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6 SPECIAL REPORT NO. 2
AN EVALUATION OF FUEL CELL
SYSTEMS FOR MILITARY VEHICLE
PROPULSION AND PORTABLE
ELECTRIC POWER GENERATION, PART 2.

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By

by Maurice J. Schlatter.

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A P P E N D I X A

POWER DENSITIES AND FUEL CONSUMPTION OF GASOLINE AND DIESEL ENGINES

In order to give a consistent basis of comparison, we have chosen to relate fuel cell systems to typical military gasoline and diesel engines. The engines chosen are the 150 hp gasoline engine and 330 hp diesel engine systems used by Cather¹ and by us² in earlier comparisons. Basic data are given in Table I and Figure 2 of this report.

Fuel utilization efficiencies for the reference engines over a range of engine power outputs and engine speeds are not available from the Cather report,¹ which gives only the brake specific fuel consumptions (bsfc) at optimum conditions. For purposes of comparison, published data for gasoline and diesel engines similar in size to the reference engines were used to obtain the curves shown in Figure 2. Average fuel consumption figures were estimated from these curves. Small adjustments were applied to bring the optimum efficiencies from the curves in line with the values calculated from Cather's data for the reference engines.

For the engines considered, there is a single condition giving maximum power output. In Table A-1 the best and poorest brake specific fuel consumptions (bsfc) within the range of available data are shown as a function of per cent of maximum power output (load factor).

These values were taken from the references listed. Fuel utilization efficiencies calculated from the bsfc values are also shown. Fuel utilization efficiencies versus per cent of maximum engine power output are plotted in Figure 2. Table A-1 also contains values for energy produced per pound and gallon of fuel as a function of engine and engine plus transmission power densities. These numbers were used in constructing the engine curves which are compared with fuel cell systems in Figures 3 and 4.

Power density data for several gasoline and diesel engines having power ratings approximating those of the reference engines (Table I) are

TABLE A-1

**POWER DENSITIES AND FUEL CONSUMPTIONS
OF GASOLINE AND DIESEL ENGINES**

Per Cent of Max., hp	Gasoline Engine				Diesel Engine			
	Power Density ^a		Fuel Consumption		Power Density ^a		Fuel Consumption	
	Engine, hp/cu ft	Engine + Transmission, hp/cu ft	bsfc lb/hp-hr	Engine Fuel Efficiency, a, %	Engine, hp/cu ft	Engine + Transmission, hp/cu ft	bsfc lb/hp-hr	Engine Fuel Efficiency, a, %
10	0.8	0.43	> 1.3	> 11.1	1.05	0.44	> 0.44	> 31.1
20	1.6	0.85	> 0.75	> 19.2	2.1	0.87	> 0.40	> 11.0
30	2.4	1.28	1.40-0.635	10.3-22.7	3.15	1.31	0.485-0.37	> 12.0
40	3.2	1.71	1.07-0.58	13.5-24.8	4.2	1.75	0.455-0.36	9.9-13.0
50	4.0	2.14	0.95-0.555	15.2-26.0	5.25	2.17	0.43-0.36	10.6-13.4
60	4.8	2.56	0.86-0.56	16.0-26.0	6.2	2.62	0.41-0.355	11.2-13.3
70	5.6	2.99	0.82-0.57	17.6-25.7	7.25	3.06	0.40-0.375	11.6-13.1
80	6.4	3.42	0.79-0.595	18.2-24.2	8.4	3.50	0.40-0.385	11.9-12.9
90	7.2	3.84	0.65	22.2	9.45	3.93	0.40	12.0-12.5
100	8.0	4.27			10.5	4.37		12.0
								34.2
								34.2
								1.75

A-2

a. Power densities, engine efficiencies, and engine + transmission fuel consumption values, are for the engines and engine-transmission systems in Table I.

b. Gasoline fuel consumption data were taken from Reference 49, Figure 113, page 220. They are for a 1946 Ford V-8 engine installed with fan, generator, muffler, tailpipe, and automatic spark advance control. The data cover the operating range from 500-2500 rpm and from about 8% to 100% of maximum power. The figures were found to correspond approximately to data points from later model engines.

c. Diesel fuel consumption data were taken from Reference 50, Figure 30. They are for a two-stroke, 4-cylinder, 200 hp diesel engine. The data cover the range 700-1600 rpm and about 25% to maximum hp.

d. It was assumed that fuel consumption characteristics of the reference engines (Table I) would correspond closely to those of the engines described in footnotes b and c. Therefore, for the gasoline engine, fuel efficiencies were calculated assuming that the minimum bsfc (0.555) corresponded to the 26% optimum efficiency calculated for the reference engine (bsfc, 0.53). With the diesel engine, the minimum bsfc (0.36) was assumed to correspond to 36% optimum efficiency for the reference diesel engine (bsfc, 0.36). These engine efficiencies are based on the net heating values of the fuels.

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given in Table A-2. The power densities of the gasoline industrial engines and highly developed military diesel engines approximate those of the reference engines. The power densities of typical industrial diesel engines are only one half to two thirds those of highly developed military diesel engines.

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TABLE A-2

**POWER DENSITIES OF GASOLINE
AND DIESEL ENGINES**

Engine	Power Rating Max. bhp ^a	Engine Weight, lb	Engine Volume, ^c cu ft	Power Density		References
				bhp/lb	bhp/cu ft	
<u>Gasoline Industrial Engines</u>						
Chevrolet 327	158	622	23.5	0.25	6.7	51
Chrysler 318	150	550	15.3	0.27	9.8	51
Ford 292	153	553	18.0	0.28	8.5	51
GMC 351	155	-	26.8	-	5.8	51
Studebaker 289	156	634	16.2	0.25	9.6	51
Average	154	590	20.0	0.26	7.7	
Reference Engine (Table I)	150	750	18.8	0.20	8.0	1
<u>Diesel Industrial Engines</u>						
Cummins 855	325	2750	55.0	0.12	5.9	51
Cummins 950	365	3020	62.1	0.12	5.9	51
GMC 851	390	5620	177.4	0.07	2.2	51
International Harvester 817	362	3540	77.7	0.10	4.7	51
Average	360	3732	93.0	0.10	4.7	
<u>Diesel Military Engines</u>						
Lycoming S and H	(100) ^b	600	14.4	0.20	(6.9) ^d	52
Caterpillar LDS-750	425	2000	42.5	0.21	10.0	53
Reference Engine (Table I)	330	1600	31.4	0.21	10.5	1

a. Maximum brake horsepower with standard accessories.

b. Estimated from gross rating (without accessories), 120 bhp.

c. "Box volume." Product of maximum dimensions.

d. Calculated from estimated maximum brake horsepower.

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APPENDIX B

POWER DENSITIES AND FUEL CONSUMPTIONS OF PRESENT FUEL CELLS

Data representative of the best reported fuel cell current densities and efficiencies are given in Table B-1. The hydrogen-oxygen data are for prototype units for which more than 500,000 hours of test data have been obtained. The hydrazine-oxygen fuel cell data are also from a prototype unit, used in this case to power a golf cart. This unit has not had anywhere near the amount of development that has been expended on the hydrogen-oxygen cells. The other data are from laboratory experiments. These cells do not have proven "operating life" at the present time.

In order to provide a consistent basis for comparison of the different fuel cell systems, it is assumed that the cell thickness in each case is one-fourth inch and that there are 48 square feet of anode surface per cubic foot of fuel cell. In the calculations, the volumes of accessory equipment are disregarded. These volumes may well reduce the power densities of the fuel cell systems to less than one half the values given.

The electric motor volumes were calculated on the basis of 10 hp per cubic foot. This value is essentially the same as was used by Cather¹ in a more general comparison of fuel cell-transmission systems. The rated motor size was taken arbitrarily as 70% of the maximum output obtainable from the fuel cell. In the case of the hydrogen-oxygen fuel cell system, the motor size was selected to correspond to 100 amperes per square foot current density which is the maximum for continuous operation of this cell. Double this current density is allowable for short periods.

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TABLE B-1

FUEL CELL PERFORMANCE DATA

Fuel Cells and Constants Used in Calculations	Cell Potential, volts	Current Density, amp/sq ft	Power Density ^a			Thermal Efficiency, ^c Fuel Cell Only, %	Power Produced per Unit of Fuel		
			Fuel Cell Only		Fuel Cell + d-c Motor, ^b		Fuel Cell Only,	Fuel Cell + d-c Motor ^d	
			w/sq ft	hp/cu ft	hp/cu ft		hp-hr/lb	hp-hr/lb	hp-hr/gal
Hydrogen-Oxygen (Union Carbide, Ref. 54)	1.01	25	25	1.65	0.8	68	16.3	11.4	6.75
$E^0 = 1.229$ volts	0.95	50	48	3.05	1.5	64	15.4	10.8	6.4
$\Delta F_c/\Delta H_c = 0.829$	0.93	75	70	4.5	2.2	63	15.0	10.5	6.2
60°C, Atm. Press., Aq. KOH	0.90	100	90	5.8	2.85	61	14.5	10.2	6.05
Electrolyte	0.88	125	110	7.1	3.45	59.5	14.2	9.95	5.9
	0.87	150	131	8.45	4.1	58.5	14.1	9.85	5.85
	0.86	175	150	9.65	4.7	58	13.9	9.75	5.8
Intermittent Operation only above 100 amp/sq ft	0.85	200	170	11.0	5.35	57.5	13.7	9.6	5.7
Current Density									
Hydrazine-Oxygen (Allis-Chalmers, Ref. 55) ^e	1.01	50	50	3.2	1.05	62.5	2.02	1.41	11.6
$E^0 = 1.55$ volts	0.94	100	94	6.05	2.0	58	1.82	1.28	10.5
$\Delta F_c/\Delta H_c = 0.963$	0.81	200	162	10.4	3.45	50	1.62	1.13	9.25
70°C, Atm. Press., 0.9M Hydrazine	0.70	300	210	13.5	4.5	43	1.40	0.98	8.05
in 5.5M KOH Electrolyte	0.585	400	234	15.1	5.0	36	1.17	0.82	6.7
	0.47	500	235	15.2	5.0	29	0.94	0.66	5.4
	0.35	600	210	13.5	-	21.5	0.70	0.49	4.0
	0.22	700	154	9.9	-	13.5	0.44	0.31	2.55
Methanol-Oxygen (Esso, Ref. 56)									
$E^0 = 1.215$ volts	0.65	9.3	6.1	0.39	0.24	52.5	2.00	1.40	9.3
$\Delta F_c/\Delta H_c = 0.984$	0.58	19	10.8	0.71	0.44	47	1.78	1.25	8.3
82°C, Atm. Press., 1.83M Methanol	0.44	47	20.7	1.33	0.83	35.5	1.35	0.94	6.25
in 30% H ₂ SO ₄ Electrolyte	0.37	67	24.8	1.60	1.00	30	1.14	0.80	5.3
	0.28	93	26.0	1.68	1.05	22.5	0.86	0.60	4.0
Propane Oxygen (G.E., Ref. 8, Fig. 16)	0.68	9.3	6.3	0.41	0.25	59.5	5.1	3.55	15.3
$E^0 = 1.091$ volts	0.61	19	11.6	0.75	0.45	53.5	4.5	3.2	13.7
$\Delta F_c/\Delta H_c = 0.958$	0.52	37	19.2	1.24	0.75	45.5	3.9	2.7	11.7
200°C, 96% H ₃ PO ₄ , Atm. Press.	0.46	56	25.8	1.66	1.00	40.5	3.4	2.4	10.4
	0.40	74	29.6	1.91	1.15	35	3.0	2.1	9.0
	0.35	93	32.6	2.10	1.27	30.5	2.6	1.8	7.9
	0.31	112	34.7	2.24	1.35	27	2.3	1.6	7.0
	0.27	130	35.1	2.26	1.36	23.5	2.0	1.4	6.1
	0.23	149	34.3	2.21	-	20	1.7	1.2	5.2
	0.20	167	33.4	2.16	-	17.5	1.5	1.05	4.5
n-Octane-Oxygen (O.E., Ref. 8, Fig. 17)	0.59	9.3	5.5	0.35	0.22	51.5	4.2	2.95	17.2
$E^0 = 1.100$ volts	0.53	19	10.1	0.65	0.41	46.5	3.8	2.65	15.5
$\Delta F_c/\Delta H_c = 0.962$	0.45	37	16.7	1.07	0.67	39.5	3.2	2.25	13.1
200°C, 96% H ₃ PO ₄ , Atm. Press.	0.38	56	21.3	1.37	0.86	33	2.7	1.9	11.0
	0.34	74	25.2	1.62	1.01	29.5	2.4	1.7	9.9
	0.29	93	27.0	1.74	1.09	25.5	2.1	1.45	8.5
	0.24	112	26.9	1.74	1.09	21	1.7	1.2	7.0
	0.21	130	27.3	1.76	1.10	18.5	1.5	1.05	6.1
	0.17	149	25.3	1.60	-	15	1.2	0.85	5.0

a. Fuel cell power density based on standard design using cells 1/4-inch thick having an anode area of 48 square feet per cubic foot of cell.

b. The d-c motor size for continuous operation is taken as 70% of the maximum fuel cell power output. Motor volume was calculated assuming 10 hp per cubic foot.

c. Thermal efficiency = $\frac{\Delta F_c}{\Delta H_c} \cdot \frac{E}{E^0}$

where ΔF_c is the free energy of combustion, ΔH_c is the heat of combustion under the same conditions, E is the actual potential across the cell terminals, and E^0 is the theoretical reversible potential for complete combustion of the fuel. The gross heat of combustion of the fuel was used in these calculations. See Table C-1.

d. The combined efficiency of the d-c motor, controls, and power train is assumed to be 70%.

e. This hydrazine-oxygen fuel cell is reported to give only about 80% of the current expected from complete oxidation of the fuel. This results from direct chemical oxidation of part of the fuel. This low "current efficiency" can probably be corrected by improved cell design and is ignored in the calculations and curves.

A P P E N D I X C

HEATS OF COMBUSTION OF SOME FUELS

Gross heats of combustion used in calculations for Table B-1 and net heats of combustion used in comparative thermal efficiency calculations in the body of this report are tabulated in Table C-1.

:msr

TABLE C-1

HEATS OF COMBUSTION OF SOME FUELS

Fuel	Net Heat of Combustion (25°C, H ₂ O Vapor)		Gross Heat of Combustion (25°C, H ₂ O Liquid)	
	Btu/lb	Btu/gal	Btu/lb	Btu/gal
Hydrogen	51,570	30,600 ^a	60,960	36,100 ^a
Methanol (aq.) ^b	8,475	56,100	9,660	64,000
Ammonia (aq.) ^b	7,120	36,400	8,790	44,900
Hydrazine (aq.) ^b	7,120	58,500	8,250	67,700
Methane	21,500	75,800 ^c	23,860	84,100 ^c
Propane	19,930	82,100	21,650	89,200
n-Octane	19,100	111,000	20,750	121,000
Motor Gasoline (30% Aromatics)	18,500	115,000	20,000	124,000
Diesel Fuel	17,500	120,000	19,000	130,000

a. -257°C.

b. Heat of combustion in aqueous solution as oxidized in fuel cells.

c. -160°C.

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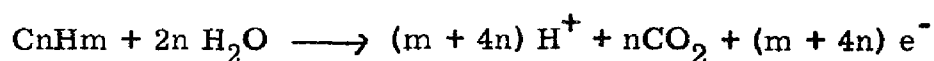
APPENDIX D

DIRECT n-NONANE - AIR FUEL CELL MATERIAL BALANCE CALCULATIONS

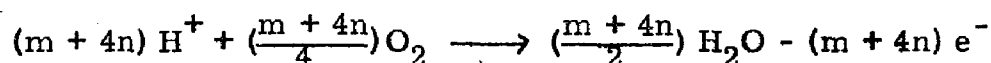
Flow rates and system stream compositions are required if water balance and fuel recovery from exhaust streams are to be analyzed. The model used as the basis for the calculations and discussion which follows and definitions of the symbols used are shown in Figure D-1.

The generalized half cell reactions for any direct hydrocarbon fuel cell using acid electrolyte are:

Anode Reaction:



Cathode Reaction:



If a = moles of hydrocarbon reacted in the fuel cell according to the half cell reactions, then the reaction stoichiometry gives the following relationships:

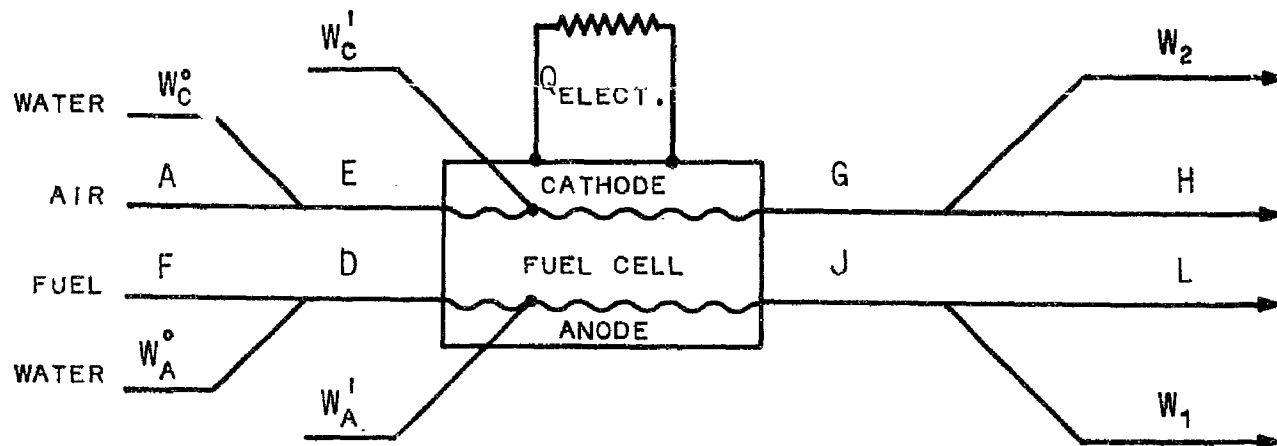
Anode Streams:*

Component	Anode Feed Ⓓ Moles	Net Reaction, Moles	For Water Balance, Moles	Anode Exhaust Ⓙ Moles
Fuel	F	-a		F-a
H ₂ O	W _A [°]	-2na	W _A '	W _A -2na
CO ₂	-	+na		+na
Total	F+W _A [°]	-(n+1)a		F+W _A [°] - (n+1)a

* The capital letters which appear in the headings of the tables in this section refer to fuel cell reactant and product streams shown in Figure D-1.

FIGURE D-1

DIRECT HYDROCARBON FUEL CELL MODEL FOR
WATER BALANCE AND FUEL RECYCLE



W_C^o = WATER PRESENT IN CATHODE FEED.

W_C^i = WATER TO OR FROM ELECTROLYTE TO CATHODE GAS STREAM:

$$1. \quad W_C = W_C^o + W_C^i$$

ANODE WATER SYMBOLS CORRESPOND TO THOSE FOR CATHODE:

$$2. \quad W_A = W_A^o + W_A^i$$

W_1 = WATER RECOVERED FOR RECYCLE FROM ANODE EXHAUST "J".

W_2 = WATER RECOVERED FOR RECYCLE FROM CATHODE EXHAUST "G".

P = ANODE AND CATHODE STREAM PRESSURE.

P_{H_2O} = VAPOR PRESSURE OF WATER FROM ELECTROLYTE.

X_F = MOLE FRACTION OF FUEL IN THE ANODE EXHAUST GAS "J".

X_{H_2O} = MOLE FRACTION OF WATER IN THE ANODE EXHAUST GAS "J".

Y = FRACTIONAL APPROACH TO WATER EQUILIBRIUM WITH ELECTROLYTE:

$$3. \quad X_{H_2O} = Y \cdot \frac{P_{H_2O}}{P} \quad (\text{ANODE EXHAUST})$$

$X_{O_2}^i$ = MOLE FRACTION OF OXYGEN IN CATHODE EXHAUST GAS "G".

$X_{H_2O}^i$ = MOLE FRACTION OF WATER IN THE CATHODE EXHAUST GAS "G".

Z = FRACTIONAL APPROACH TO WATER EQUILIBRIUM WITH ELECTROLYTE:

$$4. \quad X_{H_2O}^i = Z \cdot \frac{P_{H_2O}}{P} \quad (\text{CATHODE EXHAUST})$$

Cathode Streams:*

Component	Cathode Feed (D) Moles	Net Reaction, Moles	For Water Balance, Moles	Cathode Exhaust (G) Moles
O ₂	0.21A	$-(\frac{m+4n}{4})a$		$0.21A - (\frac{m+4n}{2})a$
N ₂	0.79A			0.79A
H ₂ O	W _C [°]	$+(\frac{m+4n}{2})a$	W _C [']	$W_C + (\frac{m+4n}{2})a$
Total	A+W _C [°]	$+(\frac{m+4n}{4})a$		$A + W_C (\frac{m+4n}{2})a$

$$a = \frac{F[(1 - X_F)(1 - X_{H_2O}) - X_F X_{H_2O}]}{X_F[2n - (n+1)X_{H_2O}] + (1 - X_{H_2O})[1 - (n+1)X_F]}$$

$$W_A = \frac{F(1 - X_F) - a[1 - (n+1)X_F]}{X_F}$$

$$W_C = \frac{X_{H_2O}[A + (\frac{m+4n}{4})X_{H_2O}] - (\frac{m+4n}{2})}{1 - X_{H_2O}}$$

For nonane hydrocarbons these relations simplify as follows:

Anode Streams:

Component	Anode Feed (E) Moles	Net Reaction, Moles	For Water Balance, Moles	Anode Exhaust (J) Moles
n-Nonane	F	-a		F-a
H ₂ O	W _A [°]	-18a	W _A [']	W _A -18a
CO ₂	-	+9a		+9a
Total	F+W _A [°]	-10a		F + W _A - 10a

* The capital letters which appear in the headings of the tables in this section refer to fuel cell reactant and product streams shown in Figure D-1.

Cathode Streams:

Component	Cathode Feed (E) Moles	Net Reaction, Moles	For Water Balance, Moles	Cathode Exhaust (G) Moles
O ₂	0.21A	-14a		0.21A - 14a
N ₂	0.79A			0.79A
H ₂ O	W _C ^o	+28a	W _C ⁱ	W _C + 28a
Total	A + W _C ^o	+14a		A + W _C + 14a

$$a = \frac{F[(1 - X_F)(1 - X_{H_2O}) - X_F X_{H_2O}]}{X_F(18 - 10 X_{H_2O}) + (1 - X_{H_2O})(1 - 10 X_F)}$$

$$W_A = \frac{F(1 - X_F) - a(1 - 10 X_F)}{X_F}$$

$$W_C = \frac{X_{H_2O}(A + 14a) - 28a}{1 - X_{H_2O}}$$

The assumptions and results from some material balance calculations for a direct nonane-air fuel cell using 94 weight per cent phosphoric acid electrolyte at 300°F and 1 atmosphere pressure are shown in Table D-1. In these calculations, it is assumed that nonane reacts only to give CO₂ and H₂O and that no conversion to lower molecular weight hydrocarbons occurs. In practice, it is probable that some such reactions will occur. The effect of this on hydrocarbon recycle losses will be discussed later.

In Case A of Table D-1, nonane is assumed to react so rapidly that its concentration in the anode exhaust can be reduced to 2 mole per cent. Calculations are based on one mole of nonane. Sufficient air is supplied so that the cathode air stream retains 5 mole per cent of unreacted oxygen. It is also assumed that the partial pressures of water from the

TABLE D-1

MATERIAL BALANCES AND STREAM COMPOSITIONS FOR A
DIRECT NONANE-AIR FUEL CELL. 94 WT. % PHOSPHORIC ACID
ELECTROLYTE AT 300°F AND 1 ATM. PRESSURE

<u>Specified Values:</u>		A		A-1	
Electrolyte Partial Pressure	p_{H_2O} , mm	200		200	
Total Pressure	P , mm	760		760	
Approach to Water Balance, Cathode Exhaust	Z	1		1	
Approach to Water Balance, Anode Exhaust	Y	1		1	
Fuel Rate	F , moles/hr	1		0.452	
Mole Fraction of Fuel in Anode Exhaust	X_F	0.02		0.02	
Mole Fraction of Water in Anode Exhaust	X_{H_2O}	0.263		0.263	
Mole Fraction of Oxygen in Cathode Exhaust	X'_{O_2}	0.05		0.05	
Mole Fraction of Water in Cathode Exhaust	X'_{H_2O}	0.263		0.263	
<u>Material Balance:</u>					
Fuel Oxidized, moles/hr	a	0.799		0.361	
<u>Anode Feed Stream (D):</u>		Moles/Hr	Mole %	Moles/Hr	g/Hr
n-Nonane	W_A^o	1.00		0.45	58.0
Water		0		0	0
Total		1.00		0.45	58.0
Water Added to Anode Stream	W_A	17.03		7.69	138.6
<u>Anode Exhaust Stream (J):</u>					
n-Nonane	W_A'	0.20	2.0	0.09	11.7
Water		2.64	26.3	1.19	21.5
Carbon Dioxide		7.19	71.7	3.25	143.0
Total		10.03	100.0	4.53	176.2
<u>Cathode Feed Stream (E):</u>					
Oxygen	W_C^o	15.41	21.0	6.96	222.8
Nitrogen		57.97	79.0	26.19	733.7
Water		0.00			
Total		73.38	100.0	33.15	956.5
Water Added to Cathode Stream	W_C	-0.17		0.08	-1.4
<u>Cathode Exhaust Stream (G):</u>					
Oxygen	W_C'	4.22	5.00	1.97	62.9
Nitrogen		57.92	68.68	26.16	733.7
Water		22.21	26.32	10.03	180.8
Total		84.35	100.00	38.16	977.4

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anode and cathode streams are equal to each other and to the partial pressure of water from the fuel cell electrolyte. In this preliminary calculation, we have also assumed that no water was added either to the hydrocarbon feed, to the fuel cell, or to the cathode air stream. As a result, the anode stream has had to draw 17.03 moles of water from the electrolyte to meet exhaust stream specifications, while the water formed at the cathode was 0.167 mole in excess of that required for the cathode exhaust. This excess is added to the electrolyte. Therefore, the fuel cell has a net requirement of 16.86 moles of water per mole of nonane in the fuel. This water could be added to the anode stream which then would greatly dilute the electrolyte where the anode feed enters the fuel cell, or it could be divided in some way between the air and fuel stream in an effort to minimize undesirable concentration effects. If this water is added as liquid, either through the electrolyte or in some other way, its heat of vaporization would provide about one fourth of the cooling required by the fuel cell at maximum power.

An attempt to relate Case A which was discussed above to a particular fuel cell situation is made in Case A-1 of Table D-1. This is discussed in Section VII-C of the report.

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APPENDIX E

COMPUTER CALCULATIONS MATHEMATICAL TREATMENTS

1. Calculation of Equilibrium Constants

The equilibrium constants for the reforming reaction, K_R , the shift reaction, K_S , and the Boudouard reaction, K_C , can be represented over small temperature intervals with very high accuracy by means of the two-parameter Arrhenius equation

$$(1.1) \quad K = Ae^{B/RT},$$

where A and B are experimental constants, R is the universal gas constant, and T the absolute temperature. Values of the equilibrium constants, K_R , K_S , and K_C , were calculated from literature values⁵⁷ of the equilibrium constants of formation in the range of 200°F to 2200°F obtained at 100°K intervals. The constants were then calculated for any temperature by linear interpolation of the natural logarithm of K, $\ln K$, against the reciprocal absolute temperature, $\frac{1}{T}$, in the proper 100°F interval.

2. Calculation of Reformer Product Composition

When feed consisting of carbon, hydrogen, and oxygen compounds in any fashion are fed to a reformer, the products are water, carbon dioxide, methane, carbon monoxide, and molecular hydrogen. Any inert gas feed, such as nitrogen, is recovered unreacted.

In the mathematical development below, parentheses around a chemical formula will indicate number of pound-moles of a product. The symbol $(\bar{})$ is used to represent pound-moles or pound-atoms in the feed streams. If the reformer feed can be represented by

$$(\bar{O}), (\bar{H}), (\bar{C}), \text{ and } (\bar{\text{Inerts}}),$$

then the following mass balance equations must be satisfied for the reformer products:

$$(2.1) \quad \begin{cases} (\overline{O}) = (H_2O) + 2(CO_2) + (CO) \\ (\overline{H}) = 2(H_2O) + 4(CH_4) + 2(H_2) \\ (\overline{C}) = (CO_2) + (CO) + (CH_4) \\ (\overline{Inerts}) = (Inerts) \end{cases}$$

The product composition consisting of five unknowns (the molecular species other than inerts) can thus be reduced to two unknowns by the equations in (2.1). Thus if we arbitrarily choose the water and carbon dioxide concentrations to be unknowns,

$$(2.2) \quad \begin{cases} (CO_2) = X \\ (H_2O) = Y \end{cases}$$

we can express the other concentrations in terms of X and Y and the known feed composition:

$$(2.3) \quad \begin{cases} (CH_4) = (\overline{C}) - (\overline{O}) + X + Y \\ (CO) = (\overline{O}) - 2X - Y \\ (H_2) = 1/2(\overline{H}) - 2(\overline{C}) + 2(\overline{O}) - 2X - 3Y \end{cases}$$

When the equations (2.2) and (2.3) are combined with the expressions for the reforming and shift equilibria, two polynomials in two unknowns are obtained

$$(2.4) \quad \begin{cases} K_R = \frac{(CO)(H_2)^3 P^2}{(CH_4)(H_2O)(Total)^2}, \text{ and} \\ K_S = \frac{(CO_2)(H_2)}{(CO)(H_2O)} \end{cases}$$

where P is pressure expressed in atmospheres and (Total) = (CO) + (H₂) + (CH₄) + (H₂O) + (CO₂) + (Inerts). This quantity has to be introduced as a normalizing factor since the components are introduced in terms of moles rather than partial pressures. The polynomials in two unknowns may be solved by one of a number of numerical methods. In our calculations the Newton-Raphson method⁵³ was used.

3. Determination of Water Needed to Inhibit Carbon Deposition

A reversible reaction which needs to be considered in the reforming process is the following:



The equilibrium constant, K_C , was calculated as a function of temperature as described in Section 1. The mass action ratio, "RT," for this reaction is given in terms of moles by:

$$(3.2) \quad \text{"RT"} = \frac{(\text{CO}_2) (\text{Total})}{(\text{CO})^2 \text{P}}$$

If "RT" is greater than K_C , carbon will not be formed. If "RT" is smaller than K_C , carbon will be deposited. The addition of a sufficient amount of water will then prevent carbon formation by reducing the carbon monoxide concentration and increasing the carbon dioxide concentration. If Z is defined as minimum amount of water necessary to prevent carbon formation, then Z must be such that the following equation is satisfied:

$$(3.3) \quad K_C = \frac{(\text{CO}_2) (\text{Total})}{(\text{CO})^2 \text{P}}$$

The method of solution follows that of Section 2 except that the Newton-Raphson method must now be applied to three polynomials in three unknowns:

$$(3.4) \quad \left\{ \begin{array}{l} K_R = \frac{(\text{CO}) (\text{H}_2)^3 \text{P}^2}{(\text{CH}_4) (\text{H}_2\text{O}) (\text{Total})^2} \\ K_S = \frac{(\text{CO}_2) (\text{H}_2)}{(\text{CO}) (\text{H}_2\text{O})} \\ K_C = \frac{(\text{CO}_2) (\text{Total})}{(\text{CO})^2 \text{P}} \end{array} \right.$$

where the components are given in terms of unknowns X, Y, and Z by:

$$(3.5) \quad \begin{array}{ll} (\text{CO}_2) & = X \\ (\text{H}_2\text{O}) & = Y \\ (\text{CH}_4) & = (\bar{\text{C}}) - (\bar{\text{O}}) + X + Y - Z \end{array}$$

$$\begin{aligned}
 (\text{CO}) &= (\bar{\text{O}}) - 2X - Y + Z \\
 (3.5 \text{ Cont'd}) \quad (\text{H}_2) &= (1/2) (\bar{\text{H}}) - 2(\bar{\text{C}}) + 2(\bar{\text{O}}) - 2X - 3Y + 3Z \\
 (\text{Total}) &= (1/2) (\bar{\text{H}}) - (\bar{\text{C}}) + 2(\bar{\text{O}}) - 2X - 2Y + 3Z + (\overline{\text{Inerts}})
 \end{aligned}$$

4. Calculation of Anode Exhaust Compositions (Oxidation in Fuel Cell Subsequent to Reforming Operation)

In these calculations, it is assumed that the reformer products are passed into the fuel cell, there to be subjected to oxidation by way of a given mechanism to a specified extent as shown in the table below.

Fuel Cell Reaction Scheme

	A	B	C	D
1	$\text{H}_2 + \text{O} = \rightarrow \text{H}_2\text{O} + 2\text{e}^-$ Final X_{H_2} Specified	$\text{H}_2 + \text{CO}_3 = \rightarrow \text{CO}_2 + \text{H}_2\text{O} + 2\text{e}^-$ Final X_{H_2} Specified	$\text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}^-$ Final X_{H_2} Specified	$\text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}^-$ Final X_{H_2} and Final Partial Pressure of Water Specified
2	$\text{H}_2 + \text{O} = \rightarrow \text{H}_2\text{O} + 2\text{e}^-$ $\text{CO} + \text{O} = \rightarrow \text{CO}_2 + 2\text{e}^-$ Final X_{H_2} and X_{CO} Specified	$\text{H}_2 + \text{CO}_3 = \rightarrow \text{CO}_2 + \text{H}_2\text{O} + 2\text{e}^-$ $\text{CO} + \text{CO}_3 = \rightarrow 2\text{CO}_2 + 2\text{e}^-$ Final X_{H_2} and X_{CO} Specified	$\text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}^-$ $\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + 2\text{H}^+ + 2\text{e}^-$ Final X_{H_2} and X_{CO} Specified	$\text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}^-$ $\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + 2\text{H}^+ + 2\text{e}^-$ Final X_{H_2} and X_{CO} and Final Partial Pressure of Water Specified

In the above table:

X_{H_2} denotes mole fraction of molecular hydrogen

X_{CO} denotes mole fraction of carbon monoxide

In the expressions below the following definitions will apply:

a = moles of H_2 oxidized at anode

b = moles of CO oxidized at anode

W_A = moles of water added to (+) or removed from (-) anode compartment of fuel cell

p_{H_2O} = partial pressure of water (atmospheres)

P = total pressure (atmospheres)

The unknown can then be expressed in terms of the known quantities for the various schemes as follows:

Scheme A-1: $a = (H_2) - X_{H_2} \text{ (Total)}$

Scheme B-1:
$$a = \frac{(H_2) - X_{H_2} \text{ (Total)}}{X_{H_2} + 1}$$

Scheme C-1:
$$a = \frac{(H_2) - X_{H_2} \text{ (Total)}}{1 - X_{H_2}}$$

Scheme D-1:
$$a = \frac{PX_{H_2} [(H_2O) + (H_2) - \text{(Total)}]}{(1 - X_{H_2})P - p_{H_2O}} + (H_2)$$

$$W_A = \frac{p_{H_2O} [(\text{Total}) - a] - P (H_2O)}{P - p_{H_2O}}$$

Scheme A-2: $a = (H_2) - X_{H_2} \text{ (Total)}$

$b = (CO) - X_{CO} \text{ (Total)}$

Scheme B-2:
$$a = \frac{(X_{CO} + 1) (H_2) - X_{H_2} [(\text{Total}) + (CO)]}{1 + X_{H_2} + X_{CO}}$$

$$b = \frac{(X_{H_2} + 1) (CO) - X_{CO} [(\text{Total}) + (H_2)]}{1 + X_{H_2} + X_{CO}}$$

Scheme C-2:
$$a = \frac{X_{H_2} [(CO) - (\text{Total})] + (1 - X_{CO})(H_2)}{1 - X_{H_2} - X_{CO}}$$

$$b = \frac{X_{CO} [(H_2) - (\text{Total})] + (1 - X_{H_2})(CO)}{1 - X_{H_2} - X_{CO}}$$

Scheme D-2:

$$a = \frac{PX_{H_2}[(H_2O) + (H_2) - (Total)]}{(1 - X_{H_2})P - P_{H_2O}} + (H_2)$$

$$b = \frac{PX_{CO}[(H_2O) + (H_2) - (Total)]}{(1 - X_{H_2})P - P_{H_2O}} + (CO)$$

$$W_A = \frac{P[(H_2O) - b] - H_2O[(Total) - a - b]}{P_{H_2O} - P}$$

The electrical energy obtained from each scheme is given by

$$(4.1) \quad E(\text{kw-hr}) = (Z_a a + Z_b b)F\epsilon = 24.33(a + b)\epsilon$$

where E is the electrical energy, Z_a and Z_b are the number of equivalents per mole of hydrogen and carbon monoxide, respectively, F is the Faraday, and ϵ is the fuel cell voltage.

5. Calculation of Anode Exhaust Compositions (Fuel Cell Oxidation Concurrent With Reforming Operation)

In these calculations it is assumed that the oxidation and reforming processes occur in a single vessel and that the exhaust products satisfy the reforming and shift equilibria. The final mole fraction of hydrogen remaining unoxidized is specified as shown in the table below:

Fuel Cell Reaction Scheme

A	B	C
$H_2 + O^- \rightarrow H_2O + 2e^-$ Final X_{H_2} Specified	$H_2 + CO_3^- \rightarrow CO_2 + H_2O + 2e^-$ Final X_{H_2} Specified	$H_2 \rightarrow 2H^+ + 2e^-$ Final X_{H_2} Specified

It is evident that for each mole of hydrogen oxidized:

In Case A-3: a gram-atom of oxygen is gained.

In Case B-3: a gram-atom of carbon and 3 gram-atoms of oxygen are gained.

In Case C-3: 2 gram-atoms of hydrogen is lost.

The extent of the oxidation is determined by specifying X_{H_2} in the exhaust, where

$$(5.1) \quad X_{H_2} = \frac{(H_2)}{(Total)}$$

Defining: (ΔO) as the number of gram-atoms of oxygen gained;
 (ΔC) as the number of gram-atoms of carbon gained; and
 $-(\Delta H)$ as the number of gram-atoms of hydrogen lost.

The final composition of components can be expressed in terms of two unknowns, X and Y, by:

$$\begin{aligned} (CO_2) &= X \\ (H_2O) &= Y \\ (CH_4) &= (C) - (O) + X + Y + (\Delta C) - (\Delta O) \\ (CO) &= (O) - 2X - Y + (\Delta O) \\ (H_2) &= (1/2)(H) - 2(C) + 2(O) - 2X - 3Y + (1/2)(\Delta H) \\ &\quad - 2(\Delta C) + 2(\Delta O) \\ (Total) &= (1/2)(H) - (C) + 2(O) - 2X - 2Y + (Inerts) \\ &\quad + (1/2)(\Delta H) - (\Delta C) + 2(\Delta O) \end{aligned}$$

The quantities (ΔO) , (ΔC) , and (ΔH) are functions of X and Y determined by equations (5.2).

For Case A-3:

$$(\Delta O) = \frac{[X_{H_2} - 1] [(1/2)(H) - (C) + 2(O) - 2X - 2Y] + X_{H_2} (Inerts) + (C) + Y}{2(1 - X_{H_2})}$$

$$(\Delta C) = (\Delta H) = 0$$

For Case B-3:

$$(\Delta O) = \frac{3[X_{H_2} - 1] [(1/2)(H) - (C) + 2(O) - 2X - 2Y] + X_{H_2} (Inerts) + (C) + Y}{4 - 5X_{H_2}}$$

$$(\Delta C) = 1/3 (\Delta O) ; (\Delta H) = 0$$

For Case C-3:

$$(\Delta H) = \frac{2\{[X_{H_2} - 1][(1/2)(H) - (C) + 2(O) - 2X - 2Y] + X_{H_2} (\text{Inerts}) + (C) + Y\}}{1 - X_{H_2}}$$

$$(\Delta O) = (\Delta C) = 0$$

Since the components in the exhaust must also satisfy the reforming and shift equilibria, the expressions above are substituted into the equations (2.4) and these equations in two unknowns are solved by means of the Newton-Raphson method.

6. Calculation of Anode Exhaust
Composition (Fuel Cell Oxidation
Concurrent with Reforming Operation -
Partial Recycle of Anode Exhaust)

In the following reaction schemes the oxidation and reforming processes occur simultaneously so that the anode exhaust products must satisfy the reforming and shift equilibria. Furthermore, it is assumed that an equilibrium has been established wherein a specified fraction, f , of the entire anode exhaust is recycled. As a result oxygen is not needed in the feed stock but is supplied during the oxidation process at the anode. In these calculations the final mole fraction of unoxidized hydrogen in the anode exhaust must be given.

Fuel Cell Reaction Scheme

A	B
$H_2 + O^= \rightarrow H_2O + 2e^-$ 4 Final X_{H_2} and fraction, f, of anode exhaust recycle specified.	$H_2 + CO_3^= \rightarrow CO_2 + H_2O + 2e^-$ Final X_{H_2} and fraction, f, of anode exhaust recycle specified.

If the equilibrium anode exhaust composition is given by

$$(6.1) \quad \begin{cases} (C') & \text{gram-atoms of carbon} \\ (H') & \text{gram-atoms of hydrogen} \\ (O') & \text{gram-atoms of oxygen and} \\ (\text{Inerts}') & \text{moles of inerts} \end{cases}$$

then the feed composition is given by:

$$(6.2) \quad \begin{cases} (\bar{C}) + f(C') & \text{gram-atoms of carbon} \\ (\bar{H}) + f(H') & \text{gram-atoms of hydrogen} \\ f(O') & \text{gram-atoms of oxygen (no internal} \\ & \text{oxygen feed)} \\ (\overline{\text{Inerts}}) + f(\text{Inerts}') & \text{moles of inerts} \end{cases}$$

where f is the fraction of the exhaust recycled. The relations between feed and exhaust composition are:

$$(6.3) \quad \begin{cases} (H') & = (\bar{H}) + f(H') \\ (C') & = (\bar{C}) + f(C') + (\Delta C) \\ (O') & = f(O') + (\Delta O) \\ (\text{Inerts}') & = (\overline{\text{Inerts}}) + f(\text{Inerts}') \end{cases}$$

where (ΔC) and (ΔO) are the gram-atoms of carbon and oxygen picked up from the electrolyte in the course of oxidation at the anode.

Equations (6.3) lead directly to:

$$(6.4) \quad \begin{cases} (H') & = g(\bar{H}) \\ (C') & = g[(\bar{C}) + (\Delta C)] \\ (O') & = g(\Delta O) \\ (\text{Inerts}') & = g(\overline{\text{Inerts}}) \end{cases}$$

where $g = 1/(1 - f)$.

As in Section 5, the final composition of components can be expressed in terms of two unknowns:

$$(6.5) \quad \begin{cases} (CO_2) & = Y \\ (H_2O) & = Y \\ (CH_4) & = g[(\bar{C}) + (\Delta C) - (\Delta O)] + X + Y \\ (CO) & = g(\Delta O) - 2X - Y \end{cases}$$

$$(6.5 \text{ Cont'd}) \quad \begin{cases} (H_2) & = g[(1/2)(\bar{H}) + 2(\Delta O) - 2(\bar{C}) - 2(\Delta C)] - 2X - 3Y \\ (\text{Total}) & = g[(1/2)(\bar{H}) + 2(\Delta O) - (\bar{C}) - (\Delta C) + (\overline{\text{Inerts}})] \\ & \quad - 2X - 2Y \end{cases}$$

The quantities (ΔO) and (ΔC) are arrived at through:

$$(6.6) \quad X_{H_2} = \frac{(H_2)}{(\text{Total})}$$

Case A-4:

$$(\Delta O) = \frac{\{X_{H_2} - 1\} \{g[(1/2)(\bar{H}) - (\bar{C})] - 2X - 2Y\} + Y + g[(C) + X_{H_2}(\overline{\text{Inerts}})]}{2g(1 - X_{H_2})}$$

$$(\Delta C) = 0$$

Case B-4:

$$(\Delta O) = \frac{3\{[X_{H_2} - 1] \{g[(1/2)(\bar{H}) - (\bar{C})] - 2X - 2Y\} + Y + g[(\bar{C}) + X_{H_2}(\overline{\text{Inerts}})]\}}{g(4 - 5X_{H_2})}$$

$$(\Delta C) = 1/3(\Delta O)$$

Here again, the equations (2.4) must be satisfied and solution is obtained by means of the Newton-Raphson method.

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APPENDIX F

THEORETICAL PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

Appendix Tables F-1 to F-30 included in this section resulted from computer calculations described in Section X-C. These tables form the basis for figures, mainly for nonane, which are discussed in Section X-D-2b and for similar figures for other hydrocarbons which are given as Appendix Figures F-1 to F-22.

