APPENDIX A

NUMBERED FIGURES REFERRED TO IN TEXT

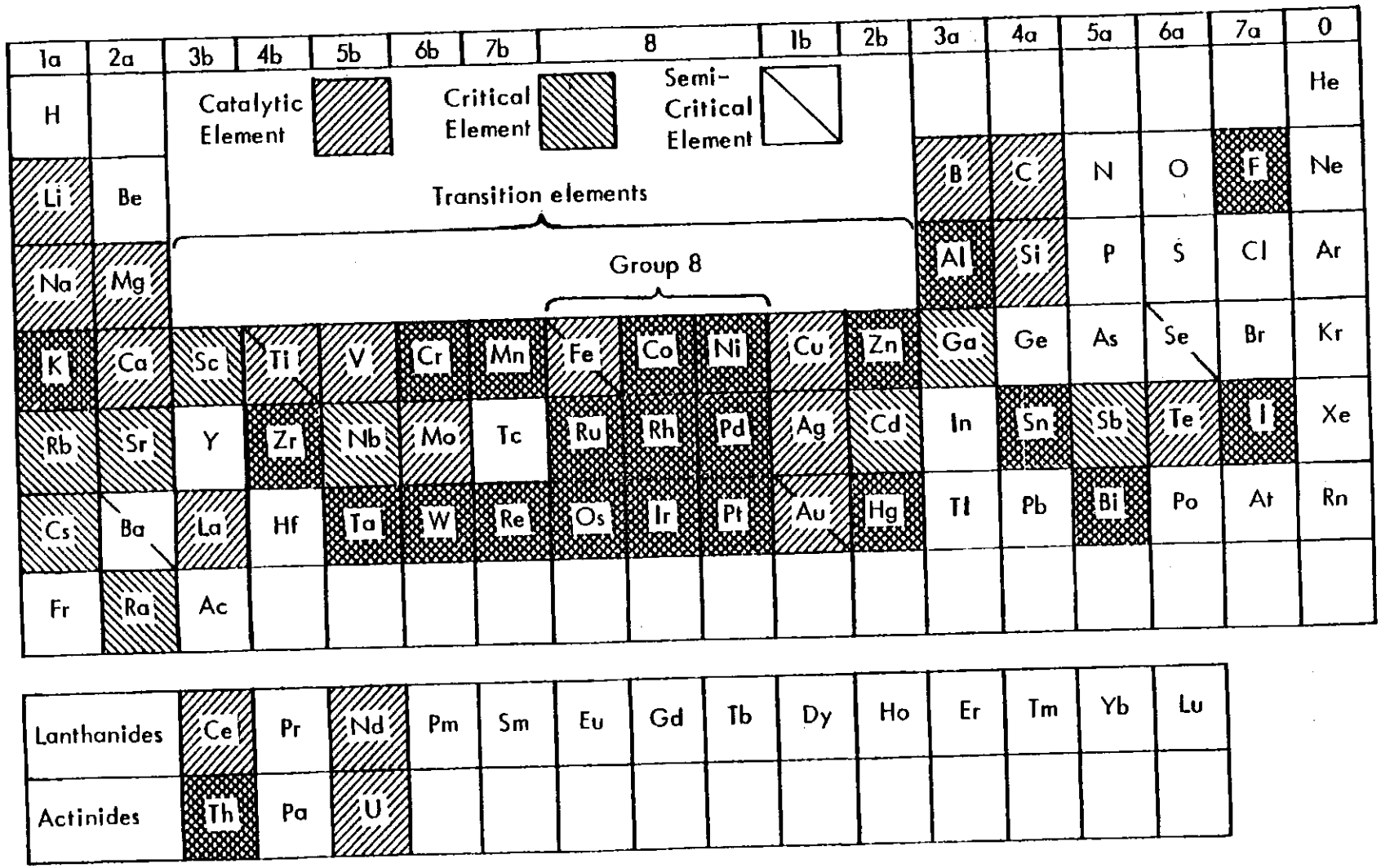


Figure 1. Periodic Table Showing Critical and Catalytic Elements

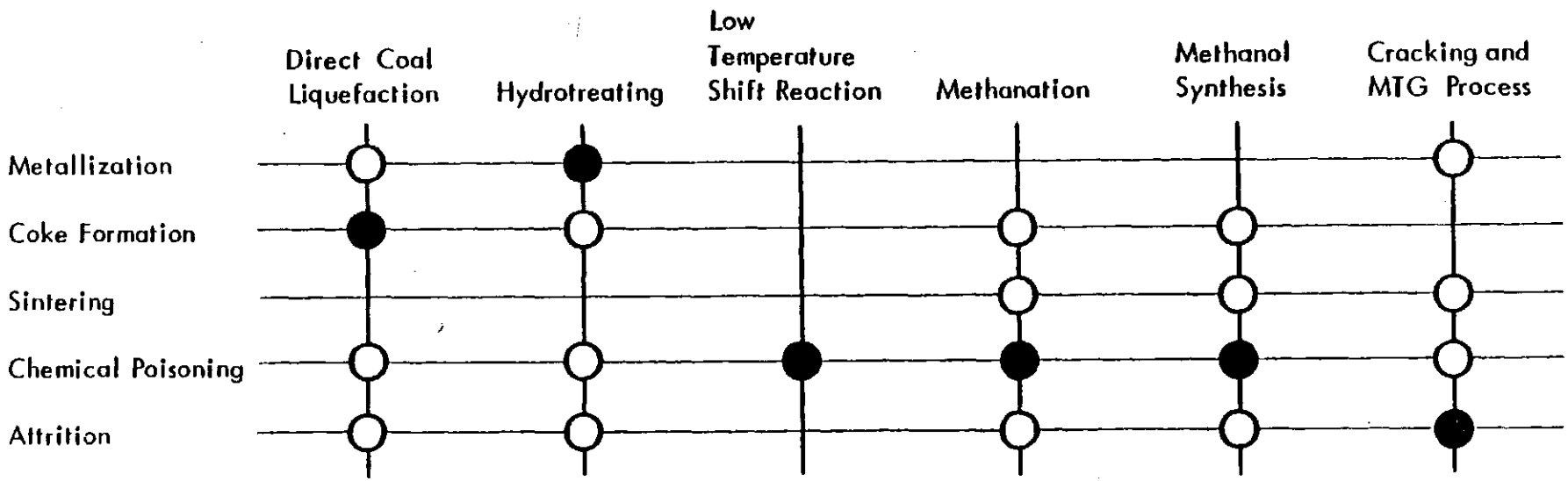


Figure 2. Causes of Catalytic Deactivation and Loss for Various Processes

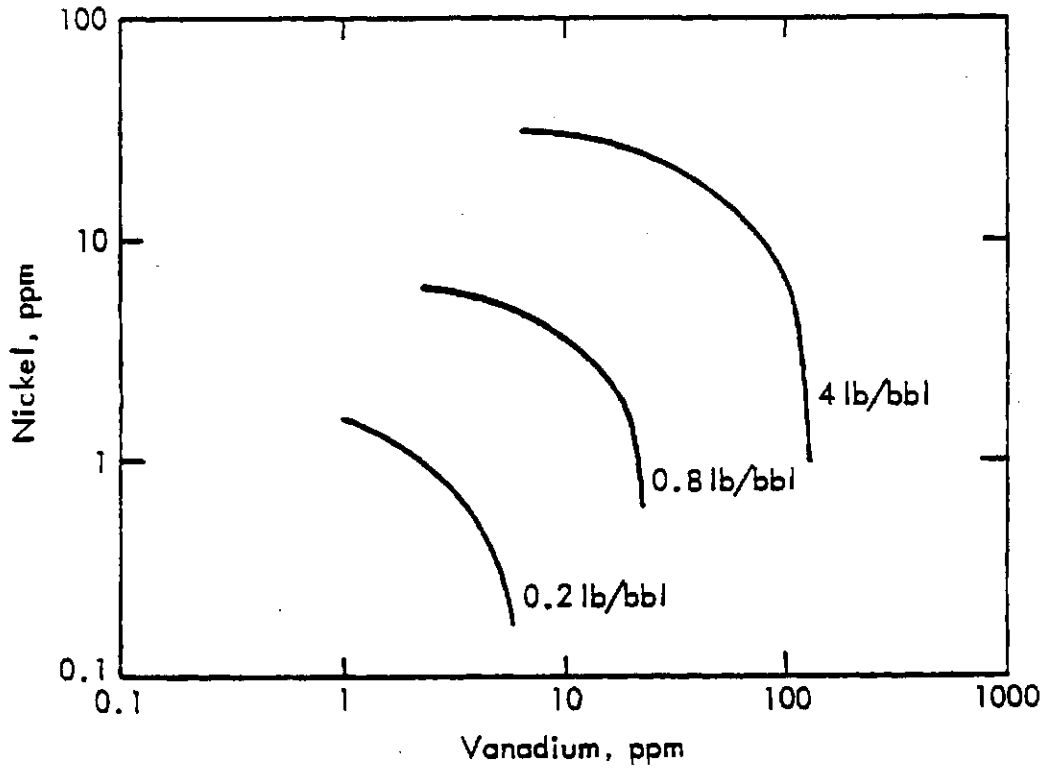


Figure 3. Variation in Catalyst Replacement Rates with Vanadium and Nickel Content for Heavy Crude Hydrotreating (2% by Weight Heavy Metal Deposits on Catalyst).

