FIGURE 50

BIMETALLIC Co/Ru CATALYST ON Al_2O_3–TiO_2 SUPPORT

PLT 700A RUN 68 H_2:CO (MOLAR)= 2.0

2.65 % Co , 0.49 % Ru , 50:50 Al_2O_3–TiO_2

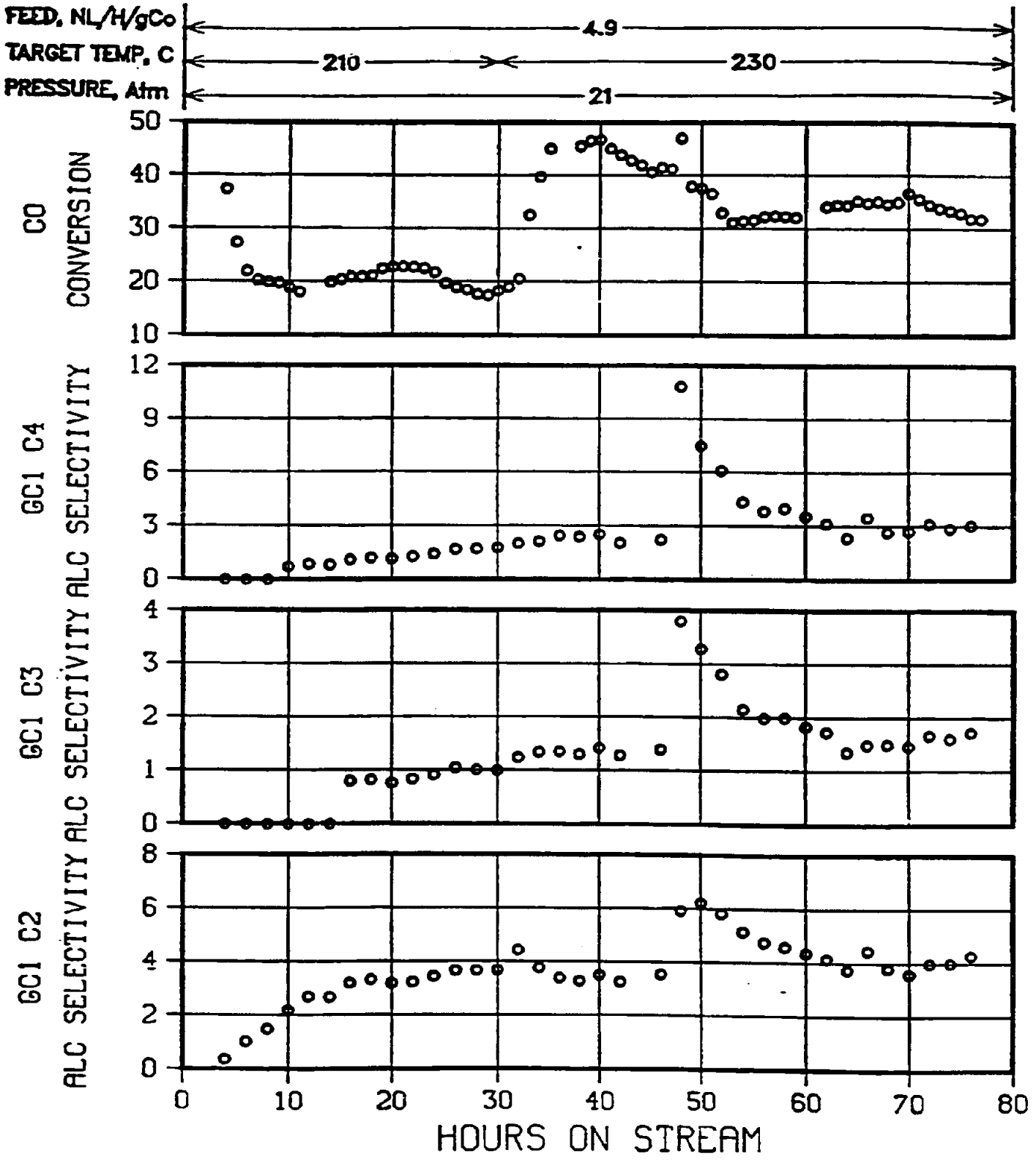


FIGURE 51

PLT 700A RUN 73 Co,Ru on 50/50 Al_2O_3/TiO_2

6531-134 w/7.45% Co via aq. impreg 2:1 H_2:CO in feed

13g Active in 160g SiO_2 sand

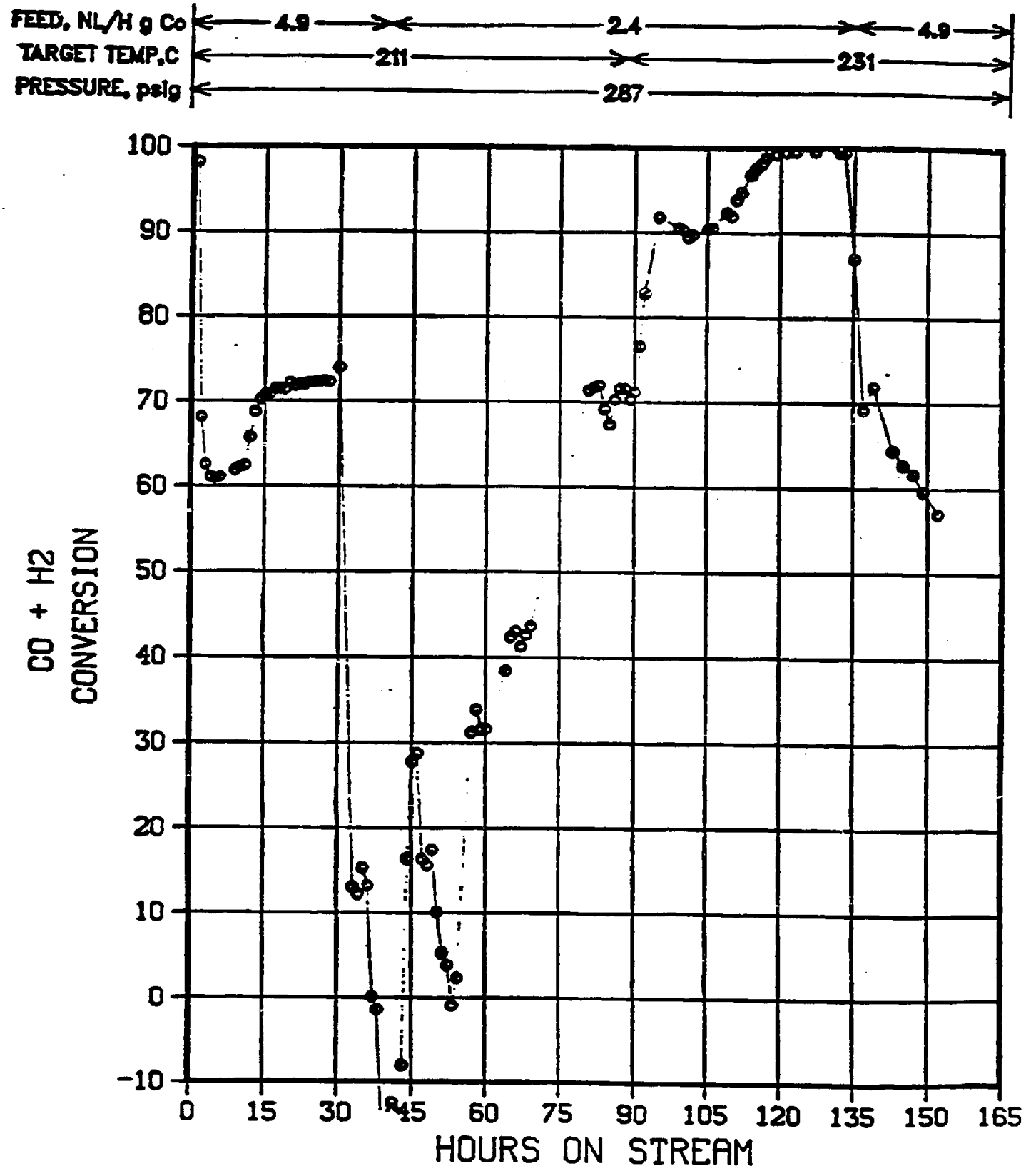


