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TECHNICAL DATA RECORD

NAA-SR-MEMO-TDR NO 9746
PAGE 1 OF 155
DATE 2-4-64
GO NO 7561
S/A NO 2560
TWR 52113

APPROVALS: J. R. Johnson

AUTHOR: A. Chesavage
A. J. Chesavage

DEPT & GROUP NO: 722-25

TITLE: Irradiation Qualification Testing of SNAP 10A Components

PROGRAM: SNAP 10A

SUBACCOUNT TITLE: Component Instrumentation Qualification Testing

SECURITY CLASSIFICATION

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STATEMENT OF PROBLEM

Determine if SNAP 10A components degrade or fail in a combined environment of temperature, vacuum, and qualification level radiation.

ABSTRACT

Selected SNAP 10A components were irradiated to about 10^{14} NVT and 5×10^{7} R at an average temperature of 136°F in a nominal vacuum of 2×10^{-5} TORR. The components were operated periodically and the electrical characteristics recorded. Pre-irradiation and post-irradiation tests were conducted.

Catastrophic degradation occurred only in the low level neutron detection system at about 1.5×10^{13} NVT and in the high level neutron power supply at about 6×10^{12} NVT.

Marginal degradation occurred in the fusistors and in the silicone rubber insert material in connectors.

The relays, low voltage trip devices, expansion compensator position demodulator, resistance thermometer sensor and bridge, and the gamma detection system operated within their respective specifications during and after irradiation.

The insulation resistance of all components was adequate during and after irradiation.

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1.0 Acknowledgement

Irradiation planning and tests were conducted in conjunction with S. Kimble and D. Walker of the Reactor Environment Unit, D/723-33. The program for computer plotted graphs was developed jointly by the Reactor Environment Unit and Applied Mathematics, D/716-61. M. Robinson of the Reactor Environment Unit reduced the raw data into computer generated graphs.

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2.0 Scope

The components tested, the test exposure received by each component and the estimated one year dose (3.1 and 3.2) the component will receive in the instrument compartment are shown in Table 1.

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TABLE I

SNAP 10A COMPONENT IRRADIATION DOSE LEVELS

Spec. No.	Component	Neutron Dose NVT x 10^{13} Test Exposure	Neutron Dose NVT x 10^{13} Est. S10A Average Refs. 3.2 & 3.20	Gamma Dose R x 10^{7} Test Exposure	Gamma Dose R x 10^{7} Est. S10A
	FIRST TEST CAPSULE				
1	Fusistor	7.8	1.5 to 8	4.5	1.5
2	Fusistor	8.7	1.5 to 8	5.5	1.5
3	Fusistor	7.3	1.5 to 8	4.5	1.5
4	Fusistor	8.2	1.5 to 8	5.5	1.5
5	Relay 6PDT	4.3	1.5 to 8	3.8	1.5
6	Relay 6PDT	4.4	1.5 to 8	4.2	1.5
7	Relay DPDT	3.7	1.5 to 8	5.2	1.5
8	Relay DPDT	2.7	1.5 to 8	3.8	1.5
9	Low Volt. Trip	4.3	1.5 to 2	3.9	1.5
10	Low Volt. Trip	4.3	1.5 to 2	3.9	1.5
11	Low Volt. Trip	4.0	1.5 to 2	4.3	1.5
12	Low Volt. Trip	4.2	1.5 to 2	4.3	1.5
13	Exp. Comp. Pos. Demod	4.4	1.5 to 2	4.3	1.5
14	RTD Bridge	6.9	1.5 to 1.8	5.1	1.5
15	RTD Sensor	5.1	1.5 to 10	4.5	1.5
	SECOND TEST CAPSULE				
1	Lo. Lev. Neut. Det.	11.9	1.4 to 1.6	6.49	1.5
1(a)	Lo. Lev. Sig. Cond. & P.S.	9.4	1.3 to 1.7	5.62	1.5
2	Hi Lev. Pow. Sup.	16.1	1.5 to 2	6.34	1.5
3	Gamma Detector	12.8	1.5 to 4	6.85	1.5
3(a)	Gamma Amp. & P.S.	10.8	1.5 to 1.7	6.06	1.5
4	Conv. Deg. Meas. Dev.	21.1	1.8 to 2	7.10	1.5
5	Connector	7.0	1 to 50	4.4	1.5

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3.0 Applicable Documents and IL's

3.1 Drawing 10FS-22001 - Component Assembly Instrument Compartment.

3.2 IL, R. J. Thomson to W. A. Flynn, "Fast Neutron Fluxes Below the SNAP 10A Shield, dated May 27, 1963.

3.3 IL, A. J. Chesavage to J. L. Johnson, "Radiation Testing of SNAP 10A Components dated May 9, 1963.

3.4 IL, A. J. Chesavage to J. L. Johnson, "Trip to Battelle Memorial Institute April 28, 1963 through May 7, 1963", dated May 13, 1963.

3.5 IL, A. J. Chesavage to J. L. Johnson, "Interim Results of Irradiation Tests on SNAP 10A, Components", dated July 25, 1963.

3.6 IL, A. J. Chesavage to J. L. Johnson, "Trip Report, Battelle Memorial Institute, Columbus, Ohio for Radiation Qualification Tests on SNAP 10A Components from July 1, 1963 through July 18, 1963," dated July 24, 1963.

3.7 Fusistor (Control Dwg.), 10FS-24007.

3.8 Relay, Magnetic Latching, (Control Dwg.) 10FS-24008.

3.9 Relay, 6 Pole Double Throw Latching (Control Dwg.) 10FS-24009.

3.10 Trip Device, Low Voltage Specification For, NE10FS-20-010.

3.11 Specification for Transducer and Demodulator, Expansion Compensator Position, NE10FS-24-008.

3.12 Specification for Detector, Temperature, Resistance Type, NE10FS-24-009.

3.13 Schematic Diagram, RTD Bridge Unit, 10FS-24001

3.14 Specification for Detector, Neutron Flux, Low Level, NE10FS-24-004.

3.15 Specification for Amplifier and Power Supply for Detector, Neutron Flux, NE10FS-24-001.

3.16 Power Supply - Radiation Detector DC/DC Specification For, NE10FS-24-002.

3.17 Detector - Gamma Radiation Specification For, NE10FS-24-003.

3.18 Specification for Amplifier, Signal Conditioning, Transistorized NE10FS-24-006.

3.19 Program Technical Requirements No. 3 (Instrumentation Irradiation) by S. G. Kimble and D. M. Walker, dated 11-12-62.

3.20 IL, "Gamma Dose Rates Below SNAP 10A Shield," from R. J. Thomson to W. A. Flynn, dated 11 September 1963.

4.0 General Test Procedure

Two capsules of components were irradiated in the 2MW(T) swimming pool Battelle Research Reactor in West Jefferson, Ohio. The irradiation dates were: May 2, 1963 through May 7, 1963 for the first capsule and July 11, 1963 through July 18, 1963 for the second capsule.

The components in the capsule were operated every two hours to determine when any failure or degradation occurred. The insulation resistance and temperature of each component and the vacuum in the chamber were monitored also.

The components were irradiated at two positions near the core. In position #3 (low flux) the neutron and gamma fluxes are in the same order of magnitude as in the SNAP 10A instrument compartment. Initial irradiation in this position permits evaluating if "rate effects" influenced the operational characteristics of the components. The relatively slow accumulation of dose was also necessary to determine the level of early degradation or failure. Position #2 (high flux) was used to accelerate the life test.

The operational summary of each capsule is shown in Tables 2 and 3.

TABLE 2 EXPERIMENT ILF-1 OPERATIONAL SUMMARY

Date	Time	Remarks
5/2/63	1515	Out-of-pile position, pumps started
5/2/63	1950	Within test temperature limits (120 to 130F)
5/3/63	0005	Secured system into position 3
5/4/63	1330	LN_2 tank changed - pressure rise noted
5/4/63	1445	Heater off and secondary exchanger on prior to position change
5/4/63	1505	No. 3 outside dosimeter removed - start into position 2
5/4/63	1520	Secured into position 2
5/5/63	2105	Fired fusistor A2521
5/6/63	1246	Fired fusistor A2523, vacuum loss alarm momentarily
5/6/63	1358	Reactor scram
5/6/63	1429	Reactor at power
5/6/63	1755	Start move from position 2 to out-of-pile position
5/6/63	1800	No. 2 outside dosimeter removed
5/6/63	1805	Secured into out-of-pile position
5/6/63	1810 to 1820	Heater adjustments
5/7/63	1900 to 1000	Heater adjustments
5/7/63	1212	Final measurements, experiment ended
5/7/63	1225	All heater power off
5/9/63	---	Vacuum pumps turned off
5/16/63	---	System removed from pool and disassembled.

TABLE 3 EXPERIMENT ILF-2 OPERATIONAL SUMMARY

Date	Time	Remarks
7/10/63	1645	Out-of-pile position, pumps started
7/11/63	0930	Temperatures within test limits
7/11/63	1000	Secured into position 3
7/12/63	1005	Operating temperatures increased
7/13/63	1246	Reactor power decreased 15 per cent
7/13/63	1306	In reference position for 20 minutes
7/13/63	1326	Secured into position 2
7/13/63	1815	In reference position for 22 minutes
7/14/63	1300	In reference position for 25 minutes
7/15/63	0835	In reference position for 25 minutes
7/15/63	2011	In reference position for 22 minutes
7/16/63	0833	In reference position for 26 minutes
7/16/63	1859	In reference position for 24 minutes
7/17/63	0840	In reference position for 17 minutes
7/17/63	1407	Reactor shutdown
7/17/63	1445	Reactor at power
7/17/63	1857	In reference position for 16 minutes
7/18/63	1200	In reference position for 21 minutes
7/18/63	1221	Out-of-pile position
7/18/63	1645	Heater power off
7/19/63	0800	Pumps off.

5.0 Test Setup

5.1 Capsule Configuration Figures 1 through 4 show the first capsule components and the enclosure in progressive steps of assembly. Figures 5 and 6 show the component array, electrical and thermocouple leads and the water coil used for heating or cooling the components. Figures 7 through 10 show the progressive assembly of the second capsule of components. Figures 11 and 12 show a typical capsule, and its wiring and piping, ready for immersion in the pool. Figure 13 shows the 4" diffusion pump.

Each specimen subassembly consisted of a top-seal plate, support rods, specimen and thermocouple leads, specimen array, and the water coil. Three glass-to-metal hermetic-type connectors (Burndy) were incorporated into the top plate. Each connector handled approximately fifty leads. The water lines were welded to a small circular plate which was clamped against the top plate by a threaded bushing and sealed by an O-ring. The connectors were sealed to the top plate by potting with epoxy.

Specimen and thermocouple leads were attached to the lower (vacuum) side of the connector pins by solder. The thermocouple leads were 28-gauge chromel-alumel commercially furnished with a silicone impregnated asbestos-magnet wire (20 AWG copper) with a silicone and polyester resin impregnated double-glass cloth insulation. Woven stainless shields were provided around specified leads on the Demodulator, and RTD Bridge.

The electrical leads were attached to the specimens (or specimen connector pins) by solder. The thermocouples were beaded and attached to selected operating specimens by potting the bead to the specimen case with epoxy (except the fusistors). The potting also served as insulation between the specimens and thermocouples.

The hexagonal enclosure was fabricated in three sections (zones). The sections were constructed of 6061 aluminum plates (baffles), 0.040-inch thick, with anodized surfaces 0.003-inch thick. The mounting plates were constructed of 6061 aluminum plates 0.050-inch thick with anodized surfaces. The anodized surfaces provided relatively high effective emissivity and good electrical insulation. The mounting plates were securely fastened to the hexagonal enclosure plates with machine screws at assembly.

Most of the specimens were fastened directly to the mounting plates. Clamps were used to hold the temperature sensor and detector chambers in place. The lead cable from the temperature sensor was extended up one of the support rods, coiled near the top of the sub-assembly just under the header plate, brought back down along another support rod, and finally fastened into a connector on the RTD Bridge. The fusistors were wrapped in 0.003-inch thick aluminum foil and clamped to the lower mounting plate with aluminum straps. A thermocouple bead (insulated with glass cloth) and case-lead-wire (ground) was inserted between the foil and each fusistor before it was clamped into place.

Dosimeter wires were enclosed in ceramic tubes and attached to each specimen in the array.

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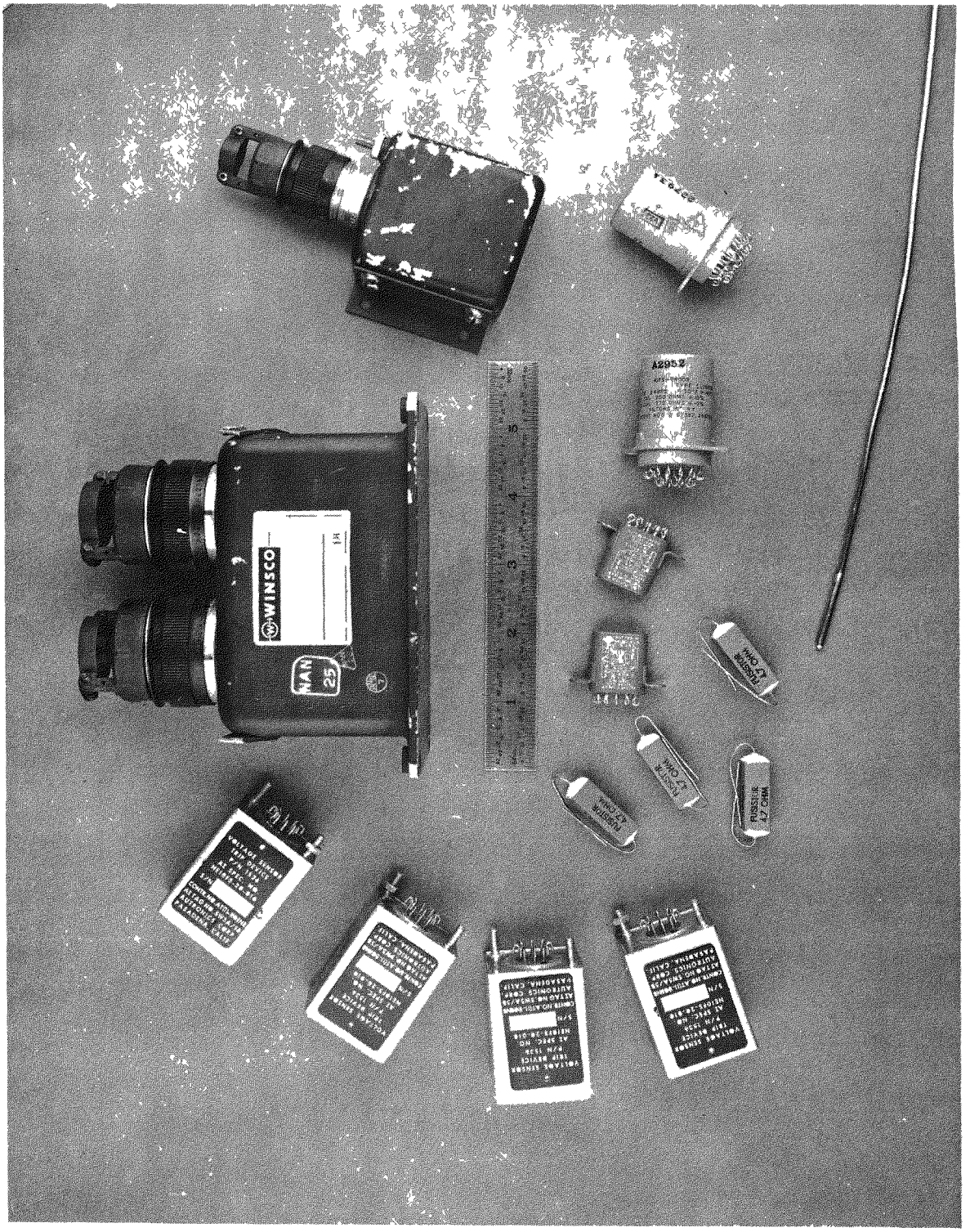

FIGURE 1

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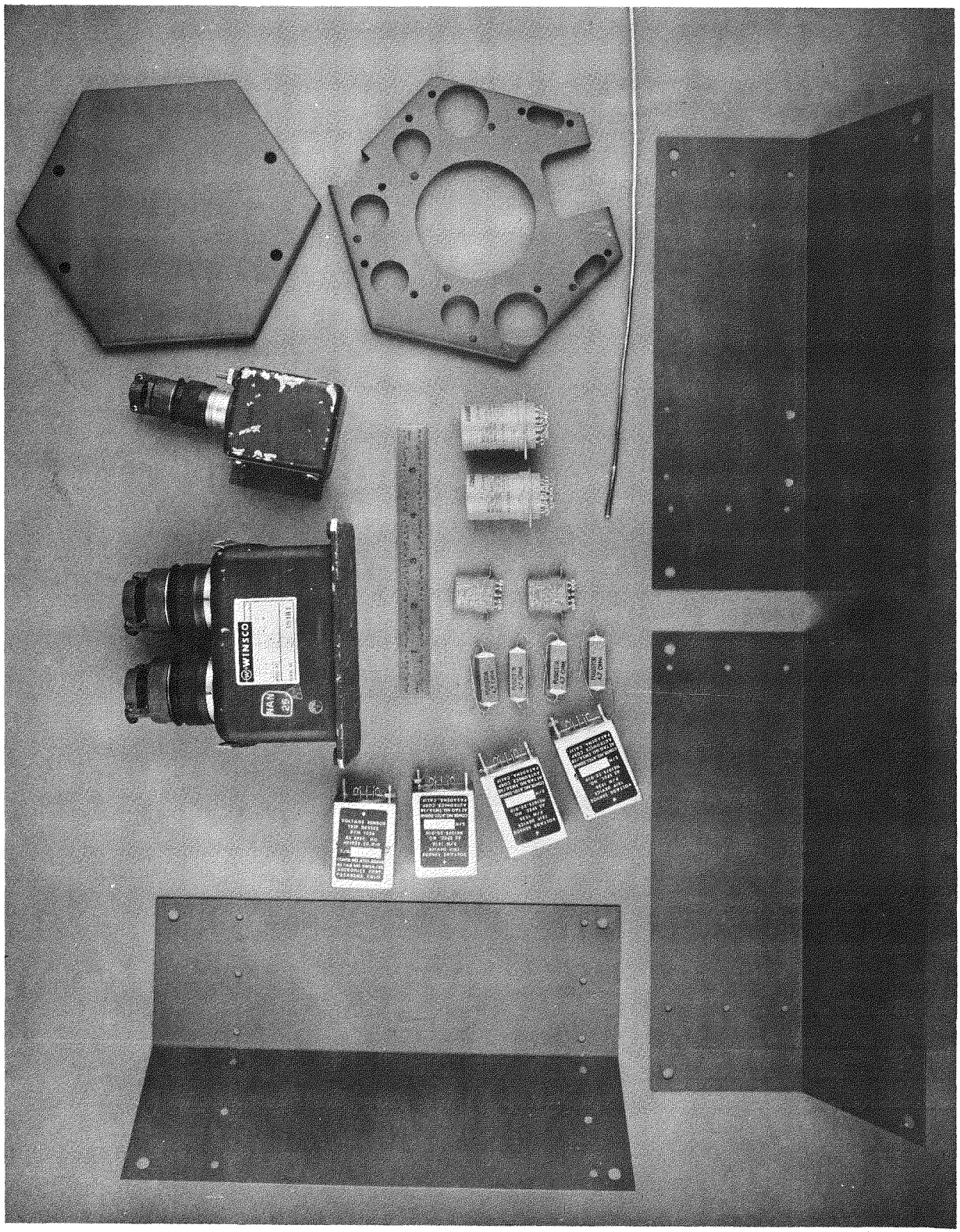

FIGURE 2

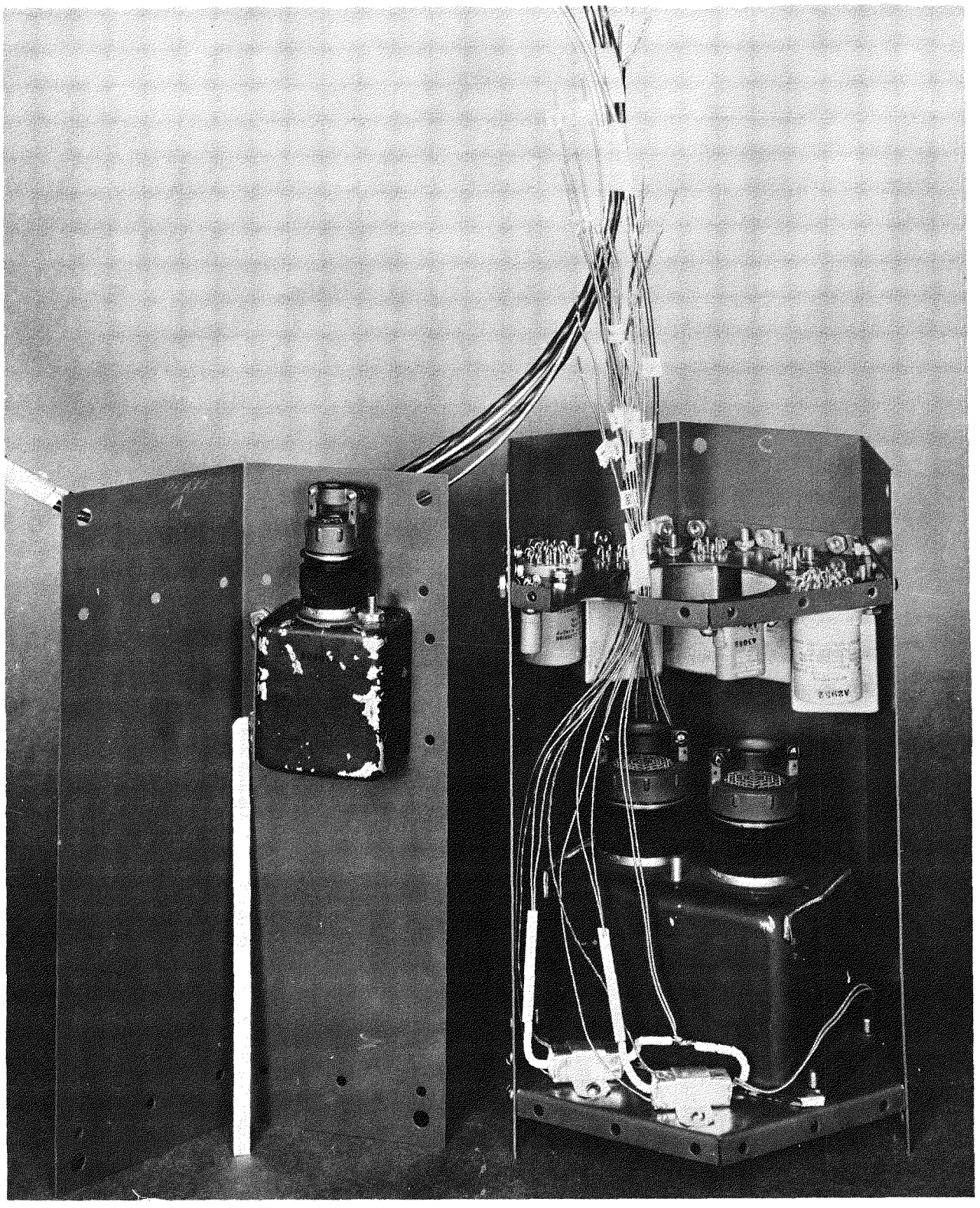

FIGURE 3

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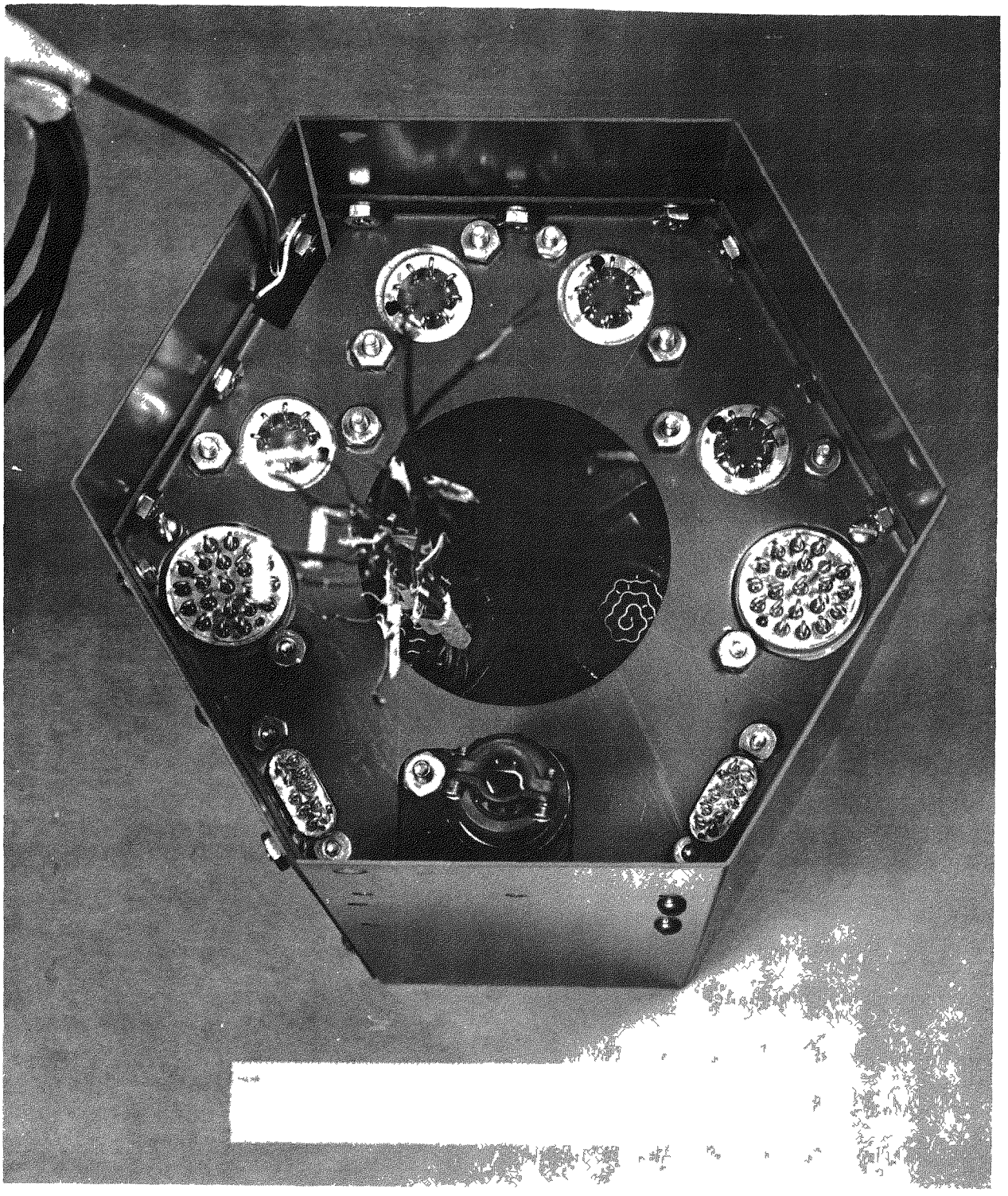