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TABLE F-1A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - CH₄ (100 MOL C BASIS), STEAM/C RATIO, 1.0

ELEMENTAL COMPOSITION					RT	EQUILIBRIUM PRODUCT COMPOSITIONS							
C (ATOMS)	H (ATOMS)	O (ATOMS)	N ₂ (MOLS)	C		H ₂ (MOLS)	CO ₂ (MOLS)	CH ₄ (MOLS)	CO (MOLS)	H ₂ (MOLS)	N ₂ (MOLS)	TOTAL (MOLS)	
100.00	600.00	100.00				MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	
CONDITIONS AND EQUILIBRIUM CONSTANTS													
P (ATM)	T (DEG F)	K _R	K _S	K _C									
1.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.1866E-10	98.40 48.871	0.76 0.376	99.24 49.247	0.00 0.000	3.03 1.506	0. 0.	201.52 100.000	
1.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	1.7857E-06	92.12 44.369	3.93 1.890	96.05 46.199	0.02 0.010	15.78 7.592	0. 0.	207.90 100.000	
1.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	4.0015E-03	76.30 33.988	11.45 5.099	87.75 39.088	0.80 0.357	48.19 21.468	0. 0.	224.50 100.000	
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	4.6835E-01	52.16 20.215	18.83 7.297	70.99 27.512	10.18 3.947	105.87 41.029	0. 0.	258.02 100.000	
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	2.0024E-00	27.92 8.789	13.23 4.165	41.16 12.954	45.61 14.358	189.77 59.733	0. 0.	317.69 100.000	
1.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	2.3081E-01	10.84 2.928	4.09 1.165	14.93 4.033	80.98 21.879	259.31 70.055	0. 0.	370.14 100.000	
1.0000	1600.00	8.2135E-02	8.2439E-01	4.0065E-02	4.4509E-02	3.74 0.957	1.01 0.259	4.75 1.216	94.24 24.133	286.77 73.435	0. 0.	390.50 100.000	
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.1678E-02	1.40 0.353	0.28 0.071	1.68 0.425	98.03 24.716	295.23 74.435	0. 0.	396.63 100.000	
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	2.8254E-03	0.60 0.150	0.09 0.024	0.69 0.174	99.21 24.890	298.02 74.763	0. 0.	398.62 100.000	
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.4918E-03	0.29 0.072	0.04 0.009	0.32 0.081	99.64 24.950	259.07 74.888	0. 0.	399.35 100.000	
2.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.3367E-10	98.85 49.142	0.58 0.286	99.42 49.428	0.00 0.000	2.30 1.144	0. 0.	201.15 100.000	
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.0750E-06	93.99 45.620	3.00 1.456	96.99 47.076	0.01 0.006	12.04 5.842	0. 0.	206.02 100.000	
2.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	4.7775E-03	81.55 37.280	8.98 4.101	90.57 41.382	0.45 0.208	37.27 17.029	0. 0.	218.86 100.000	
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	5.6291E-01	61.20 25.002	16.41 6.706	77.61 31.708	5.97 2.441	83.58 34.144	0. 0.	244.78 100.000	
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	2.2587E-00	38.12 12.995	15.22 5.189	53.34 18.185	31.44 10.718	155.20 52.912	0. 0.	293.32 100.000	
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	2.3866E-01	18.08 5.153	6.47 1.844	24.55 6.997	68.98 19.657	232.81 66.349	0. 0.	350.89 100.000	
2.0000	1600.00	8.2135E-02	8.2439E-01	4.0065E-02	4.4870E-02	7.00 1.830	1.87 0.489	8.87 2.320	89.26 23.351	275.27 72.010	0. 0.	382.26 100.000	
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.1704E-02	2.73 0.655	0.55 0.140	3.28 0.835	96.17 24.443	290.70 73.888	0. 0.	393.43 100.000	
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.8281E-03	1.18 0.298	0.19 0.047	1.37 0.345	98.44 24.781	296.08 74.530	0. 0.	397.26 100.000	
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.4922E-03	0.57 0.143	0.07 0.019	0.64 0.161	99.28 24.901	298.14 74.776	0. 0.	398.71 100.000	
4.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.5846E-10	99.13 49.348	0.44 0.217	99.56 49.565	0.00 0.000	1.75 0.869	0. 0.	200.87 100.000	
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.4046E-06	95.42 46.642	2.25 1.117	97.71 47.759	0.01 0.003	9.16 4.479	0. 0.	204.58 100.000	
4.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	5.6068E-03	85.80 40.005	6.97 3.251	92.77 43.257	0.26 0.120	28.67 13.366	0. 0.	214.46 100.000	
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	6.7259E-01	69.08 29.475	13.73 5.858	82.81 35.333	3.46 1.476	65.29 27.859	0. 0.	234.38 100.000	
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	2.5773E-00	48.34 17.771	15.67 5.760	64.00 23.531	20.33 7.475	123.66 45.464	0. 0.	271.99 100.000	

CALIFORNIA RESEARCH
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RICHMOND, CALIFORNIA

RE 647644

TABLE F-1B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - CH₄ (100 MOL C BASIS), STEAM/C RATIO, 1.0

ELEMENTAL COMPOSITION					RT	EQUILIBRIUM								TOTAL MOLS MOL PC
C (ATOMS) 100.00	H (ATOMS) 600.00	O (ATOMS) 100.00	N ₂ (MOLS) C.			H ₂ O MOLS MOL PC	CO ₂ MOLS MOL PC	CH ₄ MOLS MOL PC	CO MOLS MOL PC	H ₂ MOLS MOL PC	N ₂ MOLS MOL PC			
CONDITIONS AND EQUILIBRIUM CONSTANTS						PRODUCT COMPOSITIONS								
P (ATM)	T (DEG F)	K _R	K _S	K _C										
4.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	2.5148E-01	27.56 8.434	9.08 2.777	36.63 11.211	54.29 16.617	199.18 60.960	0. 0.			326.74 100.000
CONDITIONS LEAD TO CARBON FORMATION.														
4.0000	1600.00	8.2135E 02	8.2439E-01	4.0065E-02	4.5539E-02	12.45 3.377	3.25 0.881	15.69 4.258	81.06 21.990	256.17 69.495	0. 0.			368.61 100.000
4.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	1.1754E-02	5.22 1.347	1.04 0.269	6.26 1.616	92.70 23.923	282.26 72.845	0. 0.			387.48 100.000
4.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	3.8335E-03	2.32 0.587	0.37 0.093	2.68 0.680	96.95 24.568	292.32 74.073	0. 0.			394.63 100.000
4.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.4930E-03	1.13 0.284	0.15 0.037	1.28 0.321	98.58 24.803	296.32 74.555	0. 0.			397.45 100.000
6.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	1.6241E 10	99.26 49.445	0.37 0.185	99.63 49.630	0.00 0.000	1.49 0.740	0. 0.			200.74 100.000
6.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	2.6181E 06	96.10 47.129	1.95 0.955	98.05 48.084	0.01 0.002	7.81 3.829	0. 0.			203.91 100.000
6.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	6.1547E 03	87.82 41.355	6.00 2.823	93.82 44.178	0.19 0.087	24.54 11.556	0. 0.			212.36 100.000
6.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	7.4402E 01	73.10 31.866	12.20 5.317	85.30 37.183	2.50 1.091	56.30 24.542	0. 0.			229.40 100.000
6.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	2.8021E 00	54.01 20.662	15.29 5.848	69.30 26.510	15.42 5.858	107.39 41.083	0. 0.			261.40 100.000
CONDITIONS LEAD TO CARBON FORMATION.														
6.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	2.6189E-01	33.74 10.825	10.41 3.339	44.15 14.165	45.44 14.578	177.96 57.093	0. 0.			311.70 100.000
6.0000	1600.00	8.2135E 02	8.2439E-01	4.0065E-02	4.6145E-02	16.86 4.713	4.30 1.203	21.16 5.915	74.54 20.840	240.83 67.330	0. 0.			357.68 100.000
6.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	1.1802E-02	7.49 1.961	1.49 0.389	8.98 2.349	89.54 23.426	274.56 71.865	0. 0.			382.05 100.000
6.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	3.8385E-03	3.41 0.869	0.54 0.137	3.95 1.006	95.52 24.360	288.70 73.628	0. 0.			392.11 100.000
6.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.4938E-03	1.68 0.424	0.22 0.055	1.89 0.478	97.89 24.706	294.53 74.337	0. 0.			396.21 100.000
12.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	2.0211E 10	99.44 49.579	0.28 0.140	99.72 49.719	0.00 0.000	1.13 0.562	0. 0.			200.56 100.000
12.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	3.0226E 06	97.03 47.808	1.48 0.730	98.52 48.537	0.00 0.001	5.93 2.924	0. 0.			202.97 100.000
12.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	7.1883E 03	90.67 43.292	4.61 2.202	95.28 45.494	0.11 0.051	18.77 8.961	0. 0.			209.44 100.000
12.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	8.7941E 01	78.98 35.502	9.79 4.402	88.77 39.904	1.44 0.646	43.48 19.545	0. 0.			222.46 100.000
12.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	3.2525E 00	62.88 25.509	13.88 5.631	76.76 31.140	9.36 3.798	83.61 23.921	0. 0.			246.49 100.000
12.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	2.8547E-01	44.52 15.508	11.93 4.155	56.45 19.663	31.62 11.013	142.57 49.661	0. 0.			287.10 100.000
12.0000	1600.00	8.2135E 02	8.2439E-01	4.0065E-02	4.7727E-02	26.35 7.875	6.36 1.900	32.71 9.775	60.94 18.213	208.24 62.238	0. 0.			334.59 100.000
12.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	1.1937E-02	13.29 3.610	2.59 0.702	15.88 4.312	81.54 22.142	254.95 69.234	0. 0.			368.24 100.000
12.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	3.8544E-03	6.45 1.674	1.01 0.261	7.45 1.936	91.54 23.771	278.64 72.358	0. 0.			385.09 100.000
12.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.4962E-03	3.26 0.832	0.42 0.107	3.69 0.939	95.89 24.424	289.36 73.699	0. 0.			392.63 100.000

TABLE F-2A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - CH₄ (100 MOL C BASIS), STEAM/C RATIO 2.0

ELEMENTAL COMPOSITION													
C(ATOMS)	H(ATOMS)	O(ATOMS)	N ₂ (MOLS)										
100.00	800.00	200.00	0.										
CONDITIONS AND EQUILIBRIUM CONSTANTS					EQUILIBRIUM PRODUCT COMPOSITIONS								
P(Atm)	T(°F)	K _R	K _S	K _C	RT	H ₂ O MOL PC	CO ₂ MOL PC	CH ₄ MOL PC	CO MOL PC	H ₂ MOL PC	N ₂ MOL PC	TOTAL MOL PC	
1.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.9419E-10	197.64 65.368	1.18 0.390	98.82 32.684	0.00 0.000	4.71 1.558	0. 0.	302.36 100.000	
1.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.9489E-06	187.73 60.111	6.12 1.961	93.85 30.051	0.03 0.008	24.57 7.868	0. 0.	312.30 100.000	
1.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	7.0574E-01	162.75 48.125	18.16 5.369	80.91 23.925	0.93 0.276	75.43 22.305	0. 0.	338.18 100.000	
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	9.5125E-01	123.58 31.855	32.46 8.367	56.03 14.445	11.51 2.966	164.36 42.367	0. 0.	387.93 100.000	
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	6.0092E-00	88.32 19.172	31.33 6.801	19.66 4.267	49.01 10.639	272.36 59.121	0. 0.	460.69 100.000	
1.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.9882E-00	79.19 15.962	22.74 4.583	1.93 0.389	75.33 15.183	316.94 63.883	0. 0.	496.14 100.000	
1.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	1.3037E-00	82.52 16.515	17.63 3.529	0.15 0.031	82.21 16.452	317.17 63.473	0. 0.	499.69 100.000	
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	9.6844E-01	85.78 17.157	14.24 2.848	0.02 0.004	85.74 17.150	314.19 62.842	0. 0.	499.96 100.000	
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	7.6192E-01	88.16 17.632	11.84 2.368	0.00 0.001	88.15 17.631	311.83 62.367	0. 0.	499.99 100.000	
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	6.2661E-01	89.88 17.976	10.12 2.025	0.00 0.000	89.88 17.975	310.12 62.024	0. 0.	500.00 100.000	
2.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	2.1009E-10	198.21 65.680	0.89 0.296	99.11 32.840	0.00 0.000	3.57 1.184	0. 0.	301.79 100.000	
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.4026E-06	190.65 61.624	4.67 1.509	95.32 30.810	0.01 0.005	18.72 6.052	0. 0.	309.37 100.000	
2.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	8.1867E-03	171.16 51.964	14.15 4.297	85.31 25.901	0.53 0.162	58.22 17.675	0. 0.	329.38 100.000	
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.0794E-02	138.36 37.545	27.39 7.432	65.75 17.841	6.87 1.863	130.15 35.318	0. 0.	368.51 100.000	
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	5.3623E-00	102.50 23.678	31.05 7.172	33.55 7.750	35.40 8.178	230.40 53.223	0. 0.	432.90 100.000	
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.1410E-00	83.08 17.046	23.24 4.768	6.32 1.296	70.45 14.454	304.29 62.435	0. 0.	487.37 100.000	
2.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	6.6059E-01	82.92 16.625	17.68 3.545	0.61 0.122	81.71 16.381	315.86 63.326	0. 0.	498.78 100.000	
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	4.8498E-01	85.83 17.170	14.25 2.850	0.07 0.015	85.68 17.141	314.03 62.824	0. 0.	499.85 100.000	
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.8106E-01	88.17 17.635	11.84 2.369	0.01 0.002	88.14 17.630	311.81 62.364	0. 0.	499.98 100.000	
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.1332E-01	89.88 17.976	10.12 2.025	0.00 0.001	89.87 17.975	310.12 62.024	0. 0.	499.99 100.000	
4.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	2.6528E-10	198.64 65.917	0.68 0.225	99.32 32.959	0.00 0.000	2.71 0.900	0. 0.	301.36 100.000	
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.9237E-06	192.88 62.802	3.56 1.158	96.44 31.400	0.01 0.003	14.25 4.638	0. 0.	307.13 100.000	
4.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	9.4805E-03	177.80 55.130	10.95 3.395	88.75 27.518	0.31 0.095	44.71 13.863	0. 0.	322.51 100.000	
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.2217E-02	151.13 42.825	22.42 6.354	73.55 20.843	4.02 1.140	161.77 28.837	0. 0.	352.90 100.000	
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	5.3651E-00	118.11 29.136	29.20 7.204	47.31 11.671	23.49 5.794	187.27 46.196	0. 0.	405.38 100.000	

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TABLE F-2B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - CH₄ (100 MOL C BASIS), STEAM/C RATIO 2.0

ELEMENTAL COMPOSITION													
C(ATOMS)	H(ATOMS)	O(ATOMS)	N ₂ (MOLS)										
100.00	800.00	200.00	0										
				CONDITIONS AND EQUILIBRIUM CONSTANTS									
P(ATM)	T(°F)	KR	KS	KC	RT	H ₂ O	CO ₂	CH ₄	CO	H ₂	N ₂	TOTAL	
						MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	MOLS
						MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC
4.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	7.8149E-01	91.77	24.08	15.85	60.06	276.53	0.	468.30	100.000
						19.597	5.143	3.385	12.826	59.049	0.	100.000	
4.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	3.4684E-01	84.40	17.86	2.26	79.87	311.08	0.	495.48	100.000
						17.033	3.605	0.456	16.121	62.784	0.	100.000	
4.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	2.4399E-01	86.02	14.27	0.29	85.44	313.40	0.	499.42	100.000
						17.224	2.857	0.058	17.109	62.753	0.	100.000	
4.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	1.9072E-01	88.20	11.85	0.05	88.11	311.7	0.	499.90	100.000
						17.644	2.370	0.010	17.624	62.352	0.	100.000	
4.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.5669E-01	89.89	10.12	0.01	89.87	310.09	0.	499.98	100.000
						17.978	2.025	0.002	17.974	62.021	0.	100.000	
6.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	2.4544E-10	198.85	0.58	99.42	0.00	2.31	0.	301.15	100.000
						66.029	0.191	33.014	0.000	6.766	0.	100.000	
6.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	4.2592E-06	193.94	3.03	96.96	0.01	12.14	0.	306.07	100.000
						63.363	0.990	31.681	0.002	3.965	0.	100.000	
6.0000	800.00	2.6585E-04	9.0223E-02	3.7690E-03	1.0322E-04	180.99	9.40	90.38	0.22	38.25	0.	319.23	100.000
						56.695	2.943	28.313	0.069	11.980	0.	100.000	
6.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.3242E-02	157.59	19.74	77.33	2.93	87.75	0.	345.34	100.000
						45.634	5.716	22.393	0.848	25.409	0.	100.000	
6.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	5.5414E-00	127.06	27.48	54.54	17.97	163.85	0.	390.91	100.000
						32.505	7.030	13.953	4.598	41.914	0.	100.000	
6.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	6.8591E-01	99.09	24.50	23.59	51.92	253.73	0.	452.82	100.000
						21.883	5.410	5.209	11.465	56.033	0.	100.000	
6.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	2.4787E-01	86.48	18.11	4.59	77.31	304.35	0.	490.83	100.000
						17.619	3.689	0.934	15.750	62.008	0.	100.000	
6.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.6430E-01	86.34	14.30	0.64	85.06	312.38	0.	498.72	100.000
						17.312	2.868	0.128	17.055	62.637	0.	100.000	
6.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	1.2736E-01	88.26	11.85	0.11	88.04	311.53	0.	499.78	100.000
						17.659	2.371	0.022	17.616	62.332	0.	100.000	
6.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.0450E-01	89.90	10.12	0.02	89.85	310.05	0.	499.95	100.000
						17.981	2.025	0.005	17.972	62.017	0.	100.000	
12.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	3.0120E-10	199.13	0.44	99.56	0.00	1.75	0.	300.87	100.000
						66.182	0.145	33.091	0.000	0.581	0.	100.000	
12.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	4.9037E-06	195.39	2.30	97.69	0.00	9.22	0.	304.61	100.000
						64.145	0.756	32.072	0.001	3.027	0.	100.000	
12.0000	800.00	2.6585E-04	9.0223E-02	3.7690E-03	1.1925E-04	185.45	7.21	92.66	0.13	29.22	0.	314.67	100.000
						58.935	2.291	29.448	0.040	9.286	0.	100.000	
12.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.5236E-02	166.98	15.66	82.64	1.69	67.74	0.	334.71	100.000
						49.887	4.680	24.691	0.506	20.237	0.	100.000	
12.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	6.0479E-00	141.21	23.88	65.09	11.03	128.60	0.	369.82	100.000
						38.185	6.457	17.601	2.983	34.775	0.	100.000	
12.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	6.1920E-01	113.75	24.45	38.21	37.34	209.83	0.	423.58	100.000
						26.855	5.773	9.020	8.815	49.537	0.	100.000	
12.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	1.5880E-01	93.76	18.85	12.61	68.53	281.01	0.	474.77	100.000
						19.749	3.971	2.657	14.435	59.188	0.	100.000	
12.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	8.6346E-02	87.90	14.47	2.37	83.16	307.35	0.	495.26	100.000
						17.749	2.921	0.479	16.791	62.059	0.	100.000	
12.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	6.4256E-02	88.55	11.88	0.43	87.69	310.59	0.	499.14	100.000
						17.740	2.380	0.086	17.569	62.225	0.	100.000	
12.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	5.2353E-02	89.96	10.13	0.09	89.77	309.85	0.	499.81	100.000
						18.000	2.027	0.019	17.962	61.993	0.	100.000	

TABLE F-3A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - CH₄ (100 MOL C BASIS), STEAM/C RATIO 3.0

ELEMENTAL COMPOSITION													
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)										
100.00	1000.00	300.00	0.										
CONDITIONS AND EQUILIBRIUM CONSTANTS													
P(ATM)	T(DEG F)	KR	KS	KC	RT	H2O	CO2	CH4	CO	H2	N2	TOTAL	
						MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	MOLS
						MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC
1.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	2.4406E-10	296.89	1.55	98.45	0.00	6.22	0.	403.11	
						73.651	0.385	24.422	0.000	1.542	0.	100.000	
1.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.9241E-06	283.82	8.07	91.90	0.03	32.38	0.	416.21	
						68.193	1.940	22.080	0.007	7.780	0.	100.000	
1.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	9.8449E-03	251.05	23.95	75.00	1.05	98.95	0.	450.00	
						55.789	5.323	16.667	0.233	21.989	0.	100.000	
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.5009E-02	200.73	43.54	44.28	12.18	210.71	0.	511.45	
						39.248	8.514	8.657	2.382	41.199	0.	100.000	
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.3233E-01	163.93	45.65	9.58	44.76	316.90	0.	580.83	
						28.224	7.860	1.650	7.707	54.559	0.	100.000	
1.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	5.6587E-00	163.74	36.89	0.63	62.48	335.01	0.	598.74	
						39.347	6.162	0.105	10.435	55.952	0.	100.000	
1.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	3.6417E-00	170.21	29.84	0.05	70.11	329.69	0.	599.90	
						28.373	4.974	0.008	11.687	54.957	0.	100.000	
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	2.6176E-00	175.29	24.72	0.01	75.27	324.70	0.	599.99	
						29.215	4.120	0.001	12.546	54.118	0.	100.000	
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	2.0120E-00	179.05	20.95	0.00	79.05	320.95	0.	600.00	
						29.841	3.492	0.000	13.174	53.492	0.	100.000	
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.6286E-00	181.83	18.17	0.00	81.83	318.17	0.	600.00	
						30.304	3.029	0.000	13.638	53.029	0.	100.000	
2.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	2.6075E-10	297.64	1.18	98.82	0.00	4.72	0.	402.36	
						73.975	0.293	24.561	0.000	1.172	0.	100.000	
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	4.5063E-06	287.67	6.16	93.83	0.02	24.68	0.	412.35	
						69.763	1.493	22.754	0.004	5.985	0.	100.000	
2.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.1219E-04	262.05	18.67	80.72	0.60	76.50	0.	438.55	
						59.755	4.257	18.407	0.138	17.443	0.	100.000	
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.5929E-02	219.44	36.54	55.98	7.48	168.60	0.	488.04	
						44.964	7.487	11.470	1.533	34.546	0.	100.000	
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	9.8641E-00	177.22	43.79	21.01	35.19	280.76	0.	557.98	
						31.761	7.849	3.766	6.307	50.318	0.	100.000	
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	2.9671E-00	165.48	36.86	2.34	60.81	329.85	0.	595.33	
						27.797	6.191	0.392	10.214	55.406	0.	100.000	
2.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	1.8279E-01	170.36	29.84	0.20	69.96	329.25	0.	599.60	
						28.412	4.977	0.033	11.668	54.911	0.	100.000	
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.3094E-00	175.30	24.72	0.02	75.26	324.65	0.	599.95	
						29.220	4.120	0.004	12.544	54.112	0.	100.000	
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	1.0061E-00	179.05	20.95	0.00	79.04	320.94	0.	599.99	
						29.842	3.492	0.001	13.174	53.491	0.	100.000	
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	8.1429E-01	181.83	18.17	0.00	81.83	318.17	0.	600.00	
						30.305	3.029	0.000	13.638	53.029	0.	100.000	
4.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	3.1487E-10	298.21	0.89	99.11	0.00	3.58	0.	401.79	
						74.221	0.223	24.666	0.000	0.890	0.	100.000	
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	5.1764E-06	290.61	4.69	95.30	0.01	18.78	0.	409.40	
						70.986	1.145	23.279	0.002	4.588	0.	100.000	
4.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.2829E-04	270.77	14.44	85.21	0.35	58.81	0.	429.58	
						63.030	3.362	19.835	0.081	13.691	0.	100.000	
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.7497E-02	235.91	29.81	65.72	4.47	132.65	0.	468.56	
						50.348	6.363	14.026	0.953	28.310	0.	100.000	
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	8.7533E-00	194.71	40.29	35.01	24.70	235.27	0.	529.98	
						36.740	7.603	6.606	4.660	44.392	0.	100.000	

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TABLE F-3B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - CH₄ (100 MOL C BASIS), STEAM/C RATIO 3.0

ELEMENTAL COMPOSITION												
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)									
100.00	1000.00	300.00	0.									
CONDITIONS AND EQUILIBRIUM CONSTANTS												
P(ATM)	T(DEG F)	KR	KS	KC	KT	EQUILIBRIUM PRODUCT COMPOSITIONS						
						H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	TOTAL MOLS MOL PC
4.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.7186E-00	170.78 29.188	36.68 6.268	7.45 1.274	55.87 9.549	314.31 53.720	0. 0.	585.09 100.00
4.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	9.2781E-01	170.93 28.562	29.85 4.988	0.78 0.130	69.38 11.593	327.52 54.728	0. 0.	598.45 100.000
4.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	6.5586E-01	175.37 29.238	24.72 4.122	0.10 0.016	75.18 12.534	324.43 54.090	0. 0.	599.81 100.000
4.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	5.0320E-01	179.06 29.845	20.95 3.492	0.02 0.003	79.03 13.172	320.90 53.487	0. 0.	599.97 100.000
4.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	4.0717E-01	181.83 30.305	18.17 3.029	0.00 0.001	81.82 13.637	318.16 53.028	0. 0.	599.99 100.000
6.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	3.4972E-10	298.48 74.337	0.76 0.189	99.24 24.716	0.00 0.000	3.04 0.738	0. 0.	401.52 100.000
6.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	5.6118E-06	292.00 71.568	4.00 0.979	96.00 23.529	0.01 0.012	16.00 3.922	0. 0.	408.00 100.000
6.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.3888E-04	274.96 64.651	12.40 2.915	87.35 20.539	0.25 0.059	50.34 11.836	0. 0.	425.29 100.000
6.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.8658E-02	244.31 53.230	26.21 5.710	70.52 15.364	3.28 0.714	114.66 24.982	0. 0.	458.97 100.000
6.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	8.6222E-00	205.52 40.000	37.58 7.314	43.10 8.388	19.32 3.760	208.28 40.538	0. 0.	513.80 100.000
6.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.3539E-00	176.60 30.762	36.35 6.333	12.96 2.257	50.69 8.829	297.48 51.818	0. 0.	574.08 100.000
6.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	6.3342E-01	171.82 28.799	29.86 5.004	1.68 0.282	68.46 11.475	324.81 54.441	0. 0.	596.64 100.000
6.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	4.3854E-01	175.49 29.269	24.73 4.124	0.21 0.036	75.06 12.519	324.08 54.052	0. 0.	599.57 100.000
6.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.3563E-01	179.08 29.851	20.95 3.493	0.04 0.006	79.01 13.170	320.84 53.481	0. 0.	599.93 100.000
6.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	2.7148E-01	181.83 30.307	18.17 3.029	0.01 0.001	81.82 13.637	318.15 53.026	0. 0.	599.98 100.000
12.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	5.2986E-10	298.85 74.497	0.58 0.144	99.42 24.784	0.00 0.000	2.31 0.575	0. 0.	401.15 100.000
12.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	6.4549E-06	293.92 72.380	3.04 0.748	96.96 23.877	0.00 0.001	12.16 2.994	0. 0.	406.08 100.000
12.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.5922E-04	280.83 66.974	9.51 2.269	90.34 21.545	0.14 0.034	38.48 9.178	0. 0.	419.31 100.000
12.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.1023E-02	256.57 57.611	20.76 4.661	77.33 17.363	1.91 0.430	88.78 19.935	0. 0.	445.35 100.000
12.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	8.8992E-00	223.24 45.659	32.30 6.607	55.54 11.359	12.16 2.487	165.69 33.888	0. 0.	488.92 100.000
12.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.0529E-00	191.03 34.865	35.00 6.388	26.04 4.752	38.96 7.111	256.89 46.885	0. 0.	547.93 100.000
12.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	3.5260E-01	175.81 29.868	29.86 5.073	5.68 0.965	64.46 10.950	312.83 53.144	0. 0.	588.64 100.000
12.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	2.2273E-01	176.10 29.431	24.74 4.135	0.84 0.140	74.42 12.438	322.23 53.855	0. 0.	598.33 100.000
12.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	1.6826E-01	179.19 29.879	20.96 3.495	0.15 0.024	78.90 13.156	320.52 53.446	0. 0.	599.71 100.000
12.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.3582E-01	181.86 30.313	18.17 3.029	0.03 0.005	81.79 13.634	318.08 53.019	0. 0.	599.94 100.000

TABLE F-4A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - CH₄ (100 MOL C BASIS), STEAM/C RATIO 4.0

ELEMENTAL COMPOSITION												
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)									
100.00	1200.00	400.00	0.									
CONDITIONS AND EQUILIBRIUM CONSTANTS												
P(ATM)	T(°F)	KR	KS	KC	RT	H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	TOTAL MOLS MOL PC
1.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	3.1173E 10	396.19 78.639	1.91 0.378	98.09 19.471	0.00 0.000	7.62 1.513	0.	503.81 100.000
1.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	4.7995E 06	380.20 73.140	9.88 1.901	90.09 17.330	0.03 0.006	39.62 7.623	0.	519.83 100.000
1.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.2549E 04	340.48 60.728	29.19 5.206	69.67 12.426	1.14 0.234	120.18 21.436	0.	560.66 100.000
1.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.1600E 02	281.90 44.709	52.84 8.380	34.74 5.510	12.42 1.970	248.62 39.431	0.	630.52 100.000
1.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	2.5397E 01	248.80 36.045	56.08 8.125	4.88 0.707	39.04 5.656	341.45 49.467	0.	690.24 100.000
1.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	1.1702E 01	253.46 36.237	46.82 6.694	0.28 0.040	52.90 7.563	345.99 49.466	0.	699.45 100.000
1.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	7.2773E 00	261.17 37.313	38.85 5.550	0.02 0.003	61.13 8.733	338.78 48.400	0.	699.95 100.000
1.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	5.0885E 00	267.19 38.170	32.81 4.688	0.00 0.000	67.18 9.598	332.80 47.544	0.	699.99 100.000
1.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	3.8374E 00	271.77 38.824	28.23 4.033	0.00 0.000	71.77 10.252	328.23 46.890	0.	700.00 100.000
1.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	3.0647E 00	275.22 39.318	24.78 3.539	0.00 0.000	75.22 10.746	324.77 46.396	0.	700.00 100.000
2.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	3.4263E 10	397.11 78.965	1.45 0.287	98.55 19.598	0.00 0.000	5.78 1.150	0.	502.89 100.000
2.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	5.4891E 06	384.90 74.721	7.54 1.464	92.44 17.945	0.02 0.004	30.22 5.866	0.	515.12 100.000
2.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.4076E 04	353.75 64.680	22.79 4.168	76.54 13.995	0.67 0.122	93.17 17.036	0.	546.92 100.000
2.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.1619E 02	303.12 50.121	44.50 7.358	47.61 7.873	7.89 1.304	201.65 33.344	0.	604.77 100.000
2.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.6516E 01	259.24 38.468	53.82 7.986	13.05 1.937	33.13 4.917	314.66 46.693	0.	673.90 100.000
2.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	5.9785E 00	254.36 36.449	46.71 6.694	1.07 0.154	52.21 7.482	343.49 49.222	0.	697.85 100.000
2.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	3.6440E 00	261.25 37.330	38.84 5.551	0.09 0.013	61.07 8.726	338.57 48.380	0.	699.82 100.000
2.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	2.5448E 00	267.20 38.172	32.81 4.688	0.01 0.002	67.18 9.597	332.78 47.541	0.	699.98 100.000
2.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	1.9187E 00	271.77 38.824	28.23 4.033	0.00 0.000	71.76 10.252	328.23 46.890	0.	700.00 100.000
2.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.5324E 00	275.23 39.318	24.78 3.539	0.00 0.000	75.22 10.746	324.77 46.396	0.	700.00 100.000
4.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	3.6953E 10	397.81 79.214	1.10 0.218	98.90 19.694	0.00 0.000	4.39 0.873	0.	502.19 100.000
4.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	6.2851E 06	388.50 75.952	5.74 1.123	94.24 18.425	0.01 0.002	23.01 4.498	0.	511.51 100.000
4.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.5918E 04	364.30 67.957	17.66 3.293	81.96 15.289	0.39 0.072	71.78 13.389	0.	536.08 100.000
4.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.2883E 02	322.42 55.360	36.39 6.248	58.80 10.097	4.81 0.826	159.98 27.469	0.	582.40 100.000
4.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.3073E 01	276.16 42.577	49.53 7.636	25.69 3.960	24.79 3.821	272.46 42.006	0.	648.62 100.000

TABLE F-4B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - CH₄ (100 MOL C BASIS), STEAM/C RATIO 4.0

ELEMENTAL COMPOSITION
 C(ATOMS) H(ATOMS) O(ATOMS) N2(MOLS)
 100.0 1200.0 400.0 0

P(Atm)	T(DEG F)	CONDITIONS AND EQUILIBRIUM CONSTANTS			RT	EQUILIBRIUM			PRODUCT COMPOSITIONS			TOTAL MOLS MOL PC
		KR	KS	KC		H ₂ O MOLS MOL PC	CO ₂ MOLS MOL PC	CH ₄ MOLS MOL PC	CO MOLS MOL PC	H ₂ MOLS MOL PC	N ₂ MOLS MOL PC	
4.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	3.2244E 00	257.49 37.189	46.32 6.690	3.81 0.550	49.87 7.232	334.89 48.368	0. 0.	692.38 100.000
4.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	1.0349E 00	261.53 37.400	38.82 5.552	0.36 0.051	60.82 8.697	337.75 48.330	0. 0.	699.29 100.000
4.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	1.2734E 00	267.23 38.181	32.81 4.688	0.04 0.006	67.14 9.593	332.68 47.531	0. 0.	699.91 100.000
4.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	9.5950E-01	271.77 38.826	28.23 4.033	0.01 0.001	71.76 10.251	328.21 46.888	0. 0.	699.98 100.000
4.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	7.6621E-01	275.23 39.318	24.78 3.539	0.00 0.000	75.22 10.746	324.77 46.396	0. 0.	700.00 100.000
6.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	4.4306E 10	398.13 79.331	0.93 0.186	99.07 19.740	0.00 0.000	3.73 0.743	0. 0.	501.87 100.000
6.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	6.8090E 06	390.20 76.539	4.90 0.960	95.10 18.653	0.01 0.002	19.61 3.846	0. 0.	509.81 100.000
6.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.7147E 04	369.40 69.582	15.16 2.856	84.56 15.928	0.28 0.053	61.48 11.582	0. 0.	530.88 100.000
6.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.4029E 02	332.41 58.199	32.02 5.605	64.42 11.279	3.56 0.624	138.75 24.292	0. 0.	571.15 100.000
6.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.2276E 01	287.71 45.509	46.19 7.306	33.90 5.362	19.91 3.149	244.49 38.673	0. 0.	632.20 100.000
6.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	2.3767E 00	261.55 38.163	45.77 6.679	7.33 1.069	46.90 6.844	323.80 47.246	0. 0.	685.35 100.000
6.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	1.2369E 00	262.00 37.513	38.79 5.554	0.79 0.113	60.42 8.651	336.42 48.169	0. 0.	698.42 100.000
6.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	8.5010E-01	267.29 38.195	32.81 4.688	0.10 0.014	67.09 9.587	332.51 47.515	0. 0.	699.80 100.000
6.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	6.3981E-01	271.78 38.828	28.23 4.034	0.02 0.002	71.75 10.250	328.18 46.885	0. 0.	699.97 100.000
6.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	5.1083E-01	275.23 39.319	24.78 3.539	0.00 0.001	75.22 10.746	324.76 46.395	0. 0.	699.99 100.000
12.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	4.1445E 10	398.59 79.492	0.71 0.141	99.29 19.803	0.00 0.000	2.83 0.564	0. 0.	501.41 100.000
12.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	7.8086E 06	392.55 77.357	3.72 0.734	96.27 18.972	0.00 0.001	14.90 2.937	0. 0.	507.45 100.000
12.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.9530E 04	376.55 71.914	11.64 2.224	88.19 16.844	0.16 0.031	47.06 8.988	0. 0.	523.61 100.000
12.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.6560E 02	347.12 62.546	25.39 4.575	72.51 13.065	2.10 0.379	107.87 19.436	0. 0.	554.98 100.000
12.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.1980E 01	307.69 50.837	39.69 6.558	47.38 7.828	12.93 2.136	197.55 32.640	0. 0.	605.24 100.000
12.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	1.6370E 00	273.87 41.207	43.81 6.592	17.69 2.661	38.50 5.793	290.76 43.747	0. 0.	664.63 100.000
12.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	6.5311E-01	264.27 38.068	38.62 5.563	2.89 0.417	58.49 8.425	329.94 47.528	0. 0.	694.22 100.000
12.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	4.2813E-01	267.60 38.271	32.80 4.690	0.39 0.056	66.81 9.555	331.61 47.427	0. 0.	699.21 100.000
12.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	3.2030E-01	271.84 38.841	28.23 4.034	0.07 0.010	71.70 10.245	328.03 46.870	0. 0.	699.86 100.000
12.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	2.5548E-01	275.24 39.322	24.78 3.539	0.02 0.002	75.21 10.745	324.73 46.392	0. 0.	699.97 100.000

TABLE F-5A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - CH₄ (100 MOL C BASIS), STEAM/C RATIO 5.0

ELEMENTAL COMPOSITION												
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)									
100.00	1400.00	500.00	0.									
CONDITIONS AND EQUILIBRIUM CONSTANTS						EQUILIBRIUM PRODUCT COMPOSITIONS						
P(ATM)	T(DEG F)	KR	KS	KC	KT	H2O	CO2	CH4	CO	H2	N2	TOTAL
						MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	MOLS
						MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC
1.0000	400.0	7.9414E-12	2.0711E 02	4.0007E 09	3.5767E 10	495.52	2.24	97.76	0.00	8.96	0.	604.48
						81.975	0.310	16.173	0.000	1.482	0.	100.000
1.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	5.6091E 06	476.79	11.59	88.37	0.04	46.46	0.	623.25
						76.500	1.859	14.180	0.006	7.455	0.	100.000
1.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.5255E 04	430.76	34.01	64.77	1.22	139.71	0.	670.47
						64.247	5.073	9.660	0.182	20.838	0.	100.000
1.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.9717E 02	366.35	60.66	27.00	12.34	279.65	0.	745.99
						49.109	8.131	3.620	1.654	37.487	0.	100.000
1.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	4.4187E 01	339.09	63.55	2.64	33.81	355.63	0.	794.72
						42.668	7.997	0.332	4.254	44.749	0.	100.000
1.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	2.0059E 01	346.05	54.10	0.14	45.76	353.66	0.	799.71
						43.272	6.764	0.018	5.722	44.224	0.	100.000
1.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	1.2465E 01	354.23	45.78	0.01	54.21	345.75	0.	799.98
						44.280	5.723	0.002	6.776	43.220	0.	100.000
1.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	8.5212E 00	360.73	39.28	0.00	60.72	339.27	0.	800.00
						45.091	4.909	0.000	7.590	42.409	0.	100.000
1.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	6.3240E 00	365.79	34.21	0.00	65.79	334.21	0.	800.00
						45.723	4.277	0.000	8.223	41.776	0.	100.000
1.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	4.9934E 00	369.69	30.31	0.00	69.69	330.31	0.	800.00
						46.211	3.789	0.000	8.711	41.289	0.	100.000
2.0000	400.0	7.9414E-12	2.0711E 02	4.0007E 09	3.9148E 10	496.60	1.70	98.30	0.00	6.80	0.	603.40
						82.301	0.282	16.291	0.000	1.127	0.	100.000
2.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	6.3946E 06	482.28	8.85	91.13	0.02	35.46	0.	617.74
						78.071	1.433	14.752	0.003	5.741	0.	100.000
2.0000	800.0	2.6585E-04	9.0223E 00	3.7690E 03	1.6854E 04	446.02	26.63	72.65	0.72	108.68	0.	654.70
						68.126	4.068	11.097	0.110	16.600	0.	100.000
2.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.7999E 02	388.86	51.50	40.36	8.13	230.42	0.	719.28
						54.062	7.161	5.611	1.131	32.035	0.	100.000
2.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	2.6169E 01	346.61	61.52	8.13	30.35	337.13	0.	783.74
						44.225	7.849	1.037	3.873	43.015	0.	100.000
2.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	1.0448E 01	346.56	54.00	0.56	45.44	352.31	0.	798.87
						43.382	6.759	0.071	5.688	44.101	0.	100.000
2.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	6.2383E 00	354.27	45.78	0.05	54.17	345.63	0.	799.90
						44.289	5.723	0.006	6.773	43.209	0.	100.000
2.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	4.2611E 00	360.73	39.27	0.01	60.72	339.26	0.	799.99
						45.092	4.909	0.001	7.590	42.408	0.	100.000
2.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	4.1621E 00	365.79	34.21	0.00	65.79	334.21	0.	800.00
						45.724	4.277	0.000	8.223	41.776	0.	100.000
2.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	2.4067E 00	369.69	30.31	0.00	69.69	330.31	0.	800.00
						46.211	3.789	0.000	8.711	41.289	0.	100.000
4.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	4.6179E 10	497.42	1.29	98.71	0.00	5.16	0.	602.58
						82.549	0.214	16.381	0.000	0.826	0.	100.000
4.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	7.3036E 06	486.50	6.75	93.24	0.01	27.02	0.	613.51
						79.297	1.099	15.198	0.002	4.404	0.	100.000
4.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.8561E 04	458.25	20.66	78.92	0.42	83.91	0.	642.17
						71.301	3.218	12.289	0.065	13.067	0.	100.000
4.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.8044E 02	410.26	42.33	57.59	5.08	184.56	0.	694.82
						59.045	6.093	7.569	0.730	26.563	0.	100.000
4.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.8661E 01	361.51	57.17	18.68	24.16	301.14	0.	762.65
						47.432	7.496	2.449	3.167	39.486	0.	100.000

TABLE F-5B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - CH₄ (100 MOL C BASIS), STEAM/C RATIO 5.0

ELEMENTAL COMPOSITION													
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)										
100.00	1400.00	500.00	0.										
CONDITIONS AND EQUILIBRIUM CONSTANTS													
P(ATM)	T(DEG F)	KR	KS	KC	RT	EQUILIBRIUM PRODUCT COMPOSITIONS							
						H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	TOTAL MOLS MOL PC	
4.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	5.4499E 00	348.47 43.790	53.64 6.741	2.11 0.265	44.25 5.561	347.31 43.644	0. 0.	795.78 100.000	
4.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	3.1306E 00	354.44 44.326	45.76 5.722	0.19 0.024	54.05 6.760	345.18 43.168	0. 0.	799.62 100.000	
4.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	2.1315E 00	360.75 45.097	39.27 4.909	0.02 0.003	60.70 7.588	339.20 42.403	0. 0.	799.95 100.000	
4.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	1.5811E 00	365.79 45.724	34.21 4.277	0.00 0.001	65.78 8.223	334.20 41.775	0. 0.	799.99 100.000	
4.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.2484E 00	369.69 46.211	30.31 3.789	0.00 0.000	69.69 8.711	330.31 41.289	0. 0.	800.00 100.000	
6.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	4.4755E 10	497.81 82.666	1.10 0.182	98.90 16.424	0.00 0.000	4.39 0.728	0. 0.	602.19 100.000	
6.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	7.8994E 06	488.49 79.882	5.75 0.940	94.24 15.411	0.01 0.001	23.03 3.766	0. 0.	611.52 100.000	
6.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	2.0225E 04	464.18 72.969	17.76 2.792	81.94 12.880	0.31 0.048	71.95 11.311	0. 0.	636.13 100.000	
6.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.9520E 02	421.55 61.790	37.33 5.471	58.88 8.631	3.79 0.556	160.68 23.552	0. 0.	682.24 100.000	
6.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.6722E 01	372.92 49.919	53.55 7.169	26.48 3.544	19.97 2.673	274.13 36.695	0. 0.	747.05 100.000	
6.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	3.8634E 00	351.20 44.378	53.11 6.711	4.31 0.544	42.58 5.381	340.19 42.986	0. 0.	791.38 100.000	
6.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	2.0996E 00	354.71 44.385	45.72 5.721	0.43 0.053	53.85 6.739	344.44 43.101	0. 0.	799.15 100.000	
6.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	1.4220E 00	360.78 45.104	39.27 4.909	0.05 0.007	60.68 7.585	339.11 42.394	0. 0.	799.89 100.000	
6.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	1.0542E 00	365.80 45.726	34.21 4.277	0.01 0.001	65.78 8.223	334.18 41.774	0. 0.	799.98 100.000	
6.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	8.3227E-01	369.69 46.211	30.31 3.789	0.00 0.000	69.69 8.711	330.31 41.288	0. 0.	800.00 100.000	
12.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	5.8476E 10	498.34 82.827	0.83 0.138	99.17 16.482	0.00 0.000	3.33 0.553	0. 0.	601.66 100.000	
12.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	9.0358E 06	491.25 80.697	4.37 0.718	95.62 15.708	0.00 0.001	17.51 2.876	0. 0.	608.76 100.000	
12.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	2.2896E 04	472.52 75.282	13.65 2.175	86.17 13.729	0.18 0.028	55.14 8.786	0. 0.	627.66 100.000	
12.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	3.2023E 02	438.38 66.033	29.68 4.470	68.06 10.251	2.26 0.341	125.50 18.904	0. 0.	663.88 100.000	
12.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.5405E 01	394.06 54.779	46.26 6.431	40.32 5.605	13.42 1.865	225.30 31.320	0. 0.	719.36 100.000	
12.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	2.4248E 00	360.92 46.512	51.08 6.583	12.01 1.547	36.91 4.756	315.06 40.601	0. 0.	775.99 100.000	
12.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	1.0827E 00	356.09 44.692	45.54 5.715	1.62 0.203	52.84 6.632	340.67 42.757	0. 0.	796.76 100.000	
12.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	7.1384E-01	360.96 45.145	39.25 4.909	0.22 0.027	60.53 7.570	338.61 42.349	0. 0.	799.57 100.000	
12.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	5.2747E-01	365.83 45.733	34.21 4.277	0.04 0.005	65.75 8.220	334.10 41.766	0. 0.	799.92 100.000	
12.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	4.1620E-01	369.70 46.213	30.31 3.789	0.01 0.001	69.68 8.710	330.29 41.287	0. 0.	799.98 100.000	

TABLE F-6

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₃H₈ (100 MOL C BASIS); STEAM/C RATIO, 1.0

ELEMENTAL COMPOSITION																	
C(ATOMS)	H(ATOMS)	O(ATOMS)		N2(MOLS)													
100.00	466.67	100.00		0.													
CONDITIONS AND EQUILIBRIUM CONSTANTS																	
P(ATM)	T(DEG F)	KR	KS	KC	RT	H2O		CO2		CH4		PRODUCT		COMPOSITIONS		TOTAL	
						MOLS	PC	MOLS	PC	MOLS	PC	MOLS	PC	MOLS	PC	MOLS	PC
1.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	3.7857E-02	2.98		1.05		4.03		94.92		222.30		0.	
CONDITIONS LEAD TO CARBON FORMATION.						0.916		0.322		1.238		29.182		68.341		0.	
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.0038E-02	1.13		0.29		1.42		98.29		229.37		0.	
						0.341		0.089		0.429		29.739		69.402		0.	
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.3068E-03	0.48		0.10		0.58		99.32		231.69		0.	
						0.145		0.030		0.175		29.900		69.750		0.	
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.2941E-03	0.23		0.04		0.27		99.69		232.56		0.	
						0.070		0.012		0.081		29.956		69.882		0.	
2.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	3.7939E-02	5.57		1.95		7.52		90.52		212.72		0.	
CONDITIONS LEAD TO CARBON FORMATION.						1.749		0.614		2.363		28.441		66.833		0.	
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.0039E-02	2.20		0.57		2.77		96.66		225.60		0.	
						0.670		0.175		0.844		29.488		68.824		0.	
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.3063E-03	0.95		0.19		1.15		98.66		230.08		0.	
						0.288		0.059		0.347		29.802		69.504		0.	
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.2939E-03	0.46		0.08		0.54		99.38		231.80		0.	
						0.139		0.023		0.162		29.912		69.764		0.	
4.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	3.8088E-02	9.87		3.44		13.31		83.24		196.83		0.	
CONDITIONS LEAD TO CARBON FORMATION.						3.219		1.122		4.341		27.141		64.176		0.	
4.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.0041E-02	4.19		1.09		5.28		93.63		218.59		0.	
						1.297		0.338		1.635		29.008		67.722		0.	
4.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.3053E-03	1.87		0.38		2.25		97.37		226.96		0.	
						0.569		0.116		0.685		29.610		69.021		0.	
4.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.2936E-03	0.91		0.15		1.07		98.78		230.29		0.	
						0.276		0.046		0.322		29.825		69.531		0.	
6.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	3.8221E-02	13.33		4.62		17.95		77.42		184.10		0.	
CONDITIONS LEAD TO CARBON FORMATION.						4.482		1.554		6.036		26.031		61.896		0.	
6.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.0042E-02	6.00		1.56		7.57		90.87		212.20		0.	
						1.886		0.491		2.378		28.557		66.687		0.	
6.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.3044E-03	2.75		0.56		3.31		96.13		223.96		0.	
						0.842		0.172		1.013		29.423		68.551		0.	
6.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.2933E-03	1.36		0.23		1.59		98.19		228.81		0.	
						0.411		0.069		0.480		29.739		69.301		0.	
12.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	3.8558E-02	20.69		7.07		27.76		65.17		157.13		0.	
CONDITIONS LEAD TO CARBON FORMATION.						7.446		2.546		9.992		23.457		56.559		0.	
12.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.0046E-02	10.62		2.76		13.39		83.85		195.94		0.	
						3.465		0.902		4.366		27.351		63.916		0.	
12.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.3016E-03	5.19		1.06		6.26		92.68		215.63		0.	
						1.619		0.331		1.950		28.889		67.211		0.	
12.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.2923E-03	2.64		0.44		3.08		96.48		224.53		0.	
						0.807		0.135		0.942		29.488		68.627		0.	

TABLE F-7A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C3H8 (100 MOL C BASIS), STEAM/C RATIO, 2.0

ELEMENTAL COMPOSITION
 C(ATOMS) H(ATOMS) O(ATOMS) N2(MOLS)
 100.0 666.67 200.00 0.

P(ATM)	T(°C F)	CONDITIONS AND EQUILIBRIUM CONSTANTS				EQUILIBRIUM					PRODUCT COMPOSITIONS			TOTAL MOLS MOL PC
		KR	KS	KC	RT	H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC			
1.0000	400.0	7.9414E-12	2.0711E 02	4.0007E 09	4.6519E 09	165.67 61.897	17.16 6.412	82.84 30.948	0.00 0.000	1.99 0.743	0.	267.66 100.00		
1.0000	600.0	2.1990E-07	3.1479E 01	1.0438E 06	1.4885E 06	159.17 58.042	20.39 7.434	79.55 29.010	0.06 0.022	15.06 5.492	0.	274.23 100.000		
1.0000	800.0	2.6585E-04	9.0223E 00	3.7690E 03	5.1304E 03	139.55 47.293	29.57 10.021	69.13 23.426	1.30 0.442	55.53 18.818	0.	295.08 100.00		
1.0000	1000.0	4.9018E-02	3.7523E 00	6.4774E 01	8.1476E 01	107.73 31.829	39.72 11.734	47.44 14.017	12.84 3.795	130.73 38.625	0.	338.45 100.000		
1.0000	1200.0	2.6875E 00	1.9714E 00	3.0042E 00	5.8114E 00	80.30 19.955	35.18 8.742	15.47 3.845	49.35 12.265	222.09 55.194	0.	402.39 100.00		
1.0000	1400.0	6.3697E 01	1.2081E 00	2.7306E-01	2.1146E 00	75.41 17.511	25.95 6.026	1.36 0.315	72.69 16.881	255.21 59.266	0.	430.62 100.00		
1.0000	1600.0	8.2139E 02	8.2439E-01	4.0069E-02	1.4120E 00	79.57 18.372	20.53 4.741	0.11 0.024	79.36 18.323	253.55 58.540	0.	433.12 100.00		
1.0000	1800.0	6.7984E 03	6.0833E-01	8.3445E-03	1.0542E 00	83.19 19.198	16.83 3.883	0.01 0.003	83.16 19.192	250.12 57.724	0.	433.31 100.00		
1.0000	2000.0	4.0014E 04	4.7516E-01	2.2622E-03	8.3203E-01	85.85 19.812	14.15 3.266	0.00 0.000	85.85 19.811	247.48 57.111	0.	433.33 100.00		
1.0000	2200.0	1.8036E 05	3.8864E-01	7.5373E-04	6.8590E-01	87.80 20.261	12.20 2.816	0.00 0.000	87.80 20.261	245.54 56.662	0.	433.33 100.00		
2.0000	400.0	7.9414E-12	2.0711E 02	4.0007E 09	4.6431E 09	165.96 62.072	17.02 6.365	82.98 31.036	0.00 0.000	1.41 0.527	0.	267.37 100.000		
2.0000	600.0	2.1990E-07	3.1479E 01	1.0438E 06	1.5377E 06	161.26 59.262	19.35 7.111	80.61 29.623	0.04 0.015	10.85 3.989	0.	272.12 100.00		
2.0000	800.0	2.6585E-04	9.0223E 00	3.7690E 03	5.5515E 03	146.39 50.868	26.39 9.171	72.78 25.290	0.83 0.287	41.39 14.382	0.	287.78 100.000		
2.0000	1000.0	4.9018E-02	3.7523E 00	6.4774E 01	8.7810E 01	119.95 37.311	35.97 11.187	55.92 17.393	8.11 2.524	101.54 31.585	0.	321.50 100.000		
2.0000	1200.0	2.6875E 00	1.9714E 00	3.0042E 00	4.9520E 00	91.65 24.207	35.70 9.429	27.35 7.225	36.94 9.757	186.97 49.382	0.	378.63 100.000		
2.0000	1400.0	6.3697E 01	1.2081E 00	2.7306E-01	1.1800E 00	78.13 18.420	26.46 6.237	4.59 1.082	68.96 16.257	246.03 58.004	0.	424.16 100.00		
2.0000	1600.0	8.2139E 02	8.2439E-01	4.0069E-02	7.1300E-01	79.84 18.459	20.58 4.758	0.42 0.096	79.00 18.267	252.67 58.420	0.	432.50 100.00		
2.0000	1800.0	6.7984E 03	6.0833E-01	8.3445E-03	5.2768E-01	83.22 19.209	16.83 3.885	0.05 0.011	83.12 19.186	250.02 57.709	0.	433.24 100.00		
2.0000	2000.0	4.0014E 04	4.7516E-01	2.2622E-03	4.1609E-01	85.86 19.814	14.15 3.266	0.01 0.002	85.84 19.810	247.46 57.109	0.	433.32 100.00		
2.0000	2200.0	1.8036E 05	3.8864E-01	7.5373E-04	3.4297E-01	87.80 20.262	12.20 2.816	0.00 0.000	87.80 20.261	245.53 56.661	0.	433.33 100.00		
4.0000	400.0	7.9414E-12	2.0711E 02	4.0007E 09	4.6656E 09	166.17 62.196	16.92 6.331	83.08 31.098	0.00 0.000	1.00 0.374	0.	267.17 100.00		
4.0000	600.0	2.1990E-07	3.1479E 01	1.0438E 06	1.5760E 06	162.79 60.164	18.59 6.871	81.38 30.077	0.03 0.010	7.79 2.877	0.	270.57 100.00		
4.0000	800.0	2.6585E-04	9.0223E 00	3.7690E 03	5.9321E 03	151.67 53.746	23.90 8.469	75.57 26.779	0.53 0.189	30.53 10.818	0.	282.20 100.000		
4.0000	1000.0	4.9018E-02	3.7523E 00	6.4774E 01	9.5308E 01	130.46 42.361	32.22 10.461	62.68 20.352	5.10 1.657	77.51 25.169	0.	307.98 100.00		
4.0000	1200.0	2.6875E 00	1.9714E 00	3.0042E 00	4.7433E 00	104.34 29.427	35.03 9.881	39.38 11.105	25.59 7.216	150.24 42.371	0.	354.58 100.00		

CALIFORNIA RESEARCH
 CORPORATION
 RICHMOND, CALIFORNIA

RE 647655

TABLE F-7B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₃H₈ (100 MOL C BASIS), STEAM/C RATIO, 2.0

ELEMENTAL COMPOSITION
 C(ATOMS) 100.00 H(ATOMS) 666.67 O(ATOMS) 200.00 N₂(MOLS) 0.

