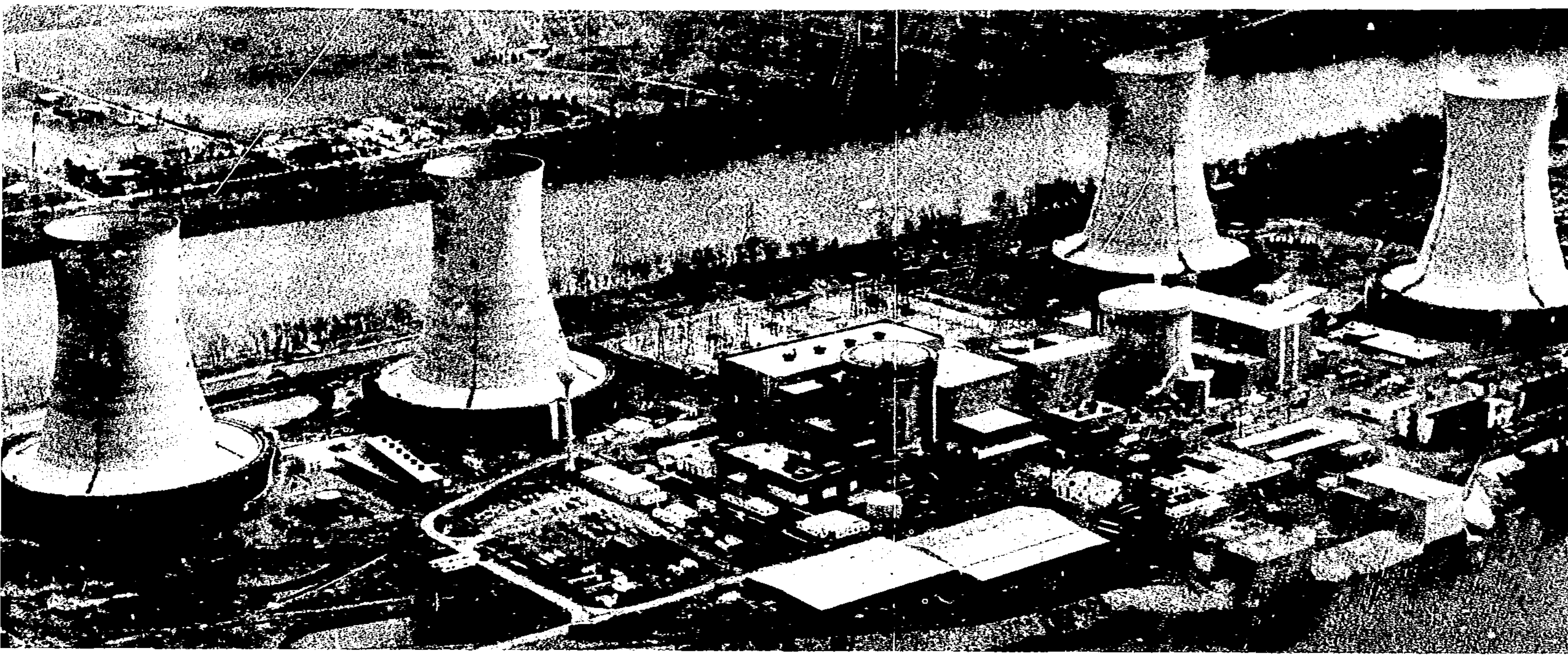
ry

MASTER

GEND-INF- 026

August 1982



This is an informal report intended for use as a preliminary or working document

GEND

General Public Utilities • Electric Power Research Institute • U.S. Nuclear Regulatory Commission • U.S. Department of Energy

Static In Situ Test of the Axial Power Shaping Rod and Shim Safety Control Rod Mechanisms

Florante T. Soberano
Joseph A. Gannon
Kenneth A. Parlee

Prepared for the
U.S. Department of Energy
Three Mile Island Operations Office
Under DOE Contract No. DE-AC07-76ID01570

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

GEND-INF-026

GEND-INF--026

DE82 022186

STATIC IN SITU TEST OF THE AXIAL POWER SHAPING ROD AND SHIM SAFETY CONTROL ROD MECHANISMS

Florante T. Soberano
Joseph A. Gannon
Kenneth A. Parlee

United Engineers and Constructors
Philadelphia, Pennsylvania

Published August 1982

Technically Edited and Published on Behalf of the GEND Group

By

EG&G Idaho, Inc.
Idaho Falls, Idaho 83415

Prepared for the
U.S. Department of Energy
Three Mile Island Operations Office
Under DOE Contract No. DE-AC07-76ID01570

ABSTRACT

There are eight Axial Power Shaping Rods (APSRs) and 61 Shim Safety Control Rods (SSCRs) within the Three Mile Island (TMI) Unit 2 reactor core. This report describes the test results for all eight APSRs and three SSCRs. The tests were performed in situ from the Control Rod Drive (CRD) system logic cabinets and the transformer cabinets located in the cable spreading room. The tests were intended to determine the condition of the Absolute Position Indicators (APIs), the stator thermocouples, and the stators, and to assess each components' survival of the TMI-2 accident.

