8.0 ECONOMIC EVALUATION

Two different ways to incorporate Cyclar technology into an F-T upgrading facility, Direct and Indirect Cyclar, have been discussed in this report. Based on the pilot plant studies detailed in Section 6, both routes are technically feasible. The purpose of this economic evaluation is to decide which route is better for the F-T reactor technologies identified in Section 7 (including the Arge plus hydrocracker LPG case).

8.1 EVALUATION PROCEDURE

The economic evaluation is the culmination of a series of steps (Figure 8.1). The pilot plant work demonstrates technical feasibility and provides data for yield estimates. Process conditions are optimized in the commercial yield estimating step. Outputs from the yield estimates are used to generate estimates of capital and operating costs.

After the first three steps are complete, enough information is generated to permit an economic evaluation However, even with this much information, the evaluation is only preliminary in nature. The estimates of capital cost are arrived at by using cost curves as well as other estimation techniques. Detailed engineering for each case is not warranted at this point. The preliminary economic evaluation is sufficient to provide an indication of which route, Direct or Indirect Cyclar, is preferable for each situation defined in Section 7.

8.1.1 Evaluation Technique

Capital requirements, operating costs, feedstock costs and product values are inputs to the economic evaluation. The evaluation revolves around two capital budgeting questions. First, do the timing and magnitude of operating profits justify the capital expenditure? Second, how does this expenditure compare to mutually exclusive alternatives?

Many procedures are available to assist a capital-budgeting decision. Payback period and return on investment (ROI) are commonly used as a first approximation. Other methods, such as discounted internal rate of return (IRR) and net present value (NPV), are more rigorous because they consider the time value of money and offer a clear decision rule. In this report, IRR is used.

To determine an IRR, capital charges and operating profits are considered in terms of present value at unit start-up ($t = 0$). The IRR is the discount rate applied to operating profits that creates a present value (PV) of profits equal to the capital expenditure (Figure 8.2). The greater the IRR, the more profitable the operation. If feedstock costs and product values are known, IRR can be determined directly. If either the feedstock cost or product value is uncertain (one must be specified), the IRR can be fixed at a minimum acceptable percentage (hurdle rate) before solving the equation. The result indicates how low feedstock costs or how high product values must be to ensure the minimum IRR.

Sensitivity analyses are also useful to perform. The IRR can be determined over a range of LPG costs, aromatics values, and hydrogen coproduct values. The cost sensitivity of LPG is important when indirect liquefaction economics is tied into upgrading economics. Product-value sensitivity is important when the aromatics from a Cyclar unit are considered as a petrochemical feedstock rather than as a gasoline blending stock. Hydrogen value can range between fuel value and chemical value, depending on the overall hydrogen needs of the specific upgrading complex in question.

8.1.2 Price and Cost Basis for Economic Evaluation

Feedstock, product, and utility prices used in this evaluation are summarized in Table 8.1. These prices are reasonably accurate for a scenario in which the price for oil is $18-19 per barrel.

If the Cyclar product were blended into a gasoline pool, it would be valued somewhere between gasoline and a BTX petrochemical value. Cyclar liquid product is inherently more valuable than gasoline because of its high octane (about 111 RONC) and low RVP (1.6 psia). Toluene is the least valuable BTX aromatic and provides a good estimate for the value of a high-octane, low-RVP blend stock.

Hydrogen may be valued anywhere between fuel gas (on an equivalent Btu basis) and its chemical value. The value is largely determined by the overall hydrogen needs of the complex in question. An intermediate value between fuel gas and chemical hydrogen was chosen for this evaluation (except for the sensitivity analysis).

8.1.3 Fuel Gas Production and Consumption

Some of the fuel gas produced within the Cyclar unit can be used to fuel fired heaters and to drive the product recovery compressor. Cyclar fuel gas is treated as a product (naturally, not the desired product), and total energy requirements are treated as a cost. The fuel gas product value credit is offset by the utility requirements (listed as "Fuel Fired" in the utility estimates, Tables 7.19 and 7.20). The fuel cost ($2.10/MM Btu) is priced to match the fuel gas product value credit ($100/MT) so that process economics is not affected. The implied heating value for the fuel is 47.6 MM Btu/MT, which is consistent with C_1-C_2 fuel gas.

Fuel gas production and consumption rates are summarized in Table 8.2. Fuel gas consumption is expressed as a percentage of fuel gas production. In each case, fuel gas is exported. More fuel gas is consumed internally in the Indirect Cyclar cases (even numbered cases) compared to the Direct Cyclar cases for three reasons:

- The lower process pressure for Indirect Cyclar requires more energy to drive the product compressor than does

Direct Cyclar because of the larger pressure differential between the product separator (low pressure) and the product recovery (high pressure) sections of the plant.

- Paraffinic Indirect Cyclar feeds have a greater heat of reaction, resulting in a larger endotherm per unit of conversion. More fuel gas is consumed in the interstage heaters to compensate for the greater endotherm.
- Direct Cyclar is able to run at higher pressure without an excessive decline in liquid-product yield. Higher pressure results in higher conversion per pass and therefore a smaller combined feed ratio (CFR). Fired heater duties are directly proportional to the CFR.

8.1.4 Treatment of Offsites

For estimating the return on the construction of a grassroots upgrading complex, the impact of offsite capital expenditure must be considered. Offsites include such items as feed and product storage and handling, steam generation, hydrogen production, waste treatment, and cooling water supply facilities.

Offsites are not included in the Cyclar evaluation because:

- Offsite requirements should be addressed after the entire upgrading complex has been defined.
- Cyclar does not require any unusual offsite support. If Cyclar were added to an existing complex. its impact is the incremental demand on the low-pressure steam, cooling water, and electricity supply and distribution grid. The increased demand on the electrical distribution system is the most costly factor. Utility requirements

for an Arge upgrading complex are estimated in a previous contract (1). These totals are compared with rough estimates of a complex with a Cyclar unit substituted for a catalytic polymerization unit (Table 8.3). Cyclar eliminates the need for offsite utilities to make hydrogen, high-pressure steam, and medium-pressure steam. The complex actually exports hydrogen, and the high pressure steam generation equipment is included in the Cyclar EEC.

- If the Cyclar liquid product were added to the gasoline pool, little if any additional product tankage is necessary.
- The goal of this evaluation is to compare Direct and Indirect Cyclar economics. Because offsite expenditure is similar for either route, it does not affect the choice between these alternatives.

8.2 CAPITAL COST AND NET OPERATING PROFIT CALCULATIONS

This section describes the treatment of capital costs and the determination of operating profits. Assumptions implicit in each category are discussed. The descriptions follow the Direct and Indirect Cyclar capital cost and operating profit summaries (Tables 8.4 through 8.7).

8.2.1 Capital Expenditure

The largest component of total capital requirement is the capitalized EEC. Construction is assumed to spread over a three-year interval, with 20%, 50%, and 30% of the total capital expended each year, respectively. Capital expenditure in the first and second years does not generate revenue until start-up. To account for this fact, an interest rate, compounded annually, is charged to reflect an opportunity cost. The alternative investment rate for these sunk funds is 10%. Applying the interest charges gives the present value of EEC capital at the time of unit start-up.

Aside from the capitalized EEC, the initial catalyst loading is added to the capital requirement, assuming that the catalyst arrives onsite just prior to start-up.

An assumption is made that the project is 100% equity financed for the purpose of making a capital budgeting decision. Debt financing has implications on the debt-equity structure and therefore the cost of capital. Assuming a cost of capital is not necessary for IRR calculations. Typically, the IRR is compared to the cost of capital in order to make go or no-go decisions. In this report, IRR's from mutually exclusive alternatives are compared in order to choose the better alternative. The implication of 100% equity financing in this case is that the interest charges added to the EEC (to arrive at a capitalized EEC) are not subtracted from income or depreciated in any form.

The equity financing assumption is consistent with the goal of making the best possible capital budgeting decision. After the best alternative (including the do-nothing alternative) is identified, specific decisions regarding how the project is actually financed can be made independently.

8.2.2 Gross Margin

Gross margin is the value added to the fresh feed as a result of processing. The key inputs to the gross-margin calculation are the mass balanced yields from Section 7 and the feedstock cost and product-value assumptions stated in Table 8.1. Mass flow rates are converted to dollar flow rates. The result is a net value added to the feed expressed in dollars per unit time.