CONDITIONS AND EQUILIBRIUM CONSTANTS
 P(ATM) T(DEG F) KR KS KC RT

EQUILIBRIUM PRODUCT COMPOSITIONS
 H₂O CO₂ CH₄ CO H₂ N₂ TOTAL
 MOLS MOLS MOLS MOLS MOLS MOLS MOLS
 MOL PC MOL PC MOL PC MOL PC MOL PC MOL PC MOL PC

4.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	7.7132E-01	84.62 20.684	27.50 6.722	12.12 2.962	60.38 14.760	224.49 54.873	0. 0.	409.13 100.00
4.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	3.6989E-01	80.82 18.786	26.75 4.824	1.57 0.365	77.68 18.056	249.33 57.969	0. 0.	430.20 100.00
4.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	2.6503E-01	83.34 19.250	16.85 3.892	0.19 0.045	82.96 19.161	249.60 57.652	0. 0.	432.95 100.00
4.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	2.0820E-01	85.88 19.821	14.15 3.267	0.03 0.007	85.81 19.806	247.39 57.099	0. 0.	433.27 100.00
4.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.7151E-01	87.80 20.263	12.20 2.816	0.01 0.002	87.79 20.260	245.52 56.659	0. 0.	433.32 100.00
6.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	4.6363E 09	166.26 62.252	16.87 6.317	83.13 31.126	0.00 0.000	0.82 0.366	0. 0.	267.28 100.00
6.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	1.5941E 06	163.48 60.575	18.25 6.762	81.73 30.283	0.02 0.008	6.40 2.371	0. 0.	269.88 100.00
6.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	6.1318E 03	154.16 55.135	22.71 8.124	76.87 27.493	0.42 0.149	25.44 9.099	0. 0.	279.60 100.00
6.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	9.9905E 01	135.74 45.023	30.18 10.011	65.92 21.865	3.90 1.292	65.75 21.808	0. 0.	301.49 100.00
6.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	4.7737E 00	111.64 32.657	34.09 9.973	45.73 13.378	20.17 5.901	130.22 38.092	0. 0.	341.87 100.00
6.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	6.5716E-01	90.32 22.793	28.21 7.120	18.54 4.677	53.25 13.438	205.94 51.971	0. 0.	396.26 100.00
6.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	2.6029E-01	82.24 19.268	21.00 4.920	3.24 0.760	75.76 17.748	244.61 57.305	0. 0.	426.85 100.00
6.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	1.7799E-01	83.55 19.319	16.88 3.904	0.43 0.100	82.69 19.119	248.92 57.558	0. 0.	432.47 100.00
6.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	1.3897E-01	85.91 19.833	14.16 3.269	0.07 0.017	85.77 19.799	247.28 57.783	0. 0.	433.19 100.00
6.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.1437E-01	87.81 20.266	12.20 2.816	0.02 0.004	87.78 20.259	245.49 56.656	0. 0.	433.30 100.00
12.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	4.6303E 09	166.38 62.324	16.81 6.297	83.19 31.162	0.00 0.000	0.58 0.216	0. 0.	266.96 100.00
12.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	1.6187E 06	164.39 61.122	17.80 6.616	82.19 30.558	0.02 0.006	4.56 1.697	0. 0.	268.96 100.00
12.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	6.4303E 03	157.55 57.070	21.09 7.639	78.64 28.485	0.27 0.099	18.51 6.706	0. 0.	276.06 100.00
12.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	1.0772E 02	143.33 49.006	27.10 9.264	70.43 24.080	2.48 0.847	49.15 16.804	0. 0.	292.48 100.00
12.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	4.9676E 00	123.15 38.088	31.85 9.852	55.00 17.011	13.14 4.065	100.18 30.984	0. 0.	323.33 100.00
12.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	5.6500E-01	102.01 27.482	29.05 7.826	31.07 8.369	39.88 10.744	169.19 45.579	0. 0.	371.20 100.00
12.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	1.5966E-01	87.53 21.112	21.85 5.271	9.38 2.263	68.77 16.587	227.05 54.767	0. 0.	414.58 100.00
12.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	9.2368E-02	84.58 19.667	17.05 3.963	1.61 0.379	81.33 18.910	245.42 57.081	0. 0.	430.08 100.00
12.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	6.9936E-02	86.10 19.896	14.19 3.278	0.29 0.066	85.53 19.763	246.66 56.997	0. 0.	432.76 100.00
12.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	5.7265E-02	87.85 20.280	12.21 2.818	0.06 0.014	87.73 20.251	245.36 56.637	0. 0.	433.21 100.00

TABLE F-8A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA -

STEAM REFORMER FEED - C₃H₈ (100 MOL C BASIS), STEAM/C RATIO, 3.0

ELEMENTAL COMPOSITION													
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)										
100.00	866.67	300.00	0.										
CONDITIONS AND EQUILIBRIUM CONSTANTS													
P(ATM)	T(DEG F)	KR	KS	KC	RT	H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	TOTAL MOLS MOL PC	
1.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	7.3333E 09	265.20 72.038	17.40 4.726	82.66 22.437	0.00 0.000	2.94 0.798	0.	368.14 100.00	
1.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	2.3230E 06	255.78 67.734	22.08 5.848	77.86 20.618	0.06 0.016	21.84 5.785	0.	377.62 100.00	
1.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	8.0279E 03	228.28 56.172	35.19 8.660	63.47 15.618	1.33 0.328	78.11 19.221	0.	406.39 100.00	
1.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	1.4165E 02	185.26 40.189	50.94 11.050	36.19 7.851	12.87 2.793	175.70 38.116	0.	460.95 100.00	
1.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.4231E 01	156.58 30.134	50.29 9.678	6.86 1.321	42.85 8.247	263.03 50.621	0.	519.61 100.00	
1.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	6.4171E 00	159.26 29.908	41.15 7.728	0.41 0.078	58.44 10.974	273.24 51.312	0.	532.51 100.00	
1.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	4.1379E 00	166.15 31.156	33.88 6.354	0.03 0.006	66.08 12.392	267.12 50.091	0.	533.27 100.00	
1.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	2.9724E 00	171.51 32.159	28.49 5.343	0.00 0.001	71.50 13.407	261.82 49.091	0.	533.33 100.00	
1.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	2.2843E 00	175.55 32.916	24.45 4.584	0.00 0.000	75.55 14.166	257.78 48.334	0.	533.33 100.00	
1.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.8490E 00	178.59 33.485	21.41 4.015	0.00 0.000	78.59 14.735	254.75 47.765	0.	533.33 100.00	
2.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	7.4262E 09	265.63 72.238	17.19 4.674	82.81 22.521	0.00 0.000	2.09 0.567	0.	367.71 100.00	
2.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	2.4104E 06	258.78 69.081	20.59 5.497	79.37 21.187	0.04 0.011	15.82 4.224	0.	374.60 100.00	
2.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	8.6185E 03	237.74 59.969	30.71 7.747	68.45 17.266	0.84 0.212	58.70 14.807	0.	396.44 100.00	
2.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	1.7422E 02	201.36 45.736	45.17 10.259	46.53 10.569	8.30 1.886	138.91 31.551	0.	440.27 100.00	
2.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.0065E 01	166.92 33.292	49.06 9.786	15.98 3.187	34.96 6.972	234.46 46.763	0.	501.37 100.00	
2.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	3.3246E 00	160.42 30.256	41.15 7.761	1.57 0.295	57.28 10.804	269.79 50.884	0.	530.20 100.00	
2.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	2.0747E 00	166.24 31.185	33.89 6.357	0.13 0.024	65.98 12.378	266.84 50.056	0.	533.08 100.00	
2.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	1.4867E 00	171.52 32.162	28.49 5.343	0.02 0.003	71.49 13.405	261.78 49.087	0.	533.30 100.00	
2.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	1.1422E 00	175.55 32.917	24.45 4.584	0.00 0.000	75.55 14.166	257.78 48.333	0.	533.33 100.00	
2.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	9.2451E-01	178.59 33.485	21.41 4.015	0.00 0.000	78.59 14.735	254.75 47.765	0.	533.33 100.00	
4.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	7.4673E 09	265.93 72.380	17.04 4.637	82.96 22.581	0.00 0.000	1.48 0.412	0.	367.41 100.00	
4.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	2.4811E 06	260.98 70.085	19.50 5.235	80.48 21.612	0.03 0.007	11.40 3.060	0.	372.38 100.00	
4.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	9.1928E 03	245.12 63.054	27.17 6.989	72.29 18.596	0.54 0.138	43.63 11.222	0.	388.75 100.00	
4.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	1.5146E 02	215.58 50.963	39.58 9.357	55.16 13.040	5.26 1.243	107.43 25.397	0.	423.01 100.00	
4.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	8.4990E 00	181.30 37.958	46.56 9.749	27.86 5.833	25.58 5.355	196.32 41.134	0.	477.62 100.00	

CALIFORNIA RESEARCH
CORPORATION
RICHMOND, CALIFORNIA

RE 647657

TABLE F-8B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₃H₈ (100 MOL-% BASIS), STEAM/C RATIO, 3.0

ELEMENTAL COMPOSITION													
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)										
100.00	866.67	300.00	0.										
CONDITIONS AND EQUILIBRIUM CONSTANTS													
P(ATM)	T(°F)	KR	KS	KC	RT	H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	TOTAL MOLS MOL PC	
4.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.8656E-00	164.10 31.381	41.11 7.863	5.21 0.996	53.68 10.265	258.82 49.496	0. 0.	522.92 100.00	
4.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	1.0488E-00	166.60 31.298	33.90 6.369	0.51 0.095	65.59 12.321	265.71 49.916	0. 0.	532.32 100.00	
4.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	7.4429E-01	171.56 32.176	28.50 5.344	0.06 0.012	71.44 13.398	261.65 49.070	0. 0.	533.21 100.00	
4.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	5.7122E-01	175.56 32.919	24.45 4.584	0.01 0.002	75.54 14.165	257.75 48.330	0. 0.	533.31 100.00	
4.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	4.6228E-01	178.59 33.486	21.41 4.015	0.00 0.000	78.59 14.735	254.74 47.764	0. 0.	533.33 100.00	
6.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	7.6319E-09	266.06 72.443	16.97 4.620	83.03 22.608	0.00 0.000	1.21 0.129	0. 0.	367.27 100.00	
6.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.5151E-06	261.99 70.545	19.00 5.115	80.98 21.806	0.02 0.006	9.39 2.527	0. 0.	371.37 100.00	
6.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	9.5095E-03	248.62 64.555	25.48 6.617	74.10 19.241	0.41 0.108	36.51 9.479	0. 0.	385.13 100.00	
6.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.5691E-02	222.81 53.751	36.59 8.826	59.40 14.330	4.01 0.968	91.72 22.126	0. 0.	414.53 100.00	
6.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	8.1512E-00	190.38 41.074	44.54 9.609	34.92 7.533	20.55 4.433	173.13 37.352	0. 0.	463.50 100.00	
6.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.4283E-00	168.38 32.723	41.00 7.968	9.38 1.824	49.62 9.642	246.18 47.843	0. 0.	514.57 100.00	
6.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	7.1154E-01	167.18 31.478	33.93 6.388	1.11 0.209	64.96 12.232	263.93 49.694	0. 0.	531.11 100.00	
6.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	4.9725E-01	171.64 32.199	28.50 5.347	0.14 0.026	71.36 13.387	261.42 49.042	0. 0.	533.06 100.00	
6.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.8095E-01	175.57 32.923	24.45 4.585	0.02 0.004	75.53 14.163	257.71 48.325	0. 0.	533.29 100.00	
6.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	3.0821E-01	178.59 33.487	21.41 4.015	0.01 0.001	78.58 14.735	254.73 47.763	0. 0.	533.32 100.00	
12.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	7.6742E-09	266.24 72.526	16.88 4.598	83.12 22.642	0.00 0.000	0.86 0.233	0. 0.	367.10 100.00	
12.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.5634E-06	263.32 71.161	18.33 4.955	81.65 22.066	0.01 0.004	6.71 1.815	0. 0.	370.03 100.00	
12.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.0004E-04	253.43 66.662	23.15 6.089	76.58 20.143	0.27 0.071	26.74 7.035	0. 0.	380.17 100.00	
12.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.6726E-02	233.32 57.960	32.07 7.967	65.39 16.244	2.54 0.630	69.23 17.198	0. 0.	402.55 100.00	
12.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	8.0452E-00	205.42 46.525	40.49 9.170	45.91 10.397	13.61 3.082	136.11 30.826	0. 0.	441.52 100.00	
12.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.0528E-00	179.68 36.423	40.32 8.173	20.00 4.055	39.68 8.043	213.64 43.307	0. 0.	493.33 100.00	
12.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	3.8620E-01	169.87 32.320	34.01 6.472	3.88 0.738	62.11 11.817	255.71 48.653	0. 0.	525.58 100.00	
12.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	2.5145E-01	172.02 32.319	28.52 5.359	0.54 0.102	70.93 13.327	260.23 48.892	0. 0.	532.25 100.00	
12.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	1.9083E-01	175.64 32.944	24.45 4.587	0.09 0.017	75.45 14.152	257.51 48.300	0. 0.	533.15 100.00	
12.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.5417E-01	178.61 33.491	21.41 4.015	0.02 0.004	78.57 14.732	254.69 47.757	0. 0.	533.29 100.00	

CALIFORNIA RESEARCH
CORPORATION
RICHMOND, CALIFORNIA

RE 647658

TABLE F-9A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₃H₈ (100 MOL C BASIS), STEAM/C RATIO, 4.0

ELEMENTAL COMPOSITION						EQUILIBRIUM PRODUCT COMPOSITIONS									
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)												
100.00	1066.67	400.00	0.												
CONDITIONS AND EQUILIBRIUM CONSTANTS															
P(ATM)	T(DEG F)	KR	KS	KC	RT	H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	TOTAL MOLS MOL PC			
1.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.0109E-1	364.73 77.834	17.63 3.763	82.37 17.577	0.00 0.000	3.87 0.826	0.	468.60 100.00			
1.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.1238E-06	352.55 73.320	23.69 4.927	76.25 15.857	0.06 0.013	28.29 5.883	0.	480.84 100.00			
1.0000	800.00	2.6585E-04	9.0223E-03	3.7690E-03	1.0909E-04	318.13 61.583	40.24 7.791	58.37 11.300	1.38 0.267	98.46 19.059	0.	516.59 100.00			
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.1673E-02	267.26 46.179	60.04 10.374	27.30 4.717	12.66 2.188	211.49 36.542	0.	578.74 100.00			
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	2.9221E-01	242.55 38.693	60.68 9.680	3.24 0.516	36.08 5.756	284.31 45.354	0.	626.86 100.00			
1.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.3809E-01	248.85 39.314	51.32 8.108	0.18 0.028	48.50 7.662	284.13 44.888	0.	632.98 100.00			
1.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	8.5514E-00	256.68 40.530	43.33 8.843	0.01 0.002	56.65 8.945	276.63 43.680	0.	633.31 100.00			
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	5.9574E-00	262.85 41.503	37.15 5.866	0.00 0.000	62.85 9.923	270.48 42.708	0.	633.33 100.00			
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	4.4819E-00	267.63 42.258	32.37 5.111	0.00 0.000	67.63 10.679	265.71 41.953	0.	633.33 100.00			
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	3.5741E-00	271.31 42.838	28.69 4.531	0.00 0.000	71.31 11.259	262.03 41.373	0.	633.33 100.00			
2.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.0128E-10	365.29 78.047	17.35 3.708	82.65 17.658	0.00 0.000	2.75 0.588	0.	468.04 100.00			
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.2528E-06	356.40 74.719	21.78 4.567	78.18 16.390	0.04 0.008	20.58 4.315	0.	476.98 100.00			
2.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.1598E-04	329.83 65.394	34.65 6.870	64.48 12.784	0.87 0.172	74.55 14.780	0.	504.37 100.00			
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.0737E-02	285.62 51.358	52.97 9.525	38.60 6.940	8.43 1.515	170.51 30.660	0.	556.14 100.00			
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.8077E-01	250.18 40.691	59.06 9.606	9.25 1.504	31.69 5.155	264.66 43.045	0.	614.84 100.00			
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	7.0124E-00	249.43 39.468	51.26 8.111	0.68 0.108	48.06 7.605	282.54 44.708	0.	631.97 100.00			
2.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	4.2809E-00	256.72 40.543	43.33 8.843	0.06 0.009	56.61 8.940	276.50 43.665	0.	633.22 100.00			
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	2.9791E-00	262.85 41.504	37.15 5.866	0.01 0.001	62.84 9.922	270.47 42.706	0.	633.32 100.00			
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	2.2410E-00	267.63 42.258	32.37 5.111	0.00 0.000	67.63 10.678	265.70 41.953	0.	633.33 100.00			
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.7871E-00	271.31 42.838	28.69 4.531	0.00 0.000	71.31 11.259	262.03 41.373	0.	633.33 100.00			
4.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.0242E-10	365.69 78.199	17.15 3.668	82.85 17.716	0.00 0.000	1.95 0.417	0.	467.64 100.00			
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.3596E-06	359.24 75.769	20.37 4.296	79.61 16.790	0.03 0.006	14.88 3.139	0.	474.12 100.00			
4.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.2323E-04	339.06 68.519	30.25 6.103	69.25 13.995	0.55 0.111	55.78 11.272	0.	494.83 100.00			
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.1010E-02	302.54 56.422	46.02 8.582	48.56 9.056	5.42 1.011	133.67 24.928	0.	536.21 100.00			
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.3515E-01	263.67 44.356	55.78 9.384	19.45 3.272	24.77 4.166	230.77 38.822	0.	594.44 100.00			

CALIFORNIA RESEARCH
CORPORATION
RICHMOND, CALIFORNIA

TABLE F-9B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₃H₈ (100 MOL C BASIS), STEAM/C RATIO, 4.0

ELEMENTAL COMPOSITION												
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)									
100.00	1066.67	400.00	0.		CONDITIONS AND EQUILIBRIUM CONSTANTS					PRODUCT COMPOSITIONS		
P(ATM)	T(DEG F)	KR	KS	KC	RT	H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	TOTAL MOLS MOL PC
4.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	3.7081E-00	251.48 40.023	51.02 8.119	2.50 0.397	46.49 7.399	276.86 44.062	0. 0.	628.34 100.00
4.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	2.1508E-00	256.90 40.592	43.32 6.845	0.22 0.035	56.45 8.920	275.98 43.607	0. 0.	632.89 100.00
4.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.4904E-00	262.88 41.510	37.15 5.867	0.03 0.004	62.82 9.920	270.40 42.699	0. 0.	633.28 100.00
4.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	1.1206E-00	267.64 42.259	32.37 5.111	0.00 0.001	67.63 10.678	265.69 41.951	0. 0.	633.33 100.00
4.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	8.9355E-01	271.31 42.838	28.69 4.531	0.00 0.000	71.31 11.259	262.03 41.373	0. 0.	633.33 100.00
6.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.0340E-10	365.87 78.267	17.07 3.651	82.93 17.741	0.00 0.000	1.60 0.342	0. 0.	467.47 100.00
6.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.4126E-06	360.54 76.253	19.72 4.171	80.26 16.974	0.02 0.005	12.28 2.597	0. 0.	472.82 100.00
6.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.2743E-04	343.46 70.050	28.06 5.723	71.52 14.586	0.42 0.087	46.82 9.554	0. 0.	490.31 100.00
6.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.1478E-02	311.33 59.171	42.26 8.031	53.59 10.185	4.15 0.789	114.83 21.824	0. 0.	526.16 100.00
6.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.2313E-01	273.29 47.081	53.14 9.154	26.43 4.553	20.43 3.520	207.18 35.691	0. 0.	580.47 100.00
6.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	2.6720E-00	254.29 40.788	50.66 8.127	4.95 0.794	44.39 7.120	269.15 43.172	0. 0.	623.44 100.00
6.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	1.4452E-00	257.19 40.674	43.31 6.848	0.50 0.079	56.20 8.887	275.14 43.512	0. 0.	632.34 100.00
6.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	9.9456E-01	262.91 41.520	37.15 5.867	0.06 0.010	62.79 9.916	270.30 42.687	0. 0.	633.21 100.00
6.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	7.4719E-01	267.64 42.261	32.37 5.111	0.01 0.002	67.62 10.677	265.67 41.949	0. 0.	633.31 100.00
6.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	5.9572E-01	271.31 42.838	28.69 4.531	0.00 0.000	71.30 11.259	262.02 41.372	0. 0.	633.33 100.00
12.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.0102E-10	366.10 78.355	16.95 3.628	83.05 17.775	0.00 0.000	1.13 0.242	0. 0.	467.23 100.00
12.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.4880E-06	362.27 76.902	18.86 4.003	81.13 17.222	0.01 0.003	8.81 1.870	0. 0.	471.08 100.00
12.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.3426E-04	349.55 72.212	25.09 5.183	74.64 15.419	0.27 0.057	34.51 7.130	0. 0.	484.06 100.00
12.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.2576E-02	324.25 63.367	36.56 7.144	60.81 11.884	2.63 0.514	87.45 17.091	0. 0.	511.71 100.00
12.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.1463E-01	290.38 52.143	47.85 8.593	38.23 6.865	13.92 2.499	166.50 29.899	0. 0.	556.88 100.00
12.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.7437E-00	263.48 43.356	49.34 8.118	12.81 2.108	37.85 6.229	244.23 40.189	0. 0.	607.71 100.00
12.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	7.5188E-01	258.65 41.082	43.22 6.864	1.87 0.297	54.92 8.722	270.95 43.335	0. 0.	629.60 100.00
12.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	4.9981E-01	263.10 41.574	37.15 5.870	0.25 0.039	62.61 9.893	269.74 42.624	0. 0.	632.84 100.00
12.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.7391E-01	267.67 42.270	32.37 5.112	0.04 0.007	67.59 10.673	265.58 41.939	0. 0.	633.25 100.00
12.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	2.9792E-01	271.32 42.840	28.69 4.531	0.01 0.001	71.30 11.258	262.02 41.370	0. 0.	633.32 100.00

TABLE F-10A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C3H8 (100 MOL C BASIS), STEAM/C RATIO, 5.0

ELEMENTAL COMPOSITION					N2(MOLS)							
C(ATOMS)	H(ATOMS)	O(ATOMS)										
100.00	1266.67	500.00			0.							
CGNDITIONS AND EQUILIBRIUM CONSTANTS												
P(ATM)	T(DEG F)	KR	KS	KC	RT							
EQUILIBRIUM PRODUCT COMPOSITIONS												
		H2O	CO2	CH4	CO	H2	N2	TOTAL				
		MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	MOLS				
		MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC				
1.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.2068E-10	464.27	17.86	82.14	0.00	4.79	0.	569.66
		81.585	3.139	14.433	0.000	0.842	0.	100.00				
1.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.8982E-06	449.46	25.24	74.70	0.06	34.47	0.	583.93
		76.972	4.322	12.793	0.011	5.903	0.	100.000				
1.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.3843E-04	408.83	44.87	53.70	1.42	117.09	0.	625.93
		65.316	7.169	8.580	0.228	18.707	0.	100.000				
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	3.1290E-02	352.85	67.46	20.32	12.22	239.85	0.	692.70
		50.939	9.739	2.933	1.764	34.625	0.	100.000				
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	5.3148E-01	333.84	67.82	1.66	30.52	296.18	0.	730.02
		45.730	9.290	0.227	4.181	40.572	0.	100.000				
1.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	2.5076E-01	341.55	58.54	0.09	41.37	291.61	0.	733.16
		46.586	7.985	0.012	5.643	39.775	0.	100.000				
1.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	1.5020E-01	349.62	50.39	0.01	49.60	283.70	0.	733.32
		47.676	6.872	0.001	6.764	38.688	0.	100.000				
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.0211E-01	356.13	43.87	0.00	56.13	277.20	0.	733.33
		48.564	5.982	0.000	7.654	37.800	0.	100.000				
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	7.5490E-00	361.31	38.69	0.00	61.31	272.02	0.	733.33
		49.269	5.276	0.000	8.360	37.094	0.	100.000				
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	5.9450E-00	365.36	34.64	0.00	65.36	267.97	0.	733.33
		49.822	4.723	0.000	8.913	36.541	0.	100.000				
2.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.2877E-10	464.96	17.52	82.48	0.00	3.41	0.	568.37
		81.806	3.082	14.512	0.000	0.600	0.	100.000				
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	4.0684E-06	454.10	22.93	77.03	0.04	25.18	0.	579.28
		78.390	3.959	13.297	0.007	4.347	0.	100.000				
2.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.4550E-04	422.47	38.31	60.79	0.90	89.29	0.	611.76
		69.059	6.263	9.937	0.147	14.595	0.	100.000				
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.8018E-02	372.13	59.71	31.84	8.45	197.53	0.	669.66
		55.569	8.917	4.754	1.261	29.498	0.	100.000				
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	3.0215E-01	338.99	66.42	5.40	28.18	283.54	0.	722.53
		46.917	9.192	0.748	3.900	39.243	0.	100.000				
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.2638E-01	341.86	58.48	0.35	41.17	290.78	0.	732.64
		46.662	7.982	0.047	5.620	39.689	0.	100.000				
2.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	7.5145E-03	349.64	50.39	0.03	49.58	283.64	0.	733.28
		47.682	6.872	0.004	6.762	38.681	0.	100.000				
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	5.1057E-00	356.14	43.87	0.00	56.13	277.19	0.	733.33
		48.564	5.982	0.001	7.654	37.799	0.	100.000				
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.7745E-00	361.31	38.69	0.00	61.31	272.02	0.	733.33
		49.269	5.276	0.000	8.360	37.094	0.	100.000				
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	2.9725E-00	365.36	34.64	0.00	65.36	267.97	0.	733.33
		49.822	4.723	0.000	8.913	36.541	0.	100.000				
4.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.2966E-10	465.46	17.27	82.73	0.00	2.42	0.	567.88
		81.964	3.041	14.568	0.000	0.426	0.	100.000				
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	4.2140E-06	457.54	21.21	78.76	0.03	18.27	0.	575.82
		79.460	3.684	13.678	0.005	3.173	0.	100.000				
4.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.5378E-04	433.35	33.04	66.39	0.57	67.21	0.	600.55
		72.158	5.502	11.055	0.095	11.191	0.	100.000				
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.7300E-02	390.92	51.77	42.69	5.54	157.04	0.	647.96
		60.331	7.990	6.538	0.855	24.236	0.	100.000				
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	2.0315E-01	350.27	63.15	13.42	23.43	256.22	0.	706.49
		49.579	8.938	1.900	3.317	36.267	0.	100.000				

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RICHMOND, CALIFORNIA
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TABLE F-10B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C3H8 (100 MOL C BASIS), STEAM/C RATIO, 5.0

ELEMENTAL COMPOSITION													
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)										
100.00	1266.67	500.00	0.										
CONDITIONS AND EQUILIBRIUM CONSTANTS													
PLATM)	T(DEG F)	KR	KS	KC	RT	EQUILIBRIUM PRODUCT COMPOSITIONS							
						H2O	CO2	CH4	CO	H2	N2	TOTAL	
						MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	
						MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	
4.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	6.5114E 00	343.07 46.950	58.25 7.972	1.32 0.181	40.43 5.533	287.63 39.364	0. 0.	730.70 100.00	
4.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	3.7668E 00	349.74 47.707	50.38 6.872	0.12 0.016	49.51 6.753	283.36 38.652	0. 0.	733.10 100.00	
4.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	2.5536E 00	356.15 48.567	43.87 5.982	0.01 0.002	56.12 7.653	277.16 37.796	0. 0.	733.31 100.00	
4.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	1.8874E 00	361.31 49.270	38.69 5.276	0.00 0.000	61.31 8.360	272.02 37.094	0. 0.	733.33 100.00	
4.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.4863E 00	365.36 49.822	34.64 4.723	0.00 0.000	65.36 8.913	267.97 36.541	0. 0.	733.33 100.00	
6.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	1.2900E 10	465.68 82.035	17.16 3.023	82.84 14.593	0.00 0.000	1.98 0.349	0. 0.	567.66 100.00	
6.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	4.2884E 06	459.13 79.955	20.43 3.557	79.55 13.854	0.02 0.004	15.10 2.630	0. 0.	574.23 100.00	
6.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.5883E 04	438.57 73.685	30.50 5.124	69.07 11.604	0.44 0.073	56.63 9.514	0. 0.	595.20 100.00	
6.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.7502E 02	400.94 62.973	47.39 7.444	48.33 7.591	4.28 0.672	135.74 21.320	0. 0.	636.68 100.00	
6.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.7569E 01	359.53 51.826	60.28 8.689	19.81 2.855	19.92 2.871	234.19 33.759	0. 0.	693.72 100.00	
6.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	4.5407E 00	344.85 47.381	57.91 7.957	2.76 0.379	39.33 5.404	282.97 38.880	0. 0.	727.82 100.00	
6.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	2.5217E 00	349.91 47.748	50.35 6.871	0.26 0.036	49.38 6.739	282.91 38.606	0. 0.	732.81 100.00	
6.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	1.7033E 00	356.17 48.573	43.87 5.982	0.03 0.005	56.12 7.651	277.10 37.790	0. 0.	733.27 100.00	
6.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	1.2584E 00	361.31 49.271	38.69 5.276	0.01 0.001	61.30 8.360	272.01 37.093	0. 0.	733.32 100.00	
6.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	9.9087E-01	365.37 49.823	34.64 4.723	0.00 0.000	65.36 8.913	267.97 36.541	0. 0.	733.33 100.00	
12.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	1.3087E 10	465.97 82.127	17.02 2.999	82.98 14.626	0.00 0.000	1.40 0.248	0. 0.	567.37 100.00	
12.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	4.3951E 06	461.24 80.622	19.37 3.386	80.61 14.091	0.01 0.003	10.86 1.899	0. 0.	572.11 100.00	
12.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.6736E 04	445.84 75.853	26.94 4.583	72.78 12.383	0.28 0.048	41.93 7.133	0. 0.	587.77 100.00	
12.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.8453E 02	415.90 67.063	40.69 6.562	56.59 9.125	2.72 0.438	104.26 16.812	0. 0.	626.16 100.00	
12.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.5367E 01	377.43 56.336	54.27 8.100	31.69 4.731	14.04 2.096	192.52 28.737	0. 0.	669.95 100.00	
12.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	2.7146E 00	351.71 49.061	56.51 7.883	8.22 1.147	35.27 4.919	265.17 36.990	0. 0.	716.89 100.00	
12.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	1.2885E 00	350.76 47.963	50.24 6.870	1.01 0.138	48.75 6.666	280.56 38.364	0. 0.	731.32 100.00	
12.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	8.5398E-01	356.27 48.600	43.86 5.983	0.13 0.018	56.01 7.641	276.80 37.759	0. 0.	733.07 100.00	
12.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	6.2947E-01	361.33 49.276	38.69 5.276	0.02 0.003	61.29 8.358	271.96 37.087	0. 0.	733.29 100.00	
12.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	4.9548E-01	365.37 49.824	34.64 4.723	0.01 0.001	65.36 8.913	267.96 36.540	0. 0.	733.32 100.00	

TABLE F-11

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₆H₁₄ (100 MOL C BASIS), STEAM/C RATIO, 1.0

ELEMENTAL COMPOSITION													
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)										
100.00	433.33	100.00	0.										
CONDITIONS AND EQUILIBRIUM CONSTANTS						EQUILIBRIUM PRODUCT COMPOSITIONS							
P(ATM)	T(°F)	KR	KS	KC	RT	H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	TOTAL MOLS MOL PC	
1.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	3.6053E-02	2.78	1.04	3.83	95.11	206.23	0.	309.00	
CONDITIONS LEAD TO CARBON FORMATION.						0.898	0.342	1.240	30.781	66.739	0.	100.000	
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	9.5909E-03	1.05	0.30	1.35	98.36	212.92	0.	313.97	
						0.335	0.094	0.429	31.327	67.815	0.	100.000	
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.1652E-03	0.45	0.10	0.55	99.35	215.11	0.	315.56	
						0.143	0.031	0.174	31.484	68.168	0.	100.000	
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.2401E-03	0.22	0.04	0.26	99.70	215.94	0.	316.15	
						0.069	0.012	0.081	31.537	68.301	0.	100.000	
2.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	3.6068E-02	5.19	1.97	7.16	90.87	197.17	0.	302.35	
CONDITIONS LEAD TO CARBON FORMATION.						1.715	0.652	2.367	30.056	65.211	0.	100.000	
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	9.5859E-03	2.05	0.58	2.63	96.80	209.36	0.	311.41	
						0.659	0.185	0.844	31.083	67.229	0.	100.000	
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.1639E-03	0.89	0.20	1.09	98.71	213.59	0.	314.49	
						0.284	0.062	0.346	31.389	67.918	0.	100.000	
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.2398E-03	0.43	0.08	0.51	99.41	215.21	0.	315.64	
						0.137	0.025	0.162	31.495	68.182	0.	100.000	
4.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	3.6096E-02	9.18	3.48	12.67	83.85	182.15	0.	291.33	
CONDITIONS LEAD TO CARBON FORMATION.						3.152	1.196	4.348	28.781	62.523	0.	100.000	
4.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	9.5763E-03	3.91	1.10	5.01	93.89	202.74	0.	306.65	
						1.275	0.359	1.634	30.618	66.114	0.	100.000	
4.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.1614E-03	1.75	0.38	2.13	97.48	210.65	0.	312.40	
						0.560	0.123	0.683	31.204	67.429	0.	100.000	
4.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.2392E-03	0.86	0.15	1.01	98.84	213.79	0.	314.64	
						0.272	0.049	0.321	31.412	67.946	0.	100.000	
6.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	3.6122E-02	12.38	4.69	17.08	78.23	170.12	0.	282.51	
CONDITIONS LEAD TO CARBON FORMATION.						4.384	1.662	6.045	27.690	60.219	0.	100.000	
6.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	9.5670E-03	5.60	1.58	7.18	91.24	196.70	0.	302.39	
						1.853	0.523	2.376	30.181	65.307	0.	100.000	
6.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.1590E-03	2.57	0.57	3.14	96.30	207.82	0.	310.39	
						0.829	0.182	1.011	31.024	66.954	0.	100.000	
6.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.2386E-03	1.27	0.23	1.50	98.27	212.39	0.	313.66	
						0.406	0.073	0.479	31.330	67.713	0.	100.000	
12.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	3.6185E-02	19.16	7.24	26.41	66.35	144.69	0.	263.85	
CONDITIONS LEAD TO CARBON FORMATION.						7.263	2.746	10.009	25.146	54.837	0.	100.000	
12.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	9.5415E-03	9.90	2.81	12.71	84.49	181.35	0.	291.25	
						3.400	0.963	4.363	29.008	62.266	0.	100.000	
12.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.1521E-03	4.86	1.07	5.93	93.00	199.95	0.	304.81	
						1.593	0.352	1.945	30.510	65.599	0.	100.000	
12.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.2369E-03	2.47	0.45	2.92	96.63	208.35	0.	310.83	
						0.796	0.143	0.939	31.090	67.032	0.	100.000	

CALIFORNIA RESEARCH
CORPORATION
RICHMOND, CALIFORNIA

RE 647663

TABLE F-12A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA -

STEAM REFORMER FEED - C₆H₁₄ (100 MOL C BASIS), STEAM/C RATIO, 2.0

ELEMENTAL COMPOSITION												
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)									
100.00	633.33	200.00	0.									
CONDITIONS AND EQUILIBRIUM CONSTANTS												
P(ATM)	T(DEG F)	KR	KS	KC	RT	EQUILIBRIUM PRODUCT COMPOSITIONS						TOTAL
						H2O	CO2	CH4	CO	H2	N2	MOLS
						MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	PC
						MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC
1.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	4.9748E-09	157.44 60.735	21.28 8.209	78.72 30.367	0.0 0.000	1.78 0.688	0.	259.23 100.000
1.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	1.3330E-06	151.53 57.137	24.20 9.125	75.73 28.555	0.07 0.026	13.68 5.157	0.	265.21 100.000
1.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	4.7757E-03	133.32 46.824	32.64 11.463	65.96 23.167	1.40 0.490	51.41 18.056	0.	284.74 100.000
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	7.8339E-01	103.51 31.720	41.66 12.766	45.17 13.841	13.17 4.037	122.82 37.636	0.	326.33 100.000
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	5.7747E-00	78.15 20.149	36.25 9.347	14.40 3.713	49.34 12.722	209.71 54.068	0.	387.86 100.000
1.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	2.1569E-00	74.32 17.942	26.90 6.495	1.22 0.295	71.88 17.352	239.90 57.916	0.	414.22 100.000
1.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	1.4473E-00	78.68 18.892	21.41 5.141	0.09 0.023	78.49 18.847	237.79 57.097	0.	416.48 100.000
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.0822E-00	82.39 19.774	17.62 4.230	0.01 0.003	82.37 19.769	234.25 56.224	0.	416.64 100.000
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	8.5512E-01	85.13 20.431	14.87 3.569	0.00 0.000	85.13 20.431	231.53 55.568	0.	416.66 100.000
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	7.0553E-01	87.14 20.914	12.86 3.086	0.00 0.000	87.14 20.914	229.52 55.086	0.	416.66 100.000
2.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	4.0711E-09	157.70 60.896	21.15 8.167	78.85 30.448	0.09 0.000	1.26 0.488	0.	258.97 100.000
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	1.3684E-06	153.44 58.284	23.25 8.833	76.70 29.133	0.05 0.018	9.82 3.732	0.	263.27 100.000
2.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	5.1155E-03	139.72 50.287	29.69 10.686	69.41 24.982	0.90 0.323	38.12 13.722	0.	277.84 100.000
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	8.3616E-01	115.04 37.103	38.27 12.343	53.31 17.193	8.42 2.717	95.01 30.644	0.	310.05 100.000
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	4.8578E-00	88.76 24.306	36.98 10.126	25.74 7.049	37.28 10.209	176.42 48.311	0.	365.18 100.000
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.1950E-00	76.76 18.800	27.40 6.712	4.17 1.021	68.43 16.758	231.56 56.710	0.	428.33 100.000
2.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	7.3023E-01	78.91 18.973	21.46 5.159	0.37 0.089	78.17 18.795	237.01 56.984	0.	415.92 100.000
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	5.4168E-01	82.42 19.784	17.63 4.231	0.04 0.010	82.33 19.763	234.16 56.211	0.	416.58 100.000
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	4.2763E-01	85.13 20.433	14.87 3.570	0.01 0.002	85.12 20.430	231.52 55.566	0.	416.65 100.000
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	3.5278E-01	87.14 20.915	12.86 3.086	0.00 0.000	87.14 20.914	229.52 55.085	0.	416.66 100.000
4.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	4.0788E-09	157.88 61.011	21.06 8.137	78.94 30.505	0.00 0.000	0.90 0.346	0.	258.78 100.000
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	1.3951E-06	154.83 59.128	22.57 8.618	77.40 29.558	0.03 0.012	7.03 2.684	0.	261.86 100.000
4.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	5.4127E-03	144.64 53.055	27.39 10.046	72.02 26.420	0.59 0.215	27.98 10.264	0.	272.62 100.000
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	8.9847E-01	124.92 42.045	34.86 11.731	59.78 20.119	5.37 1.897	72.19 24.297	0.	297.11 100.000
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	4.5999E-00	100.67 29.429	36.62 10.794	37.29 10.901	26.09 7.627	141.41 41.339	0.	342.09 100.000

CALIFORNIA RESEARCH
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TABLE F-12B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₆H₁₄ (100 MOL C BASIS), STEAM/C RATIO, 2.0

ELEMENTAL COMPOSITION													
C(ATOMS)	H(ATOMS)	O(ATOMS)	N ₂ (MOLS)										
100.00	633.33	200.00	0.										
P(ATM)	T(DEG F)	CONDITIONS AND EQUILIBRIUM CONSTANTS				EQUILIBRIUM PRODUCT COMPOSITIONS						TOTAL MOLS	MOL PC
		KR	KS	KC	KT	H ₂ MOLS MOL PC	CO ₂ MOLS MOL PC	CH ₄ MOLS MOL PC	CO MOLS MOL PC	H ₂ MOLS MOL PC	N ₂ MOLS MOL PC		
4.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	7.7120E-01	82.69 20.970	28.48 7.224	11.17 2.834	60.34 15.303	211.63 53.670	0. 0.	394.32 100.00	
4.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	3.7772E-01	79.78 19.278	21.63 5.226	1.41 0.340	76.97 18.598	234.07 56.559	0. 0.	413.85 100.00	
4.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	2.7195E-01	82.53 19.823	17.65 4.239	0.17 0.042	82.18 19.740	233.79 56.157	0. 0.	416.32 100.00	
4.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	2.1396E-01	85.15 20.440	14.88 3.571	0.03 0.007	85.10 20.426	231.46 55.557	0. 0.	416.61 100.00	
4.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.7641E-01	87.15 20.916	12.86 3.086	0.01 0.001	87.13 20.913	229.51 55.083	0. 0.	416.65 100.00	
6.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	4.0827E-09	157.97 61.062	21.02 8.124	78.98 30.531	0.00 0.000	0.71 0.283	0. 0.	258.70 100.00	
6.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	1.4078E-06	155.46 59.511	22.26 8.520	77.72 29.751	0.03 0.010	5.77 2.208	0. 0.	261.23 100.00	
6.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	5.5646E-03	146.94 54.382	26.30 9.734	73.24 27.106	0.46 0.171	23.25 8.607	0. 0.	270.19 100.00	
6.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	9.3611E-01	129.87 44.641	33.00 11.342	62.87 21.610	4.13 1.421	61.06 20.987	0. 0.	290.93 100.00	
6.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	4.6000E-00	107.52 32.597	35.88 10.879	43.41 13.159	20.71 6.278	122.33 37.086	0. 0.	329.85 100.00	
6.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	6.5161E-01	87.97 23.017	29.27 7.659	17.24 4.510	53.49 13.996	194.22 50.818	0. 0.	382.19 100.00	
6.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	2.6476E-01	81.05 19.729	21.87 5.324	2.92 0.711	75.21 18.306	229.77 55.929	0. 0.	410.82 100.00	
6.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.8252E-01	82.71 19.886	17.68 4.251	0.38 0.092	81.94 19.701	233.19 56.069	0. 0.	415.90 100.00	
6.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	1.4280E-01	85.18 20.450	14.88 3.572	0.06 0.015	85.06 20.420	231.35 55.542	0. 0.	416.54 100.00	
6.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.1764E-01	87.15 20.918	12.86 3.087	0.01 0.003	87.13 20.912	229.48 55.080	0. 0.	416.64 100.00	
12.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	4.1014E-09	158.07 61.129	20.96 8.107	79.04 30.564	0.00 0.000	0.52 0.200	0. 0.	258.59 100.00	
12.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	1.4243E-06	156.29 60.019	21.85 8.390	78.13 30.006	0.02 0.007	4.11 1.578	0. 0.	260.40 100.00	
12.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	5.7862E-03	150.06 56.221	24.81 9.297	74.88 28.053	0.31 0.116	16.85 6.313	0. 0.	266.91 100.00	
12.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	9.9876E-01	136.96 48.505	30.18 10.690	67.15 23.781	2.67 0.944	45.40 16.080	0. 0.	282.37 100.00	
12.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	4.7353E-00	118.31 37.917	34.01 10.901	52.32 16.768	13.67 4.380	93.71 30.034	0. 0.	312.92 100.00	
12.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	5.5281E-01	98.87 27.597	30.33 8.465	29.20 8.150	40.47 11.297	159.40 44.491	0. 0.	358.27 100.00	
12.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	1.6052E-01	85.83 21.484	22.74 5.693	8.58 2.146	68.68 17.191	213.68 53.486	0. 0.	399.51 100.00	
12.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	9.4428E-02	83.62 20.209	17.84 4.311	1.46 0.352	80.71 19.506	230.14 55.622	0. 0.	413.75 100.00	
12.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	7.1821E-02	85.35 20.509	14.91 3.582	0.25 0.061	84.84 20.386	230.81 55.462	0. 0.	416.16 100.00	
12.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	5.8894E-02	87.19 20.931	12.87 3.088	0.06 0.013	87.08 20.905	229.36 55.062	0. 0.	416.55 100.00	

TABLE F-13A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₆H₁₄ (100 MOL C BASIS), STEAM/C RATIO, 3.0

ELEMENTAL COMPOSITION													
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)										
100.00	833.33	300.00	0.										
CONDITIONS AND EQUILIBRIUM CONSTANTS						EQUILIBRIUM PRODUCT COMPOSITIONS							
P(ATM)	T(°F)	KR	KS	KG	RT	H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	TOTAL MOLS MOL PC	
1.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	6.5891E-09	256.99 71.453	21.50 5.978	78.50 21.825	0.00 0.000	2.68 0.744	0.	359.67 100.000	
1.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.1372E-06	248.27 67.380	25.83 7.011	74.10 20.111	0.07 0.018	20.19 5.480	0.	368.46 100.000	
1.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	7.6903E-03	222.23 56.141	38.19 9.647	60.41 15.262	1.40 0.354	73.61 18.597	0.	395.84 100.000	
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.4008E-02	181.20 40.404	52.89 11.794	34.09 7.602	13.01 2.902	167.28 37.299	0.	448.48 100.000	
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.4588E-01	154.64 30.669	51.57 10.227	6.21 1.232	42.22 8.373	249.60 49.499	0.	504.24 100.000	
1.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	6.6679E-00	157.99 30.623	42.37 8.213	0.37 0.071	57.26 11.098	257.94 49.995	0.	515.93 100.000	
1.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	4.3015E-00	164.96 31.931	35.07 6.789	0.03 0.006	64.90 12.563	251.65 48.712	0.	516.61 100.000	
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	3.0897E-00	170.38 32.978	29.62 5.733	0.00 0.001	70.38 13.622	246.27 47.667	0.	516.66 100.000	
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	2.3746E-00	174.50 33.774	25.51 4.936	0.00 0.000	74.49 14.418	242.17 46.872	0.	516.66 100.000	
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.9223E-00	177.60 34.374	22.40 4.336	0.00 0.000	77.60 15.019	239.07 46.271	0.	516.66 100.000	
2.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	6.6423E-09	257.38 71.638	21.31 5.931	78.69 21.902	0.00 0.000	1.90 0.528	0.	359.28 100.000	
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.2009E-06	251.07 68.666	24.44 6.385	75.51 20.652	0.05 0.012	14.57 3.985	0.	365.64 100.000	
2.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	8.1736E-03	231.25 59.860	33.93 8.783	65.18 16.871	0.90 0.232	55.06 14.254	0.	386.31 100.000	
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.4116E-02	196.60 45.877	47.45 11.073	44.06 10.281	8.49 1.980	131.94 30.788	0.	428.55 100.000	
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.0169E-01	164.23 33.707	50.50 10.364	14.72 3.022	34.78 7.138	222.99 45.768	0.	487.22 100.000	
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	3.4444E-00	159.01 30.943	42.38 8.247	1.39 0.271	56.23 10.942	254.87 49.597	0.	513.88 100.000	
2.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	2.1562E-00	165.04 31.957	35.08 6.792	0.11 0.022	64.81 12.550	251.40 48.679	0.	516.44 100.000	
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.5453E-00	170.39 32.981	29.62 5.733	0.01 0.003	70.37 13.620	246.24 47.663	0.	516.64 100.000	
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	1.1873E-00	174.50 33.774	25.51 4.937	0.00 0.000	74.49 14.418	242.16 46.871	0.	516.66 100.000	
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	9.6118E-01	177.60 34.374	22.40 4.336	0.00 0.000	77.60 15.019	239.07 46.271	0.	516.66 100.000	
4.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	6.6616E-09	257.66 71.771	21.17 5.897	78.83 21.958	0.00 0.000	1.35 0.375	0.	359.01 100.000	
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.2513E-06	253.12 69.619	23.43 6.443	76.54 21.053	0.03 0.008	10.46 2.877	0.	363.58 100.000	
4.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	8.6310E-03	238.26 62.867	30.58 8.069	68.84 18.164	0.58 0.153	40.73 10.747	0.	378.99 100.000	
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.4681E-02	210.20 51.031	42.18 10.240	52.38 12.716	5.44 1.321	101.71 24.692	0.	411.91 100.000	
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	8.4703E-00	177.78 38.263	48.25 10.385	26.03 5.602	25.72 5.536	186.84 40.213	0.	464.61 100.000	

CALIFORNIA RESEARCH
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RE 647666

TABLE F-13B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₆H₁₄ (100 MOL C BASIS), STEAM/C RATIO, 3.0

ELEMENTAL COMPOSITION															
C(ATOMS)	H(ATOMS)	O(ATOMS)	N ₂ (MOLS)												
100.00	833.33	300.00	0.												
P(ATM)	T(DEG F)	CONDITIONS AND EQUILIBRIUM CONSTANTS				RT	EQUILIBRIUM				PRODUCT COMPOSITIONS				TOTAL MOLS MOL PC
		KR	KS	KC	H ₂ O MOLS MOL PC		CO ₂ MOLS MOL PC	CH ₄ MOLS MOL PC	CO MOLS MOL PC	H ₂ MOLS MOL PC	N ₂ MOLS MOL PC				
4.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	1.9173E 00		162.31 31.994	42.38 8.353	4.68 0.923	52.94 10.436	244.99 48.294	0. 0.	507.30 100.000		
4.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	1.0889E 00		165.36 32.060	35.09 6.804	0.45 0.087	64.46 12.498	250.41 48.551	0. 0.	515.77 100.000		
4.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	7.7356E-01		170.43 32.994	29.62 5.735	0.05 0.011	70.32 13.614	246.13 47.647	0. 0.	516.56 100.000		
4.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	5.9379E-01		174.50 33.776	25.51 4.937	0.01 0.002	74.49 14.417	242.14 46.868	0. 0.	516.65 100.000		
4.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	4.8061E-01		177.60 34.374	22.40 4.336	0.00 0.000	77.59 15.019	239.06 46.271	0. 0.	516.66 100.000		
6.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	6.5605E 09		257.78 71.829	21.11 5.882	78.89 21.982	0.00 0.000	1.10 0.306	0. 0.	358.88 100.000		
6.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	2.2744E 06		254.04 70.053	22.97 6.333	77.01 21.236	0.02 0.007	8.60 2.372	0. 0.	362.65 100.000		
6.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	8.8774E 03		241.56 64.322	28.99 7.720	70.56 18.787	0.45 0.120	33.99 9.050	0. 0.	375.55 100.000		
6.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	1.5121E 02		217.11 53.775	39.35 9.747	56.46 13.985	4.18 1.037	86.63 21.457	0. 0.	403.74 100.000		
6.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	8.0669E 00		186.39 41.323	46.40 10.288	32.80 7.272	20.80 4.610	164.67 36.507	0. 0.	451.07 100.000		
6.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	1.4568E 00		166.21 33.267	42.31 8.468	8.52 1.705	49.18 9.842	233.42 46.718	0. 0.	499.63 100.000		
6.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	7.3768E-01		165.87 32.226	35.12 6.823	0.98 0.191	63.90 12.415	248.83 48.345	0. 0.	514.70 100.000		
6.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	5.1670E-01		170.49 33.015	29.63 5.737	0.12 0.024	70.25 13.603	245.93 47.621	0. 0.	516.42 100.000		
6.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	3.9598E-01		174.51 33.780	25.51 4.937	0.02 0.004	74.47 14.415	242.11 46.864	0. 0.	516.62 100.000		
6.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	3.2043E-01		177.60 34.375	22.40 4.336	0.00 0.001	77.59 15.018	239.06 46.270	0. 0.	516.66 100.000		
12.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	6.5840E 09		257.94 71.906	21.03 5.862	78.97 22.015	0.00 0.000	0.78 0.217	0. 0.	358.72 100.000		
12.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	2.3074E 06		255.27 70.632	22.36 6.186	77.63 21.479	0.02 0.005	6.14 1.699	0. 0.	361.41 100.000		
12.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	9.2533E 03		246.09 66.354	26.81 7.228	72.90 19.655	0.30 0.081	24.78 6.683	0. 0.	370.87 100.000		
12.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	1.5955E 02		227.12 57.905	35.10 8.949	62.22 15.863	2.68 0.684	65.11 16.599	0. 0.	392.23 100.000		
12.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	7.8753E 00		200.71 46.689	42.68 9.928	43.39 10.093	13.93 3.241	129.18 30.050	0. 0.	429.89 100.000		
12.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	1.0580E 00		176.70 36.835	41.78 8.710	18.48 3.853	39.73 8.283	203.00 42.319	0. 0.	479.77 100.000		
12.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	3.9787E-01		168.25 33.006	35.22 6.909	3.46 0.679	61.32 12.029	241.49 47.376	0. 0.	509.74 100.000		
12.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	2.6102E-01		170.83 33.125	29.65 5.750	0.48 0.093	69.87 13.549	244.88 47.484	0. 0.	515.71 100.000		
12.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	1.9833E-01		174.57 33.799	25.51 4.939	0.08 0.016	74.41 14.406	241.93 46.840	0. 0.	516.50 100.000		
12.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.6027E-01		177.61 34.379	22.40 4.337	0.02 0.003	77.58 15.016	239.02 46.265	0. 0.	516.63 100.000		

