H. J. Fought #5

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Atomic Energy Act - 1954

GROUP 1

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MASTER

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Submitted By:

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~~INFORMATION CATEGORY~~

~~Confidential RD~~

~~Authorized Classifier~~

~~Date~~

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Classification cancelled (or changed to _____)

by authority of _____

by H. J. C. TIC, date SEP 12 1973

INITIAL TEST RESULTS
SINGLE SEAL HIGH PRESSURE ISOTHERMAL TEST
(B-3, LATERAL SUPPORT SYSTEM)
(Title Unclassified)

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SPECIAL REVIEW FINAL DETERMINATION	Reviewer ☒	Class.	Date
	KAW	U	5-4-82
Class: <u>U</u>

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ABSTRACT

Under isothermal ambient temperature conditions and at pressure levels from 100 to 700 PSIA an initial component test has been performed to describe hydrogen flow past a single seal segment in the lateral support system of the reactor. The seal segment, equal in length to one of the 12 segments in the reactor, is mounted flat against flat filler strips and loaded as in the reactor by springs through plungers. The main flow past the seal segment and the auxiliary flow through the plunger annuli are simulated.

The test piece, the test equipment and test procedure are described. Measurement accuracies are specified.

The data is presented as recorded on the log sheet, as processed and printed out on the IBM 7090 digital computer and as plotted in parametric curve form.

INTRODUCTION

This test is the first of a series of flow experiments to define the hydrogen flow past a single seal segment in the lateral support and inner reflector region. In addition, the flow of the hydrogen gas through the plunger annuli from the outside to the inside of the inner reflector barrel is reproduced in accordance with reactor geometries, pressure levels and pressure differences. The flow across the seal segment is predominantly that between the filler strips and through the milled slots on the surface of the seal segments in contact with the filler strips. These two thin slots, with their major axes perpendicular to each other, form the "T" slot which is the item of major interest in this flow experiment. Seventeen "T" slots in parallel constitute the defined flow area. In addition, flow past interfaces and flow through permeable graphite constitute other active flow paths in parallel with the main flow. As regards their effect in interpreting the results of the present test, these interface and permeability flows are considered a small percent of the total flow and not affecting the flow characteristics, as such. The interfaces mentioned consist of the graphite-to-graphite contact of the seal segments with the filler strips between the milled slots, the graphite-to-aluminum contacting surfaces of the seal segment and the barrel piece, and the graphite-to-graphite contacting surfaces in the ramp portion of the scarf joint of the seal segment, refer to Figure 4. Subsequent tests will evaluate the magnitude of these interface and permeability flows, if not in the single seal rig, then in the low flow rig as separate well-controlled flow experiments depending on the demonstrated flow level and magnitude. In this initial test a gap of .002 inches between filler strips and a milled slot in the seal segment of .011 inches were chosen as being representative of a "T" slot geometry at a location in the reactor. Flow and total pressure losses in the main stream past the seal segments and in the auxiliary flow system of the plunger annuli are described in parametric form. Both flows are basically described in terms of density times pressure loss vs weight flow. Pressure loss is a total pressure loss as read; density is a total density as calculated from total pressure and total temperature as read. In this initial report, density

times pressure loss will be plotted against weight flow squared, anticipating that the slightly-variable coefficient indicated by the slope of the curve will have a simple linear relationship with a conventional loss coefficient when the component parts of the "T" slot are isolated for flow evaluation. The two narrow slots composing the "T" slot have widely different flow distributions. For purposes of associating the portion of the main flow with the particular portion of the "T" slot and in turn being able to properly define flow coefficients and Reynolds Number for each portion of the "T" slot, subsequent tests of single seals will isolate each portion of the "T" slot.

CONCLUSION

An initial isothermal hydrogen flow experiment has been performed and reported which gives flows and pressure losses across a seal segment in the lateral support and inner reflector system and across the associated plunger annuli, both representative of those in the reactor.

RECOMMENDATIONS

It is recommended that:

- A. The Single Seal High Pressure Isothermal Tests should investigate the following configuration variations.
 - 1. Filler strip gaps from 0 to .007 inches.
 - 2. Seal segment milled slot from .007 - .011 inches and unslotted combination.Items 1 and 2 should be tested in combination.
- B. Flow across the plunger annuli should be further investigated in the Low Flow Rig and should not be considered and handled as an independent variable in the Single Seal High Pressure Isothermal Tests.
- C. Graphite-to-graphite interface flows should be further investigated on the Low Flow Rig as affecting flow past the seal segment in contact with the filler strips, with the barrel piece, and with the seal segment end pieces at the ramp location in the scarf joint.
- D. The Single Seal High Pressure Isothermal Tests should be run with a H4LM graphite barrel piece impregnated to the latest barrel standards to the extent of determining if the graphite-to-aluminum interface flow can be distinguished from that of the reactor graphite-to-graphite interface.

DESCRIPTION OF TEST PIECE AND FLOW LOOP

A. TEST PIECE

Hydrogen flow passageways are effectively simulated across a single seal segment of the lateral support and inner reflector system. The graphite and aluminum pieces which define the hydrogen flow passageways are contained in a stainless-steel, high-pressure, rectangular housing, approximately twelve inches long. The configuration is flat and not circumferential as in the reactor. The filler strips are rectangular in cross-section, supported on the core side by a flat aluminum plate. These strips are fabricated of Graphitite-G graphite as in the reactor and are machined to .500 inches thick to establish the height of the flow path between the strips that approximates the average height of this flow path in the reactor. A single flat seal segment of ZTA graphite material is positioned at right angles across the filler strips. The length of this seal segment is equal to one of the twelve seal segments which make up a seal segment ring in the reactor. In this test piece, the milled slots are evenly spaced, yet duplicate on a percentage basis reactor cross-sectional flow areas per length of seal segment. The plate simulating the inner reflector graphite barrel is machined to maintain clearances with the seal segment on two sides and to be in contact with the seal segment on one other side as in the reactor. This contact of the seal segment against the barrel piece and down on the filler strips is maintained by reactor springs and plungers mounted identical to those in the reactor. The barrel piece is made of aluminum instead of graphite to avoid the excessive permeability flows of presently-available H4LM graphite. This description can be better followed by referring to photographs in Figures 1, 2 and 3 and a schematic showing hydrogen flow paths, Figure 4. Figure 1 shows the test piece disassembled and laid out as an exploded view. Figure 2 is an end-on view of the filler strips between the aluminum flat plate on the bottom and the slotted seal segment on top. Figure 3 shows the test piece with the barrel piece in place but with the two covers removed. Figures 2 and 4 emphasize

