

Table 1. List of Co-based FT Catalysts Formulated

CAT. NO.	wt% Co	wt% M	wt% Prom.	Support	Basis	Prepared
Co.001	20%	1% Re	1% La ₂ O ₃ 0.13% K	γ-alumina	U.S. Pat. 4,880,763	P
Co.002	20%	0.43% Ru	1% La ₂ O ₃	γ-alumina	U.S. Pat. 4,413,064	P
Co.003	20%	0.5% Ru	1% La ₂ O ₃	γ-alumina	U.S. Pat. 4,413,064	P
Co.004	20%	0.43% Ru	1% La ₂ O ₃	γ-alumina	Reproduce Co.002	P
Co.005	20%	0.00	0.00	γ-alumina	Base Catalyst	P
Co.005A	20%	0.4% Ru	0.00	γ-alumina	Ru added to calcined Co.005 by IW impreg.	P
Co.006	12%	0.75% Re	0.00	Titania	U.S. Pat. 4,794,009	P
Co.007	20%	0.00	0.00	Titania	Base Catalyst	P
Co.008	20%	0.00	0.00	Silica	UK Pat. Appl. GB 2 125 062 A (Kneaded with excess liquid)	P
Co.009	20%	0.5% Ru	0.00	γ-alumina	Ru-Promoted Catalyst (use Ru Chloride, single-step aqueous IW)	P
Co.010	20%	0.00	0.00	γ-alumina	Base Catalyst (non-calcined)	P
Co.010A	20%	0.4% Ru	0.00	γ-alumina	Ru added to dried Co.010 by IW impreg.	P
Co.011	20%	0.00	0.00	Silica	UK Pat. Appl. GB 2 125 062 A (Kneaded)	P
Co.012	20%	0.00	0.00	Silica	Base Catalyst (Inc. Wetness)	P
Co.013	20%	0.00	0.00	Titania	Base Catalyst like Co.007, but all aqueous	P
Co.014	12%	0.5% Ru	0.00	Titania	Ru-Promoted Catalyst (aqueous: IW co- impregnation)	P
Co.015	20%	0.43% Ru	1% La ₂ O ₃	γ-Alumina	Similar to Co.002, but all aqueous	P

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

CAT. NO.	wt% Co	wt% M*	wt% Prom.	Support	Basis	Preparation
Co.016	20%	0.43% Ru	1% La ₂ O ₃	γ-Alumina	Similar to Co.015, but calcined after Co impregnation	P
Co.017	20%	0.5% Ru	1% La ₂ O ₃	γ-Alumina	Similar to Co.003, but all aqueous	P
Co.018	20%	0.5% Ru	0.00	γ-Alumina	Ru-Promoted Catalyst (single-step, aqueous IW)	P
Co.019	20%	0.5% Ru	0.00	Silica	Ru-Promoted Catalyst (single-step, aqueous IW)	P
Co.020	0.00	0.5% Ru	0.00	γ-Alumina	Ru Base Catalyst	P
Co.020A	20%	0.4% Ru	0.00	γ-Alumina	Co added to dried Co.020 by IW impreg.	P
Co.020B	20%	0.4% Ru	0.00	γ-Alumina	Co added to reduced Co.020 by IW impreg.	P
Co.020C	20%	0.4% Ru	0.00	γ-Alumina	Co added to calcined Co.020 by IW impreg.	P
Co.021	20%	0.00	0.7% Zr	Silica	U.K. Pat. Appl. GB 2 125 062 A (single-step, aqueous kneaded)	P
Co.022	20%	0.00	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%	0.00	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%	0.00	8.5% Zr	Silica	Eur. Pat. Appl. 0 167 215 A2 (non-aqueous, IW, multiple-steps, Zr pre-impregnation)	P
Co.025	20%	0.00	8.5% Zr	Silica	Similar to Co.024 but aqueous Zr pre-impregnation	P

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

CAT. NO.	wt% Co	wt% Ni	wt% Prom.	Support	Basis	Prepared
Co.026	20%	0.00	0.00	Silica (Davison Grade 59)	Similar to Co.012 but different grade silica	P
Co.027	20%	0.5% Ru	0.00	Silica (Davison Grade 59)	Similar to Co.019 but different grade silica	P
Co.028	20%	0.5% Ru	0.5% K	γ -alumina	Ru- and K-Promoted Catalyst (single-step IW)	P
Co.029	30%	0.5% Ru	0.5% K	γ -alumina	Similar to Co.028 but 30% Co	P
Co.030	20%	0.00	0.1% Zr	γ -alumina	Zr-Promoted Catalyst (single-step aqueous IW)	P
Co.031	20%	0.00	1.4% Zr	γ -alumina	Zr-Promoted Catalyst (single-step aqueous IW)	P
Co.032	20%	0.00	8.5% Zr	γ -alumina	Zr-Promoted Catalyst (single-step aqueous IW)	P
Co.033	20%	0.00	8.5% Zr	γ -alumina	Multiple-steps, aqueous IW, Co pre-impregnation	P
Co.034	20%	0.00	8.5% Zr	γ -alumina	Multiple-steps, aqueous IW, Zr pre-impregnation	P
Co.035	20%	0.00	8.5% Zr	Silica	Zr-Promoted Catalyst (single-step aqueous, kneaded)	P
Co.036	20%	0.00	8.5% Zr	Silica	Multiple-steps, aq. Co pre-impreg. by kneading, aqueous IW Zr impreg.	P
Co.037	12%	0.00	0.00	Titania	Similar to Co.013, but TiO ₂ mainly anatase	P
Co.038	12%	0.5% Ru	0.00	Titania	Similar to Co.014, but TiO ₂ mainly anatase	P
Co.039	12%	0.00	0.00	Titania	Similar to Co.007, but only 12% Co	P
Co.040	12%	0.00	0.00	Titania	Similar to Co.013, but only 12% Co	P
Co.041	20%	0.5% Ru	8.5% Zr	Silica	Similar to Co.025, but Ru-promoted	P

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

CAT. NO.	wt% Co	wt% M ₂	wt% Prom.	Support	Basis	Prepared
Co.042	0.00	0.00	8.5% Zr	Silica	Blank Zr-promoted SiO ₂	P
Co.043	20%	0.5% Ru	8.5% Zr 0.5% K	Silica	Similar to Co.041, but K-promoted	P
Co.044	20%	0.00	15% Zr	Silica	Similar to Co.025, but 15% Zr	P
Co.045	20%	0.00	4% Zr	Silica	Similar to Co.025, but 4% Zr	P
Co.046	12%	0.75% Re	4% SiO ₂	Titania	Similar to Co.006, but SiO ₂ -promoted	-
Co.047	20%	0.5% Ru	0.3% K	γ-alumina	Similar to Co.028, but 0.3% K	P
Co.048	20%	0.5% Ru	8.5% Zr 0.3% K	Silica	Similar to Co.043, but 0.3% K	P
Co.049	20%	0.5% Ru	0.1% K	γ-alumina	Similar to Co.047, but 0.1% K	P
Co.050	20%	0.5% Ru	8.5% Zr 0.1% K	Silica	Similar to Co.048, but 0.1% K	P
Co.051	0.00	0.5% Ru	0.00	Titania (R)		P
Co.052	0.00	0.5% Ru	0.00	Titania (A)		P
Co.053	20%	0.5% Ru	0.00	γ-alumina	Similar to Co.018 (New Batch)	P
Co.054	20%	0.00	8.5% Zr 0.3% K	Silica	Similar to Co.043, but without Ru	P
Co.055	20%	1% Re	1% La ₂ O ₃	γ-alumina	Similar to Co.001, but without K	P
Co.056	20%	0.00	8.5% La ₂ O ₃	Silica	Similar to Co.025, but La instead of Zr	P
Co.057	20%	1% Re	1% La ₂ O ₃	Silica	Similar to Co.055, but with SiO ₂ support	P
Co.058	20%	0.00	1% La ₂ O ₃	γ-alumina	Similar to Co.055, but without Re (one-step impreg.)	P
Co.059	20%	0.00	1% La ₂ O ₃	γ-alumina	Similar to Co.015, but without Re (two-step impreg.)	P
Co.060	30%	0.00	0.00	γ-alumina	Similar to Co.005, but with 30% Co	P
Co.061	30%	0.5% Ru	0.00	γ-alumina	Similar to Co.053, but with 30% Co	P

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

CAT. NO.	wt% Co	wt% M	wt% Prom.	Support	Basis	Prepared
Co.062	30%	0.5% Ru	1.5% K	γ -alumina	Similar to Co.029, but with 1.5% K	P
Co.063	20%	0.00	8.5% La	γ -alumina	Multiple-steps, aqueous IW, La pre-impregnation	P
Co.064	20%	0.5% Ru	8.5% Zr	γ -alumina	Multiple-steps, aqueous IW, Zr pre-impregnation	P
Co.065	20%	0.5% Ru	8.5% Zr 0.3% K	γ -alumina	Multiple-steps, aqueous IW, Zr pre-impregnation	P
Co.066	15%	0.5% Ru, 5.0% Fe	0.00	γ -alumina	Ru- and Fe-Promoted Catalyst (single-step, aqueous IW)	P
Co.067	20%	2.0% Pd	0.00	γ -alumina	Pd-Promoted Catalyst (single-step, aqueous IW)	P
Co.068	20%	1.0% Pd	0.00	γ -alumina	Similar to Co.067, but with 1% Pd	P
Co.069	20%	2.0% Ru	0.00	γ -alumina	Similar to Co.053, but with 2% Ru	P
Co.070	13%	0	0.00	γ -alumina	Similar to Co.005, but with 13% Co	P
CAL.01 (97E-13E)	20%	0.5% Ru	0.00	γ -alumina	Similar to Co.018 (Calsicat Prep.)	P
CAL.02 (97E-16B)	20%	0.5% Ru	0.00	γ -alumina	Similar to CAL.01 (New Batch)	P
CAL.03 (97E-13F)	20%	0.5% Ru	0.00	γ -alumina	Multiple-step impreg., Similar to CAL.02	P
CAL.04 (97E-50C)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to Co.047 Stand. Calc. in Air	P
CAL.05 (97E-50D)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to Co.047 Stand. Calc. in N ₂	P
CAL.06 (97E-51A)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to Co.047 Red. and Pas. in Air	P
CAL.07 (97E-51B)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to Co.047 Red. and Protected in Paraffin (51.3% Cat. Conc.)	P
CAL.08 (97E-51C)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to Co.047 Calc., Red. and Protected in Paraffin (54.4% Cat. Conc.)	P

