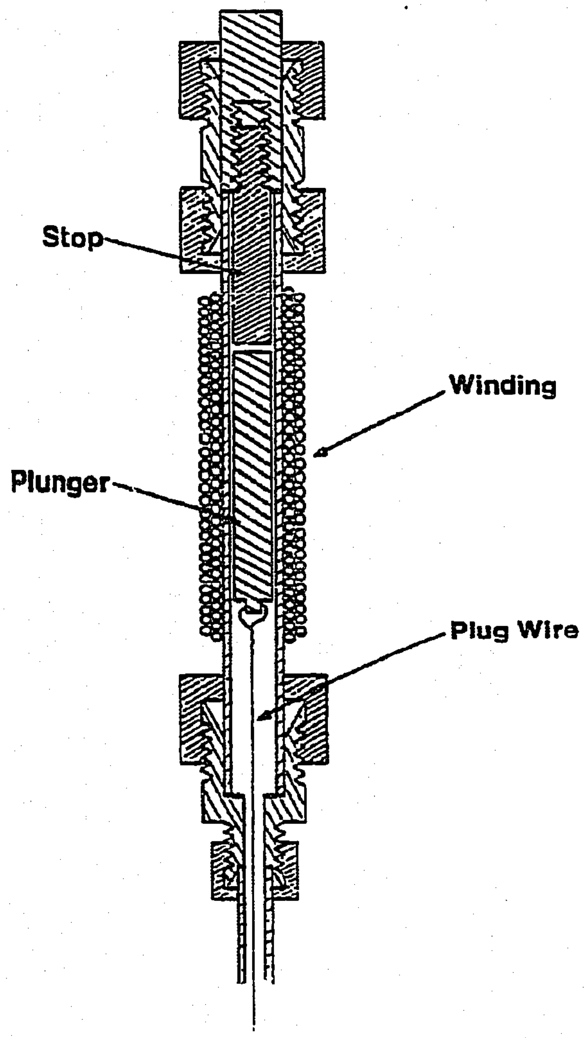

Figure 6.6. A Schematic Cross-Sectional Diagram of a Solenoid Used to Actuate the Sliding Plug.

The solenoid consists of a 187.3-mm long piece of 1/2-inch O.D. 316- stainless-steel (non-magnetizable) tubing with a 0.049-inch wall thickness. The winding is 111 mm in length and it starts 44 mm from the bottom end of the tube. It contains 2,880 turns of 23 AWG cooper-solenoid-winding wire, producing a force of 1.33 N at the start of the plunger stroke. The solenoid is connected at the base to a 1/2-inch to 1/4-inch Swagelok reducing union. This union serves as the resting point of the plunger when the solenoid is de-energized. When the plunger is in this position, approximately the top 22 mm is in the winding area.

At the top of the solenoid, an adjustable plunger stop extends down into the solenoid winding. The stop consists of a 10.0-mm diameter piece of 416- stainless steel (non-magnetizable) threaded into a 6.35-mm O.D. piece of 316- stainless steel. The stop serves to redirect the flux lines of the magnetic field so that the magnetic force at the end of the plunger stroke is greatly increased. This serves, in turn, to pull the sliding plug in the microreactor firmly against its seat. The plunger stop is fixed to the solenoid by a 1/2-inch stainless-steel Swagelok union. In this way, the solenoid can be used at high pressure with no gas leakage and the stop can still be adjusted.

The plunger itself is a piece of 416- stainless-steel rod, 76.2-mm long and 10.0 mm in diameter. Two grooves, 3.18-mm wide and 1.27-mm deep, run the length of the plunger. These grooves keep gas from building up in front of the plunger as it moves. The lower end of the plunger has a nipple to allow for attachment of the wire from the sliding plug. The wire connecting the plungers to the sliding plug runs down from the plunger, around a 90-degree bend and through the flexible stainless-steel hose. After passing through the flexible hose, the wire goes through two more 90-degree bends and finally attaches to the plug. The feed gas enters the tubing just below the solenoid at a tee union. Therefore, the wire does not go around any sharp corners, but only 90-degree tubing bends. "Flexing" of the flexible hose during vibration causes no ill effects and the plug remains seated.

As in the cold-flow model, the solenoids are powered by a 24-VDC supply and are conencted to a relay. The latter acts to alternately energize the solenoids. Therefore, one solenoid is energized while the other is de-energized. The relay is controlled via the computer interface and the H-89 microcomputer.

6.1.1.4 Associated Systems

The product-gas sampling system and the gas-chromatographic system, used in conjunction with the sliding-plug vibrofluidized-bed microreactor system are identical to the systems described in Sections 4.1.1.3 and 4.1.1.4.

6.1.2 Materials

The sliding-plug vibrofluidized-bed microreactor system for unsteady-state F-T synthesis was designed with the use of $-150 \div 300\ \mu$ fused-iron ammonia-synthesis catalyst as described in Section 4.1.2.1. However, this system does not preclude the use of other size fractions or new types of catalysts.

Gases being used with this microreactor system are similarly described in Section 4.1.2.2.

6.1.3 Experimental Procedures

6.1.3.1 Microreactor Cleaning and Catalyst Loading

The procedure to be followed when cleaning and loading the sliding-plug vibrofluidized-bed microreactor is very similar to the procedure used for the steady-state vibrofluidized-bed microreactor. First, however, the sliding plug had to be removed from the plenum zone. This was accomplished by removing the two Swagelok male connectors that screw into the base section of the microreactor and serve as plug seats. The mating surface of the three microreactor sections were then polished with number 500 emory cloth on a surfacing table. The entire interior surface of the microreactor was flushed with acetone and wiped with Kimwipes.

After the microreactor was thoroughly cleaned, the base section was placed in the wooden support apparatus and clamped in the vise. Appoximately 1 meter of the 0.356-mm diameter stainless-steel wire was then attached to each end of the sliding plug. The plug was slid into the plenum zone; and the wire was threaded through the washers and the Swagelok male connectors. A small amount of "Silver Goop" thread lubricant was applied to the threads of the connectors to prevent seizing and to facilitate later removal. The male conenctors were then tightened, compressing the copper washer.

The wire was threaded through the 1/4-inch O.D. stainless-steel tubing that is used to connect the microreactor to the flexible stainless-steel hose. Each piece of tubing has two 90-degree bends and is attached to the Swagelok fitting-end of the male connector in the base of the microreactor. Thread lubricant is also applied to the fitting threads which are exposed to the high temperature in the constant temperature bath.

Following the installation of the sliding plug, a new 2-micron sintered stainless-steel plate was made and positioned into the distributor plate recess in the base section. A thin, oval-shaped, Grafoil gasket was then placed on top of the distributor plate. This gasket prevents any gas from bypassing the distributor plate by sealing between the edges of the plate and the microrector base-section.

A silver-plated stainless-steel O-ring was then inserted into the O-ring groove and the reaction section of the microreactor was installed. One gram of -150+300 micron fused-iron catalyst was weighted and carefully poured into the reaction zone. The thermocouples were typically left in place in the reaction section between experiments.

A 20-micron, sintered stainless-steel catalyst retention plate was fitted to the gas-exit section as was a silver plated O-ring. The gas-exit section was placed on top of the reaction section. Thread lubricant was used on the bolts that clamp the three sections (i.e., base section, reaction section, and gas-exit section) together and these bolts were torqued in sequence to 27 N-m.

6.1.3.2 Mounting the Microreactor

Once the microreactor was cleaned and loaded with fresh catalyst, it was ready for attachment to the rest of the system. Four threaded rods were screwed into the tapped holes in the base section.

The microreactor was lowered into the cool fluidized-bed constant-temperature bath. These rods were, in turn, bolted to the leaf-spring supports. The two stainless-steel plug wires, eminating from the microreactor feed tubes, were then carefully threaded up through the flexible metal hose and tubing to the solenoid mounting position. In order to do this, guide wires had to be used. The compression fittings between the flexible metal hose and the microreactor feed and gas-exit lines were then tightened. The thermocouples from the microreactor were then connected to the panel meter.

At this point, the vibrator itself was mounted to the underside of the I-beam support and connected to the microreactor support system. The frequency generator was then adjusted to the point where the microreactor was vibrating at the maximum amplitude. This usually corresponded to a resonance frequency of 18-24 Hz with a peak-to-peak amplitude of 4 mm. The solenoid plungers were next attached to the plug wires. The plug was first drawn up tight against the left-hand plug stop by pulling on the plug wire.

The plunger was next attached to the plug wire 57.2 mm up from the point where the reducing union expands from 1/4- to 1/2-inch. Note that the reducing union serves as the resting point of the plunger when the solenoid is de-energized. In addition, the stroke of the plug in the plenum is 50.8 mm. Consequently, when the solenoid is de-energized, there should be approximately 6.4 mm of slack in the plug wire. This provides enough slack so that the plunger in the de-energized solenoid does not keep the plug from resting on the opposite plug-seat.

After attaching the left plunger, the left solenoid was slipped down over that plunger and attached to the reducing union. The right-hand plunger and solenoid were then installed in a similar fashion and the solenoid cooling fans were turned on.

The final step in the installation involved optimizing the pulling force at the ends of the plug stroke. This was done by adjusting the length of the plunger stops in the solenoids. These stops were constructed so that they could be adjusted to make up for any difference in plug-wire length between experiments.

6.1.3.3 System Startup and Catalyst Reduction

Before an experiment, the mass-flow meters as well as the pressure transducers were calibrated. The system was then pressure-tested at 3,446 kPa for possible leaks. The portion of the system located downstream of needle valves 1-4 (Figure 6.2) was thoroughly flushed with helium. This was done by directing three-way valves V6, V9 and V10, so that helium could flow through them. Shut-off valve V11 was opened so as to keep the pressure on either side of the sliding plugs equilized. Valves V3 and V12, and solenoid valve 5 were opened, allowing helium to flow. The solenoids were then alternately switched moving the plug back and forth. Valve V12, parallel to the back-pressure regulator, was closed and the system pressure downstream of solenoid valves 1-4 was brought up to 2,220 kPa using helium.

The F-gas feed line located upstream of solenoid valves 1 and 2 was pressurized to 4,807 kPa, as was the S-gas feed-line located upstream of solenoid valves 3 and 4. During an experiment, three-way valves V7 and V8 were always turned so that the downstream pressure was monitored. If these valves are turned from their upstream position to the downstream position during an experiment, a burst of gas will be transmitted through the microreacor.

At this point, the nitrogen ballast-gas flow was started by opening valve V1 and adjusting the associated needle valve. The back-pressure regulator was adjusted so that a downstream system-pressure of 2,220 kPa was maintained. The helium flow was stopped by shutting valve V3 and solenoid valve 5.

The next major step involved setting the F-gas, S-gas, percarburizing and reducing gas flow rates through the microreactor. The S-gas flow rate was set first. Three-way valves V9 and V10 were directed toward the F-gas and S-gas feed-lines and shut-off valve V11 remained open. The right solenoid, R, was activated, causing the plug to rest against the right-hand stop. Solenoid valves 3, 4, and 5 were then simultaneoulsy opened, purging the reactor with S-gas at 6.67×10^4 standard mm^3/s for one minute. Solenoid valve 3 was closed and the system pressure was allowed to stabilize for several minutes with a low flow of S-gas. Valve V11 was then shut, isolating the F-gas and S-gas feed lines.

The needle valve associated with solenoid valve 4 was adjusted so that the mass-flow meter was reading the desired value for the S-gas flow rate. Solenoid valve 4 was closed and three-way valves V6 and V10 were turned so that the H_2:CO:Ar precarburizing-gas mixture was flowing through the microreactor. Valve V11 was temporarliy opened to assure pressure equilization across the sliding plug and then closed.

The flow rate of precarburizing gas was then set using the appropriate needle valve and the mass-flow meter. The pressure upstream of the precarburizarion needle valve was kept at 4,807 kPa in order to maintain a critical pressure drop. The precarburization flow was stopped by directing three-way valve V10 toward the S-gas feed line.

The reducing-gas flow rate was set in a similar fashion to the S-gas flow rate. Hydrogen was used as both F-gas and the reducing gas. Different flow rates of hydrogen were used during reduction and unsteady-state synthesis. Consequently, the needle valve associated with solenoid valve 2 had to be adjusted accordingly after the catalyst reduction period.

After the downstream system was purged with hydrogen and the reduction flow was set to 3,670 standard mm^3/s, the fluidized constant-temperature bath was heated to 450°C and the heating tapes were turned on. The bath-heating period took approximately two and one-half hours. The actual reduction period consisted of six hours of isothermal reduction of the catalyst at 450°C. At the end of the reduction period, the hydrogen flow rate had to be adjusted. Hydrogen was used as F-gas in the later stages of the unsteady-state experiment. Its flow rate, however, must be set during a period when it is flowing steadily. As the final step in the reduction period, the temperature of the fluidized constant-temperature bath was lowered to that desired for the precarburization and unsteady-state synthesis experiments.

6.1.3.4 Precarburization and Unsteady-State Synthesis

Precarburization of the reduced fused-iron catalyst was used as a means of creating a bulk carbide structure before unsteady-state synthesis began. In this way, different unsteady-state experiments could be performed from a common starting composition of catalyst, and the rate of carbon deposition could be more easily determination. After the fused-iron catalyst had been reduced, precarburization was initiated simply by closing solenoid valve 2 and then simultaneously activating the right solenoid and turning three-way valve V10 toward the precarburization stream.

The precarburization gas typically used was a synthesis gas of a 4:1 H_2/CO ratio with a small percentage of argon. Argon was used as an internal standard for gas-chromatographic analysis.

At the start of precarburization, the microcomputer program, which contains the sampling-valve timing loops, was started. After the first twenty minutes of precarburization, a light gas sample was automatically flushed into the gas chromatograph. Seventeen minutes later, all light gas compounds of interest had eluted and the microcomputer switched the sampling valve, backflushing the packed column. This process was repeated every 37 minutes throughout the precarburization and unsteady-state synthesis portions of the experiment.

After two hours of catalyst precarburization with the 4:1 H_2/CO synthesis gas, the unsteady-state synthesis was started. The flow rates of F-gas and S-gas had been previously set to their desired valves for unsteady-state synthesis. Hence, the only steps required to start unsteady-state synthesis were to switch three-way valve V10 toward the S-gas feed-line and to run the solenoid-switching microcomputer program. The program, used to slide the plug and switch between solenoid valves 2 and 4, is presented in Appendix C.

When solenoid valve 2 was opened, the plug was simultaneously pulled to the left. When solenoid valve 4 was opened, the sliding plug was pulled to the right. The program allowed control of the sliding plug and solenoid valves to within hundredths of a second. The response times of the solenoid valves, however, were only on the order of one-tenth of a second. As stated earlier, light gas samples were taken every 37 minutes during the unsteady-state gas pulsing. The volume of the tubing between the reaction zone and the sampling point is approximately 30 times the volume of the reaction zone itself. Therefore, the exit-gases should be well mixed by the time they reach the sampling valves. As in the steady-state experiments, gas samples to be separated using the capillary column were taken only at the end of an experiment. The gas chromatograph oven was cooled to -20°C and a sample was then flushed onto the capillary column. The column was held at -20°C for 2 minutes and then temperature programed to 150°C at 4°C/min.

6.1.3.5 System Shut-Down

At the completion of the unsteady-state reaction period, it was desirable to rapidly stop the reaction by flushing the sliding-plug microreactor and feed-gas lines with helium. This was done by first stopping the computer program and making certain that solenoid valves 2 and 4 were closed and 5 was open. Valve V11 was then rapidly opened and three-way valves V6, V9 and V10 were switched so that helium was flowing through the microreactor.

As helium flowed through the microreactor, the nitrogen ballast-gas was shut off. Valve V12, parallel to the back-pressure regulator, was slowly opened over the course of several minutes. During this period, the plug was slid back and forth several times to insure purging of both feed lines by helium.

Once the system had reached atmospheric pressure, the constant-temperature bath was shut off and the microreactor was allowed to cool. The catalyst was still vibrofluidized as the microreactor cooled. Cooling took place over five to six hours under a maximum helium flow rate of 2,200 standard mm^3/s. The heating tapes were maintained at 200°C during the cool-down period to keep any residual F-T products from condensing in the heated portion of the equipment, including the sampling valves.

6.1.3.6 Catalyst Collection and Analysis

Once the sliding-plug microreactor had been cooled to ambient temperatures, it could be removed from the constant-temperature bath. In order to so this, the solenoids were disconnected from the reducing unions, and the plug wires were cut, releasing the solenoid plungers. The compression fittings between the flexible hose and the microreactor were disconnected, and the plug wires were removed from these hoses.

The vibrational support apparatus for the microreactor was then unbolted and the microreactor was clamped in the vise. All eight bolts holding the three sections of the microreactor together were removed. The gas-exit section was lifted off with care and the spent catalyst and any bugdust present were removed using the suction-filter apparatus. This procedure was previously described in Section 4.1.3.6.

After the spent catalyst had been meticulously removed and weighed, the sliding plug was removed from the plenum zone. Spent catalyst was stored in vials under nitrogen until being sent for total carbon and iron analyses along with Mössbauer spectroscopic determination of iron-containing phases.

CHAPTER 7

CONCLUSIONS, SIGNIFICANCE AND RECOMMENDATIONS

7.1 Conclusions

Following a review of relevant literature on F-T synthesis, vibrofluidized-beds, and unsteady-state methods for kinetic studies, an experimental investigation into the development of a microreactor system for unsteady-state F-T synthesis was carried out. Steady-state F-T synthesis experiments using a commercial fused-iron catalyst produced information on catalyst defluidization, hydrocarbon product distribution and baseline carbon deposition. Investigations in a cold-flow vibrofluidized-bed microreactor model revealed information on gas mixing in the unsteady-state system. In addition, the cold-flow model allowed observation of characteristics of the vibrofluidized catalyst in the microreactor. In the final stages of the studies, a vibrofluidized-bed microreactor system for unsteady-state F-T synthesis at commercially important reaction conditions was designed and constructed.

The following conclusions can be drawn based on the experimental studies.

1. In a vibrofluidized microreactor system for F-T synthesis under steady-state conditions using a commercial promoted fused-iron catalyst:

   a. Catalyst defluidization occurs within several hours at temperatures below 395°C when using a feed-gas H_2/CO ratio of 2:1 or less.

   b. Catalyst defluidization can be detected through observation of thermocouple temperature fluctuations in the reaction zone.

c. A shift in the probability of chain growth of hydrocarbon products to lower values occurs, as the reaction temperature is increased and as the feed-gas H_2/CO ratio is increased.

d. Bugdust is a fine, black powder produced due to excessive carbon formation which in turn causes physical degradation of the catalyst. Its structure is highly porous and bugdust contains 18-30 weight percent carbon and 50-64 weight percent iron.

e. Discrete fractions of free-flowing catalyst and bugdust (powdery, low-density carbon-rich particles) can be easily collected under conditions where liquid products and waxes do not condense in the reaction zone.

f. The rate of free carbon formation (mainly in the form of bugdust) is much greater when a feed-gas H_2/CO ratio of 1:1 was used than when a higher ratio of 2:1 is used.

2. In a cold-flow vibrofluidized-bed microreactor model for unsteady-state gas feeding:

a. Experiments with a manual 3-way ball valve substituting for the sliding-plug microreactor show quantitative gas replacement after 2.4 seconds at all flow rates investigated.

b. A 20-micron distributor plate induces feed-gas mixing by allowing gas to backflow from the reaction zone to the plenum zone during the sliding-plug movement.

c. The use of a 2-micron distributor plate eliminates the backflow of gas from the reaction zone to the plenum zone during the sliding-plug movement.

d. The geometry of the microreactor induces some mixing of the feed gases, particularly when the gases pass from the reaction zone to the gas-exit zone.

e. More gas-mixing occurs during the transition from argon to helium feeding than during the transition from helium to argon feeding. This is thought to be due to the density differences between the two gases.

f. Vibrofluidization of the catalyst in the reaction zone induces only a small amount of gas backmixing at low feed-gas velocities.

g. The use of high gas flow rates and feed-gas staggering significantly reduces undesirable gas mixing in the microreactor.

3. Experimental characterizations of a vibrofluidized-bed of fused-iron catalyst in a cold-flow microreactor model show that:

a. The solid mixing is intense, even at very low gas velocities.

b. At feed-gas velocities somewhat below those for normal gas-fluidization (below the minimum gas-fluidization velocity, U_{mf}) the surface of the vibrofluidized catalyst-bed levels out and begins to oscillate.

4. A vibrofluidized-bed microreactor system for unsteady-state F-T synthesis:

a. Has been designed and constructed, and it can be operated at commercially important reaction conditions.

b. Allows for rapid switching of feed gases on the order of several seconds.

5. In order to simulate the catalyst behavior in the freeboard region and the shallow-bed region of a "heat-tray" reactor (Figure 1.1) using the unsteady-state vibrofluidized-bed microractor system:

a. A flow rate of approximately 1,650 actual mm^3/s should be used. This will permit rapid switching of feed gases over the catalyst in the reaction zone of the microreactor.

b. A reaction temperature of 395°C is necessary to prevent defluidization of the fused-iron catalyst. This temperature is higher than that desired for operation of a "heat-tray" reactor. Therefore, a means should be developed for reducing the operating temperature in the microreactor, while maintaining a fluidized catalyst.

7.2 Significance of the Results

The development of a vibrofluidized-bed microreactor for both steady-state and unsteady-state catalytic gas-solid reactions has far-reaching significance. Before this development, there was no easy way of accurately determining integral fluid-bed kinetics in a laboratory reactor.

Fixed-bed reactors rely on changes in gas composition over static catalyst particles. Laboratory gas-fluidized-bed reactors require large flow rates of feed gas and therefore deep catalyst beds (requiring large quantities of catalyst) in order to obtain integral conversions.

The unique ability of the new microreactor system to rapidly switch feed-gas flows over an intensely-mixed solid makes this development an even more significant contribution to the areas of chemical kinetics and reaction engineering.

7.3 Recommendations for Further Studies

Based on the results of this work, the following recommendations are forwarded for future studies:

1. Repeat the steady-state carbon-deposition experiments utilizing a bifunctional catalyst, such as synthetic zeolite Fe-HZSM-5, in order to eliminate catalyst defluidization caused by accumulation of high molecular-weight products. This will allow for use of lower operating temperatures.

2. Determine the vibrofluidization characteristics of new catalysts in the cold-flow microreactor model.

3. Further explore effective means of improving feed-gas transitions in the unsteady-state cold-flow vibrofluidized-bed microreactor model.

4. Undertake model-reaction studies in the vibrofluidized-bed microreactor system. By examining some simple reactions with well-characterized kinetics, quantitative mixing tests can be performed. Some candidates for such model-reaction studies include hydrogenation of

ethylene (Wynkoop and Wilhelm, 1950) and ethanol dehydration (Bock et al., 1984). These reaction studies could be used to determine heat- and mass-transfer effects in the reaction zone of the microreactor.

5. Experimentally determine the mass-transfer coefficient in the vibrofluidized-bed microreactor. This could be done by studying the sublimation of napthalene in nitrogen as a function of flow rate and particle size.

6. Perform feed-gas-cycling F-T synthesis experiments in the unsteady-state vibrofluidized-bed microreactor system in order to determine carbon deposition rates on: (a) a fused-iron catalyst; and (b) different formulations of Fe-HZSM-5.

REFERENCES

Abdul-Kareem, H. K., P. L. Silveston, and P. R. Hudgins, "Forced Cycling of the Catalytic Oxidation of CO over V_2O_5 Catalyst - I, Concentration Cycling," Chem. Eng. Sci., 35, 2007-84 (1980).

Afanas'ev, A. D., R. A. Buyanov, and V. V. Chesnokov, "Effect of Water Vapor on Coking of Iron Oxides," Kinet. Katal., 23, 5, 1226-30 (1982).

Agrawal, P. K., W. D. Fitzharris, and J. R. Katzer, "Sulfur Poisioning and Carbon Deactivation of Alumina-Supported Ni, Co, Fe and Ru Catalysts in CO Hydrogenation," in Catalyst Deactivation (B. Delmon and G. F. Fromont, Ed.) Elsevier Scientific Publishing Company, Amsterdam, 179-200 (1980).

Alekseeva, I. N., L. Kartashov, and Y. Treger, "Study of Hydrogen Chloride Oxidation in a Vibrating Contact Bed Reactor," Khim. Prom-st., Ser.: Khlornaya Prom-st., 5, 21-22 (1980).

Amelse, J. A., L. H. Schwartz, and J. B. Butt, "Iron Alloy Fischer-Tropsch Catalysts. III," Catalysis, 72, 95-119 (1981).

Anderson, R. B. , Catalysis, Vol. IV (P. H. Emmett, Ed.), Reinhold, New York, 1956.

Anderson, R. B., "Schulz-Flory Equation," J. Catal., 55, 114-115 (1978).

Anderson, R. B., "Reply to Rebuttal by G. Henrici-Olivé and S. Olivé," J. Catal., 60, 484 (1979).

Anderson, R. B., "Nitrided Iron Catalysts for the Fischer-Tropsch Synthesis in the Eighties," Cat. Rev.-Sci. Eng., 21(1), 53-71, (1980).

Anderson, R. B., The Fischer-Tropsch Synthesis, Academic Press, Inc., Orlando, 1984.

Anderson, R. B., and Y. Chan, "Chain Growth in the Fischer-Tropsch Synthesis--A Computer Simulation of a Catalytic Process," Symposium on Advances in F-T Chemistry, Division of Petroleum Chemistry, Preprints, American Chemical Society, 578-586 (1978).

Anderson, R. B., R. A. Friedel, and H. H. Storch, "Fischer-Tropsch Reaction Mechanism Involving Stepwise Growth of Carbon Chain," J. Chem. Phys., 19(3), 313-319 (1951).

Anderson, R. B., L. J. E. Hofer, E. M. Cohn, and B. Seligman, "Studies of the Fischer-Tropsch Synthesis. IX. Phase Changes of Iron Catalysts in the Synthesis," J. Am. Chem. Soc., 73, 944-946 (1951).

Anderson, R. B., F. S. Karn, and J. F. Schultz, "Factors in Sulfur Poisoning of Iron Catalysts in Fischer-Tropsch Synthesis," J. Catal., 4, 56-63 (1965).

Anderson, R. B. , C. B. Lee, and J. C. Machiels, "The Thermodynamics of the Hydrogenation of Oxides of Carbon," Can. J. Chem. Eng., 54, 590-594 (1976).

Anderson, R. B., B. Seligman, J. F. Shultz, R. Kelly, and M. A. Elliott, "Fischer-Tropsch Synthesis," Ind. Eng. Chem., 44(2), 391-397 (1952).

Anderson, R. B., J. F. Shulz, B. Seligman, W. K. Hall, and H .H. Storch, "Studies of the Fischer-Tropsch Synthesis. VII. Nitrides of Iron as Catalysts," J. Am. Chem Soc., 72, 3502-3508 (1950).

Araki, M., and V. Ponec, ""Methanation of Carbon Monoxide on Nickel and Nickel-Copper Alloys," J. Catal., 44, 439-448 (1976).

