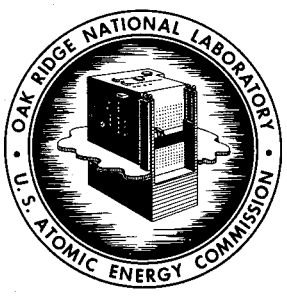

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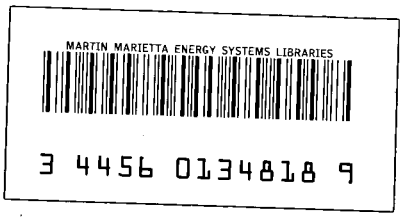

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THE REACTION OF STEAM WITH LARGE SPECIMENS OF GRAPHITE FOR THE EXPERIMENTAL GAS-COOLED REACTOR

R. E. Helms
R. E. MacPherson

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REACTOR DIVISION

THE REACTION OF STEAM WITH LARGE SPECIMENS OF GRAPHITE FOR THE EXPERIMENTAL GAS-COOLED REACTOR

R. E. Helms R. E. MacPherson

MARCH 1965

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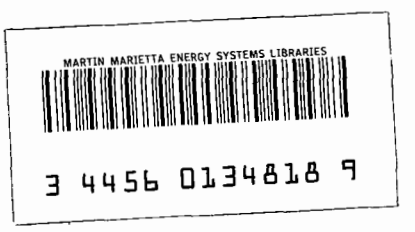

CONTENTS

THE REACTION OF STEAM WITH LARGE SPECIMENS OF GRAPHITE FOR THE EXPERIMENTAL GAS-COOLED REACTOR

R. E. Helms R. E. MacPherson

ABSTRACT

Carbon reaction rates and hydrogen generation rates have been determined for high pressure, high temperature steam flowing through a full scale EGCR fuel element graphite sleeve (Speer 901-RYL) and a geometrically identical sleeve machined from EGCR moderator graphite (National Carbon Company).

Tests were made in the temperature range of 1200 to 1600°F with both graphite sleeves. To determine the effect of pressure from 30 to 300 psig, test data were obtained using an EGCR fuel element graphite sleeve. On both specimens, tests were also conducted at different steam flow rates. Exposure of the graphite to steam over a period of time roughens the surface thus increasing the reactive surface area. This burn-off of graphite results in an increase in the nominal reaction rate.

The reaction rate of the EGCR fuel element sleeve graphite was 5.6 g/hr·ft^2 at 155 psig, 1600°F and approximately 4.0% burn-off. The reaction rate of the EGCR moderator graphite (National Carbon Company) was greater than the EGCR fuel element sleeve graphite (Speer 901-RYL) by a factor of 3.0 at 1600°F. No significant effects of pressure or steam flow rate were noted. The moderator graphite was exposed to 1550°F steam for 136 hr and 1580°F steam for 41 hr. After exposure to steam at these and lower temperatures for approximately 900 hr, the EGCR moderator graphite could be crumbled very easily. The EGCR fuel element graphite which appeared structurally sound after the test, was exposed to steam for a longer total time but only for 48 hr at a maximum temperature of 1580°F.

INTRODUCTION

The Experimental Gas-Cooled Reactor (EGCR) is graphite moderated and helium cooled.[1] The seven rod cluster of 304 stainless steel clad fuel elements is encased in a 5-in. outside diameter by 3-in. inside diameter graphite sleeve. Six of these fuel-sleeve assemblies are stacked vertically in one of the 5-1/4 inside diameter fuel channels in a moderator graphite column. There are 234 fuel channels in the EGCR core.

Two types of graphite are used in the EGCR. The graphite sleeve, that encases the fuel elements, is manufactured by the Speer Company. The moderator graphite, that has the 5-1/4 inside diameter channel holes, is manufactured by the National Carbon Company.

Since the EGCR steam generator operates at a higher pressure than the reactor coolant system, a failure of this unit would introduce steam into the reactor coolant system thus resulting in steam-carbon and steam-metal reactions.[2]

When steam reacts with carbon, the gaseous products are carbon monoxide, hydrogen, carbon dioxide, and methane. It is now generally accepted that the primary reaction is[3,4,5]

$$C + H_2O \rightleftharpoons CO + H_2 \quad . \qquad (1)$$

Carbon dioxide is then produced by the secondary "water gas shift" reaction

$$CO + H_2O \rightleftharpoons CO_2 + H_2 \quad . \qquad (2)$$

This reaction is believed to take place predominantly on the graphite surface.[6]

The formation of methane is believed to be by the direct attack of steam on carbon atoms.[4] The methane reaction is considered to be

$$2C + 2H_2O \rightleftharpoons CH_4 + CO_2 \quad . \qquad (3)$$

The amount of methane formed at the system pressures used for these tests was significant.

The rate of reaction of graphite in these tests was calculated on the basis of the rates of appearance of carbon monoxide, carbon dioxide and methane in the product gases.

To determine the steam-carbon reaction rates for the two types of graphite used in the EGCR, tests were conducted at various temperatures, pressures, and steam flow rates. These tests were performed in the facility shown in Fig. 1 and described elsewhere.[7] The reaction rate as a function of pressure was determined over the pressure range of 30 to 300 psig while holding the graphite temperature constant at 1400°F. The effect of steam flow rate was also determined at this temperature level.

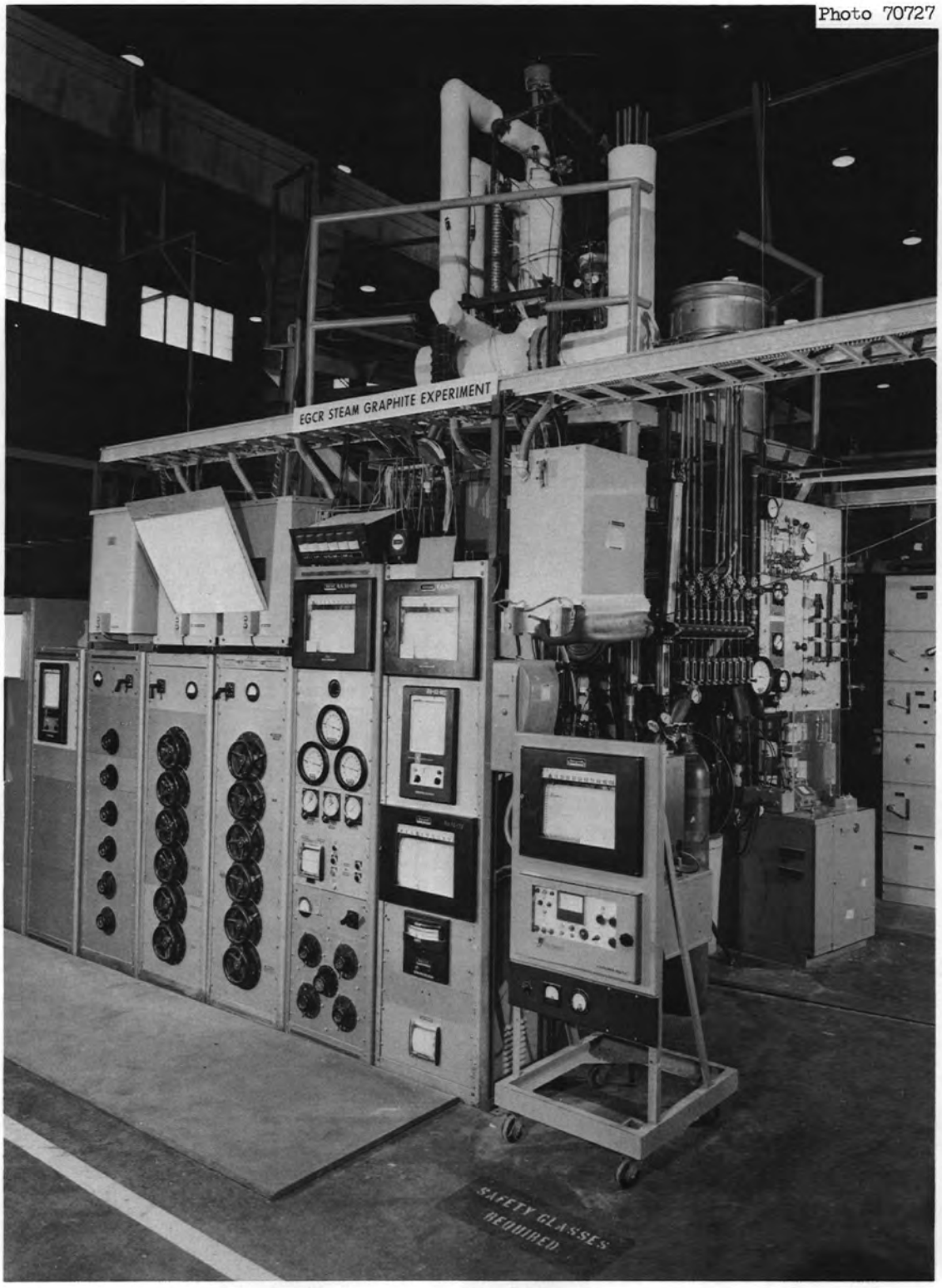

Fig. 1. Steam-Graphite Experimental Facility.

