DUN-2552

DISCLAIMER

Cover Sheet for a Hanford Historical Document Released for Public Availability

Released 1994

Prepared for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

Battelle

DT

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

[redacted] (CLASSIFICATION) DECLASSIFIED

DOUGLAS UNITED NUCLEAR, INC.

RICHLAND, WASHINGTON

DOCUMENT NO.
DUN-2552
Hanford Code:
SERIES AND COPY NO.
[redacted]
DATE
August 21, 1967

[redacted] RESTRICTED DATA

THIS DOCUMENT CONTAINS RESTRICTED DATA AS DEFINED IN THE ATOMIC ENERGY ACT OF 1954. TRANSMITTAL OR DISCLOSURE OF ITS CONTENTS IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED.

TITLE

GALVANIC CORROSION TEST MEASUREMENTS

ZIRCALOY PROCESS TUBE HYDRIDING PROBLEM

☐ OTHER OFFICIAL CLASSIFIED INFORMATION

THIS MATERIAL CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE LAWS, TITLE 18, U.S.C., SECS. 793 AND 794, THE TRANSMISSION OR REVELATION OF WHICH IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.

AUTHOR

W. R. Thorson

ISSUING FI[redacted]

RATTELLE NORTHWEST
RECEIVED
SEP 8 1980
REFERENCE COPY
TECHNICAL [illegible] SECTION

THIS D[redacted]MENT MU[redacted]OT BE LEF[redacted]ATTENDED O[redacted]ERE AN U[redacted]HORIZED [redacted]ON MAY [redacted] TO IT[redacted]HEN NOT [redacted]SE, IT MUS[redacted] STORED IN [redacted]PPROVED [redacted]ED REPO[redacted]Y WITHI[redacted] APPR[redacted] GU[redacted]ED AREA; [redacted]ILE IT IS [redacted]R POSSESSIO[redacted]D UNTIL [redacted] HAVE OB[redacted]ED A SIG[redacted] RECEIPT [redacted]OM [redacted]SIFIED F[redacted], IT IS Y[redacted] RESPONSIBI[redacted] TO KEEP [redacted] AND ITS [redacted]TENTS WI[redacted]N THE LIM[redacted]S OF [redacted]IS PROJEC[redacted]D FROM A[redacted]UNAUTHORIZE[redacted]ERSON. IT[redacted]RANSMITTA[redacted]O, AND ST[redacted]GE AT YO[redacted] PLACE [redacted]F RESIDE[redacted] IS PROHI[redacted]ED. IT IS N[redacted] TO BE DU[redacted]CATED. I[redacted]DDITIONAL [redacted]OPIES ARE [redacted]EQUIRED, OBTAIN T[redacted] FROM T[redacted]RELATED ISS[redacted] FILE. AL[redacted]ERSONS RE[redacted]NG THIS DO[redacted]MENT ARE [redacted]QUESTED TO SIGN [redacted] THE SPAC[redacted]ROVIDED BELO[redacted]

ROUTE TO:	PAYROLL NO.	LOCATION	FILES ROUTE DATE	SIGNATURE AND DATE
K. Triggs		326, 300		

DECLASSIFIED

54-5100-166 (10-65)
AEC-RLOO RICHLAND, WASH.

MASTER [redacted] (CLASSIFICATION) REFERENCE COPY

29

2

[redacted]

DUN-2552
Hanford Code:

This document classified
by [redacted]

GALVANIC CORROSION TEST MEASUREMENTS

ZIRCALOY PROCESS TUBE HYDRIDING PROBLEM

by

W. R. Thorson

August 21, 1967

DISTRIBUTION

BATTELLE-NORTHWEST

1. RL Dillon
2. B. Griggs

DOUGLAS UNITED NUCLEAR

3. WK Alexander
4. TW Ambrose
5. PA Carlson
6. RG Clough
7. DM Diediker
8. RE Dunn
9. ML Faught
10. NF Fifer
11. JM Fox, Jr.
12. G. Fullmer
13. RE Hall
14. RS Hammond
15. AK Hardin
16. HW Heacock
17. KL Hladek
18. HF Jensen
19. RT Jessen
20. JE Kaveckis
21. RV Myers
22. DW Peacock
23. RS Peterson
24. RW Reid
25. WR Thorson
26. JR Young
27. DUN Files
28. DUN Records

[redacted]

GALVANIC CORROSION TEST MEASUREMENTS

ZIRCALOY PROCESS TUBE HYDRIDING PROBLEM

I. INTRODUCTION

In September of 1965, a program was launched to investigate the cause and to determine appropriate corrective or preventive action for hydriding of Zircaloy process tubes in K Reactors. One phase of the investigation was specifically directed to the measurement of galvanic corrosion currents flowing between the Zircaloy process tube and the aluminum spacers. Production Test IP-807(2) authorized in-reactor galvanic test measurements in order to secure data relating to the hydriding problem.

It is the purpose of this report to document all the galvanic corrosion current data recorded for tests in K Reactors during the investigation of the hydride problem. The galvanic test data contained in this document also provides a basis for the conclusions stated in the final report(1) which reviews the accomplishments of the test program.

II. SUMMARY

The galvanic potentials recorded for test measurements in the K Reactor process tubes, identifies the approximate location and magnitude of the corrosion currents generated between aluminum spacers and Zircaloy process tube. The flow of galvanic currents and subsequent release of hydrogen gas can be related to the hydriding of the Zircaloy tubes.

The data enclosed in this report indicate a substantial amount of galvanic action in the downstream dummy section of the process tube. There was no evidence of any galvanic action from the fuel elements which would contribute to the large galvanic currents measured in the downstream spacers.

The use of certain metal coatings on the aluminum spacers could reverse the galvanic cell polarity and cause corrosion of the process tube which would not be desirable.

III. DISCUSSION

General

Seven separate in-reactor galvanic tests were performed, two in KE Reactor and five in KW Reactor. These tests extended over a period of nine months. Some tests were repeated, and, in general, all tests were run under similar

conditions. A great amount of data was recorded which appears as repetitive information; however, it was necessary to establish and verify results and trends through the use of repetitive testing and recording of galvanic data.