Arnold, J. H., and P. C. Keith, "Synthesis of Liquid Fuels from Natural Gas," Amer. Chem. Soc. Adv. Chem. Ser., 5, 120 (1951).

Atwood, H. E., "Kinetics for the Fischer-Tropsch Reaction," Report No. EPRI-AF-689, Electric Power Research Institute, Palo Alto, CA (1977).

Atwood, H. E., and C. O. Bennett, "Kinetics of the Fischer-Tropsch Reaction over Iron," Ind. Eng. Chem. Process Des. Dev., 18(1), 163-170 (1979).

Bachmann, D., Verfahenstechnik Z.V.D.I Beiheft, 2, 43 (1940).

Baiker, A., and W. Richarz, "Instationäre Betriebsart in der heterogenen Katalyse," Chimia, 30(11), 502 (1976).

Bailey. J. E., and F. J. M. Horn, "Improvement of the Performance of a Fixed-Bed Catalytic Reactor by Relaxed Steady-State Operation," AIChE J., 17(3), 550 (1971a).

Bailey, J. E., F. J. M. Horn, and R. C. Lin, "Cyclic Operation of Reaction Systems" Effect of Heat and Mass Transfer Resistence," AIChE J., 17(4), 818 (1971b).

Bailey, J. N., "Periodic Operation of Chemical Reactors: A Review," Chem. Eng. Commun., 1, 111-224 (1973).

Baird, M. H. I., "Vibrations and Pulsation: Bane or Blessing?", Br. Chem. Eng., 11(1), 20-25 (1966).

Baird, M. J., R. R. Schehl, and W. P. Haynes, "Fischer-Tropsch Processes Investigated at the Pittsburgh Energy Technology Center Since 1944," Ind. Eng. Chem Prod. Res. Dev., 19(2), 175-191 (1980).

Baker, R. T. K., J. R. Alonzo, J. A. Dumesic, and D. J. C. Yates, "Effect of the Surface State of Iron on Filamentous Carbon Formation," J. Catal., 77, 74-84 (1982).

Ballard, D. G. H., "Mechanism of Fischer-Tropsch Synthesis: CH_2 Polymerization versus CO Insertion," J. Mol. Catal., 19, 393-398 (1983).

Barrault, J., and C. Forquy, "Hydrogenation of Carbon Monoxide to Light Olefins on Iron-Alumina Catalysts," J. Mol. Catal., 17, 195-203 (1982).

Bartholomew, C. H., "Carbon Deposition in Steam Reforming and Methanation," Catal. Rèv.-Sci. Eng., 24(1), 67-112 (1982).

Baver, W., and J. Werther, "Modeling Complex Reaction Systems in Fluidized-Bed Reactors," Chemical Reaction Engineering-Boston, ACS Advances in Chemistry Series, 121-131 (1982).

Bell, A. T., "Catalytic Synthesis of Hydrocarbons Over Group VIII Metals. A Discussion of the Reaction Mechanism," Catal. Rev.-Sci. Eng., 23(1,2), 203-232 (1981).

Bell, A. T., and L. L. Hegedus, editors, Catalysis Under Transient Conditions, ACS Symp. Series No. 178, American Chemical Society, Washington, D.C. (1982).

Bennett, C. O., "The Transient Method and Elementary Steps in Heterogeneous Catalysis," Catal. Rev.-Sci. Eng., 13, 121-148 (1976).

Bennett, C. O., "Understanding Heterogeneous Catalysis Through the Transient Method," Catalysis Under Transient Conditions, ACS Symposium Series, No. 178, American Chemical Society, Washington, D.C. (1982).

Bennett, C. O., M. B. Cutlip, and C. C. Yang, "Gradientless Reactors and Transient Methods in Heterogeneous Catalysis," Chem. Eng. Sci., 27, 2255-2264 (1972).

Beno, M. A., J. M. Williams, M. Tachikawa, and E L. Muetterties, "Fischer-Tropsch Chemistry: Structure of a Seminal η^2-CH Cluster Drivative, $HFe_4(\eta^2\text{-}CH)(CO)_{12}$," J. Am. Chem. Soc., 102(13), 4542-4544 (1980).

Benziger, J. B., and R. J. Madix,. Reactions and Reaction Intermediates on Iron Surfaces II," J. Catal., 65, 49-58 (1980).

Berty, J. M., S. Lee, K. Sivagnanam, and F. Szeifert, "Diffusional Kinetics of Catalytic Vapor-Phase Reversible Reactions with Decreasing Total Number of Moles," Preprints from the Eighth Int. Symposium on Chemical Reaction Engineering, p. 455 (1984).

Bianchi, D., and C. O. Bennett, "Influence of the Presence of H_2 During the CO Dissociation Reaction on Iron Catalyst," J. Catal. 86, 433-436 (1984).

Bianchi, D., S. Borcar, F. Teule-Gay, and C. O. Bennett, "Evolution of Surface and Bulk Compositions of an Iron Catalyst in Relation to Catalytic Activity for the Fischer-Tropsch Reaction," J. Catal., 82, 442-456 (1983).

Bilimoria, M. R., and J. E. Bailey, "Dynamic Studies of Acetylene Hydrogenation on Nickel Catalysts," Proc. 5th Intern. Sympos. Chem. React. Eng., Houston, p. 526 (197?).

Biloen, P., "Transient Kinetic Methods," J. Mol. Catal., 21, 17-24 (1983).

Biloen, P., J. N. Helle, and W. M. H. Sachtler, "Incorporation of Surface Carbon into Hydrocarbons during Fischer-Tropsch Synthesis: Mechanistic Implications," J. Catal., 58, 95-107 (1979).

Biloen, P., "On the Mechanism of the Fischer-Tropsch Synthesis," Recueil, 32-38 (1979).

Biskis, E., and J. W. Smith, "Pulsation in a Fixed-Bed Reactor," AIChE J., 9(5), 677 (1963).

Björkman, A., "Shaking of High Pressure Vessels According to the Resonance Principle," Ind. Eng. Chem., 44(10), 2459-2463 (1952).

Blanchard, F., J. P. Reymond, B. Pommier, and S. J. Teichner, "On the Mechanism of the Fischer-Tropsch Synthesis Involving Unreduced Iron Catalyst," J. Mol. Catal., 17, 171-181 (1982).

Blyholder, G., and P. H. Emmett, "Fischer-Tropsch Synthesis Mechanism Studies. II. The Addition of Radioactive Ketene to the Synthesis Gas," J. Phys. Chem., 64, 470 (1960).

Blyholder, G., and A. J. Goodsel, "Infrared Spectra of C_2H_4 Adsorption and CO Insertion Reactions on an Fe Surface," J. Catal., 23, 374-378 (1971).

Blyholder, G., D. Shihabi, W. V. Wyatt, and R. Bartlett, "Adsorption and Interaction of C_2H_4, H_2, CO, and Organic Acids on Fe, Co, and Ni," J. Catal., 43, 122-130 (1976).

Bock, W., W. Sftzman, G. Emig, and J. Werther, "How to Find Suitable Kinetics for Modelling and Scale-up of Fluidized Bed Reactors in the Case of Complex Reaction Systems," Preprints from Eighth Int. Symp. on Chemical Reaction Engineering, p. 479 (1984).

Boehm, H. P., "Carbon from Carbon Monoxide Disproportionation on Nickel and Iron Catalysts: Morphological Studies and Possible Growth Mechanisms," Carbon, 11, 585-590 (1973).

Bond, G. C., and B. D. Turnham, "The Kinetics and Mechanism of Carbon Monoxide Hydrogenation over Silica-Supported Ruthenium-Copper Catalysts," J. Catal., 45, 128-136 (1976).

Bonzel, H. P., and G. Brodén, "On the Adsorption and Dissociation of CO on Potassium Promoted Iron," Preprints, Symposium on New Tools in Catalysis, Division of Petroleum Chemistry, American Chemical Society, p. 1260 (1978).

Bonzel, H. P., and H. J. Krebs, "Evidence for Adsorbed Hydrocarbon Intermediates During the Initial Stages of CO Hydrogenation on Iron," Preprints, Division of Fuel Chemistry, American Chemical Society, 25(2), 19-27 (1980).

Bonzel, H. P., and H. J. Krebs, "Enhanced Rate of Carbon Decomposition During Fischer-Tropsch Synthesis on K Promoted Fe," Surf. Sci., 109, L527-L531 (1981).

Boreskov, G. K., Yu. Sh. Matros, V. S. Lakhomostov, V .I. Puzhilova, and V. I. Lugovski, USSR Patent 882,056 (1981a).

Boreskov, G. K., Yu. Sh. Matros, V. S. Lakhomostov, V .I. Puzhilova, and V. I. Lugovski, USSR Patent 865,796 (1981b).

Boreskov, G. K., Yu. Sh. Matros, and V. M. Lugovski, USSR Patent 849,594 (1982a).

Boreskov, G. K., Yu Sh Matros, V. Yu. Volkov, and A. A. Ivanov, USSR Patent 2,183,501 (1982b).

Boreskov, G. K., and Y. S. Matros, "Unsteady-State Performance of Heterogeneous Catalytic Reactions, Catal. Rev.-Sci. Eng., 25(4), 511-590 (1983).

Boreskov, G. K., V. S. Lakhomostov, and Yu. Sh. Matros, USSR Patent, 2,495,342 (1982a).

Boreskov, G. K., V. S. Lakhomostov, and Yu. Sh. Matros, USSR Patent, 811,511 (1982b).

Borghard, W. G., and C. O. Bennett, "Evaluation of Commercial Catalysts for the Fischer-Tropsch Reaction," Ind. Eng. Chem. Prod. Res. Dev., 18(1), 18-26 (1979).

Bossi, A., G. Carnisio, F. Garbassi, G. Guinchi, and G. Petrini, "Isotopic Equilibration of Carbon Monoxide Catalyzed by Supported Ruthenium," J. Catal., 65, 16-24 (1980).

Boudart, M., and M. A. McDonald, "Structure Sensitivity of Hydrocarbon Synthesis from CO and H_2," J. Phys. Chem., 88, 2185-2195 (1984).

Brady, R. C. III, and R. Pettit, "Reactions of Diazomethane on Transition Metal Surfaces and Their Relationship to the Mechanism of the Fischer-Tropsch Reaction," J. Am. Chem. Soc., 102, 6182-6184 (1980).

Brady, R. C. III, and R. Pettit, "On the Mechanism of the Fischer-Tropsch Reaction. The Chain Propagation Step," J. Am. Chem. Soc., 103(5), 1287-1289 (1981).

Bratu, E. A., and G. I. Jimescu, "The Structure of the Vibrofluidized Bed," Chim. Ind.-Genie Chim., 104(13), 1657-1662 (1971).

Bretsnajder, S., M. Jasyczak, and M. Pasiuk, "Increasing the Rate of Certain Industrial Chemical Processes by the Use of Vibration," Int. Chem. Eng., 3(4), 496 (1963).

Bridge, M. E., C. M. Comrie, and R. M. Lambert, "Hydrogen Chemisorption and the Carbon Monoxide-Hydrogen Interaction on Cobalt (0001)," J. Catal., 58, 28-33 (1979).

Briggs, J. P., R. R. Hudgins, and P. L. Silveston, 5th Canadian Symp. on Catalysis, Calgary, Preprints, Edmonton, p. 118 (1977).

Brodén, G., G. Gafner, and H. P. H.Bonzel, "CO Adsorption on Potassium Promoted Fe(110)," Surf. Sci., 84, 295-314 (1979).

Browning, L. C., T. W. DeWitt, and P. H. Emmett, "Equilibria in the Systems Fe_2C-Fe-CH_4-H_2 and Fe_3C-Fe-CH_4-H_2," J. Am. Chem. Soc., 72, 4211-4217 (1950).

Brunier, E., A. Zoulalian, G. Antonini, and A. Rodriques, "Residence Time Distributions in Laminar Flow Through Reservoirs From Momentum and Mass Transport Equations," Preprints from the Eighth Int. Symp. on Chemical Reaction Engineering, p. 439 (1984).

Bub, G., and M. Baerns, "Prediction of the Performance of Catalytic Fixed Bed Reactors for Fischer-Tropsch Synthesis," Chem Eng. Sci., 35, 348-355 (1980).

Büssemeier, B., C. D. Frohning, and B. Cornils, "Lower Olefins via Fischer-Tropsch," Hydrocarbon Process., 105-112, Nov. (1976).

Butt, J. B., L. H. Schwartz, M. Baerns, and R. Malessa, "Comparison of Activity and Selectivity Maintenance for Supported Fe and FeCo Fischer-Tropsch Catalysts," Ind. Eng. Chem. Prod. Res. Dev., 23, 51-56 (1984).

Caesar, P. D., J. A. Brennan, W. E. Garwood, and J. Ciric, "Advances in Fischer-Tropsch Chemistry," J. Catal., 56, 274-278 (1979).

Caldwell, L., "An Oxidation-Reduction Model for Reaction Rate Oscillations in Fischer-Tropsch Synthesis Over Iron Catalysts," Preprint from Eighth International Symposium on Chemical Reaction Engineering, p. 151 (1984).

Cant, N. W., and A. T. Bell, "Studies of Carbon Monoxide Hydrogenation over Ruthenium Using Transient Response Techniques," J. Catal., 73, 257-271 (1982).

Chang, C. D., J. C. W. Kuo, W. H. Lang, S. M. Jacob, J.J. Wise, and A. J. Silvestri, Ind. Eng. Chem. Process Res. Dev., 17, 255 (1978).

Chang, C. D., W. H. Lang, and A. J. Silvestri, "Synthesis Gas Conversion to Aromatic Hydrocarbons," J. Catal., 56, 268 (1979).

Chen, Y. W., H. T. Wang, and J. G. Goodwin, Jr., "Effect of Preparation Methods on the Catalytic Properties of Zeolite-Supported Ruthenium in the Fischer-Tropsch Synthesis," J. Catal., 83, 415-427 (1983).

Chlenov, V. A., and N.V. Miklailov, "A New Principle in the Production of a Fluidized Bed," Dokl. Akad. Nauk SSSR, 154(3), 703-706 (1964).

Chlenov, V. A., and N. V. Miklailov, "Vibro-fluidized Bed," Russ. J. Phys. Chem., 39(2), 250-251 (1965).

Christoffel, E. G., "Laboratory Reactors and Heterogeneous Catalysis Processes," Catal. Rev.-Sci. Eng., 24(2), 159-232 (1982).

Christoffel, E. G., I. Surjo, and M. Baerns, Chemiker-Z., 102, 19 (1978).

Claybaugh, B. E., J. R. Griffin, and A. T. Watson, U.S. Patent 3,472,829 (1969).

Cohen, R. L., Applications of Mössbauer Spectroscopy, Volume 1, Academic Press, N.Y. (1976).

Collis, F. P., and J. A. Schwarz, "Selectivity Effects and Hydrocarbon-Chain Growth During Fischer-Tropsch Synthesis," J. Comp. Chem., 3(2), 135-139 (1982).

Cooper, B. J., and D. L. Trimm, "Carbon Deposition from Propylene on Polycrystalline and Single Crystal Iron," J. Catal., 62, 35-43 (1980).

Craxford, S. R., and E. K. Rideal, "The Mechanism of the Synthesis of Hydrocarbons from Water Gas," J. Chem. Soc., 1, 604 (1939).

Crone, G., and A. Renker, "Der Einflub periodischer ProzeBführung auf radikalische Polymerisationreaktionen," Chem. Ing. Tech., 51(1), 42 (1979).

Cutlip, M. B., "Concentration Forcing of Catalytic Surface Rate Processes: Part 1. Isothermal Carbon Monoxide Oxidation Over Supported Platinum," AIChE J., 25, 502-508 (1979).

Cutlip, M. B., C. N. Kenney, W. Morton, D. Mukesh, and S. C. Capsaskis, "Transient and Oscillatory Phenomena in Catalytic Reactors," Preprints from Eighth Int. Symp. on Chemical Reaction Engineering, p. 135 (1984).

Dadyburjor, D. B., "Use of Adsorption Entropy to Choose between Kinetic Mechanisms and Rate Equations for Fischer-Tropsch Synthesis," J. Catal., 82, 489-492 (1983).

Dalla Betta, R. A., and M. Shelef, "Heterogeneous Methanation: In Situ Infrared Spectroscopic Study of Ru/Al_2O_3 during the Hydrogenation of CO," J. Catal., 48, 111-119 (1977a).

Dalla Betta, R. A., and M. Shelef, "Heterogeneous Methanation: Absence of H_2-D_2 Kinetic Isotope Effect of Ni, Ru, and Pt," J. Catal., 49, 383-385 (1977b).

Dalla Betta, R. A., A. G. Piken, and M. Shelef, "Heterogeneous Methanation: Initial Rate of CO Hydrogenation on Supported Ruthenium and Nickel," J. Catal., 35, 54-60 (1974).

Darby, P. W., and C. Kemball, "Observations on the Fischer-Tropsch Synthesis over a Cobalt Catalyst at Low Pressure Using Gas Chromatography," Trans. Faraday Soc., 833-841 (1958).

Dautzenberg, F. M., J. N. Helle, R. A. van Santen, and H. Verbeek, "Pulse-Technique Analysis of the Kinetics of the Fischer-Tropsch Reaction," J. Catal., 50, 8-14 (1977).

Deans, D. R., M. T. Huckle, and R. M. Peterson, "New Column System for Isothermal Gas Chromatographic Analysis of Light Gases (H_2, O_2, N_2, CO, C_2H_4, and C_2H_2) Employing a Column Switching Technique," Chromatographia, 4, 279-285 (1971).

Deckwer, W. D., "FT Process Alternatives Hold Promise," Oil α Gas J., 198-213, Nov. 10 (1980).

Delgass, W. N., G. L. Haller, R. Kellerman, and J. H. Lunsford, Spectroscopy in Heterogeneous Catalysis, Academic Press, N.Y. (1979).

Deluzarche, A., J. P. Hindermann, R. Kieffer, A. Muth, M. Papadopoulos, and C. Tanielian, "Synthese de Fischer-Tropsch II," Tetrahedron Lett., No. 9, 797-800 (1977).

Deluzarche, A, J. P. Hindermann, and R. Kieffer, "Carbon-Monoxide-Hydrogen Reactions; Possible Reaction Mechanisms in Heterogeneous Catalysis," J. Chem. Research, 934-948 (1981).

Demitras, G. C., and E. L. Muetterties, "Metal Clusters in Catalysis-10. A New Fischer-Tropsch Synthesis," J. Am. Chem. Soc., 99(8), 2796-2797 (1977).

Denis, G. H., and R. L. Kabel, "The Effect of Temperature Changes on a Tubular Heterogeneous Catalytic Reactor," Chem. Eng. Sci., 25(6), 1057 (1970a).

Denis, G. H., and R. L. Kabel, "The Effect of Conversion of Flow Rate Variation in a Heterogeneous Catalytic Reactor," AIChE J., 16(6), 972 (1970b).

Dictor, R. A., and A. T. Bell, "An Explanation for Deviations of Fischer-Tropsch Products from a Schulz-Flory Distribution," Ind. Eng. Chem. Process Des. Dev., 22(4), 678-681 (1983).

Dictor, R. A., and A. R. Bell, "On-Line Analysis of Fischer-Tropsch Synthesis Products," Ind. Eng. Chem. Fundan., 23, 252-256 (1984).

Dietz, W. A., "Response Factors for Gas Chromatographic Analyses," J. Gas Chromatogr., 67-71, Feb. (1967).

Diffenbach, R. A., T. H. Johnson, and R. R. Schehl, "A Study of the Fischer-Tropsch Reaction Using On-Line Gas-Chromatographic Analysis," Report No. DOE/PETC/TR-82/10, U.S. Department of Energy, Washington, D. C., July (1982).

Ding, J. S. I., S. Sharma, and D. Luss, "Steady-State Multiplicity and Control of the Chlorination of Liquid n-Decane in an Adiabatic Continuous Stirred Tank Reactor," Ind. Eng. Chem. Fund., 13(1), 76 (1974).

DiSanzo, F. P., "Characterization of High Boiling Fischer-Tropsch Liquids by Liquid and Gas Chromatography," Anal. Chem., 53, 1911-1914 (1981a).

DiSanzo, F. P., "Characterization of High Boiling Fischer-Tropsch Liquids," ACS Div. of Fuel Chemistry, 26(2), 13-27 (1981b).

Dixit, R. S., and L. L. Tavlarides, "Integral Method of Analysis of Fischer-Tropsch Synthesis Reactions in a Catalyst Pellet," Chem. Eng. Sci., 37(4), 539-544 (1982).

Doriswamy, L. K., and D. G. Tajbl, "Laboratory Catalytic Reactors," Cat. Rev.-Sci. Eng., 10, 177-219 (1975).

Douglas, J. M., Process Dynamics and Control, Prentice Hall, Englewood Cliffs, N.J. (1972).

Douglas, J. M., "Periodic Reactor Operation," Ind. Eng. Chem. Process Des. Dev., 6, 43 (1967).

Douglas, J. M., and D. H. T. Rippon, "Unsteady-State Process Operation," Chem. Eng. Sci., 21, 305 (1966).

Dry, M. E., "Advances in Fischer-Tropsch Chemistry," Ind. Eng. Chem. Prod. Res. Dev., 15(4), 282-286 (1976).

Dry, M. E., "Predict Carbonation Rate on Iron Catalyst," Hydrocarbon Process., 92-94, February (1980).

Dry, M.E., "The Fischer-Tropsch Synthesis," in Catalysis (M. Boundart and J. Anderson, ed.), Vol. 1, Chapter 4, Springer-Verlag, N.Y. (1981).

Dry, M. E., "Catalytic Aspects of Industrial Fischer-Tropsch Synthesis," J. Mol. Catal., 17, 133-144 (1982a).

Dry, M. E., "Sasol's Fischer-Tropsch Experience," Hydrocarbon Process., 121-124, August (1982b).

Dry, M. E., J. A. K. DuPlessis, G. M. Leuteritz, "The Influence of Structural Promoters on the Surface Properties of Reduced Magnetite Catalysts," J. Catal., 6, 194-199 (1966).

Dry, M. E., and L. C. Ferreira, "The Distribution of Promoters in Magnetite Catalysts," J. Catal., 7, 352-358 (1967).

Dry. M. E., and G. J. Oostuizen, "The Correlation between Catalyst Surface Basicity and Hydrocarbon Selectivity in the Fischer-Tropsch Synthesis," J. Catal., 11, 18-24 (1968).

Dry, M. E., T. Shingles, and L. J. Boshoff, "Rate of the Fischer-Tropsch Reaction Over Iron Catalysts," J. Catal., 25, 99-104 (1972).

Dry, M. E., T. Shingles, L. J. Boshoff, and G. J. Oosthuizen, "Heats of Chemisorption on Promoted Iron Surfaces and the Roles of Alkali in Fischer-Tropsch Synthesis," J. Catal., 15, 190-199 (1969).

Dry, M. E., T. Shingles, L. J. Boshoff, and S. C. van H. Botha, "Factors Influencing the Formation of Carbon on Iron Fischer-Tropsch Catalysts, I," J. Catal., 17, 341-346 (1970).

Dry, M. E., T. Shingles, L. J. Boshoff, and S. C. van H. Botha, "Factors Influencing the Formation of Carbon on Iron Fischer-Tropsch Catalysts, II," J. Catal., 17, 347-354 (1970).

Dutartre, R., P. Bussière, J. A. Dalmon, and G. A. Martin, "Activation of Hydrogen on Fe/MgO Catalysts Studied by Magnetic Methods and Mössbauer Spectroscopy," J. Catal., 59, 382-394 (1979).

Dutta, S., S. C. Arnold, G. D. Suciu, and L. Verde, "Scale-up of a Catalytic Fluid-Bed Reactor Involving Complex Kinetics," Preprints from Eighth Int. Symp. on Chemical Reaction Engineering, p. 517 (1984).

Dwyer, D. J., and G. A. Somorjai, "The Role of Readsorption in Determining the Product Distribution during CO Hydrogenation over Fe Single Crystals," J. Catal., 56, 249-257 (1979).

Dwyer, D., K. Yoshida, and G. A. Somorjai, "Hydrogenation of CO and CO_2 on Clean Rhodium and Iron Foils--Correlations of Reactivities and Surface Compositions," Preprints, Symposium on Advances in Fischer-Tropsch Chemistry, Div. of Petroleum Chemistry, Amer. Chem. Soc., 521-537 (1978).

Egiazarov, Y. S., N. P. Krut'ro and A. I. Trokhimeto, " Kinetic Principles of Ethane Pyrolysis in the Presence of an Indium Oxide Catalyst," Vestsi Akad. Navuk BSSR, Ser. Khim. Navuk, 1, 44-47 (1982).

Egiebor, N. O., K. R. Ungar, and B. W. Wojciechowski, "A Classification of Fischer-Tropsch Synthesis Product Distributions,' Can. J. Chem. Eng., 62, 425-430 (1984).

Eidus, Y. T., "The Mechanism of the Fischer-Tropsch Reaction and the Initiated Hydropolymerisation of Alkenes, from Radiochemical and Kinetic Data," Russ. Chem. Rev., 36(15), 228-350 (1967).

Eisenlohr, K. H., and H. Gaensslen, "Motor Fuels from Coal--Technology and Economics," Fuel Process. Tech., 4 43-61 (1981).

Ekerdt, J. G., and A. T. Bell, "Synthesis of Hydrocarbons from CO and H_2 over Silica-Supported Ru: Reaction Rate Measurements and Infrared Spectra of Adsorbed Species," J. Catal., 58, 170-187 (1979).

Ekerdt, J. G., and A. T. Bell, "Evidence for Intermediates Involved in Fischer-Tropsch Synthesis over Ru," J. Catal., 62, 19-25 (1980).

Evans, U. R., "Oxidation of Iron in the Range 100-400°C," Nature (London), 164, 909 (1949).

Everson, R. C., E. T. Woodburn, and A. R. M. Kirk, "Fischer-Tropsch Reaction Studies with Supported Ruthenium Catalysts, J. Catal., 53, 186-197 (1978).

Feimer, J. L., "A Study of Forced-Feed Composition Cycling in the Fischer-Tropsch Synthesis," Ph.D. Thesis, University of Waterloo (1982).

Feimer, J. L., P. L. Silveston, and R. R. Hudgins, "Steady-State Study of the Fischer-Tropsch Reaction, Ind. Eng. Chem, Prod. Res. Dev., 20, 609-615 (1981).

Feimer, J. L., A. K. Jain, R. R. Hudgins, and P. L. Silveston, "Modelling Forced Periodic Operation of Catalytic Reactors," Chem. Eng. Sci. 37(2), 1797-1805 (1982a).

Feimer, J. L., P. L. Silveston, and R. R. Hudgins, "Influence of Forced Cycling on the Fischer-Tropsch Synthesis," Preprints, 8th Canadian Sympos. on Catalysis, Ontario, p. 104 (1982b).

Feimer, J. L., P. L. Silveston, and R. R. Hudgins, "Influence of Forced Cycling on the Fischer-Tropsch Syhtnesis, Part I. Response to Feed Concentration Step-Changes," Can. J. Chem. Eng., 62, 241-248 (1984).