that the main flow path across the seal segment is defined by the gap between the filler strips and by the milled slot in the seal segment itself. Gaps between the filler strips are maintained by shimming. In this configuration the gap was set at .002 inches, a nominal depth of the milled slot in the seal segment is .011 inches in this configuration; width of the slot is .440 inches. Detailed measurements of the depths of each slot are found in an attachment to the log sheet. The average difference in size of the diameters of the four plungers and associated holes in the barrel is .0012 inches. These pins are cocked in the hole by the offset "v" groove in the seal segment with which they mate, providing side thrust of the seal segment against the barrel as in the reactor. Manifolds through the housing on each side of the seal segment provide entrance and exit for the main flow past the seal segment. Auxiliary hydrogen flow is introduced on the spring side of the barrel piece. This flow merges with the main flow after passing through the plunger annuli. Specific dimensions of the diameter of the plungers and of the holes are found on the log sheet. Internal sealing to establish a system free of extraneous bypassing flows is accomplished by the combined use of "O" rings, cement and sealing compounds. Step-by-step pressure checking during the assembly demonstrates leak-free internal joints; pressure checking after final assembly demonstrates the elimination of external leakage. Wall pressure taps upstream and downstream of the seal segment and upstream of the plunger annuli are all in regions of large cross-sectional areas. Accordingly, these measurements properly record total pressures since velocities in these regions are negligible.

B. FLOW LOOP

The test piece is coupled into a flow loop consisting of a system of valves, calibrated orifices and pipe fed by a common gaseous hydrogen supply line and vented by a common exhaust. Regulated valving provides the setting of individual pressures entering the seal segment region, entering the spring chamber region and leaving the seal segment region. Wide ranges of pressure levels up to 700 psia and pressure differences up to 150 psi across the plunger annuli and 20 psi across the seal segments

can be accomplished. Each flow entering the test piece and the total flow leaving are measured, thus demonstrating flow continuity. Figure 5 shows schematically the flow diagram of this loop. Pressure drop across Daniels sharp-edged orifices indicate the hydrogen flows at the three locations mentioned above. Note that provision for a fourth flow to or from the test piece as indicated in Figure 5 is not currently being used. The flow loop consists of stainless steel pipe and flexible hose. The valves are diaphragm operated and are remotely controlled. Copper-constantan thermocouples are employed; pressure levels and pressure differences are shown on dial indicators and on a manometer mounted on a panel in the test cell and read by telescope from the control room. Figure 6 is a photograph of the test piece mounted in the flow loop next to the instrument panel.

TEST PROCEDURE

Total pressure upstream of the seal is varied over the range of 100 to 700 psia. The pressure drop across the seal is varied from a high to a low value for each of the entering pressure levels. The maximum pressure drop across the seal is limited by the flow capacity of the loop. At 700 psia the maximum pressure drop is 15 psi; the minimum as set is 2 psi. At the lower pressure levels the ΔP is varied from 2 psi to values less than 15 psi. For each combination of these pressure levels and pressure differences individual points define varying magnitudes of pressure drop across the plunger annuli. The pressure drop in this auxiliary flow is varied from zero to 150 psi. Hydrogen flow is measured entering the seal segment region, entering the plunger annuli region, and leaving the seal segment region. By choice of orifice size and by use of various ranges of dial indicator pressure gages and manometers in parallel, in some cases, an attempt is made to use the pressure and flow measuring instruments toward the top of their measuring range. Estimated expected errors in measurements both on a relative and absolute basis take into consideration inherent accuracy of the instrument and the closeness to which it can be read under test stand conditions. Accuracies on a relative basis involve ability to reproduce data without reference to a standard; accuracies on an absolute basis involve comparison to a standard or to data from other test facilities. On a relative basis at the lowest level at which the readings are taken estimated expected errors of pressure level are 2.5%; pressure differences, 1.5%; and weight flow measurements, 1.5%. Still on a relative basis at the highest level at which the readings are taken the estimated expected errors of pressure level are 0.5%; pressure differences, 0.5%; weight flow measurements, 0.5%. On an absolute basis these estimated expected errors are approximately twice those quoted above.

The readings are entered in the log sheet on the test stand, Figures 7 and 8. The data is processed by IBM 7090 digital computer. The results are printed out along with the original input on output sheets, Figures 9 through 16.

Subsequent to processing the data and evaluating flow continuity, points 7, 8 and 11 of the 61 total points involved were discarded as not meeting expected closure between flows measured entering and leaving. These three points are at the extreme low end of the flow range.

RESULTS AND DISCUSSION

Figures 17 and 18 shows density times pressure loss plotted against weight flow across the seal segment. Weight flow in Figure 17 is the sum of the flows as measured entering; in Figure 18 weight flow is as measured leaving. The density is a total based on total temperature and total pressure entering the region of the losses, pressure level being this same total pressure. The curves are parabolic type characteristic of turbulent flow. Figures 19 and 20 employ the same data but plot the density times pressure loss versus weight flow squared. These curves appear to be linear indicating that a coefficient, K , which equals $\frac{\rho \Delta P}{W^2}$ is constant. This coefficient K bears a simple linear relationship to the inverse of a conventional loss coefficient, C_L , since K can be shown to be equal to $\frac{2g A^2}{C_L}$ where A equals the flow area where the losses take place. Since it is reasonable to separate the "T" slot into two components, as mentioned previously, for purposes of applying loss coefficients and calculating Reynolds Numbers, this type of presentation of the data awaits testing of configurations where the components of the "T" slot are isolated. It is interesting to note in curves of Figures 17 through 20 that the test points correlate as a single line, within measuring accuracies, showing that $\rho \Delta P$ is independent of flow through the plunger annuli and is not affected by the small range of Reynolds Number over which groups of points at the same weight flow levels were run.

