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FINAL

TECHNOLOGY DEVELOPMENT FOR COBALT F-T CATALYSTS

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EXECUTIVE SUMMARY

During the 9th quarter of the project, results have led to a number of important conclusions.

Vista B γ - Al_2O_3 still seems to be the best alumina to use. A catalyst prepared by Calsicat using Condea alumina, which has a better initial particle size distribution for the SBCR requiring less sieving and discarding, was found to exhibit a much lower activity than a similar formulation using Vista B. The exact cause of this difference is not known since the Condea alumina has a suitable level of S impurities, surface area, and pore structure.

All catalysts prepared to date by Calsicat using Vista B have exhibited excellent particle size retention characteristics in the SBCR. Typical particle size reductions have been in the range of 0.5-2.0%.

SBCR trials made with a Co catalyst prepared by Calsicat, reduced, and coated with Soya confirmed that Soya/wax coating of the reduced catalysts does not protect the Co catalysts sufficiently from reoxidation to eliminate the need for gas phase reduction prior to SBC reaction. Co catalysts appear not to be able to be reduced suitably when suspended in a hydrocarbon liquid phase.

The optimum loading of Zr in Co/SiO_2 catalysts in order to promote activity is on the order of 4 wt%. Loadings as high as 15 wt% cause a significant reduction in overall activity. This has been confirmed by both fixed-bed and SBC reaction results. La promotion of Co/SiO_2 appears to give a rate enhancement similarly to Zr in the gas phase; however, promotion of Co/SiO_2 at the level of 8.5 wt% La gave lower activity in the SBCR than Co/SiO_2 without La.

Catalyst pretreatment effects appear to be a function of preparation. For example, catalysts

prepared using an organic solution seem to give higher activity when reduced directly and not calcined.

Co loadings of 30 wt% on alumina exhibit significantly higher activities than 20 wt% Co catalysts in excess of a linear increase. It is suggested that this is due to the fact that a greater percent of the additional Co is reducible to the metal. It is known that there is ca.3 wt% of the Co which goes to form Co aluminates. Another significant portion of the Co is not able to be completely reduced due to interaction with the oxide support. However, these effects are mostly apparent in the initial 10 wt% Co loading.

Using a mixture of Co/Al₂O₃ and a WGS catalyst results in higher activity and CO₂ formation in the SBCR. Using 15 g of the Co catalyst and either 0, 5, or 15 g of CuCr/Al₂O₃ produced CO conversions of 27.1, 29.3, and 35.8%, respectively, and CO₂ selectivities of 0.8, 2.0, and 6.3%, respectively, at 240°C.

Finally, significant work has focussed on pushing conversion to higher levels. This has been achieved by raising the temperature and lowering the flow rate. To date, the maximum conversion obtained has been 62.9% at 260°C and 540 SL/h (20% N₂ in a H₂ + CO mixture). However, low flow rates and higher temperatures result in greater heat being released than can be in many cases adequately removed since the SBCR does not have an internal heat exchanger. This results in difficulties in temperature control. In addition, the highly active and selective catalysts developed to date for use at lower temperatures start to lose activity above 240°C. This loss of activity is especially great above 260°C.

I. INTRODUCTION AND BACKGROUND

The goal of this project is the development of a commercially viable, cobalt-based Fischer-Tropsch (F-T) catalyst for use in a slurry bubble column reactor. Cobalt-based catalysts have long been known as being active for F-T synthesis. They typically possess greater activity than iron-based catalysts, historically the predominant catalyst being used commercially for the conversion of syngas based on coal, but possess two disadvantages that somewhat lessen its value: (1) cobalt tends to make more methane than iron does, and (2) cobalt is less versatile with low H_2/CO ratio syngas due to its lack of water-gas shift activity. Therefore, the major objectives of this work are (1) to develop a cobalt-based F-T catalyst with low (<5%) methane selectivity, (2) to develop a cobalt-based F-T catalyst with water-gas shift activity, and (3) to combine both these improvements into one catalyst. It will be demonstrated that these catalysts have the desired activity, selectivity, and life, and can be made reproducibly. Following this experimental work, a design and a cost estimate will be prepared for a plant to produce sufficient quantities of catalyst for scale-up studies.

II. PROJECT DESCRIPTION

The Cobalt Fischer-Tropsch Catalyst Project is divided into five tasks designed to systematically develop catalysts through thorough investigation of influences of various promoters, additives, and supports on minimizing methane selectivity and increasing water-gas-shift activity.

Cobalt has long been known to be an excellent catalyst for the F-T synthesis. Nevertheless, all currently operating F-T plants feeding coal produced syngas use iron catalysts, in spite of the fact that cobalt-based catalysts have higher activity. Two factors that lower cobalt's value as a F-T catalyst are its poorer selectivity, that is, it produces more methane and its inability to be used with low

H₂/CO ratio syngas because of its lack of water-gas shift activity. The broad objective of this proposal is to overcome these deficiencies.

In pursuing F-T catalyst development, there are several aspects that need to be considered. These are catalyst formulation, catalyst pretreatment, and catalyst performance. All of these aspects will be dealt with in this project.

In broad terms, the technical approach that will be used is outlined below.

- a. Conduct a thorough review of the literature on F-T synthesis, both the journal literature and the patent literature. In this review, identify approaches for improving methane selectivity of cobalt-based catalysts, identify additives that have WGS activity, identify catalyst formulation options, and define critical pretreatment parameters.
- b. Based on the above review, develop a list of catalyst formulations with potential for low methane selectivity and a list of catalyst formulations with potential for promoting the WGS reaction.
- c. Screen these catalysts in a small, fixed-bed reactor. If no catalyst meets the target specifications, go back to step b. Otherwise, run catalysts that meet discrimination criteria in a slurry bubble column reactor.
- d. Once catalysts with low methane selectivity and WGS activity have been identified, develop a catalyst combining both these functions and test as described above.
- e. Having found catalysts that meet the desired criteria for activity and selectivity, optimize the pretreatment conditions.
- f. Demonstrate catalyst reproducibility by having a commercial subcontractor prepare multiple batches for testing.

- g. Demonstrate catalyst stability by running aging tests in a slurry bubble column reactor.
- h. Based on above results, prepare a design for a plant to produce demonstration scale batches of catalyst. Develop capital and operating costs of this plant.

The program to carry out the above outlined work will consist of five major tasks:

Task 1 -- Catalyst Development

Task 2 -- Catalyst Testing

Task 3 -- Catalyst Reproducibility Tests

Task 4 -- Catalyst Aging Tests

Task 5 -- Preliminary Design and Cost Estimate for a Demonstration

Scale Catalyst Production Facility

All aspects of the catalyst's role in F-T processing will be addressed, including catalyst preparation, pretreatment, and performance (activity, selectivity, and aging). In addition to gathering process data, the catalyst will be subjected to a number of analytical measurements at each stage to see how various treatments have affected the catalyst and its performance.

III. OBJECTIVES

The objective of this project is to investigate the influence of various promoters, additives, and supports on minimizing the methane selectivity and increasing the water-gas shift (WGS) activity of cobalt (Co) Fischer-Tropsch (F-T) catalysts. The ultimate goal of this investigation is to identify and demonstrate a catalyst preparation procedure that will be scaled up for the reproducible synthesis of commercial quantities of supported CO catalysts with desired activity, selectivity, and lifetime for use in F-T synthesis in three-phase slurry bubble column reactors.

IV. SUMMARY OF WORK ACCOMPLISHED THIS QUARTER

Seven (7) new catalysts were formulated and prepared during this period under both subtasks 1.2 and 1.3. Two more catalysts were prepared by Calsicat.

The characterization of all the catalysts in order to determine their physical properties (BET surface area, pore volume, pore size diameter, particle size distribution), as well as the cobalt reducibility, extent of reduction, and dispersion) was continued.

Fixed-bed reactor testing of the catalysts was continued. Six (6) new catalysts were tested for their F-T synthesis performance.

An investigation of the effect of pretreatment in various atmospheres (calcination in air or nitrogen prior to reduction in hydrogen, direct reduction without prior calcination, and reduction-oxidation-reduction (ROR)) of a selected number of catalysts upon their performance for F-T synthesis was continued during this period.

A paper on "Zirconia Promotion of Fischer-Tropsch Cobalt catalysts: Behavior in Fixed-Bed and Slurry Bubble Column Reactors" was submitted for the preprints of the 209th ACS National Meeting, Division of Fuel Chemistry, Symposium on Synthesis Gas Chemistry, April 2-6, 1995 in Anaheim, CA.

Under subtask 2.2 during this reporting period a total of 11 runs were made in the two slurry bubble column reactors with eleven catalysts, including five on alumina, two from Calsicat, one WGS blend, and three on silica support. Four high CO conversion runs were made. Data were compiled to compare the CO conversions and product selectivities of the methane reduction catalysts.

V. DETAILED DESCRIPTION OF TECHNICAL PROGRESS

A. TASK 1: CATALYST DEVELOPMENT

a. Technology Assessment (Subtask 1.1)

Except for regular updating of the literature with the most recent publications, there was no activity during this period to report in this subtask.

b. Catalyst Formulation (Subtasks 1.2, 1.3, 1.4)

An updated list of all the catalysts formulated so far within Subtask 1.2 (including those catalysts listed in previous quarterly reports) is given in Table 1 with their compositions. The last column of Table 1 indicates whether the catalyst has already been prepared. Out of the 78 catalysts listed in Table 1, two (CAL.09-CAL.10) were prepared by Calsicat. Seven (7) new Co catalysts (highlighted in Table 1) were formulated and prepared during this period. The detailed formulations of the new catalysts are given in Appendix A.

Co.057, is similar to Co.055, with SiO_2 as the support instead of Al_2O_3 . Co.058 and Co.059, both alumina-supported catalysts, are similar to Co.055 and Co.015, but without Re or Ru promoters. Co.063, also an alumina-supported catalyst, is similar to Co.034, but with La_2O_3 replacing ZrO_2 as the oxide promoter. These four catalysts were formulated in order to investigate further the effects of La_2O_3 on the catalytic properties of Co. La_2O_3 addition was found in previous formulations to enhance significantly the activity of cobalt for F-T synthesis.

Co.060-Co.062, all alumina-supported catalysts, were formulated with 30% Co loading in order to achieve higher conversion levels in the slurry bubble column reactor.

CAL.09-CAL.10 were formulated with the same composition as that of Co.047 which was selected as the low methane catalyst for the reproducibility test. They were both prepared in small

batches for formulation check and determination of the best pretreatment to adopt for the preparation of the larger batches to be used for the reproducibility tests. CAL.09 was calcined in nitrogen, reduced in hydrogen, and protected in soya instead of the paraffin wax used in some of the previous samples (CAL.07 and CAL.08). CAL.10 was prepared with a different alumina (Condea) than the one (Vista-B) used so far during this project. The Condea alumina was selected for its narrow particle size distribution in the range required for slurry bubble column applications.

Under Subtask 1.3 five (5) new Co catalysts with a water-gas shift component were prepared. CoW.08 and CoW.09 are similar to catalysts which had been prepared previously, but with different loadings of the various metals. CoW.08, similar to CoW.05, but with 30% Co, was prepared by pre-impregnating the alumina with Cu-CrO and calcining this support precursor at 750 °C, before incorporating the cobalt. CoW.09, similar to CoW.06, but with 10% Cu and 8% Cr, was prepared in a similar way. CoW10-CoW12 are all Co-Fe based catalysts with other promoters (Ru and K) on either alumina or silica. The list of these catalysts is given in Table 2 with their composition, and the detailed formulations are included in Appendix A.

c. Catalyst Pretreatment (Subtask 1.5)

The investigation of the effects of pretreatment on the catalytic properties of a selected number of catalysts (Co.004, Co.015, Co.017, Co.053, Co.055 and Co.056) was continued during this period. Except for Co.053, all the catalysts were promoted with La_2O_3 and Ru or Re in the case of Co.055. The effects of pretreatment in various atmosphere (calcination in air or in nitrogen prior to reduction in H_2 , direct reduction in H_2 without prior calcination, and reduction-oxidation-reduction (ROR)) were addressed. The results are included in subtask 2.1 which summarizes the results

obtained when these catalysts were tested in the fixed bed reactor.

d. Catalyst Characterization (Subtask 1.6)

(1) Physical Properties

Table 3 gives an update on the physical property measurements carried out so far. Nitrogen physisorption at 77 K was used to obtain surface area, pore volume and pore diameter of the calcined catalysts. Average particle size of the catalysts was determined using a Microtrac particle size analyzer.

(2) Static Hydrogen Chemisorption

An updated summary of the properties of the Co catalysts as determined by H₂ chemisorption is given in Table 4. Metal dispersions and particle sizes of CAL.09 and CAL.010 were determined by CO chemisorption carried out at Calsicat. Co.004, Co.015, Co.053, and Co.055 were characterized by static hydrogen chemisorption at the University of Pittsburgh following different pretreatments.

(3) Temperature Programmed Reduction (TPR)

TPR experiments were carried out in an automated Altamira Instruments AMI-1 system. The procedure for these measurements was described in a previous quarterly report. All the TPR results obtained so far are summarized in Table 4.

B. TASK 2: CATALYST TESTING

a. Subtask 2.1 - Fixed Bed Reaction Studies:

1. F-T Synthesis

The reaction conditions and procedure were described in previous quarterly reports. Six (6) new catalysts (Co.044, Co.045, Co.056, Co.057, Co.060, CAL.10) were tested for the first time during this reporting period. Catalysts Co.004 (run #6-8), Co.015 (run #3), Co.017 (run #3), Co.053 (run #4-6), and Co.055 (run #4-7) were also retested following the different pretreatment procedures described in Subtask 1.5.

The performances of all these catalysts (highlighted in Table 5) at steady state are compared in Table 5 with those reported in the previous quarterly report. All the pertinent data (CO conversion, rates, product distributions, chain growth probabilities, Anderson-Schulz-Flory distributions, time-on-stream activity and Arrhenius plots when available) obtained with each run for each catalyst is given in Appendix B.

Co.044 and Co.045 were tested in order to investigate the effect of Zr loading on the catalytic properties of promoted Co/SiO₂ catalysts. These results and those obtained previously with similar formulations but different Zr loadings, indicate that Zr enhanced the activity of cobalt for F-T synthesis when it is pre-impregnated on the support. However, Zr loadings greater than 4 wt% did not seem to provide any significant effect beyond what was observed at the 4% level. Co.045 with its 15 wt% of Zr showed even lower activity for F-T synthesis than the catalysts containing 4 (Co.045) or 8.5 wt% (Co.024) of Zr.

Co.056 and Co.057, both SiO₂-supported catalysts, were tested in order to investigate the effect of La₂O₃ promotion on the catalytic properties of Co. The fixed-bed reactor results show that

La₂O₃ promotion had a similar enhancing effect on the activity of Co/SiO₂ catalysts for F-T synthesis to the effect observed with Zr promotion.

Co.060 was tested as part of an ongoing study of the effect of Co loading. The preliminary results indicate that, as the Co loading is increased beyond the 20 wt% level used in most of the catalysts formulated so far in this project, the additional cobalt interacts less with the support, thus resulting in a higher rate of syngas conversion per unit weight of Co.

Co.004, Co.015, Co.017, Co.053 and Co.055 were retested following various pretreatments prior to the standard reduction and reaction procedures. The results indicate that not only the pretreatment environment but also the preparation method (aqueous vs organic) may play a major role in determining the activity of these catalysts. For the catalysts prepared entirely by aqueous impregnation, the pretreatment environment (air, nitrogen, hydrogen, or ROR) did not seem to have any effect on the catalysts activity. However, when at least one step in the catalyst preparation involved an impregnation with an organic solution of one of the metal precursors, the catalyst exhibited a very high activity when it was directly reduced without prior calcination.

Finally, the last trial catalyst prepared at Calsicat, CAL.10, was also tested using the standard reaction conditions. It had a lower activity than that obtained with similar catalysts prepared with Vista-B alumina (e.g. CAL.05 or Co.047). The reason for such a behavior is not yet understood.

b. Subtask 2.2 - Slurry Bubble Column Testing ("SBCR")

1. Run Chronology

During this reporting period a total of 11 runs were performed in the SBCR's, Runs M3-30 through 34 and M4-22 through 27. A chronology of the experimental runs performed in the two

slurry bubble column reactors - M3 and M4 - is given in Appendix C. All comparisons of CO conversions and CH₄ selectivities discussed in this chronology were obtained from results obtained at the initial startup conditions, i.e. 240°C temperature, 450 psi pressure, and 2/1 H₂/CO feed gas ratio.

A complete summary of all runs made in the M3-SBCR is given in Table I in Appendix D. Four tables of data were prepared in order to compare catalyst activities for Runs 30 to 34 in M3-SBCR at the same run conditions (see Tables II, III, IV, and V in Appendix D).

A complete summary of all runs made in the M4-SBCR are given in Table VI, Appendix D. Four tables were prepared to compare catalyst activities for Runs 22 to 27 in M4-SBCR at the same run conditions (see Tables VII, VIII, IX, and X in Appendix D).

2. Discussion of Results

(a) Water-Gas Shift Activity Test

Run 22 was made in the M4-SBCR to evaluate the effect of adding a blend of equal amounts of two catalysts: 15.5 gm of Catalyst No. WGS.09 (water-gas shift catalyst) and 15.0 gm of Catalyst No. Co.005 (methane reduction). The CO conversion at startup conditions was considerably higher than observed with Catalyst Blend A in Run 14 in M4-SBCR, 35.6% vs. 29.3% (see Table 6). Also, the CO₂ selectivity was much higher, 6.3% vs. 2.0%. Some water-gas shift activity has occurred with this catalyst blend as demonstrated by the higher CO₂ yield and increase in CO conversion. Water-gas shift activity was also observed at all other run conditions.

(b) High CO Conversion Runs

Four high CO conversion runs were made during this reporting period. Three runs were made with a larger charge of catalyst, approximately 30 gm of Catalyst No. CO.053, and one run was made

with a normal charge of 15 gm of CALSICAT Catalyst No. CAL.10.

Run No. 30 in the M3-SBCR was started with a charge of 29.6 gm of Catalyst No. Co.053. The CO conversion at startup conditions was 41.8%, the same as observed in Run 29. CO conversion increased to 46.9% at 260°C, but dropped to 41.4% at 280°C. The CO conversion did not change even at temperatures up to 320°C. The run was terminated when the gas preheater plugged when the heater temperature reached 550°C. It is speculated that the catalyst activity began to decrease above 260°C. Both recovered catalysts from Runs 29 and 30 contained small amounts of iron that came from carbonyls in the CO feed gas. The lead oxide filtration beds need to be changed more frequently to prevent iron from poisoning the catalysts. A summary of the data for Run 30 is given in Table 7.

Run No. 24 in the M4-SBCR was started with 28.5 gm of Catalyst No. Co.053, see Table 8. The CO conversion at startup conditions was 50.4%, which was the highest conversion observed to date. Raising the temperature to 260°C increased the CO conversion only to 55.3% (see Period 3). Lowering the total gas rate from 900 to 540 standard liters per hour ("SLH") with 20% N₂ in the feed gas yielded a CO conversion of 62.9% with a methane selectivity of 23.2%. At this point, the reactor temperature could not be controlled since there is no way to remove the heat of reaction from inside the SBCR reactor because there is no internal heat removal device. The heat of reaction can be removed only by lowering the feed gas temperature or increasing the inert gas (N₂) flow or some combination of both.

Run No. 33 in the M3-SBCR was started with 31.4 gm of a third batch of Catalyst No. Co.053. The CO conversion at startup conditions was 41.4%, which was the same as Runs 29 and 30 in the M3-SBCR. Several run periods were made in which the reactor pressure was lowered to

300 psi, the total feed gas rate was lowered to 400 SLH, and finally the reactor temperature was raised to 260°C (see Table 9). The CO conversion reached a maximum of only 49.2%. The conversion dropped to 16.1% when the reactor was returned to startup conditions. It is believed that most of the catalyst activity was lost at the higher temperature, 260°C. Alumina based catalysts have been found to be more sensitive to higher temperatures.

Run No. 26 in the M4-SBCR was started with a charge of 15.6 gm of Catalyst No. CAL.10. This catalyst which was received from Calsicat contained 20 wt% Co with 0.5% K and 0.5% Ru on Condea alumina. The initial CO conversion was only 21.9% which was 5% lower than other Calsicat catalysts made with Vista B alumina support. Several run periods were made to investigate the effect of lowering the total gas flow from 900 to 436 SLH and nitrogen concentration in the feed gas from 60% to 6% (see Table 10). The CO conversion decreased rather than increased as expected. This run will be repeated with a larger amount of a more active catalyst.

A lot has been learned from these five runs about obtaining high CO conversion levels. To obtain high conversions in the SBCR, the following recommendations should be investigated:

- o Operate at the lowest total gas feed rate that can keep the catalyst suspended.
- o Operate at the lowest N₂ feed rate. Some N₂ is necessary since it is used as an internal standard for calculating conversions.
- o Investigate higher cobalt loading on the catalyst.
- o Increase catalyst loading in the SBCR.
- o Determine maximum reaction temperature where catalyst begins to deactivate.

Further attempts to operate at higher CO conversions will be made during the next reporting

period using the above recommendations.

(c) Calsicat Catalyst Test Run

One run was made with a catalyst supplied by Calsicat that was hydrogen reduced and coated with Soya. The CO conversion at the initial startup conditions was only 17.4% (see Run 23 in M4-SBCR of Table 11). All of the wax coated catalysts supplied by Calsicat have shown low catalyst activity.

(d) Miscellaneous Runs Made to Evaluate the Effects of Various Promoters

One run was made with a catalyst similar to base case Catalyst No. Co.001 (20% Co, 1% Re, 1% La_2O_3 , plus 0.13% K on alumina) but without K (see Run 31 in M3-SBCR in Table 12). The CO conversion was high, 30% as expected, but the CH_4 selectivity was also high, 23.7%. The addition of K should reduce the methane selectivity, but would also reduce catalyst activity as reported previously.

A run was made with a catalyst containing 20% cobalt plus 8.5% La_2O_3 on silica support. The initial CO conversion was only 11.4%, see Run 25 in M4-SBCR in Table 6. The addition of a large amount of La_2O_3 had a negative effect on the catalyst activity, reducing the CO conversion about 7% (see Run No. 9 in M3 on Table 12).

One run was made to determine the effect of adding a larger amount of Zr on a cobalt-silica catalyst. Using a 15% Zr promoted catalyst yielded a 21% CO conversion compared to 25% CO conversion with an 8.5% Zr promoted catalyst, and 23.2% CO conversion with 0.7%Zr promoter (see Runs 17, 19, and 32 in M3-SBCR, Table 12). Adding a larger amount of Zr decreased catalyst activity. The optimum concentration of Zr needed can be determined by testing additional catalysts with Zr concentrations in the range of 0.7% to 15 wt%.

Another run was made to evaluate the effect of K concentration on catalyst activity. Catalyst No. Co.050 which contained 20% Co, 0.5% Ru, 8.5% Zr, and 0.1% K on silica yielded a CO conversion of 20.4%. The CO conversion and CH₄ selectivity were the same as obtained with Catalyst Co.048 that contained 0.3% K, see Runs 9 and 27 in the M4-SBCR on Table 6. The optimum amount of K to add for methane reduction without significantly lowering catalyst activity is somewhere between 0.1 and 0.3 wt%. Adding 0.5% K decreased catalyst activity significantly, see Run 7 in Table 6.

The last catalyst tested this period was a 30 wt% Co on alumina support with no additives or promoters. The CO conversion was high, 31.4%, but the CH₄ selectivity was also high, 14%, which is also in the expected range (see Run 34 in M3-SBCR on Table 12). This will be used as a basis for comparing similar catalysts with various additives and promoters.

3. Catalyst Recovery Analyses

The catalysts charged for all runs, except for Run 20 in M3 and in M4, have been recovered and the particle size distributions have been measured. The charge and recovered weights of all catalysts are given in Table 13. The charge weights are in the H₂ reduced state while the recovered weights are in the oxidized state. Taking this into account, catalyst recoveries are quite good (greater than 90%). The mean volumetric diameters of both the charged and recovered catalysts with the calculated percent reduction in particle size are also given in Table 13. The particle size at the lower 10% pass-through point of the sample for both the charged and recovered catalysts are also given in Table 13.

A comparison of the mean volume diameters of the total feed and recovered samples shows that most of the alumina supported catalysts exhibited the least amount of particle size attrition (5 to

10%) during the reaction. The silica supported catalysts showed a 10 to 20% particle size reduction while a titanium supported catalyst had the highest reaction, 18.2% (see Run 8 in the M4-SBCR in Table 13).

Seven catalysts prepared by Calsicat have been tested in the SBCR and the particle size reduction was very low, 0.5% for CAL.08 and 1.6% for CAL.05. All these catalysts were prepared on a Vista B gamma-alumina catalyst support which has shown good resistance to attrition in the SBCR's.

If you compare the particle size of each sample of the 10% pass-through point, the increase in the amount of fines found in the recovered catalysts, as indicated by the lower particle size at the 10% point, is nearly proportional to the reduction in particle size obtained by comparing the mean volume diameters of the charge vs. recovered catalysts (see Table 13). Since the particle size of the charge catalyst was determined on the catalyst after hydrogen reduction and air oxidation, we know that attrition occurred only during the SBCR reaction.

VI. PLANS FOR THE NEXT REPORTING PERIOD

Several tasks are planned for the next reporting period:

A. The fixed-bed reactor testing of new catalysts will be continued. The fixed-bed reactor testing of the series of Al_2O_3 - and SiO_2 supported Co catalysts with a water-gas shift function will be continued.

B. The systematic characterization of all the catalysts will be continued using the following techniques:

- Selective hydrogen chemisorption on the reduced catalysts at 100°C;

- X-ray diffraction before reduction, after reduction, and after slurry bubble column reaction;
- Temperature programmed reduction (TPR);
- Temperature programmed desorption (TPD).

C. New catalyst formulations will be generated in order to pursue the effect of selectivity promoters.

D. The investigation of the effect of pretreatment conditions including calcination and reduction will be completed.

E. Additional runs will be made in the SBCR's to maximize the CO conversion.

F. Reproducibility tests and aging runs will be made on catalyst obtained from Calsicat.

G. Several catalyst formulations and mixtures will be tested for water-gas shift activity.

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VII. ASSESSMENT OF PROSPECTS FOR FUTURE PROGRESS

The technical approach which has been proposed remains the same and all the tasks are proceeding within schedule.

Table 1. List of Co-based FT Catalysts Formulated

CAT. NO.	wt% Co	wt% M	wt% Prom.	Support	Basis	Prepared
Co.001	20%	1% Re	1% La ₂ O ₃ 0.13% K	γ -alumina	U.S. Pat. 4,880,763	P
Co.002	20%	0.43% Ru	1% La ₂ O ₃	γ -alumina	U.S. Pat. 4,413,064	P
Co.003	20%	0.5% Ru	1% La ₂ O ₃	γ -alumina	U.S. Pat. 4,413,064	P
Co.004	20%	0.43% Ru	1% La ₂ O ₃	γ -alumina	Reproduce Co.002	P
Co.005	20%	0	0	γ -alumina	Base Catalyst	P
Co.005A	20%	0.4% Ru	0	γ -alumina	Ru added to calcined Co.005 by IW impreg.	P
Co.006	12%	0.75% Re	0	Titania	U.S. Pat. 4,794,009	P
Co.007	20%	0	0	Titania	Base Catalyst	P
Co.008	20%	0	0	Silica	UK Pat. Appl. GB 2 125 062 A (Kneaded with excess liquid)	P
Co.009	20%	0.5% Ru	0	γ -alumina	Ru-Promoted Catalyst (use Ru Chloride, single-step aqueous IW)	P
Co.010	20%	0	0	γ -alumina	Base Catalyst (non-calcined)	P
Co.010A	20%	0.4% Ru	0	γ -alumina	Ru added to dried Co.010 by IW impreg.	P
Co.011	20%	0	0	Silica	UK Pat. Appl. GB 2 125 062 A (Kneaded)	P
Co.012	20%	0	0	Silica	Base Catalyst (Inc. Wetness)	P
Co.013	20%	0	0	Titania	Base Catalyst like Co.007, but all aqueous	P
Co.014	12%	0.5% Ru	0	Titania	Ru-Promoted Catalyst (aqueous IW co- impregnation)	P
Co.015	20%	0.43% Ru	1% La ₂ O ₃	γ -Alumina	Similar to Co.002, but all aqueous	P
Co.016	20%	0.43% Ru	1% La ₂ O ₃	γ -Alumina	Similar to Co.015, but calcined after Co impregnation	P

Table 1. List of Co-based FT Catalysts Formulated (Contd.)

CAT. NO.	wt% Co	wt% M	wt% Prom.	Support	Basis	Prepared
Co.017	20%	0.5% Ru	1% La ₂ O ₃	γ -Alumina	Similar to Co.003, but all aqueous	P
Co.018	20%	0.5% Ru	0	γ -Alumina	Ru-Promoted Catalyst (single-step, aqueous IW)	P
Co.019	20%	0.5% Ru	0	Silica	Ru-Promoted Catalyst (single-step, aqueous IW)	P
Co.020	0	0.5% Ru	0	γ -Alumina	Ru Base Catalyst	P
Co.020A	20%	0.4% Ru	0	γ -Alumina	Co added to dried Co.020 by IW impreg.	P
Co.020B	20%	0.4% Ru	0	γ -Alumina	Co added to reduced Co.020 by IW impreg.	P
Co.020C	20%	0.4% Ru	0	γ -Alumina	Co added to calcined Co.020 by IW impreg.	P
Co.021	20%	0	0.7% Zr	Silica	U.K. Pat. Appl. GB 2 125 062 A (single-step)	P
Co.022	20%	0	0.7% Zr	Silica	U.K. Pat. Appl. GB 2 125 062 A (multiple-steps)	P
Co.023	20%	0	1.4% Zr	Silica	U.K. Pat. Appl. GB 2 125 062 A (multiple-steps)	P
Co.024	20%	0	8.5% Zr	Silica	Eur. Pat. Appl. 0 167 215 A2 (non-aqueous Zr pre-impregnation)	P
Co.025	20%	0	8.5% Zr	Silica	Similar to Co.024 but aqueous Zr pre-impregnation	P
Co.026	20%	0	0	Silica (Davison Grade 59)	Similar to Co.012 but different grade silica	P
Co.027	20%	0.5% Ru	0	Silica (Davison Grade 59)	Similar to Co.019 but different grade silica	P
Co.028	20%	0.5% Ru	0.5% K	γ -alumina	Ru- and K-Promoted Catalyst (single-step IW)	P
Co.029	30%	0.5% Ru	0.5% K	γ -alumina	Similar to Co.028 but 30% Co	P

Table 1. List of Co-based FT Catalysts Formulated (Contd.)

CAT. NO.	wt% Co	wt% M	wt% Prom.	Support	Basis	Prepared
Co.030	20%	0	0.1% Zr	γ -alumina	Zr-Promoted Catalyst (single-step aqueous IW)	P
Co.031	20%	0	1.4% Zr	γ -alumina	Zr-Promoted Catalyst (single-step aqueous IW)	P
Co.032	20%	0	8.5% Zr	γ -alumina	Zr-Promoted Catalyst (aqueous IW co-impregnation)	P
Co.033	20%	0	8.5% Zr	γ -alumina	multiple-steps, aqueous IW, Co pre-impregnation	P
Co.034	20%	0	8.5% Zr	γ -alumina	multiple-steps, aqueous IW, Zr pre-impregnation	P
Co.035	20%	0	8.5% Zr	Silica	Zr-Promoted Catalyst (single-step aqueous, kneaded)	P
Co.036	20%	0	8.5% Zr	Silica	multiple-steps, aq. Co pre-impreg. by kneading, aqueous IW Zr impreg.	P
Co.037	12%	0	0	Titania	Similar to Co.013, but TiO_2 mainly anatase	P
Co.038	12%	0.5% Ru	0	Titania	Similar to Co.014, but TiO_2 mainly anatase	P
Co.039	12%	0	0	Titania	Similar to Co.007, but only 12% Co	P
Co.040	12%	0	0	Titania	Similar to Co.013, but only 12% Co	P
Co.041	20%	0.5% Ru	8.5% Zr	Silica	Similar to Co.025, but Ru-promoted	P
Co.042	0	0	8.5% Zr	Silica	Blank Zr-promoted SiO_2	P
Co.043	20%	0.5% Ru	8.5% Zr 0.5% K	Silica	Similar to Co.041, but K-promoted	P
Co.044	20%	0	15% Zr	Silica	Similar to Co.025, but 15% Zr	P
Co.045	20%	0	4% Zr	Silica	Similar to Co.025, but 4% Zr	P
Co.046	12%	0.75% Re	4% SiO_2	Titania	Similar to Co.006, but SiO_2 -promoted	-

Table 1. List of Co-based FT Catalysts Formulated (Contd.)

CAT. NO.	wt% Co	wt% M	wt% Prom.	Support	Basis	Prepared
Co.047	20%	0.5% Ru	0.3% K	γ -alumina	Similar to Co.028, but 0.3% K	P
Co.048	20%	0.5% Ru	8.5% Zr 0.3% K	Silica	Similar to Co.043, but 0.3% K	P
Co.049	20%	0.5% Ru	0.1% K	γ -alumina	Similar to Co.047, but 0.1% K	P
Co.050	20%	0.5% Ru	8.5% Zr 0.1% K	Silica	Similar to Co.048, but 0.1% K	P
Co.051	0	0.5% Ru	0	Titania (R)		P
Co.052	0	0.5% Ru	0	Titania (A)		P
Co.053	20%	0.5% Ru	0	γ -alumina	Similar to Co.018 (New Batch)	P
Co.054	20%	0	8.5% Zr 0.3% K	Silica	Similar to Co.043, but without Ru	P
Co.055	20%	1% Re	1% La ₂ O ₃	γ -alumina	Similar to Co.001, but without K	P
Co.056	20%	0	8.5% La ₂ O ₃	Silica	Similar to Co.025, but La instead of Zr	P
Co.057	20%	1% Re	1% La ₂ O ₃	Silica	Similar to Co.055, but with SiO ₂ support	P
Co.058	20%	0	1% La ₂ O ₃	γ -alumina	Similar to Co.055, but without Re (one-step impreg.)	P
Co.059	20%	0	1% La ₂ O ₃	γ -alumina	Similar to Co.015, but without Re (two-step impreg.)	P
Co.060	30%	0	0	γ -alumina	Similar to Co.005, but with 30% Co	P
Co.061	30%	0.5% Ru	0	γ -alumina	Similar to Co.053, but with 30% Co	P
Co.062	30%	0.5% Ru	1.5% K	γ -alumina	Similar to Co.029, but with 1.5% K	P
Co.063	20%	0	8.5% La	γ -alumina	Two-steps, aqueous IW, La pre-impregnation	P
CAL.01 (97E-13E)	20%	0.5% Ru	0	γ -alumina	Similar to Co.018 (Calsicat Prep.)	P
CAL.02 (97E-16B)	20%	0.5% Ru	0	γ -alumina	Similar to CAL.01 (New Batch)	P
CAL.03 (97E-13F)	20%	0.5% Ru	0	γ -alumina	2-step impreg., Similar to CAL.02	P

Table 1. List of Co-based FT Catalysts Formulated (Contd.)