All corrosion potentials were measured between the aluminum spacers and the Zircaloy process tube in that part of the process tube downstream from the fuel elements. Standard spacers were modified for attachment of an insulated wire by means of a tapped screw on the inner surface of the spacer. Ceramic insulators were fitted to the end assemblies of some spacers in order to provide electrical isolation between elements of the test assembly for test current measurements. Wiring was run through the spacer inner annulus and out the end of the process tube assembly through a Conax pressure sealing assembly and terminated in an Amphenol connector located on the outside of the process tube nozzle assembly. The electrical connection to the process tube was made by means of placing a steel band around the outside of the barrel nozzle assembly. Test wiring from the Amphenol connector on the end of the process tube to the recorder was run up to the "D" machine room through step-plug access holes in the floor of the "D" machine room. Recorder and/or indicating instruments for measuring the galvanic currents were located in the "D" machine room.

Corrosion Test No. 1

Corrosion test No. 1 consisted of six aluminum spacers wired for reading the current flow from the process tube to the fuel element. Five spacers were completely insulated from metal contact with the process tube. The sixth spacer was not insulated from the process tube and had end-to-end metal contact with the upstream spacer.

Galvanic voltages were measured and recorded at specific intervals on all six test elements from the time of reactor start-up until the test was discontinued. It is interesting to note that test spacer No. 6 did not generate any corrosion potential until after several days of reactor operation. The probable reason for the lack of corrosion potential on test spacer No. 6 was that the test spacer was shorted to the process tube when first installed. After a period of time of exposure to the high temperature process water, the spacers became oxidized on the metal surface sufficient to insulate them from the process tube. The electrical insulation between the spacer and the process tube allows a galvanic current to flow in the external test circuit which appears as a potential measurement on the test recorder.

It should be noted from the data that negative potentials are shown for spacers during the period when the reactor coolant water was at a low temperature. This indicates that the Zircaloy tube is "anodic" with respect to the aluminum at low temperatures, whereas at higher temperatures the aluminum spacer is anodic with respect to the Zircaloy tube.

[redacted]

It was found that the insulation of wiring within the reactor tube had a reliable expected life of two to three weeks. Readings taken of galvanic voltages after wiring insulation has failed may not indicate the actual galvanic current flow due to shorted wiring within the process tube.

The test was run with all external wiring "open circuit" when not used for recording instantaneous readings. The "open circuit" condition would tend to prevent any galvanic action during 95 percent of the test period.

Corrosion Test No. 2

Corrosion test No. 2 was assembled and wired similar to test No. 1 except that spacer No. 6 was insulated on the upstream end, and test spacer No. 2 and No. 4 were aluminum plated with 304 stainless steel. The data indicate that one stainless steel plated spacer was cathodic with respect to the Zircaloy tube; the other stainless steel plated spacer remained anodic, but yielded a very low galvanic voltage.

Readings of potential between combinations of pairs of spacers are shown. The highest potentials were recorded for measurements between stainless steel plated spacer and aluminum spacer.

The test wiring was shorted to ground during 95 percent of the test period which would allow the maximum amount of corrosion and the greatest release of hydrogen.

Corrosion Test No. 3

Corrosion test No. 3 is identical to test No. 2. Data taken indicate that both stainless steel spacers are cathodic with respect to the Zircaloy tube, and that the potential generated was considerable for these two test spacers.

The test was operated with all spacer wiring shorted to the process tube ground connection during 95 percent of the test period. This would permit the greatest release of hydrogen by corrosion current.

Corrosion Test No. 4

Corrosion test No. 4 consisted of only two aluminum spacers with one insulator separating them. Both spacers contained ribs and were, therefore, in contact with the process tube. The intent of this test was to determine the extent of galvanic voltages generated by upstream spacers and conducted to the test spacers by end-to-end contact. Due to a malfunction of the recorder, no data were recorded until after one week of reactor operation. The upstream test spacer showed a galvanic current of eight times the downstream spacer indicating the effect of the galvanic currents generated by a number of upstream spacers and conducted to the test spacer by end-to-end pressure contact.

Corrosion Test No. 5

Corrosion test No. 5 consists of four dummy fuel elements wired for galvanic current measurements and are shown as test spacers 6 through 3 on Table No. 4.

Insulators were placed between all spacers, and ribs were removed from all test spacers so there would be no metal contact between the test spacers and the process tube except that for spacer No. 6 which was allowed to contact the upstream dummy perf used for separating the test unit from the uranium fuel element.

The purpose of this test was to determine the extent of the galvanic currents that might be generated by the process fuel elements and conducted downstream into the spacer, and likewise, the amount of galvanic current generated by each test spacer in the vicinity of the fuel element.

By comparing the galvanic current generated by test spacer No. 6 shown in Table No. 4 with the galvanic current of test spacer No. 4 shown in Table No. 4, we find very little increase in current for test spacer No. 6 indicating that the upstream fuel elements are not contributing to galvanic currents measured in the spacer. In Table No. 4, test No. 2 had an indicated galvanic current seven times as great as the indicated galvanic current for test spacer No. 6, further sustantiating the theory that the large amount of galvanic currents are generated by the spacers in the vicinity of the process tube where hydriding of the process tube has been extensive.

Corrosion Test No. 6 and 7

Corrosion tests No. 6 and 7 were identical tests, run at two separate time periods in order to relate normal results and to eliminate any data that did not appear repetitive in both tests. The test consisted of two spacers located downstream next to the nozzle assembly and assembled with an insulator separating the two test spacers. The test was similar to test No. 4 except that the galvanic current generated by the upstream test spacer was connected to a strip chart recorder to obtain continuous galvanic current readings from the time before reactor start-up to some period of time at reactor normal operating temperature.

