# THE STATUS OF CANADIAN ENERGY'S CO-PROCESSING TECHNOLOGIES

F.G. BOEHM AND R.D. CARON

CANADIAN ENERGY DEVELOPMENTS INC.
4222 - 97 STREET
EDMONTON, ALBERTA T6E 5Z9, CANADA

Potential commercial production of synthetic liquid fuels was for many years thought to demand liquefaction of coal or upgrading of bitumen/heavy oils. By the late 1970s, however, another concept - i.e., the simultaneous co-processing of coal and heavy oil - began to receive some serious attention; and by now co-processing technology has reached a stage of development where it may appear to be the preferred upgrading procedure. This view, and the corollary that the feedstocks used for co-processing will play an increasingly important role in Canada's energy future, is supported by what is now seen as the most probable energy scenario. This scenario being:

(a) Energy consumption, globally and in Canada, will rise by between 1 and 3 percent per year;

(b) Crude oil prices will only very slightly increase up to 1995, but rise much more rapidly thereafter;

(c) The steady depletion of Canadian light crude resources since the early 1970s will, over the next decade, be reflected in rapidly diminishing indigenous supplies of such oil; and

(d) Stiffer competition in heavy oil markets, primarily from Mexico, Saudi Arabia and Venezuela, will make it important that Canada develop its own resources rather than import increasingly large volumes of crude oil.

We can also assume that the cost of heavy oil will be slightly less than conventional crude and will rise in proportion to the crude price, as well, the cost of suitable coal will not exceed $10-13 run-of-mine/tonne and will probably only increase with inflation.

Canadian Energy Developments Inc. (CE) is therefore concentrating its efforts on developing co-processing technologies which can be shown to possess significant advantages from low feedstock costs and which, even in current market conditions, could offer acceptable rates of return. In particular, the company is working toward development of a 25,000 bbl/d (4,000 $m^3$/d) heavy oil upgrader that would use co-processing technology.

## THE CE TECHNOLOGIES

While several agencies (such as CANMET in Canada, and EPRI, HRI, etc. in the US) are exploring a broad spectrum of coal/heavy oil co-processing as means for production of synthetic liquid hydrocarbons - Canadian Energy, in cooperation with the Alberta Office of Coal Research and Technology[1], has focussed its attention on two specific process configurations.

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[1] A Division of the Alberta Energy, Government of Alberta

1. THE CCLC PROCESS

The CCLC Process consists of two stages which involves (i) a preparatory step and coal "solubilization" (or "solvolysis"), and (ii) hydrogenation of the solubilized product mix.

Depending on its API gravity, the heavy oil used in the process is fractionated by atmospheric or vacuum distillation, and the bottom stream is blended with coal to form a slurry. For the subsequent processing, coal loadings up to 45 wt %, with ash contents up to 10 wt % are used, and the first-stage coal solubilization is followed by hydrogenation at 440-460°C/14-18 MPa which consumes 2-3 wt % hydrogen.

Test runs with a feedstock comprised of 58 wt % Cold Lake vacuum bottoms[(2)], 40 wt % subbituminous C coal[(3)] and 2 wt % "throw-away" catalyst in a continuous 2 kg/h bench scale unit have quite consistently furnished ($C_5$ to -525°C) oils that accounted for over 72 wt % of the d.a.f. feedstock.

Products available for secondary upgrading typically consisted of naphtha (25%), LGO (35%), M/HGO (14%) and a residual (+525°C) oil (8%).

The CCLC Process offers a continuous operation, high conversion, and a product slate that would require very little secondary upgrading for profitable disposition.

2. THE PYROSOL PROCESS

The second processing procedure under development by Canadian Energy is the PYROSOL Process which was initially conceived by West Germany's <u>Gesellschaft für Kohleverflüssigung mbH</u> (GfK) as an alternative to its more conventional high-severity coal liquefaction technology. PYROSOL seeks to generate as high or higher oil yields, but employs milder process conditions (and expends correspondingly less hydrogen) by combining a mild hydrogenation step with subsequent hydrocoking.

CE considered this approach to be another logical starting point for development of a Canadian co-processing technology, and accordingly entered into a co-operation and licence agreement with GfK.

In its present configuration and operating mode, the PYROSOL Process uses coal loadings up to 55 wt % (with up to 10 wt % ash), conducts first-stage hydrogenation at 380-420°C/8/12 MPa (with 0.8-1.5 wt % hydrogen consumption), and carries out second-stage hydrocoking at 480-520°C/8-10 MPa.

Although not yet optimized, test runs with the same feedstock as used in the CCLC Process have yielded 68 wt % oil (on d.a.f. feedstock); and product slates for secondary upgrading have been found to consist mainly of naphtha (8%), LGO (25%), M/HGO (27%) and coker oil (8%).

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(2) These represent very heavy residua from oil sand bitumen processing

(3) From Manalta's Vesta Mine in Central Alberta

Advantages offered by the PYROSOL process will accrue from relatively low capital costs and easy operability, low hydrogen consumption, and an ability to process wastes in the form of coke before taking the products to secondary upgrading.

## THE CURRENT STATUS

Canadian Energy is now working with a fully integrated, flexible 15 kg/h pilot plant which can operate in both process modes. Results from this unit are sufficiently encouraging to allow us to expect completion of the development program by 1990 and then proceed to a selection of the most suitable of the two processes for testing in a full-size demonstration plant. Commercialization may thus be possible in the early 1990s.

