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SLURRY FISCHER-TROPSCH/MOBIL TWO-STAGE PROCESS OF CONVERTING SYNGAS TO HIGH-OCTANE GASOLINE. QUARTERLY REPORT, 1 APRIL-30 JUNE 1982

MOBIL RESEARCH AND DEVELOPMENT CORP.
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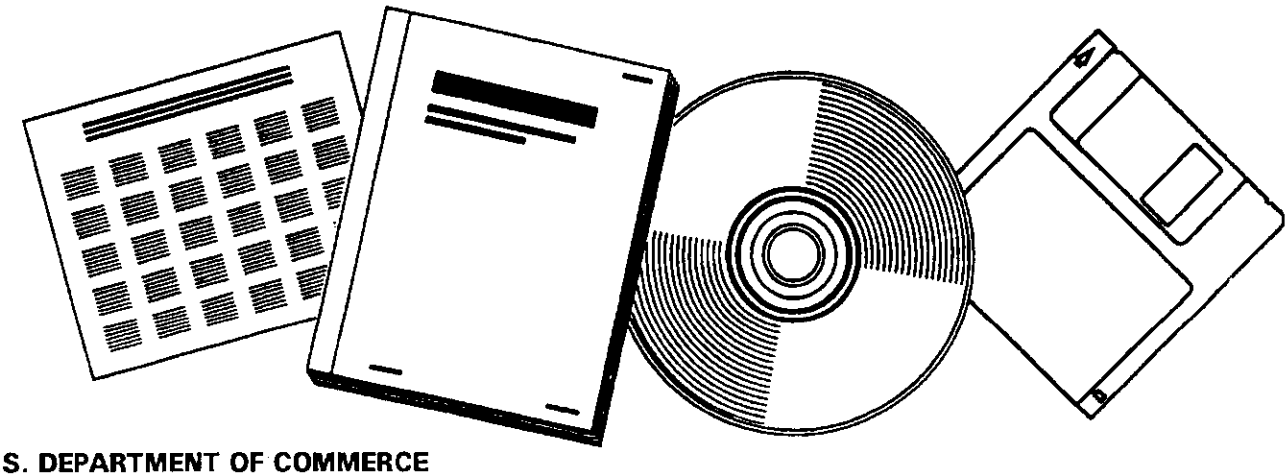

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SLURRY FISCHER-TROPSCH/MOBIL TWO-STAGE PROCESS OF CONVERTING SYNGAS TO HIGH OCTANE GASOLINE

QUARTERLY REPORT FOR THE PERIOD
1 APRIL - 30 JUNE, 1982

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I. Abstract

The first run of the pilot plant, designated as run CT-256-1, was successfully concluded after sixty-one days on stream. In this experiment, the evaluation of the first Fischer-Tropsch catalyst, a $Fe/Cu/K_2CO_3$ catalyst designated as I-A, was carried out. Furthermore, a second-stage ZSM-5 catalyst, designated as II-A, was on stream for forty-nine days. The operation went very smooth and was highly successful considering the complexity of the pilot plant. The second-stage catalyst readily converted the Fischer-Tropsch products (particularly the light olefins and heavy hydrocarbons) into high quality gasoline. A break-in regeneration of the second-stage Catalyst II-A was also successfully carried out.

After the first pilot plant run, several minor modifications were implemented to improve pilot plant operation. The major features included installation of a new slurry loading pot to facilitate the catalyst loading and electric heating tapes at the three unheated flanges of the slurry reactor. Many automatic controls were also installed. These modifications significantly improved pilot plant operation.

The second pilot plant run, CT-256-2, was initiated and run for six days during this reporting period. So far, this run has demonstrated high catalyst loading, high gas throughput, and high synthesis gas conversion. It will continue into the next reporting period.

Evaluation of the raw gasoline product from the two-stage operation has been initiated. Specifically, a modified Mobil corrosion test was conducted on two raw gasoline samples from run CT-256-1. Both samples showed trace-to-light corrosion similar to a reference unleaded gasoline.

II. Objective and Scope of the Project

The overall objective of the contract is to develop a two-stage slurry Fischer-Tropsch/ZSM-5 process for direct conversion of syngas, of the type produced in a coal gasification system, to high octane gasoline. The specific objective is to design, construct, and operate a bench-scale pilot plant so that the economic potential of this process concept can be evaluated. To accomplish these objectives, the following specific tasks will be undertaken:

Task 1 - Design of Bench-Scale Pilot Plant

A two-stage slurry F-T/ZSM-5 bench-scale pilot plant will be designed for conversion of syngas to high octane gasoline. The slurry F-T reactor will be 2" ID and and 25' high. The fixed-bed ZSM-5 reactor will be 2" ID and 4-18" high. A distillation column will be designed to obtain stabilized gasoline products.

Task 2 - Construction and Shakedown of Pilot Plant

The pilot plant will be constructed in MRDC Paulsboro Laboratory. The unit will be shaken down when completed.

Task 3 - Operation of Pilot Plant

At least three slurry F-T catalysts will be tested in the bench-scale pilot plant. One of these catalysts may be provided by DOE's alternate catalyst development projects. The best first-stage catalyst together with a ZSM-5 class zeolite catalyst will be used for process variable studies and catalyst aging tests in the bench-scale unit. Products obtained from the unit will be evaluated to define their qualities.

Task 4 - Conceptual Design Study

A preliminary conceptual design of the process will be developed for a commercial size plant for the conversion of syngas to high octane gasoline. Scoping costs of the plant will be estimated.

III. Summary of Progress to Date

The first run of the two-stage synthesis gas conversion pilot plant (designated as run CT-256-1) was successfully concluded after sixty-one days on stream. The highlights of this run were:

- The evaluation of the first Fischer-Tropsch catalyst, a $Fe/Cu/K_2CO_3$ catalyst designated as I-A, was carried out.

- Smooth operation of the BSU was demonstrated. Operating conditions were varied to explore the limits and the responses of this new pilot plant. The ranges of the operating conditions for the first-stage slurry Fischer-Tropsch reactor were:

Temperature, °C	260-282
Pressure, MPa	1.14-1.83
H_2/CO Feed Ratio, Molar	0.6-1.2
Superficial Feed-Gas Velocity, cm/s	1.0-3.2
Space Velocity, NL/gFe-hr	5-18

  The H_2+CO conversion ranged from 26 to 91 mol % and the methane plus ethane yield from 6 to 20 wt % of the total hydrocarbons produced. The ranges of the operating conditions for the second-stage fixed-bed ZSM-5 reactor were:

Temperature, Inlet, °C	288-371
Pressure, MPa	1.07-1.72
GHSV, 1/hr	716-2,600

- A second-stage ZSM-5 catalyst, designated as II-A, was on stream for forty-nine days. The conversion of the F-T products into high octane gasoline was demonstrated. Regeneration of ZSM-5 catalyst was also successfully carried out.

- Reactor-wax accumulated in the slurry F-T reactor. At the beginning of the run, as high as 33 wt % of the total hydrocarbons produced remained as reactor-wax.

- Gas holdup data, estimated from hydrodynamic studies using the slurry bubble-column reactor, were significantly higher than the values estimated from the correlation of Deckwer, et al., (1980). The gas holdup during the latter part of this run was substantially lower than that in earlier periods. Gas holdup also

lower than that in earlier periods. Gas holdup also varied with the liquid level in the bubble-column.

The maintenance and modifications of the BSU were carried out immediately after the first run. The major efforts included installation of a small slurry loading tank, replacement of a faulty reactor-wax withdrawal filter, and modification of the DP reactor liquid-level measurement system. These modifications resulted in the second successful BSU run in which high catalyst loading and high synthesis gas conversion at high gas throughput were accomplished.

The second BSU run, designated as CT-256-2, was initiated smoothly. A $Fe/Cu/K_2CO_3$ catalyst, designated as I-B, was used in the first reactor and a ZSM-5 catalyst, designated as II-B, was used in the second reactor. Both reactors were brought on stream almost simultaneously. The run was six days on stream at the end of this reporting period and is being continued.

Evaluation of the raw gasoline products collected from the ambient and chilled condensers was initiated. The gasolines obtained from run CT-256-1 were highly aromatic and had many properties associated with high aromatic content gasoline. This high aromatic content was resulted from the unintentionally high severity operation of the second-stage reactor in this first run. From a process economics point of view, lower severity operation may be preferable because the gasoline yield is expected to be higher. Two samples of raw gasoline, before and after caustic washings, were tested for corrosiveness using a modified Mobil corrosion test. The raw gasolines exhibited trace-to-light corrosiveness similar to the reference unleaded conventional gasoline.

IV. Detailed Description of Technical Progress

A. Task 3 - Operation of the Pilot Plant

1. Conclusion of Run CT-256-1

The first run of the BSU, CT-256-1, using Catalyst I-A (containing $Fe/Cu/K_2CO_3$) in the first-stage bubble-column reactor and Catalyst II-A (a ZSM-5 class catalyst) in a second-stage, fixed-bed reactor was successfully concluded on May 17, 1982. The total on-stream time was sixty-one days for Catalyst I-A and forty-nine days for Catalyst II-A. The unit was then shutdown for modifications and maintenance in preparation for the second F-T catalyst evaluation. The major events of this run are summarized in Tables 1 and 2, which include those leading up to the end of last March (fifteen days TOS) reported in the last Quarterly Report (January-March, 1982). Tables 3 and 4 summarize, respectively, the range of the process variables studies and the results from this run.

Major highlights from this run are:

- A smooth operation of the BSU was demonstrated. Process conditions were varied over a wide range to explore the operational limit of the unit. The ranges of the operating conditions for the first-stage slurry F-T reactor were:

Temperature, °C	260-282
Pressure, MPa	1.14-1.83
H_2/CO Feed Ratio, Molar	0.6-1.2
Superficial Feed-Gas Velocity, cm/s	1.0-3.2
Space Velocity, NL/gFe-hr	5-18

The H_2+CO conversion ranged from 26 to 91 mol % and the methane plus ethane yield from 7 to 20 wt % of the total hydrocarbons produced. The ranges of the operating conditions for the second-stage fixed-bed ZSM-5 reactor were:

Temperature, Inlet, °C	288-371
Pressure, MPa	1.07-1.72
GHSV, 1/hr	716-2,600

- An evaluation of a $Fe/Cu/K_2CO_3$ F-T catalyst (I-A) was completed. The results will be used to compare this catalyst against other F-T catalysts which will be evaluated later.

- The conversion of the F-T products into high octane gasoline was demonstrated.

- A significant reactor-wax accumulation in the F-T slurry reactor was observed. This accumulation is expected to increase greatly with decreasing methane and ethane yield.

Detailed operational data of this run are given in the next subsection.

In this first run, the catalyst loading in the slurry reactor was not sufficiently high in order to obtain both a high synthesis gas throughput (higher than 3 cm/s superficial feed gas velocity) and high H_2+CO conversion (higher than 85 mol %). The low catalyst loading resulted from three causes:

1. High gas holdup at the beginning of the run limited the amount of catalyst loaded into the F-T reactor.

2. Large amounts of catalyst were lost during the reactor-wax withdrawal due to a pin-hole in the wax-withdrawal filter.

3. A substantial amount of the F-T catalyst could remain in the slurry loading tank and the long line between the loading tank and the reactor.

All these problems were corrected after this run.

a. First-Stage Fischer-Tropsch Reactor Operation

The pretreatment of the F-T catalyst I-A was reported in the last Quarterly Report and will not be repeated here. After the pretreatment, the material balances for the first-stage operation were obtained on an almost daily basis. There were two ways to obtain these data. Before thirteen days TOS, the second-stage ZSM-5 reactor was bypassed and the material balances were obtained in a normal way. In the other portion of the run, when the second-stage reactor was in operation, the material balances for the first-stage operation could only be obtained through the inter-reactor sampling line, which separated and collected about 10% of the total first-stage reactor effluent. A prorating factor reflecting the total mass flow of the first-stage reactor effluent was used to convert that material flow into a total material balance.

The material balance data collected in the conventional way are summarized in Table A-1 of Appendix A while those collected using the inter-reactor sampling are summarized in Table A-2 of Appendix A. Both tables also show the process conditions for the first-stage operation. The H_2+CO conversion and methane + ethane yield data vs the time-on-stream are depicted in Figure 1. Since the methane and ethane have lower product values than the C_3^+ hydrocarbons and since they are inert over the second-stage ZSM-5 reactor, low yields of methane and ethane are essential for good process economics in this two-stage process. Consequently, their yields must be closely monitored.

The reactor-wax yields reported in Tables A-1, A-2, and A-3 (and also Tables A-7 and A-9) are those hydrocarbons remaining in the slurry reactor under processing conditions. These values are not very accurate since the accumulated reactor-wax was withdrawn very infrequently and the reactor-wax inventory in the reactor was not monitored. The yields seemed to decrease quickly with time on-stream. The hydrocarbon yields in gHC/NM^3 (H_2+CO) converted are also reported in these tables. A theoretical yield may be estimated when the fixed H/C atomic ratio for the total hydrocarbons produced is known. For example, if the H/C ratio for the total hydrocarbons produced is 2.25, then the theoretical hydrocarbon yield is 204 gHC/MN^3 (H_2+CO) converted. Any deviation from such a theoretical yield indicates the accuracy of the material balances.

In order to test the operational limit of the pilot plant and to gain experience with its operations, wide ranges of process variables were used in this run. These variations are shown in Table 1 and partially in Figure 1. For most of the time, the H_2/CO feed ratio of 0.7 was used. Reactor temperatures of 260-271°C, pressures of 1.14-1.48 MPa, and superficial feed gas velocities of 1.5 to 2 cm/s were mostly used.

The operation of this run before fifteen days was described in the last Quarterly Report and will not be repeated here. From fifteen to thirty-five days, the H_2+CO conversion ranged from 42 to 57 mol %. There was only a small decline in the H_2+CO conversion over this period. At both fifteen and thirty-five days, the superficial feed gas velocities were identical; however, both the temperature and the pressure were higher at thirty-five days (from 1.14 MPa to 1.48 MPa, and 266°C to 271°C). However, it is difficult to tell if there is substantial aging of the catalyst as indicated by the higher operating temperature and pressure since substantial amount of the catalyst (about thirty-four g) was withdrawn during this period. In addition, at twenty-one days on-stream, the feed synthesis gas was shut off for more than ten hours due to a utility (steam and cooling water) failure. Such a shut-off of synthesis gas may contribute to catalyst aging. The methane +

ethane yield stayed fairly constant and averaged about 13 wt % of the total hydrocarbons produced during this period. The reactor-wax yield is estimated to be about 6 wt %.

To achieve high H_2+CO conversion at a high synthesis gas throughput, it is essential to obtain high catalyst loading in the slurry reactor. Based on solid-content analysis, the catalyst loading in the bubble-column during the period of fifteen to thirty-five days on-stream was very low (as low as 1.6 wt %). To increase the catalyst loading, a slurry containing 210 g of fresh catalyst was put into the slurry loading tank and injected into the reactor at thirty-five days TOS. An immediate, but small increase in the H_2+CO conversion was observed. However, this increase was erased at thirty-six days when the unit was shut down for fifteen minutes due to a power failure. Another injection of a slurry containing 200 g of fresh catalyst at forty-one days TOS showed practically no effect on the H_2+CO conversion. It was speculated that a substantial amount of the catalyst had remained in the slurry loading tank and the line connecting the tank and the slurry reactor. This hypothesis was consistent with the unusually low catalyst loadings measured by the solid-content analysis of the slurry samples withdrawn from time to time. It was further supported by the higher H_2+CO conversions (70-90 mol % from 45%) observed after washing the slurry loading tank with 1,500 g n-Decane on two occasions (at TOS of forty-three and forty-seven days). After the n-Decane washings, the solid-content of the slurry sample increased to 3.85 wt %. To overcome this problem of the catalyst staying in the slurry loading tank and the slurry feeding line, the following modifications were made at the end of the run.