It was intended that the test would demonstrate the change in galvanic current between spacer and the process tube as the reactor effluent water increased in temperature during start-up. The test data indicate the effect of the process tube temperature on the generation of galvanic current. The evidence of the fast response of galvanic cell activity to a change in temperature was demonstrated by the recording of data taken during a reactor scram, where the galvanic cell current dropped to approximately zero value six minutes after reactor scram.

IV. ACKNOWLEDGEMENTS

The author wishes to acknowledge the consulting service of B. Griggs of Battelle-Northwest - Corrosion and Coolant Chemistry, and the assistance of R. L. Woodward in conducting these tests.

V. REFERENCES

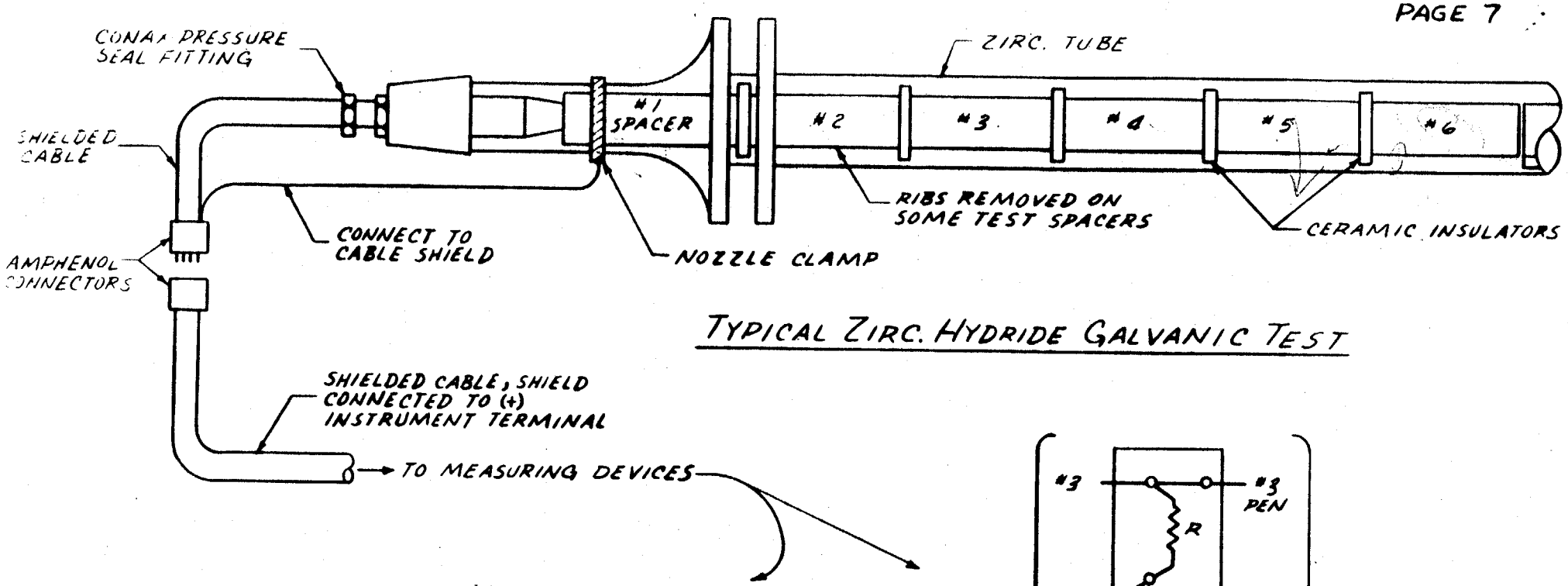
(1) Alexander, W. K., "A Review of the K Area Zircaloy Process Tube Hydriding Problem," DUN-1623, October 24, 1966. (Confidential)

(2) Alexander, W. K., "Production Test IP-807, Zircaloy Hydriding Evaluation and Control," RL-REA-2575, September 30, 1965. (Confidential)