TABLE F-14A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₆H₁₄ (100 MOL C BASIS), STEAM/C RATIO, 4.0

ELEMENTAL COMPOSITION														
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)											
100.00	1033.33	400.00	0.											
CONDITIONS AND EQUILIBRIUM CONSTANTS														
P(ATM)	T(DEG F)	KR	KS	KC	RT	EQUILIBRIUM PRODUCT COMPOSITIONS								TOTAL
						H2O	CO2	CH4	CU	H2	N2			
						MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	
						MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	
1.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	9.0817E-09	356.56 77.494	21.72 4.721	78.28 17.013	0.00 0.000	3.55 0.772	0.	460.11 100.00		
1.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.9166E-06	345.16 73.195	27.38 5.807	72.55 15.385	0.07 0.014	26.40 5.599	0.	471.57 100.00		
1.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.0613E-04	312.24 61.725	43.16 8.532	55.40 10.952	1.43 0.284	93.62 18.507	0.	505.86 100.00		
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.1810E-02	263.48 46.563	61.92 10.943	25.40 4.489	12.68 2.240	202.37 35.764	0.	565.86 100.00		
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	3.0531E-01	240.94 39.438	61.93 10.137	2.87 0.469	35.20 5.762	269.99 44.194	0.	610.93 100.00		
1.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.4512E-01	247.57 40.166	52.59 8.532	0.15 0.025	47.26 7.668	268.79 43.610	0.	616.36 100.00		
1.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	8.9757E-00	255.39 41.417	44.62 7.236	0.01 0.002	55.37 8.979	261.25 42.366	0.	616.64 100.00		
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	6.2470E-00	261.58 42.419	38.42 6.230	0.00 0.000	61.58 9.986	255.08 41.364	0.	616.66 100.00		
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	4.6971E-00	266.41 43.202	33.59 5.447	0.00 0.000	66.41 10.769	250.26 40.582	0.	616.66 100.00		
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	3.7444E-00	270.13 43.806	29.87 4.843	0.00 0.000	70.13 11.373	246.53 39.978	0.	616.66 100.00		
2.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	9.0995E-09	357.07 77.693	21.46 4.670	78.54 17.088	0.00 0.000	2.52 0.549	0.	459.59 100.00		
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.0109E-06	348.79 74.540	25.58 5.467	74.37 15.894	0.04 0.010	19.13 4.189	0.	467.92 100.00		
2.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.1171E-04	323.49 65.472	37.80 7.650	61.29 12.404	0.91 0.185	70.60 14.288	0.	494.09 100.00		
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.0623E-02	281.07 51.656	55.20 10.144	36.37 6.666	8.53 1.568	163.05 29.965	0.	544.12 100.00		
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.8639E-01	247.87 41.313	60.47 10.078	8.34 1.330	31.20 5.199	252.11 42.020	0.	599.99 100.00		
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	7.3589E-00	248.07 40.306	52.53 8.535	0.60 0.097	46.87 7.615	267.40 43.447	0.	615.47 100.00		
2.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	4.4928E-00	255.43 41.428	44.62 7.237	0.05 0.008	55.33 8.974	261.14 42.353	0.	616.57 100.00		
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	3.1239E-00	261.59 42.421	38.42 6.230	0.01 0.001	61.58 9.986	255.06 41.363	0.	616.65 100.00		
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	2.3486E-00	266.41 43.202	33.59 5.447	0.00 0.000	66.41 10.769	250.25 40.582	0.	616.66 100.00		
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.8722E-00	270.13 43.806	29.87 4.843	0.00 0.000	70.13 11.373	246.53 39.978	0.	616.66 100.00		
4.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	9.2122E-09	357.44 77.835	21.28 4.634	78.72 17.142	0.00 0.000	1.79 0.390	0.	459.23 100.00		
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.0878E-06	351.46 75.543	24.26 5.214	75.71 16.274	0.03 0.006	13.78 2.963	0.	465.24 100.00		
4.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.1752E-04	332.33 68.534	33.54 6.916	65.87 13.584	0.59 0.121	52.59 10.844	0.	484.92 100.00		
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.0678E-02	297.34 56.648	48.56 9.251	45.89 8.743	5.55 1.058	127.54 24.300	0.	524.88 100.00		
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.3716E-01	260.45 44.837	57.44 9.889	17.89 3.080	24.66 4.246	220.43 37.948	0.	580.88 100.00		

CALIFORNIA RESEARCH
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RICHMOND, CALIFORNIA

RE 647668

TABLE F-14B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₆H₁₄ (100 MOL C BASIS), STEAM/C RATIO, 4.0

ELEMENTAL COMPOSITION															
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)												
100.00	1033.33	400.00	0.												
CONDITIONS AND EQUILIBRIUM CONSTANTS															
P(ATM)	T(DEG F)	KR	KS	KC	RT	H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	PRODUCT CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	TOTAL MOLS MOL PC			
4.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	3.8728E-00	249.88 43.813	52.32 8.546	2.20 0.363	45.47 7.427	262.38 42.854	0. 0.	612.26 100.000			
4.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	2.2562E-00	255.59 41.473	44.61 7.239	0.20 0.032	55.19 8.956	260.69 42.301	0. 0.	616.27 100.000			
4.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.5628E-00	261.61 42.426	38.42 6.230	0.02 0.004	61.56 9.983	255.01 41.356	0. 0.	616.62 100.000			
4.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	1.1744E-00	266.41 43.203	33.59 5.447	0.00 0.001	66.40 10.768	250.24 40.581	0. 0.	616.66 100.000			
4.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	9.3612E-01	270.13 43.806	29.87 4.843	0.00 0.000	70.13 11.373	246.53 39.978	0. 0.	616.66 100.000			
6.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	9.0463E-09	357.60 77.898	21.20 4.618	78.80 17.165	0.00 0.000	1.46 0.319	0. 0.	459.86 100.000			
6.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.1255E-06	352.67 76.003	23.65 5.098	76.32 16.448	0.02 0.005	11.35 2.447	0. 0.	464.62 100.000			
6.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.2082E-04	336.54 70.027	31.50 6.555	68.04 14.158	0.46 0.095	44.05 9.165	0. 0.	480.28 100.000			
6.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.1015E-02	305.79 59.358	44.96 8.728	50.75 9.851	4.29 0.832	109.37 21.231	0. 0.	515.16 100.000			
6.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.2392E-01	269.56 47.493	54.98 9.686	24.54 4.323	20.49 3.609	198.03 34.889	0. 0.	567.59 100.000			
6.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	2.7747E-00	252.39 41.521	52.02 8.557	4.40 0.724	43.58 7.169	255.47 42.028	0. 0.	607.86 100.000			
6.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	1.5149E-00	255.84 41.546	44.60 7.242	0.44 0.071	54.97 8.926	259.95 42.214	0. 0.	615.79 100.000			
6.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.0427E-00	261.64 42.435	38.42 6.231	0.05 0.009	61.53 9.980	254.92 41.346	0. 0.	616.56 100.000			
6.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	7.8304E-01	266.42 43.204	33.59 5.447	0.01 0.001	66.40 10.768	250.23 40.579	0. 0.	616.65 100.000			
6.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	6.2410E-01	270.14 43.806	29.87 4.843	0.00 0.000	70.13 11.373	246.53 39.977	0. 0.	616.66 100.000			
12.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	9.1098E-09	357.81 77.981	21.09 4.597	78.91 17.197	0.00 0.000	1.04 0.226	0. 0.	458.85 100.000			
12.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.1774E-06	354.28 76.617	22.85 4.942	77.13 16.681	0.02 0.004	8.12 1.757	0. 0.	462.40 100.000			
12.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.2607E-04	342.33 72.125	28.68 6.043	71.02 14.962	0.30 0.063	32.30 6.806	0. 0.	474.63 100.000			
12.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.1870E-02	318.21 63.488	39.52 7.886	57.73 11.518	2.75 0.548	83.00 16.560	0. 0.	501.21 100.000			
12.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.1395E-01	285.86 52.458	50.01 9.178	35.87 6.582	14.12 2.591	159.07 29.191	0. 0.	544.93 100.000			
12.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.7846E-00	260.79 43.948	50.84 8.567	11.63 1.960	37.53 6.325	232.61 39.200	0. 0.	593.41 100.000			
12.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	7.8538E-01	257.12 41.918	44.53 7.259	1.64 0.268	53.83 8.776	256.27 41.779	0. 0.	613.38 100.000			
12.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	5.2377E-01	261.80 42.484	38.41 6.234	0.22 0.035	61.37 9.959	254.43 41.288	0. 0.	616.23 100.000			
12.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.9182E-01	266.45 43.213	33.59 5.448	0.04 0.006	66.37 10.764	250.15 40.569	0. 0.	616.59 100.000			
12.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	3.1210E-01	270.14 43.808	29.87 4.843	0.01 0.001	70.13 11.372	246.51 39.975	0. 0.	616.65 100.000			

TABLE F-15A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C6H14 (100 MOL C BASIS), STEAM/C RATIO, 5.0

ELEMENTAL COMPOSITION																			
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)																
100.00	1233.33	500.00	0.																
CONDITIONS AND EQUILIBRIUM CONSTANTS																			
P(ATM)	T(DEG F)	KR	KS	KC	RT	H2O		CO2		CH4		CO		H2		N2		TOTAL	
						MOLS	PC	MOLS	PC	MOLS	PC	MOLS	PC	MOLS	PC	MOLS	PC	MOLS	PC
1.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.1679E-10	456.12	21.94	78.06	0.00	4.42	0.	560.54							
						81.371	3.914	13.926	0.000	0.789	0.	100.000							
1.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.6759E-06	442.18	28.88	71.05	0.07	32.38	0.	574.56							
						76.960	5.026	12.367	0.012	5.636	0.	100.000							
1.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.3606E-04	403.10	47.72	50.81	1.47	111.94	0.	615.04							
						65.541	7.758	8.262	0.239	18.200	0.	100.000							
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	3.1927E-02	349.45	69.21	18.65	12.14	229.91	0.	679.35							
						51.438	10.188	2.746	1.786	33.842	0.	100.000							
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	5.6204E-01	332.49	68.96	1.45	29.59	281.28	0.	713.77							
						46.582	9.661	0.203	4.146	39.408	0.	100.000							
1.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	2.6561E-01	340.31	59.77	0.08	40.15	276.21	0.	716.51							
						47.495	8.342	0.011	5.604	38.549	0.	100.000							
1.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	1.5877E-01	348.32	51.69	0.01	48.30	268.34	0.	716.65							
						48.603	7.213	0.001	6.740	37.443	0.	100.000							
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.0777E-01	354.82	45.18	0.00	54.81	261.85	0.	716.66							
						49.509	6.305	0.000	7.649	36.537	0.	100.000							
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	7.9600E-00	360.01	39.99	0.00	60.01	256.66	0.	716.66							
						50.234	5.581	0.000	8.373	35.813	0.	100.000							
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	6.2645E-00	364.09	35.91	0.00	64.09	252.57	0.	716.66							
						50.804	5.010	0.000	8.943	35.243	0.	100.000							
2.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.1767E-10	456.76	21.62	78.38	0.00	3.14	0.	559.90							
						81.579	3.861	13.999	0.000	0.561	0.	100.000							
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.8031E-06	446.58	26.69	73.27	0.04	23.56	0.	570.13							
						78.328	4.681	12.851	0.008	4.132	0.	100.000							
2.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.4161E-04	416.27	41.40	57.67	0.94	85.06	0.	601.33							
						69.225	6.884	9.590	0.156	14.145	0.	100.000							
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.8192E-02	367.83	61.84	29.67	8.49	189.50	0.	657.33							
						55.958	9.408	4.513	1.292	28.829	0.	100.000							
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	3.1626E-01	337.08	67.71	4.78	27.51	270.02	0.	707.10							
						47.671	9.575	0.676	3.891	38.187	0.	100.000							
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7406E-01	1.3376E-01	340.58	59.72	0.30	39.98	275.48	0.	716.06							
						47.563	8.340	0.042	5.583	38.472	0.	100.000							
2.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	7.9428E-00	348.34	51.69	0.03	48.29	268.28	0.	716.61							
						48.609	7.213	0.004	6.738	37.437	0.	100.000							
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	5.3890E-00	354.82	45.18	0.00	54.81	261.84	0.	716.66							
						49.510	6.305	0.000	7.648	36.536	0.	100.000							
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.9800E-00	360.01	39.99	0.00	60.01	256.66	0.	716.66							
						50.234	5.581	0.000	8.373	35.813	0.	100.000							
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	3.1322E-00	364.09	35.91	0.00	64.09	252.57	0.	716.66							
						50.804	5.010	0.000	8.943	35.243	0.	100.000							
4.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.1623E-10	457.22	21.39	78.61	0.00	2.23	0.	559.45							
						81.727	3.824	14.051	0.000	0.399	0.	100.000							
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.9097E-06	449.83	25.07	74.90	0.03	17.03	0.	566.86							
						79.355	4.422	13.213	0.005	3.004	0.	100.000							
4.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.4819E-04	426.75	36.32	63.07	0.60	63.76	0.	590.52							
						72.268	6.151	10.681	0.102	10.798	0.	100.000							
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.7156E-02	385.90	54.23	40.13	5.64	150.50	0.	636.40							
						60.638	8.522	6.306	0.886	23.649	0.	100.000							
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	2.0920E-01	347.44	64.71	12.15	23.14	244.92	0.	692.36							
						50.182	9.346	1.755	3.342	35.375	0.	100.000							

CALIFORNIA RESEARCH
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RICHMOND, CALIFORNIA

RE 647670

TABLE F-15B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₆H₁₄ (100 MOL C BASIS), STEAM/C RATIO, 5.0

ELEMENTAL COMPOSITION													
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)										
100.00	1233.33	500.00	0.										
CONDITIONS AND EQUILIBRIUM CONSTANTS													
P(ATM)	T(DEG F)	KR	KS	KC	RT	H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	TOTAL MOLS MOL PC	
4.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	6.8717E 00	341.63 47.823	59.52 8.332	1.15 0.161	39.33 5.536	272.74 38.179	0. 0.	714.37 100.000	
4.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	3.9804E 00	348.42 48.631	51.68 7.213	0.10 0.014	48.22 6.731	268.04 37.411	0. 0.	716.46 100.000	
4.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	2.6953E 00	354.83 49.513	45.18 6.305	0.01 0.002	54.80 7.647	261.81 36.533	0. 0.	716.64 100.000	
4.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	1.9901E 00	360.01 50.234	39.99 5.581	0.00 0.000	60.00 8.373	256.65 35.812	0. 0.	716.66 100.000	
4.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.5661E 00	364.09 50.804	35.91 5.010	0.00 0.000	64.09 8.943	252.57 35.243	0. 0.	716.66 100.000	
6.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	1.1691E 10	457.42 81.793	21.29 3.807	78.71 14.074	0.00 0.000	1.82 0.326	0. 0.	559.24 100.000	
6.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	3.9614E 06	451.32 79.828	24.33 4.303	75.65 13.380	0.02 0.004	14.05 2.485	0. 0.	565.37 100.000	
6.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.5216E 04	431.77 73.762	33.88 5.788	65.65 11.216	0.47 0.080	53.59 9.155	0. 0.	585.36 100.000	
6.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.7191E 02	395.56 63.240	50.03 7.999	45.59 7.289	4.38 0.700	129.93 20.772	0. 0.	625.49 100.000	
6.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.7918E 01	356.12 52.343	62.03 9.118	18.15 2.668	19.81 2.912	224.24 32.959	0. 0.	680.36 100.000	
6.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	4.7731E 00	343.20 48.214	59.22 8.319	2.42 0.340	38.37 5.390	268.63 37.738	0. 0.	711.83 100.000	
6.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	2.6636E 00	348.57 48.668	51.66 7.213	0.23 0.032	48.12 6.718	267.65 37.370	0. 0.	716.21 100.000	
6.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	1.7977E 00	354.85 49.518	45.18 6.305	0.03 0.004	54.79 7.646	261.76 36.528	0. 0.	716.61 100.000	
6.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	1.3268E 00	360.01 50.235	39.99 5.581	0.00 0.001	60.00 8.372	256.64 35.811	0. 0.	716.66 100.000	
6.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.0441E 00	364.09 50.804	35.91 5.010	0.00 0.000	64.09 8.943	252.57 35.242	0. 0.	716.66 100.000	
12.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	1.1725E 10	457.69 81.879	21.16 3.785	78.84 14.105	0.00 0.000	1.29 0.231	0. 0.	558.98 100.000	
12.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	4.0367E 06	453.30 80.562	23.34 4.143	76.64 13.604	0.02 0.003	10.97 1.788	0. 0.	563.38 100.000	
12.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.5876E 04	438.73 75.875	30.48 5.271	69.22 11.970	0.30 0.053	39.50 6.831	0. 0.	578.23 100.000	
12.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.7848E 02	409.99 67.267	43.60 7.153	53.59 8.792	2.82 0.463	99.50 16.326	0. 0.	609.49 100.000	
12.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.5451E 01	373.13 56.736	56.36 8.570	29.50 4.485	14.14 2.150	184.53 28.059	0. 0.	657.67 100.000	
12.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	2.8178E 00	349.38 49.770	57.97 8.258	7.34 1.046	34.69 4.942	252.60 35.985	0. 0.	721.98 100.000	
12.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	1.3581E 00	349.31 48.860	51.56 7.213	0.88 0.122	47.56 6.653	265.60 37.152	0. 0.	714.91 100.000	
12.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	9.0103E-01	354.94 49.542	45.17 6.305	0.11 0.016	54.71 7.637	261.50 36.500	0. 0.	716.44 100.000	
12.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	6.6369E-01	360.03 50.239	39.99 5.581	0.02 0.003	59.99 8.371	256.60 35.806	0. 0.	716.63 100.000	
12.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	5.2210E-01	364.10 50.805	35.91 5.010	0.00 0.001	64.09 8.943	252.56 35.241	0. 0.	716.66 100.000	

TABLE F-16

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₉H₂₀ (100 MOL C BASIS), STEAM/C RATIO, 1.3

ELEMENTAL COMPOSITION						EQUILIBRIUM PRODUCT COMPOSITIONS								
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)			H2O	CO2	CH4	CO	H2	N2			TOTAL
100.00	422.22	100.00	C.			MOLS	MOLS	MOLS	MOLS	MOLS	MOLS			MOLS
P(ATM)	T(°F)	KR	KS	KC	RT	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC			MOL PC
1.0000	1600.00	8.2135E-02	8.2439E-01	4.0065E-02	3.5436E-02	2.71	1.06	3.76	95.18	200.87	C.			373.58
CONDITIONS LEAD TO CARBON FORMATION.						0.892	0.348	1.247	31.352	66.168	C.			100.000
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	9.4380E-03	1.03	0.30	1.32	98.38	207.44	0.			308.46
						0.333	0.096	0.429	31.894	67.249	0.			100.000
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.1167E-03	0.44	0.10	0.54	99.36	209.59	0.			310.03
						0.142	0.032	0.174	32.049	67.633	0.			100.000
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.2216E-03	0.21	0.04	0.25	99.71	210.39	0.			310.61
						0.068	0.013	0.081	32.101	67.737	0.			100.000
2.0000	1600.00	8.2135E-02	8.2439E-01	4.0065E-02	3.5436E-02	5.06	1.98	7.03	90.99	191.99	0.			297.05
CONDITIONS LEAD TO CARBON FORMATION.						1.702	0.665	2.367	30.633	64.634	C.			100.000
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	9.4311E-03	2.00	0.56	2.58	96.84	203.95	0.			305.55
						0.654	0.189	0.843	31.653	66.661	0.			100.000
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.1152E-03	0.87	0.20	1.07	98.73	208.10	C.			308.97
						0.282	0.064	0.346	31.956	67.352	C.			100.000
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.2212E-03	0.42	0.08	0.50	99.42	209.69	0.			310.11
						0.136	0.025	0.161	32.060	67.617	0.			100.000
4.0000	1600.00	8.2135E-02	8.2439E-01	4.0065E-02	3.5420E-02	8.95	3.50	12.44	84.06	177.27	C.			286.22
CONDITIONS LEAD TO CARBON FORMATION.						3.126	1.222	4.348	29.368	61.936	C.			100.000
4.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	9.4177E-03	3.81	1.10	4.92	93.98	197.46	0.			301.27
						1.266	0.367	1.633	31.193	65.541	C.			100.000
4.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.1123E-03	1.71	0.39	2.09	97.52	205.21	0.			306.92
						0.557	0.126	0.682	31.774	66.862	C.			100.000
4.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.2206E-03	0.84	0.15	0.99	98.85	208.29	C.			309.13
						0.271	0.050	0.321	31.979	67.310	C.			100.000
6.0000	1600.00	8.2135E-02	8.2439E-01	4.0065E-02	3.5410E-02	12.06	4.72	16.78	78.50	165.49	0.			277.55
CONDITIONS LEAD TO CARBON FORMATION.						4.346	1.700	6.046	28.284	59.624	C.			100.000
6.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	9.4050E-03	5.47	1.59	7.05	91.36	191.54	C.			297.01
						1.840	0.534	2.374	30.761	64.431	C.			100.000
6.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.1094E-03	2.51	0.57	3.08	96.35	202.44	C.			304.95
						0.824	0.186	1.010	31.596	66.384	C.			100.000
6.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.2195E-03	1.24	0.23	1.47	98.30	206.92	0.			308.16
						0.403	0.074	0.478	31.898	67.146	0.			100.000
12.0000	1600.00	8.2135E-02	8.2439E-01	4.0065E-02	3.5386E-02	18.65	7.30	25.95	66.75	140.57	0.			259.22
CONDITIONS LEAD TO CARBON FORMATION.						7.193	2.816	10.009	25.752	54.229	0.			100.000
12.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	9.3695E-03	9.66	2.82	12.48	84.70	176.50	0.			286.16
						3.375	0.985	4.360	29.601	61.680	0.			100.000
12.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.1010E-03	4.74	1.08	5.82	93.10	194.71	0.			299.47
						1.583	0.360	1.943	31.089	65.625	C.			100.000
12.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.2179E-03	2.42	0.45	2.86	96.69	202.97	C.			305.38
						0.791	0.147	0.938	31.662	66.463	0.			100.000

CALIFORNIA RESEARCH
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RE 647672

TABLE F-17A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₉H₂₀ (100 MOL C BASIS), STEAM/C RATIO, 2.0

ELEMENTAL COMPOSITION												
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)									
100.00	622.22	200.00	0.									
CONDITIONS AND EQUILIBRIUM CONSTANTS												
P(ATM)	T(DEG F)	KR	KS	KC	RT	H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	TOTAL MOLS MOL PC
1.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	3.8980E-09	154.69 60.329	22.65 8.834	77.35 30.164	0.00 0.000	1.72 0.672	0.	256.42 100.000
CONDITIONS LEAD TO CARBON FORMATION.												
1.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	1.2881E-06	148.96 56.809	25.48 9.718	74.45 28.391	0.07 0.027	13.25 5.754	0.	262.22 100.000
1.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	4.6652E-03	131.22 46.645	33.68 11.972	64.90 23.069	1.43 0.507	50.10 17.808	0.	281.32 100.000
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	7.7316E-01	102.08 31.673	42.32 13.129	44.40 13.776	13.28 4.121	120.22 37.301	0.	322.31 100.000
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	5.7639E-00	77.42 20.214	36.62 9.562	14.05 3.667	49.33 12.880	205.60 53.678	0.	383.02 100.000
1.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	2.1723E-00	73.94 18.090	27.24 6.663	1.18 0.288	71.59 17.513	234.81 57.446	0.	408.75 100.000
1.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	1.4601E-00	78.37 19.071	21.72 5.286	0.09 0.022	78.19 19.027	232.56 56.594	0.	410.93 100.000
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.0924E-00	82.11 19.973	17.90 4.355	0.01 0.003	82.08 19.968	228.98 55.702	0.	411.09 100.000
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	8.6348E-01	84.87 20.645	15.13 3.680	0.00 0.000	84.87 20.644	226.23 55.030	0.	411.11 100.000
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	7.1264E-01	86.91 21.140	13.09 3.185	0.00 0.000	86.91 21.140	224.20 54.536	0.	411.11 100.000
2.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	3.9167E-09	154.94 60.486	22.53 8.794	77.47 30.243	0.00 0.000	1.22 0.477	0.	256.17 100.000
CONDITIONS LEAD TO CARBON FORMATION.												
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	1.3200E-06	150.82 57.934	24.56 9.435	75.39 28.958	0.05 0.019	9.51 3.654	0.	260.34 100.000
2.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	4.9822E-03	137.47 50.068	30.81 11.220	68.27 24.866	0.92 0.336	37.09 13.510	0.	274.56 100.000
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	8.2265E-01	113.38 37.020	39.05 12.750	52.43 17.118	8.53 2.784	92.88 30.328	0.	306.26 100.000
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	4.8273E-00	87.78 24.336	37.41 10.372	25.20 6.985	37.39 10.365	172.93 47.942	0.	360.72 100.000
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.2006E-00	76.29 18.929	27.74 6.882	4.03 1.000	68.23 16.929	226.75 56.260	0.	403.35 100.000
2.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	7.3645E-01	78.59 19.150	21.77 5.304	0.36 0.087	77.88 18.976	231.81 56.483	0.	410.40 100.000
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	5.4674E-01	82.13 19.982	17.91 4.357	0.04 0.010	82.05 19.962	228.89 55.688	0.	411.03 100.000
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	4.3181E-01	84.88 20.647	15.13 3.680	0.01 0.002	84.86 20.643	226.22 55.028	0.	411.10 100.000
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	3.5633E-01	86.91 21.140	13.09 3.185	0.00 0.000	86.91 21.139	224.20 54.535	0.	411.11 100.000
4.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	3.9033E-09	155.12 60.598	22.44 8.765	77.56 30.299	0.00 0.000	0.87 0.338	0.	255.99 100.000
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	1.3441E-06	152.17 58.760	23.90 9.228	76.07 29.373	0.03 0.013	6.80 2.626	0.	258.97 100.000
4.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	5.2569E-03	142.26 52.798	28.57 10.601	70.83 26.287	0.61 0.225	27.19 10.089	0.	269.45 100.000
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	6.8113E-01	123.05 41.922	35.75 12.179	58.80 20.031	5.46 1.859	70.47 24.009	0.	293.52 100.000
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	4.5532E-00	99.43 29.422	37.16 10.995	36.58 10.826	26.26 7.770	138.51 40.987	0.	337.94 100.000

CALIFORNIA RESEARCH
CORPORATION
RICHMOND, CALIFORNIA

TABLE F-17B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₉H₂₀ (100 MOL C BASIS), STEAM/C RATIO, 2.0

ELEMENTAL COMPOSITION														
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)											
100.00	622.22	200.00	0.											
CONDITIONS AND EQUILIBRIUM CONSTANTS														
P(ATM)	T(DEG F)	KR	KS	KC	RT	H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	COMPOSITIONS H2 MOLS MOL PC		N2 MOLS MOL PC	TOTAL MOLS MOL PC	
4.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	7.7144E-01	82.03 21.067	28.83 7.403	10.86 2.789	60.31 15.489	207.36 53.252	0.		389.39 100.000	
4.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	3.8057E-01	79.42 19.447	21.93 5.371	1.35 0.332	76.71 18.783	228.98 56.068	0.		408.40 100.000	
4.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	2.7446E-01	82.24 20.020	17.93 4.365	0.17 0.040	81.91 19.939	228.54 55.636	0.		410.78 100.000	
4.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	2.1604E-01	84.90 20.653	15.13 3.681	0.03 0.007	84.84 20.640	226.16 55.019	0.		411.06 100.000	
4.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.7819E-01	86.91 21.142	13.09 3.185	0.01 0.001	86.90 21.139	224.19 54.533	0.		411.10 100.000	
6.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	3.9451E 09	155.20 60.647	22.40 8.753	77.60 30.324	0.00 0.000	0.71 0.276	0.		255.91 100.000	
CONDITIONS LEAD TO CARBON FORMATION.														
6.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	1.3554E 06	152.78 59.134	23.60 9.133	76.38 29.562	0.03 0.011	5.58 2.160	0.		258.36 100.000	
6.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	5.3963E 03	144.50 54.105	27.51 10.300	72.01 26.963	0.48 0.178	22.58 8.453	0.		267.08 100.000	
6.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	9.1632E 01	127.89 44.492	33.95 11.811	61.84 21.513	4.21 1.466	59.55 20.717	0.		287.44 100.000	
6.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	4.5436E 00	106.13 32.568	36.49 11.199	42.62 13.079	20.89 6.409	119.74 36.745	0.		325.87 100.000	
6.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	6.4995E-01	87.17 23.091	29.64 7.850	16.80 4.451	53.56 14.188	190.34 50.420	0.		377.50 100.000	
6.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	2.6641E-01	80.64 19.888	22.18 5.470	2.82 0.695	75.00 18.498	224.83 55.450	0.		405.47 100.000	
6.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	1.8417E-01	82.41 20.082	17.96 4.377	0.37 0.090	81.67 19.902	227.96 55.550	0.		410.37 100.000	
6.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	1.4418E-01	84.92 20.664	15.14 3.683	0.06 0.015	84.80 20.634	226.06 55.005	0.		410.99 100.000	
6.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.1882E-01	86.92 21.144	13.09 3.185	0.01 0.003	86.89 21.137	224.16 54.530	0.		411.08 100.000	
12.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	3.9532E 09	155.31 60.712	22.35 8.736	77.65 30.356	0.00 0.000	0.50 0.196	0.		255.81 100.000	
CONDITIONS LEAD TO CARBON FORMATION.														
12.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	1.3701E 06	153.58 59.630	23.20 9.008	76.78 29.812	0.02 0.007	3.97 1.542	0.		257.55 100.000	
12.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	5.5982E 03	147.54 55.912	26.07 9.878	73.61 27.896	0.32 0.121	16.34 6.192	0.		263.89 100.000	
12.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	9.7456E 01	134.81 48.315	31.23 11.192	66.04 23.668	2.73 0.978	44.22 15.846	0.		279.03 100.000	
12.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	4.6607E 00	116.67 37.845	34.75 11.271	51.42 16.678	13.84 4.489	91.61 29.716	0.		308.28 100.000	
12.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	5.4888E-01	97.80 27.630	30.77 8.692	28.57 8.071	40.66 11.488	156.17 44.118	0.		353.97 100.000	
12.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	1.6088E-01	85.25 21.611	23.05 5.844	8.31 2.106	68.64 17.399	209.24 53.040	0.		394.49 100.000	
12.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	9.5180E-02	83.28 20.396	18.12 4.438	1.40 0.343	80.48 19.711	225.03 55.113	0.		408.31 100.000	
12.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	7.2504E-02	85.08 20.720	15.16 3.693	0.24 0.059	84.59 20.601	225.54 54.927	0.		410.62 100.000	
12.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	5.9484E-02	86.95 21.156	13.10 3.187	0.05 0.013	86.85 21.131	224.05 54.513	0.		411.00 100.000	

TABLE F-18A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₉H₂₀ (100 MOL C BASIS), STEAM/C RATIO, 3.0

ELEMENTAL COMPOSITION												
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)									
100.00	822.22	300.00	0.									
CONDITIONS AND EQUILIBRIUM CONSTANTS												
P(ATM)	T(DEG F)	KR	KS	KC	RT	EQUILIBRIUM PRODUCT COMPOSITIONS						
						H2O	CO2	CH4	CO	H2	N2	TOTAL
						MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	MOLS
						MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC
1.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	6.4015E-09	254.26 71.249	22.87 6.409	77.13 21.613	0.00 0.000	2.6 0.728	0.	356.86 100.000
1.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.0833E-06	245.75 67.249	27.09 7.414	72.84 19.932	0.07 0.019	19.68 5.386	0.	365.43 100.000
1.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	7.5859E-03	220.18 56.120	39.20 9.990	59.38 15.135	1.42 0.363	72.16 18.393	0.	392.35 100.000
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.3962E-02	179.83 40.473	53.56 12.053	33.39 7.515	13.06 2.938	164.50 37.021	0.	444.33 100.000
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.4720E-01	153.99 30.853	52.01 10.420	6.00 1.202	41.99 8.414	245.12 49.111	0.	499.11 100.000
1.0000	1400.00	6.3697E-01	1.2081E-03	2.7306E-01	6.7587E-00	157.55 30.868	42.80 8.385	0.35 0.069	56.85 11.138	252.85 49.539	0.	510.41 100.000
1.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	4.3608E-00	164.54 32.197	35.49 6.943	0.03 0.005	64.49 12.619	246.51 48.236	0.	511.06 100.000
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	3.1322E-00	169.99 33.259	30.01 5.872	0.00 0.001	69.98 13.692	241.11 47.175	0.	511.10 100.000
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	2.4273E-00	174.12 34.068	25.88 5.063	0.00 0.000	74.12 14.502	236.99 46.367	0.	511.11 100.000
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.9490E-00	177.25 34.679	22.75 4.452	0.00 0.000	77.25 15.113	233.86 45.756	0.	511.11 100.000
2.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	6.4217E-09	254.63 71.431	22.68 6.363	77.32 21.689	0.00 0.000	1.84 0.517	0.	356.48 100.000
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.1412E-06	248.48 68.515	25.73 7.096	74.22 20.464	0.05 0.013	14.19 3.912	0.	362.67 100.000
2.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	8.0380E-03	229.06 59.812	35.01 9.143	64.07 16.731	0.91 0.238	53.91 14.076	0.	382.96 100.000
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.4021E-02	195.00 45.919	48.23 11.357	43.23 10.179	8.55 2.012	129.66 30.532	0.	424.66 100.000
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.0211E-01	163.22 33.849	50.99 10.567	14.31 2.965	34.71 7.193	219.18 45.426	0.	482.50 100.000
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	3.4880E-00	158.53 31.179	42.81 8.419	1.34 0.263	55.86 10.986	249.91 49.152	0.	508.44 100.000
2.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	2.1858E-00	164.62 32.222	35.49 6.947	0.11 0.021	64.40 12.606	246.27 48.204	0.	510.89 100.000
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.5666E-00	170.00 33.262	30.01 5.873	0.01 0.003	69.97 13.691	241.09 47.171	0.	511.08 100.000
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	1.2037E-00	174.12 34.068	25.88 5.063	0.00 0.000	74.12 14.502	236.98 46.366	0.	511.11 100.000
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	9.7449E-01	177.25 34.679	22.75 4.452	0.00 0.000	77.25 15.113	233.86 45.756	0.	511.11 100.000
4.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	6.4735E-09	254.90 71.560	22.55 6.330	77.45 21.743	0.00 0.000	1.31 0.367	0.	356.21 100.000
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.1868E-06	250.48 69.451	24.74 6.861	75.22 20.858	0.03 0.009	10.18 2.822	0.	360.66 100.000
4.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	8.4626E-03	235.94 62.791	31.73 8.445	67.68 18.010	0.59 0.158	39.82 10.596	0.	375.76 100.000
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.4536E-02	208.38 51.046	43.06 10.548	51.44 12.601	5.50 1.347	99.84 24.458	0.	408.23 100.000
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	8.4646E-00	176.59 30.365	48.82 10.607	25.41 5.521	25.76 5.597	183.70 39.909	0.	460.28 100.000

TABLE F-18B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₉H₂₀ (100 MOL C BASIS), STEAM/C RATIO, 3.0

ELEMENTAL COMPOSITION												
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)									
100.00	822.22	300.00	0.									
CONDITIONS AND EQUILIBRIUM CONSTANTS												
P(ATM)	T(DEG F)	KR	KS	KC	RT	EQUILIBRIUM COMPOSITIONS			PRODUCT COMPOSITIONS			TOTAL
						H2O	CO2	CH4	CO	H2	N2	
						MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	MOLS
						MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC
4.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	1.9364E 00	161.70	42.81	4.51	52.68	240.39	0.	502.09
						32.205	8.526	0.898	10.492	47.878	0.	100.000
4.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	1.1035E 00	164.92	35.51	0.43	64.07	245.33	0.	510.25
						32.322	6.958	0.084	12.556	48.080	0.	100.000
4.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	7.8416E-01	170.03	30.02	0.05	69.93	240.97	0.	511.01
						33.274	5.874	0.010	13.685	47.156	0.	100.000
4.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	6.0197E-01	174.13	25.88	0.01	74.11	236.96	0.	511.09
						34.070	5.063	0.002	14.501	46.364	0.	100.000
4.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	4.8726E-01	177.25	22.75	0.00	77.24	233.86	0.	511.11
						34.679	4.452	0.000	15.113	45.755	0.	100.000
6.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	6.4769E 09	255.02	22.49	77.51	0.00	1.07	0.	356.09
						71.617	6.316	21.767	0.000	0.300	0.	100.000
6.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	2.2081E 06	251.38	24.29	75.68	0.03	8.37	0.	359.75
						69.877	6.753	21.037	0.007	2.326	0.	100.000
6.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	8.6900E 03	239.19	30.17	69.36	0.46	33.20	0.	372.39
						64.231	8.103	18.626	0.125	8.916	0.	100.000
6.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	1.4943E 02	215.18	40.29	55.47	4.24	84.98	0.	400.17
						53.773	10.068	13.862	1.060	21.237	0.	100.000
6.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	8.0422E 00	185.05	47.04	32.09	20.87	161.88	0.	446.93
						41.405	10.525	7.180	4.670	36.221	0.	100.000
6.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	1.4675E 00	165.48	42.76	8.23	49.01	229.17	0.	494.64
						33.454	8.644	1.665	9.908	46.329	0.	100.000
6.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	7.4717E-01	165.41	35.51	0.94	63.53	243.82	0.	509.23
						32.483	6.977	0.185	12.475	47.880	0.	100.000
6.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	5.2375E-01	170.09	30.02	0.12	69.86	240.78	0.	510.88
						33.295	5.877	0.023	13.675	47.131	0.	100.000
6.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	4.0144E-01	174.14	25.88	0.02	74.10	236.93	0.	511.17
						34.074	5.064	0.004	14.499	46.360	0.	100.000
6.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	3.2486E-01	177.25	22.75	0.00	77.24	233.85	0.	511.10
						34.680	4.452	0.001	15.113	45.754	0.	100.000
12.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	6.4740E 09	255.18	22.41	77.59	0.00	0.74	0.	355.93
						71.692	6.296	21.799	0.000	0.212	0.	100.000
12.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	2.2372E 06	252.58	23.70	76.28	0.02	5.97	0.	358.55
						70.445	6.610	21.275	0.005	1.665	0.	100.000
12.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	9.0341E 03	243.62	28.04	71.66	0.31	24.18	0.	367.82
						66.237	7.623	19.482	0.084	6.574	0.	100.000
12.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	1.5719E 02	225.03	36.12	61.15	2.73	63.78	0.	388.81
						57.876	9.290	15.727	0.702	16.405	0.	100.000
12.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	7.8225E 00	199.12	43.42	42.54	14.04	126.91	0.	426.03
						46.738	10.192	9.985	3.295	29.789	0.	100.000
12.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	1.0603E 00	175.69	42.29	17.98	39.74	199.47	0.	475.16
						36.975	8.899	3.783	8.363	41.980	0.	100.000
12.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	4.0215E-01	167.69	35.64	3.33	61.03	236.76	0.	504.45
						33.242	7.065	0.660	12.099	46.935	0.	100.000
12.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	2.6449E-01	170.41	30.05	0.46	69.50	239.78	0.	510.19
						33.401	5.889	0.090	13.622	46.998	0.	100.000
12.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	2.0105E-01	174.19	25.88	0.08	74.04	236.76	0.	510.95
						34.092	5.066	0.015	14.490	46.337	0.	100.000
12.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.6249E-01	177.26	22.75	0.02	77.23	233.81	0.	511.08
						34.684	4.452	0.003	15.111	45.749	0.	100.000

TABLE F-19A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₉H₂₀ (100 MOL C BASIS), STEAM/C RATIO, 4.0

ELEMENTAL COMPOSITION															
C (ATCMS)	H (ATCMS)	C (ATCMS)	N ₂ (MCLS)												
100.00	1022.22	400.00	C.												
				CONDITIONS AND EQUILIBRIUM CONSTANTS				EQUILIBRIUM PRODUCT COMPOSITIONS							
P (ATM)	T (DEG F)	KR	KS	KC	RT	H ₂ O MCLS MOL PC	CO ₂ MCLS MOL PC	CH ₄ MCLS MOL PC	CO MCLS MOL PC	H ₂ MCLS MOL PC	N ₂ MCLS MOL PC	TOTAL MOLS MOL PC			
1.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	8.8695E-09	353.83 77.375	23.09 5.049	76.91 16.819	0.00 0.000	3.46 0.757	0.	457.29 100.000			
1.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.8562E-06	342.68 73.144	28.63 6.110	71.31 15.220	0.07 0.015	25.82 5.511	0.	468.50 100.000			
1.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.0522E-04	310.26 61.767	44.15 8.789	54.40 10.831	1.45 0.289	92.03 18.325	0.	502.31 100.000			
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.1869E-02	262.22 46.654	62.55 11.139	24.77 4.411	12.67 2.257	199.35 35.499	0.	561.57 100.000			
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	3.1010E-01	240.39 39.694	62.36 10.296	2.75 0.454	34.90 5.762	265.22 43.794	0.	605.61 100.000			
1.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.4768E-01	247.12 40.458	53.02 8.681	0.15 0.024	46.83 7.667	263.69 43.171	0.	610.82 100.000			
1.0000	1600.00	8.2135E-02	8.2439E-01	4.0069E-02	9.1297E-00	254.95 41.720	45.07 7.375	0.01 0.002	54.92 8.988	256.14 41.916	0.	611.09 100.000			
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	6.3522E-00	261.14 42.733	38.86 6.359	0.00 0.000	61.14 10.005	249.96 40.903	0.	611.11 100.000			
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	4.7752E-00	265.98 43.524	34.02 5.567	0.00 0.000	65.96 10.797	245.13 40.112	0.	611.11 100.000			
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	3.8063E-00	269.72 44.136	30.28 4.955	0.00 0.000	69.72 11.409	241.39 39.500	0.	611.11 100.000			
2.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	8.8713E-09	354.33 77.570	22.84 4.999	77.16 16.893	0.00 0.000	2.46 0.538	0.	456.78 100.000			
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.9425E-06	346.23 74.471	26.86 5.777	73.09 15.722	0.05 0.010	18.69 4.020	0.	464.92 100.000			
2.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.1042E-04	321.35 65.491	38.86 7.919	60.21 12.271	0.93 0.189	69.33 14.129	0.	490.68 100.000			
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.0596E-02	279.54 51.755	55.95 10.358	35.49 6.571	8.56 1.586	160.59 29.731	0.	540.13 100.000			
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.8847E-01	247.10 41.527	60.94 10.242	8.04 1.351	31.02 5.213	247.93 41.667	0.	595.03 100.000			
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	7.4849E-00	247.60 40.593	52.97 8.684	0.57 0.094	46.46 7.616	262.36 43.013	0.	609.97 100.000			
2.0000	1600.00	8.2135E-02	8.2439E-01	4.0069E-02	4.5697E-00	254.98 41.731	45.06 7.375	0.05 0.008	54.89 8.983	256.03 41.903	0.	611.02 100.000			
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	3.1765E-00	261.15 42.734	38.86 6.359	0.01 0.001	61.14 10.004	249.95 40.902	0.	611.10 100.000			
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	2.3877E-00	265.98 43.525	34.02 5.567	0.00 0.000	65.96 10.797	245.13 40.112	0.	611.11 100.000			
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.9031E-00	269.72 44.137	30.28 4.955	0.00 0.000	69.72 11.409	241.39 39.500	0.	611.11 100.000			
4.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	8.9364E-09	354.68 77.709	22.66 4.964	77.34 16.945	0.00 0.000	1.74 0.382	0.	456.43 100.000			
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.0127E-06	348.84 75.459	25.56 5.529	74.41 16.095	0.03 0.007	13.45 2.910	0.	462.30 100.000			
4.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.1581E-04	330.07 68.530	34.67 7.197	64.73 13.440	0.60 0.125	51.57 10.708	0.	481.64 100.000			
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.0580E-02	295.58 56.721	49.41 9.482	44.99 8.634	5.59 1.073	125.54 24.090	0.	521.12 100.000			
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.3794E-01	259.37 45.002	58.01 10.064	17.38 3.015	24.62 4.271	216.99 37.648	0.	576.36 100.000			

TABLE F-19B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₅H₁₂ (100 MOL C BASIS), STEAM/C RATIO, 4.0

ELEMENTAL COMPOSITION						EQUILIBRIUM PRODUCT COMPOSITIONS							
C(ATOMS)	H(ATOMS)	O(ATOMS)	N ₂ (MOLS)			H ₂	CO	CH ₄	CO	H ₂	N ₂	TOTAL	
100.00	122.22	400.00	0.	CONDITIONS AND EQUILIBRIUM CONSTANTS		MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	MOLS
PI(ATM)	T(DEG F)	KK	KS	KC	KT	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC
4.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	2.9330E-00	249.34 41.084	52.77 8.695	2.11 0.347	45.12 7.435	257.56 42.438	0. 0.	606.89 100.000	
4.0000	1600.00	8.2135E-02	8.2439E-01	4.0065E-02	2.2945E-00	255.13 41.774	45.06 7.377	0.19 0.031	54.76 8.966	255.61 41.852	0. 0.	610.74 100.000	
4.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.5890E-00	261.17 42.740	38.86 6.359	0.02 0.004	61.12 10.032	249.90 40.896	0. 0.	611.06 100.000	
4.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	1.1935E-00	265.99 43.526	34.02 5.567	0.00 0.001	65.98 10.796	245.12 40.111	0. 0.	611.10 100.000	
4.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	9.5159E-01	269.72 44.137	30.28 4.955	0.00 0.000	69.72 11.409	241.39 39.500	0. 0.	611.11 100.000	
6.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	8.7684E-09	354.84 77.771	22.58 4.948	77.42 16.968	0.00 0.000	1.42 0.312	0. 0.	456.27 100.000	
6.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.0461E-06	350.03 75.911	24.97 5.416	75.00 16.266	0.03 0.005	11.07 2.432	0. 0.	461.11 100.000	
6.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.1886E-04	334.21 70.010	32.66 6.842	66.87 14.008	0.47 0.098	43.17 9.042	0. 0.	477.37 100.000	
6.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.0876E-02	303.92 59.415	45.88 8.969	49.80 9.735	4.33 0.846	107.60 21.035	0. 0.	511.52 100.000	
6.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.2426E-01	268.31 47.632	55.60 9.870	23.91 4.244	20.57 3.638	154.99 34.616	0. 0.	563.30 100.000	
6.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	2.8123E-00	251.75 41.773	52.48 8.708	4.23 0.701	43.29 7.184	250.91 41.634	0. 0.	602.66 100.000	
6.0000	1600.00	8.2135E-02	8.2439E-01	4.0065E-02	1.5403E-00	255.37 41.845	45.04 7.381	0.42 0.068	54.54 8.937	254.91 41.769	0. 0.	610.28 100.000	
6.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.0602E-00	261.19 42.748	38.86 6.359	0.05 0.008	61.09 9.998	249.81 40.885	0. 0.	611.01 100.000	
6.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	7.9606E-01	265.99 43.527	34.02 5.567	0.01 0.001	65.97 10.796	245.10 40.109	0. 0.	611.09 100.000	
6.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	6.3441E-01	269.72 44.137	30.28 4.955	0.00 0.000	69.72 11.409	241.38 39.499	0. 0.	611.11 100.000	
12.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	8.9462E-09	355.05 77.852	22.47 4.928	77.53 16.999	0.00 0.000	1.01 0.221	0. 0.	456.06 100.000	
12.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.0910E-06	351.60 76.515	24.19 5.264	75.79 16.494	0.02 0.004	7.92 1.723	0. 0.	459.52 100.000	
12.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.2366E-04	339.90 72.087	29.89 6.340	69.80 14.803	0.31 0.065	31.61 6.705	0. 0.	471.52 100.000	
12.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.1656E-02	316.17 63.522	40.52 8.142	56.69 11.350	2.79 0.560	81.56 16.387	0. 0.	497.73 100.000	
12.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.1375E-01	284.33 52.562	50.74 9.380	35.08 6.484	14.18 2.621	156.62 28.953	0. 0.	540.95 100.000	
12.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.7995E-00	259.89 44.152	51.35 8.724	11.24 1.910	37.41 6.355	228.74 38.860	0. 0.	588.63 100.000	
12.0000	1600.00	8.2135E-02	8.2439E-01	4.0065E-02	7.9759E-01	256.59 42.204	44.98 7.398	1.57 0.258	53.45 8.792	251.38 41.347	0. 0.	607.97 100.000	
12.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	5.3247E-01	261.35 42.795	38.86 6.362	0.21 0.034	60.94 9.979	249.35 40.830	0. 0.	610.70 100.000	
12.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	3.9833E-01	266.02 43.535	34.02 5.567	0.04 0.006	65.95 10.792	245.02 40.099	0. 0.	611.04 100.000	
12.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	3.1726E-01	269.73 44.139	30.28 4.955	0.01 0.001	69.71 11.408	241.36 39.497	0. 0.	611.09 100.000	