CONTENTS

STATIC IN SITU TEST OF THE AXIAL POWER SHAPING ROD AND SHIM SAFETY CONTROL ROD MECHANISMS

INTRODUCTION

Each Axial Power Shaping Rod (APSR) and Shim Safety Control Rod (SSCR) drive mechanism is an electromechanical device consisting of an electrically driven roller nut assembly (rotor), a translating leadscrew inside a pressure vessel, and a stator and position indicating system outside the pressure vessel.

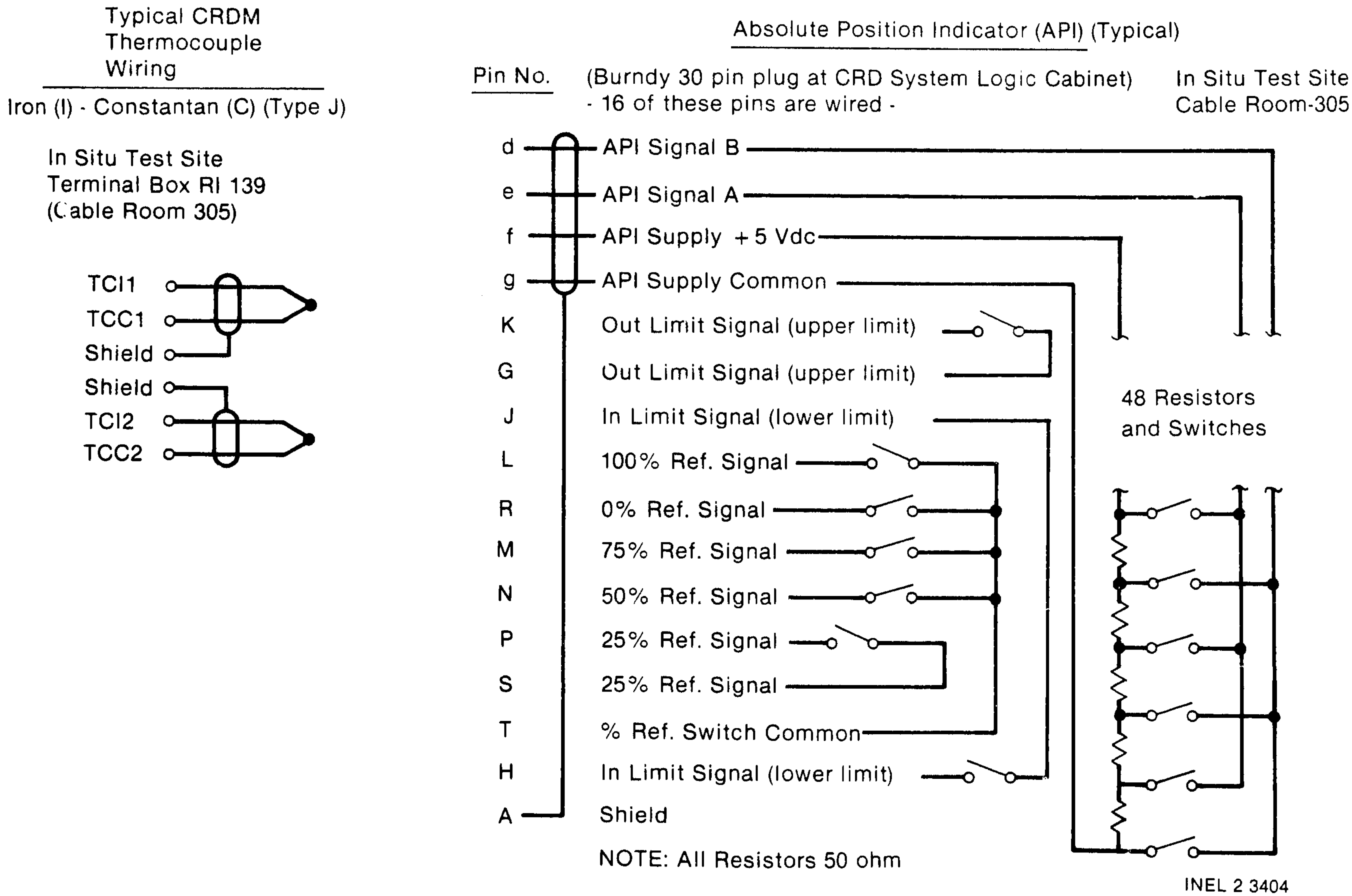
The drive is a 4-pole, reluctance type motor that incorporates a special 6-phase, star-connected winding. The stator coils are energized in a sequentially-programmed manner producing a rotating magnetic field around the rotor assembly.