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FIGURE 4

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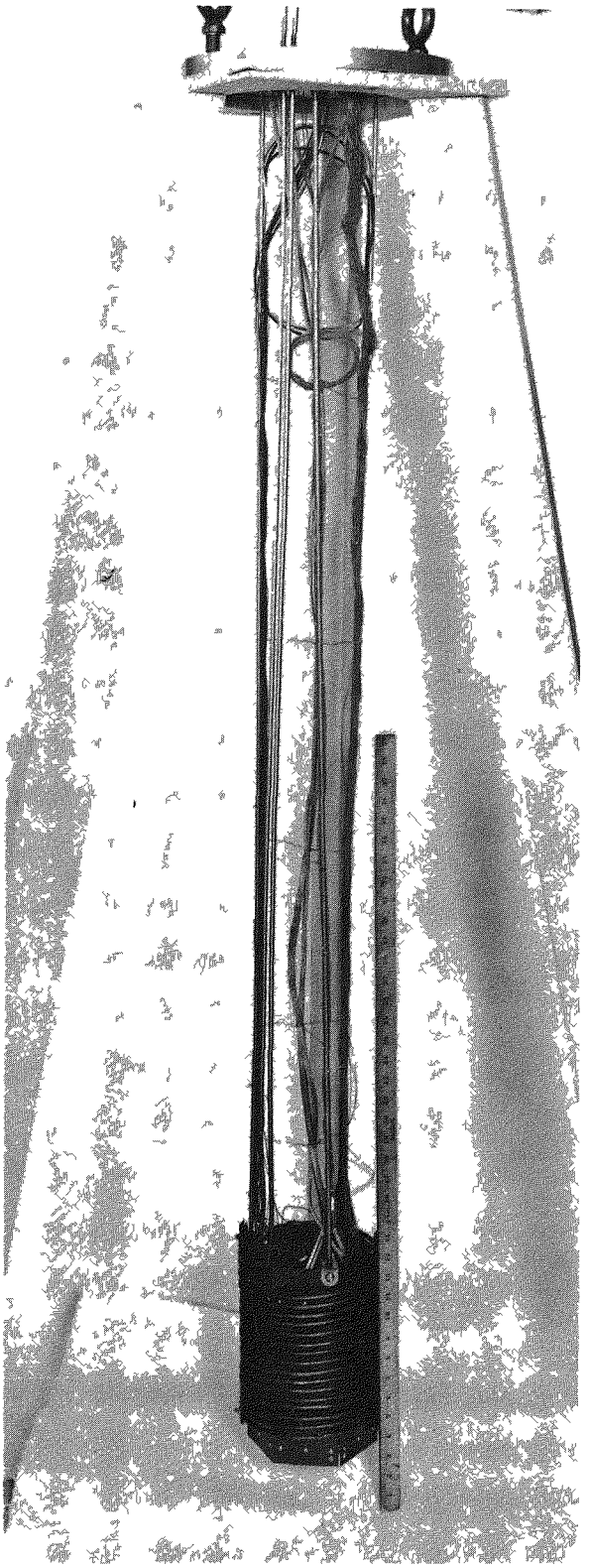

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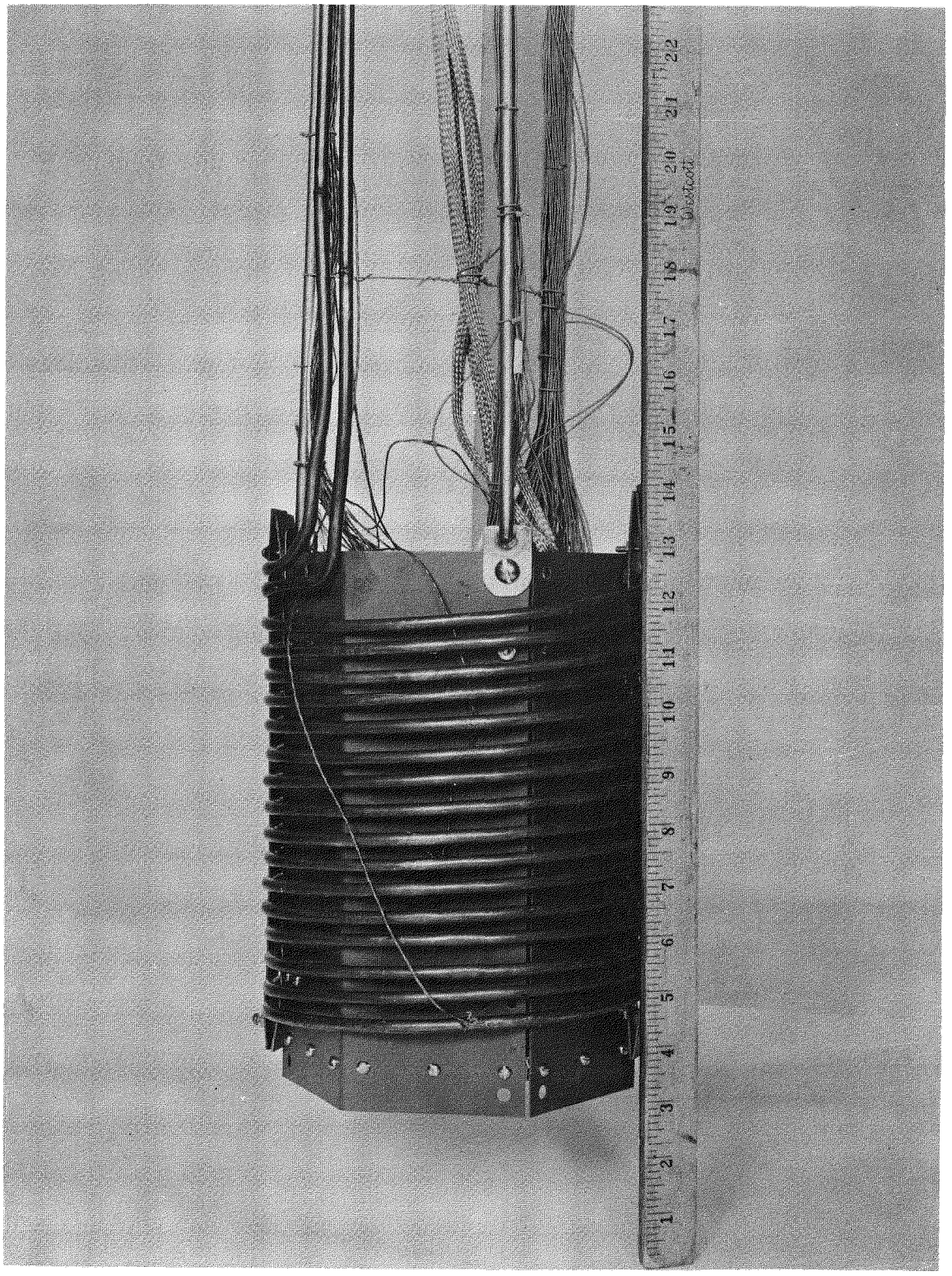

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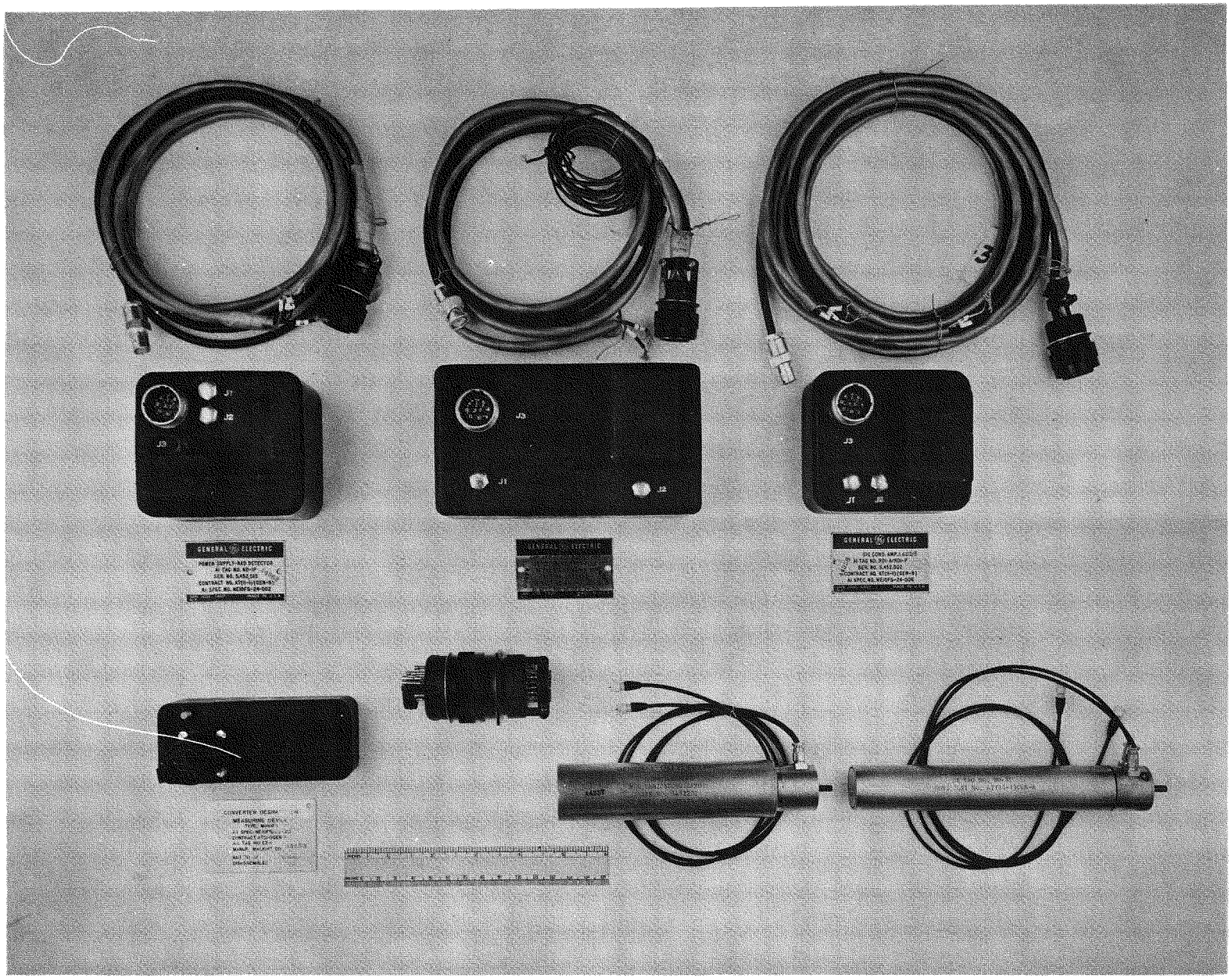

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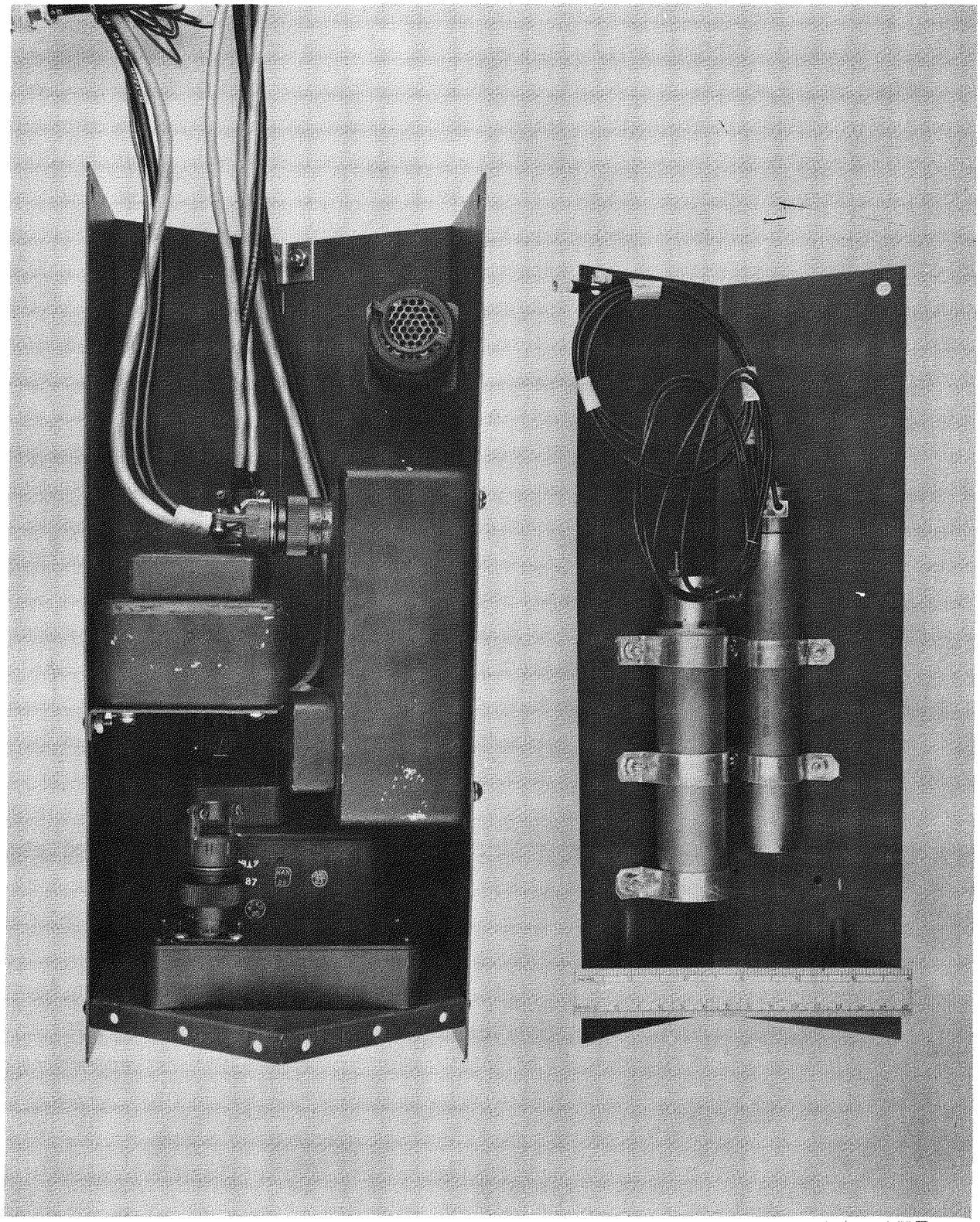

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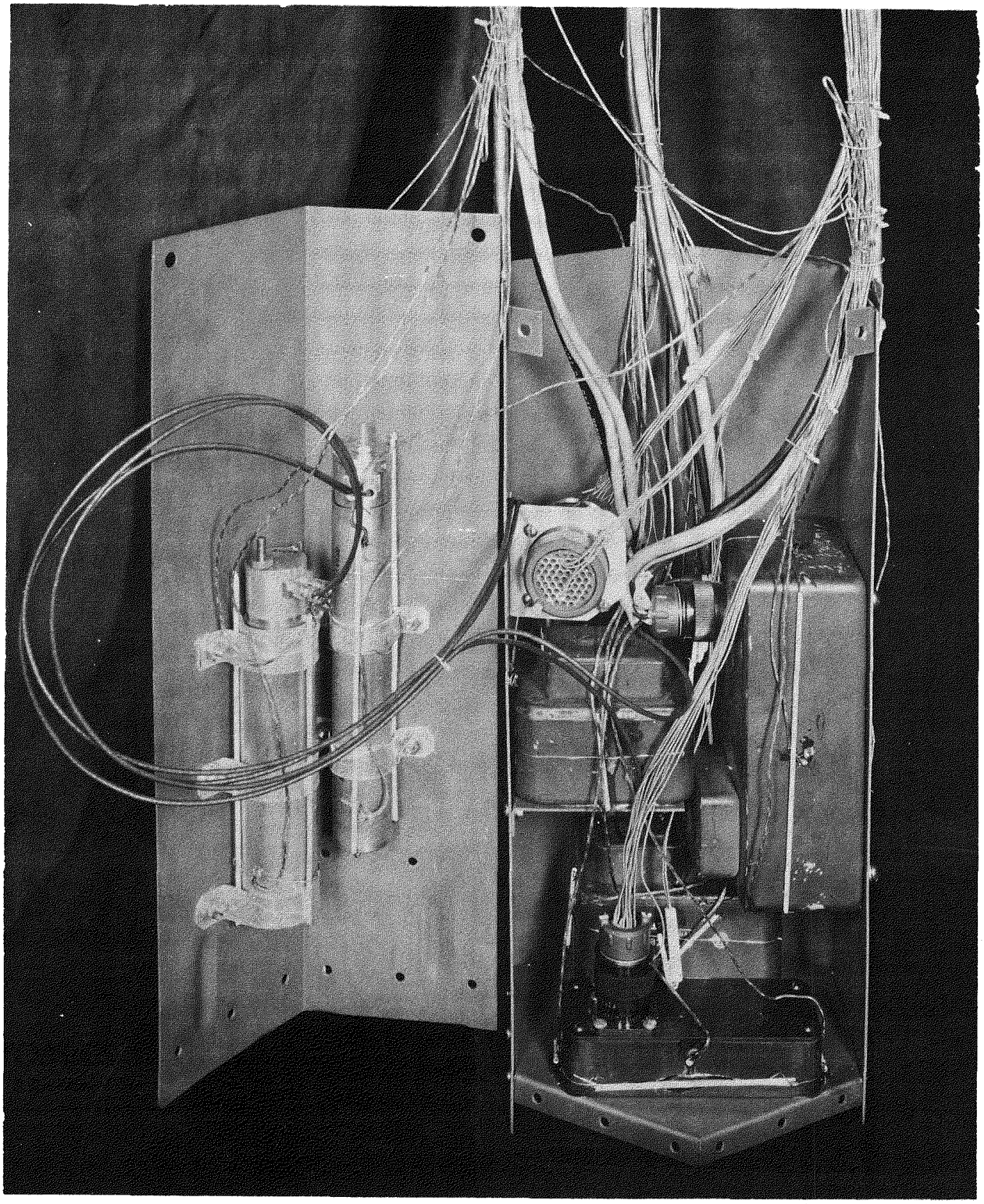

