, we got just about all the oil we needed from our own sources. Now the self-sufficiency figure is about 90%, and falling. 'Energy 2000', the government's recent national energy policy paper, predicts that by the year 2000 only 33–52% of our petroleum supplies will originate locally.

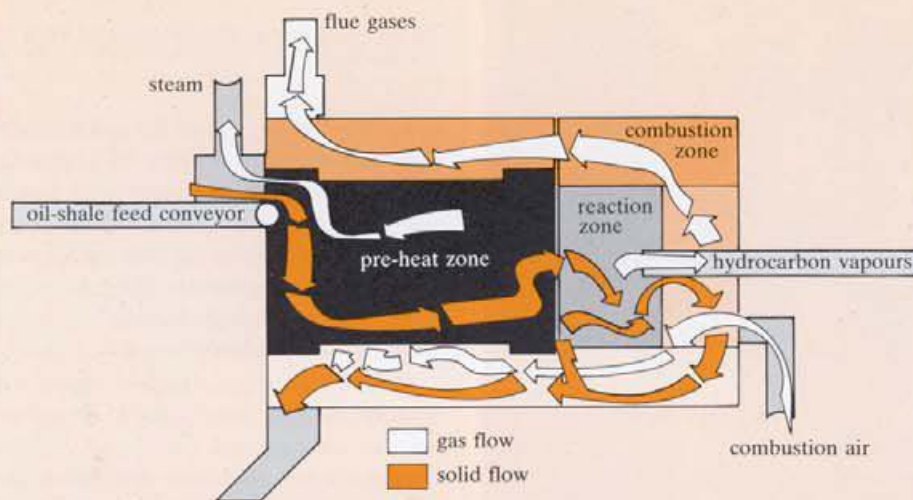
Each percentage point drop in self-sufficiency translates to 2 million extra barrels of crude that need to be imported, at an annual cost at present prices of about \$40 million. By the turn of the

century imports may run into hundreds of millions of barrels a year, costing billions of dollars.



Mining oil shale at Condor, Qld, for retorting tests.

The Taciuk retort — coming soon



Southern Pacific Petroleum has plans to build a demonstration plant to operate on Stuart oil shale. The horizontal rotating kiln of the Taciuk process would produce thousands of barrels of shale oil daily.

But cost is not the only factor at work. To ensure continuity of supply, we need to be ready to switch to alternatives if oil prices suffer another sudden increase, or access to Middle East supplies is disrupted.

We can't just import the required technology, either, since our coals and oil shales have individual characteristics that need to be taken into account. In the case of oil shale, for example, Queensland types are generally softer, wetter, and less rich

How to turn natural gas into a liquid

Chemically converting natural gas — of which methane is the major component — to larger hydrocarbon molecules that are liquid at normal temperatures would provide a valuable new source of liquid transport fuels.

At the moment, a \$1000 million gas-to-gasoline plant in New Zealand is the only one of this kind. The 14 500-barrels-per-day plant converts natural gas first to synthesis gas (a mixture of carbon monoxide and hydrogen) by steam reforming and then to methanol, and finally uses catalytic reactions to transform methanol to petrol.

The only alternative process is the classic Fischer-Tropsch synthesis (see the box on page 18), which also requires synthesis gas as the intermediate. It's

By reacting it with oxygen in a reactor filled with a fluidised bed of catalyst, methane can be turned directly into ethylene (C_2H_4) and other liquid-fuel building blocks.

unlikely that plants based on either of these processes would be built here because they are very expensive — due mainly to the steam reforming step, which contributes at least half to the total cost of liquid-fuel production. Moreover, steam reforming is inefficient in energy terms, requiring a large heat input. Can we avoid it?

A new possibility has created world-wide interest. It involves passing a mixture of natural gas and oxygen over certain catalysts, leading directly to the formation of ethane and ethylene — the latter being a basic chemical building block from which a range of liquid hydrocarbons can be created.

In one of CSIRO's largest current projects (\$1.5 million for 1987/88), scientists from the Divisions of Fuel Technology, Coal Technology, and Materials Science and Technology have taken up the challenge of taking it towards commercial feasibility. They are working with researchers from BHP's Melbourne Research Laboratory and from universities. Backing from NERDDP and the Industry Research and Development Board assists the enterprise.