CAT. NO.	wt% Co	wt% M.	wt% Prom.	Support	Basis	Prepared
CAL.04 (97E-50C)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to Co.047 Stand. Calc. in Air	P
CAL.05 (97E-50D)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to Co.047 Stand. Calc. in N ₂	P
CAL.06 (97E-51A)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to Co.047 Red. and Pas. in Air	P
CAL.07 (97E-51B)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to Co.047 Red. and Protected in Paraffin (51.3% Cat. Conc.)	P
CAL.08 (97E-51C)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to Co.047 Calc., Red. and Protected in Paraffin (54.4% Cat. Conc.)	P
CAL.09 (97E-69C)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to CAL.05, Reduced and Protected in Soya (51.7% Cat. Conc.)	P
CAL.10 (97E-79A)	20%	0.5% Ru	0.3% K	γ -alumina (Condea)	Similar to CAL.05, but on Condea Al ₂ O ₃	P

Table 2. List of Water-Gas Shift Catalysts and F-T Catalysts with WGS Function

CAT. NO.	wt% Co	wt% M	wt% Prom.	Support	Basis	Prepared
WGS.01	0	5.0% Cu	0	γ -alumina	single-step, aqu. IW	P
WGS.02	0	5.0% Cu	10% Zn	γ -alumina	single-step, aqu. IW	P
WGS.03	0	5.0% Cu	4.0% Cr	γ -alumina	single-step, aqu. IW	P
WGS.04	0	0	4.0% Cr	γ -alumina	single-step, aqu. IW	P
WGS.05	0	0	4.0% Mn	γ -alumina	single-step, aqu. IW	P
WGS.06	0	5.0% Cu	4.0% Mn	γ -alumina	single-step, aqu. IW	P
WGS.07	0	4.0% Fe	0	γ -alumina	single-step, aqu. IW	P
WGS.08	0	4.0% Fe	4.0% Cr	γ -alumina	single-step, aqu. IW	P
WGS.09	0	5.0% Cu	4.0% Cr	γ -alumina	Similar to WGS.03	P
CoW.01	20%	5.0% Cu	10% Zn	γ -alumina	multiple-steps, aqu. IW, Cu,Zn pre-impr.	P
CoW.02	20%	5.0% Cu	4.0% Cr	γ -alumina	multiple-steps, aqu. IW, Cu,Cr pre-impr.	P
CoW.03	10%	5.0% Cu	4.0% Cr	γ -alumina	similar to CoW.02 (10% Co only)	P
CoW.04	10%	10% Cu	8.0% Cr	γ -alumina	similar to CoW.03; 10% Cu and 8% Cr	P
CoW.05	20%	5.0% Cu	4.0% Cr	γ -alumina	similar to CoW.02 with support calcined at 750°C	P
CoW.06	20%	5.0% Cu	4.0% Cr	Silica	multiple-steps, aqu. IW, Cu,Cr pre-impr.	P
CoW.07	20%	5.0% Cu	4.0% Cr	Silica	similar to CoW.06, but with support calcined at 750°C	P
CoW.08	30%	5.0% Cu	4.0% Cr	γ -alumina	Similar to CoW.05, but with 30% Co	P
CoW.09	20%	10.0% Cu	8.0% Cr	Silica	similar to CoW.06, but with 10% Cu and 8% Cr	P
CoW.10	10% Co, 10% Fe	0.5% Ru	0	γ -alumina	Single Step, IW	P
CoW.11	10% Co, 10% Fe	0.5% Ru	0.5% K	γ -alumina	Single Step, IW	P
CoW.12	10% Co, 10% Fe	0.5% Ru	0	Silica	Single Step, IW	P

Table 3. Summary of Physical Properties

CATALYST	Composition	BET Surface Area (m ² /g)	Pore Volume (cc/g)	Average Pore Dia. (Å)	Average Part. Size (μm)
Vista-B Al ₂ O ₃	(0-400 mesh)	299	1.69	269	24
Vista-B Al ₂ O ₃	Calcined 500°C	240	0.49	82	
Vista-B Al ₂ O ₃	Calcined 600°C	206	0.49	95	
Vista-B Al ₂ O ₃	Calcined 600°C	174	0.47	109	
Condea Al ₂ O ₃	(as received)	219	0.53	97	77
Davison SiO ₂	(0-400 mesh)	219	0.51	89	121
Degussa P25 TiO ₂	(as received)	47	0.40	335	6
Degussa P25 TiO ₂	Dried 60°C, Calc. 350°C/16hrs	46	0.48	419	51
Degussa P25 TiO ₂	Dried 60°C, Calc. 650°C/16hrs	12	0.17	573	212
Co.001	20Co/1Re/ 1La ₂ O ₃ /0.13K/A	191	0.31	66	42 40
Co.002	20Co/0.43Ru/ 1La ₂ O ₃ /A	149	0.33	89	74
Co.003	20Co/0.5Ru/ 1La ₂ O ₃ /A	122	0.26	87	77
Co.004	20Co/0.43Ru/ 1La ₂ O ₃ /A				78
Co.005	20Co/A	173	0.34	81	65 86
Co.006	12Co/0.75Re/T	16	-	-	121
Co.007	20Co/T	11	0.10	372	
Co.008	20Co/S	181	1.06	234	
Co.009	20Co/0.5/A				
Co.010	20Co/A				
Co.011	20Co/S	211	1.07	203	107
Co.012	20Co/S	211	-	-	105
Co.013	20Co/T				
Co.014	12Co/0.5Ru/T	15	0.12	328	111

Table 3. Summary of Physical Properties (contd.)

CATALYST	Composition	BET Surface Area (m ² /g)	Pore Volume (cc/g)	Average Pore Dia. (Å)	Average Part. Size (μm)
Co.015	20Co/0.43Ru/ 1La ₂ O ₃ /A	141	-	-	67
Co.016	20Co/0.43Ru/ 1La ₂ O ₃ /A	116	-	-	79
Co.017	20Co/0.5Ru/ 1La ₂ O ₃ /A	123	-	-	73
Co.018	20Co/0.5Ru/A	158	-	-	69
Co.019	20Co/0.5Ru/S				110
Co.021	20Co/0.7Zr/S	213	1.12	210	74
Co.023	20Co/1.4Zr/S	213	-	-	
Co.024	20Co/8.5Zr/S	215	1.08	202	
Co.025	20Co/8.5Zr/S	208	0.97	187	87
Co.026	20Co/S(59)	184	-	-	
Co.027	20Co/S(59)	189	-	-	
Co.028	20Co/0.5Ru/0.5K/A	161	0.33	82	80
Co.029	30Co/0.5Ru/0.5K/A	140	-	-	76
Co.031	20Co/1.4Zr/S				75
Co.032	20Co/8.5Zr/A	155	0.30	77	
Co.034	20Co/8.5Zr/A	150	0.31	83	
Co.035	20Co/8.5Zr/S	207	1.21	233	89
Co.036	20Co/8.5Zr/S	209	-	-	
Co.037	12Co/T(A)	38	-	-	
Co.039	12Co/T(R)	13	-	-	
Co.040	12Co/T				130
Co.041	20Co/0.5Ru/8.5Zr/S	214	-	-	-
Co.044	20Co/15Zr/S				92
Co.047	20Co/0.5Ru/0.3K/A	162	0.31-	78	83
Co.048	20Co/0.5Ru/0.3K/ 8.5Zr/S				82
Co.049	20Co/0.5Ru/0.3K/A				81

Table 3. Summary of Physical Properties (contd.)

CATALYST	Composition	BET Surface Area (m ² /g)	Pore Volume (cc/g)	Average Pore Dia. (Å)	Average Part. Size (µm)
Co.053	20Co/0.5Ru/A				75
Co.054	20Co/0.3K/8.5Zr/S				101
Co.055	20Co/1Re/ 1La ₂ O ₃ /A				86
Co.056	20Co/8.5La ₂ O ₃ /S				100
CAL.01	20Co/0.5Ru/A	178	0.34	76	
CAL.02	20Co/0.5Ru/A	158	-	-	74
CAL.03	20Co/0.5Ru/A	158	-	-	
CAL.04	20Co/0.5Ru/0.3K/A	151			72
CAL.05	20Co/0.5Ru/0.3K/A	163			73
CAL.06	20Co/0.5Ru/0.3K/A	162			72
CAL.07	20Co/0.5Ru/0.3K/A	-			
CAL.08	20Co/0.5Ru/0.3K/A	-			63
CAL.09	20Co/0.5Ru/0.3K/A				63
CAL.10	20Co/0.5Ru/0.3K/A	142	-	-	83

Table 4. H₂ Chemisorption and TPR Results

Catalyst	H ₂ Chemisorption ^a				H ₂ TPR	
	Total (μ mol H ₂ /g cat)	Irrevers. (μ mol H ₂ /g cat)	Average d_p^b (nm)	% Disp.	%Co Red. ^c (TPR calc. Cat.)	% Red. ^d (stand. red.)
Co.001	174 $\pm$ 5	157 $\pm$ 5		10.2		
Co.002	155	130		9.1		
Co.003	165	140		9.6		
Co.004 ^f (1)	205	185	7	12.1	91	
(2)	132	116	11	6.6	55	
(3)	144	123	10	7.2	46	
(4)	136	122	10	6.8	41	
Co.005	48	42	20	2.8	89	58
Co.005a	129	110	11	7.6	92	84
Co.006	44	32	19	4	80	
Co.007	33	23	36	2.0	78	78
Co.008						
Co.009	133	109	13	7.8	98	
Co.010						
Co.010a	124	100	12.5	7.3	91	89
Co.011	82	70	15.6	4.8	75	75
Co.012	89	74	15	5.2	80	80
Co.013	21	17	79	1.2	97	
Co.014	38	30	21	3.7	79	
Co.015	146	124	11.7	8.6	94	94
Co.016	163	146	10.5	9.6	96	96
Co.017	202	183	8.5	11.9	97	97
Co.018	185	165	9.2	11	97	94

Table 4. H₂ Chemisorption^a and TPR Results (contd.)

Catalyst	H ₂ Chemisorption ^a				TPR	
	Total (μ mol H ₂ /g cat)	Irrev. (μ mol H ₂ /g cat)	Average d_p^b (nm)	% Disp.	%Co Red. ^c (TPR calc. Cat.)	% Red. ^d (stand. red.)
Co.018-Cl					95	
Co.019	112	92		6.6		
Co.020						
Co.020a	153	126	10	9.1	88	
Co.020b	134	113	11	7.9	86	
Co.020c	115	100	13	6.8	88	
Co.021	74	50		4.3		
Co.022	141	122		8.3	80	
Co.023	158	136		9.3	81	
Co.024	87	72		5.1	91	
Co.025	93	77		5.5	75	
Co.026						
Co.027						
Co.028	170	148		10		
Co.029	175	155		7		
Co.030						
Co.031	71	51	20	4.2	82	
Co.032	55	39	26	3.2	85	
Co.033	43	32	31	2.5	79	
Co.034	114	91	14	6.7	96	
Co.035	125	115	11	7.2	82	
Co.036	122	98		7.2		

Table 4. H₂ Chemisorption^a and TPR Results (contd.)

Catalyst	H ₂ Chemisorption ^a				TPR	
	Total (μ mol H ₂ /g cat)	Irrev. (μ mol H ₂ /g cat)	Average d_p^b (nm)	% Disp.	%Co Red. ^c (TPR calc. Cat.)	% Red. ^d (stand. red.)
Co.037	21	3	48	2	99	
Co.038	45	35	21	4.3	91	
Co.039	19	16	40	1.8	72	
Co.040	14	11	53	1.4		
Co.041	70	55		4		
Co.043	137	109		8	86	
Co.053 ^g (1)	168	139	8	8.4	60	
(2)	101	76	14	5.2	82	
(3)	138	117	10	6.9	47	
Co.054					57	
Co.055 ^h (1)	165	139	8.5	8.3	78	
(2)	179	163	8	9.0	50	
(3)	103	84	14	5.2	76	
(4)	192	165	7	9.6	-	
Co.056					58	
CAL.01	-	-	58 ^e	4.4 ^e	54	
CAL.02	-	-	63 ^e	5.1 ^e	55	
CAL.03	-	-	57 ^e	4.2 ^e	85	
CAL.04			55 ^e	3.5 ^e		
CAL.05			56 ^e	4.4 ^e		
CAL.06			57 ^e	4.2 ^e		
CAL.10			72 ^e	3.7 ^e		

(a) static H₂ chemisorption at 100°C(b) Est. assuming $H_{tot}/Co_s = 1$, $5.46 \times 10^{-20} \text{ m}^2/Co_s$, and $d_p = 5/S_{Co}/\rho$ S_{Co} is based on amt. Co reducible during standard reduction

(c) % Co reducible from TPR of calcined catalysts up to 900°C

(d) % Co reduced after standard reduction procedure

(e) Based on CO chemisorption

(f) (1)=uncalcined; (2)=calcined in air and reduced in H_2 ; (3)=calcined in He; (4)calcined in nitrogen

(g) (1) and (2)=uncalcined

(h) (1) and (3)=calcined in air; (2)=calcined in nitrogen; (4)=uncalcined

(i) Catalyst Co.018-Cl is chlorinated.

Table 5. Summary of fixed bed reaction results

Catalyst	Run	Prep	CO Conv (%)	Rare g CH ₂ / g cat/hr	R-C6+ g CH ₂ / g cat/hr	R(CO) mol/mol Co/s	wt% CH ₄	alpha	C3-C5 Ole/ Par	CO ₂ (%) (CO)	g/g cat/hr	E act. kcal/ mol	Comment
Co.001	4	(1)	2.6	0.116	0.056	6.8E-04	19.6	0.76	8.61	0.4	0.061		NSH**
Co.002	4	(2)	6.7	0.258	0.082	1.5E-03	26.1	0.64	1.97	0.1	0.012		NS
Co.003	1	(3)	5.5	0.185	0.044	1.1E-03	30.8	0.57	4.22			28.9	old startup
Co.004	1	(2) s	4.3	0.291	0.086	1.7E-03	30.4	0.62	2.77	0.1	0.025	25.9	NSH
"	2	u	11.2	0.517	0.155	3.0E-03	28.9	0.61	1.02	0.1	0.038		NSH
"	2h	u	47.6	0.548	0.211	3.2E-03	21.9	0.64	0.40	2.3	0.090		NSH, high conv. study
"	2a	f	3.8	0.177	0.063	1.0E-03	25.5	0.65	3.02	0.1	0.024		NSH, calc. after run 2, T surge
"	3	u	6.7	0.499	0.153	2.9E-03	27.8	0.61	1.45	0.1	0.036		NSH
"	3h	u	27.0	0.506	0.164	3.0E-03	27.3	0.62	0.46	0.8	0.048		NSH, high conv. study
"	4	u	1.8	0.427	0.241	2.5E-03	24.0	0.79	2.40	0.1	0.078		NSH, 10 atm
"	5	f	4.5	0.288	0.150	1.7E-03	19.4	0.75	7.84	0.1	0.03		NSH
"	6	n	6.9	0.466	0.151	2.7E-03	27.8	0.61	1.60	0.2	0.044		NSH
"	7	ROR	3.9	0.225	0.072	1.3E-03	28.8	0.61	3.01	0.2	0.042		NSH
"	8	He	5.8	0.399	0.144	2.3E-03	27.2	0.66	2.13	0.1	0.028		NSH
Co.005	2	(1)	3.3	0.087	0.037	5.1E-04	21.4	0.66	3.40	0.1	0.005		NS
"	2a		2.5	0.066	0.021	3.9E-04	25.9	0.59	4.92	0.1	0.004		CO:H ₂ :Ar = 1:2:2
"	2b		2.4	0.064	0.021	3.7E-04	26.3	0.60	6.22	0.1	0.006		+ H ₂ O (eq. 7.5% CO conv.)
"	3		3.3	0.077	0.024	4.5E-04	28.4	0.62	2.29	0.1	0.013		NSH
"	4		4.0	0.069	0.021	4.0E-04	30.0	0.62	2.16	0.2	0.009	25.1	NSH
"	5		3.9	0.171	0.084	1.0E-03	26.8	0.76	2.59	0.1	0.018		NSH, 10 atm
"	6		2.1	0.129	0.044	7.6E-04	25.7	0.64	5.53	0.1	0.017		NSH
"	7		6.7	0.084	0.040	4.9E-04	18.8	0.70	1.95	0.1	0.003		S2
Co.005a	1	(4a)	3.2	0.227	0.067	1.3E-03	30.0	0.60	3.05	0.1	0.034		NSH
Co.005b	1	(1)	2.4	0.040	0.024	2.3E-04	13.9	0.74	0.55	0.4	0.023		S2, 1/4WGS.03 + 3/4Co.005
Co.005c	1	(1)	5.7	0.071	0.031	4.1E-04	20.3	0.68	0.21	1.8	0.076		S2, 1/2WGS.03 + 1/2Co.005
Co.006	1	(5)	2.7	0.052	0.007	5.1E-04	45.0	0.49	1.90	0.1	0.006		NSH
Co.007	1	(5)	3.2	0.024	0.003	1.4E-04	49.8	0.50	0.72	0.2	0.004		NSH
Co.009	1	(1)	4.9	0.346	0.090	2.0E-03	31.1	0.57	1.69	0.1	0.020		NSH
"	2		4.9	0.338	0.091	2.0E-03	31.1	0.58	1.64	0.1	0.026		NSH
Co.010a	1	(4b) s	3.5	0.246	0.076	1.4E-03	29.5	0.62	2.58	0.2	0.040		NSH
"	2		4.1	0.262	0.080	1.5E-03	30.0	0.61	2.31	0.1	0.022		NSH
Co.011	2	(6b)	2.9	0.094	0.037	5.5E-04	22.4	0.61	4.83	0.3	0.030		NSH
Co.012	1	(1)	3.8	0.083	0.027	4.8E-04	26.3	0.64	4.40			22.5	slow CO startup (60 min)
"	2		4.4	0.085	0.030	5.0E-04	29.1	0.64	1.93	0.3	0.018		NSH
"	3		2.1	0.081	0.026	4.7E-04	28.6	0.66	3.57	0.4	0.049		NSH
"	4		2.5	0.105	0.035	6.2E-04	28.4	0.61	4.94	0.4	0.023		NSH
Co.014	1	(1)	1.5	0.028	0.009	2.8E-04	32.3	0.63	4.70	0.1	0.003		NSH
"	2		2.6	0.034	0.013	3.3E-04	27.7	0.69	10.8	0.1	0.011	26.0	NSH
Co.015	1	(4) s	6.8	0.211	0.063	1.2E-03	26.7	0.60	3.30	0.1	0.011		slow CO startup (120 min)
"	2	f	7.0	0.388	0.135	2.3E-03	26.4	0.64	1.39	0.1	0.011		NSH
"	3	u	6.7	0.375	0.123	2.2E-03	28.2	0.63	1.62	0.2	0.011		NSH
Co.016	1	(4a) s	5.2	0.161	0.035	9.4E-04	33.6	0.56	6.85				slow CO startup (30 min)
"	2	f	5.1	0.291	0.112	1.7E-03	25.1	0.68	2.48	0.1	0.01		NSH

Table 5. Summary of fixed bed reaction results (contd.)

Catalyst	Run	Prep	CO Conv (%)	Rate g CH ₂ /g cat/hr	R-C6+ g CH ₂ /g cat/hr	R (CO) mol/mol Co/s	wt% CH ₄	alpha	C3-C5 Ole/Par	CO ₂ (%)	g/g cat/hr	Eact kcal/mol	Comment
Co.017	2	(1) s	4.6	0.139	0.066	8.2E-04	22.0	0.69	3.72	0.1	0.012		NS
"	2a	s	3.7	0.111	0.043	6.5E-04	25.9	0.64	4.19	0.1	0.011		CO:H ₂ :Ar = 1:2:2
"	2b	s	3.4	0.102	0.039	6.0E-04	26.9	0.65	4.39	0.1	0.013		+ H ₂ O (eq. 7.5% CO conv.)
"	3	f	4.9	0.274	0.111	1.6E-03	23.0	0.67	2.41	0.2	0.030		NSH, calc. flow air
Co.018	2	s	3.4	0.170	0.068	1.0E-03	27.2	0.69	2.24	0.1	0.013		NS
"	2a	s	2.7	0.133	0.041	7.8E-04	33.2	0.64	2.52	0.1	0.011		CO:H ₂ :Ar = 1:2:2
"	2b	s	3.0	0.147	0.045	8.6E-04	33.6	0.63	2.41	0.1	0.015		+ H ₂ O (eq. 7.5% CO conv.)
"	3	s	4.1	0.290	0.086	1.7E-03	30.0	0.62	2.34	0.1	0.022		NSH
"	4	s	3.6	0.340	0.180	2.0E-03	25.4	0.80	1.92	0.1	0.041		NSH, 10 atm
"	5	f	7.5	0.470	0.136	2.8E-03	29.0	0.60	1.93	0.3	0.055		NSH
"	6	f	6.5	0.409	0.147	2.4E-03	24.6	0.64	2.42				NSH,S2"
Co.018Cl	1	(1)	4.5	0.320	0.075	1.9E-03	33.5	0.57	1.45	0.1	0.018		NSH
Co.019	1	(1)s	4.4	0.088	0.047	5.2E-04	15.2	0.74	7.61				NS
"	2	s	2.2	0.085	0.046	5.0E-04	18.9	0.73	8.59	0.3	0.040		NSH
"	3	f	3.4	0.142	0.071	8.3E-04	19.3	0.72	6.74	0.2	0.025		NSH
"	3h	f	16.7	0.172	0.091	1.0E-03	18.2	0.74	1.77	1.0	0.034		NSH, high conv. study
Co.020a	1	(4) s	4.6	0.343	0.085	2.0E-03	33.5	0.57	1.70	0.1	0.024		NSH
"	2		4.4	0.315	0.086	1.8E-03	31.2	0.59	1.96	0.1	0.028		NSH
Co.020b	1	(4b) s	4.4	0.311	0.084	1.8E-03	31.7	0.58	1.81	0.2	0.051		NSH
Co.020c	1	(4a) s	4.0	0.287	0.083	1.7E-03	30.4	0.60	2.38	0.1	0.017		NSH
Co.021	1	(6b)	3.4	0.109	0.032	6.4E-04	27.3	0.62	2.78	0.1	0.012	28.2	NSH
"	2		3.6	0.114	0.035	6.7E-04	28.0	0.56	2.69	0.1	0.012		NSH
Co.022	1	(6c)	3.8	0.121	0.037	7.1E-04	26.7	0.55	2.91	0.1	0.015	30.1	NSH
Co.023	1	(6c)	3.8	0.123	0.038	7.2E-04	28.3	0.56	3.18	0.2	0.023	29.5	NSH
Co.024	1	(7)	5.1	0.165	0.047	9.7E-04	32.8	0.62	2.08	0.5	0.055		NSH
"	2		5.7	0.182	0.060	1.1E-03	28.7	0.62	2.25	0.3	0.035		NSH
Co.025	1	(4)	5.0	0.160	0.062	9.4E-04	23.5	0.63	4.13	0.2	0.019	26.9	NSH
Co.026	1	(1)	4.4	0.129	0.043	5.0E-04	26.9	0.62	2.65	0.2	0.022		NSH
"	1h		22.9	0.170	0.072	6.6E-04	22.6	0.67	0.64	1.5	0.037		NSH, high conv. study
Co.027	1	(1)	4.2	0.169	0.068	6.6E-04	23.0	0.65	3.44	0.2	0.026		NSH
"	1h		17.8	0.180	0.085	7.0E-04	19.4	0.71	0.96	1.2	0.011		NSH, high conv. study
Co.028	1	(4)	3.8	0.146	0.076	5.7E-04	18.2	0.76	7.63	0.2	0.031		NSH
"	2		4.3	0.167	0.105	6.5E-04	14.7	0.80	13.2	0.2	0.030	28.4	NSH
"	3		4.5	0.206	0.126	8.0E-04	15.5	0.79	13.4	0.2	0.037		NSH, re-calc. in flow air
Co.029	1	(4)	2.8	0.173	0.105	6.7E-04	15.3	0.79	25.9	0.2	0.026		NSH
Co.031	1	(1)	1.9	0.060	0.022	3.5E-04	26.1	0.64	4.65	0.3	0.031		NSH
Co.032	1	(1)	3.3	0.183	0.079	1.1E-03	22.0	0.70	5.28	0.1	0.022		NSH
Co.033	1	(1)	1.3	0.073	0.027	4.3E-04	24.1	0.67	7.36	0.1	0.020		NSH
Co.034	1	(4)	5.0	0.275	0.107	1.6E-03	24.0	0.67	4.29	0.1	0.018		NSH
Co.035	2	(6)	4.6	0.147	0.068	8.6E-04	22.0	0.69	4.84	0.2	0.019		NSH
Co.036	2	(6c)	3.9	0.125	0.045	7.3E-04	28.9	0.67	4.20	0.1	0.013		NSH
Co.037	1	(4a)	2.7	0.053	0.011	5.2E-04	32.8	0.59	2.82				NSH
Co.038	1	(4a)	4.5	0.051	0.018	4.9E-04	25.1	0.68	4.63	0.3	0.013	24.2	NSH

Table 5. Summary of fixed bed reaction results (contd.)

Catalyst	Run	Prep	CO Conv (%)	Rate g CH ₂ / g cat/hr	R-C6+ g CH ₂ / g cat/hr	R (CO) mol/mol Co/s	wt% CH ₄	alpha	C3-C5 Ole/ Par	CO ₂ (%) (CO)	g/g cat/hr	E _{act} kcal/ mol	Comment
Co.039	1	(5)	1.1	0.021	0.004	2.0E-04	57.2	0.64	0.84	0.2	0.010	25.6	NSH, cracking in the line
"	2		3.9	0.049	0.007	4.7E-04	42.4	0.48	0.95	0.2	0.009		NSH
Co.040	1	(4a)	1.9	0.037	0.004	3.7E-04	45.2	0.53	1.79	0.2	0.007		NSH
"	2		2.8	0.033	0.004	3.3E-04	44.6	0.46	1.12	0.2	0.007		NSH
Co.041	1	(4)	3.5	0.136	0.042	8.0E-04	40.7	0.69	1.47	0.6	0.079		NSH, cracking in the line
Co.043	1	(4a)	4.6	0.104	0.062	6.1E-04	15.3	0.78	12.1	0.6	0.048		NSH, 2.5 hr on-stream
"	2		3.7	0.078	0.045	4.6E-04	16.3	0.78	7.75	0.5	0.035	35.1	NSH
Co.044	1	(4)	3.1	0.179	0.081	1.0E-03	22.7	0.73	5.16	0.3	0.020		NSH
Co.045	1	(4)	2.6	0.161	0.076	9.4E-04	22.2	0.73	6.89	0.3	0.022		NSH
Co.047	1	(4)	6.4	0.263	0.128	1.5E-03	21.3	0.73	7.20	0.3	0.040	26.6	NSH
Co.048	1	(4)	3.5	0.162	0.094	9.5E-04	16.3	0.77	17.1	0.2	0.027	28.0	NSH
Co.049	1	(4)	7.1	0.366	0.153	2.1E-03	23.4	0.69	5.63	0.3	0.043		NSH
"	2		6.0	0.388	0.160	2.3E-03	23.3	0.68	5.93	0.3	0.056		NSH, re-calcined in flow air
"	3	f	6.7	0.410	0.158	2.4E-03	25.2	0.69	4.64	0.3	0.059		NSH
"	3h	f	44.9	0.457	0.178	2.7E-03	26.5	0.67	0.67	3.8	0.131		NSH,HCS
Co.053	1	(1)	7.0	0.408	0.127	2.4E-03	27.3	0.62	3.07	0.2	0.049		NSH
"	1h		28.5	0.417	0.145	2.4E-03	26.8	0.64	0.79	1.6	0.081		NSH, high conv. study
"	2	f	6.6	0.433	0.174	2.5E-03	23.4	0.63	2.35	0.2	0.052		NSH
"	3		7.8	0.453	0.143	2.7E-03	27.6	0.62	1.67	0.1	0.027		NSH
"	3h		31.5	0.457	0.164	2.7E-03	25.4	0.65	0.52	0.9	0.044		NSH, high conv. study
"	4	u	6.1	0.426	0.142	2.5E-03	28.3	0.65	1.41	0.1	0.030		NSH
"	5	ROR	5.6	0.360	0.118	2.1E-03	27.9	0.64	1.49	0.2	0.034		NSH
"	6	f	8.2	0.485	0.163	2.8E-03	28.9	0.64	1.25	0.1	0.030		NSH
Co.054	1	(1)	1.2	0.041	0.023	2.4E-04	17.8	0.79	16.3	0.2	0.014		NSH
Co.055	1	(1) f	9.1	0.490	0.159	2.9E-03	28.9	0.63	1.31	0.2	0.034		NSH
"	2	u	4.9	0.290	0.105	1.7E-03	25.7	0.65	1.49	0.2	0.022		NSH, T surge
"	3	u	11.0	0.611	0.193	3.6E-03	29.4	0.60	1.02	0.2	0.033		NSH
"	4	u	5.9	0.380	0.124	2.2E-03	28.3	0.60	1.94	0.2	0.047		NSH
"	5	u	6.6	0.409	0.135	2.4E-03	29.6	0.59	1.83	0.2	0.030		NSH
"	6	ROR	7.5	0.469	0.145	2.7E-03	30.9	0.63	1.21	0.2	0.023		NSH
"	7	n	7.5	0.466	0.119	2.7E-03	33.5	0.60	1.11	0.2	0.031		NSH
Co.056	1	(1)	2.4	0.137	0.054	8.0E-04	23.9	0.69	8.22	0.1	0.029		NSH
"	2	u	2.2	0.137	0.054	8.0E-04	23.4	0.68	9.44	0.1	0.033		NSH
Co.057	1	(1)	2.8	0.171	0.078	1.0E-03	23.4	0.73	4.65	0.1	0.029		NSH
Co.060	1	(2)	3.8	0.244	0.097	1.4E-03	25.0	0.69	3.82	0.1	0.023		NSH
AL.01	1	(1)	4.8	0.181	0.068	1.1E-03	24.4	0.66	5.86	0.3	0.036		NSH, temp. surge (startup)
"	2		7.4	0.491	0.142	2.9E-03	28.7	0.61	2.06	0.4	0.083		NSH
"	3		2.5	0.164	0.053	9.6E-04	25.6	0.63	4.97	0.2	0.052		NSH, HT, re-reduced
"	4		7.3	0.483	0.103	2.8E-03	35.8	0.57	1.21	0.2	0.098		NSH, HT, re-calcined
AL.02	1	(1)	6.1	0.379	0.121	2.2E-03	27.3	0.63	3.04	0.2	0.040		NSH
AL.03	1	(1)	7.3	0.459	0.133	2.7E-03	29.0	0.60	2.59	0.2	0.048		NSH
AL.04	1	(1)	4.1	0.234	0.123	1.4E-03	19.1	0.71	8.98	0.2	0.026		NSH
AL.05	1	(1)	4.7	0.274	0.134	1.6E-03	20.8	0.75	6.85	0.2	0.026		NSH

Catalyst	Run	Prep	CO Conv (%)	Rate R: CH ₂ /F: cat/hr	R: C ₆ + F: CH ₂ /F: cat/hr	R: C ₆ + F: cat/hr	Co/s mol/mol	wt% CH ₄	alpha	C ₃ -C ₅ Ole/ Par	CO ₂ (%)	F: act g/g cat/hr	Comments
CAL.06	1	(1)	5.8	0.267	0.135	1.6E-03	20.7	0.74	5.50	0.2	0.021		NSH
CAL.10	1	(1)	3.5	0.196	0.097	1.1E-03	23.5	0.74	1.75	0.2	0.045		NSH
CO.W.01	1	(4a)	1.2	0.016	0.003	9.5E-05	30.2	0.58	3.78	0.2	0.006		NSH, reduced at 230 °C
"	1		0.5	0.007	0.001	3.4E-05	42.1	0.51	0.95	0.1	0.003		NSH, re-reduced at 350 °C
	2		0.2	0.006	0.000	3.4E-05	40.9	0.51	11.3	0.1	0.006		NSH, reduced at 350 °C
CO.W.02	1	(4a)	0.3	0.009	0.002	5.4E-05	25.6	0.60	4.94	0.1	0.008		NSH, reduced at 230 °C
CO.W.03	1	(4a)											NSH, negligible activity
CO.W.04	1	(4a)											S ₂ , negligible activity
CO.W.05	1	(4c)	2.8	0.035	0.006	2.1E-04	33.1	0.55	0.66	0.2	0.008		S ₂ , reduced at 350 °C
"	2	u	4.7	0.058	0.011	3.4E-04	34.8	0.50	0.85	0.2	0.009		S ₂
CO.W.06	1	(4a)	3.3	0.041	0.012	2.4E-04	26.0	0.59	2.21	0.2	0.007		S ₂ , reduced at 250 °C
"	2	u	2.6	0.032	0.004	1.9E-04	39.3	-0.46	0.99	0.3	0.012		S ₂
"	2		17.0	0.207	0.004	1.2E-03	68.7	0.32	0.37	1.7	0.07		S ₂ , rxn. at 280 °C
UOP	1	(1)	7.8	0.298	0.104	1.7E-03	22.6	0.61	1.29	0.2	0.023		NSH

action conditions: 220° C, H₂: CO = 2, 1 atm
[the catalysts are reduced and passivated before loading into reactor, then rereduced in-situ
[catalysts are calcined at UPARC (static) : except where specified in prep. column
: calcined at Pitt, static
: calcined at Pitt, flow
uncalcined
Nitrogen calcined
IR : catalyst is reduced, calcined and rereduced before it is loaded
some cases, "re-calcined" means calcination of the calcined catalyst from UPARC for a longer period
single step, aqueous incipient wetness
Two step impregnation: aqueous incipient wetness of Co + acetone/ethanol impregnation of Ru, La
three step, with calcination after each step, acetone incipient wetness
two step, aqueous incipient wetness, (a) intermediate calcination, (b) intermediate reduction, (c) intermediate
single step, acetone impregnation
single step, aqueous kneading, (a) = 150%, (b) = 110% of pore volume
(aqueous kneading for Co, calcined, then aqueous incipient wetness for Zr
Two step impregnation: organic incipient wetness + aqueous incipient wetness
New startup
New startup, heated inlet
was done in the second system
Davison Grade 59 Silica, if not specified, S refers Davison Drade 952 Silica
corrected on 3/6/1994

single step, aqueous incipient wetness
Two step impregnation: aqueous incipient wetness of Co + acetone/ethanol impregnation of Ru, La
three step, with calcination after each step, acetone incipient wetness
two step, aqueous incipient wetness, (a) intermediate calcination, (b) intermediate reduction, (c) intermediate calcination 750 °C
single step, acetone impregnation
single step, aqueous kneading, (a) = 150%, (b) = 110% of pore volume
(aqueous kneading for Co, calcined, then aqueous incipient wetness for Zr
Two step impregnation : organic incipient wetness + aqueous incipient wetness