## THE ECONOMICS OF CO-PROCESSING

Large-scale application of any co-processing technology obviously depends on demonstrating

(a) that a full-scale plant can achieve a sufficient return on investment to justify the necessary capital outlay, and

(b) that the technology is competitive with other processing options and can deliver a product that can compete against alternative fuels in the market place.

Canadian Energy has therefore initiated two feasibility studies in order to define the conditions in which a technically proven co-processing technology would have potential for commercial exploitation. One is examining the economics of stand-alone 25,000 bbl/d (4,000 $m^3/d$) heavy oil upgrader using co-processing technology and is still in progress. But the other, which is focused on the suitability of co-processing as means for converting heavy residua to acceptable refinery feedstocks, has been completed.

In that study co-processing was assumed to be integrated with refinery operations, and five cases were explored.

The first three cases (A, B and C) envisaged a plant input of 10,000 bbl/d (1,600 $m^3/d$) Cold Lake vacuum residua plus 1,371 tonnes/d subbituminous coal.

Case A then assumed maximum integration into the infrastructure of a refinery - i.e., the refinery is able to process the raw liquid products from co-processing without prior hydro-treating in the co-processing facility.

Case B envisaged intermediate integration - i.e., the refinery would only be capable of processing a moderately hydro-treated product from co-processing, and the co-processing facility would therefore include capacity for upgrading high-sulphur naphtha as well as for fluid catalytic cracking of heavy gas oils.

Case C considered minimum integration - with the refinery only capable of accepting a "synthetic crude" from the co-processing plant.

Case D, also based on minimum integration, envisaged a larger co-processing facility (16,000 bbl or 2,500 $m^3$/d Cold Lake residua and 2,193 tonnes/d of run-of-mine subbituminous coal) in order to assess the impact of plant size on capital and operating costs.

And Case E examined upgrading of two situations (E-1 and E-2) in which <u>only heavy oils</u> were processed by conventional hydrocracking in ebullated bed and subsequent delayed coking, and compared these with C and D.

E-1 envisaged processing 10,000 bbl/d of the Cold Lake vacuum residua, while E-2 was taken to operate with 16,000 bbl/d of Cold Lake residua.

In Case C and D, the plants produced 13,000 and 21,000 bbl/d (2,070 and 3,340 $m^3$/d), respectively, of ($C_5$ to -525°C) oil, and also furnished small amounts of $C_3/C_4$, sulphur and ammonia.

Capital costs for the upgrader units, expressed in 1987 $Can and including all off-site facilities and utilization systems as well as project contingencies were $310, $385, $416, $539, $410 and $504 million for Cases A, B, C, D, E-1 and E-2 respectively.

The key data for the base case, all expressed in 1992 $ Can., were then chosen as follows:

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|---|---|
| Plant start-up: | 1992 |
| Coal, f.o.b. Plant: | $16.00/tonne (*) |
| Natural gas: | $0.085/$m^3$ (*) |
| Cold Lake vacuum residua: | $20.65/bbl ($129.87/$m^3$) |
| Value of liquid products: | Case A - $31.55/bbl ($197.17/$m^3$) |
| | Case B - $33.35/bbl ($209.75/$m^3$) |
| | Case C, D and E - $35.35/bbl ($222.33/$m^3$) |
| Inflation rate to 1992: | $4% per annum |
| Oil price forecasts: | Coles, Nikiforuk, Pennell |
| Equity: | 100% |

(*) inflated to 1992

From these data, the case studies arrived to the following after-tax DCF rates of return:

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|---|---|
| Case A: | 12.4% |
| Case B: | 11.4% |
| Case C: | 11.8% |
| Case D: | 14.4% |

For E-1 and E-2 the corresponding figures were 4.0% and 6.4% respectively.

These findings allow several important inferences. Thus:

(a) A co-processing plant can offer an acceptable rate of return if heavy oil residua can be purchased at less then 80% of the price of crude oil, and such a plant is clearly more attractive than conventional heavy oil upgrading (cf. A, B, C and D vs. E-1 and E-2).

(b) Minimal benefits would be gained from refinery integration if the output of the upgrader is to be a synthetic crude, and a stand-alone upgrader, which would benefit by producing some light oils from the residua, would therefore also prove economically attractive.

(c) If the product price differentials used in the study are correct, the return on investment is not substantially affected by the extent of hydrotreating required to be conducted in the upgrader.

But perhaps the most interesting result of the study are the clear advantages which accrue to a co-processing facility from its lower feedstock costs. On a volume basis, and expressed in Canadian $$, feedstock and production costs per barrel of $C_5$ to -525°C oils would run to $18.28 in co-processing and $24.18 in conventional heavy oil upgrading (equivalent to $114.97 and $152.08 per $m^3$ respectively). And if the price of heavy residua were to increase by $5.00/bbl, the cost advantage to a co-processing facility would rise by $2.00/bbl ($12.58 $m^3$).

SUMMARY

Co-processing - i.e., simultaneous upgrading of coal and heavy oil residua - is expected to play an increasingly important role in Canada's future energy supply. Two co-processing technologies, both being developed by Canadian Energy Developments Inc., are reviewed, and six Case Studies indicating the economic potential of the process are presented. It is shown that co-processing has a significant economic advantage over conventional heavy oil upgrading, and that this advantage will increase as the cost of heavy oil increases.