

TABLE 1
LIST OF CATALYSTS AND PROPERTIES

PREP EQUIPMENT	RUN NO (PLANT)	PRECIPITATION		1ST CALCINATION		2ND CALCINATION		CATALYST	COMPOSITION WEIGHT BASIS	CATALYST PROPERTIES			BATCH SIZE, g	
		BASE	pH	MESH	T, °C	MESH	T, °C			RF ₂	STEAM SIZE	SURFACE AREA, m ² /g		PORE VOL, cc/g
IN LAB	683-81	N ₂ CO ₃	3.5	NO CALCINATION, 110°C DRIED 60-200	410				100% Fe:CO 100% Fe:VO:K	Amorphous, $\le 2.4\ \mu\text{m}$			42	
IN LAB	683-83	N ₂ CO ₃	4.3	NO CALCINATION, 110°C DRIED 60-200 60-200 60-200	275 180 450				100% Fe:CO	Amorphous, $\le 2.4\ \mu\text{m}$ 4-6 mm 5-20 mm	81 53	0.32 0.17	52 62	79% Fe ₂ O ₃ 80% Fe ₂ O ₃
IN LAB	709-71	N ₂ CO ₃	5.5	60-200	180				100% Fe:CO	Amorphous, $\le 2.4\ \mu\text{m}$			18	
IN LAB	709-49	N ₂ CO ₃	6.1	NO CALCINATION, 110°C DRIED 60-200	410				100% Fe:CO	Amorphous, $\le 2.4\ \mu\text{m}$			42	
IN LAB	683-133	N ₂ CO ₃	6.5	NO CALCINATION, 110°C DRIED 60-200	410				100% Fe:0.0Cu 100% Fe:CO:0.7K	Amorphous, $\le 2.4\ \mu\text{m}$			23	
IN LAB	683-143	N ₂ CO ₃	6.5	60-200	410				100% Fe:CO				13	
IN LAB	683-139	N ₂ CO ₃	6.5	NO CALCINATION, 110°C DRIED 60-200	410				100% Fe:0.5Cu	2.4 mm			60	Quartz
IN LAB	683-49	N ₂ CO ₃	7.9	NO CALCINATION, 110°C DRIED						none amorphous			35	
IN LAB	709-37	N ₂ CO ₃	9.5	NO CALCINATION, 110°C DRIED					100% Fe:CO	Amorphous, $\le 2.4\ \mu\text{m}$			40	
IN LAB	683-75	N ₂ CO ₃	9.7	NO CALCINATION, 110°C DRIED 60-200 60-200	180 450				100% Fe:CO	10-40 mm 10-40 mm 10-40 mm	76 41	0.20 0.19	53 89	30% Fe ₂ O ₃ 77% Fe ₂ O ₃ 87% Fe ₂ O ₃
IN LAB	683-111	NH ₄ OH	9.8	NO CALCINATION, 110°C DRIED 60-200	450				100% Fe:CO	Amorphous, $\le 2.4\ \mu\text{m}$ 15-30 mm			23	
IN LAB	709-81	N ₂ CO ₃	5.5	> 170	380	170-200	380	6.6	100% Fe:1.4Cu:0.31K				21	
PLANT 732, RUN 5, 6	709-108	N ₂ CO ₃	6.5	> 170	380	170-200	380	63.3	100% Fe:0.9Cu:0.77K		72	0.35	98	101
PLANT 732, RUN 3 (PORTIONS 2 AND 3)	709-119	N ₂ CO ₃	4.3-5.3	> 60	380	140-200	380	63.2	100% Fe:0.87Cu:1.31K	6-20 mm most 10-14 mm	84	0.21	49	278
PLANT 732, RUN 12 (PORTIONS 1, 2A, 2B)	709-129	N ₂ CO ₃	3.1-5.3	> 60	380	140-200	380	64.0	100% Fe:1.03Cu:1.07K	4-25 mm most 10-15	78	0.27	70	528
PLANT 732, RUN 14 (PORTIONS 1, 3, 4)	709-134	N ₂ CO ₃	4-4.5	> 60	380	140-200	380	67.4	100% Fe:0.69Cu:1.91K	5-25 mm most 8-12	67	0.17	50	776
PLANT 732, RUN 16 (PORTIONS 1, 3, 4)	6816-18	N ₂ CO ₃	6.5	> 60	380	140-200	380	64.4	100% Fe:1.15Cu:1.92K	10-20 mm	61	0.19	61	285