Figure 21 shows density times pressure loss versus weight flow through the plunger annuli again based on totals entering. This linear-type curve suggests laminar flow through the very narrow annuli widths. No explanation is suggested for the apparent discontinuity in slope at the extreme low-flow end of the curve.

Single Seal High Pressure Isothermal Test

Test Piece Disassembled and Laid Out as an Exploded View

Figure 1

Single Seal High Pressure Isothermal Test

End View of Filler Strips Between Aluminum Bottom Plate
and Graphite Seal Segment Showing "T" Slots

Figure 2

Single Seal High Pressure Isothermal Test

Test Piece With Covers Removed

Figure 3

Single Seal High Pressure Isothermal Test

Schematic Showing Flow Paths

Figure 4

Figure 5

Single Seal High Pressure Isothermal Test

Rig With Test Piece Installed

Figure 6

X																				
POINT ↓	P1 PSIG	P02 PSIG	P01 PSIG	P03 PSIG	P04 PSIG	DP04 INH ₂ O	DP03 INH ₂ O	DP1-4 PSID	DP1-2 INH ₂ O	DP3-1 PSID	DP02 INH ₂ O	DP01 INH ₂ O	T01 MV	T02 M.I	T03 MV	T3 M.I	T4 MV	T04 MV	REMARKS	
1 33	100	100	66.5	100	110	31.8	0		62											N G
2 34	100	100	65.0	100	100	31.2	0		60	0	0	5.3	.040	.160	.160	.150	.150	.120		
3 35	100	100	61.5	100	100	29.5	0		60		0									N G
4 36	90	9.5	62.0	90	90	27	0		59	21	0	4.2	.000	.140	.140	.120	.120	.120		
5 37	100	130	57.0	85	100	30	0		60	38.5	5	5.6	.000	.120	.120	.070	.070	.070		
6 38	100	180	54.0	93	100	29	0		60	79	8	5.3	-.070	.09	.160	.08		.120		
7 39	90	205	100	93	90	27.2	0		60	116	14	4.9	.05	.06	.14	.06		.07		
8 40	100	275	300	100	105	32.3	0		62	160	27.5	6.8	-.14	.02	.11	.02		.04		
9 41	205	200	425	205	210	40	0		68	.30	0	19	-.15	.05	.08	-.04		.00		
10 42	190	200	350	190	190	40.6	0		70	20	0	21.5	-.16	.05	.095	-.06		.01		Run Ended 1615 hrs 18 Feb 64
11 43	195	250	560	195	300	19	0		70	47	5	6.3	.08	.18	.14	.19		.12		Run 22 started 0800 hrs 19 Feb 64
12 44	195	300	550	290	195	18.5	0		70	102	17.3	5.8	.05	.12	.14	.14		.08		P Bar = 28.54 ¹⁰⁰ PSIG at 2200 p.s.i.
13 45	195	365	530	190	195	18.5	0		70	172	41	5.6	.03	.10	.15	.120		.060		At start of Run it was not used.
14 46	300	300	630	300	300	25.7	0		80	2	0	12	-.07	.08	.14	.04		.02		That Op 31 low was not reading properly so Op 31 ^{low} was not used.
15 47	300	320	625	300	300	25.5	0		80	20	.70	11.8	-.07	.06	.12	.04		.01		
16 48	290	365	590	290	290	24.6	0		80	78	14.6	11.2	-.07	.02	.14	.04		.02		
17 49	280	435	585	280	280	23.7	0		80	154	43	10.1	-.14	-.09	.14	.01		.00		
18 50	290	290	540	290	285	4.5	0		140	4	0	23.3	-.09	.00	.14	.01		.00		
19 51	285	300	535	285	285	44.3	0		140	23	1	22.6	-.19	-.07	.14	-.09		-.05		
20 52	320	400	590	320	315	44.8	0		140	85	17.6	22.5	-.17	-.001	.14	.06		-.05		
21 53	310	460	570	315	310	44	0		142	144	38.5	21.8	-.19	-.14	.14	-.12		-.08		
22 54	390	380	560	395	390	2.3	0		70	0	0	15.5	-.36	-.13	.16	-.14		-.100		
23 55	385	410	560	385	385	22.7	0		70	18	.5	15.1	-.24	-.14	.16	-.17		-.108		
24 56	385	420	520	385	395	23.5	0		70	20	12.5	16.2	-.22	-.16	.16	-.14		-.08		
25 57	400	580	620	400	400	20.3	0		68	174	58	11.6	-.28	-.25	.15	-.19		-.08		
26 58	410	485	595	410	400	42.5	0		140	78	17.2	29.9	-.36	-.29	.18	-.25		-.12		
27 59	410	515	575	400	400	27	0		140	118	29.8	29.6	-.36	-.30	.14	-.26		-.13		
28 60	390	540	560	390	385	4.5	0		140	147	44	28.4	-.40	-.32	.15	-.25		-.18		
29 61	385	395	565	385	380	48.3	0		140	18	.5	30.5	.40	.32	.14	-.34		-.19		
30 62	399	395	520	400	395	48.3	0		140	3	0	35	.31	.10	.29	-.22		-.05		
31 63	410	425	550	410	400	70	0		200	20	1.3	49.8	.25	.06	.35	.12		.08		
32 64	385	470	515	385	380	67.8	0		200	78	14.3	49.6	.30	.20	.36	.15		.10		
Prior to Test The rig passed an internal leakage Test.																				

Prior to Test The 119 passed an internal leakage Test.

WESTINGHOUSE ELECTRIC
CORPORATION

Astronuclear Laboratory
PITTSBURGH, PA.