New startup
New startup, heated inlet
was done in the second system
Davison Grade 59 Silica, if not specified, S refers Davison Drade 952 Silica
corrected overheated line on 3/6/1994

Table 6

DATE: 12/30/94

COMPARISON OF CONVERSION AND SELECTIVITY OF
METHANE REDUCTION CATALYSTS AT STARTUP CONDITIONS

Period No.					Temp.	Pres.	H2/CO Ratio							
-----					-----	-----	-----							
1					240 C	450psi	2.0							

Run	Cat.	Cat.	Conv.	Prod.	Selectivities				Alpha	Alpha	Catalyst	Composit.		
No	No	wt,g	%	Rate	%CH4	%C2	%C3+	%CO2	GC	Liq	Prom%	Metal%	Suppt	
---	---	---	---	---	---	---	---	---	---	---	---	---	---	
M-4 SBCR														
3	Co.002	15.2	29.4	1.42	17.3	2.3	79.4	1.01	0.73	0.82	1.0La	0.43Ru	Al	
4	Co.024	15.4	25.5	1.21	8.6	2.0	89.0	0.43	0.79	0.84	8.5Zr	0.0	Si	
5	Co.035	15.4	24.8	1.18	8.5	2.1	89.0	0.47	0.78	0.84	8.5Zr	0.0	Si	
6	Co.028	15.4	21.2	1.00	6.1	1.6	91.3	1.01	0.81	0.83	0.5K	0.5Ru	Al	
7	Co.043	15.4	13.0	0.61	3.7	1.8	93.4	1.06	0.79	0.85	8.5Zr	0.5Ru	Si	
											0.5K			
8	Co.006	15.0	2.7	0.13	0.1	0.2	98.0	1.75	0.67	0.85	0.0	0.75Re	Ti	
9	Co.048	15.4	19.1	0.90	9.9	1.6	87.4	1.10	0.77	0.88	8.5Zr	0.5Ru	Si	
											0.3K			
10	CAL.02	15.9	34.5	1.58	12.9	2.0	83.9	1.23	0.75	0.81	0.0	0.5Ru	Al	
11	CAL.03	15.6	29.7	1.39	13.5	2.1	83.4	1.08	0.74	0.86	0.0	0.5Ru	Al	
12	Co.053	15.9	34.2	1.56	12.6	2.0	84.2	1.23	0.75	0.83	0.0	0.5Ru	Al	
13	Co.054	15.7	10.4	0.48	4.7	1.8	92.3	1.17	0.78	0.86	8.5Zr	0.0	Si	
											0.3K			
14	BlendA	20.0	29.3	1.41	10.1	1.6	86.3	2.02	0.77	0.86	5.0Cu	4.0Cr	Al	
15	Co.034	13.0	27.5	1.54	10.4	1.6	87.2	0.80	0.78	0.84	8.5Zr	0.0	Al	
16	CAL.04	16.1	26.3	1.34	7.1	1.3	90.3	1.38	0.80	0.85	0.3K	0.5Ru	Al	
17	CAL.08	15.0	16.9	0.93	5.9	0.8	91.7	1.36	0.82	0.88	0.3K	0.5Ru	Al	
18	CAL.07	15.0	20.6	1.03	7.7	1.2	90.0	1.09	0.81	0.88	0.3K	0.5Ru	Al	
19	CAL.05	15.7	26.6	1.22	7.3	1.3	90.2	1.19	0.82	0.86	0.3K	0.5Ru	Al	
20	CAL.06	15.0	5.6	0.26	3.1	2.1	92.0	2.86	0.80	0.90	0.3K	0.5Ru	Al	
21	Co.004	15.9	39.3	1.80	15.2	2.3	81.2	1.38	0.74	0.80	1.0La	0.43Ru	Al	
22	BlendB	30.5	35.6	1.64	12.7	1.6	79.4	6.29	0.75	0.81	5.0Cu	4.0Cr	Al	
23	CAL.09	15.0	17.4	0.84	0.02	1.2	97.9	0.95	0.84	0.88	0.3K	0.5Ru	Al	
24	Co.053	28.5	50.4	1.28	14.1	2.1	81.8	2.03	0.75	0.79	0.0	0.5Ru	Al	
25	Co.056	15.0	11.4	0.55	7.8	3.6	87.2	1.43	0.67	0.87	8.5La	0.0	Si	
26	CAL.10	15.6	21.9	1.01	5.4	1.5	91.9	1.25	0.79	0.85	0.3K	0.5Ru	Al	
27	Co.050	14.6	20.4	1.01	6.8	1.9	90.2	1.04	0.78	0.87	8.5Zr	0.5Ru	Si	
											0.1K			

Note: Catalysts for all runs except Run 8 screened thru 150 x 400 mesh.
Catalyst for Run 8 screened thru 100 x 400 mesh.
Blend A contains 15.0 gm of Cat. No. Co.005 plus 5.0 gm of Cat. No. WGS.03.

Cat. Nos. CAL.07 and CAL.08 were prereduced and wax coated.
H₂ to CO ratio for Runs 16 and 17 was 1.76/1.0.
Cat. No. CAL.06 was H₂ reduced and air stabilized.
Blend B contains 15.0 gm of Cat. No. Co.005 plus 15.0 gm of Cat. No. WGS.03.
Cat. No. CAL.09 was prereduced and coated with Soya.
Cat. No. CAL.10 was prepared on Condea Alumina.

Table 7

SUMMARY OF M3 SBCR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using H₂ as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C₁+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Per No	Time Start	Time Stop	Temp C	Pres psi	H ₂ : CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefins C ₆ -18, %	Comments
												%CH ₄	%C ₂	%C ₃ +	%CO ₂			C ₃	C ₄		
30	CO.053	29.6	1	26	39	240	450	2.0	20	41.8	1.02	22.6	2.9	71.5	3.05	0.66	0.77	0.99	0.65	19.6	
30	CO.053	29.6	2	55	63	260	450	2.0	20	46.9	1.11	40.6	5.5	46.0	7.98	0.45	--	0.83	0.64		
30	CO.053	29.6	3	79	87	280	450	2.0	20	41.4	0.96	41.9	6.5	42.0	9.63	0.40	--	2.06	1.35		
30	CO.053	29.6	4	103	111	240	450	2.0	20	19.9	0.49	19.2	3.6	75.8	1.45	0.64	--	4.29	2.50	--	
30	CO.053	29.6	5	131	135	265	450	2.0	20	36.4	0.89	36.4	5.2	54.4	4.04	0.53	--	2.45	1.60	--	
30	CO.053	29.6	6	154	159	280	450	2.0	20	39.6	0.96	48.3	5.9	39.0	6.84	0.40	--	2.44	1.62	--	
30	CO.053	29.6	7	174	183	300	450	2.0	20	40.7	0.94	42.4	6.8	40.7	10.2	0.47	--	3.11	2.03	--	
30	CO.053	29.6	8	198	207	309	450	2.0	20	38.3	0.85	22.8	7.3	58.3	11.6	0.62	--	3.76	2.48	--	G.C. Calib
30	CO.053	29.6	9	220	231	310	450	2.0	20	37.5	0.87	55.5	7.2	25.5	11.8	0.13	--	3.93	2.67	--	
30	CO.053	29.6	10	242	254	320	450	2.0	20	40.8	0.90	61.7	7.4	14.5	16.4	0.00	--	3.62	2.63	--	
30	CO.053	29.6	11	270	279	320	450	1.0	20	30.8	0.92	42.9	6.0	26.9	24.2	0.30	--	5.68	4.28	--	

Table 8

SUMMARY OF M4 SBCR RUN RESULTS

a)Unless otherwise noted, total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

b)Conversion is total CO conversion over the period (Z).

c)Conversion and selectivities are calculated using N₂ as an internal standard in the GC analysis of the offgas.

d)Prod. rate: Rate for production of total hydrocarbons, C₁+ (kg/kg cat.,hr).

e)Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Per No	Time Start	Time Stop	Temp C	Pres psi	H ₂ : CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefins C ₅ -18, Z	Comments
												ZCH ₄	ZC ₂	ZC ₃ +	ZCO ₂			C ₃	C ₄		
24	CO.053	28.5	1	23	39	240	450	2.0	20	50.4	1.28	14.1	2.1	81.8	2.03	0.75	0.79	1.14	0.68	--	G.C.Calib
24	CO.053	28.5	2	54	63	250	450	2.0	20	53.5	1.34	24.2	3.6	67.9	4.24	0.66	--	0.66	0.48	--	
24	CO.053	28.5	3	78	87	260	450	2.0	30	55.3	1.36	38.2	5.2	49.0	7.64	0.53	--	0.53	0.47	--	
24	CO.053	28.5	4	102	110	260	450	2.0	30	52.8	2.13	29.1	4.0	62.1	4.79	0.64	--	0.68	0.49	--	
24	CO.053	28.5	5	126	135	260	450	2.0	30	58.9	1.90	28.5	3.9	62.8	4.90	0.65	--	0.70	0.48	--	
24	CO.053	28.5	6	146	158	260	450	2.0	30	42.6	1.74	26.9	3.8	66.3	2.96	0.65	--	0.99	0.67	--	
24	CO.053	28.5	7	175	182	260	450	2.0	30	51.5	1.31	31.6	4.5	60.0	3.90	0.60	--	0.94	0.65	--	
24	CO.053	28.5	8	199	208	260	450	2.0	30	58.1	1.89	27.6	3.7	65.1	3.67	0.66	--	0.88	0.56	--	
24	CO.053	28.5	9	218	231	260	450	2.0	30	62.9	2.05	23.2	3.0	70.6	3.20	0.71	--	0.93	0.58	--	
24	CO.053	28.5	10	259	263	275	450	2.0	30	72.1	2.24	39.1	5.0	46.4	9.53	0.57	--	0.41	0.34	--	
24	CO.053	28.5	11	290	304	260	450	2.0	30	48.8	1.62	29.0	3.8	65.4	1.83	0.65	--	1.78	1.09	--	

Feed Gas Rates

Per No	N ₂ SLH	H ₂ SLH	CO SLH	Total SLH
---	---	---	---	---

1	563	225	112	900
2	563	225	112	900
3	563	225	112	900
4	360	360	180	900
5	288	288	144	720
6	540	360	180	1080
7	563	225	112	900
8	200	288	144	632
9	108	288	144	540
10	108	288	144	540
11	108	288	144	540

Table 9

SUMMARY OF M3 SBCR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using H₂ as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C₁+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Per No	Time Start	Time Stop	Temp C	Pres psi	H ₂ : CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefins C ₆ -C ₁₈ , %	Comments
												%CH ₄	%C ₂	%C ₃ +	%CO ₂			C ₃	C ₄		
33	Co.053	31.4	1	24	39	240	450	2.0	20	41.4	0.94	23.2	3.1	69.6	4.06	0.65	0.76	0.82	0.58	21.7	G.C. Calib
33	Co.053	31.4	2	54	63	240	300	2.0	20	35.2	0.47	29.9	3.9	59.6	6.57	0.55	--	0.89	0.70	--	
33	Co.053	31.4	3	78	87	240	300	2.0	20	38.7	0.38	31.1	3.9	57.5	7.48	0.54	--	0.97	0.71	--	
33	Co.053	31.4	4	102	111	250	300	2.0	20	39.6	0.38	43.1	4.6	41.1	11.3	0.38	--	0.99	0.77	--	
33	Co.053	31.4	5	126	135	260	300	2.0	20	37.7	0.37	42.1	4.6	42.4	10.9	0.42	--	1.76	1.21	--	
33	Co.053	31.4	6	150	159	260	450	2.0	20	45.0	0.44	43.2	4.8	40.9	11.1	0.44	--	1.35	0.95	--	
33	Co.053	31.4	7	174	183	260	450	2.0	20	45.7	0.73	46.4	4.6	40.2	8.77	0.43	--	1.06	0.77	--	
33	Co.053	31.4	8	198	207	260	450	2.0	20	49.2	0.98	44.4	4.3	43.5	7.84	0.51	--	0.87	0.65	--	
33	Co.053	31.4	9	222	230	240	450	2.0	20	16.1	0.38	33.7	4.8	59.2	2.24	0.35	--	3.14	1.91	--	

Feed Gas Rates

Per No	H ₂ SLH	H ₂ SLH	CO SLH	Total SLH
1	563	225	112	900
2	338	135	67	540
3	250	100	50	400
4	250	100	50	400
5	250	100	50	400
6	250	100	50	400
7	160	160	80	400
8	100	200	100	400
9	563	225	112	900

Table 10

SUMMARY OF M4 SECR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (Z).

c) Conversion and selectivities are calculated using N₂ as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C₁+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Per wt, g	Time No	Time Start	Time Stop	Temp C	Pres psi	H ₂ : CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefins C ₅ -18, Z	Comments
												ICH ₄	IC ₂	IC ₃ +	IC ₄			C ₃	C ₄		
26	CAL.10	15.6	1	23	39	240	450	2.0	20	21.9	1.01	5.4	1.5	91.9	1.25	0.79	0.85	3.60	2.27	25.9	
26	CAL.10	15.6	2	54	63	240	450	2.0	20	21.7	1.30	8.3	1.1	89.9	1.10	0.80	--	3.78	2.45	--	
26	CAL.10	15.6	3	78	87	240	450	2.0	20	17.2	1.04	11.7	1.4	86.1	1.39	0.76	--	3.57	2.30	--	
26	CAL.10	15.6	4	102	111	240	450	2.0	20	17.7	1.01	11.9	1.4	86.0	1.40	0.77	--	3.52	2.28	--	
26	CAL.10	15.6	5	118	126	240	450	2.0	20	16.2	0.75	4.9	1.7	92.3	1.10	0.77	--	4.29	2.75	--	

Feed Gas Rates

Per No	N ₂ SLH	H ₂ SLH	CO SLH	Total SLH
1	563	225	112	900
2	108	288	144	540
3	54	288	144	486
4	25	274	137	436
5	563	225	112	900

Table 11

DATE: 12/30/94

COMPARISON OF CONVERSION AND SELECTIVITY OF
CALCICAT PRODUCED CATALYSTS AT STARTUP CONDITIONS

Period No.	Temp.	Pres.	H ₂ /CO Ratio
-----	-----	-----	-----
1	240 C	450psi	2.0

a) Total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

Flows: N₂-563 SLH, H₂-225 SLH, CO-112.5 SLH

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N₂ as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons C₁+ (kg/kg cat.,hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Catalyst Prom	Composit. Metal	Suppt
---	-----	-----	-----	-----	%CH ₄	%C ₂	%C ₃ +	%CO ₂	---	---	-----	-----	-----
M-4 SBCR													
10	CAL.02	15.9	34.5	1.58	12.9	2.0	83.9	1.23	0.75	0.81	0.0	0.5Ru	Al
11	CAL.03	15.6	29.7	1.39	13.5	2.1	83.4	1.08	0.74	0.86	0.0	0.5Ru	Al
16	CAL.04	16.1	26.3	1.34	7.1	1.3	90.3	1.38	0.80	0.85	0.3K	0.5Ru	Al
17	CAL.08	15.0	16.9	0.93	5.9	0.8	91.7	1.36	0.82	0.88	0.3K	0.5Ru	Al
18	CAL.07	15.0	20.6	1.03	7.7	1.2	90.0	1.09	0.81	0.88	0.3K	0.5Ru	Al
19	CAL.05	15.7	26.6	1.22	7.3	1.3	90.2	1.19	0.82	0.86	0.3K	0.5Ru	Al
20	CAL.06	15.0	5.6	0.26	3.1	2.1	92.0	2.86	0.80	0.90	0.3K	0.5Ru	Al
23	CAL.09	15.0	17.4	0.84	0.1	1.2	97.9	0.95	0.83	0.88	0.3K	0.5Ru	Al
26	CAL.10	15.6	21.9	1.01	5.4	1.5	91.9	1.25	0.79	0.85	0.3K	0.5Ru	Al

M-3 SBCR

12	CO.018	15.6	33.8	1.56	9.7	2.0	86.6	1.68	0.75	0.85	0.0	0.5Ru	Al
23	CO.047	15.8	28.2	1.29	7.7	1.5	89.3	1.47	0.79	0.84	0.3K	0.5Ru	Al

Note: Catalysts for all runs except Runs 17,18,& 20 screened thru 150 x 400 mesh.

Catalyst CAL.04 was calcined in air; Catalyst CAL.05 processed in N₂.

Cat. No. CAL.06 was H₂ reduced and air stabilized before charging.

Cat. Nos. CAL.08 and CAL.07 were prereduced and wax coated. CAL.08 was calcined in N₂ ; CAL.07 was reduced in H₂ without prior calcination.

H₂ to CO ratio for Runs 16 and 17 was 1.76/1.

Cat. Nos. Co.018 & Co.047 were prepared by Pitt. Shown for comparison.

Cat. No. CAL.09 was prereduced and coated with Soya.

Cat. No. CAL.10 was prepared on Condea Alumina.

Table 12

DATE: 12/30/94

COMPARISON OF CONVERSION AND SELECTIVITY OF
METHANE REDUCTION CATALYSTS AT STARTUP CONDITIONS

Period No.					Temp.	Pres.	H2/CO Ratio							
-----					-----	-----	-----							
1					240 C	450psi	2.0							

Run	Cat.	Cat.	Conv.	Prod.	Selectivities				Alpha	Alpha	Catalyst	Composit.		
No	No	wt,g	%	Rate	%CH4	%C2	%C3+	%CO2	GC	Liq	Prom%	Metal%	Suppt	

M-3	SBCR													
5	CO.003	15.1	31.7	1.53	16.7	2.4	79.8	1.16	0.71	--	1.0La	0.5Ru	Al	
6	CO.011	15.3	14.3	0.67	7.6	1.6	89.4	1.42	0.78	0.83	0.0	0.0	Si	
7	CO.012	15.8	13.9	0.63	6.1	1.5	90.6	1.74	0.80	0.89	0.0	0.0	Si	
8	CO.015	15.0	28.3	1.37	12.7	2.0	84.1	1.24	0.76	0.80	1.0La	0.43Ru	Al	
9	CO.011	15.0	18.5	0.89	8.8	1.7	88.8	0.77	0.78	0.83	0.0	0.0	Si	
11	CO.017	15.0	27.2	1.32	11.2	1.8	85.9	1.14	0.77	0.80	1.0La	0.5Ru	Al	
12	CO.018	15.6	33.8	1.56	9.7	2.0	86.6	1.68	0.75	0.85	0.0	0.5Ru	Al	
13	CO.016	14.7	26.4	1.31	(1)	1.7	89.3	0.68	0.78	0.81	1.0La	0.43Ru	Al	
14	CO.019	15.2	13.9	0.66	(2)	1.7	97.2	0.70	0.80	0.86	0.0	0.5Ru	Si	
15	CO.005	14.7	27.1	1.34	7.9	1.6	89.7	0.82	0.79	0.82	0.0	0.0	Al	
16	CO.002	15.4	30.1	1.42	12.5	2.5	83.9	1.09	0.75	0.80	1.0La	0.43Ru	Al	
17	CO.025	15.6	26.6	1.24	10.7	2.1	86.4	0.82	0.76	0.82	8.5Zr	0.0	Si	
18	CO.004	15.0	33.9	1.64	15.3	2.4	80.9	1.37	0.74	0.79	1.0La	0.43Ru	Al	
19	CO.021	15.6	23.2	1.08	9.4	2.0	88.0	0.73	0.77	0.82	0.7Zr	0.0	Si	
20	CO.041	15.8	25.3	1.16	11.0	2.1	86.0	0.88	0.76	0.84	8.5Zr	0.5Ru	Si	
21	CO.014	15.1	8.5	0.40	8.3	3.5	85.8	2.43	0.74	0.83	0.0	0.5Ru	Ti	
22	CO.040	14.5	1.8	0.09	0.0	4.0	94.1	1.89	0.71	0.82	0.0	0.0	Ti	
23	CO.047	15.8	28.2	1.29	7.7	1.5	89.3	1.47	0.79	0.84	0.3K	0.5Ru	Al	
24	CO.049	15.6	30.6	1.41	10.9	1.8	85.7	1.66	0.76	0.82	0.1K	0.5Ru	Al	
25	CO.047	15.6	28.1	1.30	8.8	1.6	88.1	1.50	0.78	0.85	0.3K	0.5Ru	Al	
26	CO.031	15.9	30.9	1.41	12.1	1.9	84.9	1.12	0.75	0.83	1.4Zr	0.0	Al	
27	CO.029	15.9	28.3	1.27	8.3	1.6	87.9	2.21	0.77	0.84	0.5K	0.5Ru	Al	
28	COW.01	15.0	1.1	0.05	0.0	12.	83.9	4.23	0.58	--	5.0Cu	10.0Zn	Al	
29	CO.053	25.2	42.0	1.19	15.8	2.3	79.5	2.42	0.73	--	0.0	0.5Ru	Al	
30	CO.053	29.6	41.8	1.02	22.6	2.9	71.5	3.05	0.66	0.77	0.0	0.5Ru	Al	
31	CO.055	15.0	30.0	1.46	23.7	3.7	70.2	2.30	0.61	0.81	1.0La	1.0Re	Al	
32	CO.044	16.4	20.9	0.93	6.7	1.9	90.8	0.56	0.77	0.83	15.0Zr	0.0	Si	
33	CO.053	31.4	41.4	0.94	23.2	3.1	69.6	4.06	0.65	0.76	0.0	0.5Ru	Al	
34	CO.060	15.6	31.4	1.46	14.0	2.3	82.2	1.48	0.75	0.79	0.0	0.0	Al	

Note: Catalyst Run 9 screened thru 170 x 400 mesh.

Catalysts For Runs 11 through 28 (except Runs 21 and 22) screened thru 150x 400 mesh.

Catalysts for Runs 21 and 22 screened thru 100 x 400 mesh.

Catalysts Nos. Co.029 and Co.060 contained 30 wt% cobalt.

G.C.Problems

- (1) Weak TCD filaments in G.C. CH4 peaks smaller than expected.
- (2) Internal valve in G.C. leaked. CH4 peak undetected.

SBCR CATALYST EXTRACTIONS

Catalyst No. (Support)	Run No.	Charge		Charge		Recovered		Reduction in Particle Size, %
		(H ₂ Reduced) wt, gm	(Oxidized) wt, gm	Particle Size, mvd, microns	Particle Size at 10% microns	Particle Size, mvd, microns	Particle Size at 10% microns	
Co.001 (Al)	1	14.5	12.63	42.02	24.25	41.06	23.62	2.3
Co.001 (Al)	2	16.5	15.18	42.02	24.25	40.09	22.86	4.6
Co.005 (Al)	3	19.5	18.41	85.66	30.46	64.53	31.27	24.7
Co.002 (Al)	4	20.1	20.4	73.61	32.86	71.19	33.50	3.3
Co.003 (Al)	5	15.1	14.54	76.81	34.40	72.57	34.25	5.5
Co.011 (Si)	6	15.3	16.03	107.09 (1)	53.19	94.02	40.44	12.2
Co.012 (Si)	7	15.8	14.73	105.22 (1)	51.33	101.37	44.44	3.7
Co.015 (Al)	8	15.0	15.52	75.63 (1)	33.15	74.68	32.68	1.3
Co.011 (Si)	9	15.0	15.92	79.88 (2)	48.31	72.44	36.31	9.3
Co.016 (Al)	10	15.5	15.72	64.60 (2)	32.16	64.38	32.78	0.3
Co.017 (Al)	11	15.0	15.09	73.14 (3)	36.29	69.95	35.62	4.4
Co.018 (Al)	12	15.6	16.97	62.89 (3)	32.56	68.16	34.74	--
Co.016 (Al)	13	14.7	13.30	67.69 (3)	35.05	64.79	34.20	4.3
Co.019 (Si)	14	15.2	15.00	92.63 (3)	42.73	84.39	36.52	8.9
Co.005 (Al)	15	14.7	15.30	80.62 (3)	45.07	71.90	36.79	10.8
Co.002 (Al)	16	15.4	14.98	73.61 (3)	32.86	67.62	32.67	8.1
Co.002 (Al)	1 (M4)	15.0	11.00	73.61 (3)	32.86	66.26	35.75	10.0
Co.025 (Si)	17	15.6	14.60	87.19 (3)	47.35	78.31	36.27	10.2
Co.004 (Al)	18	15.0	15.25	78.12 (3)	44.15	66.86	33.83	14.4
Co.021 (Si)	19	15.6	16.06	86.18 (3)	46.54	77.95	35.59	9.55
Co.041 (Si)	20	15.8	17.02	87.48 (3)	49.26	68.74	26.72	17.0
Co.021 (Si)	3 (M4)	15.2	15.1	73.61 (3)	24.46	71.38	32.33	3.03
Co.024 (Al)	4 (M4)	15.4	(4)	--	--	--	--	--
Co.035 (Si)	5 (M4)	15.4	14.08	89.14 (3)	49.29	74.76	31.67	19.2
Co.028 (Al)	6 (M4)	15.4	15.7	80.83 (3)	44.81	71.83	36.34	11.1

- (1) Screened through 100x400 mesh screens. (2) Screened through 170x400 mesh screens.
 (3) Screened through 150x400 mesh screens. (4) Did not filter, too waxy

Note: The charge weights are in the hydrogen-reduced state and the recovered weights are in the oxidized state. The particle size is reported as the mean volume diameter (mvd) as measured by a Microtrac particle size analyzer.

Table 13
(Continued)

SBCR CATALYST EXTRACTIONS

Catalyst No. (Support)	Run No.	Charge		Recovered		Charge		Recovered		Reduction in Particle Size, %
		(H ₂ Reduced) wt, gm		(Oxidized) wt, gm		Particle Size, mvd, microns	Particle Size at 10% microns	Particle Size, mvd. microns	Particle Size at 10% microns	
Co.014 (Ti)	21	15.1		15.1		111.70 (1)	32.65	106.66	33.49	4.51
Co.040 (Ti)	22	14.5		8.5		(5)	(5)	130.40	51.40	--
Co.047 (Al)	23	15.8		16.95		83.42 (3)	44.41	76.46	39.02	8.34
Co.049 (Al)	24	15.6		16.54		81.3 (3)	42.39	70.11	35.87	13.8
Co.047 (Al)	25	15.6		16.69		79.36 (3)	41.72	69.09	36.16	12.94
Co.031 (Al)	26	15.9		15.37		75.48 (3)	38.34	68.42	35.39	9.35
Co.029 (Al)	27	15.9		18.28		76.39 (3)	39.56	68.72	36.04	10.04
Co.043 (Si)	7 (M4)	15.4		15.1		(5)	(5)	85.51	40.20	--
Co.006 (Ti)	8 (M4)	15.0		9.09		121.38 (1)	52.80	99.31	38.62	18.2
Co.048 (Si)	9 (M4)	15.4		15.85		82.40 (3)	40.94	70.69	25.53	14.2
CAL.02 (Al)	10 (M4)	15.9		16.42		74.40 (3)	37.79	65.89	34.14	11.44
Co.053 (Al)	12 (M4)	15.9		16.95		82.02 (3)	43.10	69.53	35.76	15.23
Co.054 (Si)	13 (M4)	15.7		17.09		101.17 (3)	57.54	82.37	37.89	18.58
Blend A (Al)	14 (M4)	20.0		14.61		86.23 (3)	46.36	77.43	42.81	10.21
Co.034 (Al)	15 (M4)	13.0		9.52		(5)	(5)	88.26	45.28	--
CAL.04 (Al)	16 (M4)	16.1		21.78		71.54 (3)	36.28	66.50	32.82	7.05
CAL.08 (Al)	17 (M4)	15.0 (6)		14.27		63.12	25.60	62.80	26.03	0.51
CAL.07 (Al)	18 (M4)	14.5 (6)		13.37		--	--	67.02	28.12	--
CAL.05 (Al)	19 (M4)	15.7		5.62		72.75	36.90	71.62	36.55	1.55
CAL.06 (Al)	20 (M4)	15.0		(7)		72.62	37.33	--	--	--
Co.053 (Al)	29 (M3)	25.2		25.8		75.63	40.80	71.09	38.20	6.00
Co.004 (Al)	21 (M4)	15.9		15.04		81.38	41.82	72.88	37.61	10.44

-
- (1) Screened through 100x400 mesh screens.
 - (3) Screened through 150x400 mesh screens.
 - (5) Insufficient feed sample.
 - (6) Wax coated.
 - (7) Lost catalyst.

Table 13
(Continued)

SBCR CATALYST EXTRACTIONS

Catalyst No. (Support)	Run No.	Charge		Charge		Recovered		Reduction in Particle Size, %
		(H ₂ Reduced) wt, gm	(Oxidized) wt, gm	Particle Size, mvd, microns	Particle Size at 10% microns	Particle Size, mvd, microns	Particle Size at 10% microns	
Blend B (Al)	22 (M4)	30.5	31.75	77.85	43.10	73.74	38.80	5.28
CAL.09 (Al)	23 (M4)	30.0 (6)	14.34	63.12	25.60	62.10	26.32	1.62
Co.053-3 (Al)	24 (M4)	28.5	27.85	75.63	40.80	70.69	35.03	6.53
Co.055 (Al)	31 (M3)	15.0	14.67	85.58	46.27	74.56	39.00	12.88
Co.056 (Si)	25 (M4)	15.0	14.93	99.93	54.62	88.48	43.26	11.46
Co.044 (Si)	32 (M3)	16.4	17.01	92.15	49.30	84.92	40.21	7.85
CAL.10 (Al)	26 (M4)	15.6	14.63	83.05	47.11	81.12	45.87	2.32
Co.053-4 (Al)	33 (M4)	31.4	31.9	84.09	44.40	73.50	37.10	12.6
Co.050 (Al)	27 (M4)	14.6	10.62	(5)	(5)	91.37	44.07	--
Co.060 (Al)	34 (M3)	15.6	15.8	87.45	47.08	80.89	43.42	7.50

(5) Insufficient feed sample.

APPENDIX A

Co Catalyst Formulations

Catalyst Prep #	Co.057	Date Tech	Oct- 10-1994	Amount	200.0 g
Compound (%wt)		Co	Re	La ₂ O ₃	SiO ₂
		20	1	1	

Support	Silica Davison Grade 952	Amount	156.00 g
Particle Size	400 - 0 mesh	Treatment	500°C / 10 hr
Cobalt	Cobalt Nitrate	Amount	197.29 g
Metal	Perrhenic Acid	Amount	3.67 g
Promotor	La-Nitrate	Amount	5.31 g
Promotor		Amount	
Promotor		Amount	

PROCEDURE			
Preparation	X	Incipient Wetness Ion Exchange	Wet Impregnation Other
Notes	Incipient wetness: aqueous solution - ca. 1.2 ml/g support Dry catalyst precursor in an oven at 115°C / 5 hr		
Calcination	Temperature	300°C	Time 2 hr
Notes	50g of the catalyst precursor is not to be calcined !!		

Co.057: 20 wt% Co
 1 wt% Re
 1 wt% La₂O₃
 Silica

La/Re-promoted SiO₂-supported catalyst comparable to Co.055 where SiO₂ is used as support instead of Al₂O₃

Preparation Procedure:

Calcine the SiO₂ at 500°C for 10 hrs. Presieve to >38 microns (400-0 mesh).

Impregnate the support with an aqueous solution of Co nitrate [Co(NO₃)₂·6H₂O], perrhenic acid [HReO₄], lanthanum nitrate, and using an appropriate quantity to get incipient wetness (ca. 1.2 ml/g) with the desired loading of Co.

Dry the catalyst precursor in an oven for 5 hrs at 115°C with moderate stirring.

The dried catalyst is then calcined in air by raising its temperature at a heating rate of ca. 1°C/min to 300°C and holding for 2 hrs.

Reduction Procedure before Reaction:

Reduce the catalyst in a pure hydrogen flow of 3000 cc/g/hr by heating at 1°C/min to 250°C and holding for 10 hrs.

Catalyst Prep #	Co.058	Date Tech	Oct. 10-1994	Amount	200.0 g
Compound (%wt)	Co 20	La2O3 1	Al2O3		

Support	y-Alumina / Vista-B	Amount	158.00 g
Particle Size	400 - 0 mesh	Treatment	500°C / 10 hr
Cobalt	Cobalt Nitrate	Amount	197.29 g
Metal		Amount	
Promotor	La-Nitrate	Amount	5.31 g
Promotor		Amount	
Promotor		Amount	

PROCEDURE			
Preparation	X	Incipient Wetness Ion Exchange	Wet Impregnation Other
Notes	Incipient wetness: aqueous solution - ca. 1.2 ml/g support Dry catalyst precursor in an oven at 115°C / 5 hr		
Calcination	Temperature	300°C	Time 2 hr
Notes	50g of the catalyst precursor is not to be calcined !!		

Co.058: 20 wt% Co
 1 wt% La₂O₃
 γ-alumina

La-promoted Al₂O₃-supported catalyst comparable to Co.055 without Re.

Preparation Procedure:

Calcine the γ-alumina at 500°C for 10 hrs. Use Vista B alumina. Presieve to 38-63 microns (400-250 mesh).

Impregnate the support with an aqueous solution of Co nitrate [Co(NO₃)₂·6H₂O], lanthanum nitrate, and using an appropriate quantity to get incipient wetness (ca. 1.2 ml/g) with the desired loading of Co.

Dry the catalyst precursor in an oven for 5 hrs at 115°C with moderate stirring.

The dried catalyst is then calcined in air by raising its temperature at a heating rate of ca. 1°C/min to 300°C and holding for 2 hrs.

Reduction Procedure before Reaction:

Reduce the catalyst in a pure hydrogen flow of 3000 cc/g/hr by heating at 1°C/min to 350°C and holding for 10 hrs.

Catalyst Prep #	Co.059	Date Tech	Oct-10-94	Amount	200 g
Compound (%wt)	Co	La ₂ O ₃	Al ₂ O ₃		
	20	1			

Support	y-Alumina VISTA B	Amount	
Particle Size	400 - 0 mesh	Treatment	600°C / 2 hrs
Cobalt	Cobalt Nitrate	Amount	
Metal		Amount	
Promotor		Amount	
Promotor	Lanthanum Nitrate	Amount	
Promotor		Amount	

PROCEDURE			
Preparation	X	Incipient Wetness Ion Exchange	Wet Impregnation Other
Notes	Incipient wetness: aqueous solution of cobalt nitrate - ca. 1 ml/g Dry catalyst precursor at 120°C / 16 hrs Incipient wetness: aqueous solution of La		
Calcination	Temperature	300 deg C	Time 2 hr
Notes	50 g of precursor is not to be calcined		

Co.059: 20 wt% Co
 1 wt% La₂O₃
 γ-alumina

Similar to Co.015, but without Ru.

