VIII. Task 4. ECONOMIC EVALUATION

VIII.1. EXECUTIVE SUMMARY

A study of the economics of liquid fuel production by Fischer-Tropsch (F-T) processing was originally initiated for two reasons. The first was to provide assistance in assessing the near- to immediate-term potential for commercial production of liquid fuels by indirect liquefaction based on relatively inexpensive remote natural gas. The second was to examine the economics of slurry F-T processing versus two existing processes, entrained bed Synthol and fixed bed ARGE. This study was completed in 1985 by the Technical Diversification Department of Air Products and a report (Appendix 1) was written and distributed internally.

The principal results of that study were:

(1) None of the cases appeared profitable for a nominal 40,000 bbl/day facility coming onstream in 1990, regardless of the value assigned to natural gas.

(2) The slurry case appeared to have an advantage over both Synthol and ARGE. This advantage was primarily rooted in the relatively lower capital costs of the F-T synthesis areas.

In this context, further work on characterizing and developing iron-based F-T catalysts was continued under a subcontract by researchers at Texas A&M University. This work identified several promising slurry phase catalysts. Air Products' personnel performed Task 4, the Economic Evaluation.

Several important points resulted from this additional work. Catalyst performance improved substantially, giving improved conversions and similar yields as the previous catalysts, but at much lower pressures. The increased conversions required a reduced recycle stream in the F-T synthesis section. However, the lower pressure resulted in little reduction in the F-T synthesis equipment even with the reduced recycle stream; thus, equipment and operating costs were similar to the original study. Combined with depressed prices for liquid fuels, this resulted in nearly the same revenue shortfall as the original estimate ($22 vs $25/bbl).

VIII.1.1. Background

The work done by Air Products for a new slurry phase F-T catalyst and process was evaluated and documented in 1985 (Appendix 1). In this study, several new catalysts were developed and tested against known catalysts for use in the slurry mode. Existing F-T based processes (i.e. Sasol) operate in two modes; a fixed bed (ARGE) process, or an entrained bed (Synthol) process. The synthesis gas was derived from natural gas ($1.00/MMBtu) by partial oxidation (POX) for the slurry and ARGE cases, and steam methane reforming (SMR) for the Synthol case. The major difference between the cases was the H_2/CO ratio of the synthesis gas; 0.92 using POX for the slurry case, 1.7 using SMR for the ARGE case, and 2.0 for Synthol. In all cases, the synthesis gas feed rate was 875 MMscfd and the synthesis gas transfer price varied from $1.15/MSCF for the

Synthol case to $1.44/MSCF for the slurry case. As a sensitivity, synthesis gas production costs from coal gasification were developed, and the synthesis gas cost was estimated to be $5.00/MSCF based on midwestern coal costing $1.50/MMBtu.*

Computer simulations using a process simulator were performed for the synthesis loop in each case. With this information, the next step of the evaluation was to develop economics for the F-T synthesis loop and the product upgrading section. Costs were developed for each major piece of equipment in the F-T synthesis section for each case. The product upgrading unit costs, however, were developed on a "macro" basis, that is, costs were scaled from the earlier evaluation based on the total flow to the unit. The product rate was set at 40,000 bbl/day of liquid fuels, which includes liquid petroleum gas (LPG or C3's), butanes (C4's), gasoline (C5-C11), and diesel fuel (C12+). No credit was allowed for alcohols. Since only liquid products were considered, C1's and C2's from F-T synthesis were sent to an autothermal reformer where they were processed to synthesis gas and returned to the F-T synthesis section. Based on these results, the slurry route was the most attractive However, none of the cases appeared to be profitable. Below is a summary of the findings.

	40,000 bbl/day 1990 Onstream		
	Slurry	Synthol	ARGE
Capital Investment (MM $)	1,270	1,955	1,810
Required Annual Revenues (MM $)	852	979	964
($/bbl)	61	72	70
Projected Revenues (MM $)	495	481	495
($/bbl)	36	36	36
Revenue Shortfall (MM $)	357	498	469
($/bbl Output)	25	36	34

With these costs, these cases remain unprofitable even with natural gas costs assigned a value of zero ($0/MMBtu). The sensitivity cases based on coal gasification proved prohibitively expensive, losing over $1 billion annually. For comparison purposes, liquid fuel production from syngas using the Mobil MTG process was also evaluated and found to be less profitable than the slurry route. An SRI report issued in July, 1989, on liquid fuels using the Mobil MTG process also found this process to be unprofitable.