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

CAT. NO.	wt% Co	wt% M	wt% Prom.	Support	Basis	Prepared
CAL.09 (97E-69C)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to CAL.05, Reduced and Protected in Soya (51.7% Cat. Conc.)	P
CAL.10 (97E-79A)	20%	0.5% Ru	0.3% K	γ -alumina (Condea)	Similar to CAL.05, but on Condea Al_2O_3	P
CAL.11 (29F-07B)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to CAL.05	P
CAL.12 (29F-05D)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to CAL.05	P
CAL.13 (29F-07E)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to CAL.05	P
Fe.01	0%	30%Fe	1.5%Cu	Silica		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	Prepar.
WGS.01	0	5.0% Cu	0	γ -alumina	single-step, aqu. IW	P
WGS.02	0	5.0% Cu	10% Zn	γ -alumina	single-step, aqu. IW	P
WGS.03	0	5.0% Cu	4.0% Cr	γ -alumina	single-step, aqu. IW	P
WGS.04	0	0	4.0% Cr	γ -alumina	single-step, aqu. IW	P
WGS.05	0	0	4.0% Mn	γ -alumina	single-step, aqu. IW	P
WGS.06	0	5.0% Cu	4.0% Mn	γ -alumina	single-step, aqu. IW	P
WGS.07	0	4.0% Fe	0	γ -alumina	single-step, aqu. IW	P
WGS.08	0	4.0% Fe	4.0% Cr	γ -alumina	single-step, aqu. IW	P
WGS.09	0	5.0% Cu	4.0% Cr	γ -alumina	Similar to WGS.03	P
CoW.01	20%	5.0% Cu	10% Zn	γ -alumina	multiple-steps, aqu. IW, Cu,Zn pre-impr.	P
CoW.02	20%	5.0% Cu	4.0% Cr	γ -alumina	multiple-steps, aqu. IW, Cu,Cr pre-impr.	P
CoW.03	10%	5.0% Cu	4.0% Cr	γ -alumina	similar to CoW.02 (10% Co only)	P
CoW.04	10%	10% Cu	8.0% Cr	γ -alumina	similar to CoW.03; 10% Cu and 8% Cr	P
CoW.05	20%	5.0% Cu	4.0% Cr	γ -alumina	similar to CoW.02 with support calcined at 750°C	P
CoW.06	20%	5.0% Cu	4.0% Cr	Silica	multiple-steps, aqu. IW, Cu,Cr pre-impr.	P
CoW.07	20%	5.0% Cu	4.0% Cr	Silica	similar to CoW.06, but with support calcined at 750°C	P
CoW.08	30%	5.0% Cu	4.0% Cr	γ -alumina	Similar to CoW.05, but with 30% Co	P
CoW.09	20%	10.0% Cu	8.0% Cr	Silica	similar to CoW.06, but with 10% Cu and 8% Cr	P
CoW.10	10% Co, 10% Fe	0.5% Ru	0	γ -alumina	Single Step, IW	P
CoW.11	10% Co, 10% Fe	0.5% Ru	0.5% K	γ -alumina	Single Step, IW	P
CoW.12	10% Co, 10% Fe	0.5% Ru	0	Silica	Single Step, IW	P
CoW.13	10% Co, 10% Fe	0.5% Ru	0	γ -alumina	Similar to CoW.10 (2nd batch)	P

Table 3. Summary of Physical Properties

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

Table 3. Summary of Physical Properties (contd.)

CATALYST	Composition	BET Surface Area (m ² /g)	Pore Volume (cc/g)	Average Pore Dia. (Å)	Average Part. Size (µm)
Co.013	20Co/T				
Co.014	12Co/0.5Ru/T	15	0.12	328	111
Co.015	20Co/0.43Ru/ 1La ₂ O ₃ /A	141	-	-	67
Co.016	20Co/0.43Ru/ 1La ₂ O ₃ /A	116	-	-	79
Co.017	20Co/0.5Ru/ 1La ₂ O ₃ /A	123	-	-	73
Co.018	20Co/0.5Ru/A	158	-	-	69
Co.019	20Co/0.5Ru/S				110
Co.021	20Co/0.7Zr/S	213	1.12	210	74
Co.023	20Co/1.4Zr/S	213	-	-	
Co.024	20Co/8.5Zr/S	215	1.08	202	
Co.025	20Co/8.5Zr/S	208	0.97	187	87
Co.026	20Co/S(59)	184	-	-	
Co.027	20Co/S(59)	189	-	-	
Co.028	20Co/0.5Ru/0.5K/A	161	0.33	82	80
Co.029	30Co/0.5Ru/0.5K/A	140	-	-	76
Co.031	20Co/1.4Zr/S				75
Co.032	20Co/8.5Zr/A	155	0.30	77	
Co.034	20Co/8.5Zr/A	150	0.31	83	
Co.035	20Co/8.5Zr/S	207	1.21	233	89
Co.036	20Co/8.5Zr/S	209	-	-	
Co.037	12Co/T(A)	38	-	-	
Co.039	12Co/T(R)	13	-	-	
Co.040	12Co/T				130
Co.041	20Co/0.5Ru/8.5Zr/S	214	-	-	-
Co.044	20Co/15Zr/S				92

Table 3. Summary of Physical Properties (contd.)

CATALYST	Composition	BET Surface Area (m ² /g)	Pore Volume (cc/g)	Average Pore Dia. (Å)	Average Part. Size (µm)
Co.047	20Co/0.5Ru/0.3K/A	162	0.31	78	83
Co.048	20Co/0.5Ru/0.3K/ 8.5Zr/S				82
Co.049	20Co/0.5Ru/0.3K/A				81
Co.053	20Co/0.5Ru/A				75
Co.054	20Co/0.3K/8.5Zr/S				101
Co.055	20Co/1Re/ 1La ₂ O ₃ /A				86
Co.056	20Co/8.5La ₂ O ₃ /S				100
CAL.01	20Co/0.5Ru/A	178	0.34	76	
CAL.02	20Co/0.5Ru/A	158	-	-	74
CAL.03	20Co/0.5Ru/A	158	-	-	
CAL.04	20Co/0.5Ru/0.3K/A	151			72
CAL.05	20Co/0.5Ru/0.3K/A	163			73
CAL.06	20Co/0.5Ru/0.3K/A	162			72
CAL.07	20Co/0.5Ru/0.3K/A	-			
CAL.08	20Co/0.5Ru/0.3K/A	-			63
CAL.09	20Co/0.5Ru/0.3K/A				63
CAL.10	20Co/0.5Ru/0.3K/A	142	-	-	83
CAL.11	20Co/0.5Ru/0.3K/A	177	0.34	76	72
CAL.12	20Co/0.5Ru/0.3K/A	175	0.33	75	73
CAL.13	20Co/0.5Ru/0.3K/A	172	0.33	77	81
WGS.02	5Cu/A	159	-	-	-
WGS.03	5Cu/4Cr/A	190	-	-	-
CoW.01	20Co/5Cu/10Zn/A	121	-	-	-

Table 3. Summary of Physical Properties (contd.)

CATALYST	Composition	BET Surface Area (m ² /g)	Pore Volume (cc/g)	Average Pore Dia. (Å)	Average Part. Size (µm)
CoW.02	10Co/5Cu/4Cr/A	137	0.27	79	-
CoW.05	20Co/5Cu/4Cr/A	87	0.26	120	-

Table 4. H₂ Chemisorption^a and TPR Results

Catalyst	H ₂ Chemisorption				TPR	
	Total (μ mol H ₂ /g cat)	Irrev. (μ mol H ₂ /g cat)	Average (μ mol H ₂ /g cat)	% Disp.	% Co Red. ^c (TPR calc. catal.)	% Red. ^d (stand. red.)
Co.001	174 \pm 5	157 \pm 5		10.2		
Co.002	155	130		9.1		
Co.003	165	140		9.6		
Co.004 ^f	(1) 205	185	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 ^g	(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 ^h					95	