Preparation Procedure:

Calcine the γ-alumina at 600°C for 2 hrs. Use Vista B alumina. Presieve to >38 microns (400-0 mesh).

Impregnate the support with an aqueous solution of Co nitrate [Co(NO₃)₂·6H₂O] using an appropriate quantity to get incipient wetness (ca. 1 ml/g) with the desired loading of Co.

Dry the catalyst precursor for 16 hrs at 120°C.

Impregnate the catalyst precursor with an aqueous solution of lanthanum nitrate hexahydrate using an appropriate quantity to get incipient wetness with the desired loading of La₂O₃.

Dry the catalyst precursor at 90°C with moderate stirring.

?

Reduction Procedure before Reaction:

Reduce the catalyst in a pure hydrogen flow of 1000 cc/g/hr by heating to 350°C and holding overnight (for 16 hrs).

Catalyst Prep #	Co.060	Date Tech	Oct. -10-94	Amount	250.0 g
Compound (%wt)	Co 30				Al ₂ O ₃

Support	y-Alumina / Vista-B	Amount	175.00 g
Particle Size	400 - 0 mesh	Treatment	500°C / 10 hr
Cobalt	Cobalt Nitrate	Amount	369.92 g
Metal		Amount	
Promoter		Amount	
Promoter		Amount	
Promoter		Amount	

PROCEDURE

Preparation	X	Incipient Wetness Ion Exchange	Wet Impregnation Other
Notes	<p>Incipient wetness: aqueous solution - ca. 1.2 ml/g - 60% of loading in first step</p> <p>Dry catalyst precursor in an oven at 115°C / 12 hrs - calcine 300°C / 2 hrs</p> <p>Incipient wetness: aqueous solution - ca. 1.2 ml/g - remaining 40% of loading</p> <p>Repeat drying and calcination</p>		
Calcination	Temperature	_____	Time _____
Notes			

Co.060:

30 wt% Co
 γ -alumina

Non-promoted catalyst similar to Co.005, with 30% Co.

Preparation Procedure:

Calcine the γ -alumina at 500°C for 10 hrs. Use Vista B alumina. Presieve to >38 microns (400-0 mesh).

Impregnate the support in 2 steps with an aqueous solution of Co nitrate [$\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$], using an appropriate quantity to get incipient wetness (ca. 1.2 ml/g) with 60% of the desired loading of Co in the first step.

Dry in air at 115°C for 12 hours and calcine in air at 300°C for 2 hours (heating rate of ca. 1°C/min to 300°C).

In the second step, impregnate the remaining 40% of the Co. Repeat the drying and calcination procedures.

Reduction Procedure before Reaction:

Reduce the catalyst in a pure hydrogen flow of 3000 cc/g/hr by heating at 1°C/min to 350°C and holding for 10 hrs.

Catalyst Prep #	Co.061	Date Tech	Oct-10-94	Amount	250.0 g
Compound (%wt)		Co	Ru	Al ₂ O ₃	
		30	0.5		

Support	y-Alumina VISTA B	Amount	173.75 g
Particle Size	400 - 0 mesh	Treatment	500°C / 10 hrs
Cobalt	Cobalt Nitrate	Amount	369.92 g
Metal	Ruthenium Nitrosylnitrate	Amount	4.46 g
Promoter		Amount	
Promoter		Amount	
Promoter		Amount	

PROCEDURE

Preparation	X	Incipient Wetness Ion Exchange	Wet Impregnation Other
Notes	Incipient wetness: aqueous solution - ca. 1.2 ml/g - 60% of loading in first step Dry catalyst precursor in an oven at 115°C / 12 hrs - calcine 300°C / 2 hrs Incipient wetness: aqueous solution - ca. 1.2 ml/g - remaining 40% of loading Repeat drying and calcination		

Calcination	Temperature	_____	Time	_____
Notes				

Co.061:

30 wt% Co
0.5 wt% Ru
γ-alumina

Ru-promoted catalyst similar to Co.053 with 30% Co.

Preparation Procedure:

Calcine the γ-alumina at 500°C for 10 hrs. Use Vista B alumina. Presieve to >38 microns (400-0 mesh).

Impregnate the support in 2 steps with an aqueous solution of Co nitrate $[\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}]$, and Ru nitrosyl nitrate using an appropriate quantity to get incipient wetness (ca. 1.2 ml/g) with 60% of the desired loading of Co and Ru in the first step.

Dry in air at 115°C for 12 hours and calcine in air at 300°C for 2 hours (heating rate of ca. 1°C/min to 300°C).

In the second step, impregnate the remaining 40% of the Co and Ru. Repeat the drying and calcination procedures.

Reduction Procedure before Reaction:

Reduce the catalyst in a pure hydrogen flow of 3000 cc/g/hr by heating at 1°C/min to 350°C and holding for 10 hrs.

Catalyst	Co.062	Date	Oct-10-94	Amount	250.0 g
Prep #		Tech			
Compound		Co	Ru	K	Al ₂ O ₃
(%wt)		30	0.5	1.5	

Support	y-Alumina VISTA B	Amount	170.00 g
Particle Size	400 - 0 mesh	Treatment	500°C / 10 hrs
Cobalt	Cobalt Nitrate	Amount	369.92 g
Metal	Ruthenium Nitrosyl nitrate	Amount	4.66 g
Promotor	Potassium Nitrate	Amount	9.71 g
Promotor		Amount	
Promotor		Amount	

PROCEDURE			
Preparation	X	Incipient Wetness Ion Exchange	Wet Impregnation Other
Notes	Incipient wetness: aqueous solution - ca. 1.2 ml/g - 60% of loading in first step Dry catalyst precursor in an oven at 115°C / 12 hrs - calcine 300°C / 2 hrs Incipient wetness: aqueous solution - ca. 1.2 ml/g - remaining 40% of loading Repeat drying and calcination		
Calcination	Temperature	_____	Time _____
Notes			

Co.062: 30 wt% Co
 0.5 wt% Ru
 1.5 wt% K
 γ -alumina

Ru/K-promoted catalyst similar to Co.029 with 1.5% K

Preparation Procedure:

Calcine the γ -alumina at 500°C for 10 hrs. Use Vista B alumina. Presieve to >38 microns (400-0 mesh).

Impregnate the support in 2 steps with an aqueous solution of Co nitrate [$\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$], Ru nitrosyl nitrate, and K nitrate using an appropriate quantity to get incipient wetness (ca. 1.2 ml/g) with 60% of the desired loading of Co, Ru, and K in the first step.

Dry in air at 115°C for 12 hours and calcine in air at 300°C for 2 hours (heating rate of ca. 1°C/min to 300°C).

In the second step, impregnate the remaining 40% of the Co, Ru, and K. Repeat the drying and calcination procedures.

Reduction Procedure before Reaction:

Reduce the catalyst in a pure hydrogen flow of 3000 cc/g/hr by heating at 1°C/min to 350°C and holding for 10 hrs.

Catalyst Prep #	Co.063	Date Tech	Nov-07-94	Amount	200.0 g
Compound (%wt)	Co	La	Al ₂ O ₃		
	20	8.5			

Support	y-Alumina VISTA B	Amount	143.00 g
Particle Size	400 - 0 mesh	Treatment	500°C / 10 hrs
Cobalt	Cobalt Nitrate	Amount	197.29 g
Metal		Amount	
Promotor	La-Nitrate	Amount	105.91 g
Promotor		Amount	
Promotor		Amount	

PROCEDURE			
Preparation	X	Incipient Wetness Ion Exchange	Wet Impregnation Other
Notes	<p>Incipient wetness: aqueous solution of La</p> <p>Dry catalyst precursor in an oven 115°C / 5 hrs with stirring/calcine at 300 °C/2hrs</p> <p>Incipient wetness: aqueous solution of Co with catalyst precursor</p> <p>Dry catalyst precursor in an oven 115°C / 5 hrs with stirring/calcine at 300 C/2 hrs</p>		
Calcination	Temperature	300°C	Time 2 hrs
Notes	50g of the catalyst precursor are not to be calcined !!		

Co.063: 20 wt% Co
 8.5 wt% La
 Al₂O₃

La-promoted Al₂O₃-supported catalyst comparable to Co.056 with SiO₂ replaced by Al₂O₃ as the support. One-step impregnation of alumina with lanthanum nitrate followed by one-step impregnation with cobalt nitrate solution.

Preparation Procedure:

Calcine the γ -alumina at 500°C for 10 hrs. Use Vista B alumina. Presieve to >38 microns (400-0 mesh).

Impregnate the support with an aqueous solution of La nitrate using an appropriate quantity to get incipient wetness with the desired loading of La.

Dry the La-loaded Al₂O₃ in an oven for 5 hrs at 115°C with moderate stirring.

Calcine the dried support in air by raising its temperature at a heating rate of ca. 1°C/min to 300°C and holding for 2 hrs.

Impregnate the La-loaded alumina with an aqueous solution of Co nitrate [Co(NO₃)₂·6H₂O] using an appropriate quantity to get incipient wetness with the desired loading of Co.

Dry the catalyst precursor in an oven for 5 hrs at 115°C with moderate stirring.

Calcine the dried catalyst in air by raising its temperature at a heating rate of ca. 1°C/min to 300°C and holding for 2 hrs.

Reduction Procedure before Reaction:

Reduce the catalyst in a pure hydrogen flow of 3000 cc/g/hr by heating at 1°C/min to 350°C and holding for 10 hrs.

Catalyst Prep #	CoW.08	Date Tech	Oct-10-94	Amount	100.0 g
Compound (%wt)	Co	Cu	Cr	Al ₂ O ₃	
	30	5	4		

Support	γ -Alumina VISTA B	Amount	61.00 g
Particle Size	400 - 0 mesh	Treatment	500°C / 10 hrs
Metal I	Cobalt Nitrate	Amount	147.97 g
Metal II	Copper (II) Nitrate	Amount	19.01 g
Metal III	Chromium (III) Nitrate	Amount	30.77 g
Promoter		Amount	
Promoter		Amount	

PROCEDURE			
Preparation	X	Incipient Wetness Ion Exchange	Wet Impregnation Other
Notes	Incipient wetness: aqueous solution Cu + Cr, ca. 1.2 ml/g Dry catalyst precursor in an oven 110°C / 16 hrs/Calcine 750 °C 24 hrs. Incipient wetness: aqueous solution Co. Dry catalyst precursor in an oven 115°C / 5 hrs.		
Calcination	Temperature	300°C	Time 10 hrs
Notes			

CoW.08

30 wt% Co
5 wt% Cu
4 wt% Cr
 γ -alumina

Cobalt impregnation on calcined Cu-Cr/ γ -alumina. Similar to CoW.05, but with 30% Co.

Preparation Procedure

Calcine γ -alumina at 500°C for 10 hrs. Use Vista B alumina. Presieve to > 38 microns (400-0 mesh).

Impregnate the support with an aqueous solution of $\text{Cu}(\text{NO}_3)_2 \cdot x\text{H}_2\text{O}$, and $\text{Cr}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ using appropriate quantity to get incipient wetness (ca. 1.2 ml/g) with the desired loading of Cu and Cr.

Dry the catalyst precursor in an oven for 16 hours at 110°C.

The dried catalyst is then calcined in air by raising its temperature at a heating rate of ca. 1°C/min to 750°C and holding for 24 hours.

Impregnate the Cu-Cr/ Al_2O_3 with an aqueous solution of Co nitrate [$\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$] using an appropriate quantity to get incipient wetness with the desired loading of Co.

Dry the catalyst precursor in an oven for 5 hrs at 115°C with moderate stirring.

Calcine the dried catalyst in air by raising its temperature at a heating rate of ca. 1°C/min to 300°C and holding for 10 hrs.

Reduction Procedure before Reaction:

Heat the catalyst in inert gas to 120°C at a rate of 1°C/min then start adding hydrogen to give a concentration of 0.5% at the bed inlet. Raise the catalyst bed temperature to 165°C at a rate of ca. 30°C/hr. When the temperature of the bed has reached 160°C increase the hydrogen concentration in the carrier gas to 1.0%. As the reduction proceeds and the temperature rise begins to diminish, the inlet temperature may be raised to 200°C. The inlet hydrogen concentration can then be increased to about 3-5%, provided that the maximum temperature limit of 230°C is not exceeded. When the reduction appears to be complete the inlet temperature should be raised to 230°C and the inlet hydrogen concentration raised to ca. 20%.

Catalyst Prep #	CoW.09	Date Tech	Oct-10-94	Amount	100.0 g
Compound (%wt)	Co	Cu	Cr	Al ₂ O ₃	
	20	10	8		

Support	SiO ₂	Amount	62.00 g
Particle Size	400 - 0 mesh	Treatment	500°C / 10 hrs
Metal I	Cobalt Nitrate	Amount	98.64 g
Metal II	Copper (II) Nitrate	Amount	38.01 g
Metal III	Chromium (III) Nitrate	Amount	61.54 g
Promotor		Amount	
Promotor		Amount	

PROCEDURE			
Preparation	X	Incipient Wetness Ion Exchange	Wet Impregnation Other
Notes	Incipient wetness: aqueous solution Cu + Cr Dry catalyst precursor in an oven 110°C / 16 hrs/Calcine 500 °C 24 hrs. Incipient wetness: aqueous solution Co. Dry catalyst precursor in an oven 115°C / 5 hrs.		
Calcination	Temperature	300°C	Time 10 hrs
Notes			

CoW.09

20 wt% Co
10 wt% Cu
8 wt% Cr
Silica

Cobalt impregnation on calcined Cu-Cr/Silica. Similar to CoW.06, but with 10% Cu and 8% Cr.

Preparation Procedure

Calcine silica at 500°C for 10 hrs. Use Davison Grade 952 silica. Presieve to > 38 microns (400-0 mesh).

Impregnate the support with an aqueous solution of $\text{Cu}(\text{NO}_3)_2 \cdot x\text{H}_2\text{O}$, and $\text{Cr}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ using appropriate quantity to get incipient wetness (ca. 1.2 ml/g) with the desired loading of Cu and Cr.

Dry the catalyst precursor in an oven for 16 hours at 110°C.

The dried catalyst precursor is then calcined in air by raising its temperature at a heating rate of ca. 1°C/min to 500°C and holding for 24 hours.

Impregnate the Cu-Cr/SiO₂ with an aqueous solution of Co nitrate [$\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$] using an appropriate quantity to get incipient wetness with the desired loading of Co.

Dry the catalyst precursor in an oven for 5 hrs at 115°C with moderate stirring.

Calcine the dried catalyst in air by raising its temperature at a heating rate of ca. 1°C/min to 300°C and holding for 10 hrs.

Reduction Procedure before Reaction:

Heat the catalyst in inert gas to 120°C at a rate of 1°C/min then start adding hydrogen to give a concentration of 0.5% at the bed inlet. Raise the catalyst bed temperature to 165°C at a rate of ca. 30°C/hr. When the temperature of the bed has reached 160°C increase the hydrogen concentration in the carrier gas to 1.0%. As the reduction proceeds and the temperature rise begins to diminish, the inlet temperature may be raised to 200°C. The inlet hydrogen concentration can then be increased to about 3-5%, provided that the maximum temperature limit of 230°C is not exceeded. When the reduction appears to be complete the inlet temperature should be raised to 230°C and the inlet hydrogen concentration raised to ca. 20%.

Catalyst Prep #	CoW.10	Date Tech	Nov-07-94	Amount	100.0 g
Compound (%wt)	Co	Fe	Ru	Al2O3	
	10	10	0.5		

Support	γ -Alumina VISTA B	Amount	79.50 g
Particle Size	400 - 0 mesh	Treatment	500°C / 10 hrs
Metal I	Cobalt Nitrate	Amount	49.32 g
Metal II	Iron (III) Nitrate	Amount	72.31 g
Metal III Promoter Promoter	Ruthenium Nitrosyl nitrate	Amount Amount Amount	1.79 g

PROCEDURE			
Preparation	X	Incipient Wetness Ion Exchange	Wet Impregnation Other
Notes	Incipient wetness: aqueous solution Fe, Co, Ru/Ca. 1.2 ml/g Dry catalyst precursor in an oven 110°C / 5 hrs/Calcine 300 °C 10 hrs.		
Calcination	Temperature	300°C	Time 10 hrs
Notes			

CoW.10 10 wt% Fe
 10 wt% Co
 0.5 wt% Ru
 γ -alumina

Ru promoted cobalt/iron impregnated on calcined γ -alumina

Preparation Procedure

Calcine γ -alumina at 500°C for 10 hrs. Use Vista B alumina. Presieve to >38 microns (400-0 mesh).

Impregnate the support with an aqueous solution of Fe nitrate $[\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}]$, Co nitrate $[\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}]$ and Ru nitrosylnitrate $[\text{Ru}(\text{NO})(\text{NO}_3)_3 \cdot 2\text{H}_2\text{O}]$ using appropriate quantities to get incipient wetness (ca. 1.2 ml/g) with the desired loading of Fe, Co, and Ru.

Dry the catalyst precursor in an oven for 5 hrs at 115°C with moderate stirring.

Calcine the dried catalyst in air by raising its temperature at a heating rate of ca. 1°C/min to 300°C and holding for 10 hrs.

Reduction Procedure before Reaction:

Reduce the catalyst in pure hydrogen flow of 3000cc/g/hr by heating at 1°C/min to 350°C and holding for 10 hrs.

Catalyst Prep #	CoW.11	Date Tech	Nov-07-94	Amount	100.0 g
Compound (%wt)	Co	Fe	Ru	K	Al ₂ O ₃
	10	10	0.5	0.5	

Support	y-Alumina VISTA B	Amount	79.00 g
Particle Size	400 - 0 mesh	Treatment	500°C / 10 hrs
Metal I	Cobalt Nitrate	Amount	49.32 g
Metal II	Iron (III) Nitrate	Amount	72.31 g
Metal III		Amount	
Promotor	Ruthenium Nitrosylnitrate	Amount	1.79 g
Promotor	Potassium Nitrate	Amount	

PROCEDURE

Preparation	X	Incipient Wetness	Wet Impregnation
		Ion Exchange	Other
Notes	Incipient wetness: aqueous solution Fe, Co, Ru, K/ Ca. 1.2 g/ml Dry catalyst precursor in an oven 115°C / 5 hrs/Calcine 300 °C 10 hrs.		
Calcination	Temperature	300°C	Time 10 hrs
Notes			

CoW.11 10 wt% Fe
 10 wt% Co
 0.5 wt% Ru
 0.5 wt% K
 γ -alumina

Ru and K promoted cobalt/iron impregnated on calcined γ -alumina

Preparation Procedure

Calcine γ -alumina at 500°C for 10 hrs. Use Vista B alumina. Presieve to >38 microns (400-0 mesh).

Impregnate the support with an aqueous solution of Fe nitrate $[\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}]$, Co nitrate $[\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}]$, Ru nitrosyl nitrate $[\text{Ru}(\text{NO})(\text{NO}_3)_3 \cdot 2\text{H}_2\text{O}]$, and K nitrate $[\text{KNO}_3]$ using appropriate quantities to get incipient wetness (ca. 1.2 ml/g) with the desired loading of Fe, Co, Ru, and K.

Dry the catalyst precursor in an oven for 5 hrs at 115°C with moderate stirring.

Calcine the dried catalyst in air by raising its temperature at a heating rate of ca. 1°C/min to 300°C and holding for 10 hrs.

Reduction Procedure before Reaction:

Reduce the catalyst in pure hydrogen flow of 3000cc/g/hr by heating at 1°C/min to 350°C and holding for 10 hrs.

Catalyst Prep #	CoW.12	Date Tech	Nov-07-94	Amount	100.0 g
Compound (%wt)	Co	Fe	Ru	SiO ₂	
	10	10	0.5		

Support	Silica Davison Grade 59	Amount	79.50 g
Particle Size	400 - 0 mesh	Treatment	500°C / 10 hrs
Metal I	Cobalt Nitrate	Amount	49.32 g
Metal II	Iron (III) Nitrate	Amount	72.31 g
Metal III Promotor Promotor	Ruthenium Nitrosylnitrate	Amount Amount Amount	1.79 g

PROCEDURE			
Preparation	X	Incipient Wetness Ion Exchange	Wet Impregnation Other
Notes	Incipient wetness: aqueous solution Co, Fe, Ru Dry catalyst precursor in an oven 115°C / 5 hrs/Calcine 300 °C 10 hrs.		
Calcination	Temperature	300°C	Time 10 hrs
Notes			

CoW.12 10 wt% Fe
 10 wt% Co
 0.5 wt% Ru
 Silica

Ru promoted cobalt/iron impregnated on calcined silica

Preparation Procedure

Calcine silica at 500°C for 10 hrs. Use Davison Grade 952 silica. Presieve to >38 microns (400-0 mesh).

Impregnate the support with an aqueous solution of Fe nitrate $[\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}]$, Co nitrate $[\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}]$ and Ru nitrosylnitrate $[\text{Ru}(\text{NO})(\text{NO}_3)_3 \cdot 2\text{H}_2\text{O}]$ using appropriate quantities to get incipient wetness with the desired loading of Fe, Co, and Ru.

Dry the catalyst precursor in an oven for 5 hrs at 115°C with moderate stirring.

Calcine the dried catalyst in air by raising its temperature at a heating rate of ca. 1°C/min to 300°C and holding for 10 hrs.

Reduction Procedure before Reaction:

Reduce the catalyst in pure hydrogen flow of 3000cc/g/hr by heating at 1°C/min to 250°C and holding for 10 hrs.

APPENDIX B

Fixed Bed Reaction Data

Co.004 - Run #6

Co wt%	NM wt %	Promotor wt%		Support
20	Ru 0.43		La2O3 1.00	Al2O3

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.167 g

WHSV = 15.37 1/hr

time on stream = 27.5 hrs

CO₂ (g/g cat/hr) = 0.044

CO₂ (% of CO) = 0.2

O/P = 1.60

CO conversion (%)	6.9
rate (g CH ₂ /g cat/hr)	0.47
alpha	0.61
C1 (wt%)	27.8
C2 - C4 (wt%)	29.9
C5 - C12 (wt%)	40.6
C13 + (wt%)	1.8

* Calcined in Nitrogen

Performance of Co.004

Dates: 10/10/94 - 10/11/94 Run #6

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 15.4 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	6.5	12.5	15.5	27.5
reaction temperature, °C	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	25.97	28.71	26.79	27.79
C2	4.64	5.12	4.74	4.88
C3	12.26	13.28	12.38	12.61
C4	12.38	12.86	12.38	12.40
C5	11.59	10.91	11.50	11.28
C6	8.68	6.10	7.91	7.77
C7	8.29	7.87	8.18	7.97
C8	5.58	5.37	5.63	5.38
C9	3.75	3.57	3.67	3.54
C10	2.46	2.42	2.53	2.41
C11	1.67	1.65	1.74	1.58
C12	1.05	1.02	1.03	0.96
C13	0.70	0.62	0.68	0.67
C14	0.57	0.35	0.54	0.51
C15	0.40	0.14	0.30	0.27
alpha chain growth probability	0.64	0.58	0.62	0.61

C1 - C50 estimated total product distribution, weight %

C1	25.6	29.1	26.7	27.8
C2 - C4	28.9	31.7	29.4	29.9
C5 - C12	42.8	38.2	41.8	40.6
C13 - C50	2.6	0.9	2.0	1.8

CO conversion, %	8.4	6.1	7.2	6.9
rate, g CH ₂ /g cat/hr	0.56	0.41	0.49	0.47
CO ₂ formation, %	0.2	0.3	0.2	0.2

Time-on-Stream Plot for Co.004 - Run #6

Schulz-Flory Plot for Co.004 - Run #6
Time on Stream (hrs)

Co.004 - Run #7

Co wt%	NM wt %	Promotor wt%		Support
20	Ru 0.43		La2O3 1.00	Al2O3

SUMMARY REACTION DATA*

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.194 g

WHSV = 13.29 1/hr

time on stream = 27.5 hrs

CO₂ (g/g cat/hr) = 0.042

CO₂ (% of CO) = 0.2

O/P = 3.01

CO conversion (%)	3.9
rate (g CH ₂ /g cat/hr)	0.23
alpha	0.61
C1 (wt%)	28.8
C2 - C4 (wt%)	29.3
C5 - C12 (wt%)	40.4
C13 + (wt%)	1.5

* Catalyst is reduced, calcined and rereduced

Performance of Co.004

Dates: 10/24/94 - 10/25/94 Run #7

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 13.3 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	0.5	3.5	9.5	21.5	24.5	27.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	21.71	25.28	28.12	29.22	28.49	28.39
C2	13.50	4.64	5.17	5.33	5.22	5.16
C3	10.56	11.58	12.46	12.54	12.24	12.02
C4	10.83	11.65	12.25	12.09	11.88	11.67
C5	10.39	11.16	11.33	11.28	11.31	11.20
C6	7.57	8.62	7.60	6.99	8.20	8.30
C7	7.78	8.32	7.07	7.05	7.05	7.06
C8	5.54	5.88	5.13	5.04	5.02	5.04
C9	3.93	4.18	3.70	3.59	3.59	3.64
C10	2.82	3.01	2.66	2.58	2.60	2.65
C11	2.02	2.04	1.78	1.72	1.75	1.77
C12	1.47	1.49	1.22	1.15	1.19	1.31
C13	1.03	1.13	0.81	0.63	0.79	0.94
C14	0.46	0.69	0.38	0.34	0.37	0.62
C15	0.39	0.33	0.32	0.43	0.30	0.22
alpha chain growth probability	0.64	0.63	0.63	0.65	0.62	0.61

C1 - C50 estimated total product distribution, weight %

C1	21.7	25.5	28.1	28.7	28.5	28.8
C2 - C4	34.8	28.1	29.8	29.5	29.3	29.3
C5 - C12	40.9	44.2	40.0	39.0	40.2	40.4
C13 - C50	2.6	2.2	2.2	2.8	2.0	1.5

CO conversion, %	5.6	4.9	3.7	2.8	3.6	3.9
rate, g CH ₂ /g cat/hr	0.33	0.28	0.21	0.16	0.21	0.23
CO ₂ formation, %	0.3	0.3	0.4	0.4	0.3	0.2

Time-on-Stream Plot for Co.004 - Run #7

Schulz-Flory Plot for Co.004 - Run #7
Time on Stream (hrs)

Co.004 - Run #8

Co wt%	NM wt %	Promotor wt%		Support
20	Ru 0.43		La2O3 1.00	Al2O3

SUMMARY REACTION DATA*

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.164 g

WHSV = 15.66 1/hr

time on stream = 24.5 hrs

CO₂ (g/g cat/hr) = 0.028

CO₂ (% of CO) = 0.1

O/P = 2.13

CO conversion (%)	5.8
rate (g CH ₂ /g cat/hr)	0.40
alpha	0.66
C1 (wt%)	27.2
C2 - C4 (wt%)	27.4
C5 - C12 (wt%)	41.6
C13 + (wt%)	3.8

* Catalyst calcined in helium

Performance of Co.004

Dates: 11/11/94 - 11/12/94 Run #8

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 15.7 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	0.5	3.5	6.5	9.5	12.5	15.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	24.37	25.97	26.59	27.18	27.53	27.59
C2	4.41	4.63	4.69	4.76	4.82	4.82
C3	11.68	11.88	11.81	11.86	11.91	11.89
C4	11.92	12.16	11.77	11.75	11.73	11.69
C5	11.41	11.31	11.02	10.95	11.01	10.99
C6	8.99	7.89	8.99	8.79	8.52	8.60
C7	8.37	8.16	7.84	7.78	7.70	7.68
C8	5.82	5.70	5.48	5.42	5.37	5.37
C9	4.12	3.97	3.83	3.79	3.75	3.75
C10	2.92	2.79	2.71	2.69	2.64	2.66
C11	2.10	1.96	1.89	1.81	1.82	1.72
C12	1.41	1.33	1.29	1.18	1.25	1.24
C13	0.92	0.82	0.82	0.79	0.76	0.80
C14	0.79	0.77	0.65	0.70	0.64	0.65
C15	0.76	0.67	0.61	0.58	0.56	0.57
alpha chain growth probability	0.68	0.67	0.66	0.66	0.66	0.66

C1 - C50 estimated total product distribution, weight %

C1	23.5	25.2	25.9	26.5	26.9	26.9
C2 - C4	27.0	27.8	27.5	27.6	27.8	27.7
C5 - C12	44.6	42.7	42.7	42.1	41.7	41.7
C13 - C50	4.9	4.4	4.0	3.8	3.7	3.7

CO conversion, %	8.1	7.3	7.1	6.8	6.5	6.3
rate, g CH ₂ /g cat/hr	0.56	0.50	0.49	0.47	0.44	0.43
CO ₂ formation, %	0.2	0.2	0.1	0.2	0.1	0.1

Performance of Co.004

Dates: 11/11/94 - 11/12/94 Run #8

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 15.7 l/hr, H₂/CO ratio in feed = 2

time on stream, hr	18.5	21.5	24.5
reaction temperature, °C	220	220	220
pressure, atm	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	27.62	27.80	27.97
C2	4.82	4.84	4.86
C3	11.82	11.87	11.86
C4	11.63	11.58	11.49
C5	10.99	11.00	10.97
C6	8.70	8.78	8.75
C7	7.67	7.68	7.58
C8	5.39	5.33	5.33
C9	3.75	3.72	3.72
C10	2.66	2.62	2.62
C11	1.72	1.72	1.73
C12	1.21	1.09	1.12
C13	0.77	0.75	0.76
C14	0.67	0.66	0.66
C15	0.59	0.56	0.58
alpha chain growth probability	0.66	0.66	0.66

C1 - C50 estimated total product distribution, weight %

C1	26.9	27.0	27.2
C2 - C4	27.5	27.5	27.4
C5 - C12	41.8	41.7	41.6
C13 - C50	3.8	3.7	3.8

CO conversion, %	6.1	6.0	5.8
rate, g CH ₂ /g cat/hr	0.42	0.41	0.40
CO ₂ formation, %	0.1	0.2	0.1

Time-on-Stream Plot for Co.004 - Run #8

Schulz-Flory Plot for Co.004 - Run #8
Time on Stream (hrs)

Co.015 - Run #3

Co wt%	NM wt %	Promotor wt%		Support
20	Ru 0.43		La2O3 1.00	Al2O3

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.200 g

WHSV = 12.84 1/hr

time on stream = 24.5 hrs

CO₂ (g/g cat/hr) = 0.031

CO₂ (% of CO) = 0.2

O/P = 1.62

CO conversion (%)	6.7
rate (g CH ₂ /g cat/hr)	0.38
alpha	0.63
C1 (wt%)	28.2
C2 - C4 (wt%)	29.2
C5 - C12 (wt%)	40.3
C13 + (wt%)	2.3

* Catalyst reduced without any calcination

Performance of Co.015

Dates: 10/05/94 - 10/06/94 Run #3

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 12.8 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	0.5	3.5	6.5	9.5	12.5	21.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	28.23	28.03	30.00	28.81	26.13	27.79
C2	5.16	5.06	5.41	5.16	4.67	4.96
C3	13.62	12.86	13.62	12.90	11.59	12.18
C4	13.25	12.67	13.31	12.82	11.54	12.13
C5	11.26	11.41	11.64	11.94	10.69	11.46
C6	6.69	8.13	7.15	8.88	7.95	8.60
C7	7.77	7.79	6.77	6.92	10.10	7.94
C8	5.08	5.13	4.45	4.63	6.38	5.35
C9	3.34	3.35	2.89	3.00	3.99	3.51
C10	2.07	2.09	1.83	1.91	2.65	2.30
C11	1.46	1.41	1.20	1.27	1.71	1.57
C12	0.87	0.78	0.73	0.68	1.10	0.86
C13	0.64	0.56	0.43	0.44	0.63	0.57
C14	0.38	0.42	0.34	0.35	0.48	0.45
C15	0.18	0.31	0.24	0.28	0.38	0.35
alpha chain growth probability	0.59	0.62	0.61	0.61	0.63	0.63

C1 - C50 estimated total product distribution, weight %

C1	28.4	27.7	29.7	28.5	25.8	27.4
C2 - C4	32.2	30.2	32.1	30.5	27.5	28.9
C5 - C12	38.2	40.0	36.6	39.2	44.2	41.4
C13 - C50	1.2	2.1	1.6	1.8	2.5	2.3

CO conversion, %	6.5	8.0	6.7	7.0	7.6	6.6
rate, g CH ₂ /g cat/hr	0.37	0.45	0.37	0.39	0.42	0.37
CO ₂ formation, %	0.3	0.2	0.2	0.1	0.1	0.1

Performance of Co.015

Dates: 10/05/94 - 10/06/94 Run #3

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.8 l/hr, H₂/CO ratio in feed = 2

time on stream, hr	24.5	27.5
reaction temperature, °C	220	220
pressure, atm	1.0	1.0
flow, cc/min	90.0	90.0

C1 - C15 product distribution, weight %

C1	28.59	27.93
C2	5.07	4.97
C3	12.34	12.11
C4	12.17	12.03
C5	11.36	11.34
C6	7.92	8.55
C7	7.81	7.93
C8	5.30	5.37
C9	3.45	3.52
C10	2.25	2.36
C11	1.52	1.41
C12	0.89	1.08
C13	0.55	0.61
C14	0.43	0.43
C15	0.35	0.36
alpha chain growth probability	0.63	0.63

C1 - C50 estimated total product distribution, weight %

C1	28.2	27.6
C2 - C4	29.2	28.7
C5 - C12	40.3	41.3
C13 - C50	2.3	2.4

CO conversion, %	6.7	6.4
rate, g CH ₂ /g cat/hr	0.38	0.36
CO ₂ formation, %	0.2	0.1

Time-on-Stream Plot for Co.015 - Run #3

Schulz-Flory Plot for Co.015 - Run #3
Time on Stream (hrs)

Co.017 - Run #3

Co wt%	NM wt %	Promotor wt%		Support
20	Ru 0.50		La2O3 1.00	Al2O3

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.201 g

WHSV = 12.81 1/hr

time on stream = 9.5 hrs

CO₂ (g/g cat/hr) = 0.030

CO₂ (% of CO) = 0.2

O/P = 2.41

CO conversion (%)	4.9
rate (g CH ₂ /g cat/hr)	0.27
alpha	0.67
C1 (wt%)	23.0
C2 - C4 (wt%)	26.1
C5 - C12 (wt%)	46.9
C13 + (wt%)	4.0