The operating year is defined as 330 days per year. Thirty-five days are allotted for downtime, inspection, reloads, and turnaround. Based on high on-stream efficiencies for UOP's CCR Platforming units, the downtime allotment is conservative.

8.2.3 Operating Cost

Operating cost is the sum of variable and fixed costs. Operating cost is subtracted from gross margin to obtain the net operating profit.

8.2.3.1 Catalyst and Chemicals

The initial catalyst loadings are treated as a capital requirement, but reloads are treated as a variable cost of production. Catalyst cost and the expected catalyst life define a series of cash flows for catalyst replacement over the project life (20 years). Annual sinking-fund payments that are sufficient to cover all catalyst reloads are determined. The purpose of this procedure is to annualize expenditures that do not necessarily occur each year.

The Cyclar process is a moving catalyst system. An estimate of catalyst loss as a result of attrition is included in the annualized catalyst-replacement cost. Some nitrogen is consumed by the catalyst-transfer equipment, and this chemical cost is also considered.

8.2.3.2 Utilities

Utility estimates from Section 7 were combined with the utility-cost assumptions stated in Table 8.1 and expressed in dollars per unit time.

8.2.3.3 Labor

For these calculations, the assumption is made that two operators and one boardman would be required for each shift. The labor estimate is the same for both Direct and Indirect Cyclar because the CSP unit (Indirect Cyclar cases) requires little operator involvement.

A base wage rate of $15/hr is assumed. The labor estimate is for continuous coverage (24 hours a day, 365 days per year) and includes an allowance for vacations, holidays, and sick days (allowance of 15% of total work time). Supervision costs are assumed to be 25% of labor costs. Total labor costs, including supervision, are multiplied by a factor of 1.35 to account for fringe benefits. Finally, this product is multiplied by a factor of 1.5 to account for overhead, such as computer, laboratory, and administrative charges.

8.2.3.4 Maintenance

An allowance of 2% of the EEC was established as the estimate for maintaining the process unit. Maintenance labor and spare-parts inventory charges are included in this estimate.

8.2.3.5 Taxes and Insurance

An allowance of 1.5% of the EEC was established as the estimate for state and local taxes (property taxes, for example) and hazard insurance covering the unit.

8.3 IRR CALCULATIONS

As mentioned previously, IRR calculations compute the discount rate that may be applied to operating profits so that their present value equals the present value of capital expenditure at unit start-up. The higher the discount rate (or internal return), the better.

8.3.1 Income Tax Considerations

The IRR may be determined before or after income tax is figured. The more meaningful comparisons are on an after-tax basis. However, because tax rates vary widely and depend on many factors, before-tax IRR's are also presented.

For the after-tax IRR, the corporate tax rate is assumed to be 33%. Depreciation also enters into the after-tax cash flows because it is subtracted from net operating profit when determining the tax liability. Straight-line depreciation over a 10-year time span is used throughout. However, depreciation is not a cash flow. It has absolutely no impact on before-tax profits.

No investment credits are assumed for this study. Neither price support nor any special pricing arrangement for raw materials is considered.

8.3.2 Summary of IRR Results

Direct and Indirect Cyclar IRR results are compared side-by-side at the bottom of Tables 8.4 through 8.7. The results are collected in Table 8.8. Direct Cyclar is the better choice for upgrading Arge LPG, straight run or mixed with LPG from a wax hydrocracker. Indirect Cyclar is superior for upgrading LPG from either Synthol or Mobil Slurry (low-wax mode) F-T reactor technology.

8.4 DISCUSSION OF RESULTS

Feedstock olefinicity plays a major role in Direct versus Indirect Cyclar economics. The impact of olefins on the IRR for each processing route is discussed below.

8.4.1 Indirect Cyclar--Impact of Feed Olefinicity on IRR

For the Indirect Cyclar cases presented, gross margin is adversely affected by feed olefins (Figure 8.3). This result is largely because the maximum possible hydrogen yield declines with olefinicity. Also, the Huels CSP capital, catalyst, and utility requirements are proportional to feed olefinicity. Huels CSP capital and utility requirements for Case No. 8 are compared in Figure 8.4, which shows that factors affecting the Huels CSP are small relative to comparable factors affecting the Cyclar Unit.

One benefit from eliminating feed olefins is that the Cyclar unit is able to run at significantly higher LHSV and not cause excessive catalyst coking problems. Increasing LHSV reduces the reactor size and catalyst volume.

8.4.2 Direct Cyclar--Impact of Feed Olefinicity on IRR

Up to a point, Direct Cyclar IRR is a function of feed olefinicity. Aromatics yields improve as the olefin level increases, and this improvement is reflected in gross margins per metric ton of feed (Figure 8.5). The margin improves even though the theoretical maximum hydrogen coproduct yield is inversely proportional to olefinicity (less hydrogen in the feed).

Feed olefins are more reactive than paraffins. Higher conversions per pass in conjunction with higher pressure operation and lower heat of reaction result in lower utility consumptions. In each of the four comparable cases (Tables 8.4 through 8.7), the Direct Cyclar utility consumption is well below that of the corresponding Indirect Cyclar case.

Aside from catalyst regeneration equipment, EEC decreases with feed olefinicity (Figure 8.6). The negative slope indicates a larger differential between Direct and Indirect Cyclar EEC's (both excluding CCR costs). The large offset in non-CCR capital results primarily from higher pressure operation. Higher reactor pressure significantly reduces compressor capital costs. It also results in greater conversion per pass, which in turn reduces the size of the plant (smaller combined-feed ratio). The smaller combined-feed ratio for Direct Cyclar offsets the Indirect Cyclar advantage of higher LHSV operation. Finally, feed olefins are more reactive, thus reducing the demands on the interheater designs and the number of reaction stages required for a given level of conversion.

At high olefin levels, catalyst regeneration costs become excessive. For example, the relative amount of capital needed for the regeneration section of each Direct Cyclar unit increases dramatically (Figure 8.7). Costs associated with regeneration become excessive at feed olefin levels above 65 wt-%. The ratio of the IRR (Direct Cyclar IRR divided by Indirect Cyclar IRR) for each fresh-feed olefin level (Figure 8.8) reflects a rapid acceleration of regenerator costs above 65 wt-% feed olefins. The IRR ratio becomes less than 1.0, indicating an advantage for Indirect Cyclar in these cases.

8.5 SENSITIVITY CASES

Cases 7 and 8 are the bases for the sensitivity studies. In these studies, feed cost, aromatics product, and hydrogen coproduct values are varied over a wide range to observe the resulting IRR. Results are collected in Table 8.9. The before-tax IRR is used to illustrate each case in Figures 8.9 through 8.11.

8.5.1 LPG Feed Cost

The LPG feed cost has significant impact on the Cyclar IRR. The LPG cost varied between $100/MT and $180/MT (Figure 8.9).

8.5.2 Aromatics Product Value

Cyclar liquid product was valued over a range from $200/MT (below the gasoline-blending value) to $300/MT (more representative of its value as a petrochemicals feedstock). The results are illustrated in Figure 8.10.

8.5.3 Hydrogen Coproduct Value

Hydrogen was valued between $275/MT, the approximate fuel value for 95 vol-% hydrogen (at $2.10/MM Btu), and its chemical value of $635/MT (at $2.20/M SCF pure hydrogen). Although hydrogen valuation is important, it is not as critical as LPG or aromatics valuation with respect to its impact on the IRR (Figure 8.11).

8.6 CONCLUSIONS

Having olefins in a Cyclar feedstock has many advantages:

- Olefins are reactive in a Cyclar unit. Also, olefins result in significantly higher aromatics selectivities.
- For a given aromatics selectivity, olefinic feeds permit higher pressure reactor operation than do pure paraffin feeds. Capital and operating costs are thereby reduced.
- Olefins have a lower heat of reaction than do paraffins. This fact reduces the interstage reheat demands of the process.

These advantages account for higher returns for Direct Cyclar processing LPG from an Arge reactor (Case Nos. 1 and 7). However, when feed olefinicity increases above 65 wt-%, regeneration costs become excessive. This fact explains why the Indirect Cyclar options are preferable for LPG from a Synthol F-T reactor (Case No. 4) and from a Mobil Slurry F-T reactor (Case No. 6).