Feldhousen, R. W., Jr., "A Cold-Flow Experimental Simulation of Gas-Mixing Characteristics in a Vibrofluidized Microreactor System for Fischer-Tropsch Synthesis from a Low H_2:CO Gas," Masters Thesis, Virginia Polytechnic Institute and State University (1984).

Field, J. H., H. E. Benson, and R. B. Anderson, "Synthetic Liquid Fuels by Fischer-Tropsch Process," Chem. Eng. Prog., 56(4), 44-48 (1960).

Field, J. H., J. J. Demeter, A. J. Forney, and D. Bienstock, "Development of Catalysts and Reactor Systems for Methanation," Ind. Eng. Chem. Prod. Res. and Dev., 3(2), 150-153 (1964).

Fischer, J. and H. Tropsch, Brennst.-Chem., 4, 276 (1923).

Fischer, J. and H. Tropsch, Brennst.-Chem., 7, 97 (1926).

Fischer, J. and H. Koch, Brennst.-Chem., 13, 428 (1932).

Fischer, J. and H. Pichler, Brennst.-Chem., 17, 24 (1936).

Fischer, R. H. and R. E. Hildebrand, "Transportation Fuels from Synthetic Gas," Proceedings of the Symposium on Advances in Coal Utilization Technology, Institute of Gas Technology, pp. 331-344 (1979).

Flory, P. J., "Molecular Size Distribution in Linear Condensation Polymers," J. Am. Chem. Soc., 58, 1877 (1936).

Forsey, R. R., "A Dual-Column Gas Chromatographic Method for the Analysis of Light Gases," J. Gas Chromatogr., 6, 555 (1968).

Fraenkel, D., and B. C. Gates, "Shape-Selective Fischer-Tropsch Synthesis Catalyzed by Zeolite-Entrapped Cobalt Clusters," J. Am. Chem. Soc. 102(7), 2478-2480 (1980).

Friedel, R. A., and R. B. Anderson, "Composition of Synthetic Liquid Fuels. I. Product Distribution and Analysis of C_5-C_8 Paraffin Isomers from Cobalt Catalyst, J. Am. Chem Soc., 72, 1215-2307 (1950).

Frohning, C. D., and B. Cornils, "Chemical Feedstocks from Coal," Hydrocarbon Process., 1453-146, November (1974).

Frohning, C. D., H. Kölbel, M. Ralek, H. Rottig, F. Schnur, and H. Schulz, in Chemical Feedstocks From Coal, (J. Falbe, Ed.), Wiley, New York (1982).

Garrett, L. W., Jr., "Gasoline from Coal via the Synthol Process," Chem. Eng. Prog., 56(4), 39-43 (1960).

Gierlich, H. H., and M. Fremery, "Deactivation Phenomena of a Ni-based Catalyst for High Temperature Methanation," in Catalyst Deactivation (B. Delmon and G. F. Froment, Ed.), Elesvier Scientific Publishing Company, Amsterdam, Netherlands, 459-469 (1980).

Glasser, D., and R. Jackson, "A Generalized Residence Time Distribution Model for a Chemical Reactor," Reprints from the Eighth Int. Symposium on Chemical Reaction Engineering, p. 535 (1984).

Gonzalez, R. D., and H. Miura, "Methanation and Fischer-Tropsch Studies on Potassium-Promoted Silica-Supported Ru Catalysts," J. Catal., 77, 338-347 (1982).

Goodman, D. W., R. D. Kelley, T. E. Madey, and J. M. White, "Measurement of Carbide Buildup and Removal Kinetics on Ni(100)," J. Catal., 64, 479-481 (1980).

Gray, D. W., M. Lytton, M. B. Neuworth, and G. C. Tomlinson, "The Impact of Developing Technology on Indirect Liquefaction," Proceedings of Symposium on Advances in Coal Utilization Technology, Institute of Gas Technology, pp. 93-109 (1981).

Grayson, M., in Catalysis, Vol. IV (P. H. Emmett, Ed.), Reinhold, New York (1956).

Grekel. H., K. L. Hujsak, and R. Mungen, "Contracting Efficiency in Hydrocarbon Synthesis," Chem. Eng. Prog., 60(1), 56-60 (1964).

Grenoble, D. C., and M. M. Estadt, "The Chemistry and Catalysis of the Water Gas Shift Reaction," J. Catal., 67, 90-102 (1981).

Gupta, R., and A. S. Mujumdar, "Aerodynamic and Thermal Characteristics of Vibrated Fluid Beds - A Review," in Drying '80, Vol. I (A. S. Mujumdar,Ed.), Hemisphere, Washington, 141-150 (1980).

Gupta, R., B. Viswanathan, and M. V. C. Sastri, "Interaction of Hydrogen and Carbon Monoxide on Cobalt Catalysts. Part I," J. Catal., 26, 212-217 (1972).

Hackenbruch, J., W. Keim, M. Rober, and H. Strutz, "Mechanistic Considerations for the Formation of Oxygenated Species in the Fischer-Tropsch Synthesis," J. Mol. Catal. 26, 129-134 (1984).

Haggin, J., "C_1 Chemistry Development Intensities," Chem. Eng. News, 39-47 February 23 (1981).

Haggin, J., "Fischer-Tropsch: New Life for Old Technology," Chem. Eng. News, 22-32, October 26 (1981).

Haggin, J., "Progress in C_1 Chemistry Aired," Chem. Eng. News, 31-34, June 18 (1982).

Hall, W. K., W. H. Tarn, and R. B. Anderson, "Studies of the Fischer-Tropsch Synthesis. VIII. Surface Area and Pore Volume Studies of Iron Catalysts," J. Am. Chem. Soc., 72, 5436-5443 (1950).

Hall, W. K., W. H. Tarn, and R. B. Anderson, "Studies of the Fischer-Tropsch Synthesis. XIII. Structural Changes of a Reduced Iron Catalyst on Reoxidation and on Formation of Interstitial Phases," J. Am. Chem. Soc., 56, 688 (1950).

Happel, J., I. Suzuki, P. Kokayeff, and V. Fthenakis. "Multiple Isotope Tracing of Methanation over Nickel Catalyst," J. Catal., 65, 59-77 (1980).

Harney, B. M., and G. A. Mills, "Coal to Gasoline via Syngas," Hydrocarbon Process., 67-71, February (1980).

Harney, B. M., G. A. Mills, and L. M. Joseph, "High Quality Transportation Fuels from $CO-H_2$: A Competitive Option," Preprints, Symposium on Advances in Fischer-Tropsch Chemistry, Div. of Petroleum Chem., Amer. Chem. Soc., 573-577, March (1978).

Haynes, W. P., M. J. Baird, R. R. Schehl, and M. F. Zarochak, "Fischer-Tropsch Studies in a Bench-Scale Tube Wall Reactor Using Magnetite, Raney Iron, and Taconite Catalysts," Preprints, Symposium on Advances in Fischer-Tropsch Chemistry, Div. of Petroleum Chem, Amer. Chem. Soc., 599-572, (March, 1978).

Helrich, H., A. Renken, and K. Schügest, "Beeinflussung der effektiven Geschwindingkeit heterogen-katalytischer Reaktionendurch aufgezwungene Konzentrationsschwankungen," Chem. Ing. Tech., 46(15), 647 (1974).

Henrici-Olivé, G., and S. Olivé, "Mechanism of the Fischer-Tropsch Synthesis: Origin of Oxygenates," J. Mol. Catal., 24, 7-13 (1984).

Henrici-Olivé, G., and S. Olivé, "The Fischer-Tropsch Synthesis: Molecular Weight Distribution of Primary Products and Reaction Mechanism," Angew. Chem. Ind. Ed. Engl., 15(3), 136-141 (1976).

Henrici-Olivé, G., and S. Olivé, "The 'Carbide Theory' of the Fischer-Tropsch Synthesis in the Light of Homogeneous Coordination Chemistry," J. Mol. Catal., 18, 367-373 (1983).

Henrici-Olivé, G., and S. Olivé, "Letters to the Editors in Re: Fischer-Tropsch. Comments to Notes by R. B. Anderson (1) and R. J. Madon (2)," J. Catal., 60, 481-483 (1979).

Henry, J. P., "Economics and Siting of Fischer-Tropsch Coal Liquefaction," Report No. DOE/ET/2625-9, U. S. Department of Energy, Washington, D.C., July (1979).

Herrington, E. F. S., "The Fischer-Tropsch Synthesis Considered as a Polymerization Reaction," Chemistry and Industry, 346-347, Sept. 21 (1946).

Herrmann, W. A., "Organometallic Aspects of the Fischer-Tropsch Synthesis," Angew. Chem., Int. Ed., Engl., 21, 117-130 (1982).

Hirt, D. E., "Heat Transfer Between a Supernatant Gas and a Flowing Vibrofluidized Bed of Soilds," M.S. Thesis, Chemical Engineering, Virginia Polytechnic Institute and State University (July, 1984).

Hofer, L. J. E., and E. M. Cohn, "Thermomagnetic Determination of Hägg Carbide in Used Iron Fischer-Tropsch Catalysts," Anal. Chem., 22, 907-910 (1950).

Hofer, L. J. E., E. M. Cohn, and W. C. Peebles, "The Modifications of the Carbide, Fe_2C; Their Properties and Identificaation," J. Am. Chem. Soc., 71 (1949).

Hojlund-Nielsen, P. E., and J. Bogild-Hansen, "Conversion Limitations in Hydrocarbon Synthesis," J. Mol. Catal., 17, 183-193 (1982).

Hollis, O. L., and W. V. Hayes, "Water Analysis by G. C. Using Porous Polymor Columns," J. Gas Chromatogr., 235 (1966).

Hoogendoorn, J. C., "Clean Fuels from Coal," Symposium Papers, IGT, 353-365 (1973).

Hoogendoorn, J. C., "New Applications of the Fischer-Tropsch Process," Proceedings of the Symposium on Clean Fuels from Coal II, Institute of Gas Technology, Chicago, 343-358 (1975).

Horn, F. J. M., and R. C. Lin, "Periodic Processes: A Variational Approach," Ind. Eng. Chem. Process Des. Dev., 6, 21 (1967).

Hu, Y. C., "Unconventional Olefin Processes," Hydrocarbon Process., 88-96, May (1983).

Huff, G. A., Jr., "Fischer-Tropsch Synthesis in a Slurry Reactor," Doctoral Dissertation, Massachusetts Institute of Technology (1982).

Huff, G. A., Jr., and C. N. Satterfield, "Evidence for Two-Chain Growth Probabilities on Iron Catalists in the Fischer-Tropsch Synthesis," J. Catal., 85, 370-379 (1984a)

Huff, G. A., Jr., and C. N. Satterfield, "Intrinsic Kinetics of the Fischer-Tropsch Synthesis on a Reduced Fused-Magnetite Catalyst," Ind. Eng. Chem., Process Des. Dev., 23, 696-705 (1984b).

Huff, G. A., Jr., and C. N. Satterfield, "Some Kinetic Design Considerations in the Fischer-Tropsch Synthesis on a Reduced Fused-Magnetite Catalyst," Ind. Eng. Chem., Process Des. Dev., 23, 851-854 (1984c).

Hugues, F., B. Besson, P. Bussière, J. A. Dalmon, J. M. Basset, and D. Olivier, "Catalysis by Supported Iron Clusters: Unusual Selectivities in Fischer-Tropsch Synthesis and in Olefin Homologation. Considerations on the Mechanism of Fischer-Tropsch Synthesis," Nouv. J. Chim., 5(4), 207-210 (1981).

Hurst, N. W., S. J. Gentry, and A. Jones, "Temperature Programmed Reduction," Catal. Rev. - Sci. Eng., 24(2), 233-309 (1982).

Ichikawa, M., M. Sudo, M. Soma, T. Onishi, and K. Tamaru, " Catalytic Formation of Hydrocarbons (C_1-C_5) from Hydrogen and Carbon Monoxide over the Electron Donor-Acceptor Complex Films of Alkali Metals with Transition Metal Phthalocyanines or Graphite," J. Am. Chem. Soc., 91(6), 1538-1539 (1969).

Ino, T., H. Watanabe, and Y. Morita, "Synthesis of Gaseous Hydrocarbons from Carbon Monoxide and Hydrogen over Transition Metal Catalysts. Part 5. Carbon Accumulation of a Precipitated Iron Catalyst During the Reaction," Sekiyu Gakkaishi (J. Japan Petrol. Inst.), 24(3), 181-8 (1981).

Jacobs, P. A., and D. Van Wouwe, "Selective Synthesis of Hydrocarbons via Heterogeneous Fischer-Tropsch Chemistry," J. Mol. Catal., 17, 145-160 (1982).

Jain, A. K., R. R. Hudgins, and P. L. Silveston, "Evidence for Bulk-Phase Nitrogen Dissolution in Iron in Catalytic Ammonia Synthesis," Can. J. Chem. Eng., 60, 809-811 (1982a).

Jain, A. K., P. L. Silveston, and R. R. Hudgins, "Reaction Rate Resonance in the Concentration Cycling of the Catalytic Oxidation of Carbon Monoxide," Catalysis Under Transient Conditions (A. T. Bell, and L. L. Hegedus, Eds.), ACS Sympo. Ser. 178, 257-275 (1982b).

Jain, A. K., P. L. Silveston, and R. R. Hudgins, "Forced Composition Cycling Experiments in a Fixed-Bed Ammonia Synthesis Reactor," Proc. Seventh Intern. Sympos. Chem. Reaction. Eng., Boston, ACS Sympos. Ser. 196, 97-107 (1982c)

Jain, A. K., R. R. Hudgins, and P. L. Silveston, "Adsorption/Desorption Models: How Useful for Predicting Reaction Rates Under Cyclic Operation," Can. J. Chem. Eng., 61, 46-49 (1983a).

Jain, A. K., R. R. Hudgins, and P. L. Silveston, "Influence of Forced Feed Composition Cycling on the Rate of Ammonia Synthesis over an Industrial Iron Catalyst. Part I. Effect of Cycling Parameters and Mean Composition," Can. J. Chem. Eng., 61, 824-832 (1983b).

Jones, A., and B. D. McNicol, "Comparison of the Fischer-Tropsch Synthesis of Hydrocarbons and the Haber Synthesis of Ammonia," J. Catal., 47, 384-388 (1977).

Joyner, R. W., "Mechanism of Hydrocarbon Synthesis from Carbon Monoxide and Hydrogen," J. Catal., 50, 176-180 (1977).

Kadelka, J., H. Loevenich, and W. Keim, "The Reactions of Fischer-Type Carbene Complexes with Ethene," J. Organomet. Chem., 231, 219-223 (1982).

Karcher, W., and P. Glande, "Kinetic Aspects of the Carbon Deposition Reaction on Iron from CO/H_2 Mixtures," Bien. Conf. Carbon, Ext. Abstr. Program, 11th, 43-4 (1973), CONF-730601.

Karn, F. S., B. Seligman, J. F. Shultz, and R. B. Anderson, "Kinetics of the Fischer-Tropsch Synthesis on Iron Catalysts. I. Rate Data on Reduced and Nitrided Catalysts," J. Phys. Chem., 64(4), 446-451 (1960).

Karn, F. S., J. F. Shultz, and R. B. Anderson, "Kinetics of the Fischer-Tropsch Synthesis on Iron Catalysts. Pressure Dependence and Selectivity of Nitrided Catalysts," J. Am. Chem. Soc., 64, 446-451 (1960).

Kehrer, V. J., and H. Leidheiser, Jr., "The Catalytic Decomposition of Carbon Monoxide on Large Metallic Single Crystals," J. Phys. Chem., 58, 550-555 (1954).

Kelley, R. D., and D. W. Goodman, "Catalytic Methanation over Single Crystal Nickel and Ruthenium: Reaction Kinetics on Different Crystal Planes," Preprints, Div. Fuel Chem., Amer. Chem. Soc., 25(2), 26-41 (1980).

Kellner, C. S., and A. T. Bell, "Evidence for H_2/D_2 Isotope Effects on Fischer-Tropsch Synthesis over Supported Ruthenium Catalysts," J. Catal., 67, 175-185 (1981a).

Kellner, C. S., and A. T. Bell, "The Kinetics and Mechanism of Carbon Monoxide Hydrogenation over Alumina-Supported Ruthenium," J. Catal., 70, 418-432 (1981b).

Kibby, C. L., and T. P. Kobylinski, "Models of Product Distributions in Fischer-Tropsch Synthesis," Preprints, Symp. in Adv. in Synthetic Fuels, Div. of Pet. Chem., Amer. Chem. Soc., 1332-1335 (1978).

Kieffer, E. P., and H. S. Van Der Baan, "Transient Kinetics of the Fischer-Tropsch Synthesis," in Chemical Reaction Engineering--Boston, (J. Wei and C. Geogakis, Ed.), pp. 200-212, Amer. Chem. Soc., Washington, D.C. (1982).

Kikuchi, E., T. Ino, and Y. Morita, "Catalytic Synthesis of Hydrocarbon from Carbon Monoxide and Hydrogen on Lamellar Compound of Graphite Intercalated by Ferric Chloride," J. Catal., 57, 27-34 (1979).

King, D. L., "A Fischer-Tropsch Study of Supported Ruthenium Catalysts," J. Catal., 51, 386-397 (1978).

King, D. L., "An in-Situ Infared Study of CO Hydrogenation over Silica and Alumina-Supported Ruthenium and Silica-Supported Iron," J. Catal., 61, 77-86 (1980).

King, D. L., J. A. Cusumano, and R. L. Garten, "A Technological Perspective for Catalytic Processes Based on Synthesis Gas," Catal. Rev.-Sci. Eng., 23(1,2), 233-263 (1981).

King, D. L., and J. B. Peri, "An Infrared Study of Nitric Oxide Chemisorption on Alumina Supported Iron and Alkalized Iron Fischer-Tropsch Catalysts," J. Catal., 79, 164-175 (1983).

King, R. B., A. D. King, Jr., M. Z. Iqbal, and C. C. Frazier, "Transition Metal Chemistry under High Carbon Monoxide Pressure: An Infrared Spectroscopic Study of Catalysis in the Fischer-Tropsch Reaction," National Technical Information Service, Publication Nos. SRO-933-1, SRO-933-1, SRO-933-3 (1977, 1978, 1979).

Kölbel, H., and M. Ralek, "The Fischer-Tropsch Synthesis in the Liquid Phase," Catal. Rev.-Sci. Eng., 21(2), 225-274 (1980).

Krebs, H. J., H. P. Bonzel, and W. Schwarting, "Microreactor and Electron Spectroscopy Studies of Fischer-Tropsch Synthesis on Magnetite," J. Catal., 72, 199-209 (1981).

Kroeker, R. M., W. C. Kaska, and P. K. Hansma, "Formation of Hydrocarbons from Carbon Monoxide on Rhodium/Alumina Model Catalysts," J. Catal., 61, 87-95 (1980).

Kroll, W., Chem. Ing. Tech., 27, 33 (1955).

Kuchynka, K., J. Fusek, and O. Strouf, "Modelling of Fischer-Tropsch Catalytic Synthesis by Pattern Recognition Method. Chemisorption of Hydrogen on Metals," Collect. Czech. Chem. Commun., 46, 2328-2335 (1981).

Kummer, J. T., T. W. Dewitt, and P. H. Emmett, "Some Mechanism Studies on the Fischer-Tropsch Synthesis Using C^{14}," J. Am. Chem. Soc., 70, 3632 (1948).

La Cava, A. I., C. A. Bernado, and D. L. Trimm, "Studies of Deactivation of Metals by Carbon Deposition," Carbon, 20(3), 219-223 (1982).

Lazar, K., Z. Schay, and L Guczi, "Direct Evidence for the Correlation between Surface Carbon and CO + H_2 Selectivity on Iron and Iron-Ruthenium Catalysts Prepared from Metal Carbonyl Clusters," J. Mol. Catal., 17, 205-218 (1982).

Le Blanc, J.R., D. O. Moore, and A. E. Cover, "Coal Can Be Gasoline," Hydrocarbon Process., 133-138, June (1981).

Le Caër, G., J. M. Dubois, M. Pijolat, V. Perrichon, and P. Bussière, "Characterization by Mössbauer Spectoscopy of Iron Carbides Formed by Fischer-Tropsch Synthesis," J. Phys. Chem., 86 4799-4808 (1982).

le Roux, J. H., and L. J. Dry, "Fischer-Tropsch Waxes: VI. Distribution of Branches and Mechanism of Branch Formation," J. Appl. Chem. Biotechnol, 22, 719-726 (1972).

Leupold, E. J., and A. Renken, "Ein neuses verfahren zur Herstellung von Essigsaüthylester unter Anwendung instationärer Prozeßführung," Chem. Ing. Tech., 49(8) 667 (1977).

Liu, Y. A., Squires, A. M., and K. Konrad, "Fischer-Tropsch Synthesis from a Low H_2:CO Gas in a Dry Fluidized-Bed System," U.S. Dept. of Energy Report No. DOE/PC/50791-T1, DOE Technical Information Center, Oak Ridge, TN (1982).

Loktev, S. M., "Alcohols and Hydrocarbons from Carbon Oxides and Hydrogen on Fused Iron Catalysts: Developments of Synthesis and Mechanism," J. Mol. Catal., 17, 225-230 (1982).

Loktev, S. M., L. I. Makarenkova, E. V. Slivinskii, and S. D. Éntin, "Thermomagnetic Analysis of Fused Iron Catalysts for the Synthesis of Alcohols from Carbon Monoxide and Hydrogen," Kinet. Catal., 13(4), 861-990 (1972).

Loktev, S. M., L. I. Makarenkova, E. V. Slivinskii, and S. D. Éntin, "Thermomagnetic Analysis of Fused Iron Catalysts for the Synthesis of Alcohols from Carbon Monoxide and Hydrogen," Kinet. Catal., 13, 933 (1972).

Low, G. G., and A. T. Bell, "Studies of CO Desorption and Reaction with H_2 on Alumina-Supported Ru," J. Catal., 57, 397-405 (1979).

Madon, R. J., "Reply to Comments by G. Henrici-Olivé and S. Olivé," J. Catal., 60, 485-486 (1979).

Madon, R. J. and H. Shaw, "Effects of Sulfur on the Fischer-Tropsch Synthesis," Catal. Rev.-Sci. Eng., 15(1), 69-106 (1977).

Madon, R. J., and W. F. Taylor, Fischer-Tropsch Synthesis on a Precipitated Iron Catalyst," J. Catal., 69, 32-43 (1981).

Madon, R. J., E. R. Bucker, and W. Taylor, U.S. Dept. of Energy Report, Contract No. E(46-1) 8008, July (1977).

Maksimov, Y. V., I. P. Suzdalev, R. A. Arents, and S. M. Loktev, "Mössbauer Study of the ε-Iron Carbide Formed on a Fused Iron Catalyst in the Synthesis of Higher Alcohols from Carbon Monoxide and Hydrogen," Kinet. Catal., 15(5), 1097-1216 (1974).

Matsumoto, H., "The Catalytic Effct of Carbide Formation During Fischer-Tropsch Synthesis," Chem. Lett., 1041-1044 (1981).

Matsumoto, H. and C. O. Bennett, "The Transient Method Applied to the Methanation and Fischer-Tropsch Reactions over a Fused Iron Catalyst," J. Catal., 53, 331-344 (1978).

McCandlish, L. E., "On the Mechanism of Carbon-Carbon Bond Formation in the CO Hydrogenation Reaction," J. Catal., 83, 363-3[illegible] (1983).

McCarty, J. G., and H. Wise, "Hydrogenation of Surface Carbon on Alumina-Supported Nickel," J. Catal., 57, 406-416 (1979).

McCarty, J. G., P. Y. Hou, D. Sheridan, and H. Wise, "Reactivity of Surface Carbon on Nickel Catalyst: Temperature Programmed Surface Reaction with H_2 and H_2O," The North American Meeting of the Catalysis Society, Boston, MA, October (1981).

McClory, M. M., and R. D. Gonzalez, "The Role of Alkali Metals as Promoters in the Methanation and Fischer-Tropsch Reaction: An in-Situ Study," J. Catal., 89, 392-403 (1984).

Mills, G. A., and F. W. Steffgen, "Catalytic Methanation," Catal. Rev.-Sci. Eng., 8(2), 159 (1973).

Moore, S. E., and J. H. Lunsford, "The Role of Hydrogen in the Reaction of Water with Surface Carbon to Form Methane," J. Catal., 77, 297-300 (1982).

Muetterties, E. L., and J. Stein, "Mechanistic Features of Catalytic Carbon Monoxide Hydrogenation Reactions," Chem. Rev., 79(6), 479-490 (1979).

Niemantsverdriet, J. W., A. M. van der Kraan, W. L. wan Dijik, and H. S. van der Bann "Behavior of Metallic Iron Catalysts during Fischer-Tropsch Synthesis Studied with Mössbauer Spectroscopy, X-ray Diffraction, Carbon Content Determination, and Reaction Kinetic Measurements," J. Phys. Chem., 84, 3363-3370 (1980).

Niemantsverdriet, J. W., and A. M. van der Kraan, "On the Time-Dependent Behavior of Iron Catalysts in Fischer-Tropsch Synthesis," J. Catal., 72, 385-388 (1981).

Nijs, H. H., and P. A. Jacobs, "Metal Particle Size Distributions and Fischer-Tropsch Selectivity. An Extended Schulz-Flory Model," J. Catal., 65, 328-334 (1980).

Nijs, H. H., and P. A. Jacobs, "New Evidence for the Mechanism of the Fischer-Tropsch Synthesis of Hydrocarbons," J. Catal., 66, 401-411 (1980).

Nijs, H. H., and P. A. Jacobs, "On-Line Single Run Analysis of Effluents from a Fischer-Tropsch Reactor," J. Chromatogr. Sci., 19, 40-45 (1981).

Nijs, H. H., P. A. Jacobs, and J. B. Uytterheven, "Chain Limitations of Fischer-Tropsch Products in Zeolites," J. Chem. Soc., Chem. Commun., 4, 180 (1979a).

Nijs, H. H., P. A. Jacobs, and J. B. Uytterheven, "Selective Fischer-Tropsch Synthesis of Hydrocarbons: Particle Size Effect of Ruthenium Metal in Faujasite-type Zeolites," J. Chem. Soc., Chem. Commun., 23, 1095 (1979b).

Novak, S., and R. J. Madon, "Models of Hydrocarbon Product Distributions in Fischer-Tropsch Synthesis. 2. Model for Hydrocarbon Chain Growth and Cracking," Ind. Eng. Chem. Fundam., 23, 274-280 (1984).

Novak, S., R. J. Madon, and H. Suhl, "Models of Hydrocarbon Product Distributions in Fischer-Tropsch Synthesis. I," J. Chem. Phys., 74(11), 6083-6091 (1981).

Novak, S., R. J. Madon, and H. Suhl, "Secondary Effects in the Fischer-Tropsch Synthesis," J. Catal., 77, 141-151 (1982).

O'Hara, J. B., A. Bela, N. E. Jentz, and S. K. Khaderi, "Fischer-Tropsch Plant Design Criteria," Chem. Eng. Prog., 65-67, August (1976).