The control rod movement is a result of leadscrew translation when DC current is supplied to the motor stator from a sequentially-programmed power supply. In response to these electrical signals, a rotating magnetic field causes rotation of the rotor assembly. It converts the roller's rotary motion to the leadscrew's linear motion, raising or lowering the reactor control rod that is mechanically connected and locked to the leadscrew. Each APSR within the reactor is operated by a separate drive.

The APSR drive has a built-in brake. Whenever current to the stator is interrupted, the brake engages, thereby preventing rotation of the rotor assembly.

The Shim Safety Control Rod drives are designed to trip whenever power to the stator is interrupted. During such a trip, the leadscrew and the roller nut are disengaged, allowing the leadscrew and control rod to gravity-drop into the reactor core to the full IN position.

The position of the leadscrew within the drive is disclosed by the Absolute Position Indicator (API), which contains a network of resistors and equally-spaced reed switches (see Figure 1). As the leadscrew



Control Rod Drive Mechanism (CRDM)

Figure 1. Control rod drive mechanism leadscrew network of resistors and reed switches.

translates within the drive, a magnet travels with it. As the magnet travels vertically, the reed switches in the vicinity of the magnet close. When the magnet passes a reed switch, it returns to its normally open condition. The closure zone for each switch overlaps, approximately one-third the closure zone of each adjacent switch; leaving approximately one-third with no overlap. As a backup, there are separate switches which close (one each) at 0, 25, 50, 75, and 100% positions.

There are two sets of Iron-Constantan thermocouples associated with each control rod drive mechanism. These thermocouples measure the stator temperature.

There are 8 APSRs and 61 SSCRs used in the TMI-2 core. The APSRs are designated as Control Rods 62 through 69, as shown on the grid positions in Figure 2.

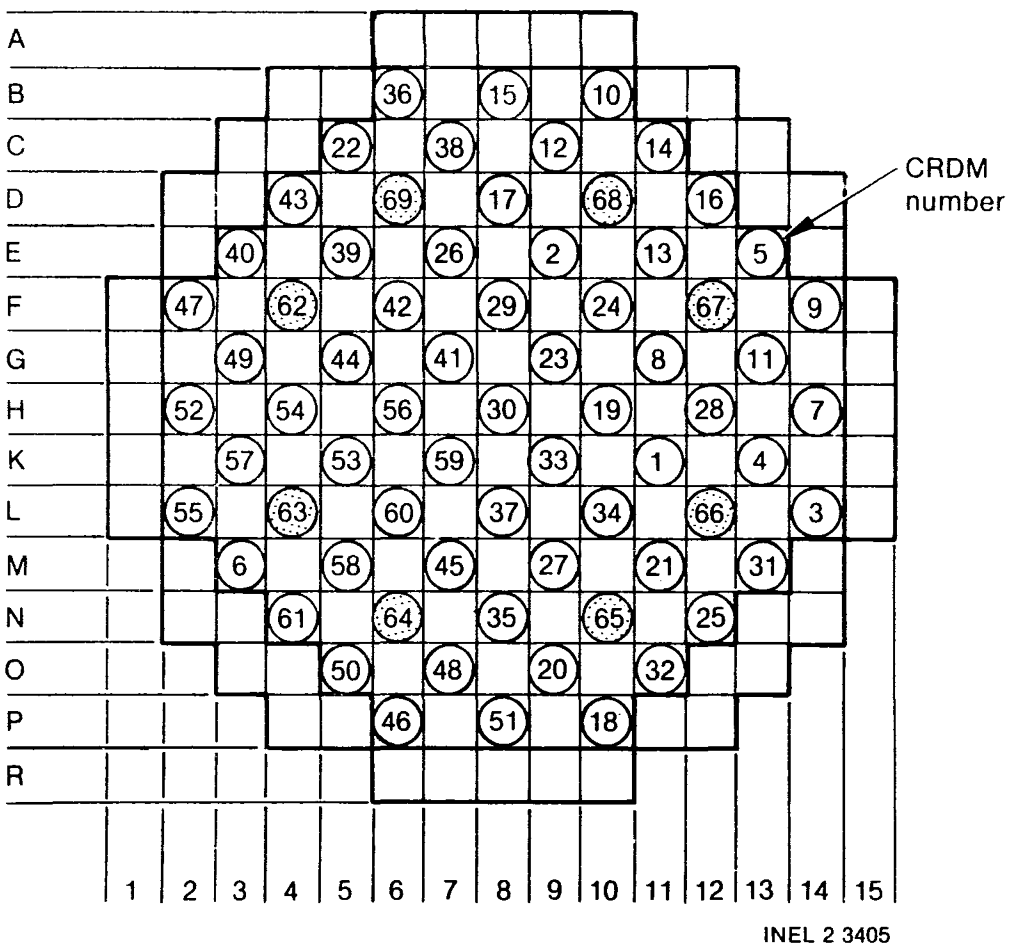


Figure 2. Core grid location of eight axial power shaping rods (ASPRs) and shim safety control rods (SSCRs). Shaded areas indicate ASPRs.