TABLE 8.1

Price and Cost Basis for Economic Analysis

Feedstock Costs and Product Values		
LPG	$0.30/gal	$140/MT
Gasoline	$0.52/gal	$195/MT
Benzene	$1.00/gal	$300/MT
Toluene	$0.85/gal	$260/MT
Mixed Xylenes	$0.98/gal	$300/MT
Hydrogen (100 vol-% purity)	$2.17/M SCF	$900/MT
Hydrogen (95 vol-% purity)	$2.06/M SCF	$635/MT
Cyclar Hydrogen (95 vol-% purity)	$1.40/M SCF	$430/MT(*)
Fuel Gas	$2.10/MM Btu	$100/MT
Utility Prices		
Power	$0.04/kWh	$0.04/kWh
600 psig, 400°C Steam	$3.80/M lb	$8.38/MT
50 psig Saturated Steam	$3.30/M lb	$7.27/MT
Boiler Feed Water	$0.40/M lb	$0.88/MT
Condensate	$0.32/M lb	$0.70/MT
Cooling Water	$0.10/M gal	$0.026/MT
Fuel Gas	$2.10/MM Btu	$1.99/GJ
Labor Costs		
Wage Rate	$15/hr	
Off-time Allowance	15%	
Fringe Benefits	35%	
Supervision	25%	
Overhead	50%	

* Hydrogen value for Cyclar product chosen between chemical hydrogen and fuel gas. Actual value depends on the overall hydrogen balance of the F-T upgrading complex.

TABLE 8.2

Internal Consumption of Cyclar Fuel Gas Product

Case No./ Cyclar Mode	Fuel Gas Production, Kg/hr	Utility Fuel Fired MM BtTu/h	Utility Fuel Fired Kg/hr	Consumption of Product Fuel Gas, %
1/Direct	6,850	34.6	727	10.6
2/Indirect	6,925	118.4	2,487	35.9
3/Direct	16,593	51.7	1,086	6.5
4/Indirect	19,175	293.2	6,160	32.1
5/Direct	12,735	85.6	1,798	14.1
6/Indirect	14,210	236.8	4,975	35.0
7/Direct	14,439	103.8	2,181	15.1
8/Indirect	12,714	222.9	4,683	36.8

TABLE 8.3

Offsite Utilities for Arge Upgrading Complex with Catalytic Condensation and with Cyclar Unit

	Catalytic Condensation	Cyclar Unit	Comment
Hydrogen (100 vol-%), MT/hr	0.675	(0.682)	(1)
Power, kW	5,342	8,535	
600 psig, 400°C Steam, MT/hr	20.1	0	(2)
150 psig, Saturated Steam, MT/hr	7.2	0	(2)
50 psig, Saturated Steam, MT/hr	17.2	18	
Cooling Water, MT/hr	1,204	1,270	
Fuel Consumed, MM Btu/hr	333.4	379.2	

(1) Upgrading complex moves from net consumer of hydrogen with need for hydrogen supply to net exporter of hydrogen.

(2) High and low pressure steam requirements completely met by Cyclar steam-generation facility. Therefore they are no longer an offsite.

TABLE 8.4

Capital Cost and Net Operating Profit Summary
LPG from Arge F-T Reactor

Case No.	1	2
Cyclar Configuration	Direct	Indirect
F-T Reactor Type	Arge	Arge
Fresh Feed Olefins, Wt-%	61.7	0.0
Combined Feed Olefins, Wt-%	52.9	3.3
Interest Charge = 10%		
Capitalization, MM $		
Huels CSP EEC	0.0	0.5
Cyclar EEC	26.2	30.7
Total ISBL EEC	26.2	31.2
1st yr Expenditure (20%)	6.3	7.6
2nd yr Expenditure (50%)	14.4	17.2
3rd yr Expenditure (30%)	7.9	9.4
Capitalized EEC	28.6	34.1
Initial CSP Catalyst Load	0.0	0.8
Initial Cyclar Catalyst Loading	5.4	4.9
Total Capital Requirement	34.0	39.8
LPG Feed Rate, kg/hr	22,229	22,229
Hydrogen Production Rate, kg/hr	843	758
Fuel Gas Production Rate, kg/hr	6,850	6,925
Aromatics Production Rate, kg/hr	14,536	14,546
Feedstock Cost / Product Values	$/MT	
LPG	140	
Hydrogen	430	
Fuel Gas	100	
Aromatics	260	
Gross Margin		
M $/day	41.15	40.52
MM $/yr (330 op. days per year)	13.58	13.37
Catalyst and Chemicals, MM $/yr	2.75	2.64
Utility Consumptions, " - " denotes export		
Electricity, kW	3,288	3,142
600 psig, 400°C Steam, MT/hr	-3.63	-18.46
50 psig Saturated Steam, MT/hr	1.86	3.17
Boiler Feed Water, MT/hr	6.35	21.50
Condensate, MT/hr	-4.26	-5.17
Cooling Water, MT/hr	212.60	331.60
Fuel Fired, MM Btu/hr	34.60	118.40
Utility Unit Costs		
Electricity, $/kWh	0.040	
600 psig, 400°C Steam, $/MT	8.380	
50 psig Saturated Steam, $/MT	7.270	
Boiler Feed Water, $/MT	0.880	
Condensate, $/MT	0.700	
Cooling Water, $/MT	0.026	
Fuel Fired, $/MM Btu	2.100	

(continued)

TABLE 8.4 - Continued

Capital Cost and Net Operating Profit Summary
LPG from Arge F-T Reactor

Case No.		1	2
Cyclar Configuration		Direct	Indirect
F-T Reactor Type		Arge	Arge
Utility Operating Costs, $/day			
( ) denotes utility export value			
Electricity		3,156	3,016
600 psig, 400°C Steam		(730)	(3,713)
50 psig Saturated Steam		325	553
Boiler Feed Water		134	454
Condensate		(72)	(87)
Cooling Water		133	207
Fuel Fired		1,744	5,967
Total Utility Consumption, $/day		4,690	6,398
MM $/yr (330 op. days per year)		1.55	2.11
Labor Cost Basis (Both Cases)			
Boardmen	1		
Operators	2		
Wage Rate, $/hr	15		
Supervision, %	25		
Fringe Benefits, %	35		
Overhead, %	50		
Total Labor Costs, MM $/yr		1.15	1.15
Maintenance, MM $/yr		0.52	0.62
Local Taxes and Insurance, MM $/yr		0.39	0.47
Operating Profit, MM $/yr			
Gross Margin		13.58	13.37
Catalyst and Chemicals		-2.75	-2.64
Utilities		-1.55	-2.11
Labor		-1.15	-1.15
Maintenance		-0.52	-0.62
Local Taxes & Insurance		-0.39	-0.47
Net Operating Profit. MM $/yr		7.22	6.38
Income Tax Rate =	33%		
Income Tax Liability. MM $/yr			
Net Operating Profit		7.22	6.38
Depreciation yrs 1-10		2.62	3.12
Taxible Income yrs 1-10		4.60	3.26
Income Tax Paid yrs 1-10		1.52	1.08
Taxible Income yrs 10+		7.22	6.38
Income Tax Paid yrs 10+		2.38	2.11
After-Tax Cash Flow, MM $/yr			
Years 1-10		5.70	5.31
Years 10+		4.84	4.28
Before-Tax IRR		20.7%	15.1%
After-Tax IRR		15.3%	11.1%