FIGURE 52

PLT 700A RUN 73 Co,Ru on 50/50 Al_2O_3/TiO_2

6531–134 w/7.45% Co via aq. impreg 2:1 H_2:CO in feed

13g Active in 160g SiO_2 sand

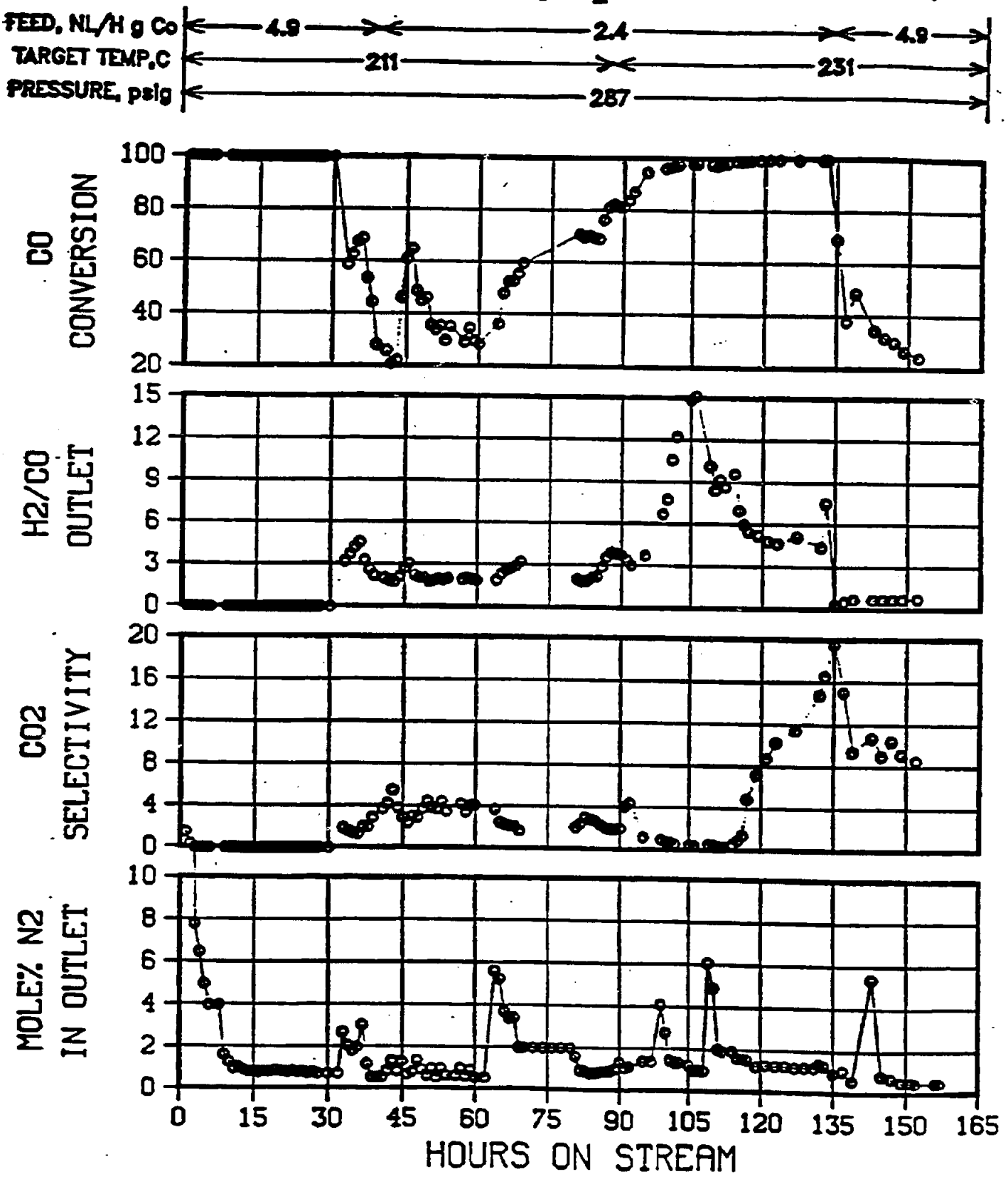


FIGURE 53

PLT 700A RUN 73 Co,Ru on 50/50 Al_2O_3/TiO_2

6531-134 w/7.45% Co via aq. impreg 2:1 H_2:CO in feed

13g Active in 160g SiO_2 sand