O'Hara, J. B., F. E. Cumare, and S. N. Rippee, "Synthetic Fuels from Coal by Fischer-Tropsch," CEP Technical Manual, Coal Processing Technology, Amer. Inst. Chem. Eng., 2, 83-87 (1975).

Ollis, D. F., and M. A. Vannice, "The Catalytic Synthesis of Hydrocarbons from H_2/CO Mixtures over the Group VIII Metals: Comments on Methanation Kinetics," J. Catal., 38, 514-515 (1975).

Olsson, R. G., and E. T. Turkdogan, "Catalytic Effect of Iron on Decomposition of Carbon Monoxide: II. Effect of Additions of H_2, H_2O, CO_2, SO_2 and H_2S," Metal Trans., 5, 21-26 (1974).

Ott, G. L., T. Fleisch, and W. N. Delgass, "Carbon Deposition and Activity Changes over FeRu Alloys during Fischer-Tropsch Synthesis," J. Catal., 65, 253-262 (1980).

Pakowski, Z., A. S. Mujumdar, and C. Strumillo, "Theory and Application of Vibrated Beds and Vibrated Fluid Beds for Drying Processes," in Advances in Drying, Volume 3 (A. S. Mujumdar, Ed.), Hemisphere Publishing Company, Washington, 245 306 (1984).

Palmer, R. L., and D. A. Vroom, "Mass-Spectrometric Measurements of Enhanced Methanation Activity over Cobalt and Nickel Foils," J. Catal., 50, 244-252 (1977).

Papic, M., "The Simultaneous Separation of C_1-C_4 Hydrocarbons on a Single Porapak Column," J. Gas Chromatogr., 6, 483 (1968).

Papic, M. M., "Coal Liquefaction via Sasol Fischer-Tropsch Synthesis," CIM Bull., 74, 60-64 (1980).

Parkash, S., S. K. Chakrabartty, and M. P. Rosynek, "Hydrocarbon Synthesis and Carbon Dioxide Adsorption on Iron Catalysts," Fuel Process. Technol., 3, 63-70 (1980).

Parkash, S., T. Kotanigawa, and S. K. Chakrabartty, "Changes in Pore Structure of Precipitated Iron Oxide Catalysts During Pretreatment and Hydrocarbon Synthesis Reaction," Fuel Process. Technol., 5, 203-212 (1982).

Pattipati, R. R., and C. Y. Wen, "Minimum Fluidization Velocity at High Temperatures," Ind. Eng. Chem., Process Des. Dev., 20, 705-708 (1981).

Peacock-Lopêz, E., and K. Lindenberg, "The Transient Flory Model and Its Application to Catalytic Polymerization," J. Phys. Chem., 88, 2270-2275 (1984).

Pichler, H., "Twenty-five Years of Synthesis of Gasoline by Catalytic Conversion of Carbon Monoxide and Hydrogen," Adv. Catal., 4, 271-341 (1952).

Pichler, H., and H. Merkel, "Chemical and Thermomagnetic Studies on Iron Catalysts for Synthesis of Hydrocarbons," U. S. Bureau of Mines Technical Paper 718 (1949).

Pichler, H. and H. Schulz, Chem. Ing. Tech., 42, 1162 (1970).

Podgurski, H. H., J. T. Kummer, T. W. DeWitt, and P. H. Emmett, "Preparation, Stability and Adsorptive Properties of the Carbides of Iron," J. Am. Chem. Soc., 72, 5382-5388 (1950).

Polyakov, L. M., Abrasion of Granular Zeolites Under Vibration Loading," Kinet. Katal, 15(3), 765-772 (1972).

Polyvakov, L. M., and É. I. Vinokurov, "Kinetics of the Abrasion of Zeolites Under Vibrations and Elevated Temperatures," Kinet. Katal, 20(5), 1311-1314 (1977).

Ponec, V., "Some Aspects of the Mechanism of Methanation and Fischer-Tropsch Synthesis," Catal. Rev. - Sci. Eng., 18(1), 151-171 (1978).

Ponec, V., and W. A. van Barneveld, "The Role of Chemisorption in Fischer-Tropsch Synthesis," Ind. Eng. Chem., Prod. Res. Dev., 18, 268-271 (1979).

Ponec, V., Z. Knor, and S. Cerny, "Role of Chemisorption in Simple Catalytic Reactions," Discuss. Faraday Soc., 41, 149-161 (1966).

Potter, O.E., "Modelling Fluidized-Bed Reactors," Catal. Rev. - Sci. Eng., 17(2), 155-202 (1978).

Probstein, R. F., and R. E. Hicks, Synthetic Fuels, McGraw-Hill Book, Co., New York (1982).

Rabo, J. A., A. P. Risch, and M. L. Poutsma, "Reactions of Carbon Monoxide and Hydrogen on Co, Ni, Ru, and Pd Metals," J. Catal., 53, 295-311 (1978).

Rao, V. U. S., R. J. Gormley, H. W. Pennline, L. C. Schneider, and R. Obermeyer, "Synthesis Gas Conversion to Gasoline Range Hydrocarbons over Medium Pore Zeolite Catalysts Containing 3d-Metals and Bimetallics," Preprints, Div. Fuel Chem., Amer. Chem. Soc., 25(2), 119-126 (1980).

Raupp, G. B., and W. N. Delgass, "Mössbauer Investigation of Supported Fe and FeNi Catalysts, I. Effect of Pretreatment on Particle Size," J. Catal., 58, 337-347 (1979a).

Raupp, G. B., and W. N. Delgass, "Mössbauer Investigation of Supported Fe and FeNi Catalysts, II. Carbides Formed by Fischer-Tropsch Synthesis," J. Catal., 58, 348-360 (1979b).

Raupp, G. B., and W. N. Delgass, "Mössbauer Investigation of Supported Fe Catalysts, III. In Situ Kinetics and Spectroscopy during Fischer-Tropsch Synthesis," J. Catal., 58 361-369 (1979c).

Renken, A., M. Muller, and H. Helmrich, "Untersuchungen zur Instabilität isothermer heterogener Festbettreaktoren," Chem. Ing. Tech., b47(24), 1029 (1975).

Renken, A., M. Muller, and C. Wandry, 4th Int. 16th Eur. Symp. Chem React. Eng. (Frankfurt/M.), 1, 107 (1976).

Renshaw, G. D., C. Roscoe, and P. L. Walker, Jr., "Disproportionation of CO, I. Over Iron and Silicon-Iron Single Crystals," J. Catal., 18, 164-133 (1970).

Renshaw, G. D., C. Roscoe, and P. L. Walker, Jr., "Disproportionation of CO, II. Over Cobalt and Nickel Single Crystals," J. Catal., 22, 394-410 (1971).

Reusov, A. V., A. Milknevich, and I. Taganov, "Study of Mass Transfer in a Fluidized Bed Confined by a Vibratory Grid," Teor. Osn. Khim. Tekhnol., 14(6), 866-70 (1980).

Reymond, J. P., P. Mériaudeau, B. Pommier, and C. O. Bennett, "Further Results on the Reaction of H_2/CO on Fused Iron by the Transient Method," J. Catal., 64, 163-172 (1980a).

Reymond, J. P., P. Mériaudeau, B. Pommier, and C. O. Bennett, "Further Results on the Reaction of H_2/CO on Fused Iron by the Transient Method," Preprints, Division of Fuel Chemistry, American Chemical Society, 25(2), 71-81 (1980b).

Riekena, M. L., A. G. Vickers, E. C. Haun, and R. C. Koltz, "A Comparison of Fischer-Tropsch Reactors," Chem. Eng. Prog., 86-90, April (1982).

Rofer-DePoorter, C. K., A Comprehensive Mechanism for the Fischer-Tropsch Synthesis," Chem. Rev., 81, 447-474 (1981).

Ruston, W. R., M. Warzee, J. Hennaut, and J. Waty, "The Solid Reaction Products of the Catalytic Decomposition of Carbon Monoxide on Iron at 550°C," Carbon, 7, 47-57 (1969).

Sacco, A., Jr., P. Thacker, T. N. Chang, and A. T. S. Chiang, "The Initiation and Growth of Filamentous Carbon from α-Iron in H_2, CH_4, H_2O, CO_2, and CO Gas Mixtures," J. Catal., 85, 224-236 (1984).

Sachtler, J. W. A., J. M. Kool, and V. Ponec, "The Role of Carbon in Methanation by Cobalt and Ruthenium," J. Catal., 56, 284-286 (1979).

Sancier, K. M., W. E. Isakson, and H. Wise, "Carburization Studies of Iron Fischer-Tropsch Catalysts," ACS Symposium Series, Amer. Chem. Soc., No. 33, 129-145 (1979).

Sanders, W. N., and J. B. Maynard, "Capillary Gas Chromatographic Method for Determining the C_3-C_{12} Hydrocarbons in Full-Range Motor Gasolines," Anal. Chem., 40, 527-535 (1968).

Sastri, M. V. C., R. Balaji Gupta, and B. Viswanathan, "Interaction of Hydrogen and Carbon Monoxide on Cobalt Catalysts. Part II," J. Catal., 32, 325-332 (1974).

Satterfield, C. N., Heterogeneous Catalysis in Practice, McGraw-Hill, New York (1980).

Satterfield, C. N., and G. A. Huff, Jr., "Usefulness of a Slurry-Type Fischer-Tropsch Reactor for Processing Synthesis Gas of Low Hydrogen-Carbon Monoxide Ratios," Can. J. Chem. Eng., 60, 159-162, (1982a).

Satterfield, C. N., and G. A. Huff, Jr., "Carbon Number Distribution of Fischer-Tropsch Products Formed on an Iron Catalyst in a Slurry Reactor," J. Catal., 73, 187-197 (1982b).

Satterfield, C. N. , G. A. Huff, Jr., and J. P. Longwell, "Product Distribution from Iron Catalyst in Fischer-Tropsch Slurry Reactors," Ind. Eng. Chem., Proc. Des. Dev., 21, 465-470 (1982).

Satterfield, C. N., G. A. Huff, Jr., and H. G. Stenger," "Effect of Carbon Formation on Liquid Viscosity and Preformance of Fischer-Tropsch Bubble Column Reactors," Ind. Eng. Chem., Process Des. Dev., 20, 666-670 (1981).

Satteffield, C. N., and H. G. Stenger, "Fischer-Tropsch Synthesis in a Slurry Reactor: Precipitated Iron-Copper-Potassium Catalyst," Ind. Eng., Chem., Process Des. Dev., 23, 849-851 (1984a).

Satterfield, C. N., and H. G. Stenger, " Fischer-Tropsch Synthesis on a Precipitated Mn/Fe Catalyst in a Well-Mixed Surry Reactor," Ind. Eng. Chem., Process Des. Dev., 23, 26-29 (1984b).

Scherzer, J., and D. Fort, "Zeolite-Supported Metal Catalysts for Fischer-Tropsch Reactions," J. Catal., 71, 111-118 (1981).

Schlesinger, M. D., H. E. Benson, E. M. Murphy, and H. H. Storch, "Chemicals from the Fischer-Tropsch Synthesis," Ind. Eng. Chem., 46, 1322-1331 (1954).

Schulz, G. V., Z. Phys. Chem, B, 30, 379 (1935).

Schulz, H., "Future Sources of Organic Raw Materials," CHEMRAWN, I, pp. 167-183, Peragamon Press, New York (1978).

Schulz, H., B. R. Rao, and M. Elstner, "^{14}C-Studien zum Reaktionsmechanismus der Fischer-Tropsch-Synthese," Erdöl Kohle, 23, 651 (1970).

Schulz, H., and A. Zein El Deen, "New Concepts and Results Concerning the Mechanism of Carbon Monoxide Hydrogenation. I. Organic Oxygen Compounds Produced During Medium-Pressure Synthesis with Iron Catalysts," Füel Process. Technol., 1, 31-44 (1977).

Schulz, H., and A. Zein El Deen, "New Concepts and Results Concerning the Mechanism of Carbon Monoxide Hydrogenation. II. Evolution of Reaction Steps on the Basis of Detailed Product Composition and Other Data," Fuel Process. Technol., 1, 45-56 (1977).

Shah, Y. T., and A. J. Perrotta, "Catalysts for Fischer-Tropsch and Isosynthesis," Ind. Eng. Chem., Prod. Des. Dev., 15(2), 123-131 (1976).

Sharma, B. K., and K. A. Kini, "Adsoption of H_2 on Precipitated Fischer-Tropsch Iron Catalysts," Curr. Sci., 45(3), 98-99 (1976)

Sharma, B. K., and P. S. M. Tripathi, "Crystal Field Surface Orbital-Bond Energy Bond Order Calculation for Hydrogen Chemisorption on Fischer-Tropsch Iron Catalyst," Indian J. Chem., 20A, 1105-1107 (1981).

Shchel'tsyn, V. K., R. M. Flid, I. L. Varsman, and T. P. Shapirovskaya, "Kinetics of the Gas-Phase Vinylation of α-pyriolidone Using Basic Catalysts," Russ. J. Phy. Chem., 42(7), 869-872 (1968).

Shelef, M., and R. A. Dalla Betta, "Reply to Comments on Heterogeneous Methanation: Absence of H_2-D_2 Kinetic Isotope Effect on Ni, Ru, and Pt," J. Catal., 60, 169-170 (1979).

Shinnar, R., and J. C. W. Kuo, "Gasifier Study for Mobil Coal to Gasoline Processes," U.S. Dept. of Energy Report FE-2766-13 (1978).

Shirazi, Z. H., and C. Stojanov, "Reaction Gas-Chromatography of Fischer-Tropsch Synthesis Products Including the Oxygen Containing Compounds," Pak. J. Sc. Ind. Res., 20(1), 1-10 (1977).

Shultz, J. F., B. Seligman, J. Lecky, and R. B. Anderson, "Studies of the Fischer-Tropsch Synthesis. XII. Composition Changes of Nitrided Iron Catalysts During Synthesis," J. Am. Chem. Soc., 74, 637-40 (1952a).

Shultz, J. F., B. Seligman, L. Shaw, and R. B. Anderson, "Effect of Nitriding on Three Types of Iron Catalysts," Ind. Eng. Chem., 44, 397-401 (1952b).

Shultz, J. F., W. K. Hall, B. Seligman, and R. B. Anderson, "Studies of the Fischer-Tropsch Synthesis. XIV. Hägg Iron Carbide as Catalysts," J. Am. Chem. Soc., 77, 213-221 (1955).

Shultz, J. F., M. Abelson, L. Shaw, and R. B. Anderson, "Fischer-Tropsch Synthesis: Nitrides and Carbonitrides of Iron as Catalysts," Ind. Eng. Chem., 49(12), 2055-2060 (1957).

Silverman, D. C, and M. Boudart, "Surface Composition of Promoted Iron Catalysts, " J. Catal., 77, 208-220 (1982).

Singh, M., "Why Not Use Fischer-Tropsch?", Hydrocarbon Process., p. 138, June (1981).

Solbakken, V., A. Solbakken, and P. H. Emmett, "The Exchange of $H_2{}^{18}O$ with the Oxygen Promoters on the Surface of Iron Catalysts," J. Catal., 15, 90-98 (1969).

Squires, A. M., "Contributions Toward a History of Fluidization," Proceedings of the Joint Meeting of American Institute of Chemical Engineers and Chemical Industry and Engineering Society of China, Beijing, Vol. 1, pp. 322-353, September (1982).

Squires, A. M., "Applications of Fluidized Beds in Coal Technology," in Alternative Energy Sources (J. P. Harnett, Ed.), pp. 59-109, Academic Press, New York, N.Y. (1976).

Stein, K. C., G. P. Thompson, and R. B. Anderson, "Iron Catalysts and the Fischer-Tropsch Synthesis," Ind. Eng. Chem., 49 410 (1957).

Stein, K. C., G. P. Thompson, and R. B. Anderson, "Studies of the Fischer-Tropsch Synthesis. XVII. Changes of Iron Catalysts During Pretreatment and Synthesis," J. Am. Chem. Soc., 61, 928-932 (1957).

Stenger, H. G., H. E. Johnson, and C. N. Satterfield, "Molecular Weight Distribution of the Heavy Wax Formation from Fischer-Tropsch Synthesis," J. Catal., 86, 477-480 (1984).

Stockinger, J. H., "Quantitative Analysis of Gaseous Products Obtained in the Conversion of Methanol-to-Gasoline," J. Chromatogr. Sci., 15 198-202 (1977).

Storch, H. H., N. Golumbic, and R. B. Anderson, The Fischer-Tropsch and Related Synthesis, John Wiley a Sons, Inc., New York (1951).

Stowe, R. A., and C. B. Murchison, Upgrade Fischer-Tropsch Liquids to Olefins and Aromatics," Hydocarbon Process., 147-150, January (1982).

Strouf, O., K. Kuchynka, and J. Fusek, "Modelling of the Catalytic Fischer-Tropsch Synthesis by Pattern Recognition. Chemisorption and Dissociation of Carbon Monoxide on Metals," Collect. Czech. Chem. Commun., 46, 2336-2344 (1981).

Studier, M. H., and R. Hayatsu, "Analyses of Complex Mixtures of Hydrocarbons by Time-of-Flight Mass Spectrometry-Open Tube Chromatography," Anal. Chem., 40(6), 1011-1013 (1968).

Suib, S. L., K. C. McMahon, L. M. Tau, and C. O. Bennett, "Synthesis, Characterization, and Fischer-Tropsch Studies of Iron-Containing Zeolites," J. Catal., 89, 20-34 (1984).

Swart, J. S., G. J. Czajkowski, and R. E. Conser, "Sasol Upgrades," Oil and Gas J., 62-66 (1981).

Takeuchi, A., J. R. Katzer, G. C. A. Schuit, "Fischer-Tropsch Product Distribution for Rh/TiO_2," J. Catal., 82, 477-478 (1983).

Tamarin, A. I., and G. Kovenski, "Effect of Gas-Distributing Grate Vibrations on the Uniformity of a Fluidized Bed," Vestst Akad. Navuk B. SSR, Ser. Fiz.-Energ. Navuk, 3, 74-77 (1974).

Tauser, S. J., and R. M. Koros, "Removal of Coke Precursors with Hydrogen: Studies with Alternating Pulses of Propane and Hydrogen," J. Catal., 27, 307-310 (1972).

Taylor, P. D., and B. W. Wojciechowski, "A Quantitative Theoretical Treatment of the Fischer-Tropsch Synthesis," Can. J. Chem. Eng., 61, 98-102 (1983).

Ta-Yu, C., L. Man-Tsuen, and C. Chun-Hao, "Report on Pilot Plant Synthesis of Liquid Fuels," Chem. Eng. Prog., 54(3), 55-58 (1958).

Thomson, W. J., J. M. Arndt, and K .L. Wright, "Applied Fischer-Tropsch Kinetics for a Flame Sprayed Iron Catalyst," Preprints, Div. Fuel Chem., Amer. Chem Soc., 25(2), 101-118 (1980).

Trimm, D. L., "The Formation and Removal of Coke from Nickel Catalyst," Catal. Rev.-Sci. Eng., 16(2), 155-189 (1977).

Trimm, D. L., "Carbon Formation on Metals other than Nickel and on Alloys," in Progress in Catalyst Deactivation (J. L. Figueiredo, Ed.), Matrinus Nijhoff Publishers, 55-70 (1982).

Tsotsis, T. T., and V. U. S. Rao, and L. M. Polinski, "Reaction Rate Oscillations During Fischer-Tropsch Synthesis on Fe-Precipitated Nu-1 Zeolite-Type Catalysts," AIChE J., 28(5), 847-860 (1982).

Turkdogan, E. T., and J. V. Vinters, "Catalytic Effect of Iron on Decomposition of Carbon Monoxide: 1. Carbon Deposition in H_2-CO Mixtures," Metal. Trans., 5, 11-19 (1974).

Underwood, R. P., and C. O. Bennett, "The CO/H_2 Reaction over Nickel-Alumina Studied by the Transient Method," J. Catal., 86, 245-253 (1984).

Unmuth, E. E., L. H. Schwartz, and J. B. Butt, "Iron Alloy Fischer-Tropsch Catalysts. I. Oxidation-Reduction Studies of the Fe-Ni System," J. Catal., 61, 242-255 (1980a).

Unmuth, E. E., L. H. Schwartz, and J. B. Butt, "Iron Alloy Fischer-Tropsch Cataylsts. II. Carburization Studies of the Fe-Ni System," J. Catal., 63, 404-414 (1980b).

Unni, M. P., R. R. Hudgins, and P. L. Silveston, "Influence of Cycling on the Rate of Oxidation of SO_2 on a Vanadia Catalyst," Can. J. Chem. Eng., 51, 623-629 (1973).

van Barneveld, W. A. A., and V. Ponec, "Influence of Alloying on the Selectivity in Fischer-Tropsch Synthesis by Nickel-Copper Alloys," J. Catal., 51, 426-430 (1978).

van Barneveld, W. A. A., and V. Ponec, "Reactions of CH_xCl_{4-x} with Hydrogen: Relation to the Fischer-Tropsch Synthesis of Hydrocarbons," J. Catal., 88, 382-387 (1984a).

van Barneveld, W. A. A., and V. Ponec, "On the Apparent Controversy Regarding the Effect of Alloying on the Selectivity of the Fischer-Tropsch Synthesis, " J. Catal., 89, 542-544 (1984b).

van Dijk, W. L., and H. S. van der Baan, "The Role of Carbon and Oxygen in the Activation of an Iron Fischer-Tropsch Catalyst at Low Pressures," J. Catal., 78, 24-33 (1982).

Vanhove, D., P. Marambo, and M. Blanchard, "Selective Analytic Synthesis of Linear Paraffins from Co and H_2 Over Cobalt Supported Catalysts," J. Chem. Soc., Chem. Commun., 14, 603 (1979).

Vogler, G. L., X. J. Jiang, J. A. Dumesic, and R. J. Madon, "The Use of Nitrous Oxide as a Surface Probe of Iron Catalysts for Fischer-Tropsch Synthesis," J. Catal., 89, 116-130 (1984).

Vannice, M. A., "The Catalytic Synthesis of Hydrocarbons from H_2/CO Mixtures over the Group VII Metals I," J. Catal., 37, 449-461 (1975a).

Vannice, M. A., "The Catalytic Synthesis of Hydrocarbons from H_2/CO Mixtures over the Group VIII Metals. II," J. Catal., 37, 462-473 (1975b).

Vannice, M. A., "The Catalytic Synthesis of Hydrocarbons from H_2/CO Mixtures over Group VIII Metals, III," J. Catal., 4, 129-134 (1975c).

Vannice, M. A., "The Catalytic Synthesis of Hydrocarbons from H_2/CO Mixtures over the Group VIII Metals, IV," J. Catal., 44 152-162 (1976a).

Vannice, M. A., "The Catalytic Synthesis of Hydrocarbons from Carbon Monoxide and Hydrogen," Catal. Rev.-Sci. Eng., 14(2), 153-191 (1976b).

Vannice, M. A., "Solid State Chemistry of Energy Conversion and Storage," Advances in Chemistry Series, Amer. Chem. Soc. No. 163, 15-32 (1977a).

Vannice, M. A., "The Catalytic Synthesis of Hydrocarbons from H_2/CO Mixtures over the Group VIII Metals, V. The Catalytic Behavior of Silica-Supported Metals," J. Catal., 50, 228-236 (1977b).

Vannice, M. A., "Catalytic Activation of Carbon Monoxide on Metal Surfaces," Catalysis (J. R. Anderson and M. Bondart, Ed.), 3, Chapter 3, Springer-Verlag, N.Y. (1982).

Vannice, M. A., and R. L. Garten, "Metal-Supported Effects on the Activity and Selectivity of Ni Catalysts in CO/H_2 Synthesis Reactions," J. Catal., 56, 236-248 (1979).

Vannice, M. A., and R. L. Garten, "The Influence of the Support on the Catalytic Behavior of Ruthenium in CO/H_2 Synthesis Reactions," J. Catal., 63, 255-260 (1980a).

Vannice, M. A., and R. L. Garten, "CO Hydrogentation Reactions over Titania-Supported Nickel," J. Catal., 66, 2452-247 (1980b).

Wandrey, V. and A. Renken, "Zur Beeinflussung der Produktverteilungdurch periodische Kozentrationsschwankungen bei der Oxidation von Kohlenwasserstoffen," Chem. Ing. Tech., 45(12), 854 (1977a).

Wandrey, V., and A. Renken, "Ignition and Extinction of Autothermal Reactors at Periodic Operation," Chem. Eng. Sci., 32(4), 448 (1977b).

Wang, C. J., and J. C. Ekerdt, "Evidence for Alkyl Intermediates during Fischer-Tropsch Synthesis and Their Relation to Hydrocarbon Products," J. Catal., 86, 239-244 (1984).

Weil, B. H., and J. C. Lane, The Technology of the Fischer-Tropsch Process, Constable α Co., Ltd., London (1949).

Wen, C. Y., and L. T. Fan, Models for Flow Systems and Chemical Reactors, Marcel Dekker, Inc., N.Y. (1975).

Wen, C. Y., and Y. H. Yu, "A Generalized Method for Predicting the Minimum Fluidization Velocity, AIChE J., 12, 610-612 (1966).

Wentrcek, P. R., B. J. Wood, and H. Wise, "The Role of Surface Carbon in Catalytic Methanation," J. Catal., 43, 363-366 (1976).

White, G. A., T. R. Roszkowski, and D. W. Stanbridge, "Predict Carbon Formation," Hydrocarbon Process., 120-136, July (1975).

Wilson, T. P., "Comments on Heterogeneous Methanation: Absence of H_2-D_2 Kinetic Isotope Effect on Ni, Ru, and Pt," J. Catal., 60, 167-168 (1979).

Wroski, S., R. Pohorecki, A. Wolny, A. Mroz, and H. Moniuk, Polish Patent 96, 257 (1976).

Wynkoop, R., and R. Wilhelm, "Kinetics in a Tubular Reactor: Hydrogenation of Ethylene over a Cooper-Magnesia Catalyst," Chem. Eng. Prog., 46, 300 (1950).

Yang, C. H., and A. G. Oblad, "Catalytic Synthesis of Light Olefinic Hydrocarbons from CO and H_2 over Some Iron Catalysts," Symposium on Advances in Fischer-Tropsch Chemistry, Div. of Pet. Chem., ACS, pp. 513-521 (1978).

Yokoyama, A., H. Komiyama, H. Inoue, T. Masumoto, and H. Kimura, "The Fischer-Tropsch Synthesis by Amorphous $Fe_{20}Ni_{60}P_{20}$ and $Fe_{90}Zr_{10}$ Catalysts," Chemical Reaction Engineering, Advances in Chemistry Series, Amer. Chem. Sco. pp. 237-248 (1982).

Zein el Deen, A., J. Jacobs, and M. Baerns, Proceedings of 5th International Sympos. Chem. Reac. Eng., Houston, pp. 26-36 (1977).

Zenz, F. A., and D. F. Othmer, Fluidization and Fluid-Particle Systems, Reinhold Publishing Corp., New York (1960).

