

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 <sub>2</sub> O <sub>3</sub><br>0.13% K | γ-alumina | U.S. Pat.<br>4,880,763                                                  | P        |
| Co.002   | 20%    | 0.43% Ru | 1% La <sub>2</sub> O <sub>3</sub>            | γ-alumina | U.S. Pat.<br>4,413,064                                                  | P        |
| Co.003   | 20%    | 0.5% Ru  | 1% La <sub>2</sub> O <sub>3</sub>            | γ-alumina | U.S. Pat.<br>4,413,064                                                  | P        |
| Co.004   | 20%    | 0.43% Ru | 1% La <sub>2</sub> O <sub>3</sub>            | 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<br>Co.005 by IW<br>impreg.                         | P        |
| Co.006   | 12%    | 0.75% Re | 0                                            | Titania   | U.S. Pat.<br>4,794,009                                                  | P        |
| Co.007   | 20%    | 0        | 0                                            | Titania   | Base Catalyst                                                           | P        |
| Co.008   | 20%    | 0        | 0                                            | Silica    | UK Pat. Appl.<br>GB 2 125 062 A<br>(Kneaded with excess<br>liquid)      | P        |
| Co.009   | 20%    | 0.5% Ru  | 0                                            | γ-alumina | Ru-Promoted Catalyst<br>(use Ru Chloride,<br>single-step aqueous<br>IW) | P        |
| Co.010   | 20%    | 0        | 0                                            | γ-alumina | Base Catalyst<br>(non-calcined)                                         | P        |
| Co.010A  | 20%    | 0.4% Ru  | 0                                            | γ-alumina | Ru added to dried<br>Co.010 by IW<br>impreg.                            | P        |
| Co.011   | 20%    | 0        | 0                                            | Silica    | UK Pat. Appl.<br>GB 2 125 062 A<br>(Kneaded)                            | P        |
| Co.012   | 20%    | 0        | 0                                            | Silica    | Base Catalyst<br>(Inc. Wetness)                                         | P        |
| Co.013   | 20%    | 0        | 0                                            | Titania   | Base Catalyst<br>like Co.007, but all<br>aqueous                        | P        |
| Co.014   | 12%    | 0.5% Ru  | 0                                            | Titania   | Ru-Promoted Catalyst<br>(aqueous IW co-<br>impregnation)                | P        |
| Co.015   | 20%    | 0.43% Ru | 1% La <sub>2</sub> O <sub>3</sub>            | γ-Alumina | Similar to Co.002,<br>but all aqueous                                   | P        |

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

| CAT. NO. | wt% Co | wt% M    | wt% Prom.                         | Support                   | Basis                                                                                        | Prepared |
|----------|--------|----------|-----------------------------------|---------------------------|----------------------------------------------------------------------------------------------|----------|
| Co.016   | 20%    | 0.43% Ru | 1% La <sub>2</sub> O <sub>3</sub> | γ-Alumina                 | Similar to Co.015, but calcined after Co impregnation                                        | P        |
| Co.017   | 20%    | 0.5% Ru  | 1% La <sub>2</sub> O <sub>3</sub> | 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, aqueous kneaded)                                | P        |
| Co.022   | 20%    | 0        | 0.7% Zr                           | Silica                    | U.K. Pat. Appl. GB 2 125 062 A (aqueous, multiple-steps, kneaded Co pre-impregnation, IW Zr) | P        |
| Co.023   | 20%    | 0        | 1.4% Zr                           | Silica                    | U.K. Pat. Appl. GB 2 125 062 A (aqueous, multiple-steps, kneaded Co pre-impregnation, IW Zr) | P        |
| Co.024   | 20%    | 0        | 8.5% Zr                           | Silica                    | Eur. Pat. Appl. 0 167 215 A2 (non-aqueous, IW, multiple-steps, 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        |

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| CAT. NO. | wt% Co | wt% M   | wt% Prom.         | Support                      | Basis                                                                         | Prepared |
|----------|--------|---------|-------------------|------------------------------|-------------------------------------------------------------------------------|----------|
| Co.027   | 20%    | 0.5% Ru | 0                 | Silica<br>(Davison Grade 59) | Similar to Co.019<br>but different grade<br>silica                            | P        |
| Co.028   | 20%    | 0.5% Ru | 0.5% K            | $\gamma$ -alumina            | Ru- and K-Promoted<br>Catalyst (single-step<br>IW)                            | P        |
| Co.029   | 30%    | 0.5% Ru | 0.5% K            | $\gamma$ -alumina            | Similar to Co.028 but<br>30% Co                                               | P        |
| Co.030   | 20%    | 0       | 0.1% Zr           | $\gamma$ -alumina            | Zr-Promoted Catalyst<br>(single-step aqueous<br>IW)                           | P        |
| Co.031   | 20%    | 0       | 1.4% Zr           | $\gamma$ -alumina            | Zr-Promoted Catalyst<br>(single-step aqueous<br>IW)                           | P        |
| Co.032   | 20%    | 0       | 8.5% Zr           | $\gamma$ -alumina            | Zr-Promoted Catalyst<br>(single-step aqueous<br>IW )                          | P        |
| Co.033   | 20%    | 0       | 8.5% Zr           | $\gamma$ -alumina            | Multiple-steps,<br>aqueous IW, Co pre-<br>impregnation                        | P        |
| Co.034   | 20%    | 0       | 8.5% Zr           | $\gamma$ -alumina            | Multiple-steps,<br>aqueous IW, Zr pre-<br>impregnation                        | P        |
| Co.035   | 20%    | 0       | 8.5% Zr           | Silica                       | Zr-Promoted Catalyst<br>(single-step aqueous,<br>kneaded)                     | P        |
| Co.036   | 20%    | 0       | 8.5% Zr           | Silica                       | Mltiple-steps, aq. Co<br>pre-impreg. by<br>kneading, aqueous<br>IW Zr impreg. | P        |
| Co.037   | 12%    | 0       | 0                 | Titania                      | Similar to Co.013,<br>but $\text{TiO}_2$ mainly<br>anatase                    | P        |
| Co.038   | 12%    | 0.5% Ru | 0                 | Titania                      | Similar to Co.014,<br>but $\text{TiO}_2$ mainly<br>anatase                    | P        |
| Co.039   | 12%    | 0       | 0                 | Titania                      | Similar to Co.007,<br>but only 12% Co                                         | P        |
| Co.040   | 12%    | 0       | 0                 | Titania                      | Similar to Co.013,<br>but only 12% Co                                         | P        |
| Co.041   | 20%    | 0.5% Ru | 8.5% Zr           | Silica                       | Similar to Co.025,<br>but Ru-promoted                                         | P        |
| Co.042   | 0      | 0       | 8.5% Zr           | Silica                       | Blank Zr-promoted<br>$\text{SiO}_2$                                           | P        |
| Co.043   | 20%    | 0.5% Ru | 8.5% Zr<br>0.5% K | Silica                       | Similar to Co.041,<br>but K-promoted                                          | P        |