Researchers at the Division of Materials Science and Technology are involved in preparation of the catalysts, and those at the Division of Fuel Technology are investigating catalyst performance. At the Division of Coal Technology, work is focused on catalyst formulation and development of suitable reactors.

Encouraging results have spurred on the work. Using catalysts suspended in a small fluidised-bed reactor, Mr Jim Edwards and Mr Ralph Tyler, at the Division of Coal Technology, have obtained methane conversions in excess of 20%. More than 60% of the product takes the form of higher hydrocarbons.

Current research is directed towards improving the yield of hydrocarbons, and minimising the production of undesirable carbon oxides. Finding better catalysts and optimising reaction conditions seem to be the keys.

Conversion of all the methane in a single pass is unlikely, and it will be necessary to recycle the unconverted methane to the reactor after removal of the products. Pure oxygen (rather than air) must be used to avoid diluting the methane with nitrogen.

Since some oxides of carbon will inevitably form, the combined reactions give out lots of heat. With its excellent mixing characteristics, the fluidised-bed reactor is ideally suited to cope with this problem. It keeps temperatures constant and ensures that methane and oxygen mixtures, potentially explosive, always operate safely inside their explosive limits.

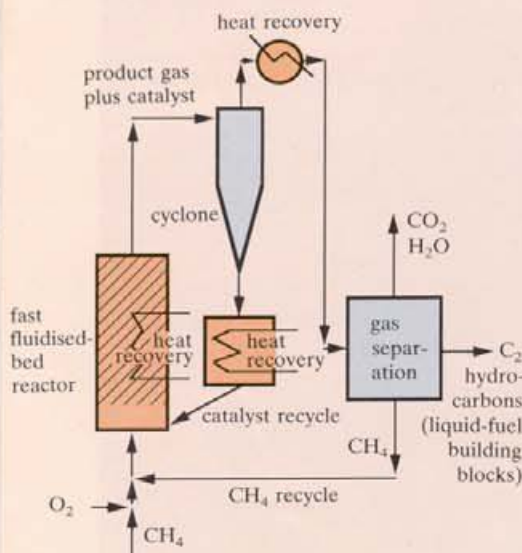
As the next step in the undertaking, Mr Edwards and Mr Tyler have recently built a larger fluidised-bed reactor 60 mm in diameter.

By their calculations, a commercial reactor some metres in diameter and carrying 100 tonnes of suspended catalyst could produce 770 tonnes of hydrocarbons a day — an attractive goal. Those hydrocarbons should be readily convertible to 6000 barrels of liquid fuels.

The production of liquid fuels via the catalytic oxidative coupling of methane. J.H. Edwards and R.J. Tyler. In 'Methane Conversion', ed. D.M. Bibby *et al.* (Elsevier Science Publishers B.V.: Amsterdam 1988.)

The oxidative coupling of methane in a fluidised-bed reactor. J.H. Edwards and R.J. Tyler, *Catalysis Today*, 1988 (in press).

Direct oxidative coupling at work



than much-studied American ones, and their mineral compositions also differ.

And, since developing a commercial plant may take 10 years or more, we need to get involved in the practicalities now if we want to be in a position to produce synfuels in large quantities by the time our oil reserves run out.

As part of its preparations for future shortages, Japan has spent \$500 million to initiate Australia's first oil-from-coal plant in Victoria's Latrobe Valley. Set up as a collaborative effort of Japan's New Energy Development Organisation and the Victorian and Australian governments, the 150-barrels-a-day hydro-liquefaction plant began producing liquid fuels from brown coal in April last year. The plant first dries and pulverises the coal, then uses solvents and hydrogen under pressure to turn it into a liquid. Further processing removes the ash, and additional hydrogenation upgrades the liquid to a refinery-grade feed.

Oil shale to shale oil

Also with an eye to the future, the oil shale companies Southern Pacific Petroleum and Central Pacific Minerals announced earlier this year that they are planning to build a semi-commercial demonstration plant, costing up to \$30 million, near Gladstone, Qld. It would use the Canadian Taciuk process — a single horizontal rotating kiln — to daily turn 2000–10 000 tonnes of Stuart oil shale into 1600–8000 barrels of high-quality shale oil.