TABLE 8.5

Capital Cost and Net Operating Profit Summary
LPG from Synthol F-T Reactor

Case No.	3	4
Cyclar Configuration	Direct	Indirect
F-T Reactor Type	Synthol	Synthol
Fresh Feed Olefins, Wt-%	84.0	0.0
Combined Feed Olefins, Wt-%	73.7	3.1
Interest Charge = 10%		
Capitalization, MM $		
Huels CSP EEC	0.0	1.0
Cyclar EEC	54.4	52.2
Total ISBL EEC	54.4	53.2
1st yr Expenditure (20%)	13.2	12.9
2nd yr Expenditure (50%)	29.9	29.3
3rd yr Expenditure (30%)	16.3	16.0
Capitalized EEC	59.4	58.1
Initial CSP Catalyst Load	0.0	3.1
Initial Cyclar Catalyst Loading	15.4	12.6
Total Capital Requirement	74.8	73.7
LPG Feed Rate, kg/hr	59,121	59,121
Hydrogen Production Rate, kg/hr	1,961	1,190
Fuel Gas Production Rate, kg/hr	16,593	19,175
Aromatics Production Rate, kg/hr	40,567	38,756
Feedstock Cost / Product Values	$/MT	
LPG	140	
Hydrogen	430	
Fuel Gas	100	
Aromatics	260	
Gross Margin		
M $/day	114.55	101.49
MM $/yr (330 op. days per year)	37.80	33.49
Catalyst and Chemicals, MM $/yr	15.06	7.04
Utility Consumptions, " - " denotes export		
Electricity, kW	10,019	7,678
600 psig, 400°C Steam, MT/hr	-11.38	-42.32
50 psig Saturated Steam, MT/hr	4.40	8.44
Boiler Feed Water, MT/hr	19.19	53.34
Condensate, MT/hr	-11.29	-14.02
Cooling Water, MT/hr	557.50	921.10
Fuel Fired, MM Btu/hr	51.70	293.20
Utility Unit Costs		
Electricity, $/kWh	0.040	
600 psig, 400°C Steam, $/MT	8.380	
50 psig Saturated Steam, $/MT	7.270	
Boiler Feed Water, $/MT	0.880	
Condensate, $/MT	0.700	
Cooling Water, $/MT	0.026	
Fuel Fired, $/MM Btu	2.100	

(continued)

TABLE 8.5 - Continued

Capital Cost and Net Operating Profit Summary
LPG from Synthol F-T Reactor

Case No. Cyclar Configuration F-T Reactor Type		3 Direct Synthol	4 Indirect Synthol
Utility Operating Costs, $/day			
( ) denotes utility export value			
Electricity		9,618	7,371
600 psig, 400°C Steam		(2,289)	(8,511)
50 psig Saturated Steam		768	1,473
Boiler Feed Water		405	1,127
Condensate		(190)	(236)
Cooling Water		348	575
Fuel Fired		2,606	14,777
Total Utility Consumption, $/day		11,266	16,575
MM $/yr (330 op. days per year)		3.72	5.47
Labor Cost Basis (Both Cases)			
Boardmen	1		
Operators	2		
Wage Rate, $/hr	15		
Supervision, %	25		
Fringe Benefits, %	35		
Overhead, %	50		
Total Labor Costs, MM $/yr		1.15	1.15
Maintenance, MM $/yr		1.09	1.06
Local Taxes and Insurance, MM $/yr		0.82	0.80
Operating Profit, MM $/yr			
Gross Margin		37.80	33.49
Catalyst and Chemicals		-15.06	-7.04
Utilities		-3.72	-5.47
Labor		-1.15	-1.15
Maintenance		-1.09	-1.06
Local Taxes & Ins.		-0.82	-0.80
Net Operating Profit, MM $/yr		15.97	17.98
Income Tax Rate =	33%		
Income Tax Liability, MM $/yr			
Net Operating Profit		15.97	17.98
Depreciation yrs 1-10		5.44	5.32
Taxible Income yrs 1-10		10.53	12.66
Income Tax Paid yrs 1-10		3.48	4.18
Taxible Income yrs 10+		15.97	17.98
Income Tax Paid yrs 10+		5.27	5.93
After-Tax Cash Flow, MM $/yr			
Years 1-10		12.50	13.80
Years 10+		10.70	12.04
Before-Tax IRR		20.9%	24.1%
After-Tax IRR		15.3%	17.6%

TABLE 8.6

Capital Cost and Net Operating Profit Summary
LPG from Mobil Slurry F-T Reactor

Case No.	5	6
Cyclar Configuration	Direct	Indirect
F-T Reactor Type	M-Slurry	M-Slurry
Fresh Feed Olefins, Wt-%	78.1	0.0
Combined Feed Olefins, Wt-%	68.1	3.3
Interest Charge = 10%		
Capitalization, MM $		
Huels CSP EEC	0.0	0.8
Cyclar EEC	47.0	44.2
Total ISBL EEC	47.0	45.0
1st yr Expenditure (20%)	11.4	10.9
2nd yr Expenditure (50%)	25.9	24.8
3rd yr Expenditure (30%)	14.1	13.5
Capitalized EEC	51.3	49.1
Initial CSP Catalyst Load	0.0	2.1
Initial Cyclar Catalyst Loading	12.0	9.5
Total Capital Requirement	63.3	60.8
LPG Feed Rate, kg/hr	44,221	44,221
Hydrogen Production Rate, kg/hr	1,522	1,051
Fuel Gas Production Rate, kg/hr	12,735	14,210
Aromatics Production Rate, kg/hr	29,964	28,960
Feedstock Cost / Product Values	$/MT	
LPG	140	
Hydrogen	430	
Fuel Gas	100	
Aromatics	260	
Gross Margin		
M $/day	84.66	77.08
MM $/yr (330 op. days per year)	27.94	25.44
Catalyst and Chemicals, MM $/yr	11.68	5.27
Utility Consumptions, " - " denotes export		
Electricity, kW	7,949	5,942
600 psig, 400°C Steam, MT/hr	-8.30	-36.83
50 psig Saturated Steam, MT/hr	3.40	6.40
Boiler Feed Water, MT/hr	14.06	43.04
Condensate, MT/hr	-8.98	-10.43
Cooling Water, MT/hr	424.70	680.80
Fuel Fired, MM Btu/hr	85.60	236.80
Utility Unit Costs		
Electricity, $/kWh	0.040	
600 psig, 400°C Steam, $/MT	8.380	
50 psig Saturated Steam, $/MT	7.270	
Boiler Feed Water, $/MT	0.880	
Condensate, $/MT	0.700	
Cooling Water, $/MT	0.026	
Fuel Fired, $/MM Btu	2.100	

(continued)

TABLE 8.6 - Continued

Capital Cost and Net Operating Profit Summary
LPG from Mobil Slurry F-T Reactor

Case No.	5	6
Cyclar Configuration	Direct	Indirect
F-T Reactor Type	M-Slurry	M-Slurry
Utility Operating Costs, $/day		
( ) denotes utility export value		
Electricity	7,631	5,704
600 psig, 400°C Steam	(1,669)	(7,407)
50 psig Saturated Steam	593	1,117
Boiler Feed Water	297	909
Condensate	(151)	(175)
Cooling Water	265	425
Fuel Fired	4,314	11,935
Total Utility Consumption, $/day	11,280	12,507
MM $/yr (330 op. days per year)	3.72	4.13

Labor Cost Basis (Both Cases)	
Boardmen	1
Operators	2
Wage Rate, $/hr	15
Supervision, %	25
Fringe Benefits, %	35
Overhead, %	50

	5	6
Total Labor Costs, MM $/yr	1.15	1.15
Maintenance, MM $/yr	0.94	0.90
Local Taxes and Insurance, MM $/yr	0.71	0.68
Operating Profit, MM $/yr		
Gross Margin	27.94	25.44
Catalyst and Chemicals	-11.68	-5.27
Utilities	-3.72	-4.13
Labor	-1.15	-1.15
Maintenance	-0.94	-0.90
Local Taxes & Ins.	-0.71	-0.68
Net Operating Profit, MM $/yr	9.75	13.31
Income Tax Rate = 33%		
Income Tax Liability, MM $/yr		
Net Operating Profit	9.75	13.31
Depreciation yrs 1-10	4.70	4.50
Taxible Income yrs 1-10	5.05	8.81
Income Tax Paid yrs 1-10	1.67	2.91
Taxible Income yrs 10+	9.75	13.31
Income Tax Paid yrs 10+	3.22	4.39
After-Tax Cash Flow, MM $/yr		
Years 1-10	8.08	10.40
Years 10+	6.53	8.92
Before-Tax IRR	14.3%	21.5%
After-Tax IRR	10.4%	15.8%

TABLE 8.7

Capital Cost and Net Operating Profit Summary
LPG from Arge F-T Reactor and Wax Hydrocracker