PROCEDURE

After assembling a graphite sleeve in the test section of the experimental facility (Fig. 2), the temperature of the autoclave vessel that houses the superheater, test section and regenerator was raised to approximately 1000°F. The power to the boiler was then turned on and cooling was applied to the condenser. The saturation temperature corresponding to the desired operating pressure level was set on the boiler temperature controller. Condenser cooling was adjusted until the desired steam flow rate was obtained. The inlet steam temperature to the test section was increased by adjusting the superheater power until the desired operating temperature was obtained. Power adjustments were then made to the guard heaters around the test section to obtain an isothermal region.

The concentrations of the various reaction product gases in the off-gas stream were analyzed by an on-line gas chromatograph set up to give one complete analysis every 20 min. Off-gas volume was measured by a wet-test meter. The total volume of gas produced was recorded every hour.

Using the average concentration of a particular gas for each hourly period, the total volume of a given gas (CO, CO_2, CH_4 or H_2) produced in an eight (8) hour period is calculated as follows:

$$V_x = \sum_{1 \rightarrow 8} (V_1X_1 + V_2X_2 + \cdots V_8X_8) \qquad (4)$$

V_x = Total volume of each gas component produced during the total time to obtain a data point (approximately eight hours), cc

V_{1-8} = Volume of gas produced during a recorded period (approximately one hour), cc

X_{1-8} = Concentration of each gas component during an hour (average of three analyses), cc/100 cc

The average production of each gas component (H_2, CO, CO_2 or CH_4) is calculated as follows:

$$R_x = \frac{V_x}{T} \qquad (5)$$

R_x = Average production rate of each gas component, cc/min

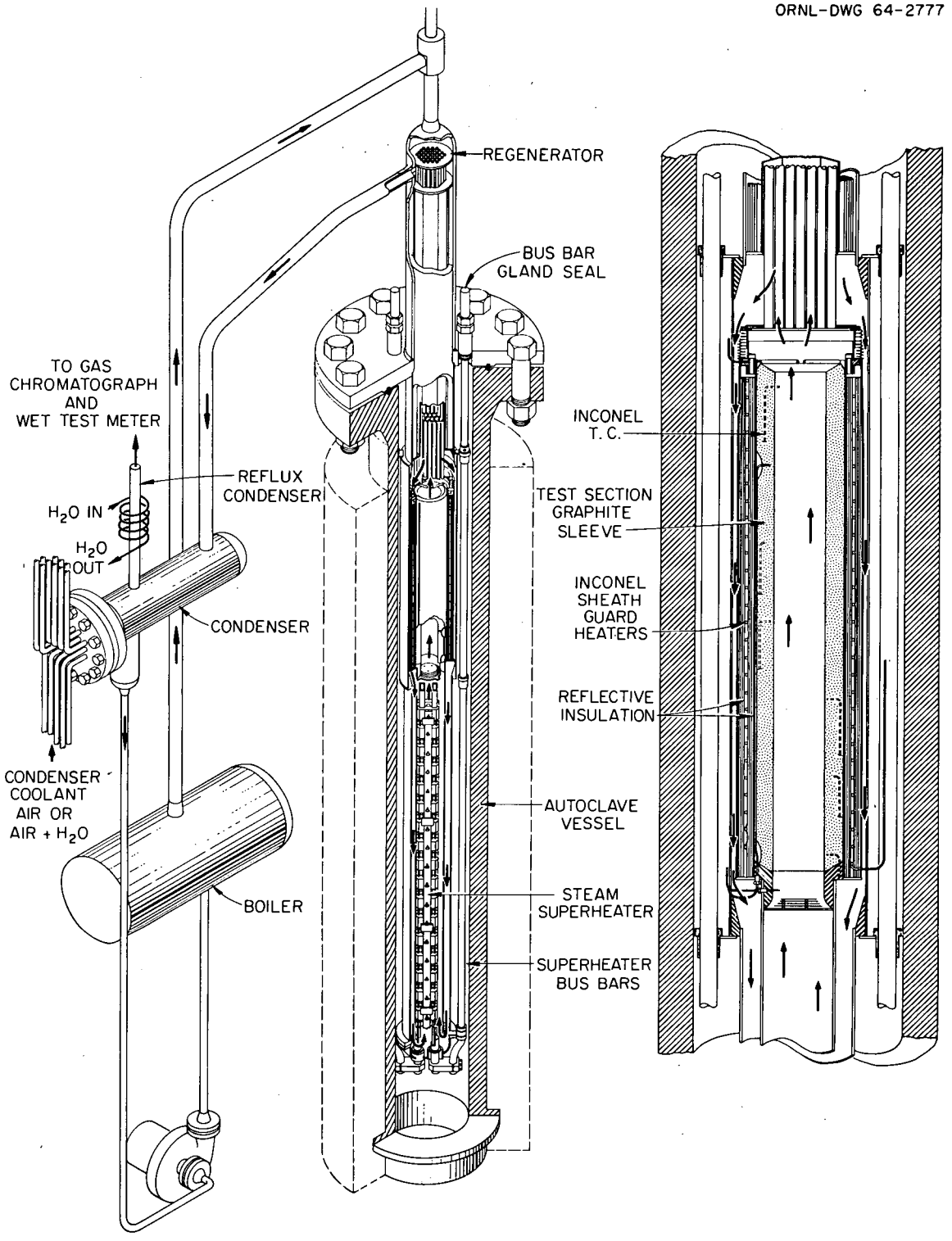

Fig. 2. Steam-Graphite Experimental Facility.

V_x = Total volume of each gas component produced during the total time to obtain a data point, cc

T = Total time to obtain a data point, min (approximately 8 hr)

Using the average production rate of the carbon containing gas components CO, CO_2, CH_4 and the internal surface area, the carbon reacting per unit of time per unit of initial nominal surface area (g/hr·ft) is calculated as follows

$$R_{CA} = \frac{12 \times 60}{22{,}400} \left[\frac{R_{CO} + R_{CO_2} + R_{CH_4}}{A} \right] \qquad (6)$$

R_{CA} = Carbon reacting per unit of time per unit of surface area, $g/hr \cdot ft^2$

R_{CO} = Gas production rate of CO, scc/min

R_{CO_2} = Gas production rate of CO_2, scc/min

R_{CH_4} = Gas production rate of CH_4, scc/min

A = Initial nominal internal surface area of the test specimen, ft^2 (1.891 ft^2)

Using the average reaction rate R_{CA}, the initial nominal surface area and the operating time, the cumulative total carbon burned to the end of each data point period was calculated. The percentage burn-off was then determined based on the total weight loss of carbon at the end of a data point period and the original weight of the test specimen. The percentage burn-off is included in Table 1 of Appendix A and Appendix B.

Figure 3 shows the hourly average gas concentrations of CO, CO_2, CH_4 and H_2 as obtained from the gas chromatograph, the steam flow rate, the total production rate of gas on an hourly basis, the average production rates of gas for eight (8) hour periods, and the average production rates of H_2 for eight (8) hour periods for a typical data run at a given temperature and pressure. Fluctuations in the hour-to-hour total gas production rate reflect difficulties experienced in controlling the off-gas flow rate to keep the system gas inventory relatively constant.