TABLE F-20A

PROJECT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₉H₂₀ (100 MOL C BASIS), STEAM/C RATIO, 5.0

ELEMENTAL COMPOSITION														
C (ATCMS)	H (ATCMS)	C (ATCMS)	N ₂ (MCLS)											
100.00	1222.22	500.00	C.											
CONDITIONS AND EQUILIBRIUM CONSTANTS					EQUILIBRIUM PRODUCT COMPOSITIONS									
PIATP	T (DEG F)	KR	KS	KC	RT	H ₂ O MCLS MOL PC	CO ₂ MCLS MOL PC	CH ₄ MCLS MOL PC	CO MCLS MOL PC	H ₂ MCLS MOL PC	N ₂ MCLS MOL PC	TOTAL MOLS MOL PC		
1.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.1385E-10	453.40 81.296	23.30 4.178	76.70 13.752	0.00 0.000	4.31 0.773	0. C.	557.71 100.000		
1.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.6117E-06	439.72 76.948	30.10 5.268	69.83 12.219	0.07 0.012	31.73 5.553	0. C.	571.46 100.000		
1.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.3537E-04	401.17 65.612	48.67 7.961	49.84 8.152	1.48 0.243	110.26 18.033	0. C.	611.42 100.000		
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	3.2169E-02	348.31 51.609	69.80 10.342	18.10 2.687	12.10 1.793	226.59 33.574	0. C.	674.90 100.000		
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	5.7321E-01	332.03 46.874	69.35 9.790	1.38 0.195	29.27 4.133	276.32 39.009	0. C.	708.35 100.000		
1.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	2.7102E-01	339.88 47.806	60.19 8.466	0.07 0.010	39.74 5.589	271.08 38.129	0. C.	710.97 100.000		
1.0000	1600.00	8.2135E-02	8.2439E-01	4.0065E-02	1.6188E-01	347.87 48.920	52.14 7.332	0.01 0.001	47.86 6.730	263.23 37.017	0. C.	711.10 100.000		
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.0983E-01	354.36 49.832	45.64 6.418	0.00 0.000	54.36 7.644	256.75 36.105	0. C.	711.11 100.000		
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	8.1095E-00	359.55 50.562	40.45 5.688	0.00 0.000	59.55 8.375	251.56 35.375	0. C.	711.11 100.000		
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	6.3807E-00	363.65 51.138	36.35 5.112	0.00 0.000	63.65 8.951	247.46 34.799	0. C.	711.11 100.000		
2.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.1338E-10	454.02 81.499	22.99 4.126	77.01 13.824	0.00 0.000	3.06 0.550	0. C.	557.09 100.000		
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.7276E-06	444.05 78.301	27.95 4.929	72.00 12.696	0.05 0.008	23.06 4.066	0. C.	567.11 100.000		
2.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.4045E-04	414.18 69.276	42.43 7.097	56.62 9.470	0.95 0.159	83.69 13.998	0. C.	597.88 100.000		
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.8265E-02	366.39 56.089	62.56 9.576	28.94 4.431	8.50 1.301	186.84 28.602	0. C.	653.22 100.000		
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	3.2145E-01	336.44 47.930	68.14 9.707	4.58 0.653	27.28 3.886	265.50 37.824	0. C.	701.94 100.000		
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.3644E-01	340.14 47.871	60.14 8.464	0.29 0.040	39.57 5.569	270.39 38.055	0. C.	710.54 100.000		
2.0000	1600.00	8.2135E-02	8.2439E-01	4.0065E-02	8.0986E-00	347.89 48.925	52.14 7.332	0.02 0.003	47.84 6.728	263.17 37.011	0. C.	711.06 100.000		
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	5.4921E-00	354.36 49.833	45.64 6.418	0.00 0.000	54.36 7.644	256.74 36.105	0. C.	711.10 100.000		
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	4.0548E-00	359.55 50.563	40.45 5.688	0.00 0.000	59.55 8.375	251.55 35.375	0. C.	711.11 100.000		
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	3.1904E-00	363.65 51.138	36.35 5.112	0.00 0.000	63.65 8.951	247.46 34.799	0. C.	711.11 100.000		
4.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.1268E-10	454.47 81.645	22.77 4.090	77.23 13.875	0.00 0.000	2.17 0.390	0. C.	556.64 100.000		
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.8241E-06	447.25 79.314	26.36 4.675	73.61 13.053	0.03 0.006	16.60 2.953	0. C.	563.90 100.000		
4.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.4652E-04	424.53 72.298	37.43 6.374	61.96 10.552	0.61 0.104	62.67 10.872	0. C.	587.19 100.000		
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.7125E-02	384.21 60.739	55.06 8.704	39.27 6.209	5.67 0.896	148.33 23.452	0. C.	632.56 100.000		
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	2.1145E-01	346.50 50.389	65.24 9.487	11.73 1.706	23.03 3.349	241.14 35.068	0. C.	687.64 100.000		

CALIFORNIA RESEARCH
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TABLE F-20B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₉H₂₀ (100 MOL C BASIS), STEAM/C RATIO, 5.0

ELEMENTAL COMPOSITION						N2(MOLS) %									
C(ATOMS)	H(ATOMS)	O(ATOMS)													
100.00	1222.22	500.00													
CONDITIONS AND EQUILIBRIUM CONSTANTS															
P(ATM)	T(°F)	KR	KS	KC	KT	H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	TOTAL MOLS MOL PC			
4.0000	1400.00	6.3697E-01	1.2381E-00	2.7306E-01	7.0032E-00	341.14 48.122	59.95 8.457	1.10 0.155	38.95 5.454	267.78 37.772	0. 0.	708.92 100.000			
4.0000	1600.00	8.2135E-02	8.2439E-01	4.0065E-02	4.0582E-00	347.97 48.947	52.12 7.332	0.10 0.014	47.78 6.721	262.95 36.987	0. 0.	710.92 100.000			
4.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	2.7468E-00	354.37 49.835	45.64 6.418	0.01 0.002	54.35 7.643	256.71 36.102	0. 0.	711.09 100.000			
4.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	2.0275E-00	359.56 50.563	40.45 5.688	0.00 0.000	59.55 8.375	251.55 35.374	0. 0.	711.11 100.000			
4.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.5952E-00	363.65 51.138	36.35 5.112	0.00 0.000	63.65 8.951	247.46 34.799	0. 0.	711.11 100.000			
6.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.1313E-10	454.67 81.709	22.67 4.073	77.33 13.898	0.00 0.000	1.78 0.319	0. 0.	556.44 100.000			
6.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.8704E-00	448.70 79.779	25.64 4.558	74.34 13.218	0.02 0.004	13.73 2.441	0. 0.	562.43 100.000			
6.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.5015E-04	429.48 73.780	35.02 6.016	64.50 11.081	0.48 0.082	52.63 9.041	0. 0.	582.11 100.000			
6.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.7105E-02	353.75 63.327	50.92 8.189	44.67 7.184	4.41 0.710	128.02 20.590	0. 0.	621.77 100.000			
6.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.8051E-01	354.98 52.520	62.62 9.265	17.61 2.605	19.77 2.925	220.92 32.685	0. 0.	675.90 100.000			
6.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	4.8581E-00	342.64 48.499	59.66 8.445	2.31 0.327	38.03 5.383	263.85 37.346	0. 0.	706.49 100.000			
6.0000	1600.00	8.2135E-02	8.2439E-01	4.0065E-02	2.7153E-00	348.11 48.982	52.11 7.332	0.22 0.030	47.68 6.709	262.57 36.947	0. 0.	710.68 100.000			
6.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.8320E-00	354.39 49.840	45.64 6.418	0.03 0.004	54.33 7.641	256.67 36.097	0. 0.	711.06 100.000			
6.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	1.3518E-00	359.56 50.564	40.45 5.688	0.00 0.001	59.55 8.374	251.54 35.374	0. 0.	711.10 100.000			
6.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.0635E-00	363.65 51.139	36.35 5.112	0.00 0.000	63.65 8.951	247.46 34.799	0. 0.	711.11 100.000			
12.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.1502E-10	454.93 81.794	22.54 4.052	77.46 13.928	0.00 0.000	1.26 0.226	0. 0.	556.18 100.000			
12.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.9363E-00	450.65 80.403	24.67 4.401	75.31 13.437	0.02 0.003	9.84 1.755	0. 0.	560.48 100.000			
12.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.5626E-04	436.34 75.875	31.67 5.508	68.01 11.827	0.31 0.054	38.74 6.736	0. 0.	575.08 100.000			
12.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.7669E-02	408.00 67.331	44.57 7.356	52.57 8.676	2.85 0.471	97.96 16.166	0. 0.	605.96 100.000			
12.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.5490E-01	371.70 56.871	57.07 8.732	28.76 4.401	14.17 2.167	181.89 27.829	0. 0.	653.58 100.000			
12.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	2.8558E-00	348.59 50.014	58.46 8.388	7.06 1.012	34.48 4.947	248.41 35.639	0. 0.	697.00 100.000			
12.0000	1600.00	8.2135E-02	8.2439E-01	4.0065E-02	1.3835E-00	348.81 49.167	52.02 7.332	0.83 0.117	47.15 6.646	260.63 36.737	0. 0.	709.44 100.000			
12.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	9.1816E-01	354.48 49.864	45.63 6.419	0.11 0.015	54.26 7.633	256.42 36.070	0. 0.	710.89 100.000			
12.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	6.7615E-01	359.57 50.568	40.45 5.688	0.02 0.003	59.54 8.373	251.50 35.369	0. 0.	711.07 100.000			
12.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	5.3175E-01	363.65 51.139	36.35 5.112	0.00 0.001	63.64 8.950	247.45 34.798	0. 0.	711.10 100.000			

TABLE F-21

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₂H₆N₂ (100 MOL C BASIS), STEAM/C RATIO, 1.0

ELEMENTAL COMPOSITION
 C(ATOMS) H(ATOMS) O(ATOMS) N₂(MOLS)
 100.00 400.00 100.00 0.

CONDITIONS AND EQUILIBRIUM CONSTANTS						EQUILIBRIUM PRODUCT COMPOSITIONS							TOTAL
PIATM	T(DEG F)	KR	KS	KC	RT	H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	MOLS MOL PC	
1.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	3.4180E-02	2.57 0.877	1.06 0.362	3.63 1.239	95.31 32.558	190.18 64.964	0. 0.	292.74 100.00	
CONDITIONS LEAD TO CARBON FORMATION.													
1.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	9.1257E-03	0.98 0.328	0.30 0.100	1.27 0.428	98.43 33.091	196.48 66.054	0. 0.	297.45 100.00	
1.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	3.0177E-03	0.42 0.140	0.10 0.033	0.52 0.174	99.38 33.242	198.54 66.411	0. 0.	298.96 100.00	
1.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.1838E-03	0.20 0.067	0.04 0.013	0.24 0.081	99.72 33.293	199.32 66.545	0. 0.	299.52 100.00	
2.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	3.4132E-02	4.79 1.673	1.98 0.693	6.78 2.365	91.24 31.852	181.66 63.417	0. 0.	286.45 100.00	
2.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	9.1150E-03	1.90 0.645	0.58 0.197	2.48 0.841	96.94 32.856	193.13 65.461	0. 0.	295.04 100.00	
2.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	3.0157E-03	0.83 0.278	0.20 0.066	1.03 0.345	98.78 33.152	197.12 66.158	0. 0.	297.95 100.00	
2.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.1834E-03	0.40 0.135	0.08 0.026	0.48 0.161	99.44 33.254	198.64 66.425	0. 0.	299.04 100.00	
4.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	3.4044E-02	8.47 3.069	3.52 1.276	11.99 4.345	84.49 30.609	167.54 60.701	0. 0.	276.01 100.00	
4.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	9.0945E-03	3.62 1.247	1.11 0.382	4.73 1.629	94.16 32.408	186.91 64.334	0. 0.	290.54 100.00	
4.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	3.0118E-03	1.62 0.549	0.39 0.131	2.01 0.680	97.60 32.976	194.35 65.664	0. 0.	295.97 100.00	
4.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.1825E-03	0.80 0.267	0.16 0.052	0.95 0.319	98.89 33.175	197.30 66.187	0. 0.	298.13 100.00	
6.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	3.3966E-02	11.41 4.263	4.76 1.778	16.17 6.042	79.07 29.541	156.25 58.376	0. 0.	267.66 100.00	
6.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	9.0750E-03	5.19 1.812	1.60 0.557	6.78 2.369	91.62 31.987	181.24 63.276	0. 0.	286.43 100.00	
6.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	3.0080E-03	2.39 0.812	0.57 0.194	2.96 1.006	96.47 32.804	191.69 65.184	0. 0.	294.08 100.00	
6.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.1817E-03	1.18 0.398	0.23 0.078	1.41 0.476	98.36 33.097	195.99 65.951	0. 0.	297.17 100.00	
12.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	3.3773E-02	17.60 7.039	7.41 2.963	25.00 10.002	67.59 27.037	132.4 52.960	0. 0.	249.99 100.00	
12.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	9.0211E-03	9.16 3.319	2.84 1.030	12.00 4.349	85.15 30.853	166.83 60.448	0. 0.	275.99 100.00	
12.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	2.9970E-03	4.51 1.561	1.08 0.376	5.59 1.936	93.32 32.312	184.31 63.815	0. 0.	288.82 100.00	
12.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.1792E-03	2.30 0.781	0.45 0.153	2.75 0.934	96.80 32.869	192.20 65.263	0. 0.	294.50 100.00	

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RE 647681

TABLE F-22A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - CNH₂N (100 MOL C BASIS), STEAM/C RATIO, 2.0

ELEMENTAL COMPOSITION													
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)										
100.00	600.00	200.00	0.										
CONDITIONS AND EQUILIBRIUM CONSTANTS							EQUILIBRIUM PRODUCT COMPOSITIONS						
P(ATM)	T(DEG F)	KR	KS	KC	RT		H2O	CO2	CH4	CO	H2	N2	TOTAL
							MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	MOLS
							MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC
1.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	3.6152E-09		149.19	25.40	74.60	0.00	1.61	0.	250.81
CONDITIONS LEAD TO CARBON FORMATION.							59.486	10.128	29.743	0.001	0.643	0.	100.000
1.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	1.2062E-06		143.81	28.06	71.87	0.08	12.46	0.	256.27
							56.117	10.948	28.044	0.030	4.861	0.	100.000
1.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	4.4545E-03		126.97	35.77	62.74	1.48	47.55	0.	274.52
							46.252	13.031	22.856	0.541	17.320	0.	100.000
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	7.5300E-01		99.20	43.65	42.85	13.50	115.10	0.	314.30
							31.562	13.889	13.634	4.295	36.621	0.	100.000
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	5.7448E-00		75.94	37.38	13.33	49.29	197.40	0.	373.35
							20.341	10.013	3.570	13.202	52.874	0.	100.000
1.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	2.2052E-00		73.16	27.93	1.09	70.98	224.65	0.	397.82
							18.391	7.020	0.274	17.843	56.472	0.	100.000
1.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	1.4872E-00		77.72	22.37	0.08	77.55	222.12	0.	399.83
							19.437	5.594	0.021	19.395	55.553	0.	100.000
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.1140E-00		81.51	18.50	0.01	81.49	218.47	0.	399.98
							20.379	4.624	0.002	20.374	54.620	0.	100.000
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	8.8132E-01		84.33	15.67	0.00	84.33	215.66	0.	400.00
							21.083	3.917	0.000	21.083	53.916	0.	100.000
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	7.2785E-01		86.41	13.59	0.00	86.41	213.59	0.	400.00
							21.603	3.397	0.000	21.603	53.397	0.	100.000
2.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	3.6119E-09		149.43	25.28	74.71	0.00	1.14	0.	250.57
CONDITIONS LEAD TO CARBON FORMATION.							59.635	10.091	29.817	0.000	0.456	0.	100.000
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	1.2325E-06		145.56	27.19	72.75	0.05	8.93	0.	254.49
							57.198	10.685	28.588	0.021	3.508	0.	100.000
2.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	4.7312E-03		132.93	33.05	65.98	0.97	35.11	0.	268.04
							49.593	12.331	24.616	0.361	13.099	0.	100.000
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	7.9625E-01		110.01	40.63	50.64	8.73	88.70	0.	298.71
							36.829	13.601	16.953	2.922	29.694	0.	100.000
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	4.7677E-00		85.80	38.30	24.10	37.59	166.00	0.	351.80
							24.388	10.888	6.851	10.686	47.186	0.	100.000
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.2128E-00		75.33	28.42	3.76	67.82	217.15	0.	392.48
							19.194	7.242	0.957	17.279	55.327	0.	100.000
2.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	7.4972E-01		77.92	22.41	0.33	77.26	221.43	0.	399.34
							19.511	5.612	0.082	19.347	55.448	0.	100.000
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	5.5753E-01		81.54	18.50	0.04	81.46	218.39	0.	399.92
							20.388	4.626	0.010	20.369	54.607	0.	100.000
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	4.4072E-01		84.34	15.67	0.01	84.32	215.65	0.	399.99
							21.085	3.917	0.002	21.082	53.914	0.	100.000
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	3.6393E-01		86.41	13.59	0.00	86.41	213.58	0.	400.00
							21.604	3.397	0.000	21.603	53.396	0.	100.000
4.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	3.6224E-09		149.60	25.20	74.80	0.00	0.81	0.	250.40
CONDITIONS LEAD TO CARBON FORMATION.							59.742	10.064	29.871	0.000	0.323	0.	100.000
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	1.2524E-06		146.83	26.57	73.40	0.04	6.38	0.	253.21
							57.989	10.492	28.987	0.014	2.518	0.	100.000
4.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	4.9668E-03		137.49	30.94	68.42	0.64	25.67	0.	263.15
							52.246	11.756	26.001	0.243	9.754	0.	100.000
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	8.4763E-01		119.26	37.55	56.81	5.63	67.11	0.	286.37
							41.645	13.114	19.839	1.967	23.435	0.	100.000
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	4.4614E-00		96.91	38.25	35.16	26.58	132.76	0.	329.67
							29.396	11.603	10.666	8.064	40.271	0.	100.000

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RE 647682

TABLE F-22B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₂H₆N₂ (100 MOL C BASIS), STEAM/C RATIO, 2.0

ELEMENTAL COMPOSITION				N ₂ (MOLS)									
C (ATOMS)	H (ATOMS)	O (ATOMS)											
100.00	600.00	200.00			0.								
CONDITIONS AND EQUILIBRIUM CONSTANTS							EQUILIBRIUM PRODUCT COMPOSITIONS						
P (ATM)	T (DEG F)	K _R	K _S	K _C	R _T		H ₂ O	CO ₂	CH ₄	CO	H ₂	N ₂	TOTAL
							MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	MOLS
							MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC
4.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	7.7239E-01		80.70	29.53	10.23	60.23	198.84	0.	379.54
							21.262	7.782	2.696	15.870	52.390	0.	100.000
4.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	3.8667E-01		78.67	22.58	1.25	76.17	218.82	0.	397.50
							19.792	5.680	0.315	19.163	55.050	0.	100.000
4.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	2.7980E-01		81.63	18.52	0.15	81.33	218.06	0.	399.70
							20.423	4.634	0.038	20.347	54.557	0.	100.000
4.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	2.2049E-01		84.35	15.67	0.03	84.30	215.60	0.	399.95
							21.091	3.919	0.006	21.078	53.906	0.	100.000
4.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.8199E-01		86.42	13.59	0.01	86.41	213.57	0.	399.99
							21.605	3.397	0.001	21.602	53.394	0.	100.000
6.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	3.6291E 09		149.67	25.16	74.83	0.00	0.66	0.	250.33
CONDITIONS LEAD TO CARBON FORMATION.							59.789	10.053	29.894	0.000	0.264	0.	100.000
6.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	1.2614E 06		147.40	26.28	73.69	0.03	5.23	0.	252.63
							58.347	10.405	29.167	0.012	2.070	0.	100.000
6.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	5.0849E 03		139.61	29.94	69.55	0.51	21.29	0.	260.90
							53.511	11.477	26.659	0.194	8.159	0.	100.000
6.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	8.7835E 01		123.88	35.88	59.75	4.37	56.62	0.	280.49
							44.164	12.791	21.303	1.558	20.184	0.	100.000
6.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	4.4329E 00		103.30	37.73	41.03	21.24	114.63	0.	317.93
							32.492	11.867	12.906	6.680	36.055	0.	100.000
6.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	6.4693E-01		85.55	30.39	15.93	53.68	182.59	0.	368.14
							23.237	8.254	4.328	14.582	49.599	0.	100.000
6.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	2.6998E-01		79.79	22.82	2.61	74.57	214.98	0.	394.78
							20.212	5.780	0.661	18.889	54.457	0.	100.000
6.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	1.8767E-01		81.79	18.55	0.34	81.11	217.53	0.	399.32
							20.482	4.646	0.085	20.312	54.476	0.	100.000
6.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	1.4714E-01		84.38	15.68	0.06	84.27	215.51	0.	399.89
							21.101	3.920	0.014	21.073	53.892	0.	100.000
6.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.2135E-01		86.42	13.59	0.01	86.40	213.55	0.	399.98
							21.607	3.397	0.003	21.601	53.391	0.	100.000
12.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	3.5992E 09		149.77	25.12	74.88	0.00	0.47	0.	250.23
CONDITIONS LEAD TO CARBON FORMATION.							59.851	10.037	29.925	0.000	0.187	0.	100.000
12.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	1.2733E 06		148.15	25.91	74.07	0.02	3.72	0.	251.87
							58.820	10.289	29.406	0.008	1.477	0.	100.000
12.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	5.2540E 03		142.48	28.59	71.07	0.34	15.38	0.	257.86
							55.256	11.087	27.562	0.133	5.963	0.	100.000
12.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	9.2868E 01		130.47	33.34	63.81	2.85	41.92	0.	272.39
							47.898	12.239	23.425	1.048	15.389	0.	100.000
12.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	4.5159E 00		113.35	36.23	49.59	14.18	87.48	0.	300.83
							37.680	12.044	16.483	4.715	29.078	0.	100.000
12.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	5.4124E-01		95.64	31.66	27.30	41.03	149.75	0.	345.39
							27.691	9.167	7.905	11.880	43.357	0.	100.000
12.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	1.6173E-01		84.07	23.70	7.78	68.52	200.37	0.	384.45
							21.869	6.165	2.023	17.823	52.119	0.	100.000
12.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	9.6796E-02		82.58	18.71	1.29	80.00	214.84	0.	397.42
							20.779	4.707	0.324	20.131	54.059	0.	100.000
12.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	7.3964E-02		84.52	15.70	0.22	84.07	215.03	0.	399.55
							21.154	3.930	0.056	21.042	53.818	0.	100.000
12.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	6.0746E-02		86.45	13.59	0.05	86.36	213.45	0.	399.90
							21.619	3.399	0.012	21.595	53.375	0.	100.000

TABLE F-23A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₂H₆N₂ (100 MOL C BASIS), STEAM/C RATIO, 3.0

ELEMENTAL COMPOSITION														
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)											
100.00	800.00	300.00	0.											
CONDITIONS AND EQUILIBRIUM CONSTANTS														
P(ATM)	T(DEG F)	KR	KS	KC	RT	H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	TOTAL MOLS MOL PC		
1.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	5.9297E-09	248.77 70.829	25.61 7.293	74.39 21.179	0.00 0.000	2.46 0.700	0.	351.23 100.000		
1.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	1.9861E-06	240.67 66.966	29.63 8.243	70.30 19.561	0.07 0.020	18.72 5.210	0.	359.40 100.000		
1.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	7.3882E-03	216.07 56.062	41.23 10.699	57.30 14.867	1.47 0.381	69.34 17.991	0.	385.40 100.000		
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.3877E-02	177.08 40.609	54.89 12.589	31.97 7.332	13.13 3.012	158.98 36.458	0.	436.05 100.000		
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.5006E-01	152.67 31.231	52.91 10.823	5.58 1.141	41.52 8.493	236.17 48.313	0.	488.84 100.000		
1.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	6.9525E-00	156.65 31.370	43.67 8.746	0.32 0.064	56.01 11.216	242.71 48.604	0.	499.36 100.000		
1.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	4.4872E-03	163.68 32.740	36.34 7.269	0.02 0.005	63.63 12.728	236.27 47.258	0.	499.95 100.000		
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	3.2230E-00	169.17 33.834	30.83 6.167	0.00 0.001	69.16 13.833	230.83 46.166	0.	499.99 100.000		
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	2.4773E-00	173.35 34.669	26.65 5.331	0.00 0.000	73.35 14.669	226.65 45.331	0.	500.00 100.000		
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	2.0059E-00	176.51 35.303	23.49 4.697	0.00 0.000	76.51 15.303	223.49 44.697	0.	500.00 100.000		
2.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	6.0571E-09	249.13 71.003	25.43 7.249	74.56 21.251	0.00 0.000	1.74 0.497	0.	350.87 100.000		
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.0339E-06	243.29 68.193	28.33 7.941	71.62 20.075	0.05 0.014	13.47 3.777	0.	356.76 100.000		
2.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	7.7839E-03	224.64 59.697	37.20 9.887	61.85 16.435	0.95 0.252	51.66 13.729	0.	376.31 100.000		
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.3841E-02	191.76 45.997	49.79 11.943	41.55 9.966	8.66 2.077	125.14 30.017	0.	416.90 100.000		
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.0303E-01	161.49 34.138	51.98 10.989	13.47 2.848	34.54 7.302	211.57 44.723	0.	473.05 100.000		
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	3.5813E-00	157.54 31.663	43.69 8.780	1.23 0.246	55.09 11.072	240.01 48.238	0.	497.55 100.000		
2.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	2.2488E-00	163.75 32.764	36.35 7.272	0.10 0.023	63.55 12.716	236.05 47.228	0.	499.80 100.000		
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.6119E-00	169.18 33.837	30.84 6.167	0.01 0.002	69.15 13.831	230.80 46.162	0.	499.98 100.000		
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	1.2387E-00	173.35 34.670	26.65 5.331	0.00 0.000	73.34 14.669	226.65 45.330	0.	500.00 100.000		
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.0030E-00	176.51 35.303	23.49 4.697	0.00 0.000	76.51 15.303	223.49 44.697	0.	500.00 100.000		
4.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	6.0300E-09	249.38 71.127	25.31 7.218	74.69 21.303	0.00 0.000	1.23 0.352	0.	350.62 100.000		
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.0713E-06	245.19 69.098	27.39 7.718	72.58 20.454	0.03 0.010	9.65 2.720	0.	354.84 100.000		
4.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	8.1506E-03	231.28 62.619	34.05 9.219	65.33 17.688	0.62 0.168	38.06 10.305	0.	369.34 100.000		
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.4259E-02	204.72 51.065	44.83 11.184	49.55 12.360	5.61 1.400	96.18 23.991	0.	400.90 100.000		
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	8.4595E-00	174.19 38.569	49.99 11.068	24.18 5.354	25.83 5.719	177.45 39.289	0.	451.64 100.000		

CALIFORNIA RESEARCH
CORPORATION
RICHMOND, CALIFORNIA

RE 647684

TABLE F-23B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - CNH_2N (100 MOL C BASIS), STEAM/C RATIO, 3.0

ELEMENTAL COMPOSITION																			
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)																
100.00	800.00	300.00	0.																
CONDITIONS AND EQUILIBRIUM CONSTANTS																			
P(ATM)	T(DEG F)	KR	KS	KC	RT	H2O		CO2		CH4		CO		H2		N2		TOTAL	
						MOLS	MOL PC	MOLS	MOL PC	MOLS	MOL PC	MOLS	MOL PC	MOLS	MOL PC	MOLS	MOL PC	MOLS	MOL PC
4.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.9774E-00	160.46	32.637	43.71	8.890	4.17	0.848	52.12	10.601	231.19	47.023	0.	0.	491.66	100.000
4.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	1.1346E-00	164.03	32.857	36.36	7.284	0.39	0.079	63.24	12.669	235.19	47.111	0.	0.	499.22	100.000
4.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	8.0682E-01	169.21	33.848	30.84	6.169	0.05	0.009	69.11	13.826	230.70	46.148	0.	0.	499.91	100.000
4.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	6.1947E-01	173.35	34.672	26.65	5.331	0.01	0.002	73.34	14.668	226.63	45.328	0.	0.	499.98	100.000
4.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	5.0150E-01	176.52	35.303	23.49	4.697	0.00	0.000	76.51	15.302	223.48	44.697	0.	0.	500.00	100.000
6.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	5.9983E-09	249.50	71.182	25.25	7.204	74.75	21.326	0.00	0.000	1.01	0.288	0.	0.	350.50	100.000
6.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.0888E-06	246.05	69.510	26.96	7.617	73.01	20.626	0.03	0.008	7.93	2.240	0.	0.	353.98	100.000
6.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	8.3445E-03	234.40	64.027	32.56	8.893	66.95	18.289	0.49	0.133	31.69	8.657	0.	0.	366.09	100.000
6.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.4607E-02	211.30	53.758	42.18	10.731	53.47	13.605	4.35	1.107	81.76	20.800	0.	0.	393.05	100.000
6.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	7.9984E-00	182.34	41.565	48.32	11.015	32.66	6.989	21.02	4.791	156.34	35.639	0.	0.	438.68	100.000
6.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.4907E-00	163.99	33.836	43.68	9.012	7.67	1.583	48.65	10.038	220.67	45.531	0.	0.	484.66	100.000
6.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	7.6749E-01	164.47	33.008	36.39	7.303	0.86	0.173	62.75	12.593	233.81	46.923	0.	0.	498.28	100.000
6.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	5.3882E-01	169.26	33.867	30.84	6.171	0.11	0.021	69.05	13.816	230.52	46.125	0.	0.	499.79	100.000
6.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	4.1310E-01	173.36	34.675	26.66	5.331	0.02	0.004	73.33	14.666	226.60	45.324	0.	0.	499.96	100.000
6.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	3.3435E-01	176.52	35.304	23.49	4.697	0.00	0.001	76.51	15.302	223.48	44.696	0.	0.	499.99	100.000
12.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	5.9684E-09	249.64	71.254	25.18	7.186	74.82	21.356	0.00	0.000	0.71	0.204	0.	0.	350.36	100.000
12.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.1124E-06	247.18	70.057	26.40	7.482	73.58	20.855	0.02	0.005	5.65	1.601	0.	0.	352.83	100.000
12.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	8.6345E-03	238.65	65.984	30.51	8.436	69.16	19.122	0.33	0.090	23.03	6.367	0.	0.	361.68	100.000
12.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.5273E-02	220.80	57.800	38.19	9.996	58.99	15.442	2.82	0.739	61.21	16.023	0.	0.	382.02	100.000
12.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	7.7230E-00	195.91	46.831	44.93	10.739	40.83	9.761	14.24	3.434	122.42	29.265	0.	0.	418.33	100.000
12.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.0660E-00	173.65	37.258	43.31	9.293	16.96	3.640	39.73	8.523	192.42	41.286	0.	0.	466.07	100.000
12.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	4.1137E-01	166.56	33.725	36.50	7.391	3.06	0.620	60.43	12.236	227.31	46.027	0.	0.	493.87	100.000
12.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	2.7192E-01	169.55	33.967	30.87	6.184	0.42	0.084	68.72	13.766	229.62	46.000	0.	0.	499.17	100.000
12.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	2.0687E-01	173.41	34.692	26.66	5.334	0.07	0.014	73.27	14.658	226.45	45.302	0.	0.	499.86	100.000
12.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.6723E-01	176.53	35.308	23.49	4.698	0.02	0.003	76.50	15.300	223.44	44.691	0.	0.	499.97	100.000

TABLE F-24A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - CNH₂N (100 MOL C BASIS), STEAM/C RATIO, 4.0

ELEMENTAL COMPOSITION													
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)										
100.00	1650.00	400.00	0.										
P(ATM)	T(°F)	CONDITIONS AND EQUILIBRIUM CONSTANTS				RT	EQUILIBRIUM PRODUCT COMPOSITIONS						
		KR	KS	KC	H2O MOLS MOL PC		CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	TOTAL MOLS MOL PC	
1.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	8.2934E 09	348.36 77.131	25.82 5.717	74.18 16.424	0.00 0.000	3.29 0.728	0.	451.64 100.00	
1.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	2.7480E 06	337.68 73.029	31.12 6.731	68.80 14.880	0.07 0.016	24.71 5.345	0.	462.39 100.00	
1.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.0355E 04	306.26 61.842	46.13 9.315	52.39 10.578	1.49 0.300	88.97 17.966	0.	495.23 100.00	
1.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.2009E 02	259.67 46.958	63.83 11.543	23.50 4.251	12.66 2.290	193.32 34.958	0.	552.99 100.00	
1.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	3.2039E 01	239.29 40.220	63.22 10.626	2.52 0.423	34.26 5.759	255.67 42.973	0.	594.97 100.00	
1.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	1.5314E 01	246.22 41.054	53.92 8.990	0.13 0.022	45.95 7.662	253.52 42.272	0.	599.73 100.00	
1.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	9.4593E 00	254.03 42.339	45.98 7.664	0.01 0.002	54.01 9.001	245.95 40.993	0.	599.98 100.00	
1.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	6.5773E 00	260.23 43.372	39.77 6.628	0.00 0.000	60.23 10.038	239.76 39.961	0.	600.00 100.00	
1.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	4.9426E 00	265.09 44.183	34.91 5.818	0.00 0.000	65.09 10.849	234.90 39.151	0.	600.00 100.00	
1.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	3.9388E 00	268.87 44.811	31.13 5.189	0.00 0.000	68.87 11.478	231.13 38.522	0.	600.00 100.00	
2.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	8.4220E 09	348.83 77.318	25.58 5.670	74.42 16.494	0.00 0.000	2.33 0.517	0.	451.17 100.00	
2.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	2.8200E 06	341.10 74.321	29.43 6.412	70.52 15.366	0.05 0.011	17.86 3.890	0.	458.95 100.00	
2.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.0802E 04	317.05 65.518	41.00 8.472	58.05 11.995	0.96 0.198	66.86 13.817	0.	483.91 100.00	
2.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.0559E 02	276.46 51.952	57.46 10.797	33.92 6.374	8.62 1.620	155.69 29.257	0.	532.16 100.00	
2.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.9297E 01	245.55 41.967	61.91 10.581	7.46 1.274	30.64 5.236	239.54 40.941	0.	585.09 100.00	
2.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	7.7548E 00	246.65 41.180	53.87 8.994	0.52 0.087	45.61 7.615	252.31 42.125	0.	598.96 100.00	
2.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	4.7343E 00	254.06 42.349	45.98 7.665	0.04 0.007	53.98 8.997	245.85 40.981	0.	599.91 100.00	
2.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	3.2890E 00	260.24 43.374	39.77 6.628	0.01 0.001	60.23 10.038	239.75 39.959	0.	599.99 100.00	
2.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	2.4713E 00	265.10 44.183	34.91 5.818	0.00 0.000	65.09 10.849	234.90 39.151	0.	600.00 100.00	
2.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.9694E 00	268.87 44.811	31.13 5.189	0.00 0.000	68.87 11.478	231.13 38.522	0.	600.00 100.00	
4.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	8.4082E 09	349.17 77.452	25.41 5.637	74.59 16.544	0.00 0.000	1.65 0.367	0.	450.83 100.00	
4.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	2.8772E 06	343.60 75.280	28.18 6.175	71.78 15.727	0.03 0.007	12.83 2.811	0.	456.43 100.00	
4.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.1265E 04	325.50 68.509	36.94 7.774	62.44 13.142	0.62 0.131	49.62 10.443	0.	475.12 100.00	
4.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.0402E 02	292.05 56.861	51.14 9.956	43.19 8.409	5.67 1.105	121.57 23.670	0.	513.62 100.00	
4.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.3966E 01	257.20 45.338	59.15 10.426	16.35 2.882	24.51 4.320	210.10 37.035	0.	567.31 100.00	

TABLE F-24B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₂H₆N₂ (100 MOL C BASIS), STEAM/C RATIO, 4.0

ELEMENTAL COMPOSITION				CONDITIONS AND EQUILIBRIUM CONSTANTS				EQUILIBRIUM PRODUCT COMPOSITIONS								
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)	P(ATM)	T(DEG F)	KR	KS	KC	RT	H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	TOTAL MOLS MOL PC
100.00	1000.00	400.00	0.													
4.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	4.0621E-00	248.23	53.69	1.93	44.38	247.91	0.	596.15	100.00			
						41.640	9.006	0.323	7.445	41.586	0.	100.00				
4.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	2.3765E-00	254.19	45.98	0.17	53.85	245.47	0.	599.66	100.00			
						42.390	7.667	0.028	8.981	40.934	0.	100.00				
4.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.6453E-00	260.25	39.77	0.02	60.21	239.71	0.	599.96	100.00			
						43.379	6.628	0.003	10.036	39.954	0.	100.00				
4.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	1.2358E-00	265.10	34.91	0.00	65.09	234.89	0.	599.99	100.00			
						44.184	5.818	0.001	10.849	39.150	0.	100.00				
4.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	9.8473E-01	268.87	31.13	0.00	68.87	231.13	0.	600.00	100.00			
						44.811	5.189	0.000	11.478	38.522	0.	100.00				
6.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	8.5058E-09	349.32	25.34	74.66	0.00	1.35	0.	450.68	100.00			
						77.511	5.622	16.567	0.000	0.300	0.	100.00				
6.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.9042E-06	344.74	27.62	72.35	0.03	10.55	0.	455.29	100.00			
						75.718	6.066	15.892	0.006	2.318	0.	100.00				
6.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.1526E-04	329.51	35.00	64.51	0.49	41.47	0.	470.98	100.00			
						69.963	7.432	13.697	0.104	8.805	0.	100.00				
6.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.0617E-02	300.16	47.72	47.87	4.41	104.10	0.	504.25	100.00			
						59.525	9.463	9.494	0.875	20.644	0.	100.00				
6.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.2507E-01	265.79	56.86	22.64	20.50	188.93	0.	554.71	100.00			
						47.914	10.250	4.082	3.696	34.059	0.	100.00				
6.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	2.8936E-00	250.45	53.43	3.88	42.69	241.78	0.	592.24	100.00			
						42.290	9.021	0.655	7.208	40.825	0.	100.00				
6.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	1.5945E-00	254.41	45.97	0.38	53.66	244.83	0.	599.24	100.00			
						42.456	7.671	0.063	8.954	40.857	0.	100.00				
6.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.0977E-00	260.28	39.77	0.05	60.19	239.63	0.	599.91	100.00			
						43.387	6.629	0.008	10.032	39.944	0.	100.00				
6.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	8.2394E-01	265.10	34.91	0.01	65.09	234.88	0.	599.98	100.00			
						44.185	5.818	0.001	10.848	39.148	0.	100.00				
6.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	6.5650E-01	268.87	31.13	0.00	68.86	231.13	0.	600.00	100.00			
						44.812	5.189	0.000	11.477	38.522	0.	100.00				
12.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	8.6021E-09	349.52	25.24	74.76	0.00	0.96	0.	450.48	100.00			
						77.589	5.603	16.596	0.000	0.212	0.	100.00				
12.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.9405E-06	346.24	26.87	73.11	0.02	7.54	0.	453.78	100.00			
						76.302	5.922	16.112	0.004	1.661	0.	100.00				
12.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.1933E-04	335.01	32.33	67.34	0.32	30.30	0.	465.31	100.00			
						71.997	6.949	14.473	0.070	6.512	0.	100.00				
12.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.1257E-02	312.06	42.54	54.60	2.86	78.75	0.	490.80	100.00			
						63.581	8.668	11.124	0.583	16.045	0.	100.00				
12.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.1356E-01	281.27	52.22	33.49	14.29	151.75	0.	533.02	100.00			
						52.769	9.797	6.283	2.681	28.470	0.	100.00				
12.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.8334E-00	258.07	52.39	10.47	37.14	220.99	0.	579.06	100.00			
						44.568	9.048	1.808	6.413	38.163	0.	100.00				
12.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	8.2381E-01	255.52	45.91	1.43	52.66	241.62	0.	597.14	100.00			
						42.790	7.688	0.239	8.819	40.463	0.	100.00				
12.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	5.5111E-01	260.42	39.77	0.19	60.05	239.21	0.	599.63	100.00			
						43.430	6.632	0.031	10.014	39.893	0.	100.00				
12.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	4.1225E-01	265.13	34.91	0.03	65.06	234.81	0.	599.94	100.00			
						44.192	5.818	0.005	10.845	39.139	0.	100.00				
12.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	3.2830E-01	268.87	31.13	0.01	68.86	231.11	0.	599.99	100.00			
						44.813	5.189	0.001	11.477	38.520	0.	100.00				

TABLE F-25A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₂H₆N₂ (100 MOL C BASIS), STEAM/C RATIO, 5.0

ELEMENTAL COMPOSITION												
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)									
100.00	1200.00	500.00	0.									
CONDITIONS AND EQUILIBRIUM CONSTANTS												
P(ATM)	T(°F)	KR	KS	KC	RT	EQUILIBRIUM PRODUCT COMPOSITIONS						
						H2O	CO2	CH4	CO	H2	N2	TOTAL
						MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	MOLS
						MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC
1.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.0755E-10	447.94 81.141	26.03 4.715	73.97 13.399	0.00 0.000	4.11 0.745	0.	552.06 100.000
1.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.4958E-06	434.79 76.915	32.57 5.762	67.36 11.916	0.07 0.013	30.50 5.395	0.	565.28 100.000
1.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.3414E-04	397.28 65.751	50.60 8.375	47.89 7.925	1.51 0.250	106.94 17.699	0.	644.23 100.000
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	3.2700E-02	346.03 51.958	70.97 10.657	17.01 2.553	12.02 1.805	219.95 33.027	0.	665.99 100.000
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	5.9723E-01	331.12 47.472	70.13 10.055	1.25 0.179	28.62 4.103	266.38 38.191	0.	697.50 100.000
1.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	2.8261E-01	339.01 48.440	61.05 8.723	0.07 0.009	38.88 5.556	260.86 37.272	0.	699.87 100.000
1.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	1.6857E-01	346.95 49.565	53.06 7.580	0.01 0.001	46.94 6.706	253.04 36.149	0.	699.99 100.000
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.1425E-01	353.42 50.489	46.58 6.654	0.00 0.000	53.42 7.632	246.58 35.225	0.	700.00 100.000
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	8.4300E-00	358.62 51.231	41.38 5.912	0.00 0.000	58.62 8.374	241.38 34.483	0.	700.00 100.000
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	6.6300E-00	362.73 51.819	37.27 5.324	0.00 0.000	62.73 8.961	237.27 33.896	0.	700.00 100.000
2.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.0746E-10	448.54 81.337	25.73 4.666	74.27 13.468	0.00 0.000	2.92 0.529	0.	551.46 100.000
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.5918E-06	438.97 78.236	30.49 5.434	69.46 12.380	0.05 0.009	22.11 3.941	0.	561.08 100.000
2.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.3833E-04	409.98 69.370	44.52 7.534	54.50 9.222	0.98 0.165	81.02 13.709	0.	591.00 100.000
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.8452E-02	363.50 56.354	63.99 9.921	27.49 4.262	8.52 1.320	181.53 28.143	0.	645.02 100.000
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	3.3264E-01	335.17 48.463	69.02 9.980	4.19 0.606	26.79 3.873	256.44 37.078	0.	691.61 100.000
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.4221E-01	339.25 48.500	61.01 8.722	0.26 0.037	38.73 5.538	260.23 37.203	0.	699.48 100.000
2.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	8.4327E-00	346.97 49.570	53.05 7.580	0.02 0.003	46.92 6.704	252.99 36.143	0.	699.96 100.000
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	5.7130E-00	353.42 50.490	46.58 6.654	0.00 0.000	53.42 7.631	246.57 35.225	0.	699.99 100.000
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	4.2151E-00	358.62 51.231	41.38 5.912	0.00 0.000	58.62 8.374	241.38 34.483	0.	700.00 100.000
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	3.3150E-00	362.73 51.819	37.27 5.324	0.00 0.000	62.73 8.961	237.27 33.896	0.	700.00 100.000
4.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	1.0881E-10	448.97 81.477	25.52 4.631	74.48 13.517	0.00 0.000	2.07 0.376	0.	551.34 100.000
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.6703E-06	442.05 79.222	28.96 5.190	71.01 12.726	0.03 0.006	15.94 2.856	0.	557.99 100.000
4.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.4348E-04	420.05 72.350	39.66 6.831	59.71 10.284	0.63 0.109	60.53 10.426	0.	580.58 100.000
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.7088E-02	380.82 60.941	56.73 9.078	37.55 6.009	5.72 0.915	144.08 23.056	0.	624.96 100.000
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	2.1636E-01	344.61 50.814	66.30 9.776	10.91 1.609	22.79 3.361	233.57 34.441	0.	678.18 100.000

CALIFORNIA RESEARCH
CORPORATION
RICHMOND, CALIFORNIA

TABLE F-25B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₂H₆N₂ (100 MOL C BASIS), STEAM/C RATIO, 5.0

ELEMENTAL COMPOSITION													
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)										
100.00	1200.00	500.00	0.										
CONDITIONS AND EQUILIBRIUM CONSTANTS					EQUILIBRIUM PRODUCT COMPOSITIONS								
P(ATM)	T(°F)	KR	KS	KC	RT	H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	TOTAL MOLS MOL PC	
4.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	7.2858E 00	340.16 48.732	60.84 8.716	0.99 0.142	38.17 5.469	257.86 36.942	0. 0.	698.02 100.000	
4.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	4.2249E 00	347.04 49.590	53.04 7.580	0.07 0.012	46.87 6.697	252.78 36.121	0. 0.	699.83 100.000	
4.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	2.8572E 00	353.43 50.492	46.58 6.654	0.01 0.002	53.41 7.630	246.55 35.222	0. 0.	699.98 100.000	
4.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	2.1076E 00	358.62 51.232	41.38 5.912	0.00 0.000	58.62 8.374	241.38 34.482	0. 0.	700.00 100.000	
4.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.6575E 00	362.73 51.819	37.27 5.324	0.00 0.000	62.73 8.961	237.27 33.896	0. 0.	700.00 100.000	
6.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	1.0776E 10	449.15 81.539	25.42 4.615	74.58 13.539	0.00 0.000	1.69 0.307	0. 0.	550.85 100.000	
6.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	3.7096E 06	443.45 79.674	28.26 5.078	71.71 12.884	0.03 0.005	13.13 2.359	0. 0.	556.58 100.000	
6.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.159E 04	424.87 73.809	37.32 6.483	62.19 10.803	0.49 0.086	50.76 8.819	0. 0.	575.63 100.000	
6.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.6959E 02	390.11 63.498	52.71 8.579	42.82 6.969	4.47 0.728	124.26 20.225	0. 0.	614.37 100.000	
6.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.8343E 01	352.70 52.881	63.82 9.568	16.52 2.476	19.67 2.949	214.27 32.126	0. 0.	666.97 100.000	
6.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	5.0410E 00	341.52 49.083	60.57 8.705	2.10 0.301	37.33 5.365	254.28 36.545	0. 0.	695.80 100.000	
6.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	2.8260E 00	347.16 49.622	53.03 7.580	0.19 0.028	46.78 6.686	252.45 36.084	0. 0.	699.61 100.000	
6.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	1.9056E 00	353.45 50.496	46.58 6.654	0.02 0.003	53.40 7.629	246.50 35.217	0. 0.	699.95 100.000	
6.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	1.4052E 00	358.62 51.233	41.38 5.912	0.00 0.001	58.61 8.374	241.37 34.482	0. 0.	699.99 100.000	
6.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.1050E 00	362.73 51.819	37.27 5.324	0.00 0.000	62.73 8.961	237.27 33.895	0. 0.	700.00 100.000	
12.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	1.0786E 10	449.40 81.620	25.30 4.595	74.70 13.567	0.00 0.000	1.20 0.218	0. 0.	550.60 100.000	
12.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	3.7625E 06	445.31 80.279	27.34 4.928	72.65 13.096	0.02 0.003	9.40 1.694	0. 0.	554.71 100.000	
12.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.5170E 04	431.52 75.865	34.08 5.991	65.60 11.533	0.33 0.057	37.28 6.554	0. 0.	568.80 100.000	
12.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.7345E 02	403.99 67.454	46.55 7.772	50.54 8.439	2.91 0.487	94.93 15.849	0. 0.	598.92 100.000	
12.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.5584E 01	368.80 57.143	58.49 9.063	27.30 4.229	14.21 2.201	176.61 27.363	0. 0.	645.41 100.000	
12.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	2.9383E 00	347.03 50.512	52.47 8.656	6.42 0.945	34.04 4.955	239.99 34.932	0. 0.	687.01 100.000	
12.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	1.4380E 00	347.80 49.793	52.95 7.581	0.75 0.108	46.30 6.628	250.69 35.890	0. 0.	698.49 100.000	
12.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	9.5487E-01	353.53 50.518	46.57 6.655	0.10 0.014	53.33 7.621	246.28 35.192	0. 0.	699.81 100.000	
12.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	7.0284E-01	358.64 51.236	41.38 5.912	0.02 0.002	58.60 8.372	241.33 34.477	0. 0.	699.97 100.000	
12.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	5.5256E-01	362.73 51.820	37.27 5.324	0.00 0.001	62.73 8.961	237.26 33.895	0. 0.	699.99 100.000	

TABLE F-26

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - CNHW (100 MOL C BASIS), STEAM/C RATIO, 1.0