Since the 1985 report, Professor Burkur at Texas A&M has done extensive work characterizing and developing catalysts for the slurry mode of operation. Several improvements were made, leading to catalysts that have much higher conversion rates with little loss of selectivity, and operate at significantly lower pressures (225 psia vs. 315 psia). A follow-on evaluation was requested to assess the economic viability of these new catalysts. The scope of this evaluation follows the original work done in 1985. The total amount of product remains at 40,000 bbl/day of liquid fuels. With this production rate, the product upgrading and offsite sections remain consistent. Therefore, only

*A revised Product Cost Summary is located in Appendix 2.

the F-T synthesis section was estimated in any detail. This is consistent with the original analysis. Also, in this study only the slurry process is evaluated given the original findings. Three cases, each based on a different catalyst, were evaluated. The first case assumes a catalyst developed at Air Products that was used for the original study (original case). The second case assumes a commercial catalyst developed by Ruhrchemie and tested by Professor Burkur (commercial case). The third case assumes a catalyst developed and tested by Professor Burkur that is somewhat similar to the commercial catalyst (new case). To complete the analysis, projected revenues were based on current prices for the products and the estimate was done in 1990 dollars. Costs and revenues were projected to 1995 and 2000 for forecasting purposes.

VIII.1.2 Synthesis Gas Production

In the 1985 study, the syngas molar (H_2/CO) ratio was assumed to be 0.92 for both the feed gas and usage requirement. In the recently completed catalyst characterization work, the syngas molar ratio was assumed to be 0.67, possibly reflecting syngas produced from coal-based sources. However, in the original study, synthesis gas from coal was found to be over three times more expensive than the synthesis gas from methane. Given the past finding, synthesis gas cost for this case was assumed to be that for remote natural gas ($1.00/MMBtu). With the required molar ratios, synthesis gas is produced by POX of methane. With the lower H_2/CO ratio the synthesis is somewhat more expensive, but less feed is required with the improved product split produced by the new catalyst. The synthesis gas costs are reported as an operating cost including capital equipment. Therefore, the total plant cost reported does not include the synthesis gas plant. In this way, different syngas production methods can be evaluated easily. Synthesis gas costs ranged from $1.26/MSCF for the commercial and original catalysts to $1.29/MSCF for the new catalyst. These values assume that credits for H_2 in the purge and steam from the syngas plant are obtained. Without these credits, the syngas costs are about $0.17/MSCF higher.

VIII.1.3 F-T Synthesis and Product Upgrading

The next step in the evaluation was to develop economics for the F-T synthesis loop and the product upgrading sections. Computer simulations were performed for the synthesis loop for the slurry case in the original study, which allowed some preliminary equipment sizing for the F-T synthesis area. This methodology was then used to determine equipment sizing for the F-T synthesis section for the commercial catalyst and new catalyst cases.

While costs were developed for major pieces of equipment in the synthesis loop itself, costs were developed on a macro basis (i.e., total flow to a unit) for the product upgrading costs. Since it was desirable to produce all liquid product slate, C1's and C2's from F-T synthesis were sent to an autothermal reformer, processed to synthesis gas and returned as F-T synthesis feed.

The results of the economic analysis are presented below. The table gives capital costs and annual required revenues for F-T synthesis, and product upgrading for three catalysts based on the slurry mode for a nominal

40,000 bbl/day facility. The required revenues provide for covering costs plus a 7.5% net profit after tax. Also tabulated are projected 1990 revenues and the revenue shortfall for each case. The projected revenues are based on product prices obtained from Air Products' Corporate Energy Department.