The companies' interest follows collaborative research with the CSIRO Division of Fuel Technology and testing of Stuart oil shale in a Taciuk pilot plant in Canada.

For the last 5 years, the companies have heavily supported CSIRO research into recovery of oil from shale. Earlier this year, the Division of Fuel Technology received a grant of \$610 000 for additional oil-shale work over the next 2 years — the major portion from the government's National

Queensland has a lot of oil shale.

The oil shale State



Energy Research Development and Demonstration Program (NERDDP), and the rest from the companies.

Indeed, NERDDP has this year provided \$1.5 million for synfuels research. The money is split between CSIRO and corporate research teams at BHP, Esso, and Southern Pacific Petroleum. CSR was in the field, but dropped out last year, although its leases on the huge Julia Creek oil-shale deposit remain in force.

The latest grant will allow CSIRO to expand knowledge of oil-shale retorting. It will build on the pioneering work done over previous years when characterisation of oil-shale properties was the main consideration.

Dr Greg Duffy, the leader of the CSIRO oil-shale research team, says the main aim now is to investigate how shale from the Stuart and Condon deposits in Queensland (two of the largest and richest in Australia) can be processed into oil using one integrated plant. The challenge is to optimise the plant design so that production costs are reduced to an absolute minimum. There's no doubt in his mind that oil from shale will prove to be the cheapest alternative liquid fuel, and hence that it will be

Mining and retorting oil shale at Torbane, N.S.W., in 1880.

the first alternative to begin commercial production in Australia.

This article looks at current oil-shale research in CSIRO. Accompanying boxes give outlines of other approaches to producing liquid fuels that are currently under investigation; they may be 'dark horses', but if one or other manages to clear that lingering price hurdle we may finally be home and hosed so far as our liquid-fuel requirements are concerned.

Briefly, these techniques involve:

- ▷ reacting natural gas (mainly methane) with oxygen under conditions where liquid fuel precursors (like ethylene) are formed directly — this novel approach bypasses the preliminary step of making 'synthesis gas' (carbon monoxide and hydrogen) by reacting the methane with steam — and so cuts costs
- ▷ simplifying the Fischer-Tropsch process of converting coal into liquid fuel (which goes by a synthesis gas route) by radically modifying reaction conditions and using natural gas instead of coal as the starting point — a 'slurry-phase' reactor and a throw-away catalyst are promising options
- ▷ rapidly heating fine coal to drive off tar (a crude liquid fuel); although CSIRO's research into this 'flash pyrolysis' process has ceased, in some major respects it shows considerable advantages and shouldn't be overlooked

The rock that burns

Australia's deposits of oil shale have considerably more energy locked away

deposit	estimated shale oil resource (GL)	average oil yield (L per tonne)
Condon	1534	67
Duaringa	591	82
Julia Creek	238	60
Lowmead	117	84
Nagoorin	421	91
Nagoorin South	74	78
Rundle	421	105
Stuart	399	94
Yaamba	658	95



The North-west Shelf has a lot of natural gas — but it would need a long pipeline to get it to the east coast. Now, if we could convert it to a liquid fuel...

than our deposits of petroleum and natural gas combined, although not as much as our coal reserves (see the table on page 21).

Four countries are each currently mining at least a million tonnes of oil shale per year — Brazil, China, the United States, and Russia. With progress in developing the Stuart deposit, Australia seems likely to be next on the list.

In 1802, two visiting French scientists exploring the Blue Mountains of New South Wales found 'considerable masses of a bituminous schist which burns with a very lively flame, giving off thick smoke and an extremely pronounced odour of bitumen'.

Early pioneers soon discovered that oil extracted from the rock was good for fuelling kerosene lamps, and the Australian oil-shale industry, perhaps our first secondary industry, began.

In the 1860s, primitive underground mining procedures were used to recover oil shale from rich deposits around Sydney. Recovering oil this way was environmentally damaging and relied on simple inefficient retorts.