APPENDIX A

Calculations for (1) Minimum Fluidization Velocity of the Fused-Iron Catalyst in the Microreactor, (2) Pressure Drop Across the Distributor Plates and (3) Changes in Feed-Line Volume Upon Switching the Sliding Plenum Across the Plenum Zone

A.1. Minimum Fluidization Velocity of the Fused-Iron Catalyst in the Microreactor

For the calculation, the smoothed correlation of particulate fluidization as given by Zenz and Othmer (1960) was used. The minimum fluidization velocity v_ε, under actual conditions was read from Figure A.1 after first calculating Ω and Δ. A void fraction of 0.5 was assumed.

$$\Omega = \frac{4}{3}\left[\frac{\mu_f(\rho_p-\rho_f)g}{\rho_f^2}\right]^{1/3}$$

$$\Delta = \frac{3}{4}\left[\frac{\mu_f^2}{\rho_f(\rho_p-\rho_f)g}\right]^{1/3}$$

where:

v_ε = superficial velocity ($\frac{ft}{s}$)

D_p = partical diameter (ft)

μ_f = fluid viscosity (lb/ft-s)

ρ_p = apparent particle density (lb/ft^3)

ρ_f = fluid density (lb/ft^3)

g = 32.2 ft/s

An average particle diameter of 225μ was assumed as well.

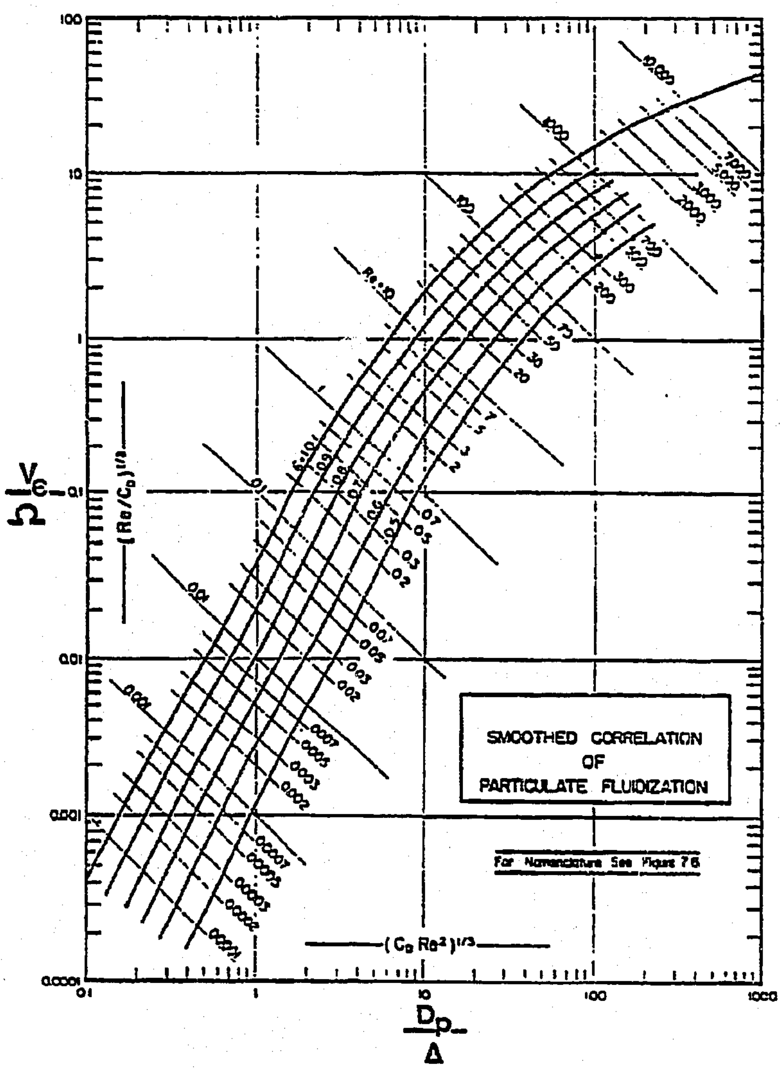

Figure A.1. The Smoothed Correlation of Particulate Fluidization Used to Calculate the Minimum Gas-Fluidization Velocity (V_ε) of a Fused-Iron Catalyst (Taken from Zenz and Othmer, 1960). D_p is the Particle Diameter, Ω and Δ are Defined in Section A.1.

A.2 Pressure Drop Across Different Micron-Grade Sintered Stainless-Steel Distributor Plates

The following equation relating the fluid flow to pressure drop across porous plates has been provided by Mott Metallurgical Corporation for their products:

$$\Delta P^2 = P^2_{upstream} - P^2_{downstream} = \delta\mu RT \frac{\rho_s}{30} t\left[1 + \frac{\beta\rho_s}{60\alpha\mu}Q\right]Q$$

P = pressure (psi)

α = viscous resistance coefficient (in^{-2})

β = inertial resistance coefficient (in^{-1})

ρ_s = density of gas at S.T.P. ($slugs/ft^3$)

R = gas constant = 1.71×10^3 (ft.lb/slug °R)

T = temperature (°R)

t = porous wall thickness (in)

Q = flow ($SCFM/in^2$)

μ = viscosity of flow (slugs/in.sec.)

For 1/16-inch thick porous stainless steel the following coefficients are specified:

Micron Grade	α (in^{-2})	β (in^{-1})
2	8.41×10^8	1.25×10^5
20	3.55×10^7	6.02×10^3

An approximation to the volume of gas backflowing across the distributor plate can be made. This is done by measuring the magnitude and duration of the pressure inversion with a rapid-response differential-pressure transducer. The pressure drop across the distributor plate for the same gas at a typical flow rate is then calculated. By ratioing the measured pressure inversion and the calculated pressure drop, the volume of gas backflowing can be approximated. For example:

Given a 20-μ distributor plate and argon flowing at 400 actual mm^3/s and conditions of 25°C and 101 kPa, what is the pressure drop?

$$\Delta P = 1.42 \times 10^{-2} \text{ kPa}$$

If a pressure inversion of 0.346 kPa is observed for a duration of 0.013 seconds after the feed gas is switched from argon to helium, what is the volume of gas backflowing across the distributor plate?

$$\frac{0.346 \text{ kPa}}{0.0142 \text{ kPa}} \cdot 400 \frac{mm^3}{S} \cdot 0.013S \approx 127 \text{ mm}^3$$

A.3 Changes in Feed-Line Volume Upon Switching the Sliding Plug Across the Plenum Zone.

When the sliding plug is drawn across the plenum zone, gas is compressed into the feed line ahead of the plug. By measuring the increase in pressure in the appropriate feed line, the amount of gas entering that feed line by compression can be calculated. The remainder of the gas originally in the plenum is either compressed through the distributor plate or flows anularly around the plug.

Volume of Feed Line = 26,383 mm^3

$\Delta P_{Ar \rightarrow He}$ = ΔP upon switching from Ar to He = 3.175 kPa

$\Delta P_{He \rightarrow Ar}$ = ΔP upon switching from He to Ar = 2.864 kPa

$P_{final\ Ar \rightarrow He}$ = final feed-line pressure upon switching from Ar to He = 141.000 kPa

$P_{final\ He \rightarrow Ar}$ = final feed-line pressure upon switching from He to Ar = 140.685 kPa

Absolute System Pressure = 137.825 kPa

$\Delta V_{Feed\ Line}$ = change in volume of the feed line upon plug switching

$$\Delta V_{Feed\ Line} = \frac{\Delta P \cdot V_{Feed\ Line}}{P_{final}}$$

For the transition from argon-to-helium flow how much argon is compressed into the feed line? (Experiment 1-4)

$\Delta V_{feed\ line,\ Ar \rightarrow He}$ = 594 mm^3 or 37% of the gas in the plenum

For the transition from helium-to-argon flow how much helium is compressed into the feed line:

$\Delta V_{\text{feed line,He}\to\text{Ar}} = 537\ \text{mm}^3$ or 33% of the gas in the plenum.

APPENDIX B

Steady-State Analysis Results Including Definitions of Input Parameters and Output Labels on Gas-Chromatographic Data Tables for (1) Light Gas Analyses and Mass Balances and (2) Hydrocarbon Product Distribution and Rate of Production from Capillary Analyses. In Addition (3) Temperature-Fluctuation Plots are Presented for Steady-State Experiments.

B.1 Light Gas Analysis--Output from the Microcomputer Data Compilation Program "MASSBAL. BAS."

1. Input

A. Number of moles of CO fed per mole of Ar fed

i. obtained by GC analysis of S-gas.

B. H_2/CO ratio of feed gas

i. As specified by AIRCO.

C. Temperature

D. Number of data points.

E. Peak areas from light gas chromatogram for Co, Ar, CH_4 and CO_2.

2. Output

A. CO CONV: Fractional molar conversion of CO fed to the microreactor.

B. CO_2/CO CONV: The number of moles of CO_2 produced per mole of CO converted (fraction of C from CO converted that goes to CO_2).

C. CH_4/CO CONV: The number of moles of CH_4 produced per mole of CO converted (fraction of CO converted that goes to CH_4).

D. CO/Ar FED; The number of moles of CO fed per mole of Ar fed. An input parameter.

E. H_2/CO RATIO: Molar ratio of feed gases. An input parameter.

F. H_2O IMPLIED: An approximation of water production. Calculation of this value assumes the following:

i. All oxygen produced from the reacted amount of CO and not as as CO_2 is present as H_2O.

ii. No oxygenates are produced. Huff (1982) states that with the same catalyst in a slurry reactor, less than 1.1% of oxygen is present as oxygenates.

G. $-CH_2-$IMPLIED: Carbon which is not produced as CO, CO_2, or CH_4 is assumed to be in the form of $-CH_2-$. This is the mole fraction of C fed converted to $-CH_2-$.

H. H_2 CONV IMPLIED: An <u>approximation</u> based on actual CH_4 production and the above approximations for H_2O and $-CH_2-$ production.

I. H_2 USED IMPLIED: Estimate of the number of moles of H_2 used. The maximum number of moles of H_2 that can be used is the H_2/CO ratio of the feed gas.

J. H_2/CO USAGE: An estimate of the number of moles of H_2 used divided by the number of moles of CO used, the H_2/CO usage ratio.

K. $-CH_2-/CO$ CONV: The mole fraction of converted carbon that went into making $-CH_2-$.

L. CALC KEQ: The calculated equilibrium constant for the water-gas shift reaction at the temperature of the reaction.

$$K_{eq} = 0.0102e^{4730/T}$$

M. EXPT KEQ: The estimated experimental value of the equilibrium constant for the water-gas shift reaction.

$$K_{eq} = \frac{X_{CO_2} X_{H_2}}{X_{CO} X_{H_2O}}$$

N. SUM = 1π: The sum of the moles of CO_2, CH_4 and $-CH_2-$ produced per mole of CO converted should add up to 1. This is an internal check on the calculation.

O. SAMPLE NUMBER: The light-gas sample identification listed chronologically. The first sample is taken 17 minutes after the start of the reaction. Subsequent samples are taken every 37 minutes.

Table B-1

The Light Gas Analysis and Implied Mass Balance from Steady-State Experiment B-1.

DATE OF EXPERIMENT 8/4/84 STEADY STATE EXPERIMENT B-1

THIS EXPERIMENT USES 2.08:1 S-GAS FOR A 10 HOUR RUN.

TEMPERATURE= 633 # DATA PTS.= 16

SAMPLE NUMBER	CO CONV	CO2/CO CONV	CH4/CO CONV	CO/AR FED	H2/CO RATIO
1	.966422	.276265	.134523	4.636	2.08
2	.911641	.324402	.0908617	4.636	2.08
3	.800833	.362191	.103271	4.636	2.08
4	.891407	.346604	.092405	4.636	2.08
5	.895311	.340445	.0851629	4.636	2.08
6	.856242	.342975	.0873825	4.636	2.08
7	.803611	.348946	.0925898	4.636	2.08
8	.783492	.351834	.0946133	4.636	2.08
9	.764561	.353385	.0978475	4.636	2.08
10	.747883	.347915	.0969203	4.636	2.08
11	.736883	.350057	.0970436	4.636	2.08
12	.713293	.355382	.0974296	4.636	2.08
13	.666796	.356057	.0972869	4.636	2.08
14	.648861	.35015	.0955955	4.636	2.08
15	.612656	.353272	.0992683	4.636	2.08
16	.593922	.354004	.0994546	4.636	2.08

SAMPLE NUMBER	H2 CONV IMPLIED	-CH2- IMPLIED	H2O IMPLIED	H2 USED IMPLIED	H2/CO USAGE
1	.606675	.569426	.432445	1.26188	1.30573
2	.489857	.53307	.320165	1.0189	1.11766
3	.391446	.428076	.230725	.814207	1.0167
4	.451101	.500068	.273476	.938291	1.0526
5	.457913	.51426	.285704	.952458	1.06383
6	.43572	.437752	.268903	.906277	1.05846
7	.404027	.443787	.242777	.840376	1.04575
8	.393853	.436433	.233577	.819214	1.03876
9	.381432	.419566	.224192	.793379	1.03769
10	.378679	.415198	.227483	.787652	1.05317
11	.370876	.407422	.220981	.771423	1.04687
12	.353162	.389759	.206021	.734576	1.03128
13	.329909	.364503	.191962	.686211	1.02912
14	.326036	.359635	.194464	.678155	1.04515
15	.306167	.335405	.179788	.636827	1.03945
16	.296231	.324603	.173421	.61616	1.03744

SAMPLE NUMBER	-CH2- /CO CONV	CALC KEQ	EXPT KEQ	SUM=1?
1	.559213	17.9392	15.0427	1
2	.584737	17.9392	11.0927	1
3	.504538	17.9392	8.35168	1
4	.560988	17.9392	11.878	1
5	.574393	17.9392	11.4905	1
6	.569643	17.9392	8.9164	1
7	.558464	17.9392	7.3907	1
8	.553503	17.9392	7.08078	1
9	.548768	17.9392	6.58535	1
10	.555164	17.9392	5.86322	1
11	.551890	17.9392	5.30543	1
12	.547188	17.9392	5.74531	1
13	.546656	17.9392	5.17351	1
14	.554255	17.9392	4.96432	1
15	.54746	17.9392	4.46535	1
16	.546542	17.9392	4.37039	1

Table B-2

The Light Gas Analysis and Implied Mass Balance from Steady-State Experiment B-2.

DATE OF EXPERIMENT 8/8/84 STEADY STATE EXPERIMENT B-2

THIS EXPERIMENT USES 2.08:1 S-GAS FOR A 2 HOUR AND 3 MIN RUN.

TEMPERATURE= 633 # DATA PTS.= 3

SAMPLE NUMBER	CO CONV	CO2/CO CONV	CH4/CO CONV	CO/AR FED	H2/CO RATIO
1	.963068	.13424	.142716	4.636	2.08
2	.892212	.329666	.0931131	4.636	2.08
3	.754651	.363142	.0994475	4.636	2.08

SAMPLE NUMBER	H2 CONV IMPLIED	-CH2- IMPLIED	H2O IMPLIED	H2 USED IMPLIED	H2/CO USAGE
1	.305642	.696341	.704504	1.67573	1.74
2	.473608	.515004	.303948	.985105	1.10412
3	.366449	.405557	.20656	.762214	1.01002

SAMPLE NUMBER	-CH2- /CO CONV	CALC KEQ	EXPT KEQ	SUM=1?
1	.723044	17.9392	2.00872	1
2	.577221	17.9392	6.82983	1
3	.537411	17.9392	7.12582	1

Table B-3

The Light Gas Analysis and Implied Mass Balance from Steady-State Experiment B-3.

DATE OF EXPERIMENT 3/10/84 STEADY STATE EXPERIMENT B-3

THIS EXPERIMENT USES 4.0:1 S-GAS FOR A 10 HOURS AND 0 MIN RUN.

TEMPERATURE= 633 # DATA PTS.= 15

SAMPLE NUMBER	CO CONV	CO2/CO CONV	CH4/CO CONV	CO/AR FED	H2/CO RATIO
1	.973567	.0962746	.201998	4.636	4
2	.956313	.17781	.156962	4.636	4
3	.952031	.186357	.150122	4.636	4
4	.951405	.182455	.164748	4.636	4
5	.951987	.175773	.169086	4.636	4
6	.949969	.181263	.174073	4.636	4
7	.949731	.178116	.18173	4.636	4
8	.947566	.179716	.191255	4.636	4
9	.94181	.182996	.19458	4.636	4
10	.932798	.189936	.200122	4.636	4
11	.929033	.194449	.196096	4.636	4
12	.925626	.202317	.193371	4.636	4
13	.923659	.203195	.191578	4.636	4
14	.927369	.199923	.184958	4.636	4
15	.926805	.207322	.179122	4.636	4

SAMPLE NUMBER	H2 CONV IMPLIED	-CH2- IMPLIED	H2O IMPLIED	H2 USED IMPLIED	H2/CO USAGE
1	.465651	.683179	.786108	1.8626	1.91317
2	.388151	.636167	.61623	1.55261	1.62353
3	.378326	.631217	.596244	1.5133	1.58955
4	.384696	.621074	.604227	1.53878	1.61738
5	.390735	.623636	.61732	1.56194	1.64177
6	.38718	.612412	.605582	1.54872	1.63029
7	.391143	.607974	.611407	1.56457	1.64738
8	.391371	.596047	.606981	1.56548	1.65211
9	.387459	.586205	.597115	1.54983	1.64857
10	.380188	.568953	.578454	1.52075	1.63021
11	.374574	.566204	.567734	1.4983	1.61275
12	.367108	.559367	.551086	1.46843	1.58643
13	.365306	.559024	.548294	1.46122	1.58133
14	.367514	.570442	.556565	1.47006	1.58519
15	.360795	.563647	.542511	1.44318	1.55716

SAMPLE NUMBER	-CH2- /CO CONV	CALC KEQ	EXPT KEQ	SUM=1?
1	.701727	17.9392	9.64139	1
2	.665229	17.9392	15.4583	1
3	.663021	17.9392	15.4668	1
4	.652797	17.9392	14.5504	1
5	.655141	17.9392	13.[illegible]	1
6	.644665	17.9392	13.9315	1
7	.640154	17.9392	13.4043	1
8	.639029	17.9392	13.0264	1
9	.622424	17.9392	12.1533	1
10	.609742	17.9392	11.[illegible]	1
11	.609455	17.9392	11.2168	1
12	.604513	17.9392	11.567	1
13	.605[illegible]	17.9392	11.3836	1
14	.615119	17.9392	11.5034	1
15	.613556	17.9392	12.3721	1

Table B-4

The Light Gas Analysis and Implied Mass Balance from Steady-State Experiment B-4.

DATE OF EXPERIMENT 8/14/84 STEADY STATE EXPERIMENT B-4

THIS EXPERIMENT USES 1.03:1 S-GAS FOR A 1 HOURS AND 2 MIN RUN.

TEMPERATURE= 633 # DATA PTS.= 2

SAMPLE NUMBER	CO CONV	CO2/CO CONV	CH4/CO CONV	CO/AR FED	H2/CO RATIO
1	.962339	.152279	.0953146	10.882	1.03
2	.388091	.428382	.0931238	10.882	1.03

SAMPLE NUMBER	H2 CONV IMPLIED	-CH2- IMPLIED	H2O IMPLIED	H2 USED IMPLIED	H2/CO USAGE
1	1.53092	.724106	.669284	1.57485	1.63848
2	.304436	.1857	.0555838	.310567	.807978

SAMPLE NUMBER	-CH2- /CO CONV	CALC KEQ	EXPT KEQ	SUM=1?
1	.752406	17.9392	-3.18361	1
2	.478494	17.9392	3.50159	1

Table B-5

The Light Gas Analysis and Implied Mass Balance
from Steady-State Experiment B-5.

DATE OF EXPERIMENT 8/16/84 STEADY STATE EXPERIMENT B-5

THIS EXPERIMENT USES 1.03:1 S-GAS FOR A 2 HOURS AND 13 MIN RUN.

TEMPERATURE= 633 # DATA PTS.= 4

SAMPLE NUMBER	CO CONV	CO2/CO CONV	CH4/CO CONV	CO/AR FED	H2/CO RATIO
1	.76013	.152638	.0943774	10.882	1.03
2	.402497	.465347	.0911527	10.882	1.03
3	.344521	.43468	.0937697	10.882	1.03
4	.328153	.449026	.10217	10.882	1.03

SAMPLE NUMBER	H2 CONV IMPLIED	-CH2- IMPLIED	H2O IMPLIED	H2 USED IMPLIED	H2/CO USAGE
1	1.52545	.722963	.667026	1.57122	1.63646
2	.271632	.178508	.0278959	.279781	.695113
3	.264155	.162459	.0450085	.272079	.729731
4	.240569	.147276	.0334546	.247736	.755093

SAMPLE NUMBER	-CH2- /CO CONV	CALC KEQ	EXPT KEQ	SUM=1?
1	.752935	17.9392	-2.98244	1
2	.443501	17.9392	8.46039	1
3	.471551	17.9392	3.8473	1
4	.448804	17.9392	5.12799	1

Table B-6

The Light Gas Analysis and Implied Mass Balance
from Steady-State Experiment B-6.

DATE OF EXPERIMENT 8/19/84 STEADY STATE EXPERIMENT B-6

THIS EXPERIMENT USES 2.08:1 S-GAS FOR A 2 HOURS AND 57 MIN RUN.

TEMPERATURE= 633 # DATA PTS.= 5

SAMPLE NUMBER	CO CONV	CO2/CO CONV	CH4/CO CONV	CO/AR FED	H2/CO RATIO
1	.963713	.103359	.125136	4.636	2.08
2	.911443	.322224	.0769925	4.636	2.08
3	.778902	.353329	.0937585	4.636	2.08
4	.603076	.370037	.0914459	4.636	2.08
5	.418807	.35195	.0998239	4.636	2.08

SAMPLE NUMBER	H2 CONV IMPLIED	-CH2- IMPLIED	H2O IMPLIED	H2 USED IMPLIED	H2/CO USAGE
1	.837639	.74204	.757808	1.74229	1.79856
2	.486536	.54758	.324065	1.01199	1.11022
3	.387118	.430664	.228484	.805206	1.03377
4	.294528	.324766	.156755	.591819	.981334
5	.210204	.229601	.124009	.437224	1.04397

SAMPLE NUMBER	-CH2- /CO CONV	CALC KEQ	EXPT KEQ	SUM=1?
1	.766006	17.9392	1.50202	1
2	.600783	17.9392	10.9297	1
3	.552912	17.9392	6.94433	1
4	.538517	17.9392	5.3376	1
5	.548226	17.9392	3.3597	1

Table B-7

The Light Gas Analysis and Implied Mass Balance
from Steady-State Experiment B-7.

DATE OF EXPERIMENT 8/21/84 STEADY STATE EXPERIMENT B-7

THIS EXPERIMENT USES 2.08:1 S-GAS FOR A 2 HOURS AND 45 MIN RUN.

TEMPERATURE= 633 # DATA PTS.= 4

SAMPLE NUMBER	CO CONV	CO2/CO CONV	CH4/CO CONV	CO/AR FED	H2/CO RATIO
1	.972577	.103765	.137887	4.636	2.08
2	.915845	.321638	.0791721	4.636	2.08
3	.72949	.367079	.0964375	4.636	2.08
4	.562199	.375146	.0904873	4.636	2.08

SAMPLE NUMBER	H2 CONV IMPLIED	-CH2- IMPLIED	H2O IMPLIED	H2 USED IMPLIED	H2/CO USAGE
1	.849411	.747277	.770737	1.76677	1.31659
2	.49062	.548766	.326705	1.02049	1.11426
3	.349034	.39136	.19393	.72599	.995203
4	.263625	.303627	.141884	.54834	.965048

SAMPLE NUMBER	-CH2- /CO CONV	CALC KEQ	EXPT KEQ	SUM=1?
1	.768346	17.9392	1.49556	1
2	.59919	17.9392	11.3516	1
3	.536484	17.9392	6.9115	1
4	.534366	17.9392	5.32904	1

Table B-8

The Light Gas Analysis and Implied Mass Balance from Steady-State Experiment C-1.

DATE OF EXPERIMENT 8/24/84 STEADY STATE EXPERIMENT C-1

THIS EXPERIMENT USES 2.08:1 S-GAS FOR A 2 HOURS AND 4 MIN RUN.

TEMPERATURE= 673 # DATA PTS.= 3

SAMPLE NUMBER	CO CONV	CO2/CO CONV	CH4/CO CONV	CO/AR FED	H2/CO RATIO
1	.967754	.102517	.175733	4.636	2.08
2	.879722	.323356	.162606	4.636	2.08
3	.934199	.300664	.129202	4.636	2.08

SAMPLE NUMBER	H2 CONV IMPLIED	-CH2- IMPLIED	H2O IMPLIED	H2 USED IMPLIED	H2/CO USAGE
1	.869202	.698477	.769332	1.80794	1.86818
2	.504376	.452211	.310795	1.0491	1.19254
3	.551155	.532599	.372401	1.1464	1.22715

SAMPLE NUMBER	-CH2- /CO CONV	CALC KEQ	EXPT KEQ	SUM=1?
1	.721751	11.5059	1.088	1
2	.514038	11.5059	7.84478	1
3	.570114	11.5059	10.702	1

Table B-9

The Light Gas Analysis and Implied Mass Balance
from Steady-State Experiment C-2.

DATE OF EXPERIMENT 3/27/84 STEADY STATE EXPERIMENT C-2

THIS EXPERIMENT USES 1.03:1 S-GAS FOR A 1 HOUR AND 0 MIN RUN.

TEMPERATURE= 673 # DATA PTS.= 2

SAMPLE NUMBER	CO CONV	CO2/CO CONV	CH4/CO CONV	CO/AR FED	H2/CO RATIO
1	.95979	.15042	.132879	10.832	1.03
2	.947319	.396654	.0796436	10.832	1.03

SAMPLE NUMBER	H2 CONV IMPLIED	-CH2- IMPLIED	H2O IMPLIED	H2 USED IMPLIED	H2/CO USAGE
1	1.36699	.687883	.671048	1.614	1.68162
2	.817712	.495923	.195424	.842243	.889081

SAMPLE NUMBER	-CH2- /CO CONV	CALC KEQ	EXPT KEQ	SUM=1?
1	.716702	11.5059	-3.12471	1
2	.523502	11.5059	6.85627	1

Table B-10.

The Light Gas Analysis and Implied Mass Balance from Steady-State Experiment D-1.

DATE OF EXPERIMENT 8/29/84 STEADY STATE EXPERIMENT D-1

THIS EXPERIMENT USES 1.03:1 S-GAS FOR A 1 HOUR AND 15 MIN RUN.

TEMPERATURE= 653 # DATA PTS.= 2

SAMPLE NUMBER	CO CONV	CO2/CO CONV	CH4/CO CONV	CO/AR FED	H2/CO RATIO
1	.968372	.117161	.12634	10.882	1.03
2	.489223	.438333	.112811	10.882	1.03

SAMPLE NUMBER	H2 CONV IMPLIED	-CH2- IMPLIED	H20 IMPLIED	H2 USED IMPLIED	H2/CO USAGE
1	1.66866	.732573	.741461	1.71872	1.77496
2	.378939	.21959	.0603374	.390307	.797811

SAMPLE NUMBER	-CH2-/CO CONV	CALC KEQ	EXPT KEQ	SUM=1?
1	.756499	14.2695	-3.33199	1
2	.448355	14.2695	4.45107	1

Table B-11

The Light Gas Analysis and Implied Mass Balance from Steady-State Experiment D-2.