FLUID FLOW LAB

LOG SHEET

B-3 SINGLE SEAL ISOTHERMAL TEST

TEST RECORD BOOK NO 1735729 RUN NO 22 SHEET 1 OF 2
TIME OF DAY 1500 hrs DATE 18 Feb 64
ENGINEER R. J. Stoffen OPERATOR Botti + Morris
REF JUNCTION 32°F TEST GAS Hydrogen
SUPPLY PRESSURE BEFORE 1000 SUPPLY PRESSURE AFTER 300
SUPPLY TEMP BEFORE 35°F SUPPLY TEMP AFTER 30°F
BAR PRESSURE 2891 @ 64°F SEGMENT I

CONFIGURATION

DIM IN INCHES A₁ .3755 ACT B₁ .3738 ACT X .002 ACT
 A₂ .3750 ACT B₂ .3738 ACT Y .011 NOM
 A₃ .3746 ACT B₃ .3738 ACT
 A₄ .3748 ACT E₄ .3738 ACT

Figure 7

POINT	P1 PSIG	P02 PSIG	P01 PSIG	P03 PSIG	P04 PSIG	DP04 INH ₂ O	DP03 INH ₂ O	DP1-4 PSID	DP1-2 INH ₂ O	DP3-1 PSID	DP02 INH ₂ O	DP01 INH ₂ O	T01 M/V	T02 M/V	T03 M/V	T3 MV	T4 MV	T04 M/V	REMARKS
1 33	400	555	615	400	395	66	0		200	150	41.3	38.5	.33	.25	.33	.16		.08	
2 34	410	410	540	410	400	70	0		198	2	0	50	.39	.17	.34	.22		.09	
3 35	495	490	570	500	490	26.5	0		80	0	0	22	.37	.104	.86	.24		.12	
4 36	490	565	555	490	485	26.5	0		80	20	1.5	22	.33	.15	.39	.22		.10	End of Run 12.12 hrs 19 Feb 64
5 37	700	680	700	700	690	41	0		84	0	0	40	.11	.20	.38	.16		.13	Start of Run 0945 hrs Per 29.19 Q517
6 38	700	710	750	700	690	37	0		80	22	4	32	.08	.17	.38	.18		.12	20 Feb 64
7 39	700	750	750	705	700	35.5	0		80	60	23.5	31	.03	.12	.38	.11		.10	
8 40	690	685	690	685	670	117	0		248	0	0	110	.02	.12	.38	.05		.09	
9 41	700	760	765	710	690	118	0		252	62	23	98	.15	.01	.39	.03		.07	
10 42	695	715	725	695	680	116	0		248	22	3.5	102	.15	.03	.35	.01		.04	
11 43	640	640	640	630	600	174	0		390	0	0	158	.17	.08	.38	.02		.01	
12 44	490	465	740	490	480	36	0		80	80	23	22	.08	.01	.36	.00		.05	
13 45	500	640	660	500	500	33	0		80	148	57	22	.12	.02	.36	.00		.07	End of Run 1035 hrs 20 Feb 64
14 46	495	575	770	495	490	66	0		160	84	22.2	39	.220	.06	.000	.05		.17	Start of Run 0700 hrs 21 Feb 64
15 47	555	580	770	555	550	79	0		190	24	3	56	.340	.120	.000	.09		.220	Per 29.25 "Hy @ 55°F"
16 48	430	430	590	430	425	60	0		196	0	0	43	.340	.080	.000	.140		.240	
17 49	570	710	770	570	560	82	0		800	142	53	56	.390	.30	.000	.170		.20	
18 50	545	710	770	545	530	100	0		245	155	47	62	.420	.360	.000	.240		.20	
19 51	495	580	770	500	485	97	0		244	80	21.2	58	.460	.390	.010	.310		.230	
20 52	450	470	710																N. G.
21 53	490	510	770	490	480	96	0		235	20	1.6	62	.470	.470	.380	.000		.220	
22 54	465	465	750	460	450	96	0		220	0	0	53	.540	.315	.020	.360		.240	
23 55	625	625	700	620	600	126	0		300	0	0	105	.570	.250	.00	.410		.240	
24 56	600	620	680	600	585	124	0		300	18	.9	104	.580	.320	.00	.400		.240	
25 57	570	610	650	570	560	117	0		282	40	6.6	97	.620	.450	.020	.390		.260	
26 58	585	680	780	590	575	120	0		300	94	27.8	85	.590	.520	.060	.380		.120	
27 59	585	685	780	590	580	66	0		164	100	28	47	.600	.540	.060	.440		.190	
28 60	600	620	785	610	600	68	0		164	20	1.6	50	.620	.500	.050	.440		.200	
29 61	600	640	785	605	600	68	0		164	42	7.9	50	.610	.530	.060	.410		.190	
30 62	600	600	785	605	600	68	0		158	0	0	50	.610	.480	.090	.420		.200	
31 63	680	700	730	680	660	161	0		390	20	2	140	.670	.460	.10	.440		.230	
32 64	700	770	790	700	680	159	0		388	82	22.6	130	.70	.57	.10	.470		.20	End of Run 0905 hrs 21 Feb 64

Prior to test The rig passed an internal leakage test

WESTINGHOUSE ELECTRIC CORPORATION
Astronuclear Laboratory
PITTSBURGH, PA.

FLUID FLOW LAB
LOG SHEET

B-3 SINGLE SEAL ISOTHERMAL TEST

TEST RECORD BOOK NO 1735730 RUN NO 22 SHEET 2 OF 2
TIME OF DAY 1500 hrs DATE 18 Feb 64
ENGINEER R.J. Steffen OPERATOR Botti & No1113
REF JUNCTION 32°F TEST GAS Hydrogen
SUPPLY PRESSURE BEFORE 1000 SUPPLY PRESSURE AFTER 300
SUPPLY TEMP BEFORE 35°F SUPPLY TEMP AFTER 30°F
BAR PRESSURE 2891 @ 54°F SEGMENT I

CONFIGURATION

DIM IN INCHES A1 .3755 ACT B1 .3138 ACT X .002 ACT
A2 .3750 ACT B2 .3738 ACT Y .011 NOM
A3 .3746 ACT B3 .3738 ACT
A4 .3748 ACT B4 .3738 ACT