Nevertheless, the oil produced was an important commodity, used for lighting, heating, and cooking. Shale-oil production, although small in scale, employed one in every 1000 Australians in 1880.

Any future Australian shale-oil scheme will almost certainly be located on the very much larger, but less rich, Queensland shale deposits. It will have to be exceedingly large, and much more efficient and more environmentally acceptable than the old industry was.

The favoured oil shale from the Kerosene Creek portion of the Stuart deposit returns about 200 litres of oil per tonne of dry shale — and the whole deposit averages less than half this amount. Therefore, lots of shale will need to be mined — by open-cut



An experimental rig used by CSIRO scientists to study the pyrolysis of oil shale.

methods — to make economic quantities of oil. The shale will be heated in huge automatic retorts to turn the kerogen bound in the rock into an oily vapour that will condense into the wanted oil. Later, refineries will convert the oil into petrol, diesel, aviation fuel, and the like.

The likely scale of a commercial undertaking is vast. To provide Australia's present liquid fuel needs, about 1 million tonnes of oil shale would have to be mined and processed each day. Like any complex synfuel plant, the enterprise would also have big requirements for money. Mr Jim Edwards of the CSIRO Division of Coal Technology has carried out economic assessments of possible synfuel plants. Although the costing relates to the situation a decade ago, many of the evaluations are still apt.

For example, he finds that the final capital and operating costs of deriving oil

Fischer-Tropsch not forgotten

In 1923, Doctors Fischer and Tropsch discovered a new way to turn coal into oil. They gasified coal by reacting it with steam and, in a second stage, condensed the resulting synthesis gas (a mixture of carbon monoxide and hydrogen) into a cocktail of liquids by pressure-cooking it with a catalyst.

Although Fischer-Tropsch synthesis has drawbacks — two stages aren't as desirable as one, and catalyst poisoning is a problem — the South African SASOL version of it was the only commercial-scale synfuels plant in the world until the New Zealand gas-to-gasoline plant came along. SASOL produces more than 60% of South Africa's liquid fuel requirements from low-grade coal, using Fischer-Tropsch synthesis.

The same process can be used, of course, on the synthesis gas produced by steam reforming of natural gas. Dr Alf Ekstrom

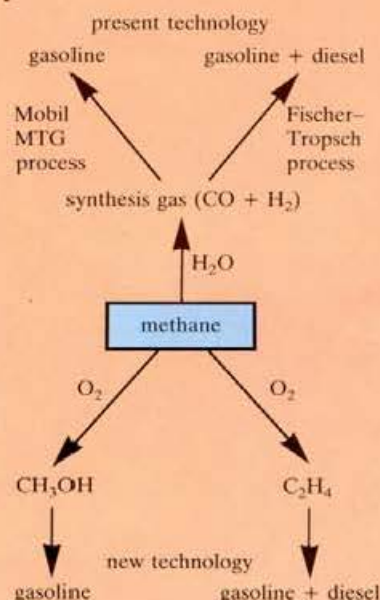
and Dr Alan Chaffee, of the Division of Fuel Technology, are investigating the potential for improving Fischer-Tropsch synthesis using natural gas as the starting point. Indeed, SASOL has also recently announced construction of such a plant.

The CSIRO program is based on the use of a slurry-phase reactor. In this system, the catalyst, in finely divided form, is suspended in a stirred hot-wax medium (up till now, fixed- and fluidised-bed reactors have been the norm). The fine size gives rapid reaction, and the stirred liquid wax provides excellent temperature uniformity, despite large amounts of heat released in the reactions.

A new cheap catalyst showing exceptionally high activity has recently been developed, and it favours formation of the sorts of liquids — gasoline, kerosene, and distillate — that refiners find attractive.

The Fischer-Tropsch process is used in South Africa and the Mobil MTG process in New Zealand. Direct oxidative coupling, under investigation by CSIRO, avoids the costly synthesis gas step.

Liquid fuels from methane



from coal are about the same as those involved with shale, despite contrasts in the budget details. The expense of retorting oil shale greatly exceeds that of processing coal because, for a given oil output, about three times as much shale needs to be processed. This is a direct result of shale's high level of inorganics (about 85%) compared with coal's 40% (as mined) or 20% (washed).