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

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

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

Catalyst	H ₂ Chemisorption ^a				TPR	
	Total (μ mol H ₂ /g cat)	Irrev. (μ mol H ₂ /g cat)	Average d. (nm)	% Disp.	%Co Red. (TPR calc. catal.)	% Red. (stand. red.)
Co.041	70	55		4		
Co.043	137	109		8	86	
Co.047	146	-	9.6	7.3		
Co.053 ¹	(1) 168	139	8	8.4	97	
	(2) 101	76	14	5.2	82	
	(3) 138	117	10	6.9	47	
Co.054					57	
Co.055 ¹	(1) 165	139	8.5	8.3	78	
	(2) 179	163	8	9.0	50	
	(3) 103	84	14	5.2	76	
	(4) 192	165	7	9.6	-	
Co.056					58	
Co.60	65		14.4	2.1		
Co.61	277		7.6	9.2		
Co.66	-		-	-	81	
Co.067	-		-	-	88	
Co.068	-		-	-	76	
Co.069	167		8.0	8.4	98	
CoW.10	-			--	71	
CAL.01	169	-	8.3(5.8 ^e)	4.4 ^e	54	
CAL.02	-	-	(6.3 ^e)	5.1 ^e	55	
CAL.03	-	-	5.7 ^e	4.2 ^e	85	
CAL.04	93		15.1(5.5 ^e)	3.5 ^e		
CAL.05	100		14.1(5.6 ^e)	4.4 ^e		
CAL.06			5.7 ^e	4.2 ^e		
CAL.10			7.2 ^e	3.7 ^e		
CAL.11	171		8.3	8.5		

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

Catalyst	H ₂ Chemisorption				TPR	
	Total (μ mol/ H ₂ /g cat)	Irreversible (μ mol/ H ₂ /g cat)	Average d _p (nm)	% Disp.	% Co Red. ^c (TPR calc. catal.)	% Red. (stand. red.)
CAL.12	146		9.6	7.3		
CAL.13	180		7.8	9.0		

(a) static H₂ chemisorption at 100°C

(b) Est. assuming $H_{int}/Co_s = 1$, $5.46 \times 10^{-20} \text{ m}^2/Co_s$, and $d_p = 5/S_{Co}/\rho$

S_{Co} is based on amt. Co reducible during standard reduction

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

(d) % Co reduced after standard reduction procedure

(e) Based on CO chemisorption

(f) (1)=uncalcined; (2)=flow calcined in air and reduced in H₂; (3)=ROR (4)=calcined in He; (5)=calcined in nitrogen

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

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

(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 Reactor Data

Catalyst	Run	Prep	CO Conv (%)	Rate g CH ₂ /g cat/h	R-CO+ g CH ₂ /g cat/h	R (CO) mol/mol Co/s	wt% CH ₄	alpha	CO ₂ (%) (CO)	g/g cat/h	E act kcal/mol	Comment
Co.001	4	(1)	2.6	0.116	0.056	6.8E-04	19.6	0.76	0.4	0.061		NSH**
Co.002	4	(2)	6.7	0.258	0.082	1.5E-03	26.1	0.64	0.1	0.012		NS
Co.003	1	(3)	5.5	0.185	0.044	1.1E-03	30.8	0.57			28.9	old startup
Co.004	1	(2) s	4.3	0.291	0.086	1.7E-03	30.4	0.62	0.1	0.025	25.9	NSH
"	2	u	11.2	0.517	0.155	3.0E-03	28.9	0.61	0.1	0.038		NSH
"	2h	u	47.6	0.548	0.211	3.2E-03	21.9	0.64	2.3	0.090		NSH, high conv. study
"	2a	f	3.8	0.177	0.063	1.0E-03	25.5	0.65	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	0.1	0.036		NSH
"	3h	u	27.0	0.506	0.164	3.0E-03	27.3	0.62	0.8	0.048		NSH, high conv. study
"	4	u	1.8	0.427	0.241	2.5E-03	24.0	0.79	0.1	0.078		NSH, 10 atm
"	5	f	4.5	0.288	0.150	1.7E-03	19.4	0.75	0.1	0.03		NSH
"	6	n	6.9	0.466	0.151	2.7E-03	27.8	0.61	0.2	0.044		NSH
"	7	ROR	3.9	0.225	0.072	1.3E-03	28.8	0.61	0.2	0.042		NSH
"	8	He	5.8	0.399	0.144	2.3E-03	27.2	0.66	0.1	0.028		NSH
Co.005	2	(1)	3.3	0.087	0.037	5.1E-04	21.4	0.66	0.1	0.005		NS
"	2a		2.5	0.066	0.021	3.9E-04	25.9	0.59	0.1	0.004		CO:H ₂ :Ar = 1:2:2
"	2b		2.4	0.064	0.021	3.7E-04	26.3	0.60	0.1	0.006		+ H ₂ O (eq. 7.5% CO conv.)
"	3		3.3	0.077	0.024	4.5E-04	28.4	0.62	0.1	0.013		NSH
"	4		4.0	0.069	0.021	4.0E-04	30.0	0.62	0.2	0.009	25.1	NSH
"	5		3.9	0.171	0.084	1.0E-03	26.8	0.76	0.1	0.018		NSH, 10 atm
"	6		2.1	0.129	0.044	7.6E-04	25.7	0.64	0.1	0.017		NSH
"	7		6.7	0.084	0.040	4.9E-04	18.8	0.70	0.1	0.003		S2
"	8		2.7	0.154	0.067	9.0E-04	22.6	0.71	0.1	0.019		D (1:2), NSH
"	8a		2.5	0.140	0.059	8.4E-04	23.4	0.72	0.1	0.019		Ar added to rxn mix
"	8b		4.2	0.239	0.045	1.4E-03	40.0	0.60	0.1	0.032		Rxn @ 240 °C
"	8c		3.5	0.196	0.026	1.1E-03	49.6	0.59	0.1	0.049		Rxn @ 260 °C
"	8d		2.5	0.140	0.059	8.4E-04	23.4	0.72	0.1	0.019		Rxn @ 280 °C
"	9		1.5	0.082	0.025	4.8E-04	27.7	0.60	0.1	0.014		D (1:4), NSH
"	9a		1.4	0.075	0.020	4.4E-04	29.9	0.61	0.1	0.016		Ar added to rxn mix
"	9b	(1)	1.4	0.078	0.004	4.5E-04	62.9	0.58	0.3	0.055		Rxn @ 280 °C
"	10		1.9	0.106	0.045	6.2E-04	23.0	0.70	0.1	0.016		D (1:2), NSH
"	10a		1.6	0.090	0.024	5.3E-04	25.3	0.68	0.1	0.017		Ar added to rxn mix
"	10b		1.8	0.100	0.005	5.9E-04	48.0	0.65	0.2	0.037		Rxn @ 280 °C
"	10c		0.4	0.024	0.010	2.3E-04	25.9	0.76	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	0.1	0.034		NSH
Co.005b	1	(1)	2.4	0.040	0.024	2.3E-04	13.9	0.74	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	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	0.1	0.006		NSH
Co.007	1	(5)	3.2	0.024	33	7.0E-03	49.8	0.50	0.2	0.004		NSH
Co.009	1	(1)	4.9	0.346			31.1	0.57	0.1	0.020		NSH
"	2		4.9	0.338			31.1	0.58	0.1	0.026		NSH
Co.010a	1	(4b) s	3.5	0.246	0.076	1.4E-03	29.5	0.62	0.2	0.040		NSH
"	2		4.1	0.262	0.080	1.5E-03	30.0	0.61	0.1	0.022		NSH

Table 5. Summary of Fixed Bed Reactor Data (cont.'d)

Catalyst	Run	Prep	CO Conv (%)	Rate g CH ₂ /g cat/hr	P-C6+ g CH ₂ /g cat/hr	R(Co) mol/mol Co/s	wt% CH ₄	alpha	CO ₂ (%)	p/g cat/hr	E _{act} kcal/mol	Comment
Co.011	2	(6b)	2.9	0.094	0.037	5.5E-04	22.4	0.61	0.3	0.030		NSH
Co.012	1	(1)	3.8	0.083	0.027	4.8E-04	26.3	0.64			22.5	slow CO startup (60 min)
"	2		4.4	0.085	0.030	5.0E-04	29.1	0.64	0.3	0.018		NSH
"	3		2.1	0.081	0.026	4.7E-04	28.6	0.66	0.4	0.049		NSH
"	4		2.5	0.105	0.035	6.2E-04	28.4	0.61	0.4	0.023		NSH
Co.014	1	(1)	1.5	0.028	0.009	2.8E-04	32.3	0.63	0.1	0.003		NSH
"	2		2.6	0.034	0.013	3.3E-04	27.7	0.69	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	0.1	0.011		slow CO startup (120 min)
"	2	f	7.0	0.388	0.135	2.3E-03	26.4	0.64	0.1	0.011		NSH
"	3	u	6.7	0.375	0.123	2.2E-03	28.2	0.63	0.2	0.011		NSH
Co.016	1	(4a) s	5.2	0.161	0.035	9.4E-04	33.6	0.56				slow CO startup (30 min)
"	2	f	5.1	0.291	0.112	1.7E-03	25.1	0.68	0.1	0.01		NSH
Co.017	2	(1) s	4.6	0.139	0.066	8.2E-04	22.0	0.69	0.1	0.012		NS
"	2a	s	3.7	0.111	0.043	6.5E-04	25.9	0.64	0.1	0.011		CO:H ₂ :Ar = 1:2:2
"	2b	s	3.4	0.102	0.039	6.0E-04	26.9	0.65	0.1	0.013		+ H ₂ O (eq. 7.5% CO conv.)
"	3	f	4.9	0.274	0.111	1.6E-03	23.0	0.67	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	0.1	0.013		NS
"	2a	s	2.7	0.133	0.041	7.8E-04	33.2	0.64	0.1	0.011		CO:H ₂ :Ar = 1:2:2
"	2b	s	3.0	0.147	0.045	8.6E-04	33.6	0.63	0.1	0.015		+ H ₂ O (eq. 7.5% CO conv.)
"	3	s	4.1	0.290	0.086	1.7E-03	30.0	0.62	0.1	0.022		NSH
"	4	s	3.6	0.340	0.180	2.0E-03	25.4	0.80	0.1	0.041		NSH, 10 atm
"	5	f	7.5	0.470	0.136	2.8E-03	29.0	0.60	0.3	0.055		NSH
Co.018Cl	1	(1)	4.5	0.320	0.075	1.9E-03	33.5	0.57	0.1	0.018		NSH
Co.019	1	(1)s	4.4	0.088	0.047	5.2E-04	15.2	0.74				NS
"	2	s	2.2	0.085	0.046	4.9E-04	18.9	0.73	0.3	0.040		NSH
"	3	f	3.4	0.142	0.071	8.3E-04	19.3	0.72	0.2	0.025		NSH
Co.020a	1	(4) s	4.6	0.343	0.085	2.0E-03	33.5	0.57	0.1	0.024		NSH
"	2		4.4	0.315	0.086	1.8E-03	31.2	0.59	0.1	0.028		NSH
Co.020b	1	(4b) s	4.4	0.311	0.084	1.8E-03	31.7	0.58	0.2	0.051		NSH
Co.020c	1	(4a) s	4.0	0.287	0.083	1.7E-03	30.4	0.60	0.1	0.017		NSH
Co.021	1	(6b)	3.4	0.109	0.032	6.4E-04	27.3	0.62	0.1	0.012	28.2	NSH
"	2		3.6	0.114	0.035	6.7E-04	28.0	0.56	0.1	0.012		NSH
Co.022	1	(6c)	3.8	0.121	0.037	7.1E-04	26.7	0.55	0.1	0.015	30.1	NSH
Co.023	1	(6c)	3.8	0.123	0.038	7.2E-04	28.3	0.56	0.2	0.023	29.5	NSH
Co.024	1	(7)	5.1	0.165	0.047	9.7E-04	32.8	0.62	0.5	0.055		NSH
"	2		5.7	0.182	0.060	1.1E-03	28.7	0.62	0.3	0.035		NSH
Co.025	1	(4)	5.0	0.160	0.062	9.4E-04	23.5	0.63	0.2	0.019	26.9	NSH
"	2		2.0	0.113	0.037	6.6E-04	26.8	0.61				NSH
"	2a		0.7	0.040	0.007	2.3E-04	49.5	0.66				Rxn @ 280 °C
Co.026	1	(1)	4.4	0.129	0.043	5.0E-04	26.9	0.62	0.2	0.022		NSH
"	1h		22.9	0.170	0.072	6.6E-04	22.6	0.67	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	0.2	0.026		NSH
"	1h		17.8	0.180	0.085	7.0E-04	19.4	0.71	1.2	0.011		NSH, high conv. study