* Reaction data for only 10 hrs. on stream because of T serge after 10 hrs

Performance of Co.017

Dates: 10/03/94 - 10/04/94 Run #3

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 12.8 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	0.5	3.5	6.5	9.5
reaction temperature, °C	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	21.38	22.13	20.46	23.34
C2	4.07	4.14	11.99	4.39
C3	10.97	10.56	9.43	10.65
C4	11.92	11.48	10.33	11.52
C5	12.09	11.73	10.62	11.89
C6	9.71	9.57	8.85	9.38
C7	9.24	9.20	8.50	8.51
C8	6.57	6.70	6.19	6.26
C9	4.56	4.69	4.42	4.54
C10	3.10	3.21	3.14	3.29
C11	2.25	2.32	2.21	2.29
C12	1.52	1.57	1.41	1.50
C13	1.22	1.08	0.99	1.05
C14	0.83	0.93	0.85	0.81
C15	0.56	0.69	0.61	0.60
alpha chain growth probability	0.66	0.68	0.67	0.67

C1 - C50 estimated total product distribution, weight %

C1	21.2	21.6	20.1	23.0
C2 - C4	26.7	25.6	31.1	26.1
C5 - C12	48.4	48.1	44.8	46.9
C13 - C50	3.8	4.7	4.0	4.0

CO conversion, %	7.0	6.5	6.5	4.9
rate, g CH ₂ /g cat/hr	0.39	0.36	0.36	0.27
CO ₂ formation, %	0.1	0.2	0.1	0.2

Time-on-Stream Plot for Co.017 - Run #3

Schulz-Flory Plot for Co.017 - Run #3
Time on Stream (hrs)

Co.044 - Run #1

Co wt%	NM wt %	Promotor wt%		Support
20			Zr 15.00	SiO ₂

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm
 T = 220 °C
 H₂/CO = 2
 weight of catalyst = 0.198 g
 WHSV = 13.01 1/hr
 time on stream = 24.5 hrs

CO₂ (g/g cat/hr) = 0.020
 CO₂ (% of CO) = 0.1
 O/P = 5.16

CO conversion (%)	3.1
rate (g CH ₂ /g cat/hr)	0.18
alpha	0.73
C1 (wt%)	22.7
C2 - C4 (wt%)	23.6
C5 - C12 (wt%)	44.3
C13 + (wt%)	9.5

Performance of Co.044

Dates: 11/30/94 - 12/01/94 Run #1

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 13.0 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	0.5	3.5	6.5	9.5	12.5	15.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	20.65	23.18	21.94	22.79	23.46	24.04
C2	4.60	5.06	4.74	4.85	4.94	5.04
C3	11.14	11.28	10.10	10.00	10.04	10.12
C4	11.79	11.90	10.47	10.50	10.40	10.43
C5	12.03	12.34	11.05	11.04	10.97	10.98
C6	8.55	10.26	9.92	9.85	9.49	8.58
C7	8.59	0.03	8.22	8.02	7.90	7.95
C8	6.37	6.71	6.16	6.02	6.02	6.05
C9	4.82	5.08	4.61	4.54	4.54	4.57
C10	3.62	3.84	3.60	3.53	3.57	3.54
C11	2.66	2.82	2.56	2.56	2.58	2.57
C12	1.84	2.11	1.89	2.05	1.95	1.88
C13	1.29	1.76	1.60	1.48	1.51	1.55
C14	1.10	1.75	1.56	1.43	1.35	1.40
C15	0.95	1.88	1.59	1.32	1.26	1.30
alpha chain growth probability	0.69	0.74	0.73	0.72	0.71	0.72

C1 - C50 estimated total product distribution, weight %

C1	19.8	20.7	20.0	21.3	22.0	22.5
C2 - C4	26.5	25.2	23.1	23.7	23.8	23.9
C5 - C12	47.4	41.7	46.4	46.2	46.0	44.9
C13 - C50	6.3	12.3	10.5	8.8	8.3	8.7

CO conversion, %	4.7	4.1	4.0	3.7	3.6	3.4
rate, g CH ₂ /g cat/hr	0.27	0.23	0.23	0.21	0.20	0.19
CO ₂ formation, %	0.2	0.2	0.1	0.1	0.1	0.1

Performance of Co.044

Dates: 11/30/94 - 12/01/94 Run #1

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 13.0 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	18.5	21.5	24.5
reaction temperature, °C	220	220	220
pressure, atm	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	24.24	24.37	24.51
C2	5.10	5.14	5.18
C3	10.18	10.16	10.15
C4	10.34	10.33	10.17
C5	10.82	10.85	10.81
C6	8.41	8.34	8.56
C7	8.04	8.01	7.96
C8	6.08	6.04	5.95
C9	4.55	4.56	4.49
C10	3.56	3.53	3.47
C11	2.54	2.51	2.47
C12	1.89	1.89	1.85
C13	1.48	1.50	1.50
C14	1.38	1.46	1.50
C15	1.38	1.33	1.42
alpha chain growth probability	0.72	0.72	0.73

C1 - C50 estimated total product distribution, weight %

C1	22.5	22.7	22.7
C2 - C4	23.8	23.9	23.6
C5 - C12	44.5	44.5	44.3
C13 - C50	9.2	8.9	9.5

CO conversion, %	3.3	3.2	3.1
rate, g CH ₂ /g cat/hr	0.19	0.18	0.18
CO ₂ formation, %	0.1	0.1	0.1

Time-on-Stream Plot for Co.044 - Run #1

Schulz-Flory Plot for Co.044 - Run #1
Time on Stream (hrs)

Co.045 - Run #1

Co wt%	NM wt %	Promotor wt%		Support
20			Zr 4.00	SiO2

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.185 g

WHSV = 13.91 1/hr

time on stream = 21.5 hrs

CO₂ (g/g cat/hr) = 0.022

CO₂ (% of CO) = 0.1

O/P = 6.89

CO conversion (%)	2.6
rate (g CH ₂ /g cat/hr)	0.16
alpha	0.73
C1 (wt%)	22.2
C2 - C4 (wt%)	22.8
C5 - C12 (wt%)	44.8
C13 + (wt%)	10.2

Performance of Co.045

Dates: 12/03/94 - 12/04/94 Run #1

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 13.9 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	0.5	3.5	6.5	9.5	12.0	15.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	19.46	21.01	22.19	22.81	24.13	23.54
C2	4.40	4.68	4.85	4.98	5.25	5.13
C3	9.90	9.46	9.50	9.53	13.96	9.55
C4	10.80	9.91	9.80	9.87	2.79	9.80
C5	11.69	10.86	10.73	10.58	10.97	10.64
C6	9.90	9.36	8.60	8.75	9.24	8.89
C7	8.91	8.59	8.77	8.46	8.42	8.10
C8	6.77	6.52	6.44	6.44	6.48	6.25
C9	5.23	5.00	5.04	4.95	4.95	4.82
C10	3.99	3.85	3.92	3.86	3.91	3.80
C11	2.91	2.82	2.80	2.80	2.85	2.75
C12	2.21	2.23	2.19	2.14	2.14	2.04
C13	1.51	1.81	1.84	1.67	1.71	1.64
C14	1.28	1.82	1.68	1.60	1.60	1.58
C15	1.04	2.07	1.64	1.58	1.58	1.48
alpha chain growth probability	0.70	0.75	0.74	0.74	0.74	0.73

C1 - C50 estimated total product distribution, weight %

C1	18.7	18.5	20.3	20.9	22.2	21.8
C2 - C4	24.2	21.2	22.1	22.4	20.2	22.6
C5 - C12	50.1	46.5	46.5	46.0	46.9	45.6
C13 - C50	7.0	13.9	11.1	10.7	10.7	10.0

CO conversion, %	3.8	3.6	3.2	3.0	2.7	2.7
rate, g CH ₂ /g cat/hr	0.23	0.22	0.19	0.18	0.17	0.17
CO ₂ formation, %	0.1	0.1	0.1	0.1	0.1	0.1

Performance of Co.045

Dates: 12/03/94 - 12/04/94 Run #1

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 13.9 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	18.5	21.5
reaction temperature, °C	220	220
pressure, atm	1.0	1.0
flow, cc/min	90.0	90.0

C1 - C15 product distribution, weight %

C1	23.70	24.15
C2	5.16	5.26
C3	9.61	9.73
C4	9.73	9.81
C5	10.52	10.40
C6	8.74	8.78
C7	7.98	8.08
C8	6.14	6.18
C9	4.69	4.64
C10	3.72	3.66
C11	2.79	2.70
C12	2.57	2.03
C13	1.65	1.56
C14	1.51	1.50
C15	1.50	1.52
alpha chain growth probability	0.72	0.73

C1 - C50 estimated total product distribution, weight %

C1	22.0	22.2
C2 - C4	22.7	22.8
C5 - C12	45.4	44.8
C13 - C50	9.9	10.2

CO conversion, %	2.7	2.6
rate, g CH ₂ /g cat/hr	0.16	0.16
CO ₂ formation, %	0.1	0.1

Time-on-Stream Plot for Co.045 - Run #1

Schulz-Flory Plot for Co.045 - Run #1
Time on Stream (hrs)

Co.053 - Run #4

Co wt%	NM wt %	Promotor wt%		Support
20	Ru 0.50			Al ₂ O ₃

SUMMARY REACTION DATA*

Reaction Conditions:

P = 1.0 atm
 T = 220 °C
 H₂/CO = 2
 weight of catalyst = 0.160 g
 WHSV = 16.07 1/hr
 time on stream = 18.5 hrs

CO₂ (g/g cat/hr) = 0.030
 CO₂ (% of CO) = 0.1
 O/P = 1.41

CO conversion (%)	6.1
rate (g CH ₂ /g cat/hr)	0.43
alpha	0.65
C1 (wt%)	28.3
C2 - C4 (wt%)	29.0
C5 - C12 (wt%)	39.6
C13 + (wt%)	3.1

* Catalyst reduced without calcination

Performance of Co.053

Dates: 10/12/94 - 10/13/94 Run #4

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 16.1 l/hr, H₂/CO ratio in feed = 2

time on stream, hr	3.5	9.5	12.5	15.5	18.5	24.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	29.00	29.18	27.03	28.75	28.98	29.41
C2	5.16	5.17	12.96	5.08	5.11	5.21
C3	12.81	12.69	11.64	12.44	12.50	12.74
C4	12.41	12.29	11.24	12.13	12.14	12.27
C5	11.08	10.94	10.05	11.07	11.00	10.98
C6	7.66	7.24	6.80	7.85	7.85	7.27
C7	7.57	7.60	6.80	7.63	7.65	7.54
C8	4.95	5.08	4.62	5.08	5.09	5.01
C9	3.28	3.37	3.10	3.42	3.36	3.42
C10	2.13	2.28	2.06	2.25	2.25	2.26
C11	1.41	1.51	1.34	1.48	1.55	1.51
C12	0.90	1.01	0.84	1.09	0.85	0.98
C13	0.71	0.67	0.61	0.68	0.65	0.64
C14	0.58	0.56	0.52	0.58	0.56	0.52
C15	0.34	0.41	0.40	0.47	0.47	0.24
alpha chain growth probability	0.63	0.64	0.64	0.65	0.65	0.61

C1 - C50 estimated total product distribution, weight %

C1	28.7	28.7	26.5	28.1	28.3	29.4
C2 - C4	30.1	29.7	35.1	29.0	29.0	30.3
C5 - C12	39.0	38.9	35.7	39.8	39.6	38.7
C13 - C50	2.2	2.7	2.6	3.1	3.1	1.6

CO conversion, %	6.8	6.2	6.8	6.1	6.1	5.2
rate, g CH ₂ /g cat/hr	0.48	0.43	0.48	0.43	0.43	0.37
CO ₂ formation, %	0.2	0.2	0.2	0.1	0.1	0.2

Performance of Co.053

Dates: 10/12/94 - 10/13/94 Run #4

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 16.1 1/hr, H₂/CO ratio in feed = 2

time on stream, hr
reaction temperature, °C
pressure, atm
flow, cc/min

C1 - C15 product distribution, weight %

C1

C2

C3

C4

C5

C6

C7

C8

C9

C10

C11

C12

C13

C14

C15

alpha chain growth probability

C1 - C50 estimated total product distribution, weight %

C1

C2 - C4

C5 - C12

C13 - C50

CO conversion, %
rate, g CH₂/g cat/hr
CO₂ formation, %

Time-on-Stream Plot for Co.053 - Run #4

Schulz-Flory Plot for Co.053 - Run #4

Time on Stream (hrs)

hrs.

Co.053 - Run #5

Co wt%	NM wt %	Promotor wt%		Support
20	Ru 0.50			Al ₂ O ₃

SUMMARY REACTION DATA*

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.175 g

WHSV = 14.69 1/hr

time on stream = 27.5 hrs

CO₂ (g/g cat/hr) = 0.034

CO₂ (% of CO) = 0.2

O/P = 1.49

CO conversion (%)	5.6
rate (g CH ₂ /g cat/hr)	0.36
alpha	0.64
C1 (wt%)	27.9
C2 - C4 (wt%)	29.5
C5 - C12 (wt%)	40.0
C13 + (wt%)	2.6

* Catalyst is reduced , calcined and rereduced

Performance of Co.053

Dates: 10/17/94 - 10/18/94 Run #5

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 14.7 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	0.5	9.5	12.5	15.5	24.5	27.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	26.42	28.47	28.57	28.76	28.17	28.48
C2	4.77	5.07	5.07	5.07	4.96	5.01
C3	12.73	13.04	12.99	12.91	12.66	12.70
C4	12.71	12.70	12.65	12.52	12.36	12.34
C5	11.66	11.30	11.26	11.22	11.38	11.24
C6	8.43	7.52	7.41	7.54	8.21	8.05
C7	8.17	7.88	7.84	7.75	7.93	7.83
C8	5.27	5.06	5.17	5.09	5.16	5.06
C9	3.47	3.26	3.20	3.33	3.32	3.33
C10	2.10	2.06	2.09	2.06	2.17	2.19
C11	1.55	1.35	1.34	1.33	1.26	1.30
C12	1.08	0.85	0.84	0.82	0.82	0.87
C13	0.87	0.68	0.68	0.66	0.66	0.64
C14	0.59	0.51	0.55	0.55	0.56	0.56
C15	0.19	0.24	0.34	0.39	0.37	0.40
alpha chain growth probability	0.59	0.61	0.62	0.63	0.63	0.64

C1 - C50 estimated total product distribution, weight %

C1	26.7	28.4	28.2	28.2	27.7	27.9
C2 - C4	30.5	30.8	30.3	29.9	29.5	29.5
C5 - C12	41.4	39.2	39.2	39.3	40.4	40.0
C13 - C50	1.3	1.6	2.2	2.6	2.5	2.6

CO conversion, %	6.7	5.7	5.6	5.8	5.5	5.6
rate, g CH ₂ /g cat/hr	0.43	0.37	0.36	0.37	0.36	0.36
CO ₂ formation, %	0.2	0.2	0.2	0.2	0.1	0.2

Time-on-Stream Plot for Co.053 - Run #5

Schulz-Flory Plot for Co.053 - Run #5

Time on Stream (hrs)

hrs.

Co.053 - Run #6

Co wt%	NM wt %	Promotor wt%		Support
20	Ru 0.50			Al ₂ O ₃

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm
 T = 220 °C
 H₂/CO = 2
 weight of catalyst = 0.191 g
 WHSV = 13.50 1/hr
 time on stream = 24.5 hrs

CO₂ (g/g cat/hr) = 0.030
 CO₂ (% of CO) = 0.1
 O/P = 1.25

CO conversion (%)	8.2
rate (g CH ₂ /g cat/hr)	0.49
alpha	0.64
C1 (wt%)	28.9
C2 - C4 (wt%)	28.1
C5 - C12 (wt%)	40.0
C13 + (wt%)	3.0

Performance of Co.053

Dates: 11/03/94 - 11/04/94 Run #6

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 13.5 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	0.5	3.5	6.5	9.5	12.5	15.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	31.34	31.17	32.00	31.40	31.63	31.31
C2	5.30	5.20	5.28	5.17	5.17	5.13
C3	12.76	12.61	12.70	12.58	12.55	12.57
C4	12.68	12.66	12.60	12.43	12.31	12.39
C5	11.34	11.24	11.14	11.19	11.07	11.15
C6	8.30	8.31	7.63	8.60	8.37	8.55
C7	6.38	6.40	6.49	6.51	6.51	6.51
C8	4.14	4.17	4.26	4.28	4.34	4.41
C9	2.70	2.69	2.77	2.82	2.86	2.86
C10	1.70	1.72	1.79	1.75	1.80	1.80
C11	1.20	1.23	1.22	1.20	1.23	1.27
C12	0.74	0.72	0.76	0.78	0.81	0.77
C13	0.62	0.60	0.51	0.51	0.52	0.48
C14	0.45	1.16	0.43	0.42	0.44	0.42
C15	0.35	0.11	0.42	0.37	0.38	0.37
alpha chain growth probability	0.63	0.56	0.64	0.63	0.63	0.63

C1 - C50 estimated total product distribution, weight %

C1	30.8	31.8	31.2	30.7	31.0	30.7
C2 - C4	30.2	31.0	29.8	29.6	29.4	29.5
C5 - C12	36.7	36.4	36.3	37.3	37.1	37.4
C13 - C50	2.3	0.7	2.8	2.4	2.5	2.4

CO conversion, %	10.4	9.1	9.2	8.7	8.8	8.4
rate, g CH ₂ /g cat/hr	0.62	0.54	0.54	0.51	0.52	0.49
CO ₂ formation, %	0.3	0.2	0.2	0.2	0.1	0.2

Performance of Co.053

Dates: 11/03/94 - 11/04/94 Run #6

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 13.5 l/hr, H₂/CO ratio in feed = 2

time on stream, hr	18.5	21.5	24.5
reaction temperature, °C	220	220	220
pressure, atm	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	31.24	30.77	29.63
C2	5.11	5.05	4.86
C3	12.52	12.51	12.09
C4	12.30	10.77	11.84
C5	11.17	11.22	10.90
C6	8.55	6.67	8.49
C7	6.63	7.90	7.62
C8	4.41	5.26	5.11
C9	2.90	3.45	3.37
C10	1.83	2.24	2.16
C11	1.22	1.52	1.46
C12	0.79	1.02	0.90
C13	0.51	0.61	0.59
C14	0.44	0.54	0.51
C15	0.37	0.46	0.45
alpha chain growth probability	0.63	0.65	0.64

C1 - C50 estimated total product distribution, weight %

C1	30.6	30.1	28.9
C2 - C4	29.3	27.7	28.1
C5 - C12	37.6	39.2	40.0
C13 - C50	2.4	3.0	3.0

CO conversion, %	8.3	8.1	8.2
rate, g CH ₂ /g cat/hr	0.49	0.48	0.49
CO ₂ formation, %	0.2	0.1	0.1

Time-on-Stream Plot for Co.053 - Run #6

Schulz-Flory Plot for Co.053 - Run #6

Time on Stream (hrs)

hrs.

Co.055 - Run #4

Co wt%	NM wt %	Promotor wt%		Support
20	Re 1.00		La2O3 1.00	Al2O3

SUMMARY REACTION DATA*

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.174 g

WHSV = 14.80 1/hr

time on stream = 21.5 hrs

CO₂ (g/g cat/hr) = 0.047

CO₂ (% of CO) = 0.2

O/P = 1.94

CO conversion (%)	5.9
rate (g CH ₂ /g cat/hr)	0.38
alpha	0.60
C1 (wt%)	28.3
C2 - C4 (wt%)	29.2
C5 - C12 (wt%)	41.0
C13 + (wt%)	1.4

* Catalyst calcined without calcination

Performance of Co.055

Dates: 10/20/94 - 10/21/94 Run #4

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 14.8 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	3.5	6.5	9.5	12.5	21.5
reaction temperature, °C	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	28.31	27.51	27.23	28.09	27.97
C2	4.94	4.80	4.71	4.85	4.84
C3	12.93	12.41	12.04	12.29	12.22
C4	12.51	12.12	11.80	11.91	11.79
C5	10.77	10.90	10.92	10.80	10.92
C6	6.35	7.10	7.47	7.02	7.45
C7	8.07	8.19	8.19	8.03	8.02
C8	5.56	5.75	5.77	5.64	5.64
C9	3.78	3.97	4.01	3.89	3.90
C10	2.48	2.64	2.74	2.66	2.65
C11	1.82	1.86	1.94	1.89	1.77
C12	1.12	1.35	1.29	1.18	1.28
C13	0.76	0.82	0.87	0.83	0.82
C14	0.33	0.43	0.68	0.64	0.51
C15	0.28	0.15	0.34	0.31	0.20
alpha chain growth probability	0.62	0.58	0.63	0.62	0.60

C1 - C50 estimated total product distribution, weight %

C1	28.3	28.1	27.3	28.2	28.3
C2 - C4	30.4	30.0	28.6	29.1	29.2
C5 - C12	39.4	40.9	41.8	40.6	41.0
C13 - C50	1.9	1.0	2.3	2.0	1.4

CO conversion, %	5.4	6.6	7.2	6.8	5.9
rate, g CH ₂ /g cat/hr	0.35	0.42	0.47	0.44	0.38
CO ₂ formation, %	0.3	0.2	0.2	0.2	0.2

Time-on-Stream Plot for Co.055 - Run #4

Schulz-Flory Plot for Co.055 - Run #4
Time on Stream (hrs)

Co.055 - Run #5

Co wt%	NM wt %	Promotor wt%		Support
20	Re 1.00		La2O3 1.00	Al2O3

SUMMARY REACTION DATA*

Reaction Conditions:

P = 1.0 atm
 T = 220 °C
 H₂/CO = 2
 weight of catalyst = 0.180 g
 WHSV = 14.28 1/hr
 time on stream = 24.5 hrs

CO₂ (g/g cat/hr) = 0.030
 CO₂ (% of CO) = 0.1
 O/P = 1.83

CO conversion (%)	6.6
rate (g CH ₂ /g cat/hr)	0.41
alpha	0.59
C1 (wt%)	29.6
C2 - C4 (wt%)	28.1
C5 - C12 (wt%)	41.1
C13 + (wt%)	1.2

* Catalyst is directly reduced without calcination

Performance of Co.055

Dates: 11/07/94 - 11/08/94 Run #5

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 14.3 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	0.5	3.5	6.5	9.5	12.5	15.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	27.20	28.68	28.15	28.62	28.72	28.88
C2	4.67	4.80	4.68	4.73	4.74	4.76
C3	11.75	11.75	11.42	11.44	11.45	11.48
C4	11.87	11.74	11.31	11.31	11.27	11.39
C5	11.18	10.77	10.56	10.50	10.52	10.53
C6	8.68	8.44	8.71	8.57	8.57	8.56
C7	8.28	7.91	7.76	7.71	7.66	7.61
C8	5.73	5.51	5.50	5.39	5.37	5.36
C9	3.94	3.78	3.82	3.80	3.80	3.81
C10	2.55	2.47	2.64	2.67	2.66	2.69
C11	2.12	1.84	1.86	1.83	1.85	1.86
C12	0.96	1.13	1.19	1.21	1.20	1.24
C13	0.69	0.71	0.84	0.78	0.77	0.73
C14	0.29	0.36	0.85	0.73	0.74	0.57
C15	0.10	0.12	0.70	0.70	0.65	0.54
alpha chain growth probability	0.56	0.57	0.67	0.67	0.67	0.66

C1 - C50 estimated total product distribution, weight %

C1	27.9	29.3	27.1	27.6	27.8	28.2
C2 - C4	29.0	28.9	26.4	26.5	26.6	27.0
C5 - C12	42.5	41.0	41.8	41.4	41.3	41.2
C13 - C50	0.7	0.8	4.6	4.6	4.3	3.5

CO conversion, %	9.3	8.7	8.5	8.2	7.8	7.5
rate, g CH ₂ /g cat/hr	0.58	0.54	0.53	0.51	0.49	0.47
CO ₂ formation, %	0.2	0.2	0.2	0.2	0.2	0.2

Performance of Co.055

Dates: 11/07/94 - 11/08/94 Run #5

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 14.3 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	18.5	21.5	24.5
reaction temperature, °C	220	220	220
pressure, atm	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	29.21	28.78	29.10
C2	4.81	4.75	4.80
C3	11.56	11.46	11.55
C4	11.09	11.15	11.20
C5	10.47	10.53	10.59
C6	8.44	8.56	8.60
C7	7.59	7.63	7.67
C8	5.34	5.36	5.39
C9	3.76	3.78	3.79
C10	2.66	2.70	2.66
C11	1.90	1.92	2.12
C12	1.24	1.21	1.35
C13	0.74	0.78	0.63
C14	0.64	0.71	0.37
C15	0.55	0.69	0.18
alpha chain growth probability	0.66	0.67	0.59

C1 - C50 estimated total product distribution, weight %

C1	28.6	27.8	29.6
C2 - C4	26.9	26.4	28.1
C5 - C12	41.0	41.3	41.1
C13 - C50	3.6	4.5	1.2

CO conversion, %	7.4	7.2	6.6
rate, g CH ₂ /g cat/hr	0.46	0.45	0.41
CO ₂ formation, %	0.2	0.1	0.1

Time-on-Stream Plot for Co.055 - Run #5

Schulz-Flory Plot for Co.055 - Run #5
Time on Stream (hrs)

Co.055 - Run #6

Co wt%	NM wt %	Promotor wt%		Support
20	Re 1.00		La ₂ O ₃ 1.00	Al ₂ O ₃

SUMMARY REACTION DATA*

Reaction Conditions:

P = 1.0 atm
 T = 220 °C
 H₂/CO = 2
 weight of catalyst = 0.180 g
 WHSV = 14.31 1/hr
 time on stream = 27.5 hrs

CO₂ (g/g cat/hr) = 0.023
 CO₂ (% of CO) = 0.1
 O/P = 1.21

CO conversion (%)	7.5
rate (g CH ₂ /g cat/hr)	0.47
alpha	0.63
C1 (wt%)	30.9
C2 - C4 (wt%)	29.1
C5 - C12 (wt%)	37.6
C13 + (wt%)	2.4

* Catalyst is reduced, calcined and rereduced before loading

Performance of Co.055

Dates: 11/14/94 - 11/15/94 Run #6

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 14.3 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	27.5
reaction temperature, °C	220
pressure, atm	1.0
flow, cc/min	90.0

C1 - C15 product distribution, weight %

C1	31.53
C2	4.98
C3	12.71
C4	12.09
C5	10.66
C6	7.91
C7	7.28
C8	4.68
C9	3.05
C10	1.94
C11	1.25
C12	0.67
C13	0.45
C14	0.40
C15	0.37
alpha chain growth probability	0.63

C1 - C50 estimated total product distribution, weight %

C1	30.9
C2 - C4	29.1
C5 - C12	37.6
C13 - C50	2.4

CO conversion, %	7.5
rate, g CH ₂ /g cat/hr	0.47
CO ₂ formation, %	0.1

Performance of Co.055

Dates: 11/14/94 - 11/15/94 Run #6

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 14.3 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	0.5	3.5	6.5	9.5	21.5	24.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	31.93	32.27	31.84	31.85	30.96	31.10
C2	5.23	5.21	5.13	5.11	4.93	4.94
C3	13.13	13.04	12.98	12.95	12.59	12.66
C4	12.73	12.68	12.60	12.59	12.01	12.10
C5	11.25	11.12	11.12	11.08	10.84	10.77
C6	8.12	8.08	8.46	8.38	7.88	7.98
C7	6.40	6.28	6.34	6.38	7.44	7.37
C8	4.18	4.09	4.14	4.18	4.76	4.74
C9	2.74	2.64	2.64	2.68	3.14	3.14
C10	1.64	1.71	1.84	1.84	2.18	1.97
C11	1.20	1.23	1.16	1.14	1.23	1.31
C12	0.73	0.92	0.64	0.73	0.82	0.71
C13	0.41	0.42	0.41	0.42	0.47	0.46
C14	0.23	0.24	0.35	0.33	0.38	0.39
C15	0.08	0.08	0.35	0.34	0.36	0.37
alpha chain growth probability	0.55	0.55	0.63	0.63	0.63	0.63

C1 - C50 estimated total product distribution, weight %

C1	32.3	32.7	31.1	31.2	30.4	30.5
C2 - C4	31.4	31.3	30.0	30.0	29.0	29.1
C5 - C12	35.7	35.4	36.5	36.5	38.3	38.0
C13 - C50	0.6	0.6	2.3	2.2	2.3	2.4

CO conversion, %	9.1	8.3	7.9	7.5	7.3	7.3
rate, g CH ₂ /g cat/hr	0.57	0.52	0.49	0.47	0.46	0.46
CO ₂ formation, %	0.2	0.2	0.2	0.2	0.2	0.1

Time-on-Stream Plot for Co.055 - Run #6

Schulz-Flory Plot for Co.055 - Run #6
Time on Stream (hrs)

Co.055 - Run #7

Co wt%	NM wt %	Promotor wt%		Support
20	Re 1.00		La2O3 1.00	Al2O3

SUMMARY REACTION DATA*

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.180 g

WHSV = 14.29 1/hr

time on stream = 24.5 hrs

CO₂ (g/g cat/hr) = 0.031

CO₂ (% of CO) = 0.1

O/P = 1.11

CO conversion (%)	7.5
rate (g CH ₂ /g cat/hr)	0.47
alpha	0.60
C1 (wt%)	33.5
C2 - C4 (wt%)	31.1
C5 - C12 (wt%)	34.0
C13 + (wt%)	1.4

* Catalyst calcined in Nitrogen

Performance of Co.055

Dates: 11/16/94 - 11/17/94 Run #7

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 14.3 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	0.5	3.5	6.5	9.5	12.5	15.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	33.97	34.37	33.97	33.64	34.01	34.40
C2	5.47	5.48	5.37	5.30	5.34	5.37
C3	13.37	13.57	13.30	13.21	13.34	13.38
C4	12.84	13.11	12.71	12.67	12.59	12.67
C5	11.07	11.19	10.93	10.84	10.89	10.87
C6	7.71	7.91	7.92	7.88	7.86	7.78
C7	6.01	6.00	5.93	6.24	5.98	5.92
C8	3.78	3.76	3.72	3.97	3.75	3.74
C9	2.36	2.34	2.32	2.44	2.30	2.32
C10	1.37	0.02	1.60	1.66	1.72	1.38
C11	0.98	0.96	0.90	0.92	1.00	0.92
C12	0.48	0.47	0.57	0.46	0.46	0.46
C13	0.32	0.30	0.30	0.30	0.30	0.31
C14	0.18	0.26	0.25	0.24	0.21	0.24
C15	0.08	0.25	0.23	0.23	0.26	0.24
alpha chain growth probability	0.55	0.61	0.60	0.61	0.61	0.60

C1 - C50 estimated total product distribution, weight %

C1	34.1	33.8	33.5	33.1	33.4	33.9
C2 - C4	31.8	31.6	30.9	30.7	30.7	30.9
C5 - C12	33.5	32.9	34.0	34.6	34.2	33.6
C13 - C50	0.6	1.6	1.5	1.5	1.7	1.6

CO conversion, %	9.8	8.8	8.5	8.3	8.0	7.9
rate, g CH ₂ /g cat/hr	0.61	0.55	0.53	0.52	0.50	0.49
CO ₂ formation, %	0.2	0.2	0.2	0.2	0.1	0.1

Performance of Co.055

Dates: 11/16/94 - 11/17/94 Run #7

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 14.3 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	18.5	21.5	24.5
reaction temperature, °C	220	220	220
pressure, atm	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	34.16	33.77	33.94
C2	5.34	5.29	5.30
C3	13.44	13.44	13.50
C4	12.71	12.72	12.73
C5	10.98	11.05	11.02
C6	7.81	7.96	7.95
C7	5.99	6.04	6.03
C8	3.76	3.75	3.79
C9	2.29	2.32	2.29
C10	1.37	1.58	1.39
C11	0.91	0.81	0.91
C12	0.52	0.53	0.46
C13	0.28	0.27	0.27
C14	0.23	0.23	0.23
C15	0.21	0.23	0.20
alpha chain growth probability	0.60	0.60	0.60

C1 - C50 estimated total product distribution, weight %

C1	33.7	33.2	33.5
C2 - C4	31.1	31.0	31.1
C5 - C12	33.8	34.3	34.0
C13 - C50	1.4	1.5	1.4

CO conversion, %	7.7	7.6	7.5
rate, g CH ₂ /g cat/hr	0.48	0.47	0.47
CO ₂ formation, %	0.2	0.2	0.1

Time-on-Stream Plot for Co.055 - Run #7

Schulz-Flory Plot for Co.055 - Run #7 Time on Stream (hrs)

Co.056 - Run #1

Co wt%	NM wt %	Promotor wt%		Support
20		La 8.50		SiO2

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.200 g

WHSV = 12.88 1/hr

time on stream = 27.5 hrs

CO₂ (g/g cat/hr) = 0.029

CO₂ (% of CO) = 0.1

O/P = 8.22

CO conversion (%)	2.4
rate (g CH ₂ /g cat/hr)	0.14
alpha	0.69
C1 (wt%)	23.9
C2 - C4 (wt%)	27.2
C5 - C12 (wt%)	43.3
C13 + (wt%)	5.6

Performance of Co.056

Dates: 10/07/94 - 10/08/94 Run #1

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 12.9 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	0.5	3.5	6.5	12.5	15.5	18.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	18.31	22.20	21.64	23.61	24.59	23.75
C2	4.51	5.60	5.39	5.83	6.05	5.86
C3	9.98	11.03	10.33	10.88	11.22	10.80
C4	10.91	11.28	10.63	10.92	11.16	10.77
C5	11.98	11.41	11.38	11.19	10.57	11.27
C6	10.24	6.59	9.02	7.99	7.99	8.79
C7	8.97	8.50	8.43	8.08	7.85	8.00
C8	6.81	6.51	6.41	6.11	5.88	5.98
C9	5.16	4.93	4.81	4.43	4.36	4.39
C10	3.94	3.79	3.78	3.56	3.33	3.31
C11	2.83	2.71	2.57	2.38	2.24	2.27
C12	2.05	1.92	1.98	1.72	1.69	1.70
C13	1.66	1.54	1.39	1.33	1.24	1.19
C14	1.40	1.24	1.20	1.07	0.98	1.02
C15	1.25	0.75	1.04	0.91	0.84	0.89
alpha chain growth probability	0.72	0.69	0.71	0.70	0.69	0.70

C1 - C50 estimated total product distribution, weight %

C1	17.3	21.9	20.7	22.7	23.8	22.8
C2 - C4	24.0	27.5	25.2	26.6	27.5	26.4
C5 - C12	50.3	45.5	47.1	44.6	43.2	44.9
C13 - C50	8.4	5.1	7.0	6.0	5.6	5.9