1. Use a smaller slurry loading tank (1 L instead of 26 L) to reduce the vessel internal surface area.

2. Shorten the line connecting the loading tank to the slurry reactor.

3. Locate the loading tank above the 610 cm flange so that the slurry feeding will always be in the down-flowed direction.

4. Use a portable mechanical stirrer inside the slurry loading tank.

With these modifications,a high catalyst loading was successfully achieved in the next run.

Process variable studies were conducted during the present run, which included:

- Temperature
- Pressure
- Superficial feed-gas velocity
- Feed H_2/CO ratio

Table 5 summarizes the effect of the reactor temperature on the slurry reactor performance. As expected, the H_2+CO conversion went up strongly with the temperature (ranged from 268 to 282°C). However, the methane, ethane, and propane yields changed little over this range of temperature. This is contrary to what was reported by Koelbel and Ralek (1980); however, Koelbel and Ralek did not quantify this effect. An activation energy for the H_2+CO conversion of 135 kJ/gMol was estimated assuming a first-order kinetics without accounting for the effect of the mass-transfer resistance on the H_2+CO conversion. This value is substantially larger than values ranging from 81 to 94 kJ/gMol on Fe/Cu catalysts reported by various sources (Schlesinger, et al., 1954; Deckwer, et al, 1980). Note that if the mass-transfer resistance is taken into account, the estimated activation energy would become even larger. The exit H_2/CO ratio increased greatly with the higher H_2+CO conversion. This trend is expected because the feed H_2/CO ratio of 0.7 is higher than the H_2/CO usage ratio.

The effect of the reactor pressure is summarized in Table 6. The experiments were run with the same superficial feed-gas velocity, and no appreciable change on the H_2+CO conversion was observed. At low pressure operation (1.14 MPa or 150 psig), a moderate increase in the methane and ethane yield was observed. No definitive trend of the exit H_2/CO ratio can be observed.

Table 7 summarizes the effect of the superficial feed-gas velocity on the slurry F-T reactor performance. The variation on the feed-gas velocity reflected directly on the space velocity. As expected, the H_2+CO conversion went up with decreasing space velocity. No other significant variations on the reactor performance were observed.

The last process variable studied was the feed H_2/CO ratio and the results are reported in Table 8. The effect on the H_2+CO conversion showed no definitive trend. The fact that the H_2+CO conversion at forty-eight days TOS was significantly higher than those at fifty days TOS further complicated the matter. The difference may be due mainly to the dynamic behavior of the system resulting from the changing H_2/CO ratio. Nevertheless, the effect on the methane and ethane yield could be clearly observed. High H_2/CO feed significantly increased the methane

and ethane yield. Furthermore, when the feed H_2/CO ratios are substantially higher than the H_2/CO usage ratio (about 0.6), the exit H_2/CO ratios become very large because there is large excess of the hydrogen. In the middle and at the end of the feed H_2/CO variable study, the ratio was restored to that at the beginning of the experiment (0.7) to check the state of the catalyst. The H_2+CO conversion changed drastically from 84 mol % to 74% and then to 72%. It is questionable if this change can be attributed to the one-day operation at the 0.6 H_2/CO feed gas.

Analyses of F-T products are very complicated and costly. There are altogether five product phases, i.e., gaseous, light hydrocarbon liquid, heavy hydrocarbon liquid, reactor-wax, and aqueous. The light and heavy hydrocarbon liquid phases were collected from the chilled and ambient condensers, and the hot condenser, respectively, and usually were combined into a single hydrocarbon liquid phase for analysis. The analyses of the gaseous phase usually posed no problem. The analyses of all other streams to give detailed breakdowns of the hydrocarbons and oxygenates, however, were very time-consuming and only made occasionally. The selectivities of hydrocarbon lumps given in Tables A-1 and A-2 were mainly based on the following analyses and assumptions:

- On-line GC analyses of the gaseous phases.
- "Carbon-number distribution" analyses of the liquid hydrocarbon phases using capillary-column GC technique.
- No analyses of the organic oxygenates in both the aqueous and the liquid hydrocarbon phases.

The "Carbon-Number Distribution" analysis does not give PONA or oxygenate component breakdowns, but it does provide quick and consistent carbon-number breakdown for the F-T hydrocarbon fraction. This analysis is very useful for monitoring the slurry F-T reactor operation.

In four balances covering TOS from 2.3 to 5.4 days, detailed analyses of the C_{11}^- liquid hydrocarbon fraction and the aqueous phases were done. The C_{11}^- fractions were distilled from the liquid hydrocarbon phases. A Sep-Pak Silica Gel LC was used for the separation of the hydrocarbons and the oxygenates. Each fraction was then analyzed by gas chromatographs. The results are summarized in Tables A-3 and A-4. Table A-3 also includes those balances in which no liquid phase analyses were carried out. In those cases, only the compositions from the gaseous phase are reported. Since at the startup of this run the separators were filled with a mixture of non-F-T hydrocarbons, it took about five days for the oxygenates in the liquid hydrocarbon

phases to reach a steady state, as indicated in Table A-4. The total oxygenates there reached about 5 g/100 g of the total hydrocarbon yield and were dominated by alcohols. For the same four balances, the aqueous phases were analyzed using a gas chromatograph and their compositions are reported in Table A-5. The yield of the organic oxygenates there reached about 1.8 g/100 g of the total hydrocarbon yield in three days. The components were dominated by alcohols (94 wt %, mainly in C_1-C_3 alcohols) with small yields of ketones (5 wt %) and esters (<1 wt %). The method for detailed analysis of the C_{12}^+ fraction of the hydrocarbon liquid phases has been developed, but was not used in this run.

Six reactor-wax samples were analyzed for C_{13}-C_{74} hydrocarbons by a GC and results are given in Table A-6. It is expected that there are little lighter or heavier hydrocarbons, and oxygenates in the reactor-wax. Although the carbon-number distribution in the reactor-wax was complicated by the two intermittent injections of fresh catalyst slurries at 34.8 and 40.8 days TOS, some definitive trends of the shifting of the carbon-number distribution during the run can be observed:

- Large reduction of C_{26}-C_{28} (from about 20 wt % to about 10 wt %).
- Large increase of C_{29}-C_{32} (from about 9 wt % to about 19 wt %).
- Moderate reduction of C_{34}-C_{36} (from about 27 wt % to 18-20 wt %).
- Large increase of C_{44}-C_{63} (from about 10 wt % to 18-22 wt %).

It was not possible to determine if the distribution reached an equilibrium at fifty-six days TOS. Further investigation will be needed.

Based on a hypothesis with a single parameter of chain-growth probability, the carbon-number distribution of the F-T products may be described by the well-known Schulz-Flory distribution (Flory, 1967) represented by the following equation:

$$\log (M_I/I) = \log (\ell n^2 \alpha) + I \log \alpha \qquad (1)$$

A Schulz-Flory type C-number distribution plot based on the material balance at fifty-two days TOS is given in Figure 2. An α value, representing the chain-growth probability, of 0.70 is estimated from the plot for the hydrocarbons excluding the reactor-wax. The distribution, however, shows large deviation

from the Schulz-Flory distribution when the reactor-wax is included. The reactor-wax yield at fifty-two days TOS was estimated to be about 6 wt % of the total hydrocarbon produced. This yield number may not be very accurate. Further observations will be needed. Furthermore, the C-number of the reactor-wax may not have reached equilibrium, as indicated in the preceeding paragraph.

As reported in the last Quarterly Report, some gas holdup values were estimated by measuring the weight of the reactor liquid withdrawn between the different viewports along the bubble-column reactor. The results are summarized below:

TOS Days	Avg. u_g cm/s	w_c Wt %	Viewport Positions, cm	ϵ_g, Vol % This Study	ϵ_g, Vol % Deckwer (1980)
6.8	2.6	2.6	762/610	48	14
33.9	2.2	1.7	762/610	41	13
60.8	1.8	2.5	762/610	14	10
61.1	2.2	2.5	610/305	22	13
61.1	2.2	2.6	305/0	42	13

Several conclusions can be drawn from these data. Firstly, the gas holdup during the earlier part of the run was substantially higher than at the latter part of the run. This was probably due to the changing wax character. Secondly, the gas holdup varied with the liquid level in the bubble-column. And lastly, the gas holdup values are significantly higher than the corresponding ones estimated from the following correlation:

$$\epsilon_g = 0.053\ (u_g)^{1.1} \qquad (2)$$

given by Deckwer, et al., (1980).

The operation of this run was voluntarily terminated after sixty-one days TOS, since it would be extremely difficult to simulaneously achieve high H_2+CO conversion and high gas throughput in this run. After the shutdown, the catalyst slurry was drained from the reactor. Slurry samples were taken for solid-content analysis and an attempt was made to account for the catalyst inventory. The 605 g of the catalyst initially loaded into the slurry loading tank plus the 390 g added during the run gave a total of 995 g added into the loading tank. However,the solid analysis of the slurry sample unloaded after the end of the run gave only sixty-nine g of the catalyst. Later rinsing of the slurry loading tank and the slurry reactor gave another 125 g. Analysis of the solid-content of all the slurries withdrawn

during the run gave 429 g. Altogether, 372 g of the catalyst could not be accounted for. After careful examination, it was concluded that the following may be the contributing causes for this discrepancy:

1. Substantial amount of the catalyst remaining in the catalyst loading tank and the line connecting the tank and the reactor.

2. Inaccuracies in the sampling of slurry samples.

3. Some catalyst loss in the slurry withdrawal lines and DP lines.

Some discussions of the first two causes are warranted. At the startup of this run, a slurry with 13.1 wt % catalyst loading was charged to the slurry reactor through the slurry loading tank. Due to an unexpected high slurry level in the reactor with a nitrogen flow, 43% of the charged slurry was immediately unloaded to avoid a slurry overflow into the disengagement section of the reactor. Several attempts to obtain representative slurry samples from the drained slurry for solid-content analysis were tried. Eventually, using a mechanical agitator in a hot slurry container, two samples were obtained to give a consistent solid-content reading (6.6 and 6.9 wt %). These numbers indicated that probably about 333 g of the catalyst remained in the slurry loading tank. Some modifications were proposed and listed in the earlier part of this subsection to overcome this problem of catalyst remaining in the slurry loading tank.

b. Second-Stage Fixed-Bed ZSM-5 Reactor Operation

The second-stage reactor, containing a ZSM-5 class catalyst, designated II-A, was put on-stream at thirteen days TOS. The performance of the second-stage reactor from the break-in period up to fifteen days had been reported in last Quarterly Report. In the ensuing period, the second-stage reactor continued to perform smoothly. The material balances were performed almost daily and are summarized in Table A-7 of Appendix A. The properties of the raw liquid products collected from the ambient and chilled condensers are summarized in Table A-8, while detailed hydrocarbon compositions are given in Table A-9. Two types of material balance information are included in Table A-7; one obtained without an inter-reactor sampling and the other with an inter-reactor sampling. The type without an inter-reactor sampling is conventional and requires no elaboration here. The type with an inter-reactor sampling, however, diverted about 10% of the first-stage reactor effluent

to the inter-reactor sampling line. Consequently a prorating factor for a total material balance to reflect the total weight of the first-stage reactor effluent is used.

In this trial run of a second-stage ZSM-5 reactor, the initial reactor inlet temperature was set arbitrarily at 371°C, which resulted in a very high catalytic activity. This high activity reflected in a high conversion of the light olefins, and large formation of propane, butanes and aromatics. This yield trend means a low C_5+ and alkylate yields. Therefore, in order to increase the gasoline yield (including the alkylate), it was imperative to lower the second-stage ZSM-5 catalyst severity. This was achieved by lowering the reactor inlet temperature to 329°C over a six-day period. The inlet temperature was further reduced to 302°C after another seventeen days. However, for a majority of the time, the severity of the second-stage operation was very high. This was mainly caused by the unexpected low gas throughput in the first-stage reactor because of the low catalyst loading problem that was mentioned earlier.

One useful criterion to measure the severity of the second-stage operation is the molar $i\text{-}C_4/(C_3^= + C_4^=)$ ratio. A high severity operation indicates high conversion of propene and butenes and large formation of i-butanes which gives a high ratio of $i\text{-}C_4/(C_3^= + C_4^=)$. In addition, a value of unity of this ratio indicates theoretically the best alkylate yield by the alkylation of the propene and butenes with the i-butanes produced from the second-stage reactor. A ratio of unity, therefore, usually coincides with a high total gasoline yield. From Table A-7, this ratio was above 1.39 at all time and above 3.0 most of the time. This further indicates a high operational severity.

Generally speaking, the operation of the second-stage rector was very successful except for the lack of information on low severity operations. From the process economics point of view, high severity operation of the second-stage reactor may not be desirable since there may be too much loss in gasoline yield with a small increase on the gasoline octane number. However, more data are needed before any conclusion can be drawn for this important question.

The raw gasoline collected in the chilled and ambient condensers contained small amounts of acids based on acid number analyses. Those acids, however, can be removed by simple water washing. In one instance, twenty g of a raw gasoline sample with an acid number of 0.19 mgKOH/g was washed twice with fifty g of distilled water. The acid number was reduced to zero after the washings. A test to minimize the amount of the water required for washings is planned.

The operation of recycling the gas from the ambient separator to the inlet of the second-stage reactor was broken in during the period of forty-nine to fifty-six days TOS and again during the period of fifty-seven to sixty-one days TOS. The recycle compressor was running smoothly.

Several temperature profiles in the second-stage reactor are shown in Figure 3. The temperature rises in the reactor were in the same order of magnitude as those expected.

c. Second-Stage ZSM-5 Catalyst Regeneration

The second-stage ZSM-5 catalyst, even though only moderately deactivated after forty-nine days on-stream, was oxidatively regenerated to check out the regeneration facilities of the BSU. These facilities include a regeneration recycle compressor, make-up air compressor, regeneration product GC system and the detachable regeneration piping.

For safety reasons, the reactor to be regenerated was first physcially isolated from the rest of the BSU by disconnecting the pipings between them. The reactor was then connected with the regeneration piping circuit and the whole circuit was purged and pressured by nitrogen to 1.14 MPa. A nitrogen flow rate of 6.1 Nm^3/kg catalyst-hr was maintained by the recycle compressor. The reactor was then heated up to 343°C and 0.079 Nm^3/hr make-up air was then introduced. The maximum catalyst bed temperature was maintained at or below 485°C by adjusting the reactor inlet temperature and the make-up air flow rate.

The O_2-concentration at the reactor exit was continuously monitored during the course of regeneration using an electrochemical oxygen analyzer. The exit O_2-concentration was maintained at less than 1 mol % by adjusting the make-up air flow rate when the reactor inlet temperature was less than 466°C. At the end of regeneration, the reactor exit O_2-concentration was allowed to increase to 7 mol %. At that time, the axial catalyst bed temperature was practically uniform at about 483°C. The total regeneration took about fourteen hours and the total product water collected during that period was 6.3 g.

2. Bench-Scale Unit Maintenance and Modifications

After the end of the first run, the BSU was shut down for modifications. The major items included:

1. A new but smaller (1 L) catalyst slurry loading tank was constructed to replace the 26 L loading tank in the original design. The new tank was connected to the slurry reactor at 610 cm above the feed-gas distributor

with a 90 cm line. The length of the connecting line was kept short to minimize catalyst loss in the line.

2. The wax withdrawal filter was replaced with a new filter of 10 μm openings. The old filter was found to have a pinhole.

3. A small, 2 μm filter was installed horizontally at 457 cm above the feed-gas distributor for testing.

4. The slurry sampling vessels E-1, 2, 3, and 4 were relocated from the ground level to the sampling points to minimize the catalyst loss and settling in the lines connecting the vessels and the reactor.

5. A new design was adopted for the N_2-purge orifices used for the DP-cell legs of the slurry reactor liquid-level measurement system. This new design had the orifice tip pointed downward instead of horizontally. A downward design may be better in keeping the slurry out of the DP-cell legs.