Table 5. Summary of Fixed Bed Reactor Data (cont.'d)

Catalyst	Run	Prep	CO Conv (%)	Rate g CH ₂ /g cat/hr	R-C6+ g CH ₂ /g cat/hr	R (Co) mol/mol Co/s	wt% CH ₄	alpha	CO ₂		E act kcal/mol	Comment
									(%)	g/g cat/hr		
Co.028	1	(4)	3.8	0.146	0.076	5.7E-04	18.2	0.76	0.2	0.031	28.4	NSH
"	2		4.3	0.167	0.105	6.5E-04	14.7	0.80	0.2	0.030		NSH
"	3		4.5	0.206	0.126	8.0E-04	15.5	0.79	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	0.2	0.026		NSH
Co.031	1	(1)	1.9	0.060	0.022	3.5E-04	26.1	0.64	0.3	0.031		NSH
Co.032	1	(1)	3.3	0.183	0.079	1.1E-03	22.0	0.70	0.1	0.022		NSH
Co.033	1	(1)	1.3	0.073	0.027	4.3E-04	24.1	0.67	0.1	0.020		NSH
Co.034	1	(4)	5.0	0.275	0.107	1.6E-03	24.0	0.67	0.1	0.018		NSH
Co.035	2	(6)	4.6	0.147	0.068	8.6E-04	22.0	0.69	0.2	0.019		NSH
Co.036	2	(6c)	3.9	0.125	0.045	7.3E-04	28.9	0.67	0.1	0.013		NSH
Co.037	1	(4a)	2.7	0.053	0.011	5.2E-04	32.8	0.59				NSH
Co.038	1	(4a)	4.5	0.051	0.018	4.9E-04	25.1	0.68	0.3	0.013	24.2	NSH
Co.039	1	(5)	1.1	0.021	0.004	2.0E-04	57.2	0.64	0.2	0.010	25.6	NSH, cracking in the line
"	2		3.9	0.049	0.007	4.7E-04	42.4	0.48	0.2	0.009		NSH
Co.040	1	(4a)	1.9	0.037	0.004	3.7E-04	45.2	0.53	0.2	0.007		NSH
"	2		2.8	0.033	0.004	3.3E-04	44.6	0.46	0.2	0.007		NSH
Co.041	1	(4)	3.5	0.136	0.042	8.0E-04	40.7	0.69	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	0.6	0.048	35.1	NSH, 2.5 hr on-stream
"	2		3.7	0.078	0.045	4.6E-04	16.3	0.78	0.5	0.035		NSH
Co.044	1	(4)	3.1	0.179	0.081	1.0E-03	22.7	0.73	0.3	0.020		NSH
Co.045	1	(4)	2.6	0.161	0.076	9.4E-04	22.2	0.73	0.3	0.022		NSH
Co.047	1	(4)	6.4	0.263	0.128	1.5E-03	21.3	0.73	0.3	0.040	26.6	NSH
Co.048	1	(4)	3.5	0.162	0.094	9.5E-04	16.3	0.77	0.2	0.027	28.0	NSH
Co.049	1	(4)	7.1	0.366	0.153	2.1E-03	23.4	0.69	0.3	0.043		NSH
"	2		6.0	0.388	0.160	2.3E-03	23.3	0.68	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	0.3	0.059		NSH
"	3h	f	44.9	0.457	0.178	2.7E-03	26.5	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	0.2	0.049		NSH
"	1h		28.5	0.417	0.145	2.4E-03	26.8	0.64	1.6	0.081		NSH, high conv. study
"	2	f	6.6	0.433	0.174	2.5E-03	23.4	0.63	0.2	0.052		NSH
"	3		7.8	0.453	0.143	2.7E-03	27.6	0.62	0.1	0.027		NSH
"	3h		31.5	0.457	0.164	2.7E-03	25.4	0.65	0.9	0.044		NSH, high conv. study
"	4	u	6.1	0.426	0.142	2.5E-03	28.3	0.65	0.1	0.030		NSH
"	5	ROR	5.6	0.360	0.118	2.1E-03	27.9	0.64	0.2	0.034		NSH, ROR
"	6	f	8.2	0.485	0.163	2.8E-03	28.9	0.64	0.1	0.030		NSH
"	7	f	9.4	0.552	0.147	3.2E-03	34.3	0.60	0.1	0.044		NSH, Rxn @ 227 °C
"	7a	f	1.7	0.099	0.018	5.8E-04	38.1	0.60	0.2	0.028		Rxn @ 245 °C, T surge 280 °C
"	7b	f	2.0	0.119	0.031	7.0E-04	32.1	0.62	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	0.1	0.036		NSH
"	8a	f	6.3	0.368	0.103	2.2E-03	32.8	0.65	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	0.1	0.033		Rxn @ 240 °C, T surge 275 °C
"	9	f	4.3	0.470	0.225	2.8E-03	21.6	0.69	0.2	0.046		D (1:2), NSH
"	9a	f	7.5	0.411	0.067	2.4E-03	46.9	0.62	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	0.1	0.046	Rxn @ 240 °C	

Table 5. Summary of Fixed Bed Reactor Data (cont.'d)