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| CAT. NO.            | wt% Co | wt% M   | wt% Prom.         | Support                    | Basis                                                                      | Prepared |
|---------------------|--------|---------|-------------------|----------------------------|----------------------------------------------------------------------------|----------|
| Co.064              | 20%    | 0.5% Ru | 8.5% Zr           | $\gamma$ -alumina          | Multiple-steps, aqueous IW, Zr pre-impregnation                            | -        |
| Co.065              | 20%    | 0.5% Ru | 8.5% Zr<br>0.3% K | $\gamma$ -alumina          | Multiple-steps, aqueous IW, Zr pre-impregnation                            |          |
| CAL.01<br>(97E-13E) | 20%    | 0.5% Ru | 0                 | $\gamma$ -alumina          | Similar to Co.018 (Calsicat Prep.)                                         | P        |
| CAL.02<br>(97E-16B) | 20%    | 0.5% Ru | 0                 | $\gamma$ -alumina          | Similar to CAL.01 (New Batch)                                              | P        |
| CAL.03<br>(97E-13F) | 20%    | 0.5% Ru | 0                 | $\gamma$ -alumina          | Multiple-step impreg., Similar to CAL.02                                   | P        |
| CAL.04<br>(97E-50C) | 20%    | 0.5% Ru | 0.3% K            | $\gamma$ -alumina          | Similar to Co.047 Stand. Calc. in Air                                      | P        |
| CAL.05<br>(97E-50D) | 20%    | 0.5% Ru | 0.3% K            | $\gamma$ -alumina          | Similar to Co.047 Stand. Calc. in $N_2$                                    | P        |
| CAL.06<br>(97E-51A) | 20%    | 0.5% Ru | 0.3% K            | $\gamma$ -alumina          | Similar to Co.047 Red. and Pas. in Air                                     | P        |
| CAL.07<br>(97E-51B) | 20%    | 0.5% Ru | 0.3% K            | $\gamma$ -alumina          | Similar to Co.047 Red. and Protected in Paraffin (51.3% Cat. Conc.)        | P        |
| CAL.08<br>(97E-51C) | 20%    | 0.5% Ru | 0.3% K            | $\gamma$ -alumina          | Similar to Co.047 Calc., Red. and Protected in Paraffin (54.4% Cat. Conc.) | P        |
| CAL.09<br>(97E-69C) | 20%    | 0.5% Ru | 0.3% K            | $\gamma$ -alumina          | Similar to CAL.05, Reduced and Protected in Soya (51.7% Cat. Conc.)        | P        |
| CAL.10<br>(97E-79A) | 20%    | 0.5% Ru | 0.3% K            | $\gamma$ -alumina (Condea) | Similar to CAL.05, but on Condea $Al_2O_3$                                 | P        |
| CAL.11<br>(29F-07B) | 20%    | 0.5% Ru | 0.3% K            | $\gamma$ -alumina          | Similar to CAL.05                                                          | P        |
| CAL.12<br>(29F-05D) | 20%    | 0.5% Ru | 0.3% K            | $\gamma$ -alumina          | Similar to CAL.05                                                          | P        |
| CAL.13<br>(29F-07E) | 20%    | 0.5% Ru | 0.3% K            | $\gamma$ -alumina          | Similar to CAL.05                                                          | 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         | $\gamma$ -alumina | single-step, aqu. IW                                  | P        |
| WGS.02   | 0              | 5.0% Cu  | 10% Zn    | $\gamma$ -alumina | single-step, aqu. IW                                  | P        |
| WGS.03   | 0              | 5.0% Cu  | 4.0% Cr   | $\gamma$ -alumina | single-step, aqu. IW                                  | P        |
| WGS.04   | 0              | 0        | 4.0% Cr   | $\gamma$ -alumina | single-step, aqu. IW                                  | P        |
| WGS.05   | 0              | 0        | 4.0% Mn   | $\gamma$ -alumina | single-step, aqu. IW                                  | P        |
| WGS.06   | 0              | 5.0% Cu  | 4.0% Mn   | $\gamma$ -alumina | single-step, aqu. IW                                  | P        |
| WGS.07   | 0              | 4.0% Fe  | 0         | $\gamma$ -alumina | single-step, aqu. IW                                  | P        |
| WGS.08   | 0              | 4.0% Fe  | 4.0% Cr   | $\gamma$ -alumina | single-step, aqu. IW                                  | P        |
| WGS.09   | 0              | 5.0% Cu  | 4.0% Cr   | $\gamma$ -alumina | Similar to WGS.03                                     | P        |
| CoW.01   | 20%            | 5.0% Cu  | 10% Zn    | $\gamma$ -alumina | multiple-steps, aqu. IW, Cu,Zn pre-impr.              | P        |
| CoW.02   | 20%            | 5.0% Cu  | 4.0% Cr   | $\gamma$ -alumina | multiple-steps, aqu. IW, Cu,Cr pre-impr.              | P        |
| CoW.03   | 10%            | 5.0% Cu  | 4.0% Cr   | $\gamma$ -alumina | similar to CoW.02 (10% Co only)                       | P        |
| CoW.04   | 10%            | 10% Cu   | 8.0% Cr   | $\gamma$ -alumina | similar to CoW.03; 10% Cu and 8% Cr                   | P        |
| CoW.05   | 20%            | 5.0% Cu  | 4.0% Cr   | $\gamma$ -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   | $\gamma$ -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         | $\gamma$ -alumina | Single Step, IW                                       | P        |
| CoW.11   | 10% Co, 10% Fe | 0.5% Ru  | 0.5% K    | $\gamma$ -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 <sup>2</sup> /g) | Pore Volume (cc/g) | Average Pore Dia. (Å) | Average Part. Size (µm) |
|----------------------------------------|-------------------------------------------------------|--------------------------------------|--------------------|-----------------------|-------------------------|
| Vista-B Al <sub>2</sub> O <sub>3</sub> | (0-400 mesh)                                          | 299                                  | 1.69               | 269                   | 24                      |
| Vista-B Al <sub>2</sub> O <sub>3</sub> | Calcined 500°C                                        | 240                                  | 0.49               | 82                    |                         |
| Vista-B Al <sub>2</sub> O <sub>3</sub> | Calcined 600°C                                        | 206                                  | 0.49               | 95                    |                         |
| Vista-B Al <sub>2</sub> O <sub>3</sub> | Calcined 600°C                                        | 174                                  | 0.47               | 109                   |                         |
| Condea Al <sub>2</sub> O <sub>3</sub>  | (as received)                                         | 219                                  | 0.53               | 97                    | 77                      |
| Davison SiO <sub>2</sub>               | (0-400 mesh)                                          | 219                                  | 0.51               | 89                    | 121                     |
| Degussa P25 TiO <sub>2</sub>           | (as received)                                         | 47                                   | 0.40               | 335                   | 6                       |
| Degussa P25 TiO <sub>2</sub>           | Dried 60°C, Calc. 350°C/16hrs                         | 46                                   | 0.48               | 419                   | 51                      |
| Degussa P25 TiO <sub>2</sub>           | Dried 60°C, Calc. 650°C/16hrs                         | 12                                   | 0.17               | 573                   | 212                     |
| Co.001                                 | 20Co/1Re/<br>1La <sub>2</sub> O <sub>3</sub> /0.13K/A | 191                                  | 0.31               | 66                    | 42<br>40                |
| Co.002                                 | 20Co/0.43Ru/<br>1La <sub>2</sub> O <sub>3</sub> /A    | 149                                  | 0.33               | 89                    | 74                      |
| Co.003                                 | 20Co/0.5Ru/<br>1La <sub>2</sub> O <sub>3</sub> /A     | 122                                  | 0.26               | 87                    | 77                      |
| Co.004                                 | 20Co/0.43Ru/<br>1La <sub>2</sub> O <sub>3</sub> /A    |                                      |                    |                       | 78                      |
| Co.005                                 | 20Co/A                                                | 173                                  | 0.34               | 81                    | 65<br>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 <sup>2</sup> /g) | Pore Volume (cc/g) | Average Pore Dia. (Å) | Average Part. Size (µm) |
|----------|----------------------------------------------------|--------------------------------------|--------------------|-----------------------|-------------------------|
| Co.015   | 20Co/0.43Ru/<br>1La <sub>2</sub> O <sub>3</sub> /A | 141                                  | -                  | -                     | 67                      |
| Co.016   | 20Co/0.43Ru/<br>1La <sub>2</sub> O <sub>3</sub> /A | 116                                  | -                  | -                     | 79                      |
| Co.017   | 20Co/0.5Ru/<br>1La <sub>2</sub> O <sub>3</sub> /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/<br>8.5Zr/S                        |                                      |                    |                       | 82                      |

Table 3. Summary of Physical Properties (contd.)