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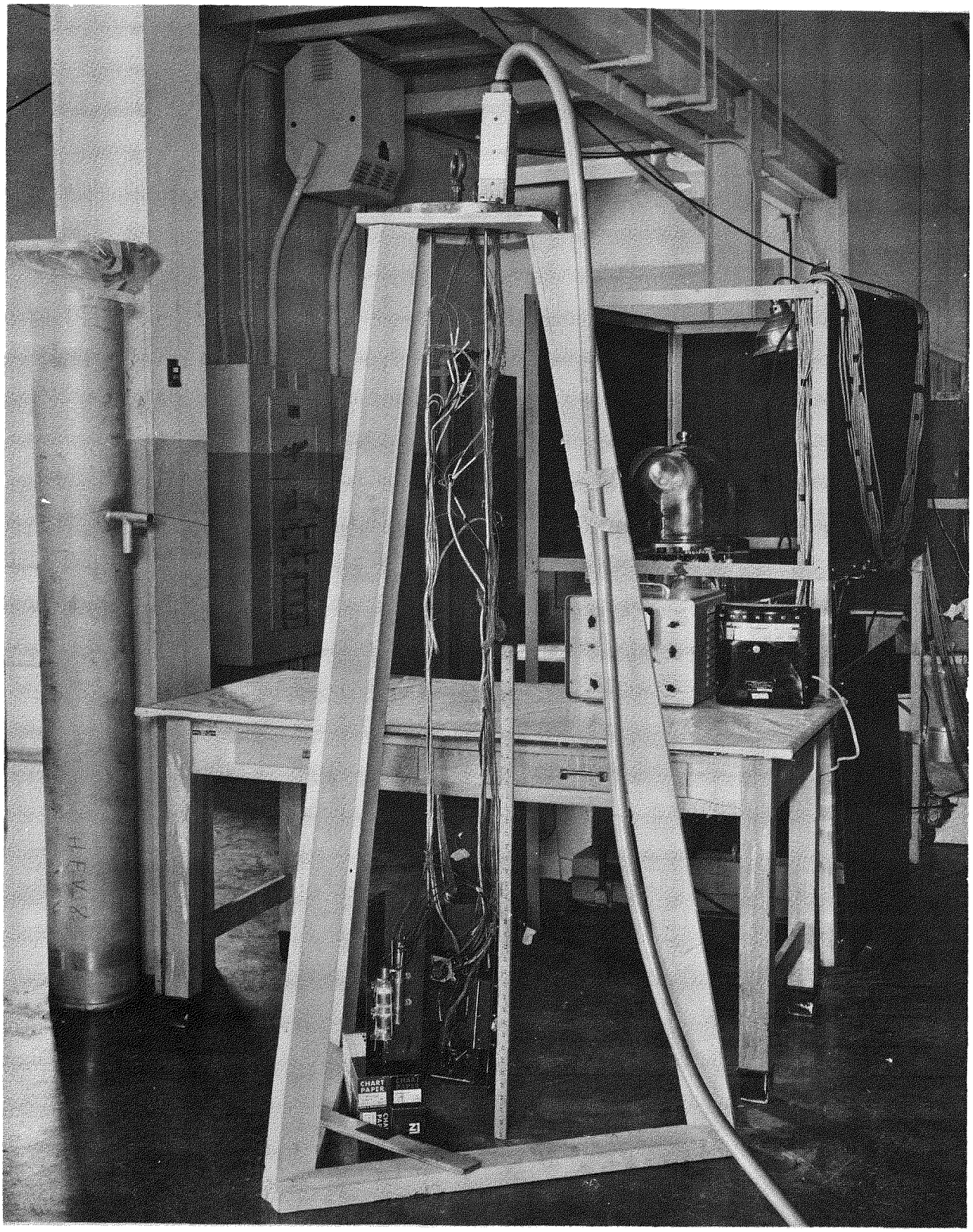
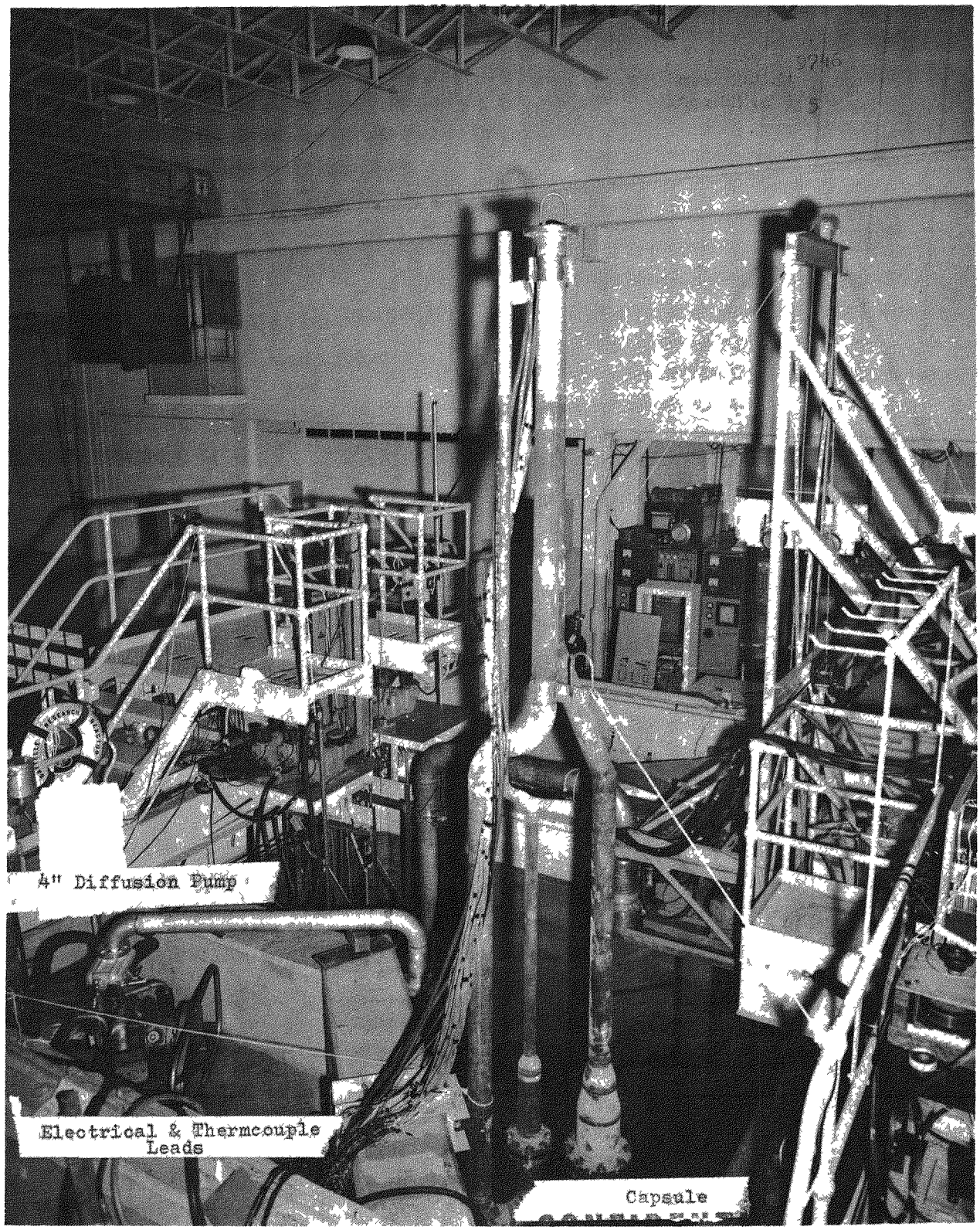


FIGURE 10



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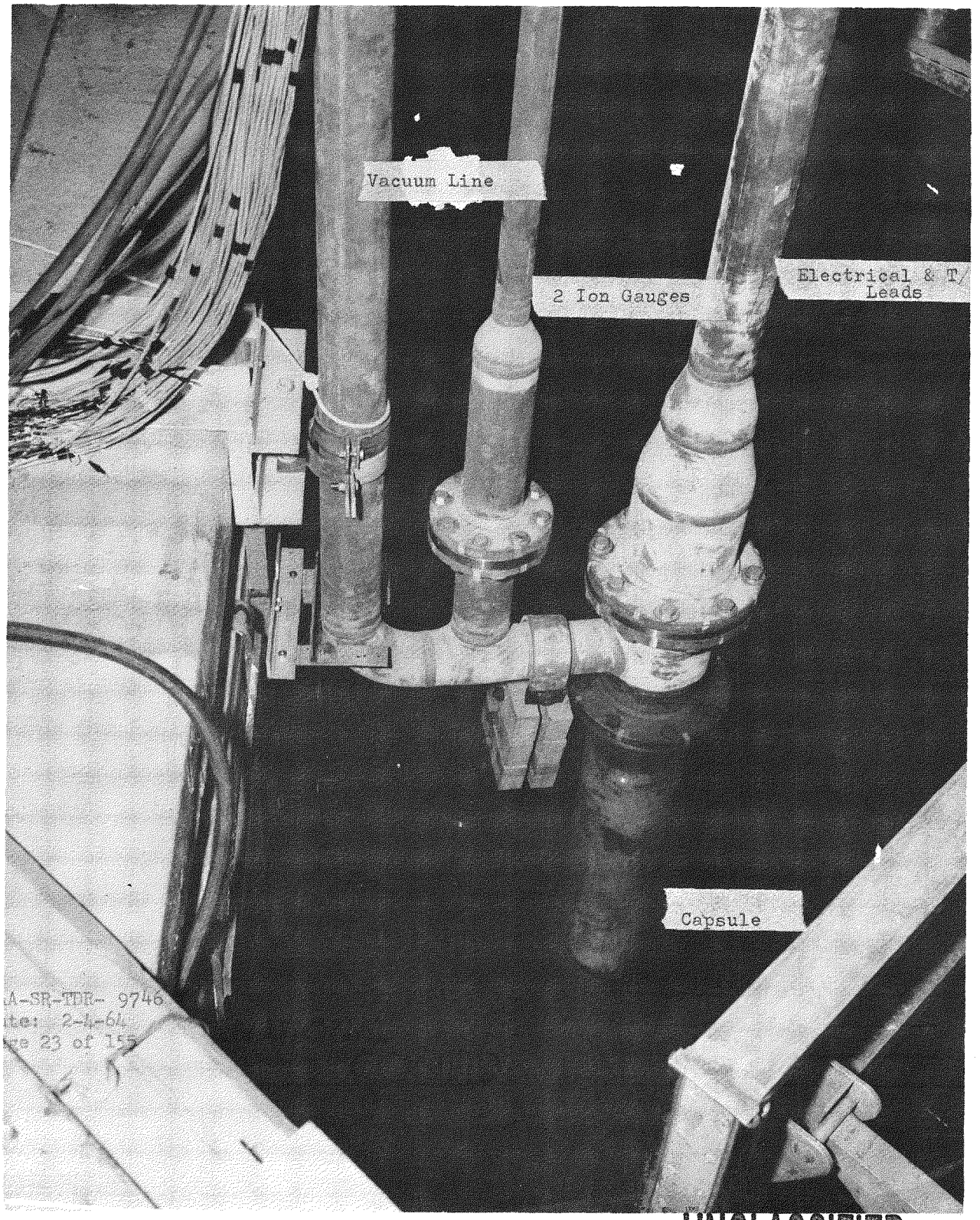

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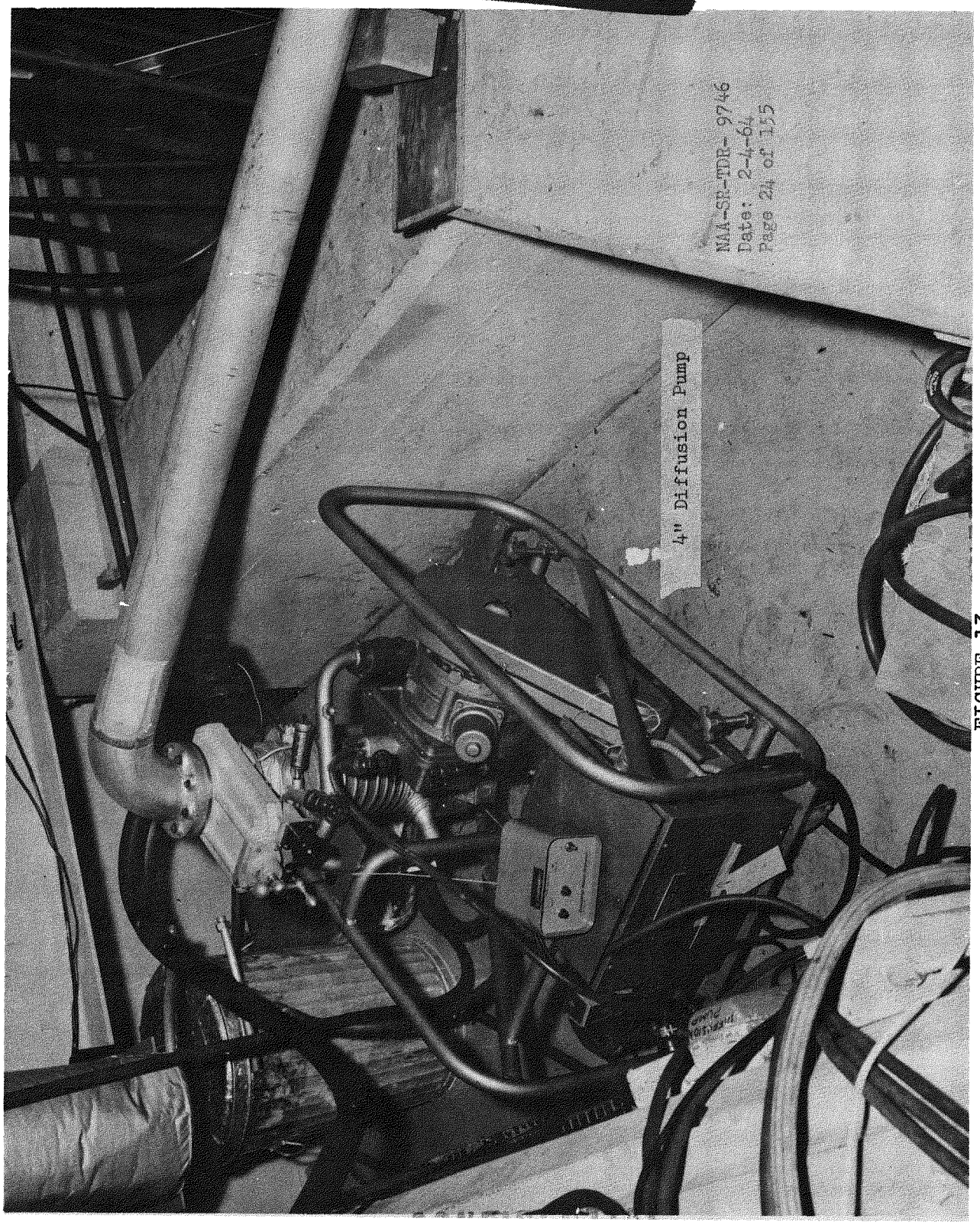

FIGURE 13

5.2 Instrumentation and Wiring The measuring lead layout is shown in Figure 14. The connections between the capsule header and the pool side terminal box were by means of 2 and 3-wire shielded cables. Connections between the pool-side terminal box and the instrument room terminal box are made of 14 gauge, solid, plastic insulated wire in a grounded wire trough.

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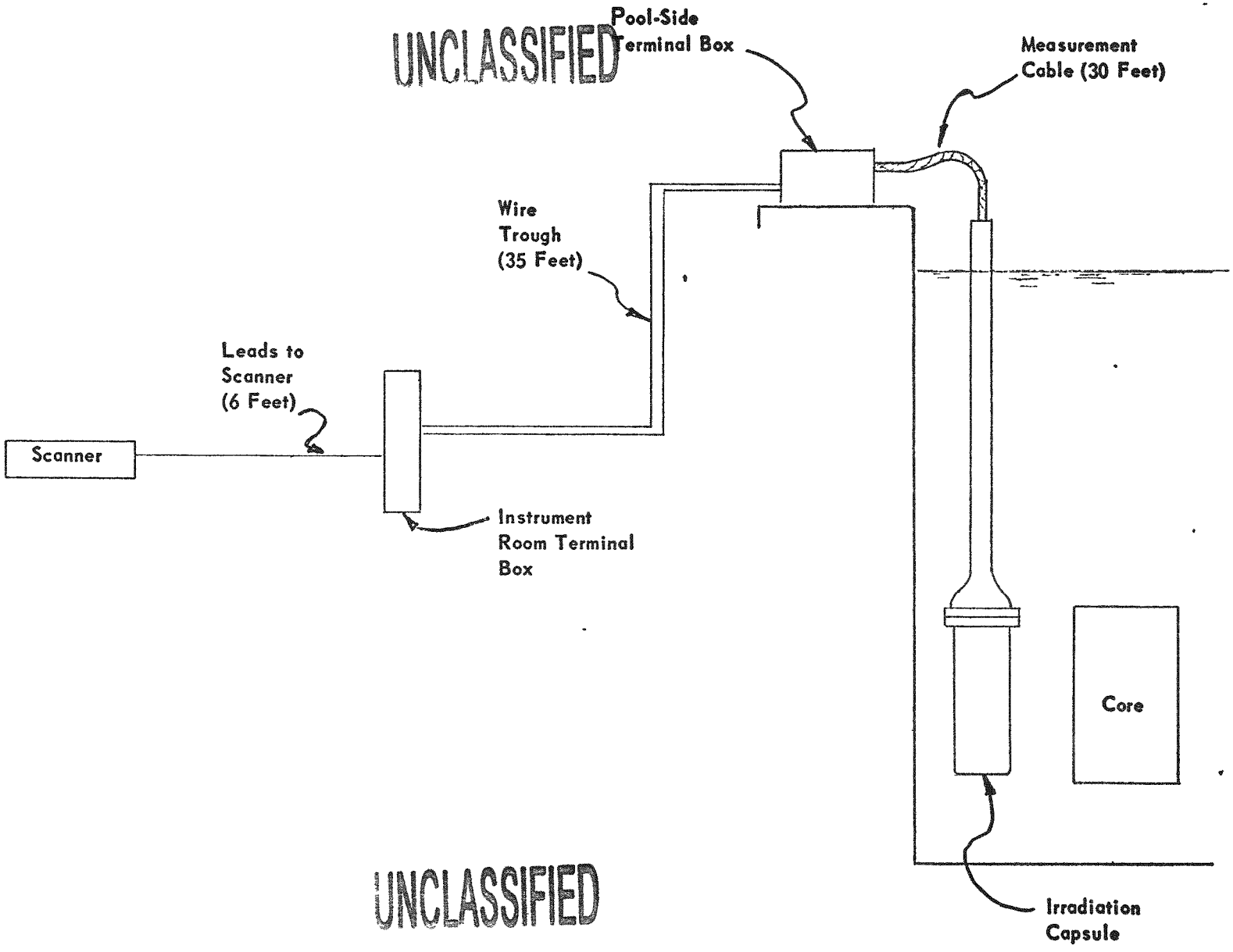

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FIGURE 14. MEASURING LEAD LAYOUT

Typical connections in the instrument room are shown in Figure 15. The manual scanning panel is connected to the instrument room terminal box. The manual scanning panel is made up of multi-pin AN type connectors. The connectors are all of the same configuration with specimens of different types connected to different pins. Connection is made between the manual scanning panel and the interconnection by means of a mating AN type connector with all pins connected. Power supplies, digital voltmeters, and other equipment are connected to the interconnection panel.

The measuring connection required for the various specimens, switches, and other controls are constructed in plug-in boxes. These boxes connect to the interconnection box by means of two ribbon type connectors. Insertion of a measuring circuit box makes the proper connections between the power supplies, meters, other equipment, and the test specimens.

Figure 16 shows the equipment in the air conditioned humidity controlled instrument room.

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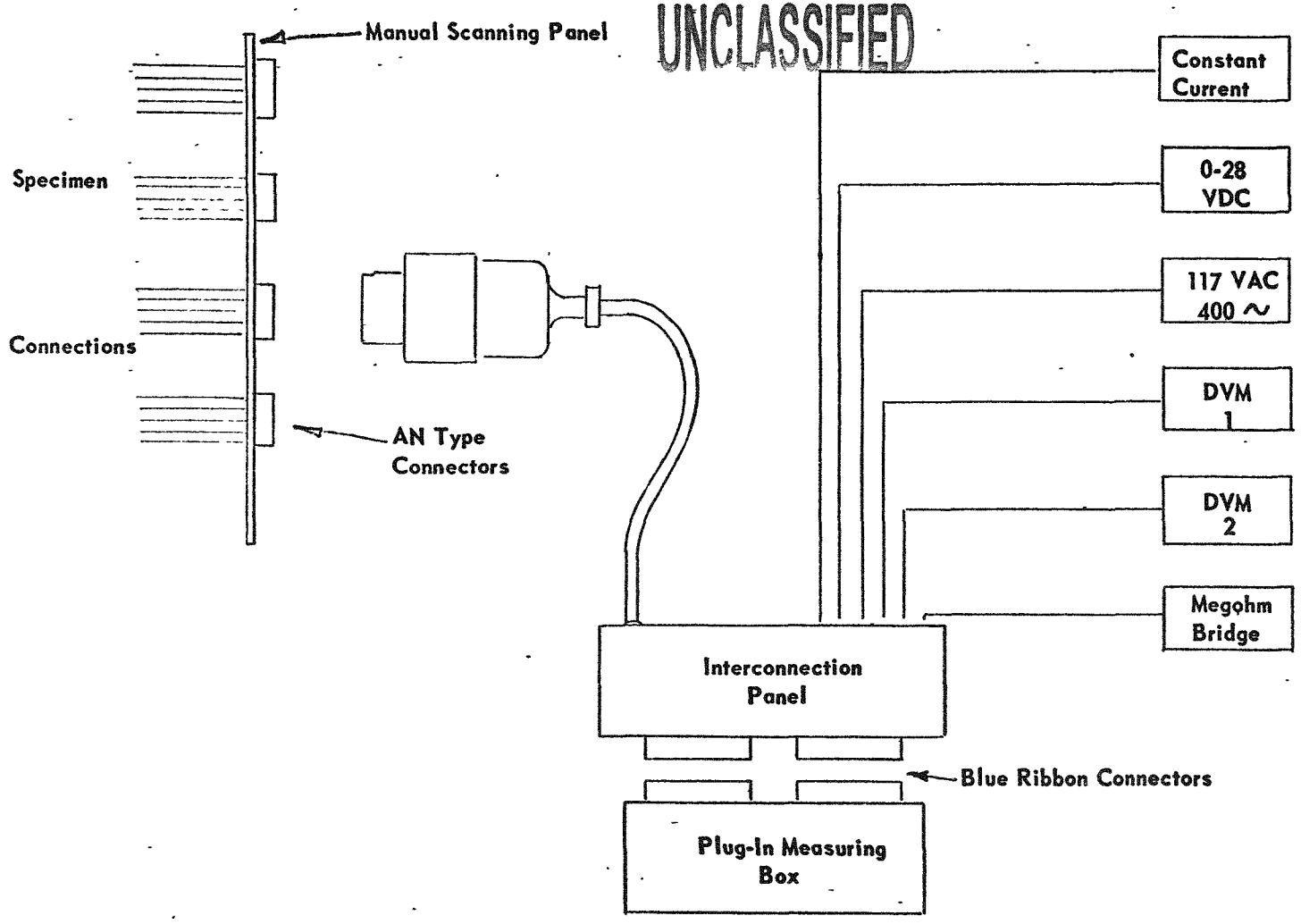

FIGURE 15. TYPICAL INSTRUMENT ROOM CONNECTIONS

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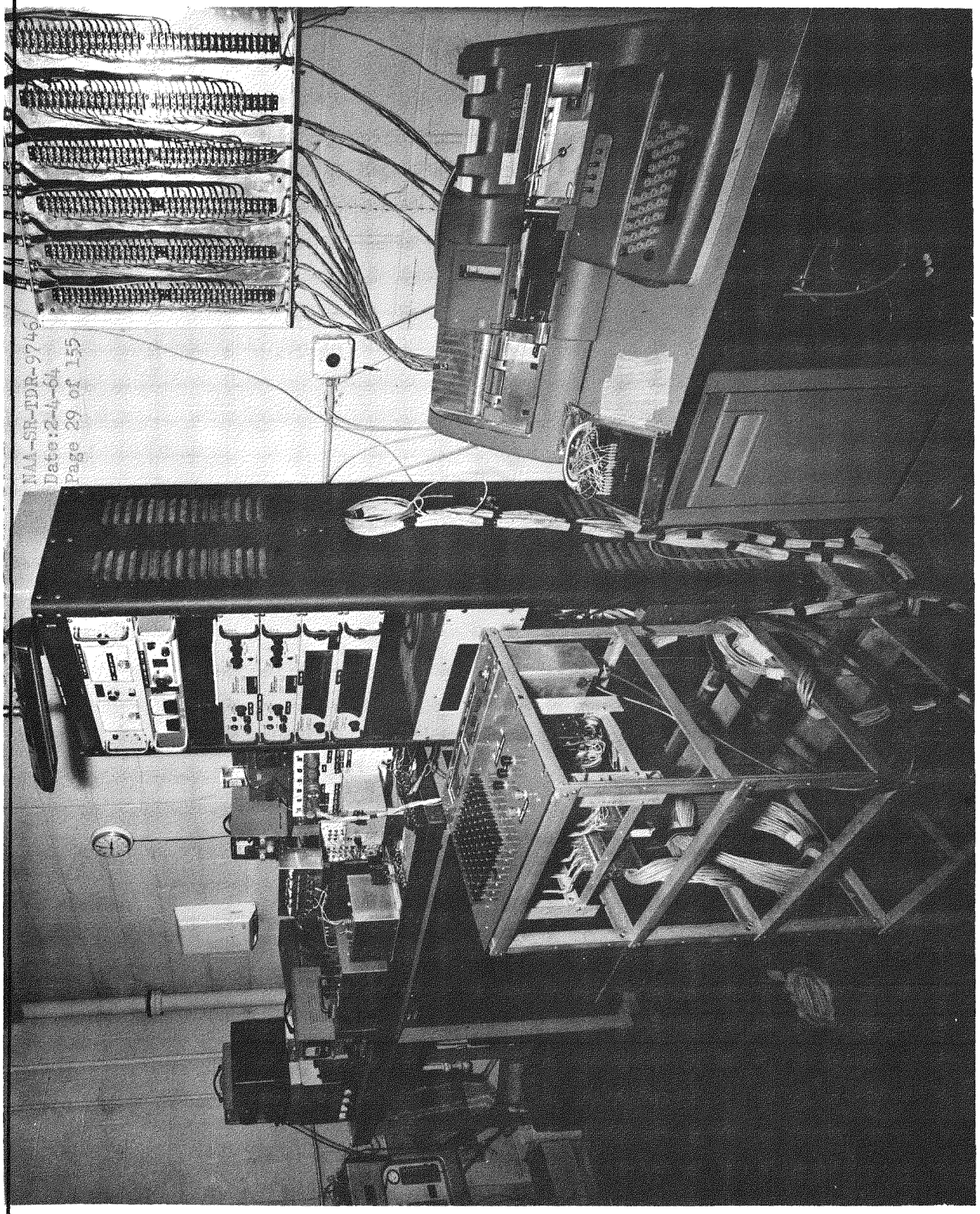

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FIGURE 16

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5.3 Data Recording Data are recorded directly in punch cards by two means: (1) directly from digital voltmeters, and (2) by means of a manual entry keyboard. When the digital voltmeters are used, the operator performs the necessary measuring circuit adjustments, allows the digital voltmeters to balance, and locks the readings in the digital voltmeters. The measuring circuits are then turned off and the specimens disconnected at the scanning panel (all specimen leads are grounded for specimens which may be affected by electrical noise). The operator then depresses the "punch" buttons and the data are recorded in punch cards.