The balancing factor is oil quality. The primary liquid produced by shale retorting has a considerably higher hydrogen content than tar produced by coal pyrolysis (the corresponding H:C ratios are about 1.7:1 and 1.1:1). And shale oil has lower levels of bothersome oxygen, nitrogen, and sulfur than coal tar (perhaps 4% compared with 12%).

Geologists, chemists, engineers...

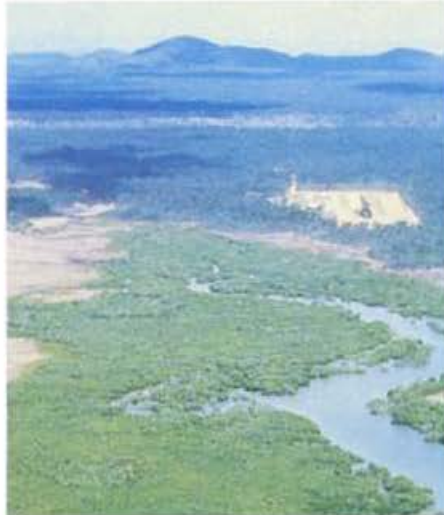
The CSIRO's oil shale research began with basic work on the geology and definition of the resource by Dr John Saxby and his colleagues at the CSIRO Division of Coal Technology (see *Ecos* 27). Later work at the Division of Fuel Technology has involved characterisation of oil shales and the oils derived from them. More recently, the work in the latter Division has shifted to research aimed at a better understanding of the retorting process and how different reactor configurations perform. Brief descriptions of some key aspects of this Division's research follow.

CHEMISTRY OF AUSTRALIAN OIL SHALES

Kerogen is the stuff in shale from which shale oil is derived. It is the residue of algae that lived in shallow lakes millions of years ago (most Queensland deposits are of Tertiary age — about 50 million years old — whereas the Julia Creek deposit dates from the Cretaceous, about 100 million years ago).

Since kerogen is mixed with many minerals, the chemical reactions involved with its extraction are far from simple. Most of the major minerals, such as clays, carbonates, and iron-containing compounds, can undergo dehydration, dehydroxylation, decomposition, or oxidation during drying, retorting, and combustion. Retorting at 450–550°C can induce high-temperature reactions that can affect the economics of the various processing stages (through absorbing or releasing heat) and can also give rise to air and water pollution.

Mineralogical studies of Rundle, Stuart, Condor, Nagoorin, Duaringa, and Lowmead oil shales by Dr John Patterson and his colleagues have so far uncovered no major impediment to successful retorting.



The unassuming beginning of a huge enterprise? The Rundle oil shale deposit.

The main problem is iron pyrite, present in some oil shales, which decomposes during retorting to produce undesirable gaseous sulfur compounds.

TRACE ELEMENTS IN OIL SHALE

Metals such as vanadium, selenium, nickel, and arsenic are present in Australian oil shales, and these can be mobilised during retorting. Arsenic and selenium, in particular, can pose problems in treatment and disposal of retort water. Vanadium, nickel, and arsenic can poison catalysts used in refining the oil.

Using results from neutron activation analysis and inductively coupled atomic emission spectrometry, Dr Patterson has found that, generally, Australian shales do not contain troublesome concentrations of these elements. A notable exception is Julia Creek oil shale, which contains, among other trace elements, high levels of vanadium.

Dr Chris Fookes, also of the Division, has used nuclear magnetic resonance to demonstrate that much of the vanadium is associated with porphyrins — of which chlorophyll from plants and algae is the precursor. Apparently, the chlorophyll structure has a vacancy just right for the vanadium (and also nickel) atoms to fit into.

FLUIDISED-BED PROCESSING

Dr Nguyen Dung and his Divisional colleagues have studied the retorting characteristics of eight Australian oil shales, using a bench-scale fluidised-bed reactor 48 mm in diameter. Their aim was to minimise cracking and coking of the shale oil. Both these reactions can reduce the yield of oil from the retorting process (in cracking, the oil molecules are broken down to smaller, gaseous, ones; in coking, they are reduced to a solid carbon).