6. The flow rate measurement of feed H_2, CO, total charge and the combined off-gas were automated.

7. Heating tapes were installed at the originally unheated flanges located at 305, 610, and 762 cm above the feed-gas distributor. Temperature controllers TIC-24, 25, and 26 were assigned for their temperature control.

8. A new thermocouple was installed at 8 cm above the feed-gas distributor to monitor the slurry temperature close to the distributor. Also, the thermocouple at 30 cm location was found not completely inserted into the slurry reactor and was later reinserted properly.

The first two modifications were most essential in order to achieve high catalyst loading that is required to achieve simultaneously high synthesis gas conversion and throughput. Their success was later demonstrated in the high catalyst loading operation of the second BSU run. The third modification was minor. The 2 μm filter was shown in the later run to be impractical since the wax withdrawal rate was very low.

The fourth modification contributed to less catalyst loss and improvement in obtaining slurry samples. The fifth modification was essential for measuring the slurry level in the slurry reactor. Its operation was not successful during the second run mainly due to the operator's inexperience, but it has since proven successful.

The last three modifications were not essential for BSU operation, but they contributed to easier operation and in obtaining improved operational data.

3. Run CT-256-2 - Startup

After turnaround of the BSU for maintenance and modifications, the unit was smoothly started up on June 24, 1982 to evaluate a second F-T catalyst, designated as I-B ($Fe/Cu/K_2CO_3$). A second ZSM-5 catalyst, designated as II-B, was also adopted for this operation. In the following, a description of this run up to the end of this reporting period is presented.

a. Slurry Catalyst Loading

The procedure for loading the slurry catalyst into the first-stage reactor was basically the same as that used for run CT-256-1 except for the following improvements:

- The startup slurry was prepared using 4,000 g of spent reactor-wax (containing about 0.5 wt % solid), 895 g of FT-200 Vestowax(1), and 1,375 g I-B catalyst in 791 g Mobil base stock F-509(2). The initial catalyst loading was 19.5 wt %.

- The slurry was loaded into the reactor through a new 1 L size loading tank, followed by washing with 500 mL of n-decane. During washing, a portable stirrer was inserted into the tank to agitate the slurry there to ensure a good washing.

The static slurry level, not including the washing n-decane, was estimated to be 427 cm. Reactor slurry samples withdrawn later showed that high catalyst loading was indeed achieved.

During run CT-256-1, the gas holdup in the F-T column in the latter part of the run was substantially lower than that at the beginning of the run. The reactor-wax produced by the F-T reactions might be the major contributor to this lower gas holdup. Since a low gas holdup is essential for achieving high catalyst loading in the reactor, spent wax from the last run was used in this run. Right after loading, with a nitrogen flow at 4 cm/s, the expanded slurry level reached between 610 and 762 cm viewports. The gas holdup was estimated to be approximately 35 vol % which is substantially less than the initial gas holdup (63 vol %) observed in the last run.

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(1) A F-T paraffin wax with an average molecular weight of 600.
(2) A proprietary high molecular-weight paraffinic base stock.

b. Fischer-Tropsch Catalyst Pretreatment

The pretreatment conditions for the F-T catalyst I-B were:

H_2+CO flow rate	=	1.84 Nm^3/hr
H_2/CO feed ratio, molar	=	0.70
Superficial feed-gas vel.	=	4.0 cm/s
Space Velocity	=	2.0 NL/gFe-hr
Temperature	=	280°C
Pressure	=	1.14 MPa

These conditions were similar to what was used in the last run except for the low space velocity, which resulted directly from the high catalyst loading achieved in this run.

The course of pretreatment was carefully monitored by measuring the product gas volume contraction, H_2 and CO conversion, and CO_2 and methane concentration in the product gas. All these quantities increased with time-on-stream as shown in Figure 4. The pretreatment was terminated after 11 hours when CO conversion reached 82 mol %.

c. Brief Description of Synthesis Operation

To the end of this reporting period, the synthesis operation of this run was run only for five days. For completeness, the detailed description of the operation is postponed to the next Quarterly Report. A brief description of the synthesis operation is given below.

The synthesis operation of the slurry F-T reactor was commenced immediately after the F-T catalyst pretreatment by lowering the slurry reactor temperature to 260°C. The H_2+CO conversion dropped readily to about 45 mol %, but increased to 85% in about four days. This increase in the conversion was attributed to activation of the F-T catalyst under the synthesis condition. During this period, the methane and ethane yield was about 10.5 wt % of the total hydrocarbons produced.

After two hours on-stream, a slurry sample was withdrawn from the 30 cm sampling port. The sample contained 23.6 wt % catalyst based on a solid-content analysis. At four days on-stream, slurry samples were withdrawn from 30, 152, 305, and 610 cm sampling ports. Solid-content analysis of each sample gave the following results:

Sampling Location, cm	Catalyst Content, Wt %
30	17.5
152	16.1
305	14.3
610	9.9

A significant catalyst concentration profile existed along the bubble-column reactor at a feed-gas superficial velocity of 4 cm/s. However, by adopting this profile and a set of practical operation conditions, a mathematical model calculation showed that the predicted H_2+CO conversion was within 1% of the conversion predicted using a uniform catalyst concentration profile. The average catalyst concentration based on this profile was estimated to be about 13.5 wt % which was substantially less than the original catalyst loading of 19.5 wt %. This difference may be due to substantial reactor-wax accumulation in the slurry reactor.

A second-stage reactor, containing 215 g of II-B ZSM-5 catalyst, was brought into operation at two hours after the beginning of the synthesis operation. The initial reactor inlet temperature was 288°C. In anticipation of the catalyst aging due to coking, the reactor inlet temperature was raised at a rate of 3.3°C per day during this early period. A more required rate of increase of the inlet temperature will be established later in this operation.

4. Product Evaluation

During the twenty-eight to forty-eight days on stream period, two raw gasoline samples from the run CT-256-1 were obtained which had ASTM D-974 acid numbers of 0.15 (forty-eight days TOS) and 0.28 (twenty-eight to thirty days TOS). Because of limited sample size available at the current time, standard corrosion tests could not be run; however, modified in-house tests was conducted to obtain relative comparisons of corrosion tendencies for the two acid number levels and a conventional petroleum sourced unleaded gasoline. The modified test used a tall bottle with a galvanized iron strip standing in a bottom water layer, with the gasoline sample above, and with air exposure at the top. Results, judged after 4 weeks storage at 43°C, indicated trace-to-light corrosion for the 0.15 and 0.28 acid number samples and reference unleaded gasoline. Similar gasoline samples of 150 mL were then washed first with 15 mL of 15 wt % caustic soda solution and then with 15 mL of distilled water, and finally subjected to the same test. However, no significant improvements in the corrosion testing results were observed. When larger samples become available, standard corrosion tests will be conducted to better define product performance.

Several samples of raw gasoline collected from the ambient and chilled condensers were analyzed for gasoline properties, such as specific gravity, acid number, PONA, octane numbers and ASTM distillation. The results are summarized in Table A-8 and reflect strongly the consequence of high severity operation of the current run, including high aromatic content, high octane number, and high specific gravity. The first three samples exhibited foaming at the end of ASTM D-86 distillation and distillations were stopped prematurely. This unusual phenomena may be related to the fact that these three samples were obtained under the most severe condition in the second-stage operation. In typical operational conditions, this problem will not exist. The acid numbers of the unwashed samples indicated that there were small amount of acids in the raw gasoline. As was mentioned earlier, simple water washing removed practically all acids.

It shall be emphasized that the raw gasolines obtained in the run CT-256-1 were not typical because the trial operation of the second-stage reactor was unusually severe. No further work on product evaluation will be done on these gasolines.

5. Conclusions

The first run of the two-stage synthesis gas conversion pilot plant (designated as run CT-256-1) was successfully concluded after sixty-one days on stream. The highlights of this run were:

- The evaluation of the first Fischer-Tropsch catalyst, a $Fe/Cu/K_2CO_3$ catalyst designated as I-A, was carried out.
- Smooth operation of the BSU was demonstrated. Operating conditions were varied to explore the limits and the responses of this new pilot plant. The ranges of the operating conditions were:

Temperature, °C	260-282
Pressure, MPa	1.14-1.83
H2/CO Feed Ratio, Molar	0.6-1.2
Superficial Feed-Gas Vel., cm/s	1.0-3.2
Space Velocity, NL/gFe-hr	5-18

The H_2+CO conversion ranged from 26 to 91 mol % and the methane plus ethane yield ranged from 7 to 20 wt % of the total hydrocarbons produced. The ranges of the operating conditions for the second-stage fixed-bed ZSM-5 reactor were:

Temperature, Inlet °C	288-371
Pressure, MPa	1.07-1.72
GHSV, 1/hr	716-2,600

- A second-stage ZSM-5 catalyst, designated as II-A, was on stream for forty-nine days. The conversion of the F-T products into high octane gasoline was demonstrated. Regeneratioin of ZSM-5 catalyst was also successfully carried out.

- Reactor-wax accumulated in the slurry F-T reactor. At the beginning of the run, as high as 33 wt % of the total hydrocarbons produced remained as reactor-wax.

- Gas holdup data, estimated from hydrodynamic studies using the slurry bubble-column reactor, were significantly higher than the values estimated from correlation of Deckwer, et al. (1980). The gas holdup during the latter period of this run was substantially lower than that in earlier periods. Gas holdup varied with the liquid level in the bubble-column.

The maintenance and modifications of the BSU were carried out immediately after the first run. The major efforts included installation of a small catalyst slurry loading tank, replacement of a faulty reactor-wax withdrawal filter, and modification of the DP reactor liquid-level measurement system. These modifications resulted in the successful second BSU run in which high catalyst loading, and high synthesis gas conversion at high gas throughput were accomplished.

The second BSU run, designated as CT-256-2, was initiated smoothly. A $Fe/Cu/K_2CO_3$ catalyst, designated as I-B, was used in the first reactor, and a ZSM-5 catalyst, designated as II-B, was used in the second reactor. Both reactors were brought on stream almost simultaneously. The run was six days on stream at the end of this reporting period and is being continued.

Evaluation of the raw gasoline products collected from the ambient and chilled condensers was initiated. The gasolines obtained from run CT-256-1 were highly aromatic and had many properties associated with high aromatic content gasoline. This high aromatic content was resulted from the unintentionally high severity operation of the second-stage reactor in this first run. From a process economics point of view, lower severity operation may be preferable because the gasoline yield is expected to be higher. Two samples of raw gasoline, before and after caustic washings, were tested for corrosiveness using a modified Mobil

corrosion test. The raw gasoline exhibited trace-to-light corrosiveness similar to a reference conventional unleaded gasoline.

6. Future Work

- The run CT-256-2 for evaluation of the F-T catalyst I-B will be completed.
- The evaluation of the raw gasoline product from the BSU will be continued.
- A hydrodynamic study using a hot, non-reacting bubble-column will be completed.

V. NOMENCLATURE

I	Carbon number
GHSV	Gas hourly space velocity, (mL gas (STP)/hr-mL reactor)
M_I	Weight fraction of the I carbon number hydrocarbon
P	Pressure, (MPa)
SV	Space velocity, (NL/gFe-hr)
T	Temperature, (°C)
u	Superficial velocity, (cm/s)

Greek Letters

α	Probability of the chain-growth
ϵ_g	Gas holdup, (mL gas/mL expanded slurry)

Superscripts

i	At reactor inlet

Subscripts

c	Catalyst
g	Gas

VI. Literature

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Table 1. Major Events in Run CT-256-1
(excluding Reactor-wax and Slurry Inventory)

TOS, Days	Major Events
0	Pretreatment
0.5	Upset: High slurry-level alarm
5-8.1	1st stage: 1.3--2.2 cm/s
	260--266 °C
12.6	2nd stage: start-up
13.7-19.0	1st stage: 1.14--1.48 MPa
	1.6--1.8 cm/s
	266--268 °C
	2nd stage: 371--329 °C
21.3	Upset: steam and cooling water failure
21.7	Upset: Power failure
26.7	1st stage: 268--271 °C
29.8-36.1	2nd stage: 329--302 °C
36.2	Upset: Power failure
41.9-47.6	1st stage: 268--274 °C
	1.8--3.2 cm/s
	2nd stage: 292--316 °C
48.0-52.8	1st stage: 0.7--1.2--0.7 H2/CO
54.8-58.0	1st stage: 268--282 °C
	1.3--2.2 cm/s
	1.14--1.83 MPa
58.0	Charge H2 off. 1.8--1.0 cm/s
58.1	Charge H2 back on. 1.0--1.8 cm/s
58.3	Syn-gas off; N2 on
58.4	Syn-gas on
60.5-60.8	Hydrodynamic study
61.1	End of Run CT-256-1

Table 2. Major Events in Run CT-256-1
(Reactor-wax and Slurry Inventory)

TOS, Days	Major events
-1.3	Slurry loading
-0.6	Slurry unloading: 2041 g, 6.7 % solid
0.1	Slurry sampling : 35 g, from 152 cm, 4.66 % solid
1.9/3.0	Wax withdrawal : 291/440 g, 2.54 % solid
4.0	Slurry sampling : 42 g, from 152 cm, 2.64 % solid
6.8	Wax withdrawal : 1624 g, 2.6 % solid
6.8/18.9	Slurry sampling : 60/64 g, from 152 cm, 2.6/1.78 % solid
33.9/34.7	Wax withdrawal : 1351/626 g, 1.6 % solid
34.8	Slurry sampling : 30 g, from 152 cm, 1.69 % solid
	Slurry loading : 200 g cat I-A, 11.8 g Mobil base stock F-509,1048 g FT-200 wax
40.8	Slurry sampling : 19.2 g, from 152 cm, 1.5 % solid
	Wax withdrawal : 1026 g, 1.59 % solid
	Slurry loading : 190 g cat I-A, 119 g Mobil base stock F-509, 1000 g FT-200 wax, 1000 g n-Decane
41.8/42.7	Slurry sampling : 50/54 g, from 152 cm, 1.9 % solid
43.5	Solvent loading : 1500 g n-Decane
43.8	Slurry sampling : 34 g, from 152 cm, 2.64 % solid
46.9	Solvent loading : 1500 g n-Decane
47.8/55.7	Slurry sampling : 118/245 g, from 30/152 cm, 3.85/2.62 % solid
	Wax withdrawal : 1473 g, 2.54 % solid
60.8	Slurry sampling : 265.2/38.7/53.8/135.1 g, from 30/152/305/610 cm, 3.04/2.53/2.69/1.91 % solid
	Wax withdrawal : 5093 g, 2.22 % solid
61.1	Slurry unloading: 2660 g, 2.6 % solid
	End of Run CT-256-1

Table 3

Ranges of Process Variables Studied in Run CT-256-1

First-Stage	Range of Process Variables
Temperature, °C	260-282
Pressure, MPa	1.14-1.83
Superficial Feed-Gas Vel., cm/s	1.0-3.2
Space Velocity, NL/gFe-hr	5-18
Feed H_2/ CO molar ratio	0.6-1.2
Second-Stage	
Inlet Temperature, °C	288-371
Gas Phase Space Vel., 1/hr	716-2600

Table 4

Ranges of Operation Results (Run CT-256-1)

First-Stage	Range of Results
H_2+CO Conv., mol %	26-91
Methane + Ethane Yield, wt % HC	6-20
Reactor-Wax Yield, wt % HC	5-33

Second-Stage Hydrocarbon Yield, Wt %

	Before Alkylation	After Alkylation
C_1+C_2	10-14	10-14
C_3-C_4	29-44	19-40
C_5-C_{11}	36-51	39-62
C_{12}^+ (excl. reactor-wax)	1-4	1-4

Properties of Raw Liquid Hydrocarbons[1]

Aromatics, Wt %	17-81
Acid No., mgKOH/gHC	0.09-1.8
Octane No., R+0	90-98
R+3	96-101
M+0	79-85
M+3	85-93

[1]Collected in ambient and chilled condensers.