Where equipment used to perform measurements does not have an electrical digital readout, measurements are recorded with the manual entry keyboard. The bridge is balanced, or the meter is read. The operator then punches the reading into the keyboard. The reading appears in an in-line readout for verification. When verified, the operator depresses the "punch" buttons and the data are recorded in punch cards.

Identification information is entered in the punch cards by means of a manual crossbar type information entry. The time of measurement is entered in each card directly from a digital clock.

The measurements were recorded in punch cards using the following format and codes.

Card Column	
1-5	Battelle identification code: G 5277
26-31	Date: 061263 = June 12, 1963
32	SNAP 10A Instrumentation Code: 2
33-34	Capsule number: 01 and 02
42-43	Measurements codes: 09 - insulation resistance 10 - resistance 20 - resistance, relay reset coil 11 - contact resistance 12 - pull-in voltage 13 - drop-out voltage 14 - output voltage 23 - capsule temperature 24 - capsule vacuum
44-47	Time
48-51	Specimen number
52-55	Date One
56-57	Data One Decimal
62-65	Data Two
66-67	Data Two Decimal
71-78	Operator code
74-76	Temperature code, capsule 1 only
78-80	Temperature code, capsule 1 only

The measurements are contained in two data fields referred to as Data One (card columns 52-55) and Data Two (card columns 62-65). All 9's in a data field indicate a failure, and all 8's in a data field indicate a missing reading.

The decimal code is powers of 10 plus 50. For example:

49 = 0.0xxxx
50 = 0.xxx
51 =.x.xxx.
52 = xx.xx
53 = xxx.x
54 = xxxx.

5.4 Dosimetry Since fast neutrons generally cause most radiation damage in electronic components and the dose at which damage occurs depends on the fast neutron spectrum, the fast neutron flux spectrum in the capsule was shaped to approximate the SNAP 10A instrument compartment spectrum. The best obtainable concurrent gamma dose was a factor of 3 to 10 times the annual SNAP 10A compartment dose.

The capsule gamma dose was calculated. The neutron dose was measured by counting activation of two dosimetry wires, one cobalt and nickel cobalt, attached to each test component. Two dosimeter wires were also attached to the outside of the capsule to determine the average capsule dose at each of the two flux positions.

Figure 17 is a plan view of the core showing the location of the two flux positions. The bottom of the specimen array was at the same elevation as the horizontal centerline of the core. The neutron dose at each component depends upon its position in the array and varies by a factor of 3.2 between extremes.

FIGURE 17

ILF-2 EXPERIMENT
SYSTEM POSITIONS

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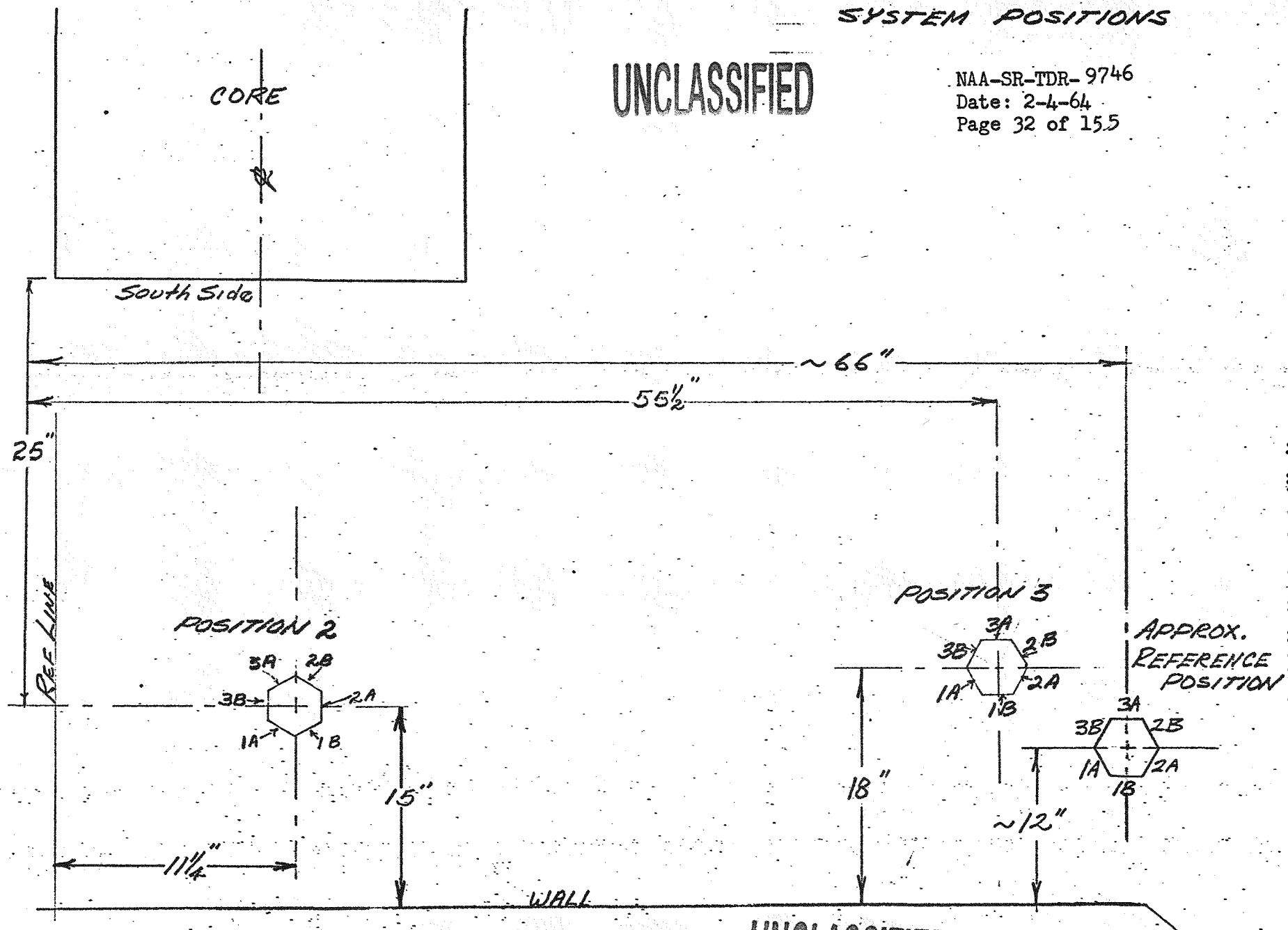

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5.4 Continued.

For the first capsule, the neutron exposure for each component is broken down into 5 energy groups in Table 4 for low flux position 3 and in Table 5 for high flux position 2. Group I is the thermal neutron exposure (0-0.4 ev). Group II is the resonance neutron exposure (0.4-100 ev). Group III is the resonance neutron exposure (100-1000 ev). Group IV is the fast neutron exposure from 0.1 to 0.5 Mev. Group V is the fast neutron exposure above 0.5 Mev.

TABLE 4 - POSITION 3 (LOW FLUX)

Spec.#	Component	Group I NVTX10^{11}	Group II NVTX10^{11}	Group III NVTX10^{11}	Group IV NVTX10^{11}	Group V NVTX10^{12}	Gamma X 10^{6}R
1	Fusistor	0.98	2.57	1.13	1.21	1.09	4.25
2	Fusistor	1.09	2.86	1.25	1.36	1.22	4.25
3	Fusistor	0.79	2.37	1.04	1.13	1.01	5.50
4	Fusistor	1.19	2.70	1.18	1.28	1.15	5.50
5	Relay 6PDT	0.49	1.40	0.61	0.67	0.59	4.52
6	Relay 6PDT	0.49	1.46	0.64	0.69	0.62	3.71
7	Relay DPDT	0.40	1.22	0.54	0.58	0.52	3.71
8	Relay DPDT	0.41	0.88	0.38	0.41	0.37	3.71
9	Low Volt. Trip	0.48	1.42	0.62	0.67	0.60	4.64
10	Low Volt. Trip	0.50	1.39	0.61	0.66	0.59	4.64
11	Low Volt. Trip	0.49	1.32	0.58	0.63	0.56	4.64
12	Low Volt. Trip	0.50	1.38	0.60	0.65	0.59	3.74
13	Pos. Demod.	0.50	1.46	0.64	0.63	0.62	3.74
14	RTD Sensor	0.81	1.68	0.74	0.80	0.72	5.50
15	RTD Bridge	0.83	2.25	0.99	1.07	0.96	4.91

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TABLE 5 - POSITION 2 (HIGH FLUX)

Spec.#	Component	Group I NVTX10^{12}	Group II NVTX10^{13}	Group III NVTX10^{13}	Group IV NVTX10^{13}	Group V NVTX10^{13}	Gamma X 10^{7}R
1	Fusistor	5.71	2.72	1.19	1.44	6.35	4.44
2	Fusistor	6.33	3.03	1.33	1.61	7.08	5.49
3	Fusistor	4.58	2.51	1.10	1.32	5.86	4.44
4	Fusistor	6.59	2.86	1.25	1.52	6.67	5.49
5	Relay 6PDT	2.83	1.48	0.65	0.78	3.46	3.78
6	Relay 6DPT	2.86	1.54	0.68	0.82	3.60	4.13
7	Relay DPDT	2.31	1.29	0.57	0.69	3.02	4.13
8	Relay DPDT	2.88	0.93	0.41	0.49	2.16	3.78
9	Low Volt. Trip	2.76	1.50	0.66	0.80	3.50	3.83
10	Low Volt. Trip	2.94	1.47	0.65	0.78	3.44	3.88
11	Low Volt. Trip	2.84	1.40	0.61	0.74	3.26	4.28
12	Low Volt. Trip	2.90	1.46	0.64	0.77	3.41	4.23
13	Pos. Demod.	2.92	1.54	0.68	0.82	3.60	4.28
14	RTD Sensor	4.71	1.78	0.78	0.94	4.16	4.44
15	RTD Bridge	4.31	2.39	1.05	1.26	5.57	5.09

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On the second capsule, one dosimetry wire was attached to the exposed core side of each component. The other wire was attached to the self-shielded back of each component. The intent was to determine the dose gradient across each component. Table 6 summarizes the fast neutron dose gradient across each component. The exposed/self-shielded side dose ratios ranged from 1.6 to 2.5. Tables 7 through 12 show the average, maximum and minimum dose at each component.

TABLE 6

COMPONENT DOSE GRADIENTS

COMPONENT		FAST NEUTRON DOSE X 10^{14}			
No.	Description	Avg.	Max.	Min.	Max./Min
(1)A4359	Low Level Neut. Det.	.88	1.19	.64	1.8
(1)A4360	Low Level Neut. Amp. & PS	.60	.94	.37	2.5
(2)A4362	High Level PS	1.14	1.61	.66	2.5
(3)A4357	Gamma Det.	.95	1.28	.76	1.7
(3)A4358	Gamma Amp. & PS	.83	1.09	.66	1.6
(4)A4253	Conv. Deg. Meas. Dev.	1.60	2.11	1.26	1.7
(5)A4	Connector	.70	.70	.70	---

AVERAGE EXPOSURES

TABLE 7. POSITION III

Component	Group I, X 10^{11} n/cm^2	Group II, X 10^{11} n/cm^2	Group III, X 10^{11} n/cm^2	Group IV, X 10^{11} n/cm^2	Group V, X 10^{12} n/cm^2	Gamma Dose X 10^6R
Connector	0.78	3.06	1.34	1.54	1.30	4.14
Gamma Amp & P.S.	1.19	3.60	1.58	1.82	1.53	8.06
Low Level Neutron Amp. & P.S.	0.88	2.61	1.14	1.32	1.11	5.62
High Level Neutron P.S.	2.01	4.92	2.15	2.48	2.09	6.34
Converter Degradation Unit	3.63	6.98	3.06	3.52	2.97	7.10
Low Level Neutron Det.	1.13	3.80	1.66	1.92	1.62	6.49
Gamma Detector	1.49	4.12	1.80	2.08	1.75	6.85

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AVERAGE EXPOSURES

TABLE 8. POSITION II

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Component	Group I, X 10^{13} n/cm^2	Group II, X 10^{13} n/cm^2	Group III, X 10^{13} n/cm^2	Group IV, X 10^{13} n/cm^2	Group V, X 10^{14} n/cm^2	Gamma Dose, X 10^8 R
Connector	0.37	2.41	1.06	1.30	0.56	0.78
Gamma, Amp. & P.S.	0.56	2.84	1.24	1.53	0.66	0.93
Low Level Neutron Amp. & P.S.	0.42	2.05	0.90	1.11	0.48	0.88
High Level Neutron & P.S.	0.96	3.85	1.69	2.09	0.90	0.93
Converter Degradation Unit	1.73	5.50	2.41	2.97	1.28	1.18
Low Level Neutron Detector	0.54	2.99	1.31	1.58	0.70	0.99
Gamma Detector	0.71	3.24	1.42	1.75	0.76	1.05

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MAXIMUM EXPOSURE

TABLE 9. POSITION III

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Component	Group I, X 10^{11} n/cm^2	Group II, X 10^{11} n/cm^2	Group III, X 10^{11} n/cm^2	Group IV, X 10^{11} n/cm^2	Group V, X 10^{12} n/cm^2
Connector	0.78	3.06	1.34	1.54	1.30
Gamma Amp. & P.S.	1.50	4.76	2.09	2.40	2.02
Low Level Neutron Amp. & P.S.	1.22	4.10	1.79	2.06	1.76
High Level Neutron P.S.	3.02	6.98	3.06	3.52	2.97
Converter Degradation Unit	4.57	9.14	4.00	4.61	3.89
Low Level Neutron Detector	1.84	5.19	2.27	2.62	2.20
Gamma Detector	2.19	5.53	2.42	2.79	2.35

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MAXIMUM EXPOSURE

TABLE 10. POSITION II

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Component	Group I, $X10^{13}$ n/cm^2	Group II, $X\ 10^{13}$ n/cm^2	Group III, $X10^{13}$ n/cm^2	Group IV, $X\ 10^{13}$ n/cm^2	Group V, $X\ 10^{14}$ n/cm^2
Connector	0.37	2.41	1.06	1.30	0.56
Gamma Amp. & P.S.	0.71	3.75	1.64	2.03	0.88
Low Level Neutron Amp & P.S.	0.58	3.23	1.42	1.74	0.75
High Level Neutron P.S.	1.44	5.50	2.41	2.97	1.28
Converter Degradation Unit	2.17	7.21	3.16	3.88	1.68
Low Level Neutron Detector	0.88	4.09	1.79	2.20	0.95
Gamma Detector	1.04	4.36	1.91	2.35	1.02

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MINIMUM EXPOSURE

TABLE 11. POSITION III

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Component	Group I, X 10^{11} n/cm^2	Group II, X 10^{11} n/cm^2	Group III, X 10^{11} n/cm^2	Group IV, X 10^{11} n/cm^2	Group V, X 10^{11} n/cm^2
Connector	0.78	3.06	1.34	1.54	1.30
Gamma Amp. & P.S.	0.87	2.90	1.27	1.46	1.23
Low Level Neutron Amp. & P.S.	0.60	1.60	0.70	0.81	0.68
High Level Neutron P.S.	1.34	2.90	1.27	1.46	1.23
Converter Degradation Unit	2.66	5.40	2.40	2.77	2.33
Low Level Neutron Detector	0.64	2.82	1.24	1.42	1.20
Gamma Detector	1.10	3.29	1.44	1.66	1.41

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MINIMUM EXPOSURE

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TABLE 12. POSITION II

Component	Group I, X 10^{13} n/cm^2	Group II, X 10^{13} n/cm^2	Group III, X 10^{13} n/cm^2	Group IV, X 10^{13} n/cm^2	Group V, X 10^{14} n/cm^2
Connector	0.37	2.41	1.06	1.30	0.56
Gamma Amp. & P.S.	0.41	2.28	1.00	1.23	0.53
Low Level Neutron Amp. & P.S.	0.28	1.26	0.55	0.68	0.29
High Level Neutron P.S.	0.64	2.28	1.00	1.23	0.53
Converter Degradation Unit	1.26	4.32	1.89	2.33	1.01
Low Level Neutron Detector	0.30	2.22	0.97	1.10	0.52
Gamma Detector	0.52	2.59	1.15	1.40	0.60

The irradiation history for the two capsules is shown on figures 18 and 19.

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Figure18

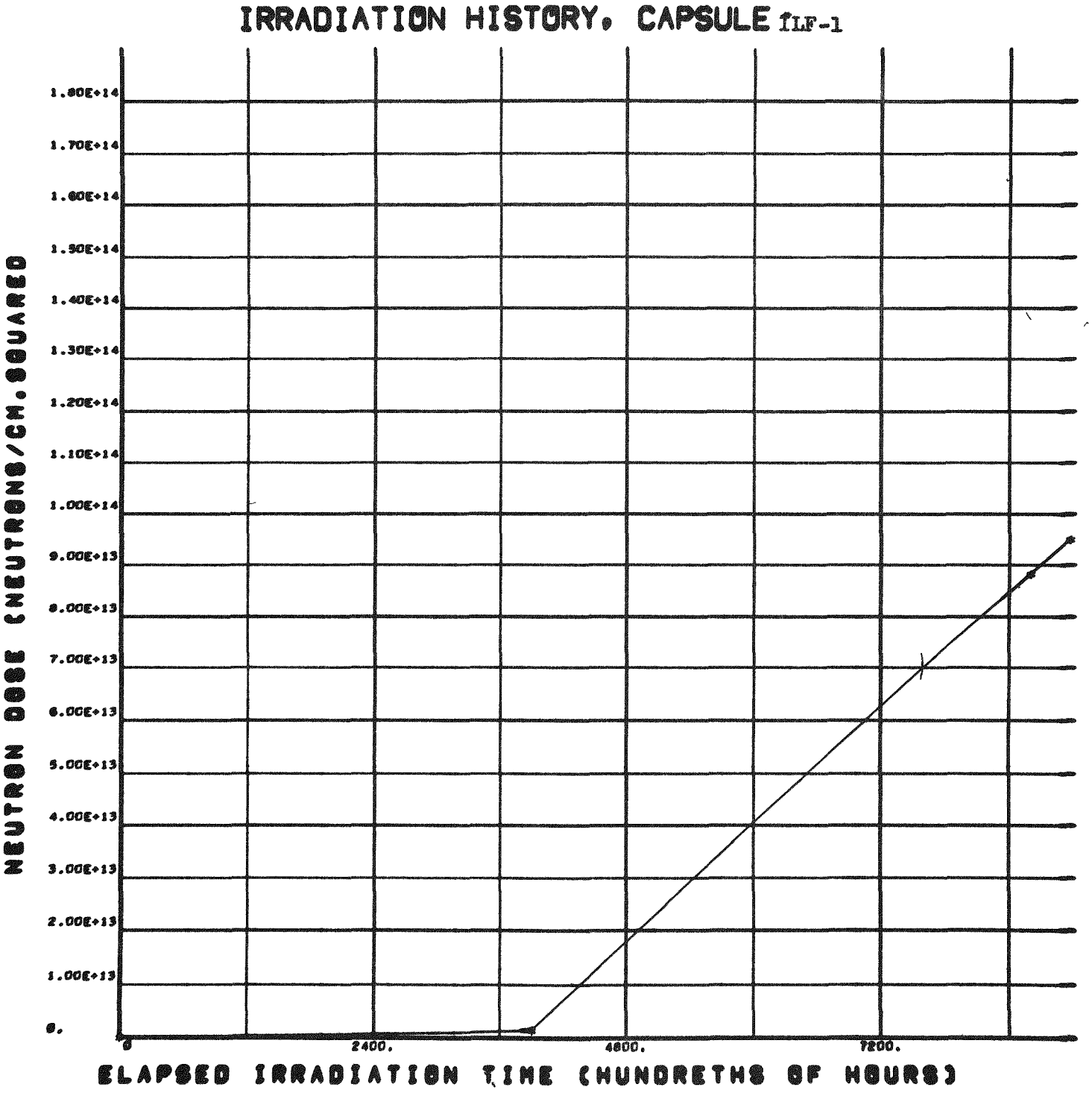

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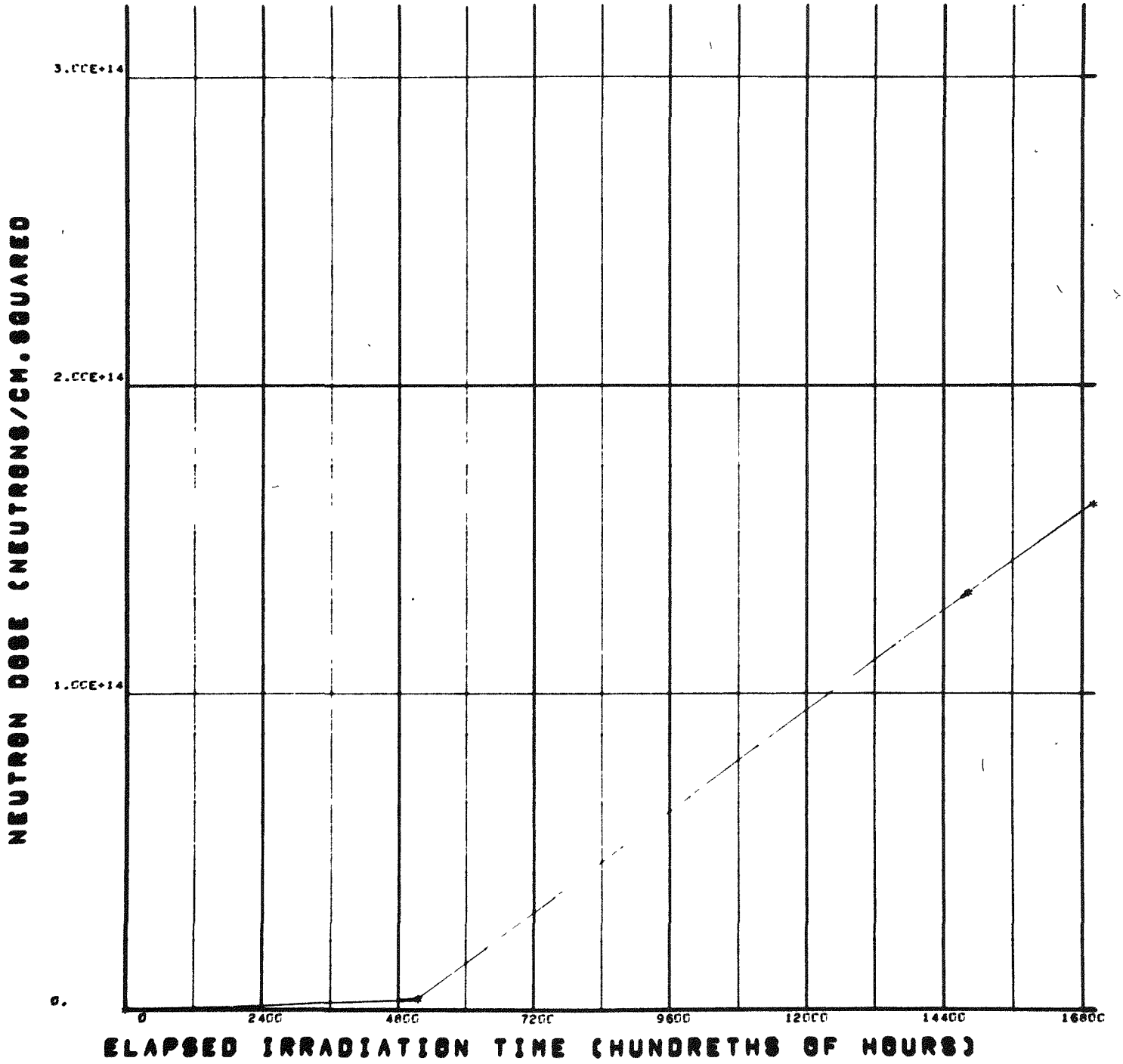
Figure19

IRRADIATION HISTORY, CAPSULE ILF-2



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5.5 Vacuum The general layout of the in-pile vacuum system was shown in Figure 11. This system consists of (1) a test section of standard 8-inch pipe, (2) a tee-section, (3) a vacuum line (4-inch pipe) leading to the pump, (4) a specimen-lead housing tube (4-inch pipe) leading to the surface of the pool, and (5) an ionization-gage-lead-housing tube (2-inch pipe) leading to the surface. All the piping in the system is 6061-T6 aluminum. The arrangement of the system permits a specimen subassembly to be inserted at the top of the tee section. The top-seal plate both supports the specimen subassembly and serves as a point of exit for the specimen leads. The specimen-lead-housing is sealed to the top-seal plate. The two ionization gages are located in the vacuum line adjacent to the point where it enters the tee section. Another lead-housing tube surrounds the gages and the ionization-gage-indicator leads.