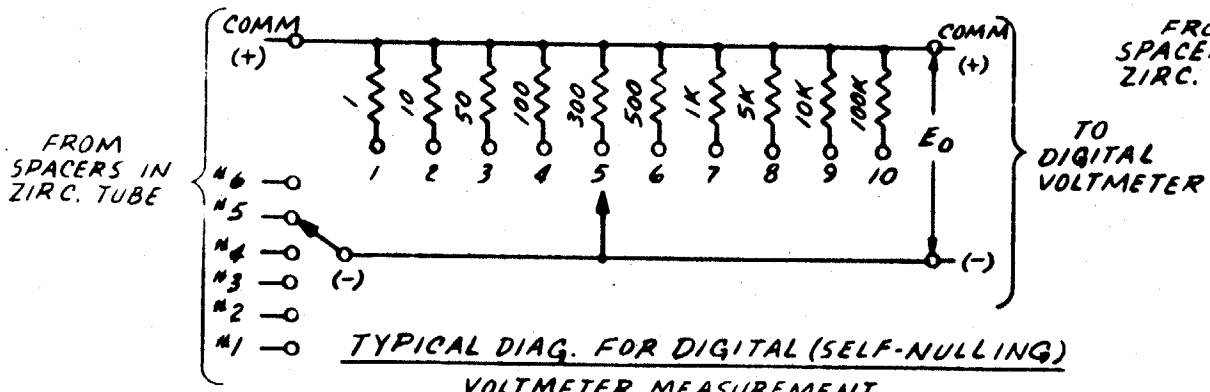
W. R. Thorson

Senior Engineer
Plant Design

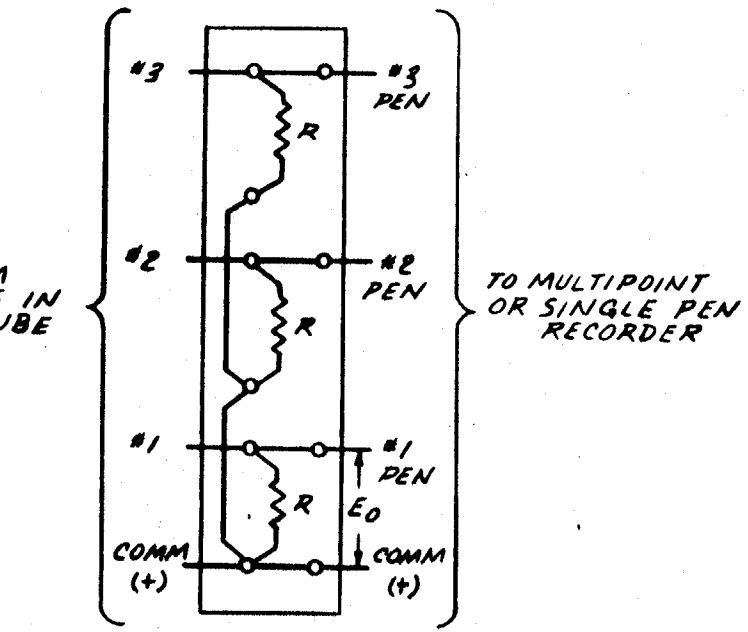
WRT:lek



TYPICAL ZIRC. HYDRIDE GALVANIC TEST



TYPICAL DIAG. FOR DIGITAL (SELF-NULLING) VOLTMETER MEASUREMENT



TYPICAL DIAG. FOR RECORDER MEASUREMENT

FIGURE 1

[redacted]

TABLE NO. 1

TEST ASSEMBLY SPECIFICATIONS

TEST NO. 1 REACTOR KE TUBE NO. 5079 DATE INSTALLED 12-5-65

Test	Materials	Spacer Insulator		Ribs		Special Conditions
		Up Stream	Down Stream	Yes	No	
1	Aluminum	X	X		X	
2	Aluminum	X	X		X	
3	Aluminum	X	X		X	
4	Aluminum	X	X		X	
5	Aluminum	X	X		X	
6	Aluminum		X	X		

All readings taken on Digital Volt meter.

Galvanic cell wiring left open circuit when voltage readings not being taken.

upstream sequence.

[redacted]

[redacted]

DECLASSIFIED

TABLE NO. 1

TEST NO. 1 REACTOR KE TUBE NO. 5079 DATE INSTALLED 12-5-65

Load Resistance	Galvanic Voltage - Millivolt Test						Date Time	Remarks
	1	2	3	4	5	6		
1 ohm	0	0	0	0	0	0	12-5-65 8:00 AM	
10	0	0	0	0	0	0		
50	0	0	0	0	0	0		
100	0	0	0	0	0	0		
300	0	-1	-1	-1	0	0		
500	-1	-2	-1	-1	-1	0		
1K	0	-2	-2	-2	-1	0		
5K	-5	-11	-9	-7	-6	0		
10K	-11	-18	-16	-13	-11	0		
100K	-23	-42	-35	-23	-10	0		
1 ohm	0	0	0	0	0	0	12-6-65 10:00 AM	
10	0	0	0	0	0	0		
50	0	0	0	0	0	0		
100	0	0	0	0	0	0		
300	0	-1	-1	0	0	0		
500	1	-3	-1	-1	-1	0		
1K	1	-5	-3	-2	-1	0		
5K	2	-20	-13	-7	-7	0		
10K	4	-29	-23	-11	-13	0		
100K	11	-71	-43	-24	-32	0		
1 ohm	14	11	6	9	12	52	12-7-65 1:30 PM	
10	100	62	21	38	84	236		
50	220	105	27	53	198	380		
100	260	113	28	56	233	400		
300	313	120	29	57	270	---		
500	330	123	29	58	282	---		
1K	345	124	29	59	293	---		
5K	350	124	29	59	296	---		
10K	350	124	29	59	298	---		
100K	350	124	29	59	298	---		

[redacted]

TABLE NO. 1

TEST NO. 1 REACTOR KE TUBE NO. 5079 DATE INSTALLED 12-5-65

Load Resistance	Galvanic Voltage - Millivolt Test 1	2	3	4	5	6	Date Time	Remarks
1 ohm	9	9	10	11	10	41	12-8-65 1:00 PM	
10	66	74	53	71	88	213		
50	188	221	90	153	273	385		
100	253	305	98	180	381	440		
300	378	431	104	203	510	493		
500	419	480	106	203	550	510		
1K	462	520	107	208	586	517		
5K	506	560	108	210	622	523		
10K	512	570	108	210	622	---		
100K	523	577	108	211	628	---		
1 ohm	11	10	10	10	10	43	12-9-65 11:00 AM	
10	82	72	68	66	85	229		
50	212	192	139	129	270	435		
100	275	248	159	148	388	503		
300	353	314	177	163	515	563		
500	379	333	181	166	555	581		
1K	405	349	184	167	592	595		
5K	437	364	187	171	623	612		
10K	445	366	189	173	632	614		
100K	465	368	189	173	634	615		
1 ohm	12	9	10	10	11	49	12-10-65 2:00 PM	
10	90	68	72	67	90	254		
50	220	183	164	148	276	471		
100	278	237	197	175	385	534		
300	350	299	227	200	516	585		
500	375	317	234	208	557	610		
1K	394	325	253	211	595	624		
5K	413	337	258	215	629	638		
10K	415	338	259	216	634	643		
100K	416	342	261	216	638	646		

[redacted]