Case No.	7	8
Cyclar Configuration	Direct	Indirect
F-T Reactor Type	Arge + HC	Arge + HC
Fresh Feed Olefins, Wt-%	31.8	0.0
Combined Feed Olefins, Wt-%	27.3	3.5
Interest Charge = 10%		
Capitalization, MM $		
Huels CSP EEC	0.0	0.8
Cyclar EEC	33.4	42.1
Total ISBL EEC	33.4	42.9
1st yr Expenditure (20%)	8.1	10.4
2nd yr Expenditure (50%)	18.4	23.6
3rd yr Expenditure (30%)	10.0	12.9
Capitalized EEC	36.5	46.8
Initial CSP Catalyst Load	0.0	0.9
Initial Cyclar Catalyst Loading	8.5	8.4
Total Capital Requirement	44.9	56.1
LPG Feed Rate, kg/hr	43,129	43,129
Hydrogen Production Rate, kg/hr	1,925	2,187
Fuel Gas Production Rate, kg/hr	14,439	12,714
Aromatics Production Rate, kg/hr	26,765	28,228
Feedstock Cost / Product Values	$/MT	
LPG	140	
Hydrogen	430	
Fuel Gas	100	
Aromatics	260	
Gross Margin		
M $/day	76.62	84.31
MM $/yr (330 op. days per year)	25.28	27.82
Catalyst and Chemicals, MM $/yr	4.43	4.44
Utility Consumptions, " - " denotes export		
Electricity, kW	4,368	5,076
600 psig, 400°C Steam, MT/hr	-13.65	-34.84
50 psig Saturated Steam, MT/hr	3.95	5.99
Boiler Feed Water, MT/hr	18.87	40.55
Condensate, MT/hr	-8.25	-10.11
Cooling Water, MT/hr	403.30	579.60
Fuel Fired, MM Btu/hr	103.80	222.90
Utility Unit Costs		
Electricity, $/kWh	0.040	
600 psig, 400°C Steam, $/MT	8.380	
50 psig Saturated Steam, $/MT	7.270	
Boiler Feed Water, $/MT	0.880	
Condensate, $/MT	0.700	
Cooling Water, $/MT	0.026	
Fuel Fired, $/MM Btu	2.100	

(continued)

TABLE 8.7 - Continued

Capital Cost and Net Operating Profit Summary
LPG from Arge F-T Reactor and Wax Hydrocracker

Case No.		7	8
Cyclar Configuration		Direct	Indirect
F-T Reactor Type		Arge + HC	Arge + HC
Utility Operating Costs, $/day			
( ) denotes utility export value			
Electricity		4,193	4,873
600 psig, 400°C Steam		(2,745)	(7,007)
50 psig Saturated Steam		689	1,045
Boiler Feed Water		399	856
Condensate		(139)	(170)
Cooling Water		252	362
Fuel Fired		5,232	11,234
Total Utility Consumption, $/day		7,880	11,193
MM $/yr (330 op. days per year)		2.60	3.69
Labor Cost Basis (Both Cases)			
Boardmen	1		
Operators	2		
Wage Rate, $/hr	15		
Supervision, %	25		
Fringe Benefits, %	35		
Overhead, %	50		
Total Labor Costs, MM $/yr		1.15	1.15
Maintenance, MM $/yr		0.67	0.86
Local Taxes and Insurance, MM $/yr		0.50	0.64
Operating Profit, MM $/yr			
Gross Margin		25.28	27.82
Catalyst and Chemicals		-4.43	-4.44
Utilities		-2.60	-3.69
Labor		-1.15	-1.15
Maintenance		-0.67	-0.86
Local Taxes & Ins.		-0.50	-0.64
Net Operating Profit, MM $/yr		15.94	17.04
Income Tax Rate = 33%			
Income Tax Liability, MM $/yr			
Net Operating Profit		15.94	17.04
Depreciation yrs 1-10		3.34	4.29
Taxible Income yrs 1-10		12.60	12.75
Income Tax Paid yrs 1-10		4.16	4.21
Taxible Income yrs 10+		15.94	17.04
Income Tax Paid yrs 10+		5.26	5.62
After-Tax Cash Flow, MM $/yr			
Years 1-10		11.78	12.83
Years 10+		10.68	11.42
Before-Tax IRR		35.4%	30.2%
After-Tax IRR		25.7%	22.2%

TABLE 8.8

Summary of IRR Results

Case No./ Cyclar Mode	Feed Rate Kg/hr	Cyclar Fresh-Feed Olefins Wt-%	Before-Tax IRR, %	After Tax IRR, %	IRR Ratio (Before Tax)*
1/Direct	22,229	61.7	20.7	15.3	1.37
2/Indirect	22,229	0.0	15.1	11.1	1.37
3/Direct	59,121	84.0	20.9	15.3	0.87
4/Indirect	59,121	0.0	24.1	17.6	0.87
5/Direct	44,221	78.1	14.3	10.4	0.66
6/Indirect	44,221	0.0	21.5	15.8	0.66
7/Direct	43,129	31.8	35.4	25.7	1.17
8/Indirect	43,129	0.0	30.2	22.2	1.17

* IRR ratio defined as Direct IRR divided by Indirect IRR. Ratios greater than 1.00 indicate relative advantage of Direct Cyclar over Indirect Cyclar. Ratios less than 1.00 indicate relative advantage of Indirect Cyclar over Direct Cyclar.

TABLE 8.9

Sensitivity Cases

	Direct Cyclar (a)		Indirect Cyclar (b)	
	Before-Tax IRR, %	After-Tax IRR, %	Before-Tax IRR, %	After-Tax IRR, %
LPG Cost, $/MT				
100	65.9	46.5	54.7	39.0
140	35.4	25.7	30.2	22.2
180	0.1	-0.9	1.8	0.6
Aromatics Value, $/MT				
200	3.7	2.1	2.6	1.2
260	35.4	25.7	30.2	22.2
300	54.3	38.7	46.3	33.3
Hydrogen Value, $/MT				
275	30.1	22.0	25.3	18.6
430	35.4	25.7	30.2	22.2
635	42.4	30.6	36.6	26.7

Note: All base-case data in Table 8.7
(a) Base case for Direct Cyclar: Case No. 7
(b) Base case for Indirect Cyclar: Case No. 8

FIGURE 8.1

EVALUATION OF NEW TECHNOLOGY ALTERNATIVES

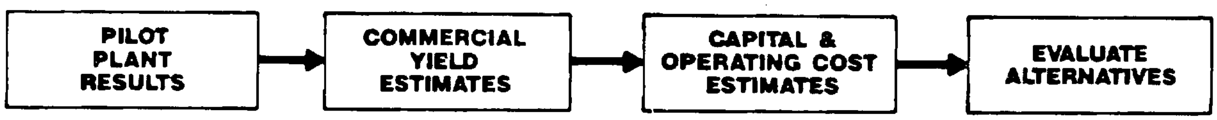


FIGURE 8.2

WHAT IS IRR?