The vacuum line is connected to the 4-inch pumping unit (NRC system furnished by AI)located at the south side of the reactor pool. The instrument leads from the system terminate in a junction box at this point.

Typical vacuum levels during the irradiation are shown in Figure 20. Vacuum measured at the test section were between 10^{-3} and 10^{-4} torr throughout the experiments except for a momentary rise at the time that the fusistor A2523 was tested. At this time, the loss-of-vacuum alarm, which was set at 1×10^{-3} torr, was actuated. However, the vacuum dropped back to its previous level almost immediately. The vacuum measured at the pump was generally about 20 times lower than that measured at the test section. The vacuums measured during ILF-1 operation (10^{-4} torr range) can be compared to the vacuums measured in the system previously without any specimen subassembly (6×10^{-6} torr). This difference is indicative of a larger pumping load presumably from lead and specimen outgassing.

Graph 1 shows the vacuum levels measuring during the second capsule irradiation.

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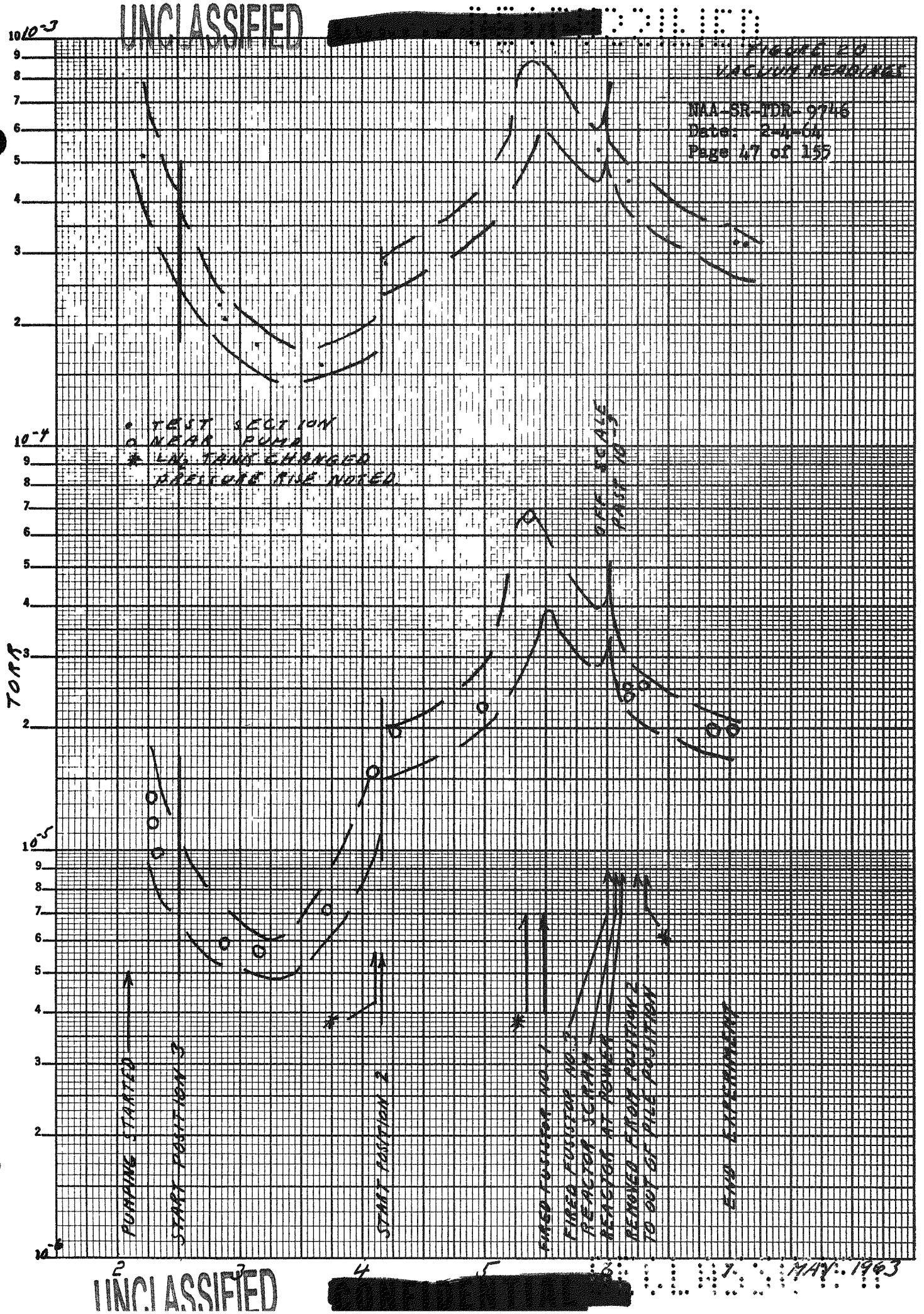
FIGURE 20
VACUUM READINGS
NAA-SR-TDR-9746
Date: 2-4-64
Page 47 of 157
• TEST SECTION
o NEAR PUMP
* LN2 TANK CHANGED
PRESSURE RISE NOTED
OFF SCALE
PAST 10-3
TORR
PUMPING STARTED
START POSITION 3
START POSITION 2
FIRED FUSITOR NO. 1
FIRED FUSITOR NO. 2
REACTOR SCRAM
REACTOR AT POWER
REMOVED FROM POSITION 2
TO OUT OF PILE POSITION
END EXPERIMENT
MAY 1963

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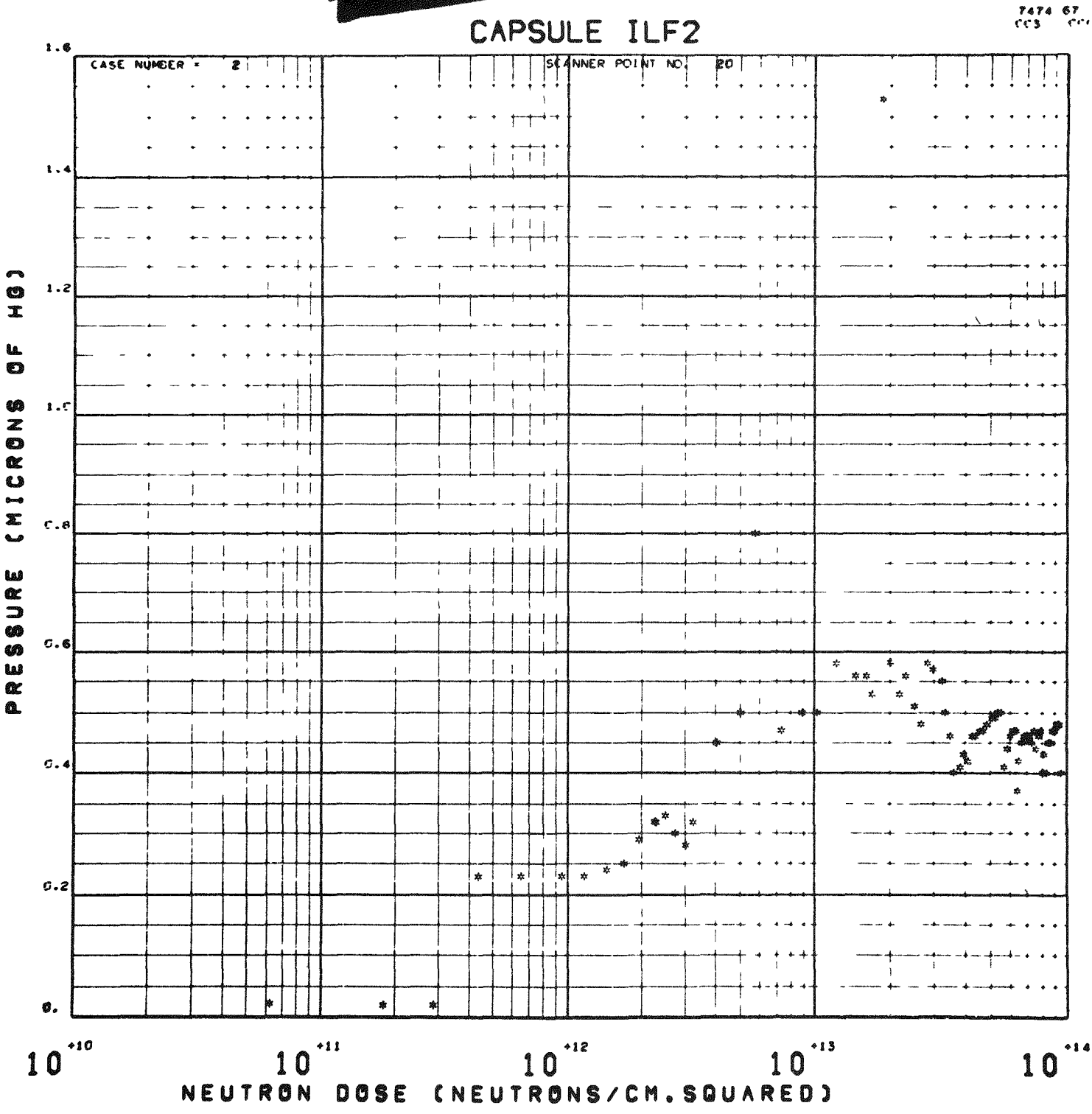
Graph 1



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5.6 Temperature Using maximum heat transfer as the criterion, the hexagonal baffle array surrounded by the water coil was selected after considering several other configurations. Appendix I contains the calculations for; desired water coil temperatures, temperature gradients, and transient effects due to fusistor firing tests.

All the specimen temperatures were monitored throughout the experiment and typical variations and limits are shown in Figure 21 and Table 13. The average temperature in the second capsule is shown in graph 2. The drop in temperature noted in Figure 21 at "Start Position 2" was the result of increasing the coolant to avoid overheating as the system was moved into the higher gamma heat position. Also in Figure 21, the effects of the higher gamma heat generation in position 2 is evident from the greater temperature spread and the abrupt temperature drop during the reactor scram.

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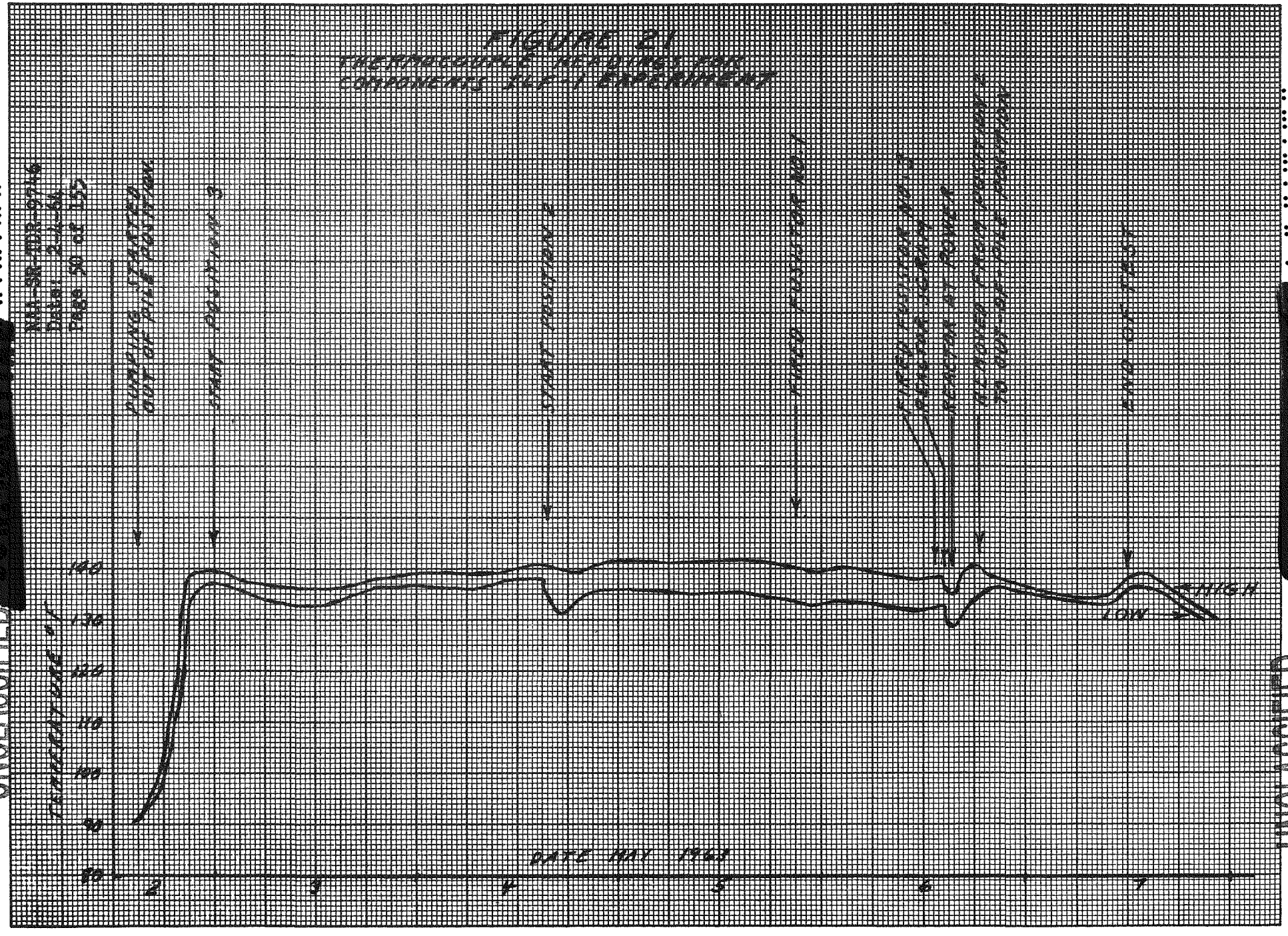

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TABLE 13. SPECIMENS AND OPERATING TEMPERATURES ILF-1 EXPERIMENT

Specimen	Serial No.	Position 3 Median Temp., °F(a)	Position 3 +°F	Position 3 -°F	Position 2 Median Temp., °F(a)	Position 2 +°F	Position 2 -°F
Low Voltage Switch	A3271	137(b)	4	4	138(b)	3	3
Low Voltage Switch	A3272	137(b)	4	4	137(b)	3	3
Low Voltage Switch	A3273	139(b)	4	4	139(b)	4	4
Low Voltage Switch	A3274	137(b)	3	3	136(b)	3	3
Relay	A3041	139(b)	5	5	136(b)	3	3
Relay	A3042	138(b)	5	5	136(b)	2	2
Relay	A2981	139(b)	5	5	136(b)	3	3
Relay	A2952	139	5	5	136(b)	3	3
Fusistor	A2521	136	3	3	135(b,c)	2	2
Fusistor	A2522	136	3	3	135	2	2
Fusistor	A2523	136	3	3	135(b)	2	2
Fusistor	A2524	136	3	3	135(c)	2	2
RTD Bridge	A3131	137	3	3	136	3	3
RTD Bridge Four	A3131	137	3	3	137	3	3
RTD Bridge Thermo-couples	A3131	136	3	3	138	3	3
RTD Bridge	A3131	138	3	3	138	3	3
RTD Sensor Two	--	136	3	3	133	3	3
RTD Sensor Thermo-couples	--	136	3	3	132	3	3
PT Demodulator	A2407	137	3	3	136	3	3

(a) Temperature during steady-state operation.
(b) Temperature fluctuations of these items were noted during short periods when they were being tested.
(c) Temperature excursions were noted for these items. Fusistor A2524 temperature record indicates a rise to -230 F at 0425 on 5/4/63, and fusistor A2521 temperature record shows a rise to 250F at 0630 on 5/4/63.

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Graph 2

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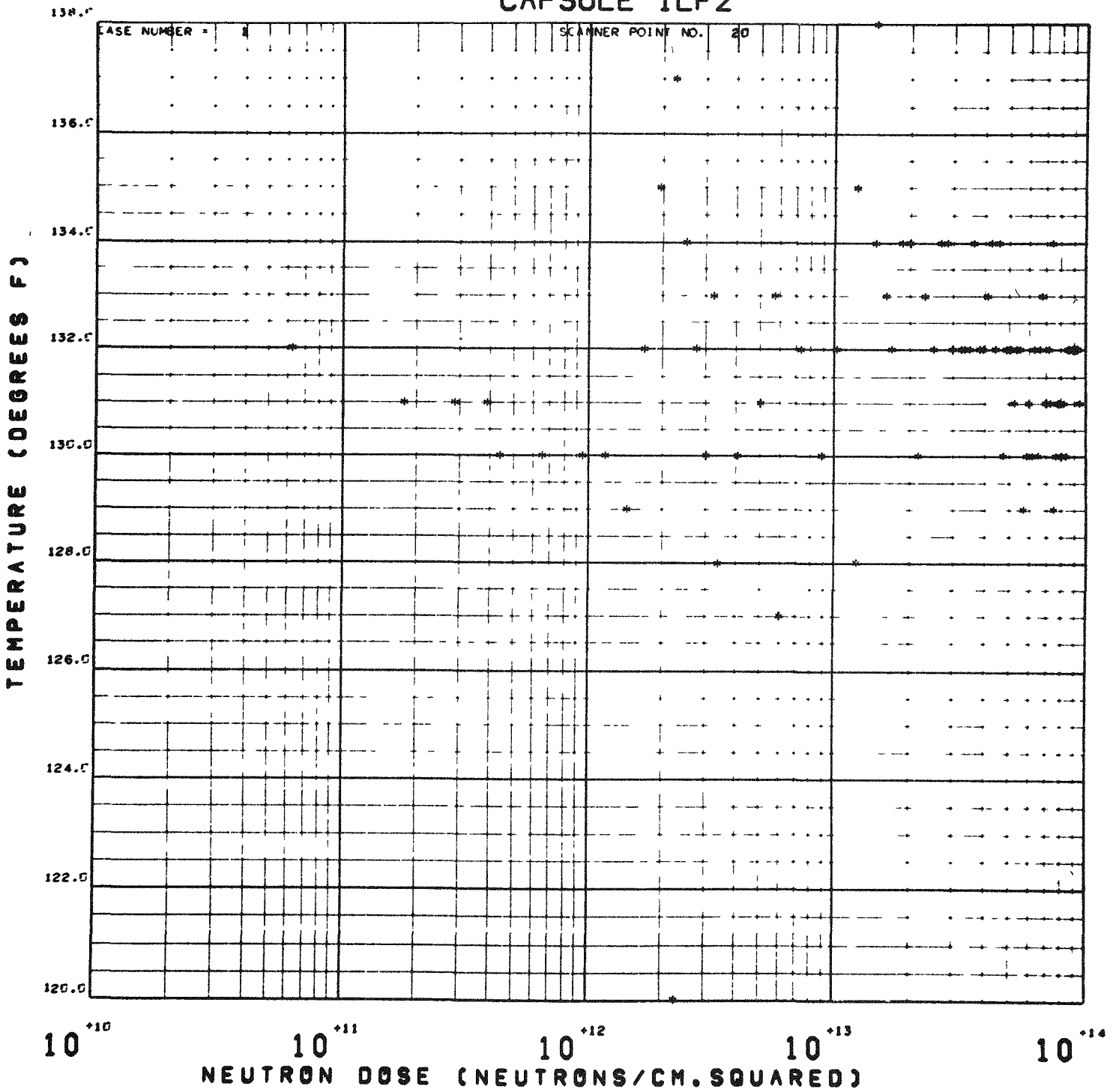
CAPSULE ILF2



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Most of the specimens operated between 135F and 140F during this experiment. The RTD sensor, since it was clamped to one of the baffle plates, tended to equilibrate at the baffle temperature, which was somewhat lower in temperature than the other specimens during position 2 operation. After steady-state was attained in any position the variation of most of the thermocouple readings was about ± 3F.

Temperature fluctuations of the relays and low voltage trip devices were noted during periods when they were being tested. The relays appeared to be the most affected. Apparently a violation of the first two assumptions in the temperature gradient analysis (discussed in Appendix I) was present during the test periods for both the relays and low-voltage switches.

The two fusistors which were fired during the experiment showed the expected temperature rise as a function of the firing time. Fusistor A2521 was fired at about 2108 on 5/3/63 and showed a temperature rise of about 5F for a firing time of about 0.3 seconds. Fusistor A2523 was fired at about 1245 on 5/6/63 and showed a temperature rise of 60-100 F for a firing time of about 6 seconds. In neither case did the specimen array exhibit any noticeable temperature rise as a result of the fusistor firings.

6.0 Results of Tests for Each Type of Component

6.1 General Figures 22 and 23 show the component arrays after irradiation. No superficial damage was evident.

6.1.1 Dosimetry The dose shown on each graph is the average dose received by the component.

6.1.2 Insulation Resistance The sharp change in insulation resistance noted on the graphs occurred when the capsule was moved from the low flux to the high flux position. Most of these sudden decreases in insulation resistance readings are probably due to increased ionization in the insulation and do not represent a sharp degradation in insulation resistance. Due to ionization, insulation resistance readings changed when the megger leads were reversed. The readings shown on all graphs are the lower of the two readings.