ELEMENTAL COMPOSITION												
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)									
100.00	300.00	100.00	0.									
CONDITIONS AND EQUILIBRIUM CONSTANTS												
P(ATM)	T(°F)	KR	KS	KC	RT	H2O	CO2	CH4	CO	H2	N2	TOTAL
						MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	MOLS
						MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	7.5952E-03	0.73	0.30	1.03	98.67	147.21	0.	247.94
CONDITIONS LEAD TO CARBON FORMATION.						0.295	0.120	0.415	39.797	59.373	0.	100.000
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	2.5313E-03	0.32	0.10	0.42	99.48	148.85	0.	249.17
						0.127	0.040	0.167	39.926	59.739	0.	100.000
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	9.9807E-04	0.15	0.04	0.19	99.77	149.46	0.	249.61
						0.061	0.016	0.077	39.909	59.877	0.	100.000
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	7.5695E-03	1.42	0.58	2.01	97.41	144.56	0.	245.98
CONDITIONS LEAD TO CARBON FORMATION.						0.579	0.237	0.817	39.599	58.768	0.	100.000
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	2.5274E-03	0.63	0.20	0.83	98.97	147.72	0.	248.35
						0.252	0.080	0.332	39.853	59.482	0.	100.000
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	9.9731E-04	0.31	0.08	0.38	99.54	148.93	0.	249.23
						0.122	0.032	0.154	39.937	59.754	0.	100.000
4.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	7.5200E-03	2.71	1.12	3.83	95.05	139.63	0.	242.34
CONDITIONS LEAD TO CARBON FORMATION.						1.117	0.463	1.580	39.221	57.618	0.	100.000
4.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	2.5197E-03	1.23	0.39	1.62	97.99	145.54	0.	246.76
						0.497	0.159	0.656	39.710	58.979	0.	100.000
4.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	9.9580E-04	0.60	0.16	0.76	99.08	147.87	0.	248.48
						0.243	0.063	0.307	39.875	59.512	0.	100.000
6.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	7.4730E-03	3.87	1.62	5.49	92.89	135.15	0.	239.52
CONDITIONS LEAD TO CARBON FORMATION.						1.620	0.677	2.297	38.863	56.543	0.	100.000
6.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	2.5122E-03	1.80	0.58	2.38	97.04	143.44	0.	245.24
						0.734	0.236	0.970	39.570	58.490	0.	100.000
6.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	9.9430E-04	0.90	0.23	1.13	98.63	146.84	0.	247.74
						0.362	0.095	0.457	39.814	59.272	0.	100.000
12.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	7.3452E-03	6.80	2.92	9.71	87.37	123.78	0.	230.57
CONDITIONS LEAD TO CARBON FORMATION.						2.947	1.266	4.213	37.892	53.682	0.	100.000
12.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	2.4907E-03	3.39	1.11	4.50	94.40	137.62	0.	241.01
						1.407	0.459	1.865	39.168	57.101	0.	100.000
12.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	9.8991E-04	1.74	0.46	2.20	97.34	143.86	0.	245.60
						0.710	0.187	0.896	39.634	58.573	0.	100.000

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RICHMOND, CALIFORNIA
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TABLE F-27A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₃H₈ (100 MOL C BASIS), STEAM/C RATIO, 2.0

ELEMENTAL COMPOSITION						EQUILIBRIUM PRODUCT COMPOSITIONS									
C(ATCMS)	H(ATCMS)	C(ATCMS)	N2(MOLS)			H2C	CO2	CH4	CO	H2	N2			TOTAL	
100.00	500.00	200.00	C.			MOLS	MOLS	MOLS	MOLS	MOLS	MOLS			MOLS	
PC	PC	PC	PC			PC	PC	PC	PC	PC	PC			PC	
CONDITIONS AND EQUILIBRIUM CONSTANTS															
PI(ATM)	T(DEG F)	KR	KS	KC	RT										
1.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	3.6396E-03	107.28	45.49	52.76	1.75	27.19	0.	244.47			
CONDITIONS LEAD TO CARBON FORMATION.						43.861	18.666	21.583	0.715	15.214	C.	100.000			
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	6.6711E-01	85.70	49.93	35.63	14.44	93.03	0.	278.74			
						30.747	17.911	12.783	5.182	33.377	0.	100.000			
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	5.7120E-00	68.92	41.16	10.08	48.75	160.92	C.	329.84			
						20.855	12.480	3.057	14.781	48.787	0.	100.000			
1.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	2.3983E-00	69.18	31.55	0.73	67.72	179.36	C.	348.54			
						19.848	9.053	0.209	19.429	51.461	0.	100.000			
1.0000	1600.00	8.2135E-02	8.2439E-01	4.0065E-02	1.6445E-00	74.23	25.82	0.05	74.12	175.66	0.	349.89			
						21.215	7.380	0.015	21.185	50.204	0.	100.000			
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.2402E-00	78.25	21.71	0.01	78.28	171.70	0.	349.99			
						22.370	6.204	0.002	22.366	49.058	0.	100.000			
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	9.8615E-01	81.35	18.65	0.00	81.35	168.64	0.	350.00			
						23.244	5.328	0.000	23.244	48.184	0.	100.000			
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	8.1772E-01	83.65	16.35	0.00	83.65	166.35	0.	350.00			
						23.900	4.671	0.000	23.900	47.528	0.	100.000			
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	9.3934E-05	121.66	39.14	60.80	0.07	6.75	0.	228.41			
CONDITIONS LEAD TO CARBON FORMATION.						53.264	17.134	26.617	0.030	2.955	0.	100.000			
2.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	3.7943E-03	111.98	43.43	55.40	1.17	27.22	0.	239.19			
						46.814	18.156	23.162	0.489	11.379	0.	100.000			
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	6.8668E-01	94.32	48.02	42.35	9.63	70.99	0.	265.31			
						35.552	18.101	15.961	3.630	26.756	C.	100.000			
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	4.5278E-00	76.43	42.63	19.06	38.32	135.45	0.	311.88			
						24.508	13.667	6.111	12.285	43.429	0.	100.000			
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.2901E-00	70.58	32.01	2.59	65.40	174.24	0.	344.82			
						20.469	9.282	0.751	18.967	50.531	0.	100.000			
2.0000	1600.00	8.2135E-02	8.2439E-01	4.0065E-02	8.2705E-01	74.35	25.86	0.21	73.93	175.22	0.	349.57			
						21.269	7.358	0.061	21.148	50.124	0.	100.000			
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	6.2051E-01	78.31	21.72	0.02	78.26	171.65	0.	349.95			
						22.376	6.206	0.007	22.362	49.048	0.	100.000			
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	4.9312E-01	81.36	18.65	0.00	81.35	168.64	0.	349.99			
						23.245	5.328	0.001	23.243	48.183	0.	100.000			
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	4.0887E-01	83.65	16.35	0.00	83.65	166.35	0.	350.00			
						23.901	4.671	0.000	23.900	47.528	0.	100.000			
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	9.4863E-05	122.62	38.67	61.29	0.05	4.81	0.	227.43			
CONDITIONS LEAD TO CARBON FORMATION.						53.917	17.001	26.948	0.021	2.113	0.	100.000			
4.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	3.9193E-03	115.53	41.84	57.37	0.79	19.74	0.	235.27			
						49.104	17.784	24.384	0.337	8.390	0.	100.000			
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	7.1305E-01	101.63	45.98	47.61	6.41	53.15	0.	254.78			
						39.889	18.047	18.687	2.515	20.861	0.	100.000			
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	4.0758E-00	85.08	43.49	28.56	27.95	107.80	0.	292.87			
						29.049	14.848	9.753	9.543	36.807	0.	100.000			
4.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	7.8700E-01	74.29	33.15	7.44	59.41	160.83	0.	335.12			
						22.168	9.893	2.220	17.727	47.992	0.	100.000			
4.0000	1600.00	8.2135E-02	8.2439E-01	4.0065E-02	4.2298E-01	74.81	26.01	0.82	73.17	173.54	0.	348.36			
						21.476	7.465	0.236	21.005	49.818	0.	100.000			
4.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	3.1107E-01	78.36	21.73	0.10	78.17	171.44	0.	349.81			
						22.402	6.213	0.028	22.346	49.011	C.	100.000			
4.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	2.4666E-01	81.37	18.65	0.02	81.33	168.60	0.	349.57			
						23.249	5.329	0.004	23.240	48.177	0.	100.000			
4.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	2.0445E-01	83.65	16.35	0.00	83.65	166.34	0.	349.99			
						23.902	4.671	0.001	23.900	47.526	0.	100.000			

TABLE F-27B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₃H₈ (100 MOL C BASIS), STEAM/C RATIO, 2.0

ELEMENTAL COMPOSITION
 C (ATOMS) H (ATOMS) O (ATOMS) N₂ (MOLS)
 100.00 500.00 200.00 0.

CONDITIONS AND EQUILIBRIUM CONSTANTS
 P (ATM) T (DEG F) K_R K_S K_C R_T

EQUILIBRIUM PRODUCT COMPOSITIONS
 H₂ CO CH₄ C₂ H₂ N₂
 MOLS MOLS MOLS MOLS MOLS MOLS
 MOL PC MOL PC MOL PC MOL PC MOL PC MOL PC

6.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	9.5285E 05	123.05	38.45	61.51	0.04	3.94	0.	226.99
CONDITIONS LEAD TO CARBON FORMATION.						54.211	16.941	27.057	0.017	1.734	0.	100.000
6.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	3.9795E 03	117.16	41.10	58.27	0.62	16.30	0.	233.47
						50.184	17.604	24.956	0.272	6.984	0.	100.000
6.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	7.2900E 01	105.25	44.85	50.09	5.06	44.57	0.	249.81
						42.120	17.952	20.052	2.026	17.840	0.	100.000
6.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	3.9696E 00	90.06	43.60	33.65	22.75	92.63	0.	282.69
						31.857	15.422	11.905	8.047	32.768	0.	100.000
6.0000	1400.00	6.3697E 01	1.2681E 00	2.7306E-01	6.4001E-01	77.82	34.16	11.98	53.86	148.22	0.	326.04
						23.868	10.478	3.675	16.519	45.460	0.	100.000
6.0000	1600.00	8.2135E 02	8.2439E-01	4.0065E-02	2.9186E-01	75.52	26.22	1.74	72.03	171.00	0.	346.52
						21.753	7.568	0.502	20.788	49.349	0.	100.000
6.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	2.0827E-01	78.45	21.76	0.22	78.02	171.11	0.	349.57
						22.443	6.225	0.062	22.320	48.950	0.	100.000
6.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	1.6456E-01	81.38	18.65	0.04	81.31	168.55	0.	349.93
						23.256	5.331	0.010	23.236	48.166	0.	100.000
6.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.3632E-01	83.66	16.35	0.01	83.64	166.33	0.	349.99
						23.903	4.672	0.002	23.899	47.524	0.	100.000
12.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	9.5846E 05	123.62	38.18	61.79	0.03	2.79	0.	226.41
CONDITIONS LEAD TO CARBON FORMATION.						54.598	16.862	27.253	0.012	1.234	0.	100.000
12.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	4.0629E 03	119.36	40.10	59.46	0.44	11.71	0.	231.07
						51.657	17.354	25.734	0.189	5.067	0.	100.000
12.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	7.5451E 01	110.36	43.12	53.48	3.40	32.67	0.	243.04
						45.410	17.741	22.005	1.400	13.444	0.	100.000
12.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	3.9202E 00	97.84	43.23	41.08	15.69	70.00	0.	267.84
						36.530	16.141	15.336	5.858	26.135	0.	100.000
12.0000	1400.00	6.3697E 01	1.2681E 00	2.7306E-01	5.1095E-01	85.42	36.05	21.47	42.49	121.65	0.	307.07
						27.818	11.739	6.991	13.837	39.615	0.	100.000
12.0000	1600.00	8.2135E 02	8.2439E-01	4.0065E-02	1.6835E-01	78.35	27.10	5.45	67.45	160.75	0.	339.10
						23.106	7.992	1.608	19.890	47.404	0.	100.000
12.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	1.0648E-01	78.93	21.90	0.83	77.27	169.41	0.	348.34
						22.659	6.267	0.239	22.182	48.633	0.	100.000
12.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	8.2584E-02	81.46	18.68	0.14	81.18	168.26	0.	349.72
						23.294	5.340	0.040	23.214	48.112	0.	100.000
12.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	6.8214E-02	83.66	16.35	0.03	83.62	166.26	0.	349.94
						23.911	4.674	0.009	23.894	47.512	0.	100.000

CALIFORNIA RESEARCH
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 RICHMOND, CALIFORNIA
 RE 647692

TABLE F-28A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - CNHN (100 MOL C BASIS), STEAM/C RATIO, 3.0

ELEMENTAL COMPOSITION												
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)									
100.00	700.00	300.00	0.									
CONDITIONS AND EQUILIBRIUM CONSTANTS					EQUILIBRIUM PRODUCT COMPOSITIONS							
P(ATM)	T(°F)	KR	KS	KC	KT	H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	TOTAL MOLS MOL PC
1.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	4.8933E-09	224.03 68.726	37.99 11.653	62.01 19.024	0.00 0.000	1.95 0.597	0.	325.97 100.000
1.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	1.6657E-06	217.51 65.400	41.20 12.388	58.71 17.653	0.09 0.027	15.07 4.532	0.	332.58 100.000
1.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	6.6616E-03	197.01 55.555	50.67 14.289	47.69 13.447	1.64 0.463	57.61 16.246	0.	354.63 100.000
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.3666E-02	164.32 41.178	61.16 15.326	25.48 -6.385	13.36 3.349	134.72 33.762	0.	399.04 100.000
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.6767E-01	146.48 33.110	57.32 12.955	3.80 0.858	38.89 8.790	195.93 44.287	0.	442.41 100.000
1.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	8.0924E-01	152.10 33.831	48.10 10.699	0.20 0.045	51.70 11.498	197.49 43.927	0.	449.59 100.000
1.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	5.2304E-01	159.25 35.391	40.76 9.059	0.02 0.003	59.22 13.161	190.72 42.385	0.	449.97 100.000
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	3.7584E-00	164.86 36.637	35.14 7.808	0.00 0.000	64.86 14.414	185.13 41.141	0.	450.00 100.000
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	2.8915E-00	169.22 37.604	30.78 6.841	0.00 0.000	69.22 15.381	180.78 40.174	0.	450.00 100.000
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	2.3439E-00	172.57 38.349	27.43 6.096	0.00 0.000	72.57 16.126	177.43 39.429	0.	450.00 100.000
2.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	4.8663E-09	224.31 68.873	37.84 11.620	62.16 19.084	0.00 0.000	1.38 0.423	0.	325.69 100.000
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	1.6883E-06	219.63 66.470	40.15 12.151	59.79 18.093	0.06 0.019	10.79 3.267	0.	330.43 100.000
2.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	6.8717E-03	204.27 58.896	47.32 13.644	51.59 14.874	1.09 0.315	42.56 12.271	0.	346.83 100.000
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.3205E-02	176.74 46.224	57.09 14.930	33.82 8.846	9.09 2.378	105.61 27.622	0.	382.35 100.000
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.0952E-01	153.00 35.547	56.80 13.196	9.80 2.276	33.41 7.762	177.41 41.219	0.	430.41 100.000
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	4.1345E-00	152.66 34.042	48.13 10.732	0.78 0.175	51.09 11.393	195.78 43.658	0.	448.43 100.000
2.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	2.6195E-00	159.29 35.408	40.77 9.062	0.06 0.014	59.17 13.152	190.58 42.364	0.	449.88 100.000
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.8796E-00	164.87 36.639	35.14 7.809	0.01 0.002	64.85 14.413	185.12 41.138	0.	449.99 100.000
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	1.4458E-00	169.22 37.604	30.78 6.841	0.00 0.000	69.21 15.381	180.78 40.174	0.	450.00 100.000
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	1.1720E-00	172.57 38.349	27.43 6.096	0.00 0.000	72.57 16.126	177.43 39.429	0.	450.00 100.000
4.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	4.8783E-09	224.51 68.977	37.74 11.596	62.26 19.127	0.00 0.000	0.98 0.300	0.	325.49 100.000
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	1.7051E-06	221.17 67.251	39.39 11.978	60.56 18.416	0.04 0.013	7.70 2.342	0.	328.87 100.000
4.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	7.0610E-03	209.82 61.545	44.72 13.119	54.54 15.998	0.73 0.216	31.10 9.122	0.	340.92 100.000
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.3237E-02	187.73 50.963	53.10 14.415	40.82 11.083	6.08 1.650	80.63 21.889	0.	368.35 100.000
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	8.5665E-00	163.07 39.503	55.53 13.453	18.60 4.506	25.87 6.266	149.73 36.272	0.	412.80 100.000

TABLE F-28B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₃H₈ (100 MOL C BASIS), STEAM/C RATIO, 3.0

ELEMENTAL COMPOSITION												
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)									
100.00	700.00	300.00	0.									
CONDITIONS AND EQUILIBRIUM CONSTANTS												
P(ATM)	T(°F)	K _R	K _S	K _C	R _T	H ₂ O MOLS MOL PC	CO ₂ MOLS MOL PC	CH ₄ MOLS MOL PC	CO MOLS MOL PC	H ₂ MOLS MOL PC	N ₂ MOLS MOL PC	TOTAL MOLS MOL PC
4.0000	1400.0	6.3697E 01	1.2081E 00	2.7306E-01	2.2283E 00	154.56 34.773	48.21 10.646	2.76 0.622	49.03 11.031	189.92 42.729	0.	444.47 100.00
4.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	1.3182E 00	159.46 35.474	40.79 9.074	0.24 0.054	58.97 13.118	190.5 42.280	0.	449.51 100.00
4.0000	1800.0	6.7984E 03	6.0833E-01	8.3445E-03	9.4047E-01	164.89 36.647	35.14 7.810	0.03 0.006	64.83 14.409	185.05 41.128	0.	449.94 100.00
4.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	7.2299E-01	169.22 37.605	30.78 6.841	0.00 0.001	69.21 15.380	180.77 40.172	0.	449.99 100.00
4.0000	2200.0	1.8036E 05	3.8864E-01	7.5373E-04	5.8600E-01	172.57 38.349	27.43 6.096	0.00 0.000	72.57 16.126	177.43 39.429	0.	450.00 100.00
6.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	4.8615E 09	224.60 69.024	37.70 11.585	62.30 19.146	0.00 0.000	0.80 0.245	0.	325.40 100.00
6.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	1.7129E 06	221.86 67.604	39.05 11.900	60.91 18.561	0.04 0.011	6.31 1.924	0.	328.17 100.00
6.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	7.1581E 03	212.40 62.807	43.51 12.865	55.91 16.532	0.59 0.173	25.78 7.623	0.	338.18 100.00
6.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	1.3363E 02	193.29 53.467	50.96 14.097	44.25 12.240	4.79 1.326	68.22 18.871	0.	361.51 100.00
6.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	7.9088E 00	169.73 42.250	54.40 13.542	24.14 6.008	21.46 5.342	132.00 32.857	0.	401.73 100.00
6.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	1.6386E 00	156.98 35.721	48.28 10.986	5.26 1.198	46.46 10.571	182.49 41.525	0.	439.47 100.00
6.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	8.8796E-01	159.73 35.580	40.82 9.092	0.54 0.120	58.64 13.063	189.19 42.144	0.	448.92 100.00
6.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	6.2775E-01	164.92 36.659	35.15 7.812	0.07 0.014	64.79 14.402	184.95 41.112	0.	449.87 100.00
6.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	4.8209E-01	169.23 37.607	30.79 6.842	0.01 0.002	69.20 15.379	180.75 40.169	0.	449.98 100.00
6.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	3.9068E-01	172.57 38.350	27.43 6.096	0.00 0.001	72.57 16.126	177.42 39.428	0.	450.00 100.00
12.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	4.8692E 09	224.72 69.084	37.64 11.572	62.36 19.171	0.00 0.000	0.56 0.173	0.	325.28 100.00
12.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	1.7235E 06	222.77 68.071	38.60 11.796	61.37 18.753	0.02 0.008	4.49 1.372	0.	327.26 100.00
12.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	7.2992E 03	215.90 64.542	41.85 12.512	57.75 17.264	0.40 0.120	18.61 5.563	0.	334.50 100.00
12.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	1.3654E 02	201.28 57.193	47.76 13.571	49.04 13.934	3.20 0.910	50.65 14.392	0.	351.93 100.00
12.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	7.3788E 00	180.99 47.128	52.00 13.540	32.98 8.589	15.02 3.910	103.05 26.833	0.	384.03 100.00
12.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	1.1130E 00	164.14 38.614	48.32 11.368	12.46 2.931	39.22 9.226	160.94 37.861	0.	425.08 100.00
12.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	4.6730E-01	161.03 36.101	40.95 9.181	1.98 0.443	57.07 12.795	185.02 41.479	0.	446.54 100.00
12.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	3.1592E-01	165.09 36.728	35.17 7.824	0.26 0.057	64.57 14.366	184.40 41.024	0.	449.49 100.00
12.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	2.4130E-01	169.25 37.619	30.79 6.843	0.04 0.010	69.17 15.373	180.66 40.155	0.	449.91 100.00
12.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.9539E-01	172.58 38.352	27.43 6.096	0.01 0.002	72.56 16.125	177.40 39.425	0.	449.98 100.00

TABLE F-29A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₂H₆ (100 MOL % BASIS), STEAM/C RATIO, 4.

ELEMENTAL COMPOSITION
 C(ATOMS) H(ATOMS) O(ATOMS) N2(MOLS)
 1.000 9.000 400.00 0.

CONDITIONS AND EQUILIBRIUM CONSTANTS
 P(Atm) T(DEG F) K_K K_S K_C K_T

EQUILIBRIUM PRODUCT COMPOSITIONS
 H₂O CO₂ CH₄ CO H₂ N₂
 MOLS MOLS MOLS MOLS MOLS MOLS
 MOL PC MOL PC MOL PC MOL PC MOL PC MOL PC

1.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	7.0237E-09	323.67 75.918	38.17 8.952	61.83 14.503	0.00 0.0000	2.67 0.626	0. 0.	426.4 100.00
1.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.3996E-06	314.81 72.325	42.55 9.775	57.36 13.170	0.00 0.020	20.46 4.700	0. 0.	435.27 100.00
1.0000	800.00	2.6585E-04	9.0223E-03	3.7690E-03	9.8000E-03	287.82 62.057	55.28 11.919	43.16 9.293	1.62 0.349	75.98 16.362	0. 0.	463.80 100.00
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.3111E-02	248.08 48.228	69.73 13.557	17.81 3.462	12.46 2.422	166.30 32.331	0. 0.	514.38 100.00
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	3.8264E-01	234.20 42.829	67.38 12.323	1.58 0.290	31.03 5.675	212.63 38.884	0. 0.	546.83 100.00
1.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.8561E-01	241.74 43.965	58.35 10.611	0.08 0.015	41.57 7.561	208.10 37.848	0. 0.	549.84 100.00
1.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	1.1416E-01	249.39 45.345	50.61 9.203	0.01 0.001	49.38 8.979	200.59 36.472	0. 0.	549.99 100.00
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	7.9145E-00	255.57 46.467	44.43 8.079	0.00 0.000	55.57 10.103	194.43 35.351	0. 0.	550.00 100.00
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	5.9384E-00	260.49 47.362	39.51 7.183	0.00 0.000	60.49 10.998	189.51 34.456	0. 0.	550.00 100.00
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	4.7292E-00	264.37 48.067	35.63 6.478	0.00 0.000	64.37 11.704	185.63 33.751	0. 0.	550.00 100.00
2.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	7.0885E-09	324.05 76.079	37.97 8.915	62.03 14.562	0.00 0.0000	1.89 0.444	0. 0.	425.95 100.00
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.4326E-06	317.68 73.473	41.13 9.512	58.81 13.601	0.06 0.014	14.70 3.400	0. 0.	432.38 100.00
2.0000	800.00	2.6585E-04	9.0223E-03	3.7690E-03	9.9910E-03	297.20 65.482	50.86 11.206	48.06 10.590	1.07 0.237	56.67 12.485	0. 0.	453.87 100.00
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.0734E-02	262.32 52.836	64.45 12.982	26.77 5.391	8.78 1.769	134.15 27.021	0. 0.	496.47 100.00
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	2.2099E-01	238.49 44.164	66.50 12.315	4.99 0.925	28.50 5.279	201.52 37.318	0. 0.	540.01 100.00
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	9.3627E-00	242.00 44.050	58.32 10.616	0.32 0.058	41.36 7.529	207.37 37.747	0. 0.	549.37 100.00
2.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	5.7116E-00	249.41 45.352	50.61 9.203	0.03 0.005	49.36 8.976	200.54 36.464	0. 0.	549.95 100.00
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	3.9576E-00	255.57 46.468	44.43 8.079	0.00 0.001	55.56 10.103	194.42 35.350	0. 0.	549.99 100.00
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	2.9693E-00	260.49 47.362	39.51 7.183	0.00 0.000	60.49 10.998	189.51 34.456	0. 0.	550.00 100.00
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	2.3646E-00	264.37 48.067	35.63 6.478	0.00 0.000	64.37 11.704	185.63 33.751	0. 0.	550.00 100.00
4.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	6.9867E-07	324.33 76.193	37.83 8.888	62.16 14.604	0.00 0.0000	1.34 0.315	0. 0.	425.67 100.00
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	2.4581E-06	319.76 74.315	40.10 9.319	59.86 13.912	0.04 0.010	10.52 2.444	0. 0.	430.28 100.00
4.0000	800.00	2.6585E-04	9.0223E-03	3.7690E-03	1.9206E-04	304.50 68.239	47.39 10.620	51.89 11.629	0.72 0.161	41.72 9.350	0. 0.	446.22 100.00
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	1.9929E-02	275.77 57.427	59.13 12.314	34.90 7.267	5.97 1.243	104.44 21.749	0. 0.	480.20 100.00
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	1.5127E-01	247.32 46.985	64.50 12.253	11.81 2.244	23.69 4.503	179.06 34.017	0. 0.	526.37 100.00

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 RICHMOND, CALIFORNIA

RE 647695

TABLE F-29B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - C₂H₆ (100 MOL C BASIS), STEAM/C RATIO, 4.0

ELEMENTAL COMPOSITION															
C(ATOMS)	H(ATOMS)	O(ATOMS)	N ₂ (MOLS)												
100.00	900.00	400.00	0.												
CONDITIONS AND EQUILIBRIUM CONSTANTS								EQUILIBRIUM				PRODUCT COMPOSITIONS			
P(ATM)	T(°F)	K _R	K _S	K _C	R _T	H ₂ O MOLS MOL PC	CO ₂ MOLS MOL PC	CH ₄ MOLS MOL PC	CO MOLS MOL PC	H ₂ MOLS MOL PC	N ₂ MOLS MOL PC	TOTAL			
4.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	4.8396E 00	242.98 44.371	58.22 10.632	1.20 0.219	40.58 7.411	204.62 37.367	0.	547.60 100.00			
4.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	2.8636E 00	249.49 45.379	50.61 9.235	0.10 0.019	49.29 8.965	200.33 36.432	0.	549.80 100.00			
4.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	1.9794E 00	255.58 46.471	44.43 8.079	0.01 0.002	55.56 10.101	194.40 35.346	0.	549.98 100.00			
4.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	1.4847E 00	260.49 47.363	39.51 7.183	0.00 0.000	60.49 10.998	189.50 34.455	0.	550.00 100.00			
4.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.1823E 00	264.37 48.068	35.63 6.478	0.00 0.000	64.37 11.704	185.63 33.751	0.	550.00 100.00			
6.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	7.0150E 09	324.45 76.244	37.77 8.876	62.23 14.623	0.00 0.000	1.09 0.257	0.	425.55 100.00			
6.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	2.4697E 06	320.70 74.698	39.63 9.231	60.33 14.053	0.03 0.008	8.63 2.310	0.	429.33 100.00			
6.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.0328E 04	307.93 69.566	45.75 10.336	53.68 12.127	0.57 0.129	34.72 7.843	0.	442.64 100.00			
6.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	1.9815E 02	282.79 59.921	56.24 11.917	39.03 8.271	4.73 1.001	89.15 18.889	0.	471.94 100.00			
6.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.3148E 01	254.23 49.266	62.76 12.161	16.98 3.291	20.26 3.926	161.81 31.356	0.	516.03 100.00			
6.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	3.3889E 00	244.41 44.843	58.07 10.654	2.48 0.455	39.45 7.239	200.63 36.810	0.	545.04 100.00			
6.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	1.9176E 00	249.62 45.423	50.61 9.209	0.23 0.042	49.16 8.946	199.92 36.380	0.	549.54 100.00			
6.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	1.3203E 00	255.59 46.477	44.43 8.080	0.03 0.000	55.54 10.099	194.35 35.340	0.	549.94 100.00			
6.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	9.8989E-01	260.50 47.364	39.51 7.184	0.00 0.001	60.49 10.998	189.49 34.454	0.	549.99 100.00			
6.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	7.8823E-01	264.37 48.068	35.63 6.478	0.00 0.000	64.37 11.704	185.63 33.750	0.	550.00 100.00			
12.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	6.9431E 09	324.61 76.310	37.69 8.861	62.31 14.647	0.00 0.000	0.77 0.182	0.	425.39 100.00			
12.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	2.4860E 06	321.94 75.205	39.02 9.115	60.96 14.240	0.02 0.006	6.15 1.436	0.	428.08 100.00			
12.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.0517E 04	312.60 71.405	43.50 9.937	56.11 12.816	0.39 0.089	25.19 5.753	0.	437.79 100.00			
12.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	1.9923E 02	293.09 63.705	51.88 11.276	44.96 9.773	3.16 0.687	66.98 14.559	0.	460.07 100.00			
12.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.1449E 01	267.14 53.698	59.11 11.882	26.26 5.278	14.63 2.941	130.34 26.201	0.	497.49 100.00			
12.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	2.0470E 00	249.74 46.623	57.44 10.723	7.17 1.339	35.39 6.607	185.91 34.708	0.	535.65 100.00			
12.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	9.8119E-01	250.29 45.653	50.59 9.227	0.88 0.160	48.53 8.853	197.96 36.107	0.	548.25 100.00			
12.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	6.6202E-01	255.68 46.505	44.44 8.082	0.11 0.020	55.45 10.087	194.10 35.305	0.	549.78 100.00			
12.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	4.9517E-01	260.51 47.368	39.51 7.184	0.02 0.003	60.47 10.996	189.45 34.448	0.	549.96 100.00			
12.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	3.9416E-01	264.37 48.069	35.63 6.478	0.00 0.001	64.37 11.703	185.62 33.749	0.	549.99 100.00			

TABLE F-30A

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

STEAM REFORMER FEED - CNHN (100 MOL C BASIS), STEAM/C RATIO 5.0

ELEMENTAL COMPOSITION													
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)										
100.00	1100.00	500.00	0.										
CONDITIONS AND EQUILIBRIUM CONSTANTS													
P(ATM)	T(DEG F)	KR	KS	KC	RT	EQUILIBRIUM			PRODUCT COMPOSITIONS			TOTAL	
						H2O	CO2	CH4	CO	H2	N2	MOLS	
						MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	MOLS	
						MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	MOL PC	
1.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	9.1718E-09	423.31	38.35	61.65	0.00	3.39	0.	526.69	
						80.371	7.280	11.706	0.000	0.643	0.	100.00	
1.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.1309E-06	412.20	43.86	56.06	0.09	25.68	0.	537.88	
						76.634	8.153	10.422	0.016	4.774	0.	100.00	
1.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.3109E-04	379.44	59.48	38.91	1.61	92.74	0.	572.17	
						66.315	10.395	6.801	0.282	16.208	0.	100.00	
1.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	3.6155E-02	335.86	76.32	12.19	11.49	189.76	0.	625.63	
						53.685	12.199	1.948	1.837	30.332	0.	100.00	
1.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	7.4254E-01	326.89	73.85	0.75	25.40	221.61	0.	648.50	
						50.407	11.388	0.115	3.916	34.173	0.	100.00	
1.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	3.5204E-01	334.79	65.25	0.04	34.71	215.14	0.	649.92	
						51.511	10.040	0.006	5.340	33.102	0.	100.00	
1.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	2.0853E-01	342.39	57.62	0.00	42.38	207.61	0.	649.99	
						52.675	8.864	0.000	6.520	31.940	0.	100.00	
1.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	1.4066E-01	348.69	51.31	0.00	48.69	201.31	0.	650.00	
						53.645	7.893	0.000	7.491	30.970	0.	100.00	
1.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	1.0347E-01	353.85	46.15	0.00	53.85	196.15	0.	650.00	
						54.438	7.101	0.000	8.284	30.177	0.	100.00	
1.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	8.1222E-00	357.99	42.01	0.00	57.99	192.01	0.	650.00	
						55.075	6.464	0.000	8.921	29.541	0.	100.00	
2.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	9.1753E-09	423.80	38.10	61.90	0.00	2.40	0.	526.20	
						80.540	7.240	11.763	0.000	0.456	0.	100.00	
2.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.1733E-06	415.77	42.08	57.86	0.06	18.51	0.	534.29	
						77.819	7.877	10.829	0.011	3.465	0.	100.00	
2.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.3185E-04	390.63	54.15	44.78	1.07	69.82	0.	560.45	
						69.699	9.662	7.989	0.191	12.458	0.	100.00	
2.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.9915E-02	350.36	70.59	20.94	8.47	157.75	0.	608.11	
						57.614	11.607	3.444	1.393	25.942	0.	100.00	
2.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	4.0138E-01	329.49	73.14	2.63	24.24	215.26	0.	644.75	
						51.104	11.343	0.407	3.759	33.386	0.	100.00	
2.0000	1400.00	6.3697E-01	1.2081E-00	2.7306E-01	1.7678E-01	334.93	65.23	0.15	34.62	214.77	0.	649.70	
						51.551	10.040	0.023	5.329	33.057	0.	100.00	
2.0000	1600.00	8.2139E-02	8.2439E-01	4.0069E-02	1.0430E-01	342.40	57.62	0.01	42.37	207.58	0.	649.97	
						52.678	8.864	0.002	6.519	31.936	0.	100.00	
2.0000	1800.00	6.7984E-03	6.0833E-01	8.3445E-03	7.0334E-00	348.69	51.31	0.00	48.69	201.30	0.	650.00	
						53.646	7.893	0.000	7.491	30.970	0.	100.00	
2.0000	2000.00	4.0014E-04	4.7516E-01	2.2622E-03	5.1735E-00	353.85	46.15	0.00	53.85	196.15	0.	650.00	
						54.438	7.101	0.000	8.284	30.177	0.	100.00	
2.0000	2200.00	1.8036E-05	3.8864E-01	7.5373E-04	4.0611E-00	357.99	42.01	0.00	57.99	192.01	0.	650.00	
						55.075	6.464	0.000	8.921	29.541	0.	100.00	
4.0000	400.00	7.9414E-12	2.0711E-02	4.0007E-09	9.1979E-09	424.15	37.92	62.07	0.00	1.70	0.	525.85	
						80.660	7.212	11.805	0.000	0.323	0.	100.00	
4.0000	600.00	2.1990E-07	3.1479E-01	1.0438E-06	3.2065E-06	418.38	40.79	59.17	0.04	13.27	0.	531.66	
						78.694	7.672	11.130	0.008	2.497	0.	100.00	
4.0000	800.00	2.6585E-04	9.0223E-00	3.7690E-03	1.3375E-04	399.47	49.91	49.37	0.72	51.79	0.	551.25	
						72.465	9.054	8.957	0.130	9.394	0.	100.00	
4.0000	1000.00	4.9018E-02	3.7523E-00	6.4774E-01	2.7419E-02	365.28	64.41	29.70	5.89	125.32	0.	590.61	
						61.849	10.906	5.028	0.997	21.219	0.	100.00	
4.0000	1200.00	2.6875E-00	1.9714E-00	3.0042E-00	2.4728E-01	336.18	71.22	7.40	21.39	199.02	0.	635.20	
						52.925	11.211	1.165	3.367	31.332	0.	100.00	

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TABLE F-30B

PRODUCT COMPOSITIONS FROM HYDROCARBON STEAM REFORMING AND SHIFT EQUILIBRIA

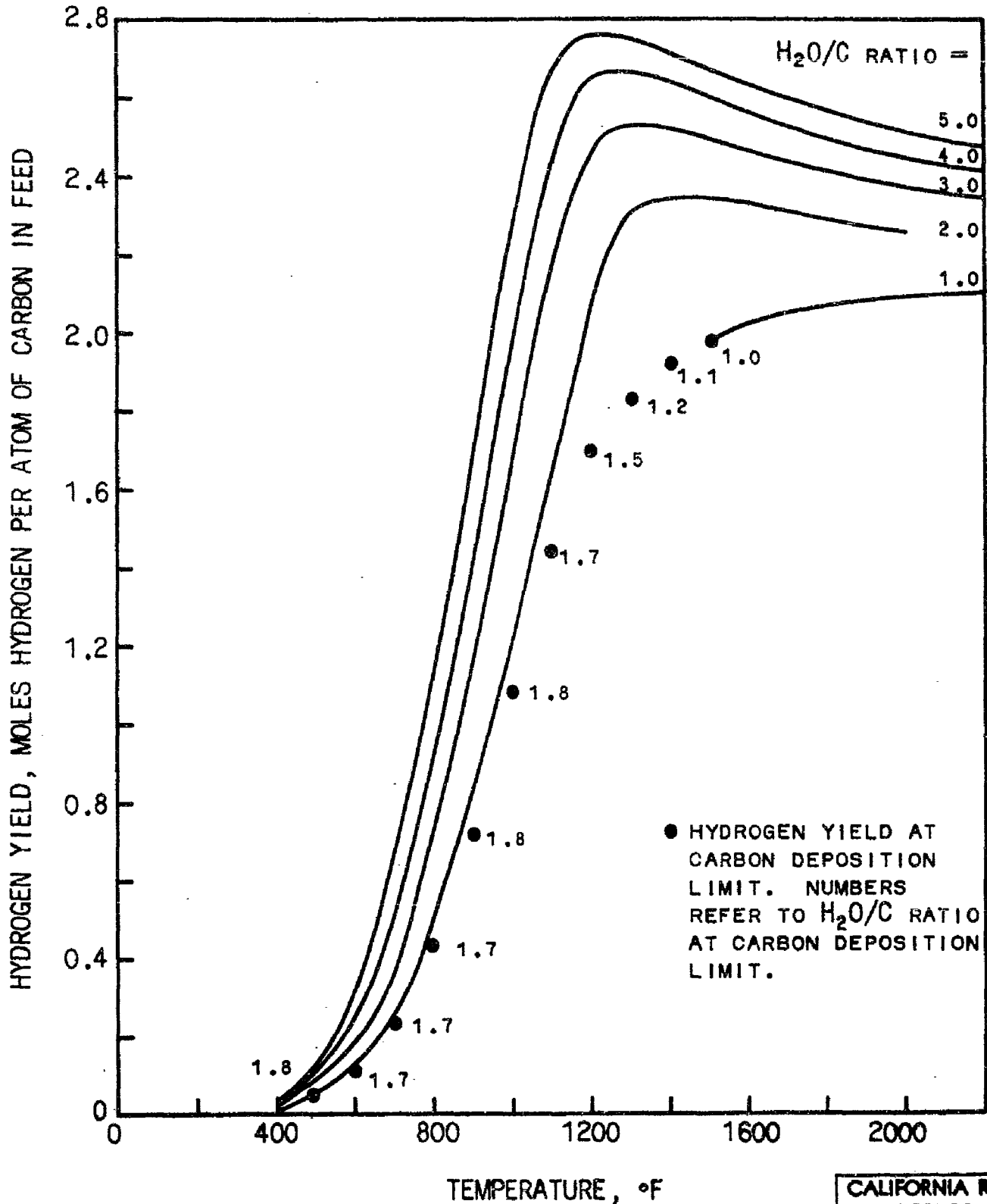
STEAM REFORMER FEED - CNHN (100 MOL C BASIS), STEAM/C RATIO 5.0

ELEMENTAL COMPOSITION												
C(ATOMS)	H(ATOMS)	O(ATOMS)	N2(MOLS)									
100.00	1100.00	500.00	0.									
CONDITIONS AND EQUILIBRIUM CONSTANTS												
P(ATM)	T(DEG F)	KR	KS	KC	RT	H2O MOLS MOL PC	CO2 MOLS MOL PC	CH4 MOLS MOL PC	CO MOLS MOL PC	H2 MOLS MOL PC	N2 MOLS MOL PC	TOTAL MOLS MOL PC
4.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	8.9881E 00	335.47 51.704	65.13 10.038	0.59 0.091	34.28 5.284	213.35 32.883	0. 0.	648.82 100.000
4.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	5.2221E 00	342.44 52.691	57.61 8.865	0.05 0.008	42.34 6.514	207.46 31.922	0. 0.	649.90 100.000
4.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	3.5173E 00	348.70 53.647	51.31 7.894	0.01 0.001	48.69 7.490	201.29 30.968	0. 0.	649.99 100.000
4.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	2.5868E 00	353.85 54.438	46.15 7.101	0.00 0.000	53.85 8.284	196.15 30.177	0. 0.	650.00 100.000
4.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	2.0306E 00	357.99 55.075	42.01 6.464	0.00 0.000	57.99 8.921	192.01 29.541	0. 0.	650.00 100.000
6.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	9.1281E 09	424.31 80.713	37.85 7.199	62.15 11.823	0.00 0.000	1.39 0.264	0. 0.	525.72 100.000
6.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	3.2241E 06	419.56 79.092	40.20 7.579	59.76 11.266	0.03 0.006	10.91 2.056	0. 0.	530.47 100.000
6.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.3505E 04	403.66 73.809	47.88 8.755	51.55 9.425	0.57 0.104	43.24 7.906	0. 0.	546.90 100.000
6.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.6790E 02	373.39 64.233	60.96 10.486	34.35 5.909	4.70 0.808	107.92 18.564	0. 0.	581.31 100.000
6.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	2.0252E 01	342.42 54.656	69.34 11.068	11.75 1.876	18.91 3.018	184.08 29.382	0. 0.	626.49 100.000
6.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	6.1508E 00	336.31 51.943	64.97 10.034	1.27 0.197	33.76 5.214	211.14 32.611	0. 0.	647.45 100.000
6.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	3.4893E 00	342.51 52.712	57.60 8.865	0.11 0.018	42.28 6.507	207.26 31.898	0. 0.	649.77 100.000
6.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	2.3455E 00	348.71 53.650	51.31 7.894	0.01 0.002	48.68 7.489	201.26 30.965	0. 0.	649.97 100.000
6.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	1.7246E 00	353.85 54.439	46.15 7.101	0.00 0.000	53.84 8.284	196.15 30.177	0. 0.	650.00 100.000
6.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	1.3537E 00	357.99 55.075	42.01 6.464	0.00 0.000	57.98 8.921	192.01 29.541	0. 0.	650.00 100.000
12.0000	400.00	7.9414E-12	2.0711E 02	4.0007E 09	9.2191E 09	424.51 80.783	37.75 7.183	62.25 11.847	0.00 0.000	0.98 0.187	0. 0.	525.49 100.000
12.0000	600.00	2.1990E-07	3.1479E 01	1.0438E 06	3.2454E 06	421.12 79.622	39.43 7.455	60.55 11.448	0.02 0.004	7.78 1.471	0. 0.	528.90 100.000
12.0000	800.00	2.6585E-04	9.0223E 00	3.7690E 03	1.3724E 04	409.43 75.686	45.09 8.336	54.52 10.079	0.38 0.071	31.53 5.828	0. 0.	540.96 100.000
12.0000	1000.00	4.9018E-02	3.7523E 00	6.4774E 01	2.6436E 02	385.56 67.928	55.64 9.803	41.20 7.259	3.16 0.556	82.04 14.454	0. 0.	567.60 100.000
12.0000	1200.00	2.6875E 00	1.9714E 00	3.0042E 00	1.6357E 01	355.60 58.429	65.09 10.696	20.70 3.401	14.21 2.334	153.00 25.139	0. 0.	608.60 100.000
12.0000	1400.00	6.3697E 01	1.2081E 00	2.7306E-01	3.4496E 00	339.93 52.978	64.26 10.015	4.18 0.652	31.56 4.919	201.71 31.436	0. 0.	641.63 100.000
12.0000	1600.00	8.2139E 02	8.2439E-01	4.0069E-02	1.7657E 00	342.89 52.824	57.56 8.868	0.45 0.069	41.99 6.469	206.22 31.770	0. 0.	649.11 100.000
12.0000	1800.00	6.7984E 03	6.0833E-01	8.3445E-03	1.1745E 00	348.75 53.664	51.30 7.894	0.06 0.003	48.64 7.484	201.13 30.949	0. 0.	649.89 100.000
12.0000	2000.00	4.0014E 04	4.7516E-01	2.2622E-03	8.6253E-01	353.86 54.441	46.15 7.101	0.01 0.002	53.84 8.283	196.12 30.174	0. 0.	649.98 100.000
12.0000	2200.00	1.8036E 05	3.8864E-01	7.5373E-04	6.7690E-01	357.99 55.075	42.01 6.464	0.00 0.000	57.98 8.921	192.01 29.540	0. 0.	650.00 100.000

FIGURE F-1

EFFECT OF TEMPERATURE AND STEAM/CARBON RATIO ON
HYDROGEN YIELD FROM C_9H_{20} HYDROCARBONS

1 ATMOSPHERE PRESSURE



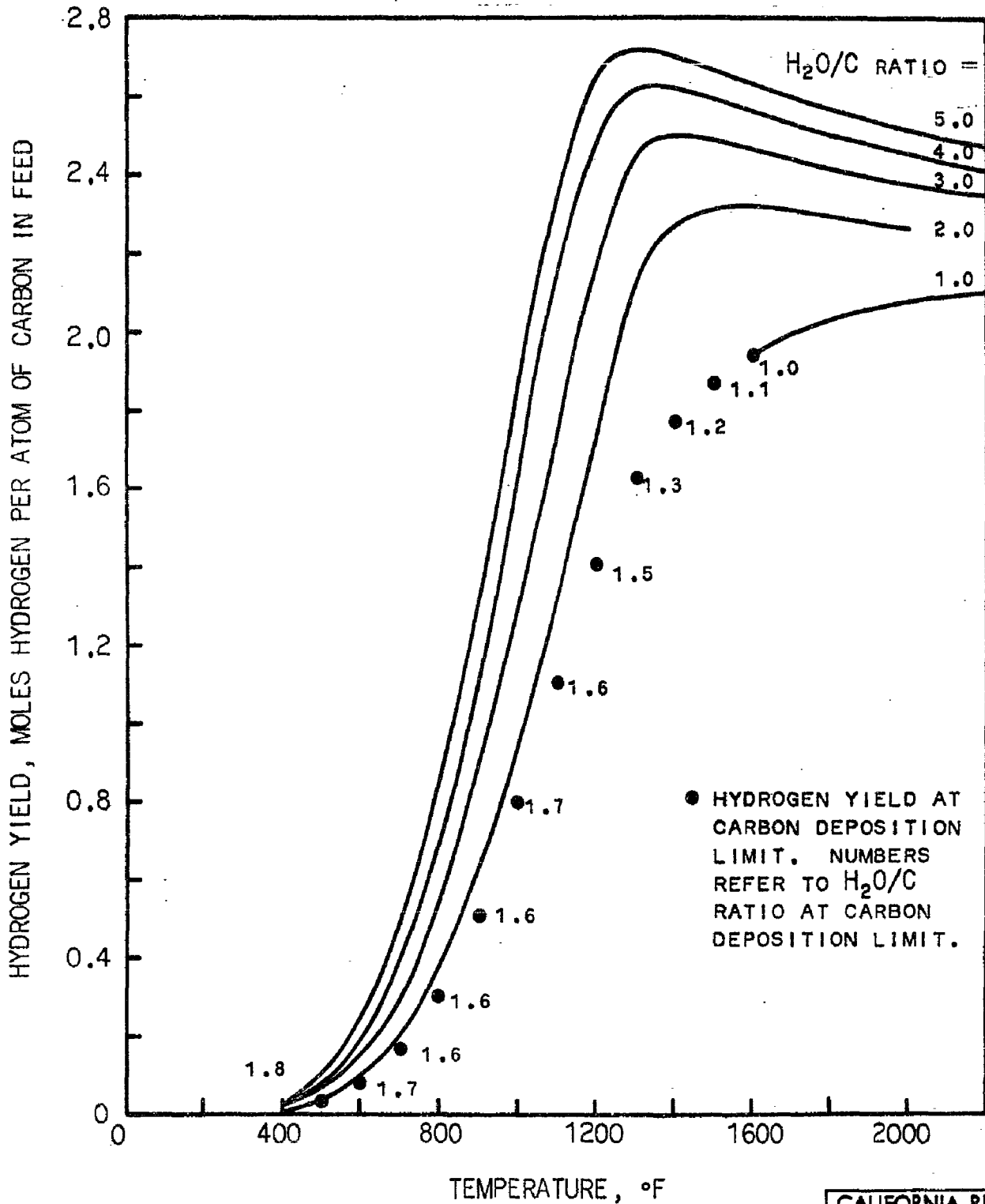
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MJS RE 647527

FIGURE F-2

EFFECT OF TEMPERATURE AND STEAM/CARBON RATIO ON
HYDROGEN YIELD FROM C_9H_{20} HYDROCARBONS

2 ATMOSPHERES PRESSURE



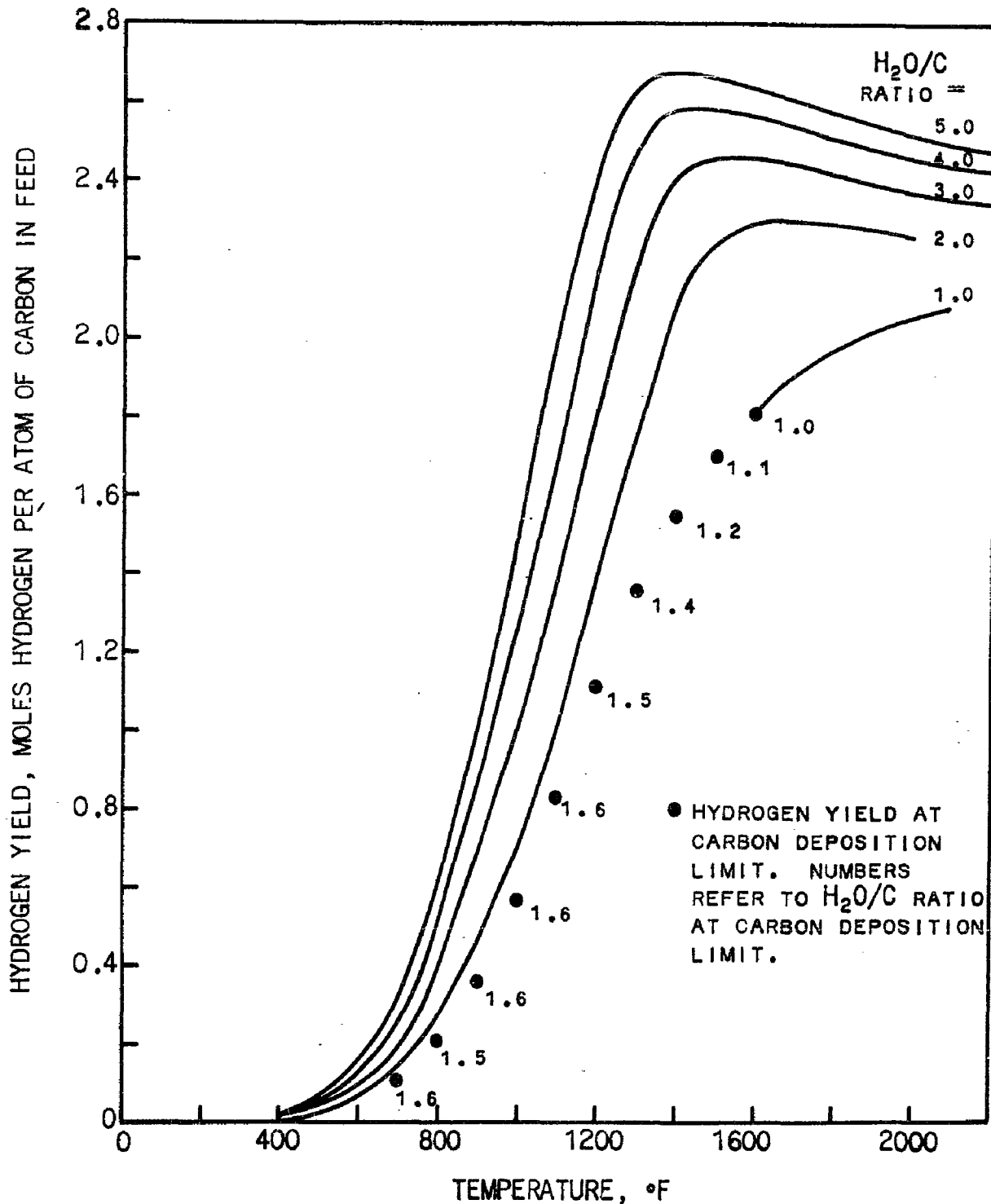
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MJS RE 647528