| CATALYST | Composition                                     | BET Surface Area (m <sup>2</sup> /g) | Pore Volume (cc/g) | Average Pore Dia. (Å) | Average Part. Size (μm) |
|----------|-------------------------------------------------|--------------------------------------|--------------------|-----------------------|-------------------------|
| Co.049   | 20Co/0.5Ru/0.3K/A                               |                                      |                    |                       | 81                      |
| Co.053   | 20Co/0.5Ru/A                                    |                                      |                    |                       | 75                      |
| Co.054   | 20Co/0.3K/8.5Zr/S                               |                                      |                    |                       | 101                     |
| Co.055   | 20Co/1Re/<br>1La <sub>2</sub> O <sub>3</sub> /A |                                      |                    |                       | 86                      |
| Co.056   | 20Co/8.5La <sub>2</sub> O <sub>3</sub> /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. H<sub>2</sub> Chemisorption<sup>a</sup> and TPR Results

| Catalyst              | H <sub>2</sub> Chemisorption <sup>a</sup>      |                                                 |                                                |            | TPR                                            |                                         |
|-----------------------|------------------------------------------------|-------------------------------------------------|------------------------------------------------|------------|------------------------------------------------|-----------------------------------------|
|                       | Total<br>( $\mu$ mol<br>H <sub>2</sub> /g cat) | Irrev.<br>( $\mu$ mol<br>H <sub>2</sub> /g cat) | Average<br>d <sub>p</sub> <sup>b</sup><br>(nm) | %<br>Disp. | %Co Red. <sup>c</sup><br>(TPR calc.<br>catal.) | % Red. <sup>d</sup><br>(stand.<br>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 <sup>e</sup>   | (1) 205                                        | 185                                             | 6.9                                            | 12.1       | 91                                             |                                         |
|                       | (1) 147                                        | -                                               | 9.6                                            | 7.4        | -                                              |                                         |
|                       | (1) 167                                        | -                                               | 8.4                                            | 8.4        | -                                              |                                         |
|                       | (2) 126                                        | -                                               | 11.1                                           | 6.3        | 64                                             |                                         |
|                       | (3) 132                                        | 116                                             | 10.6                                           | 6.6        | 55                                             |                                         |
|                       | (4) 144                                        | 123                                             | 9.8                                            | 7.2        | 46                                             |                                         |
|                       | (5) 136                                        | 122                                             | 10.3                                           | 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 <sup>e</sup>   | (1) 146                                        | 124                                             | 11.7                                           | 8.6        | 94                                             | 94                                      |
|                       | (2) 181                                        | -                                               | 7.8                                            | 9.1        | -                                              |                                         |
|                       | (2) 194                                        | -                                               | 7.2                                            | 9.7        | -                                              |                                         |
| 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                                      |
| Co.018Cl <sup>h</sup> |                                                |                                                 |                                                |            | 95                                             |                                         |
| Co.019                | 112                                            | 92                                              |                                                | 6.6        |                                                |                                         |

Table 4. H<sub>2</sub> Chemisorption<sup>a</sup> and TPR Results (contd.)

| Catalyst | H <sub>2</sub> Chemisorption <sup>a</sup>      |                                                 |                                                |            | TPR                                            |                                         |
|----------|------------------------------------------------|-------------------------------------------------|------------------------------------------------|------------|------------------------------------------------|-----------------------------------------|
|          | Total<br>( $\mu$ mol<br>H <sub>2</sub> /g cat) | Irrev.<br>( $\mu$ mol<br>H <sub>2</sub> /g cat) | Average<br>d <sub>p</sub> <sup>b</sup><br>(nm) | %<br>Disp. | %Co Red. <sup>c</sup><br>(TPR calc.<br>catal.) | % Red. <sup>d</sup><br>(stand.<br>red.) |
| 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        |                                                |                                         |
| 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                                             |                                         |

Table 4. H<sub>2</sub> Chemisorption<sup>a</sup> and TPR Results (contd.)

| Catalyst            | H <sub>2</sub> Chemisorption <sup>a</sup>      |                                                 |                            |                          | TPR                                            |                                         |
|---------------------|------------------------------------------------|-------------------------------------------------|----------------------------|--------------------------|------------------------------------------------|-----------------------------------------|
|                     | Total<br>( $\mu$ mol<br>H <sub>2</sub> /g cat) | Irrev.<br>( $\mu$ mol<br>H <sub>2</sub> /g cat) | Average<br>$d_p^b$<br>(nm) | %<br>Disp.               | %Co Red. <sup>c</sup><br>(TPR calc.<br>catal.) | % Red. <sup>d</sup><br>(stand.<br>red.) |
| CO.047              | 146                                            | -                                               | 9.6                        | 7.3                      |                                                |                                         |
| Co.053 <sup>i</sup> | (1) 168<br>(2) 101<br>(3) 138                  | 139<br>76<br>117                                | 8<br>14<br>10              | 8.4<br>5.2<br>6.9        | 60<br>82<br>47                                 |                                         |
| Co.054              |                                                |                                                 |                            |                          | 57                                             |                                         |
| Co.055 <sup>j</sup> | (1) 165<br>(2) 179<br>(3) 103<br>(4) 192       | 139<br>163<br>84<br>165                         | 8.5<br>8<br>14<br>7        | 8.3<br>9.0<br>5.2<br>9.6 | 78<br>50<br>76<br>-                            |                                         |
| Co.056              |                                                |                                                 |                            |                          | 58                                             |                                         |
| Co.60               | 65                                             |                                                 | 14.4                       | 2.1                      |                                                |                                         |
| Co.61               | 277                                            |                                                 | 7.6                        | 9.2                      |                                                |                                         |
| CAL.01              | 169                                            | -                                               | 8.3(5.8°)                  | 4.4°                     | 54                                             |                                         |
| CAL.02              | -                                              | -                                               | (6.3°)                     | 5.1°                     | 55                                             |                                         |
| CAL.03              | -                                              | -                                               | 5.7°                       | 4.2°                     | 85                                             |                                         |
| CAL.04              | 93                                             |                                                 | 15.1(5.5°)                 | 3.5°                     |                                                |                                         |
| CAL.05              | 100                                            |                                                 | 14.1(5.6°)                 | 4.4°                     |                                                |                                         |
| CAL.06              |                                                |                                                 | 5.7°                       | 4.2°                     |                                                |                                         |
| CAL.10              |                                                |                                                 | 7.2°                       | 3.7°                     |                                                |                                         |
| CAL.11              | 171                                            |                                                 | 8.3                        | 8.5                      |                                                |                                         |
| CAL.12              | 146                                            |                                                 | 9.6                        | 7.3                      |                                                |                                         |
| CAL.13              | 180                                            |                                                 | 7.8                        | 9.0                      |                                                |                                         |

(a) static H<sub>2</sub> chemisorption at 100°C(b) Est. assuming  $H_{2,0}/Co_0 = 1$ ,  $5.46 \times 10^{-20} \text{ m}^2/Co_0$ , 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)=flow calcined in air and reduced in H<sub>2</sub>; (3)=ROR (4)=calcined in He; (5)=calcined in nitrogen

(g) (1)=flow calcined in air; (2)=uncalcined

(h) Co.018Cl = Chlorinated Co.018

Table 4. H<sub>2</sub> Chemisorption<sup>a</sup> and TPR Results (contd.)