Pre-irradiation and post-irradiation insulation resistance readings were generally in the same order of magnitude indicating no degradation. Graphs 3 through 10 show the insulation resistance of the twisted pair "worst case" dummy leads. The lowest dummy lead insulation resistances were 10^9 ohms for capsule 1 and 10^8 ohms for capsule 2.

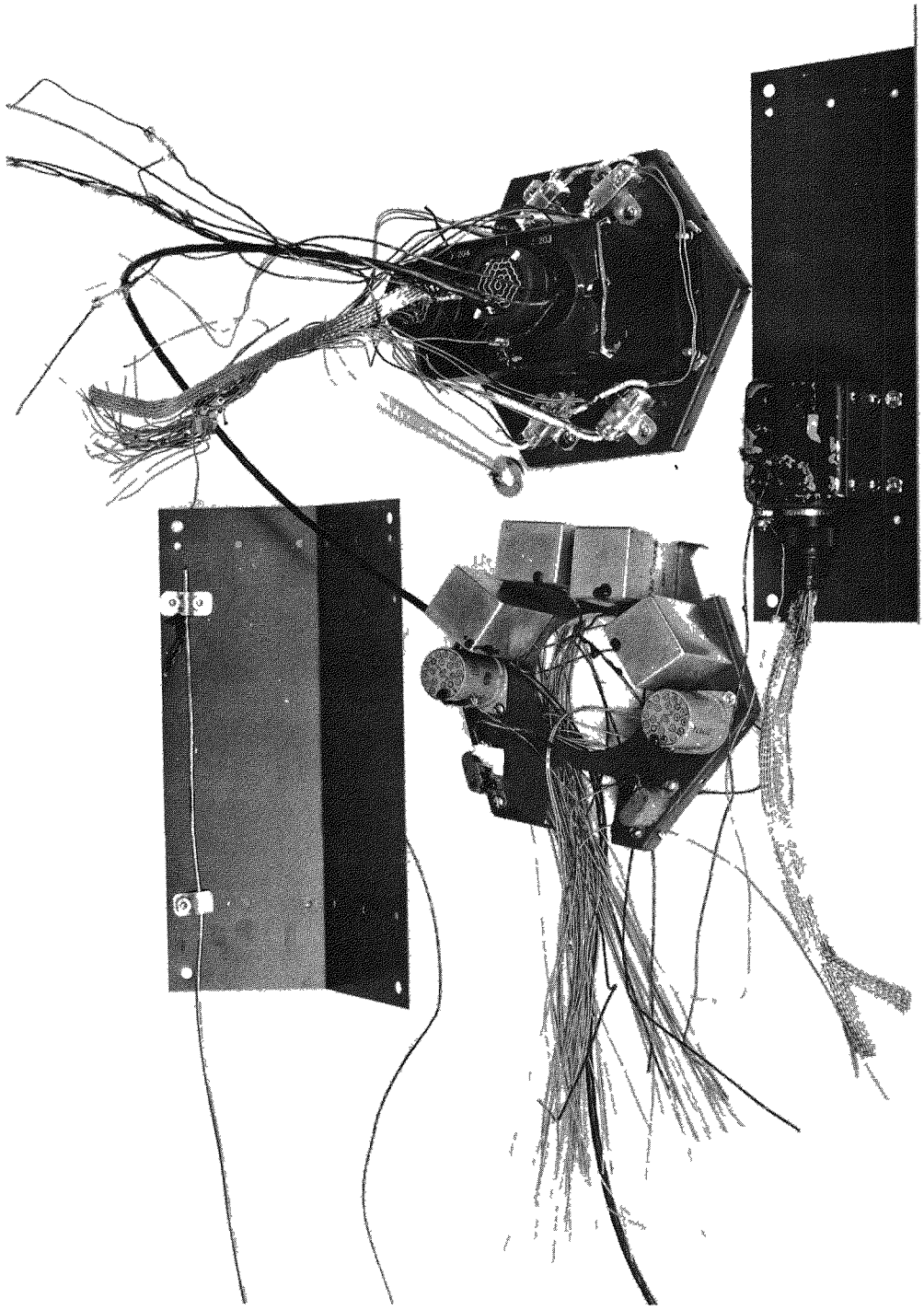

FIGURE 22

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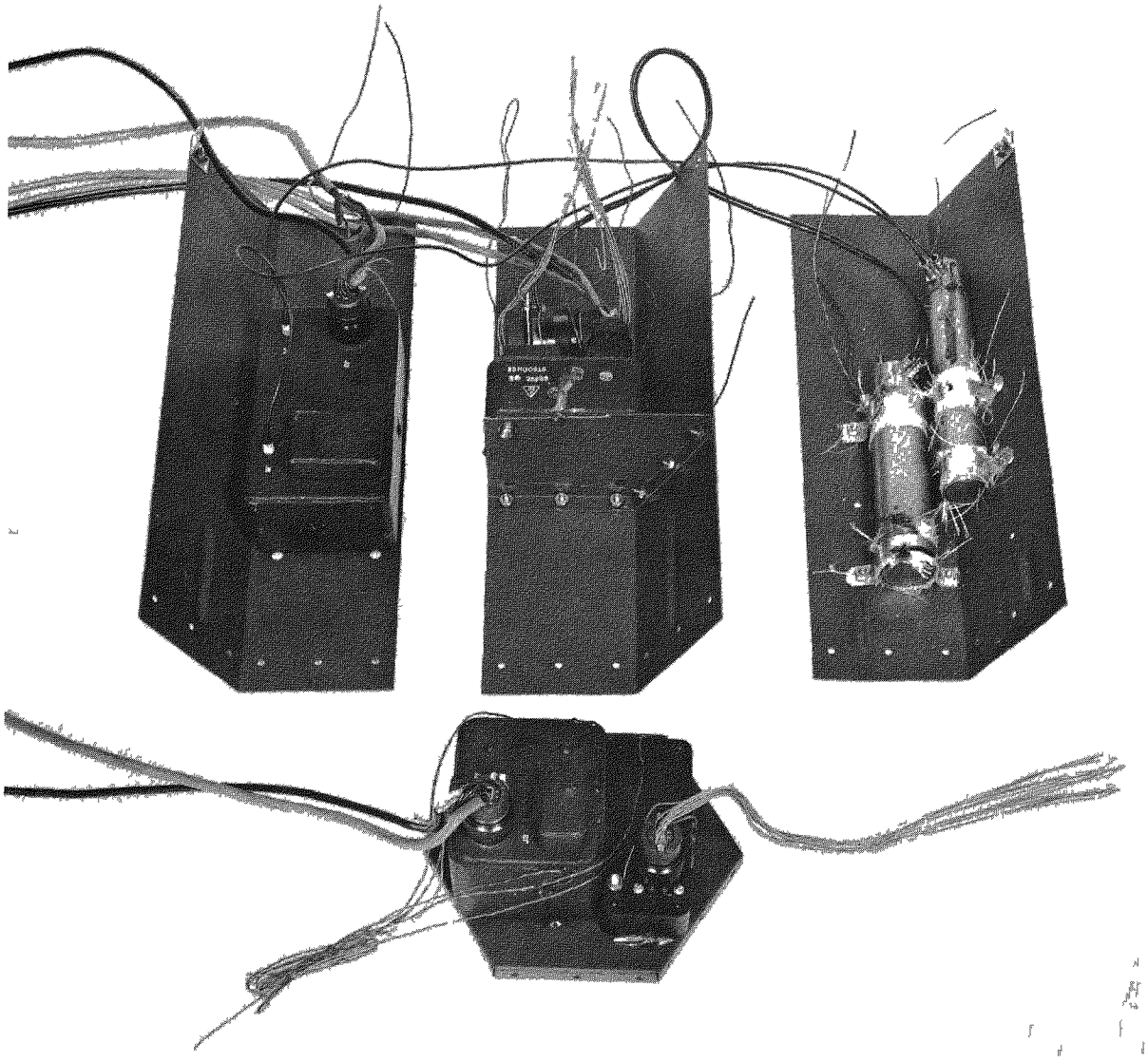

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FIGURE 23

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Graph 3

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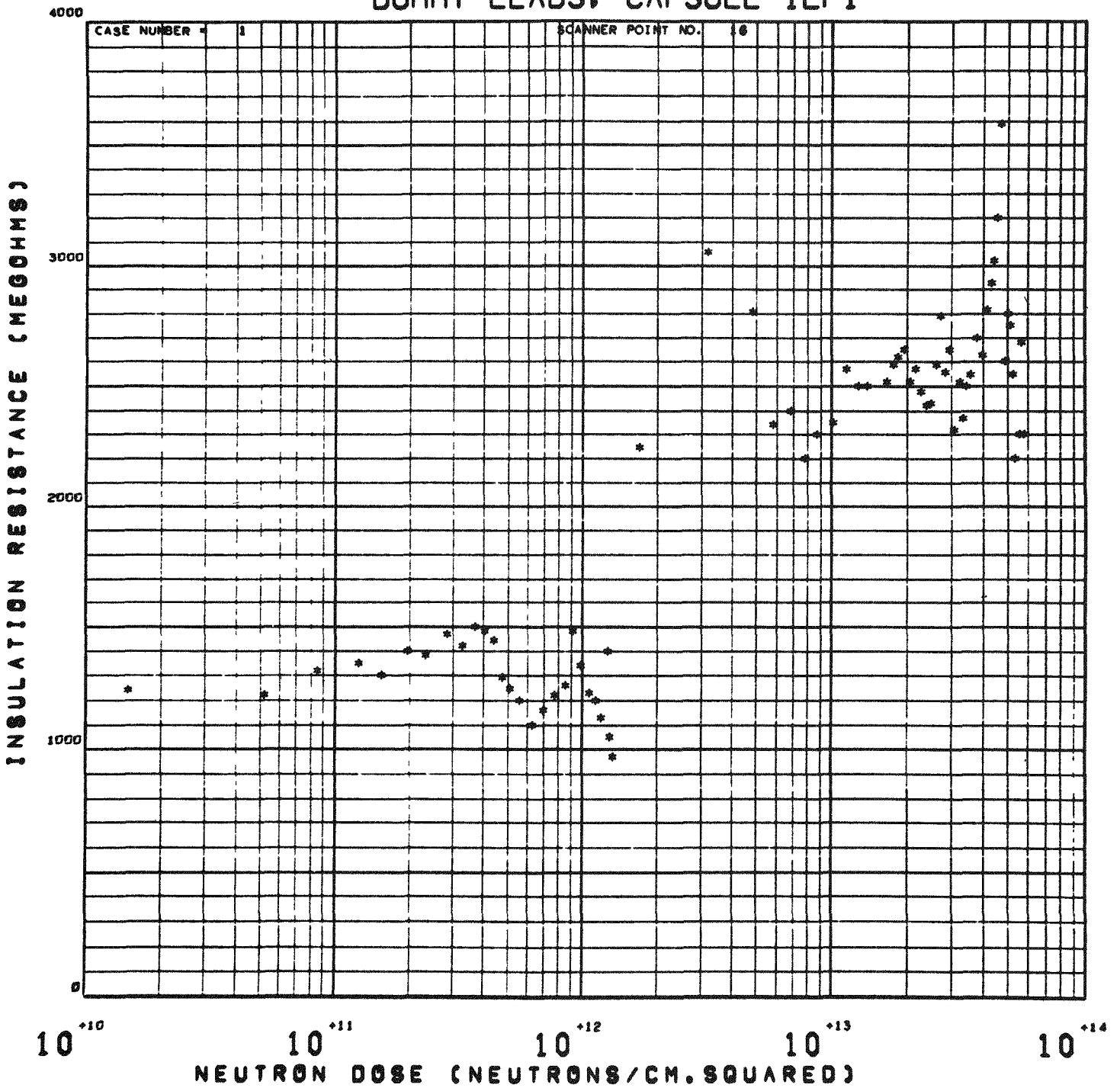
DUMMY LEADS, CAPSULE ILF1



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Graph 4

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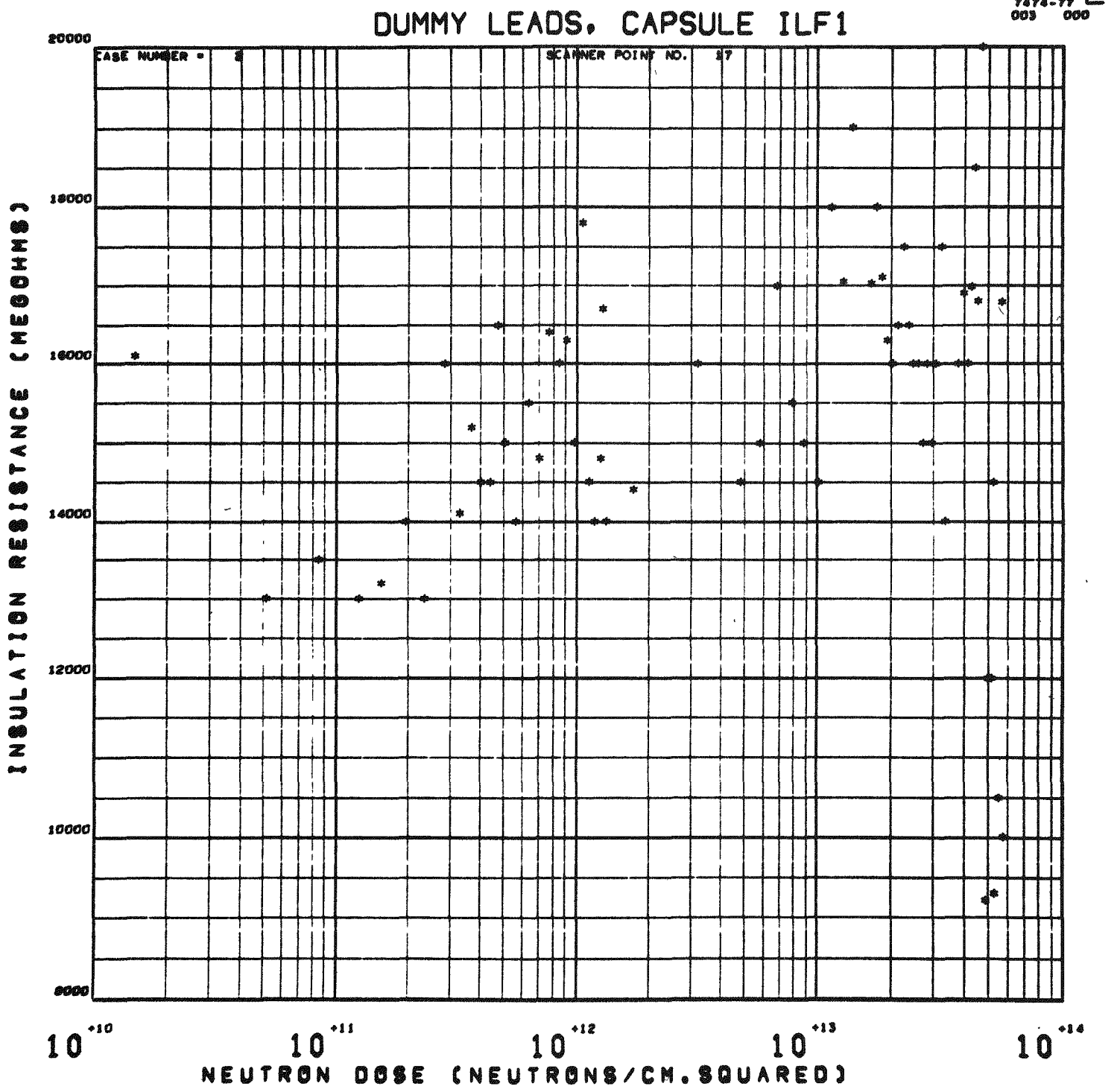

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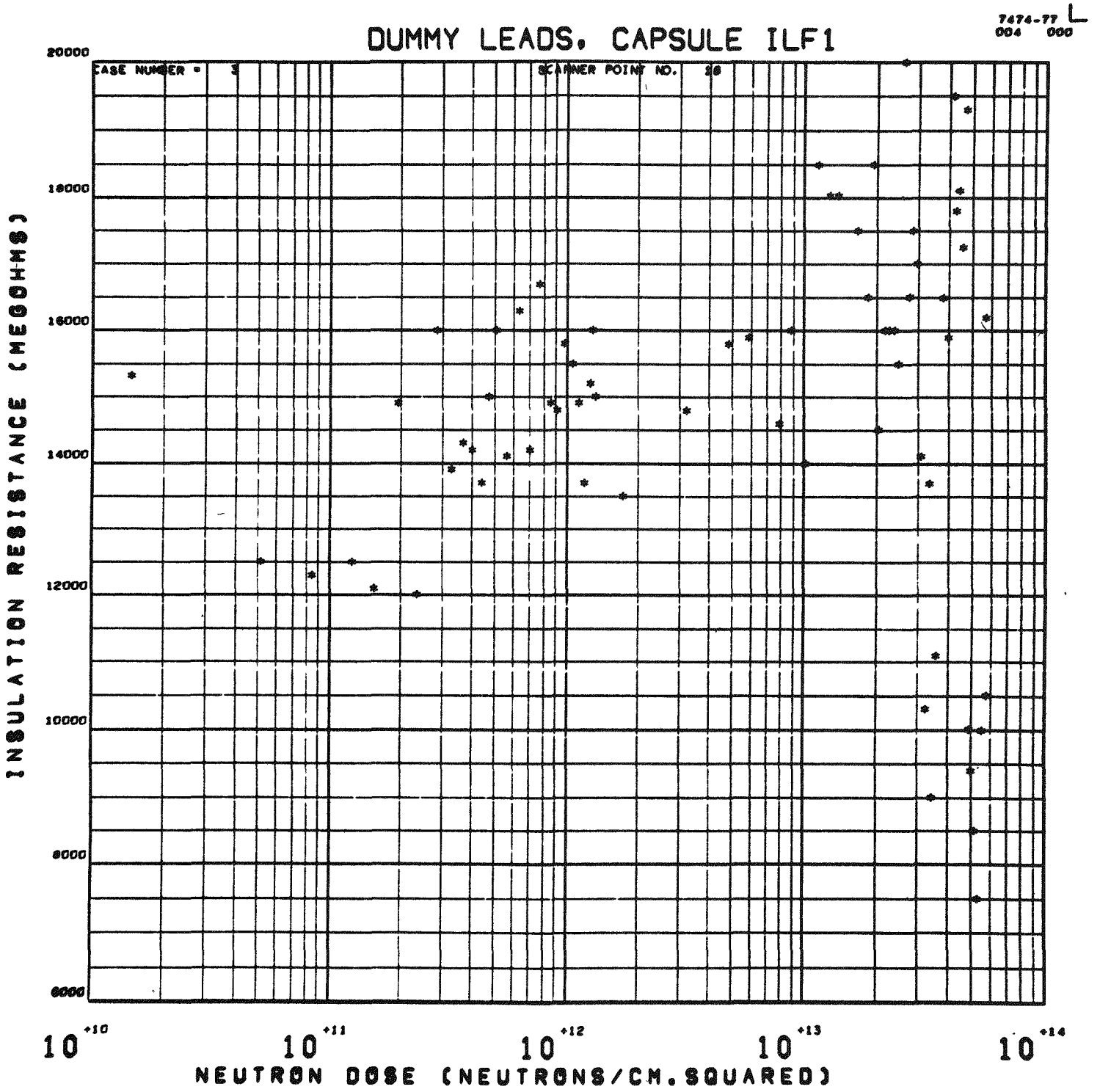
Graph 5



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Graph 6

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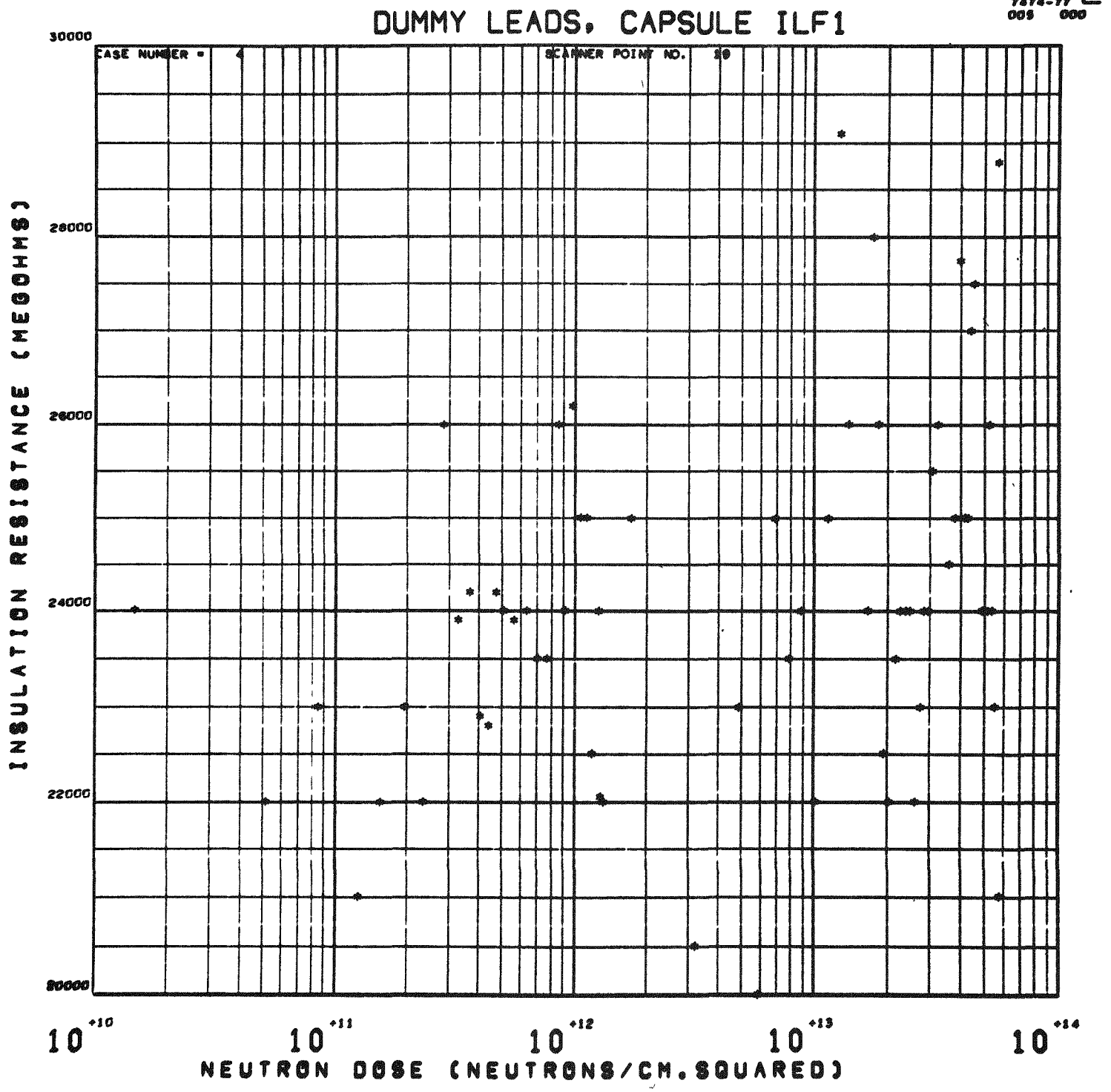