Dr Dung's experiments have shown that oil shales with hydrocarbons high in hydrogen (high H:C ratio) are best for retorting.

They produce the largest yields of oil, and that oil retains a good H:C ratio, beneficial in refining.

Adding steam to the retort gave mixed results. With most shales, it increased yields by about 15% (one showed a 33% increase), but the drawbacks were a lower H:C ratio, a higher sulfur content, and heavier-grade oils.

When hot shale ash was fed to the retort (as a heat source), it promoted coking of the oil, so yields were reduced. A similar result was observed by Dr Duffy and colleagues with their 150 mm-diameter continuous pyrolyser.

This is unfortunate, because most retorting processes call for the mixing of hot ash and fresh shale as the way of extracting the ash's heat. Be that as it may, there does seem to be an inescapable trade-off between thermal efficiency and oil yield. At a typical ash:shale ratio of 2:1, yields were down 20–30% for Condor and Stuart shales.

Dr Dung and Dr Duffy understand their results to mean that high-boiling-point oils are adsorbed onto shale ash, where they undergo coking to produce gas and a non-volatile residue, mostly carbon. This would explain why yields of naphtha (boiling point less than 175°C) and kerosene (175–240°C) were less affected by the presence of ash, whereas yields of diesel (240–340°C) and light and heavy gas oil (above 340°C) decreased as ash levels in the retort rose.

Dr Dung has devised a new concept for a retort in which oil shale is rapidly heated in the absence of shale ash. The advantages of his concept are a small retort volume, minimal dilution of the product gas, and no oil loss due to the presence of shale ash. Moreover, little oil is lost through thermal cracking, and the process is self-sufficient in energy and requires only a simple oil condensation system.

The diagram on page 20 shows how it works. Spent shale, burning in a fluidised-bed combustor, provides the heat. Fresh oil-shale particles are rapidly heated by being blown through a network of horizontal pipes criss-crossing the burning bed.

Dr Dung has simulated the system in a mathematical model, and it appears to work well. He hopes to conduct experiments to verify the apparent advantages of the system. He is optimistic that the new approach could provide a major cost reduction in extracting oil from shale.

UPGRADING SHALE OILS

Dr Fookes and his colleagues have analysed oils from most Australian oil-shale deposits

Oil, quick as a flash!

Owners of solid-fuel stoves are familiar with tar. The sticky liquid, driven from the fuel by heat, condenses on the inside of the chimney.

But that tar is a (crude) liquid fuel. And for at least 200 years, tar and light oil produced as a by-product of coke production (in which coal is pyrolysed) have been used as fuels and chemical feedstocks.

In 1985, CSIRO completed an 11-year project to investigate the feasibility of making liquid transport fuels by flash pyrolysis. Unlike slow retorting processes, this scheme involved rapid decomposition of fine coal into gas, tar, and char by injecting it into a fluidised bed of hot sand. ('Flash', in this context, means less than a second.) In this way, and with rapid quenching of the volatile material, the yield of tar could be maximised.

Descriptions of the early phases of this work, undertaken by a team at the Division of Coal Technology led by Mr Ian Smith, are given in *Ecos* 5 (1975) and *Ecos* 16 (1978). Here, we summarise the main findings.

Briefly, the work has shown the technical feasibility of the process: there don't appear to be any practical obstacles to setting up a pyrolyser next to a power station, extracting the tar, and burning the char and gases in the power station. A 20-kg-per-hour pilot plant has operated for long periods on bituminous, sub-bituminous, and brown coals. Its performance was similar to that of a laboratory version 20 000 times smaller, and the scientists expect that a commercial unit — involving a further scale-up of a similar magnitude

— would perform in much the same way.

Moreover, in extended hydrogenation tests, tars from the coals have been successfully converted to oil of refinery-feedstock grade. Data from the pilot plant have been used to calculate the cost of the process, and here is where the major obstacle pops up.

Mr Jim Edwards has performed an economic assessment of a full-scale flash pyrolysis unit operating on high-yielding Millmerran sub-bituminous coal (which gives 25% oil recovery). His general conclusion is that the oil from flash pyrolysis costs about the same as that obtained from coal hydrogenation, Fischer-Tropsch synthesis, or solvent-refining — \$80–100 a barrel at mid-1980s prices.