Table 1A

COMPARISON OF SLURRY VERSUS FIXED-BED FISCHER-TROPSCH SYNTHESIS REACTORS

	Fixed-Bed Reactor Current Technology (Sasol) South Africa	Slurry-Reactor Desired Technology
Temperature, °C	225	260
Syngas feed H ₂ :CO	2.0	0.5
Advantages	Commercial	1. No water gas shift reactor 2. Simpler heat removal
Iron Catalyst Stability	Acceptable	Expected to be poor due to severe operating conditions

TABLE 2
Conditions for Fixed-Bed Runs 48 and 49 (Plant 700A)

Run	Plant	Catalyst					Diluent			Bed Inches	Temperature		Pressure		Feed					Hour
		Number	% Fe	Wt, g	Vol, cc	Mesh	Net.	Mesh	Wt, g		In °C	Max °C	In atm	Out atm	% H ₂	% CO	% Ar	H ₂ O	Rate sec/min	
48	700A	C-73-1-101	67.69	10	4	170-200	α-Al ₂ O ₃	60-200	100	8	100 [†] 280	11.2	11.0	37.95	56.52	5.53	0.07	335	2.96	0-8
										280	13.2	11.2-11.9								9-12
49	700A	C-73-1-101	67.69	10	4	> 100	α-Al ₂ O ₃	> 100	100	100 [†] 280	11.2	11.2	100 [†] 280							0-7
										280										7-12
										280								105	1.40	12-19
										280								61	0.94	19-31
										280	35.7	35								31-43
										249-250										43-58
										250	15.3	15.0	31.81	62.2	5.99	0.51	273	2.40	60-92	

TABLE 3
Summary of Fixed-Bed Run 49 (Plant 700A)

Hours	T, °C	P, atm	H ₂ :CO feed	NI/hr/gFe	Conversions, %		Selectivities	
					CO	CO + H ₂	C ₁	CO ₂
12	280	11	0.7	3	10	9	7	11
25	280	11	0.7	0.54	23	21	3.3	42
40	280	35	0.7	0.54	70	69	3.2	40
56	250	35	0.7	0.54	30	32	2.5	32
63	250	15	0.5	2.4	10	11	2.2	24

TABLE 4
Conditions for Fixed-Bed
Run 52 (Plant 700A)

Run	Plant	Catalyst				Diluent		Bed Inches	Temperature °C		Pressure atm		Feed					Hours				
		Number	% Fe	Wt, g	Nature	Wt, g	In		Out	In	Out	% H ₂	% CO	% Ar	H ₂ O	Rate cc/min	ML/h/g oil					
52	700A	MCSO-4		8.28		100	5 1/4	110 [†]	110 [†]		0		38.61	85.12	0.27	0.70	174	1.06	0-6			
								250 [†]	250 [†]											6-27		
								270	276												27-40	
								270	276												40-51	
								260	294												51-59	
								259	262		12.8										59-64	
								257	260									89	.94		64-70	
								277	260									90	.88		70-80	
									259	13.2								88	.83		80-90	
																				47	.46	90-90
																				39	.37	90-103

TABLE 5
Conditions for Fixed-Bed Run 53 (Plant 700A)