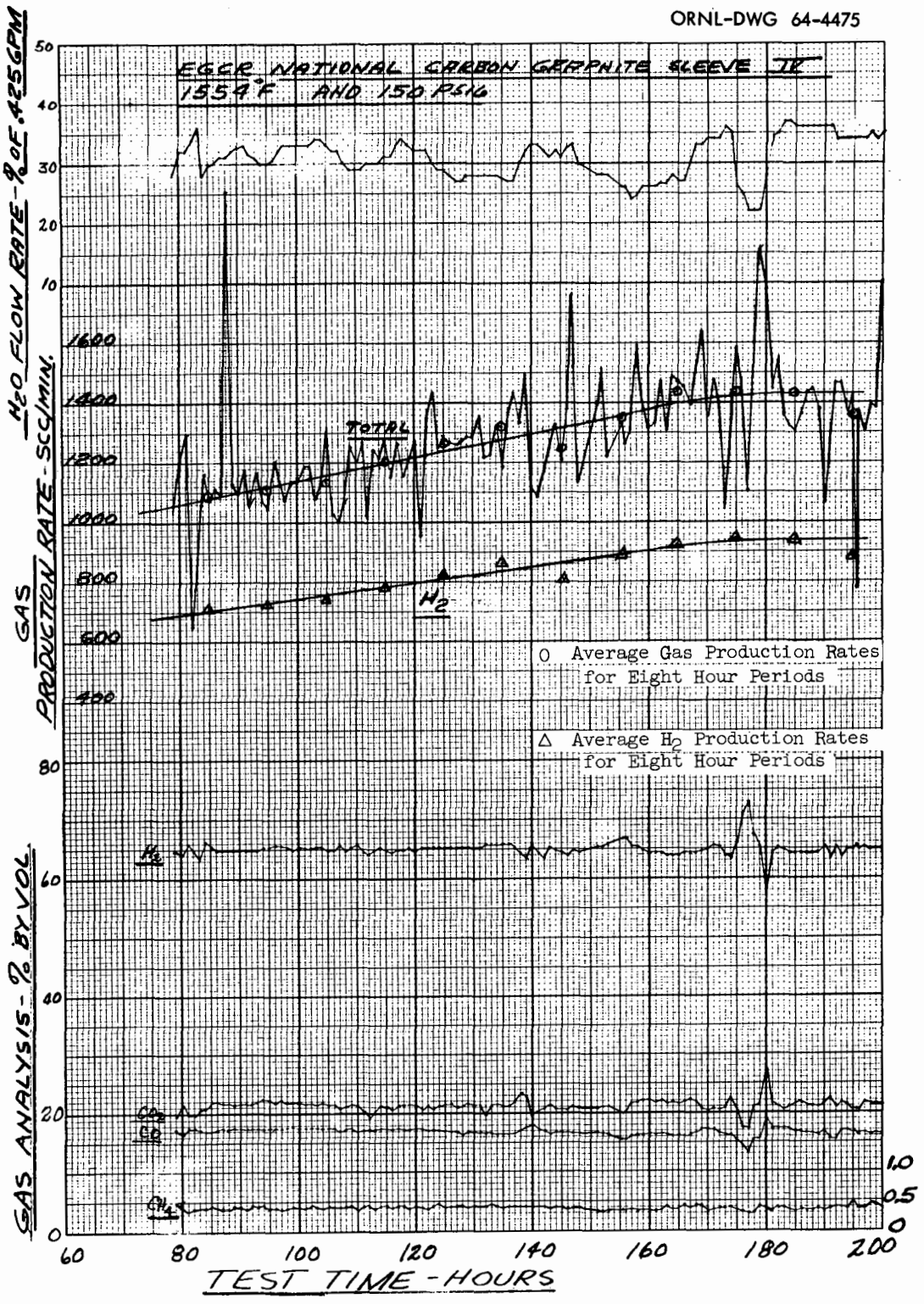

Fig. 3. Typical Data for the Steam-Graphite Experiment.

RESULTS

EGCR Fuel Element Graphite Sleeve - Speer 901-RYL

During initial operation the fuel element graphite sleeve (Speer 901-RYL) was held at 1200°F and 155 psig system pressure for approximately 115 hr. Following this period, the graphite and steam temperature was increased to a maximum of 1580°F and lowered in a series of steps to obtain the reaction rate data shown in Figs. 4 and 5. Complete results of this procedure are given in Appendix A, Table 1 as points 3.1 through 3.21. Figure 4 shows the carbon removal rate as a function of temperature while Fig. 5 shows the hydrogen production rate as a function of temperature, both over a wide burn-off range.

The graphite temperature was then held constant at 1400°F and the system pressure was varied to determine the reaction rate as a function of system pressure for points 3.21A through 3.37 in Table 1 of Appendix A. As shown in Fig. 6, there was no significant effect of steam pressure on reaction rate. However, as the system pressure was increased, the CO/CO_2 ratio decreased. During the course of this test of the effect of pressure the reaction rate in terms of the grams of carbon per unit of time per unit of initial nominal surface area increases with the time. The hydrogen generation rate also increases with test time. The increase of the carbon reaction rate and the hydrogen generation rate is attributed to an increase in reactive surface area due to graphite burn-off.[8,9]

Examination of the overall test results also indicated no major effect of steam flow rate on the reaction rate. In a specific examination of this factor (data points 3.34 through 3.37, Table 1, Appendix A) the Reynolds number was varied by a factor of two, with other variables held constant, and the reaction rate remained essentially constant. Abel and Holden[3] report that the carbon-steam reaction is not a function of steam flow rate below 1900°F.

During the course of the test, measurements of off-gas production rates indicated a total graphite burn-off of 12.2%. A comparison of the total weight of the sleeve before and after test showed a weight loss of 13.5%. The difference in these values is attributed to mechanical losses of graphite from the surface of the test piece during the test and during the process

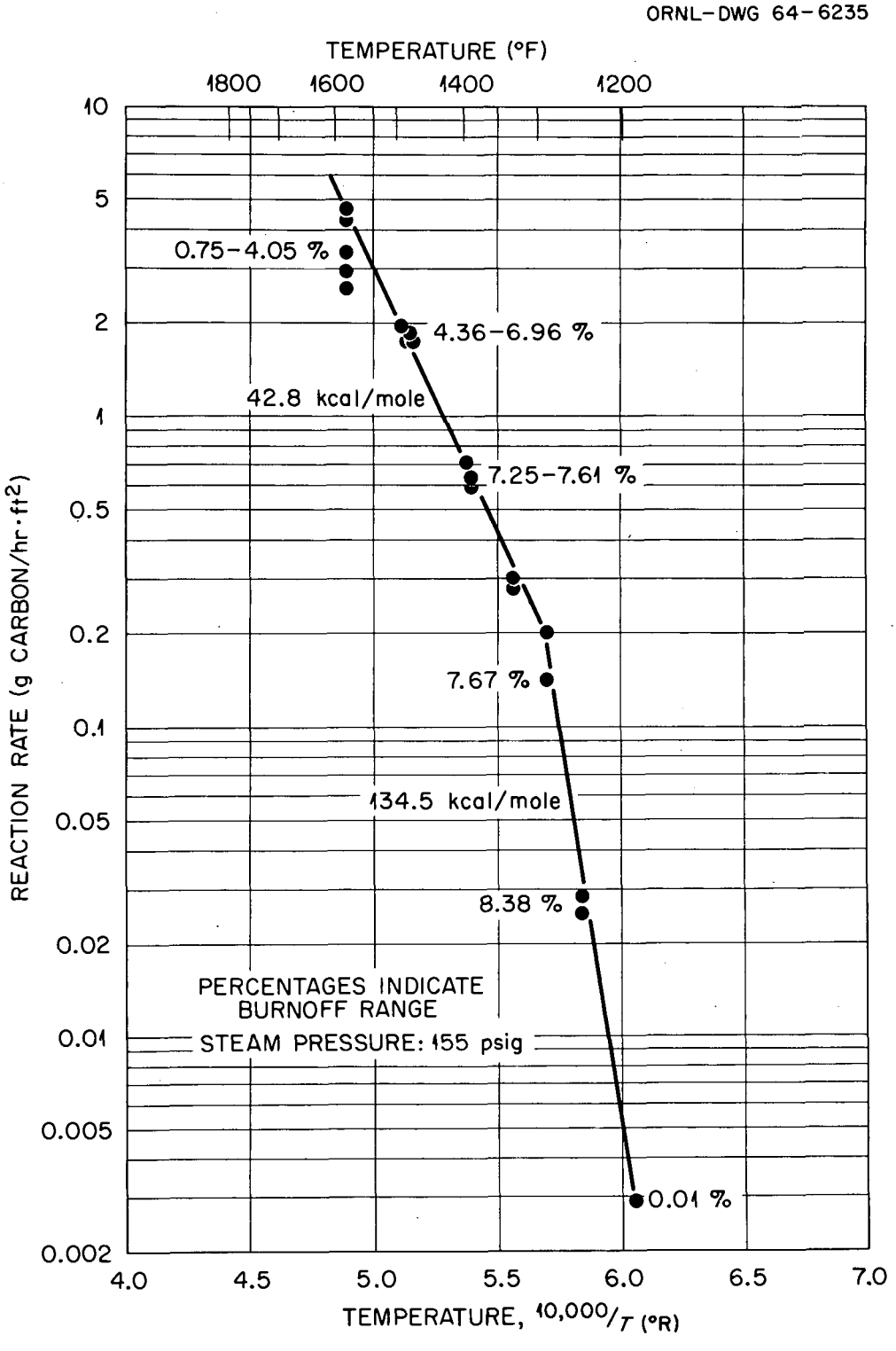

Fig. 4. Steam-Graphite Reaction Rate for EGCR Fuel Element Graphite Sleeve; Speer 901-RYL.

