9.0 CONCLUSIONS

Conclusions about pilot plant testing or Cyclar economics have been made at the end of each section. This section contains a comment about how Indirect Cyclar is specified in high-olefin situations as well as a final general conclusion about Cyclar in a F-T upgrading complex.

9.1 DIRECT VS. INDIRECT CYCLAR

The economic analysis of Section 8 was designed to choose between the Direct and Indirect Cyclar options for upgrading LPG. In two cases Direct Cyclar was preferable, and in two cases Indirect Cyclar was preferable. Based on what has been learned in this contract, the Indirect Cyclar units that best fit into an F-T upgrading complex do not use complete saturation. Instead, partial saturation of the feed is employed to take advantage of the LPG olefins, without the excessive costs associated with high-catalyst coking rates at olefin levels above 65 wt-%.

Three hypothetical situations are envisioned for using Cyclar in an F-T upgrading complex. If fresh-feed olefins were 40 wt-% or less, no saturation is needed, and Direct Cyclar should be chosen. If fresh-feed olefins were to exceed 65 wt-%, a Huels CSP unit designed for partial feed saturation should be chosen. The LPG's between 40 and 65 wt-% fresh-feed olefins are in a gray area. In theory, partial saturation is not needed; however, operating in a less-sensitive regime with respect to coke formation is preferable. Process-unit upsets and feed-composition fluctuations can cause major problems when operating too near this critical point. One suggestion made in this report is to target the partial saturation for 50 wt-% olefins in cases where feed olefins are in excess of 55 wt-% and to install the appropriate blank-off flanges for adding a partial saturation unit if required at a later date (because of a feed-composition change, for example) in units designed for LPGs between 40 and 55 wt-% olefins. These proposed criteria are summarized in Table 9.1.

9.2 GENERAL CONCLUSION

Cyclar is a promising technology for use within an F-T product upgrading complex. Cyclar directly addresses the problem of what to do with F-T LPG. Cyclar not only uses C_3 and C_4 olefins (which could be polymerized as an alternative) but also C_3 and C_4 paraffins. With the exception of alkylation (that uses only the isobutane), few process alternatives are available for the direct conversion of LPG paraffins into liquid products.

For a 5,675 MT/day Arge upgrading complex with a wax hydrocracker operating at high severity (large LPG production rate), a Cyclar unit contributes more than 4,500 BPSD of a high-octane (106 R+M/2), low-RVP (1.6 psia) aromatics product. The liquid product is 89.1 wt-% BTX aromatics and 10.9 wt-% heavier aromatics. Aside from the liquid product, Cyclar makes a valuable 95 vol-% purity hydrogen coproduct. The hydrogen production rate exceeds 1,200 SCFB of LPG feed, or about 14 MM SCFD hydrogen production for the complex referenced above. This hydrogen production is sufficient to change the upgrading complex from a hydrogen consumer to a net exporter of hydrogen.

TABLE 9.1

Proposed Saturation Unit Requirements for Olefinic LPG's

Fresh-Feed Olefins, Wt-%	Saturation Unit
0-40	CSP unit is not required.
40-55	Provide appropriate blank-off flanges to add CSP at later date if desired.
Above 55	Specify CSP unit capable of reducing the Cyclar fresh-feed olefin level to 50 wt-% olefins.

10.0 ACKNOWLEDGMENTS

The majority of funding for this program was provided by the U.S. Department of Energy under Contract No. DE-AC22-86PC90014. The authors would like to acknowledge not only the financial support but also the administrative and technical support provided by the Pittsburgh Energy Technology Center (PETC) and the DOE Office of Coal Conversion.

The authors also wish to acknowledge major contributions made by Joseph Kocal, Lawrence Matson, and Ronald Kraft of the UOP Des Plaines Technical Center; David Martindale and Patrick Sajbel of UOP Marketing Services; and Douglas Nafis and Charles Luebke of UOP Engineering Research and Development.

11.0 REFERENCES

1. P. P. Shah, "Fischer-Tropsch Wax Characterization and Upgrading Final Report", prepared under U.S. DOE Contract No. DE-AC22-85PC80017, June 6, 1988.

2. Mark E. Dry, Catalyst Science and Technology, 1(1981):159.

3. P. A. Jacobs and D. V. Wouve, Journal of Molecular Catalysis, 17(1982):145.

4. H. Abrevaya, "The Development of a Selective Ruthenium Fischer-Tropsch Catalyst," prepared under U.S. DOE Contract No. DE-AC22-84PC70023, Feb. 28, 1989.

5. R. F. Anderson, J. A. Johnson, and J. R. Mowry, "Cyclar," presented at the American Institute of Chemical Engineers Spring National Meeting, Houston, TX, Mar. 1985.

6. R. W. Bennett, R. L. Peer, and S. T. Bakas," Advances in CCR Platforming -- The Second Generation," presented at the NPRA Annual Meeting, San Antonio, TX, Mar. 20-22, 1988.

7. M. E. Dry, "The Sasol Route to Fuels," Chem. Tech., (Dec. 1982):744-50.

8. J. C. W. Kuo, "Two Stage Process for Conversion of Synthesis Gas," Mobil Research and Development Corporation Final Report to DOE, Oct. 1985, prepared under U.S. DOE Contract No. DE-AC22-83PC60019.

12.0 LIST OF ABBREVIATIONS

Abbreviation	Meaning
A_9+	Heavy Aromatics (Nine or More Carbons)
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
BTX	Benzene, Toluene, and Xylenes (including Ethylbenzene)
BFW	Boiler Feed Water
BP	British Petroleum
BPSD	Barrels per Stream Day
Btu	British Thermal Unit
°C	Degrees Centigrade (Celsius)
$C_\#$	Carbon Number (e.g., C_1 = Methane)
CF	Combined-Feed Basis
CFR	Combined-Feed Ratio
CSP	(Huels) Complete Saturation Process
DB	Direct Cyclar Blend
DOE	United States Department of Energy
EEC	Estimated Erected Cost
EP	End Point
°F	Degrees Fahrenheit
FF	Fresh-Feed Basis
F-T	Fischer-Tropsch
gal	U.S. Gallon
GC	Gas Chromatography
GJ	Giga Joule
HC	Hydrocarbon
HCU	Hydrocracking Unit
HPS	High-Pressure Steam
IB	Indirect Cyclar Blend
IBP	Initial Boiling Point
IRR	Internal Rate of Return
ISBL	Inside Battery Limits
kW	Kilowatt
kWh	Kilowatt Hour

List of Abbreviations (Continued)

Abbreviation	Meaning
LHSV	Liquid Hourly Space Velocity
LPG	Liquefied Petroleum Gas
lb	Pound (Mass)
LPS	Low-Pressure Steam
M	Thousands
MM	Millions
MON	Motor Octane Number
MT	Metric Ton (1,000 kg)
MTA	Metric Tons per Annum
MTD	Metric Tons per Day
NPV	Net Present Value
ROI	Return on Investment
P	Pressure (Reactor)
PETC	Pittsburgh Energy Technology Center
ppm	Parts per Million
psi(a)	Pounds per Square Inch (Absolute)
psi(g)	Pounds per Square Inch (Gauge)
RON	Research Octane Number
RVP	Reid Vapor Pressure
SCF	Standard Cubic Feet
SCFB	Standard Cubic Feet per Barrel
SCFD	Standard Cubic Feet per Day
Wt	Weight (Mass)
Vol	Volume
(R+M)/2	Average of Research + Motor Octane