Run	Plant	Catalyst				Diluent		Bed Inches	Temperature		Pressure		Feed					Hours
		Number	% Fe	Wt, g	Nature	Wt, g	In °C		Max °C	In atm	Out atm	% H ₂	% CO	% Ar	H ₂ -CO	Flow scm/min	N ₂ /h ₂ cat	
53	700A	MCSO-4		10			14 1/4	110 246	11.9	9.2	38.61	85.21	0.27	0.70	267	1.5	0-5	
								246	12.9								5-15	
								258	13.3								15-23	
								260									23-29	
								270									29-41	
								280									41-51	
								270	12.6	9.5							51-54	
								200	17.4	12.8							54-57	
								257	16.0						127	.76	57-64	
									15.3						104	.82	64-69	
									14.3						66	.40	69-79	
									13.3						57	.34	79-84	
								257	12.9						47	.26	84-204	

Table 5a

STEM CHARACTERIZATION OF CATALYST

PLANT 752, Run 15, portion 2
(particle size: 10-20nm)

Particle #	Weight %	
	Fe	Cu
1	98.07	1.93
2	98.49	1.51
3	97.88	2.12
4	98.23	1.77
5	98.20	1.80
6	98.46	1.54
7	97.88	2.12
8	98.06	1.94
9	98.31	1.69
10	97.94	2.06
Average	98.15 ± 0.22	1.85 ± 0.22

PLANT 752, Run 15, portion 1
(particle size: 10-20nm)

Particle #	Weight %	
	Fe	Cu
1	98.25	1.75
2	98.30	1.70
3	98.62	1.38
4	98.63	1.37
5	97.60	2.40
6	97.77	2.23
7	97.91	2.09
8	98.45	1.55
9	97.88	2.12
10	98.08	1.92
Average	98.15 ± 0.36	1.85 ± 0.36

Table 5a Cont'd

STEM CHARACTERIZATION OF CATALYST

PLANT 752, Run 15, portion 4
(particle size: $\leq 10\text{nm}$)

Particle #	Weight %	
	Fe	Cu
1	98.42	1.58
2	97.82	2.18
3	98.28	1.70
4	97.99	2.01
5	98.05	1.95
6	98.40	1.60
7	98.31	1.69
8	97.91	2.09
9	98.07	1.93
10	98.53	1.47
Average	98.18 \pm 0.24	1.82 \pm 0.24

PLANT 752, Run 15, portion 5
(particle size: $\leq 10\text{nm}$)

Particle #	Weight %	
	Fe	Cu
1	97.81	2.19
2	97.57	2.43
3	97.93	2.07
4	97.51	2.49
5	97.75	2.25
6	97.89	2.11
7	97.23	2.77
8	97.82	2.18
9	98.13	1.87
10	98.23	1.77
Average	97.79 \pm 0.29	2.21 \pm 0.29

Table 5a Cont'd

STEM CHARACTERIZATION OF CATALYST

PLANT 752, Run 15, portion 1B
(particle size: $\leq 10\text{nm}$)

Particle #	Weight %	
	Fe	Cu
1	96.01	3.99
2	94.83	5.17
3	97.00	3.00
4	96.89	3.11
5	97.29	2.71
6	96.78	3.22
7	96.94	3.06
8	97.33	2.67
9	96.90	3.10
10	96.76	3.22
Average	96.67 ± 0.74	3.33 ± 0.74

PLANT 752, Run 15, portion 3
(particle size: 10-20nm)

Particle #	Weight %	
	Fe	Cu
1	98.59	1.41
2	98.71	1.29
3	98.88	1.12
4	98.81	1.19
5	98.62	1.38
6	98.30	1.70
7	98.91	1.09
8	98.88	1.12
9	98.72	1.28
10	98.82	1.18
Average	98.75 ± 0.18	1.25 ± 0.18