FIGURE F-3

EFFECT OF TEMPERATURE AND STEAM/CARBON RATIO ON
HYDROGEN YIELD FROM C_9H_{20} HYDROCARBONS

4 ATMOSPHERES PRESSURE



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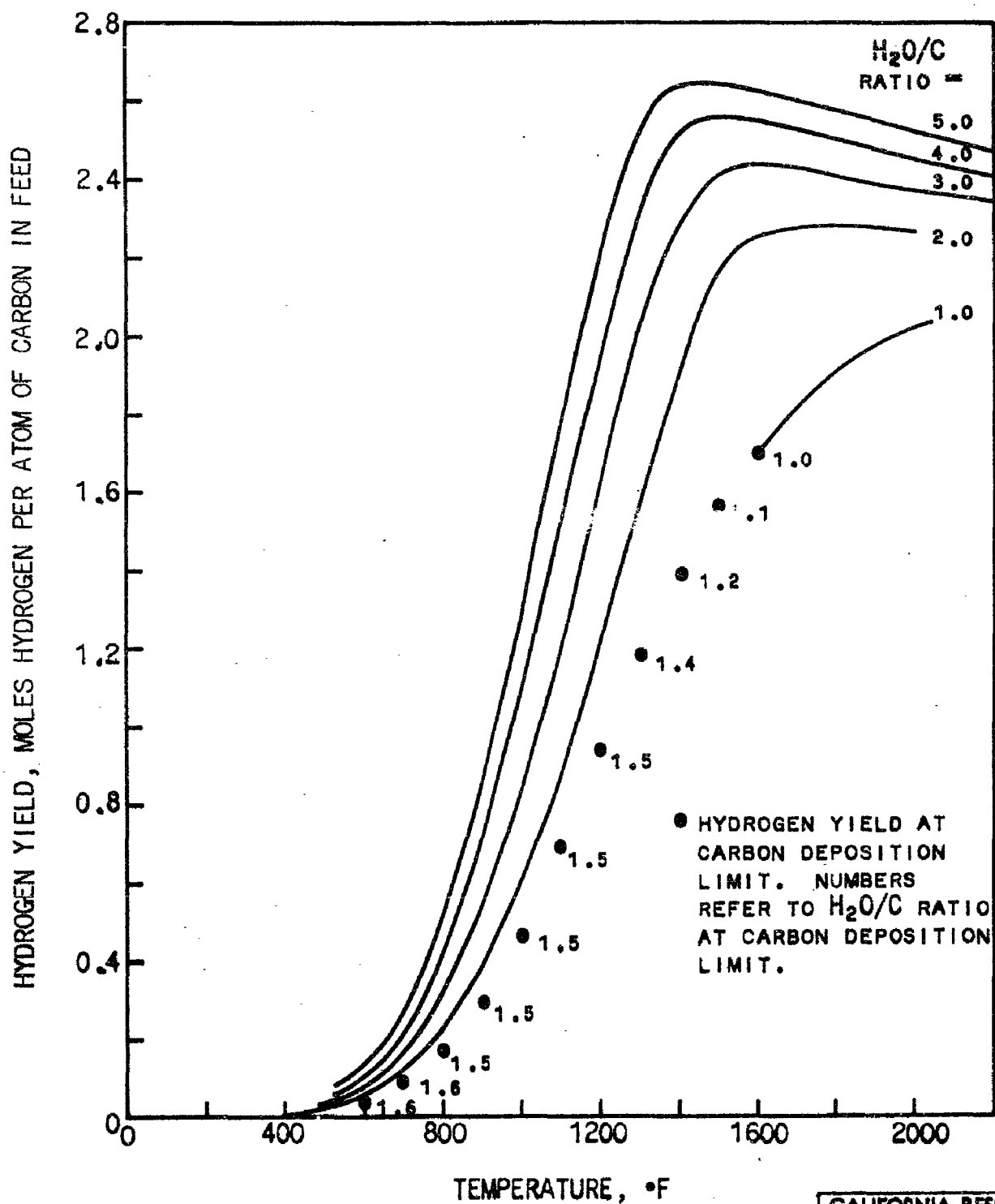
F-59

11-6-64

FIGURE F-4

EFFECT OF TEMPERATURE AND STEAM/CARBON RATIO ON
HYDROGEN YIELD FROM C_9H_{20} HYDROCARBONS

6 ATMOSPHERES PRESSURE



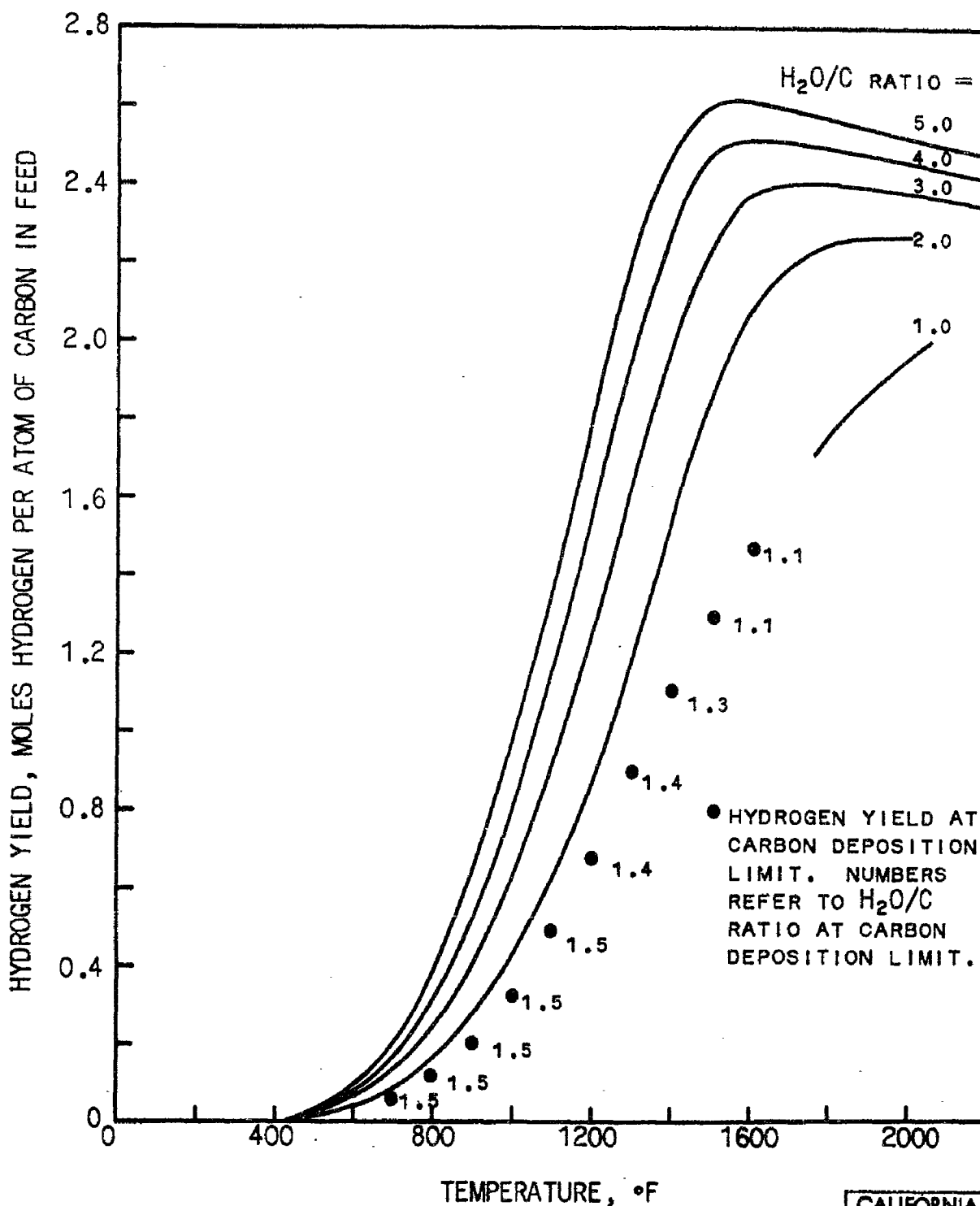
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MJS RE 647530

FIGURE F-5

EFFECT OF TEMPERATURE AND STEAM/CARBON RATIO ON
HYDROGEN YIELD FROM C_9H_{20} HYDROCARBONS

12 ATMOSPHERES PRESSURE



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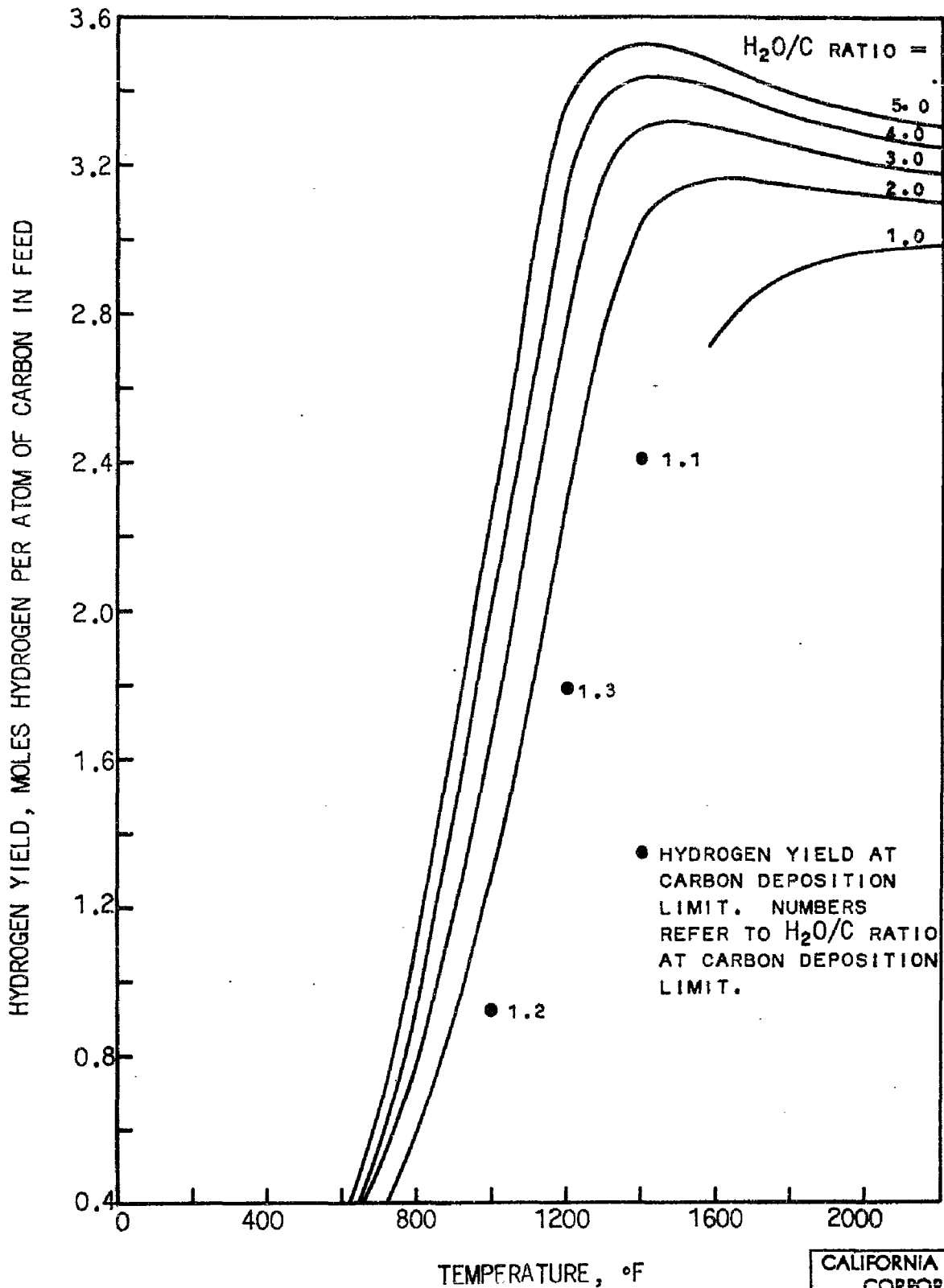
MJS RE 647531

FIGURE F-6

A-F-6

EFFECT OF TEMPERATURE AND STEAM/CARBON RATIO ON
HYDROGEN YIELD FROM CH_4

2 ATMOSPHERES PRESSURE

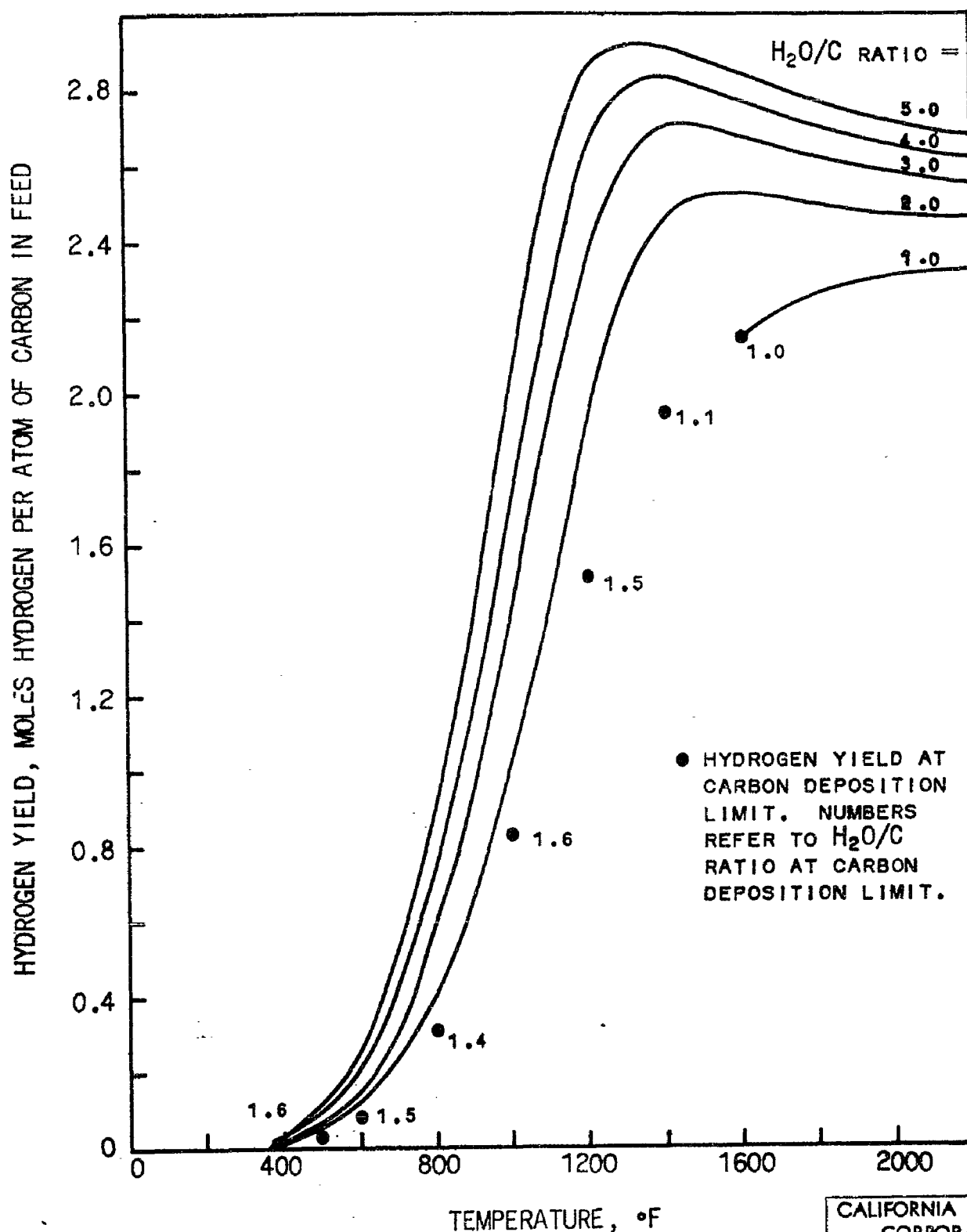


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FIGURE F-7

EFFECT OF TEMPERATURE AND STEAM/CARBON RATIO ON
HYDROGEN YIELD FROM C_3H_8

2 ATMOSPHERES PRESSURE



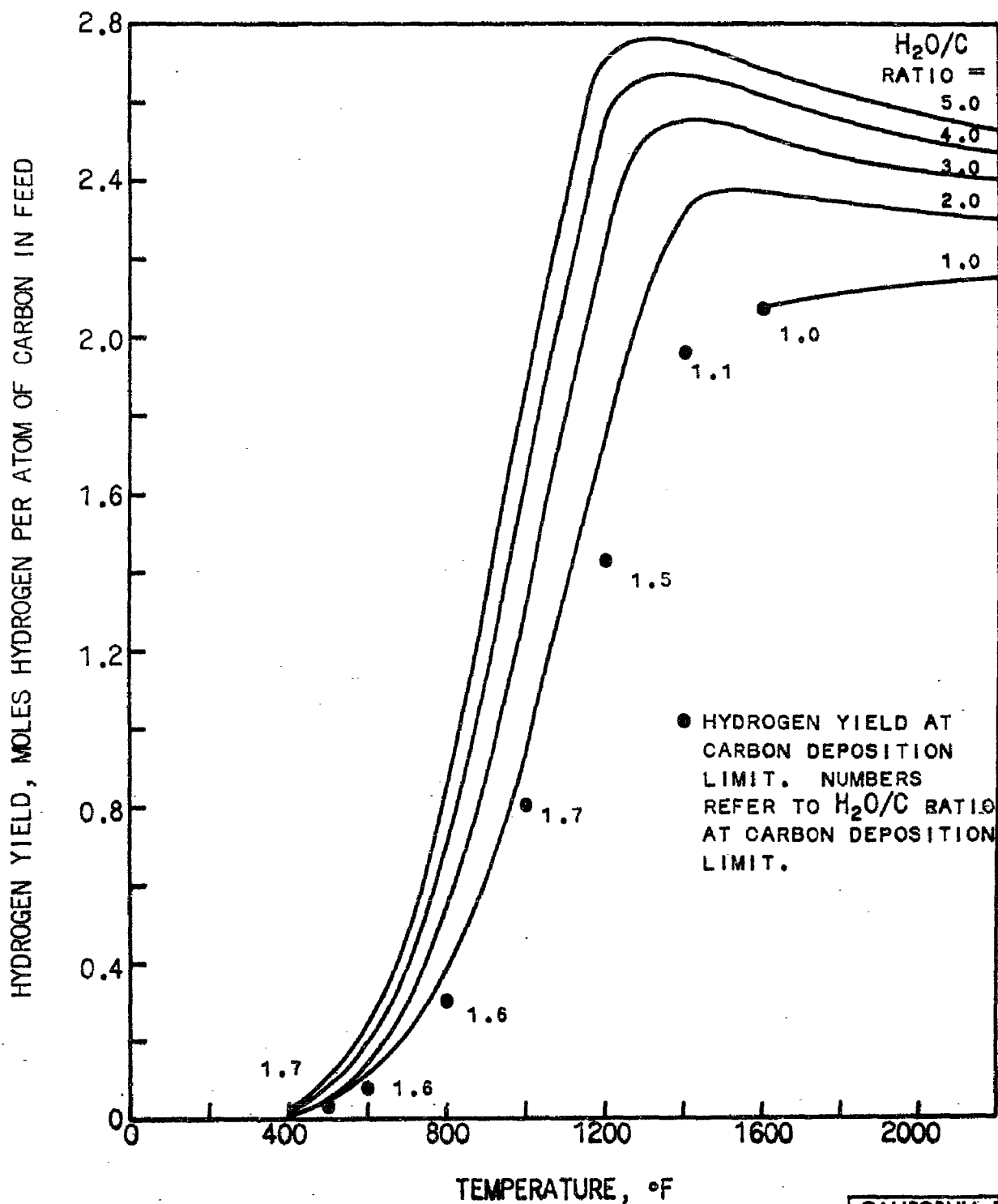
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FIGURE F-8

EFFECT OF TEMPERATURE AND STEAM/CARBON RATIO ON
HYDROGEN YIELD FROM C_6H_{14} HYDROCARBONS

2 ATMOSPHERES PRESSURE



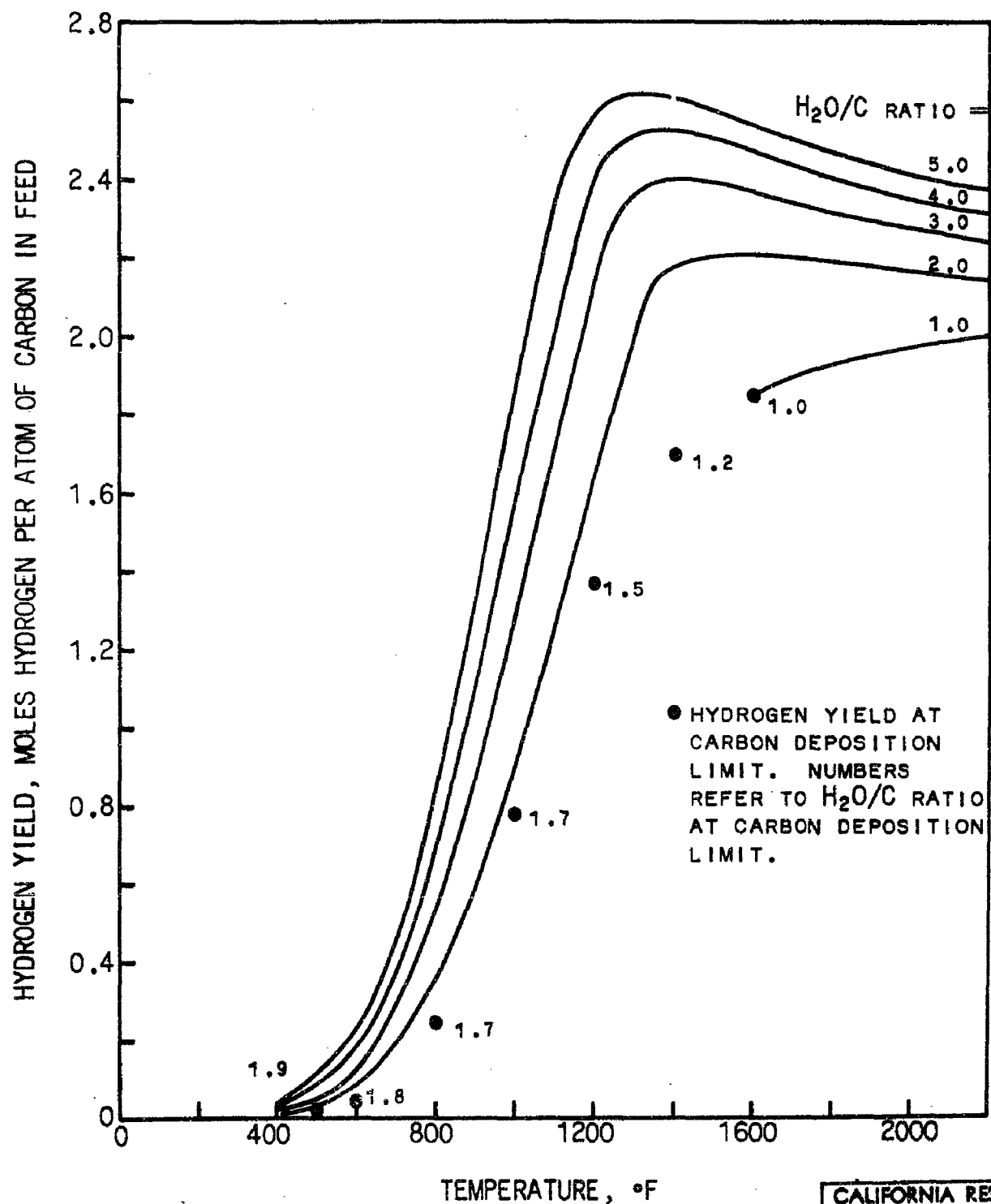
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MJS RE 647534

FIGURE F-9

EFFECT OF TEMPERATURE AND STEAM/CARBON RATIO ON
HYDROGEN YIELD FROM C_NH_{2N} HYDROCARBONS

2 ATMOSPHERES PRESSURE



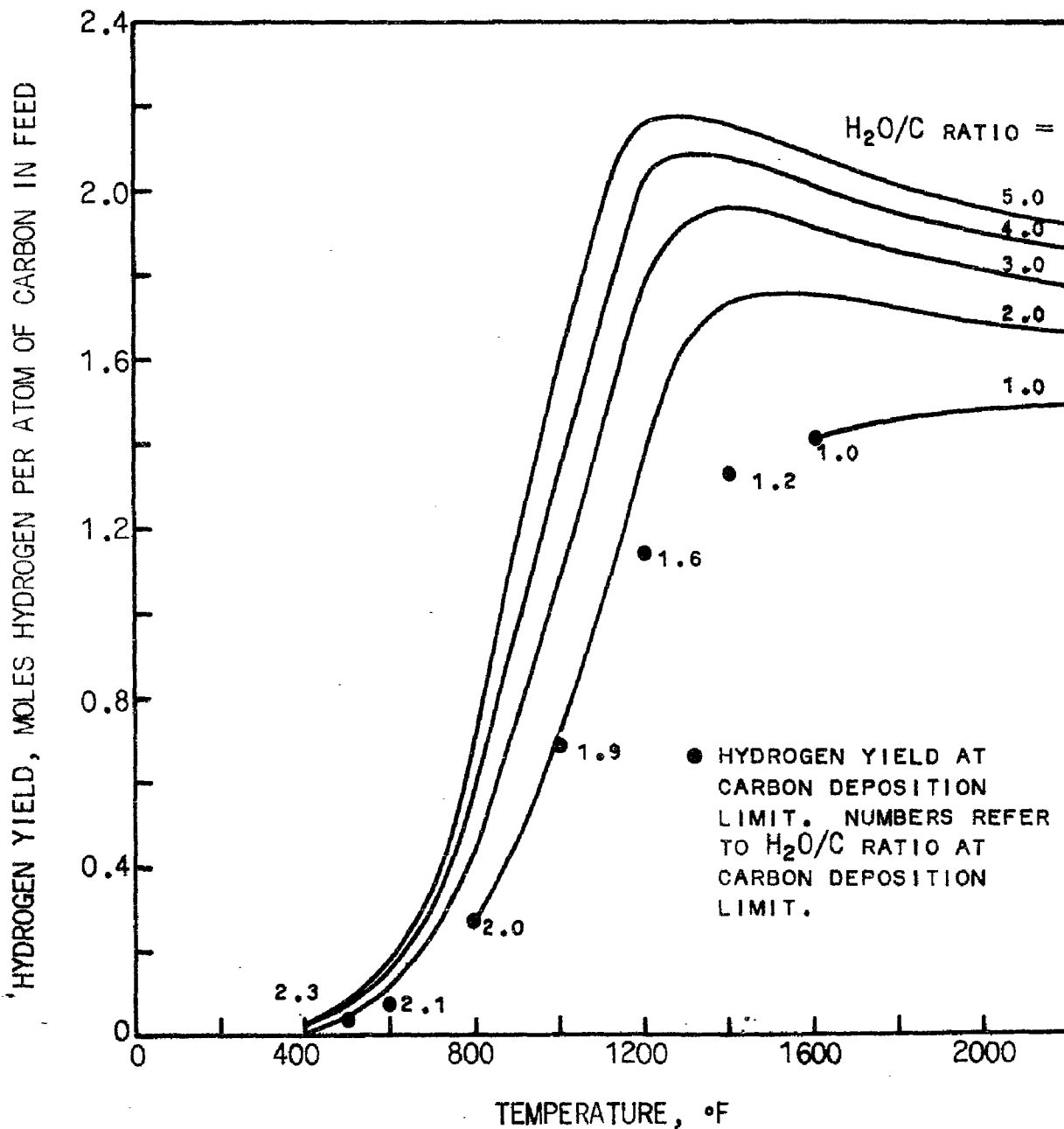
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FIGURE F-10

EFFECT OF TEMPERATURE AND STEAM/CARBON RATIO ON
HYDROGEN YIELD FROM C_NH_N HYDROCARBONS

2 ATMOSPHERES PRESSURE

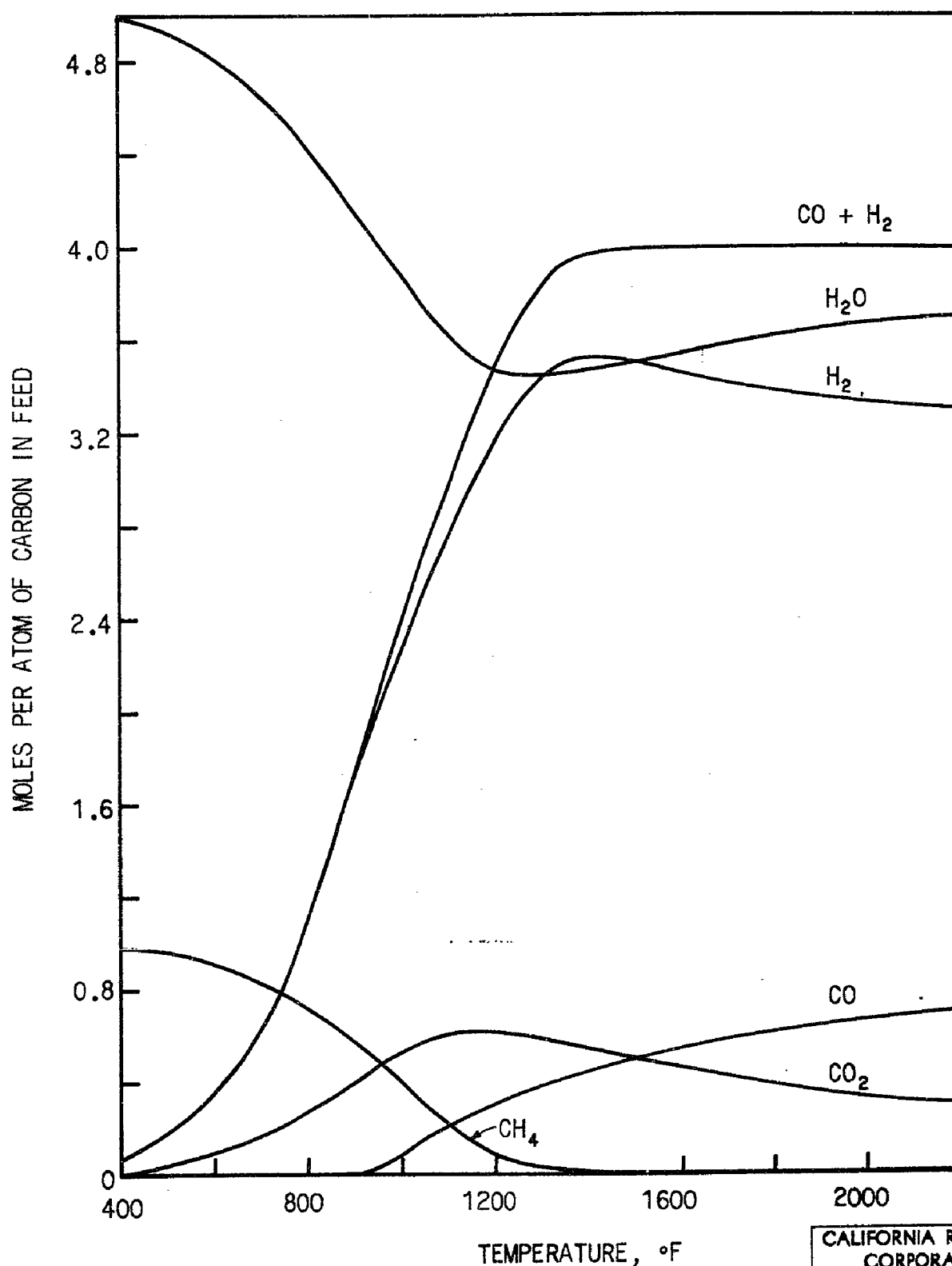


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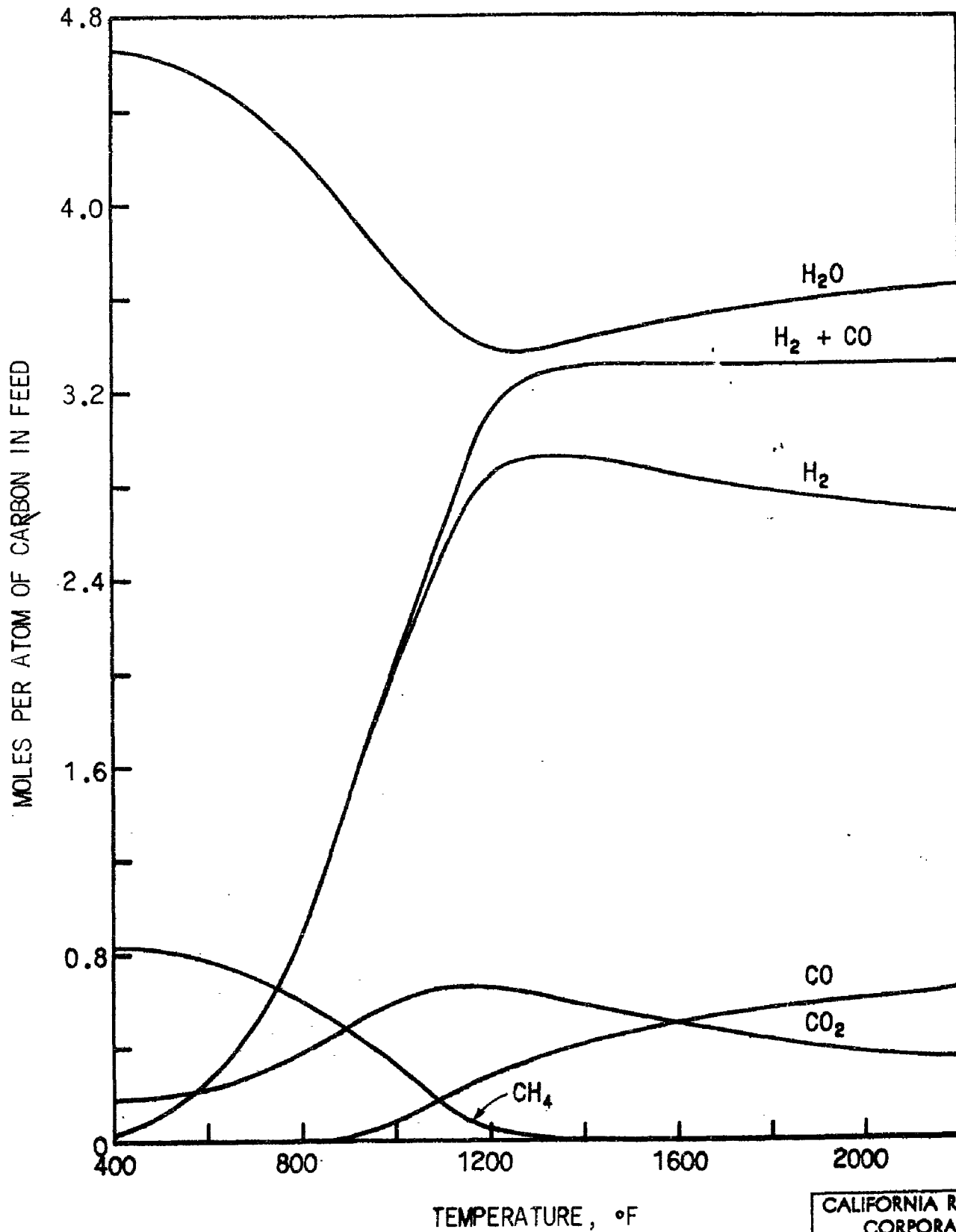
EFFECT OF TEMPERATURE ON COMPOSITION OF
STEAM REFORMATE FROM CH_4 - STEAM/CARBON RATIO, 5.0

2 ATMOSPHERES PRESSURE

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EFFECT OF TEMPERATURE ON COMPOSITION OF
STEAM REFORMATE FROM C_3H_8 - STEAM/CARBON RATIO, 5.0

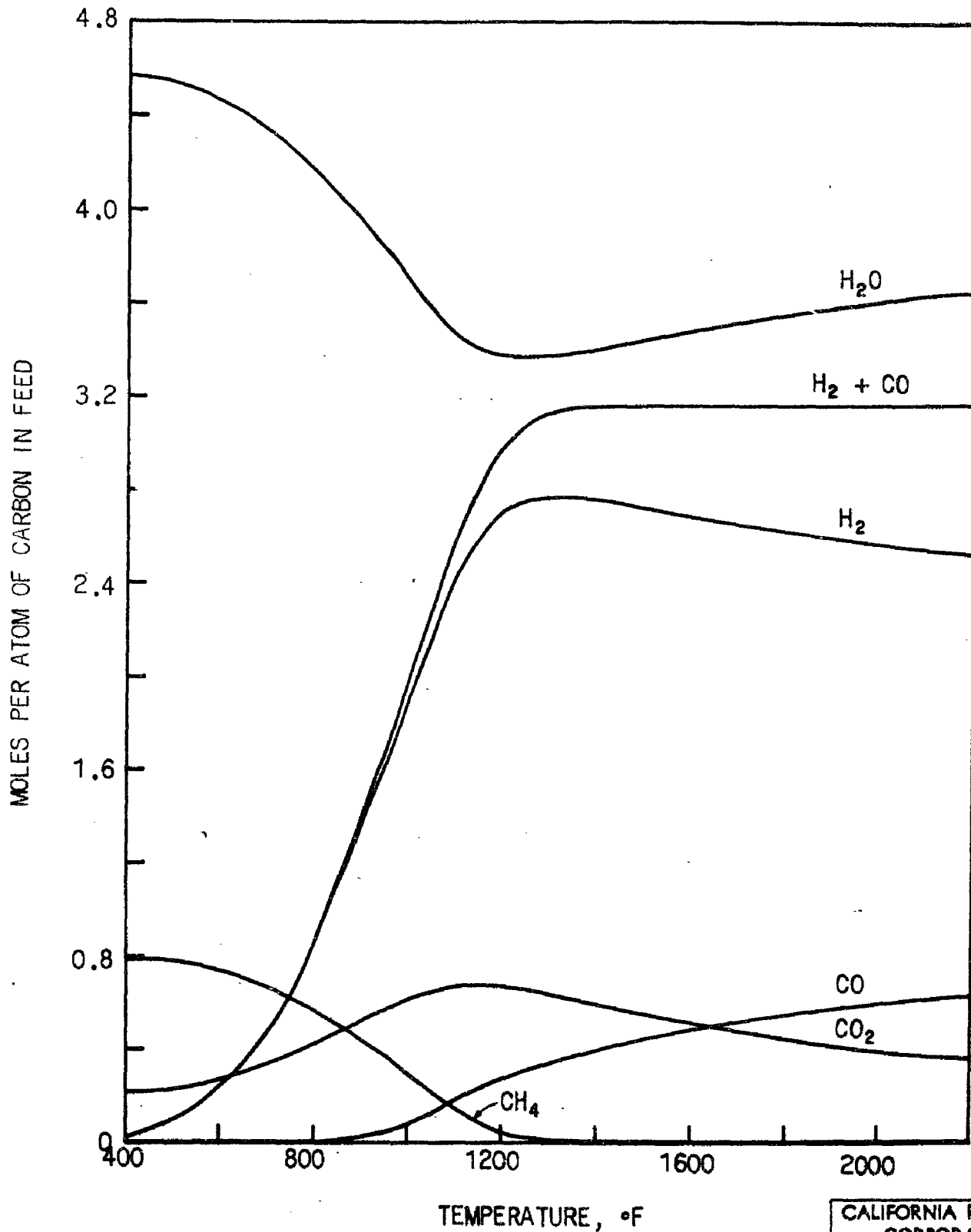
2 ATMOSPHERES PRESSURE

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EFFECT OF TEMPERATURE ON COMPOSITION OF
STEAM REFORMATE FROM C_6H_{14} HYDROCARBONS - STEAM/CARBON RATIO, 5.0

2 ATMOSPHERES PRESSURE

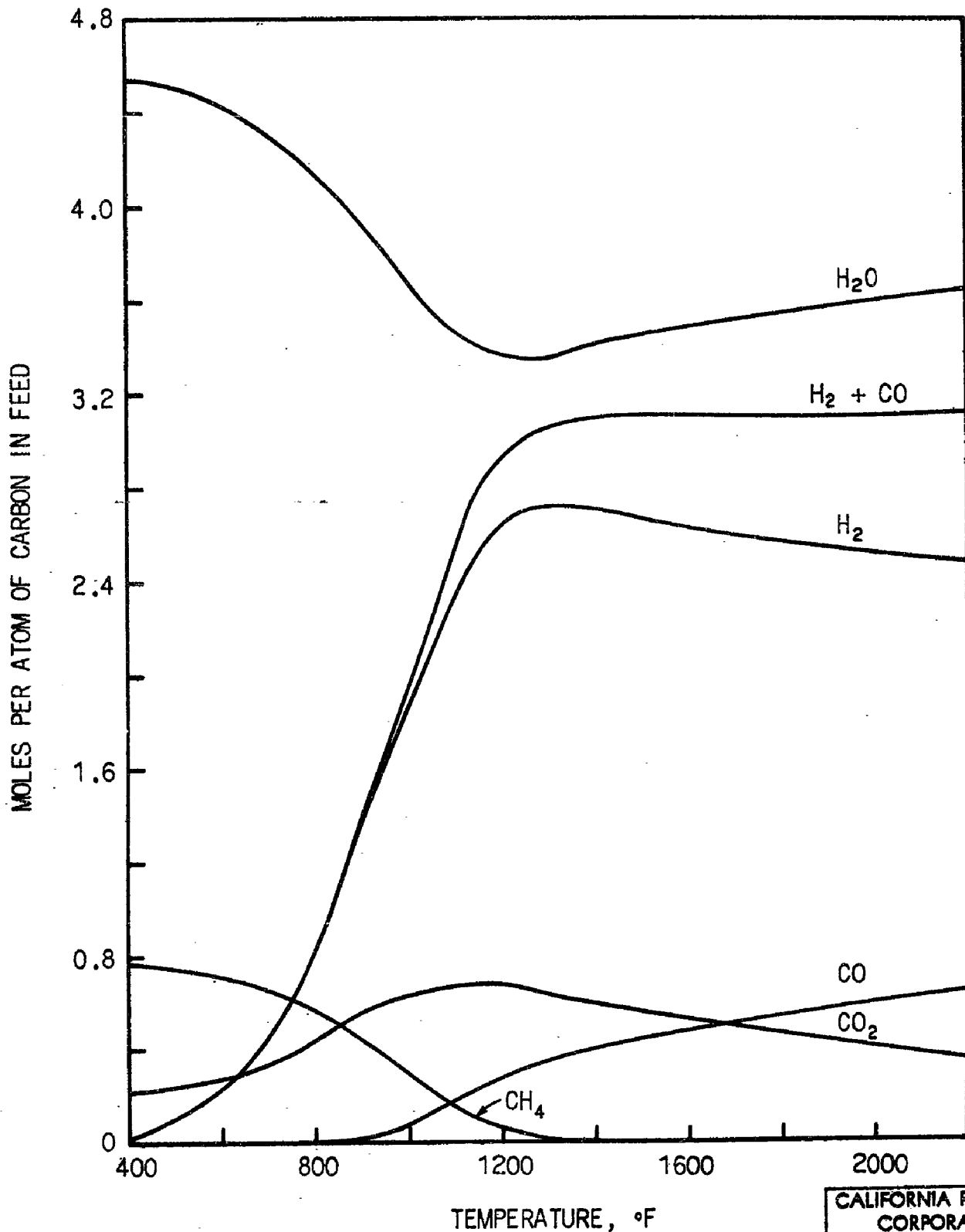


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FIGURE F-14

EFFECT OF TEMPERATURE ON COMPOSITION OF STEAM REFORMATE FROM
 C_9H_{20} HYDROCARBONS - STEAM/CARBON RATIO, 5.0

2 ATMOSPHERES PRESSURE



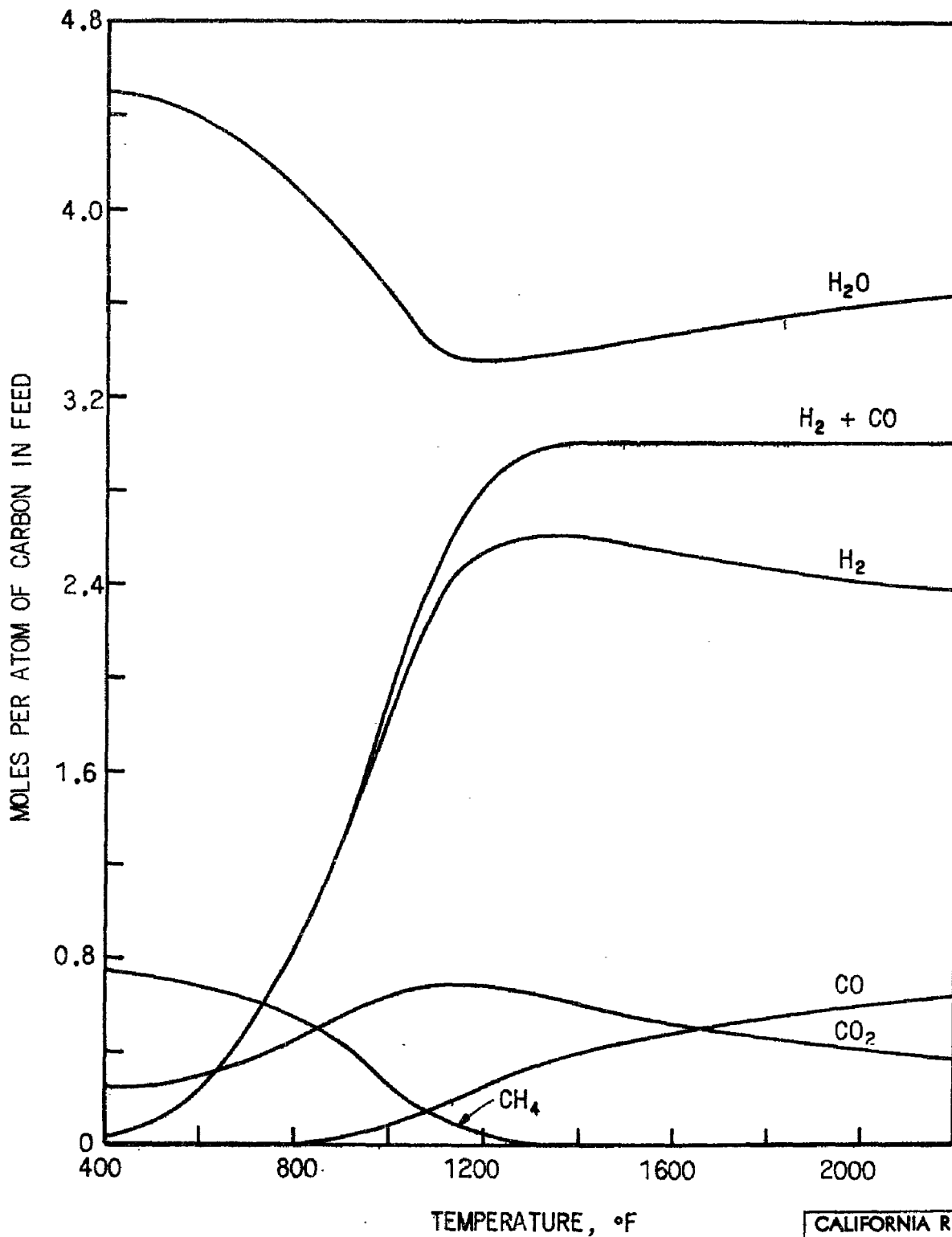
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F-70