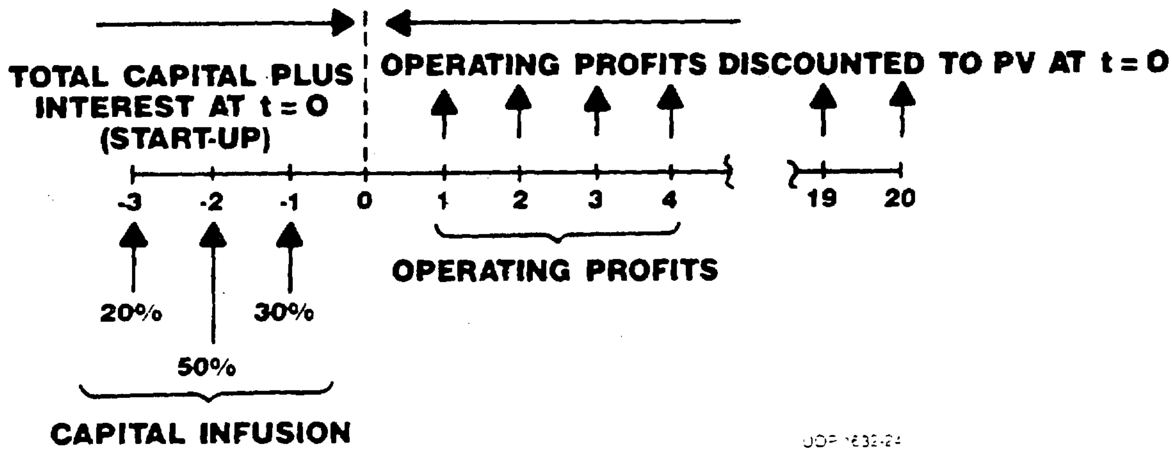
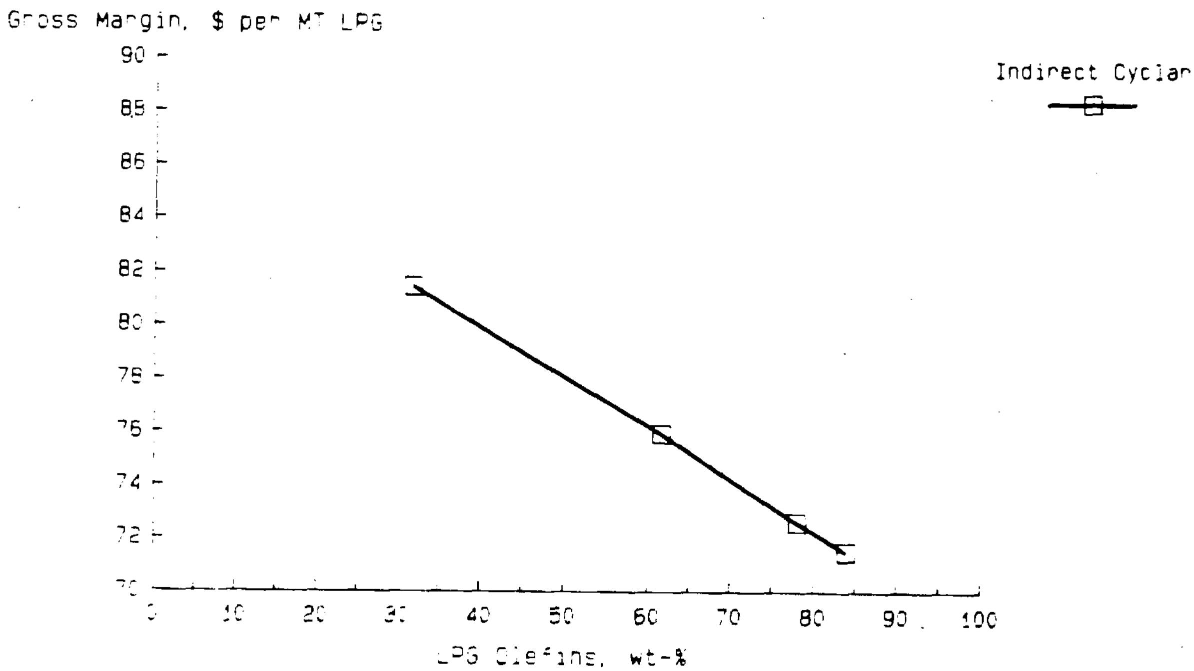


FIGURE 8.3

Gross Margin per MT LPG Feed
Indirect Cyclar



All Data From Tables 8.4 Through 8.7

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FIGURE 8.4

HUELS CSP PORTION OF INDIRECT CYCLAR CAPITAL AND UTILITY REQUIREMENTS

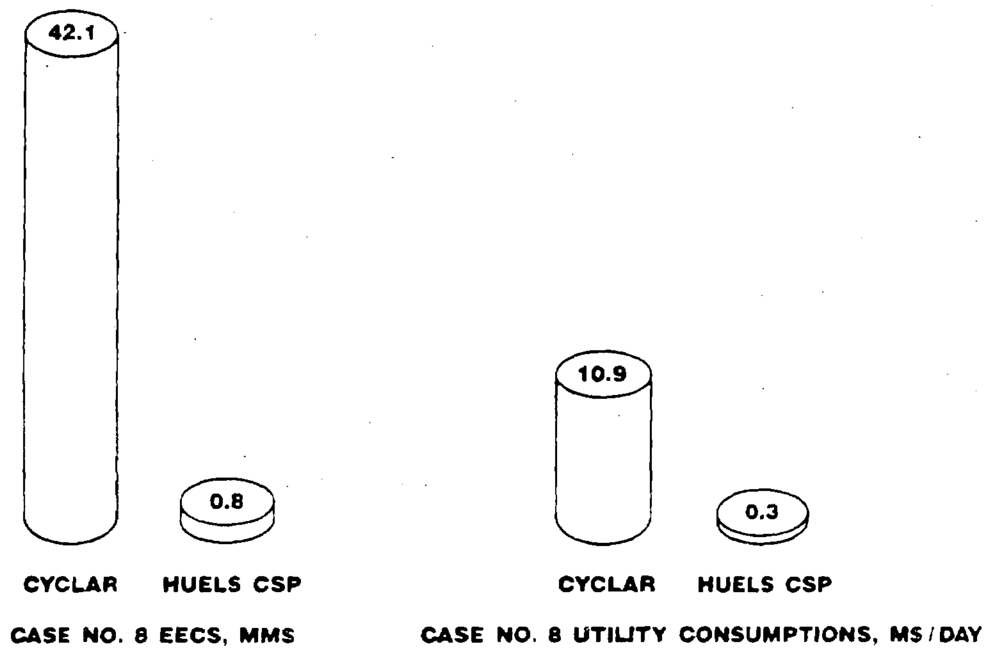
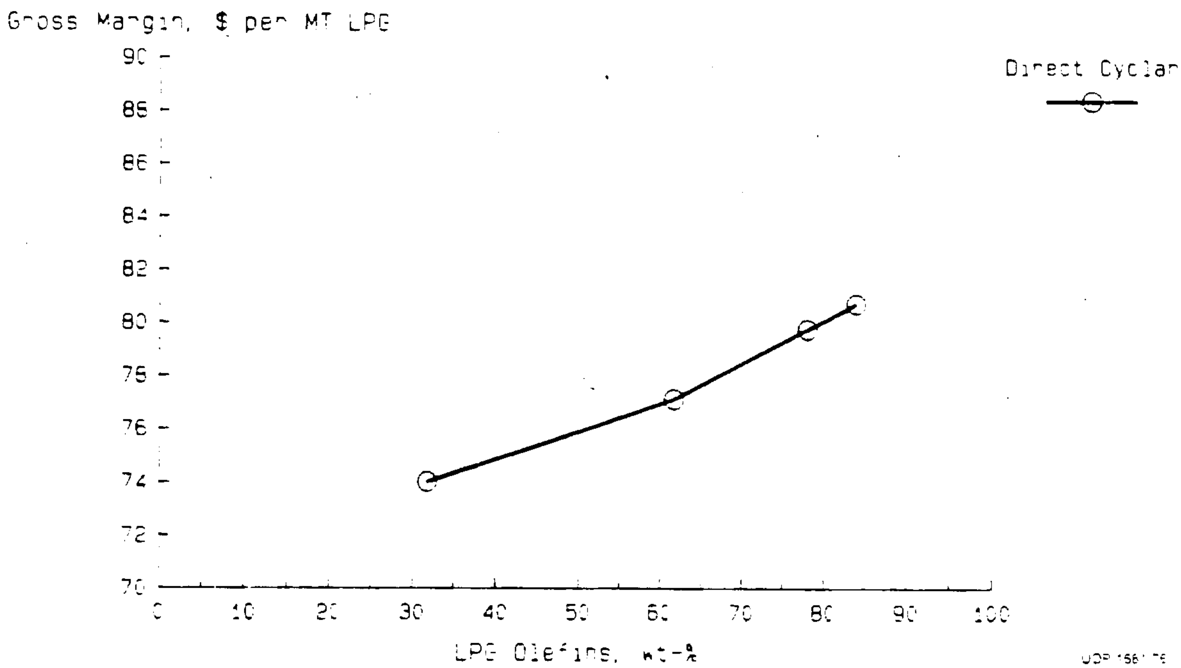