Catalyst	Run	Prep	CO Conv (%)	R _{ac} g CH ₂ /g cat/hr	R-C ₆ + g CH ₂ /g cat/hr	R (Co) mol/mol Co/s	wt% CH ₄	alpha	CO ₂ (%)	g/g cat/hr	E _{act} kcal/mol	Comment
Co.053	10		5.6	0.304	0.091	1.8E-03	29.2	0.60	0.2	0.008		D(1:2) , NSH
"	10a		11.9	0.647	0.116	3.8E-03	42.7	0.59	0.2	0.046		Rxn @ 240 °C
"	10b		7.5	0.411	0.067	2.4E-03	46.9	0.62	0.4	0.070		Rxn @ 260 °C
"	10c		3.0	0.163	0.035	9.6E-04	38.8	0.69	0.3	0.054		Rxn @ 280 °C
"	11		5.4	0.289	0.102	1.7E-03	26.9	0.64	0.1	0.022		D (1:2) ,NSH
"	11a		3.8	0.205	0.047	1.2E-03	38.7	0.69	0.3	0.060		Rxn @ 280 °C
"	12	f	8.1	0.433	0.145	2.5E-03	26.6	0.60	0.2	0.029		D (1:2) ,NSH
"	12a	f	5.3	0.283	0.063	1.7E-03	39.4	0.69	0.4	0.083		Rxn @ 280 °C
"	12b	f	1.4	0.080	0.054	4.7E-04	20.0	0.78	0.1	0.02		Rxn @ 220
"	13	f	8.3	0.444	0.143	2.6E-03	29.3	0.65	0.2	0.037		Cal(10hr) & red after run 12
"	14		6.7	0.375	0.161	2.2E-03	24.8	0.74	0.1	0.025		Cal(24hr) & red after rxn @EI
Co.054	1	(1)	1.2	0.041	0.023	2.4E-04	17.8	0.79	0.2	0.014		NSH
Co.055	1	(1) f	9.1	0.490	0.159	2.9E-03	28.9	0.63	0.2	0.034		NSH
"	2	u	4.9	0.290	0.105	1.7E-03	25.7	0.65	0.2	0.022		NSH, T surge
"	3	u	11.0	0.611	0.193	3.6E-03	29.4	0.60	0.2	0.033		NSH
"	4	u	5.9	0.380	0.124	2.2E-03	28.3	0.60	0.2	0.047		NSH
"	5	u	6.6	0.409	0.135	2.4E-03	29.6	0.59	0.2	0.030		NSH
"	6	ROR	7.5	0.469	0.145	2.7E-03	30.9	0.63	0.2	0.023		NSH
"	7	n	7.5	0.466	0.119	2.7E-03	33.5	0.60	0.2	0.031		NSH
"	8		6.1	0.344	0.108	2.0E-03	29.7	0.66				NSH
"	8a		0.7	0.037	0.005	2.3E-04	41.2	0.66				Rxn @ 280 °C
Co.056	1	(1)	2.4	0.137	0.054	8.0E-04	23.9	0.69	0.1	0.029		NSH
"	2	u	2.2	0.137	0.054	8.0E-04	23.4	0.68	0.1	0.033		NSH
Co.057	1	(1)	2.8	0.171	0.078	1.0E-03	23.4	0.73	0.1	0.029		NSH
Co.060	1	(2)	3.8	0.244	0.097	1.4E-03	25.0	0.69	0.1	0.023		NSH
Co.061	1	(2)	9.4	0.556	0.188	3.3E-03	29.2	0.67	0.1	0.035		NSH
Co.064	1	(2)	7.1	0.384	0.130	2.2E-03	27.5	0.64	0.1	0.028		NSH
Co.066	1	(1)	1.7	0.100	0.031	7.8E-04	27.7	0.67				NSH
"	1a		0.9	0.050	0.009	3.9E-04	32.9	0.68				Rxn @ 280 °C
Co.067	1	(1)	2.2	0.130	0.045	7.5E-04	25.0	0.67				NSH
"	1a		1.6	0.090	0.010	5.2E-04	46.9	0.61				Rxn @ 280 °C
Co.068	1	(1)	4.0	0.220	0.065	1.3E-03	28.8	0.62				NSH
"	1a		1.7	0.100	0.010	6.8E-04	42.7	0.57				Rxn @ 280 °C
"	2		4.5	0.250	0.066	1.5E-03	31.4	0.61				NSH
"	2a		7.6	0.420	0.038	2.5E-03	50.0	0.46				Rxn @ 240 °C
"	3		5.7	0.300		1.8E-03	30.0	0.63				NSH
"	3a		7.5	0.400		2.4E-03	54.3	0.54				Rxn @ 260 °C
Co.069	1	(1)	5.5	0.310		1.8E-03	29.0	0.66				NSH
CAL.01	1	(1)	4.8	0.181	0.068	1.1E-03	24.4	0.66	0.3	0.036		NSH, temp. surge (startup)
"	2		7.4	0.491	0.142	2.9E-03	28.7	0.61	0.4	0.083		NSH
"	3		2.5	0.164	0.053	9.6E-04	25.6	0.63	0.2	0.052		NSH, HT, re-reduced
"	4		7.3	0.483	0.103	2.8E-03	35.8	0.57	0.2	0.098		NSH, HT, re-calcined

Table 5. Summary of Fixed Bed Reactor Data (cont.'d)

Catalyst	Run	Prep	CO Conv (%)	Rate g CH ₂ /g cat/hr	R-C6+ g CH ₂ /g cat/hr	R (Co) mol/mol Co/s	wt% CH ₄	alpha	CO ₂ (%)	g/g cat/hr	E act kcal/mol	Comment
CAL.02	1	(1)	6.1	0.379	0.121	2.2E-03	27.3	0.63	0.2	0.040		NSH
CAL.03	1	(1)	7.3	0.459	0.133	2.7E-03	29.0	0.60	0.2	0.048		NSH
CAL.04	1	(1)	4.1	0.234	0.123	1.4E-03	19.1	0.71	0.2	0.026		NSH
CAL.05	1	(1)	4.7	0.274	0.134	1.6E-03	20.8	0.75	0.2	0.026		NSH
CAL.06	1	(1)	5.8	0.267	0.135	1.6E-03	20.7	0.74	0.2	0.021		NSH
CAL. 10	1	(1)	3.5	0.196	0.097	1.1E-03	23.5	0.74	0.2	0.05		NSH
CAL.11	1	(1)	5.2	0.281	0.147	1.6E-03	20.0	0.75	0.2	0.029		NSH
CAL.12	1	(1)	5.2	0.288	0.143	1.7E-03	21.6	0.73	0.2	0.035		NSH
CAL.13	1	(1)	4.6	0.258	0.142	1.5E-03	18.0	0.77	0.2	0.024		NSH
CoW.01	1	(4a)	1.2	0.016	0.003	9.5E-05	30.2	0.58	0.2	0.006		NSH, reduced at 230 °C
"	1		0.5	0.007	0.001	3.4E-05	42.1	0.51	0.1	0.003		NSH, re-reduced at 350 °C
"	2		0.2	0.006	0.000	3.4E-05	40.9	0.51	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	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	0.2	0.008		S2, reduced at 350 °C
"	2	u	4.7	0.058	0.011	3.4E-04	34.8	0.50	0.2	0.009		S2
"	3	(4c)	0.8	0.020	0.005	1.2E-04	32.8	0.64				NSH
"	3a	(4c)	3.5	0.100	0.008	6.0E-04	54.2	0.58				Rxn @ 280°C
CoW.06	1	(4a)	3.3	0.041	0.012	2.4E-04	26.0	0.59	0.2	0.007		S2, reduced at 250 °C
"	2	u	2.6	0.032	0.004	1.9E-04	39.3	0.46	0.3	0.012		S2
CoW.06	2		17.0	0.207	0.004	1.2E-03	68.7	0.32	1.7	0.07		S2, rxn. at 280 °C
CoW.10	1	?	1.2	0.070	0.021	8.2E-04	31.8	0.67				NSH
CoW.10	1a	?	0.9	0.050	0.010	5.9E-04	36.6	0.66				Rxn @ 280°C
UOP	1	(1)	7.8	0.298	0.104	1.7E-03	22.6	0.61	0.2	0.023		NSH

Table 5. Summary of Fixed Bed Reactor Data (cont.'d)

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°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. Results of Hydrogenation of Isobutene in the Presence of CO^a

Catalyst	Rate ^b 120°C ($\mu\text{mol/g}\cdot\text{s}$)	TOF 120°C ($10^{-3}/\text{s}$)	Rate 180°C ($\mu\text{mol/g}\cdot\text{s}$)	TOF 180°C ($10^{-3}/\text{s}$)	E _a (kJ/mol)
Co.005	0.031	0.33	0.86	9.1	82
Co.053	0.068	0.20	3.1	9.3	94
Co.069	0.075	0.19	3.2	8.2	97
Co.067	0.543	-	14.6	-	83
Co.068	0.550	-	18.9	-	89
Co.066	0.046	-	1.4	-	85
CoW.10	0.040	-	1.2	-	87

- a reaction conditions: H₂:IB:CO=4:1:0.14, P_{tot}=1 atm, P_{IB}=0.07 atm, WHSV = 28-35 h⁻¹, helium balance.
- b initial data (taken after 5 min on-stream).

Table 7. Results of Boudouard Reaction Using 500 μl Pulses of CO^{a}

Catalyst	Rate 220°C ($\mu\text{mol/g}\cdot\text{s}$)	TOF 220°C (1/s)	Rate 260°C ($\mu\text{mol/g}\cdot\text{s}$)	TOF 260°C (1/s)	Ea (kJ/mol)
Co.005	3.2 ^h	-	30.6	0.34	123 ^b
Co.053	52.8	0.16	227.8	0.68	94 ^c
Co.069	61.1	0.18	-	-	-
Co.067	25.0	-	-	-	102 ^c
Co.068	52.8	-	100.0	-	110 ^c
Co.066	19.4	-	-	-	117 ^f
Co.W10	8.3	-	-	-	105 ^g

- a reaction conditions: 500 μl CO pulse size, $P_{\text{tot}}=2.5$ atm, 50-150 mg catalyst, 72 cc/min He.
 b determined on a partially deactivated catalyst by average of 5 pulses at every temperature (240 - 280°C).
 c determined between 190 and 220°C.
 d determined between 220 and 240°C (two points only).
 e determined between 210 and 230°C.
 f determined between 210 and 250°C.
 g determined between 220 and 250°C.
 h obtained by extrapolation using the Arrhenius relationship due to immeasurably low conversion.