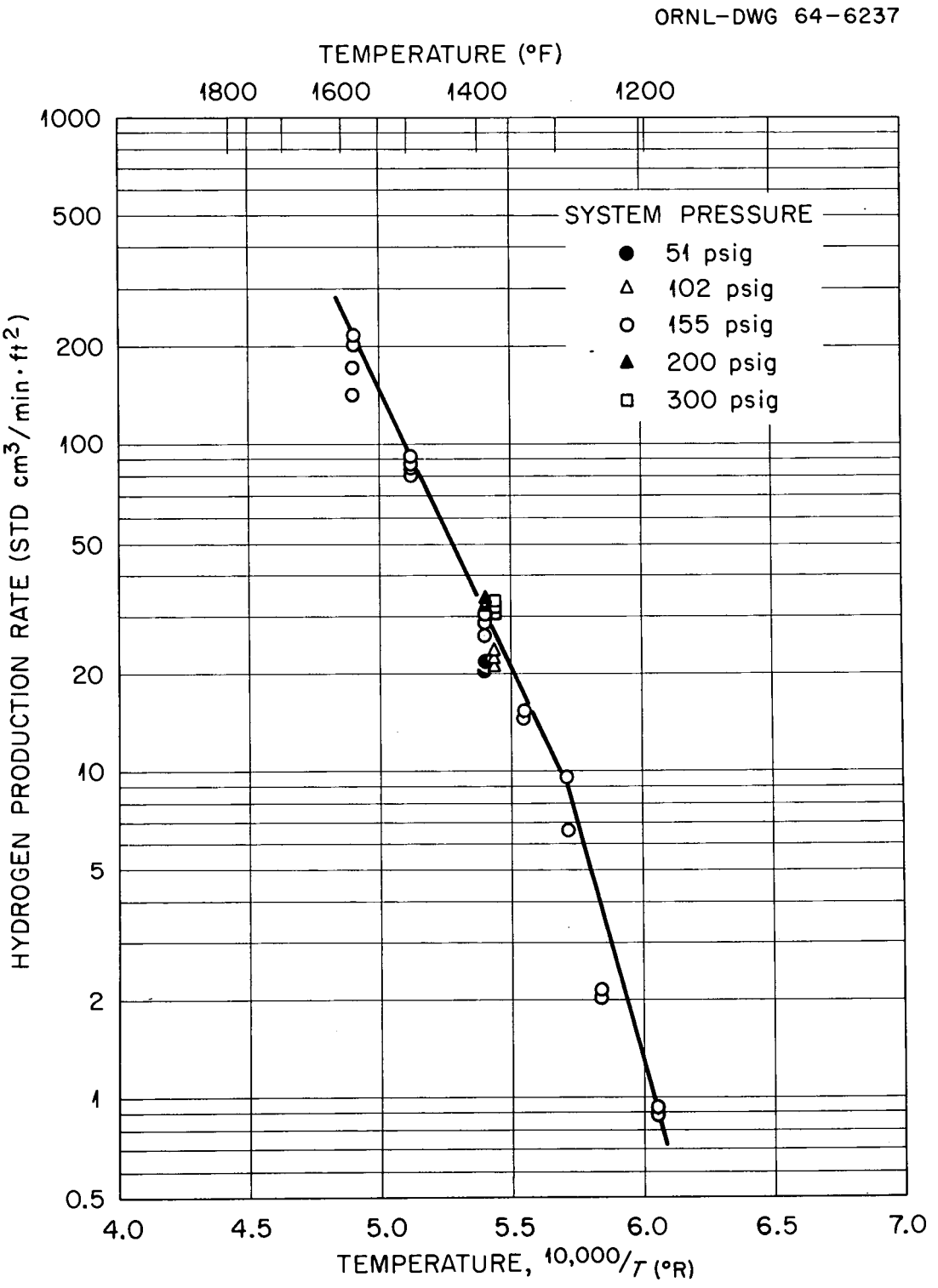

Fig. 5. Hydrogen Production Rate for EGCR Fuel Element Graphite Sleeve; Speer 901-RYL.

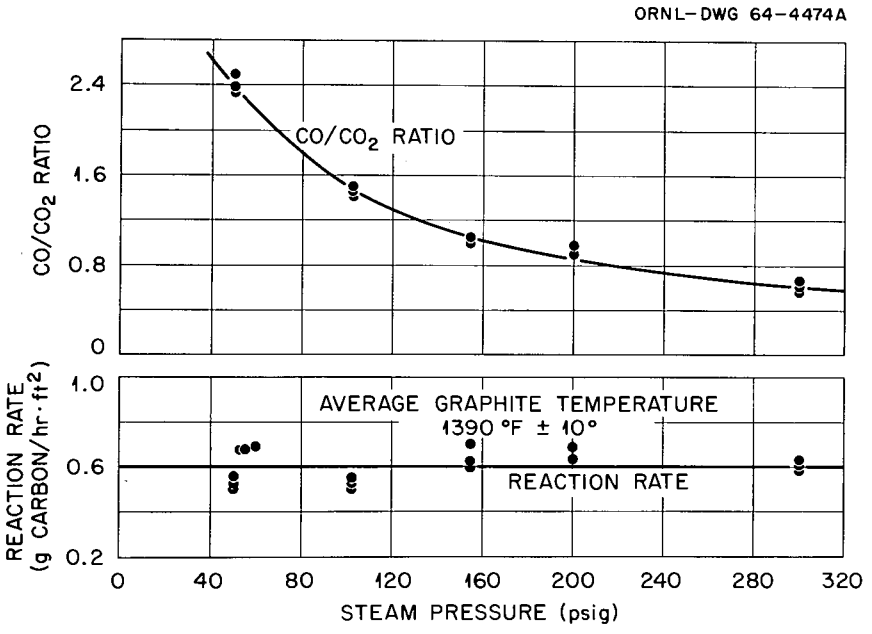

Fig. 6. Effect of Steam Pressure on Graphite Reaction Rate and CO/CO_2 Ratio for EGCR Fuel Element Sleeve; Speer 901-RYL.

of removal from the test section. The accuracy of measurement of all gas components with the gas chromatograph could also contribute to this error.

Upon completion of the test the sleeve was cut into halves as shown in Fig. 7. The graphite removal was not uniform axially along the sleeve. More graphite was removed from the steam inlet end. Since the graphite had been isothermal for the major portion of the test, the tapered removal of graphite axially along the sleeve indicates a decrease in reaction rate due to the increase in H_2 and CO concentration in the fluid boundary layer along the sleeve.

EGCR Moderator Graphite Sleeve - National Carbon Company

This sleeve was machined from a section of a spare moderator graphite column. After installation in the test facility, the sleeve was outgassed at 1200°F. The temperature was then raised to 1550°F to begin the test data runs shown in Appendix B, Table 1. The system pressure was held constant at 155 psig during the entire test period.

The steam-graphite reaction rate in terms of the amount of carbon burned per unit of time per unit of initial surface area of the sleeve was calculated using the test data and Eq. 6. The carbon reaction rate as a function of temperature is shown in Fig. 8. The hydrogen production rate was calculated using the test data and Eq. 5 and expressed in terms of the initial surface area of the sleeve. The hydrogen production rate as a function of temperature is shown in Fig. 9.

As with the fuel element sleeve graphite, tests at various steam flow rates showed no significant effect on reaction rate. Data points 4.66 through 4.82, Table 1, Appendix B cover these tests and reflect no systematic effect of flow rate for a fivefold change in steam Reynolds number.

After obtaining data at various temperature levels, the test section was removed from the autoclave vessel. Before removing the sleeve from the test section, the sleeve was in cylindrical form as shown in Fig. 10. When an attempt was made to remove the sleeve from the test section, the sleeve crumbled into many pieces as shown in Fig. 11.

The graphite weight loss as calculated from total off gas production was 50.6% compared to a value of 49.5% based on weight measurements before and after test.