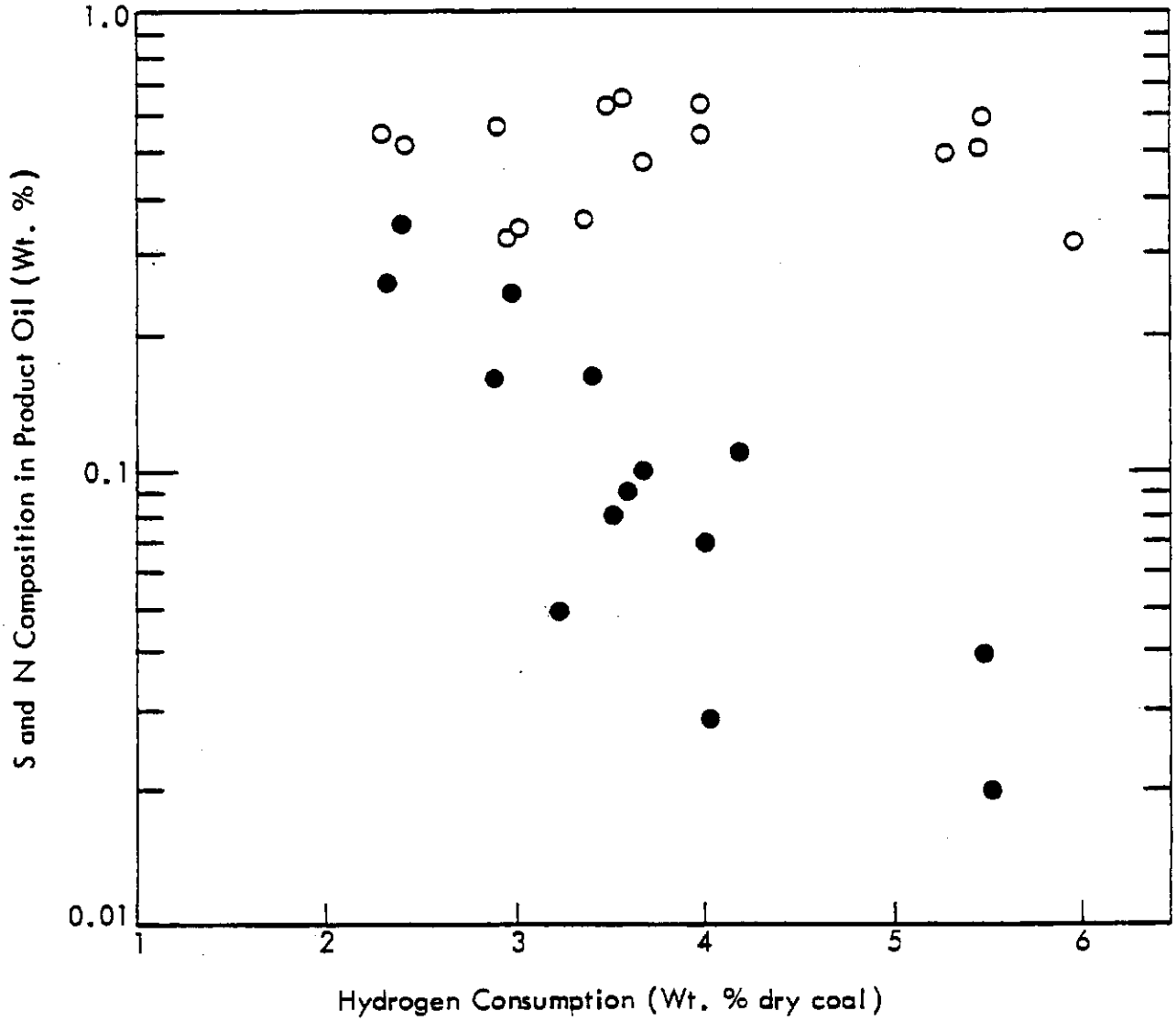


Figure 4. Reactivity of H-Coal Catalyst for Hydrodesulfurization (•) and Hydrodenitrification (o) in the Hydrotreatment of Liquified Coal. (Mori, S., and T. O'Hara, "Upgrading of Coal Derived Liquids," Annual Report No. IMMR 45-PR8-74, Commonwealth of Kentucky, 1979).