As the figures are 3–4 times greater than the cost of natural crude oil, there is little incentive to consider building a synfuels plant.

Nevertheless, circumstances may change, and some scientifically important facts emerged from the flash pyrolysis study. Some examples follow.

THE TAR

The optimum tar yield occurred when the pulverised coal was heated at 600°C for about half a second. The tar vapours were swept out of the reactor in the fluidising gas, quenched, and collected. The tar was pumped directly to a continuous hydrogenation unit for upgrading to oil.

Interestingly, the major factor determining the yield of tar — for bituminous and sub-bituminous coals of any origin — was simply the coal's hydrogen : carbon ratio.

Yields varied from 10 to 40%, depending on the coal.

The tars are aromatic, high-boiling-point materials, solid at room temperature, that contain nitrogen, oxygen, and sulfur; they also contain quantities of fine solids carried over from the pyrolyser. These characteristics, plus their ready tendency to form coke on hydrogenation catalysts, make them hard to handle. They need to be hydrogenated to make them suitable as a refinery feedstock and, unless special hydrogenation systems are used, fouling of the catalyst is inevitable.

Those are tough requirements, but with the help of Dr Peter Wailes and his colleagues at the CSIRO Division of Chemicals and Polymers, the team developed a catalytic hydrogenator that answered these needs. It's a slurry-phase reactor in which the tars are vigorously mixed, at 14 MPa and about 460°C, with hydrogen and a simple cheap (throwaway) catalyst — sulfided red mud, a by-product of bauxite refining.

The result was a synthetic crude oil — a high-volatility liquid that, without further treatment, could be distilled into petrol, kerosene, and diesel fractions. No coking was evident.

THE CHAR

After the powdered coal is pyrolysed, the products are first passed, still hot (550°C), through a high-efficiency cyclone to separate out most of the char. The char represents about 50% of the original dry ash-free coal. Even when the char is used to supply all the process heat, hydrogen,

to see how suitable they'd be for processing in existing oil refineries.

Most of their work has been on Julia Creek shale oil under a NERDDP-funded arrangement with CSR Limited, which was completed recently. The Julia Creek

deposit, at 70 litres of oil per tonne, contains proved reserves of 2000 million barrels, comparable with Bass Strait's.

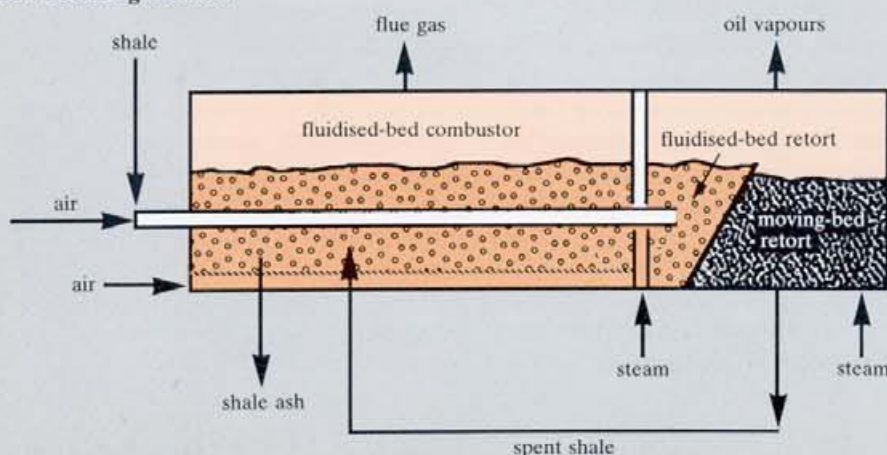
However, Julia Creek shale oil is aromatic, meaning it has a low hydrogen:carbon ratio (1.4:1). This is fine for producing

petrol, which is a highly aromatic product, but not so good for kerosene (jet fuel) and diesel, which need to be low in aromatic compounds. Lots of hydrogen would need to be added to produce these latter fractions in refineries.