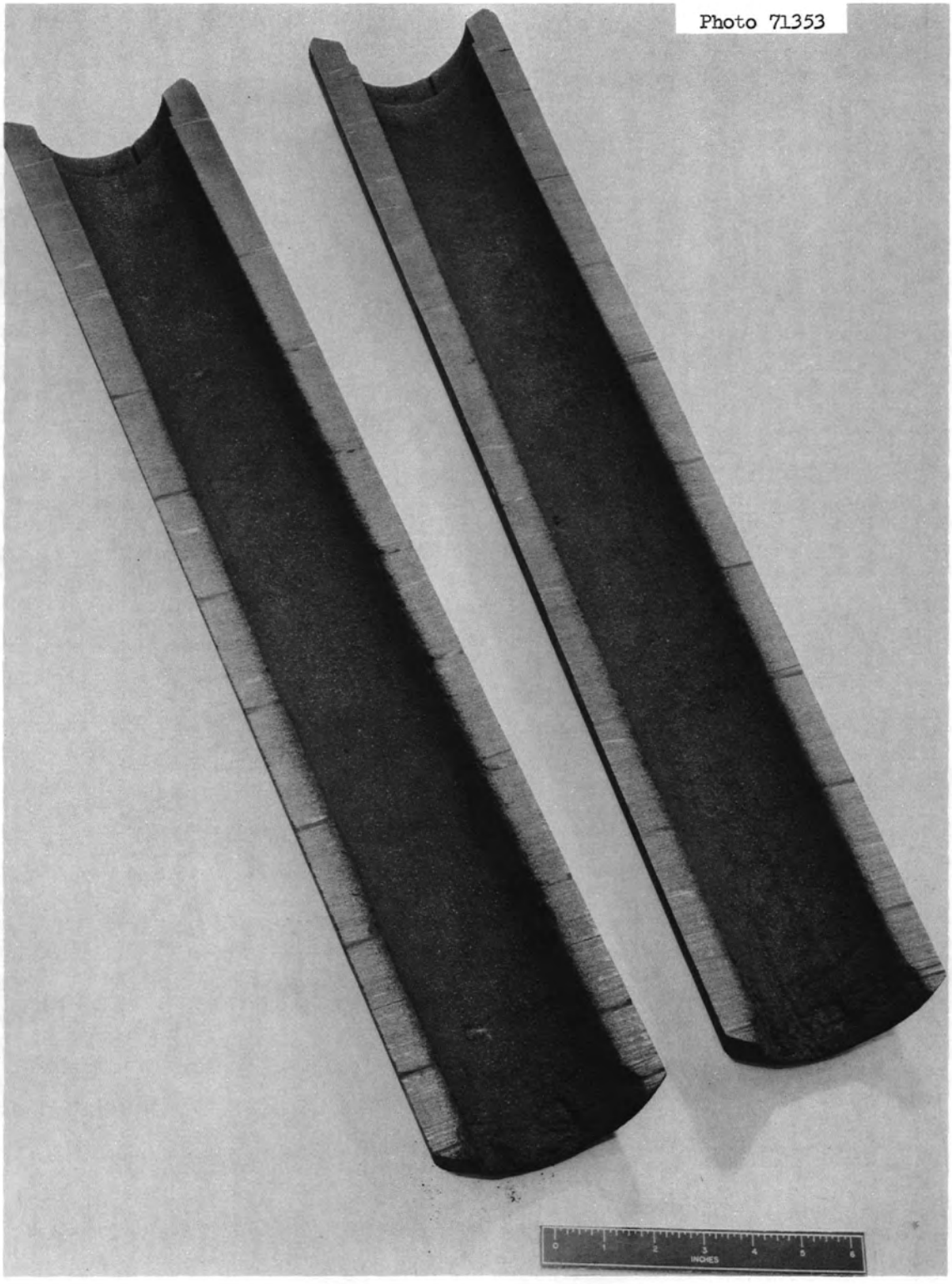

Fig. 7. Speer (901-RYL) Graphite Sleeve After Completion of Test and Sawed Into Halves.

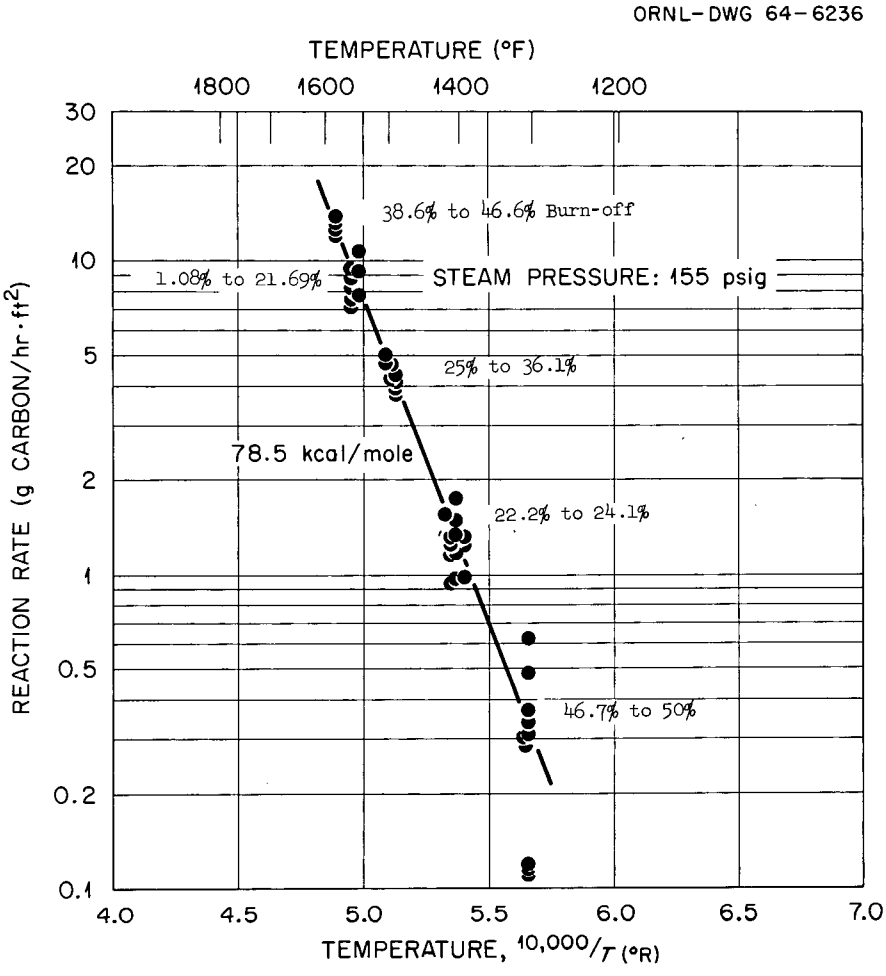

Fig. 8. Steam-Graphite Reaction Rate for EGCR Moderator Graphite Sleeve; National Carbon Company.

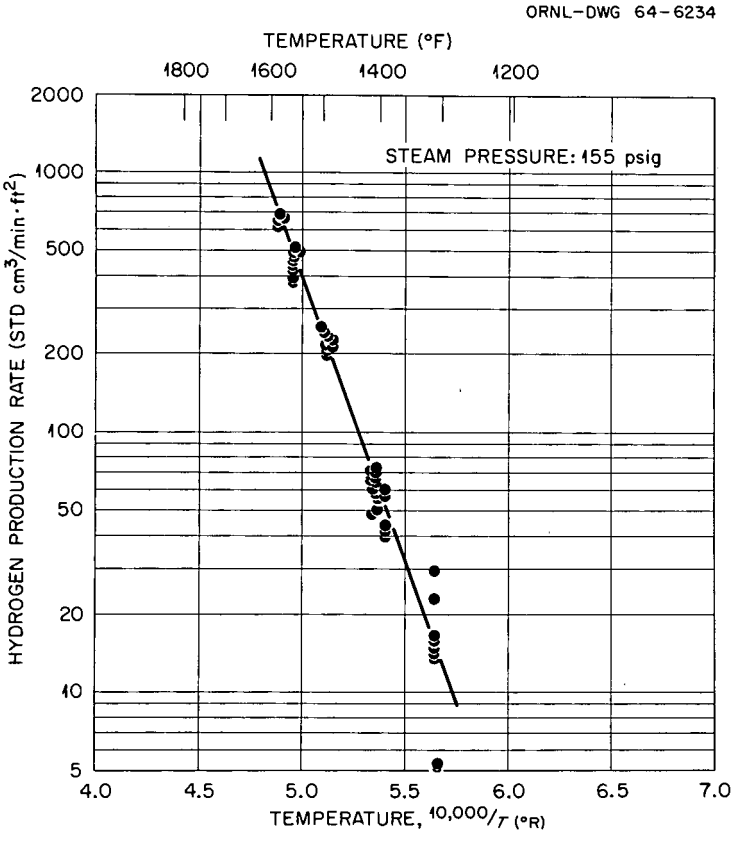

Fig. 9. Hydrogen Production Rate of EGCR Moderator Graphite National Carbon Company.