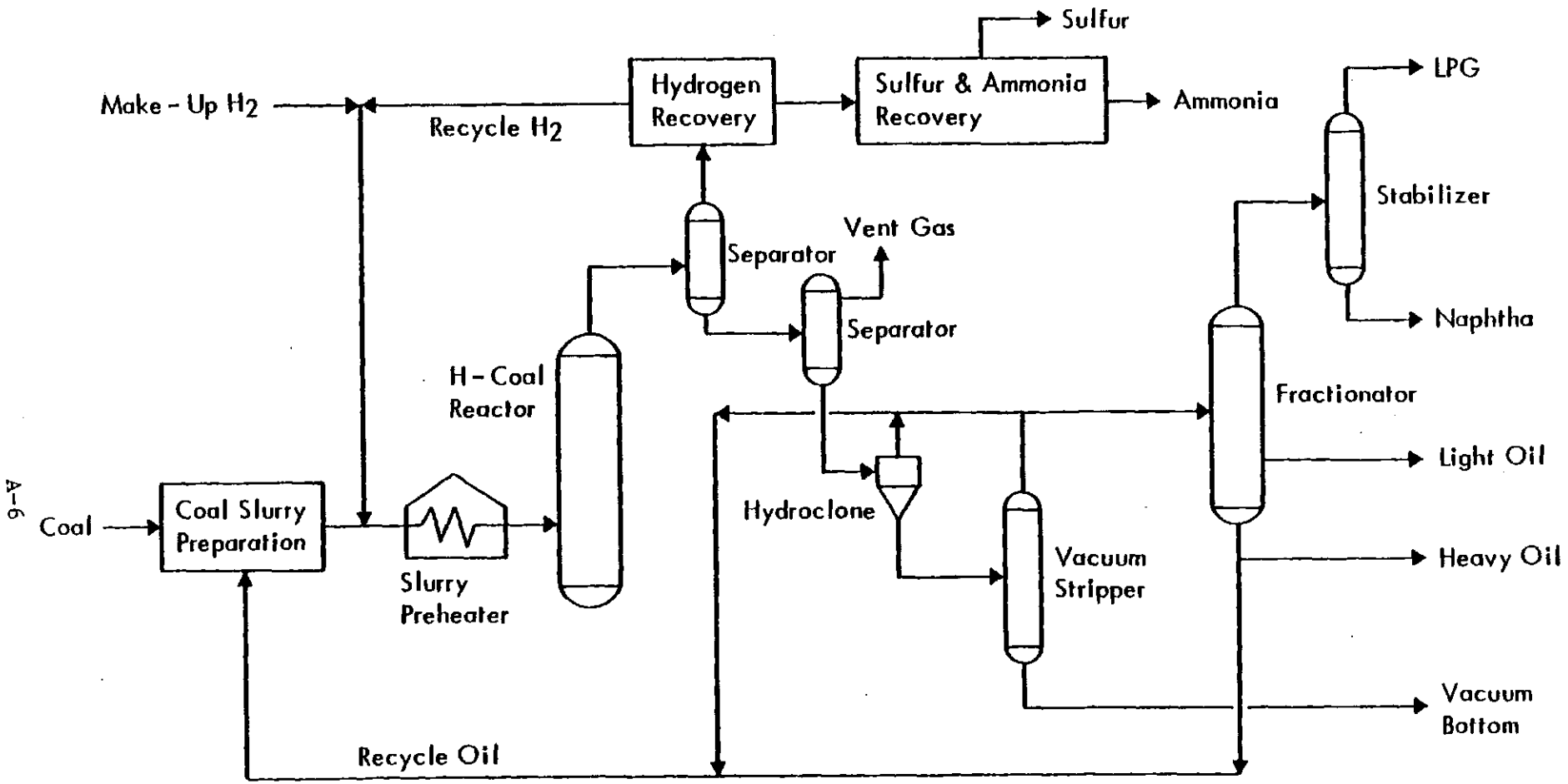


Figure 5. H-Coal Liquefaction Process

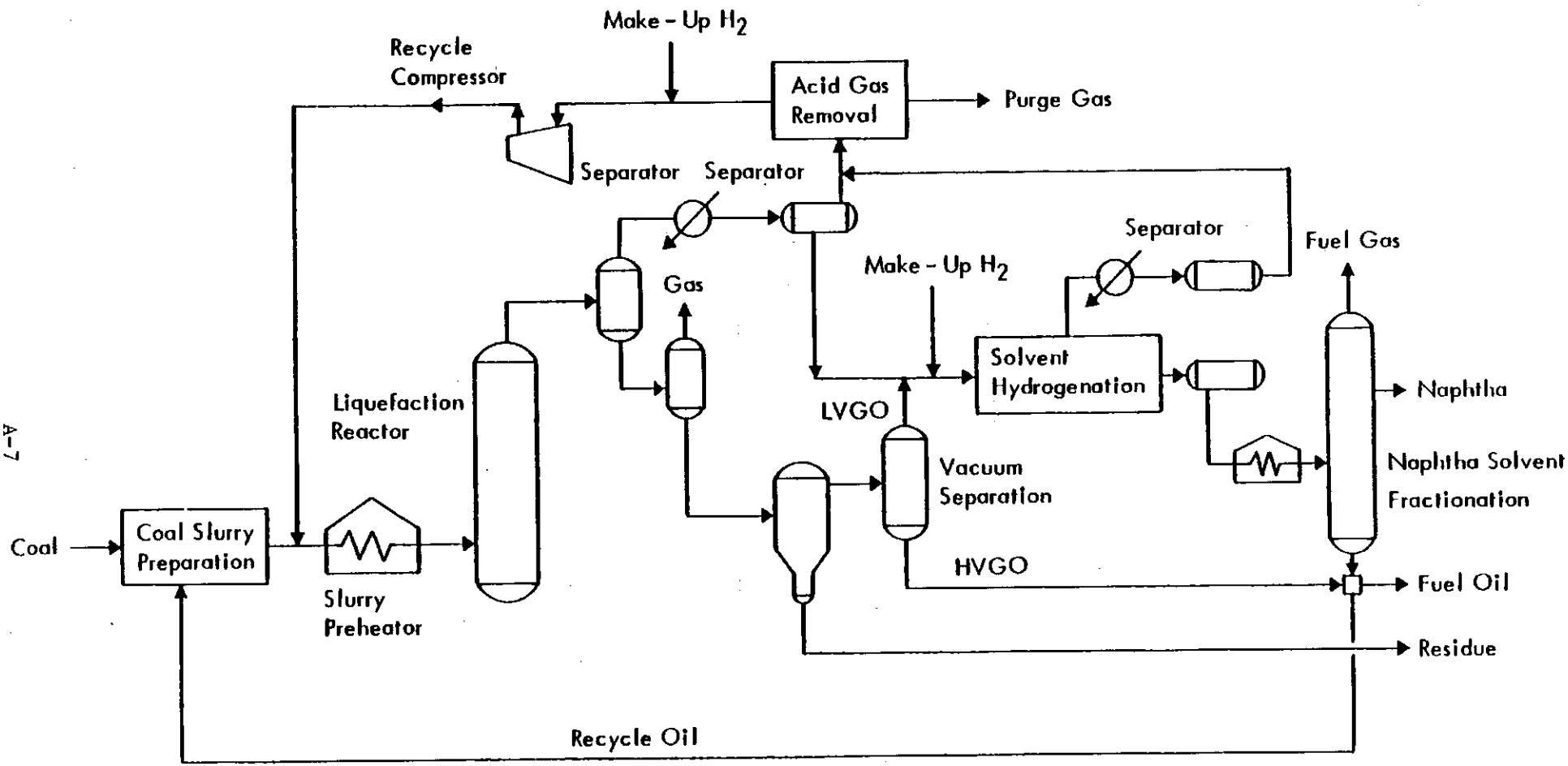


Figure 6. Exxon Donor Solvent Liquefaction Process

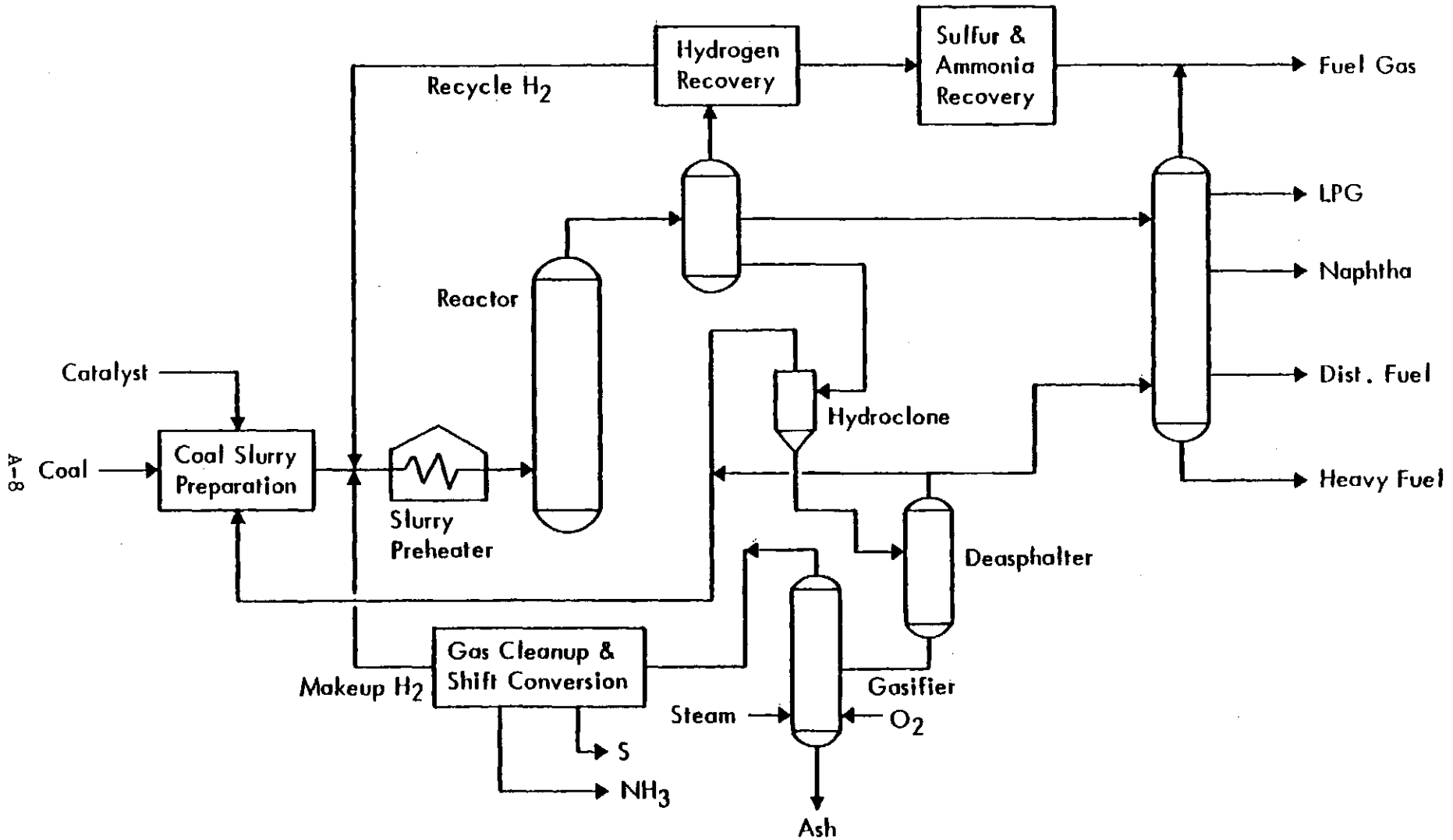


Figure 7. Dow Liquefaction Process

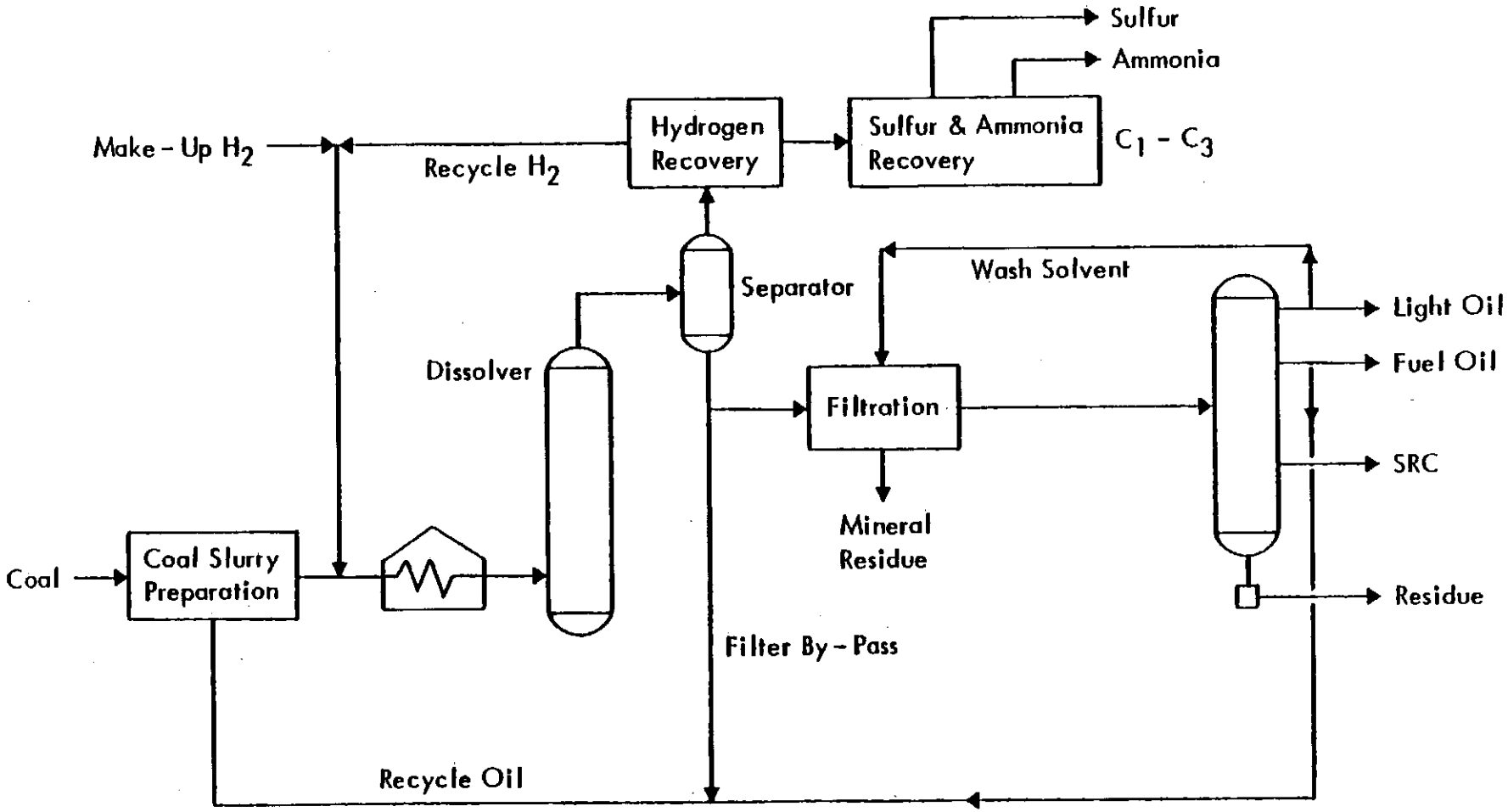


Figure 8. Solvent Refined Coal Process