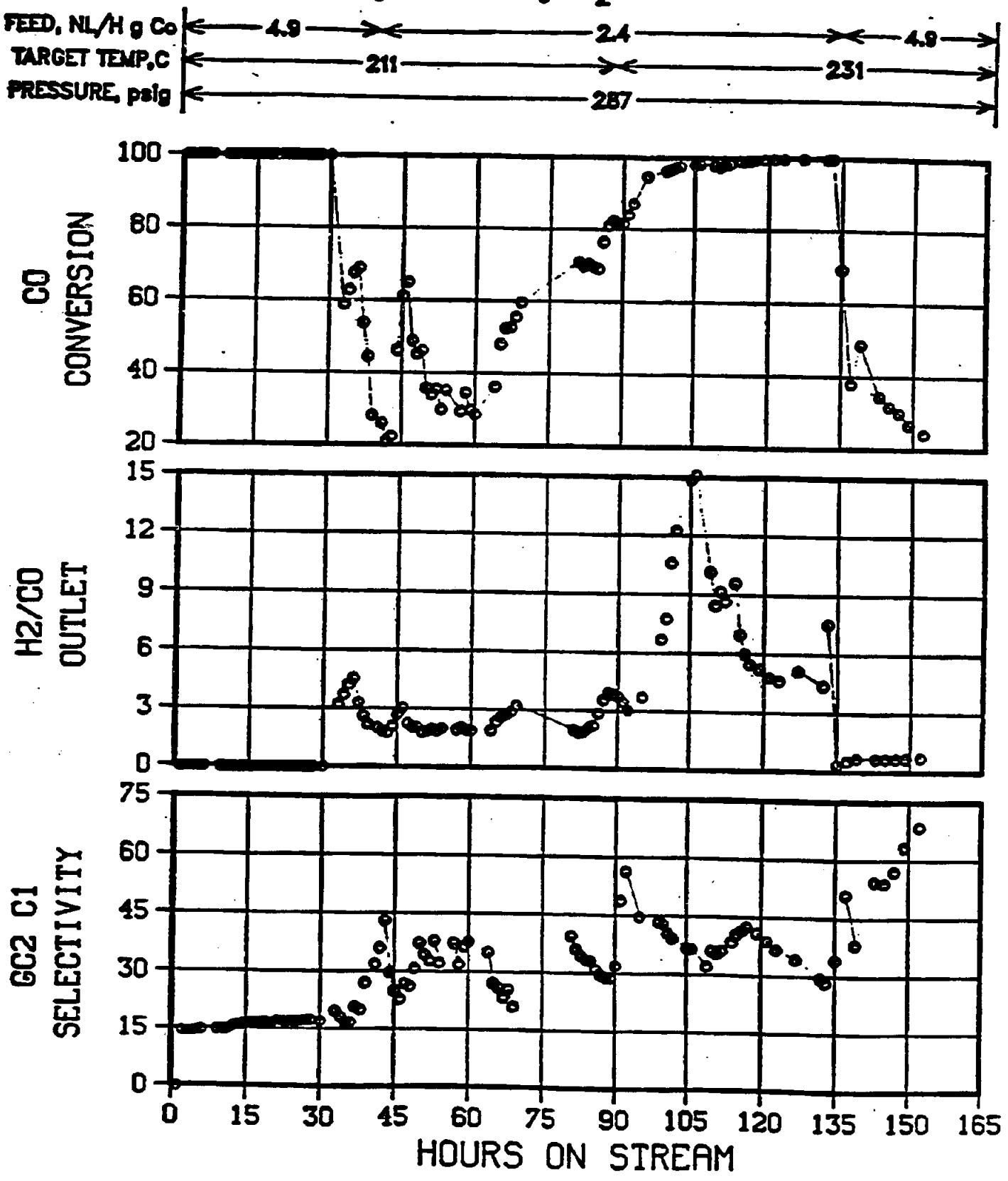


FIGURE 54

PLT 700A RUN 73 Co,Ru on 50/50 Al_2O_3/TiO_2

6531–134 w/7.45% Co via aq. impreg 2:1 H_2:CO in feed

13g Active in 160g SiO_2 sand

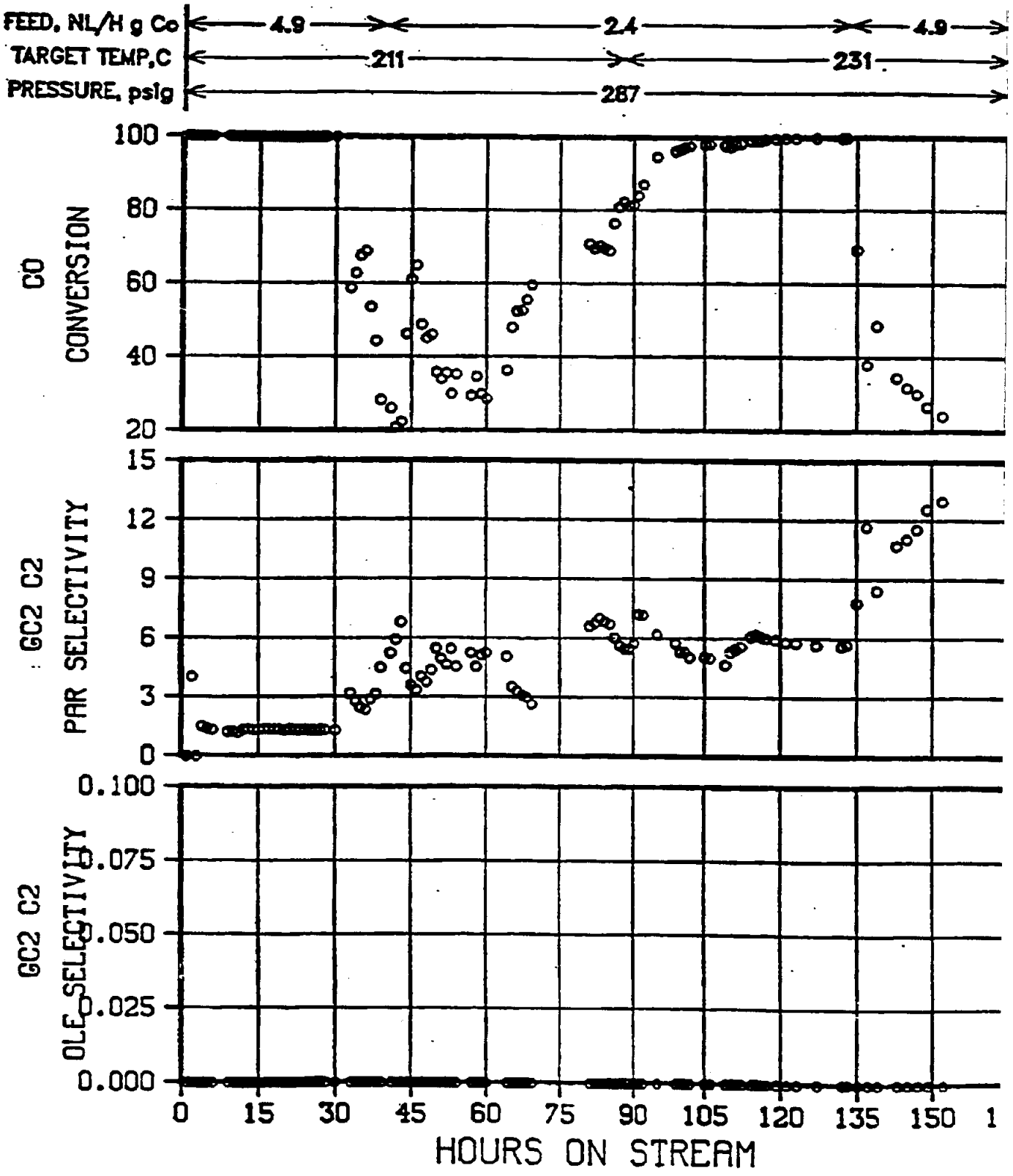


FIGURE 55

PLT 700A RUN 73 Co,Ru on 50/50 Al_2O_3/TiO_2

6531-134 w/7.45% Co via aq. impreg 2:1 H_2:CO in feed

13g Active in 160g SiO_2 sand