(i) (1)=flow calcined in air; (2)=uncalcined; (3)=ROR

(j) (1)=calcined in air; (2)=calcined in nitrogen; (3)=uncalcined; (4)=ROR

Table 5. Summary of Fixed Bed Reaction Results

| Catalyst | Run | Prep   | CO<br>Conv.<br>(%) | Rate<br>g CH <sub>2</sub> /<br>g cat/hr | R-C6+<br>g CH <sub>2</sub> /<br>g cat/hr | R (CO)<br>mol/mol<br>Co/s | wt%<br>CH <sub>4</sub> | alpha | C3-C5<br>Ole/<br>Par | CO <sub>2</sub><br>(%)<br>g/g<br>cat/hr | E act.<br>kcal/<br>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 run2, 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 <sub>2</sub> :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 <sub>2</sub> 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                                     |
| "        | 8   |        | 2.7                | 0.154                                   | 0.067                                    | 9.0E-04                   | 22.6                   | 0.71  | 3.01                 | 0.1                                     | 0.019                  |             | D (1:2), NSH                           |
| "        | 8a  |        | 2.5                | 0.140                                   | 0.059                                    | 8.4E-04                   | 23.4                   | 0.72  | 3.65                 | 0.1                                     | 0.019                  |             | Ar added to rxn mix                    |
| "        | 8b  |        | 4.2                | 0.239                                   | 0.045                                    | 1.4E-03                   | 40.0                   | 0.60  | 2.42                 | 0.1                                     | 0.032                  |             | Rxn @ 240 °C                           |
| "        | 8c  |        | 3.5                | 0.196                                   | 0.026                                    | 1.1E-03                   | 49.6                   | 0.59  | 3.38                 | 0.1                                     | 0.049                  |             | Rxn @ 260 °C                           |
| "        | 8d  |        | 2.5                | 0.140                                   | 0.059                                    | 8.4E-04                   | 23.4                   | 0.72  | 3.65                 | 0.1                                     | 0.019                  |             | Rxn @ 280 °C                           |
| "        | 9   |        | 1.5                | 0.082                                   | 0.025                                    | 4.8E-04                   | 27.7                   | 0.60  | 2.90                 | 0.1                                     | 0.014                  |             | D (1:4), NSH                           |
| "        | 9a  |        | 1.4                | 0.075                                   | 0.020                                    | 4.4E-04                   | 29.9                   | 0.61  | 3.14                 | 0.1                                     | 0.016                  |             | Ar added to rxn mix                    |
| "        | 9b  |        | 1.4                | 0.078                                   | 0.004                                    | 4.5E-04                   | 62.9                   | 0.58  | 5.07                 | 0.3                                     | 0.055                  |             | Rxn @ 280 °C                           |
| "        | 10  |        | 1.9                | 0.106                                   | 0.045                                    | 6.2E-04                   | 23.0                   | 0.70  | 4.13                 | 0.1                                     | 0.016                  |             | D (1:2), NSH                           |
| "        | 10a |        | 1.6                | 0.090                                   | 0.024                                    | 5.3E-04                   | 25.3                   | 0.68  | 4.50                 | 0.1                                     | 0.017                  |             | Ar added to rxn mix                    |
| "        | 10b |        | 1.8                | 0.100                                   | 0.005                                    | 5.9E-04                   | 48.0                   | 0.65  | 5.00                 | 0.2                                     | 0.037                  |             | Rxn @ 280 °C                           |
| "        | 10c |        | 0.4                | 0.024                                   | 0.010                                    | 2.3E-04                   | 25.9                   | 0.76  | 1.98                 | 0.1                                     | 0.013                  | 13.8        | at 220 after rxn @280                  |
| 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)    | 2.7                | 0.045                                   | 0.024                                    | 2.6E-04                   | 16.0                   | 0.74  | 0.61                 | 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                                    | 7.0E-03                   | 49.8                   | 0.50  | 0.72                 | 0.2                                     | 0.004                  |             | NSH                                    |
| Co.009   | 1   | (1)    | 4.9                | 0.346                                   | 0.090                                    | 2.0 E -0                  | 31.1                   | 0.57  | 1.69                 | 0.1                                     | 0.020                  |             | NSH                                    |
| "        | 2   |        | 4.9                | 0.338                                   | 0.091                                    | 2.0 E -0                  | 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                                    |

Table 5. Summary of Fixed Bed Reaction Results (contd.)

| Catalyst | Run | Prep   | CO<br>Conv<br>(%) | Rate<br>g CH <sub>2</sub> /g cat/hr | R-C6+<br>g CH <sub>2</sub> /g cat/hr | R (CO)<br>mol/mol<br>Co/s | wt%<br>CH <sub>4</sub> | alpha | C3-C5<br>Ole/<br>Par | CO <sub>2</sub><br>(%)<br>(CO) | g/g<br>cat/hr | E act<br>kcal/<br>mol | Comment                                |
|----------|-----|--------|-------------------|-------------------------------------|--------------------------------------|---------------------------|------------------------|-------|----------------------|--------------------------------|---------------|-----------------------|----------------------------------------|
| 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                                    |
| 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 <sub>2</sub> :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 <sub>2</sub> 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 <sub>2</sub> :Ar = 1:2:2          |
| Co.018   | 2b  | s      | 3.0               | 0.147                               | 0.045                                | 8.6E-04                   | 33.6                   | 0.63  | 2.41                 | 0.1                            | 0.015         |                       | + H <sub>2</sub> 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                                    |
| 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                                | 4.9E-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                                    |
| 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         | 28.4                  | NSH                                    |
| "        | 2   |        | 4.3               | 0.167                               | 0.105                                | 6.5E-04                   | 14.7                   | 0.80  | 13.2                 | 0.2                            | 0.030         |                       | 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                                    |

Table 5. Summary of Fixed Bed Reaction Results (contd.)

| Catalyst | Run | Prep | CO<br>Conv<br>(%) | Rate<br>g CH <sub>2</sub> /<br>g cat/hr | R-C5+<br>g CH <sub>2</sub> /<br>g cat/hr | R (Co)<br>mol/mol<br>Co/s | wt%<br>CH <sub>4</sub> | alpha | C3-C5<br>Ole/<br>Par | CO <sub>2</sub><br>(%)<br>g/g<br>cat/hr | E act<br>kcal/<br>mol | Comment |                              |
|----------|-----|------|-------------------|-----------------------------------------|------------------------------------------|---------------------------|------------------------|-------|----------------------|-----------------------------------------|-----------------------|---------|------------------------------|
| 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                          |
| 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, ROR                     |
| "        | 6   | f    | 8.2               | 0.485                                   | 0.163                                    | 2.8E-03                   | 28.9                   | 0.64  | 1.25                 | 0.1                                     | 0.030                 |         | NSH                          |
| "        | 7   | f    | 9.4               | 0.552                                   | 0.147                                    | 3.2E-03                   | 34.3                   | 0.60  | 1.17                 | 0.1                                     | 0.044                 |         | NSH, Rxn @ 227 °C            |
| "        | 7a  | f    | 1.7               | 0.099                                   | 0.018                                    | 5.8E-04                   | 38.1                   | 0.60  | 8.37                 | 0.2                                     | 0.028                 |         | xn @245 °C, T surge 280 °C   |
| "        | 7b  | f    | 2.0               | 0.119                                   | 0.031                                    | 7.0E-04                   | 32.1                   | 0.62  | 4.20                 | 0.1                                     | 0.021                 |         | cal(5 hr) & red after run 7  |
| "        | 8   | f    | 7.7               | 0.450                                   | 0.144                                    | 2.6E-03                   | 30.3                   | 0.65  | 1.27                 | 0.1                                     | 0.036                 |         | NSH                          |
| "        | 8a  | f    | 6.3               | 0.368                                   | 0.103                                    | 2.2E-03                   | 32.8                   | 0.65  | 1.44                 | 0.1                                     | 0.047                 |         | Ar added to the rxn mix.     |
| "        | 8b  | f    | 3.0               | 0.177                                   | 0.037                                    | 1.0E-03                   | 37.3                   | 0.65  | 3.79                 | 0.1                                     | 0.033                 |         | xn @ 240 °C , T surge 275 °  |
| "        | 9   | f    | 4.3               | 0.470                                   | 0.225                                    | 2.8E-03                   | 21.6                   | 0.69  | 1.49                 | 0.2                                     | 0.046                 |         | D (1:2), NSH                 |
| "        | 9a  | f    | 7.5               | 0.411                                   | 0.067                                    | 2.4E-03                   | 46.9                   | 0.62  | 3.65                 | 0.2                                     | 0.070                 |         | Ar added to the rxn mix.     |
| "        | 9b  | f    | 11.9              | 0.647                                   | 0.116                                    | 3.8E-03                   | 42.7                   | 0.59  | 1.10                 | 0.1                                     | 0.046                 |         | Rxn @ 240 °C                 |
| "        | 10  |      | 5.6               | 0.304                                   | 0.091                                    | 1.8E-03                   | 29.2                   | 0.60  | 1.56                 | 0.2                                     | 0.008                 |         | D(1:2) , NSH                 |
| "        | 10a |      | 11.9              | 0.647                                   | 0.116                                    | 3.8E-03                   | 42.7                   | 0.59  | 1.10                 | 0.2                                     | 0.046                 |         | Rxn @ 240 °C                 |
| "        | 10b |      | 7.5               | 0.411                                   | 0.067                                    | 2.4E-03                   | 46.9                   | 0.62  | 3.65                 | 0.4                                     | 0.070                 |         | Rxn @ 260 °C                 |
| "        | 10c |      | 3.0               | 0.163                                   | 0.035                                    | 9.6E-04                   | 38.8                   | 0.69  | 10.0                 | 0.3                                     | 0.054                 |         | Rxn @ 280 °C                 |
| "        | 11  |      | 5.4               | 0.289                                   | 0.102                                    | 1.7E-03                   | 26.9                   | 0.64  | 1.55                 | 0.1                                     | 0.022                 |         | D (1:2) ,NSH                 |