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Graph 7

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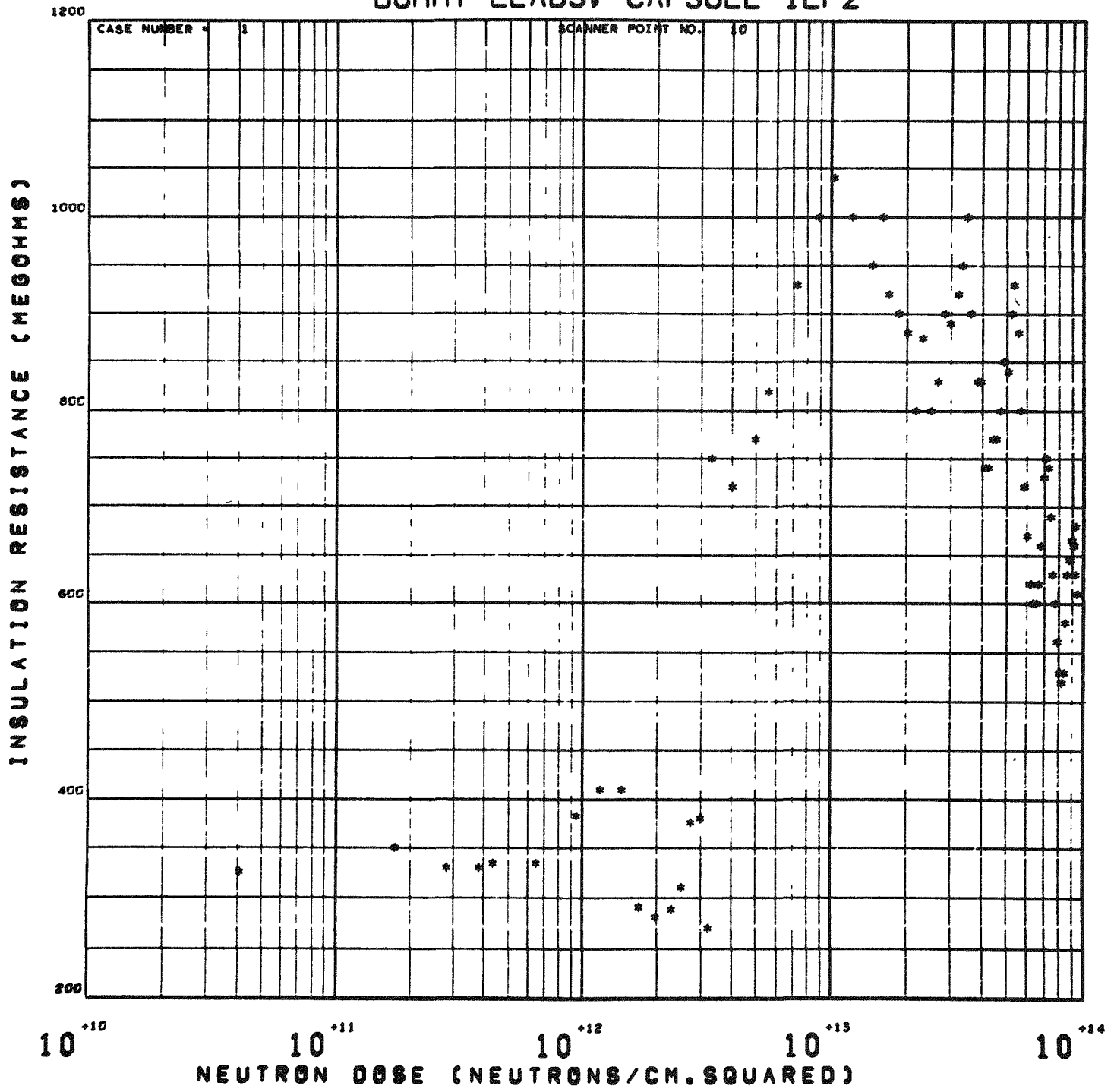
DUMMY LEADS, CAPSULE ILF2



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Graph 8

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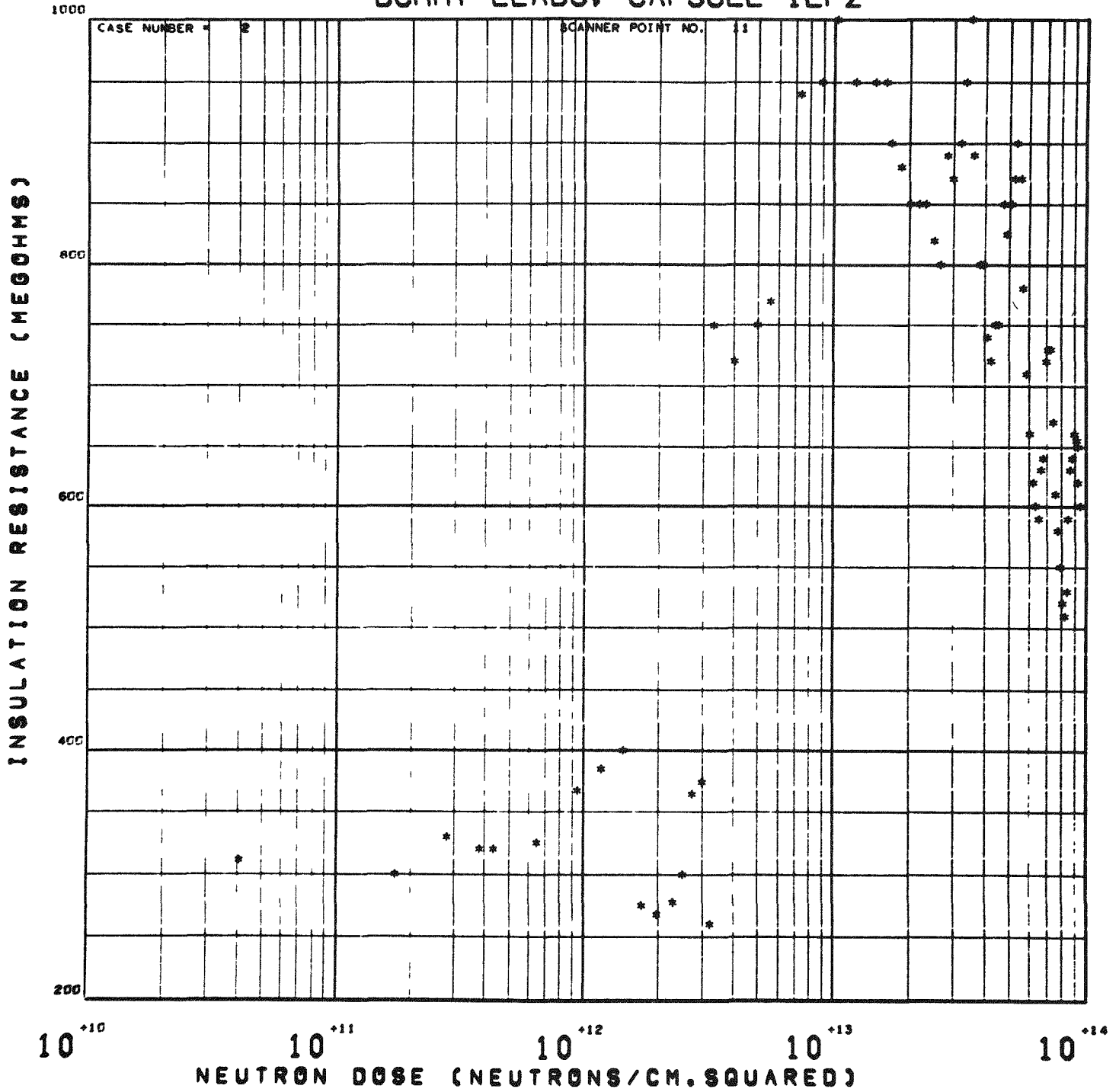
DUMMY LEADS, CAPSULE ILF2



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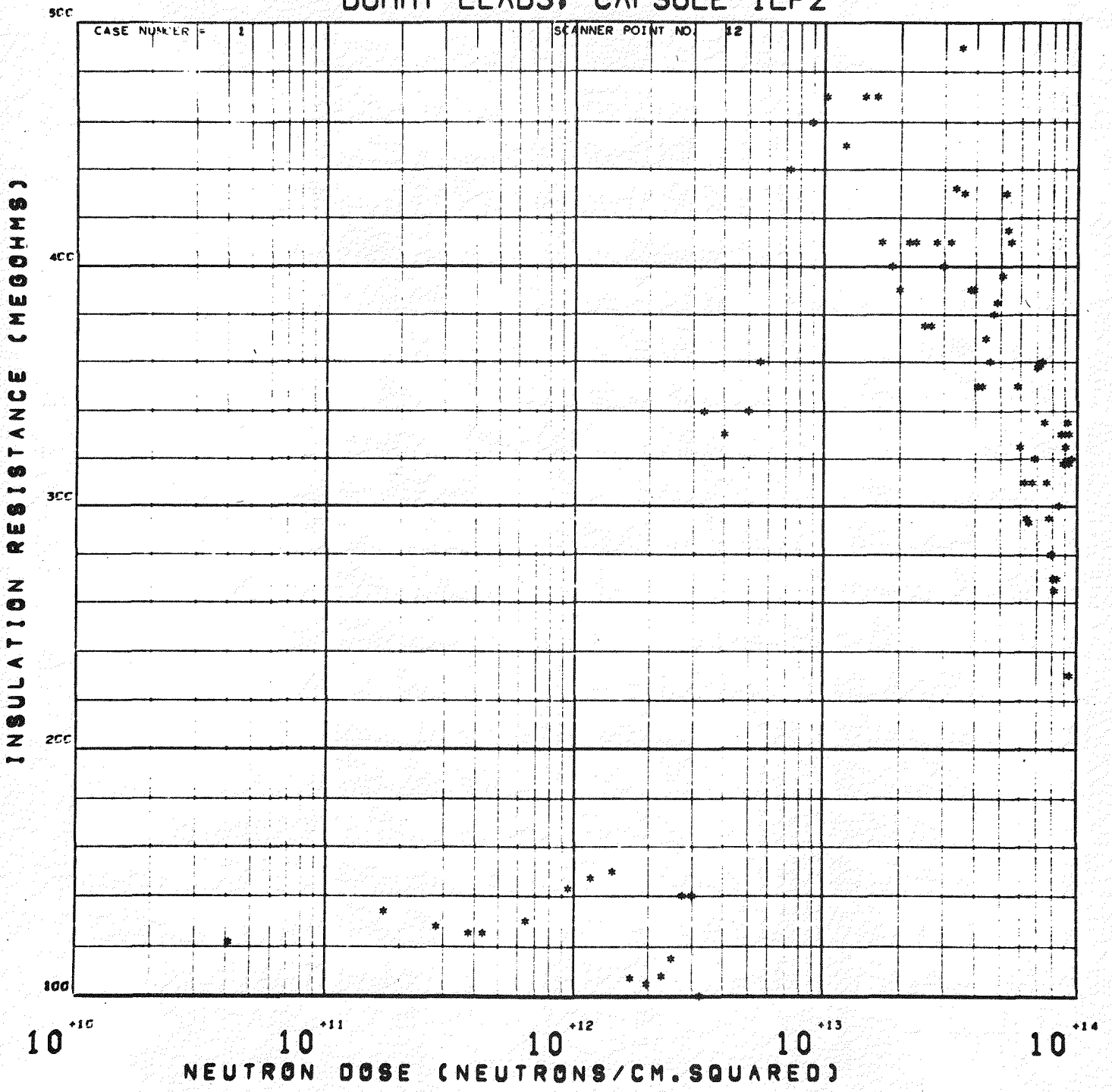
Graph 9

7474-90 L
002 000

DUMMY LEADS, CAPSULE ILF2



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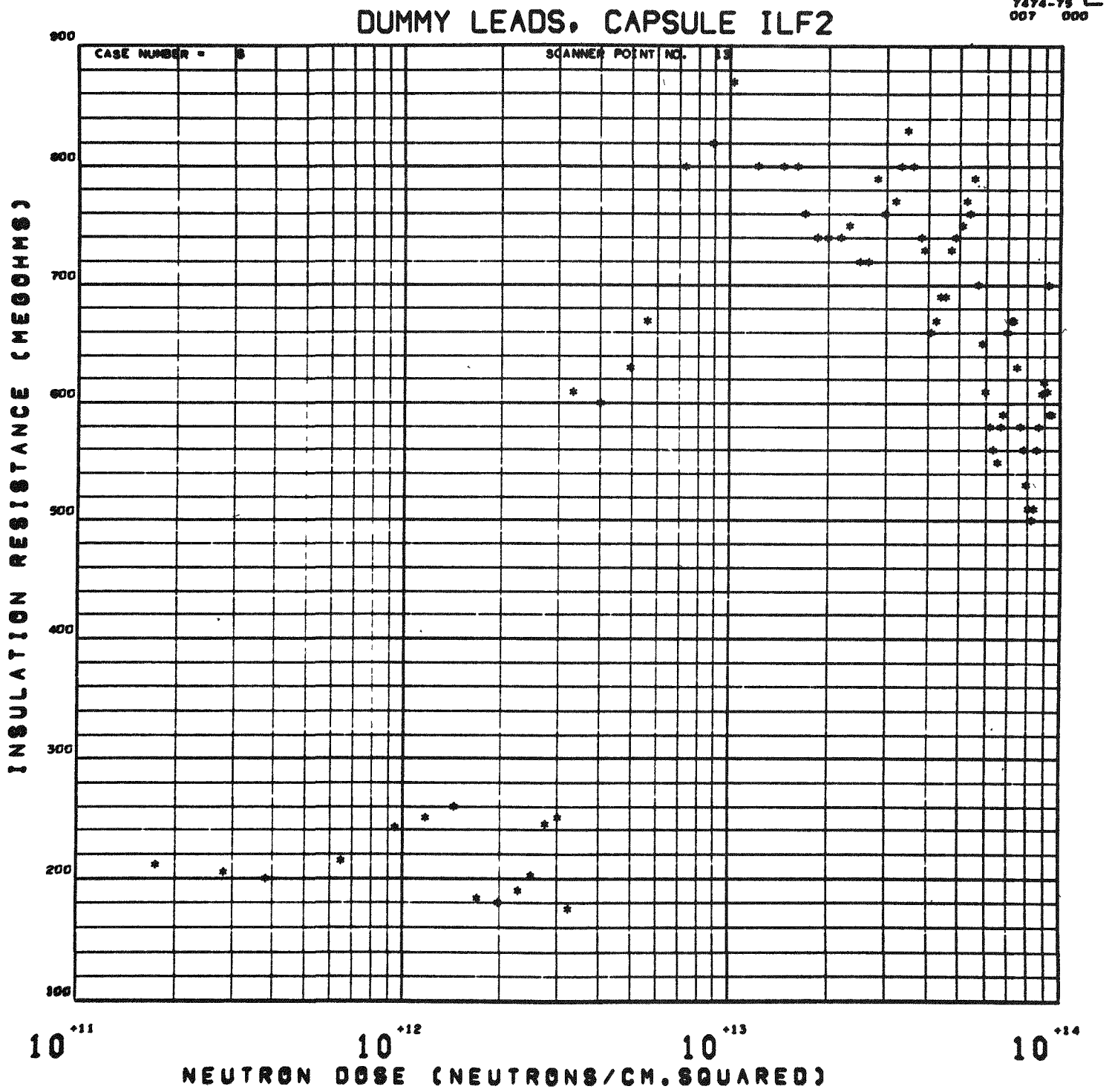
Graph 10

7474-79 L
007 000



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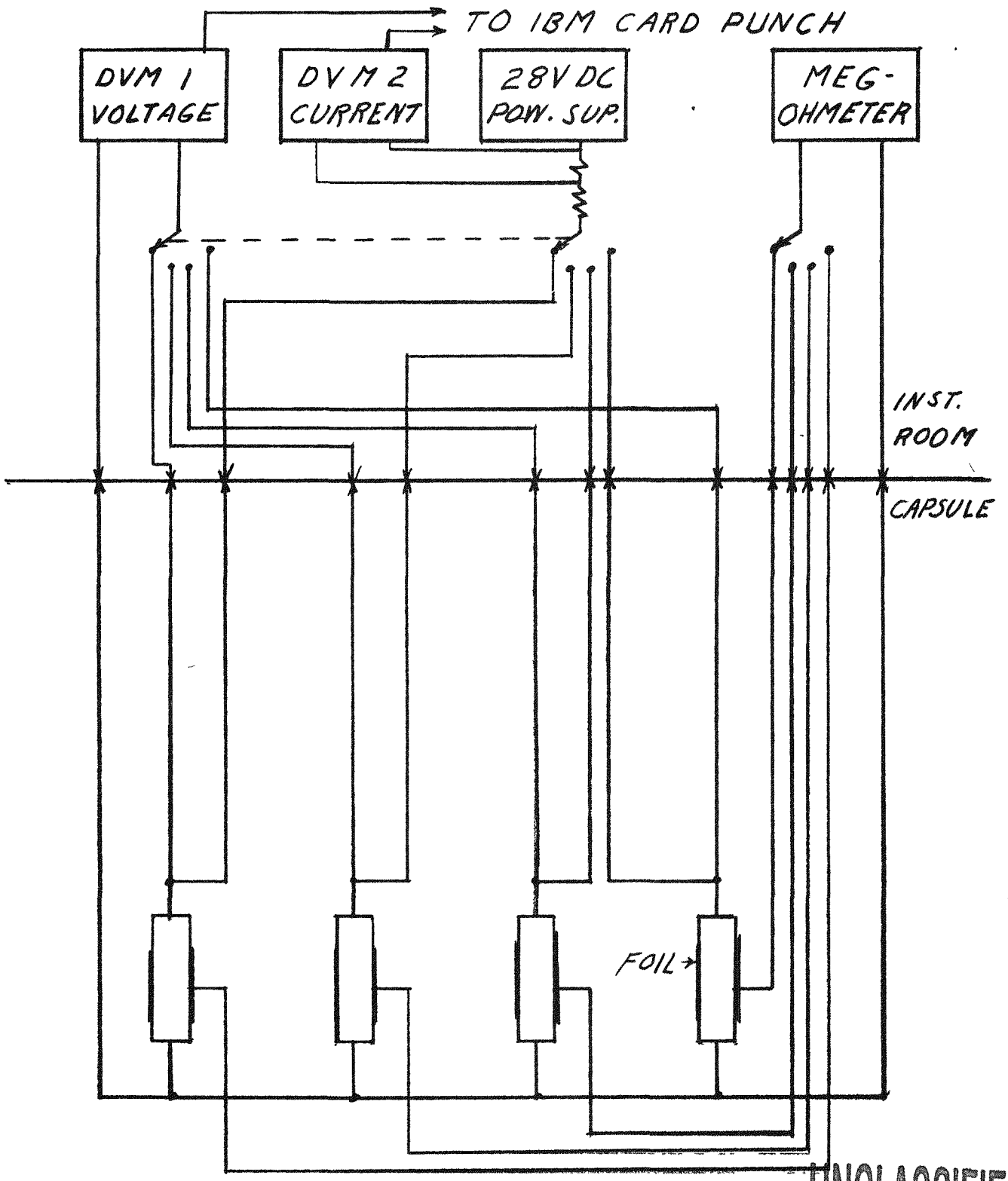

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D.V.M. 1 POWER UNIT EI MODEL 3000A AEC 64123
DVM MODEL 3400 AEC 64124

DVM. 2 MODELS SAME AS DVM 1 AEC 64098 & AEC (NONE)

P.S HARRISON MODEL 809A A.E.C. 169979

MEGOHMETER GR TYPE 54AB BMI I 28815

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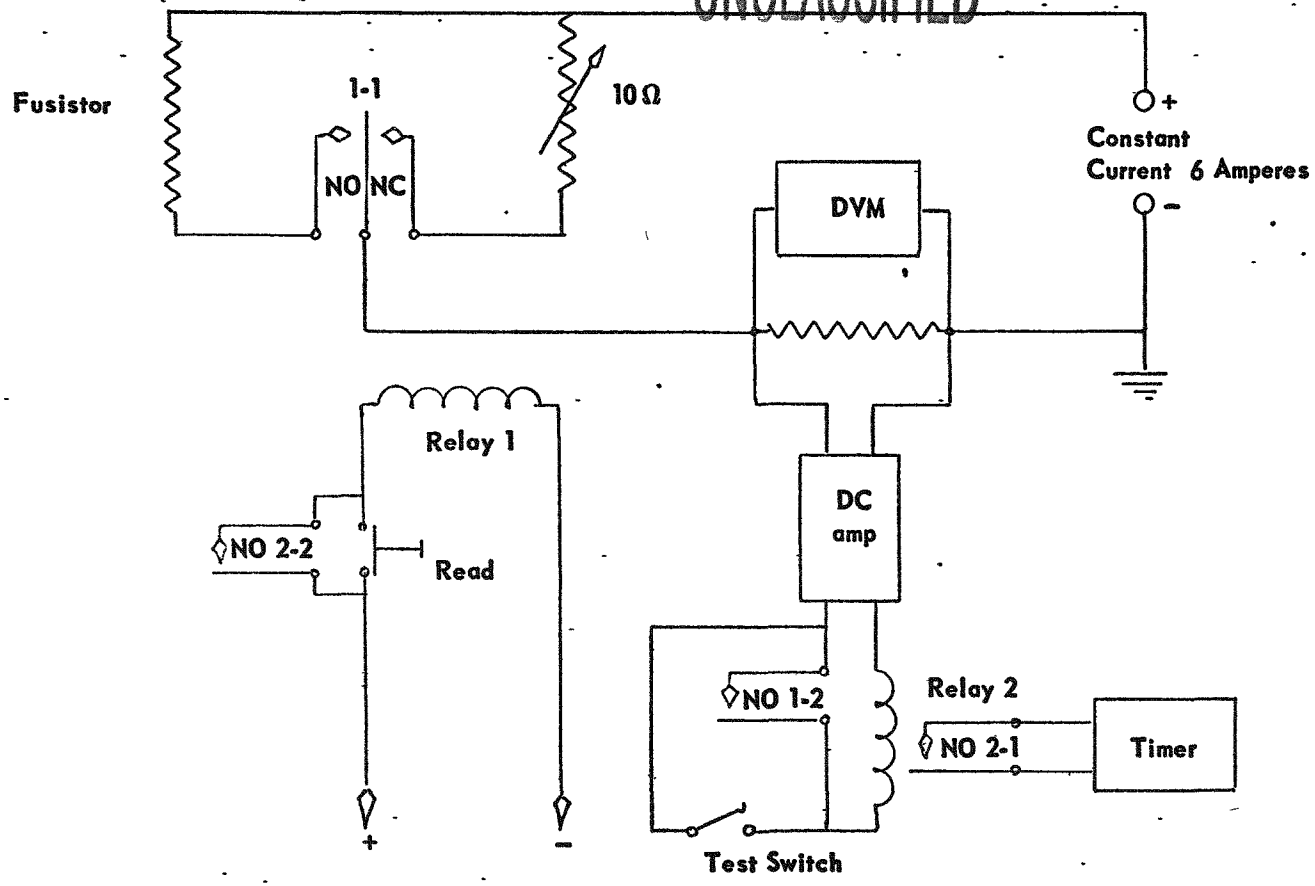

FIGURE 25. FUSISTOR FIRING TIME CIRCUIT

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6.2 Fusistors

6.2.1 Test Setup Figures 24 and 25 show the techniques used to monitor the fusistors and to fire two fusistors.

6.2.2 Test Results The insulation resistance of the fusistors was adequate as shown in graphs 11 through 14. The resistance of the fusistors exceeded the specification limits during irradiation as shown in graphs 15 and 18. The post-irradiation resistance at ambient was within specifications as shown in table 14. The specification resistance limits are 4.465 to 4.935 ohms at ambient temperature.