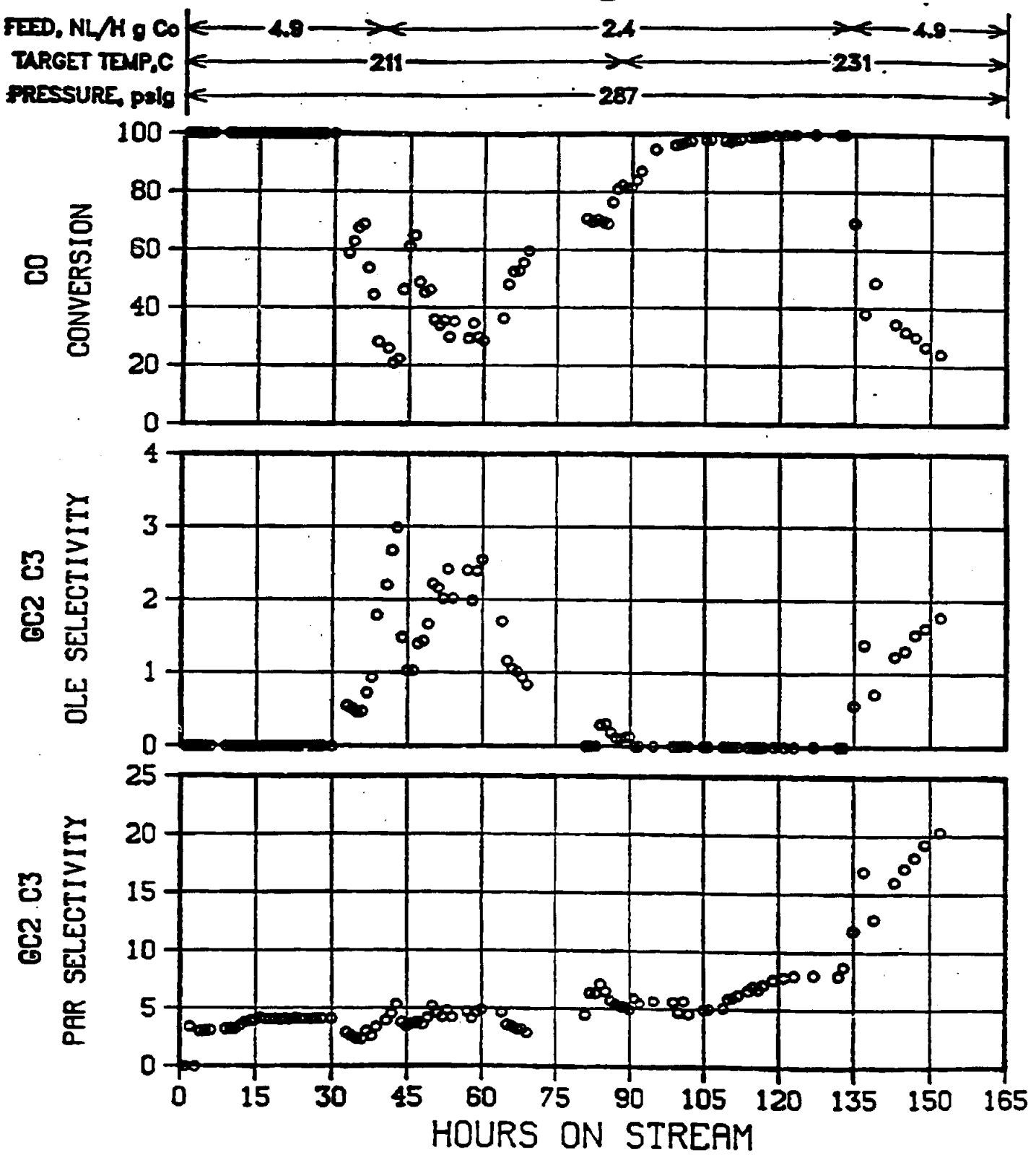


FIGURE 56

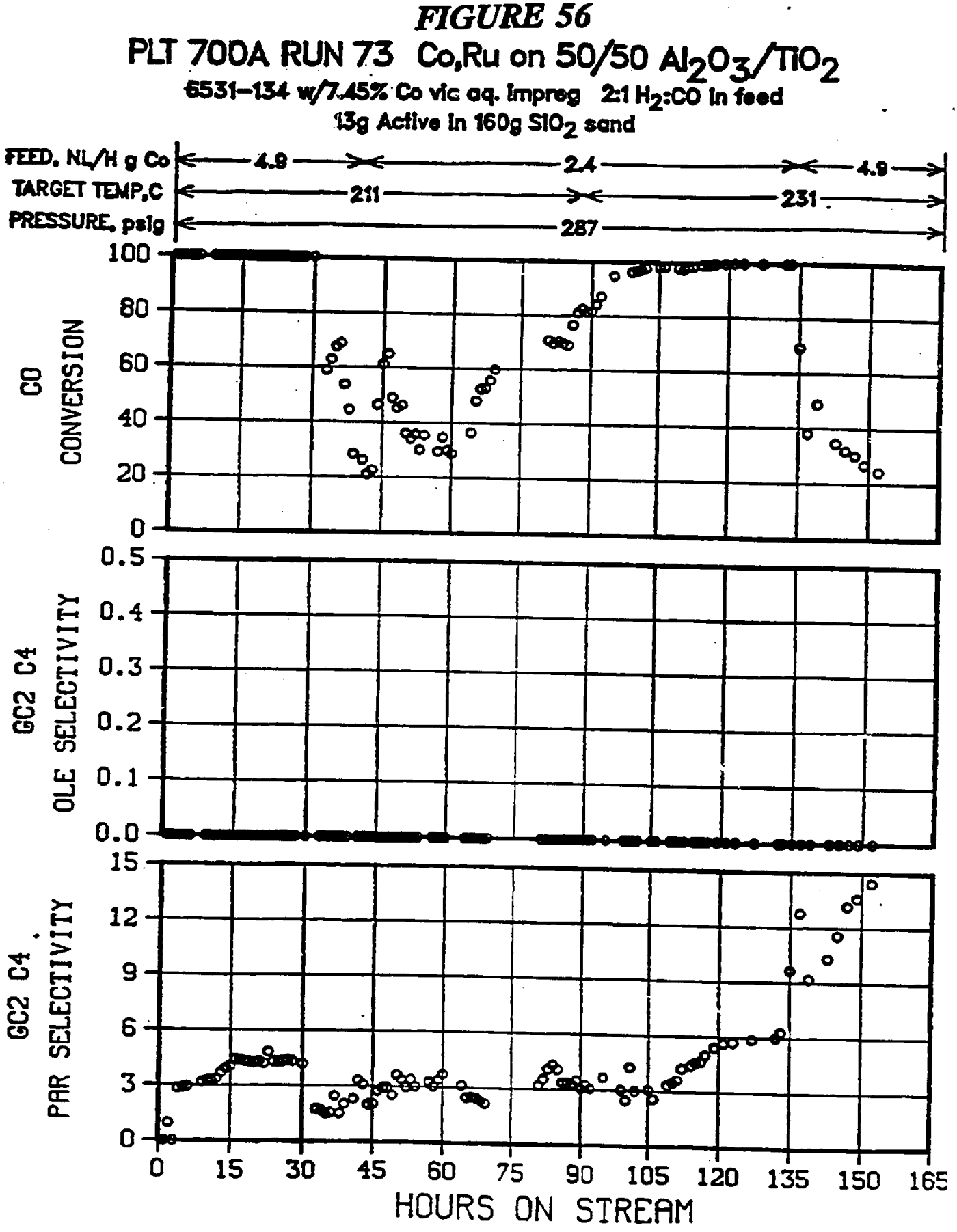

PLT 700A RUN 73 Co,Ru on 50/50 Al_2O_3/TiO_2
6531-134 w/7.45% Co vic aq. impreg 2:1 H_2:CO in feed
13g Active in 160g SiO_2 sand
FEED, NL/H g Co
TARGET TEMP,C
PRESSURE, psig
4.9
2.4
4.9
211
231
287
CO CONVERSION
GC2 C4 OLE SELECTIVITY
GC2 C4 PAR SELECTIVITY
HOURS ON STREAM