ORIFICE SIZE
ORIFICE O1 .485 INCHES
O2 .076
O3 .124
O4 .485

Figure 8

MASS FLOW AND RHO DELTAP PRODUCTS FOR SINGLE SEAL TEST DATA														
ORIFICE	RUN NUMBER 22				BAR. PRESS. = 28.91IN.HG = 14.20PSIA									
	K(BETA)SQ.				USQ.				FSUBA				Y	
	01	1.6169E-01			9.1580E-01				9.9900E-01				1.0000E 00	
	02	1.1890E-02			2.9810E-01				9.9900E-01				1.0000E 00	
	04	1.6169E-01			9.1580E-01				9.9900E-01				1.0000E 00	
INPUT DATA														
POINT	P1	DP12	DP31	T3	P01	T01	DP01	P02	T02	DP02	P04	T04	DP04	
	PSIG	PSID	PSID	MV	PSIG	MV	IN.H2O	PSIG	MV	IN.H2O	PSIG	MV	IN.H2O	
2.0	100.0	2.16	0.	0.150	650.0	0.040	5.30	100.0	0.160	0.	100.0	0.120	31.20	
4.0	90.0	2.13	21.0	0.120	620.0	0.	4.20	95.0	0.140	0.	90.0	0.120	27.00	
5.0	100.0	2.16	38.5	0.070	570.0	0.	5.60	130.0	0.120	0.50	100.0	0.070	30.00	
6.0	100.0	2.16	79.0	0.080	540.0	-0.070	5.30	180.0	0.090	8.00	100.0	0.120	29.00	
7.0	90.0	2.16	116.0	0.060	100.0	-0.050	4.90	205.0	0.060	14.00	90.0	0.070	27.20	
8.0	100.0	2.24	160.0	0.020	300.0	-0.140	6.80	275.0	0.020	27.50	105.0	0.040	32.30	
9.0	205.0	2.45	0.3	-0.040	425.0	-0.150	19.00	200.0	0.050	0.	210.0	0.	40.00	
10.0	190.0	2.53	20.0	-0.060	350.0	-0.160	21.50	200.0	0.050	0.	190.0	0.010	40.60	

Figure 9

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

OUTPUT DATA

RUN NUMBER 22

FLOW RATES IN LB/SEC RHO*DP IN LB.SQ/FT**5

W01	RHO1*DP12	W04	W01+W02	W02	RHO3*DP31	W02(SQ)	W04(SQ)	(W01+W02)SQ
1.6844E-02	1.3454E 01	1.7073E-02	1.6844E-02	0.	0.	0.	2.9149E-04	2.9371E-04
1.4689E-02	1.2156E 01	1.5174E-02	1.4689E-02	0.	1.2621E 02	0.	2.3025E-04	2.1575E-04
1.6296E-02	1.3505E 01	1.6781E-02	1.6354E-02	5.8101E-05	2.8975E 02	3.3757E-09	2.8159E-04	2.6746E-04
1.5502E-02	1.3595E 01	1.6460E-02	1.5772E-02	2.6982E-04	7.6649E 02	7.2802E-08	2.7094E-04	2.4876E-04
6.8204E-03	1.2386E 01	1.5266E-02	7.2000E-03	3.7956E-04	1.2963E 03	1.4407E-07	2.3304E-04	5.1840E-05
1.3332E-02	1.4195E 01	1.7812E-02	1.3944E-02	6.1133E-04	2.2604E 03	3.7373E-07	3.1728E-04	1.9443E-04
2.6294E-02	2.9707E 01	2.7181E-02	2.6294E-02	0.	3.3729E 00	0.	7.3882E-04	6.9136E-04
2.5522E-02	2.8623E 01	2.6132E-02	2.5522E-02	0.	2.3041E 02	0.	6.8200E-04	6.5138E-04

Figure 10

CONFIDENTIAL
RESTRICTED DATA

Atomic Energy Act - 1954

MASS FLOW AND RHO DELTAP PRODUCTS FOR SINGLE SEAL TEST DATA

ORIFICE	RUN NUMBER 22	BAR. PRESS. = 28.64IN.HG = 14.07PSIA		
01	K(BETA)SQ.	DSQ.	FSUBA	Y
02	1.6169E-01	9.1580E-01	9.9900E-01	1.0000E 00
04	1.1890E-02	2.9810E-01	9.9900E-01	1.0000E 00
	1.6169E-01	9.1580E-01	9.9900E-01	1.0000E 00