CO conversion, %	4.7	2.4	3.1	2.7	2.6	2.6
rate, g CH ₂ /g cat/hr	0.26	0.13	0.17	0.15	0.15	0.15
CO ₂ formation, %	0.2	0.3	0.2	0.2	0.2	0.2

Performance of Co.056

Dates: 10/07/94 - 10/08/94 Run #1

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 12.9 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	21.5	24.5	27.5
reaction temperature, °C	220	220	220
pressure, atm	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	23.95	25.31	24.84
C2	5.94	6.25	6.15
C3	10.90	11.44	11.16
C4	10.83	11.26	11.00
C5	11.30	10.82	11.24
C6	9.03	8.00	7.95
C7	7.87	7.60	7.88
C8	5.86	5.60	5.79
C9	4.24	4.05	4.18
C10	3.22	3.10	3.18
C11	2.15	2.08	2.16
C12	1.61	1.53	1.55
C13	1.21	1.16	1.11
C14	0.99	0.95	0.97
C15	0.90	0.85	0.85
alpha chain growth probability	0.70	0.69	0.69

C1 - C50 estimated total product distribution, weight %

C1	23.0	24.3	23.9
C2 - C4	26.5	27.8	27.2
C5 - C12	44.6	42.2	43.3
C13 - C50	6.0	5.6	5.6

CO conversion, %	2.6	2.5	2.4
rate, g CH ₂ /g cat/hr	0.15	0.14	0.14
CO ₂ formation, %	0.2	0.2	0.1

Time-on-Stream Plot for Co.056 - Run #1

Schulz-Flory Plot for Co.056 - Run #1 Time on Stream (hrs)

Co.056 - Run #2

Co wt%	NM wt %	Promotor wt%		Support
20		La 8.50		SiO2

SUMMARY REACTION DATA*

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.184 g

WHSV = 13.94 1/hr

time on stream = 21.5 hrs

CO₂ (g/g cat/hr) = 0.033

CO₂ (% of CO) = 0.2

O/P = 9.44

CO conversion (%)	2.2
rate (g CH ₂ /g cat/hr)	0.14
alpha	0.68
C1 (wt%)	23.4
C2 - C4 (wt%)	27.3
C5 - C12 (wt%)	44.7
C13 + (wt%)	4.7

* Catalyst is directly reduced without calcination

Performance of Co.056

Dates: 11/09/94 - 11/10/94 Run #2

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 13.9 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	0.5	3.5	6.5	9.5	12.5	15.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	18.82	20.53	21.03	21.86	23.29	22.98
C2	4.76	5.20	5.29	5.48	5.85	5.76
C3	10.26	10.24	10.12	10.30	10.86	10.66
C4	11.10	10.36	10.37	10.42	11.00	10.69
C5	12.24	11.51	11.08	11.12	11.62	11.18
C6	10.01	8.14	9.33	9.25	8.71	8.30
C7	9.48	8.85	8.43	8.39	6.64	8.18
C8	7.26	6.78	6.42	6.36	1.80	6.16
C9	5.48	5.10	4.82	4.81	4.70	4.55
C10	3.85	3.59	3.74	3.68	4.84	3.75
C11	2.97	3.24	2.58	2.51	3.45	2.39
C12	1.95	2.14	1.94	1.97	2.59	1.70
C13	1.15	1.84	1.74	1.38	1.87	1.28
C14	0.50	1.63	1.65	1.28	1.55	1.21
C15	0.17	0.86	1.46	1.20	1.21	1.21
alpha chain growth probability	0.59	0.70	0.73	0.72	0.71	0.72

C1 - C50 estimated total product distribution, weight %

C1	19.6	20.3	19.5	20.6	22.4	21.5
C2 - C4	27.2	25.5	23.9	24.7	26.6	25.4
C5 - C12	52.0	48.2	46.8	46.7	42.7	45.1
C13 - C50	1.2	5.9	9.8	8.0	8.3	8.1

CO conversion, %	3.3	2.9	2.9	2.6	2.4	2.5
rate, g CH ₂ /g cat/hr	0.20	0.18	0.17	0.16	0.14	0.15
CO ₂ formation, %	0.2	0.1	0.1	0.1	0.1	0.1

Performance of Co.056

Dates: 11/09/94 - 11/10/94 Run #2

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 13.9 l/hr, H₂/CO ratio in feed = 2

time on stream, hr	18.5	21.5
reaction temperature, °C	220	220
pressure, atm	1.0	1.0
flow, cc/min	90.0	90.0

C1 - C15 product distribution, weight %

C1	23.48	23.87
C2	5.90	6.00
C3	10.88	10.97
C4	10.70	10.89
C5	11.26	11.37
C6	8.15	8.49
C7	8.19	8.15
C8	6.04	6.00
C9	4.47	4.34
C10	3.37	3.08
C11	2.26	2.42
C12	1.77	1.66
C13	1.33	1.10
C14	1.22	0.96
C15	0.98	0.70
alpha chain growth probability	0.70	0.68

C1 - C50 estimated total product distribution, weight %

C1	22.5	23.4
C2 - C4	26.3	27.3
C5 - C12	44.7	44.7
C13 - C50	6.5	4.7

CO conversion, %	2.3	2.2
rate, g CH ₂ /g cat/hr	0.14	0.14
CO ₂ formation, %	0.1	0.2

Time-on-Stream Plot for Co.056 - Run #2

Schulz-Flory Plot for Co.056 - Run #2
Time on Stream (hrs)

Co.057 - Run #1

Co wt%	NM wt %	Promotor wt%		Support
20	Re 1.00		La ₂ O ₃ 1.00	SiO ₂

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.183 g

WHSV = 14.03 1/hr

time on stream = 18.5 hrs

CO₂ (g/g cat/hr) = 0.029

CO₂ (% of CO) = 0.1

O/P = 4.65

CO conversion (%)	2.8
rate (g CH ₂ /g cat/hr)	0.17
alpha	0.73
C1 (wt%)	23.4
C2 - C4 (wt%)	23.2
C5 - C12 (wt%)	42.5
C13 + (wt%)	10.9

Performance of Co.057

Dates: 11/27/94 - 11/28/94 Run #1

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 14.0 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	0.5	3.5	6.5	9.5	12.5	15.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	22.84	24.29	25.01	25.25	25.82	25.87
C2	4.79	4.98	5.08	5.14	5.25	5.31
C3	10.28	10.02	9.94	9.91	10.02	10.07
C4	11.06	10.48	10.34	10.26	10.33	10.33
C5	11.78	11.00	10.81	10.76	10.83	10.79
C6	9.90	9.31	9.39	9.47	8.49	8.67
C7	8.33	7.83	7.72	7.73	7.75	7.72
C8	6.34	5.87	5.78	5.71	5.71	5.69
C9	4.80	4.42	4.38	4.29	4.31	4.26
C10	3.61	3.39	3.31	3.27	3.35	3.19
C11	2.47	2.39	2.30	2.34	2.26	2.21
C12	1.70	1.75	1.76	1.72	1.71	1.66
C13	1.10	1.41	1.40	1.34	1.33	1.32
C14	0.74	1.49	1.43	1.38	1.33	1.37
C15	0.26	1.37	1.36	1.43	1.49	1.54
alpha chain growth probability	0.62	0.72	0.72	0.73	0.73	0.73

C1 - C50 estimated total product distribution, weight %

C1	23.4	22.5	23.1	23.2	23.5	23.5
C2 - C4	26.7	23.6	23.5	23.2	23.3	23.3
C5 - C12	48.1	44.8	44.4	44.1	43.2	43.0
C13 - C50	1.8	9.1	9.0	9.5	9.9	10.2

CO conversion, %	3.5	3.4	3.2	3.0	2.9	2.8
rate, g CH ₂ /g cat/hr	0.21	0.21	0.20	0.19	0.18	0.17
CO ₂ formation, %	0.2	0.2	0.2	0.2	0.2	0.2

Performance of Co.057

Dates: 11/27/94 - 11/28/94 Run #1

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 14.0 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	18.5	21.5
reaction temperature, °C	220	220
pressure, atm	1.0	1.0
flow, cc/min	90.0	90.0

C1 - C15 product distribution, weight %

C1	26.13	22.25
C2	5.41	4.62
C3	10.22	8.64
C4	10.28	8.73
C5	10.85	13.01
C6	8.54	7.37
C7	7.59	9.25
C8	5.66	6.91
C9	4.15	5.10
C10	3.12	4.03
C11	2.13	2.67
C12	1.59	2.01
C13	1.29	1.61
C14	1.39	1.62
C15	1.66	2.19
alpha chain growth probability	0.73	0.75

C1 - C50 estimated total product distribution, weight %

C1	23.4	19.2
C2 - C4	23.2	19.0
C5 - C12	42.5	47.3
C13 - C50	10.9	14.5

CO conversion, %	2.8	3.3
rate, g CH ₂ /g cat/hr	0.17	0.20
CO ₂ formation, %	0.1	0.2

Time-on-Stream Plot for Co.057 - Run #1

Schulz-Flory Plot for Co.057 - Run #1
Time on Stream (hrs)

Co.060 - Run #1

Co wt%	NM wt %	Promotor wt%		Support
30				Al ₂ O ₃

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.176 g

WHSV = 14.59 1/hr

time on stream = 24.5 hrs

CO₂ (g/g cat/hr) = 0.023

CO₂ (% of CO) = 0.1

O/P = 3.82

CO conversion (%)	3.8
rate (g CH ₂ /g cat/hr)	0.24
alpha	0.69
C1 (wt%)	25.0
C2 - C4 (wt%)	26.2
C5 - C12 (wt%)	43.0
C13 + (wt%)	5.8

Performance of Co.060

Dates: 11/21/94 - 11/22/94 Run #1

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 14.6 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	0.5	3.5	6.5	9.5	12.5	15.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	22.80	23.87	24.74	25.26	24.94	25.45
C2	4.44	4.55	4.65	4.73	4.66	4.72
C3	11.31	11.25	11.36	11.38	11.12	11.22
C4	11.70	11.48	11.49	11.34	11.20	11.25
C5	11.56	11.38	11.29	11.42	11.15	11.17
C6	9.19	9.02	8.77	9.22	8.98	9.00
C7	7.89	7.78	7.66	7.24	7.55	7.45
C8	5.83	5.71	5.57	5.33	5.55	5.44
C9	4.40	4.25	4.13	4.02	4.16	4.03
C10	3.38	3.18	3.11	3.03	3.12	3.04
C11	2.51	2.33	2.23	2.21	2.53	2.22
C12	1.92	1.80	1.64	1.62	1.63	1.70
C13	1.33	1.33	1.28	1.21	1.31	1.21
C14	0.98	1.11	1.14	1.05	1.15	1.12
C15	0.76	0.96	0.94	0.94	0.97	0.97
alpha chain growth probability	0.68	0.69	0.69	0.69	0.70	0.70

C1 - C50 estimated total product distribution, weight %

C1	22.3	22.9	23.7	24.1	23.9	24.3
C2 - C4	26.9	26.1	26.3	26.2	25.8	26.0
C5 - C12	45.8	44.7	43.8	43.5	43.9	43.3
C13 - C50	5.1	6.3	6.2	6.2	6.4	6.4

CO conversion, %	4.5	4.4	4.3	4.1	4.1	4.0
rate, g CH ₂ /g cat/hr	0.29	0.28	0.27	0.26	0.26	0.26
CO ₂ formation, %	0.1	0.1	0.1	0.1	0.1	0.1

Performance of Co.060

Dates: 11/21/94 - 11/22/94 Run #1

flow rate = 90.0 cc/min, loading= 0.2 g, WHSV = 14.6 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	18.5	21.5	24.5
reaction temperature, °C	220	220	220
pressure, atm	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	25.75	25.84	26.03
C2	4.76	4.77	4.80
C3	11.26	11.23	11.26
C4	11.20	11.19	11.16
C5	11.09	11.12	11.06
C6	8.89	8.91	8.93
C7	7.47	7.50	7.40
C8	5.45	5.49	5.40
C9	4.05	4.02	3.94
C10	3.06	3.06	3.01
C11	2.20	2.15	2.47
C12	1.55	1.53	1.54
C13	1.22	1.20	1.13
C14	1.08	1.05	0.99
C15	0.96	0.94	0.87
alpha chain growth probability	0.70	0.69	0.69

C1 - C50 estimated total product distribution, weight %

C1	24.5	24.6	25.0
C2 - C4	25.9	25.9	26.2
C5 - C12	43.2	43.2	43.0
C13 - C50	6.3	6.2	5.8

CO conversion, %	4.0	3.9	3.8
rate, g CH ₂ /g cat/hr	0.25	0.25	0.24
CO ₂ formation, %	0.1	0.1	0.1

Time-on-Stream Plot for Co.060 - Run #1

Schulz-Flory Plot for Co.060 - Run #1
Time on Stream (hrs)

Cal.10 - Run #1

Co wt%	NM wt %	Promotor wt%		Support
20	Ru 0.50	K 0.30		Al ₂ O ₃

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm
 T = 220 °C
 H₂/CO = 2
 weight of catalyst = 0.198 g
 WHSV = 12.99 1/hr
 time on stream = 24.5 hrs

CO₂ (g/g cat/hr) = 0.045
 CO₂ (% of CO) = 0.2
 O/P = 1.75

CO conversion (%)	3.5
rate (g CH ₂ /g cat/hr)	0.20
alpha	0.74
C1 (wt%)	23.5
C2 - C4 (wt%)	19.9
C5 - C12 (wt%)	46.0
C13 + (wt%)	10.6

Performance of Cal.10

Dates: 11/18/94 - 11/19/94 Run #1

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 13.0 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	0.5	3.5	6.5	9.5	12.5	15.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	22.57	24.99	25.69	25.46	24.87	24.25
C2	4.04	4.30	4.35	4.33	4.26	4.20
C3	8.21	8.19	8.20	8.21	8.19	8.10
C4	9.30	8.92	8.67	8.75	8.78	8.62
C5	10.14	9.26	9.01	9.10	9.14	9.11
C6	9.01	7.65	8.23	8.20	8.37	8.31
C7	9.16	8.23	7.89	8.01	8.12	8.20
C8	7.48	6.66	6.34	6.51	6.62	6.73
C9	6.04	5.22	5.14	5.25	5.34	5.52
C10	4.98	4.78	4.27	4.36	4.48	4.59
C11	3.85	3.55	3.32	3.51	3.58	3.73
C12	2.78	2.86	2.81	2.85	2.76	2.92
C13	1.61	2.51	2.26	2.13	2.11	2.25
C14	0.63	2.25	2.01	1.77	1.78	1.87
C15	0.21	0.63	1.83	1.57	1.60	1.61
alpha chain growth probability	0.61	0.68	0.75	0.74	0.74	0.74

C1 - C50 estimated total product distribution, weight %

C1	24.0	26.0	23.5	23.8	23.2	22.7
C2 - C4	22.9	22.2	19.4	19.9	19.8	19.6
C5 - C12	51.6	47.3	44.4	45.3	45.8	46.3
C13 - C50	1.5	4.5	12.7	11.0	11.1	11.3

CO conversion, %	3.6	3.8	4.3	3.9	3.8	3.7
rate, g CH ₂ /g cat/hr	0.21	0.21	0.24	0.22	0.22	0.21
CO ₂ formation, %	0.3	0.5	0.3	0.2	0.2	0.2

Performance of Cal.10

Dates: 11/18/94 - 11/19/94 Run #1

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 13.0 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	18.5	21.5	24.5
reaction temperature, °C	220	220	220
pressure, atm	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	23.56	23.37	24.84
C2	4.14	4.13	4.29
C3	8.03	8.02	8.24
C4	8.58	8.55	8.57
C5	9.12	9.14	9.10
C6	8.33	8.47	8.33
C7	8.28	8.33	8.10
C8	6.81	6.79	6.61
C9	5.61	5.68	5.39
C10	4.71	4.47	4.53
C11	3.75	4.01	3.60
C12	3.05	2.94	2.85
C13	2.45	2.39	2.22
C14	2.03	2.01	1.81
C15	1.55	1.68	1.51
alpha chain growth probability	0.74	0.75	0.74

C1 - C50 estimated total product distribution, weight %

C1	22.3	21.9	23.5
C2 - C4	19.7	19.4	19.9
C5 - C12	47.0	46.8	46.0
C13 - C50	11.0	11.9	10.6

CO conversion, %	3.4	3.4	3.5
rate, g CH ₂ /g cat/hr	0.20	0.19	0.20
CO ₂ formation, %	0.2	0.2	0.2

Time-on-Stream Plot for Cal.10 - Run #1

Schulz-Flory Plot for Cal.10 - Run #1
Time on Stream (hrs)

APPENDIX C

Chronolgy of Runs in Slurry Bubble Column Reactors

APPENDIX C

CHRONOLOGY OF RUNS MADE IN THE SLURRY BUBBLE COLUMN REACTORS DURING THE FOURTH QUARTER OF 1994

Task 2.0 -- Catalyst Testing

Subtask 2.2 -- "Slurry Bubble Column Testing"

Run No. 22 in the M4-SBCR was started on October 3rd with a blend of two catalysts: 15.5 gm of Catalyst No. WGS.09 and 15.0 gm of Catalyst No. Co.005. The first catalyst is a water-gas shift catalyst and the second is a methane reduction catalyst. The CO conversion with this blend at startup conditions was considerably higher than observed with Catalyst No. Co.005 in Run 15 in M3-SBCR, 35.6% vs. 27.1%. Also, the CO₂ selectivity was much higher, 6.3% vs. 0.8%. Some water-gas shift activity has occurred with this catalyst blend as demonstrated by the higher CO₂ yield and increase in CO conversion. Several run periods were made in which the H₂/CO ratio was lowered to 1/1 and 0.7/1 at 240°, 260°, and 280°C reaction temperatures. The CO conversion decreased as the H₂/CO ratio was decreased and the CO conversion increased when the reaction temperature was raised. Water-gas shift activity was observed at all run conditions.

Run No. 30 in the M3-SBCR was started on October 10th with a charge of 29.6 gm of Catalyst No. Co.053-2. The purpose of this run was to run at conditions that would yield the highest CO conversion attainable in the SBCR. The CO conversion at startup conditions was 41.8%, the same as observed previously in Run 29 with the same catalyst charge. The CO conversion increased to 46.9% at 260°C reaction temperature. The CO conversion, however, dropped to 41.4% when the reaction temperature was increased to 280°C. The reaction temperature was increased to 300°C, 310°C, and finally to 320°C, but the CO conversion did not exceed 40% at any of these temperatures. The run was shut down after 279 hours after the gas preheater plugged when the heater temperature reached 550°C. It is speculated that the catalyst activity began to decrease above 260°C because the reaction temperature may have been increased too rapidly. This run will be repeated using the M4-SBCR.

Run No. 23 in the M4-SBCR was started on October 17th with a charge of 29.1 gm of Catalyst No. CAL.09. This was a catalyst that was supplied by Calsicat that was hydrogen reduced and coated with Soya. The catalyst was mixed with synfluid, heated, and charged to the SBCR under a nitrogen blanket. The CO conversion at the initial startup conditions was only 17.4%. The run was terminated after two run periods because the catalyst activity was only 60% of the expected activity.

Run No. 24 in the M4-SBCR was started on October 24th with a charge of 28.5 gm of Catalyst No. Co.053-3. The purpose of this run was to attain the highest CO conversion possible. The CO conversion at startup conditions was 50.4%, which is the highest conversion observed to date. The M4-SBCR appears to yield a little higher catalyst activity than M3-SBCR for some unknown reason. The CO conversion rose to 53.5% at 250°C reaction temperature (Period 2) and

to 55.3% at 260°C (Period 3). In Period No. 4, the N₂ feed rate was decreased from 60% of the total to 40% with a corresponding increase in the H₂ and CO feed rates. The CO conversion dropped to 52.8%, but the production rate increased from 1.36 to 2.13 gm C₁⁺/gm catalyst/hr. The total gas feed rate was then lowered from 900 standard liter per hour (SLH) to 700 SLH for Period 5. The CO conversion rose to 58.9%. Increasing the total feed gas rate to 1080 SLH (50% N₂) lowered the CO conversion to 42.6% for Period 6. At this time the gas feed rates were returned to startup rates for an activity check. The CO conversion averaged 51.5% compared to 55.3% obtained in Period 3 made at the same run conditions. This was considered to be a normal loss of catalyst activity.

For Period 8, the total feed gas rate was reduced from 900 SLH to 632 SLH with about 32% N₂ in the feed. The CO conversion rose to 58.1%. Lowering the total feed gas rate to 540 SLH (20% N₂) for Period 9 yielded a CO conversion of 60.0%. It was decided to raise the reactor temperature to 270°C to further increase the CO conversion. The reaction temperature; however, increased rapidly and could not be controlled because the SBCR has no provision for heat removal. The reactor stabilized at 275°C for about 5 hours with a CO conversion of 72%. The reactor temperature then rose to 292°C before dropping to 255°C by the next morning. The reactor was stabilized at 260°C for an activity check. The CO conversion was only 49%, so it was decided to terminate the run. A chilled water cooling coil will be installed in the feed gas line before attempting high CO conversion runs. This run demonstrated that higher CO conversion levels can be obtained by reducing the N₂ feed composition and total gas feed rate. Also, a method to remove the heat of reaction must be found for the SBCR before attempting to reach higher CO conversion levels.

Run No. 31 in the M3-SBCR was started on October 31st with a charge of 15.0 gm of Catalyst No. Co.055. This catalyst contained 20 wt% Co plus 1.0 wt% Re and 1.0 wt% La₂O₃ promoters on an alumina catalyst support. The CO conversion at startup conditions was good, 30.0%, with a high production rate, 1.46 gm C₁⁺/gm catalyst/hr, but the CH₄ selectivity, however, was quite high, 23.7%. The catalyst is similar to Co.001, the original startup benchmark catalyst used in Run 2 in the M3-SBCR, but without K added.

Run No. 25 in the M4-SBCR was started on November 8th with a charge of 15.0 gm of Catalyst No. Co.056. This catalyst contained 20 wt% Co plus 8.5% La₂O₃ on silica catalyst support. The CO conversion at startup conditions was only 11.4% and 4.5% at 220°C reaction temperature. The run was terminated after 63 hours on stream due to the low catalyst activity.

Run No. 32 in the M3-SBCR was started on November 14th with a charge of 16.4 gm of Catalyst No. Co.044. This catalyst contained 20 wt% Co plus 15% Zr promoter on silica support. The purpose of this run was to determine the effect of adding a larger amount of Zr on catalyst activity. The greater amount of Zr yielded a 21% CO conversion compared to 25% CO conversion with an 8.5% Zr on a cobalt-silica catalyst and 23.2% CO conversion with a 0.7% Zr promoter on a cobalt-silica catalyst.

Run No. 26 in the M4-SBCR was started on November 17th with a charge of 15.6 gm of Catalyst No. CAL.10. This catalyst which was received from Calsicat contained 20 wt% Co with 0.3% K and 0.5% Ru on Condea alumina. The Condea alumina is similar to Vista B alumina which has demonstrated good attrition resistance. The CO conversion at startup conditions was only 21.9%

versus 26.5% obtained with Catalysts CAL.04 and CAL.05 which were made with Vista B alumina support. It was decided not to follow the usual schedule of run conditions, but to investigate the effect of lowering the total syngas and nitrogen flows into the reactor on catalyst activity. The reaction was held at 240°C, 450 psi pressure, and 2/1 H₂/CO feed ratio with lower total gas flow rates. Lowering the total gas rate from 900 SLH (60% N₂) to 540 SLH (20% N₂) did not affect the CO conversion, but increased the hydrocarbon production rate about 30%. Lowering the N₂ feed concentration to 12%, and then to 6% decreased rather than increased the CO conversion. This run was terminated because the catalyst activity was too low. It was decided to install a smaller N₂ mass flow meter to improve the accuracy at lower N₂ feed rates. Since the CO and H₂ conversions are calculated from both the mass flow meter rates and from G.C. analyses of the feed and product gases using N₂ as an internal standard, it is necessary to get accurate low N₂ flow rates.

Run No. 33 in the M3-SBCR was started on November 28th with a charge of 31.4 gm of Catalyst No. Co.053-4. This was another attempt to obtain the highest CO conversion possible. A chilled water precooling coil was installed on the feed gas line to help heat removal during high conversion levels. The CO conversion at startup conditions was only 41.4%, but was the same as Runs 29 and 30 in M3-SBCR. The M4-SBCR gave higher CO conversion, 50.4%, for some unknown reason. In Period No. 2, the three gas feed rates were decreased proportionally to 60% of startup (540 SLH) and the reaction pressure was lowered to 300 psi. The CO conversion dropped to 35.2% and the C₁⁺ production rate decreased 50%. Lowering the total gas rate to 400 SLH raised the CO conversion to 38.7%. The CO conversion rose to 39.6% at 250°C reaction temperature, and dropped to 37.7% at 260°C temperature. Raising the pressure back to 450 psi only increased the CO conversion to 45.0%. For Period 7, the N₂ composition was lowered from 60 to 40%. The CO conversion stayed the same, 45.7%. Lowering the N₂ composition to 25% increased the CO conversion to 49.2%. The run conditions were changed to startup conditions. The CO conversion dropped to 16.1% vs. 41.4% in Period 1. There was considerable loss of catalyst activity over the duration of this run, probably when the reaction temperature was raised to 260°C.

Run No. 27 in the M4-SBCR was started on December 5th with a charge of 14.6 gm of Catalyst No. Co.050. This catalyst contained 20% Co plus 0.5% Ru, 8.5% Zr, and 0.1% K promoters on silica support. The CO conversion at startup conditions was 20.4%, which is the same as obtained with Catalyst No. Co.048 that contained 0.3% K. The methane selectivities were also similar, approximately 10%. The optimum amount of K to add for methane reduction without significantly lowering catalyst activity is somewhere between 0.1 and 0.3 wt%.

Run No. 34 in the M3-SBCR was started on December 12th with a charge of 15.6 gm of Catalyst No. Co.060. This catalyst contained 30 wt% Co on alumina support with no promoters. The CO conversion was 31.4%, which is in the range that was expected without any metals or promoters added. The methane selectivity was approximately 14%, which was also in the expected range.

During the shutdown period over the Christmas holiday, a number of routine maintenance checks were made. A smaller N₂ mass flow meter was installed and calibrated on M4-SBCR. All other gas flow meters had calibration rechecks made and were found to be in good order. All necessary repairs were made on both SBCR reactor systems.

APPENDIX D

Slurry Bubble Column Reactor Data

Table I

SUMMARY OF H3 SBCR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using H₂ as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C₁+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Per No	Time Start	Time Stop	Temp C	Pres psi	H ₂ : CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities %CH ₄	%C ₂	%C ₃ +	%CO ₂	Alpha GC	Alpha Liq	Olefin/Paraf C ₃	C ₄	Olefins C ₆ -18, %	Comments
2	CO.001	16.5	1	162	177	225	450	2.0	20	15.9	0.70	2.3	0.8	96.4	0.53	0.98	0.88	5.00	2.27	25.2	
2	CO.001	16.5	2	202	228	200	450	2.0	20	3.9	0.17	0.0	0.0	99.9	0.00	0.81	0.91	0.00	0.00	21.7	
2	CO.001	16.5	3	254	280	240	450	2.0	20	30.9	1.36	11.7	1.8	85.5	1.04	0.87	0.77	2.63	1.64	22.4	
2	CO.001	16.5	4	302	323	225	450	1.2	20	9.9	0.59	0.7	0.3	98.4	0.67	0.76	0.90	0.00	7.14	29.4	
2	CO.001	16.5	5	350	372	225	450	2.0	20	15.3	0.68	6.0	1.0	92.5	0.49	0.84	0.88	4.00	2.70	23.1	
2	CO.001	16.5	6	398	420	225	300	2.0	20	12.5	0.55	6.1	1.1	92.2	0.63	0.79	0.86	4.35	2.86	21.7	
2	CO.001	16.5	7	446	468	240	300	2.0	20	22.9	1.02	16.5	0.8	81.5	1.16	0.71	0.79	3.03	1.79	22.4	
2	CO.001	16.5	8	494	516	240	600	2.0	20	29.9	1.33	12.6	1.6	85.0	0.84	0.76	0.82	2.63	1.69	22.4	
2	CO.001	16.5	9	517	540	240	600	2.0	0	29.5	1.31	12.0	1.7	85.3	0.96	0.76	--	2.50	1.56	22.4	
2	CO.001	16.5	9	541	564	240	600	2.0	0	28.4	1.26	10.4	1.7	87.1	0.89	0.77	--	3.03	1.72	--	
2	CO.001	16.5	9	565	588	240	600	2.0	0	27.9	1.27	11.1	1.7	86.2	0.93	0.76	--	3.03	1.72	--	
2	CO.001	16.5	9	589	612	240	600	2.0	0	27.0	1.20	10.7	1.7	86.7	0.89	0.76	0.82	2.78	2.00	--	
2	CO.001	16.5	10	637	660	240	600	2.0	20	26.4	1.17	11.0	1.7	86.4	0.85	0.77	0.83	2.86	1.96	22.4	G.C. Calib
2	CO.001	16.5	11	684	706	225	450	2.0	20	11.6	0.51	5.4	1.0	93.0	0.61	0.81	0.87	5.26	3.45	23.8	
3	CO.005	19.5	1	12	36	240	450	2.0	20	33.2	1.23	5.6	1.6	91.8	1.06	0.80	0.81	2.04	1.27	23.1	G.C. Calib
3	CO.005	19.5	2	60	84	220	450	2.0	20	15.0	0.56	2.9	0.6	96.2	0.24	0.86	0.87	4.55	3.23	21.7	
3	CO.005	19.5	3	108	132	240	450	1.2	20	18.5	0.94	6.9	1.0	91.3	0.85	0.81	--	5.88	3.85	26.6	
3	CO.005	19.5	4	156	179	240	450	2.0	20	29.6	1.11	11.5	1.8	85.8	0.91	0.76	0.78	2.22	1.39	21.7	
4	CO.002	20.1	1	37	59	240	450	2.0	20	36.1	1.32	22.9	3.2	72.4	1.51	0.66	0.77	0.65	0.31	16.8	
4	CO.002	20.1	2	85	106	220	450	2.0	20	16.6	0.60	3.8	1.1	94.7	0.35	0.84	0.88	2.44	0.89	--	
4	CO.002	20.1	3	133	149	210	600	1.0	20	5.2	0.28	0.0	0.0	99.1	0.87	0.89	0.94	0.00	0.00	--	Power Fail
5	CO.003	15.1	1	15	35	240	450	2.0	20	31.7	1.53	16.7	2.4	79.8	1.16	0.71	--	1.30	0.60	18.2	G.C. Calib
5	CO.003	15.1	2	61	83	220	450	2.0	20	13.2	0.63	5.1	1.0	93.4	0.51	0.82	0.90	4.55	1.89	--	
5	CO.003	15.1	3	88	107	240	450	2.0	20	28.4	1.37	15.1	2.4	81.4	1.11	0.75	--	1.45	0.97	--	
5	CO.003	15.1	4	133	155	240	450	1.0	20	13.1	0.95	4.2	1.2	93.3	1.24	0.83	0.88	6.67	3.70	--	
5	CO.003	15.1	5	181	203	240	600	1.0	20	13.4	0.97	3.9	1.1	93.7	1.30	0.81	--	5.26	3.45	30.1	
5	CO.003	15.1	6	217	227	240	450	2.0	20	25.4	1.23	14.9	2.4	81.7	1.03	0.73	--	1.89	1.19	--	
6	CO.011	15.3	1	13	35	240	450	2.0	20	14.3	0.67	7.6	1.6	89.4	1.42	0.78	0.83	4.17	2.57	21.7	
6	CO.011	15.3	2	61	83	220	450	2.0	20	5.1	0.23	0.0	0.0	97.2	2.78	0.87	0.82	--	--	--	
6	CO.011	15.3	3	88	107	240	450	2.0	20	13.5	0.63	5.4	1.7	91.1	1.86	0.79	--	4.00	2.83	--	
6	CO.011	15.3	4	133	155	240	450	1.0	20	6.3	0.44	0.4	1.0	95.5	3.05	0.82	0.88	--	--	--	
6	CO.011	15.3	5	181	203	240	600	1.0	20	6.7	0.46	0.2	0.9	96.0	2.91	0.84	0.89	12.00	3.67	27.3	G.C. Calib
6	CO.011	15.3	6	217	226	240	450	2.0	20	12.0	0.57	5.9	1.8	90.4	1.91	0.78	--	4.40	2.43	--	

Table I
(Continued)

SUMMARY OF M3 SBCR RUN RESULTS

a)Unless otherwise noted, total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

b)Conversion is total CO conversion over the period (%).

c)Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d)Prod. rate: Rate for production of total hydrocarbons,C1+ (kg/kg cat.,hr).