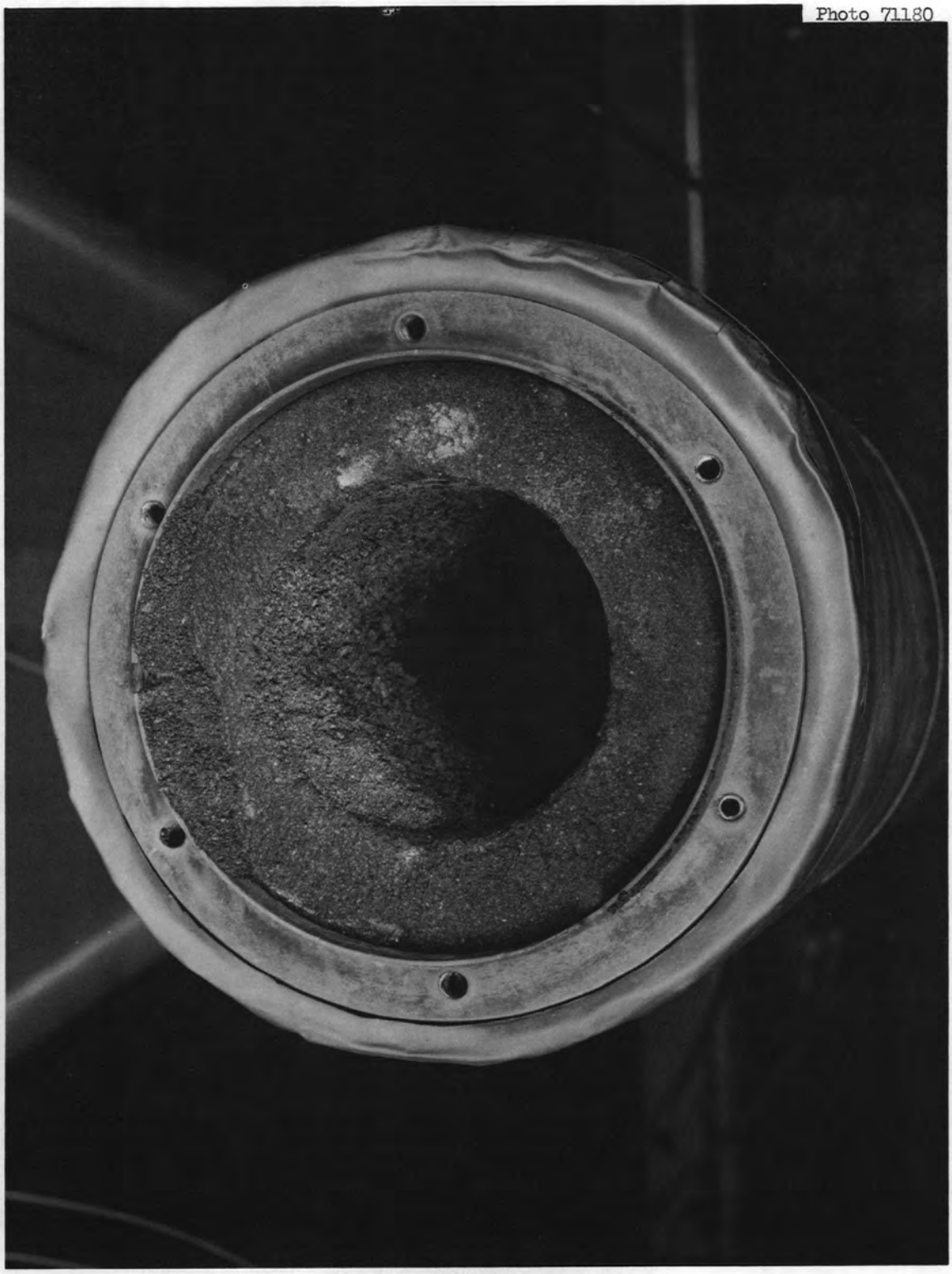

Fig. 10. EGCR Moderator Graphite, National Carbon Company – Before Removing from Test Section.

Fig. 11. EGCR Moderator Graphite, National Carbon Company – After Removal from Test Section.

Since the graphite sleeve shown in Figs. 10 and 11 was exposed to steam for a longer period of time than would be experienced in an EGCR hazard accident, a new sleeve machined from the same EGCR moderator graphite column No. 265 was installed in the test facility. After exposure to superheated steam for 24 hr at 1400°F, the sleeve as shown in Fig. 12 appeared physically sound.

CONCLUSIONS

Table 1 briefly summarizes the results of these tests.

	Speer 901-RYL	National Carbon Company
Activation Energy, k cal/mole*	42.8	78.5
Reaction Rate, g/hr·ft^2		
(Burnoff % Indicated)		
1600°F	5.6 (4.0)	16.0 (46.6)
1500°F	2.0 (6.9)	5.0 (36.1)
1400°F	0.7 (7.61)	1.3 (24.1)
Hydrogen Production Rate std cm^3/min·ft^2		
(Burnoff % Indicated)		
1600°F	270 (4.0)	810 (46.6)
1500°F	98 (6.9)	250 (36.1)
1400°F	34 (7.61)	62 (24.1)

*Test procedure compromised determination of activation energy in that graphite burnoff (and therefore steam-graphite reaction rates) were not constant over the temperature range investigated. Actual values would be somewhat higher than those measured.

The results can be used in a hazards evaluation to predict a hydrogen evolution rate for the reaction of steam with EGCR fuel element sleeve and moderator graphites. In using these data, conservative predictions will be obtained since the results apply directly only to the upstream end of the core. Because of the decrease in reaction rate resulting from the increase in concentration of H_2 and CO in the boundary layer along the flow path, overall production rates for the core would be lower.

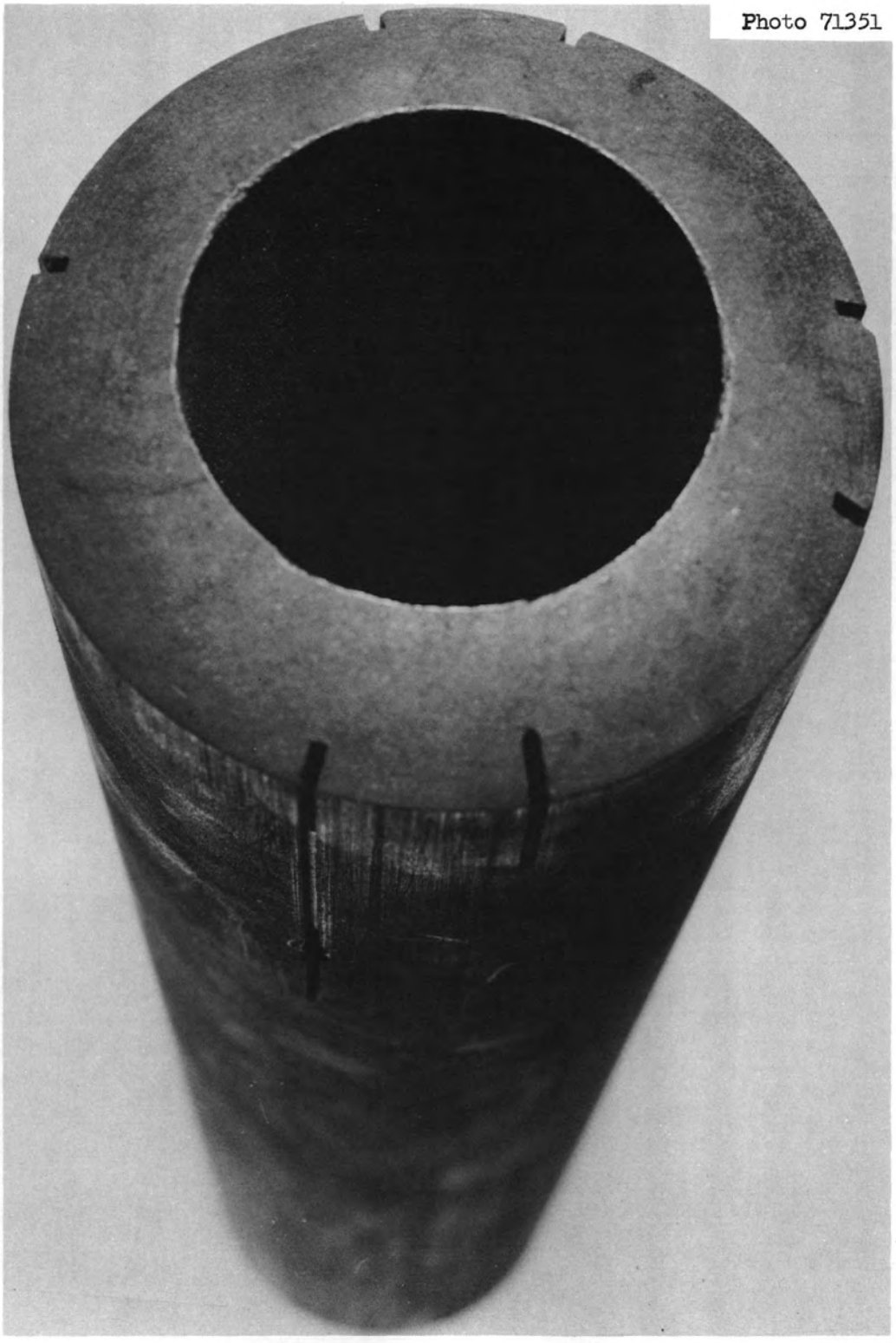

Fig. 12. EGCR Moderator Graphite, National Carbon Company – 24 hr Steam Exposure at 1400°F.