	40,000 bbl/day 1990 Onstream Slurry Mode		
	Original	Commercial	New
Capital Investment (MM $)	827.5	840.6	800.3
Required Annual Revenues (MM $)	621.6	650.6	621.3
($/bbl)	47.1	49.3	47.1
Projected Revenues (MM $)	320.5	317.2	322.1
($/bbl)	24.4	23.8	24.9
Revenue Shortfall (MM $)	301.1	333.4	299.2
($/bbl Output)	22.7	25.5	22.2

Although there seems to be substantial improvement in catalyst performance, with much lower operating pressures, slightly lower temperature and much higher conversion, the overall cost benefit is negligible. The higher conversion gives much smaller recycle streams, but the F-T synthesis section equipment remains about the same size because the pressure reduction actually increases the acfm (actual cubic feet per minute) of the feed stream. The product upgrading section costs remain nearly constant since the quantity of product remains constant. The actual escalation to 1990 was much less than that predicted in the initial study. However, the product prices and cost of oil are also much less than that predicted, which results in the revenue shortfall remaining about the same ($22 vs $25/bbl).

VIII.2. INTRODUCTION/BACKGROUND

The objective of the project undertaken by Air Products, under contract to the U.S. Department of Energy (DOE), was to develop a consistent technical/economic data base on the use of iron-based catalysts in F-T synthesis reactions. This data base was developed to allow the unambiguous comparison of the performance of these catalysts with each other and with state-of-the-art iron catalyst compositions. Particular attention was devoted to generating reproducible kinetic and selectivity data and to developing reproducible improved compositions. The aim of Task 4 (Economic Evaluation) was to develop the relative economic impact for the improved catalyst compositions and compare these economics with the base case catalyst economics. Product yield structure, F-T reactor residence time, and key process flow rates were obtained from data determined in Tasks 2 and 3. These economic studies included relative capital costs, operating costs, and required revenues for the catalyst, as well as a sensitivity study of the relative assigned values of the principle products (i.e., diesel and gasoline).

The original catalyst development work, in which several catalysts were tested in the slurry mode, was done at Air Products. An economic analysis (Appendix 1) was completed in late 1985 that examined the economics of the slurry phase F-T process and catalyst versus the economics of two existing commercial F-T processes, entrained bed Synthol and fixed bed ARGE. These analyses assumed the synthesis gas source to be remote natural gas valued at $1.00/MMBtu. As a sensitivity, the three F-T processes were also compared to a case where the source of the synthesis gas was midwestern coal. In addition, the economics of these three cases were compared to the economics of liquid fuels production from the Mobil Methanol-to-Gasoline (MTG) process and also to the economics of LNG.

The size of the proposed commercial facility evaluated was chosen based on the flow of synthesis gas ($CO + H_2$) to the F-T synthesis units. This was set at 96,000 lb mole/hour (875 MMscfd), and essentially matched the plant size chosen for an earlier F-T economic study performed for DOE by the Mitre Corporation[1] which was based on the amount of coal fed to the plant. Since light gases (C1's and C2's) formed in the F-T synthesis reaction are also reformed to synthesis gas and sent back to the F-T reactors, the total amount of synthesis gas fed to the F-T reactors was somewhat different for each case. However, in terms of liquid product output, each F-T case was considered to be nominally 40,000 bbl/day. The costs of producing synthesis gas by steam methane reforming and partial oxidation (POX) of methane were evaluated, and POX was found to be most economical when the H_2/CO ratio was 1.7 (or less when the natural gas price is $1.00/MMBtu). Syngas sourcing is sensitive to gas cost, in that POX is cheaper at lower H_2/CO ratios and higher natural gas costs push the POX advantage to higher H_2/CO ratios. The coal-based synthesis gas process used in the study was based on Shell pressurized gasifiers operating at 400 psi with a 0.5 H_2/CO ratio at gasifier outlet. However, synthesis gas costs were approximately three times that of natural gas.

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(1) Mitre Corporation, "Impact of Developmental Technology on Indirect Liquefaction," Government Report for Department of Energy, Contract No. EF-77-C-01-2783, MTR-80W326.