OBJECTIVES

The objectives of the in-situ testing are:

- To determine the condition of stators and Absolute Position Indicators of eight APSRs and three SSCRs
- To determine the condition of stator thermocouples of 11 control rod drives (10 pheripheral and 1 central)
- To assess the components' survival of the TMI-2 accident.

MEASUREMENTS

Twenty-one control rod drive mechanisms were involved in the test; the eight APSRs (CRDMs 62 through 69) and SSCRs 01, 03, 09, 10, 18, 22, 30, 35, 46, 47, 50, and 55. The mechanisms of the APSRs and SSCRs 01, 35, and 50 were tested for their stator and position indicators; the mechanism SSCRs 03, 09, 10, 18, 22, 30, 36, 46, 47, 55, and 64 were tested for their thermocouple.

The test of the APSRs and SSCRs was carried out at the Control Rod Drive (CRD) system logic cabinets, transformer cabinets, and Terminal Box RI139 located in the cable spreading room. It consisted principally of resistance, capacitance, inductance, time domain reflectometry (TDR), insulation resistance measurements on the stator feeder circuits of all the mechanisms, and resistance and inductance measurements of the thermocouple circuits. Also, temperature readings were obtained from eight thermocouples. These measurements were made with the cables to the devices separated from the remainder of their control circuits. The measurement points are shown in Figures 3 and 4.

The inductance-capacitance-resistance (LCR) and insulation resistance for the stators were measured from each winding to neutral. These data are shown in Tables 1 and 2, respectively.

The tests, conducted on the position indicators, were basically resistance measurements. The results are shown in Table 3.

TDR measurements were performed only on the stator feeder cables and one position indicator cable. The TDR measurements on each stator were made between each stator winding and ground, and between neutral and ground.

The DC resistance data for the thermocouples are shown in Table 4.

Temperature data are shown in Table 5.