DECLASSIFIED

TABLE NO. 1

TEST NO. 1 REACTOR KE TUBE NO. 5079 DATE INSTALLED 12-5-65

Load Resistance	Galvanic Voltage - Millivolt Test						Date Time	Remarks
	1	2	3	4	5	6		
1 ohm	12	9	11	10	10	50	12-13-65 1:45 PM	
10	91	71	84	78	87	265		
50	221	208	234	217	269	491		
100	278	284	311	278	394	554		
300	354	395	408	345	534	608		
500	381	435	437	364	583	630		
1K	407	472	467	370	613	645		
5K	427	510	492	384	653	659		
10K	427	516	493	387	658	662		
100K	428	524	495	390	663	667		
1 ohm	10	10	13	12	12	56	12-15-65 2:00 PM	
10	76	83	102	100	94	315		
50	202	253	287	322	279	560		
100	266	372	400	450	391	640		
300	344	543	558	610	546	712		
500	374	605	607	664	596	730		
1K	402	666	656	721	648	756		
5K	440	726	710	783	707	756		
10K	450	734	721	792	719	757		
100K	458	739	732	798	735	758		
1 ohm	10	10	13	11	12	46	12-17-65 11:00 AM	
10	75	85	97	99	92	290		
50	201	265	277	373	276	524		
100	263	375	381	453	367	570		
300	342	545	520	604	515	619		
500	370	608	584	653	570	635		
1K	400	670	634	710	616	660		
5K	424	730	680	770	675	670		
10K	442	738	690	779	690	673		
100K	448	744	700	782	710	690		

[redacted]

TABLE NO. 1

TEST NO. 1 REACTOR KE TUBE NO. 5079 DATE INSTALLED 12-5-65

Load Resistance	Galvanic Voltage - Millivolt Test 1						Date Time	Remarks
	1	2	3	4	5	6		
1 ohm	10	11	0	13	11	49	12-21-65 9:00 AM	Test [illegible] no. 3 wiring failure.
10	73	92	-	98	98	260		
50	204	288	-	290	314	497		
100	275	413	-	409	443	579		
300	392	600	-	578	603	650		
500	443	670	-	638	665	680		
1K	502	740	-	694	730	740		
5K	570	818	-	757	805	768		
10K	585	829	-	775	813	770		
100K	597	836	-	795	825	770		
1 ohm	10	16	-	11	12	55	12-22-65 1:30 PM	Test no. 3 wiring failure. All voltage readings very erratic.
10	73	119	-	80	92	280		
50	210	337	-	245	277	503		
100	293	457	-	346	390	590		
300	434	612	-	506	540	664		
500	498	665	-	561	598	694		
1K	565	722	-	612	650	719		
5K	632	769	-	662	704	740		
10K	644	784	-	672	718	747		
100K	650	793	-	685	730	746		
1 ohm	14	22	-	13	17	37	12-28-65 9:00 AM	Test no. 3 wiring failure. All voltage readings very erratic.
10	130	170	-	91	120	207		
50	300	430	-	280	290	383		
100	370	550	-	380	370	460		
300	470	670	-	460	450	500		
500	492	700	-	491	460	540		
1K	526	722	-	530	500	550		
5K	537	737	-	560	503	560		
10K	545	745	-	564	504	560		
100K	550	750	-	570	514	560		

[redacted]

DECLASSIFIED

TABLE NO. 1

TEST NO. 1 REACTOR KE TUBE NO. 5079 DATE INSTALLED 12-5-65

Load Resistance	Galvanic Voltage - Millivolt Test						Date Time	Remarks
	1	2	3	4	5	6		
1 ohm	32	46	45	45	45	46	1-3-66 9:30 AM	All voltage readings very erratic.
10	200	264	243	220	244	274		
50	430	500	450	510	460	512		
100	515	568	520	570	525	575		
300	580	620	580	520	580	638		
500	605	630	604	647	610	640		
1K	620	606	620	655	620	640		
5K	640	607	630	655	630	640		
10K	660	613	645	660	640	640		
100K	660	630	650	660	645	643		
1 ohm	14	18	8	-	-	-	1-10-66 9:30 AM	All voltage readings very erratic. Test discontinued. Amphenol plug at end of tube found to be full of water. Test removed 1-14-66
10	90	130	72	-	-	-		
50	275	360	170	-	-	-		
100	400	465	250	-	-	-		
300	520	600	380	-	-	-		
500	580	640	440	-	-	-		
1K	630	670	490	-	-	-		
5K	650	740	530	-	-	-		
10K	660	745	530	-	-	-		
100K	660	750	560	-	-	-		

[redacted]

TABLE NO. 2

TEST NO. 2 REACTOR KE TUBE NO. 5079 DATE INSTALLED 1-14-66

Test Dummy No.	Spacer Material	Spacer Insulator		Ribs		Special Conditions
		Up Stream	Down Stream	Yes	No	
1	Aluminum	X	X		X	
2	Aluminum with type 304 stainless steel plating.	X	X		X	
3	Aluminum	X	X		X	
4	Plated 304-SS	X	X		X	
5	Aluminum	X	X		X	
6	Aluminum	X	X	X		

All readings taken on Digital Volt meter.

Galvanic cell wiring left open when voltage readings not being taken.

Test assembly located downstream next to nozzle. Test spacers numbered in sequence upstream.

No voltage readings taken during first seven days after test installation due to a mismatch in amphenol connectors on the reactor rear face.

TABLE NO. 2

TEST NO. 2 REACTOR KE TUBE NO. 5079 DATE INSTALLED 1-14-66

Load Resistance	Galvanic Voltage - Millivolt Test						Date Time	Remarks
	1	2	3	4	5	6		
1 ohm	0	0	0	0	0	0	1-21-66 5:10 PM	Reactor at low power level.
10	0	-2	1	1	0	0		
50	1	-7	2	3	1	1		
100	2	-13	4	8	2	3		
300	5	-31	11	13	7	6		
500	8	-47	17	20	11	8		
1K	14	-74	27	32	20	9		
5K	33	-158	51	61	49	11		
10K	38	-202	60	72	62	12		
100K	48	-240	70	82	82	12		
1 ohm	8	-1	7	0	6	9	1-24-66 1:45 PM	
10	55	-7	57	2	52	72		
50	170	-26	188	7	180	224		
100	233	-45	273	12	268	318		
300	304	-78	418	21	412	440		
500	342	-99	471	25	466	484		
1K	366	-114	520	28	518	522		
5K	395	-131	580	31	571	558		
10K	400	-134	590	31	581	560		
100K	404	-137	602	31	590	566		
1 ohm	8	0	11	1	9	11	1-25-66 1:30 PM	
10	61	-1	83	4	72	89		
50	174	-5	253	19	233	269		
100	237	-9	357	33	337	374		
300	332	-15	509	58	492	524		
500	371	-19	563	71	545	576		
1K	409	-21	610	83	598	624		
5K	447	-25	659	97	647	672		
10K	455	-25	670	101	659	681		
100K	461	-25	677	104	668	690		