The F-T reaction areas studied were the major difference from the original study. The Air Products case used a slurry reactor; the reactor was essentially a bubble column with the liquid phase consisting of molten wax in which a coprecipitated Fe/Cu/K catalyst is suspended by motion of the gas bubbles traveling up the column operating at 500°F and 315 psia. The Synthol process uses entrained bed reactors where feed gas and fused iron catalyst are entered as a mixture with the reaction carried out at 600°F and 315 psia. The ARGE reactor is similar to those used in Sasol I, which used a promoted iron catalyst in tubes that operates from 390° to 480°F and 355 psia. The reaction product processing sections were similar for all cases, since the reaction products are the same and only the relative quantities of each product change.

The capital cost estimates for each of these cases are summarized in Table VIII-1. The slurry case required approximately two-thirds the capital of the other F-T synthesis methods, with the largest savings in the reaction area itself. Synthesis gas production area capital costs were not included and synthesis gas costs were treated as operating costs. Production costs and required annual revenue for the F-T cases are summarized in Table VIII-2. The required revenues were such that operating costs were covered and a 7.5% after-tax return on investment was realized. The required revenues were then compared to the projected revenues. The net result showed shortfall revenues of $25/bbl for the slurry case, which was much lower than the other cases, but still not economical. The projected product prices would have to be about $60/bbl for breakeven in 1990 rather than the $35/bbl actually projected for the slurry case. Liquid fuels from the Mobil MTG process were projected to have a revenue shortfall of about $28/bbl; somewhat greater than the slurry case.

VIII.3. SCOPE OF THE PRESENT STUDY

Since the previous study showed that the F-T slurry mode offered a significant advantage over the Synthol and ARGE modes, only the slurry case was evaluated. Since that study, Professor D. B. Burkur and his associates at Texas A&M University developed iron-based F-T catalysts for this slurry phase reaction. Significant improvements in catalyst activity and selectivity were made and will be discussed shortly. Professor Burkur also tested several commercial catalysts, one of which, Ruhrchemie LP 33/81, demonstrated good properties. The scope of this report will encompass three cases, all using the slurry mode for the F-T reactor. The first case assumes the coprecipitated Fe/Cu/K catalyst developed by Air Products (original case). The second case assumes the Ruhrchemie catalyst, Fe/Cu/K supported on silica, and the results reported by Professor Burkur (commercial case). The third case assumes the catalyst developed by Professor Burkur, Fe/Cu/K also supported on silica, and the results reported by Professor Burkur, et al. (new case). The differences between the commercial case and the new case are the specific elemental and silica ratios, and the activation conditions.

Table VIII-1

Capital Investment Summary for Liquid Fuels Synthesis (MM$)[1]
(1990 START-UP)

	Slurry	Synthol	ARGE
F-T Synthesis	$ 255	$ 615	$ 550
Product Upgrading	150	180	150
Autothermal Reforming	110	135	115
Wax Hydrocracking	30	-	35
Utilities and Offsites	165	165	165
Contingency	180	275	255
Subtotal (1985 $)	890	1,370	1,270
Work In Progress Escalation	130	200	185
Interest During Construction	250	385	355
TOTAL	$1,270	$1,955	$1,810

NOTE:
(1) Excludes investment for synthesis gas production. Purchase of synthesis gas is treated as an operating cost in Table VIII-2.

Table VIII-2

Annual Costs for Fischer-Tropsch Synthesis (MM$/Year)
Nominal Plant Capacity 40,000 bbl/day
(1990 Onstream)

	Slurry	Synthol	ARGE
Synthesis Gas(1)	416	332	352
Other Operating	106	139	141
Capital Related(2)	330	508	471
Total 1990 Required Revenue	852	979	964
Projected 1990 Revenues	495	481	495
Revenue Shortfall	357	498	469
Revenue Shortfall ($/bbl Product)	25	36	34

NOTES:
(1) Synthesis gas from partial oxidation for the slurry and ARGE cases and steam methane reforming for Synthol.
(2) Includes an allowance for 7.5% net profit after-tax return on investment.

The facility was sized to produce a nominal 40,000 bbl/day of liquid fuels. This was done to keep the product upgrading section in the same relative size and keep the required equipment consistent. The required offsites and utilities also remained constant. In addition, only the equipment in the F-T reaction section was estimated, since this is the section of the plant where major changes took place. This method is consistent with the previous study. There was also a difference in the process conditions of the F-T synthesis section that had an impact on the F-T section only. A flow sheet depicting the overall process flow diagram is presented in Figure VIII-1.