Table 5. Summary of Fixed Bed Reaction Results (contd.)

| Catalyst | Run | Prep  | CO<br>Conv<br>(%) | Rate<br>g CH <sub>2</sub> /<br>g cat/hr | R-Co+<br>g CH <sub>2</sub> /<br>g cat/hr | R (Co)<br>mol/mol<br>Co/s | wt%<br>CH <sub>4</sub> | alpha | C3-C5<br>Gle/<br>Par | CO <sub>2</sub><br>(%)<br>g/g<br>cat/hr | E act<br>kcal/<br>mol | Comment                    |
|----------|-----|-------|-------------------|-----------------------------------------|------------------------------------------|---------------------------|------------------------|-------|----------------------|-----------------------------------------|-----------------------|----------------------------|
| Co.053   | 11a |       | 3.8               | 0.205                                   | 0.047                                    | 1.2E-03                   | 38.7                   | 0.69  | 9.14                 | 0.3                                     | 0.060                 | Rxn @ 280 °C               |
| 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                                    | 9.5E-04                   | 25.0                   | 0.69  | 3.82                 | 0.1                                     | 0.023                 | NSH                        |
| Co.061   | 1   | (2)   | 9.4               | 0.556                                   | 0.188                                    | 2.2E-03                   | 29.2                   | 0.67  | 1.42                 | 0.1                                     | 0.035                 | NSH                        |
| CAL.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       |
| CAL.02   | 1   | (1)   | 6.1               | 0.379                                   | 0.121                                    | 2.2E-03                   | 27.3                   | 0.63  | 3.04                 | 0.2                                     | 0.040                 | NSH                        |
| CAL.03   | 1   | (1)   | 7.3               | 0.459                                   | 0.133                                    | 2.7E-03                   | 29.0                   | 0.60  | 2.59                 | 0.2                                     | 0.048                 | NSH                        |
| CAL.04   | 1   | (1)   | 4.1               | 0.234                                   | 0.123                                    | 1.4E-03                   | 19.1                   | 0.71  | 8.98                 | 0.2                                     | 0.026                 | NSH                        |
| CAL.05   | 1   | (1)   | 4.7               | 0.274                                   | 0.134                                    | 1.6E-03                   | 20.8                   | 0.75  | 6.85                 | 0.2                                     | 0.026                 | NSH                        |
| 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                                     | 0.05                  | NSH                        |
| CAL.11   | 1   | (1)   | 5.2               | 0.281                                   | 0.147                                    | 1.6E-03                   | 20.0                   | 0.75  | 4.71                 | 0.2                                     | 0.029                 | NSH                        |
| CAL.12   | 1   | (1)   | 5.2               | 0.288                                   | 0.143                                    | 1.7E-03                   | 21.6                   | 0.73  | 3.89                 | 0.2                                     | 0.035                 | NSH                        |
| CAL.13   | 1   | (1)   | 4.6               | 0.258                                   | 0.142                                    | 1.5E-03                   | 18.0                   | 0.77  | 3.38                 | 0.2                                     | 0.024                 | NSH                        |
| CoW.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     |
| CoW.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     |
| CoW.03   | 1   | (4a)  |                   |                                         |                                          |                           |                        |       |                      |                                         |                       | NSH, negligible activity   |
| CoW.04   | 1   | (4a)  |                   |                                         |                                          |                           |                        |       |                      |                                         |                       | S2, negligible activity    |
| CoW.05   | 1   | (4c)  | 2.8               | 0.035                                   | 0.006                                    | 2.1E-04                   | 33.1                   | 0.55  | 0.66                 | 0.2                                     | 0.008                 | S2, 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                 | S2                         |
| CoW.06   | 1   | (4a)  | 3.3               | 0.041                                   | 0.012                                    | 2.4E-04                   | 26.0                   | 0.59  | 2.21                 | 0.2                                     | 0.007                 | S2, reduced at 250 °C      |
| "        | 2   | u     | 16.6              | 0.207                                   | 0.004                                    | 1.2E-03                   | 68.7                   | 0.32  | 0.37                 | 0.3                                     | 0.073                 | S2                         |
| CoW.06   | 2   |       | 17.0              | 0.207                                   | 0.004                                    | 1.2E-03                   | 68.7                   | 0.32  | 0.37                 | 1.7                                     | 0.07                  | S2, 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                        |

Table 5. Summary of Fixed Bed Reaction Results (contd.)

Reaction Conditions:  $T = 220^{\circ}\text{C}$ ,  $\text{H}_2:\text{CO} = 2, 1 \text{ atm}$

All the catalysts are reduced and passivated before loading into reactor, then rereduced in-situ

All catalysts are calcined at UPARC (static) : except where specified in prep. column

s : calcined at Pitt, static

f : calcined at Pitt, flow

u : uncalcined

n : Nitrogen calcined

In some cases, "re-calcined" means calcination of the calcined catalyst from UPARC for a longer period

(1) single step, aqueous incipient wetness

(2) Two step impregnation: aqueous incipient wetness of Co + acetone/ethanol impregnation of Ru, La

(3) three step, with calcination after each step, acetone incipient wetness

(4) two step, aqueous incipient wetness, (a) intermediate calcination, (b) intermediate reduction,

(c) intermediate calcination  $750^{\circ}\text{C}$

(5) single step, acetone impregnation

(6) single step, aqueous kneading, (a) = 150%, (b) = 110% of pore volume

(6c) aqueous kneading for Co, calcined, then aqueous incipient wetness for Zr

(7) Two step impregnation : organic incipient wetness + aqueous incipient wetness

NS New startup

NSH New startup, heated inlet

S2 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

D (x:y) Catalyst bed dilution with x parts cat. and y parts -alumina

Co.018Cl Chlorinated Co.018

Table 6

## SUMMARY OF M3 SECR RUN RESULTS

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

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

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

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

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 |      |          | Comments   |
|--------|---------|------------|--------|------------|-----------|--------|----------|--------|-------------|---------|------------|---------------|-----|------|------|----------|-----------|----------------------|------|----------|------------|
|        |         |            |        |            |           |        |          |        |             |         |            | %CH4          | %C2 | %C3+ | %CO2 |          |           | C3                   | C4   | C6-18, % |            |
| 35     | C0.041  | 26.0       | 1      | 23         | 39        | 240    | 450      | 2.0    | 20          | 35.7    | 1.00       | 13.6          | 2.1 | 82.9 | 1.41 | 0.79     | 0.82      | 1.09                 | 0.74 | 18.2     | G.C. Calib |
| 35     | C0.041  | 26.0       | 2      | 54         | 63        | 250    | 450      | 2.0    | 20          | 42.1    | 1.17       | 27.3          | 4.6 | 64.4 | 3.78 | 0.65     | --        | 0.49                 | 0.41 | --       |            |
| 35     | C0.041  | 26.0       | 3      | 78         | 87        | 260    | 450      | 2.0    | 20          | 45.1    | 1.24       | 41.7          | 6.8 | 44.9 | 6.58 | 0.51     | --        | 0.35                 | 0.37 | --       |            |
| 35     | C0.041  | 26.0       | 4      | 102        | 111       | 260    | 450      | 2.0    | 20          | 46.7    | 0.77       | 39.1          | 4.6 | 49.9 | 6.40 | 0.56     | --        | 0.66                 | 0.52 | --       |            |
| 35     | C0.041  | 26.0       | 5      | 126        | 135       | 260    | 450      | 2.0    | 20          | 49.6    | 0.61       | 39.4          | 4.0 | 49.6 | 7.00 | 0.57     | --        | 0.70                 | 0.52 | --       |            |
| 35     | C0.041  | 26.0       | 6      | 150        | 159       | 260    | 450      | 2.0    | 20          | 47.9    | 0.95       | 33.1          | 3.9 | 58.7 | 4.32 | 0.64     | --        | 0.75                 | 0.52 | --       |            |
| 35     | C0.041  | 26.0       | 7      | 174        | 183       | 260    | 450      | 2.0    | 20          | 49.7    | 1.24       | 30.9          | 4.4 | 61.3 | 3.50 | 0.66     | --        | 0.71                 | 0.49 | --       |            |
| 35     | C0.041  | 26.0       | 8      | 198        | 206       | 240    | 450      | 2.0    | 20          | 19.6    | 0.55       | 17.3          | 2.6 | 79.1 | 0.93 | 0.71     | --        | 2.08                 | 1.63 | --       |            |