MJS RE. 647540

EFFECT OF TEMPERATURE ON COMPOSITION OF
STEAM REFORMATE FROM C_NH_{2N} HYDROCARBONS - STEAM/CARBON RATIO, 5.0

2 ATMOSPHERES PRESSURE

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FIGURE F-16

EFFECT OF TEMPERATURE ON COMPOSITION OF
STEAM REFORMATE FROM C_NH_N HYDROCARBONS - STEAM/CARBON RATIO, 5.0

2 ATMOSPHERES PRESSURE

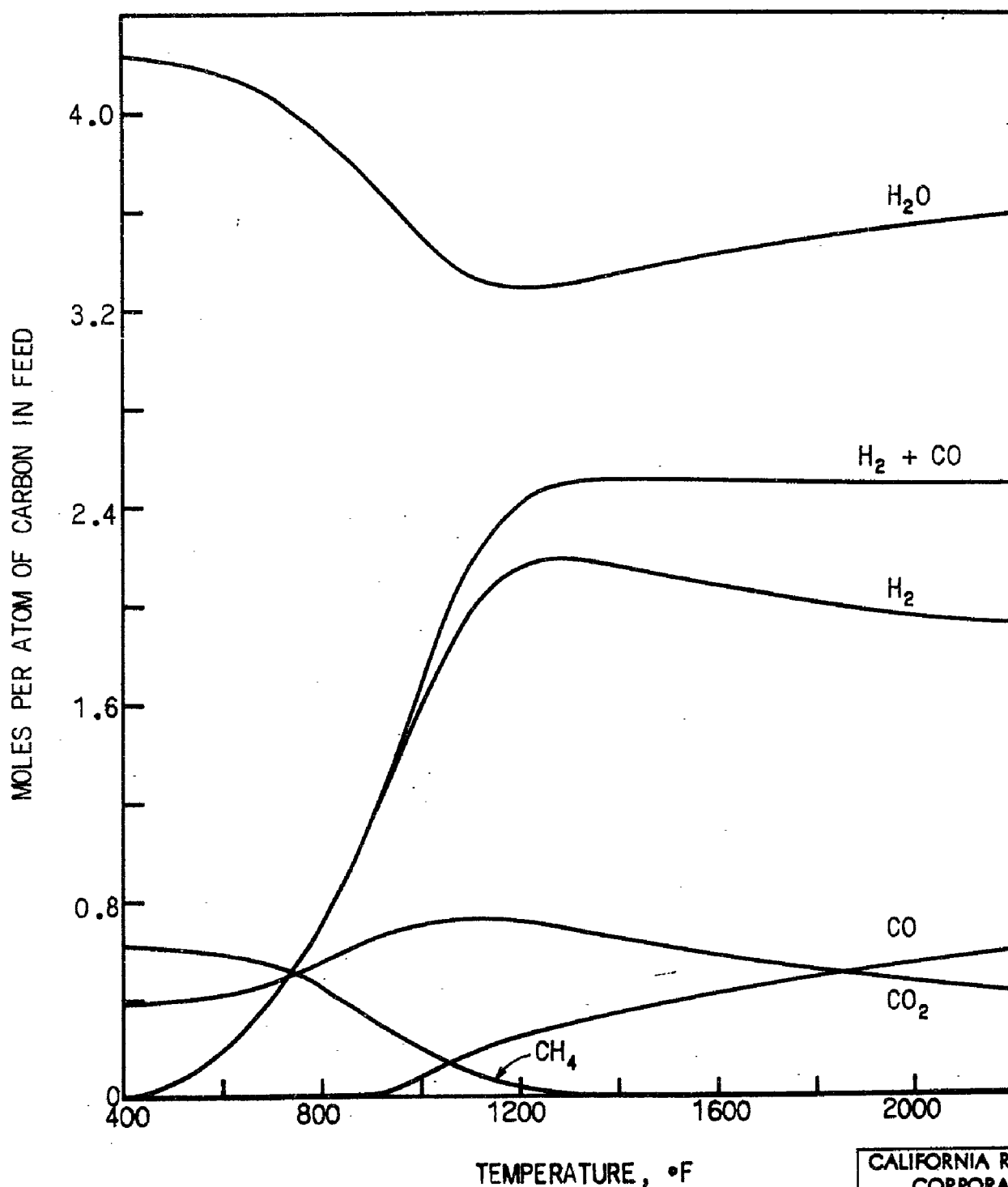
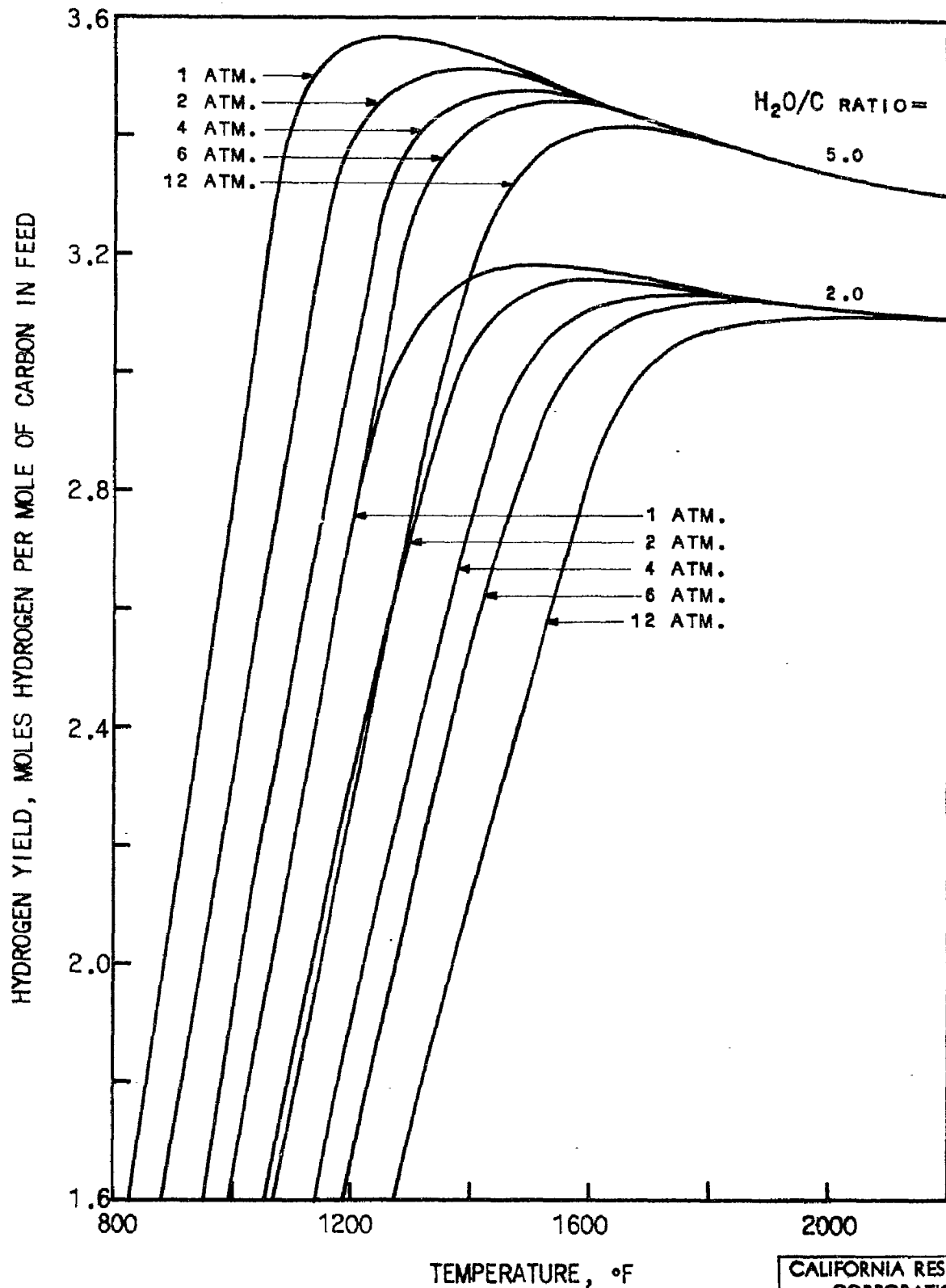
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FIGURE F-17

A-F-17

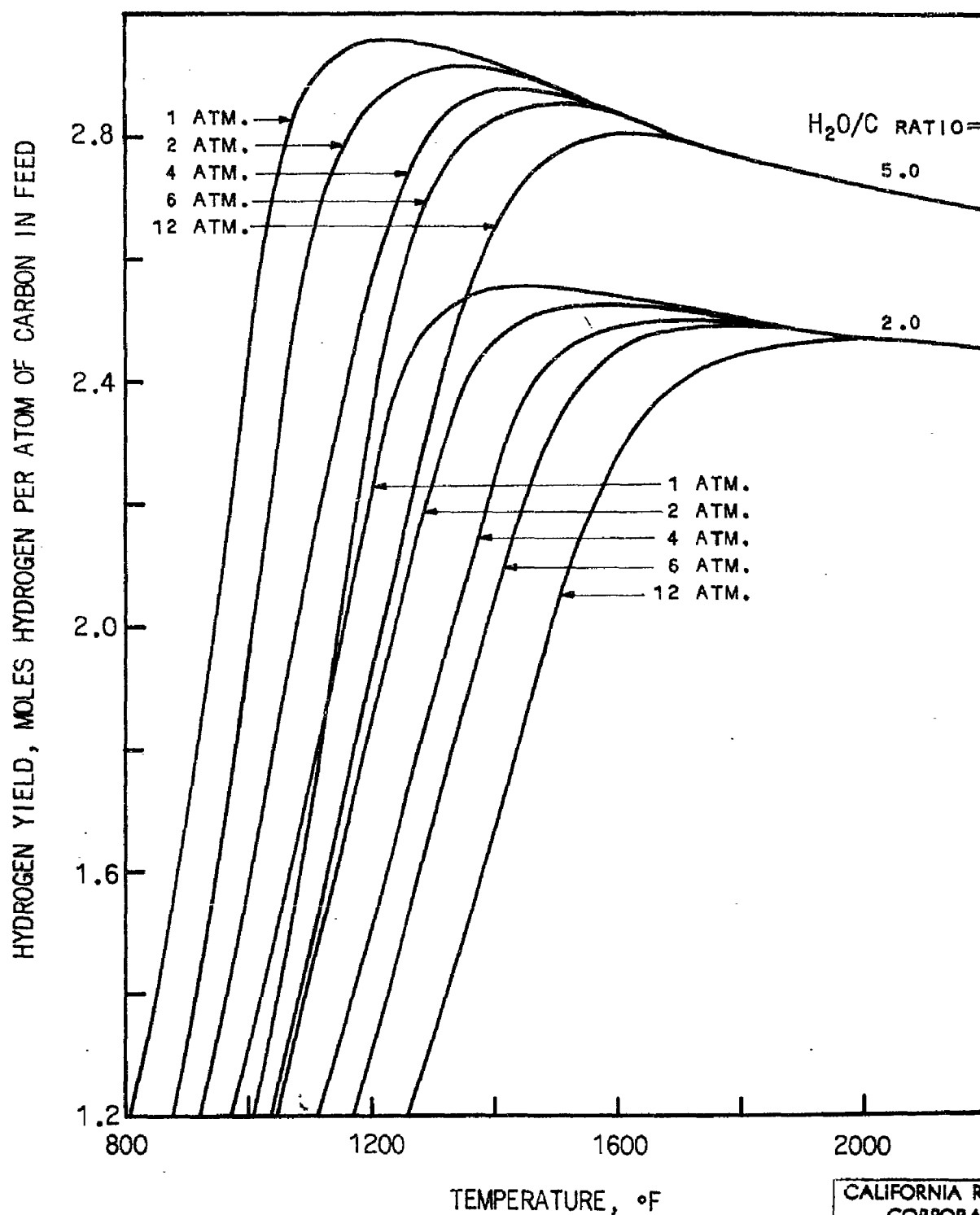
EFFECT OF PRESSURE ON HYDROGEN YIELD FROM CH_4
STEAM/CARBON RATIOS, 2.0 AND 5.0



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FIGURE F-18

EFFECT OF PRESSURE ON HYDROGEN YIELD FROM C_3H_8
STEAM/CARBON RATIOS, 2.0 AND 5.0



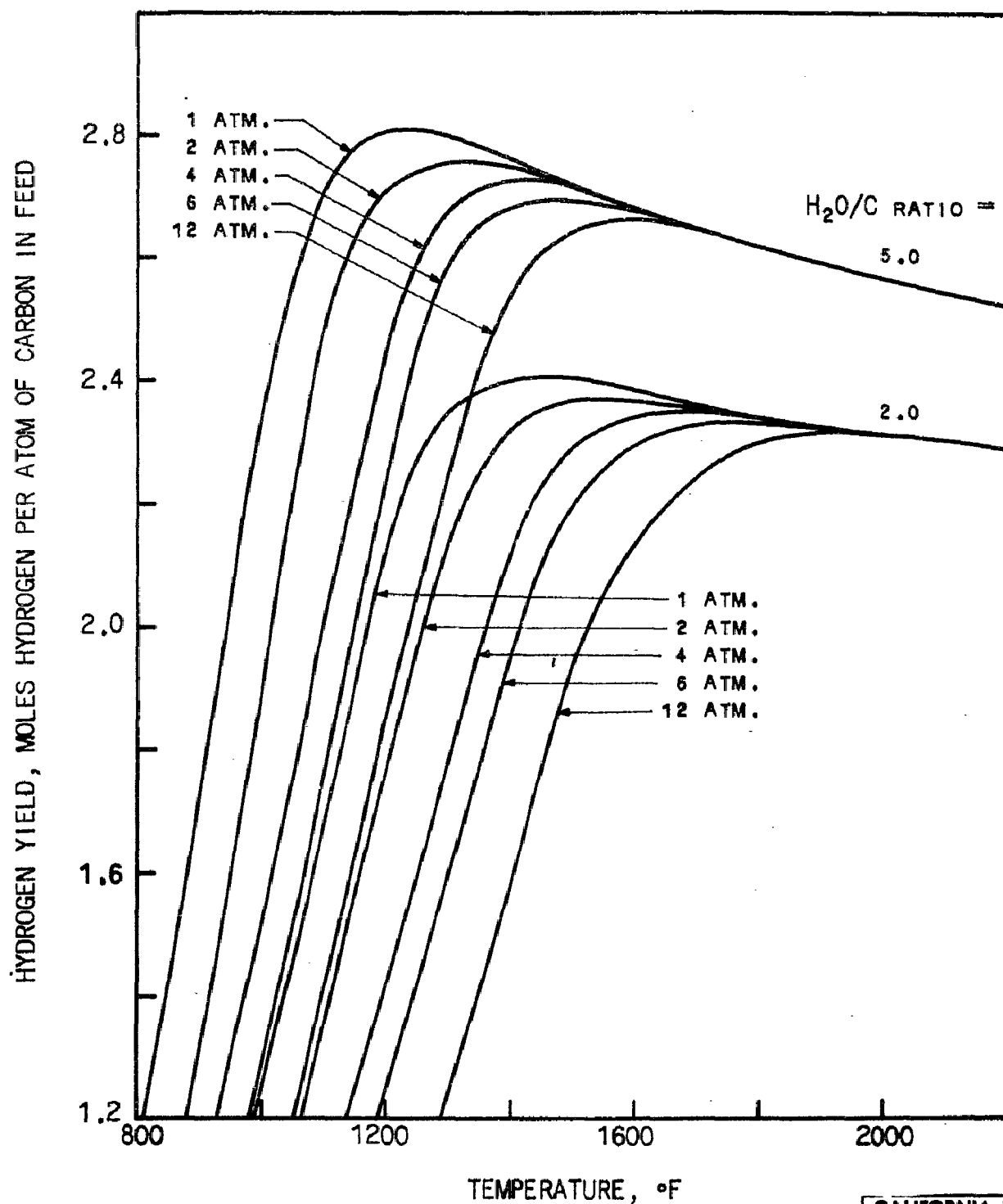
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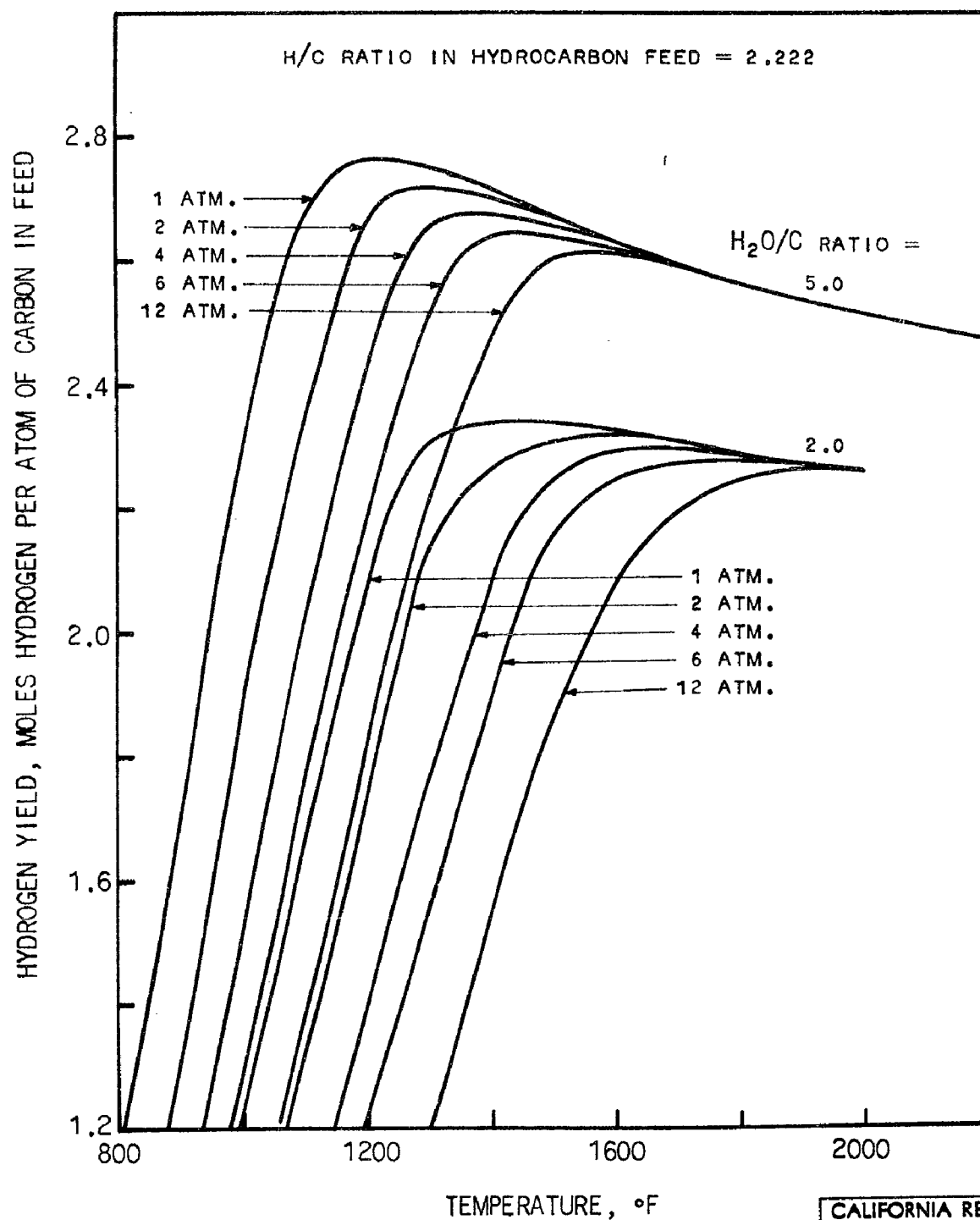
FIGURE F-19

EFFECT OF PRESSURE ON HYDROGEN YIELD FROM C_6H_{14} HYDROCARBONS
STEAM/CARBON RATIOS, 2.0 AND 5.0



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FIGURE F-20
EFFECT OF PRESSURE ON HYDROGEN YIELD FROM
 C_9H_{20} HYDROCARBONS

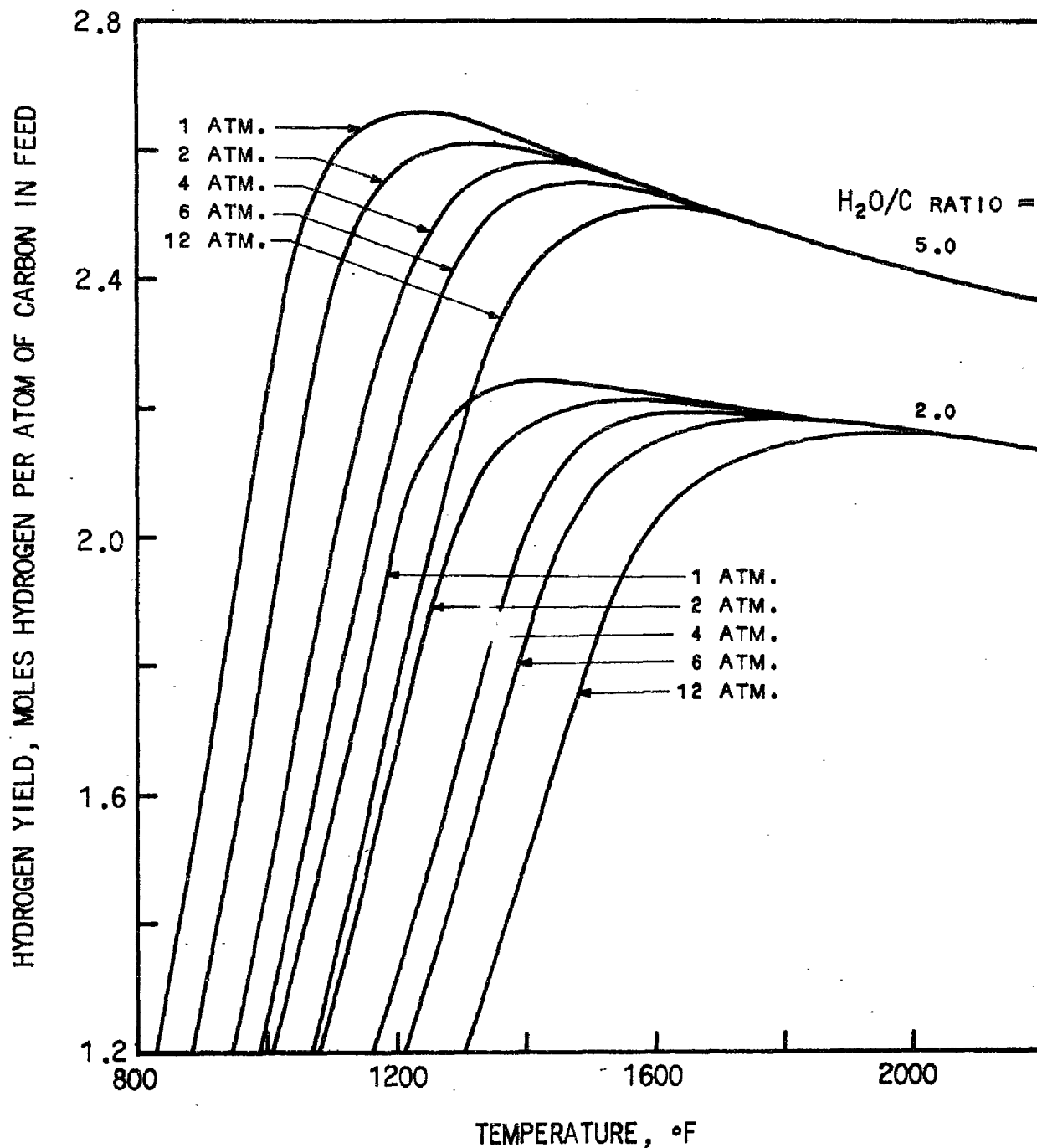


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MJS RE 647546

FIGURE F-21

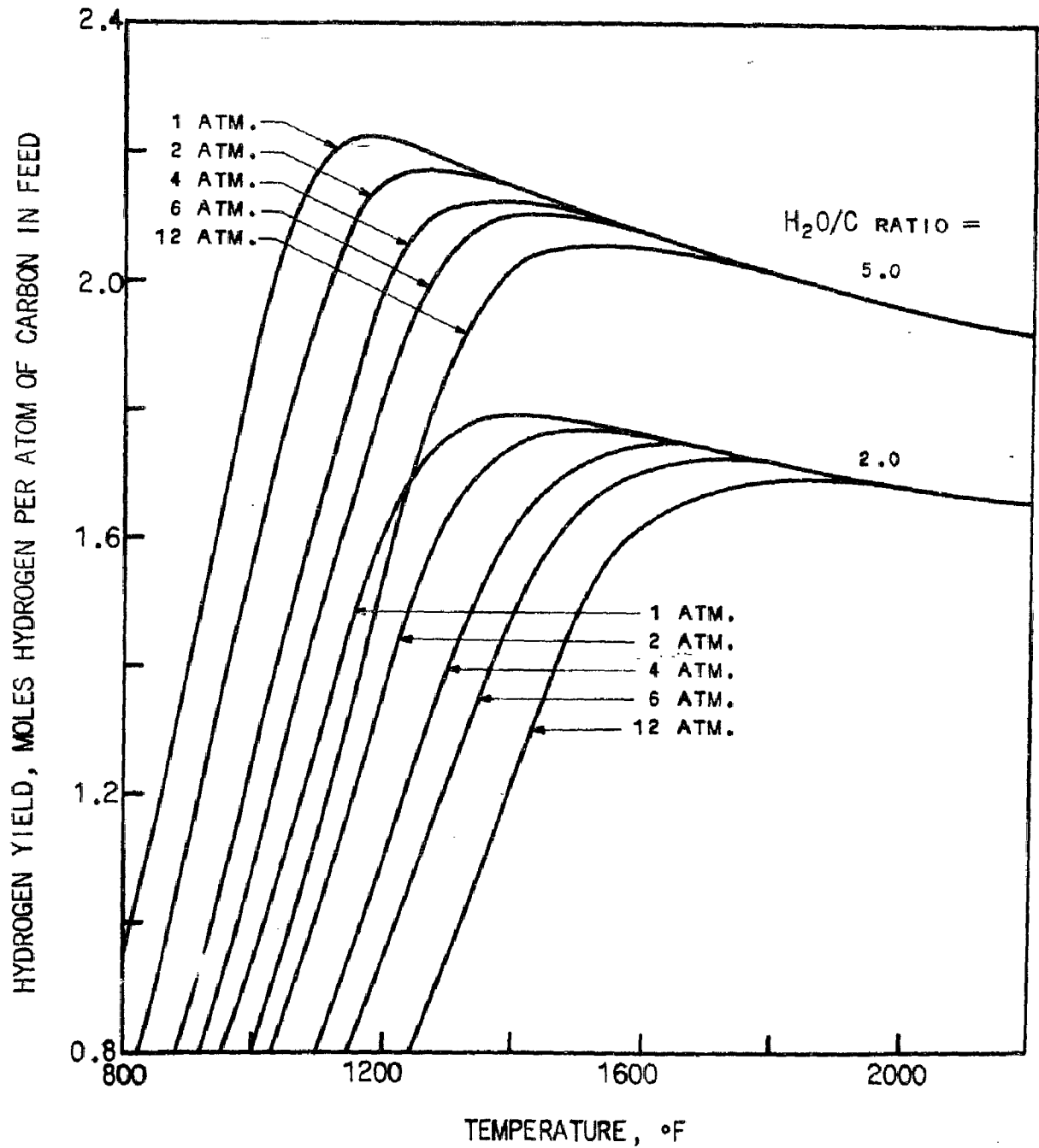
EFFECT OF PRESSURE ON HYDROGEN YIELD FROM C_NH_{2N} HYDROCARBONS
STEAM/CARBON RATIOS, 2.0 AND 5.0



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FIGURE F-22

EFFECT OF PRESSURE ON HYDROGEN YIELD FROM C_NH_M HYDROCARBONS
STEAM/CARBON RATIOS, 2.0 AND 5.0



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A P P E N D I X G

THEORETICAL CARBON DEPOSITION LIMITS IN HYDROCARBON STEAM REFORMING

The carbon deposition limits plotted in Appendix Figures G-1 to G-6 were obtained as described in Section X-C. Carbon deposition limits are discussed in Section X-D-1.

:msr

FIGURE G-1

A-E-1

EFFECT OF PRESSURE ON STEAM/CARBON RATIO REQUIRED TO
PREVENT CARBON DEPOSITION FROM CH_4

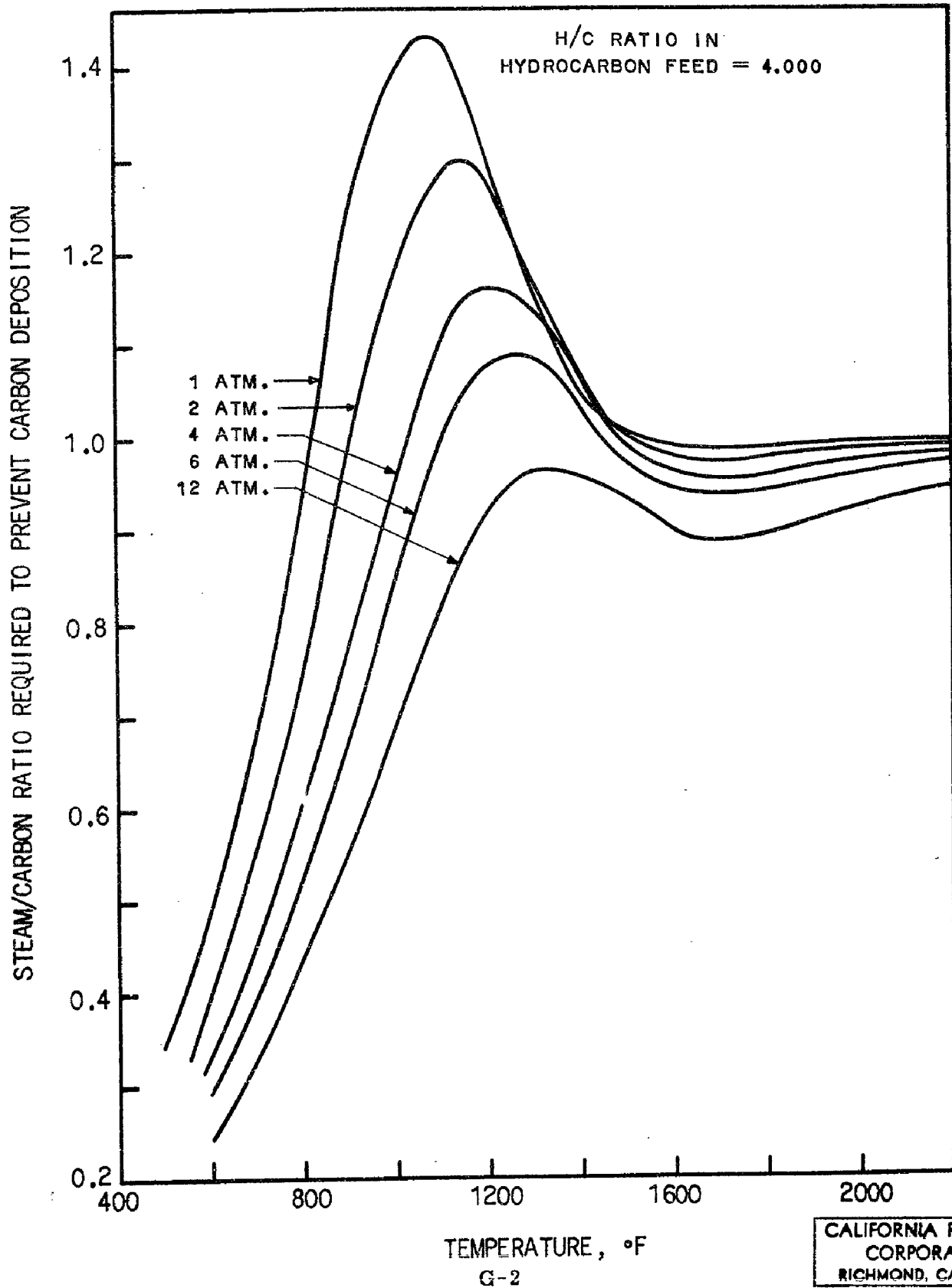
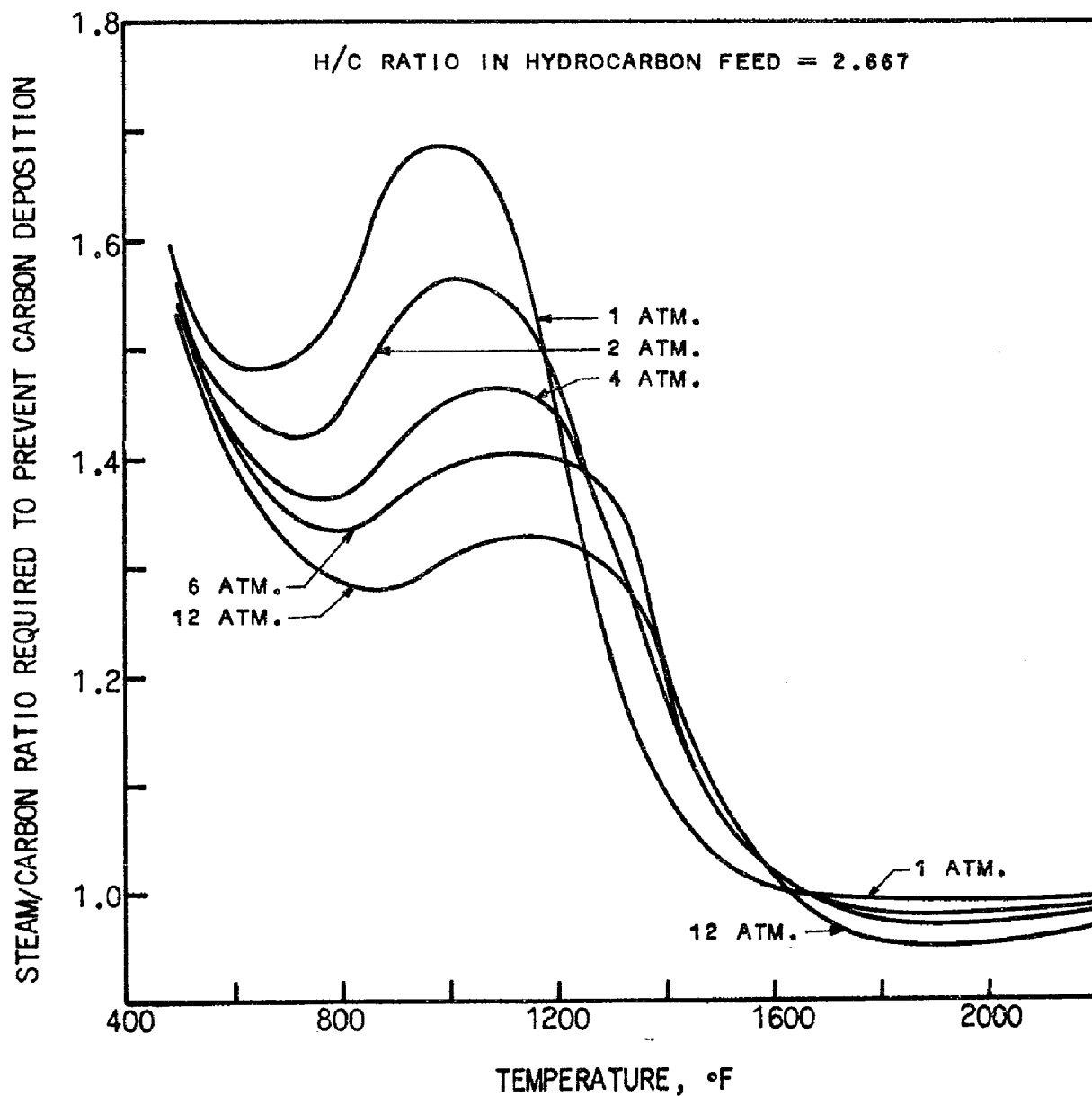


FIGURE G-2

EFFECT OF PRESSURE ON STEAM/CARBON RATIO REQUIRED TO
PREVENT CARBON DEPOSITION FROM C_3H_8



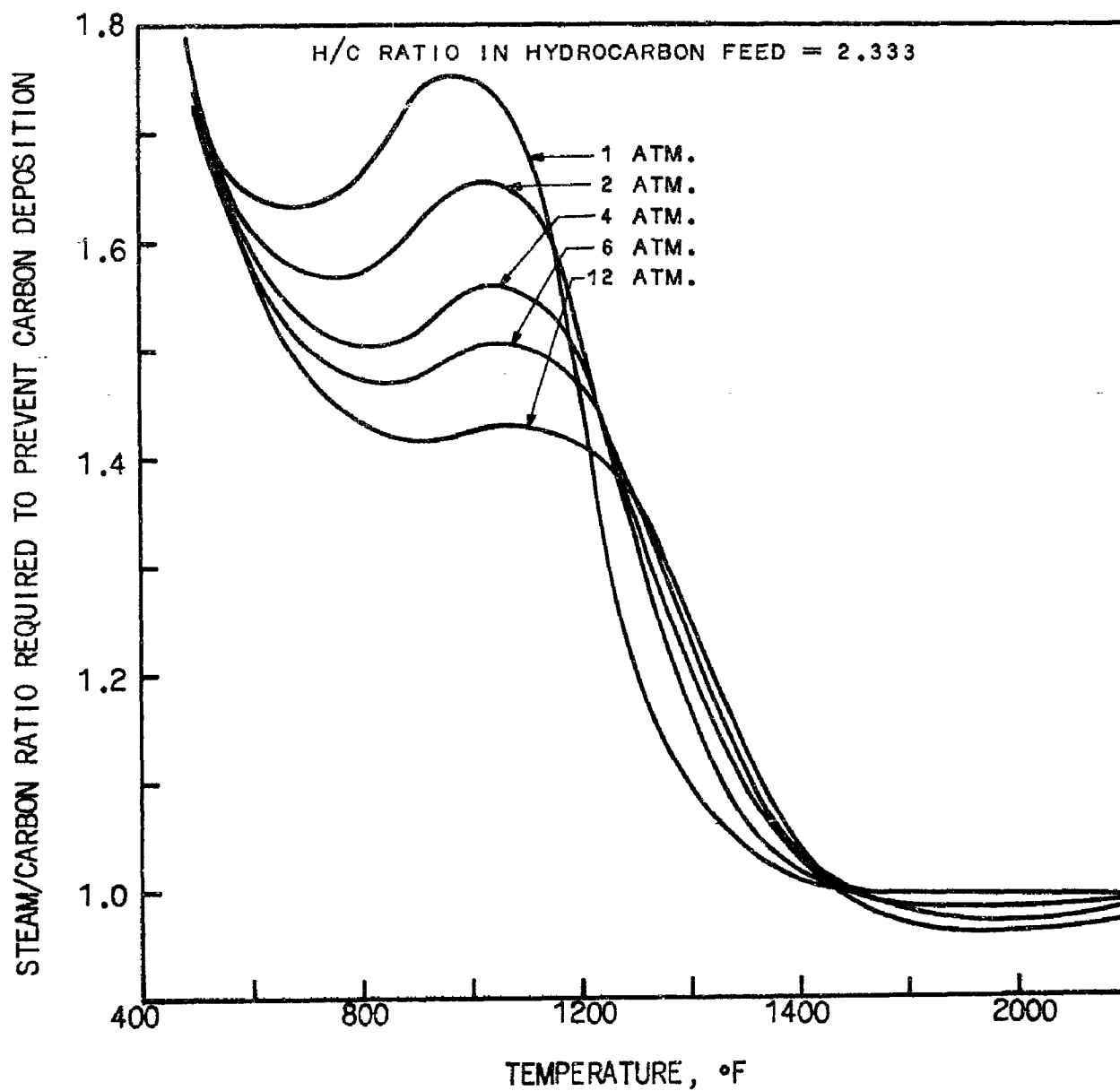
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FIGURE G-3

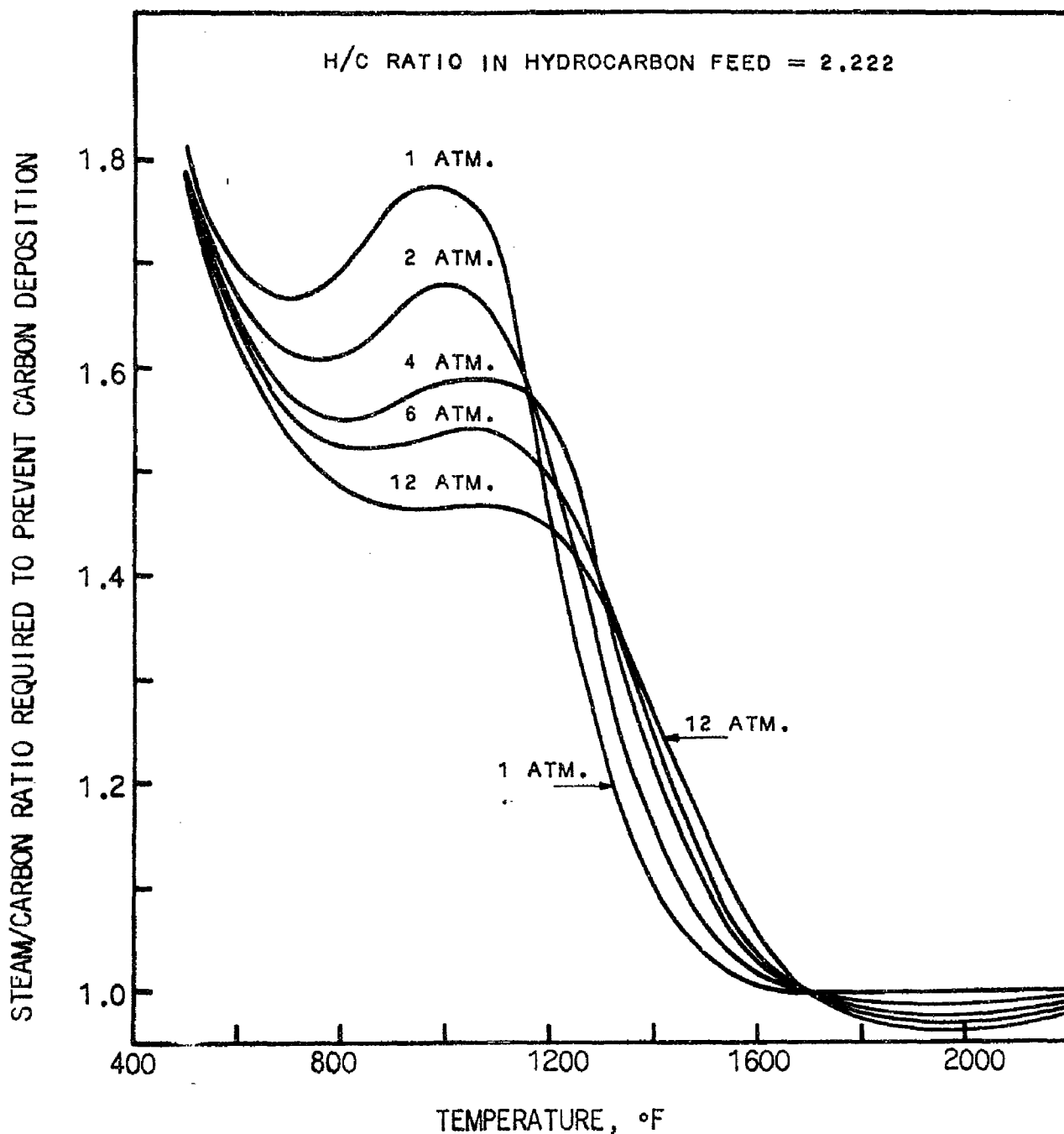
EFFECT OF PRESSURE ON STEAM/CARBON RATIO REQUIRED TO
PREVENT CARBON DEPOSITION FROM C_6H_{14} HYDROCARBONS



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FIGURE G-4

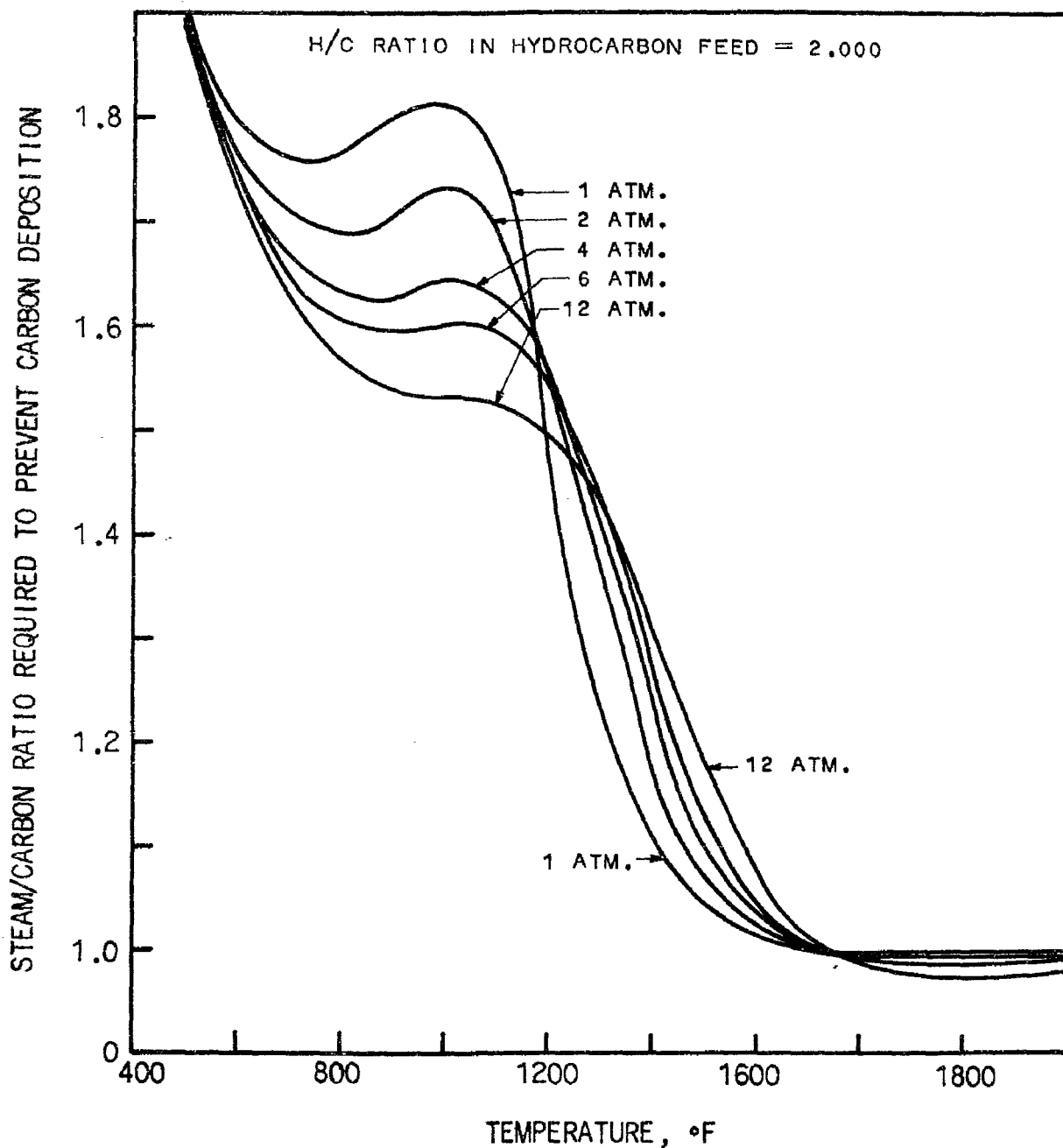
EFFECT OF PRESSURE ON STEAM/CARBON RATIO REQUIRED
TO PREVENT CARBON DEPOSITION FROM C_9H_{20} HYDROCARBONS



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FIGURE G-5

EFFECT OF PRESSURE ON STEAM/CARBON RATIO REQUIRED TO
PREVENT CARBON DEPOSITION FROM C_NH_{2N} HYDROCARBONS



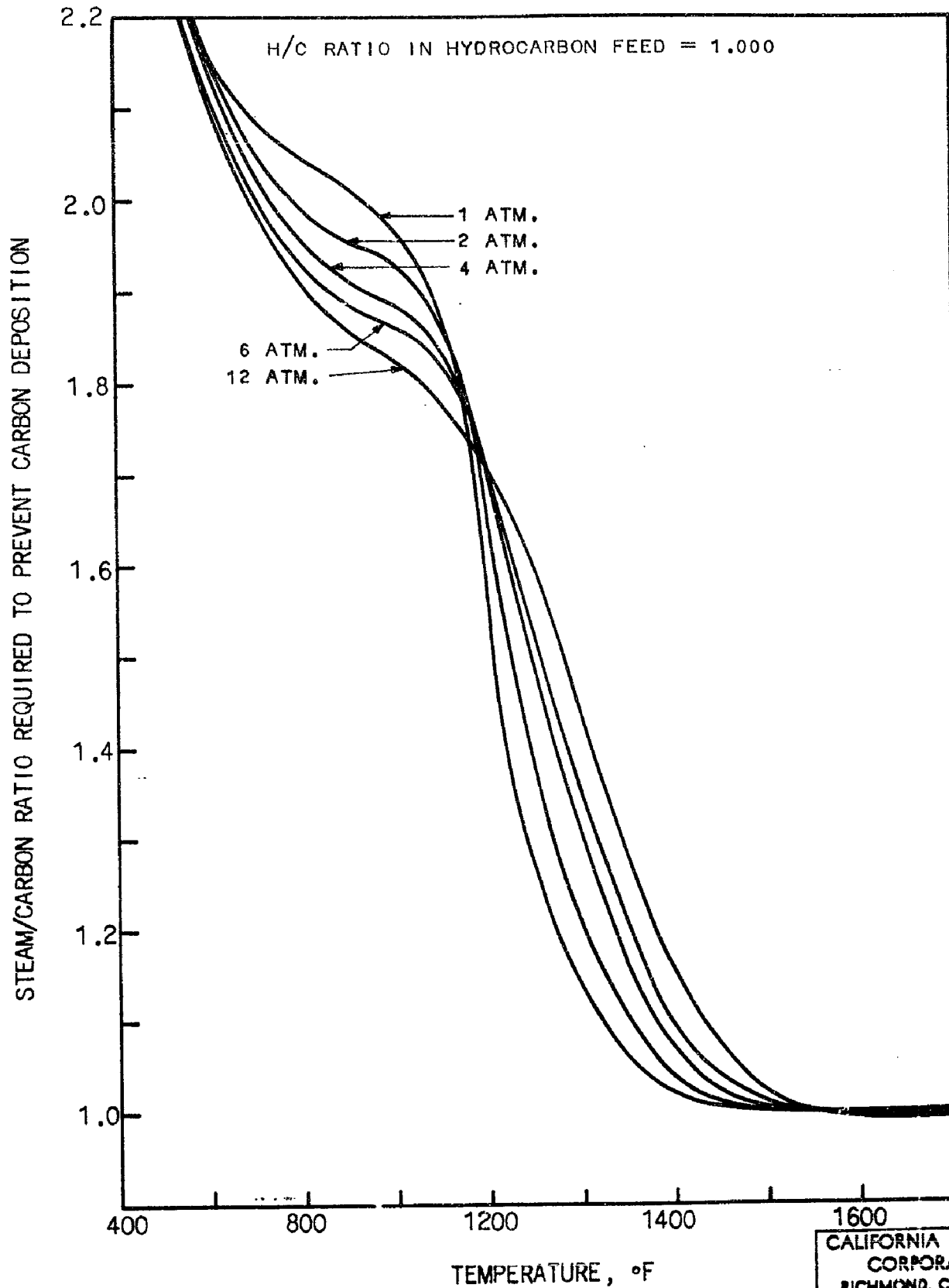
G-6

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FIGURE G-6

A-E-6

EFFECT OF PRESSURE ON STEAM CARBON RATIO REQUIRED TO PREVENT CARBON DEPOSITION FROM C_NH_N HYDROCARBONS



G-7

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