The cost basis for the capital estimate was in 1990 dollars with costs and revenues projected to 1995 and 2000. The projected revenues will be recalculated to reflect current costs.

VIII.4. CATALYST COMPARISON

A comparison of each catalyst in each case is summarized in Table VIII-3. One important difference is the H_2/CO ratio of 0.92 used in the original study compared to the H_2/CO ratio of 0.67 used in the other two cases. One effect of the lower H_2/CO ratio is that the original catalyst would probably not function effectively with this syngas feed composition. This lower ratio reflects syngas produced from coal rather than natural gas, and is somewhat more expensive than the higher ratio syngases when all are produced from natural gas.

An important result of Professor Burkur's work is that the silica-supported, iron-based catalysts operated in the slurry mode at much lower pressures (225 psia vs. 315 psia) and that the conversions were much higher (50% vs. 14%) in the experimental apparatus. One drawback based on these results was the slightly lower conversion to hydrocarbons (28% vs. 31%). The higher conversion rate caused the recycle stream to be much smaller, about 12% of the feed stream, than the original case, about 60% of the feed stream. In all cases, 95% of the syngas fed from the syngas unit was converted per pass (excluding the recycle stream) and 5% was purged. The F-T synthesis reactor output, though not exact, was very similar for each catalyst under the conditions tested. Approximately 10 wt% of the hydrocarbon products were C1's and C2's recycled back to synthesis gas through the autothermal reformer.

VIII.5. SYNTHESIS GAS PRODUCTION

For the original catalyst case, the H_2/CO ratio was assumed to be 0.92 based on the lab experiments made for the 1985 study. These conditions were kept the same for this study. Given the past finding, where the cost of synthesis gas from coal was up to three times that for synthesis gas from natural gas, this study also assumed natural gas as a feedstock to the synthesis gas production unit. In the catalyst testing work reported earlier, the new and commercial catalysts were tested with syngas streams having a H_2/CO feed ratio of 0.67. The 1985 report also found that, in cases with low H_2/CO ratios (<2), and this synthesis gas, a POX of natural gas was the preferred route. The crude synthesis gas is then treated in a CO_2 removal unit (i.e., MEA), where a CO_2 stream is recycled to the POX unit, and is further treated in a cryogenic unit (HYCO) to achieve the above H_2/CO ratio.