Dr Fookes found another drawback of Julia Creek shale oil — its high levels of sulfur (4.9%), nitrogen (1.1%), and the metals arsenic (26 p.p.m.) and vanadium (184 p.p.m.). Sulfur and nitrogen would need to be removed by hydrotreatment, but the metals would readily poison the hydrotreating catalysts. A Julia Creek

Dr Dung's idea for retorting oil shale relies on blowing the shale through horizontal tubes surrounded by a hot fluidised bed of burning spent shale. In this way, shale is pyrolysed without contacting ash — preventing a considerable loss of oil.

A new retorting method





This rig for flash pyrolysis studies can, each hour, turn 20 kg of coal into char and tar.

and electrical energy, a substantial surplus of it still remains.

The simplest answer is to burn it in a power-station boiler. The CSIRO scientists have burnt chars in a pilot-scale pulverised-fuel combustor and found that they burn

without problems. The ease with which they burnt differed little from that of their parent coal.

DIFFERENT APPROACHES

Flash pyrolysis can be used to make more than just liquid fuels. With funds from the Australian Aluminium Development

Council, CSIRO and Comalco built a second 20-kg-per-hour pyrolyser to investigate the production of carbon anodes for aluminium smelting. It seems that the tars, after suitable coking, show promise in making the high-purity carbons needed for this purpose.

At about 900°C, tar yields are low, but the yields of methane and olefin gases are high. Data from elevated-temperature operation have been shared with an American chemical company that sees the potential to make chemical feedstocks in this way.

Adding hydrogen and a catalyst to the pyrolysis unit promotes the formation of a light, mobile tar. This hydropyrolysis method has the distinct advantage of getting hydrogen to react with other hydrocarbons at atmospheric pressure — a rare achievement — but, unfortunately, the CSIRO scientists have so far achieved only low yields of liquids.

New approaches to coal pyrolysis. I.W. Smith. *Proceedings, EPRI Coal Pyrolysis Workshop, Palo Alto, February 1981.*

Oil from coal: the CSIRO flash pyrolysis process. J.H. Edwards, I.W. Smith, R.J. Tyler, and P.C. Wailes. *Proceedings, Chemeca 86 Conference, Adelaide, August 1986.*

An assessment of reaction systems for the primary upgrading of flash pyrolysis coal tar. J.H. Edwards, K. Schluter, and R.J. Tyler. *Proceedings, Australian Coal Science Conference, Newcastle, December 1986.*

Making oil from coal. *Ecos* No. 5, August 1975, 3-9.

Oil from coal — 3 years on. *Ecos* No. 16, May 1978, 21-4.

Coal can keep us going for a long time; our petroleum can't, unless major new discoveries are made. Shale oil can make a substantial contribution.

How long will they last?

	primary and secondary reserves (PJ)	Australian use 1983-84 (PJ per year)	number of years at this rate
coal	3 174 887	1247	2546
shale oil	153 180	nil	a long time
petroleum	18 733	1285	15
natural gas	58 620	489	120

refinery, processing 100 000 barrels of raw oil a day, would annually accumulate more than 1000 tonnes of metals on the working catalyst.

Fortunately, vanadium and other metals tend to accumulate in the heavy oil fraction (boiling point greater than 450°C) so this stream could be diverted (say, to make coke) or returned to the retort. Dr Fookes and his CSR collaborators were able to produce specification-quality unleaded petrol, diesel, and aviation fuel.

Alternatively, if a refinery wanted a substitute crude from which it could make whatever it liked, the only problem would be a slightly higher cost. Basically, all that's needed is a two-stage hydrotreatment of the whole oil, followed by removal of the naphtha (boiling point less than 175°C) and further upgrading of the remainder.

The naphtha could be refined to produce petrol, and the other fractions turned into kerosene and diesel. If syncrude was required, then the naphtha could be recombined with the heavier material and refining could start from there.

Oil shale in your petrol tank? One lump or two?

Andrew Bell

More about the topic

Proceedings of the Fourth Australian Workshop on Oil Shale, Brisbane, December 1987.

A new era for oil shale. A. Bell. *Ecos* No. 27, February 1981, 11-15.

'Energy 2000: A National Energy Policy Paper.' (Department of Primary Industries and Energy: Canberra 1988.)