## Feed Gas Rates

| Per No | N2 SLH | H2 SLH | CO SLH | Total SLH |
|--------|--------|--------|--------|-----------|
| 1      | 568    | 225    | 112    | 905       |
| 2      | 568    | 225    | 112    | 905       |
| 3      | 568    | 225    | 112    | 905       |
| 4      | 341    | 135    | 68     | 544       |
| 5      | 253    | 100    | 50     | 403       |
| 6      | 163    | 160    | 80     | 403       |
| 7      | 103    | 200    | 100    | 403       |
| 8      | 571    | 225    | 112    | 908       |

Table 7

## SUMMARY OF M4 SBCR RUN RESULTS

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

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

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

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

)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   |                  |           |
| 30     | Co.011  | 15.9       | 1      | 23         | 40        | 240    | 450      | 2.0    | 20          | 8.0     | 0.36       | 5.8           | 3.9 | 87.8 | 2.49 | 0.71     | 0.89      | 5.75         | 3.00 | 22.4             | G.C.Calib |
| 30     | Co.011  | 15.9       | 2      | 54         | 64        | 250    | 450      | 2.0    | 20          | 15.8    | 0.72       | 10.0          | 3.0 | 84.8 | 2.28 | 0.74     | --        | 4.22         | 2.40 | --               |           |
| 30     | Co.011  | 15.9       | 3      | 78         | 87        | 260    | 450      | 2.0    | 20          | 23.6    | 1.06       | 18.1          | 3.7 | 74.5 | 3.72 | 0.67     | --        | 2.21         | 1.54 | --               |           |
| 30     | Co.011  | 15.9       | 4      | 102        | 111       | 270    | 450      | 2.0    | 20          | 28.3    | 1.26       | 26.5          | 3.4 | 64.9 | 5.23 | 0.60     | --        | 1.67         | 1.14 | --               | G.C.Calib |
| 30     | Co.011  | 15.9       | 5      | 126        | 135       | 278    | 450      | 2.0    | 20          | 28.5    | 1.27       | 34.5          | 4.0 | 55.1 | 6.43 | 0.53     | --        | 1.84         | 1.26 | --               |           |
| 30     | Co.011  | 15.9       | 6      | 150        | 159       | 280    | 450      | 2.0    | 20          | 36.0    | 0.95       | 40.3          | 4.5 | 47.9 | 7.32 | 0.48     | --        | 1.77         | 1.20 | --               |           |
| 30     | Co.011  | 15.9       | 7      | 174        | 183       | 280    | 450      | 2.0    | 20          | 38.5    | 0.77       | 43.7          | 4.7 | 43.7 | 7.90 | 0.45     | --        | 1.93         | 1.29 | --               |           |
| 30     | Co.011  | 15.9       | 8      | 198        | 207       | 280    | 450      | 2.0    | 20          | 36.0    | 1.15       | 38.5          | 4.5 | 50.9 | 6.07 | 0.52     | --        | 2.18         | 1.43 | --               |           |
| 30     | Co.011  | 15.9       | 9      | 222        | 230       | 240    | 450      | 2.0    | 20          | 4.4     | 0.20       | 1.9           | 4.0 | 85.5 | 3.63 | 0.66     | --        | 6.00         | 3.67 | --               |           |

## Feed Gas Rates

| Per No | N2 SLH | H2 SLH | CO SLH | Total SLH |
|--------|--------|--------|--------|-----------|
| 1      | 558    | 225    | 112    | 895       |
| 2      | 558    | 225    | 112    | 895       |
| 3      | 558    | 225    | 112    | 895       |
| 4      | 558    | 225    | 112    | 895       |
| 5      | 558    | 225    | 112    | 895       |
| 6      | 338    | 135    | 67     | 540       |
| 7      | 250    | 100    | 50     | 400       |
| 8      | 160    | 160    | 80     | 400       |
| 9      | 558    | 225    | 112    | 895       |

Table 8

DATE: 03/31/95

COMPARISON OF CONVERSION AND SELECTIVITY OF  
COBALT BASED F-T CATALYSTS AT STARTUP CONDITIONS

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

| Run No   | Cat. No | Cat. wt,g | Conv. % | Prod. Rate | Selectivities    |                 |                   |                  | Alpha GC | Alpha Liq | Catalyst Prom% | Composit. Metal% | Suppt |
|----------|---------|-----------|---------|------------|------------------|-----------------|-------------------|------------------|----------|-----------|----------------|------------------|-------|
| ---      | ---     | ---       | ---     | ---        | %CH <sub>4</sub> | %C <sub>2</sub> | %C <sub>3</sub> + | %CO <sub>2</sub> | ---      | ---       | ---            | ---              | ---   |
| 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.  
H<sub>2</sub> to CO ratio for Runs 16 and 17 was 1.76/1.0.

Cat. No. CAL.06 was H<sub>2</sub> 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 8  
(Continued)

DATE: 03/31/95

COMPARISON OF CONVERSION AND SELECTIVITY OF  
COBALT BASED F-T CATALYSTS AT STARTUP CONDITIONS

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

| Run No   | Cat. No | Cat. wt,g | Conv. % | Prod. Rate | Selectivities    |                 |                   |                  | Alpha GC | Alpha Liq | Catalyst Prom% | Composit. Metal% | Suppt |
|----------|---------|-----------|---------|------------|------------------|-----------------|-------------------|------------------|----------|-----------|----------------|------------------|-------|
| ---      | ---     | ---       | ---     | ---        | %CH <sub>4</sub> | %C <sub>2</sub> | %C <sub>3</sub> + | %CO <sub>2</sub> | ---      | ---       | ---            | ---              | ---   |
| M-4 SBCR |         |           |         |            |                  |                 |                   |                  |          |           |                |                  |       |
| 28       | Co.057  | 15.8      | 18.7    | 0.86       | 5.3              | 1.5             | 92.2              | 0.98             | 0.81     | 0.85      | 1.0La          | 1.0Re            | Si    |
| 29       | Co.061  | 45.4      | 29.0    | 0.46       | 14.4             | 2.6             | 81.6              | 1.53             | 0.72     | 0.80      | 0.0            | 0.5Ru            | Al    |
| 30       | Co.011  | 15.9      | 8.0     | 0.36       | 5.8              | 3.9             | 87.8              | 2.49             | 0.71     | 0.89      | 0.0            | 0.0              | Si    |
| 31       | CAL.12  | 15.9      | 27.6    | 1.26       | 7.9              | 1.0             | 90.0              | 1.11             | 0.79     | 0.84      | 0.3K           | 0.5Ru            | Al    |
| 32       | CAL.11  | 15.9      | 30.6    | 1.40       | 7.8              | 1.4             | 89.6              | 1.18             | 0.80     | 0.84      | 0.3K           | 0.5Ru            | Al    |
| 33       | CAL.13  | 15.9      | 28.1    | 1.28       | 6.4              | 1.4             | 90.9              | 1.29             | 0.81     | 0.85      | 0.3K           | 0.5Ru            | Al    |

Note: Catalysts for all runs screened thru 150 x 400 mesh.  
Catalyst No. Co.061 contains 30 wt.% cobalt.