DATE OF EXPERIMENT 9/4/84 STEADY STATE EXPERIMENT D-2

THIS EXPERIMENT USES 2.08:1 S-GAS FOR A 2 HOUR AND 48 MIN RUN.

TEMPERATURE= 653 # DATA PTS.= 5

SAMPLE NUMBER	CO CONV	CO2/CO CONV	CH4/CO CONV	CO/AR FED	H2/CO RATIO
1	.98133	.0654104	.133736	4.636	2.08
2	.913697	.315628	.115813	4.636	2.08
3	.908702	.325845	.11064	4.636	2.08
4	.919893	.32263	.101275	4.636	2.08
5	.897258	.332323	.10012	4.636	2.08

SAMPLE NUMBER	H2 CONV IMPLIED	-CH2- IMPLIED	H2O IMPLIED	H2 USED IMPLIED	H2/CO USAGE
1	.937691	.736835	.852951	1.9504	1.98751
2	.513486	.519486	.33692	1.06805	1.16893
3	.495026	.512067	.316509	1.02965	1.1331
4	.500981	.529761	.325954	1.04204	1.13279
5	.46992	.503121	.296649	.977434	1.10164

SAMPLE NUMBER	-CH2- /CO CONV	CALC KEQ	EXPT KEQ	SUM=1?
1	.750853	14.2695	.522391	1
2	.568584	14.2695	10.0365	1
3	.563515	14.2695	10.7626	1
4	.575894	14.2695	11.8048	1
5	.567052	14.2695	9.7352	1

Table B-12

The Light Gas Analysis and Implied Mass Balance from Steady-State Experiment E-1.

DATE OF EXPERIMENT 9/8/84 STEADY STATE EXPERIMENT E-1

THIS EXPERIMENT USES 2.08:1 S-GAS FOR A 2 HOUR AND 50 MIN RUN.

TEMPERATURE= 663 # DATA PTS.= 5

SAMPLE NUMBER	CO CONV	CO2/CO CONV	CH4/CO CONV	CO/AR FED	H2/CO RATIO
1	.959728	.153064	.146365	4.636	2.08
2	.951051	.339254	.144345	4.636	2.08
3	.931852	.314166	.116154	4.636	2.08
4	.932198	.313923	.110444	4.636	2.08
5	.94235	.300319	.110432	4.636	2.08

SAMPLE NUMBER	H2 CONV IMPLIED	-CH2- IMPLIED	H2O IMPLIED	H2 USED IMPLIED	H2/CO USAGE
1	.773475	.672358	.665929	1.61923	1.68717
2	.460951	.439483	.273606	.958779	1.12658
3	.525804	.530357	.346339	1.09367	1.17365
4	.523768	.536604	.346921	1.08944	1.16868
5	.547979	.555231	.376338	1.1098	1.20952

SAMPLE NUMBER	-CH2- /CO CONV	CALC KEQ	EXPT KEQ	SUM=1?
1	.700871	12.7926	2.52392	1
2	.516401	12.7926	7.94845	1
3	.56965	12.7926	12.2342	1
4	.575634	12.7926	12.2236	1
5	.589198	12.7926	12.2643	1

Table B-13

The Light Gas Analysis and Implied Mass Balance from Steady-State Experiment F-1.

DATE OF EXPERIMENT 9/11/84 STEADY STATE EXPERIMENT F-1
THIS EXPERIMENT USES 4.0:1 S-GAS FOR A 3 HOUR AND 30 MIN RUN.

TEMPERATURE= 668 # DATA PTS.= 6

SAMPLE NUMBER	CO CONV	CO2/CO CONV	CH4/CO CONV	CO/AR FED	H2/CO RATIO
1	.991424	.0230512	.32396	4.636	4
2	.952072	.148586	.245386	4.636	4
3	.953104	.143642	.285975	4.636	4
4	.948115	.151273	.319167	4.636	4
5	.937733	.163631	.328821	4.636	4
6	.933073	.166705	.322957	4.636	4

SAMPLE NUMBER	H2 CONV IMPLIED	-CH2- IMPLIED	H2O IMPLIED	H2 USED IMPLIED	H2/CO USAGE
1	.558367	.647389	.245717	2.33547	2.35461
2	.428344	.576983	.669144	1.71333	1.79980
3	.442014	.543635	.679293	1.76806	1.85505
4	.442138	.502079	.661283	1.76355	1.86553
5	.430836	.475698	.630785	1.72335	1.83773
6	.425213	.476185	.62198	1.70085	1.82264

SAMPLE NUMBER	-CH2- /CO CONV	CALC KEQ	EXPT KEQ	SUM=1?
1	.652989	12.1274	4.97222	1
2	.606023	12.1274	10.0863	1
3	.570383	12.1274	9.59208	1
4	.529555	12.1274	9.32846	1
5	.507499	12.1274	8.89719	1
6	.510338	12.1274	8.59189	1

Table B-14

The Light Gas Analysis and Implied Mass Balance from Steady-State Experiment F-2.

DATE OF EXPERIMENT 9/13/84 STEADY STATE EXPERIMENT F-2

THIS EXPERIMENT USES 4.0:1 S-GAS FOR A 2 HOUR AND 0 MIN RUN.

TEMPERATURE= 668 # DATA PTS.= 3

SAMPLE NUMBER	CO CONV	CO2/CO CONV	CH4/CO CONV	CO/AR FED	H2/CO RATIO
1	.971771	*******	.296196	4.636	4
2	.964579	.10431	.287981	4.636	4
3	.965401	.0996195	.33188	4.636	4

SAMPLE NUMBER	H2 CONV IMPLIED	-CH2- IMPLIED	H2O IMPLIED	H2 USED IMPLIED	H2/CO USAGE
1	.557842	.683934	.971764	2.23137	2.29619
2	.476273	.586184	.763348	1.90509	1.97505
3	.49067	.548831	.773055	1.96263	2.03302

SAMPLE NUMBER	-CH2- [illegible] CONV	CALC KEQ	EXPT KEQ	SUM=1?
1	.703801	12.1274	*******	1
2	.607709	12.1274	7.79565	1
3	.568501	12.1274	7.3254	1

****** INDICATES THAT THE CO2 PEAK WAS NOT INTEGRATED IN THIS SAMPLE

Table B-15

The Light Gas Analysis and Implied Mass Balance from Steady-State Experiment F-3.

DATE OF EXPERIMENT 9/18/84 STEADY STATE EXPERIMENT F-3

THIS EXPERIMENT USES 2.08:1 S-GAS FOR A 1 HOUR AND 0 MIN RUN
AFTER FIRST EXPOSING IT TO 4:1 PRECARB. GAS FOR 2 HOURS.

TEMPERATURE= 663 # DATA PTS.= 5

SAMPLE NUMBER	CO CONV	CO2/CO CONV	CH4/CO CONV	CO/AR FED	H2/CO RATIO
1	.985622	.0361131	.312424	4.636	4
2	.955101	.139341	.248323	4.636	4
3	.950854	.145242	.282584	4.636	4
4	.949619	.147303	.319799	4.636	2.08
5	.912643	.312974	.160159	4.636	2.08

SAMPLE NUMBER	H2 CONV IMPLIED	-CH2- IMPLIED	H2O IMPLIED	H2 USED IMPLIED	H2/CO USAGE
1	.543099	.642096	.914434	2.17239	2.20409
2	.436673	.584365	.687976	1.74669	1.82988
3	.439023	.544054	.674646	1.75609	1.84686
4	.356661	.505575	.663906	1.78186	1.87639
5	.535843	.480841	.341376	1.11455	1.22124

SAMPLE NUMBER	-CH2- /CO CONV	CALC KEQ	EXPT KEQ	SUM=1?
1	.651463	12.1274	4.94773	1
2	.611635	12.1274	9.74309	1
3	.572175	12.1274	9.34639	1
4	.532398	12.1274	1.24172	1
5	.526866	12.1274	9.2472	1

Table B-16

The Light Gas Analysis and Implied Mass Balance from Steady-State Experiment F-4.

DATE OF EXPERIMENT 9/20/84 STEADY STATE EXPERIMENT F-4

THIS EXPERIMENT USES 2.03:1 S-GAS FOR A 2 HOUR RUN
AFTER FIRST EXPOSING IT TO 4:1 PRECARB. GAS FOR 2 HOURS.

TEMPERATURE= 668 # DATA PTS.= 6

SAMPLE NUMBER	CO CONV	CO2/CO CONV	CH4/CO CONV	CO/AR FED	H2/CO RATIO
1	.984279	.0403736	.29192	4.636	4
2	.951694	.145227	.245333	4.636	4
3	.949076	.149819	.289544	4.636	4
4	.942934	.153585	.314931	4.636	2.08
5	.920779	.309185	.152934	4.636	2.08
6	.93619	.296109	.134311	4.636	2.08

SAMPLE NUMBER	H2 CONV IMPLIED	-CH2- IMPLIED	H2O IMPLIED	H2 USED IMPLIED	H2/CO USAGE
1	.534163	.65721	.904801	2.13667	2.1708
2	.430559	.58	.675271	1.72224	1.80965
3	.436596	.532087	.664697	1.74638	1.84009
4	.840561	.501155	.653294	1.74837	1.85416
5	.542454	.495269	.351397	1.1288	1.22508
6	.560807	.533236	.381762	1.16646	1.24593

SAMPLE NUMBER	-CH2- /CO CONV	CALC KEQ	EXPT KEQ	SUM=1?
1	.667707	12.1274	5.20561	1
2	.60944	12.1274	9.65094	1
3	.560637	12.1274	9.46477	1
4	.531464	12.1274	1.38826	1
5	.53768	12.1274	9.73277	1
6	.569581	12.1274	10.3957	1

Table B-17

The Light Gas Analysis and Implied Mass Balance from Steady-State Experiment F-5.

DATE OF EXPERIMENT 9/25/84 STEADY STATE EXPERIMENT F-5

THIS EXPERIMENT USES 1.03:1 S-GAS FOR A 22 MINUTE RUN
AFTER FIRST EXPOSING IT TO 4:1 PRECARB. GAS FOR 2 HOURS.

TEMPERATURE= 663 # DATA PTS.= 3

SAMPLE NUMBER	CO CONV	CO2/CO CONV	CH4/CO CONV	CO/AR FED	H2/CO RATIO
1	.937643	.242925	.171306	10.892	4
2	.93993	.234862	.196517	10.892	4
3	.930952	.26168	.175897	10.392	4

SAMPLE NUMBER	H2 CONV IMPLIED	-CH2- IMPLIED	H2O IMPLIED	H2 USED IMPLIED	H2/CO USAGE
1	.338145	.549243	.48209	1.35258	1.44253
2	.298556	.461536	.382915	1.19422	1.34193
3	.323705	.523589	.443729	1.29482	1.39086

SAMPLE NUMBER	-CH2- /CO CONV	CALC KEQ	EXPT KEQ	SUM=1?
1	.585769	12.1274	20.0596	1
2	.518621	12.1274	16.3761	1
3	.562423	12.1274	21.5092	1

B.2 Major Hydrocarbon Product Analysis--Output from the Microcomputer Data Compilation Program "HEAVY. BAS."

1. Input

   A. Moles of CH_4 produced per mole of CO converted.

      i. Obtained from light-gas analysis.

   B. Flow Rate of the synthesis gas.

   C. Fraction of CO in the S-gas feed.

   D. Moles of CO converted per mole of CO fed.

      i. Obtained from the light-gas analysis.

   E. Moles of CO_2 produced per mole of CO converted.

      i. Obtained from the light-gas analysis.

   F. Peak areas for 24 hydrocarbons.

2. Output

   A. NORM AREA: Normalized peak areas of the 24 hydrocarbon. Normalized to CH_4.

   B. WT FRACT: The weight fraction of each hydrocarbon peak. Assumes FID response factors for all hydrocarbons are 1.

   C. HC/CO CONV: The moles of hydrocarbon produced per mole of CO consumed.

   D. RATE PROD: The rate of production of each hydrocarbon product i.. mmoles per hour.

   E. M.W.: The molecular weight of each hydrocarbon. For fused peaks (C_2 and C_3) the average molecular weight is used.

   F. MOLE CΔ: The number of moles of each carbon number hydrocarbon product produced per mole of CO converted.

   G. MOLFRC CΔ: The mole fraction of each carbon number hydrocarbon product produced.

   H. WT CΔ: The weight fraction of each carbon number of hydrocarbon product.

I. WTFRAC CΔ: The weight fraction of each carbon number hydrocarbon product.

J. RATE CΔ: The rate of production of each carbon number hydrocarbon product in mmoles per hour.

Table B-18

The Hydrocarbon Product Distribution and Rate of Production as Analyzed by Gas Chromatography for Steady-State Experiment B-1.

DATE OF EXPERIMENT 3/4/84 STEADY STATE W/O PRECARB.

EXPERIMENT B-1: THIS EXPERIMENT CONSISTS OF 10 HOURS OF 2.08:1 S-GAS FLOW AT 633K.

PEAK #	NORM AREA	WT FRACT.	HC/CO CONV	RATE PROD	M.W.
1	1	.262098	.09945	10.7847	16.043
2	.573734	.151698	.0317747	3.44574	29.062
3	.696402	.182525	.025786	2.79631	43.089
4	.429139	.112476	.0122029	1.32332	56.108
5	.066339	.0175131	1.83467E-03	.198957	58.124
6	.0162383	4.25601E-03	4.61743E-04	.0500734	56.108
7	.019747	5.17565E-03	5.61522E-04	.0608933	56.108
8	.271563	.0711759	6.17768E-03	.669926	70.135
9	.0498735	.0130717	1.10235E-03	.119597	72.151
10	.0128193	3.3599E-03	2.91621E-04	.0316242	70.135
11	.0105182	2.75678E-03	2.39274E-04	.0259476	70.135
12	.205957	.0539808	3.90436E-03	.423401	84.162
13	.0377479	9.89362E-03	6.98354E-04	.0757858	86.178
14	.0127213	3.33423E-03	2.41161E-04	.0261522	84.162
15	.12519	.0328119	2.02421E-03	.220596	98.189
16	.0261281	6.84811E-03	4.16015E-04	.0451139	100.205
17	3.37005E-03	8.83283E-04	5.47601E-05	5.93335E-03	98.189
18	8.60057E-03	2.25419E-03	1.39751E-04	.015155	98.189
19	.0930641	.0243919	1.32315E-03	.143489	112.216
20	.0255406	6.69413E-03	3.56725E-04	.0386843	114.232
21	.0638107	.0167246	8.06448E-04	.0874537	126.243
22	.0174623	4.57682E-03	2.17222E-04	.0235562	128.259
23	.0309017	8.099[illegible]-03	3.51486E-04	.0381162	140.27
24	.012953	3.396[illegible]-03	1.453E-04	.0157568	142.286

CARBON #	MOLES C#	MOLFRC C#	WT C#	WTFRAC C#	RATE C#
1	.09945	.521849	.262098	.262098	10.7847
2	.0317747	.166733	.151698	.151698	3.44574
3	.025786	.135308	.182525	.182525	2.79631
4	.0150609	.0790296	.139426	.139426	1.63325
5	7.81143E-03	.0409893	.0903643	.0903643	.847095
6	4.34433E-03	.0254201	.0672086	.0672086	[illegible]
7	2.64474E-03	.0138779	.0427975	.0427975	[illegible]
8	1.67995E-03	8.81503E-03	.031086	.031086	.182174
9	1.02367E-03	5.37155E-03	.0213014	.0213014	.11101
10	4.96786E-04	2.60631E-03	.0114955	.0114955	.0538729

TOTAL PEAK AREA= 467574
TOTAL MOLE CARBON PRODUCED AS OLE&PAR/MOLE CO CONV= .414857
MOLE RATIO C1/(C2-C4)= 1.16619
WEIGHT FRACTION C1/(C2-C5) .415222
RATES ARE IN UNITS OF MMOLES PER HOUR
AVG MOL WTS ARE USED FOR C2 AND C3 HYDROCBNS DUE TO FUSED PEAKS
TOT MOLS C PRODUCED AS CO2 AND OLE&PARA/MOLE CO CONV= [illegible]

Table B-19

The Hydrocarbon Product Distribution and Rate of Production as Analyzed by Gas Chromatography for Steady-State Experiment B-2.

DATE OF EXPERIMENT 8/9/84 STEADY STATE W/O PRECARB.

EXPERIMENT B-2: THIS EXPERIMENT CONSISTS OF 2 HOURS AND 3 MIN OF 2.08:1 S-GAS FLOW AT 633K.

PEAK #	NORM AREA	WT FRACT.	HC/CO CONV	RATE PROD	M.W.
1	1	.268172	.09945	13.4465	16.043
2	.601216	.161229	.0330062	4.46273	29.062
3	.681716	.182817	.0252422	3.41297	43.088
4	.415909	.111535	.0118267	1.59907	56.108
5	.0607559	.0163011	1.66854E-03	.225602	58.124
6	.0161563	4.33266E-03	4.59417E-04	.0621173	56.108
7	.0176762	4.74026E-03	5.02637E-04	.0679603	56.108
8	.262424	.0703745	5.96979E-03	.807163	70.135
9	.0426375	.0114476	9.43948E-04	.12763	72.151
10	.0123903	3.32271E-03	2.81861E-04	.0381101	70.135
11	.0107339	2.87586E-03	2.43955E-04	.0329843	70.135
12	.213353	.0572168	4.04469E-03	.546876	84.162
13	.034249	9.18463E-03	6.34078E-04	.0857328	86.178
14	.0144168	3.86618E-03	2.73302E-04	.0369529	84.162
15	.115633	.0310095	1.87892E-03	.254046	98.189
16	.0273474	7.33382E-03	4.35429E-04	.0588739	100.205
17	3.22E-03	8.63512E-04	5.23218E-05	7.07437E-03	98.189
18	.0101385	2.71886E-03	1.64741E-04	.0222744	98.189
19	.0720671	.0193264	1.02464E-03	.138541	112.216
20	.0175919	4.71762E-03	2.45704E-04	.0332213	114.232
21	.0497973	.0133542	6.29346E-04	.085093	126.243
22	.0142367	3.81787E-03	1.77097E-04	.023945	128.259
23	.0261709	7.0183E-03	2.97674E-04	.0402485	140.27
24	9.04076E-03	2.42448E-03	1.01376E-04	.0137069	142.286

CARBON #	MOLES C#	MOLFRC C#	WT C#	WTFRAC C#	RATE C#
1	.09945	.524651	.268172	.268172	13.4465
2	.0330062	.174125	.161229	.161229	4.46273
3	.0252422	.133166	.182817	.182817	3.41297
4	.0144573	.0762698	.136909	.136909	1.95475
5	7.43956E-03	.0392475	.0880209	.0880209	1.00589
6	4.95206E-03	.0261247	.0702676	.0702676	.669563
7	2.53141E-03	.0133545	.0419256	.0419256	.342269
8	1.27035E-03	6.70179E-03	.024044	.024044	.171762
9	8.06442E-04	4.25441E-03	.0171721	.0171721	.109038
10	3.99052E-04	2.10521E-03	9.44278E-03	9.44278E-03	.0539553

TOTAL PEAK AREA= 662411
TOTAL MOLE CARBON PRODUCED AS OLE&PAR/MOLE CO CONV= .40506
MOLE RATIO C1/(C2-C6)= 1.16866
WEIGHT FRACTION C1/(C2-C5) .419514
RATES ARE IN UNITS OF MMOLES PER HOUR
AVG MOL WTS ARE USED FOR C2 AND C3 HYDROCBNS DUE TO FUSED PEAKS
TOT MOLE C PRODUCED AS CO2 AND OLE&PARA/MOLE CO CONV= .748052

Table B-20

The Hydrocarbon Product Distribution and Rate of Production as Analyzed by Gas Chromatography for Steady-State Experiment B-3.

DATE OF EXPERIMENT 8/10/84 STEADY STATE W/O PRECARB.

EXPERIMENT B-3: THIS EXPERIMENT CONSISTS OF 10 HOURS OF 4.0:1 S-GAS FLOW AT 633K.

PEAK #	NORM AREA	WT FRACT.	HC/CO CONV	RATE PROD	M.W.
1	1	.327338	.1791	18.8321	16.043
2	.47654	.155989	.0471145	4.95401	29.062
3	.579579	.189718	.038648	4.06377	43.088
4	.347677	.113808	.0178046	1.87212	56.108
5	.0570124	.0186623	3.81835E-03	.296345	58.124
6	.013626	4.4603E-03	6.97799E-04	.0733714	56.108
7	.0147805	4.93822E-03	7.56913E-04	.0795881	58.124
8	.208017	.0680919	8.52209E-03	.896083	70.135
9	.0389259	.0127419	1.55016E-03	.162997	72.151
10	.0105226	3.44444E-03	4.31091E-04	.0453285	70.135
11	7.23268E-03	2.36753E-03	2.96309E-04	.0311564	70.135
12	.112713	.0368951	3.84802E-03	.404613	84.162
13	.0241421	7.90263E-03	8.04935E-04	.0846375	86.178
14	7.63145E-03	2.49806E-03	2.60539E-04	.0273953	84.162
15	.053626	.0175533	1.56926E-03	.165005	98.189
16	.0112655	3.68761E-03	3.23029E-04	.033964	100.205
17	1.62084E-03	5.30562E-04	4.74306E-05	4.98725E-03	98.189
18	6.00418E-03	1.96539E-03	1.757E-04	.0184744	98.189
19	.0360765	.0118092	9.23743E-04	.0971301	112.216
20	9.4967E-03	3.10863E-03	2.38873E-04	.0251171	114.232
21	.0196077	6.41832E-03	4.46272E-04	.0469247	126.243
22	5.96559E-03	1.95276E-03	1.33643E-04	.0140524	128.259
23	9.34556E-03	3.05915E-03	1.91435E-04	.0201291	140.27
24	3.54398E-03	1.16008E-03	7.15666E-05	7.5251E-03	142.286

CARBON #	MOLES C#	MOLFRC C#	WT C#	WTFRAC C#	RATE C#
1	.1791	.583317	.327338	.327338	18.8321
2	.0471145	.15358	.155989	.155989	4.95401
3	.038648	.125982	.189718	.189718	4.06377
4	.0220776	.071967	.141763	.141763	2.33143
5	.0107997	.0352039	.0866458	.0866458	1.13537
6	4.9135E-03	.0160167	.0472958	.0472958	.516645
7	2.11542E-03	6.89567E-03	.0237374	.0237374	.222432
8	1.16262E-03	3.78981E-03	.0149178	.0149178	.122247
9	5.79915E-04	1.89036E-03	8.37108E-03	8.37108E-03	.0609771
10	2.63002E-04	8.57313E-04	4.21923E-03	4.21923E-03	.0276542

TOTAL PEAK AREA= 949937

TOTAL MOLE CARBON PRODUCED AS OLE&PAR/MOLE CO CONV= .593021

MOLE RATIO C1/(C2-C6)= 1.44958

WEIGHT FRACTION C1/(C2-C5) .52676

RATES ARE IN UNITS OF MMOLES PER HOUR

AVG MOL WTS ARE USED FOR C2 AND C3 HYDROCBNS DUE TO FUSED PEAKS

TOT MOLE C PRODUCED AS CO2 AND OLE&PARA/MOLE CO CONV= .800321

Table B-21

The Hydrocarbon Product Distribution and Rate of Production as Analyzed by Gas Chromatography for Steady-State Experiment C-1.

DATE OF EXPERIMENT 8/24/84 STEADY STATE W/O PRECARB.

EXPERIMENT C-1: THIS EXPERIMENT CONSISTS OF 2 HOURS AND 4 MIN OF 2.08:1 S-GAS FLOW AT 673K.