TABLE 5b
STEM Examination of Catalyst 6616-18

<u>Particle #</u>	<u>Weight %</u>		
	<u>Fe</u>	<u>Cu</u>	<u>K</u>
1	95.53	3.58	0.89
2	95.77	3.63	0.60
3	89.63	3.00	7.37
4	95.91	3.22	0.87
5	95.63	3.63	0.74
6	95.84	3.17	0.99
7	95.68	3.23	1.09
8	95.52	3.43	1.04
9	95.88	3.20	0.92
10	95.29	2.86	1.85
11	96.05	2.51	1.44
12	95.98	3.17	0.85
13	94.92	4.05	1.03
14	95.94	2.57	1.49
Avg.	95.26 ± 1.65	3.23 ± 0.42	1.51 ± 1.72

TABLE 6
Conditions for Fixed-Bed
Runs 50 and 51 (Plant 700A)

Run	Plant	Catalyst					Effluent			Bed Inches	Temperature		Pressure		Feed						Hours
		Number	% Fe	Wt. g	Vol cc	Mesh	Net.	Mesh	Wt. g		In	Max	In	Out	% H ₂	% CO	% Ar	H ₂ CO	Rate mo/min	N ₂ /H ₂ Fe	
50	700A	5709-01	67	10			α -Al ₂ O ₃		100	8 1/4	100†	9.5	9.0	38.52	85.09	8.92	0.68	325	3.70	0-0	
											279	320	9.0†	9.0							0-0
51	700A	5709-01	67	0.28			γ -Al ₂ O ₃		21	10 1/4	110†	9.2	9.0	39.52	85.08	8.92	0.69	179	2.75	19-301	
											270	320	9.0	9.0							202-322
										270-320†	9.5	9.0									14-38
										272	301										25-35
										259	298	13.3	12.8								25-35
										259	300-320										25-35
										240	251										50-60
										240	252										50-60
										247	270										66-70
										236											70-200
										↓	↓	↓	↓	38.61	85.12	8.27	0.70	↓	↓	200-600	

Product Distributions in Run 51

SIGNAL RESEARCH CENTER
 PROGRAM 1016 - FISCHER/TROPSCH DATA BASE - OVERALL PRODUCT DATA ANALYSIS REPORT - PART 1 OF 6

06APR69

PLANT NUMBER 700
 RUN NUMBER 51
 TEST NUMBER 1

Table 7

TOTAL PRODUCT DISTRIBUTION

WEIGHT FCIS WITHOUT ARGON
 HYDROGEN 1.033 1.033
 CARBON MONOXIDE 30.593 30.593
 CARBON DIOXIDE 63.820 63.820
 WATER 2.154 2.154
 HYDROCARBONS 22.028 22.028
 OXYGENATES 0.372 0.372

HYDROCARBON DISTRIBUTION

C1 7.649 7.649
 C2 - C4 27.642 27.521
 C5 - C11 45.850 45.560
 C12 - C18 10.317 12.282
 C19 - C25 3.436 6.490
 C26 PLUS 5.106 7.497
 C1 - C44 97.843 97.990
 C45 PLUS 2.157 2.010

OXYGENATES DISTRIBUTION

ALCOHOLS 60.642 60.642
 ALDEHYDES 19.358 19.358
 OTHER OXYGENATES 0.000 0.000

MOLE FCIS WITHOUT ARGON

HYDROGEN 16.103 16.244
 CARBON MONOXIDE 33.416 33.460
 CARBON DIOXIDE 51.443 51.611
 WATER 4.242 4.256
 HYDROCARBONS 12.489 12.203
 OXYGENATES 0.225 0.226

RECOVERIES

OVERALL 109.049 109.049
 CARBON 108.940 108.983
 HYDROGEN 113.982 113.620
 OXYGEN 109.824 109.824
 ARGON 104.958 104.958

CORRECTED RECOVERIES *

OVERALL 103.694 103.694
 CARBON 103.794 103.635
 HYDROGEN 108.598 108.253
 OXYGEN 104.636 104.636

*

CORRECTED RECOVERY - (RECOVERY/AT RECOVERY) * 100

TABLE 8
 Conditions for Slurry-Bed
 Run 1 (Plant 700B)