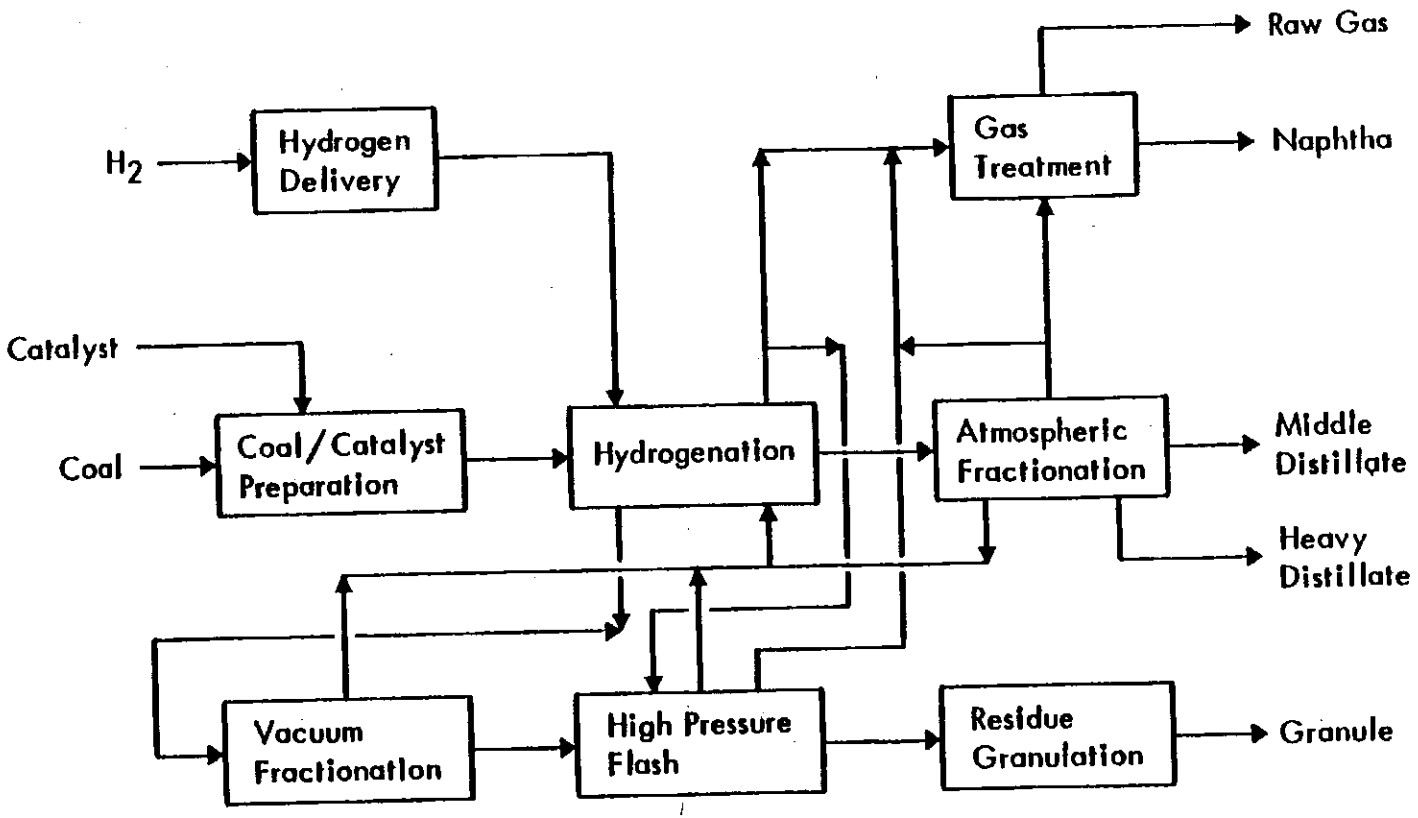


Figure 9. Bergius-Pier Process

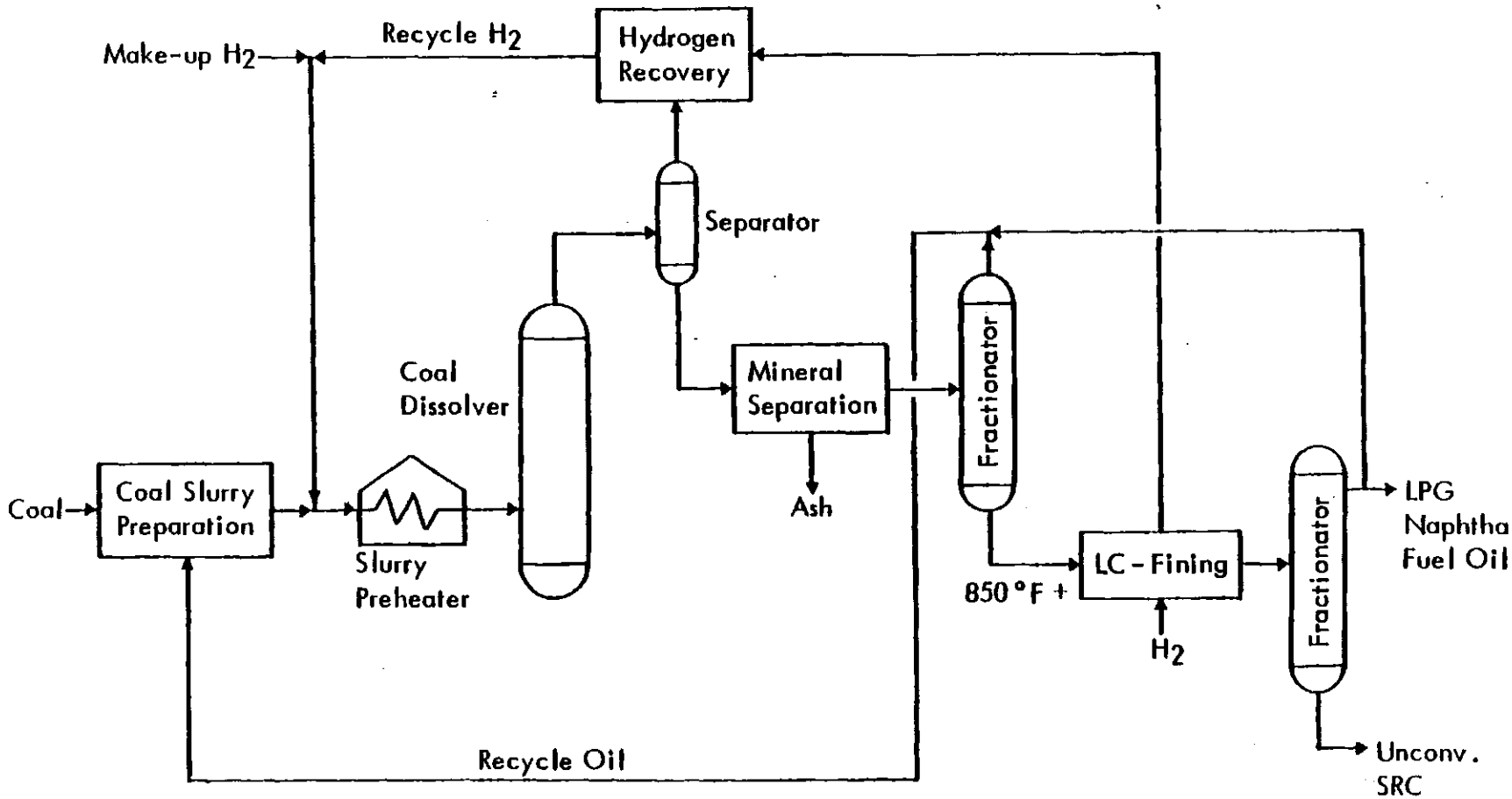


Figure 10. C.E. Lummus Two-Stage Coal Liquefaction Process

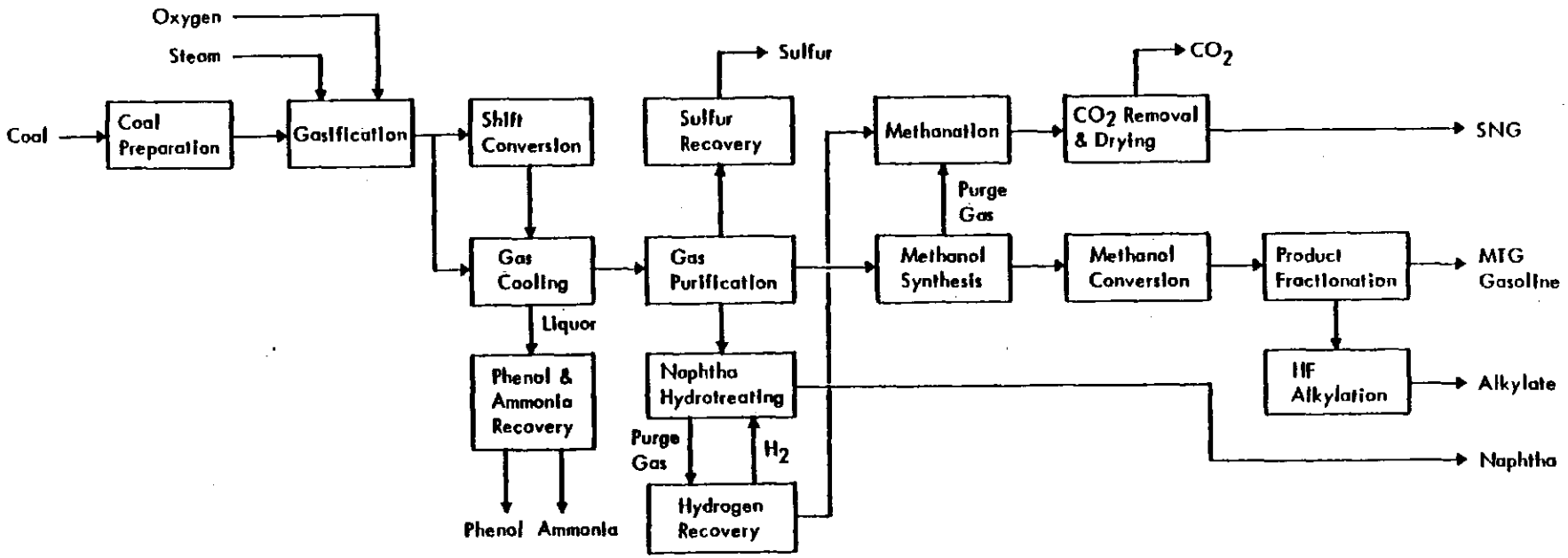


Figure 11. Mobil Methanol-to-Gasoline Process

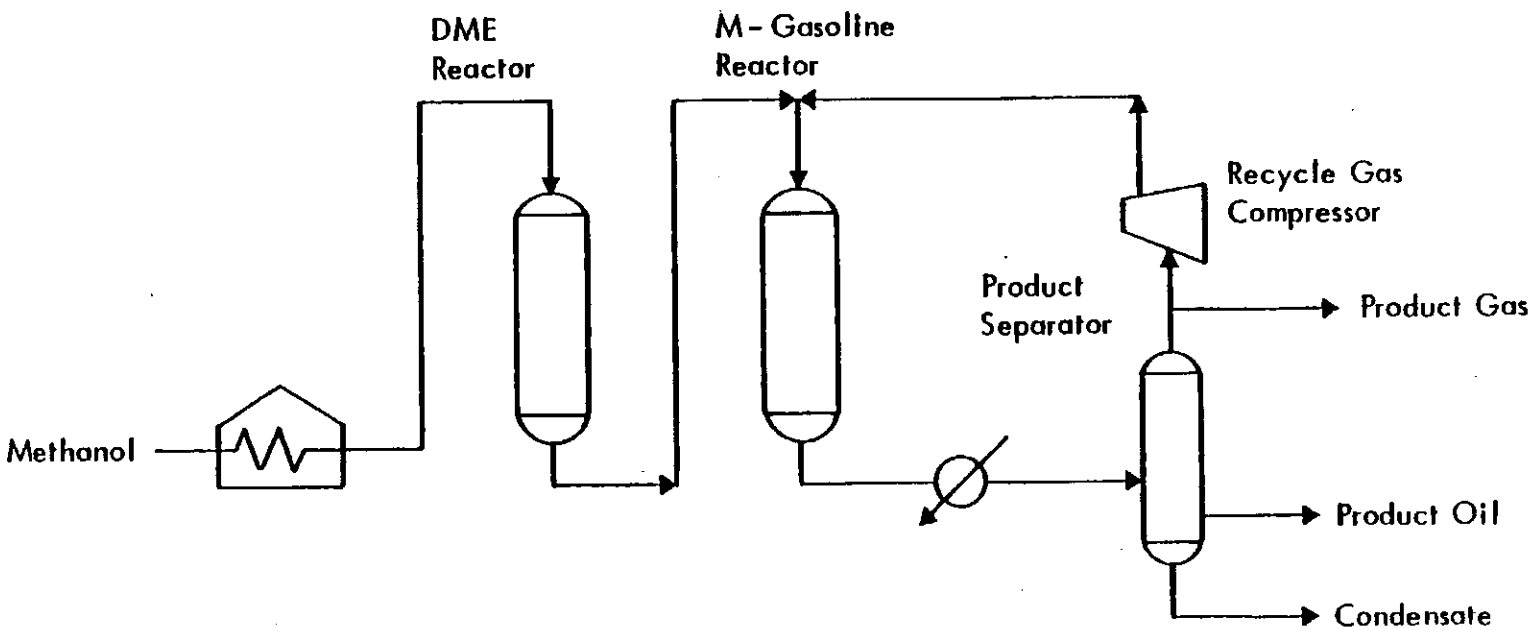


Figure 12. Methanol Conversion Step of Mobil MTG Process