PEAK #	NORM AREA	WT FRACT.	HC/CO CONV	RATE PROD	M.W.
1	1	.342877	.1292	21.6253	16.043
2	.458467	.157198	.0326987	5.47305	29.063
3	.54247	.186001	.026095	4.36774	43.089
4	.333099	.114212	.0123054	2.05966	56.108
5	.0434648	.0149031	1.55E-03	.259435	56.124
6	.0129689	4.44674E-03	4.791E-04	.0801909	56.108
7	.0147911	5.07153E-03	5.46417E-04	.0714582	56.108
8	.185355	.0635539	5.47794E-03	.916887	70.135
9	.0283379	9.71642E-03	8.14092E-04	.136261	72.151
10	9.11623E-03	3.12575E-03	2.69419E-04	.0450949	70.135
11	.0103033	3.53276E-03	3.04501E-04	.0509666	70.135
12	.0991032	.0339805	2.44147E-03	.408649	84.162
13	.0178055	6.10511E-03	4.2826E-04	.0716813	86.178
14	7.92919E-03	2.71874E-03	1.95282E-04	.0326859	84.162
15	.0536379	.0183912	1.13229E-03	.18952	98.189
16	.0104542	3.58452E-03	2.16248E-04	.0361952	100.205
17	2.69166E-03	9.22908E-04	5.68205E-05	9.51052E-03	98.189
18	3.31381E-03	1.13623E-03	6.99541E-05	.0117088	98.189
19	.0340752	.0116836	6.29408E-04	.105349	112.216
20	8.62163E-03	2.95616E-03	1.56441E-04	.0261848	114.232
21	.0216504	7.42343E-03	3.55473E-04	.0594985	126.243
22	4.6284E-03	1.58697E-03	7.47982E-05	.0125196	128.259
23	.0104725	3.59077E-03	1.54751E-04	.0259019	140.27
24	3.70949E-03	1.2719E-03	5.40381E-05	9.0448E-03	142.286

CARBON #	MOLES C#	MOLFRC C#	WT C#	WTFRAC C#	RATE C#
1	.1292	.598964	.342877	.342877	21.6253
2	.0326987	.151589	.157198	.157198	5.47305
3	.026095	.120975	.186001	.186001	4.36774
4	.0148809	.0689872	.138633	.138633	2.49075
5	6.86595E-03	.0318301	.0799288	.0799288	1.14921
6	3.06501E-03	.0142092	.0428143	.0428144	.513016
7	1.47531E-03	6.83946E-03	.0240349	.0240349	.246935
8	7.85849E-04	3.64315E-03	.0146398	.0146398	.131534
9	4.30271E-04	1.99471E-03	9.0104E-03	9.0104E-03	.0720181
10	2.08789E-04	9.67933E-04	4.86257E-03	4.86257E-03	.0349467

TOTAL PEAK AREA= 1.12037E+06
TOTAL MOLE CARBON PRODUCED AS OLE&PAR/MOLE CO CONV= .4077
MOLE RATIO C1/(C2-C6)= 1.54535
WEIGHT FRACTION C1/(C2-C5) .567138
RATES ARE IN UNITS OF MMOLES PER HOUR
AVG MOL WTS ARE USED FOR C2 AND C3 HYDROCBNS DUE TO FUSED PEAKS
TOT MOLE C PRODUCED AS CO2 AND OLE&PARA/MOLE CO CONV= .7064

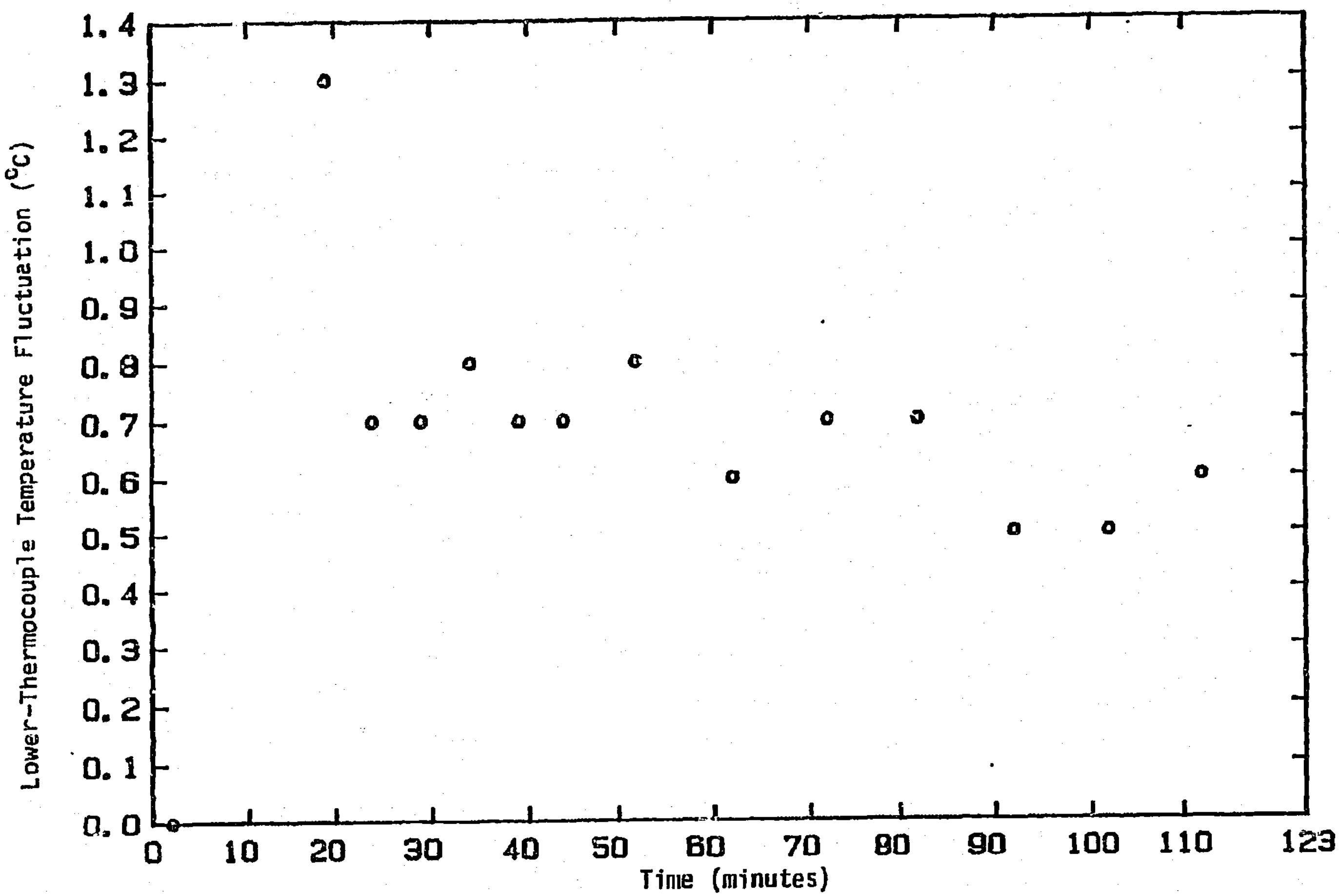

Figure B.1. Lower-Thermocouple Temperature Fluctuation as a Function of Time for Run B-2 Using a Feed Gas of 2.08:1 H_2/CO Ratio at 360°C and 2220 kPa.

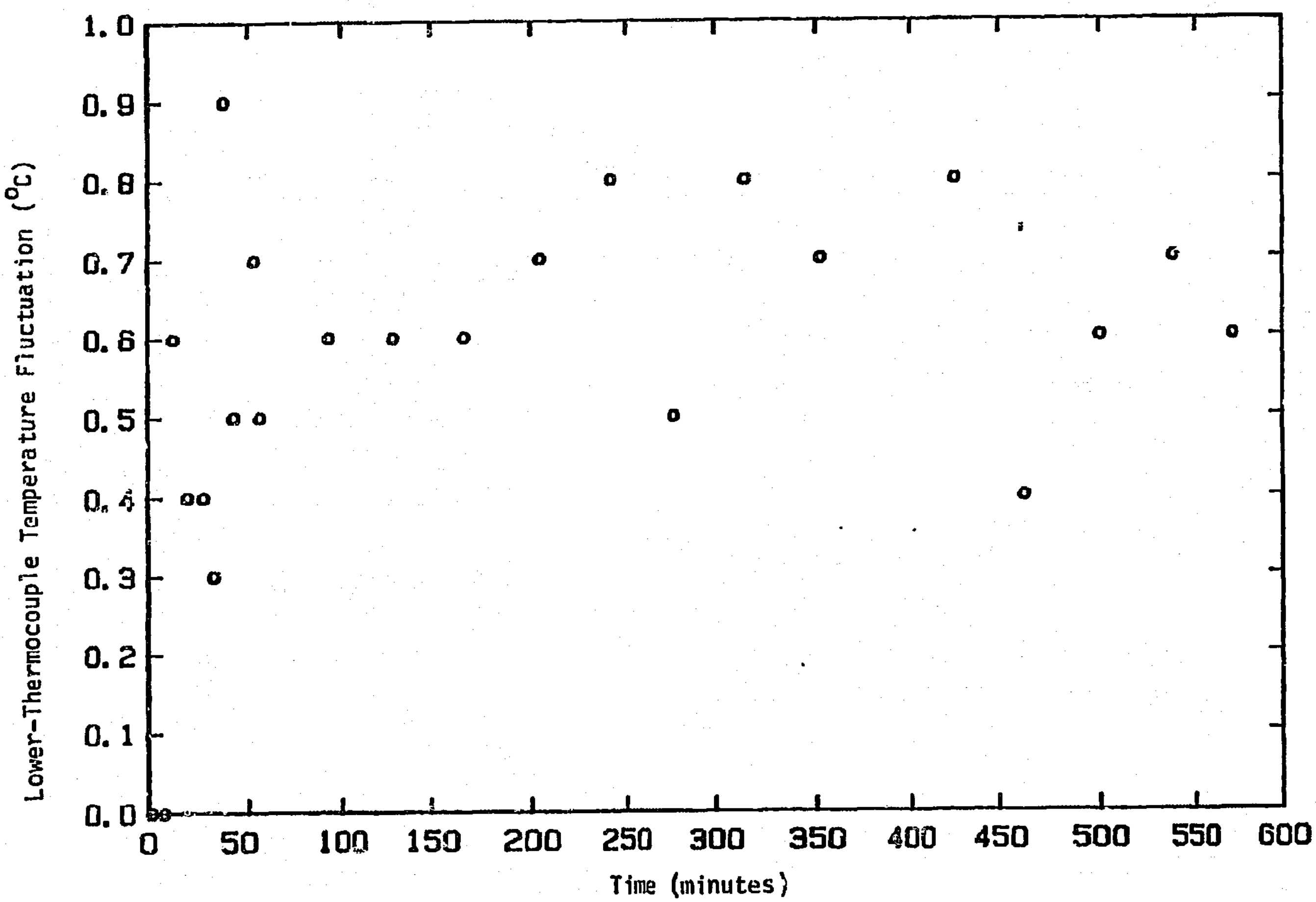

Figure B.2. Lower-Thermocouple Temperature Fluctuation as a Function of Time for Run B-3 Using a Feed Gas of 4:1 H_2/CO Ratio at 360°C and 2220 kPa.

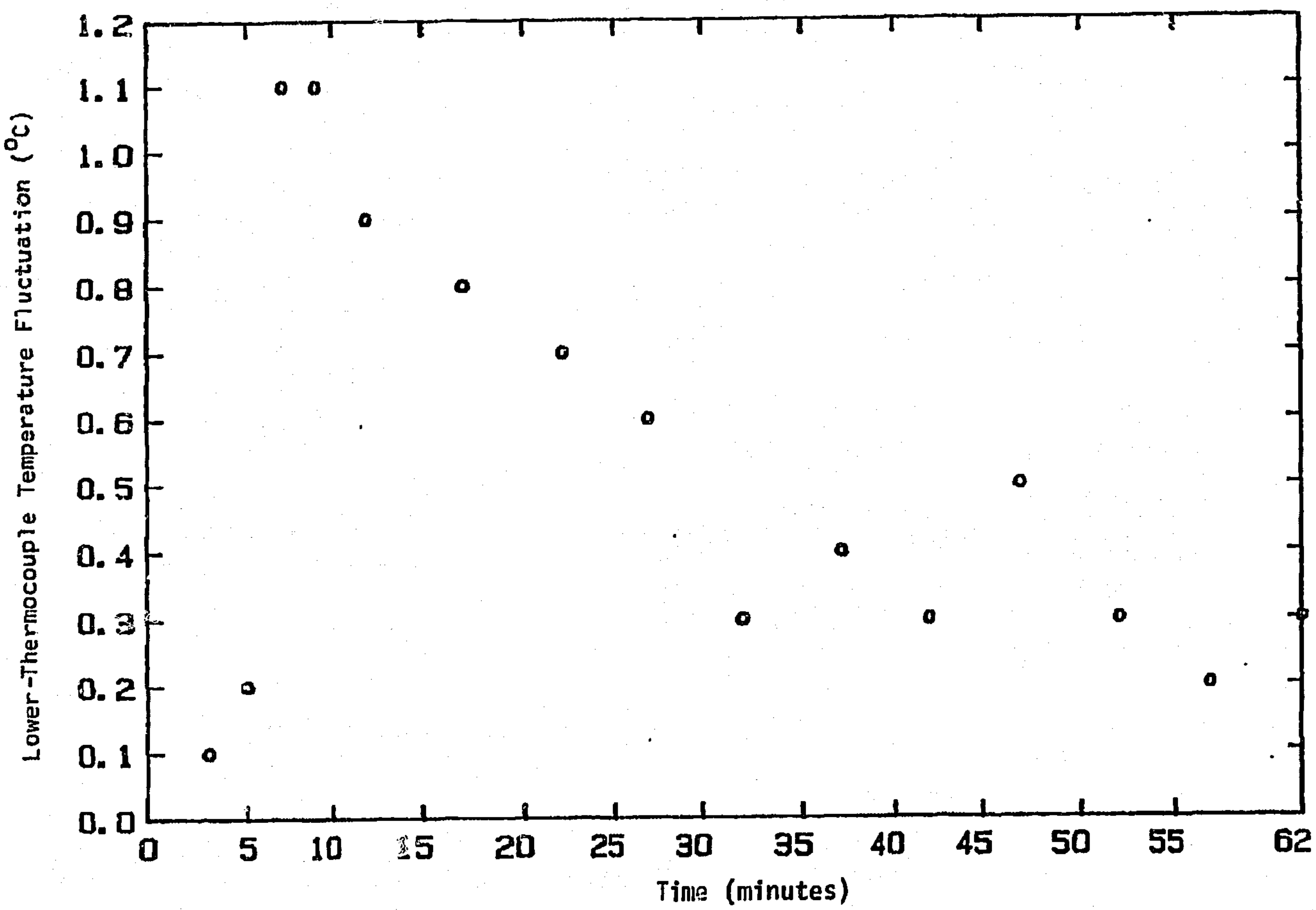

Figure B.3. Lower-Thermocouple Temperature Fluctuation as a Function of Time for Run B-4 Using a Feed Gas of 1.03:1 H_2/CO Ratio at 360°C and 2220 kPa.

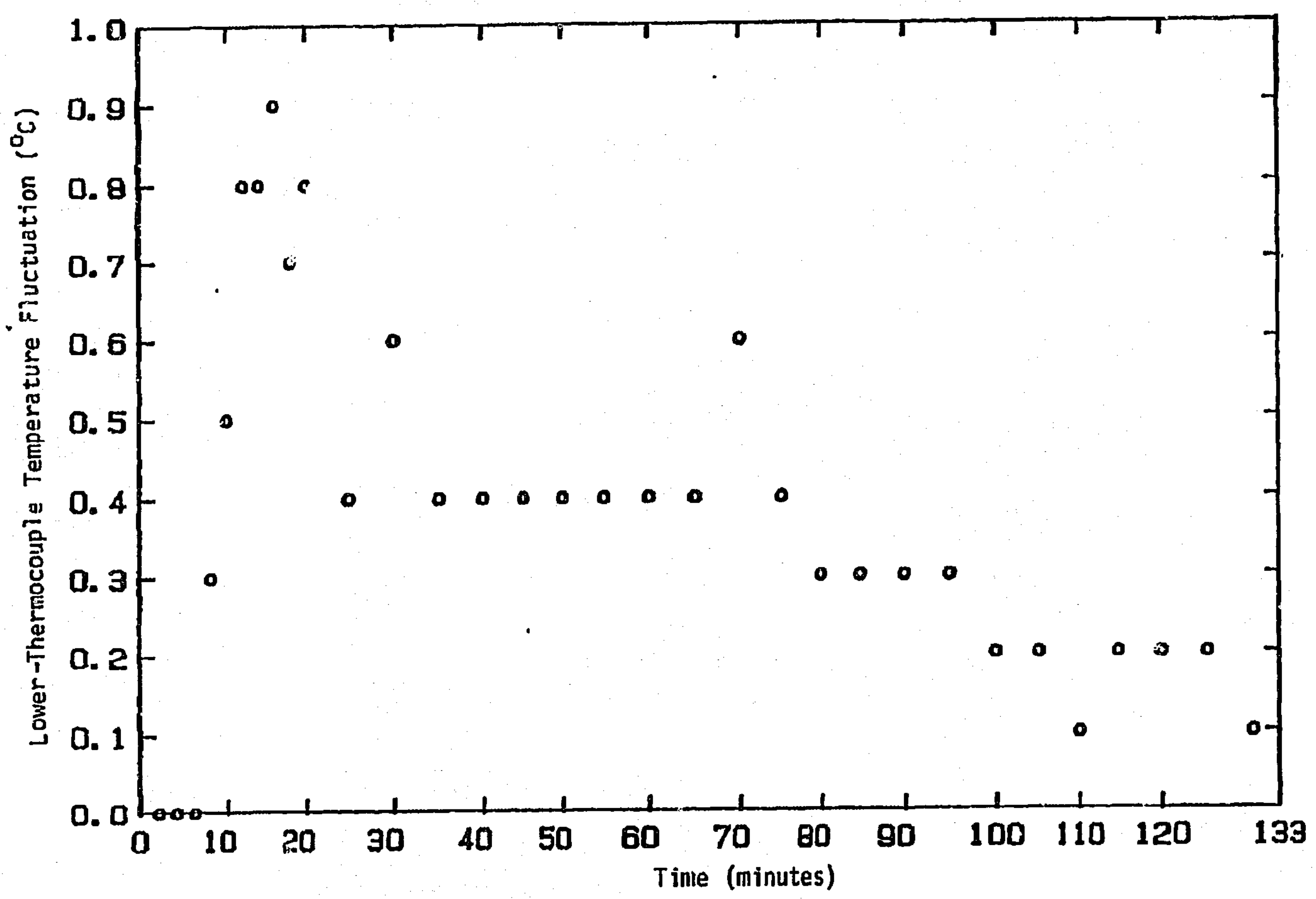

Figure B.4. Lower-Thermocouple Temperature Fluctuation as a Function of Time for Run B-5 Using a Feed Gas of 1.03:1 H_2/CO Ratio at 360°C and 2220 kPa.

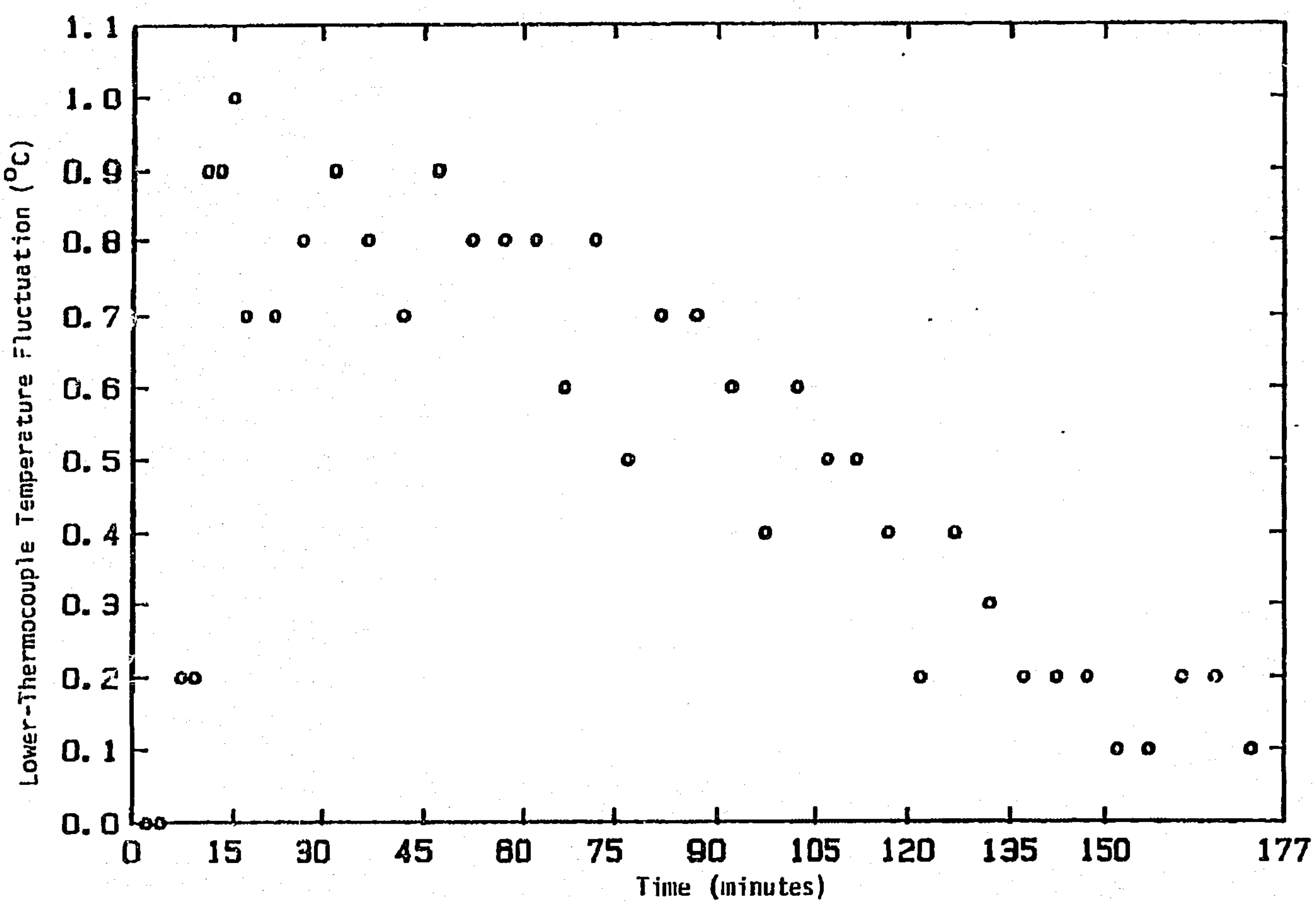

Figure B.5. Lower-Thermocouple Temperature Fluctuation as a Function of Time for Run B-6 Using a Feed Gas of 2.08:1 H_2/CO Ratio at 360°C and 2220 kPa.

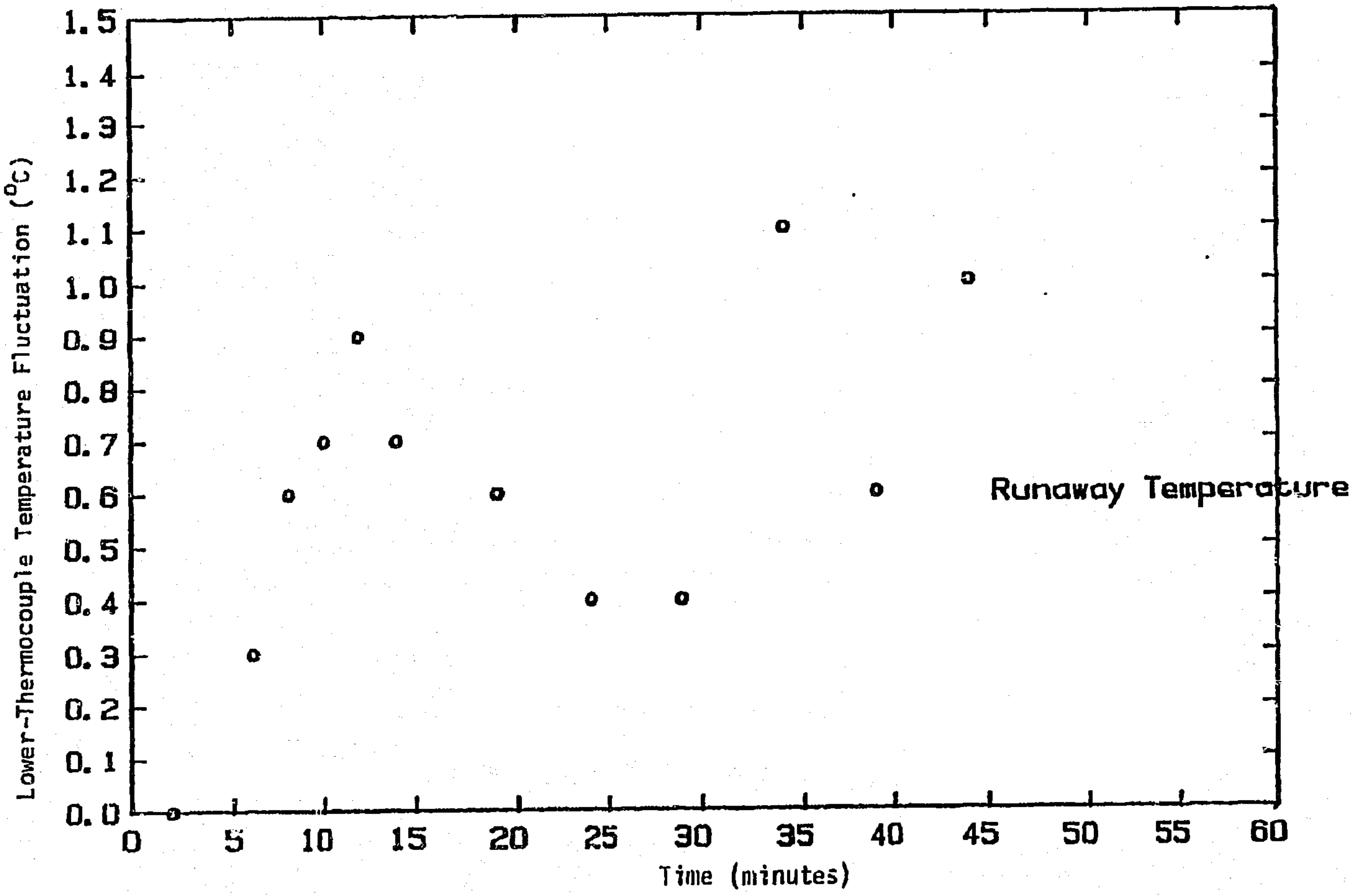

Figure B.6. Lower-Thermocouple Temperature Fluctuation as a Function of Time for Run C-2 Using a Feed Gas of 1.03:1 H_2/CO Ratio at 400°C and 2220 kPa.

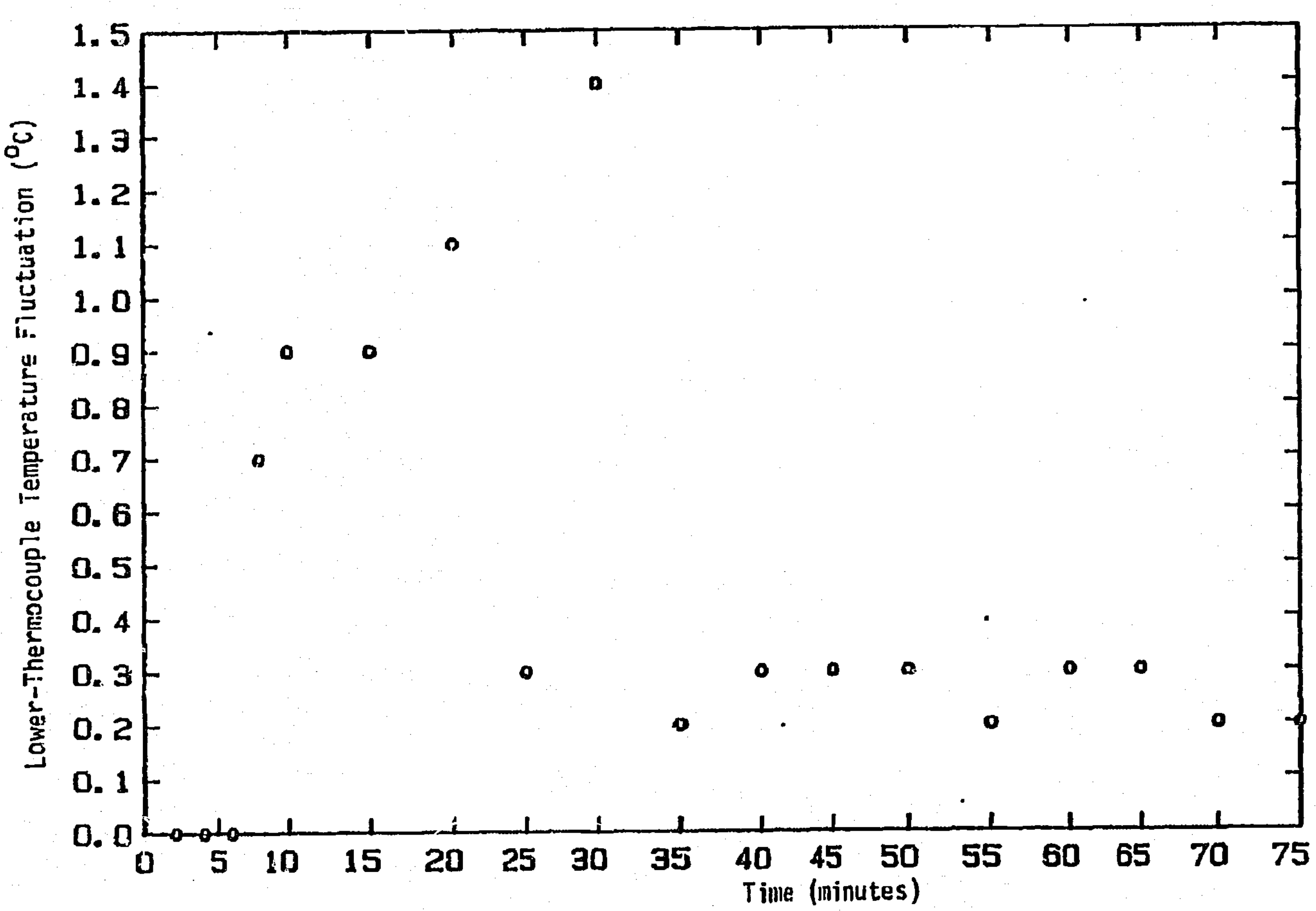

Figure B.7. Lower-Thermocouple Temperature Fluctuation as a Function of Time for Run D-1 Using a Feed Gas of 1.03:1 H_2/CO Ratio at 380°C and 2220 kPa.