[redacted]

TABLE NO. 2

TEST NO. 2 REACTOR KE TUBE NO. 5079 DATE INSTALLED 1-14-66

Load Resistance	Galvanic Voltage - Millivolt Test 1						Date Time	Remarks
	1	2	3	4	5	6		
1 ohm	6	0	8	1	6	8	1-27-66 2:00 PM	
10	51	-2	61	4	52	68		
50	145	-9	197	17	181	212		
100	197	-14	285	30	270	305		
300	280	-24	428	55	420	446		
500	310	-27	476	68	477	498		
1K	337	-30	530	81	530	551		
5K	360	-34	585	96	585	601		
10K	370	-34	595	99	596	611		
100K	380	-34	603	102	606	620		
1 ohm	9	-1	10	0	9	11	2-4-66 1:15 PM	
10	69	-7	77	2	66	80		
50	185	-26	226	7	219	248		
100	245	-41	321	13	320	350		
300	319	-72	475	24	481	496		
500	346	-86	528	30	542	554		
1K	368	-100	572	38	598	605		
5K	391	-114	640	45	662	658		
10K	397	-117	656	48	677	672		
100K	403	-120	667	51	688	682		

Voltage Readings Between Test

	MV		MV		
1-2	33	3-4	33	2-4-66 1:15 PM	Load resistance across leads between
1-3	-13	3-5	-2		
1-4	16	3-6	0		
1-5	-12	4-5	-30		
1-6	-11	4-6	-22		Minus readings indicates test unit no. on left is anodic. All others opposite polarity.
2-3	-38	5-6	1		
2-4	-3				
2-5	-29				
2-6	-27				

[redacted]

TABLE NO. 3

TEST NO. 3 REACTOR KW TUBE NO. 3667 DATE INSTALLED 2-18-66

Test	Material	Spacer Insulator		Ribs		Special Conditions
		Up Stream	Down Stream	Yes	No	
1	Aluminum	X	X		X	
2	Plated 304-SS	X	X		X	
3	Aluminum	X	X		X	
4	Plated 304-SS	X	X		X	
5	Aluminum	X	X		X	
6	Aluminum	X	X	X		

All readings taken on Digital Volt meter.

Test 2 and 4 wiring shorted except when voltage readings were taken. Test 1, 3, 5, and 6 wiring left open except when voltage readings were taken.

Tube 3667 was installed new for this test.

Test assembly located downstream next to nozzle. Test numbered in sequence upstream.

[redacted]

TABLE NO. 3

TEST NO. 3 REACTOR KW TUBE NO. 3667 DATE INSTALLED 2-18-66

Load Resistance	Galvanic Voltage - Millivolts Test 1						Date Time	Remarks
	1	2	3	4	5	6		
1 ohm	10	-1	11	-1	7	18	2-21-66 1:00 PM	Readings on no. 6, erratic.
10	75	-6	76	-6	51	87		
50	205	-27	209	-25	147	157		
100	280	-47	293	-25	209	200		
300	378	-88	472	-89	308	230		
500	414	-109	570	-111	359	239		
1K	440	-134	657	-140	426	242		
5K	478	-168	771	-187	493	247		
10K	488	-174	793	-193	515	247		
100K	497	-180	811	-202	533	247		
1 ohm	8	-1	10	-1	7	24	2-22-66 3:00 PM	
10	62	-9	68	-5	55	125		
50	169	-37	188	-20	160	258		
100	224	-63	259	-33	222	322		
300	291	-118	428	-65	347	474		
500	320	-145	491	-85	427	510		
1K	347	-175	608	-115	490	542		
5K	375	-212	720	-137	586	567		
10K	384	-220	750	-145	607	586		
100K	395	-226	790	-150	625	591		
1 ohm	7	-1	9	-1	7	23	2-23-66 2:30 PM	Readings on no. 6 partically erratic.
10	58	-10	64	-6	55	125		
50	156	-41	179	-22	153	247		
100	208	-69	247	-37	214	390		
300	280	-128	406	-71	323	450		
500	310	-161	483	-92	403	510		
1K	330	-194	580	-116	481	535		
5K	355	-235	697	-154	547	-		
10K	363	-241	720	-162	585	-		
100K	373	-247	750	-166	598	-		

[redacted]

TABLE NO. 3

TEST NO. 3 REACTOR KW TUBE NO. 3667 DATE INSTALLED 2-18-66

Load Resistance	Galvanic Voltage - Millivolt Test D						Date Time	Remarks
	1	2	3	4	5	6		
1 ohm	7	-1	8	-1	6	21	2-25-66	
10	52	-11	59	-4	48	114	2:30 PM	
50	141	-43	168	-20	145	235		
100	195	-72	236	-35	206	275		
300	264	-137	385	-70	320	450		
500	288	-169	467	-92	412	490		
1K	310	-205	548	-113	476	520		
5K	338	-250	663	-148	565	---		
10K	346	-259	691	-159	581	---		
199K	354	-266	715	-170	597	---		
1 ohm	7	-1	8	-1	7	23	2-28-66	
10	52	-11	62	-5	52	127	2:30 PM	
50	143	-45	179	-21	157	272		
100	188	-73	251	-36	222	350		
300	257	-142	406	-73	350	475		
500	272	-174	480	-88	430	490		
1K	299	-213	560	-111	504	520		
5K	317	-260	660	-145	589	550		
10K	324	-269	686	-156	600	---		
100K	332	-275	714	-167	620	---		
1 ohm	6	-2	8	-1	6	20	3-2-66	
10	48	-11	60	-5	49	116	3:00 PM	
50	132	-45	173	-21	151	258		
100	176	-74	243	-35	217	300		
300	232	-141	399	-76	340	412		
500	266	-177	470	-87	408	430		
1K	290	-213	539	-112	476	490		
5K	309	-262	660	-147	562	520		
10K	314	-271	684	-156	590	---		
100K	321	-281	719	-162	597	---		