e)Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Per No	Time Start	Time Stop	Temp C	Pres psi	H2: CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf C3	C4	Olefins C6-18,%	Comments
7	CO.012	15.8	1	14	36	240	450	2.0	20	13.9	0.63	6.1	1.5	90.6	1.74	0.80	0.89	4.00	2.57	17.5	
7	CO.012	15.8	2	62	84	220	450	2.0	20	5.1	0.23	0.0	0.2	97.8	2.02	0.89	0.90	--	2.50	--	
7	CO.012	15.8	3	88	92	240	450	2.0	20	13.1	0.59	6.1	1.7	90.4	1.75	0.80	--	5.00	2.25	--	Power Fail
7	CO.012	15.8	4	134	156	240	450	1.0	20	3.9	0.26	4.8	2.3	86.3	6.64	0.70	0.85	16.00	3.50	--	
7	CO.012	15.8	5	182	204	240	600	1.0	20	4.3	0.28	0.1	2.1	91.6	9.29	0.75	0.82	8.50	3.50	30.8	
7	CO.012	15.8	6	218	227	240	450	2.0	20	7.2	0.32	7.3	3.2	85.1	4.45	0.70	--	5.00	3.17	--	
8	CO.015	15.0	1	14	35	240	450	2.0	20	28.3	1.37	12.7	2.0	84.1	1.24	0.76	0.80	1.61	1.07	19.6	G.C.Calib
8	CO.015	15.0	2	61	83	220	450	2.0	20	11.5	0.56	4.4	1.0	93.9	0.80	0.81	0.89	3.60	2.14	--	
8	CO.015	15.0	3	97	106	240	450	2.0	20	26.4	1.28	13.2	2.1	83.5	1.12	0.75	--	1.69	1.20	--	
8	CO.015	15.0	4	133	155	240	450	1.0	20	11.5	0.83	4.8	1.2	92.5	1.53	0.80	0.85	5.60	3.29	--	
8	CO.015	15.0	5	181	191	240	600	1.0	20	12.4	0.90	4.9	0.8	93.6	0.73	0.84	0.85	5.20	3.14	30.8	Power Fail
9	CO.011	15.0	1	13	35	240	450	2.0	20	18.5	0.89	8.8	1.7	88.8	0.77	0.78	0.83	3.18	1.85	20.3	G.C.Calib
9	CO.011	15.0	2	61	82	220	450	2.0	20	6.3	0.31	0.0	1.0	98.6	0.41	0.88	0.93	12.00	1.80	--	
9	CO.011	15.0	3	97	107	240	450	2.0	20	16.6	0.80	8.4	2.1	88.7	0.81	0.77	--	3.30	2.00	--	
9	CO.011	15.0	4	133	155	240	450	1.0	20	8.0	0.58	1.3	1.3	96.3	1.16	0.82	0.87	7.00	2.83	--	
9	CO.011	15.0	5	181	203	240	600	1.0	20	8.7	0.63	1.4	1.1	96.4	1.05	0.83	0.87	5.00	2.67	30.5	
9	CO.011	15.0	6	228	229	240	450	2.0	20	14.7	0.71	7.9	2.2	89.1	0.85	0.78	--	3.78	1.67	--	Power Fail
11	CO.017	15.0	1	9	31	240	450	2.0	20	27.2	1.32	11.2	1.8	85.9	1.14	0.77	0.80	2.09	1.20	30.8	
11	CO.017	15.0	2	55	79	220	450	2.0	20	11.4	0.55	5.0	0.0	94.8	0.22	0.88	0.90	5.00	3.20	--	
11	CO.017	15.0	3	81	103	240	450	2.0	20	25.9	1.26	11.7	1.6	85.6	1.14	0.77	--	1.95	1.26	--	
11	CO.017	15.0	4	129	151	240	450	1.0	20	11.6	0.84	5.0	0.0	93.9	1.19	0.82	0.86	25.0	2.88	--	
11	CO.017	15.0	5	177	199	240	600	1.0	20	11.6	0.84	4.2	0.0	94.7	1.17	0.86	0.86	24.0	1.63	21.0	G.C.Calib
11	CO.017	15.0	6	213	221	240	450	2.0	20	24.3	1.20	12.1	1.4	86.4	0.08	0.78	--	2.47	1.64	--	
12	CO.018	15.6	1	13	35	240	450	2.0	20	33.8	1.56	9.7	2.0	86.6	1.68	0.75	0.85	1.81	1.13	21.0	G.C.Calib
12	CO.018	15.6	2	61	80	220	450	2.0	20	12.6	0.59	2.8	0.0	97.1	0.08	0.90	0.88	--	--	--	
12	CO.018	15.6	3	97	107	240	450	2.0	20	27.9	1.30	9.4	1.9	87.7	1.03	0.75	--	2.65	2.17	--	
12	CO.018	15.6	4	133	155	240	450	1.0	20	12.4	0.86	3.3	0.0	95.0	1.67	0.80	0.86	--	--	--	
12	CO.018	15.6	5	181	203	240	600	1.0	20	13.0	0.90	3.2	0.0	94.9	1.86	0.80	0.85	--	--	38.5	
12	CO.018	15.6	6	217	226	240	450	2.0	20	26.4	1.22	10.1	1.4	86.8	1.74	0.73	--	2.89	2.05	--	

Table I
(Continued)

SUMMARY OF M3 SBCR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Per No	Time Start	Time Stop	Temp C	Pres H2: psi	Synfl CO	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefins C6-18,%	Comments	
											%CH4	%C2	%C3+	%CO2			C3	C4			
13	CO.016	14.7	1	16	35	240	450	2.0	20	26.4	1.31	8.3	1.7	89.3	0.68	0.78	0.81	2.00	1.41	21.7	G.C.Calib
13	CO.016	14.7	2	65	83	220	450	2.0	20	9.7	0.48	0.0	0.99	9.00	0.91	0.88	--	--	--	TCD weak.	
13	CO.016	14.7	3	89	105	240	450	2.0	20	25.2	1.25	9.2	1.7	88.6	0.51	0.78	--	2.10	1.41	--	CH4 peaks
13	CO.016	14.7	4	134	155	240	450	1.0	20	10.9	0.81	1.2	0.7	97.7	0.32	0.84	0.86	--	--	--	are lower
13	CO.016	14.7	5	181	203	240	600	1.0	20	11.4	0.85	0.0	0.4	99.3	0.25	0.92	0.86	--	--	32.2	than
13	CO.016	14.7	6	210	226	240	450	2.0	20	22.7	1.12	3.8	1.9	93.7	0.46	0.79	--	2.37	1.41	--	expected.
14	CO.019	15.2	1	14	35	240	450	2.0	20	13.9	0.66	0.4	1.7	97.2	0.70	0.80	0.86	5.33	2.67	26.6	G.C.Calib
14	CO.019	15.2	2	66	83	220	450	2.0	20	3.8	0.18	0.0	1.7	96.7	1.56	0.88	--	--	--	--	New TCD
14	CO.019	15.2	3	88	105	240	450	2.0	20	12.2	0.57	0.0	2.0	96.3	1.67	0.80	--	5.60	3.80	--	
14	CO.019	15.2	4	133	155	240	450	1.0	20	--	--	--	--	--	0.85	--	--	--	--	--	Repair G.C
14	CO.019	15.2	5	169	178	240	600	1.0	20	5.9	0.41	0.0	1.5	96.1	2.42	0.80	--	8.50	13.00	--	Valve Leak
14	CO.019	15.2	6	193	203	240	450	2.0	20	10.2	0.48	0.8	2.2	95.0	1.96	0.79	--	4.80	3.40	--	CH4 peaks
14	CO.019	15.2	7	217	226	240	450	1.0	20	5.1	0.36	0.0	1.6	95.4	3.09	0.80	--	--	--	--	undetected
15	CO.005	14.7	1	25	35	240	450	2.0	20	27.1	1.34	7.9	1.6	89.7	0.82	0.79	0.82	2.30	1.38	23.1	G.C.Calib
15	CO.005	14.7	2	62	83	220	450	2.0	20	10.7	0.53	0.0	0.9	98.4	0.70	0.83	0.88	4.25	3.25	--	
15	CO.005	14.7	3	86	105	240	450	2.0	20	25.3	1.25	7.6	1.8	89.6	1.01	0.78	--	2.42	1.50	--	
15	CO.005	14.7	4	134	155	240	450	1.0	20	11.6	0.85	0.0	1.1	97.5	1.37	0.82	0.85	7.00	4.60	--	
15	CO.005	14.7	5	182	203	240	600	1.0	20	12.3	0.90	0.0	1.0	97.7	1.33	0.83	0.85	7.00	4.40	--	
15	CO.005	14.7	6	210	226	240	450	2.0	20	23.0	1.13	5.9	1.8	91.4	0.99	0.78	--	3.20	2.00	--	
16	CO.002	15.4	1	14	35	240	450	2.0	20	30.1	1.42	12.5	2.5	83.9	1.09	0.75	0.80	1.00	0.66	17.5	
16	CO.002	15.4	2	67	83	220	450	2.0	20	12.8	0.60	4.2	1.3	93.9	0.65	0.80	0.86	2.57	1.63	--	G.C.Calib
16	CO.002	15.4	3	91	107	240	450	2.0	20	28.2	1.34	17.3	2.9	78.8	0.99	0.71	--	0.93	0.65	--	
16	CO.002	15.4	4	136	155	240	450	1.0	20	12.6	0.89	4.4	1.6	92.8	1.21	0.79	0.84	4.43	2.88	--	
16	CO.002	15.4	5	182	198	240	600	1.0	20	13.1	0.92	3.6	1.4	93.9	1.12	0.81	0.84	4.29	2.75	25.2	
16	CO.002	15.4	6	209	227	240	450	2.0	20	25.6	1.22	17.4	3.1	78.7	0.83	0.71	--	1.00	0.66	--	
17	CO.025	15.6	1	21	35	240	450	2.0	20	26.6	1.24	10.7	2.1	86.4	0.82	0.76	0.82	2.25	1.47	21.7	G.C.Calib
17	CO.025	15.6	2	62	83	220	450	2.0	20	8.4	0.39	0.0	1.1	96.9	1.94	0.82	0.92	6.50	3.00	--	
17	CO.025	15.6	3	90	107	240	450	2.0	20	21.5	1.00	9.0	2.0	88.0	1.03	0.77	--	2.64	1.64	--	
17	CO.025	15.6	4	134	155	240	450	1.0	20	10.3	0.71	0.8	1.2	96.7	1.30	0.82	0.93	7.67	4.25	--	
17	CO.025	15.6	5	181	203	240	600	1.0	20	11.7	0.81	1.3	1.1	96.5	1.12	0.83	0.88	8.00	4.25	32.9	
17	CO.025	15.6	6	217	226	240	450	2.0	20	19.9	0.93	9.3	2.2	87.7	0.91	0.76	--	2.92	1.85	--	
18	CO.004	15.0	1	20	39	240	450	2.0	20	33.9	1.64	15.3	2.4	80.9	1.37	0.74	0.79	1.17	0.78	20.3	Repair G.C
18	CO.004	15.0	2	66	87	220	450	2.0	20	15.1	0.73	4.1	1.6	94.0	0.29	0.81	0.85	3.83	2.25	--	
18	CO.004	15.0	3	92	111	240	450	2.0	20	32.7	1.59	15.7	2.6	80.2	1.49	0.73	--	1.20	0.80	--	
18	CO.004	15.0	4	138	159	240	450	1.0	20	14.7	1.06	4.1	1.2	93.2	1.44	0.80	0.83	6.17	3.75	--	
18	CO.004	15.0	5	186	207	240	600	1.0	20	15.0	1.09	3.6	1.1	94.1	1.18	0.82	0.83	5.67	4.00	33.6	
18	CO.004	15.0	6	214	230	240	450	2.0	20	28.4	1.38	14.9	2.5	86.5	1.13	0.73	--	1.58	1.03	--	

SUMMARY OF H3 SACR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm³/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

(c) Conversion and selectivities are calculated using M as an internal

standard in the GC analysis of the offgas.

(d) Prod. rate: Rate for production of total hydrocarbons, $Cl_1 + (kg/kg \text{ car.} \cdot hr)$.

e)Alpha: Based on GC analysis of offgas and liquid products.

[illegible]

Table I
(Continued)

SUMMARY OF M3 SBCR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using H₂ as an internal standard in the GC analysis of the offgas.

d) Prod. rates: Rate for production of total hydrocarbons, C₁+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Per No	Time Start	Time Stop	Temp C	Pres psi	H ₂ : CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefins C ₆ -18, %	Comments
No	No	wt, g	No	Start	Stop	C	psi	CO	cc/hr	%	Rate	%CH ₄	%C ₂	%C ₃ +	%CO ₂	GC	Liq	C ₃	C ₄	C ₆ -18, %	
27	CO.029	15.9	1	23	39	240	450	2.0	20	28.3	1.27	8.3	1.6	87.9	2.21	0.77	0.84	3.40	2.20	27.3	
27	CO.029	15.9	2	71	87	220	450	2.0	20	9.5	0.43	1.7	1.1	96.0	1.23	0.80	0.89	5.67	3.00	--	
27	CO.029	15.9	3	99	111	240	450	2.0	20	25.7	1.16	7.7	1.6	88.8	1.86	0.78	--	4.00	2.36	--	
27	CO.029	15.9	4	150	159	240	450	1.0	20	12.0	0.82	1.9	0.9	95.4	1.88	0.83	0.90	8.33	4.75	--	
27	CO.029	15.9	5	191	207	240	600	1.0	20	12.1	0.82	1.7	0.9	95.6	1.75	0.83	0.89	7.67	4.75	39.9	
27	CO.029	15.9	6	222	230	240	450	2.0	20	23.7	1.08	8.2	1.7	88.5	1.60	0.78	--	3.92	2.67	--	
28	CO.01	15.0	1	19	36	240	450	2.0	20	1.1	0.05	0.0	12.	83.9	4.23	0.58	--	3.33	2.50	--	Shut down
29	CO.053	25.2	1	21	39	240	450	2.0	20	42.0	1.19	15.8	2.3	79.5	2.42	0.73	--	1.00	0.67	17.5	
29	CO.053	25.2	2	71	87	220	450	2.0	20	20.5	0.59	5.7	4.8	89.0	0.50	0.79	0.84	3.38	2.10	--	
29	CO.053	25.2	3	95	111	240	450	2.0	20	39.2	1.13	15.8	2.9	79.2	2.09	0.72	--	1.11	0.74	--	
29	CO.053	25.2	4	143	159	240	450	1.0	20	18.4	0.79	5.3	2.6	90.6	1.52	0.80	0.84	5.86	3.56	--	
29	CO.053	25.2	5	191	207	240	600	1.0	20	19.7	0.85	4.6	1.2	92.9	1.34	0.82	--	5.71	3.44	33.6	
29	CO.053	25.2	6	239	255	240	600	2.0	20	40.8	1.17	14.8	2.1	81.4	1.68	0.75	0.80	1.10	0.74	--	
29	CO.053	25.2	7	303	304	240	450	2.0	20	31.5	0.45	21.0	3.9	72.2	2.93	0.63	--	1.34	0.97	--	G.C.Repair
29	CO.053	25.2	8	332	351	260	450	2.0	20	31.0	0.44	36.4	5.3	52.6	5.74	0.52	--	2.60	1.75	--	
29	CO.053	25.2	9	375	376	240	450	2.0	20	18.0	0.55	23.0	3.5	72.1	1.46	0.66	--	3.21	2.05	--	
29	CO.053	25.2	10	415	423	240	450	2.0	20	21.6	0.98	14.4	2.5	82.4	0.82	0.72	--	2.87	1.79	--	G.C.Repair
30	CO.053	29.6	1	26	39	240	450	2.0	20	41.8	1.02	22.6	2.9	71.5	3.05	0.66	0.77	0.99	0.65	19.6	
30	CO.053	29.6	2	55	63	260	450	2.0	20	46.9	1.11	40.6	5.5	46.0	7.98	0.45	--	0.83	0.64	--	
30	CO.053	29.6	3	79	87	280	450	2.0	20	41.4	0.96	41.9	6.5	42.0	9.63	0.40	--	2.06	1.35	--	
30	CO.053	29.6	4	103	111	240	450	2.0	20	19.9	0.49	19.2	3.6	75.8	1.45	0.64	--	4.29	2.50	--	
30	CO.053	29.6	5	131	135	265	450	2.0	20	36.4	0.89	36.4	5.2	54.4	4.04	0.53	--	2.45	1.60	--	
30	CO.053	29.6	6	154	159	280	450	2.0	20	39.6	0.96	48.3	5.9	39.0	6.84	0.40	--	2.44	1.62	--	
30	CO.053	29.6	7	174	183	300	450	2.0	20	40.7	0.94	42.4	6.8	40.7	10.2	0.47	--	3.11	2.03	--	
30	CO.053	29.6	8	198	207	309	450	2.0	20	38.3	0.85	22.8	7.3	58.3	11.6	0.62	--	3.76	2.48	--	G.C.Calib
30	CO.053	29.6	9	220	231	310	450	2.0	20	37.5	0.87	55.5	7.2	25.5	11.8	0.13	--	3.93	2.67	--	
30	CO.053	29.6	10	242	254	320	450	2.0	20	40.8	0.90	61.7	7.4	14.5	16.4	0.00	--	3.62	2.63	--	
30	CO.053	29.6	11	270	279	320	450	1.0	20	30.8	0.92	42.9	6.0	26.9	24.2	0.30	--	5.68	4.28	--	

Table I
(Continued)

SUMMARY OF M3 SBCR RUN RESULTS

a) Unless otherwise noted, total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using H2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Per No	Time Start	Time Stop	Temp C	Pres psi	H2: CO	Synfld cc/hr	Conv. %	Prod. Rate	Selectivity			Alpha GC	Alpha Liq	Olefin/Paraf		Olefins C6-C18, %	Comments
												%CH4	%C2H6	%C3+			C3	C4		
31	Co.055	15.0	1	23	39	240	450	2.0	20	30.0	1.46	23.7	3.73	70.2	0.61	0.81	0.90	0.60	20.3	
31	Co.055	15.0	2	71	87	220	450	2.0	20	9.1	0.44	10.6	2.53	85.7	0.61	0.85	2.89	1.80	--	
31	Co.055	15.0	3	98	110	240	450	2.0	20	25.8	1.26	23.9	3.94	70.1	0.58	--	1.06	0.70	--	
31	Co.055	15.0	4	143	159	240	450	1.0	20	14.7	1.06	5.5	1.44	91.7	0.78	0.83	5.71	3.22	--	
31	Co.055	15.0	5	196	207	240	600	1.0	20	16.1	1.16	4.7	1.21	92.8	0.80	0.83	6.17	3.11	33.6	
31	Co.055	15.0	6	222	234	240	450	2.0	20	29.1	1.42	18.0	2.84	77.8	0.69	--	1.40	0.91	--	
32	Co.044	16.4	1	23	39	240	450	2.0	20	20.9	0.93	6.7	1.91	90.8	0.77	0.83	3.42	2.17	23.1	
32	Co.044	16.4	2	71	87	220	450	2.0	20	10.3	0.46	0.0	0.92	98.8	0.85	--	4.33	4.50	--	
32	Co.044	16.4	3	102	110	240	450	2.0	20	21.8	0.97	6.4	1.72	91.3	0.79	--	3.00	1.77	--	
32	Co.044	16.4	4	143	159	240	450	1.0	20	9.87	0.25	2.1	3.19	92.5	0.61	0.87	7.33	4.00	--	
32	Co.044	16.4	5	174	182	240	450	2.0	20	20.2	0.89	6.8	1.85	90.8	0.79	--	2.92	1.75	--	
33	Co.053	31.4	1	24	39	240	450	2.0	20	41.4	0.94	23.2	3.14	69.6	0.65	0.76	0.82	0.58	21.7	G.C. Calib
33	Co.053	31.4	2	54	63	240	300	2.0	20	35.2	0.47	29.9	3.93	59.6	0.55	--	0.89	0.70	--	
33	Co.053	31.4	3	78	87	240	300	2.0	20	38.7	0.38	31.1	3.90	57.5	0.54	--	0.97	0.71	--	
33	Co.053	31.4	4	102	111	250	300	2.0	20	39.6	0.38	43.1	4.60	41.1	0.38	--	0.99	0.77	--	
33	Co.053	31.4	5	126	135	260	300	2.0	20	37.7	0.37	42.1	4.59	42.4	0.42	--	1.76	1.21	--	
33	Co.053	31.4	6	150	159	260	450	2.0	20	45.0	0.44	43.2	4.80	40.9	0.44	--	1.35	0.95	--	
33	Co.053	31.4	7	174	183	260	450	2.0	20	45.7	0.73	46.4	4.63	40.2	0.43	--	1.06	0.77	--	
33	Co.053	31.4	8	198	207	260	450	2.0	20	49.2	0.98	44.4	4.26	43.5	0.51	--	0.87	0.65	--	
33	Co.053	31.4	9	222	230	240	450	2.0	20	16.1	0.38	33.7	4.79	59.2	0.35	--	3.14	1.91	--	
34	Co.060	15.6	1	23	32	240	450	2.0	20	31.4	1.46	14.0	2.34	82.2	0.75	0.79	1.61	1.00	23.1	G.C. Calib
34	Co.060	15.6	2	71	87	220	450	2.0	20	13.0	0.60	0.1	1.77	97.8	0.81	0.88	4.00	2.83	--	G.C. Calib
34	Co.060	15.6	3	102	111	240	450	2.0	20	28.8	1.34	14.1	2.40	82.2	0.73	--	1.87	1.17	--	
34	Co.060	15.6	4	150	157	240	450	1.0	20	13.5	0.94	4.3	1.75	92.5	0.77	0.85	7.00	4.67	--	
34	Co.060	15.6	5	191	207	240	600	1.0	20	12.8	0.89	2.2	1.64	94.9	0.82	0.86	6.60	4.33	38.5	G.C. Calib
34	Co.060	15.6	6	222	230	240	450	2.0	20	24.9	1.16	13.8	2.78	82.2	0.74	--	2.73	1.73	--	

Table II

COMPARISON OF CONVERSION AND SELECTIVITY OF
METHANE REDUCTION CATALYSTS AT STARTUP CONDITIONS

Period No.	Temp.	Pres.	H ₂ /CO Ratio
-----	-----	-----	-----
1	240 C	450psi	2.0

a) Total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

Flows: N₂-563 SLH, H₂-225 SLH, CO-112.5 SLH.

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N₂ as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons C+1 (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Catalyst Prom%	Composit. Metal%	Suppt
-----	-----	-----	-----	-----	%CH ₄	%C ₂	%C ₃ +	%CO ₂	-----	-----	-----	-----	-----
M-3 SBCR													
5	CO.003	15.1	31.7	1.53	16.7	2.4	79.8	1.16	0.71	--	1.0La	0.5Ru	Al
6	CO.011	15.3	14.3	0.67	7.6	1.6	89.4	1.42	0.78	0.83	0.0	0.0	Si
7	CO.012	15.8	13.9	0.63	6.1	1.5	90.6	1.74	0.80	0.89	0.0	0.0	Si
8	CO.015	15.0	28.3	1.37	12.7	2.0	84.1	1.24	0.76	0.80	1.0La	0.43Ru	Al
9	CO.011	15.0	18.5	0.89	8.8	1.7	88.8	0.77	0.78	0.83	0.0	0.0	Si
11	CO.017	15.0	27.2	1.32	11.2	1.8	85.9	1.14	0.77	0.80	1.0La	0.5Ru	Al
12	CO.018	15.6	33.8	1.56	9.7	2.0	86.6	1.68	0.75	0.85	0.0	0.5Ru	Al
13	CO.016	14.7	26.4	1.31	(1)	1.7	89.3	0.68	0.78	0.81	1.0La	0.43Ru	Al
14	CO.019	15.2	13.9	0.66	(2)	1.7	97.2	0.70	0.80	0.86	0.0	0.5Ru	Si
15	CO.005	14.7	27.1	1.34	7.9	1.6	89.7	0.82	0.79	0.82	0.0	0.0	Al
16	CO.002	15.4	30.1	1.42	12.5	2.5	83.9	1.09	0.75	0.80	1.0La	0.43Ru	Al
17	CO.025	15.6	26.6	1.24	10.7	2.1	86.4	0.82	0.76	0.82	8.5Zr	0.0	Si
18	CO.004	15.0	33.9	1.64	15.3	2.4	80.9	1.37	0.74	0.79	1.0La	0.43Ru	Al
19	CO.021	15.6	23.2	1.08	9.4	2.0	88.0	0.73	0.77	0.82	0.7Zr	0.0	Si
20	CO.041	15.8	25.3	1.16	11.0	2.1	86.0	0.88	0.76	0.84	8.5Zr	0.5Ru	Si
21	CO.014	15.1	8.5	0.40	8.3	3.5	85.8	2.43	0.74	0.83	0.0	0.5Ru	Ti
22	CO.040	14.5	1.8	0.09	0.0	4.0	94.1	1.89	0.71	0.82	0.0	0.0	Ti
23	CO.047	15.8	28.2	1.29	7.7	1.5	89.3	1.47	0.79	0.84	0.3K	0.5Ru	Al
24	CO.049	15.6	30.6	1.41	10.9	1.8	85.7	1.66	0.76	0.82	0.1K	0.5Ru	Al
25	CO.047	15.6	28.1	1.30	8.8	1.6	88.1	1.50	0.78	0.85	0.3K	0.5Ru	Al
26	CO.031	15.9	30.9	1.41	12.1	1.9	84.9	1.12	0.75	0.83	1.4Zr	0.0	Al
27	CO.029	15.9	28.3	1.27	8.3	1.6	87.9	2.21	0.77	0.84	0.5K	0.5Ru	Al
28	COW.01	15.0	1.1	0.05	0.0	12.	83.9	4.23	0.58	--	5.0Cu	10.0Zn	Al
29	CO.053	25.2	42.0	1.19	15.8	2.3	79.5	2.42	0.73	--	0.0	0.5Ru	Al
30	CO.053	29.6	41.8	1.02	22.6	2.9	71.5	3.05	0.66	0.77	0.0	0.5Ru	Al
31	CO.055	15.0	30.0	1.46	23.7	3.7	70.2	2.30	0.61	0.81	1.0La	1.0Re	Al
32	CO.044	16.4	20.9	0.93	6.7	1.9	90.8	0.56	0.77	0.83	15Zr	0.0	Si
33	CO.053	31.4	41.4	0.94	23.2	3.1	69.6	4.06	0.65	0.76	0.0	0.5Ru	Al
34	CO.060	15.6	31.4	1.46	14.0	2.3	82.2	1.48	0.75	0.79	0.0	0.0	Al

Note: Catalyst Run 9 screened thru 170 x 400 mesh.

Catalysts For Runs 11 through 28 (except Runs 21 and 22) screened thru 150x 400 mesh.

Catalysts for Runs 21 and 22 screened thru 100 x 400 mesh.

Catalysts Nos. Co.029 and Co.060 contained 30 wt% cobalt.

G.C. Problems

(1) Weak TCD filaments in G.C. CH₄ peaks smaller than expected.

(2) Internal valve in G.C. leaked. CH₄ peak undetected.

Table III

M3 SBCR RUN RESULTS

COMPARISON OF CATALYST ACTIVITY AT SIMILAR RUN CONDITIONS

Period No.	Temp.	Pres.	H ₂ /CO Ratio
-----	-----	-----	-----
2	220 C	450psi	2.0

a) Total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

Flows: N₂-563 SLH, H₂-225 SLH, CO-112.5 SLH

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N₂ as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C₁+ (kg/kg cat., hr)

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin C ₃	Paraf C ₄	Olefin C ₆₋₁₈
---	---	---	---	---	%CH ₄	%C ₂	%C ₃ +	%CO ₂	---	---	---	---	---
5	CO.003	15.1	13.2	0.63	5.1	1.0	93.4	0.5	0.82	0.90	4.55	1.89	--
6	CO.011	15.3	5.1	0.23	0.0	0.0	97.2	2.8	0.87	0.82	--	--	--
7	CO.012	15.8	5.1	0.23	0.0	0.2	97.8	2.0	0.89	0.90	--	2.50	--
8	CO.015	15.0	11.5	0.56	4.4	1.0	93.9	0.8	0.81	0.89	3.60	2.14	--
9	CO.011	15.0	6.3	0.31	0.0	1.0	98.6	0.4	0.88	0.93	12.00	1.80	--
11	CO.017	15.0	11.4	0.55	5.0	0.0	94.8	0.2	0.88	0.90	5.00	3.20	--
12	CO.018	15.6	12.6	0.59	2.8	0.0	97.1	0.1	0.90	0.88	--	--	--
13	CO.016	14.7	9.7	0.48	(1)	0.1	99.9	0.0	0.91	0.88	--	--	--
14	CO.019	15.2	3.8	0.18	(2)	1.7	96.7	1.6	0.88	--	--	--	--
15	CO.005	14.7	10.7	0.53	0.0	0.9	98.4	0.7	0.83	0.88	4.25	3.25	--
16	CO.002	15.4	12.8	0.60	4.2	1.3	93.9	0.7	0.80	0.86	2.57	1.63	--
17	CO.025	15.6	8.4	0.39	0.0	1.1	96.9	1.9	0.82	0.92	6.50	3.00	--
18	CO.004	15.0	15.1	0.73	4.1	1.6	94.0	0.3	0.81	0.85	3.83	2.25	--
19	CO.021	15.6	8.3	0.38	0.0	1.3	98.2	0.5	0.82	0.88	4.33	3.33	--
20	CO.041	15.8	9.1	0.41	0.0	1.5	97.8	0.7	0.82	0.91	8.00	2.75	--
21	CO.014	15.1	3.2	0.15	0.0	2.3	85.8	4.3	0.76	0.86	3.50	3.00	--
22	CO.040	14.5	0.7	0.35	0.0	0.7	97.1	2.2	0.91	--	1.00	2.00	--
23	CO.047	15.8	---	---	(3)	---	---	---	---	---	---	---	--
24	CO.049	15.6	12.0	1.07	2.7	0.9	95.3	1.1	0.81	0.95	4.25	3.25	--
25	CO.047	15.6	7.4	0.34	1.5	1.2	96.3	1.0	0.76	0.89	3.00	4.67	--
26	CO.031	15.9	13.6	0.62	3.9	0.9	94.6	0.5	0.80	0.85	4.20	2.67	--
27	CO.029	15.9	9.5	0.43	1.7	1.1	96.0	1.2	0.80	0.89	5.67	3.00	--
29	CO.053	25.2	20.5	0.59	5.7	4.8	89.0	0.5	0.79	0.84	3.38	2.10	--
31	CO.055	15.0	9.1	0.44	10.6	2.5	85.7	1.1	0.61	0.85	2.89	1.80	--
32	CO.044	16.4	10.3	0.46	0.0	0.9	98.8	0.3	0.85	--	4.33	4.50	--
34	CO.060	15.6	13.0	0.60	0.1	1.8	97.8	0.4	0.81	0.88	4.00	2.83	--

Note: Catalyst Run 9 screened thru 170 x 400 mesh.

Catalysts for Runs 11 thru 27 (except Runs 21 and 22) screened through 150 x 400 mesh.

Catalysts for Runs 21 and 22 screened thru 100 x 400.

(1) Weak TCD filaments in G.C. CH₄ peaks smaller than expected.

(2) Internal valve in G.C. leaked. CH₄ peak undetected.

(3) Replaced dual column restrictor valve.

Table IV

DATE: 12/30/94

M3 SBCR RUN RESULTS

COMPARISON OF CATALYST ACTIVITY AT SIMILAR RUN CONDITIONS

Period No.	Temp.	Pres.	H2/CO Ratio
-----	-----	-----	-----
4	240 C	450psi	1.0

a) Total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

Flows: N2-562 SLH, H2-119 SLH, CO-119 SLH

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat.,hr)

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefin C6-18,
					%CH4	%C2	%C3+	%CO2			C3	C4	
5	CO.003	15.1	13.1	0.95	4.2	1.2	93.3	1.2	0.83	0.88	6.67	3.70	--
6	CO.011	15.3	6.3	0.44	0.4	1.0	95.5	3.1	0.82	0.88	--	--	--
7	CO.012	15.8	3.9	0.26	4.8	2.3	86.3	6.6	0.70	0.85	16.00	3.50	--
8	CO.015	15.0	11.5	0.83	4.8	1.2	92.5	1.5	0.80	0.85	5.60	3.29	--
9	CO.011	15.0	8.0	0.58	1.3	1.3	96.3	1.2	0.82	0.87	7.00	2.83	--
11	CO.017	15.0	11.6	0.84	5.0	0.0	93.9	1.2	0.82	0.86	25.00	2.88	--
12	CO.018	15.6	12.4	0.86	3.3	0.0	95.0	1.7	0.80	0.86	--	--	--
13	CO.016	14.7	10.9	0.81	(1)	0.8	97.7	0.3	0.84	0.86	--	--	--
14	CO.019	15.2	--	--	(2)	--	--	--	0.80	--	--	--	--
15	CO.005	14.7	11.6	0.85	0.0	1.1	97.5	1.4	0.82	0.85	7.00	4.60	--
16	CO.002	15.4	12.6	0.89	4.4	1.6	92.8	1.2	0.79	0.84	4.43	2.88	--
17	CO.025	15.6	10.3	0.71	0.8	1.2	96.7	1.3	0.82	0.93	7.67	4.25	--
18	CO.004	15.0	14.7	1.06	4.1	1.2	93.2	1.4	0.80	0.83	6.17	3.75	--
19	CO.021	15.6	9.9	0.69	1.7	1.4	95.5	1.4	0.81	0.83	6.00	3.80	--
20	CO.041	15.8	12.7	0.88	1.9	1.2	95.9	1.0	0.83	0.86	9.00	4.20	--
21	CO.014	15.1	2.2	0.15	0.0	2.8	89.3	7.9	0.67	0.84	9.00	4.00	--
23	CO.047	15.8	11.9	0.81	2.9	0.9	94.1	2.1	0.82	0.88	7.33	4.75	--
24	CO.049	15.6	12.6	0.87	3.1	1.0	94.1	1.8	0.81	0.86	8.33	4.20	--
25	CO.047	15.6	10.8	0.75	3.0	1.0	94.2	1.8	0.81	0.90	8.00	4.75	--
26	CO.031	15.9	12.9	0.88	3.6	1.1	94.3	1.1	0.80	0.88	7.75	4.00	--
27	CO.029	15.9	12.0	0.82	1.9	0.9	95.4	1.9	0.83	0.90	8.33	4.75	--
29	CO.053	25.2	18.4	0.79	5.3	2.6	90.6	1.5	0.80	0.84	5.86	3.56	--
31	CO.055	15.0	14.7	1.06	5.5	1.4	91.7	1.4	0.78	0.83	5.71	3.22	--
32	CO.044	16.4	9.9	0.25	2.1	3.2	92.5	2.2	0.61	0.87	7.33	4.00	--
34	CO.060	15.6	13.5	0.94	4.3	1.8	92.5	1.5	0.77	0.85	7.00	4.67	--

Note: Catalyst Run 9 screened thru 170 x 400 mesh.

Catalysts for Runs 11 thru 20 and Run 27 (except Runs 21 and 22)

screened thru 150 x 400 mesh.

Catalysts for Runs 21 and 22 screened thru 100 x 400 mesh.

(1) Weak TCD filaments in G.C. CH4 peaks smaller than expected.

(2) Internal valve in G.C. leaked. CH4 peak undetected.