Table 8

SUMMARY OF M3 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		
48	Cow.13	15.5	1	23	38	240	450	2.0	20	8.5	0.39	10.9	8.1	76.9	4.30	0.74	0.89	4.00	3.00	21.0	G.C. Calib
48	Cow.13	15.5	2	47	62	260	450	2.0	20	20.0	0.90	19.9	5.0	68.5	6.61	0.64	--	2.56	1.74	--	--
48	Cow.13	15.5	3	71	86	279	450	2.0	20	25.7	1.11	34.5	6.0	48.1	11.4	0.48	--	2.17	1.52	--	--
48	Cow.13	15.5	4	95	110	300	450	2.0	20	28.0	1.12	41.2	7.4	32.0	19.4	0.35	--	2.22	1.61	--	--
48	Cow.13	15.5	5	117	133	240	450	2.0	20	2.62	0.12	12.3	18.66	2.9	6.2	0.66	--	5.00	3.50	--	--
49	Co.068	15.5	1	23	39	242	450	2.0	20	26.7	1.26	18.9	4.6	75.3	1.19	0.68	0.77	0.52	0.34	20.3	
49	Co.068	15.5	2	47	62	259	450	2.0	20	34.5	1.62	35.3	6.4	55.0	3.38	0.54	--	0.35	0.27	--	--
49	Co.068	15.5	3	71	86	278	450	2.0	20	34.6	1.61	53.2	7.5	33.0	6.30	0.34	--	0.59	0.46	--	--
49	Co.068	15.5	4	102	110	299	450	2.0	20	28.4	1.31	63.2	8.4	20.3	8.11	--	--	1.07	0.81	--	--
49	Co.068	15.5	5	114	116	241	450	2.0	20	3.8	0.18	34.8	16.74	5.8	2.65	0.55	--	2.57	1.60	--	--
50	Co.066	15.5	1	23	38	240	450	2.0	20	21.1	0.99	11.3	3.5	83.6	1.58	0.72	0.81	3.19	1.94	--	--
50	Co.066	15.5	2	47	62	260	450	2.0	20	36.1	1.66	21.6	4.2	70.1	4.09	0.64	--	1.72	1.13	--	--
50	Co.066	15.5	3	71	86	279	450	2.0	20	36.9	1.66	37.6	6.2	48.1	8.10	0.47	--	2.01	1.37	--	--
50	Co.066	15.5	4	95	110	299	450	2.0	20	31.1	1.35	40.7	7.9	39.7	11.7	0.37	--	3.35	2.27	--	--
50	Co.066	15.5	5	119	133	239	450	2.0	20	3.7	0.17	15.1	17.06	4.6	3.31	0.67	--	7.00	12.00	--	--

Table 9

**START-UP CONDITIONS AND ACTIVATION PROCEDURE
FOR IRON F-T CATALYSTS**

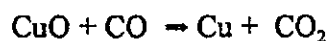
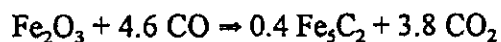
Start-up conditions:

- Catalyst Composition: 86.6 wt% Fe₂O₃, 12.5 wt% CuO, and 0.05 K₂O
- 29 wt% slurry
- Start-up medium: Synfluid

Activation Procedure:

- Pressure = 75 psig
- Heat up to 220°C (428°F) under 100% N₂
- Space velocity = 2,000 sl/hr-kg Fe
- Switch to 75% CO / 25% N₂ at 220°C
- Heat up to 270°C (518°F) at 17°C (30°F) / hr
- Monitor CO₂ concentration in effluent and cumulative CO₂ production

- **ACTIVATION CHEMISTRY**



- Stop activation after 12 hr on-stream at 270°C (the carbiding should have leveled off by that time with CO₂ concentrations in the effluent of 1-2%. The carbiding should be about 90-95% complete based on Fe₃C₂ formation)
- Start H₂ blending at about 100% of theoretical activation
- Slowly blend H₂ at activation conditions to reach H₂/CO = 0.7
- Change to F-T conditions (see Table)

Table 9
(Continued)

(TENTATIVE) F-T RUN PLAN

Period No.	Description	Space Velocity (sl/hr kg-Fe)	Reactor Pressure (psig)	Teator Temperature (°C)	Days On-Stream
1	Activation	2000	75	270	1
2	Base Line	2400	175	270	2
3	High Prod.	11700*	750*	300	2
4	High Lin. Vel.	11700*	500	300	2
5	Return to B. L.	2400	175	270	2

*750 psi or maximum pressure achievable on the SBCR

Table 10

SUMMARY OF M3 SBGR RUN RESULTS USING LaPorte IRON CATALYST

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.

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
											XCH4	XC2	XC3+	XCO2			C3	C4	C6-C18, %	
C3950	58.0	1	1	16	270	77	0.0	0	--	0.58	--	--	100	--	--	--	--	--	--	Cat Reduct
C3950	58.0	2	27	64	270	174	0.7	0	17.4	0.04	9.3	7.2	32.4	51.1	0.40	--	1.11	1.13	--	
C3950	58.0	3	65	70	300	600	0.7	0	--	--	--	--	--	--	--	--	--	--	--	Rx Plugged

Feed Gas Rates

Per No	N2 SLH	H2 SLH	CO SLH	Total SLH
1	14	0	52	66
2	48	29	41	118
3	86	139	198	423

Table 11

SUMMARY OF M3 SBCR RUN RESULTS USING LaPorte IRON CATALYST

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

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

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

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

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

Run No	Cat. No	Cat. wt,g	Per No	Time Start	Time Stop	Temp C	Pres psi	H2: CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf Olefins			Comments
												XCH4	XC2	XC3+	XCO2			C3	C4	C5-C18, %	
52	C3950	58.0	2	25	36	271	450	2.0	0	19.0	0.16	33.4	8.6	23.3	34.8	0.44	--	0.28	0.06	--	
52	C3950	58.0	3	49	62	276	450	2.0	0	29.2	0.24	28.7	12.9	21.9	36.5	0.39	--	0.30	0.28	--	
52	C3950	58.0	4	69	86	279	450	2.0	0	29.4	0.25	23.5	14.4	26.6	35.6	0.45	--	0.38	0.32	--	
52	C3950	58.0	5	96	110	288	450	2.0	0	35.8	0.29	26.5	14.1	21.4	38.0	0.37	--	0.38	0.33	--	
52	C3950	58.0	6	126	134	299	450	2.0	0	92.3	0.76	48.7	9.3	2.14	39.9	--	--	0.39	0.36	--	
52	C3950	58.0	7	138	158	304	600	2.0	0	97.8	0.82	47.8	6.0	8.0	38.2	0.16	--	0.21	0.22	--	
52	C3950	58.0	8	164	165	310	600	1.0	0	98.4	1.44	31.6	--	42.6	25.8	0.65	--	0.12	0.15	--	Rx.Plugged

Feed Gas Rates

Per No	N2 SLH	H2 SLH	CO SLH	Total SLH
2	563	225	112	900
3	563	225	112	900
4	563	225	112	900
5	563	225	112	900
6	563	225	112	900
7	563	225	112	900
8	562	169	169	900

Table 12

SUMMARY OF M3 SBCR RUN RESULTS USING LaPorte IRON CATALYST

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 (X).

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 C3	C4	Olefins C6-C18, %	Comments
3	C3950	58.0	2	28	42	258	450	1.0	0	13.5	0.14	12.7	11.8	30.0	45.5	0.18	--	0.88	0.78	--	
3	C3950	58.0	3	52	66	270	450	1.0	0	21.9	0.23	12.9	10.9	30.9	45.6	0.34	--	0.67	0.59	--	
3	C3950	58.0	4	76	90	280	450	1.0	0	25.7	0.27	15.7	11.4	26.2	46.7	0.12	--	0.56	0.50	--	
3	C3950	58.0	5	100	114	290	450	1.0	0	25.4	0.27	17.1	11.9	24.5	46.5	0.04	--	0.60	0.55	--	
3	C3950	58.0	6	124	138	298	450	1.0	0	28.5	0.29	17.6	11.8	24.0	46.7	--	--	0.72	0.64	--	
3	C3950	58.0	7	148	159	300	450	0.7	0	27.2	0.33	11.8	9.7	30.7	47.7	0.37	--	1.16	1.00	--	
3	C3950	58.0	8	170	172	302	600	0.7	0	29.4	0.35	11.8	9.5	30.5	48.3	0.40	--	0.79	0.72	--	Rx.Plugged

Feed Gas Rates

Per No	N2 SLH	H2 SLH	CO SLH	Total SLH
2	562	169	169	900
3	562	169	169	900
4	562	169	169	900
5	562	169	169	900
6	562	169	169	900
7	560	140	200	900
8	560	140	200	900

Table 13

SUMMARY OF M3 SBCR RUN RESULTS USING LaPorte IRON CATALYST

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 (X).

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. 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	
											%C4	%C2	%C3+	%CO2			C3	C4	C6-C18,X	
5	C3950	43.0	1	15	270	75	0.0	0	--	--	--	--	--	--	--	--	--	--	--	Cat Reduct
5	C3950	43.0	2	26	38	270	175	0.7	0	18.7	0.27	9.5	7.0	34.5	49.1	0.44	--	0.92	0.78	--
5	C3950	43.0	3	50	58	270	175	0.7	0	28.1	0.21	8.8	6.7	35.9	48.6	0.48	--	0.66	0.59	--
5	C3950	43.0	4	74	86	300	175	0.7	0	35.5	0.26	12.4	8.1	30.8	48.6	0.41	--	0.90	0.96	--
5	C3950	43.0	5	97	98	295	500	0.7	0	65.1	1.31	18.7	9.1	21.2	51.0	0.27	--	0.90	0.73	Rx Plugged

Feed Gas Rates

Per No	N2 SLH	H2 SLH	CO SLH	Total SLH
1	16	0	42	58
2	40	130	185	355
3	22	65	93	180
4	22	65	93	180
5	250	180	260	690