FIGURE VIII-1
F-T SLURRY PHASE
FLOW SHEET

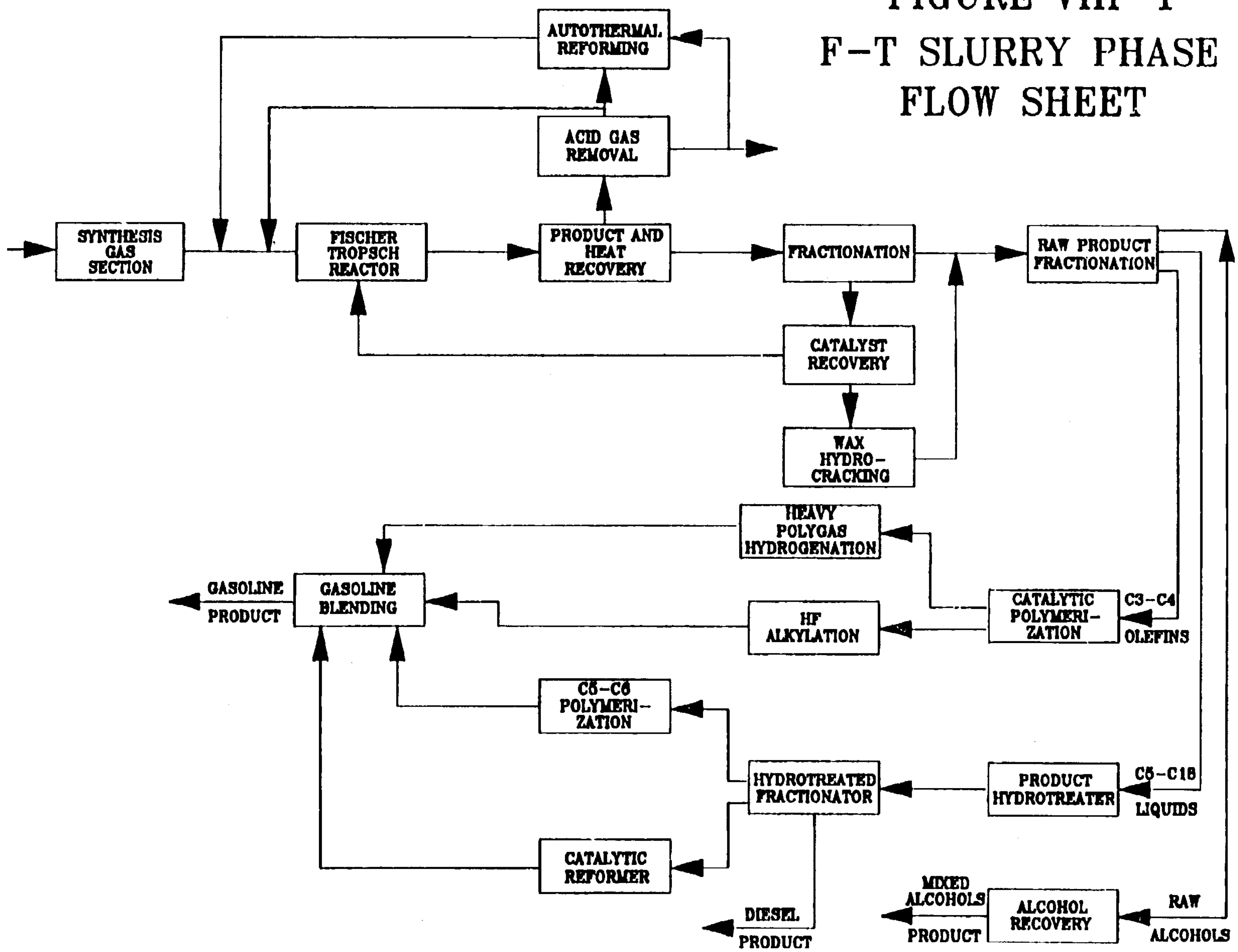

Table VIII-3

Catalyst Comparison

Catalysts:	Original	Commercial	New
H_2/CO Ratio (molar)	.92	.67	.67
Reactor Pressure (psia)	315	225	225
Reactor Temperature (°C)	260	250	250
Experimental Conversion (%)	14	44	52
Products (wt%)			
CO_2	54.9	59.9	62.0
H_2O	13.4	11.7	9.1
Alcohols	1.2	1.5	1.1
Hydrocarbons	30.5	26.9	27.8

Synthesis gas costs are reported in this study as an operating cost, including the capital equipment. Therefore, the total plant cost reported does not include the synthesis gas plant. In this way, different syngas production methods can be evaluated easily. Synthesis gas costs ranged from $1.26/MSCF for the commercial and original catalysts to $1.29/MSCF for the new catalyst. These values assume that credits for H_2 in the purge as a fuel valve and steam from the syngas plant are obtained. Without these credits, syngas costs are about $0.17/MSCF higher. The syngas cost has two components: the capital equipment portion is about $0.27/MSCF of syngas and the balance is natural gas feedstock cost.

VIII.6. CAPITAL INVESTMENT

The summary of the capital investment for each of the three cases is given in Table VIII-4. The methodology for developing this estimate is similar to that used to develop the original estimate. Only the equipment found in the F-T synthesis section was individually estimated based on computer simulations to size equipment and flow schemes. The estimates were made on a mid-1990 cost basis for the F-T synthesis section based on the experimentally determined performance of each catalyst. Costs for the remaining sections of the plant were determined on a 'macro' basis, that is, costs for these sections were based on total flow to that unit. Table VIII-4 gives the investment summary for the original case catalyst for both the 1985 estimate and this estimate. From this comparison, the difference in the projected and actual escalation is significant. Capital equipment is estimated to cost 27% less in actual 1990 dollars than what was projected in 1985, and represents a substantial savings. In comparing the three cases, the new catalyst case has an 11% cost savings in the F-T section and an overall capital equipment savings of 3%.