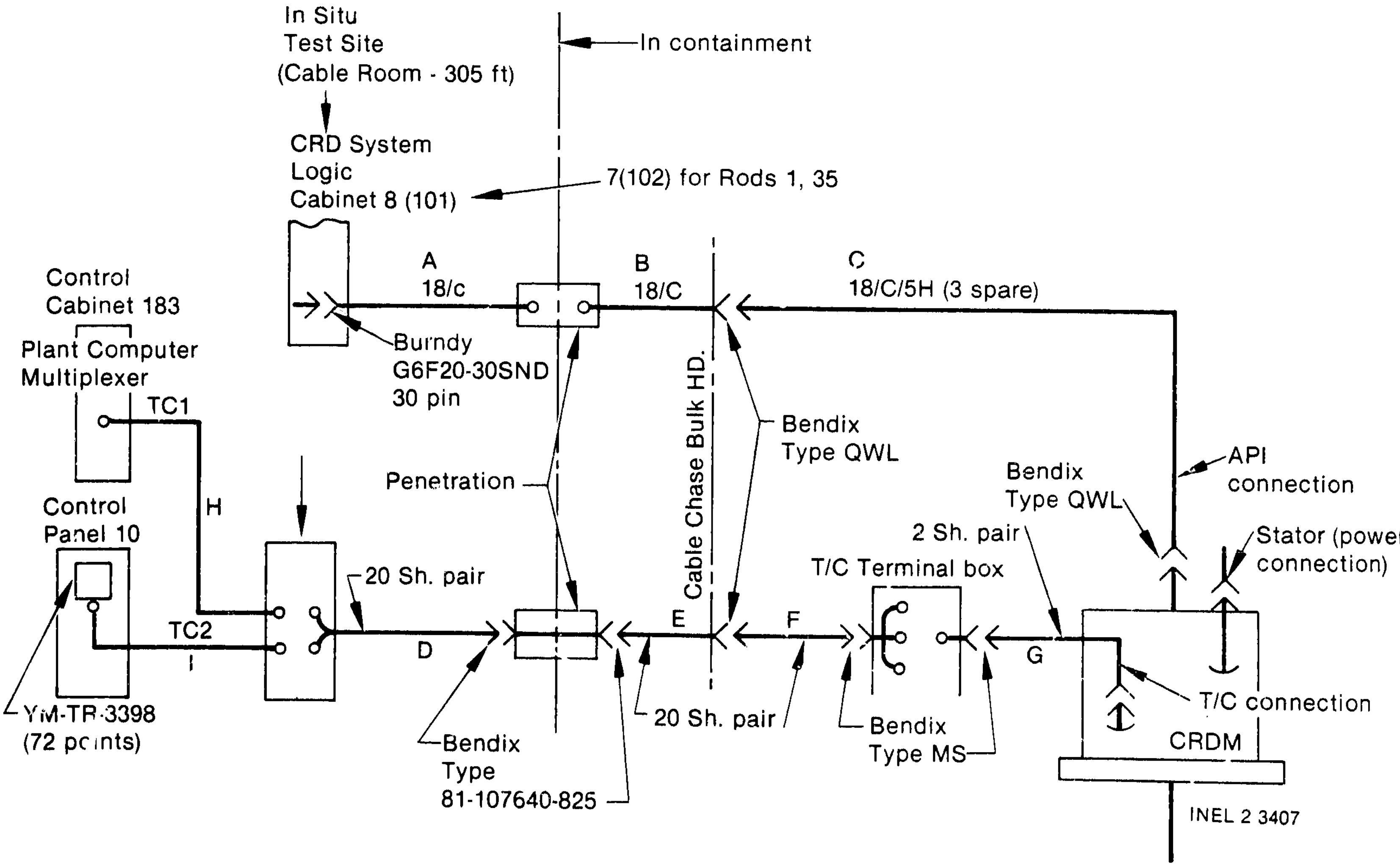


Figure 3. Control rod drive mechanism absolute position indication and thermocouple block diagram.