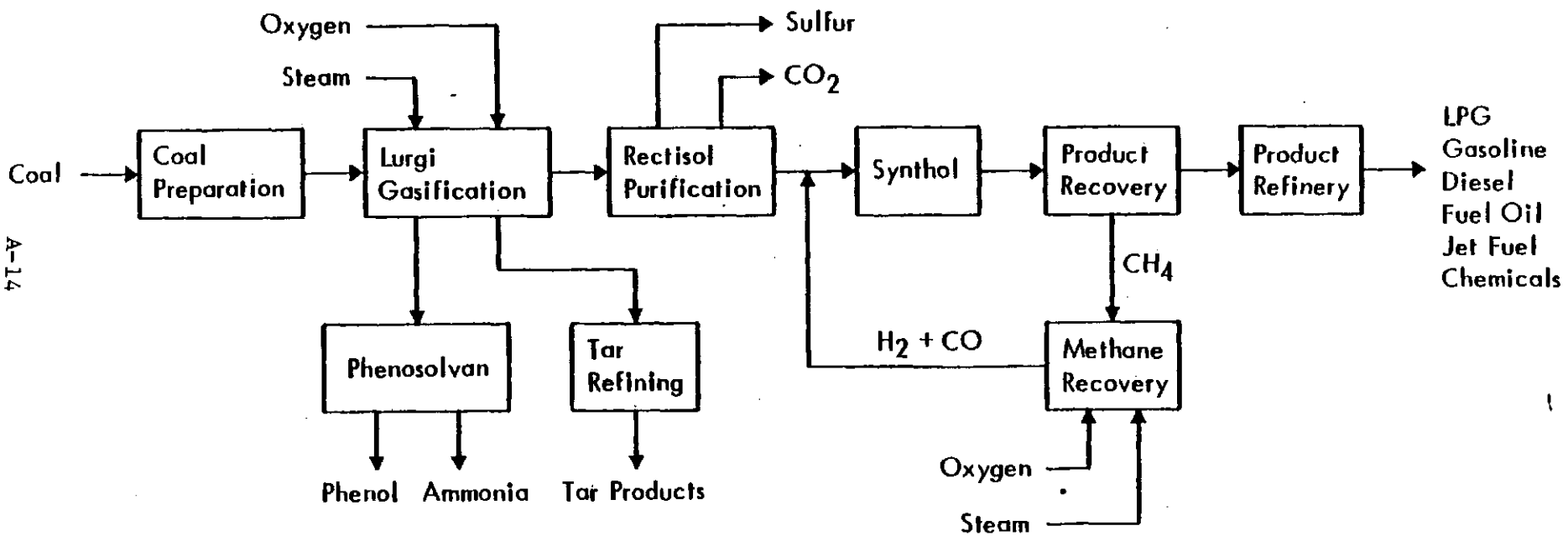


Figure 13. Sasol Indirect Liquefaction Process

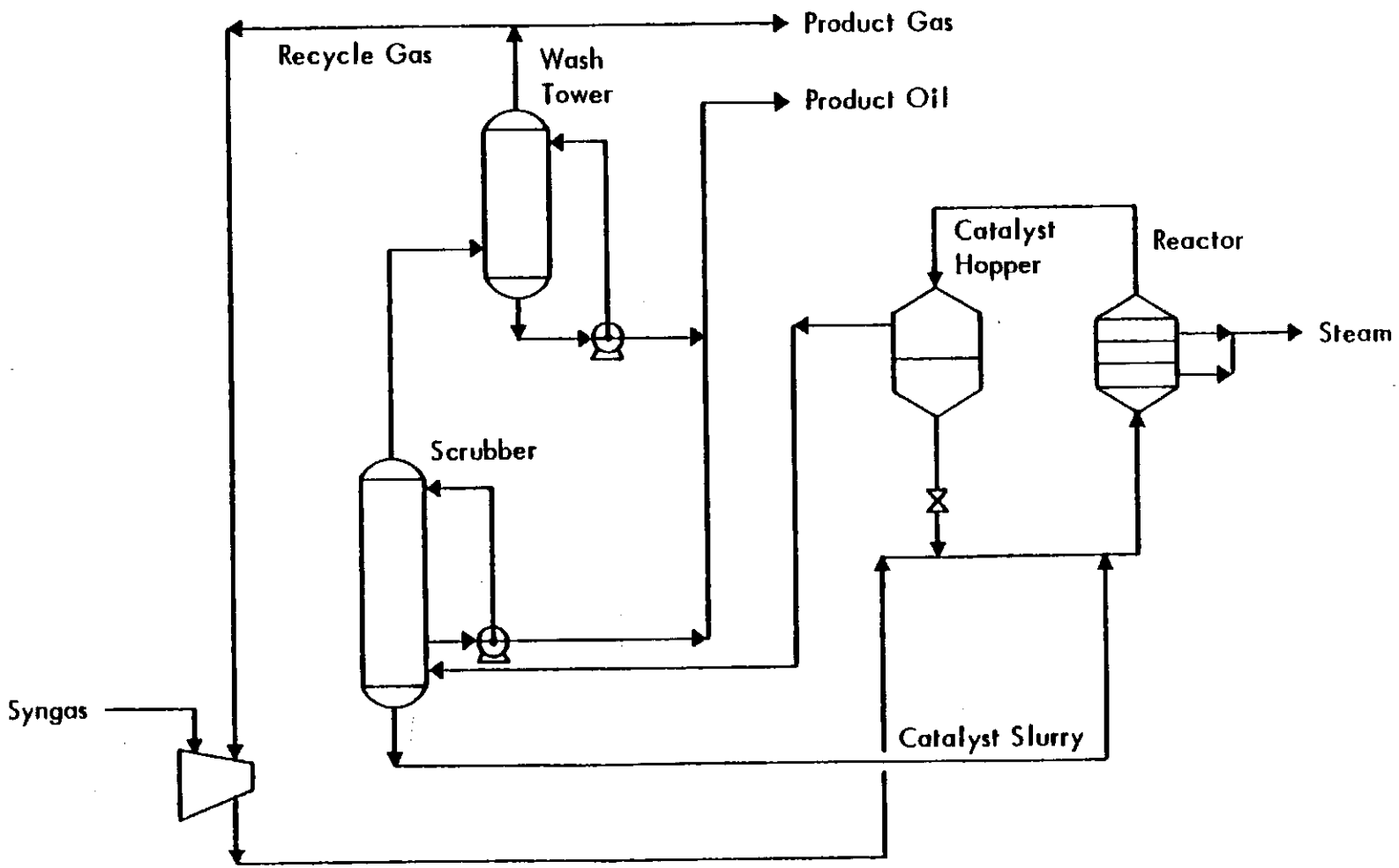


Figure 14. Fischer-Tropsch Process (Synthol)

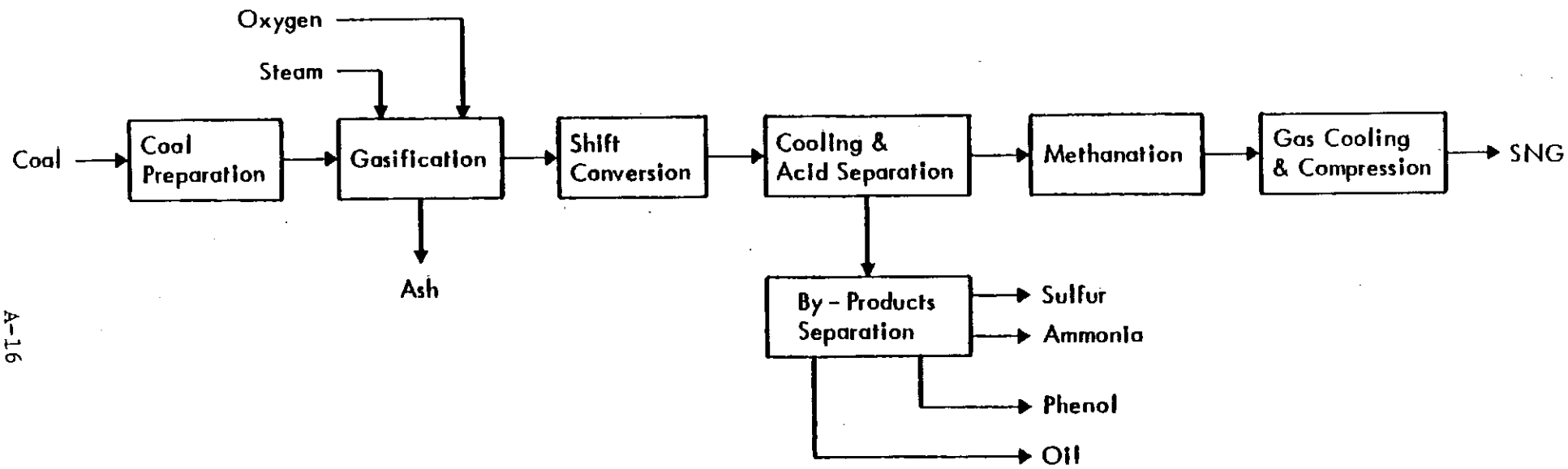


Figure 15. Conoco Coal Gasification Process

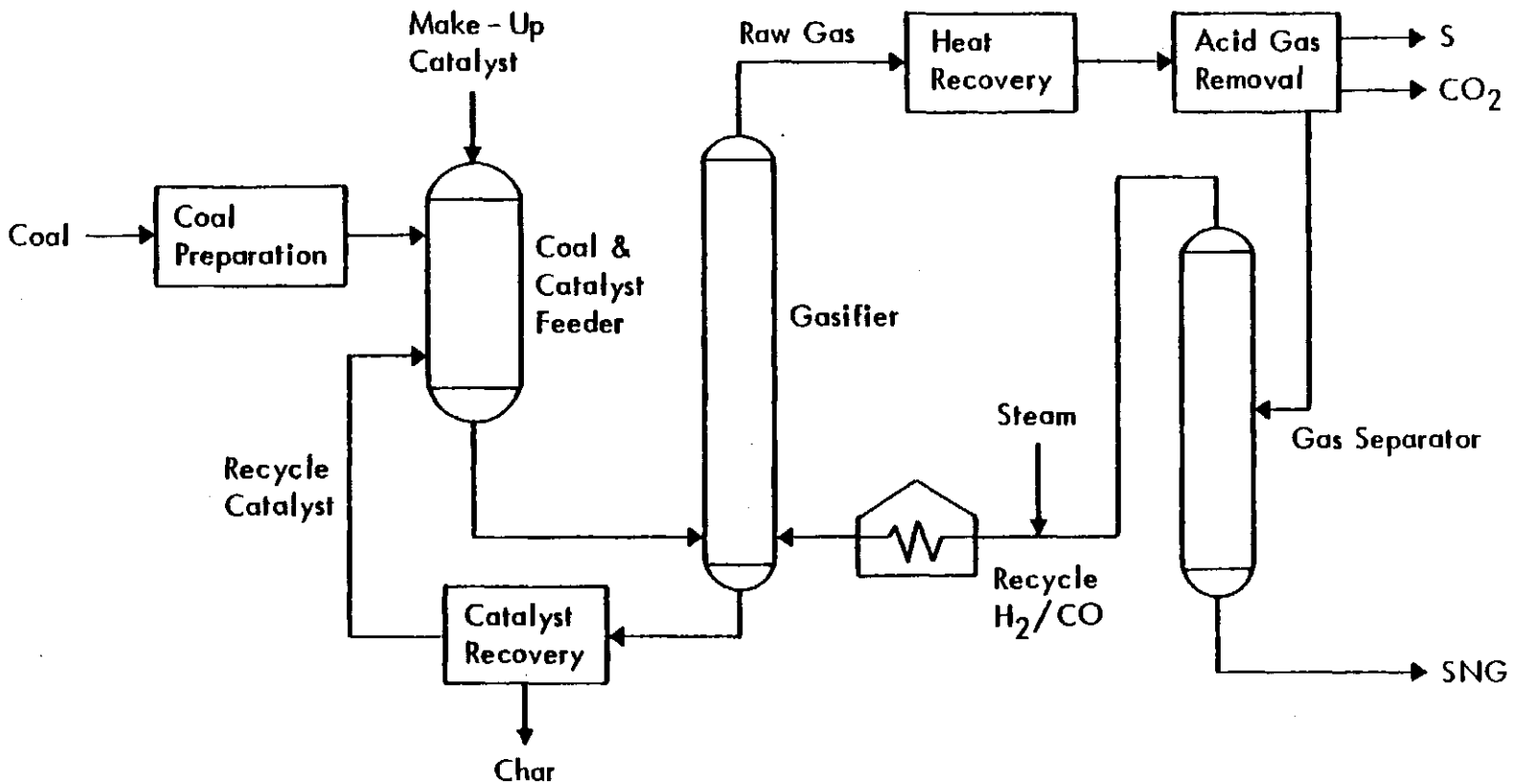
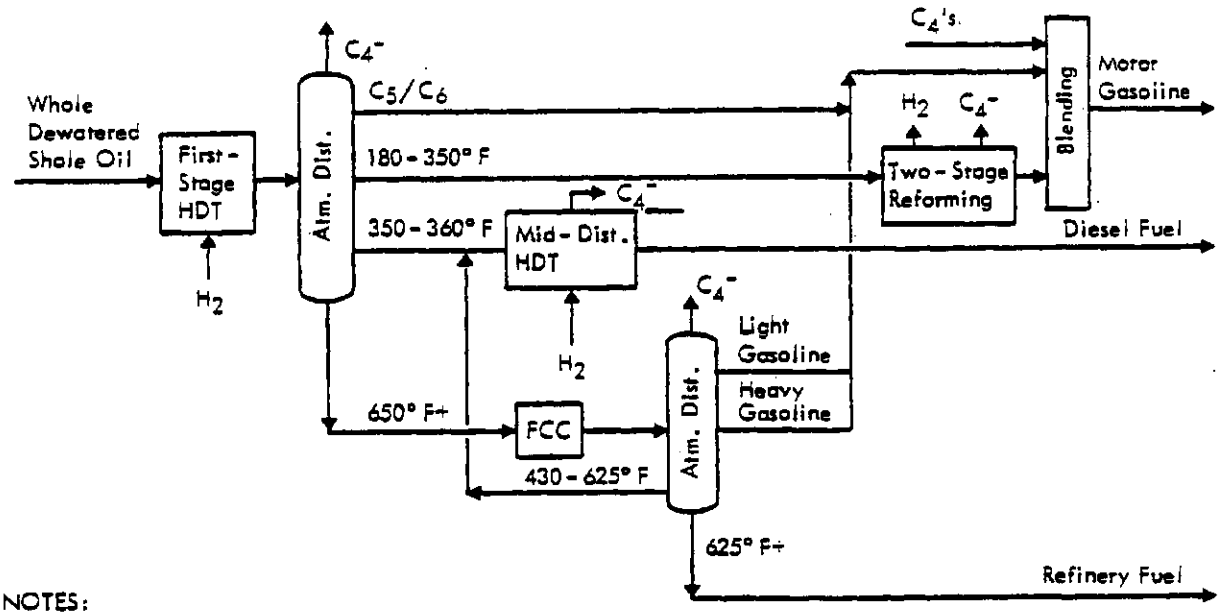