Table 5

Effect of Temperature on Slurry F-T Reactor Performance[1]

(Run CT-256-1)

Temperature, °C	268	271	277	282	268
TOS, Days	54.2	54.8	55.1	55.5	55.7
H_2+CO Conv., Mol %	68	72	84	91	69
Methane, Wt %	10	10	10	9	9
Methane + Ethane, Wt %	13	13	13	11	12
Exit H_2/CO, molar	.79	.76	1.0	1.5	.77

[1] 0.7 H_2/CO, 1.48 MPa, 1.8 cm/s superficial feed-gas velocity (4.9 NL/gFe-hr space velocity).

Table 6

Effect of Pressure on Slurry F-T Reactor Performance[1]

(Run CT-256-1)

TOS, Days	56.6	56.8	56.9	57.6
Pressure, MPa	1.48	1.83	1.14	1.48
Space Velocity, NL/gFe-hr	5.8	7.2	4.5	5.8
H_2+CO Conv., Mol %	59	58	59	56
Methane, Wt %	9	9	11	10
Methane + Ethane, Wt %	12	12	14	12
Exit H_2/CO, molar	.66	.63	.88	.73

[1] 0.7 H_2/CO, 268°C, 1.8 cm/s superficial feed-gas velocity.

Table 7

Effect of Superficial Feed-Gas Velocity on Slurry F-T Reactor Performance[1]

(Run CT-256-1)

TOS, Days	55.8	56.0	56.2	56.3
Superficial Feed-Gas Vel., cm/s	1.8	1.3	2.2	1.8
Space Velocity, NL/gFe-hr	5.8	3.9	7.8	5.8
H_2+CO Conv., Mol %	61	70	51	61
Methane, Wt %	9	8	9	9
Methane + Ethane, Wt %	12	10	12	12
Exit H_2/CO, Molar	.76	.76	.75	.70

[1] 0.7 H_2/CO, 268°C, 1.48 MPa.

Table 8

Effect of Feed H_2/CO Ratio on Slurry F-T Reactor Performance[1]

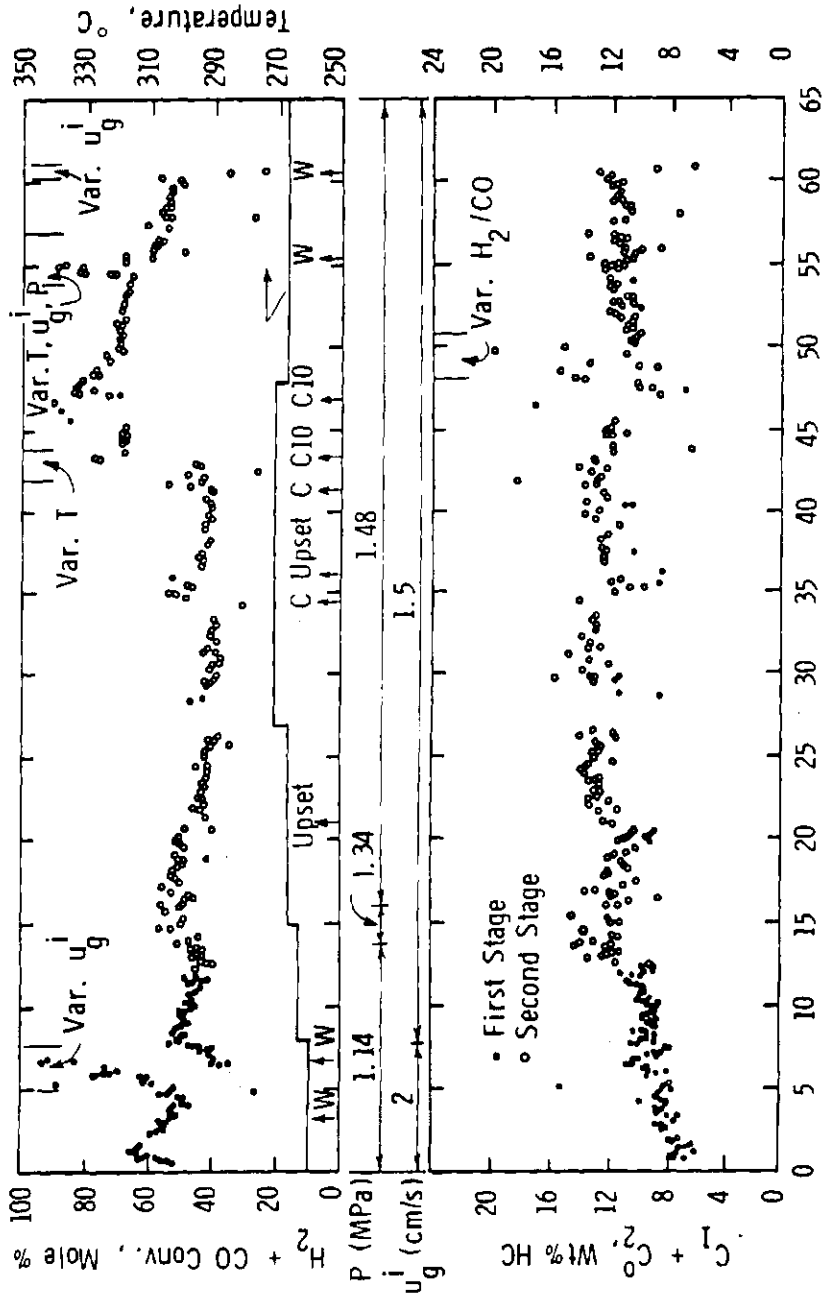
(Run CT-256-1)

TOS, Days	47.7	48.1	48.8	49.6	49.9	50.4
Feed H_2/CO, Molar	.7	1	.6	.7	1.2	.7
H_2+CO Conv., Mol %	84	85	79	74	76	72
Methane, Wt %	8	10	7	9	14	9
Methane + Ethane, Wt %	11	14	9	11	20	11
Exit H_2/CO, Molar	1.2	6.1	.88	.82	17	.90

[1] 268°C, 1.48 MPa, 1.8 cm/s superficial feed gas velocity (4.9 NL/gFe-hr space velocity).

Figure 1

SYNTHESIS GAS CONVERSION AND METHANE + ETHANE YIELD
(Run-CT-256-1, 1st Stage Catalyst, I-A: Ppted. $Fe/Cu/K_2CO_3$;
2nd Stage Catalyst, II-A: ZSM-5)



C - Catalyst Loaded; C10 - Normal Decane Loaded; W - Wax Withdrawal

Figure 2

SCHULZ-FLORY DISTRIBUTIONS FOR FIRST-STAGE F-T PRODUCTS
(Run CT-256-1,52 Days TOS)

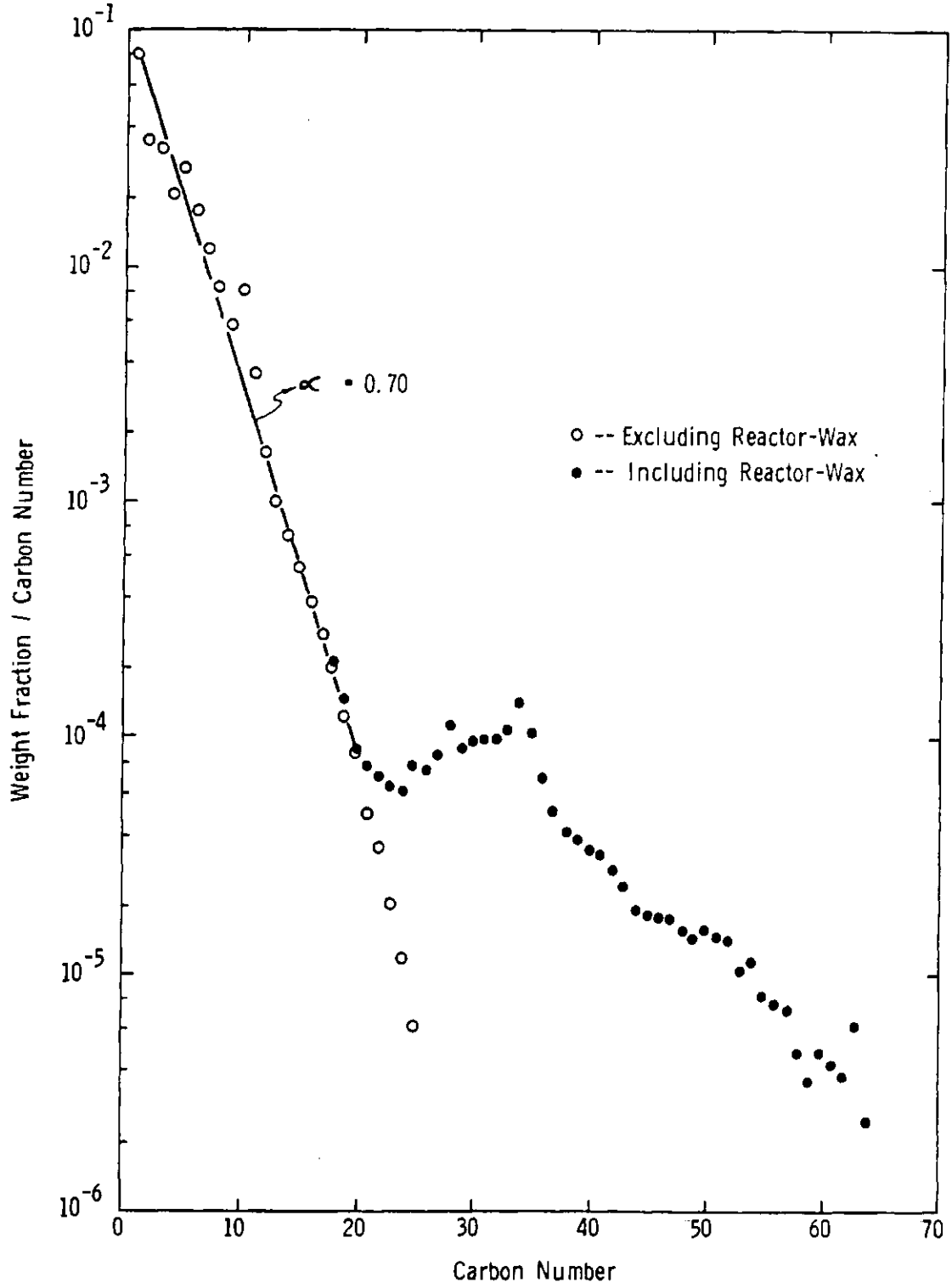


Figure 3

SECOND-STAGE FIXED-BED ZSM-5 REACTOR TEMPERATURE PROFILES
(Run-CT-256-1)

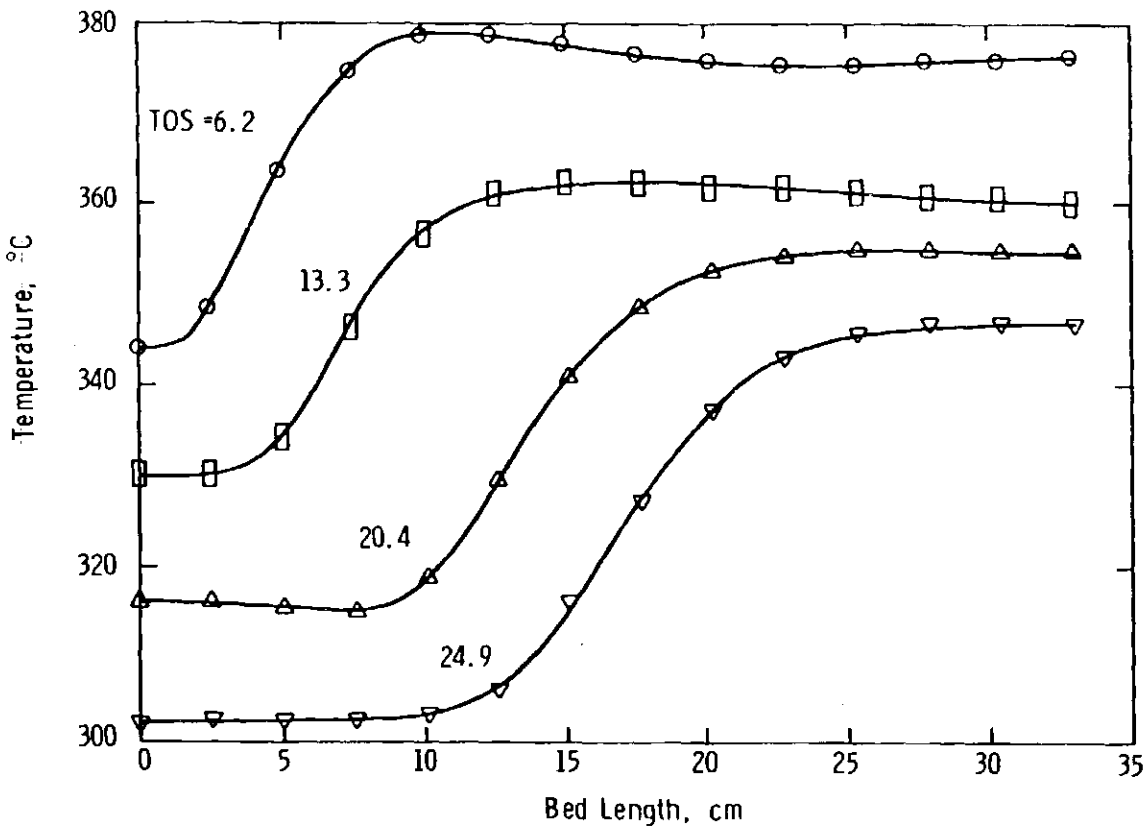
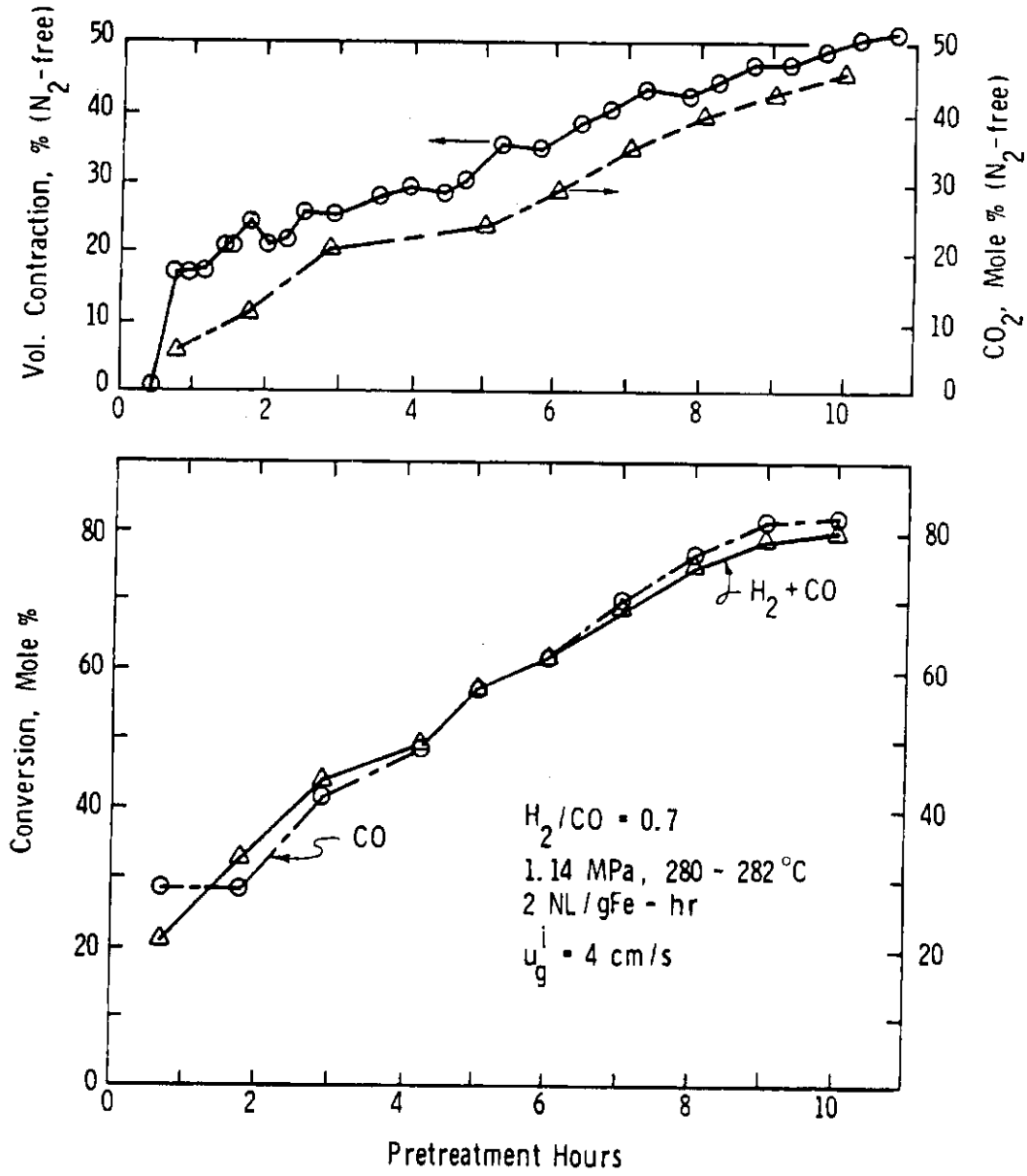