Run	Plant	Catalyst				Diluent			Temp In °C	Press Out, atm	Feed				Hours		
		Number	% Fe	Vol, g	Mesh	Nature	% Solids (wet)	% H ₂			% CO	% Ar	H ₂ -CO	Rate cc/min			
1	700B	6708-108	67.3	35		C ₂	15	200	120 [†] 200	12.9	38.61	63.12	0.27	0.70	802	2.1	0-21
									200						614	1.8	21-30
									200						592	1.0	30-35
									200						300	0.84	35-50
									27	14.9					330	0.84	39-47
															266	0.74	47-59
											31.53	62.28	0.19	0.51	311	0.80	59-63
															335	0.86	63-100
															293	0.72	103-207

TABLE 10
 Conditions for Slurry-Bed
 Run 6 (Plant 700B)

Run	Plant	Catalyst					Wax Medium				Temp. In °C	Filter		Free Out, atm	Feed					Hours	
		Number	% Fe	Wt., g	Mesh Size	Shell Hgt., in.	Nature	% Solids	Wt., g (wet)	Rpm		Pore Size, μ	Height Inches		% H ₂	% CO	% Ar	H ₂ O	Rate cc/min		N ₂ /Ar /O ₂
6	700B	5706- 139	64.0	107.5	140- 400	4 11/16	C ₂₁	22	360	1000	260	0.7	5 1/4	11	33.17	63.19	5.64	0.71	2270	2.0	0-12
											236			15							12-15
																			1600	1.4	15-33
																			1900		33-66
																					66-72

TABLE 10a
Conditions for Slurry-Bed
Runs 7 and 8

Run	Plant	Catalyst				Diluent			Rpm	Temp, °C	Filter		Press. Out, atm	Feed						Hours													
		Number	% Fe	Wt, g	Mesh Size	Static H ₂ , in	Mixture	% Solids			Wt, g (max)	Pore Size, μ		Height, inches	% H ₂	% CO	% N ₂	H ₂ , CO	Rate, sec/min		ML/h /g Fe												
7	7008	5705-139	64	107.5	140-400	4 1/4	C ₇₀	22	380	1000	280	17-45	4 1/4	11	39.49	64.50	5.95	0.72	1980	1.7	0-12												
										↓	↓			↓		↓																	
										↓	258			15																			
										1250																							
										↓																							
8	7008	5705-139	64	95	140-400	4 1/4	C ₇₀	20	380	1000	280	5-18	4 1/4	11	39.64	64.41	5.95	0.73	1980	2.0	0-12												
										↓	↓			↓		↓																	
										↓	205			15																			
										1200	258																						
										↓																							
										1300					39.49	64.77	5.74	0.72															
										↓					↓																		
										1300																							
										1500																							
										1300																							
										1300					39.57	64.47	5.86	0.73															
										↓					↓																		
										1300																							
										↓																							
										1300																							
										1300					39.57	64.54	5.89	0.73															
										↓					↓																		
										1300																							
										↓																							
										1300																							
										1300					39.27	64.63	6.10	0.72															
										↓					↓																		
										1300																							
										↓																							
										1300																							
										1300					39.49	64.76	5.75	0.72															
										↓					↓																		
										1300																							
										↓																							
										1300																							
										1300					39.49	64.76	5.75	0.72															
										↓					↓																		
										1300																							
										↓																							
										1300																							
										1300					39.57	64.55	5.89	0.73															
										↓					↓																		
										1300																							
										↓																							
										1300																							

TABLE 11
Conditions for Slurry-Bed
Runs 9, 10 and 11 (Plant 700B)