Figure 16. Exxon Catalytic Coal Gasification Process

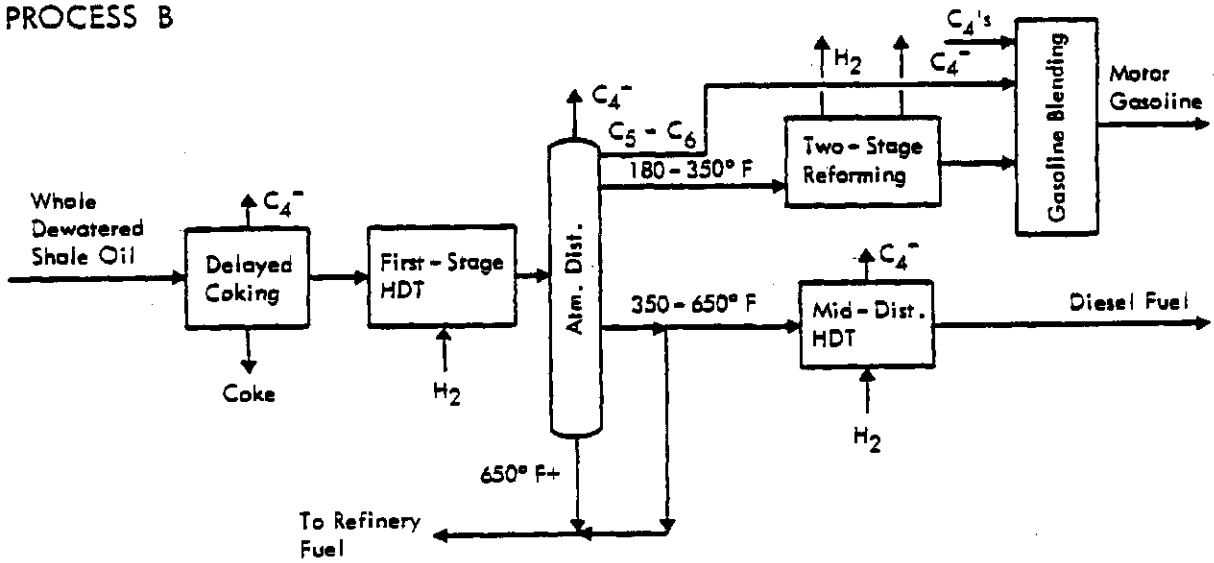
PROCESS A



NOTES:

1. C_4^- is butanes and lighter. Used for H_2 plant feed, gasoline blending, and refinery fuel.
2. Foul gas and water treated to recovery NH_3 and sulfur.
3. HDT = Hydrotreating; FCC = Fluid Catalytic Cracking.

PROCESS B

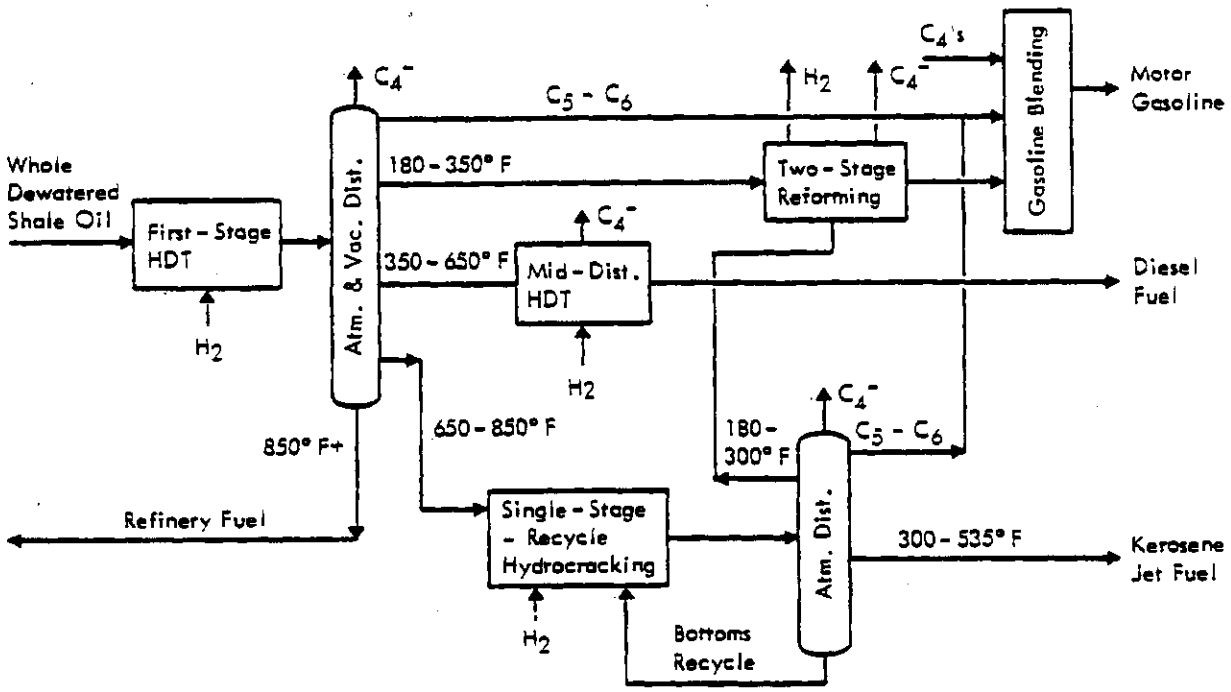


NOTES:

1. C_4^- is butanes and lighter. Used for hydrogen plant feed, gasoline blending, refinery fuel, and liquified petroleum gas (LPG).
2. Foul gas and water treated to recover NH_3 and sulfur.
3. HDT = Hydrotreating.

Figure 17. Three Shale Oil Upgrading Processes

PROCESS C



NOTES:

1. HDT = Hydrotreating.
2. C_4^- is butanes and lighter. Used for H_2 plant feed, gasoline blending, and refinery fuel.
3. Foul gas and water treated to recover NH_3 and sulfur.
4. Some naphtha from first-stage HDT also used for H_2 plant feed.

Figure 17 (concluded)

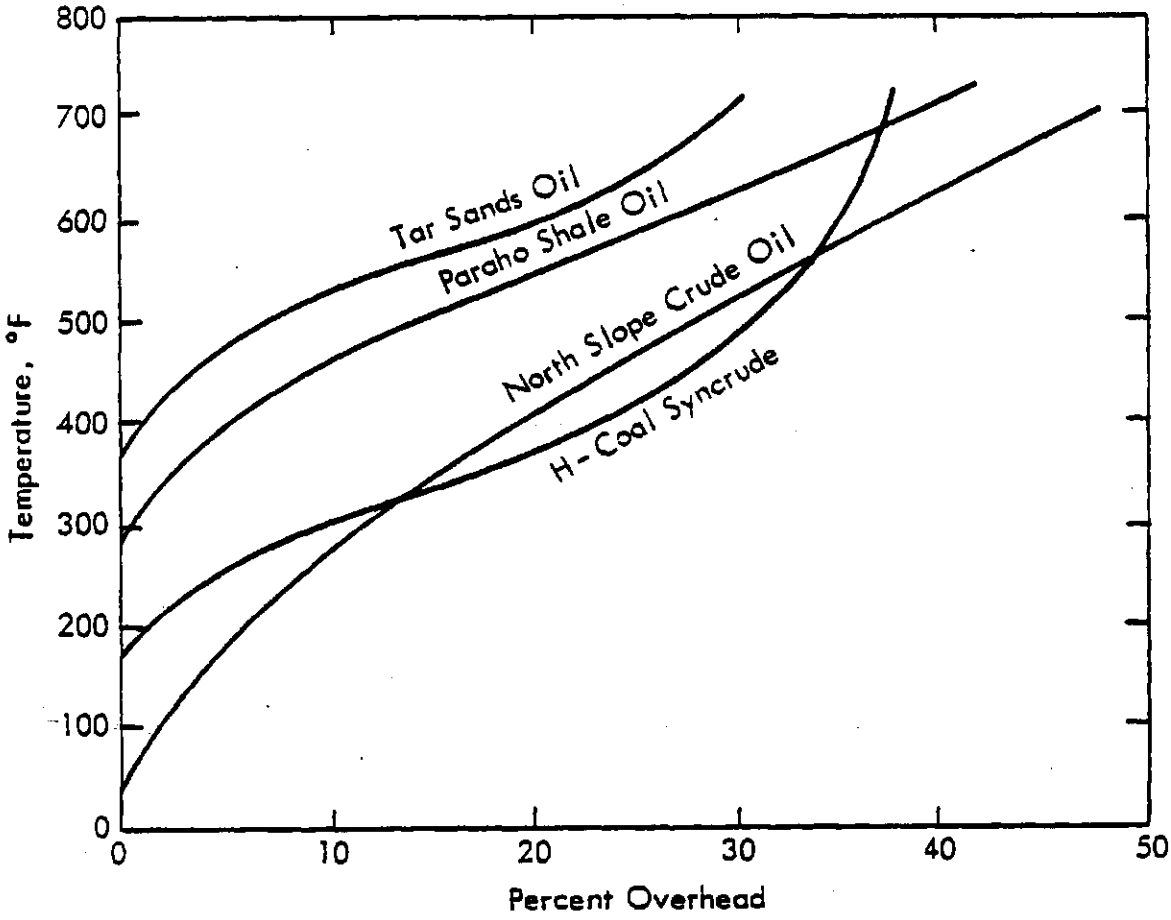


Figure 18. Boiling Range Distributions of a Petroleum Crude H-Coal Oil, and Tar Sands Oil and Shale Oil Before Upgrading (Gallagher, J. P., W. H. Humes, and J. O. Siemssen, "Cat Cracking to Upgrade Synthetic Crudes," Vol. 75, 6, Nov. (1979), p. 46)