TABLE NO. 3

TEST NO. 3 REACTOR KW TUBE NO. 3667 DATE INSTALLED 2-18-66

Load Resistance	Galvanic Voltage - Millivolt Test						Date Time	Remarks
	1	2	3	4	5	6		
1 ohm	6	-1	8	-1	7	23	3-7-66	
10	46	-11	59	-4	52	131	9:30 AM	
50	130	-42	171	-17	159	292		
100	175	-68	243	-27	228	379		
300	233	-130	390	-51	364	480		
500	259	-167	465	-66	437	530		
1K	290	-201	547	-84	517	550		
5K	313	-251	663	-109	615	575		
10K	318	-259	693	-112	634	---		
100K	329	-268	727	-121	652	---		
1 ohm	5	-1	6	-1	5	19	3-10-66	
10	38	-10	47	-4	41	110	1:30 PM	
50	113	-37	146	-16	135	254		
100	155	-61	211	-26	199	337		
300	214	-121	350	-49	324	460		
500	240	-155	420	-62	393	490		
1K	264	-188	498	-77	470	544		
5K	290	-239	617	-108	570	592		
10K	300	-250	647	-110	606	---		
100K	307	-255	685	-113	606	---		
1 ohm	5	-1	7	-1	6	13	3-18-66	
10	42	-10	52	-6	47	49	2:00 PM	
50	119	-42	157	-24	144	244		
100	161	-71	224	-39	210	334		
300	216	-142	257	-87	336	464		
500	240	-180	419	-103	401	517		
1K	262	-219	504	-127	482	540		
5K	283	-282	618	-171	570	615		
10K	289	-294	656	-177	590	627		
100K	296	-306	677	-187	610	650		

[redacted]

DECLASSIFIED

DUN-2552

Page 21

TABLE NO. 3

TEST NO. 3 REACTOR KW TUBE NO. 3667 DATE INSTALLED 2-18-66

Load Resistance	Galvanic Voltage - Millivolt Test						Date Time	Remarks
	1	2	3	4	5	6		
1 ohm	5	-1	7	-1	7	15	3-23-66 2:15 PM	
10	42	-9	53	-4	52	105		
50	121	-35	161	-16	160	274		
100	163	-60	231	-26	231	376		
300	217	-121	367	-53	366	508		
500	244	-153	441	-68	438	561		
1K	281	-196	529	-90	525	617		
5K	307	-258	689	-123	643	692		
10K	319	-274	738	-131	673	709		
100K	329	-288	778	-138	700	723		
1 ohm	5	-1	7	0	7	16	3-25-66 2:00 PM	
10	44	-9	52	-3	49	103		
50	128	-36	162	-15	146	271		
100	174	-60	233	-27	210	377		
300	233	-122	365	-56	336	509		
500	261	-151	443	-69	421	558		
1K	285	-197	527	-91	520	614		
5K	309	-259	687	-122	639	690		
10K	318	-276	733	-130	668	707		
100K	328	-290	774	-136	699	721		
1 ohm	5	-1	7	-1	7	16	3-28-66 1:15 PM	
10	44	-8	53	-5	50	103		
50	131	-34	157	-20	151	246		
100	178	-58	223	-33	215	328		
300	240	-113	352	-63	340	478		
500	262	-144	426	-79	415	532		
1K	283	-185	510	-100	494	585		
5K	305	-240	640	-134	614	665		
10K	313	-253	725	-147	660	690		
100K	318	-264	765	-150	683	705		

[redacted]

TABLE NO. 3

TEST NO. 3 REACTOR KW TUBE NO. 3667 DATE INSTALLED 2-18-66

Load Resistance	Galvanic Voltage - Millivolt Test						Date Time	Remarks
	1	2	3	4	5	6		
1 ohm	5	-1	7	-1	7	15	3-31-66 2:15 PM	
10	42	-8	53	-3	51	106		
50	124	-35	160	-16	162	273		
100	171	-62	233	-25	231	378		
300	218	-124	365	-54	342	506		
500	247	-157	443	-69	426	557		
1K	283	-197	529	-92	527	614		
5K	309	-259	689	-123	645	690		
10K	318	-276	741	-132	674	710		
100K	329	-292	772	-137	702	725		
1 ohm	6	-1	8	-1	9	20	4-6-66 1:30 PM	
10	49	-9	63	-6	61	122		
50	133	-35	186	-23	178	278		
100	175	-59	262	-37	247	364		
300	225	-113	418	-71	370	506		
500	257	-142	490	-88	435	550		
1K	275	-180	610	-112	507	596		
5K	294	-230	760	-146	589	640		
10K	302	-241	790	-152	601	658		
100K	310	-250	840	-159	620	670		

TABLE NO. 4

TEST ASSEMBLY SPECIFICATIONS

TEST NO. 4&5 REACTOR KW TUBE NO. 5-4453 4-3667 DATE INSTALLED 5(5-16-66) 4(4-26-66)

Test Dummy No.	Spacer Material	Spacer Insulator		Ribs		Special Conditions
		Up Stream	Down Stream	Yes	No	
1	Aluminum	X		X		No. 1 loaded with 3 ohm resistor.
2	Aluminum		X	X		No. 2 loaded with 1 ohm resistor.
3	304-SS plated	X	X		X	No. 3 loaded with 3 ohm resistor.
4	Aluminum	X	X		X	No. 4 loaded with 3 ohm resistor.
5	Nickle plated	X	X		X	No. 5 loaded with 3 ohm resistor.
6	Aluminum		X		X	No. 6 loaded with 3 ohm resistor.