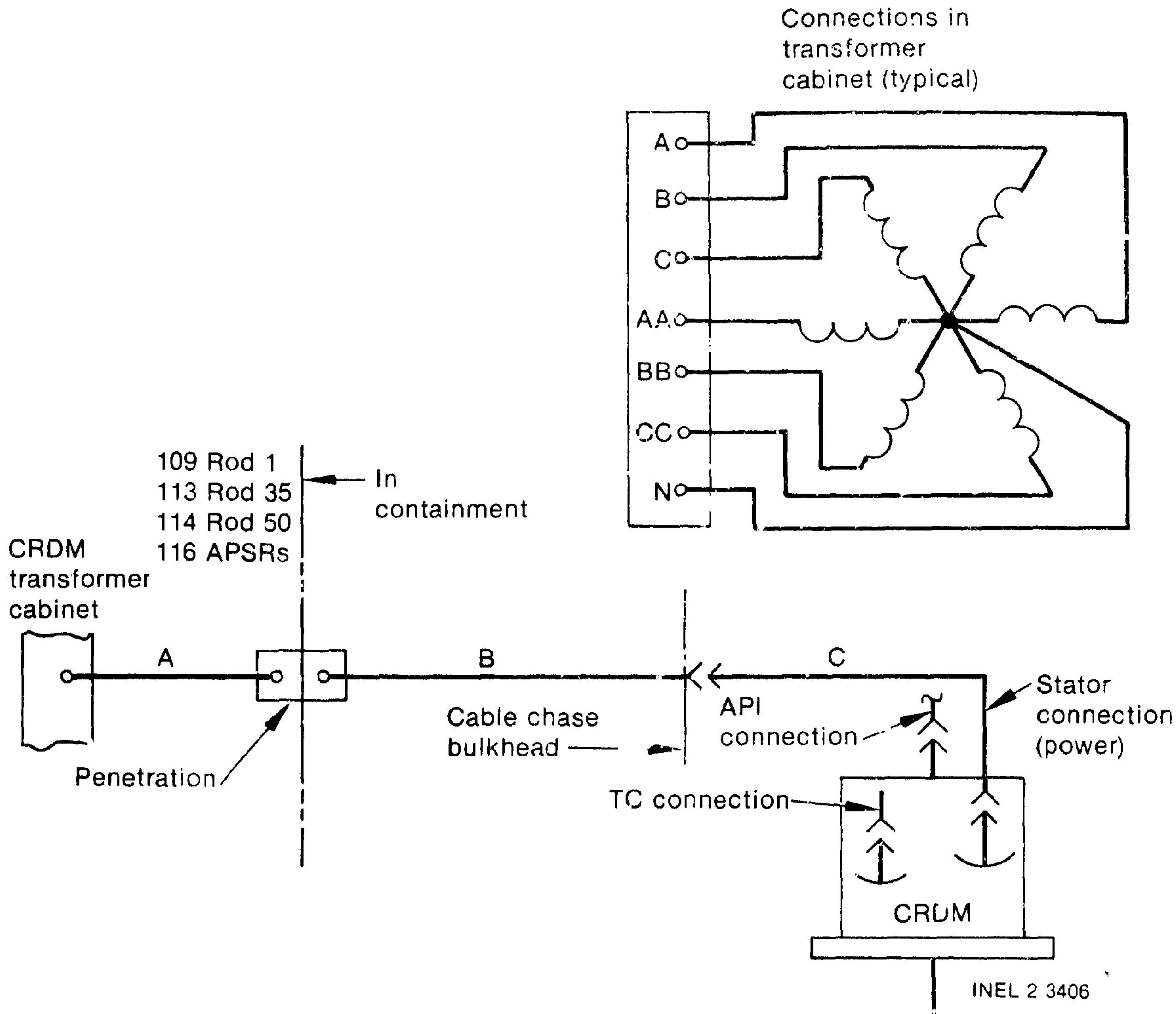


Figure 4. Control rod drive mechanism drive stator block diagram.

TABLE 1. PRIMARY STATOR INDUCTANCE--CAPACITANCE--RESISTANCE IN-SITU MEASUREMENT DATA (Axial Power Shaping Rods [APSRs] and Shim Safety Control Rods [SSCRs] 01, -35, and 50 were tested for their stator and position indicators; the others were tested for their thermocouple. Hz, kHz values indicate frequency.)

Control Rod Number	Test Point	Capacitance (nF) C_p (10 kHz)	Capacitance (nF) D (10 kHz)	Inductance (mH) L_p (120 Hz)	Inductance (mH) L_p (10 kHz)	Inductance (mH) Q (120 Hz)	Inductance (mH) Q (10 kHz)	Effective Series Resistance (ohms) R_p (1 kHz)	DC Resistance (ohms)
01	A-N	--	--	220	321	1.658	0.616	1263	7.89
	B-N	--	--	223	321	1.621	0.607	1244	7.87
	C-N	--	--	222	316	1.656	0.622	1258	7.90
	AA-N	--	--	221	320	1.645	0.609	1245	7.89
	BB-N	--	--	224	326	1.623	0.601	1252	7.87
	CC-N	--	--	222	318	1.653	0.616	1254	7.87
35	A-N	--	--	213	294	1.689	0.663	1245	7.91
	B-N	--	--	210	284	1.712	0.690	1253	7.91
	C-N	--	--	210	289	1.724	0.682	1259	7.90
	AA-N	--	--	213	293	1.689	0.667	1249	7.80
	BB-N	--	--	210	287	1.718	0.690	1264	7.89
	CC-N	--	--	210	289	1.721	0.681	1258	7.89
50	A-N	--	--	214	297	1.689	0.657	1248	7.97
	B-N	--	--	217	305	1.653	0.636	1239	7.98
	C-N	--	--	214	302	1.686	0.648	1249	7.96
	AA-N	--	--	213	298	1.692	0.655	1250	7.95
	BB-N	--	-	217	309	1.650	0.627	1236	7.96
	CC-N	--	--	214	301	1.686	0.648	1246	7.97
62	A-N	55.3[a]	3.42[a]	212	--	1.678	--	819	7.98
	B-N	59.7[a]	3.22[a]	210	--	1.701	--	806	7.96
	C-N	58.8[a]	3.24[a]	208	--	1.715	--	813	7.95
	AA-N	54.5[a]	3.50[a]	212	--	1.672	--	812	7.94
	BB-N	59.9[a]	3.18[a]	210	--	1.701	--	813	7.94
	CC-N	57.9[a]	3.31[a]	208	--	1.715	--	808	7.93

TABLE 1. (continued)

Control Rod Number	Test Point	Capacitance (nF) Cp (10 kHz)	D (10 kHz)	Inductance (mH) Lp (120 Hz)	Lp (10 kHz)	Q (120 Hz)	Q (10 kHz)	Effective Series Resistance (ohms) Rp (1 kHz)	DC Resistance (ohms)
63	A-N	139.1	0.145	222	329	1.661	0.612	1289	8.05
	B-N	138.8	0.145	221	332	1.689	0.605	1288	8.06
	C-N	139.2	0.147	219	336	1.701	0.601	1290	8.06
	AA-N	136.7	0.140	222	328	1.664	0.613	1291	8.08
	BB-N	137.5	0.145	221	332	1.695	0.611	1299	8.08
	CC-N	137.8	0.141	220	331	1.701	0.611	1297	8.09
64	A-N	137.0	0.148	221	304	1.637	0.641	1247	7.95
	B-N	137.2	0.146	218	306	1.675	0.646	1268	7.97
	C-N	136.2	0.151	217	300	1.678	0.655	1259	7.94
	AA-N	134.0	0.143	221	301	1.642	0.650	1252	7.94
	BB-N	139.0	0.148	217	304	1.672	0.649	1266	7.94
	CC-N	135.9	0.148	217	297	1.645	0.660	1255	7.97
65	A-N	137.0	0.148	221	303	1.637	0.643	1247	7.91
	B-N	137.2	0.146	218	306	1.675	0.648	1268	7.94
	C-N	136.2	0.152	217	300	1.678	0.657	1260	7.90
	AA-N	134.0	0.143	221	300	1.642	0.652	1252	--
	BB-N	139.0	0.148	218	304	1.672	0.651	1266	7.92
	CC-N	138.5	0.147	217	296	1.675	0.661	1255	7.96
66	A-N	137.6	0.144	216	282	1.650	0.695	1255	7.83
	B-N	136.5	0.143	214	279	1.689	0.715	1277	7.85
	C-N	137.0	0.147	213	279	1.695	0.712	1269	7.88
	AA-N	136.6	0.153	217	284	1.669	0.705	1280	7.87
	BB-N	136.4	0.141	214	284	1.689	0.707	1280	7.86
	CC-N	137.7	0.154	213	279	1.704	0.714	1276	7.85