Run	Plant	Catalyst				Wax Medium				Temp in, °C	Filter		Press Out, atm	Feed							
		Number	Fe, %	Wt., g	Mesh Size	Static Ht, in.	Nature	Solids, %	Wt., g (max)		Rpm	Pore Size, μm		Height in.	H ₂ , %	CO, %	Ar, %	H ₂ O	Rate sec/min	ML/h /gFe	Hr
9	700B	5709- 139	64	95	140-400	4-5/8	C ₇₇	20	360	1000	280	5-16	4-14/16	11	39.49	54.77	5.74	0.72	1960	1.9	0-12
										↓	245			↓	39.49	54.62	5.69	0.72	1420	1.4	12-14
										1100	258			15	↓	↓	↓	↓	↓	↓	14-28
										1200	↓			↓	↓	↓	↓	↓	↓	↓	28-30
										1300	↓			↓	39.35	54.95	5.86	↓	↓	↓	30-78
10	700B	5709- 164	67.4	95	140-400	4-5/8	C ₇₇	20	360	1300	280	1-5	2-3/4	11	39.31	54.13	6.63	0.72	1960	1.9	0-6
										↓	256			15	↓	↓	↓	↓	1420	1.3	6-24
										↓	265			↓	↓	↓	↓	↓	↓	↓	24-30
11	700B	5709- 164	67.4	95	140-400	4-9/16	C ₇₇	20	360	1300	200	0.7	2-7/8	11	38.76	56.44	6.32	0.65	1960	1.9	0-12
										↓	258			↓	↓	↓	↓	↓	↓	↓	12-14
										↓	↓			15	39.46	53.86	6.60	0.73	↓	↓	14-18
										↓	↓			↓	↓	↓	↓	↓	1000	1.0	18-38
										↓	↓			↓	39.29	64.10	6.53	0.73	710	0.67	38-64

Table 12

Performance of Precipitated Iron Catalyst
in 11 Autoclave Reactors in Series at 21 ATM, 0.7 H₂: CO Feed
(wt-%)

	<u>265°C</u>	<u>275°C</u>	<u>Target</u>
C ₁	4.3	5.8	--
C ₂ (Ethane + Ethylene)	4.6	6.0	--
C ₁ + C ₂	8.9	11.8	7
Sv, nL/h-gFe	1.1	1.6	≥2

Table 13

Approximate Product Distribution (Wt-%) at 68%
Conversion, 265°C, 300-324 Hours

	<u>N-Paraffin</u>	<u>α-Olefin</u>	<u>Alcohol</u>	<u>Aldehyde</u>	<u>Unidentified</u>	<u>Total</u>
C ₁	5.5	--	--	--	--	5.5%
C ₂	0.9	5.0	2.9	0.2	--	9.0%
C ₃ -C ₄	3.0	11.7	2.0	1.5	--	18.2%
C ₅ -C ₁₁	3.8	8.9	2.9	1.1	7.3	24.0%
C ₁₂ -C ₁₈	-3.0	-6.0	0	0	-4.0	13%
C ₁₉ -C ₂₅	--	--	--	--	9.9	9.9%
C ₂₆ ⁺	--	--	--	--	20.4	20.4%
	<u>16.2</u>	<u>31.6</u>	<u>7.8</u>	<u>2.8</u>	<u>41.6</u>	<u>100.0</u>

Table 14

Approximate Product Distribution (Wt-%) at 83%
Conversion, 275°C, 660-684 Hours

	<u>N-Parafin</u>	<u>α-Olefin</u>	<u>Alcohol</u>	<u>Aldehyde</u>	<u>Unidentified</u>	<u>Total</u>
C ₁	6.2	--	--	--	--	6.2%
C ₂	2.4	4.1	4.6	0.3	--	11.4%
C ₃ -C ₄	3.3	16.5	2.6	1.0	--	23.4%
C ₅ -C ₁₁	4.0	11.1	2.1	0.8	10.6	28.6%
C ₁₂ -C ₁₈	-3.0	-6.3	0	0	-1.9	11.2%
C ₁₉ -C ₂₅	--	--	--	--	4.7	4.7%
C ₂₆ ⁺	<u>--</u>	<u>--</u>	<u>--</u>	<u>--</u>	<u>14.5</u>	<u>14.5%</u>
	<u>18.9</u>	<u>38.0</u>	<u>9.3</u>	<u>2.1</u>	<u>31.7</u>	<u>100.0</u>