M3 SBCR RUN RESULTS

COMPARISON OF CATALYST ACTIVITY AT SIMILAR RUN CONDITIONS

Period No.	Temp.	Pres.	H2/CO Ratio
-----	-----	-----	-----
5	240 C	600psi	1.0

a) Total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

Flows: N2-562 SLH, H2-119 SLH, CO-119 SLH

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat.,hr)

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		
					%CH4	%C2	%C3+	%CO2			C3	C4	C6-18,%
5	CO.003	15.1	13.4	0.97	3.9	1.1	93.7	1.3	0.81	--	5.26	3.45	30.1
6	CO.011	15.3	6.7	0.46	0.2	0.9	96.0	2.9	0.84	0.89	12.00	3.67	27.3
7	CO.012	15.8	4.3	0.28	0.1	2.1	91.6	6.3	0.75	0.82	8.50	3.50	--
8	CO.015	15.0	12.4	0.90	4.9	0.8	93.6	0.7	0.84	0.85	5.20	3.14	30.8
9	CO.011	15.0	8.7	0.63	1.4	1.1	96.4	1.1	0.83	0.87	5.00	2.67	30.5
11	CO.017	15.0	11.6	0.84	4.2	0.0	94.7	1.2	0.86	0.86	24.00	1.63	21.0
12	CO.018	15.6	13.0	0.90	3.2	0.0	94.9	1.9	0.80	0.85	--	--	38.5
13	CO.016	14.7	11.4	0.85	(1)	0.5	99.2	0.3	0.92	0.86	--	--	32.2
14	CO.019	15.2	5.9	0.41	(2)	1.5	96.1	2.4	0.80	--	--	--	--
15	CO.005	14.7	23.0	0.90	0.0	1.0	97.7	1.3	0.83	0.85	7.00	4.40	36.4
16	CO.002	15.4	13.1	0.92	3.6	1.4	93.9	1.1	0.81	0.84	4.29	2.75	25.2
17	CO.025	15.6	19.9	0.81	9.3	1.1	96.5	1.1	0.83	0.88	8.00	4.25	32.9
18	CO.004	15.0	15.0	1.09	3.6	1.1	94.1	1.2	0.82	0.83	5.67	4.00	33.6
19	CO.021	15.6	11.5	0.80	1.8	1.2	95.8	1.2	0.83	0.85	6.50	3.80	30.8
20	CO.041	15.8	13.2	0.91	2.0	1.0	96.1	0.9	0.84	0.87	7.00	3.50	31.5
21	Co.014	15.1	2.1	0.15	0.0	2.6	94.8	2.7	0.71	0.81	4.50	3.50	23.1
23	CO.047	15.8	11.8	0.80	2.6	0.8	94.6	2.0	0.82	0.87	7.00	3.60	38.5
24	CO.049	15.6	13.4	0.92	2.6	0.9	94.8	1.7	0.82	0.88	8.33	4.20	37.8
25	CO.047	15.6	12.4	0.86	2.2	0.8	95.6	1.3	0.83	0.86	7.33	4.50	36.4
26	CO.031	15.9	13.9	0.95	3.5	1.0	94.4	1.1	0.81	0.85	6.80	3.71	30.1
27	CO.029	15.9	12.1	0.82	1.7	0.9	95.6	1.8	0.83	0.89	7.67	4.75	39.9
29	CO.053	25.2	19.7	0.85	4.6	1.2	92.9	1.3	0.82	0.85	5.71	3.44	33.6
31	CO.055	15.0	16.1	1.16	4.7	1.2	92.8	1.3	0.80	0.83	6.17	3.11	33.6
34	CO.060	15.6	12.8	0.89	2.2	1.6	94.9	1.2	0.82	0.86	6.60	4.33	38.5

Note: Catalyst Run 9 screened thru 170 x 400 mesh.

Catalysts for Runs 11 thru 27 (except Runs 21 and 22) screened thru 150 x 400 mesh.

Catalyst for Run 21 screened thru 100 x 400 mesh.

(1) Weak TCD filaments in G.C. CH4 peaks smaller than expected.

(2) Internal valve in G.C. leaked. CH4 peak undetected.

Table VI

SUMMARY OF H4 SBCR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Per No	Time Start	Time Stop	Temp C	Pres psi	H2: CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefins C6-18, %	Comments
												%CH4	%C2	%C3+	%CO2			C3	C4		
3	CO.002	15.2	1	25	35	240	450	2.0	20	29.4	1.42	17.3	2.2	79.4	1.01	0.73	0.82	0.91	0.60	17.5	
3	CO.002	15.2	2	73	83	220	450	2.0	20	11.8	0.56	4.7	1.0	93.7	0.59	0.81	0.90	2.71	1.63	--	G.C. Calib
3	CO.002	15.2	3	97	107	240	450	2.0	20	26.4	1.28	16.0	3.1	80.1	0.88	0.73	--	0.98	0.66	--	
3	CO.002	15.2	4	145	155	240	450	1.0	20	11.6	0.83	3.9	2.4	92.8	0.84	0.81	0.87	4.29	3.14	--	G.C. Calib
3	CO.002	15.2	5	182	203	240	600	1.0	20	12.9	0.92	4.0	1.5	93.5	0.91	0.81	0.82	4.29	2.75	24.5	
3	CO.002	15.2	6	217	226	240	450	2.0	20	24.2	1.17	17.1	3.1	79.0	0.83	0.71	--	1.03	0.70	--	
4	CO.024	15.4	1	20	37	240	450	2.0	20	25.5	1.21	8.6	2.0	89.0	0.43	0.79	0.84	2.93	1.93	21.7	
4	CO.024	15.4	2	68	85	220	450	2.0	0	9.5	0.45	0.0	2.1	97.6	0.27	0.83	0.91	5.33	4.00	--	No Synfl
4	CO.024	15.4	3	92	109	240	450	2.0	0	23.7	1.13	9.5	2.1	88.0	0.45	0.77	--	2.81	1.88	--	
4	CO.024	15.4	4	140	157	240	450	1.0	0	10.3	0.73	0.5	1.6	97.2	0.71	0.83	0.87	8.33	4.75	--	
4	CO.024	15.4	5	188	205	240	600	1.0	0	11.3	0.80	0.9	1.5	97.0	0.65	0.83	0.87	6.50	3.80	36.4	
4	CO.024	15.4	6	212	229	240	450	2.0	0	21.5	1.02	9.3	2.3	87.9	0.50	0.76	--	2.93	2.07	--	
5	CO.035	15.4	1	16	37	240	450	2.0	20	24.8	1.18	8.5	2.1	89.0	0.47	0.78	0.84	3.13	1.94	23.1	
5	CO.035	15.4	2	68	85	220	450	2.0	20	8.8	0.42	0.0	2.3	97.4	0.31	0.82	--	5.33	4.00	--	
5	CO.035	15.4	3	99	109	240	450	2.0	20	23.5	1.11	8.7	2.1	88.6	0.61	0.77	--	3.07	1.94	--	
5	CO.035	15.4	4	136	157	240	450	1.0	20	10.4	0.73	0.9	0.0	98.4	0.65	--	0.83	--	--	--	G.C. Calib
5	CO.035	15.4	5	184	205	240	600	1.0	20	10.7	0.76	0.7	1.4	97.1	0.75	0.84	0.88	6.25	4.50	27.3	
5	CO.035	15.4	6	212	228	240	450	2.0	20	19.4	0.92	7.8	2.3	89.4	0.56	0.79	--	3.08	1.77	--	
6	CO.028	15.4	1	23	40	240	450	2.0	20	21.2	1.00	6.1	1.6	91.3	1.01	0.81	0.83	4.86	3.00	28.7	
6	CO.028	15.4	2	67	88	220	450	2.0	20	6.6	0.31	0.0	1.9	97.4	0.72	0.83	0.90	5.50	4.00	--	
6	CO.028	15.4	3	95	112	240	450	2.0	20	20.1	0.94	5.8	1.6	91.6	1.02	0.81	--	4.25	2.67	--	
6	CO.028	15.4	4	139	160	240	450	1.0	20	9.2	0.65	0.0	1.3	97.3	1.46	0.85	0.88	9.50	3.75	--	
6	CO.028	15.4	5	189	208	240	600	1.0	20	9.5	0.67	0.0	1.1	97.5	1.36	0.85	0.88	6.00	3.50	40.6	
6	CO.028	15.4	6	213	232	240	450	2.0	20	18.0	0.84	5.7	1.6	91.5	1.12	0.80	--	4.57	2.88	--	
7	CO.043	15.4	1	18	39	240	450	2.0	20	13.0	0.61	3.7	1.8	93.4	1.06	0.79	0.85	5.60	3.17	27.3	
7	CO.043	15.4	2	53	63	220	450	2.0	20	4.3	0.20	0.0	1.4	96.3	2.25	0.81	0.91	4.00	3.00	--	
7	CO.043	15.4	3	94	111	240	450	2.0	20	12.3	0.58	3.0	1.5	93.9	1.58	0.80	--	5.00	2.83	--	
7	CO.043	15.4	4	138	159	240	450	1.0	20	5.2	0.37	0.0	0.0	99.4	0.64	0.83	0.89	7.00	5.00	--	
7	CO.043	15.4	5	191	207	240	600	1.0	20	5.9	0.41	0.0	2.2	94.8	2.99	0.82	0.89	6.00	3.75	30.1	G.C. Calib
7	CO.043	15.4	6	215	231	240	450	2.0	20	10.2	0.47	4.7	2.1	91.4	1.79	0.78	--	5.50	3.20	--	Repair G.C
8	CO.006	15.0	1	19	40	240	450	2.0	20	2.7	0.13	0.1	0.2	98.8	1.75	0.67	0.85	3.33	2.33	16.1	Shut down

Table VI
(Continued)

SUMMARY OF H4 SBCR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using H₂ as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C₁+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Per wt,g	Time No	Time Start	Temp Stop	Pres C	H2: psi	Synfl CO	Conv. cc/hr	Prod. %	Selectivities %CH4	%C2	%C3+	%CO2	Alpha GC	Alpha Liq	Olefin/Paraf C3	C4	Olefins C6-18,%	Comments
9	CO.048	15.4	1	19	40	240	450 2.0	12	19.1	0.90	9.9	1.6	87.4	1.05	0.77	0.88	3.60	2.09	20.3	
9	CO.048	15.4	2	70	84	220	450 2.0	12	6.1	0.28	1.8	1.0	95.2	1.93	0.80	0.91	3.67	3.00	--	
9	CO.048	15.4	3	93	111	240	450 2.0	20	17.8	0.84	10.1	1.7	86.9	1.33	0.77	--	3.30	2.10	--	
9	CO.048	15.4	4	139	159	240	450 1.0	20	8.2	0.57	2.3	1.0	93.8	2.98	0.82	0.90	8.50	4.33	--	
9	CO.048	15.4	5	189	207	240	600 1.0	20	11.9	0.83	2.7	0.9	94.4	1.93	0.84	0.89	5.75	3.20	14.0	
9	CO.048	15.4	6	217	226	240	450 2.0	20	24.2	1.17	17.1	3.1	79.0	0.83	0.71	--	1.03	0.70	--	
10	CAL.02	15.9	1	19	40	240	450 2.0	20	34.5	1.58	12.9	2.0	83.9	1.23	0.75	0.84	1.66	1.06	21.0	
10	CAL.02	15.9	2	69	88	220	450 2.0	20	14.9	0.68	4.6	0.9	94.0	0.47	0.81	0.88	4.40	2.29	--	
10	CAL.02	15.9	3	91	112	240	450 2.0	20	34.2	1.57	12.6	2.0	84.4	1.00	0.75	--	1.71	1.06	--	
10	CAL.02	15.9	4	139	160	240	450 1.0	20	14.6	1.00	4.6	1.1	93.3	0.97	0.80	0.88	7.20	4.00	--	
10	CAL.02	15.9	5	187	201	240	600 1.0	20	16.4	1.12	4.2	1.0	94.0	0.89	0.82	0.86	5.83	3.86	35.7	
10	CAL.02	15.9	6	215	230	240	450 2.0	20	30.9	1.42	13.3	2.1	83.7	0.90	0.74	--	1.90	1.21	--	
11	CAL.03	15.6	1	19	40	240	450 2.0	20	29.7	1.39	13.5	2.1	83.4	1.08	0.74	0.86	1.65	1.03	18.2	ShutDown
12	CO.053	15.9	1	22	40	240	450 2.0	20	34.2	1.56	12.6	2.0	84.2	1.23	0.75	0.83	1.60	1.00	24.5	
12	CO.053	15.9	2	69	88	220	450 2.0	20	14.4	0.66	4.3	1.0	94.3	0.48	0.81	0.89	4.20	2.67	--	
12	CO.053	15.9	3	93	112	240	450 2.0	20	34.0	1.56	13.4	2.2	83.2	1.21	0.74	--	1.50	0.94	--	
12	CO.053	15.9	4	150	152	240	450 1.0	20	13.3	0.91	4.3	1.2	93.3	1.18	0.80	0.89	6.60	3.71	--	
12	CO.053	15.9	5	189	208	240	600 1.0	20	15.6	1.06	4.0	0.9	94.0	1.01	0.82	0.87	5.50	3.57	32.2	
12	CO.053	15.9	6	223	231	240	450 2.0	20	29.8	1.37	12.8	2.0	84.3	0.94	0.75	--	1.89	1.10	--	
13	CO.054	15.7	1	23	40	240	450 2.0	20	10.4	0.48	4.7	1.8	92.3	1.17	0.78	0.86	5.75	4.00	25.9	
13	CO.054	15.7	2	71	88	220	450 2.0	20	0.2	0.01	0.0	19.0	60.8	19.5	0.33	0.94	8.00	5.00	--	
13	CO.054	15.7	3	102	112	240	450 2.0	20	10.6	0.49	4.5	1.5	92.8	1.23	0.79	--	5.50	3.75	--	
13	CO.054	15.7	4	143	160	240	450 1.0	20	5.2	0.36	0.0	1.2	97.0	1.85	0.83	0.95	6.00	4.50	--	
13	CO.054	15.7	5	191	208	240	600 1.0	20	5.0	0.34	0.0	1.3	96.9	1.78	0.82	0.93	6.50	3.33	30.8	
13	CO.054	15.7	6	223	230	240	450 2.0	20	8.8	0.40	4.7	2.0	91.7	1.54	0.78	--	5.00	3.50	--	
14	BlendA	20.0	1	25	39	240	450 2.0	20	29.3	1.41	10.1	1.6	86.3	2.02	0.77	0.86	2.23	1.35	23.1	
14	BlendA	20.0	2	69	87	220	450 2.0	20	12.4	0.60	4.3	0.9	93.9	0.95	0.81	0.91	3.80	2.33	--	
14	BlendA	20.0	3	93	111	240	450 2.0	20	27.5	1.33	10.5	1.7	86.4	1.44	0.76	--	2.09	1.32	--	
14	BlendA	20.0	4	143	158	240	450 1.0	20	12.7	0.91	3.4	1.0	94.0	1.61	0.81	0.86	7.50	3.83	--	
14	BlendA	20.0	5	191	207	240	600 1.0	20	14.1	1.02	3.7	1.0	93.8	1.45	0.82	0.89	6.40	3.43	32.9	
14	BlendA	20.0	6	215	231	240	450 2.0	20	27.0	1.29	11.5	1.9	85.5	1.12	0.76	--	2.04	1.30	--	

SUMMARY OF M4-SECR RUN RESULTS

- a)Unless otherwise noted, total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.
b)Conversion is total CO conversion over the period (%).
c)Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.
d)Prod. rate: Rate for production of total hydrocarbons,C1+ (kg/kg cat.,hr).
e)Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Per No	Time Start	Time Stop	Temp C	Pres psi	H2: CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities	Alpha GC	Alpha Liq	Olefin/Paraf C3	C4	Olefins C5-18,i	Comments
15	CO.034	13.0	1	21	39	240	450	2.0	20	27.5	1.54	10.4 1.6 87.2 0.80	0.78	0.84	2.21	1.40	21.0	G.C.Calib
15	CO.034	13.0	2	45	87	220	450	2.0	20	11.0	0.61	4.0 0.9 94.5 0.59	0.82	0.90	4.00	3.00	--	
15	CO.034	13.0	3	95	111	240	450	2.0	20	25.6	1.49	11.5 1.9 85.9 0.82	0.76	--	2.10	1.33	--	
15	CO.034	13.0	4	141	159	240	450	1.0	20	11.2	0.94	3.9 1.0 94.0 1.02	0.82	0.87	8.33	4.00	--	
15	CO.034	13.0	5	189	207	240	600	1.0	20	11.8	0.99	3.9 1.1 94.0 1.03	0.83		5.75	3.80	37.8	
15	CO.034	13.0	6	215	231	240	450	2.0	20	21.6	1.19	10.9 1.9 86.3 0.87	0.76	--	3.33	2.15	--	
16	CAL.04	16.1	1	21	39	240	450	1.8	20	26.3	1.34	7.1 1.3 90.3 1.38	0.80	0.85	4.80	3.18	32.9	H2/CO:
16	CAL.04	16.1	2	54	163	220	450	1.8	20	8.4	0.42	2.6 1.0 94.1 2.31	0.80	0.88	5.00	4.00	--	1.76/1.0
17	CAL.08	15.0	1	21	39	240	450	1.8	20	16.9	0.93	5.9 1.0 91.7 1.36	0.82	0.88	5.20	3.33	28.7	H2/CO:
17	CAL.08	15.0	2	47	62	220	450	1.8	20	5.4	0.28	0.1 0.8 96.9 2.23	0.83	--	4.00	3.00	--	1.76/1.0
18	CAL.07	15.0	1	21	39	240	450	2.0	20	20.6	1.03	7.7 1.2 90.0 1.09	0.81	0.88	5.00	3.00	32.2	
18	CAL.07	15.0	2	47	62	220	450	2.0	20	6.7	0.33	1.8 1.4 95.0 1.81	0.84	--	4.00	3.00	--	
19	CAL.05	15.7	1	23	39	240	450	2.0	20	26.6	1.22	7.3 1.3 90.2 1.19	0.82	0.86	4.11	2.70	18.2	G.C.Calib
19	CAL.05	15.7	2	47	62	220	450	2.0	20	9.0	0.41	2.3 1.4 94.8 1.56	0.84	--	5.50	3.00	--	
20	CAL.06	15.0	1	15	30	240	450	2.0	20	5.6	0.26	3.1 2.1 92.0 2.86	0.80	0.90	4.50	3.50	30.8	G.C.Calib
20	CAL.06	15.0	2	55	63	240	450	2.0	20	3.5	0.16	0.0 3.3 92.8 3.87	0.80	0.85	3.00	2.50	--	
20	CAL.06	15.0	3	103	110	240	450	2.0	20	1.7	0.08	0.0 3.3 89.5 7.22	0.80	--	1.50	3.00	--	Cat.Loss
21	CO.004	15.9	1	23	40	240	450	2.0	20	39.3	1.80	15.2 2.3 81.2 1.38	0.74	0.89	1.16	0.73	23.1	
21	CO.004	15.9	2	71	88	220	450	2.0	20	16.1	0.74	8.1 1.2 90.2 0.48	0.78	0.87	3.38	2.22	--	
21	CO.004	15.9	3	105	110	240	450	2.0	20	37.6	1.47	16.4 2.3 80.2 1.20	0.73	--	1.10	0.70	--	
21	CO.004	15.9	4	136	138	240	450	1.0	20	14.9	1.02	7.4 1.4 89.9 1.29	0.77	0.84	4.67	2.82	--	
21	CO.004	15.9	5	166	184	240	600	1.0	20	18.4	1.26	6.1 1.1 91.9 0.94	0.81	0.84	5.25	2.91	--	G.C.Repair
21	CO.004	15.9	6	199	207	240	600	2.0	20	39.0	1.80	14.2 1.9 83.0 0.91	0.78	0.82	0.85	0.77	--	
21	CO.004	15.9	7	212	214	240	450	2.0	20	34.6	1.59	15.8 2.3 81.0 1.00	0.76	--	0.86	0.81	--	G.C.Repair
22	BlendB	30.5	1	23	39	240	450	2.0	20	35.6	1.64	12.7 1.6 79.4 6.29	0.75	0.81	1.40	0.81	27.3	
22	BlendB	30.5	2	78	87	240	450	1.0	20	15.8	1.07	1.5 0.9 90.5 7.06	0.80	0.83	5.00	2.22	38.5	G.C.Calib
22	BlendB	30.5	3	125	135	240	450	0.7	20	10.6	0.86	0.8 0.8 92.6 5.83	0.82	0.87	7.33	3.20	33.6	G.C.Calib
22	BlendB	30.5	4	150	158	240	450	1.0	20	14.1	0.99	3.9 1.0 91.0 4.07	0.80	--	5.40	2.25	--	
22	BlendB	30.5	5	174	183	240	450	2.0	20	30.1	1.44	13.2 1.8 82.4 2.56	0.75	--	1.33	0.69	--	
22	BlendB	30.5	6	191	207	260	450	1.0	20	23.5	1.63	10.0 1.9 82.1 6.02	0.74	--	2.92	1.15	--	
22	BlendB	30.5	7	223	232	280	450	1.0	20	26.9	1.79	17.8 3.1 68.4 10.7	0.64	--	3.00	1.88	--	
22	BlendB	30.5	8	247	255	280	450	0.7	20	17.1	1.34	8.8 2.6 78.8 9.8	0.70	--	6.00	3.53	--	
23	CAL.09	15.0	1	23	40	240	450	2.0	20	17.4	0.84	0.02 1.2 97.9 0.95	0.84	0.88	5.40	3.33	29.4	G.C.Calib
23	CAL.09	15.0	2	57	63	220	450	2.0	20	6.6	0.32	0.2 0.9 98.0 0.92	0.90	--	4.00	3.00	--	

Table VI
(Continued)

SUMMARY OF M4 SBCE RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N₂ as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C₁+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Per No	Time Start	Time Stop	Temp C	Pres psi	H ₂ : CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefins C ₅ -18, %	Comments
No	No	wt, g	No	Start	Stop	C	psi	CO	cc/hr	%	Rate	XC ₄	XC ₂	XC ₃ +	XC ₂	GC	Liq	C ₃	C ₄	C ₅ -18, %	
25	CO.056	15.0	1	23	39	240	450	2.0	20	11.4	0.55	7.8	3.6	87.2	1.43	0.67	0.87	3.60	2.30	20.3	
25	CO.056	15.0	2	47	63	220	450	2.0	20	4.5	0.22	0.3	2.7	95.7	1.27	0.73	--	4.67	3.00	--	
26	CAL.10	15.6	1	23	39	240	450	2.0	20	21.9	1.01	5.4	1.5	91.9	1.25	0.79	0.85	3.60	2.27	25.9	
26	CAL.10	15.6	2	54	63	240	450	2.0	20	21.7	1.30	8.3	1.1	89.9	0.68	0.80	--	3.78	2.45	--	
26	CAL.10	15.6	3	78	87	240	450	2.0	20	17.2	1.04	11.7	1.4	86.1	0.78	0.76	--	3.57	2.30	--	
26	CAL.10	15.6	4	102	111	240	450	2.0	20	17.7	1.01	11.9	1.4	86.0	0.73	0.77	--	3.52	2.28	--	
26	CAL.10	15.6	5	118	126	240	450	2.0	20	16.2	0.75	4.9	1.7	92.3	1.10	0.77	--	4.29	2.75	--	
27	Co.050	14.6	1	23	39	240	450	2.0	20	20.4	1.01	6.8	1.9	90.2	1.04	0.78	0.87	2.50	1.69	18.9	
27	Co.050	14.6	2	78	87	220	450	2.0	20	8.1	0.39	0.0	4.8	92.6	2.56	0.79	0.87	8.50	3.00	--	
27	Co.050	14.6	3	102	111	240	450	2.0	20	19.8	0.98	9.1	2.6	87.0	1.30	0.76	--	2.50	1.69	--	
27	Co.050	14.6	4	142	157	240	450	1.0	20	8.4	0.61	1.1	2.9	93.3	2.78	0.79	0.90	6.25	5.00	--	
27	Co.050	14.6	5	173	182	240	450	2.0	20	17.3	0.87	9.9	3.0	85.4	1.74	0.75	--	2.50	1.75	--	

Table VII

DATE: 12/30/94

M4 SBCR RUN RESULTS

COMPARISON OF CATALYST ACTIVITY AT SIMILAR RUN CONDITIONS

Period No.	Temp.	Pres.	H2/CO Ratio
-----	-----	-----	-----
1	240 C	450psi	2.0

a) Total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

Flows: N2-563 SLH, H2-225 SLH, CO-112.5 SLH

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons C1+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		
---	---	---	---	---	%CH4	%C2	%C3+	%CO2	---	---	C3	C4	C6-18, %
3	CO.002	15.2	29.4	1.42	17.3	2.3	79.4	1.01	0.73	0.82	0.91	0.60	17.5
4	CO.024	15.4	25.5	1.21	8.6	2.0	89.0	0.43	0.79	0.84	2.93	1.93	21.7
5	CO.035	15.4	24.8	1.18	8.5	2.1	89.0	0.47	0.78	0.84	3.13	1.94	23.1
6	CO.028	15.4	21.2	1.00	6.1	1.6	91.3	1.01	0.81	0.83	4.86	3.00	28.7
7	CO.043	15.4	13.0	0.61	3.7	1.8	93.4	1.06	0.79	0.85	5.60	3.17	27.3
8	CO.006	15.0	2.7	0.25	0.1	0.2	98.8	1.75	0.67	0.85	3.33	2.33	16.1
9	CO.048	15.4	19.1	0.90	9.9	1.6	87.4	1.05	0.77	0.88	3.60	2.09	20.3
10	CAL.02	15.9	34.5	1.58	12.9	2.0	83.9	1.23	0.75	0.81	1.66	1.06	21.0
11	CAL.03	15.6	29.7	1.39	13.5	2.1	83.4	1.08	0.74	0.86	1.65	1.03	18.2
12	CO.053	15.9	34.2	1.56	12.6	2.0	84.2	1.23	0.75	0.83	1.60	1.00	24.5
13	CO.054	15.7	10.4	0.48	4.7	1.8	92.3	1.17	0.78	0.86	5.75	4.00	25.9
14	BlendA	20.0	29.3	1.41	10.1	1.6	86.3	2.02	0.77	0.86	2.23	1.35	23.1
15	CO.034	13.0	27.5	1.54	10.4	1.6	87.2	0.80	0.78	0.84	2.21	1.40	21.0
16	CAL.04	16.1	26.3	1.34	7.1	1.3	90.3	1.38	0.80	0.85	4.80	3.18	32.9
17	CAL.08	15.0	16.9	0.93	5.9	1.0	91.7	1.36	0.82	0.88	5.20	3.33	28.7
18	CAL.07	15.0	20.6	1.03	7.7	1.2	90.0	1.09	0.81	0.88	5.00	3.00	32.2
19	CAL.05	15.7	26.6	1.22	7.3	1.3	90.2	1.19	0.82	0.86	4.11	3.00	28.7
20	CAL.06	15.0	5.6	0.26	3.1	2.1	92.0	2.86	0.80	0.90	4.50	3.50	30.8
21	CO.004	15.9	39.3	1.80	15.2	2.3	81.2	1.38	0.74	0.80	1.16	0.73	23.1
23	CAL.09	15.0	17.4	0.84	0.0	1.2	97.9	0.95	0.83	0.88	5.40	3.33	29.4
24	CO.053	28.5	50.4	1.28	14.1	2.1	81.8	2.03	0.75	0.79	1.14	0.68	21.7
25	CO.056	15.0	11.4	0.55	7.8	3.6	87.2	1.43	0.67	0.87	3.60	2.30	20.3
26	CAL.10	15.6	21.9	1.01	5.4	1.5	91.9	1.25	0.79	0.85	3.60	2.27	25.9
27	Co.050	14.6	20.4	1.01	6.8	1.9	90.2	1.04	0.78	0.87	2.50	1.69	18.9

Note: Catalysts for Runs 3 thru 15 (except 8) screened through 150 x 400 mesh.

Catalyst for Run 8 screened thru 100 x 400 mesh.

Cat. Nos. CAL.08 and CAL.07 were prereduced and coated with wax.

H2 to CO ratio for Runs 16 and 17 was 1.76/1.0.

Cat. No. CAL.06 was H2 reduced and air stabilized.

Cat. No. CAL.09 was prereduced and coated with Soya.

M4 SBGR RUN RESULTS

COMPARISON OF CATALYST ACTIVITY AT SIMILAR RUN CONDITIONS

Period No.	Temp.	Pres.	H ₂ /CO Ratio
-----	-----	-----	-----
2	220 C	450psi	2.0

a) Total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

Flows: N₂-563 SLH, H₂-225 SLH, CO-112.5 SLH

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N₂ as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons C₁+ (kg/kg cat.,hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin C ₃	Paraf C ₄	Olefin C ₆₋₁₈ , %
---	---	---	---	---	%CH ₄	%C ₂	%C ₃ +	%CO ₂	---	---	---	---	---
3	CO.002	15.2	11.8	0.56	4.7	1.0	93.7	0.59	0.81	0.90	2.71	1.63	--
4	CO.024	15.4	9.5	0.45	0.0	2.1	97.6	0.27	0.83	0.91	5.33	4.00	--
5	CO.035	15.4	8.8	0.42	0.0	2.3	97.4	0.31	0.82	--	5.33	4.00	--
6	CO.028	15.4	6.6	0.31	0.0	1.9	97.4	0.72	0.83	0.90	5.50	4.00	--
7	CO.043	15.4	4.3	0.20	0.0	1.4	96.3	2.25	0.81	0.91	4.00	3.00	--
9	CO.048	15.4	6.1	0.28	1.8	1.0	95.2	1.93	0.80	0.91	3.67	3.00	--
10	CAL.02	15.9	14.9	0.68	4.6	0.9	94.0	0.47	0.81	0.88	4.40	2.29	--
12	CO.053	15.9	14.4	0.66	4.3	1.0	94.3	0.48	0.81	0.89	4.20	2.67	--
13	CO.054	15.7	0.2	0.01	0.0	20.	60.8	19.5	0.33	0.94	8.00	5.00	--
14	Blend A	20.0	12.4	0.60	4.3	0.9	93.9	0.95	0.81	0.91	3.80	2.33	--
15	CO.034	13.0	11.0	0.61	4.0	0.9	94.5	0.59	0.82	0.90	4.00	3.00	--
16	CAL.04	16.1	8.4	0.42	2.6	1.0	94.1	2.31	0.80	0.88	5.00	4.00	--
17	CAL.08	15.0	5.4	0.28	0.1	0.8	96.9	2.23	0.83	--	4.00	3.00	--
18	CAL.07	15.0	6.7	0.33	1.8	1.4	95.0	1.81	0.85	--	4.00	3.00	--
19	CAL.05	15.7	9.0	0.41	2.3	1.4	94.8	1.56	0.84	--	5.50	3.00	--
20	CAL.06	15.0	3.5	0.16	0.0	3.3	92.8	3.87	0.80	0.85	3.00	2.50	--
21	CO.004	15.9	16.1	0.74	8.1	1.2	90.2	0.48	0.78	0.86	3.38	2.22	--
23	CAL.09	15.0	6.6	0.32	0.2	0.9	98.0	0.92	0.90	--	4.00	3.00	--
25	CO.056	15.0	4.5	0.22	0.3	2.7	95.7	1.27	0.73	--	4.67	3.00	--
27	Co.050	14.6	8.1	0.39	0.0	4.8	92.6	2.56	0.79	0.87	8.50	3.00	--

Note: Catalysts for Runs 3 through 15 screened thru 150 x 400 mesh.

Blend A contains 15.0 gm of Cat. No. CO.005 plus 5.0 gm of Cat. No. WGS.03.

Cat. NOs. CAL.08 and CAL.07 were prereduced and wax coated.

H₂ to CO for Runs 16 and 17 was 1.76/1.0.

Cat. No. CAL.06 was H₂ reduced and air stabilized before charging.

Cat. No. CAL.09 was prereduced and coated with Soya.

Table IX

DATE: 09/30/94

M4 SBCR RUN RESULTS

COMPARISON OF CATALYST ACTIVITY AT SIMILAR RUN CONDITIONS

Period No.	Temp.	Pres.	H2/CO Ratio
4	240 C	450psi	1.0

a) Total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

Flows: N2-562 SLH, H2-119 SLH, CO-119 SLH

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons C1+ (kg/kg cat.,hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf C3	Olefin C4	Olefin C6-18,%
					%CH4	%C2	%C3+	%CO2					
3	CO.002	15.2	11.6	0.83	3.9	2.4	92.8	0.84	0.81	0.87	4.29	3.14	--
4	CO.024	15.4	10.3	0.73	0.5	1.6	97.2	0.71	0.83	0.87	8.33	4.75	--
5	CO.035	15.4	10.4	0.73	0.9	0.0	98.4	0.65	--	0.83	--	--	--
6	CO.028	15.4	9.2	0.65	0.0	1.3	97.3	1.46	0.85	0.88	9.50	3.75	--
7	CO.043	15.4	5.2	0.37	0.0	0.0	99.4	0.64	0.83	0.89	7.00	5.00	--
9	CO.048	15.4	8.2	0.57	2.3	1.0	93.8	3.00	0.82	0.90	8.50	4.33	--
10	CAL.02	15.9	14.6	1.00	4.6	1.0	93.3	0.97	0.80	0.88	7.20	4.00	--
12	CO.053	15.9	13.3	0.91	4.3	1.2	93.3	1.18	0.80	0.89	6.60	3.71	--
13	CO.054	15.7	5.2	0.36	0.0	1.2	97.0	1.85	0.83	0.95	6.00	4.50	--
14	BlendA	20.0	12.7	0.91	3.4	1.0	94.0	1.61	0.81	0.86	7.50	3.83	--
15	CO.034	13.0	11.2	0.94	3.9	1.0	94.0	1.02	0.82	0.87	8.33	4.00	--
21	CO.004	15.9	14.9	1.02	7.4	1.4	89.9	1.29	0.77	0.84	4.67	2.82	--

Note: Catalysts for Runs 3 through 21 screened thru 150 x 400 mesh.

Table X

DATE: 12/30/94

M4 SBCR RUN RESULTS

COMPARISON OF CATALYST ACTIVITY AT SIMILAR RUN CONDITIONS

Period No.	Temp.	Pres.	H2/CO Ratio
-----	-----	-----	-----
5	240 C	600psi	1.0

a) Total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

Flows: N2-562 SLH, H2-119 SLH, CO-119 SLH

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons C1+ (kg/kg cat.,hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf C3	Olefin C4	Olefin C6-18,%
---	---	---	---	---	---	---	---	---	---	---	---	---	---
3	CO.002	15.2	12.9	0.92	4.0	1.5	93.5	0.91	0.81	0.82	4.29	2.75	24.5
4	CO.024	15.4	11.3	0.80	0.9	1.5	97.0	0.65	0.83	0.87	6.50	3.80	36.4
5	CO.035	15.4	10.7	0.76	0.7	1.4	97.1	0.75	0.84	0.88	6.25	4.50	27.3
6	CO.028	15.4	9.5	0.67	0.0	1.1	97.5	1.36	0.85	0.88	6.00	3.50	40.6
7	CO.043	15.4	5.9	0.41	0.0	2.2	94.8	2.99	0.82	0.89	6.00	3.75	30.1
9	CO.048	15.4	11.9	0.83	2.7	0.9	94.4	1.93	0.84	0.89	5.75	3.20	14.0
10	CAL.02	15.9	16.4	1.12	4.2	1.0	94.0	0.89	0.82	0.86	5.83	3.86	35.7
12	CO.053	15.9	15.6	1.06	4.0	0.9	94.0	1.0	0.82	0.87	5.50	3.57	32.2
13	CO.054	15.7	5.0	0.34	0.0	1.3	96.9	1.78	0.82	0.93	6.50	3.33	30.8
14	BlendA	20.0	14.1	1.02	3.7	1.0	93.8	1.45	0.82	0.89	6.40	3.43	32.9
15	CO.034	13.0	11.8	0.99	3.9	1.1	94.0	1.03	0.83	0.87	5.75	3.80	37.8
21	CO.004	15.9	18.4	1.26	6.1	1.1	91.9	0.94	0.81	0.84	5.25	2.91	32.2

Note: Catalysts for Runs 3 through 21 screened thru 150 x 400 mesh.