FIGURE 57

PLT 700A RUN 73 Co,Ru on 50/50 Al_2O_3/TiO_2

6531-134 w/7.45% Co via aq. impreg 2:1 H_2:CO in feed

13g Active in 160g SiO_2 sand

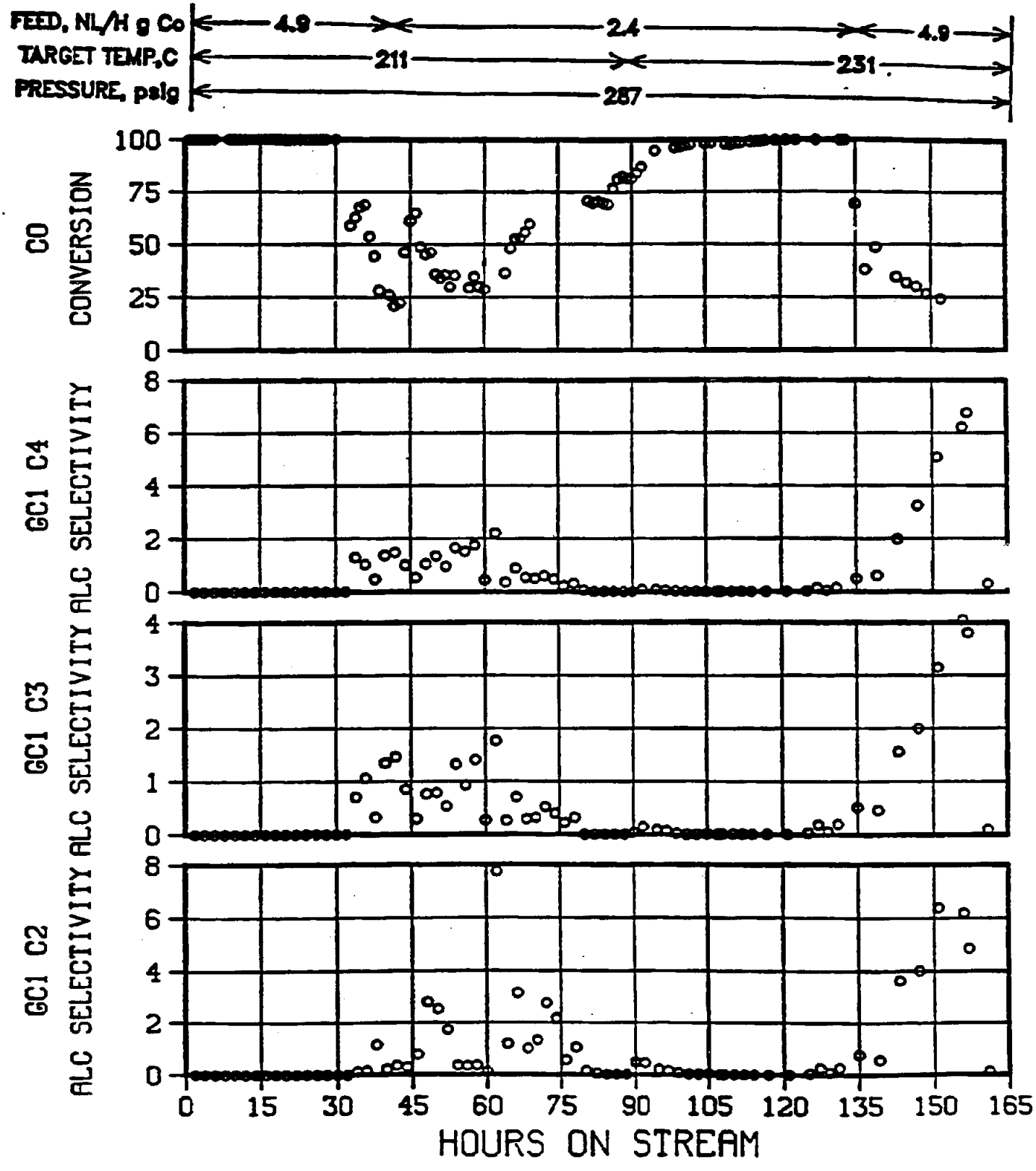


FIGURE 58

Particle Analysis

12524-27

Particle #	Weight % Si	Weight % Mn	Weight % Co	Weight % Zr
1	68.33	4.30	24.78	2.59
2	73.21	3.56	21.43	1.81
3	76.71	3.30	17.41	2.51
4	77.68	3.09	16.37	2.86
5	77.09	3.44	16.87	2.60
6	74.35	3.51	19.69	2.45
7	74.10	3.73	20.00	2.17
8	72.41	3.60	20.14	3.86
9	69.38	4.77	23.79	2.06
10	79.47	2.91	16.49	1.13
11	72.49	4.49	21.66	1.36
Average	79.11 ± 3.45	3.70 ± 0.58	19.88 ± 2.90	2.31 ± 0.75

FIGURE 59

Crystallite Atomic % Composition and Ratio as a Function of Size

6531-86

Crystallite Size (nm)	Atomic % Mn	Atomic % Co	Atomic % Zr	Atomic % Ru	Atomic Ratios Mn/Co	Atomic Ratios Zr/Co	Atomic Ratios Ru/Co
20	0.91	99.09	0	0	0.01	0	0
15	1.49	98.32	0.04	0.14	0.02	0.0004	0.001
20	0.66	99.28	0	0.07	0.01	0	0.001
20	11.08	87.52	0.71	0.69	0.13	0.01	0.01
6	8.57	91.43	0	0	0.09	0	0
6	1.05	98.40	0.21	0.33	0.01	0.002	0.003
8	2.14	96.57	0.49	0.81	0.02	0.01	0.01
10	2.55	94.98	1.00	1.47	0.03	0.01	0.02
8	2.09	94.42	2.53	0.96	0.02	0.03	0.01
15	6.50	84.11	5.37	4.01	0.08	0.06	0.05
10	0.99	98.83	0.18	0	0.01	0.002	0
8	0.67	98.94	0.02	0.36	0.01	0.0002	0.004
10	0.75	99.21	0	0.04	0.01	0	0.0004