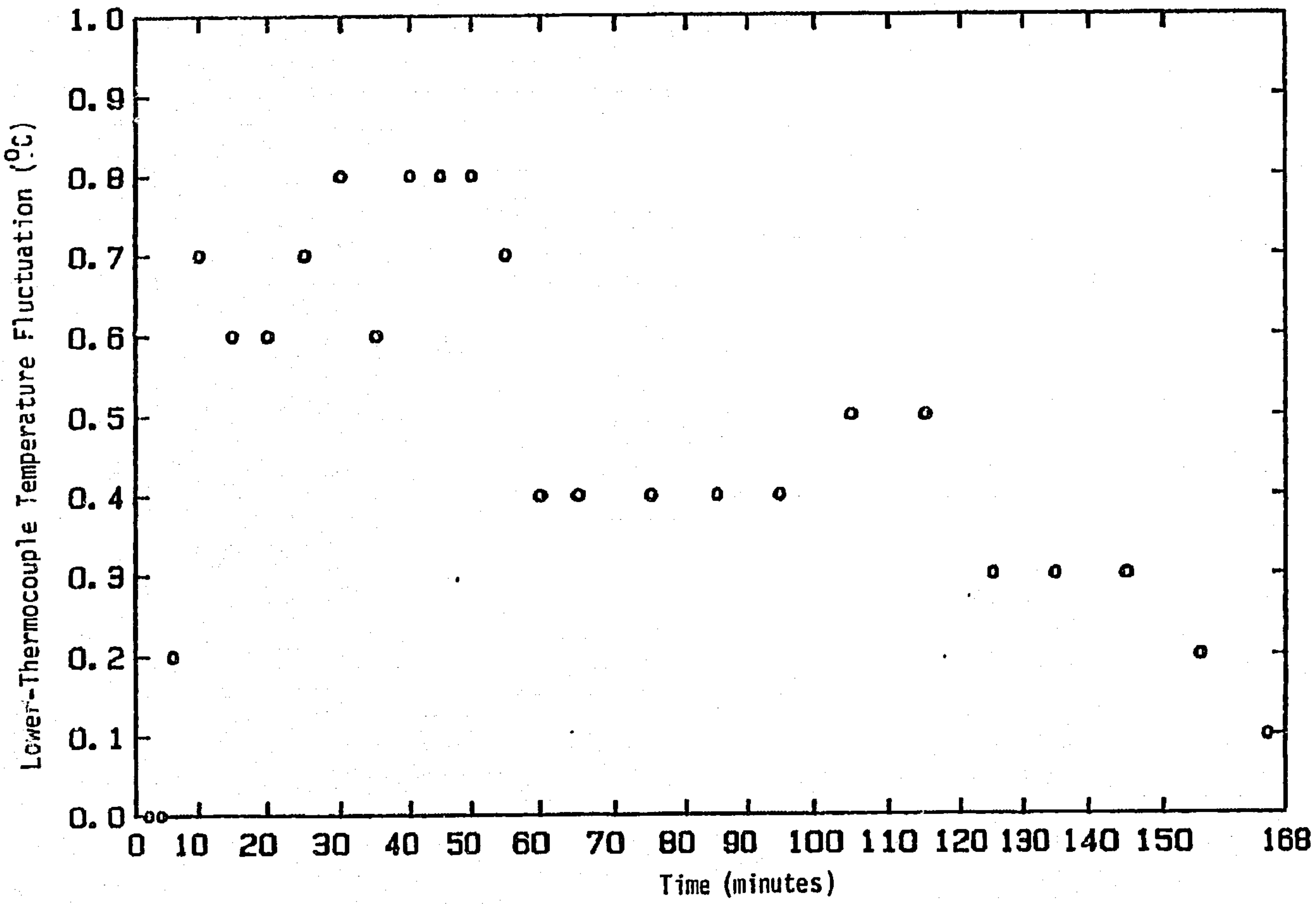

Figure B.8. Lower-Thermocouple Temperature Fluctuation as a Function of Time for Run D-2 Using a Feed Gas of 2.08:1 H_2/CO Ratio at 380°C and 2220 kPa.

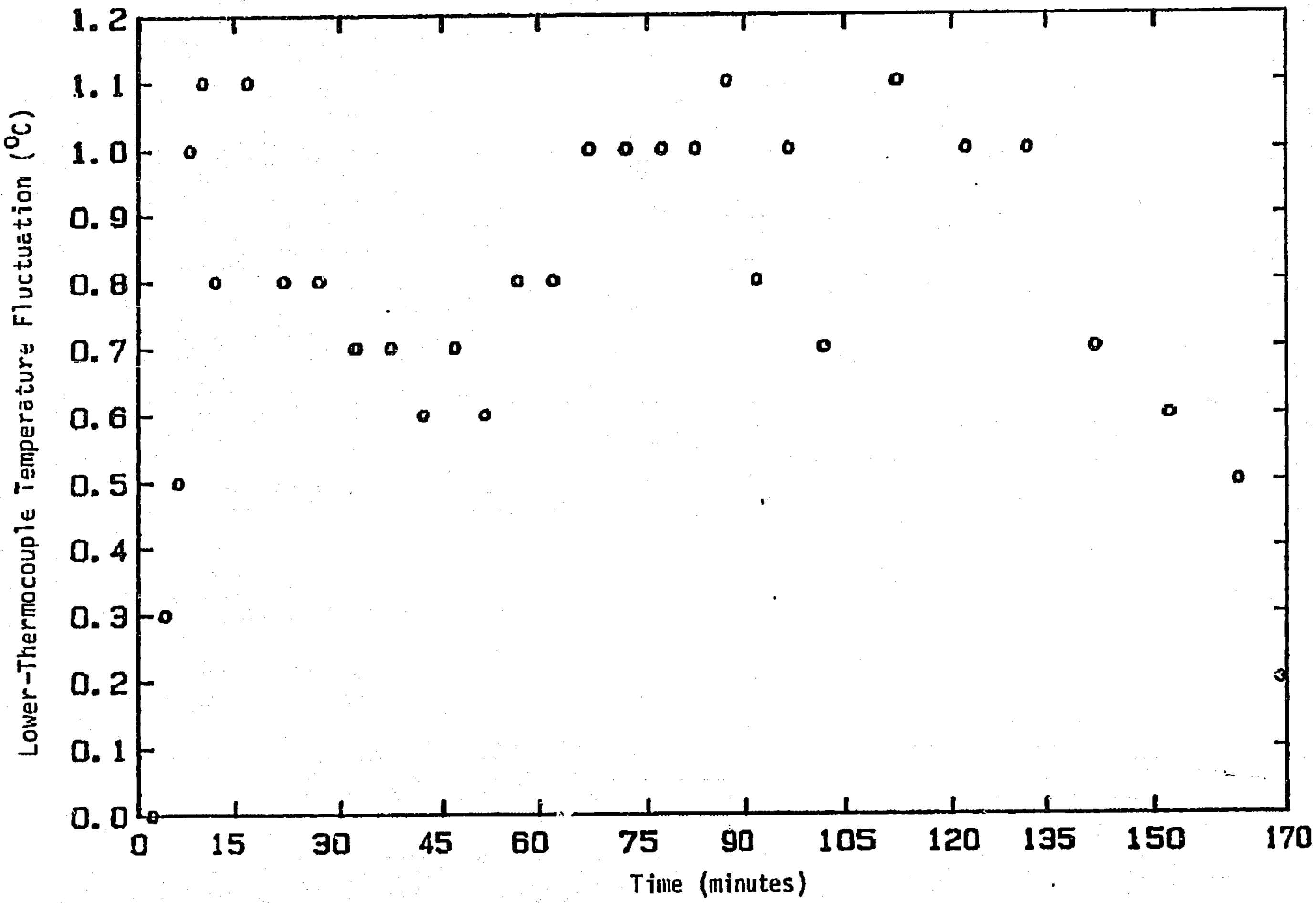

Figure B.9. Lower-Thermocouple Temperature Fluctuation as a Function of Time for Run E-1 Using a Feed Gas of 208:1 H_2/CO Ratio at 390°C and 2220 kPa.

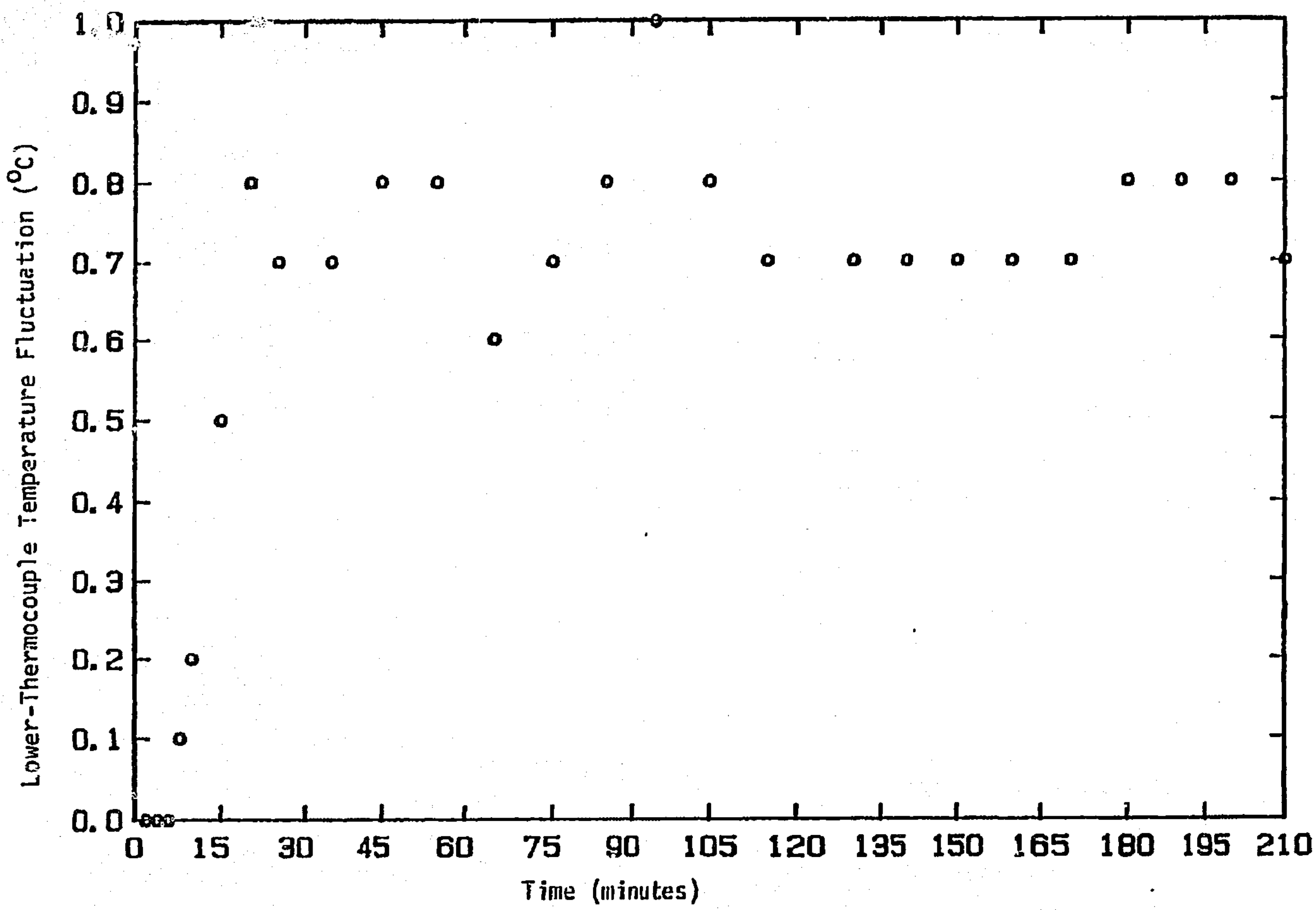

Figure B.10. Lower-Thermocouple Temperature Fluctuation as a Function of Time for Run F-1 Using a Feed Gas of 4:1 H_2/CO Ratio at 395°C and 2220 kPa.

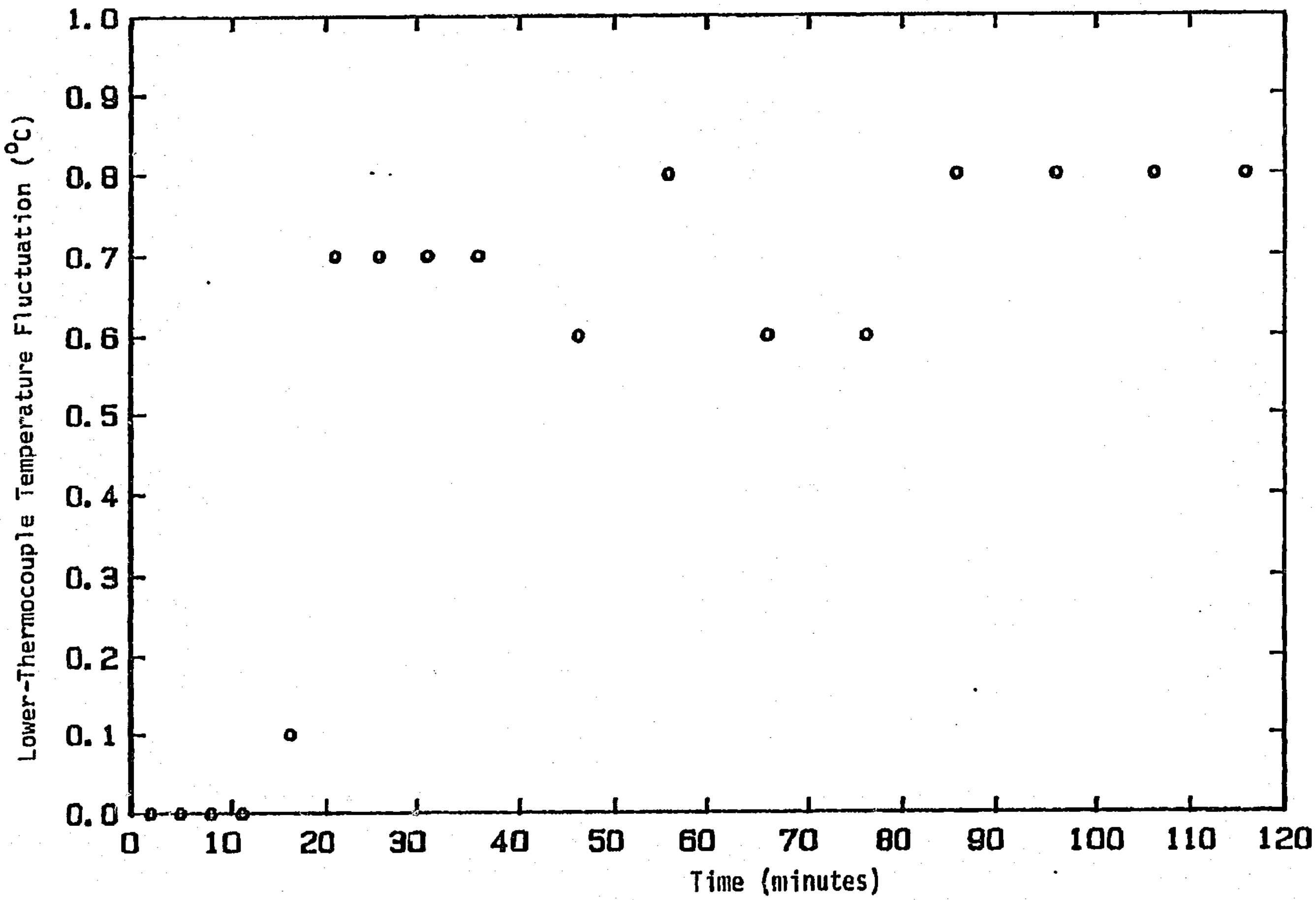

Figure B.11. Lower-Thermocouple Temperature Fluctuation as a Function of Time for Run F-2 Using a Feed Gas of 4:1 H_2/CO Ratio at 395°C and 2220 kPa.

APPENDIX C

Microcomputer Programs for: (1) Feed-Gas Cycling and Product Analysis During Unsteady-State Fischer-Tropsch Synthesis; (2) Data Compilation for Light-Gas Products (MASSBAL.BAS); and (3) Data Compilation for the Hydrocarbon Product Distribution from Capillary Analysis (HEAVY.BAS).

```
10 GOSUB 540
20 REM  THIS SECTION SWITCHES S- AND F-GAS SOLENOID VALVES
30 REM  AS WELL AS THE SLIDING PLUG.
40 CN=0
50 OUT 215,128
60 OUT 212,16
70 OUT 213,4
80 CN=CN+1
90 GOSUB 230
100 IF CN=10 THEN GOSUB 1690 ELSE
110 IF CN=20  THEN GOSUB 2020 ELSE
120 FOR I=1 TO 1500
130 NEXT I
140 OUT 215,128
150 OUT 212,8
160 OUT 213,6
170 GOSUB 380
180 FOR I=1 TO 750
190 NEXT I
200 GOTO 50
210 REM  THIS SUBROUTINE CONTROLS CHANGES IN COMPUTER GRAPHICS DURING
220 REM  CYCLING.
230 PRINT CHR$(27);CHR$(70);
240 PRINT CHR$(27);CHR$(89);CHR$(37);CHR$(37);CHR$(97);
250 PRINT CHR$(27);CHR$(89);CHR$(37);CHR$(43);CHR$(97);
260 PRINT CHR$(27);CHR$(89);CHR$(37);CHR$(71);CHR$(104);
270 PRINT CHR$(27);CHR$(89);CHR$(37);CHR$(92);CHR$(97);
280 PRINT CHR$(27);CHR$(89);CHR$(37);CHR$(98);CHR$(107);
290 PRINT CHR$(27);CHR$(89);CHR$(48);CHR$(63);CHR$(105);
300 PRINT CHR$(105);CHR$(105);CHR$(32);CHR$(32);CHR$(32);
310 PRINT CHR$(32);CHR$(32);CHR$(125);
320 PRINT CHR$(27);CHR$(71);
330 PRINT CHR$(27);CHR$(112);CHR$(27);CHR$(89);CHR$(54);CHR$(47);
340 PRINT "********** F-GAS REACTOR FEED **********";
350 PRINT "CYCLE # =";CN;"   ";
360 PRINT CHR$(27);CHR$(113);
370 RETURN
380 PRINT CHR$(27);CHR$(70);
390 PRINT CHR$(27);CHR$(89);CHR$(37);CHR$(37);CHR$(97);
400 PRINT CHR$(27);CHR$(89);CHR$(37);CHR$(43);CHR$(107);
410 PRINT CHR$(27);CHR$(89);CHR$(37);CHR$(71);CHR$(104);
420 PRINT CHR$(27);CHR$(89);CHR$(37);CHR$(92);CHR$(97);
430 PRINT CHR$(27);CHR$(89);CHR$(37);CHR$(98);CHR$(97);
440 PRINT CHR$(27);CHR$(89);CHR$(48);CHR$(63);CHR$(124);
450 PRINT CHR$(32);CHR$(32);CHR$(32);CHR$(32);CHR$(32);
460 PRINT CHR$(105);CHR$(105);CHR$(105);
470 PRINT CHR$(27);CHR$(71);
480 PRINT CHR$(27);CHR$(112);CHR$(27);CHR$(89);CHR$(54);CHR$(47);
490 PRINT "********** S-GAS REACTOR FEED **********";
500 PRINT CHR$(27);CHR$(113);
510 RETURN
520 REM THIS SUBROUTINE DRAWS A DIAGRAM OF THE REACTOR SYSTEM
530 REM AND ALLOWS VISUAL MONITORING OF THE GAS SWITCHING.
540 PRINT CHR$(27);CHR$(89);CHR$(27);CHR$(70);
550 FOR J=1 TO 6
560 PRINT CHR$(32);
570 NEXT J
580 PRINT "S-GAS";
590 FOR J=1 TO 50
600 PRINT CHR$(32);
610 NEXT J
620 PRINT "F-GAS"
630 FOR I=1 TO 4
640 FOR J=1 TO 4
650 PRINT CHR$(32);
660 NEXT J
670 PRINT CHR$(32);CHR$(96);CHR$(32);CHR$(32);CHR$(32);CHR$(32);CHR$(32);
680 PRINT CHR$(96);
690 FOR J=1 TO 42
700 PRINT CHR$(32);
710 NEXT J
720 PRINT CHR$(32);CHR$(96);CHR$(32);CHR$(32);CHR$(32);CHR$(32);CHR$(32);
```

Figure C.1 A Microcomputer Program for Control of Feed-Gas Cycling and Product Sampling During Unsteady-State Fisher-Tropsch Synthesis Experiments.

```
730 PRINT CHR$(96)
740 NEXT I
750 FOR J=1 TO 35
760 PRINT CHR$(32);
770 NEXT J
780 PRINT CHR$(102);
790 FOR J=1 TO 3
800 PRINT CHR$(97);
810 NEXT J
820 PRINT CHR$(96);
830 FOR J=1 TO 4
840 PRINT CHR$(97);
850 NEXT J
860 PRINT CHR$(32);
870 PRINT "F-T PRODUCT"
880 FOR I=1 TO 7
890 FOR J=1 TO 4
900 PRINT CHR$(32);
910 NEXT J
920 PRINT CHR$(32);CHR$(96);CHR$(32);CHR$(32);CHR$(32);CHR$(32);CHR$(32);
930 PRINT CHR$(96);
940 FOR J=1 TO 23
950 PRINT CHR$(32);
960 NEXT J
970 PRINT CHR$(96);
980 FOR J=1 TO 24
990 PRINT CHR$(32);
1000 NEXT J
1010 PRINT CHR$(96);
1020 FOR J=1 TO 5
1030 PRINT CHR$(32);
1040 NEXT J
1050 PRINT CHR$(96)
1060 NEXT I
1070 FOR I=1 TO 3
1080 FOR J=1 TO 5
1090 PRINT CHR$(32);
1100 NEXT J
1110 PRINT CHR$(96);
1120 FOR J=1 TO 5
1130 PRINT CHR$(32);
1140 NEXT J
1150 PRINT CHR$(96);
1160 FOR J=1 TO 19
1170 PRINT CHR$(32);
1180 NEXT J
1190 FOR J=1 TO 9
1200 PRINT CHR$(105);
1210 NEXT J
1220 FOR J=1 TO 20
1230 PRINT CHR$(32);
1240 NEXT J
1250 PRINT CHR$(96);
1260 FOR J=1 TO 5
1270 PRINT CHR$(32);
1280 NEXT J
1290 PRINT CHR$(96)
1300 NEXT I
1310 FOR J=1 TO 5
1320 PRINT CHR$(32);
1330 NEXT J
1340 PRINT CHR$(101);
1350 FOR J=1 TO 5
1360 PRINT CHR$(97);
1370 NEXT J
1380 PRINT CHR$(117);
1390 FOR J=1 TO 19
1400 PRINT CHR$(97);
1410 NEXT J
1420 FOR J=1 TO 5
1430 PRINT CHR$(105);
1440 NEXT J
```

Figure C.1 (Continued)

```
1450 FOR J=1 TO 5
1460 PRINT CHR$(32);
1470 NEXT J
1480 PRINT CHR$(125);
1490 FOR J=1 TO 20
1500 PRINT CHR$(97);
1510 NEXT J
1520 PRINT CHR$(117);
1530 FOR J=1 TO 5
1540 PRINT CHR$(97);
1550 NEXT J
1560 PRINT CHR$(100)
1570 FOR J=1 TO 31
1580 PRINT CHR$(32);
1590 NEXT J
1600 FOR J=1 TO 8
1610 PRINT CHR$(105);
1620 NEXT J
1630 PRINT CHR$(105)
1640 PRINT CHR$(27);CHR$(71)
1650 RETURN
1660 REM THIS SUBROUTINE CAUSES A SAMPLE TO BE FLUSHED INTO THE
1670 REM PACKED COLUMN OF THE GAS CHROMATOGRAPH BY TURNING THE
1680 REM SAMPLING VALVE.
1690 FOR I=1 TO 80
1700 PRINT CHR$(27);CHR$(60);CHR$(7);
1710 PRINT CHR$(27);CHR$(91);CHR$(63);CHR$(50);CHR$(104);
1720 NEXT I
1730 PRINT CHR$(27);CHR$(106);
1740 CR=5
1750 PRINT CHR$(27);CHR$(120);CHR$(49);
1760 PRINT CHR$(27);CHR$(60);CHR$(7);
1770 PRINT CHR$(27);CHR$(91);CHR$(63);CHR$(50);CHR$(104);
1780 PRINT CHR$(27);CHR$(89);CHR$(56);CHR$(32);
1790 IF CR=0 THEN PRINT ">>>LIGHT GAS SAMPLING<<<<<<<<<<<<<<<<<<<<"  ELSE
1800 IF CR=0 THEN 1820 ELSE
1810 PRINT "            ";CR;"                                            ";
1820 CR=CR-1
1830 FOR J=1 TO 65
1840 NEXT J
1850 IF CR<0 THEN 1870 ELSE
1860 GOTO 1760
1870 PRINT CHR$(27);CHR$(107);
1880 OUT 215,128
1890 OUT 213,4
1900 OUT 212,16
1910 OUT 214,128
1920 FOR I=1 TO 250
1930 NEXT I
1940 OUT 215,128
1950 OUT 213,4
1960 OUT 212,16
1970 OUT 214,0
1980 I=1500
1990 RETURN
2000 REM  THIS SUBROUTINE TURNS THE SAMPLING VALVE EFFECTIVELY
2010 REM  BACKFLUSHING THE PACKED COLUMN.
2020 PRINT CHR$(27);CHR$(106);
2030 PRINT CHR$(27);CHR$(120);CHR$(49);
2040 PRINT CHR$(27);CHR$(89);CHR$(56);CHR$(32);
2050 PRINT CHR$(27);CHR$(60);CHR$(7);
2060 PRINT CHR$(27);CHR$(91);CHR$(63);CHR$(50);CHR$(104);
2070 PRINT ">>>THE PACKED COLUMN IS BEING BACKFLUSHED<<<"
2080 PRINT CHR$(27);CHR$(107);
2090 OUT 215,128
2100 OUT 213,4
2110 OUT 212,144
2120 OUT 214,0
2130 FOR I=1 TO 250
2140 NEXT I
2150 OUT 215,128
2160 OUT 213,4
2170 OUT 212,16
2180 OUT 214,0
2190 CN=0
2200 RETURN
```

Figure C.1 (Continued)