Figure 4

RUN CT-256-2 CATALYST PRETREATMENT
(CATALYST I-B)



APPENDIX A

MATERIAL BALANCE DATA FROM CT-256

Table A-1
First-Stage Fischer-Tropsch Bubble-Column
Operating Conditions and Material Balances
Second-Stage Not-Operative
Run CT-256-1

(Nitrogen-Free Basis)					
M.B. No.	1- 1	1- 2	1- 3	1- 4	1- 6
Days On-stream	2.3	3.3	4.4	5.4	11.8
First-Stage Conditions:					
Charge H2/CO (Molar)	0.719	0.734	0.752	0.627	0.603
Temperature, ^{o}C	260	260	260	260	265
Pressure, MPa	1.136	1.136	1.136	1.136	1.136
Feed Sup. Vel., cm/s	2.250	2.250	2.250	2.060	1.767
Space Vel., NL/gFe-hr	8.54	9.12	9.20	8.42	9.96
N2 in Feed, Mol %	11.0	11.3	11.6	12.6	14.6
Conversions, Mol % :					
H2	49.95	44.39	45.16	47.86	38.51
CO	68.14	60.35	53.64	53.34	44.81
H2+CO	60.53	53.59	50.00	51.23	42.44
Yields, Wt % of Products :					
Hydrocarbons (1)	17.81	16.12	14.53	13.24	11.04
CO2	47.09	41.85	39.31	38.72	31.26
H2O (1)	0.85	1.00	0.66	0.62	0.31
H2	2.58	2.84	2.74	2.28	2.65
CO	31.67	38.20	42.76	45.14	54.74
Total	100	100	100	100	100
Bal Recovery, Wt % of Charge:	96.32	98.79	102.28	99.06	97.27
Selectivities, Wt % of HC :					
Methane	5.69	5.79	6.17	6.62	8.64
Ethene	3.39	3.57	3.79	4.05	4.65
Ethane	1.48	1.39	1.42	1.47	1.59
Propene	5.97	6.05	6.62	6.90	7.84
Propane	0.85	0.87	0.96	1.03	1.31
Butenes	4.93	5.06	5.57	5.92	6.60
i-Butane	0.06	0.07	0.06	0.06	0.05
n-Butane	0.92	0.95	1.05	1.11	1.43
C5 - C11	23.72	25.18	29.89	32.87	0.00
C12+ (Excl. Rx. Wax)	16.57	20.73	18.72	18.17	0.00
Light Hydrocarbons (3)	0.00	0.00	0.00	0.00	28.42
Heavy Hydrocarbons (4)	0.00	0.00	0.00	0.00	17.79
Slurry Rx. Wax	33.00	25.00	19.00	14.00	7.00
Total	100	100	100	100	100
g HC/Nm^3 (H2+CO) conv.:	228	239	238	219	217
C5 - C11 PONA, Wt % :					
Paraffins	21.89	22.62	22.15	19.72	(2)
Olefins	78.11	77.38	77.85	80.28	(2)
Naphthenes	0.00	0.00	0.00	0.00	(2)
Aromatics	0.00	0.00	0.00	0.00	(2)

(1) Including Oxygenates (2) Not Available
(3) Collected in Chilled and Ambient Condensers
(4) collected in Hot Condenser

Table A-2
First-Stage Fischer-Tropsch Bubble-Column
Operating Conditions and Material Balances
Based On Inter-Reactor Sample
Run CT-256-1

(Nitrogen-Free Basis)					
M.B. No.	1- 30	1- 31	1- 34	1- 41	1- 43
Days On-stream	41.4	42.4	45.4	52.4	54.3
First-Stage Conditions:					
Charge H2/CO (Molar)	0.672	0.679	0.669	0.656	0.651
Temperature, ^{o}C	267	269	269	267	268
Pressure, MPa	1.48	1.48	1.48	1.48	1.48
Feed Sup. Vel., cm/s	1.737	1.761	1.767	1.691	1.666
Space Vel., NL/gFe-hr	5.244	5.318	5.335	5.26	5.183
N2 in Feed, Mol %	13.0	13.0	13.0	10.8	11.4
Conversions, Mol % :					
H2	59.76	60.29	63.21	65.07	62.04
CO	46.70	49.99	72.45	72.88	67.29
H2+CO	51.95	54.15	68.74	69.79	65.22
Yields, Wt % of Products :					
Hydrocarbons (1)	11.75	13.66	18.01	18.45	15.80
CO2	35.13	34.53	54.94	54.58	53.82
H2O (1)	0.00	0.00	0.00	0.00	0.00
H2	1.88	1.94	1.64	1.55	1.57
CO	51.24	49.88	25.42	25.42	28.81
Total	100.00	100.00	100.00	100.00	100.00
Bal Recovery, Wt % of Charge:	99.56	98.01	102.69	101.49	106.84
Selectivities, Wt % of HC :					
Methane	8.50	7.62	8.33	7.92	9.70
Ethene	4.31	3.62	3.64	4.37	5.08
Ethane	1.56	1.34	2.14	1.89	2.21
Propene	7.08	5.82	7.84	7.59	9.03
Propane	1.57	1.32	1.71	1.71	2.08
Butenes	5.94	4.84	6.82	6.32	7.71
i-Butane	0.07	0.07	0.08	0.11	0.00
n-Butane	1.52	1.28	1.66	1.61	2.03
C5 - C11	39.88	42.00	44.80	40.60	17.92
C12+ (Excl. Rx. Wax)	23.32	25.94	16.34	21.24	0.00
Light Hydrocarbons (2)	0.00	0.00	0.00	0.00	19.18
Heavy Hydrocarbons (3)	0.00	0.00	0.00	0.00	18.15
Slurry Rx. Wax	6.00	6.00	6.00	6.00	6.00
Total	100.00	100.00	100.00	100.00	100.00
g HC/Nm^3 (H2+CO) conv.:	186	199	220	221	215
Olefins, Wt % by C-No. :					
C2	73.45	72.95	63.01	69.86	69.68
C3	81.82	81.48	82.12	81.60	81.32
C4	78.88	78.18	79.67	78.62	79.19

(1) Including Oxygenates (2) Collected in Chilled and Ambient Condensers
(3) Collected in Hot Condenser

Table A-3

Composition of Hydrocarbon Products from

First-Stage Slurry F-T Reactor

Run CT-256-1

M.B. No.	1-1	1-2	1-3	1-4	1-6	(1) 1-30	(1) 1-31	(1) 1-34	(1) 1-41	(1) 1-43
Days On-Stream	2.3	3.3	4.4	5.4	11.8	41.4	42.4	45.4	52.4	54.3
METHANE	5.68	5.80	6.16	6.62	8.64	8.50	7.62	8.33	7.92	9.70
ETHENE	3.39	3.57	3.79	4.05	4.65	4.31	3.62	3.64	4.37	5.08
ETHANE	1.48	1.39	1.42	1.47	1.59	1.56	1.34	2.14	1.89	2.21
PROPENE	5.97	6.05	6.62	6.90	7.84	7.08	5.82	7.84	7.59	9.03
PROPANE	0.85	0.87	0.96	1.03	1.31	1.57	1.32	1.71	1.71	2.08
BUTENES	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
I-BUTANE	0.06	0.07	0.06	0.06	0.05	0.07	0.07	0.08	0.11	0.00
1-BUTENE+2-METHYLPROPENE	4.74	4.86	5.38	5.70	6.41	5.81	4.77	6.58	6.14	7.51
N-BUTANE	0.92	0.94	1.05	1.11	1.43	1.52	1.28	1.66	1.61	2.03
TRANS-2-BUTENE	0.07	0.07	0.05	0.06	0.05	0.03	0.07	0.09	0.06	0.07
CIS-2-BUTENE	0.12	0.14	0.13	0.13	0.13	0.10	0.00	0.15	0.12	0.13
PENTENES	0.18	0.02	0.03	0.45	0.00	0.00	0.00	0.00	0.00	0.00
3-METHYL-1-BUTENE	0.30	0.30	0.32	0.35	0.33	0.29	0.21	0.36	0.44	0.50
1-PENTANE	0.21	0.13	0.15	0.13	0.13	0.04	0.09	0.29	0.24	0.39
1-PENTENE	3.53	3.75	4.27	4.51	4.92	4.13	3.31	5.02	4.24	5.33
2-METHYL-1-BUTENE	0.17	0.19	0.18	0.19	0.20	0.13	0.13	0.19	0.18	0.20
N-PENTANE	0.72	0.76	0.87	0.93	1.07	1.07	0.88	1.27	1.18	1.49
TRANS-2-PENTENE	0.07	0.05	0.05	0.06	0.07	0.00	0.00	0.08	0.04	0.05
CIS-2-PENTENE	0.07	0.07	0.07	0.08	0.07	0.04	0.00	0.09	0.06	0.07
UNKNOWN C5-MONOOLEFINS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.02
HEXENES + ISO-HEXANES	0.42	0.44	0.43	0.47	0.51	0.35	0.26	0.78	0.74	0.96
ISO-HEXANES	0.02	0.02	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00
ISO-HEXENES	0.30	0.07	0.09	0.58	0.00	0.00	0.00	0.00	0.00	0.00
1-HEXENE	2.71	3.19	3.76	3.75	3.44	2.55	1.91	3.35	2.81	3.47
C-2-HEXENE	0.01	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
T-2-HEXENE	0.01	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
N-HEXANE	0.62	0.75	0.87	0.86	0.76	0.67	0.53	0.91	0.81	1.03
HEPTENES + ISO-HEPTANES	0.24	0.22	0.25	0.20	0.18	0.12	0.00	0.53	0.43	0.55
1-HEPTENE	1.98	2.65	3.33	3.10	1.78	1.05	0.72	1.79	1.42	1.85
C-2-HEPTENE	0.03	0.04	0.05	0.06	0.00	0.00	0.00	0.00	0.00	0.00
T-2-HEPTENE	0.03	0.03	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.00
ISO-HEPTANES	0.03	0.06	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00
ISO-HEPTENES	0.50	0.21	0.28	0.92	0.00	0.00	0.00	0.00	0.00	0.00
N-HEPTANE	0.50	0.66	0.83	0.79	0.42	0.30	0.18	0.50	0.44	0.59
C8-OLEFINS + ISO-P	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.28	0.21	0.29
1-OCTENE	1.35	2.27	2.91	2.61	0.57	0.20	0.00	0.66	0.52	0.68
C-2-OCTENE	0.06	0.09	0.11	0.10	0.00	0.00	0.00	0.00	0.00	0.00
T-2-OCTENE	0.04	0.06	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00
ISO-OCTANES	0.10	0.09	0.12	0.16	0.00	0.00	0.00	0.00	0.00	0.00
ISO-OCTENES	0.75	0.39	0.48	1.28	0.00	0.00	0.00	0.00	0.00	0.00
N-OCTANE	0.76	0.71	0.90	0.80	0.16	0.00	0.00	0.23	0.19	0.23
C9-OLEFINS + ISO-P	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.06
1-NONENE	1.50	1.91	2.38	2.12	0.06	0.00	0.00	0.17	0.16	0.16
C-2-NONENE	0.08	0.09	0.11	0.10	0.00	0.00	0.00	0.00	0.00	0.00
T-2-NONENE	0.07	0.08	0.09	0.09	0.00	0.00	0.00	0.00	0.00	0.00
ISO-NONANES	0.13	0.10	0.12	0.18	0.00	0.00	0.00	0.00	0.00	0.00
ISO-NONENES	0.82	0.41	0.53	1.27	0.00	0.00	0.00	0.00	0.00	0.00
N-NONANE	0.52	0.67	0.83	0.71	0.00	0.00	0.00	0.00	0.00	0.00
N-DECANE	0.64	0.77	0.84	0.69	0.00	0.00	0.00	0.03	0.03	0.00
1-DECENE	1.33	1.61	1.91	1.62	0.00	0.00	0.00	0.03	0.06	0.00
C-2-DECENE	0.10	0.11	0.13	0.11	0.00	0.00	0.00	0.00	0.00	0.00
T-2-DECENE	0.07	0.09	0.09	0.09	0.00	0.00	0.00	0.00	0.00	0.00
ISO-DECANES	0.15	0.10	0.12	0.15	0.00	0.00	0.00	0.00	0.00	0.00
ISO-DECENES	0.72	0.32	0.41	0.99	0.00	0.00	0.00	0.00	0.00	0.00
N-UNDECANE	0.38	0.45	0.43	0.41	0.00	0.00	0.00	0.00	0.00	0.00
1-UNDECENE	0.77	0.87	0.88	0.85	0.00	0.00	0.00	0.00	0.00	0.00
C-2-UNDECENE	0.06	0.06	0.06	0.07	0.00	0.00	0.00	0.00	0.00	0.00
T-2-UNDECENE	0.04	0.05	0.05	0.04	0.00	0.00	0.00	0.00	0.00	0.00
ISO-UNDECANES	0.09	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00
ISO-UNDECENES	0.57	0.26	0.26	0.65	0.00	0.00	0.00	0.00	0.00	0.00
N-DODECANE	0.12	0.15	0.16	0.13	0.00	0.00	0.00	0.00	0.00	0.00
1-DODECENE	0.20	0.17	0.21	0.22	0.00	0.00	0.00	0.00	0.00	0.00
C-2-DODECENE	0.02	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
T-2-DODECENE	0.01	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
ISO-DODECANES	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
ISO-DODECENES	0.20	0.01	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00
N-TRIDECANE	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
1-TRIDECENE	0.03	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
C-2-TRIDECENE	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
T-2-TRIDECENE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ISO-TRIDECENES	0.03	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
UNKNOWN LITE HYDRO-CARB LIQ (2)	0.00	0.00	0.00	0.00	28.42	25.44	30.41	21.95	24.37	19.18
UNKNOWN HVY HYDRO-CARB LIQ (3)	0.00	0.00	0.00	0.00	17.69	26.82	29.23	22.53	23.24	18.10
UNKNOWN C12+	15.90	20.38	18.36	17.39	0.00	0.00	0.00	0.00	0.00	0.00
SLURRY REACTOR WAX	33.00	25.00	19.00	14.00	7.00	6.00	6.00	6.00	6.00	6.00

(1) Based on Inter-Reactor Sample
(2) Collected in Chilled and Ambient Condensers
(3) Collected in Hot Condenser

Table A-4
Composition of Fischer-Tropsch
Hydrocarbon Phase Oxygenates
Run CT-256-1