FIGURE 60

Co-Ru Atomic Composition and Ratio as a Function of Crystallite Size

Ru/Co on MgO (6531-120)

Crystallite Size (nm)	Atomic % Co	Atomic % Ru	Ru/Co Atomic Ratio
15	93.74	6.26	0.067
10	96.00	4.00	0.042
15	93.78	6.22	0.066
10	92.78	7.22	0.078
25	91.37	8.63	0.094
20	97.13	2.87	0.030
30	96.83	3.17	0.033
30	95.24	4.76	0.050
20	98.53	1.47	0.015
20	92.00	8.00	0.087

FIGURE 61

Crystallite Atomic % Composition and Ratio as a Function of Size

6531-112

Crystallite Size (nm)	Atomic % Co	Atomic % Ru	Atomic Ratio Ru/Co
4	98.53	1.47	0.01
6	100.00	0.00	0.00
4	100.00	0.00	0.00
4	100.00	0.00	0.00
4	100.00	0.00	0.00
4	100.00	0.00	0.00
6	98.67	1.33	0.01
4	100.00	0.00	0.01
4	96.22	3.78	0.04
6	96.46	3.54	0.04
4	100.00	0.00	0.00
6	95.51	4.49	0.05
4	94.7	5.30	0.06
3	99.55	0.45	0.004
	93.58	6.42	0.07

FIGURE 62

6531-160

Crystallite Size (nm)	Weight %		Atomic %		Atomic Ratio
	Co	Ru	Co	Ru	Ru/Co
4	89.54	10.46	93.63	6.37	0.068
4	60.64	39.36	72.54	27.46	0.38
4	10.49	89.51	16.74	83.26	4.97
4	59.85	40.15	71.89	28.11	0.39
4	37.24	62.76	50.47	49.56	0.98
6	54.19	45.81	66.99	33.01	0.49
10	85.94	14.06	91.29	8.71	0.095
10	73.67	26.33	82.76	17.24	0.21
50	94.07	5.93	96.46	3.54	0.037
30	92.56	7.44	95.53	4.47	0.047
30	93.28	6.72	95.97	4.03	0.042
100	95.71	4.29	97.45	2.55	0.026
20	94.02	5.98	96.42	3.58	0.037
8	95.59	4.41	97.38	2.62	0.027
20	92.34	7.66	95.39	4.61	0.048
20	94.77	5.23	96.88	3.12	0.032
15	95.98	4.02	97.62	2.38	0.024
15	97.57	2.43	98.57	1.43	0.014
10	96.81	3.19	98.12	1.88	0.019
15	93.36	6.64	96.02	3.98	0.041
15	97.57	2.43	98.57	1.43	0.015

FIGURE 63

Particle Analysis

6531-104

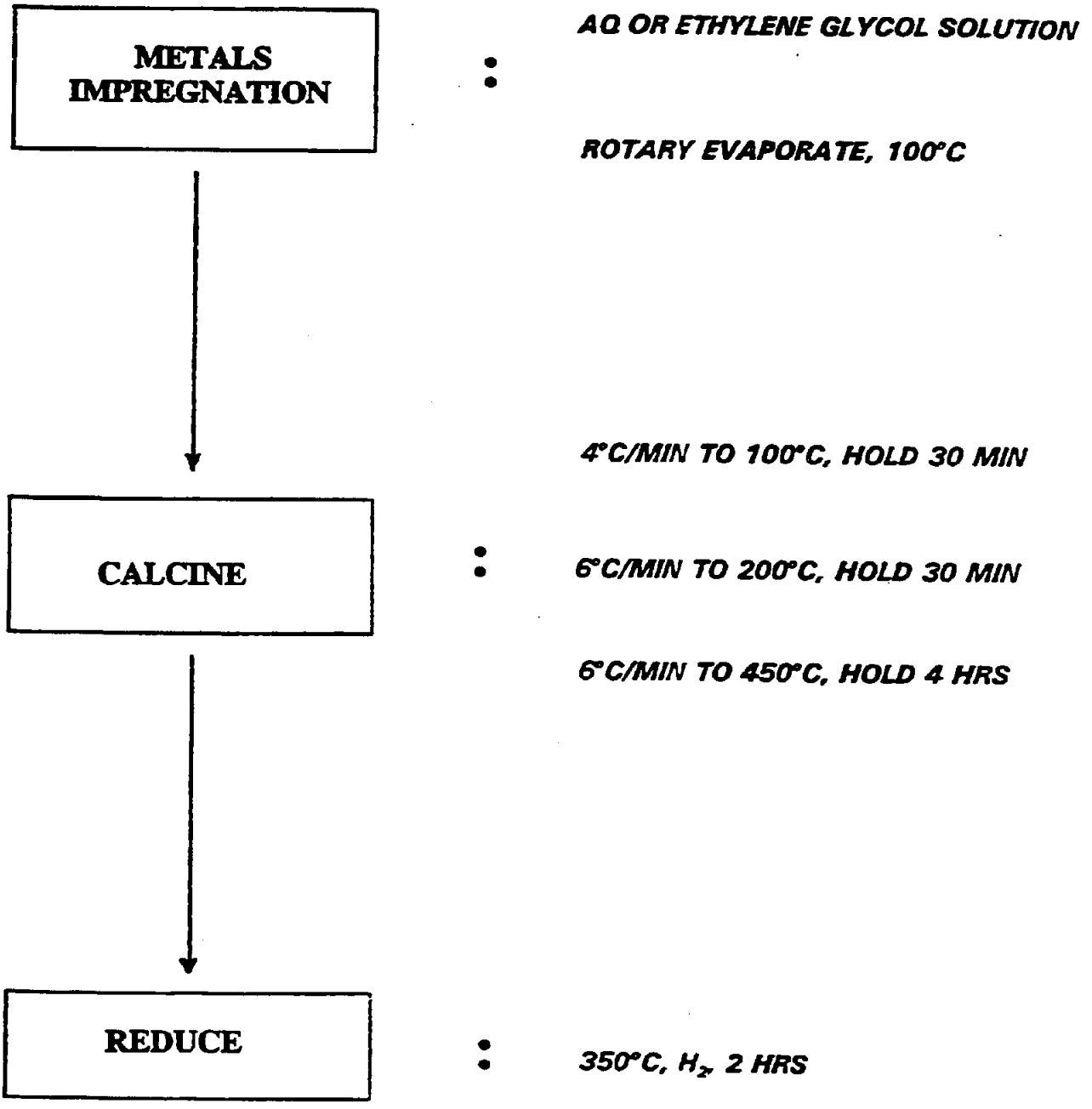
Particle #	Weight % Al	Weight % Ti	Weight % Co	Weight % Rn
1	42.18	50.21	6.33	1.28
2	44.51	48.49	5.43	1.57
3	43.94	57.23	3.83	0.00
4	43.15	53.77	3.03	0.05
5	43.15	53.27	3.58	0.00
6	41.83	54.52	3.52	0.13
7	44.02	52.51	3.47	0.00
8	48.33	47.6	4.03	0.04
9	47.53	49.18	3.26	0.03
10	47.36	48.76	3.82	0.06
11	47.04	48.98	3.91	0.07
Average	44.82 ± 2.32	50.86 ± 2.44	4.02 ± 0.99	0.29 ± 0.56