INPUT DATA

POINT	P1 PSIG	DP12 PSID	DP31 PSID	T3 MV	P01 PSIG	T01 MV	DP01 IN.H2O	P02 PSIG	T02 MV	DP02 IN.H2O	P04 PSIG	T04 MV	DP04 IN.H2O
11.0	195.0	2.53	47.0	0.190	560.0	0.080	6.30	250.0	0.180	5.00	300.0	0.120	19.00
12.0	195.0	2.53	102.0	0.140	550.0	0.050	5.80	300.0	0.120	17.30	195.0	0.080	18.50
13.0	195.0	2.53	172.0	0.120	550.0	0.030	5.60	365.0	0.100	41.00	195.0	0.060	18.50
14.0	300.0	2.88	2.0	0.040	630.0	-0.070	12.00	300.0	0.080	0.	300.0	0.020	25.70
15.0	300.0	2.88	20.0	0.040	625.0	-0.070	11.80	320.0	0.060	0.70	300.0	0.010	25.50
16.0	290.0	2.88	78.0	0.040	590.0	-0.070	11.20	365.0	0.020	14.60	290.0	0.020	24.60
17.0	280.0	2.88	154.0	0.010	585.0	-0.140	10.10	435.0	-0.090	43.00	280.0	0.	23.70
18.0	290.0	5.05	4.0	-0.010	540.0	-0.090	23.30	290.0	0.	0.	285.0	0.	45.00
19.0	285.0	5.05	23.0	-0.090	535.0	-0.190	22.60	300.0	-0.070	1.00	285.0	-0.050	44.30
20.0	320.0	5.05	85.0	-0.060	590.0	-0.170	22.50	400.0	-0.100	17.60	315.0	-0.050	44.80
21.0	310.0	5.12	144.0	-0.120	570.0	-0.190	21.80	460.0	-0.140	38.50	310.0	-0.080	44.00
22.0	390.0	2.53	0.	-0.140	560.0	-0.260	15.50	380.0	-0.130	0.	390.0	-0.100	23.00
23.0	385.0	2.53	18.0	-0.170	560.0	-0.240	15.10	410.0	-0.140	0.50	385.0	-0.100	22.70
24.0	395.0	2.53	70.0	-0.140	520.0	-0.230	16.20	470.0	-0.160	12.50	395.0	-0.080	23.50
25.0	400.0	2.45	174.0	-0.190	620.0	-0.280	11.60	580.0	-0.250	58.00	400.0	-0.080	20.30
26.0	410.0	5.05	78.0	-0.250	595.0	-0.360	29.90	485.0	-0.290	17.20	400.0	-0.120	47.50
27.0	410.0	5.05	118.0	-0.260	575.0	-0.360	29.60	515.0	-0.300	29.80	400.0	-0.130	47.00
28.0	390.0	5.05	147.0	-0.250	560.0	-0.400	28.40	540.0	-0.320	44.00	385.0	-0.120	45.00
29.0	385.0	5.05	18.0	-0.340	565.0	-0.400	30.50	395.0	-0.320	0.50	380.0	-0.190	48.30
30.0	399.0	5.05	3.0	-0.220	520.0	-0.310	35.00	395.0	-0.100	0.	395.0	-0.050	48.30
31.0	410.0	7.22	20.0	-0.120	550.0	-0.290	49.80	425.0	-0.060	1.30	400.0	0.080	70.00
32.0	385.0	7.22	78.0	-0.150	515.0	-0.300	49.60	470.0	-0.200	14.30	380.0	0.100	67.80
33.0	400.0	7.23	150.0	-0.160	615.0	-0.330	38.50	555.0	-0.250	41.30	395.0	0.080	66.00
34.0	410.0	7.15	2.0	-0.220	540.0	-0.390	50.00	410.0	-0.170	0.	400.0	0.090	70.00
35.0	495.0	2.89	0.	-0.240	570.0	-0.370	22.00	490.0	-0.040	0.	490.0	0.120	26.90
36.0	490.0	2.89	20.0	-0.220	555.0	-0.330	22.00	505.0	-0.150	1.50	485.0	0.100	26.50

Figure 11

OUTPUT DATA
RUN NUMBER 22
FLOW RATES IN LB/SEC RHO*DP IN LB.SQ/FT**5

W01	RHO1*DP12	W04	W01+W02	W02	RHO3*DP31	W02(SQ)	W04(SQ)	(W01+W02)SQ
1.7074E-02	2.8637E 01	2.2009E-02	1.7321E-02	2.4737E-04	6.0877E 02	6.1190E-08	4.8439E-04	3.0003E-04
1.6265E-02	2.8717E 01	1.7789E-02	1.6768E-02	5.0269E-04	1.6253E 03	2.5270E-07	3.1644E-04	2.8116E-04
1.5997E-02	2.8771E 01	1.7805E-02	1.6847E-02	8.4987E-04	3.3835E 03	7.2227E-07	3.1703E-04	2.8382E-04
2.5098E-02	4.9462E 01	2.5717E-02	2.5098E-02	0.	3.2703E 01	0.	6.6134E-04	6.2991E-04
2.4794E-02	4.9462E 01	2.5628E-02	2.4898E-02	1.0454E-04	3.4627E 02	1.0928E-08	6.5681E-04	6.1993E-04
2.3502E-02	4.7907E 01	2.4761E-02	2.4011E-02	5.0905E-04	1.5500E 03	2.5913E-07	6.1313E-04	5.7655E-04
2.2303E-02	4.6663E 01	2.3929E-02	2.3257E-02	9.5445E-04	3.6095E 03	9.1097E-07	5.7258E-04	5.4090E-04
3.2531E-02	8.4164E 01	3.3248E-02	3.2531E-02	0.	6.3994E 01	0.	1.1054E-03	1.0583E-03
3.2051E-02	8.3602E 01	3.3067E-02	3.2173E-02	1.2194E-04	3.8822E 02	1.4870E-08	1.0934E-03	1.0351E-03
3.3471E-02	9.3072E 01	3.4860E-02	3.4058E-02	5.8705E-04	1.8737E 03	3.4463E-07	1.2152E-03	1.1600E-03
3.2442E-02	9.1753E 01	3.4336E-02	3.3372E-02	9.2967E-04	3.5716E 03	8.6428E-07	1.1790E-03	1.1137E-03
2.7219E-02	5.6734E 01	2.7702E-02	2.7219E-02	0.	0.	0.	7.6738E-04	7.4088E-04
2.6839E-02	5.5933E 01	2.7352E-02	2.6940E-02	1.0031E-04	3.9906E 02	1.0062E-08	7.4815E-04	7.2574E-04
2.6824E-02	5.7255E 01	2.8144E-02	2.7359E-02	5.3569E-04	1.7809E 03	2.8696E-07	7.9208E-04	7.4853E-04
2.4739E-02	5.6388E 01	2.6314E-02	2.6020E-02	1.2809E-03	5.4655E 03	1.6407E-06	6.9245E-04	6.7704E-04
3.9104E-02	1.1994E 02	4.0330E-02	3.9745E-02	6.4191E-04	2.1029E 03	4.1204E-07	1.6265E-03	1.5797E-03
3.8279E-02	1.1994E 02	4.0136E-02	3.9149E-02	8.6982E-04	3.4396E 03	7.5658E-07	1.6109E-03	1.5327E-03
3.7102E-02	1.1484E 02	3.8548E-02	3.8184E-02	1.0821E-03	4.3520E 03	1.1710E-06	1.4860E-03	1.4580E-03
3.8612E-02	1.1344E 02	3.9825E-02	3.8711E-02	9.9422E-05	4.0580E 02	9.8847E-09	1.5860E-03	1.4985E-03
3.9583E-02	1.1630E 02	4.0291E-02	3.9583E-02	0.	6.6672E 01	0.	1.6233E-03	1.5668E-03
4.8349E-02	1.6961E 02	4.8497E-02	4.8513E-02	1.6390E-04	4.7030E 02	2.6862E-08	2.3520E-03	2.3535E-03
4.6881E-02	1.6057E 02	4.6538E-02	4.7456E-02	5.7407E-04	1.9779E 03	3.2956E-07	2.1658E-03	2.2520E-03
4.5008E-02	1.6723E 02	4.6811E-02	4.6066E-02	1.0585E-03	4.5062E 03	1.1204E-06	2.1913E-03	2.1221E-03
4.8360E-02	1.7033E 02	4.8475E-02	4.8360E-02	0.	4.5535E 01	0.	2.3498E-03	2.3387E-03
3.2881E-02	8.2180E 01	3.2801E-02	3.2881E-02	0.	0.	0.	1.0759E-03	1.0812E-03
3.2402E-02	8.1066E 01	3.2671E-02	3.2594E-02	1.9192E-04	5.6134E 02	3.6835E-08	1.0674E-03	1.0624E-03