Conclusions to be drawn based on the tests conducted to date are as follows:

1. The significant variables affecting the reaction rate of steam with graphite are (a) temperature, (b) burnoff which tends to increase the reactive surface area, and (c) the concentration of CO and H_2 in the fluid boundary layer.

2. Reaction rate is a negligible function of system pressure in the pressure range of 30 to 300 psig.

3. The CO/CO_2 concentration ratio decreases as the steam pressure increases.

4. The reaction rate does not appear to be significantly affected by a fivefold increase in steam Reynolds number.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the contributions of the Reactor Division Design Department for assistance in designing the test facility, of D. L. Clark who designed the boiler control, of J. E. Attrell and A. S. Meyer, Jr. of the Analytical Chemistry Division who adapted the gas chromatograph for on-line analysis, of Dr. J. F. Bailey, R. B. Knight and W. B. Cottrell for their technical assistance, of J. E. Smith for the tensile and compressive test, of J. E. Wolfe for his assistance in collecting test data and of the many Y-12 craft personnel who helped build the test facility.

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Appendix A. Test Data for EGCR Fuel Element Graphite Sleeve — Speer 901-RYL.

Table 1. EGCR Fuel Element Graphite Sleeve; Speer 901-RYL

Data Point	Timer		Test Section				Average Gas Production Rate at STP (scc/min)				Reaction Rate		Burn Off %	$\frac{CO}{CO_2}$
	Start	End	System Pres. Psig	Steam Flow Rate lb/hr	N_{Re}	Average Graphite Temp. °F	H_2	CO_2	CH_4	CO	R_{CA} g/hr·ft^2	R_{H_2A} scc/min·ft^2		
3.1	53	73.1	155	Outgassing graphite										
3.2	141	148.7	155	49.6	3220	1192	1.75	.084	.036	.050	.0028	.92		.59
3.3	148.7	166.2	155	49.6	3220	1192	1.67	.100	.030	.042	.0029	.88	.01	.42
3.4	189.5	193.5	155	39.7	2030	1580	270.6	70.4	1.58	82.97	2.63	143.1	.75	1.18
3.5	193.5	197	155	39.7	2030	1581	274	79.6	1.7	91.2	2.93	144.9	.933	1.14
3.6	197	214	155	35.7	1830	1580	326.3	91.5	3.03	111.6	3.41	172.5	2.00	1.22
3.7	214	219.4	155	33.7	1730	1580	388.8	108.1	2.58	142.5	4.3	205.6	2.43	1.31
3.8	219.4	238.3	155	35.7	1840	1574	404.3	119.9	3.03	150.7	4.65	213.8	4.05	1.26
3.9	241.3	245	155	45.7	2460	1492	174.2	50.3	1.2	64.2	1.96	92.1	4.36	1.28
3.10	245	309.3	155	53.6	2900	1482	154.9	45.2	.95	56.6	1.75	81.9	6.10	1.25
3.11	309.3	316.3	155	53.6	2910	1476	163.9	45.1	1.03	61.7	1.84	86.6	6.34	1.36
3.12	316.3	335.6	155	53.6	2910	1477	157.2	42.2	.99	59.04	1.74	83.1	6.96	1.4
3.13	340.95	357.6	155	59.6	3400	1391	49.5	16.03	.25	19.12	.602	26.2	7.25	1.19
3.14	361.3	382.3	155	59.6	3400	1392	53.68	16.3	.28	20.8	.635	28.8	7.55	1.28
3.15	382.6	387.3	155	57.6	3270	1398	57.8	19.1	.33	22.7	.713	30.6	7.61	1.19
3.16	389	406.3	155	61.6	3740	1292	12.68	3.76	.059	4.55	.142	6.69	7.67	1.21
3.17	406.3	410.9	155	61.6	3740	1292	18.18	5.38	.078	6.5	.203	9.62	7.69	1.21
3.18	413.9	432.9	155	59.6	3510	1340	28.5	7.37	.125	10.4	.302	15.06	7.81	1.41
3.19	483.6	506.6	155	57.6	3370	1353	28.7	7.15	.126	9.19	.280	15.16	8.20	1.28
3.20	559.9	573.6	155	63.6	3970	1251	3.88	.41	.0105	1.06	.025	2.05	8.35	2.61
3.21	623	647.1	155	63.6	3974	1252	4.18	.81	.0104	.84	.028	2.21	8.38	1.04
3.21a	652.2	670.6	27.5	39.28	2218	1410	38.38	7.37	.155	23.15	.519			3.14
3.22	677.2	695.4	51	47.4	2697	1396	38.99	8.89	.173	21.67	.522	20.6		2.50
3.23	695.8	700.8	51	46.0	2697	1396	39.90	9.29	.174	22.12	.536	21.1		2.38
3.24	700.8	718.8	51	46.8	2660	1397	41.6	9.83	.177	23.12	.562	21.99		2.35
3.25	724.45	755.9	102	53.2	3060	1382	44.1	12.68	.190	18.95	.540	23.3		1.49
3.26	755.9	787.9	102	53.2	3060	1382	41.14	12.42	.182	17.63	.513	21.75		1.42
3.27	787.9	815.4	101	53.2	3060	1382	43.01	12.98	.189	19.24	.551	22.7		1.48
3.28	820.1	841.1	200	62.2	3560	1387	60.1	18.97	.28	18.69	.644	31.78		.985
3.29	841.1	863.1	200	62.6	3570	1391	61.6	21.56	.309	19.47	.701	32.56		.903
3.30	868.45	887.8	300	68.7	3953	1378	62.2	22.11	.327	14.4	.626	32.88		.651
3.31	887.8	910.8	300	66.4	3821	1380	57.54	21.79	.303	13.30	.601	30.4		.61
3.32	913.8	917.1	300	46.45	2670	1383	59.21	23.31	.315	13.92	.63	31.3		.597
3.33	917.1	983.8	300	45.48	2617	1383	56.73	21.48	.294	12.47	.584	30.0		.581
3.34	1022.6	1030.7	56	32.76	1860	1401	54.9	12.65	.279	28.2	.699	29.0		2.23
3.35	1030.7	1047.7	53.9	33.92	1928	1399	52.57	12.50	.271	27.25	.68	27.8		2.18
3.36	1054.7	1071.8	55.6	66.26	3780	1392	54.80	12.51	.27	27.66	.686	28.9		2.21
3.37	1071.8	1075.8	55.5	65.2	3706	1399	58.92	13.76	.501	30.66	.76	31.1		2.22

Appendix B. Test Data for EGCR Moderator Graphite Sleeve — National Carbon Company.