Test No. 4 Notes Spacers 1 & 2

No data recorded during first week of operation due to malfunction of multipoint.

All data taken on multipoint recorder with 0-100 mv scale - 11 inch chart.

Test spacer no.1 in contact with tube nozzle.

Test No. 5 Notes Spacers 3, 4, 5, & 6

Data recorded on same multipoint recorder used for test no. 4

Test spacer no. 6 located one spacer space from downstream fuel element. Other test spacers located in following sequence downstream -- no: 6, blank spacer no. 5, no. 4, no. 3, blank spacer.

TABLE NO. 4

RECORDED GALVANIC VOLTAGES

TEST NO. 4 & 5

Date	Time	No. - Millivolts						Remarks
		#1	#2	#3	#4	#5	#6	
5-18-66	10:00 AM	19	48	9	24	5	28	
	12:00 M	19	49	9	24	5	27	
	3:00 PM	20	53	10	25	5	28	
	6:00 PM	22	59	10		3	29	
	9:00 PM	21	55	10		3	29	
	12:00 M	20	50	10		2	29	
5-19-66	6:00 AM	20	52	9		2	29	
	10:00 AM	20	53	10		3	28	
	6:00 PM	22	57	10		2	29	
5-20-66	6:00 AM	21	55	8		2	28	
	10:00 AM	21	54	9		3	28	
	6:00 PM	21	53	9		5	28	
5-21-66	6:00 AM	20	49	7		1	28	
	10:00 AM	19	48	7		2	28	
	6:00 PM	19	47	7		5	28	
5-22-66	6:00 AM	18	43	6		2	28	
	10:00 AM	18	42	6		2	28	
	6:00 PM	18	42	6		2	28	
5-23-66	6:00 AM	18	42	6		1	28	
	10:00 AM	18	42	5		2	27	
	6:00 PM	18	42	5		1		
5-24-66	6:00 AM	18	42	6		1		
	10:00 AM	18	40	6		1		
	6:00 PM	18	42	5		0		
5-25-66	6:00 AM	17	41	5		-2		
	10:00 AM	17	40	5		-2		
	6:00 PM	17	40	4		-4		
5-26-66	6:00 AM	17	40	4		-4		
	10:00 AM	17	41	4		-5		
	6:00 PM	17	40	3		-8		
5-27-66	6:00 AM	--	--	4		-6		
	10:00 AM	erratic	erratic	4		-5		
	6:00 PM			4		-8		
5-28-66	6:00 AM			4		-5		
	10:00 AM			4		-7		
	6:00 PM			4		-8		
	8:00 PM			3				End of test recording

TABLE NO. 5

TEST ASSEMBLY SPECIFICATIONS

TEST NO. 6 REACTOR KW TUBE NO. 3667 DATE INSTALLED 6-9-66

Test	Materials	Spacer Insulator		Ribs		Special Conditions
		Up Stream	Down Stream	Yes	No	
1	Aluminum	X		X		No. 1 not recorded.
2	Aluminum		X	X		No. 2 loaded with 5 ohm resistor.

All data taken on strip chart recorder, 0-100 mv with zero setting adjusted to 10 mv.

Test assembly located so that test assembly. No. 2 insulated from no. 1 but not from upstream elements.

Reactor operated two short time periods previous to this startup. No data recorded during first two reactor operating periods.

TABLE NO. 5

RECORDED GALVANIC VOLTAGES

TEST NO. 6

DATE	TIME	TEST [illegible] MV
6-22-66	4:00 AM	0
	5:00	5
	6:00	7
	7:00	8
	8:00	9
	9:00	11
	10:00	20
	11:00	25
	12:00	26
	1:00 PM	35
	2:00	46
	3:00	58
	4:00	55
	5:00	52
	6:00	47
	7:00	58
	8:00	68
	9:00	72
	10:00	74
	11:00	65
	12:00	68
6-23-66	1:00 AM	72
	2:00	75
	3:00	74
	4:00	73
	5:00	72
	6:00	73
	7:00	66
	8:00	65
	9:00	63
	10:00	60
	11:00	58
	12:00	55
	1:00 PM	55
	2:00 PM	57
6-23-66	3:00 PM	61
	4:00	63
	5:00	64
	6:00	65
	7:00	66
	8:00	67
	9:00	66
	10:00	65
	11:00	63
	12:00	65
6-24-66	1:00 AM	67
	2:00	68
	3:00	69
	4:00	69
	5:00	68
	6:00	69
	7:00	67
	8:00	65
	9:00	64
	10:00	63
	11:00	64
	12:00	65
	1:00 PM	65
	2:00	64
	3:00	63
	4:00	63
	5:00	64
	6:00	66
	7:00	66
	8:00	67

TABLE NO. 6

TEST ASSEMBLY SPECIFICATIONS

TEST NO. 7 REACTOR KW TUBE NO. 3667 DATE INSTALLED 8-5-66

Test Dummy No.	Spacer Materials	Spacer Insulator		Ribs		Special Conditions
		Up Stream	Down Stream	Yes	No	
1	Aluminum	X		X		No. 1 not recorded.
2	Aluminum		X	X		No. 2 loaded with 5 ohm resistor.

All data taken on strip chart recorder, 0-100 mv with zero setting adjusted to 10 mv.

Test assembly located so that test spacer no.1 in contact with nozzle assembly. No. 2 insulated from no. 1 but not from upstream spacer elements.

No data recorded until two days after reactor start-up. Test assembly conditions same as for test no. 6.

TABLE NO. 6

RECORDED GALVANIC VOLTAGES

TEST NO. 7

DATE	TIME	TEST mv	REMARKS
8-30-66	11:00 AM	55	
9-2-66	1:10 PM	59	
9-15-66	10:00 AM	48	
9-15-66	7:00 PM	55	
9-16-66	5:00 AM	52	
9-16-66	5:00 PM	55	
9-16-66	11:00 PM	52	
9-17-66	7:10 AM	52	
9-17-66	3:00 PM	53	