FIGURE 8.5

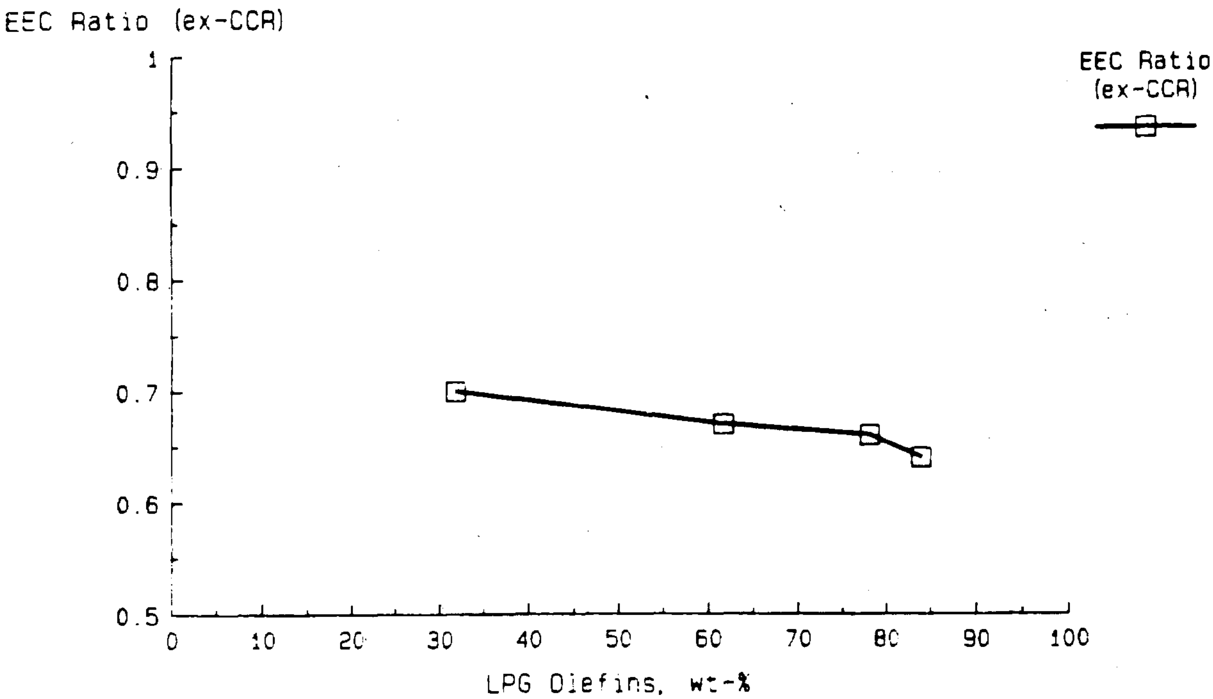
Gross Margin per MT LPG Feed
Direct Cyclar



All Data From Tables 8.4 Through 8.7

FIGURE 8.6

**EEC Ratio (Excluding CCR Section)
Direct Cyclar / Indirect Cyclar**



Example: Ratio of 0.65 indicates Direct Cyclar
EEC (excluding CCR section) is only 65% of
corresponding Indirect Cyclar EEC (ex-CCR)

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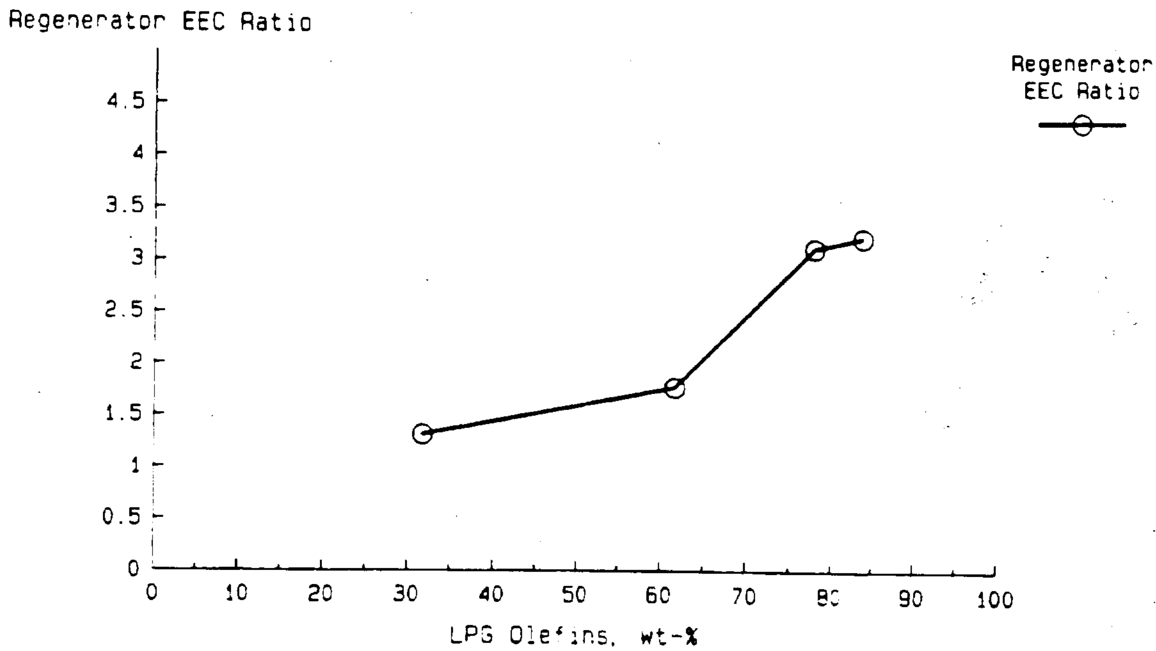
FIGURE 8.7

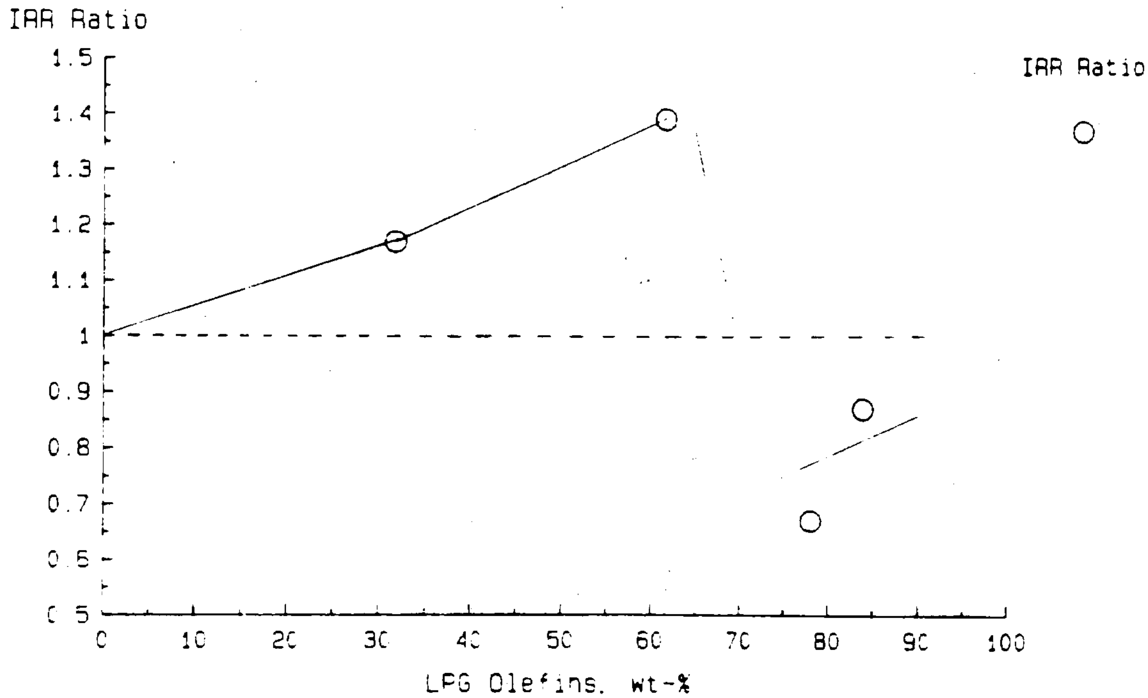
Regenerator EEC Ratio
Direct Cyclar / Indirect Cyclar



Example Ratio of 1.3 indicates Direct Cyclar regenerator EEC is 30% greater than corresponding Indirect Cyclar regenerator EEC.