FIGURE 64

6531-134

Particle #	Weight %			
	Al	Ti	Co	Ru
1	44.80	40.41	13.21	1.58
2	54.86	36.10	7.68	1.36
3	48.60	43.96	6.12	1.32
4	52.29	37.75	8.64	1.32
5	41.66	44.02	12.58	1.74
6	64.20	25.59	9.18	1.03
7	55.54	37.08	6.09	1.29
8	46.30	40.97	11.25	1.48
9	59.36	30.11	8.59	1.94
10	41.14	39.19	18.44	1.22
11	51.83	34.56	12.55	1.07
12	46.29	36.72	15.06	1.92
13	47.01	38.74	12.93	1.32
14	46.67	40.36	11.72	1.25
15	45.21	37.03	15.89	1.86
Average	49.72 ± 6.54	37.51 ± 4.82	11.33 ± 3.60	1.45 ± 0.30

FIGURE 65
STANDARD CATALYST PREPARATION



PROPERTIES OF SUPPORTED METAL OXIDES ON STEAMED Y ZEOLITE (CATALYST PRECURSORS PRIOR TO REDUCTION)

ATOMIC ABSORBTION SPECTROSCOPY		
CATALYST SOURCE RUN NO	SUPPORT	AAS, WT %
TARRYTOWN 65[1]	STEAMED, ACID-WASHED Y ZEOL	Co, 8.3; Mn, 1.3; Zr, 1.0
DES PLAINES 81[1]	STEAMED Y ZEOLITE[2]	Co, 8.1; Mn, O.36; Zr, 1.0
DES PLAINES 82[1]	STEAMED Y ZEOLITE[2]	Co, 7.3; Mn, 0.64; Zr, 0.99
DES PLAINES 78[1]	STEAMED Y ZEOLITE[2]	Co, 7.3; Ru, 1.2; Mn, 0.6; Zr, 1.0
DES PLAINES 80[1]	STEAMED Y ZEOLITE[2]	Co, 7.5

1. AQUEOUS IMPREGNATION
2. SA = 591 m^2/g; PV = 51 cc/G

FIGURE 66

PERFORMANCE OF CATALYSTS ON STEAMED Y ZEOLITE HYDROCARBON PRODUCTS

THREE-CONDITION SCREENING TEST SUMMARY			
RUN NO	% CO CONVERSION/HYDROCARBON SELECS; C_1; C_2; $C_2^=$; C_3; $C_3^=$		
	CONDITION 1	2	3
65	58/7: 0.6: 0.00: 1.7: 2		
81	35/18: 3.2: 0.00: 4.0: 3.0	78/17: 2.8: 0.2: 3.5: 2.2	82/18: 3.0: 0.15: 3.7: 2.3
82	40/17: 3.8: 0.00: 6.0: 4.0	75/18: 3.3: 0.2: 5.0: 2.1	85/17: 3.0: 0.15: 5.0: 1.5
78	35/24: 5: 2: 4.8: 1.5	65/30: 2.2: 0.00: 4.9: 1.6	80/27: 2.2: 0.00: 5: 1.3
80	41/18: 1.8: 0.00: 2.8: 1.9	77/18: 1.8: 0.00: 2.9: 1.2	86/17: 2.2: 0.00: 3.0: 1.1

FIGURE 67

PERFORMANCE OF CATALYSTS ON STEAMED Y ZEOLITE ALCOHOL PRODUCTS

THREE-CONDITION SCREENING TEST SUMMARY			
RUN NO	% CO CONV/ALCOHOL SELECS; C_2: C_3: C_4 CONDITION		
	1	2	3
65	58/0.5: 0.2: 0.2		
81	35/0.00: 0.00: 0.00	70:0.2: 0.05: 0.02	82/0.1: 0.02: 0.02
82	40/0.4: 0.1: 0.00	75/0.2: 0.05: 0.03	85/0.10: 0.03: 0.02
78	35/0.4: 0.00: 0.00	65/0.3: 0.06: 0.04	80/0.2: 0.06: 0.06
80	41/0.1: 0.00: 0.00	77/0.1: 0.03: 0.01	86/0.1: 0.02: 0.01

FIGURE 68

CATALYST PRECURSORS: SUPPORTED OXIDES ON STEAMED/ACID-WASHED Y ZEOLITES

SUPPORT PROPERTIES			CATALYST NO./ RUN NO.	CATALYST METALS, AAS WT%		
TRTMNTS	SA[1]/PV[2]	Al[3]		Co	Mn	Zr
STMD	591/0.51	5.24	6531-176/80 6531-167/81 6531-166/82	7.5 8.1 7.3	 0.4 0.6	 1.0 1.0
STMD/ HNO_3[4]	562/0.49	4.83	6531-178/83 6531-180/84	7.7 8.5	 1.7	 1.1
STMD/ HNO_3[5]	586/0.51	3.86	6531-182/85	9.4		
STMD/ HNO_3[6]	596/0.54	2.94	6531-188/86 6531-186/87	9.1 8.9		

1. m^2/g
2. cc/g
3. wt %
4. WASH 36 HOURS WITH 2M HNO_3.
5. WASH 36 HOURS WITH 3M HNO_3.
6. WASH 72 HOURS WITH 3M HNO_3.

FIGURE 69

FIGURE 70

ACTIVITY AND HYDROCARBON SELECTIVITY OF CATALYSTS

Run No.	*Test Conditions*	*CO Conversion, %*	*Hydrocarbon Selectivity, %*				
			C_1	C_2	$C_2^=$	C_3	$C_3^=$
65	*1*	*58*	*7*	*0.6*	*0*	*1.7*	*2.0*
80	*1*	*41*	*18*	*1.8*	*0*	*2.8*	*1.9*
	2	*77*	*18*	*1.8*	*0*	*2.9*	*1.2*
	3	*86*	*17*	*2.2*	*0*	*3.0*	*1.1*
83	*1*	*43*	*18*	*2.5*	*0*	*3.2*	*2.4*
	2	*70*	*20*	*2.5*	*0*	*3.2*	*2.0*
	3	*81*	*20*	*2.5*	*0.1*	*3.2*	*1.7*
81	*1*	*35*	*18*	*3.2*	*0*	*4.0*	*3.0*
	2	*78*	*17*	*2.8*	*0.2*	*3.5*	*2.2*
	3	*82*	*18*	*3.0*	*0.2*	*3.7*	*2.3*
82	*1*	*40*	*17*	*3.8*	*0*	*6.0*	*4.0*
	2	*75*	*18*	*3.3*	*0.2*	*5.0*	*2.1*
	3	*85*	*17*	*3.0*	*0.2*	*5.0*	*1.5*
84	*1*	*32*	*18*	*4.1*	*0*	*5.1*	*4.1*
	2	*72*	*16*	*3.6*	*0.2*	*4.2*	*3.0*
	3	*85*	*17*	*3.3*	*0.2*	*3.8*	*2.7*

FIGURE 70 CONT.