TABLE 1. (continued)

Control Rod Number	Test Point	Capacitance (nF) C_p (10 kHz)	D (10 kHz)	Inductance (mH) L_p (120 Hz)	L_p (10 kHz)	Q (120 Hz)	Q (10 kHz)	Effective Series Resistance (ohms) R_p (1 kHz)	DC Resistance (ohms)
67	A-N	134.3	0.150	209	266	1.704	0.764	1300	7.93
	B-N	133.2	0.144	205	262	1.730	0.755	1300	7.93
	C-N	135.8	0.150	203	259	1.742	0.784	1303	7.94
	AA-N	131.8	0.140	207	264	1.704	0.767	1299	7.95
	BB-N	134.8	0.149	205	263	1.727	0.776	1309	7.95
	CC-N	134.0	0.144	203	259	1.742	0.787	1304	7.93
68	A-N	139.5	0.137	217	315	1.680	0.631	850	7.80
	B-N	138.8	0.138	218	328	1.710	0.615	844	7.80
	C-N	138.8	0.139	217	321	1.720	0.631	843	7.90
	AA-N	169.0	0.201	217	312	1.690	0.640	854	7.90
	BB-N	168.7	0.194	218	326	1.710	0.622	852	7.80
	CC-N	170.5	0.201	216	320	1.720	0.633	845	7.80
69	A-N	169.0	0.200	229	347	1.650	0.571	--	8.0
	B-N	165.0	0.189	226	337	1.680	0.594	--	8.0
	C-N	167.6	0.193	225	341	1.690	0.580	--	8.0
	AA-N	166.0	0.188	229	344	1.660	0.580	--	8.0
	BB-N	167.5	0.196	225	338	1.690	0.590	--	8.0
	CC-N	166.5	0.187	225	341	1.690	0.580	--	8.0

a. 1 kHz.

TABLE 2. STATOR CIRCUIT INSULATION RESISTANCE DATA
(Measured in ohms)

Tests Points	Control Rod Number (ohms)									
	35 $(X10^{11})$	50 $(X10^{11})$	62 $(X10^{9})$	63 $(X10^{11})$	64 $(X10^{12})$	65 $(X10^{11})$	66 $(X10^{9})$	67 $(X10^{11})$	68 $(X10^{9})$	69 $(X10^{10})$
A-Ground	1.5	1.0	1.3	4.0	2.0	1.0	1.2	6.8	5.0	5.2
B-Ground	1.4	1.3	1.3	4.0	2.0	1.0	1.2	6.5	5.0	5.2
C-Ground	1.4	1.6	1.3	4.1	2.0	1.0	1.3	6.5	5.0	5.2
AA-Ground	1.3	2.0	1.3	4.0	2.0	1.0	1.3	6.4	5.0	5.1
BB-Ground	1.3	2.3	1.3	4.0	2.25	1.0	1.3	6.3	5.0	5.1
CC-Ground	1.3	.6	1.3	4.2	2.25	1.0	1.3	6.2	5.0	5.1
N-Ground	1.3	2.9	1.2	4.8	3.0	1.0	1.3	6.2	5.0	5.1

TABLE 3. ABSOLUTE POSITION INDICATOR (API) DC RESISTANCE MEASUREMENT DATA
(Measured in ohms)

Test Points	Control Rod Number										
	62	63	64	65	66	67	68	69	01	35	50
d-e	52.64	Open	Open	Open	Open	52.75	Open	52.59	Open	Open	Open
d-g	602.2	603	604	602	602.4	602.4	601.2	602.1	--	--	--
e-g	653.0	Open	Open	Open	Open	652.3	Open	652.1	--	--	--
f-g	2400	2402	2401	2402	2402	2385	2388	2401	2400	2400	2402
K-G	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
J-H	Open	Open	Open	Open	Open	Open	Open	Open	2.94	2.1	2.02
L-T	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
R-T	Open	Open	Open	Open	Open	Open	Open	Open	2.59	2.50	2.54
N-T	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open
P-S	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open	Open