Table 14. Catalyst Performance Comparison: LaPorte vs. EI Runs

Reactor Run No. Period No.	AFDU AF-R12.1	AFDU AF-R12.2	AFDU AF-R12.4	AFDU AF-R12.5	EI 51 2	EI 52 2	EI 52 6	EI 52 7	EI 52 8	EI 53 3	EI 53 6	EI 53 7	EI 53 8	EI 55 2
CONDITIONS														
Slurry Conc. (%)	25	23	15	13.8	18	18	18	18	18	18	18	18	18	14
Temp. (°C)	270	302	303	270	270	271	299	304	310	268	300	300	302	270
Pressure (psi)	175	750	500	175	174	450	450	600	600	450	450	450	600	175
Inlet H ₂ /CO ratio	0.7	0.7	0.7	0.7	0.7	2	2	2	1	1	1	0.7	0.7	0.7
SV (SI/h kg-Fe)	2534	12266	18682	3665	3335	15517	15517	15517	15517	15517	15517	15517	15517	13340
Catal. loading (lbs)	445	445	?	?	58 g	58 g	58 g	58g	58 g	58 g	58 g	58 g	58 g	43g
Lin. Vel. (cm/s)	5.8	7.3	11	5.5	1.0	3.1	3.3	2.5	2.5	3.1	3.3	3.3	3.3	3.0
Time-on-stream (h)	9	33	13	12	37	11	134	158	165	42	138	159	172	26
ACTIVITY														
CO conv. (%)	84.7	54.2	15.6	10	17.4	19.0	92.3	97.8	98.4	13.5	28.5	27.2	29.4	18.7
g HC/h g-Fe	0.424	1.405	0.875	0.106	0.065	0.262	1.246	1.344	2.361	0.229	0.475	0.541	0.574	0.27
SELECTIVITY														
HC (CO ₂ free)	13.40	11.80	5.55	3.87	19.0	51.2	61.3	77.3	42.6	23.3	32.9	22.7	22.8	18.6
CH ₄ (mol% C)	12.19	12.39	9.16	8.24	14.7	13.2	11.7	9.7	-	21.7	22.1	18.6	18.3	13.7
C ₂	74.41	75.81	85.29	87.89	66.3	35.7	27.0	13.0	57.4	55.0	45.0	58.7	58.9	67.6
C ₃ +	-	-	0.68	-	0.40	0.44	-	0.16	0.65	0.18	-	0.37	0.40	0.44
α (gas phase)	44.9	43.7	20.0	22.4	51.1	34.8	39.9	38.2	25.8	45.5	46.7	47.7	48.3	49.1
CO ₂ (mol%)														

LaPorte Catalyst: 86.6 wt% Fe₂O₃, 12.5 wt% CuO, and 0.05 wt% K₂O (61 wt% Fe)
 Activation Procedure: P = 75 psig; Heat up to 220°C under 100% N₂; SV = 2,000 sl/hr-kg Fe; Switch to 75% CO/25% N₂; Heat up to 270°C at 17°C/hr; Time = ca. 12 hrs.

SUMMARY OF M4 SBCR COBALT ONLY CATALYST AGING RUN

)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 C3	C4	Olefins C6-18, %	Comments
												ZCH4	ZC2	ZC3+	ZCO2						
37	C0.005	25.0	1	1	18	216	450	2.0	20	8.1	0.23	0	--	--	--	--	--	--	--	--	
37	C0.005	25.0	2	20	38	221	450	2.0	20	12.5	0.36	1.5	3.9	93.9	0.71	0.90	0.89	--	--	28.6	
37	C0.005	25.0	3	41	62	221	450	2.0	20	14.4	0.42	2.9	--	96.5	0.60	0.91	--	--	--	--	Repair G.C
37	C0.005	25.0	4	65	86	221	450	2.0	20	14.8	0.43	3.4	5.0	91.1	0.49	0.88	--	6.33	--	--	
37	C0.005	25.0	5	89	110	221	450	2.0	20	14.4	0.42	3.6	9.0	86.8	0.60	0.85	--	6.67	7.50	--	
37	C0.005	25.0	6	113	134	221	450	2.0	20	14.1	0.41	3.8	8.0	87.7	0.58	0.85	--	5.00	15.00	--	
37	C0.005	25.0	7	137	158	222	450	2.0	20	14.8	0.43	4.4	6.6	88.5	0.55	0.82	0.90	5.50	3.20	23.1	
37	C0.005	25.0	8	165	182	221	450	2.0	20	14.1	0.41	4.3	5.3	89.9	0.50	0.80	--	5.50	4.25	--	
37	C0.005	25.0	9	185	206	220	450	2.0	20	13.3	0.39	3.9	3.6	92.0	0.53	0.79	--	5.25	3.20	--	
37	C0.005	25.0	10	209	230	221	450	2.0	20	13.6	0.39	5.1	3.2	91.3	0.51	0.78	--	5.50	2.67	--	
37	C0.005	25.0	11	233	254	221	450	2.0	20	13.5	0.39	4.7	3.6	91.2	0.48	0.78	0.89	4.60	3.20	22.4	
37	C0.005	25.0	12	257	278	221	450	2.0	20	13.3	0.39	4.5	3.1	91.9	0.49	0.78	--	4.40	2.67	--	
37	C0.005	25.0	13	281	302	221	450	2.0	20	13.1	0.38	4.7	3.3	91.5	0.49	0.78	--	4.40	2.67	--	
37	C0.005	25.0	14	305	326	221	450	2.0	20	12.7	0.37	4.9	4.1	90.5	0.52	0.78	--	4.40	2.67	--	
37	C0.005	25.0	15	329	350	221	450	2.0	20	12.4	0.36	4.9	3.9	90.6	0.54	0.77	--	4.60	2.67	--	
37	C0.005	25.0	16	353	374	221	450	2.0	0	12.5	0.36	5.2	3.8	90.5	0.54	0.77	0.83	4.60	2.67	--	Stop Syn F
37	C0.005	25.0	17	377	397	221	450	2.0	0	12.5	0.36	5.1	3.3	90.9	0.56	0.77	--	4.60	2.67	--	
37	C0.005	25.0	18	401	422	221	450	2.0	0	12.9	0.37	5.3	3.9	90.4	0.42	0.77	0.87	4.80	2.83	--	
37	C0.005	25.0	19	425	446	221	450	2.0	0	12.3	0.36	5.1	3.1	91.6	0.44	0.77	--	4.60	2.83	--	
37	C0.005	25.0	20	449	470	221	450	2.0	0	8.6	0.41	10.4	2.5	86.7	0.37	0.72	--	4.14	2.63	--	
37	C0.005	25.0	21	473	494	221	450	2.0	0	9.1	0.43	10.5	2.6	86.5	0.37	0.74	--	4.43	2.63	25.2	
37	C0.005	25.0	22	497	518	221	450	2.0	0	8.9	0.42	10.8	2.8	85.9	0.45	0.73	0.86	4.43	2.63	--	
37	C0.005	25.0	23	521	542	221	450	2.0	0	8.7	0.41	10.9	2.7	85.9	0.50	0.73	--	4.43	2.63	--	
37	C0.005	25.0	24	545	554	221	450	2.0	0	8.5	0.41	10.9	3.2	85.3	0.50	0.72	--	4.43	3.00	--	
37	C0.005	25.0	25	574	590	221	450	2.0	0	8.1	0.38	10.9	3.5	84.9	0.55	0.72	--	4.29	2.86	--	
37	C0.005	25.0	26	593	614	221	450	2.0	0	7.9	0.37	10.8	3.5	85.1	0.54	0.72	--	4.14	2.86	--	
37	C0.005	25.0	27	617	638	220	450	2.0	0	7.6	0.36	10.8	3.1	85.6	0.57	0.72	0.86	4.00	2.71	--	
37	C0.005	25.0	28	641	662	220	450	2.0	0	7.6	0.36	10.8	2.6	85.9	0.54	0.72	--	4.00	2.71	--	
37	C0.005	25.0	29	674	686	221	450	1.5	0	5.6	0.32	8.4	2.6	88.2	0.78	0.73	--	5.00	2.83	--	
37	C0.005	25.0	30	698	710	221	450	1.5	0	4.8	0.29	10.3	3.0	85.9	0.81	0.71	0.85	5.00	3.40	--	
37	C0.005	25.0	31	731	734	215	450	1.5	0	3.2	0.19	8.3	4.5	85.1	2.03	0.70	--	4.50	12.00	--	
37	C0.005	25.0	32	742	758	221	450	1.5	20	5.6	0.35	8.6	3.1	87.6	0.71	0.75	--	4.80	3.20	--	Add Syn F1
37	C0.005	25.0	33	774	782	220	450	2.0	20	10.4	0.31	4.7	3.0	91.6	0.70	0.75	--	4.40	2.50	--	
37	C0.005	25.0	34	785	806	220	450	2.0	20	10.3	0.29	4.7	2.9	91.6	0.70	0.75	--	3.67	2.50	--	
37	C0.005	25.0	35	813	830	220	450	1.5	20	4.5	0.28	9.7	3.3	86.2	0.82	0.72	--	4.60	3.20	--	

Feed Gas Rates

Per No	N2 SLH	H2 SLH	CO SLH	Total SLH
1	563	225	112	900
20	360	360	180	900
29	360	324	216	900
30	300	360	240	900
33	563	225	112	900
35	300	360	240	900

SOCR CATALYST EXTRACTIONS

Catalyst No. (Support)	Run No.	Charge		Recovered (Oxidized) wt, gm	Charge		Recovered		Reduction in Particle Size,
		(H ₂ Reduced) wt, gm	wt, gm		Particle Size, mvd, microns	Particle Size at 10% microns	Particle Size, mvd, microns	Particle Size at 10% microns	
Co.001 (Al)	1	14.5	12.63	42.02	24.25	41.06	23.62	2.3	
Co.001 (Al)	2	16.5	15.18	42.02	24.25	40.09	22.86	4.6	
Co.005 (Al)	3	19.5	18.41	85.66	30.46	64.53	31.27	24.7	
Co.002 (Al)	4	20.1	20.4	73.61	32.86	71.19	33.50	3.3	
Co.003 (Al)	5	15.1	14.54	76.81	34.40	72.57	34.25	5.5	
Co.011 (Si)	6	15.3	16.03	107.09 (1)	53.19	94.02	40.44	12.2	
Co.012 (Si)	7	15.8	14.73	105.22 (1)	51.33	101.37	44.44	3.7	
Co.015 (Al)	8	15.0	15.52	75.63 (1)	33.15	74.68	32.68	1.3	
Co.011 (Si)	9	15.0	15.92	79.00 (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	15.1	---	---	---	---	---	
Co.035 (Si)	5 (M4)	15.4	(4)	89.14 (3)	49.29	74.76	31.67	19.2	
Co.028 (Al)	6 (M4)	15.4	14.08	80.83 (3)	44.81	71.83	36.34	11.1	
Co.028 (Al)	6 (M4)	15.4	15.7	---	---	---	---	---	

(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 16
(Continued)

SBCR CATALYST EXTRACTIONS

Catalyst No. (Support)	Run No.	Charge		Recovered (Oxidized) wt, gm	Charge		Recovered		Particle Size at 10 μ		Reduction in Particle Size, μ
		(H ₂ Reduced) wt, gm	(H ₂ Reduced) wt, gm		Particle Size, mvd, microns	Particle Size, mvd, microns	Particle Size, mvd, microns	Particle Size at 10 μ microns	Particle Size at 10 μ 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)	0.5	(5)	130.40	51.40	---			
Co.047 (Al)	23	15.8	83.42 (1)	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 (1)	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)	16.28	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)	80.26	45.20	---			
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	41.02	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.