M.B. No.	1-1	1-2	1-3	1-4
Days On-stream	2.2	3.3	4.4	5.4
Component, Wt %				
METHANOL	0.10	0.12	0.21	0.29
ETHANOL	0.64	0.71	1.12	1.49
ACETONE	0.05	0.07	0.13	0.15
N-PROPANOL	0.60	0.61	0.91	1.16
N-BUTANONE	0.05	0.05	0.09	0.12
N-BUTANOL	0.68	0.64	0.94	1.15
N-2-BUTANOL	0.02	0.02	0.02	0.02
OTHER BUTANOLS	0.02	0.02	0.03	0.04
C5-N-METHYL KETONE	0.06	0.06	0.12	0.13
N-1-PENTANOL	0.54	0.49	0.68	0.77
N-2-PENTANOL	0.02	0.02	0.03	0.04
OTHER PENTANOLS	0.05	0.04	0.06	0.07
C6+ ALKANOLS	4.96	6.30	7.40	7.50
Total, Wt %	7.8	9.2	11.7	12.9
Yield per HC Produced, g/100g	3.01	3.7	4.7	5.1

Table A-5
Composition of Fischer-Tropsch
Aqueous Phase Organic Oxygenates
Run CT-256-1

M.B.No.	1-1	1-2	1-3	1-4
Days On-stream	2.3	3.3	4.4	5.4
Component, Wt %				
METHANOL	3.15	3.29	4.22	4.50
ETHANOL	8.45	12.34	15.64	16.31
ACETONE	0.42	0.74	1.02	1.04
N-PROPANOL	2.18	3.42	4.52	4.62
N-BUTANONE	0.09	0.20	0.30	0.31
N-BUTANOL	0.80	1.29	1.78	1.85
N-2-BUTANOL	0.02	0.04	0.05	0.05
OTHER BUTANOLS	0.03	0.06	0.09	0.09
I-PENANONE	0.01	0.01	0.01	0.01
C5-ESTERS	0.03	0.03	0.09	0.10
C5-ESTERS + I-PENTANONE	0.03	0.10	0.17	0.19
N-1-PENTANOL	0.25	0.40	0.56	0.59
N-2-PENTANOL	0.00	0.00	0.02	0.01
OTHER PENTANOLS	0.03	0.05	0.09	0.09
C6-N-METHYL KETONE	0.02	0.02	0.08	0.09
N-1-HEXANOL	0.05	0.08	0.12	0.13
N-1-HEPTANOL	0.01	0.01	0.02	0.03
N-1-NONANOL	0.04	0.11	0.22	0.33
Total, Wt %	15.61	22.19	29.30	30.34
Yield per HC Produced, g/100g	1.01	1.83	1.80	1.83

Table A-6 Composition of Fischer-Tropsch Reactor-wax
Run CT-256-1

Days On-stream	1.9	3.0	6.8	34	41	56
Carbon No.			Weight %			
13	0.04	0.04	0	0	0	0
14	0.04	0.09	0.13	0	0	0
15	0.08	0.18	0.21	0	0	0
16	0.08	0.35	0.27	0	0	0
17	0.13	0.87	0.36	0.05	0	0
18	0.24	0.66	0.59	0.11	0	0.33
19	0.52	0.88	0.72	0.24	0.08	0.61
20	0.67	1.11	1.13	0.29	0.10	0.41
21	0.70	0.96	1.15	0.41	0.10	0.95
22	0.80	1.06	1.40	0.51	0.12	1.26
23	0.99	1.29	1.55	0.61	0.31	1.52
24	1.35	1.48	1.82	0.73	0.57	1.81
25	2.68	2.04	2.28	0.90	1.82	2.95
26	4.79	3.96	4.16	1.55	1.60	3.16
27	10.86	10.02	9.87	3.41	2.50	3.79
28	6.44	6.06	5.15	4.89	4.27	5.20
29	1.78	1.81	2.14	3.35	3.07	4.37
30	1.80	1.81	2.42	5.17	4.15	4.79
31	1.34	2.29	2.90	4.44	4.58	5.09
32	3.77	3.69	4.06	6.49	5.02	5.41
33	6.15	6.05	6.62	8.67	6.52	6.02
34	9.75	10.01	10.24	11.12	8.20	7.94
35	12.35	12.85	10.67	9.31	8.97	6.00
36	4.77	4.19	4.89	4.76	4.64	3.99
37	2.14	2.56	2.24	3.35	3.46	3.05
38	2.27	1.74	2.05	2.98	2.82	2.52
39	2.58	2.49	1.89	2.64	2.82	2.42
40	2.91	3.02	2.29	3.05	2.57	2.24
41	2.76	2.05	2.25	2.84	2.63	2.22
42	2.42	2.31	1.80	2.31	2.23	1.94
43	1.76	1.55	1.31	1.79	1.76	1.70
44	0.99	0.93	0.96	1.36	1.71	1.39
45	0.81	0.71	0.87	1.15	1.56	1.35
46	0.75	0.76	0.81	1.08	1.55	1.32
47	0.68	0.70	0.78	0.98	1.54	1.35
48	0.63	0.67	0.70	0.89	1.56	1.22
49	0.65	0.61	0.63	0.80	1.46	1.16
50	0.59	0.56	0.63	0.75	1.61	1.31
51	0.53	0.48	0.57	0.70	1.45	1.22
52	0.55	0.47	0.56	0.64	1.35	1.18
53	0.49	0.43	0.52	0.53	1.36	0.90
54	0.41	0.38	0.49	0.48	1.31	0.99
55	0.36	0.40	0.42	0.45	0.86	0.76
56	0.35	0.35	0.40	0.43	1.03	0.60
57	0.39	0.35	0.39	0.39	0.80	0.58
58	0.34	0.34	0.38	0.35	0.69	0.44
59	0.30	0.31	0.32	0.30	0.63	0.35
60	0.27	0.26	0.31	0.28	0.67	0.47
61	0.28	0.26	0.32	0.26	0.60	0.42
62	0.26	0.23	0.25	0.26	0.66	0.39
63	0.24	0.23	0.24	0.26	0.56	0.63
64	0.23	0.26	0.26	0.25	0.48	0.26
65	0.21	0.12	0.21	0.20	0.37	0
66	0.21	0.22	0.16	0.17	0.31	0
67	0.19	0.15	0.16	0.16	0.21	0
68	0.19	0.15	0.12	0.15	0.18	0
69	0.02	0.17	0	0.16	0.19	0
70	0.02	0.06	0	0.17	0.16	0
71	0.08	0.03	0	0.11	0.18	0
72	0.01	0	0	0.13	0	0
73	0	0	0	0.07	0	0
74	0	0	0	0.04	0	0
Total	100	100	100	100	100	100

Table A-7
Second-Stage Fixed-Bed ZSM-5 Reactor
Operating Conditions and Material Balances
Run CT-256-1

(Nitrogen-Free Basis) M.B. No.	1- 7	1- 9	1- 10	1- 13	1- 14	1- 15	1- 16	1- 17	1- 18
Days On-stream	13.5	17.1	19.1	22.2	22.6	23.6	24.6	25.6	27.6
First-Stage Conditions:									
Charge H2/CO (Molar)	0.631	0.666	0.656	0.669	0.641	0.669	0.672	0.678	0.643
Temperature, °C	265	268	268	268	268	267	268	268	271
Pressure, MPa	1.14	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48
Feed Sup. Vel., cm/s	1.746	1.656	1.668	1.712	1.786	1.767	1.768	1.763	1.789
Space Vel., NL/gFe-hr	9.786	12.009	12.096	12.415	12.952	12.813	12.821	12.784	12.973
N2 in Feed, Mol %	14.9	12.5	11.5	12.8	12.8	12.7	12.4	12.7	12.7
Second-Stage Conditions:									
Temp., Inlet, °C	371	344	330	333	329	330	328	330	327
Outlet, °C	395	376	366	352	359	359	361	361	361
Pressure, MPa	1.067	1.411	1.411	1.398	1.384	1.391	1.398	1.398	1.398
GHSV, hr	963	1142	1132	1212	1212	1203	1201	1201	1175
Days On-stream	0.9	4.5	6.5	9.5	10.0	11.0	12.0	13.0	15.0
Conversions, Mol % :									
H2	40.66	45.73	47.77	41.26	41.45	42.57	41.77	41.69	45.15
CO	41.21	45.27	48.05	39.58	43.75	42.77	43.03	41.57	44.33
H2+CO	41.00	45.45	47.94	40.25	42.85	42.69	42.53	41.62	44.65
Yields, Wt % of Products :									
Hydrocarbons	11.72	12.98	13.19	10.46	11.68	11.92	11.88	11.82	11.72
CO2	30.28	33.14	35.88	28.73	30.27	30.21	30.16	29.45	30.72
H2O	0.63	0.97	0.96	0.71	1.01	1.02	0.99	0.96	0.66
H2	2.52	2.41	2.27	2.69	2.62	2.62	2.69	2.69	2.49
CO	54.86	50.50	47.71	57.41	54.42	54.23	54.28	55.08	54.41
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Bal Recovery, Wt % of Charge:	101.91	102.73	103.25	100.28	98.97	100.51	100.03	100.87	98.15
Selectivities, Wt % of HC :									
Methane	9.18	8.87	8.94	10.72	9.41	9.18	9.15	8.87	9.37
Ethene	0.58	0.49	0.48	0.45	0.44	0.45	0.45	0.44	0.00
Ethane	2.37	2.44	2.62	2.70	2.63	2.54	2.52	2.38	2.34
Propene	0.87	0.84	0.85	0.74	0.78	0.78	0.81	0.80	0.82
Propane	16.87	13.94	14.66	11.13	11.72	11.61	11.80	11.15	11.44
Butenes	0.73	0.79	0.79	0.84	0.89	0.87	0.89	0.90	0.94
i-Butane	16.64	15.25	15.61	14.27	14.60	14.48	14.45	13.84	14.24
n-Butane	8.36	8.66	9.22	8.33	8.76	8.80	8.53	8.33	8.77
C5 - C11	35.75	39.83	38.98	42.89	43.26	43.75	43.78	45.32	44.82
C12+ (Excl. Rx. Wax)	1.65	1.89	1.86	1.92	1.52	1.55	1.63	1.96	1.27
Slurry Rx. Wax	7.00	7.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
i-C4/(C3= + C4=) Molar	8.49	7.73	7.83	7.53	7.32	7.34	7.06	6.78	6.77
g HC/Nm^3 (H2+CO) conv.:	246	243	237	215	225	231	230	236	215
Olefins, Wt % by C-No. :									
C2	19.76	16.59	15.46	14.31	14.46	14.92	15.06	15.58	0.03
C3	4.90	5.68	5.48	6.23	6.20	6.26	6.44	6.70	6.66
C4	2.85	3.18	3.08	3.60	3.67	3.61	3.74	3.91	3.94
C5 - C11 PONA, Wt % :									
Paraffins	56.96	39.85	40.98	41.76	41.91	42.06	(2)	(2)	45.79
Olefins	24.58	13.77	12.38	14.97	13.51	13.33	(2)	(2)	2.57
Naphthenes	0.53	2.55	3.00	4.23	4.82	5.02	(2)	(2)	6.99
Aromatics	17.93	43.83	43.64	39.05	39.76	39.59	(2)	(2)	44.65

(1) Denotes MB adjusted for Inter-Reactor Sampling
(2) Not Available

Table A-7 (Continued)
Second-Stage Fixed-Bed ZSM-5 Reactor
Operating Conditions and Material Balances
Run CT-256-1

(Nitrogen-Free Basis)								(1)	(1)
M.B. No.	1- 19	1- 20	1- 22	1- 23	1- 27	1- 28	1- 29	1- 30	1- 31
Days On-stream	28.8	30.4	33.2	34.4	36.4	37.4	40.4	41.4	42.4
First-Stage Conditions:									
Charge H2/CO (Molar)	0.637	0.647	0.629	0.667	0.653	0.680	0.669	0.672	0.679
Temperature, °C	271	270	270	270	270	270	271	267	269
Pressure, MPa	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48
Feed Sup. Vel., cm/s	1.789	1.726	1.752	1.802	1.771	1.754	1.755	1.737	1.761
Space Vel., NL/gFe-hr	12.97	12.52	12.71	16.23	6.76	6.69	6.69	5.24	5.32
N2 in Feed, Mol %	12.0	12.6	12.3	13.1	13.3	12.3	12.1	13.0	13.0
Second-Stage Conditions:									
Temp., Inlet, °C	328	317	317	317	302	302	301	303	303
Outlet, °C	361	353	354	352	346	346	348	348	350
Pressure, MPa	1.398	1.384	1.391	1.391	1.377	1.370	1.377	1.377	1.377
GHSV, hr	1094	1111	1181	1240	1047	1030	1054	1127	1111
Days On-stream	16.2	17.8	20.5	21.8	23.8	24.8	27.7	28.7	29.7
Conversions, Mol % :									
H2	50.66	45.80	39.73	39.27	65.46	50.39	48.20	43.81	48.97
CO	47.96	46.16	45.74	35.14	47.55	53.75	51.66	48.90	49.62
H2+CO	49.01	46.02	43.42	36.79	54.63	52.39	50.27	46.85	49.35
Yields, Wt % of Products :									
Hydrocarbons	11.32	12.90	11.69	8.60	12.61	13.03	12.20	12.53	12.36
CO2	30.14	31.01	32.63	25.37	35.27	34.38	33.37	34.99	35.40
H2O	1.16	0.57	1.50	0.10	0.81	0.92	0.86	0.77	0.91
H2	2.39	2.49	2.60	2.84	1.54	2.58	2.63	2.62	2.43
CO	54.98	53.04	51.58	63.09	49.76	49.08	50.94	49.10	48.92
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Bal Recovery, Wt % of Charge:	92.12	97.50	100.47	98.42	100.47	91.65	92.19	99.36	98.50
Selectivities, Wt % of HC :									
Methane	9.41	8.34	9.52	10.45	8.56	8.63	9.27	8.91	9.38
Ethene	0.00	0.43	0.51	0.64	0.45	0.46	0.52	0.51	0.54
Ethane	2.42	1.95	2.14	2.34	1.99	1.90	1.94	1.90	1.96
Propene	0.77	0.72	0.88	1.12	0.77	0.80	0.91	0.93	0.96
Propane	12.25	10.15	11.02	11.76	9.85	9.53	9.29	8.97	9.38
Butenes	0.92	0.88	1.11	1.37	1.01	1.06	1.19	1.26	1.35
i-Butane	14.84	12.90	14.36	15.99	13.30	12.99	12.86	12.85	13.45
n-Butane	9.16	8.39	9.08	9.76	8.55	8.65	8.32	8.16	8.52
C5 - C11	42.74	48.12	44.20	39.84	47.55	48.42	48.22	48.82	47.14
C12+ (Excl. Rx. Wax)	1.49	2.11	1.18	0.70	1.98	1.56	1.48	1.70	1.33
Slurry Rx. Wax	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
i-C4/(C3= + C4=) Molar	7.36	6.75	6.08	5.39	6.32	5.89	5.18	4.96	4.94
g HC/Nm^3 (H2+CO) conv.:	177	227	228	191	193	184	182	219	201
Olefins, Wt % by C-No. :									
C2	0.00	17.95	19.35	21.51	18.49	19.36	21.25	21.03	21.59
C3	5.89	6.63	7.40	8.69	7.26	7.76	8.89	9.39	9.30
C4	3.70	3.98	4.50	5.06	4.40	4.68	5.31	5.66	5.78
C5 - C11 PONA, Wt % :									
Paraffins	49.77	44.71	52.11	62.40	47.67	49.94	(2)	50.41	52.88
Olefins	1.06	1.17	2.02	2.79	3.14	2.21	(2)	2.45	3.26
Naphthenes	6.98	7.28	7.83	8.35	8.16	8.40	(2)	9.52	9.07
Aromatics	42.19	46.85	38.04	26.46	41.03	39.45	(2)	37.62	34.79

(1) Denotes MB adjusted for Inter-Reactor Sampling
(2) Not Available

Table A-7 (Continued)
Second-Stage Fixed-Bed ZSM-5 Reactor
Operating Conditions and Material Balances
Run CT-256-1