These savings are not as great as one would expect from the large reduction in the recycle stream. This results from lowering the reactor's operating pressure from 315 psia to 225 psia, which increases the actual gas volumetric flow to the point where it nearly offsets the flow rate reduction resulting from the decrease in the recycle flow rate. The net result is nearly equal to the capital equipment costs.

VIII.7. REQUIRED REVENUES

Required revenues are the amount of money that has to be generated to cover operating costs, interest related costs, and to provide a 7.5% return on investment on an after-tax basis. Operating costs are split into two categories: synthesis gas cost (includes syngas plant investment), and other operating costs, which include power, water, labor and plant overheads. These required revenues are given in Table VIII-5 for two scenarios. The first shows required revenues for natural gas valued at $1.00/MMBtu. The second case shows required revenues for natural gas with no value ($0.MMBtu). The original catalyst case shows the required revenues calculated for both studies. There is a large reduction in required revenues between the estimates, again largely reflecting the change in projected versus actual escalation observed. There is little difference in the required revenue between the new catalyst and the original catalyst cases. The capital related

Table VIII-4

Capital Investment Summary - $MM
Basis: 1990

Catalysts:	Original 1985 Study	1990 Study	Commercial	New
F-T Synthesis	255.	195.2	185.7	174.0
Product Upgrading	150.	114.8	114.8	114.8
Autothermal Reforming	110.	84.2	102.4	92.2
Wax Hydrotreater	30.	23.0	22.9	18.3
Utilities & Offsites	165.	126.3	126.3	126.3
Contingency	180.	137.8	140.0	133.3
Subtotal	890.	681.3	692.1	658.9
Interest	250.	146.2	148.5	141.4
Total	1,140.	827.5	840.6	800.3

Table VIII-5

Required Revenues ($MM/Year)
Basis: 1990

• Natural Gas Cost @ $1.00/MMBtu

Catalysts	Original 1985 Study	1990 Study	Commercial	New
Synthesis Gas	416.	362.5	390.3	370.5
Other Operating	106.	48.5	48.5	48.5
Capital Related	330.	210.6	211.8	202.3
Total 1990 Req Revenue	852.	621.6	650.6	621.3

• Natural Gas Cost @ $0.00/MMBtu

Catalysts:	Original	Commercial	New
Synthesis Gas	89.2	96.0	94.8
Other Operating	48.5	48.5	48.5
Capital Related	210.6	211.8	202.3
Total 1990 Req Revenue	348.3	356.3	345.6

savings are offset by the higher syngas costs that result from the lower H_2/CO ratio in the new catalyst case. The synthesis gas costing only $1.00/MMBtu accounts for more than 50% of these required revenues.

Table VIII-6 gives projected required revenues for 1995 and 2000. The natural gas cost for these timeframes remains at $1.00/MM BTU. Natural gas costs still account for 50% of the required revenues, even though they remain constant.

VIII.8. PRODUCT REVENUES

The projected product prices and revenues based on the 1985 and 1990 estimates are shown in Table VIII-7. These values show the same result as the capital equipment estimates. That is, the actual 1990 product prices are not as high as those predicted in 1985, resulting in lower revenues. The revenue breakdown by product type for each of the three catalysts is shown in Table VIII-8 and does show that there is a slight difference in the product mix. This results from the larger price differential between gasoline and diesel fuels now than what was projected. The average price of liquid fuels is now about $24/bbl versus the projected price of $36/bbl. Crude oil prices are estimated to escalate at the normal inflation rate for the next five years and about 2% in real terms for the five years beyond that (to 2000). Of course, oil and other fuel prices are a large determinate of the overall inflation rate and therefore it is somewhat difficult to predict large revenue increases without a correspondingly large, albeit lagging, increase in costs.