(Continued)

SBCR CATALYST EXTRACTIONS

Catalyst No. (Support)	Run No.	Charge		Charge		Recovered		Recovered		Reduction in Particle Size, %
		(H ₂ Reduced) wt, gm	Particle Size, mvd, microns	Particle Size at 10% microns	Particle Size, mvd, microns	Particle Size at 10% microns	Particle Size, mvd, microns			
Blend B (Al)	22 (M4)	30.5	77.85	43.10	73.74	38.80	5.28			
CAL.09 (Al)	23 (M4)	30.0 (6)	63.12	25.60	62.10	26.32	1.62			
Co.053-3 (Al)	24 (M4)	28.5	75.63	40.80	70.69	35.03	6.53			
Co.055 (Al)	31 (M3)	15.0	85.58	46.27	74.56	39.00	12.88			
Co.056 (Si)	25 (M4)	15.0	99.93	54.62	88.48	43.26	11.46			
Co.044 (Si)	32 (M3)	16.4	92.15	49.30	84.92	40.21	7.85			
CAL.10 (Al)	26 (M4)	15.6	83.05	47.11	81.12	45.87	2.32			
Co.053-4 (Al)	33 (M4)	31.4	84.09	44.40	73.50	37.10	12.6			
Co.050 (Al)	27 (M4)	14.6	(5)	(5)	91.37	44.07	--			
Co.060 (Al)	34 (M3)	15.6	87.45	47.08	80.89	43.42	7.50			
Co.041 (Si)	35 (M3)	26.0	87.48	49.26	80.63	31.75	7.83			
Co.057 (Si)	28 (M4)	15.8	98.85	55.78	82.94	36.71	16.10			
Co.032 (Al)	36 (M3)	15.9	78.22	43.34	78.55	36.02	9.81			
Co.045 (Si)	37 (M3)	15.9	95.67	53.59	68.84	22.06	28.04			
Co.061 (Si)	29 (M4)	45.4	--	--	(7)	(7)	--			
Co.011 (Si)	30 (M4)	15.9	83.99	40.60	54.04	13.72	35.66			
Co.003 (Al)	50%									
Solids		135								
CAL.12 (Al)	31 (M4)	15.9	78.93	39.94	73.02	36.97	7.49			
CAL.11 (Al)	32 (M4)	15.9	72.75	38.67	72.85	40.91	0			
Co.058 (Al)	38 (M3)	15.9	71.92	38.83	69.91	36.68	2.8			
Co.064 (Al)	39 (M3)	15.9	85.69	45.95	78.99	42.90	7.82			
			83.74	44.86	70.37	35.17	16.0			

(5) Insufficient feed sample

(6) Wax coated

(7) Lost catalyst

Table 16
(Continued)

SBCR CATALYST EXTRACTIONS

Catalyst No. (Support)	Run No.	Charge		Recovered (Oxidized) wt, gm	Charge		Recovered		Reduction in Particle Size, %
		(H ₂ Reduced) wt, gm	Particle Size, mvd, microns		Particle Size at 10% microns	Particle Size, mvd, microns	Particle Size at 10% microns		
Co.063 (Al)	40 (M3)	15.0	88.99	12.02	80.70	48.36	44.32	9.32	
Co.062 (Al)	41 (M3)	15.0	82.85	14.48	72.90	44.80	38.55	12.0	
Co.065 (Al)	42 (M3)	15.9	83.08	17.24	71.81	44.17	37.63	13.6	
CoW.12 (SI)	43 (M3)	9.1	(5)	9.44	105.95	(5)	49.99	--	
CoW.11 (Al)	44 (M3)	15.6	80.32	15.24	66.93	42.03	34.40	16.7	
CAL.13 (Al)	33 (M4)	15.9	80.60	14.45 (8)	104.15	43.53	59.24	--	
Fe.01 (SI)	45 (M3)	15.9	84.91	15.96	78.01	46.55	39.01	8.1	
CoW.05	46 (M3)	15.7	79.45	14.14	76.03	42.54	39.88	4.3	
CAL.13 (Al)	35 (M4)	25.0	80.66	27.0	74.18	43.53	36.16	8.0	
Co.070 (Al)	47 (M3)	15.6	85.64	17.0	78.41	45.59	40.91	8.4	
CoW.13 (Al)	48 (M3)	15.5	74.45	16.0	71.64	39.00	37.84	3.8	
Co.068 (Al)	49 (M3)	15.5	80.05	18.0	118.58	42.27	62.82	48.1 (9)	
Co.066 (Al)	50 (M3)	15.5	77.19	16.0	72.28	39.49	37.48	6.4	
Co.005 (Al)	37 (M4)	25.0	84.71	28.0	75.47	46.56	37.56	19.3	

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- (5) Insufficient feed sample.
 (8) Catalyst was rinsed with solvent only,
 not Soxhlet extracted.
 (9) Particle size increased.

Table 17. Performance of Co Catalysts in CSTR and SBCR

(AT 240°C)

CATALYST	ACTIVITY		SELECTIVITY (mol% C converted)	
	CO Conversion (%)	Rate (g ^o CH ₄ /g cat./hr)	CH ₄	C ₂₊
CST REACTOR RESULTS^a				
Co.005 (20Co/Al ₂ O ₃)	61.1	1.33	6.6	92.2
Co.053 (20Co0.5Ru/Al ₂ O ₃)	64.7	1.39	9.9	88.8
Co.041 (20Co0.5Ru8.5Zr/Al ₂ O ₃)	59.6	1.30	8.5	89.7
CAL.13 (20Co/0.5Ru0.3KAl ₂ O ₃)	73.3	1.69	4.1	95.4
SBC REACTOR RESULTS^b				
Co.005 (20Co/Al ₂ O ₃)	27.1	1.34	7.9	89.7
Co.053 (20Co0.5Ru/Al ₂ O ₃)	34.2	1.56	7.8	84.2
Co.041 (20Co0.5Ru8.5Zr/Al ₂ O ₃)	15.8	1.16	11.0	86.0
CAL.13 (20Co/0.5Ru0.3KAl ₂ O ₃)	28.1	1.28	6.4	90.9

(a) Catalyst weight: ca. 17g, Screened thru 150x400 mesh; Calcined and reduced externally; P = 450psig, T = 240°C, H₂/CO = 2; Total flow rate: 300 SI/hr; Diluent: Ar = ca. 40%

(b) Catalyst weight: ca. 15g, Screened thru 150x400 mesh; Calcined and reduced externally; T = 240°C, P = 450 psi, H₂/CO ratio = 2, Total flow rate: ca. 15 L/min or 3 cm/sec linear velocity, Diluent: N₂: ca. 60%

Table 18. Performance of Co Catalysts in CSTR and SBCR

(AT 220°C)

CATALYST	ACTIVITY		SELECTIVITY (mol% C converted)	
	CO Conversion (%)	Rate (g CH ₄ /g cat/hr)	CH ₄	C ₃ +
CST REACTOR RESULTS^a				
Co.005 (20Co/Al ₂ O ₃)	32.6	0.72	4.8	94.1
Co.053 (20Co0.5Ru/Al ₂ O ₃)	25.5	0.56	9.1	88.6
Co.041 (20Co0.5Ru8.5Zr/Al ₂ O ₃)	20.7	0.45	10.5	86.9
CAL.13 (20Co0.5Ru0.3K/Al ₂ O ₃)	31.2	0.74	4.5	95.0
SBC REACTOR RESULTS^b				
Co.005 (20Co/Al ₂ O ₃)	10.7	0.53	0.0	98.4
Co.053 (20Co0.5Ru/Al ₂ O ₃)	14.4	0.66	4.3	94.3
Co.041 (20Co0.5Ru8.5Zr/Al ₂ O ₃)	9.1	0.41	0.0	97.8
CAL.13 (20Co0.5Ru0.3K/Al ₂ O ₃)	-	-	-	-

(a) Catalyst weight: ca. 17g, Screened thru 150x400 mesh; Calcined and reduced externally; P = 450psig, T = 220°C, H₂/CO = 2; Total flow rate: 300 Sl/hr; Diluent: Ar = ca. 40%

(b) Catalyst weight: ca. 15g, Screened thru 150x400 mesh; Calcined and reduced externally; T = 220°C, P = 450 psi, H₂/CO ratio = 2, Total flow rate: ca. 15 L/min or 3 cm/sec linear velocity, Diluent: N₂: ca. 60%