(Nitrogen-Free Basis)			(1)		
M.B. No.	1- 32	1- 33	1- 34	1- 35	1- 37
Days On-stream	43.4	44.4	45.4	46.4	48.4
First-Stage Conditions:					
Charge H2/CO (Molar)	0.646	0.669	0.669	0.655	0.910
Temperature, °C	272	266	269	270	267
Pressure, MPa	1.48	1.48	1.48	1.48	1.48
Feed Sup. Vel., cm/s	1.758	1.766	1.767	1.783	1.730
Space Vel., NL/gFe-hr	5.308	5.332	5.335	5.383	5.356
N2 in Feed, Mol %	13.1	12.9	13.0	12.7	12.5
Second-Stage Conditions:					
Temp., Inlet, °C	302	300	303	304	316
Outlet, °C	351	361	360	363	382
Pressure, MPa	1.370	1.377	1.377	1.377	1.384
GHSV, hr	1104	958	972	982	832
Days On-stream	30.7	31.7	32.7	33.7	35.7
Conversions, Mol % :					
H2	49.15	66.50	64.46	62.47	69.27
CO	49.76	75.53	73.70	72.90	95.78
H2+CO	49.52	71.91	69.99	68.77	83.15
Yields, Wt % of Products :					
Hydrocarbons	11.90	16.05	19.40	19.99	26.46
CO2	35.54	58.45	54.53	53.09	65.70
H2O	0.94	0.73	0.02	0.00	2.05
H2	2.32	1.54	1.59	1.65	1.87
CO	49.28	23.24	24.46	25.26	3.92
Total	100.00	100.00	100.00	100.00	100.00
Bal Recovery, Wt % of Charge:	97.85	100.31	102.04	101.94	100.89
Selectivities, Wt % of HC :					
Methane	10.08	9.89	8.43	8.19	9.61
Ethene	0.58	0.45	0.38	0.43	0.50
Ethane	2.00	2.63	2.27	2.18	3.85
Propene	1.09	0.90	0.79	0.90	1.12
Propane	9.20	10.35	9.02	8.05	8.88
Butenes	1.54	1.31	1.16	1.37	1.70
i-Butane	13.29	13.88	12.06	11.16	11.08
n-Butane	8.64	9.17	8.08	7.70	7.61
C5 - C11	46.29	43.40	49.37	51.40	47.47
C12+ (Excl. Rx. Wax)	1.30	2.01	2.44	2.61	2.19
Slurry Rx. Wax	6.00	6.00	6.00	6.00	6.00
Total	100.00	100.00	100.00	100.00	100.00
i-C4/(C3= + C4=) Molar	4.29	5.35	5.26	4.19	3.35
g HC/Nm^3 (H2+CO) conv.:	196	182	230	243	229
Olefins, Wt % by C-No. :					
C2	22.37	14.65	14.44	16.40	11.40
C3	10.61	7.97	8.06	10.11	11.20
C4	6.54	5.37	5.44	6.75	8.34
C5 - C11 PONA, Wt % :					
Paraffins	55.19	49.87	46.27	46.36	45.89
Olefins	4.11	3.11	2.49	3.65	3.54
Naphthenes	9.42	7.49	8.35	8.13	8.36
Aromatics	31.29	39.53	42.89	41.87	42.21

(1) Denotes MB adjusted for Inter-Reactor Sampling
(2) Not Available

Table A-8

Second-Stage ZSM-5 Reactor Raw Liquid Hydrocarbon[1] Properties
(Run CT-256-1)

Days On-Stream	16.1	27.1	28.8	36.4	39.1	42.4	47.9	48.4	56.4
Sp. Gr.	0.840	0.801	0.817	0.813	0.804	0.783	0.788	0.778	0.799
Acid No. (Unwashed), mgKOH/g	0.09	0.02	0.01	0.33	0.01	0.30	0.15	0.15	0.68
PONA, Wt %									
Paraffins	15.5	18.2	21.6	21.7	26.9	27.6	31.1	32.3	24.7
Olefins	1.6	0.8	0.9	3.6	1.4	2.8	2.6	4.0	6.2
Naphthenes	1.3	8.6	5.2	11.1	12.	13.5	10.1	10.9	11.1
Aromatics	81.6	72.4	72.3	63.6	59.7	56.1	56.2	52.8	58.0
Octane Numbers:									
R+O	>95	95.9	98.2	96.9	-	96.7	95.6	-	96.0
R+3	104.5	101.1	100.7	100.9	-	101.1	100.5	-	100.5
ASTM Distillation, °C									
IBP	44	44	43	42	34	46	33	33	37
50, Vol %	131	122	130	128	127	127	123	135	129
90, Vol %	179	172	178	177	179	178	172	177	186
95, Vol %	-	191	-	202	214	211	198	208	233
EP	-	-	-	234	230	234	230	249	238
Loss, Vol %	0	0	0	0	0.3	0.7	0.7	0.5	1.9
Residue, Vol %	10.0[2]	6.0[2]	7.5[2]	2.0	2.7	2.3	2.1	1.5	2.1

[1]Collected from the ambient and chilled condensers. Hydrocarbons collectd in the hot condenser was very small.
[2]Distillation stopped early due to foaming at the end of distillation.

Table A-9
Composition of Hydrocarbon Products from
Two-Stage Slurry F-T/ZSM-5 Syngas Conversion
Run CT-256-1

M.B. No.	1- 7	1- 9	1-10	1-13	1-14	1-15	1-16	1-17	1-18
Days On-stream	13.5	17.1	19.1	22.2	22.6	23.6	24.6	25.6	27.6
METHANE	9.18	8.87	8.94	10.72	9.41	9.18	9.15	8.87	9.37
ETHENE	0.58	0.49	0.48	0.45	0.44	0.45	0.45	0.44	0.00
ETHANE	2.37	2.44	2.62	2.70	2.63	2.54	2.52	2.38	2.34
PROPENE	0.87	0.84	0.85	0.74	0.78	0.78	0.81	0.80	0.82
PROPANE	16.87	13.94	14.66	11.13	11.72	11.61	11.80	11.15	11.44
I-BUTANE	16.64	15.25	15.61	14.27	14.60	14.46	14.45	13.84	14.24
1-BUTENE+2-METHYLPROPENE	0.46	0.47	0.48	0.50	0.54	0.53	0.54	0.55	0.58
N-BUTANE	8.36	8.66	9.22	8.33	8.76	8.80	8.53	8.33	8.77
TRANS-2-BUTENE	0.17	0.19	0.18	0.20	0.20	0.20	0.21	0.21	0.22
CIS-2-BUTENE	0.10	0.13	0.12	0.14	0.15	0.15	0.14	0.14	0.15
3-METHYL-1-BUTENE	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I-PENTANE	7.52	8.60	9.06	9.34	9.33	9.39	8.53	8.51	9.12
1-PENTENE	0.13	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
2-METHYL-1-BUTENE	0.01	0.06	0.06	0.08	0.07	0.07	0.06	0.06	0.07
N-PENTANE	1.77	2.57	2.77	3.33	3.39	3.46	3.02	3.02	3.47
TRANS-2-PENTENE	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.01
CIS-2-PENTENE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
2-METHYL-2-BUTENE	0.00	0.02	0.02	0.03	0.03	0.03	0.00	0.00	0.03
UNKNOWN C5-MONOOLEFINS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C5-DIOLEFINS (DIENES)	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2,2-DIMETHYLBUTANE	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.18
CYCLOPENTANE	0.02	0.06	0.06	0.06	0.07	0.07	0.00	0.00	0.27
HEXENES + ISO-HEXANES	0.58	0.62	0.62	0.69	0.68	0.67	0.67	0.68	0.04
2,3-DIMETHYLBUTANE	0.01	0.09	0.10	0.10	0.10	0.11	0.00	0.00	0.38
2-METHYLPENTANE	0.09	0.45	0.54	0.62	0.66	0.69	0.00	0.00	2.41
3-METHYLPENTANE	0.09	0.37	0.42	0.45	0.47	0.49	0.00	0.00	1.49
HEXENES	0.72	0.02	0.03	0.02	0.03	0.02	0.00	0.00	0.03
1-HEXENE	0.95	1.33	1.35	1.84	1.76	1.79	1.76	1.78	0.00
N-HEXANE	0.86	1.07	1.13	1.44	1.36	1.40	1.08	1.06	0.85
2,4-DIMETHYLPENTANE	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01
METHYLCYCLOPENTANE	0.04	0.20	0.24	0.33	0.37	0.39	0.00	0.00	0.90
3,3-DIMETHYLPENTANE	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.01
CYCLOHEXANE	0.00	0.01	0.01	0.02	0.02	0.02	0.00	0.00	0.02
HEPTENES + ISO-HEPTANES	0.38	0.62	0.58	1.15	1.01	1.03	1.03	1.09	0.04
1-HEPTENE	1.36	0.87	0.79	0.67	0.63	0.61	0.62	0.58	0.00
2-METHYLHEXANE	0.03	0.16	0.21	0.28	0.31	0.33	0.00	0.00	0.61
2,3-DIMETHYLPENTANE	0.02	0.12	0.13	0.16	0.18	0.18	0.00	0.00	0.21
3-METHYLHEXANE	0.06	0.26	0.32	0.42	0.45	0.48	0.00	0.00	0.74
1-CIS-3-DIMETHYL-N5	0.01	0.04	0.06	0.10	0.12	0.13	0.00	0.00	0.21
1-TRANS-3-DIMETHYL-N5	0.01	0.07	0.02	0.14	0.16	0.17	0.00	0.00	0.25
1-TRANS-2-DIMETHYL-N5	0.01	0.07	0.09	0.12	0.14	0.15	0.00	0.00	0.22
N-HEPTANE	0.19	0.21	0.22	0.37	0.39	0.35	0.29	0.25	0.27
C7-OLEFINS	0.85	0.02	0.13	0.04	0.04	0.03	0.00	0.00	0.03
METHYLCYCLOHEXANE	0.03	0.16	0.19	0.29	0.34	0.36	0.00	0.00	0.37
C8-OLEFINS + ISO-P	0.24	0.25	0.24	0.82	0.72	0.70	0.71	0.76	0.05
1-OCTENE	1.75	1.52	1.13	1.31	1.15	1.12	1.13	1.14	0.00
MONOMETHYL-ISO-C8-P	0.05	0.13	0.18	0.29	0.33	0.35	0.00	0.00	0.35
OTHER ISO-C8-P	0.01	0.05	0.06	0.09	0.11	0.11	0.00	0.00	0.10
C8-OLEFINS	1.02	0.02	0.06	0.03	0.03	0.03	0.00	0.00	0.05
C8-NAPHTHENES (N5+N6)	0.06	0.34	0.41	0.62	0.72	0.76	0.00	0.00	0.73
N-OCTANE	0.26	0.00	0.01	0.06	0.06	0.06	0.10	0.05	0.01
C9-OLEFINS + ISO-P	0.49	0.74	0.40	0.37	0.32	0.32	0.37	0.38	0.80
1-NONENE	0.00	0.00	0.00	0.06	0.05	0.05	0.11	0.11	0.00
MONOMETHYL-ISO-C9-P	0.03	0.02	0.03	0.06	0.07	0.08	0.00	0.00	0.08
OTHER ISO-C9-P	0.01	0.04	0.04	0.07	0.08	0.09	0.00	0.00	0.08
C9-OLEFINS	0.84	0.00	0.03	0.01	0.00	0.01	0.00	0.00	0.02
C9-NAPHTHENES (N5+N6)	0.01	0.07	0.08	0.13	0.16	0.17	0.00	0.00	0.17
N-NONANE	0.20	0.01	0.02	0.02	0.02	0.02	0.00	0.00	0.02
ISO-C10-P + O + N5 + N6	8.57	1.08	0.10	0.11	0.12	0.13	0.00	0.00	0.09
BENZENE	0.36	0.82	0.76	0.60	0.60	0.61	0.00	0.00	1.13
TOLUENE	2.37	5.68	5.47	4.79	5.08	4.99	0.00	0.00	5.81
ETHYLBENZENE	0.04	0.59	0.61	0.72	0.76	0.77	0.00	0.00	0.86
P-XYLENE	0.19	0.00	0.00	0.58	0.00	0.00	0.00	0.00	0.00
M-XYLENE	1.15	4.14	3.98	3.43	4.11	4.13	0.00	0.00	4.47
O-XYLENE	0.49	1.25	1.19	1.17	1.19	1.20	0.00	0.00	1.33
N-PROPYLBENZENE	0.02	0.04	0.05	0.05	0.05	0.05	0.00	0.00	0.06
1-METHYL-3-ETHYL-BENZENE	0.31	1.10	1.13	1.39	1.46	1.47	0.00	0.00	1.68
1,3,5-TRIMETHYL-BENZENE	0.19	0.21	0.17	0.11	0.09	0.09	0.00	0.00	0.09
1-METHYL-2-ETHYLBENZENE	0.10	0.24	0.24	0.28	0.28	0.29	0.00	0.00	0.33
ISO-C4-BENZENE	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
1,2,4-TRIMETHYLBENZENE	0.51	1.27	1.27	1.46	1.50	1.54	0.00	0.00	1.76
1-METHYL-2-ISO-C3-BENZENE	0.00	0.00	0.15	0.13	0.11	0.11	0.00	0.00	0.12
1,3-DIETHYLBENZENE	0.01	0.03	0.03	0.03	0.03	0.04	0.00	0.00	0.04
1-METHYL-3-N-C3-BENZENE	0.00	0.10	0.11	0.15	0.16	0.16	0.00	0.00	0.19
N-C4-BENZENE	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.02
1,2,3-TRIMETHYLBENZENE	0.00	0.00	0.11	0.09	0.09	0.07	0.00	0.00	0.07
1,2-DIETHYLBENZENE	0.03	0.02	0.02	0.03	0.04	0.04	0.00	0.00	0.05
C10-ALKYLBENZENES	0.21	0.44	0.43	0.50	0.50	0.51	0.00	0.00	0.59
1,2,4,5-TETRAMETHYLBENZENE	0.00	0.07	0.06	0.08	0.08	0.10	0.00	0.00	0.10
1,2,3,5-TETRAMETHYLBENZENE	0.00	0.01	0.06	0.06	0.06	0.07	0.00	0.00	0.06
C11-ALKYLBENZENES	0.33	1.28	0.98	1.05	1.01	1.03	0.00	0.00	1.16
NAPHTHALENE	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.01
METHYL-NAPHTHALENES	0.00	0.14	0.13	0.05	0.00	0.04	0.00	0.00	0.09
UNKNOWNS (HC AROMATICS)	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
UNKNOWN LITE HYDRO-CARB LIQ (1)	0.00	0.00	0.00	0.00	0.00	0.00	24.29	25.85	0.00
UNKNOWN C12+	1.65	1.89	1.86	1.92	1.52	1.55	1.63	1.96	1.27
SLURRY REACTOR WAX	7.00	7.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00

(1)Collected in Chilled and Ambient Condensers

Table A-9 (Continued)
Composition of Hydrocarbon Products from
Two-Stage Slurry F-T/ZSM-5 Syngas Conversion
Run CT-256-1