TABLE 4. THERMOCOUPLE LEADS RESISTANCE DATA
(Measured in ohms)

Thermocouple Leads	Control Rod Number										
	30	64	22	36	10	09	03	18	46	55	47
Iron 1 - Constantan 1	56.66	53.47	54.67	52.50	52.04	53.62	54.53	52.61	54.65	53.89	51.10
Iron 1-Shielded	17.50	16.85	17.29	16.92	16.82	17.26	17.36	17.03	17.28	17.30	16.75
Constantan 1 - Shielded	51.85	49.31	50.69	48.46	47.78	49.68	50.19	48.60	50.39	49.64	47.13
Iron 2 - Constantan 2	56.59	52.88	Open	54.15	52.59	52.39	55.45	53.21	55.13	54.73	52.14
Iron 2-Shielded	17.33	16.55	Open	17.16	16.77	17.07	17.42	16.96	17.32	17.33	16.69
Constantan 2 - Shielded	52.14	48.87	Open	49.84	48.51	49.56	51.07	49.38	51.09	50.43	48.12

TABLE 5. CDR STATOR TEMPERATURE DATA
(Measured in Farenheit and Kelvin)

	Control Rod Number							
	36	10	09	03	18	46	55	47
Temperature (°F)								
Thermocouple 1	73	73	72	70	73	74	75	73
2	74	73	72	70	72	73	74	76
Temperature (K)								
Thermocouple 1	295.9	295.9	295.4	294.3	295.9	296.5	297.0	295.9
2	296.5	295.9	295.4	294.3	295.4	295.9	296.5	297.6

ANALYSIS RESULTS

The measurements made on the stators have indicated no obvious trace of failure or anomaly. The windings are intact, as evidenced by the consistent DC resistance measurements ranging from about 7.8 to 8.1 ohms. These measured data are in close agreement to the designed stator phase resistance value of 0.2 to 5.82 ohms. The difference of about 2.5 ohms between the designed and actual resistance is attributed to resistance of the cables, splices, connectors, etc. This is further corroborated by the LCR data. Likewise, the insulation resistance of the stator feeder circuits appears good. It exceeded the minimum requirements of 10 megohms. (The measurements for Rod 1 registered an unrealistic resistance of infinity, which may have been a measurement error.) Since TDR measurements were made between ground and the wires in the cable, unknown variables like the effect of the distance between the cable and the ground strap or cable tray diminish definitive interpretation.

The condition of the electrical network of the position indicators of Control Rods 01, 35, and 50, and the APSRs is commensurate with the estimated positions of the associated rods. The resistor networks that are associated with the position indicators are all intact as shown by the resistance measurements in Table 3. Only those switches associated with the estimated rod positions are closed. The shim safety rods are in the full IN position, and the APSRs are confidently estimated to be in the 26 to 27% withdrawn position. Whether the closed switches may be stuck or welded in that position cannot be determined by the test.

All the stator thermocouples tested appear to be good except for one thermocouple in Rod 22 (see Table 4). The thermocouple resistance data furnished by the vendor are 6 $\pm$ 0.5 ohms across the iron and constantan lead wires. An American Wire Gage (AWG) 16 iron-constantan lead wire has a double length resistance of 0.137 ohm/ft (0.539 chm/m). The total pulled length of each of the thermocouple cables corresponding to the stators tested is approximately 105 m. Using this number as the effective wire length (cable lay, penetration wires and trim are assumed to negate each other), this length would translate to approximately 47 ohms; the circuit resistance would be approximately 53 ohms. This calculated value is consistent with the measured circuit resistance shown in Table 4. Furthermore, the resistance measurements from each lead to the shield verify the ratios of iron, constantan and shield resistance. They are consistent with a lack of undesired contact between leads or between leads and shields. The second thermocouple associated with control Rod 22 has an open circuit.

The assessed condition of the thermocouple circuits is further supported by the uniformity of temperature measurements (see Table 5) that are commensurate with the conditions at the stator locations on the reactor head.

Although the inductance data obtained for thermocouple leads were consistent, they were not considered useful in characterizing the condition of the circuit; therefore, they were not presented in this report.

CONCLUSIONS

The stators of SSCRs 01, 35, 50 and APSRs 62 though 69 apparently survived the accident. Likewise, the stator thermocouples, except for one on Rod 22, appear to be good. The position indicators, resistor networks, and switch circuits permitted to be closed, by virture of estimated rod positions, appear to be in good condition.