FIGURE 8.8

IRR Ratios
Direct Cyclar / Indirect Cyclar



Example: Ratio of 1.4 indicates a 40% IRR advantage for Direct Cyclar relative to Indirect Cyclar (< 1.0 is disadvantage)

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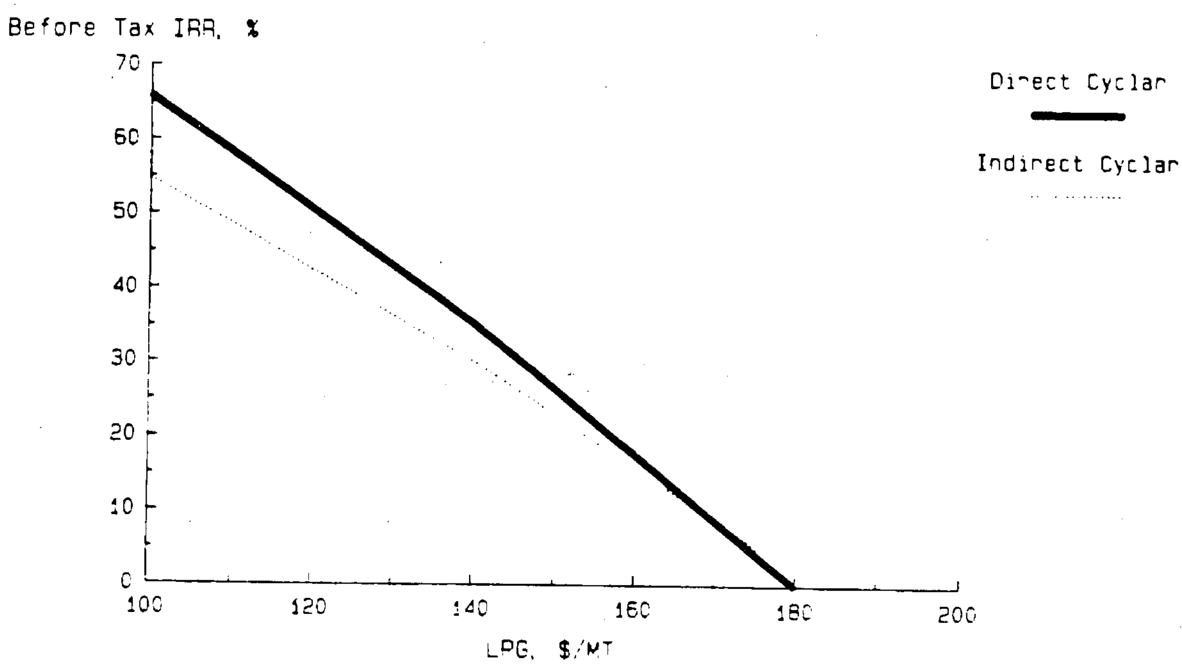
FIGURE 8.9

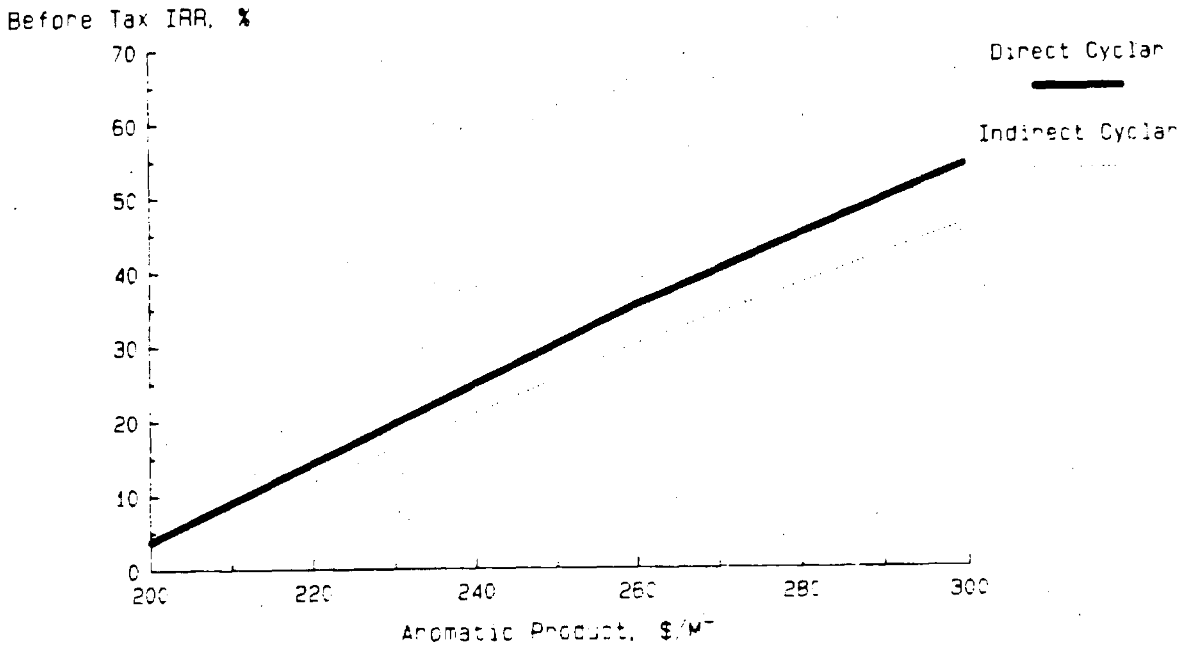
LPG Feedstock Cost Sensitivity



Base Cases: Direct Cyclar (Case No. 7)
Indirect Cyclar (Case No. 8)
All base case data in Table 8.7

FIGURE 8.10

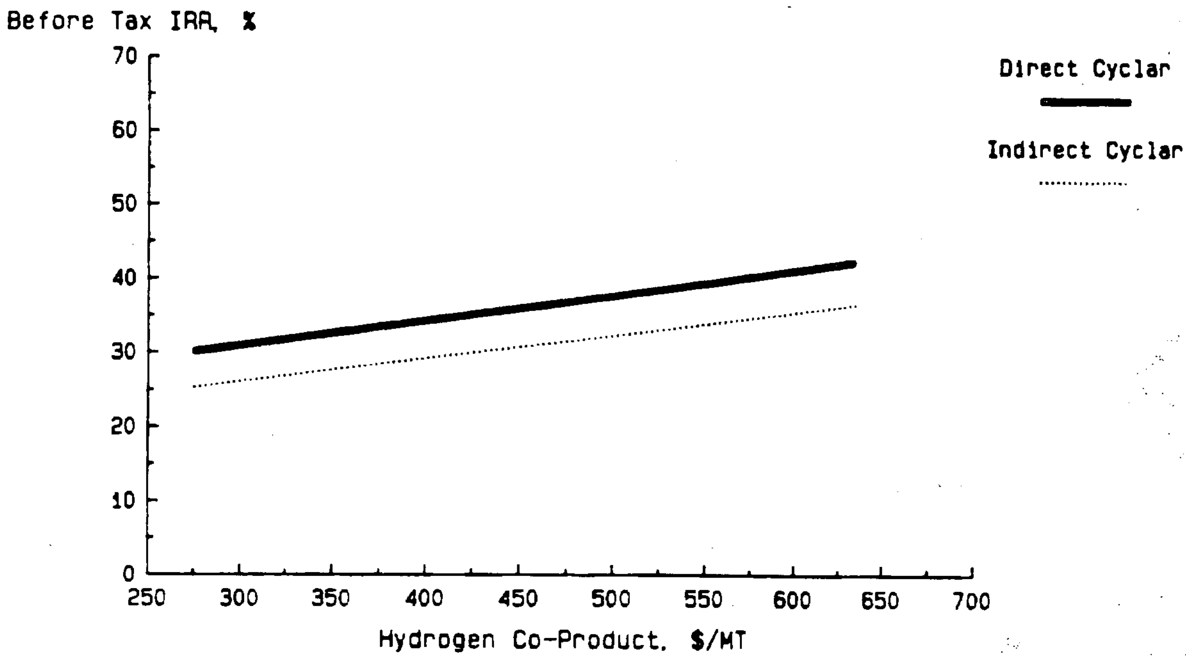
Aromatic Product Value Sensitivity



Base Cases: Direct Cyclar (Case No. 7)
Indirect Cyclar (Case No. 8)
All base case data in Table 8.7

FIGURE 8.11

Hydrogen Co-Product Value Sensitivity



Base Cases: Direct Cyclar (Case No. 7)
Indirect Cyclar (Case No. 8)
All base case data in Table 8.7

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