Table 1. EGCR Moderator Graphite; National Carbon Company

Data Point	Timer		Test Section				Average Gas Production Rate at STP (scc/min)				Reaction Rate			Burn Off %	$\frac{CO}{CO_2}$
	Start	End	System Pres. Psig	Steam Flow Rate lb/hr	N_{Re}	Average Graphite Temp. °F	H_2	CO_2	CH_4	CO	R_C g/hr	R_{CA} g/hr·ft^2	R_{H_2A} scc/min·ft^2		
4.1	79	87	155	62.3	3250	1553	708.8	229.4	4.28	188.5	13.57	7.18	374.8	1.08	.822
4.2	87	95	155	62.3	3250	1553	718.9	240.8	4.45	193.5	14.1	7.45	380.2	2.21	.80
4.3	95	103	155	64.9	3390	1552	739.4	246.4	4.61	199.7	14.5	7.66	391	3.37	.81
4.4	103	111	155	61.6	3220	1553	737.2	239.4	4.61	196.1	14.14	7.48	389.8	4.50	.82
4.5	111	119	155	62.6	3270	1551	782.6	251.2	4.97	209.1	14.95	7.909	413.8	5.70	.83
4.6	119	127	155	59.3	3080	1554	815.4	263.9	5.09	213.5	15.51	8.20	431.2	6.90	.81
4.7	127	135	155	55.2	2870	1556	835.9	270.2	5.28	213	15.7	8.30	442.1	8.20	.79
4.8	135	143	155	60.8	3170	1551	823.9	273	5.20	216.5	15.9	8.41	435.7	9.47	.79
4.9	143	153	155	60.2	3130	1554	858.5	275.3	4.77	220.7	16.09	8.51	454	11.0	.80
4.10	153	162	155	50.9	2640	1555	866.4	282.5	4.44	212	16.04	8.48	458	12.50	.75
4.11	162	170	155	59.2	3070	1555	942.3	313.5	5.75	241.9	18.03	9.54	498.3	13.96	.77
4.12	170	178	155	58.1	3020	1557	896	266	4.62	206.7	15.34	8.11	473.9	15.19	.78
4.13	178	186	155	65.9	3440	1548	977.8	341	5.66	266	19.7	10.42	517	16.8	.78
4.14	186	194	155	70.0	3660	1547	879	292	4.95	226	16.79	8.88	464.8	18.1	.77
4.15	194	201.1	155	68.5	3600	1544	928	303	5.90	234	17.46	9.23	491	19.4	.77
4.16	201.1	209	155	65.0	3390	1548	785	257	4.95	193	14.64	7.74	415	20.6	.75
4.17	209	215.1	155	63.6	3320	1547	901.9	292	5.58	228.3	16.89	8.93	476.9	21.69	.78
4.18	220	228	155	73.0	4140	1402	97.7	28.5	.47	27.8	1.83	.97	51.7	22.3	.97
4.19	228	236	155	67.8	3850	1408	92.7	28.3	.47	25.8	1.75	.93	49.1	22.4	.91
4.20	236	244	155	66.3	3750	1414	115.7	37.2	.58	32.4	2.25	1.19	61.2	22.6	.87
4.21	244	252	155	69.5	3933	1414	125	37.1	.63	34.7	2.33	1.23	66.1	22.8	.93
4.22	252	260	155	72.1	4080	1413	128.8	40.6	.65	35.2	2.46	1.30	68.12	23.0	.87
4.23	260	268	155	52.2	2940	1416	55.4	16.5	.24	12.2	.93	.49	29.3	23.1	.73
4.24	268	276	155	68.5	3880	1405	231.4	65.1	1.04	54.8	3.88	2.05	122.4	23.4	.84
4.25	276	284	155	73.90	4200	1394	89.8	29.3	.42	24.2	1.73	.92	47.8	23.5	.82
4.26	284	293	155	72.70.	4140	1426	148.9	56.8	.75	39.8	2.81	1.48	78.7	23.8	.85
4.27	293	301	155	68.7	3910	1396	107.7	34.9	.51	29.2	2.08	1.10	57	23.9	.83
4.28	301	309	155	66.5	3790	1396	49.8	15.6	.20	13.2	.935	.495	26.3	24.0	.84
4.29	309	312.5	155	64.4	3660	1389	141.6	43.9	.488	38.2	2.65	1.40	74.8	24.1	.87
4.30	316.5	324	155	58.6	3140	1502	485.9	165.7	2.87	117.3	9.19	4.86	256.9	25.0	.70
4.31	324	332	155	57.0	3050	1501	409	132.2	2.43	101.8	7.60	4.02	216.0	25.6	.77
4.32	332	340	155	57.4	3070	1502	476.1	161.1	2.81	118.9	9.09	4.81	251.7	26.4	.74
4.33	340	348	155	58.8	3150	1500	488.6	167.2	2.96	124.3	9.47	5.01	258.4	27.1	.74
4.34	348	356	155	58.8	3150	1495	464.5	159.4	2.22	119.4	9.03	4.77	245.6	27.8	.74
4.35	356	365	155	59.6	3210	1493	454.2	155.8	2.59	115.4	8.80	4.65	240.2	28.6	.74
4.36	365	373	155	60.9	3290	1492	460.3	159	2.66	117.3	8.96	4.74	243.4	29.3	.74
4.37	373	381	155	63.6	3430	1489	446.1	155.5	2.07	115.8	8.79	4.65	236	30.0	.74
4.38	381	389.1	155	61.1	3240	1488	404.2	142	2.34	103.3	7.96	4.21	213.7	30.7	.73
4.39	389.1	397.1	155	60.0	3240	1487	427.2	151	2.33	109.6	8.45	4.46	225.9	31.3	.73
4.40	397.1	405.1	155	61.9	3340	1488	438.5	149.9	2.37	113.1	8.53	4.51	231.9	32.0	.75
4.41	405	413	155	60.6	3270	1486	396.9	135.5	2.23	100.8	7.67	4.05	209.8	32.7	.74
4.42	413	421	155	60.0	3230	1486	422.6	143.2	2.52	108.1	8.16	4.31	223.4	33.3	.75
4.43	421	429	155	62.0	3350	1485	378	125.8	2.08	97	7.23	3.82	200	33.9	.77
4.44	429	437	155	60.3	3260	1484	409.8	137.2	2.31	103.9	7.83	4.14	216.7	34.5	.75
4.45	437	445.1	155	58.7	3170	1485	436.6	147.5	2.51	111.1	8.39	4.43	230.8	35.2	.75
4.46	445.1	453	155	59.6	3220	1487	419.1	144	2.39	106.8	8.14	4.30	221.6	35.6	.74
4.47	453	459	155	60.6	3270	1487	425.5	145.2	2.06	108.9	8.23	4.35	225	36.11	.75
4.48	462	470	155	59.6	3050	1580	1246	513	7.95	252	24.86	13.15	659	36.6	.49
4.49	470	478	155	59.1	3030	1585	1157	469	6.80	238	22.96	12.14	612	38.6	.50
4.50	478	486	155	57.3	2940	1583	1301	506	8.31	286	25.73	13.6	688	40.4	.56
4.51	486	494	155	53.4	2740	1582	1215	504	8.28	265	24.98	13.21	642	42.5	.52
4.52	494	503	155	57.4	2940	1580	1155	473	8.10	262	23.89	12.64	611	44.5	.55
4.53	555.7	563	155	68.3	4110	1307	10.01	3.44	.039	3.5	.227	.120	5.29	46.6	1.01
4.54	563	571	155	71.5	4320	1301	9.85	3.48	.04	3.16	.215	.115	5.21	46.7	.90
4.55	571	579	155	57.6	3470	1302	9.84	3.89	.03	2.96	.221	.117	5.21	46.7	.76
4.56	579	587	155	50.2	3030	1314	31.3	9.72	.107	8.12	.577	.305	16.5	46.7	.83
4.57	587	595	155	53.6	3230	1313	27.9	9.14	.098	7.51	.538	.284	14.8	46.8	.82
4.58	595	603	155	52.7	3180	1309	25.8	11	.099	7.86	.609	.322	13.7	46.8	.71
4.59	603	611	155	49.7	2990	1310	26.3	10.9	.102	7.79	.604	.319	13.89	46.9	.71
4.60	611	619	155	51.6	3110	1310	26.86	10.4	.102	7.82	.588	.311	14.21		.75
4.61	619	627	155	54.5	3340	1311	43.7	16.5	.148	12.13	.924	.488	23.13		.73
4.62	627	635	155	66.5	4010	1303	30.6	12.8	.112	8.89	.702	.371	16.20	47.1	.69
4.63	635	643	155	73.5	4440	1294	28.30	10.7	.105	9.13	.64	.338	14.96	47.2	.85
4.64	643	647.9	155	73.5	4440	1293	56.6	18.3	.183	18.4	1.18	.627	29.9	47.2	1.00
4.65	650.7	659	155	99.5	4700	1391	82.3	32.9	.35	23.6	1.83	.967	43.5	47.4	.72
4.66	659	667	155	104.5	5980	1389	112.3	41.5	.47	32.1	2.38	1.25	59.4		.77
4.67	667	675.2	155	109.3	6250	1386	108.1	45.3	.44	31.7	2.49	1.32	57.2		.70
4.68	675.2	684	155	122.6	7010	1386	78.9	28.8	.34	23.3	1.68	.892	41.76		.81
4.69	684	692	155	115.6	6610	1386	75.49	31.25	.35	21.5	1.71	.903	39.92	48.17	.69
4.70	692	700	155	109.6	6270	1385	109.6	42.1	.48	31.6	2.38	1.26	57.9		.75
4.71	700	709	155	33.8	1940	1411	113.6	44.3	.52	29	2.37	1.25	60.1		.65
4.72	709	717	155	28.8	1480	1406	133.6	41.8	.47	27.5	2.24	1.18	70.7		.66
4.73	717	725	155	27.8	1570	1417	126.2	56.2	.57	33.8	2.91	1.54	66.7	48.97	.60
4.74	725	733	155	23.8	1340	1406	138.6	66.3	.62	37.7	3.36	1.78	73.3		.57
4.75	733	742	155	23.8	1340	1403	109.7	46.9	.497	30.5	2.51	1.33	58		.65
4.76	742	750	155	23.8	1340	1402	126.7	51.2	.53	33.6	2.74	1.45	67.1		.66
4.77	750	758	155	27.8	1580	1399	123.8	52.6	.53	33.8	2.79	1.48	65.5		.64
4.78	758	766	155	39.7	2259	1396	113.6	42.9	.44	34.3	2.49	1.32	60.1	50.1	.80
4.79	766	774	155	32.9	1876	1392	69.1	26.9	.25	18.9	1.48	.78	36.6		.70
4.80	774	782	155	32.8	1864	1395	88.2	28.2	.31	20.4	1.57	.83	46.6		.72
4.81	782	790.1	155	30.8	1751	1389	87.7	21.4	.24	14.6	1.16	.62	46.4		.68
4.82	790.1	798	155	29.8	1705	1386	102	19.7	.31	15.9	1.15	.61	53.9	50.6	.81

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