Figure 12

MASS FLOW AND RHO DELTAP PRODUCTS FOR SINGLE SEAL TEST DATA

ORIFICE		RUN NUMBER 22			BAR. PRESS. = 29.19IN.HG = 14.34PSIA								
		K(BETA)SQ.			DSQ.		FSUBA		Y				
01		1.6169E-01			9.1580E-01		9.9900E-01		1.0000E 00				
02		1.1890E-02			2.9810E-01		9.9900E-01		1.0000E 00				
04		1.6169E-01			9.1580E-01		9.9900E-01		1.0000E 00				
INPUT DATA													
POINT	P1	DP12	DP31	T3	P01	T01	DP01	P02	T02	DP02	P04	T04	DP04
	PSIG	PSID	PSID	MV	PSIG	MV	IN.H2O	PSIG	MV	IN.H2O	PSIG	MV	IN.H2O
37.0	700.0	3.03	0.	0.160	700.0	0.110	40.00	680.0	0.200	0.	690.0	0.130	41.00
38.0	700.0	2.89	22.0	0.180	750.0	0.080	32.00	710.0	0.170	4.60	690.0	0.120	37.00
39.0	700.0	2.89	60.0	0.110	750.0	0.030	31.00	750.0	0.120	23.50	700.0	0.100	35.50
40.0	690.0	8.96	0.	0.050	690.0	-0.020	110.00	685.0	0.120	0.	670.0	0.090	117.00
41.0	700.0	9.11	62.0	0.030	765.0	-0.150	98.00	760.0	-0.010	23.00	690.0	0.070	118.00
42.0	695.0	8.96	22.0	0.	725.0	-0.150	102.00	715.0	0.030	3.50	680.0	0.040	116.00
43.0	640.0	14.09	0.	-0.020	640.0	-0.170	158.00	640.0	0.080	0.	600.0	0.010	174.00
44.0	490.0	2.89	80.0	0.	740.0	-0.080	22.00	465.0	0.010	23.00	480.0	0.050	36.00
45.0	500.0	2.89	148.0	0.	660.0	-0.120	22.00	640.0	-0.020	57.00	500.0	0.070	33.00

Figure 13

OUTPUT DATA

RUN NUMBER 22

FLOW RATES IN LB/SEC RHO*DP IN LB.SQ/FT**5

W01	RHO1*DP12	W04	W01+W02	W02	RHO3*DP31	W02(SQ)	W04(SQ)	(W01+W02)SQ
4.7781E-02	1.1444E 02	4.8001E-02	4.7781E-02	0.	0.	0.	2.3041E-03	2.2830E-03
4.4219E-02	1.0945E 02	4.5620E-02	4.4583E-02	3.6312E-04	8.3418E 02	1.3185E-07	2.0812E-03	1.9876E-03
4.3624E-02	1.0996E 02	4.5034E-02	4.4529E-02	9.0539E-04	2.4061E 03	8.1972E-07	2.0280E-03	1.9829E-03
7.9173E-02	3.3787E 02	8.0109E-02	7.9173E-02	0.	0.	0.	6.4175E-03	6.2683E-03
7.8963E-02	3.5258E 02	8.1658E-02	7.9870E-02	9.0679E-04	2.5112E 03	8.2226E-07	6.6680E-03	6.3792E-03
7.8534E-02	3.4442E 02	8.0516E-02	7.8877E-02	3.4300E-04	8.4245E 02	1.1765E-07	6.4827E-03	6.2215E-03
9.2214E-02	5.0179E 02	9.3047E-02	9.2214E-02	0.	0.	0.	8.6578E-03	8.5033E-03
3.6706E-02	7.9155E 01	3.7991E-02	3.7423E-02	7.1732E-04	2.4509E 03	5.1455E-07	1.4433E-03	1.4005E-03
3.4832E-02	8.1000E 01	3.7052E-02	3.6149E-02	1.3163E-03	5.1374E 03	1.7327E-06	1.3729E-03	1.3067E-03