M.B. No.	1-32	1-33	1-34	1-35	1-37
Days On-stream	43.4	44.4	45.4	46.4	48.4
METHANE	10.08	9.89	8.43	8.19	9.61
ETHENE	0.58	0.45	0.38	0.43	0.50
ETHANE	2.00	2.63	2.27	2.18	3.85
PROPENE	1.09	0.90	0.79	0.90	1.12
PROPANE	9.20	10.35	9.02	8.05	8.88
BUTENES	0.00	0.00	0.00	0.00	0.00
I-BUTANE	13.29	13.88	12.06	11.16	11.08
1-BUTENE+2-METHYLPROPENE	0.94	0.80	0.70	0.83	1.02
N-BUTANE	8.64	9.17	8.08	7.70	7.61
TRANS-2-BUTENE	0.36	0.31	0.28	0.32	0.41
CIS-2-BUTENE	0.24	0.20	0.18	0.21	0.27
3-METHYL-1-BUTENE	0.00	0.00	0.00	0.02	0.03
I-PENTANE	9.34	8.58	8.15	7.98	7.47
1-PENTENE	0.00	0.02	0.02	0.02	0.03
2-METHYL-1-BUTENE	0.14	0.13	0.12	0.14	0.18
N-PENTANE	4.55	4.19	4.16	4.20	3.88
TRANS-2-PENTENE	0.11	0.09	0.08	0.10	0.13
CIS-2-PENTENE	0.04	0.04	0.04	0.04	0.06
2-METHYL-2-BUTENE	0.09	0.08	0.10	0.13	0.19
UNKNOWN C5-MONOOLEFINS	0.31	0.27	0.23	0.27	0.00
C5-DIOLEFINS (DIENES)	0.00	0.00	0.00	0.00	0.00
2,2-DIMETHYLBUTANE	0.00	0.00	0.01	0.01	0.01
CYCLOPENTANE	0.20	0.12	0.19	0.10	0.20
HEXENES + ISO-HEXANES	0.00	0.01	0.00	0.03	0.31
2,3-DIMETHYLBUTANE	0.31	0.18	0.23	0.23	0.21
2-METHYLPENTANE	3.24	2.52	2.98	3.05	2.60
3-METHYLPENTANE	1.58	1.11	1.40	1.43	1.26
HEXENES	0.11	0.13	0.12	0.23	0.22
N-HEXANE	1.62	1.25	1.48	1.62	1.46
2,4-DIMETHYLPENTANE	0.01	0.01	0.01	0.01	0.01
METHYLCYCLOPENTANE	1.08	0.71	0.95	1.00	0.94
3,3-DIMETHYLPENTANE	0.01	0.00	0.01	0.01	0.01
CYCLOHEXANE	0.03	0.02	0.03	0.00	0.03
HEPTENES + ISO-HEPTANES	0.24	0.12	0.10	0.12	0.06
2-METHYLHEXANE	0.98	0.72	0.93	1.04	0.86
2,3-DIMETHYLPENTANE	0.24	0.16	0.23	0.27	0.24
3-METHYLHEXANE	1.07	0.74	1.01	1.10	0.92
1-CIS-3-DIMETHYL-N5	0.38	0.25	0.34	0.37	0.33
1-TRANS-3-DIMETHYL-N5	0.27	0.20	0.29	0.33	0.32
1-TRANS-2-DIMETHYL-N5	0.31	0.21	0.28	0.29	0.26
N-HEPTANE	0.56	0.37	0.43	0.51	0.49
C7-OLEFINS	0.18	0.13	0.17	0.35	0.26
METHYLCYCLOHEXANE	0.50	0.27	0.29	0.39	0.32
C8-OLEFINS + ISO-P	0.14	0.05	0.02	0.05	0.00
MONOMETHYL-ISO-C8-P	0.73	0.70	0.83	0.94	0.80
OTHER ISO-C8-P	0.17	0.13	0.17	0.28	0.17
C8-OLEFINS	0.25	0.22	0.16	0.27	0.38
C8-NAPHTHENES (N5+N6)	1.25	1.08	1.36	1.36	1.25
N-OCTANE	0.11	0.10	0.08	0.03	0.13
C9-OLEFINS + ISO-P	0.15	0.03	0.00	0.00	0.00
MONOMETHYL-ISO-C9-P	0.27	0.29	0.30	0.35	0.30
OTHER ISO-C9-P	0.20	0.15	0.17	0.20	0.15
C9-OLEFINS	0.13	0.05	0.07	0.15	0.14
C9-NAPHTHENES (N5+N6)	0.36	0.39	0.40	0.34	0.33
N-NONANE	0.03	0.02	0.02	0.03	0.01
ISO-C10-P + O + N5 + N6	0.41	0.42	0.26	0.51	0.48
BENZENE	0.67	0.53	0.74	0.77	0.74
TOLUENE	3.35	3.10	4.18	4.38	4.03
ETHYLBENZENE	1.18	1.14	1.39	1.41	1.20
P-XYLENE	0.00	0.00	1.25	0.00	0.00
M-XYLENE	2.89	3.64	3.35	4.61	4.39
O-XYLENE	0.84	1.10	1.36	1.35	1.31
N-PROPYLBENZENE	0.09	0.11	0.12	0.13	0.14
1-METHYL-3-ETHYL-BENZENE	2.00	2.67	3.06	3.17	3.02
1,3,5-TRIMETHYL-BENZENE	0.03	0.04	0.05	0.04	0.05
1-METHYL-2-ETHYLBENZENE	0.13	0.20	0.33	0.24	0.20
ISO-C4-BENZENE	0.01	0.01	0.01	0.01	0.02
1,2,4-TRIMETHYLBENZENE	1.25	1.67	1.94	1.97	1.92
1-METHYL-2-ISO-C3-BENZENE	0.02	0.04	0.05	0.04	0.03
1,3-DIETHYLBENZENE	0.05	0.07	0.11	0.08	0.12
1-METHYL-3-N-C3-BENZENE	0.34	0.45	0.47	0.52	0.48
N-C4-BENZENE	0.01	0.00	0.00	0.02	0.00
1,2,3-TRIMETHYLBENZENE	0.04	0.09	0.11	0.09	0.10
1,2-DIETHYLBENZENE	0.09	0.13	0.15	0.15	0.15
1-METHYL-2-N-C3-BENZENE	0.00	0.00	0.00	0.00	0.00
C10-ALKYLBENZENES	0.64	0.85	0.94	0.97	0.87
1,2,4,5-TETRAMETHYLBENZENE	0.08	0.10	0.11	0.12	0.10
1,2,3,5-TETRAMETHYLBENZENE	0.03	0.06	0.06	0.06	0.04
1,2,3,4-TETRAMETHYLBENZENE	0.07	0.09	0.18	0.19	0.15
C11-ALKYLBENZENES	0.66	1.02	1.10	1.16	0.87
NAPHTHALENE	0.00	0.01	0.00	0.00	0.00
METHYL-NAPHTHALENES	0.02	0.04	0.00	0.05	0.00
UNKNOWNS (HC PARAFFINICS)	0.12	0.00	0.00	0.00	0.00
UNKNOWNS (HC AROMATICS)	0.00	0.00	0.14	0.00	0.11
UNKNOWN C12+	1.30	2.01	2.44	2.61	2.19
SLURRY REACTOR WAX	6.00	6.00	6.00	6.00	6.00

Table A-9 (Continued)
Composition of Hydrocarbon Products from
Two-Stage Slurry F-T/ZSM-5 Syngas Conversion
Run CT-256-1

M.B. No.	1-19	1-20	1-22	1-23	1-27	1-28	1-29	1-30	1-31
Days On-stream	28.8	30.4	33.2	34.4	36.4	37.4	40.4	41.4	42.4
METHANE	9.41	8.34	9.52	10.45	8.56	8.63	9.27	8.91	9.38
ETHENE	0.00	0.43	0.51	0.64	0.45	0.46	0.52	0.51	0.54
ETHANE	2.47	1.95	2.14	2.34	1.99	1.90	1.94	1.90	1.96
PROPENE	0.77	0.72	0.88	1.12	0.77	0.80	0.91	0.93	0.96
PROPANE	12.25	10.15	11.02	11.76	9.85	9.53	9.29	8.97	9.38
I-BUTANE	14.84	12.90	14.36	15.99	13.30	12.99	12.86	12.85	13.45
1-BUTENE+2-METHYLPROPENE	0.55	0.55	0.67	0.84	0.63	0.66	0.73	0.75	0.82
N-BUTANE	9.16	8.39	9.08	9.76	8.55	8.65	8.32	8.16	8.52
TRANS-2-BUTENE	0.23	0.20	0.27	0.32	0.23	0.24	0.27	0.30	0.32
CIS-2-BUTENE	0.15	0.13	0.17	0.21	0.15	0.16	0.18	0.21	0.21
3-METHYL-1-BUTENE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I-PENTANE	9.61	8.88	9.60	10.83	9.22	9.20	8.45	9.10	9.42
1-PENTENE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2-METHYL-1-BUTENE	0.07	0.06	0.10	0.09	0.08	0.09	0.09	0.10	0.13
N-PENTANE	3.61	3.69	4.09	4.42	3.54	4.27	3.76	4.25	4.46
TRANS-2-PENTENE	0.01	0.01	0.01	0.01	0.05	0.01	0.00	0.07	0.07
CIS-2-PENTENE	0.01	0.03	0.06	0.05	0.00	0.06	0.06	0.03	0.03
2-METHYL-2-BUTENE	0.03	0.04	0.04	0.03	0.62	0.05	0.00	0.06	0.06
UNKNOWN C5-MONOOLEFINS	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.25	0.28
C5-DIOLEFINS (DIENES)	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00
2,2-DIMETHYLBUTANE	0.18	0.17	0.22	0.27	0.00	0.20	0.25	0.01	0.01
CYCLOPENTANE	0.27	0.26	0.26	0.29	0.21	0.22	0.17	0.22	0.22
HEXENES + ISO-HEXANES	0.04	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00
2,3-DIMETHYLBUTANE	0.39	0.37	0.37	0.43	0.35	0.33	0.25	0.34	0.33
2-METHYLPENTANE	2.49	2.63	2.88	3.04	3.00	3.11	2.17	3.12	3.23
3-METHYLPENTANE	1.52	1.59	1.60	1.69	1.57	1.58	1.05	1.61	1.62
HEXENES	0.02	0.03	0.03	0.04	0.11	0.05	0.00	0.07	0.10
N-HEXANE	0.86	0.98	1.16	1.25	1.22	1.36	0.84	1.47	1.51
2,4-DIMETHYLPENTANE	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01
METHYLCYCLOPENTANE	0.90	0.96	1.03	1.11	0.98	1.01	0.58	1.06	1.09
3,3-DIMETHYLPENTANE	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01
CYCLOHEXANE	0.02	0.02	0.00	0.01	0.00	0.02	0.00	0.03	0.02
HEPTENES + ISO-HEPTANES	0.04	0.15	0.21	0.24	0.17	0.19	0.20	0.19	0.19
2-METHYLHEXANE	0.60	0.72	0.76	0.77	0.84	0.94	0.37	0.96	0.93
2,3-DIMETHYLPENTANE	0.20	0.24	0.21	0.19	0.24	0.24	0.04	0.26	0.24
3-METHYLHEXANE	0.73	0.84	0.84	0.79	0.94	1.02	0.37	1.04	1.04
1-CIS-3-DIMETHYL-N5	0.20	0.24	0.29	0.31	0.32	0.34	0.12	0.38	0.36
1-TRANS-3-DIMETHYL-N5	0.24	0.21	0.19	0.14	0.24	0.25	0.00	0.28	0.26
1-TRANS-2-DIMETHYL-N5	0.22	0.28	0.27	0.29	0.29	0.29	0.12	0.32	0.31
N-HEPTANE	0.26	0.29	0.36	0.44	0.34	0.42	0.20	0.50	0.49
C7-OLEFINS	0.03	0.04	0.06	0.04	0.09	0.08	0.00	0.08	0.17
METHYLCYCLOHEXANE	0.35	0.45	0.41	0.35	0.38	0.33	0.04	0.58	0.52
C8-OLEFINS + ISO-P	0.05	0.09	0.14	0.28	0.00	0.17	0.14	0.13	0.13
MONOMETHYL-ISO-C8-P	0.31	0.44	0.43	0.31	0.60	0.65	0.00	0.77	0.67
OTHER ISO-C8-P	0.09	0.13	0.11	0.09	0.15	0.10	0.00	0.19	0.16
C8-OLEFINS	0.04	0.05	0.07	0.06	0.14	0.23	0.00	0.12	0.22
C8-NAPHTHENES (N5+N6)	0.66	0.89	0.81	0.64	1.13	1.28	0.00	1.40	1.19
N-OCTANE	0.01	0.01	0.02	0.03	0.03	0.04	0.00	0.06	0.03
C9-OLEFINS + ISO-P	0.05	0.00	0.11	0.23	0.00	0.10	0.10	0.05	0.05
MONOMETHYL-ISO-C9-P	0.07	0.11	0.08	0.09	0.18	0.20	0.00	0.26	0.22
OTHER ISO-C9-P	0.07	0.11	0.07	0.07	0.14	0.15	0.00	0.20	0.15
C9-OLEFINS	0.02	0.01	0.07	0.02	0.02	0.03	0.00	0.04	0.09
C9-NAPHTHENES (N5+N6)	0.14	0.20	0.20	0.16	0.32	0.32	0.00	0.38	0.31
N-NONANE	0.02	0.03	0.02	0.02	0.03	0.03	0.00	0.04	0.03
ISO-C10-P + O + N5 + N6	0.15	0.22	0.20	0.14	0.26	0.29	0.00	0.42	0.36
N-DECANE	0.06	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1-DECENE	0.06	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BENZENE	1.13	1.16	0.91	0.82	0.86	0.78	0.35	0.75	0.79
TOLUENE	5.43	6.24	4.47	3.12	4.39	4.59	0.71	4.00	3.78
ETHYLBENZENE	1.20	1.43	1.26	1.22	1.12	1.44	0.39	1.33	1.25
P-XYLENE	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
M-XYLENE	3.87	4.98	2.63	1.79	4.56	4.05	0.00	3.90	3.42
O-XYLENE	1.13	1.48	1.06	0.53	1.36	1.19	0.00	1.16	1.01
N-PROPYLBENZENE	0.05	0.06	0.05	0.03	0.08	0.07	0.00	0.08	0.07
1-METHYL-3-ETHYL-BENZENE	1.40	1.93	1.62	0.89	2.23	2.24	0.00	2.39	2.04
1,3,5-TRIMETHYL-BENZENE	0.08	0.10	0.05	0.02	0.07	0.05	0.00	0.04	0.04
1-METHYL-2-ETHYLBENZENE	0.24	0.32	0.23	0.11	0.29	0.27	0.00	0.23	0.20
ISO-C4-BENZENE	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.01
1,2,4-TRIMETHYLBENZENE	1.46	1.95	1.44	0.77	1.90	1.74	0.00	1.75	1.47
1-METHYL-2-ISO-C3-BENZENE	0.10	0.13	0.07	0.03	0.09	0.07	0.00	0.05	0.04
1,3-DIETHYLBENZENE	0.04	0.05	0.04	0.02	0.08	0.07	0.00	0.05	0.05
1-METHYL-3-N-C3-BENZENE	0.16	0.22	0.20	0.13	0.26	0.30	0.00	0.36	0.30
N-C4-BENZENE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
1,2,3-TRIMETHYLBENZENE	0.08	0.11	0.05	0.04	0.09	0.09	0.00	0.07	0.06
1,2-DIETHYLBENZENE	0.04	0.05	0.05	0.04	0.08	0.09	0.00	0.11	0.09
1-METHYL-2-N-C3-BENZENE	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
C10-ALKYLBENZENES	0.50	0.68	0.54	0.32	0.74	0.76	0.00	0.81	0.66
1,2,4,5-TETRAMETHYLBENZENE	0.09	0.12	0.09	0.03	0.07	0.12	0.00	0.12	0.10
1,2,3,5-TETRAMETHYLBENZENE	0.05	0.07	0.05	0.00	0.01	0.07	0.00	0.06	0.05
1,2,3,4-TETRAMETHYLBENZENE	0.01	0.00	0.00	0.02	0.21	0.01	0.00	0.15	0.10
C11-ALKYLBENZENES	0.97	1.26	0.89	0.60	1.05	1.07	0.00	0.99	0.83
NAPHTHALENE	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
METHYL-NAPHTHALENES	0.00	0.09	0.00	0.00	0.00	0.02	0.00	0.05	0.04
UNKNOWNS (HC AROMATICS)	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00
UNKNOWN LITE HYDRO-CARB LIQ (1)	0.00	0.00	0.00	0.00	0.00	0.00	27.38	0.00	0.00
UNKNOWN C12+	1.49	2.11	1.18	0.70	1.98	1.56	1.48	1.70	1.33
SLURRY REACTOR WAX	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00

(1) Collected in Chilled and Ambient Condensers.

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