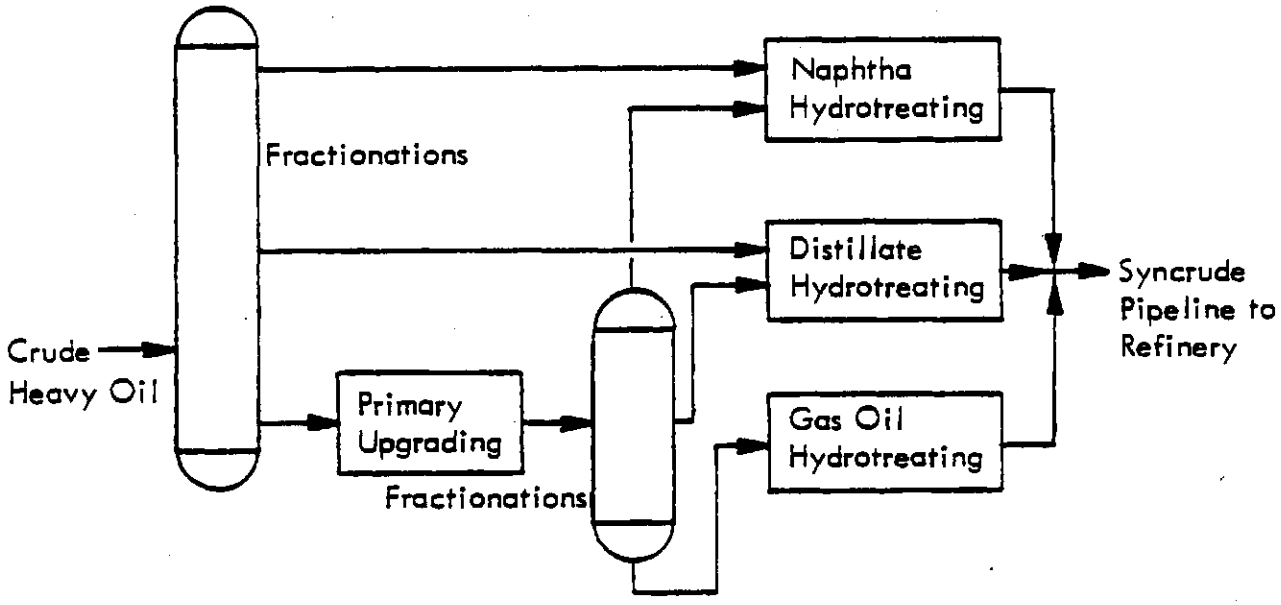


Figure 19. Process for Upgrading Tar Sands, Shale Oil, and Heavy Crude Oil

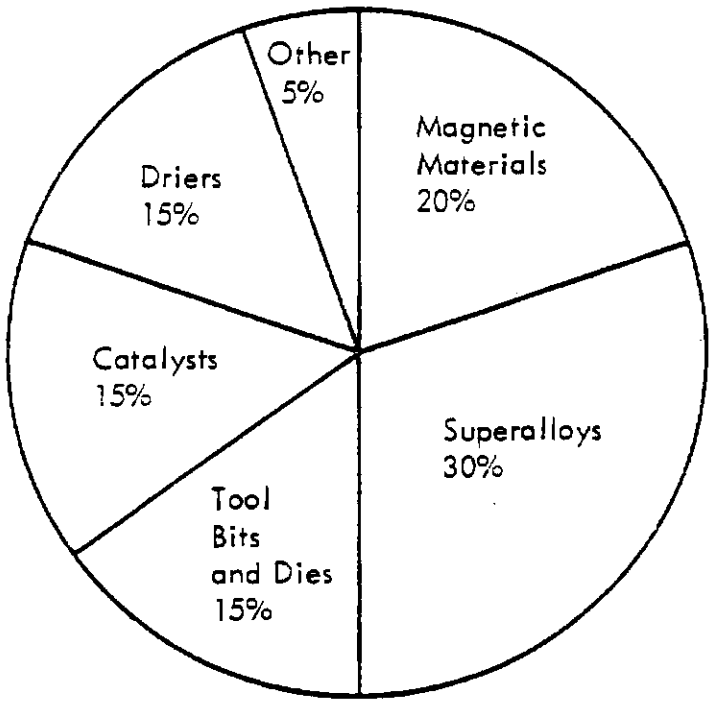


Figure 20. Distribution of Current Cobalt Consumption in the United States (U.S. Bureau of Mines, "Mineral Commodity Summaries 1981," U.S. Government Printing Office 1981-703-002/39, 1981)

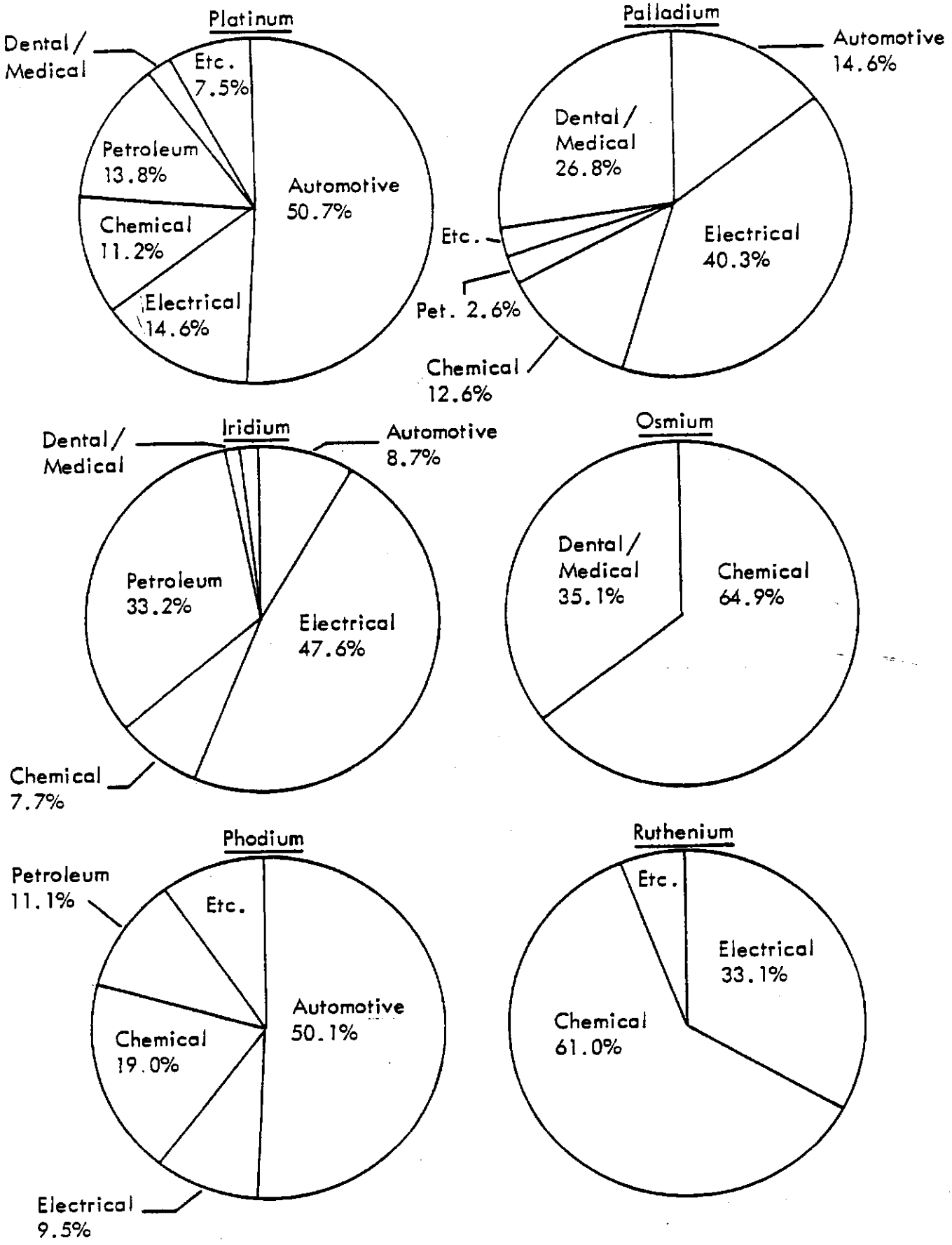


Figure 21. Consumption and Distribution of Platinum Metals in United States by Industry (U.S. Bureau of Mines, 1981)

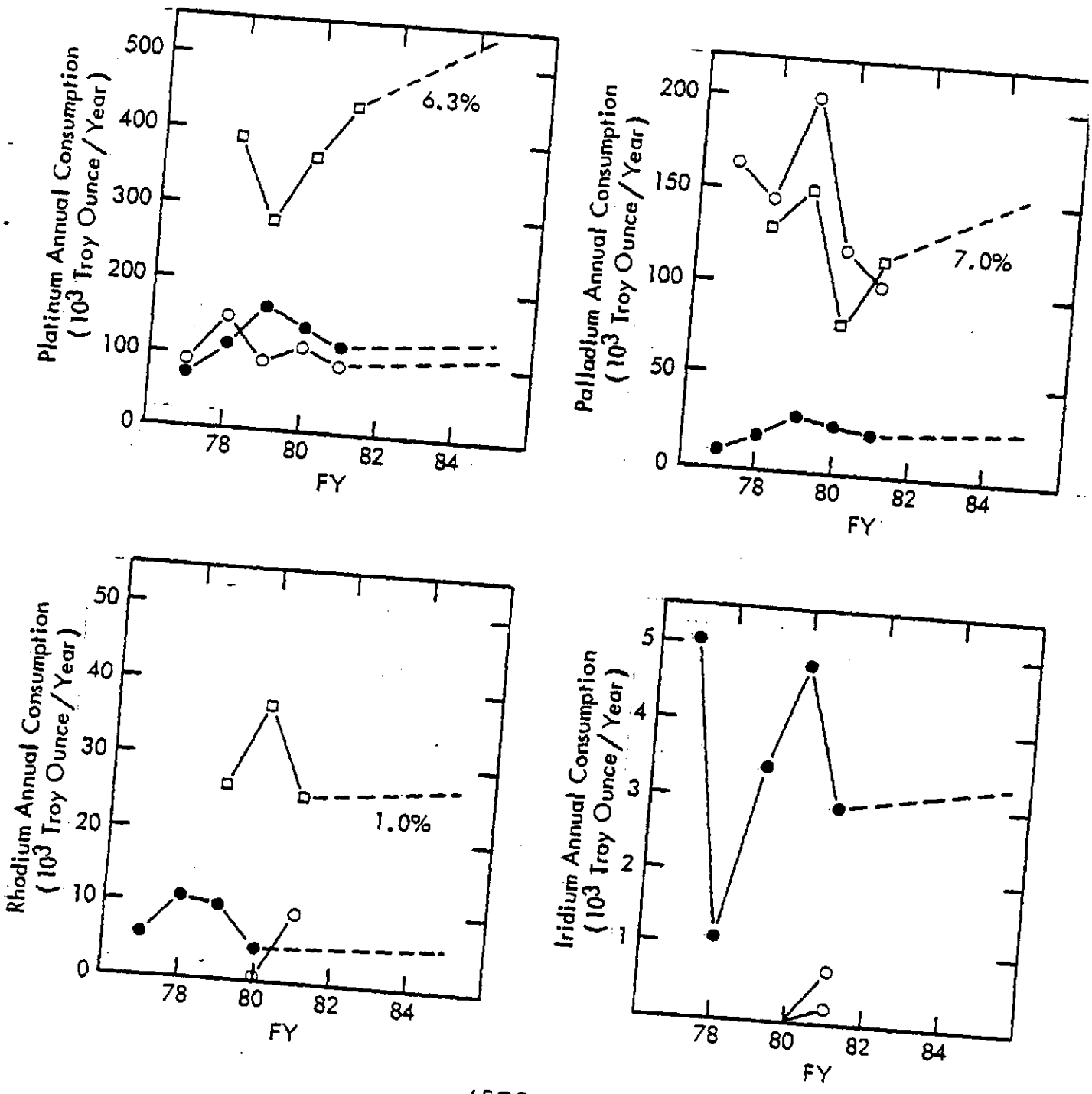


Figure 22. Platinum Group Metals Consumption from 1977 to 1935. The Broken Lines and Accompanying Percentages are the Predicted Rates of Consumption (U.S. Bureau of Mines)

APPENDIX B

PROCEDURE FOR ESTIMATING CATALYST METALS CONSUMPTION FOR 50,000 BPD PLANT

The designated catalyst used in the H-coal process is HDS-1442A, 1/16-in. diameter extrudates, and the analysis of the calcined catalyst by weight percent is:

Molybdenum	8.92%
Cobalt	2.15
Al_2O_3	86.33
Others	2.60
	100.00%

According to the mode operations plan,* the catalyst replacement rate is 1.0 lb/ton dry coal, and the yield of syncrude (by a syncrude mode) is 2.5 bbl/ton-coal. The crude oil production per pound of catalyst would then be

$$\frac{2.5 \text{ bbl/ton-coal}}{1.0 \text{ lb/ton-coal}} = 2.5 \text{ bbl/lb-catalyst}$$

And the annual cobalt consumption for 50,000 BPD plant producing syncrude would be

$$\frac{365(D/Y) \times 50{,}000 \text{ (bbl/D)}}{2.5(\text{bbl/lb-cat.})/0.0215(\text{lb-Co/lb-cat.})} = 157{,}000 \text{ lb/year} = 71.2 \text{ ton-Co/year}$$

Using the same procedure, the annual molybdenum consumption for the plant is calculated to be 295.4 ton-Mo/year.

* H-coal Pilot Plant, Mode Operations Plan, by ASFI, December 4, 1978, (Contract No. Ex-76-C-01-2260).