VIII.9. RESULTS

The results of the economic analysis are presented in Table VIII-9. The projected revenue shortfall originally estimated at $25/bbl for the F-T slurry mode has been reduced to $22.5/bbl. As discussed earlier, the capital costs are estimated to be less than previous studies have shown. The catalysts have been improved, but because of pressure changes the actual equipment sizing remains about the same, so the apparent reduction in costs resulted in actual escalation being less than projected in 1985. Accordingly, this had the same effect on product revenues, which resulted in the revenue shortfall remaining about the same. In 2000, revenue shortfall is estimated to be reduced to $18/bbl assuming constant natural gas costs.

If natural gas were available at no cost ($0/MMBtu) the revenue shortfall in 1990 dollars is reduced to about $2/bbl (see Table VIII-10). For this plant to have break-even economics, product prices would have to increase by $23/bbl to an average price of $47/bbl for gasoline and diesel fuels.

Table VIII-6

Projected Revenues in 1990/1995/2000 ($MM/Year)
Basis: Natural Gas Cost @ $1.0/MMBTU

Catalysts:	Original	Commercial	New
• 1990 Cost Basis			
Synthesis Gas	362.5	390.3	370.5
Other Operating	48.5	48.5	48.5
Capital Related	210.6	211.8	202.3
Total Req Revenue	621.6	650.6	621.3
• 1995 Cost Basis			
Synthesis Gas	390.1	420.1	399.9
Other Operating	63.5	63.5	63.5
Capital Related	272.0	276.1	263.6
Total Req Revenue	725.6	759.7	727.0
• 2000 Cost Basis			
Synthesis Gas	426.4	459.0	438.4
Other Operating	83.2	83.2	83.2
Capital Related	361.0	366.0	350.0
Total Req Revenue	870.6	908.2	871.6

Table VIII-7

1990 Product Prices & Revenues Based on
1985 Projection Vs 1990 Projection

- 1990 Product Price ($/bbl)

	1985 Projection	1990 Projection
C3	17.40	11.00
C4	21.00	12.50
C5 - C11	36.60	25.65
C12 - C18	36.12	23.00

- 1990 Projected Revenue ($MM/Year)

Catalysts:	Original	Commercial	New
1985 Projected	475.1	474.8	475.0
1990 Projected	320.5	317.2	322.1

Table VIII-8

Product Revenue Breakdown (%)
1990 Cost Basis

Catalysts:	Original	Commercial	New
C3	1.1	1.2	1.1
C4	0.2	0.3	0.2
C5 - C11	45.0	51.5	48.8
C12 - C18	53.7	47.1	49.8
TOTAL	100.0	100.0	100.0

Table VIII-9

Product Cost Summary - $MM
Basis: Natural Gas Cost @ $1.0/MMBtu

Catalysts:		Original	Commercial	New
• 1990 Cost Basis				
Annual Cost		621.6	650.6	621.3
Product Revenue		320.5	317.2	322.1
Revenue Shortfall	($MM)	301.1	333.4	299.2
	($/bbl)	22.7	25.5	22.5
• 1995 Cost Basis				
Annual Cost		725.6	759.7	727.0
Product Revenue		418.9	414.6	421.0
Revenue Shortfall	($MM)	306.7	345.1	306.0
	($/bbl)	23.1	26.0	23.1
• 2000 Cost Basis				
Annual Cost		870.6	908.2	871.6
Product Revenue		629.9	623.4	633.0
Revenue Shortfall	($MM)	240.7	284.8	238.6
	($/bbl)	18.1	21.5	18.0

Table VIII-10

Product Cost Summary - $MM
Basis: 1990 Cost

Catalysts:		Original	Commercial	New
• Natural Gas Cost @ $1.00/MMBtu				
Annual Cost		621.6	650.6	621.3
Product Revenue		320.5	317.2	322.1
Revenue Shortfall	($MM)	301.1	333.4	299.2
	($/bbl)	22.7	25.5	22.5
• Natural Gas Cost @ $0.00/MMBtu				
Annual Cost		348.3	356.3	345.6
Product Revenue		320.5	317.2	322.1
Revenue Shortfall	($MM)	27.8	39.1	23.5
	($/bbl)	2.1	2.9	1.8