Figure 14

MASS FLOW AND RHO DELTAP PRODUCTS FOR SINGLE SEAL TEST DATA

ORIFICE		RUN NUMBER 22		BAR. PRESS. = 29.25IN.HG = 14.37PSIA				Y					
		K(BETA)SQ.		DSQ.		FSUBA							
01		1.6169E-01		9.1580E-01		9.9900E-01		1.0000E 00					
02		1.1890E-02		2.9810E-01		9.9900E-01		1.0000E 00					
04		1.6169E-01		9.1580E-01		9.9900E-01		1.0000E 00					
INPUT DATA													
POINT	P1	DP12	DP31	T3	P01	T01	DP01	P02	T02	DP02	P04	T04	DP04
	PSIG	PSID	PSID	MV	PSIG	MV	IN.H2O	PSIG	MV	IN.H2O	PSIG	MV	IN.H2O
46.0	495.0	5.78	84.0	-0.050	770.0	-0.220	39.00	575.0	-0.060	22.70	490.0	-0.170	66.00
47.0	555.0	6.86	24.0	-0.090	770.0	-0.340	56.00	580.0	-0.120	3.00	550.0	-0.220	79.00
48.0	430.0	7.08	0.	-0.140	590.0	-0.340	43.00	430.0	-0.080	0.	425.0	-0.240	60.00
49.0	570.0	7.23	142.0	-0.170	770.0	-0.390	56.00	710.0	-0.300	53.00	560.0	-0.200	82.00
50.0	545.0	8.85	155.0	-0.240	770.0	-0.420	62.00	710.0	-0.360	47.00	530.0	-0.200	100.00
51.0	495.0	8.82	80.0	-0.310	770.0	-0.460	58.00	580.0	-0.390	21.20	485.0	-0.230	97.00
53.0	490.0	8.49	20.0	-0.290	770.0	-0.470	62.00	510.0	-0.380	1.60	480.0	-0.220	96.00
54.0	465.0	7.95	0.	-0.360	750.0	-0.540	53.00	465.0	-0.315	0.	450.0	-0.240	90.00
55.0	625.0	10.84	0.	-0.410	700.0	-0.570	105.00	625.0	-0.250	0.	600.0	-0.240	126.00
56.0	600.0	10.48	18.0	-0.400	680.0	-0.580	104.00	620.0	-0.320	0.90	585.0	-0.240	124.00
57.0	570.0	10.41	40.0	-0.390	650.0	-0.620	97.00	610.0	-0.450	6.60	560.0	-0.260	117.00
58.0	585.0	10.84	94.0	-0.380	780.0	-0.590	85.00	680.0	-0.520	27.80	575.0	-0.190	120.00
59.0	585.0	5.93	100.0	-0.440	780.0	-0.600	47.00	685.0	-0.540	28.00	580.0	-0.190	66.00
60.0	600.0	5.93	20.0	-0.440	785.0	-0.620	50.00	620.0	-0.500	1.60	600.0	-0.200	68.00
61.0	600.0	5.93	42.0	-0.410	785.0	-0.610	50.00	640.0	-0.530	7.90	600.0	-0.190	68.00
62.0	600.0	5.71	0.	-0.420	785.0	-0.610	50.00	600.0	-0.480	0.	600.0	-0.200	68.00
63.0	680.0	14.09	20.0	-0.440	730.0	-0.670	140.00	700.0	-0.460	2.00	660.0	-0.220	161.00
64.0	700.0	14.02	82.0	-0.470	790.0	-0.700	130.00	770.0	-0.570	22.60	680.0	-0.200	159.00

Figure 15

OUTPUT DATA

RUN NUMBER 22

FLOW RATES IN LB/SEC RHO*DP IN LB./SQ/FT**5

W01	RHO1*DP12	W04	W01+W02	W02	RHO3*DP31	W02(SQ)	W04(SQ)	(W01+W02)SQ
5.0137E-02	1.6203E 02	5.2494E-02	5.0919E-02	7.8220E-04	2.6254E 03	6.1184E-07	2.7557E-03	2.5927E-03
6.0433E-02	2.1696E 02	6.0822E-02	6.0722E-02	2.8956E-04	7.5298E 02	8.3843E-08	3.6993E-03	3.6872E-03
4.6671E-02	1.7570E 02	4.6939E-02	4.6671E-02	0.	0.	0.	2.2033E-03	2.1781E-03
6.0584E-02	2.3571E 02	6.2438E-02	6.1935E-02	1.3515E-03	5.4888E 03	1.8266E-06	3.8986E-03	3.8359E-03
6.3842E-02	2.7732E 02	6.7170E-02	6.5119E-02	1.2765E-03	5.9336E 03	1.6295E-06	4.5118E-03	4.2405E-03
6.1873E-02	2.5325E 02	6.3515E-02	6.2653E-02	7.8000E-04	2.5469E 03	6.0840E-07	4.0342E-03	3.9255E-03
6.4004E-02	2.4168E 02	6.2846E-02	6.4205E-02	2.0147E-04	5.6522E 02	4.0592E-08	3.9496E-03	4.1223E-03
5.8653E-02	2.1688E 02	5.9070E-02	5.8653E-02	0.	0.	0.	3.4893E-03	3.4402E-03
8.0025E-02	3.9288E 02	8.0135E-02	8.0025E-02	0.	0.	0.	6.4216E-03	6.4039E-03
7.8596E-02	3.6577E 02	7.8545E-02	7.8761E-02	1.6531E-04	6.2031E 02	2.7327E-08	6.1694E-03	6.2033E-03
7.4452E-02	3.4749E 02	7.4802E-02	7.4899E-02	4.4712E-04	1.3597E 03	1.9991E-07	5.5953E-03	5.6099E-03
7.5866E-02	3.6973E 02	7.6451E-02	7.6835E-02	9.6966E-04	3.5424E 03	9.4025E-07	5.8447E-03	5.9036E-03
5.6443E-02	2.0247E 02	5.6931E-02	5.7420E-02	9.7754E-04	3.8239E 03	9.5558E-07	3.2412E-03	3.2971E-03
5.8453E-02	2.0783E 02	5.8755E-02	5.8676E-02	2.2242E-04	6.9420E 02	4.9470E-08	3.4521E-03	3.4429E-03
5.8423E-02	2.0761E 02	5.8726E-02	5.8925E-02	5.0251E-04	1.5035E 03	2.5251E-07	3.4488E-03	3.4722E-03
5.8423E-02	1.9991E 02	5.8755E-02	5.8423E-02	0.	0.	0.	3.4521E-03	3.4132E-03
9.4754E-02	5.5905E 02	9.4686E-02	9.5017E-02	2.6288E-04	7.8099E 02	6.9105E-08	8.9655E-03	9.0282E-03
9.4935E-02	5.7359E 02	9.5347E-02	9.5864E-02	9.2971E-04	3.5748E 03	8.6436E-07	9.0910E-03	9.1900E-03

Figure 16

Figure 17

Figure 18

Figure 19

Figure 20

Figure 21