APPENDIX C

INCREMENTAL CATALYTIC METAL DEMAND FOR SYNFUEL PROCESSES FOR THE PRODUCTION OF 6 MILLION BPP FOR OIL PRODUCTS OR 10 BILLION SCFD SNG

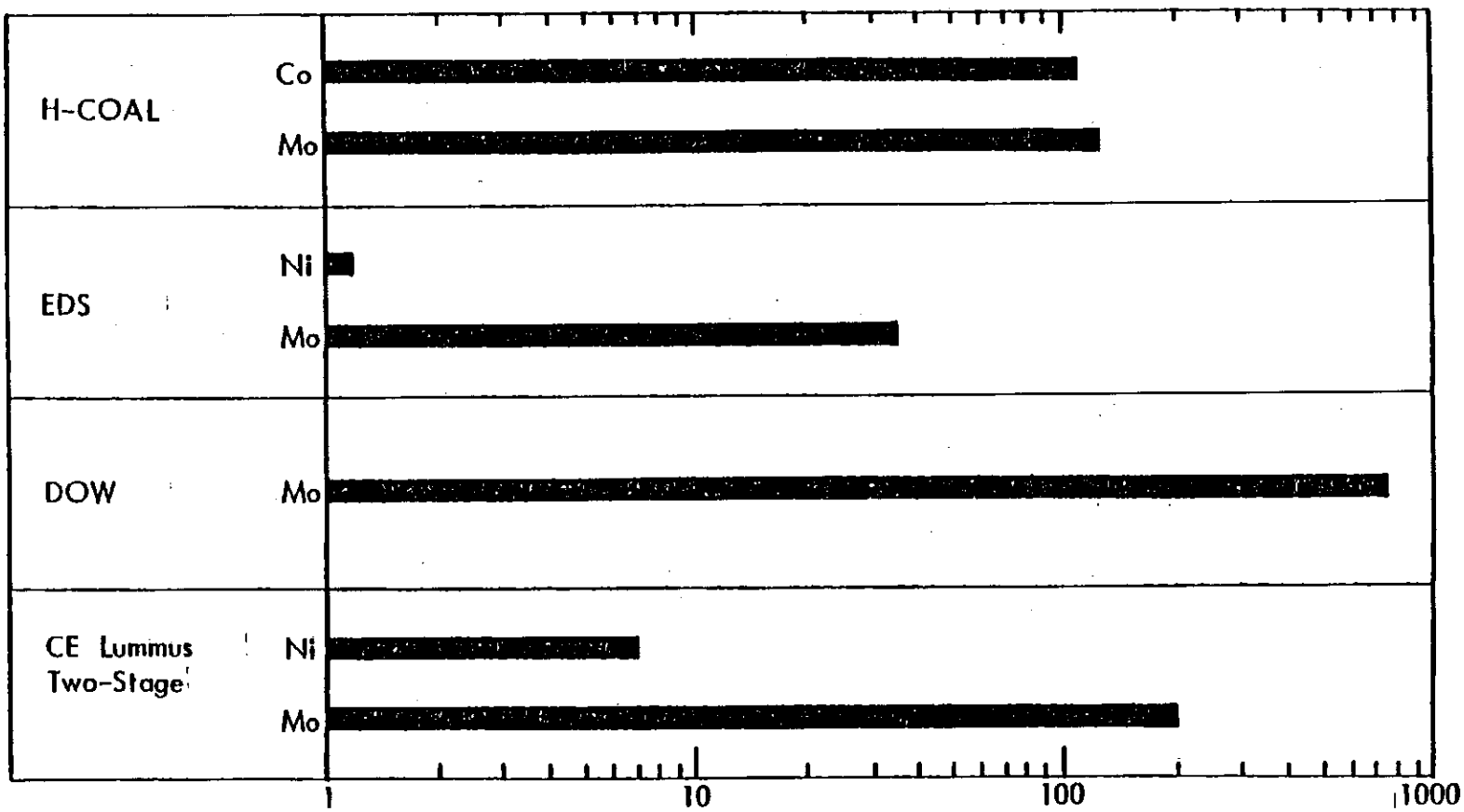


Figure C-1. Incremental Catalyst Metal Demands for Coal Liquefaction Process, by Individual Process, without Catalyst Recovery or Recycle, for Production of 6 mm BBL/d

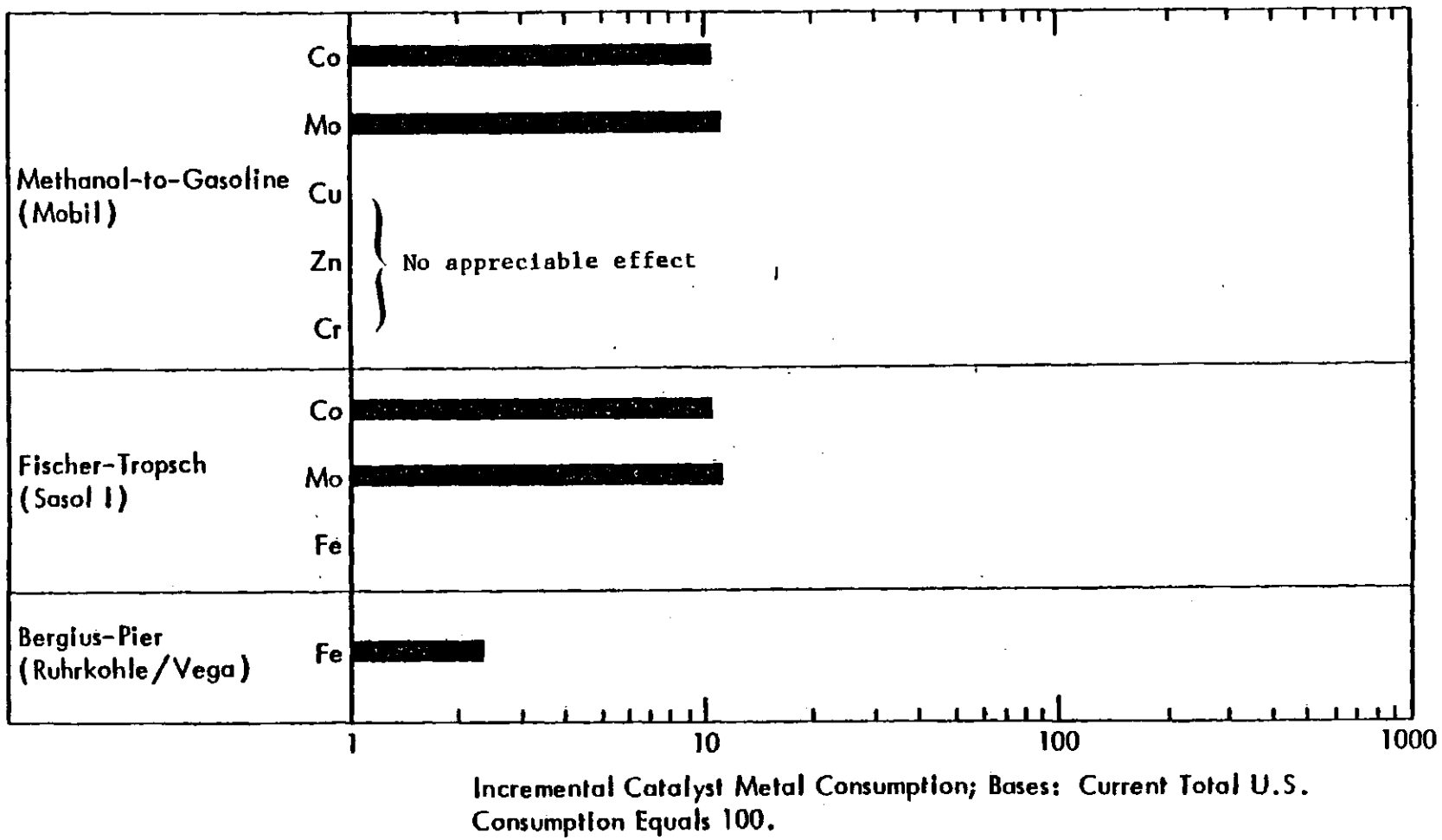


Figure C-2. Incremental Catalyst Metal Demands for Coal Liquefaction Processes Without Catalyst Recovery of Recycle for the Production of 6 mm BBL/d

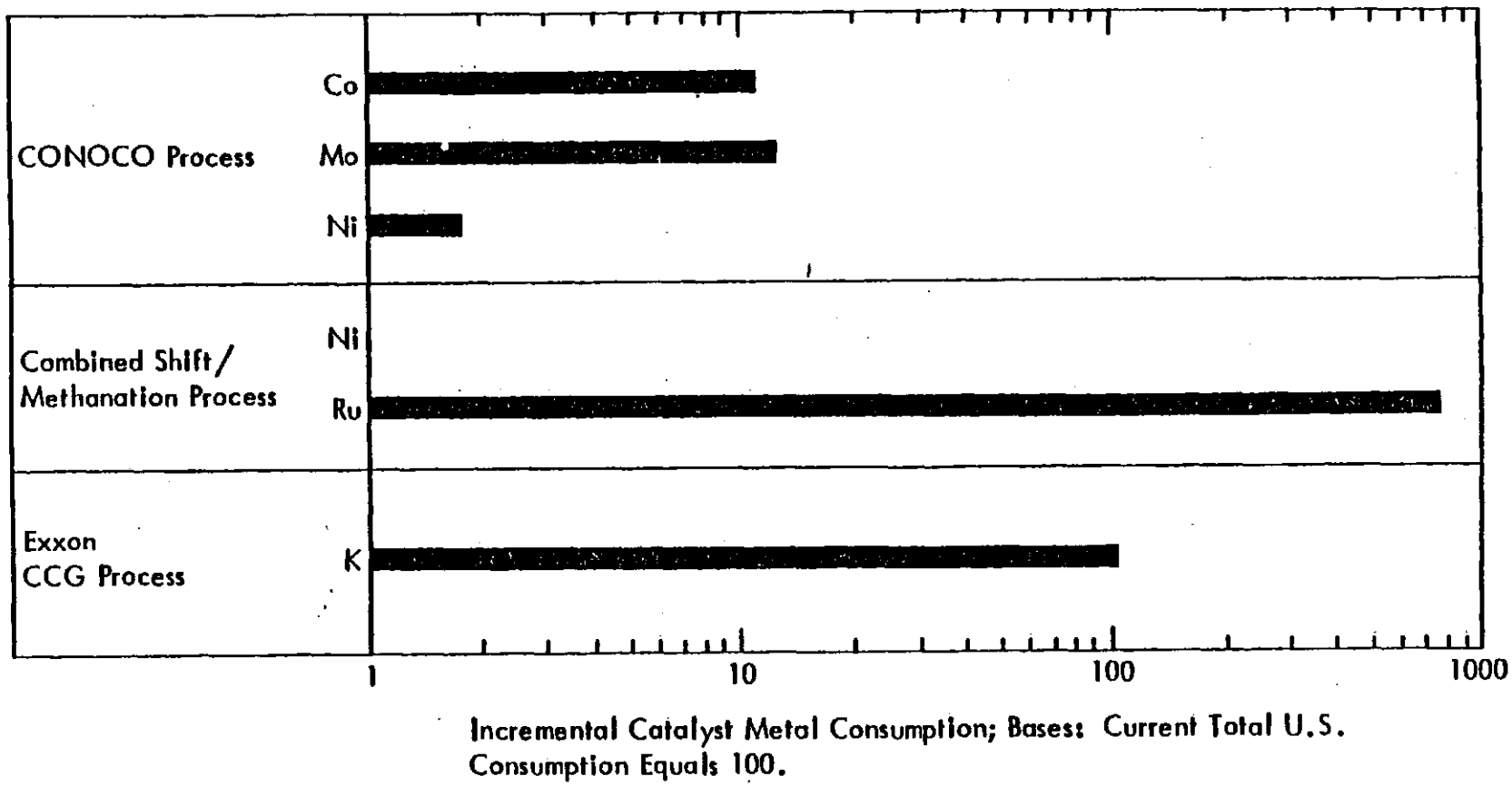


Figure C-3. Incremental Catalyst Metal Demands for Coal Gasification Processes Without Catalyst Recovery or Recycle for the Production of 10 mmm SCF/d