ACTIVITY AND HYDROCARBON SELECTIVITY OF CATALYSTS

Run No.	Test Conditions	CO Conversion, %	Hydrocarbon Selectivity, %				
			C_1	C_2	$C_2^=$	C_3	$C_3^=$
65	1	58	7	0.6	0	1.7	2.0
85	1	51	15	1.6	0	2.1	2.0
	2	83	14	1.6	0	2.1	1.5
	3	95	13	1.7	0	2.4	1.3
86	1	40	15	3.2	0	4.2	5.0
	2	82	15	3.0	0	4.0	3.0
	3	85	16	3.0	0	3.1	3.0
87	1	82	10	1.1	0.1	1.3	2.0
	2	90	13	1.3	0	2.0	1.0
	3	95	12	1.4	0	2.0	1.1

FIGURE 71

ACTIVITY AND ALCOHOL SELECTIVITY OF CATALYSTS

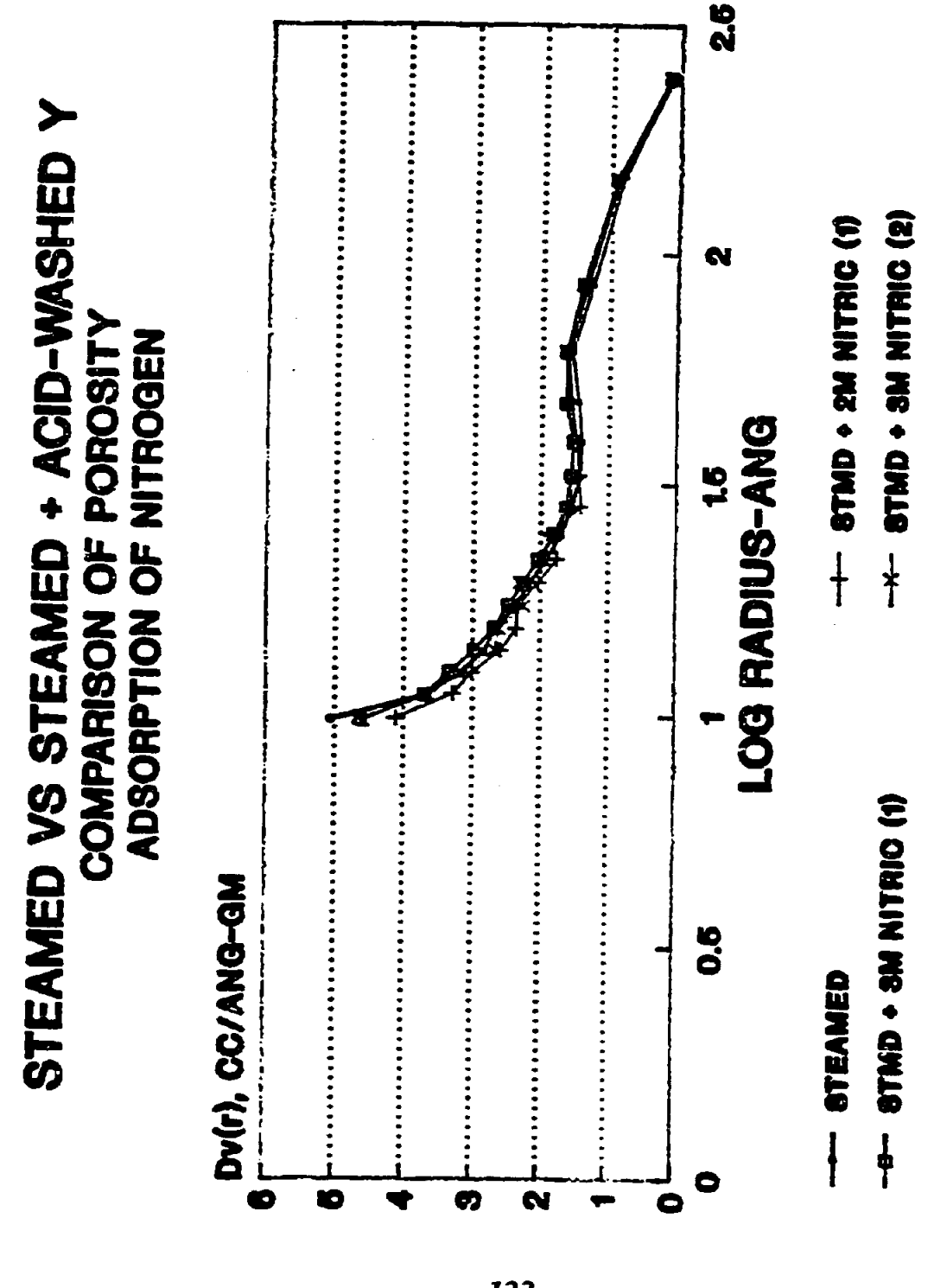
Run No.	Test Conditions	CO Conversion, %	Alcohol Selectivity, %		
			C_2	C_3	C_4
65	1	58	0.5	0.6	2.0
80	1	41	0.1	0	0
	2	77	0.1	0.03	0.01
	3	86	0.1	0.02	0.01
83	1	43	0.3	0	0
	2	70	0.2	0.03	0.01
	3	81	0.2	0.03	0.01
81	1	35	0	0	0
	2	70	0.2	0.05	0.02
	3	82	0.1	0.02	0.02
82	1	40	0.4	0.1	0
	2	75	0.2	0.05	0.03
	3	85	0.1	0.03	0.02
84	1	32	0.4	0.1	0.08
	2	72	0.3	0.1	0.05
	3	85	0.2	0.08	0.03

FIGURE 71 CONT.

ACTIVITY AND ALCOHOL SELECTIVITY OF CATALYSTS

Run No.	Test Conditions	CO Conversion, %	Alcohol Selectivity, %		
			C_2	C_3	C_4
65	1	58	0.5	0.6	2.0
85	1	51	0.3	0.2	0.1
	2	83	0.1	0.05	0.05
	3	95	0.1	0.05	0.05
86	1	40	0.5	0.2	0.15
	2	82	0.4	0.2	0.1
	3	85	0.2	0.1	0.05
87	1	82	0.2	0.05	0.03
	2	90	0.4	0.1	0.03
	3	95	0.2	0.03	0

FIGURE 72


STEAMED VS STEAMED + ACID-WASHED Y
COMPARISON OF POROSITY
ADSORPTION OF NITROGEN
Dv(r), CC/ANG-GM
0
1
2
3
4
5
6
0
0.5
1
1.5
2
2.5
LOG RADIUS-ANG
STEAMED
STMD + 3M NITRIC (1)
STMD + 2M NITRIC (1)
STMD + 3M NITRIC (2)
(1) 36 HR WASH
(2) 72 HR WASH