COMPARISON OF CONVERSION AND SELECTIVITY OF  
COBALT BASED F-T CATALYSTS AT STARTUP CONDITIONS

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

| Run No   | Cat. No | Cat. wt,g | Conv. % | Prod. Rate | Selectivities |     |      |      | Alpha GC | Alpha Liq | Catalyst Prom% | Composit. Metal% | Suppt |
|----------|---------|-----------|---------|------------|---------------|-----|------|------|----------|-----------|----------------|------------------|-------|
|          |         |           |         |            | %CH4          | %C2 | %C3+ | %CO2 |          |           |                |                  |       |
| 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    |
| 35       | CO.041  | 26.0      | 35.7    | 1.00       | 13.6          | 2.1 | 82.9 | 1.41 | 0.79     | 0.82      | 8.5Zr          | 0.5Ru            | Si    |
| 36       | CO.032  | 15.9      | 24.0    | 1.10       | 9.1           | 1.8 | 88.2 | 0.83 | 0.77     | 0.83      | 8.5Zr          | 0.0              | Al    |
| 37       | CO.045  | 15.9      | 14.8    | 0.67       | 8.0           | 1.7 | 89.4 | 0.91 | 0.76     | 0.84      | 4.0Zr          | 0.0              | Si    |
| 38       | Co.058  | 15.9      | 28.0    | 1.28       | 11.9          | 2.1 | 85.1 | 0.91 | 0.75     | 0.85      | 1.0La          | 0.0              | Al    |
| 39       | Co.064  | 15.9      | 34.2    | 1.56       | 13.6          | 2.3 | 82.6 | 1.55 | 0.73     | 0.85      | 8.5Zr          | 0.5Ru            | 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.  
 Catalyst No. CO.029 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.

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

| Period No.<br>----- | Temp.<br>----- | Pres.<br>----- | H <sub>2</sub> /CO Ratio<br>----- |
|---------------------|----------------|----------------|-----------------------------------|
| 1                   | 240 C          | 450psi         | 2.0                               |

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

Flows: N<sub>2</sub>-563 SLH, H<sub>2</sub>-225 SLH, CO-112.5 SLH

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

c) Conversion and selectivities are calculated using N<sub>2</sub> as an internal standard in the GC analysis of the offgas.

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

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

| Run      | Cat.   | Cat. | Conv. | Prod. | Selectivities    |                 |                   |                  | Alpha | Alpha | Catalyst |        | Composit. |
|----------|--------|------|-------|-------|------------------|-----------------|-------------------|------------------|-------|-------|----------|--------|-----------|
| No       | No     | wt,g | %     | Rate  | %CH <sub>4</sub> | %C <sub>2</sub> | %C <sub>3</sub> + | %CO <sub>2</sub> | GC    | Liq   | Prom%    | Metal% | Suppt     |
| 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        |
| 31       | CAL.12 | 15.9 | 27.6  | 1.26  | 7.9              | 1.0             | 90.0              | 1.11             | 0.79  | 0.84  | 0.3K     | 0.5Ru  | Al        |
| 32       | CAL.11 | 15.9 | 30.6  | 1.40  | 7.8              | 1.4             | 89.6              | 1.18             | 0.80  | 0.84  | 0.3K     | 0.5Ru  | Al        |
| 33       | Cal.13 | 15.9 | 28.1  | 1.28  | 6.4              | 1.4             | 90.9              | 1.29             | 0.81  | 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 N<sub>2</sub>.

Cat. No. CAL.06 was H<sub>2</sub> reduced and air stabilized before charging.

Cat. Nos. CAL.08 and CAL.07 were prereduced and wax coated. CAL.08 was calcined in N<sub>2</sub>; CAL.07 was reduced in H<sub>2</sub> without prior calcination. H<sub>2</sub> 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 11

## SBCR CATALYST EXTRACTIONS

| Catalyst No.<br>(Support) | Run No. | Charge                             |        | Recovered            |        | Charge                            |                                       | Recovered                         |                                       | Reduction<br>in Particle<br>Size,<br>% |
|---------------------------|---------|------------------------------------|--------|----------------------|--------|-----------------------------------|---------------------------------------|-----------------------------------|---------------------------------------|----------------------------------------|
|                           |         | (H <sub>2</sub> Reduced)<br>wt, gm | wt, gm | (Oxidized)<br>wt, gm | wt, gm | Particle<br>Size, mvd,<br>microns | Particle<br>Size<br>at 10%<br>microns | Particle<br>Size, mvd,<br>microns | Particle<br>Size<br>at 10%<br>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 11  
(Continued)

SBCR CATALYST EXTRACTIONS

| Catalyst No.<br>(Support) | Run No. | Charge                             |                                   | Recovered            |                                       | Charge                                |                                       | Recovered                             |                                       | Reduction<br>in Particle<br>Size,<br>% |
|---------------------------|---------|------------------------------------|-----------------------------------|----------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|----------------------------------------|
|                           |         | (H <sub>2</sub> Reduced)<br>wt, gm | Particle<br>Size, mvd,<br>microns | (Oxidized)<br>wt, gm | Particle<br>Size<br>at 10%<br>microns | Particle<br>Size<br>at 10%<br>microns | Particle<br>Size<br>at 10%<br>microns | Particle<br>Size<br>at 10%<br>microns | Particle<br>Size<br>at 10%<br>microns |                                        |
| Co.014 (Ti)               | 21      | 15.1                               | 111.70 (1)                        | 15.1                 | 32.65                                 | 106.66                                | 33.49                                 | 4.51                                  |                                       |                                        |
| Co.040 (Ti)               | 22      | 14.5                               | (5)                               | 8.5                  | (5)                                   | 130.40                                | 51.40                                 | --                                    |                                       |                                        |
| Co.047 (Al)               | 23      | 15.8                               | 83.42 (3)                         | 16.95                | 44.41                                 | 76.46                                 | 39.02                                 | 8.34                                  |                                       |                                        |
| Co.049 (Al)               | 24      | 15.6                               | 81.3 (3)                          | 16.54                | 42.39                                 | 70.11                                 | 35.87                                 | 13.8                                  |                                       |                                        |
| Co.047 (Al)               | 25      | 15.6                               | 79.36 (3)                         | 16.69                | 41.72                                 | 69.09                                 | 36.16                                 | 12.94                                 |                                       |                                        |
| Co.031 (Al)               | 26      | 15.9                               | 75.48 (3)                         | 15.37                | 38.34                                 | 68.42                                 | 35.39                                 | 9.35                                  |                                       |                                        |
| Co.029 (Al)               | 27      | 15.9                               | 76.39 (3)                         | 18.28                | 39.56                                 | 68.72                                 | 36.04                                 | 10.04                                 |                                       |                                        |
| Co.043 (Si)               | 7 (M4)  | 15.4                               | (5)                               | 15.1                 | (5)                                   | 85.51                                 | 40.20                                 | --                                    |                                       |                                        |
| Co.006 (Ti)               | 8 (M4)  | 15.0                               | 121.38 (1)                        | 9.09                 | 52.80                                 | 99.31                                 | 38.62                                 | 18.2                                  |                                       |                                        |
| Co.048 (Si)               | 9 (M4)  | 15.4                               | 82.40 (3)                         | 15.85                | 40.94                                 | 70.69                                 | 25.53                                 | 14.2                                  |                                       |                                        |
| CAL.02 (Al)               | 10 (M4) | 15.9                               | 74.40 (3)                         | 16.42                | 37.79                                 | 65.89                                 | 34.14                                 | 11.44                                 |                                       |                                        |
| Co.053 (Al)               | 12 (M4) | 15.9                               | 82.02 (3)                         | 16.95                | 43.10                                 | 69.53                                 | 35.76                                 | 15.23                                 |                                       |                                        |
| Co.054 (Si)               | 13 (M4) | 15.7                               | 101.17 (3)                        | 17.09                | 57.54                                 | 82.37                                 | 37.89                                 | 18.58                                 |                                       |                                        |
| Blend A (Al)              | 14 (M4) | 20.0                               | 86.23 (3)                         | 14.61                | 46.36                                 | 77.43                                 | 42.81                                 | 10.21                                 |                                       |                                        |
| Co.034 (Al)               | 15 (M4) | 13.0                               | (5)                               | 9.52                 | (5)                                   | 88.26                                 | 45.28                                 | --                                    |                                       |                                        |
| CAL.04 (Al)               | 16 (M4) | 16.1                               | 71.54 (3)                         | 21.78                | 36.28                                 | 66.50                                 | 32.82                                 | 7.05                                  |                                       |                                        |
| CAL.08 (Al)               | 17 (M4) | 15.0 (6)                           | 63.12                             | 14.27                | 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                               | 72.75                             | 5.62                 | 36.90                                 | 71.62                                 | 36.55                                 | 1.55                                  |                                       |                                        |
| CAL.06 (Al)               | 20 (M4) | 15.0                               | 72.62                             | (7)                  | 37.33                                 | --                                    | --                                    | --                                    |                                       |                                        |
| Co.053 (Al)               | 29 (M3) | 25.2                               | 75.63                             | 25.8                 | 40.80                                 | 71.09                                 | 38.20                                 | 6.00                                  |                                       |                                        |
| Co.004 (Al)               | 21 (M4) | 15.9                               | 81.38                             | 15.04                | 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 11  
(Continued)

SBCR CATALYST EXTRACTIONS

| Catalyst No.<br>(Support) | Run No.     | Charge                   |      |        | Charge                            |                                   |                                       | Recovered                             |                                   |                                       | Charge                                |                                   |                                       | Recovered |  |  | Reduction<br>in Particle<br>Size,<br>% |
|---------------------------|-------------|--------------------------|------|--------|-----------------------------------|-----------------------------------|---------------------------------------|---------------------------------------|-----------------------------------|---------------------------------------|---------------------------------------|-----------------------------------|---------------------------------------|-----------|--|--|----------------------------------------|
|                           |             | (H <sub>2</sub> Reduced) |      | wt, gm | Recovered<br>(Oxidized)<br>wt. gm | Particle<br>Size, mvd,<br>microns | Particle<br>Size<br>at 10%<br>microns | Particle<br>Size<br>at 10%<br>microns | Particle<br>Size, mvd,<br>microns | Particle<br>Size<br>at 10%<br>microns | Particle<br>Size<br>at 10%<br>microns | Particle<br>Size, mvd,<br>microns | Particle<br>Size<br>at 10%<br>microns |           |  |  |                                        |
|                           |             |                          |      |        |                                   |                                   |                                       |                                       |                                   |                                       |                                       |                                   |                                       |           |  |  |                                        |
| Blend B (Al)              | 22 (M4)     | 30.5                     |      | 31.75  | 77.85                             | 43.10                             | 73.74                                 | 38.80                                 | 5.28                              |                                       |                                       |                                   |                                       |           |  |  |                                        |
|                           | 23 (M4)     | 30.0 (6)                 |      | 14.34  | 63.12                             | 25.60                             | 62.10                                 | 26.32                                 | 1.62                              |                                       |                                       |                                   |                                       |           |  |  |                                        |
|                           | 24 (M4)     | 28.5                     |      | 27.85  | 75.63                             | 40.80                             | 70.69                                 | 35.03                                 | 6.53                              |                                       |                                       |                                   |                                       |           |  |  |                                        |
|                           | 31 (M3)     | 15.0                     |      | 14.67  | 85.58                             | 46.27                             | 74.56                                 | 39.00                                 | 12.88                             |                                       |                                       |                                   |                                       |           |  |  |                                        |
|                           | 25 (M4)     | 15.0                     |      | 14.93  | 99.93                             | 54.62                             | 88.48                                 | 43.26                                 | 11.46                             |                                       |                                       |                                   |                                       |           |  |  |                                        |
|                           | 32 (M3)     | 16.4                     |      | 17.01  | 92.15                             | 49.30                             | 84.92                                 | 40.21                                 | 7.85                              |                                       |                                       |                                   |                                       |           |  |  |                                        |
|                           | 26 (M4)     | 15.6                     |      | 14.63  | 83.05                             | 47.11                             | 81.12                                 | 45.87                                 | 2.32                              |                                       |                                       |                                   |                                       |           |  |  |                                        |
|                           | 33 (M4)     | 31.4                     |      | 31.9   | 84.09                             | 44.40                             | 73.50                                 | 37.10                                 | 12.6                              |                                       |                                       |                                   |                                       |           |  |  |                                        |
|                           | 27 (M4)     | 14.6                     |      | 10.62  | (5)                               | (5)                               | 91.37                                 | 44.07                                 | --                                |                                       |                                       |                                   |                                       |           |  |  |                                        |
|                           | 34 (M3)     | 15.6                     |      | 15.8   | 87.45                             | 47.08                             | 80.89                                 | 43.42                                 | 7.50                              |                                       |                                       |                                   |                                       |           |  |  |                                        |
| Co.060 (Al)               | 35 (M3)     | 26.0                     |      | 24.23  | 87.48                             | 49.26                             | 80.63                                 | 31.75                                 | 7.83                              |                                       |                                       |                                   |                                       |           |  |  |                                        |
|                           | 28 (M4)     | 15.8                     |      | 14.64  | 98.85                             | 55.78                             | 82.94                                 | 36.71                                 | 16.10                             |                                       |                                       |                                   |                                       |           |  |  |                                        |
|                           | 36 (M3)     | 15.9                     |      | 14.66  | 78.22                             | 43.34                             | 78.55                                 | 36.02                                 | 9.81                              |                                       |                                       |                                   |                                       |           |  |  |                                        |
|                           | 37 (M3)     | 15.9                     |      | 15.67  | 95.67                             | 53.59                             | 68.84                                 | 22.06                                 | 28.04                             |                                       |                                       |                                   |                                       |           |  |  |                                        |
|                           | 29 (M4)     | 45.4                     |      | 10     | --                                | --                                | (7)                                   | (7)                                   | --                                |                                       |                                       |                                   |                                       |           |  |  |                                        |
|                           | 30 (M4)     | 15.9                     |      | 15.82  | 83.99                             | 40.60                             | 54.04                                 | 13.72                                 | 35.66                             |                                       |                                       |                                   |                                       |           |  |  |                                        |
|                           | 50%         |                          |      |        |                                   |                                   |                                       |                                       |                                   |                                       |                                       |                                   |                                       |           |  |  |                                        |
|                           | Solids      | 135                      |      | 130    |                                   |                                   |                                       |                                       |                                   |                                       |                                       |                                   |                                       |           |  |  |                                        |
|                           | CAL.12 (Al) | 31 (M4)                  | 15.9 |        | 11.86                             | 78.93                             | 39.94                                 | 73.02                                 | 36.97                             | 7.49                                  |                                       |                                   |                                       |           |  |  |                                        |
|                           |             | 32 (M4)                  | 15.9 |        | 17.87                             | 72.75                             | 38.67                                 | 72.85                                 | 40.91                             | 0                                     |                                       |                                   |                                       |           |  |  |                                        |
| 38 (M3)                   |             | 15.9                     |      | 15.29  | 71.92                             | 38.83                             | 69.91                                 | 36.68                                 | 2.8                               |                                       |                                       |                                   |                                       |           |  |  |                                        |
| 39 (M3)                   |             | 15.9                     |      | 14.86  | 85.69                             | 45.95                             | 78.99                                 | 42.90                                 | 7.82                              |                                       |                                       |                                   |                                       |           |  |  |                                        |
| Co.064 (Al)               |             |                          |      | 83.74  | 44.86                             | 70.37                             | 35.17                                 | 16.0                                  |                                   |                                       |                                       |                                   |                                       |           |  |  |                                        |

(5) Insufficient feed sample

(6) Wax coated

(7) Lost catalyst