TABLE 14

Fusistor #	Pre-Irrad. Res.	Max. during Irrad.	Post-irrad. Res.
A2521	4.768	Fired	Fired
A2522	4.777	5.28	4.856
A2523	4.861	Fired	Fired
A2524	4.688	5.18	4.702

Two fusistors were fired during the test. The first fusistor was fired at 3.3×10^{13}NVT using a constant current of 6 amperes. The firing time was 340 milliseconds. At the time of the second fusistor firing the fusistor resistances were approximately 5.1 ohms. Firing the fusistor using a 6 amp constant current would not be realistic since the required 30.6 volts is higher than the NPU voltage. The second fusistor was fired at 4×10^{13}NVT using a constant voltage supply of 28 volts. The firing time of 5.925 seconds exceeded the specification limit of 5 seconds.

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Graph 11

7474-66 L
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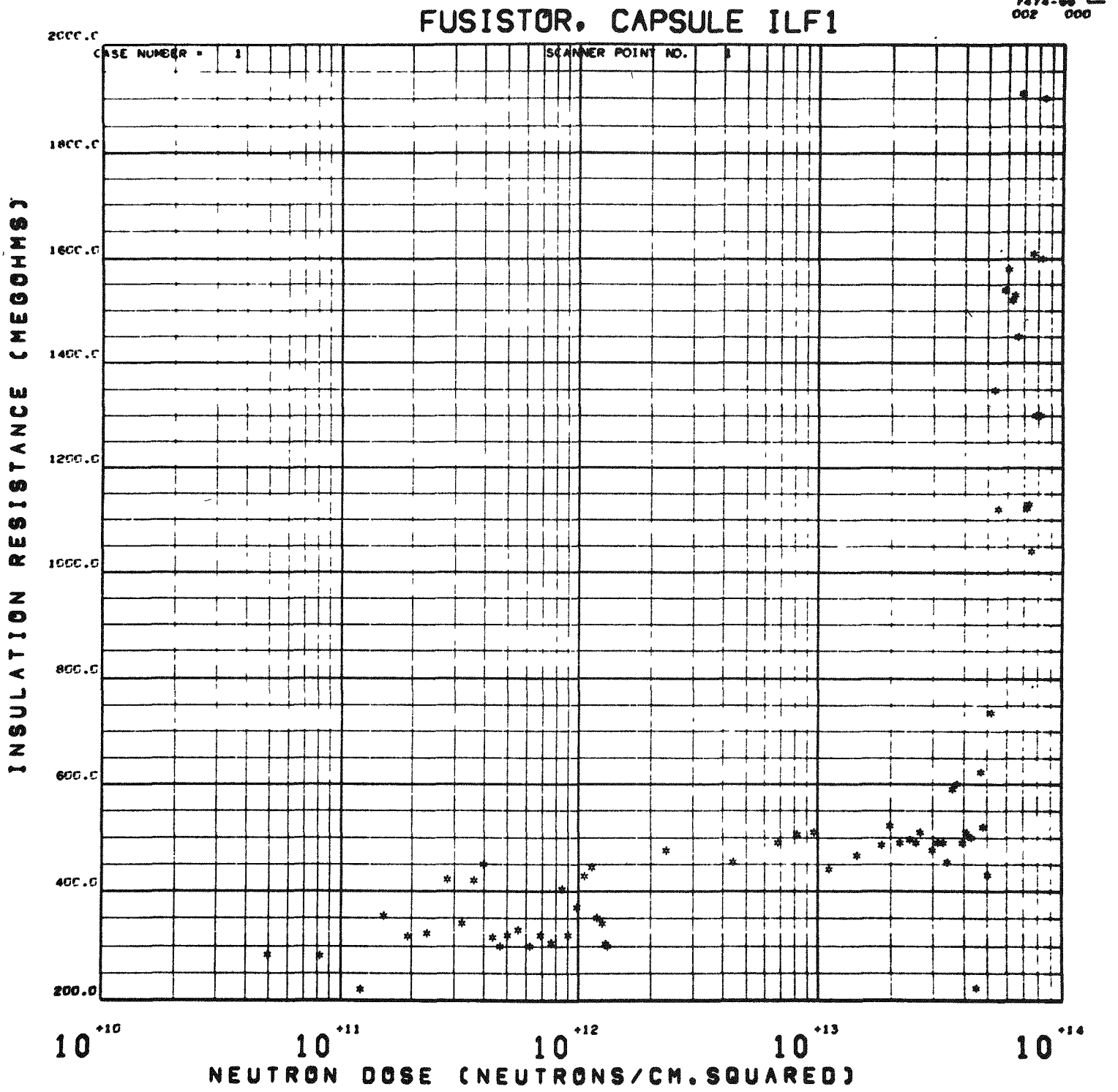

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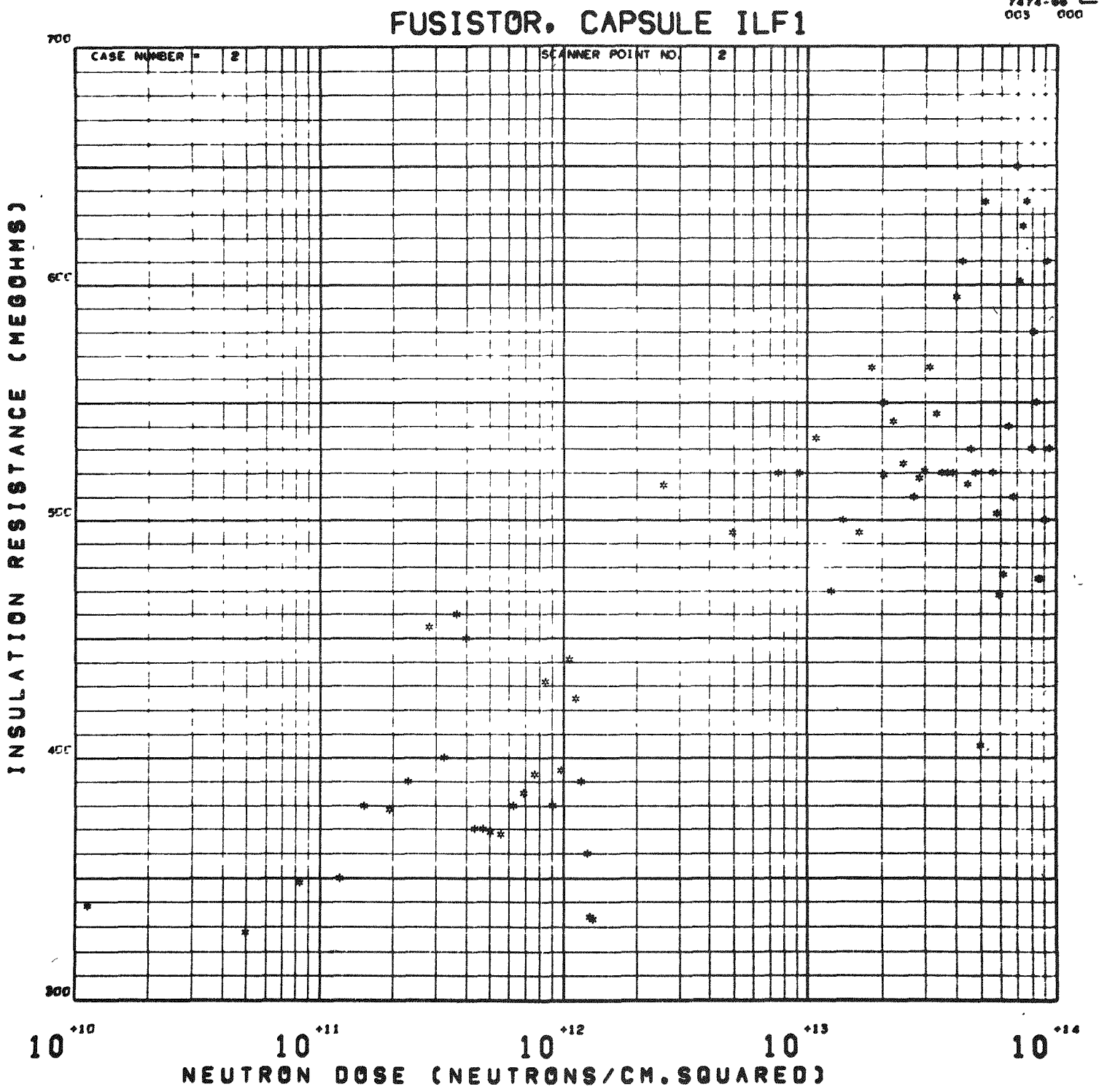
Graph 12

7474-66 L
003 000



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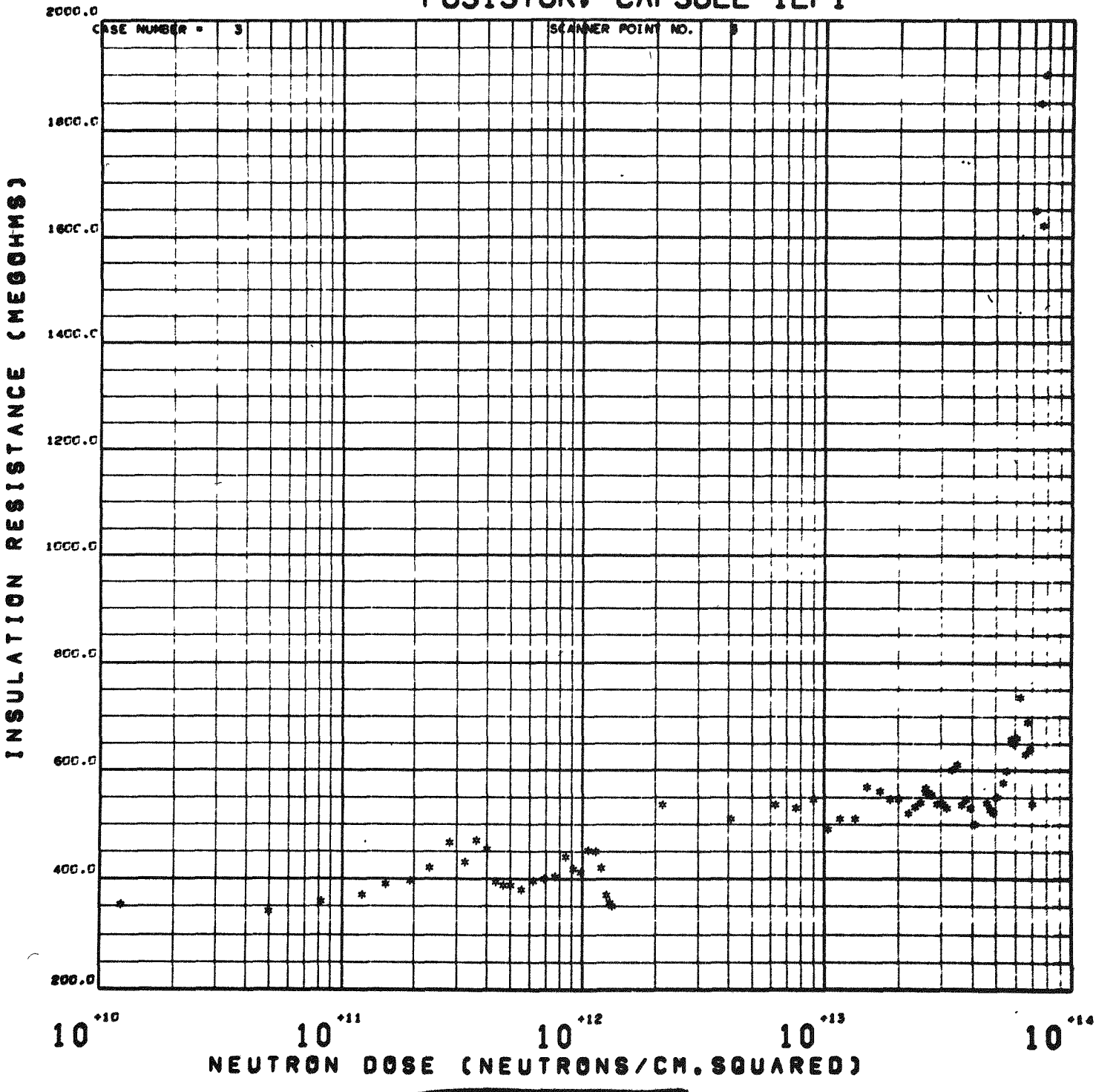
Graph 13

7474-66 L
004 000

FUSISTOR, CAPSULE ILF1



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Graph 14

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7474-66 L
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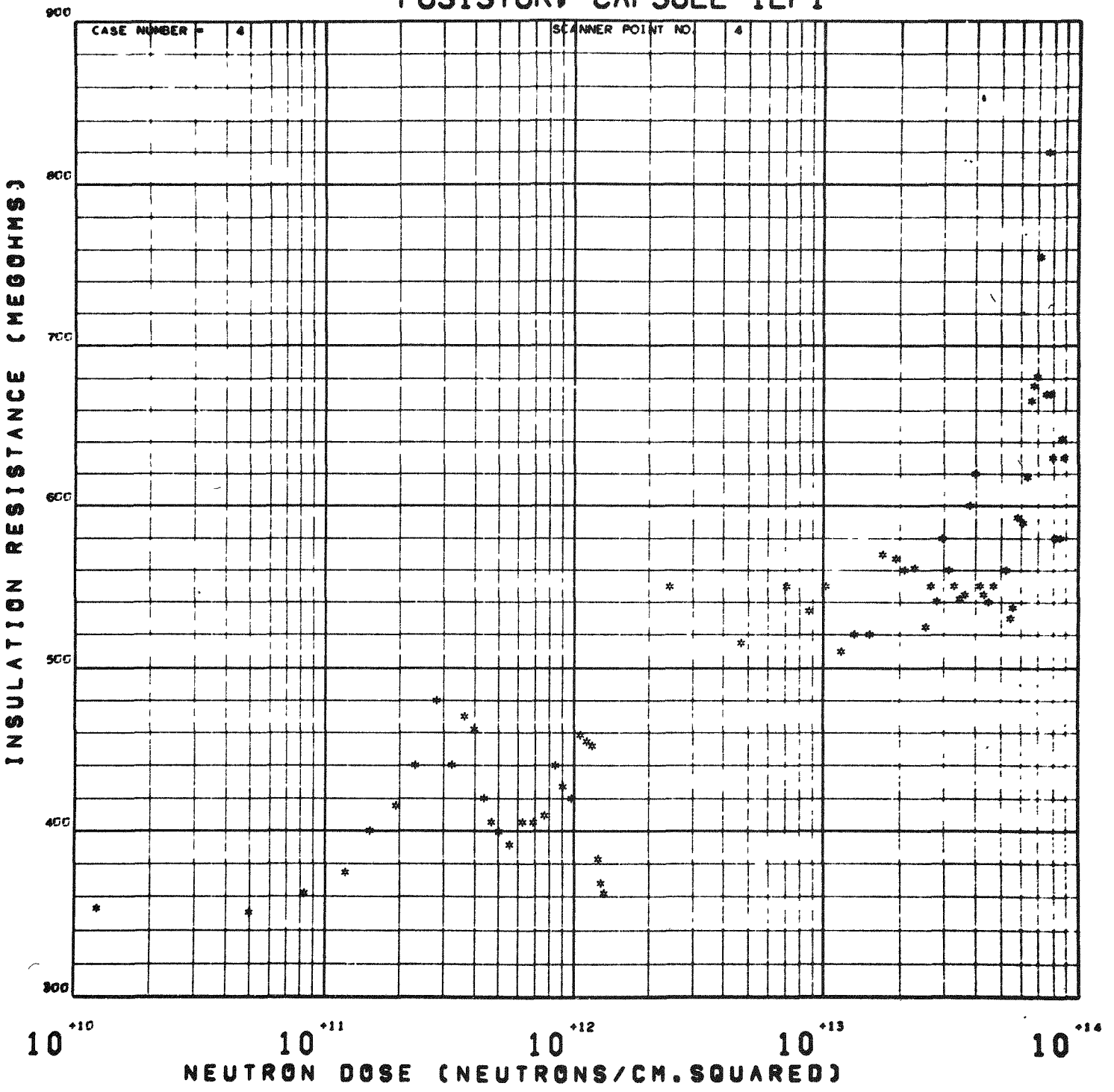
FUSISTOR, CAPSULE ILF1



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Graph 15

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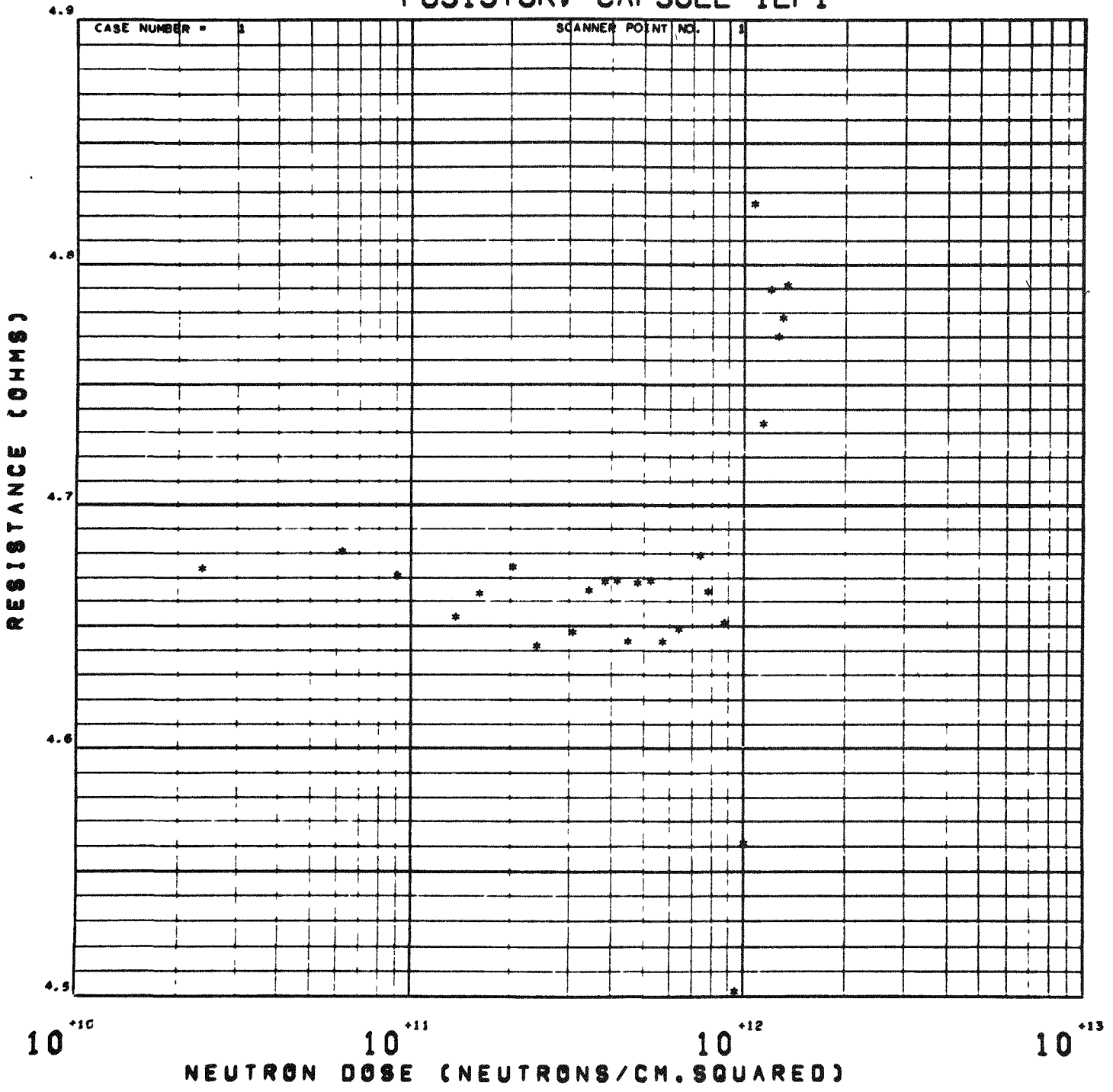
7474-66 L
002 000

FUSISTOR, CAPSULE ILF1



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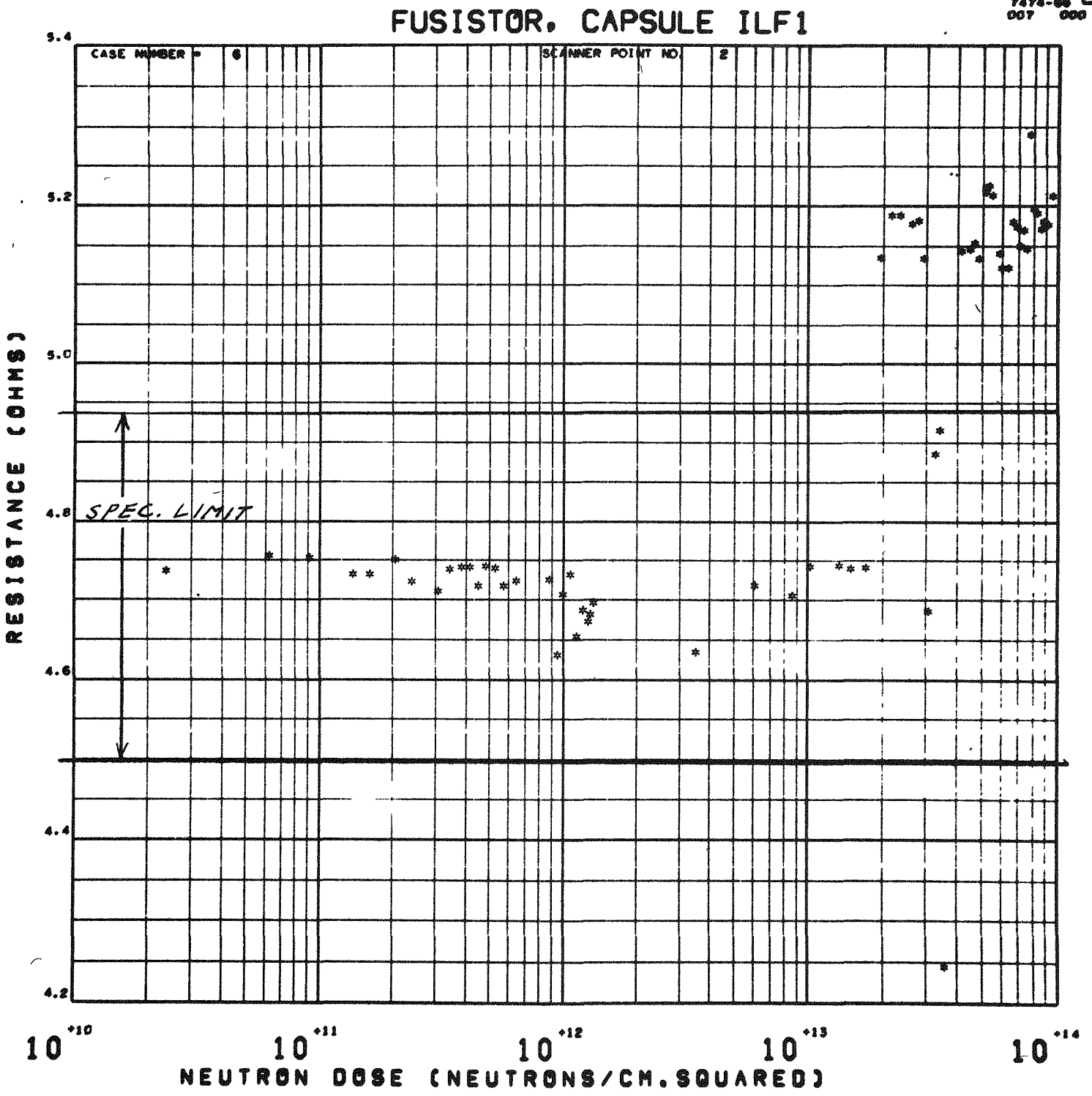
[redacted]

Graph 16

7474-66 L
007 000



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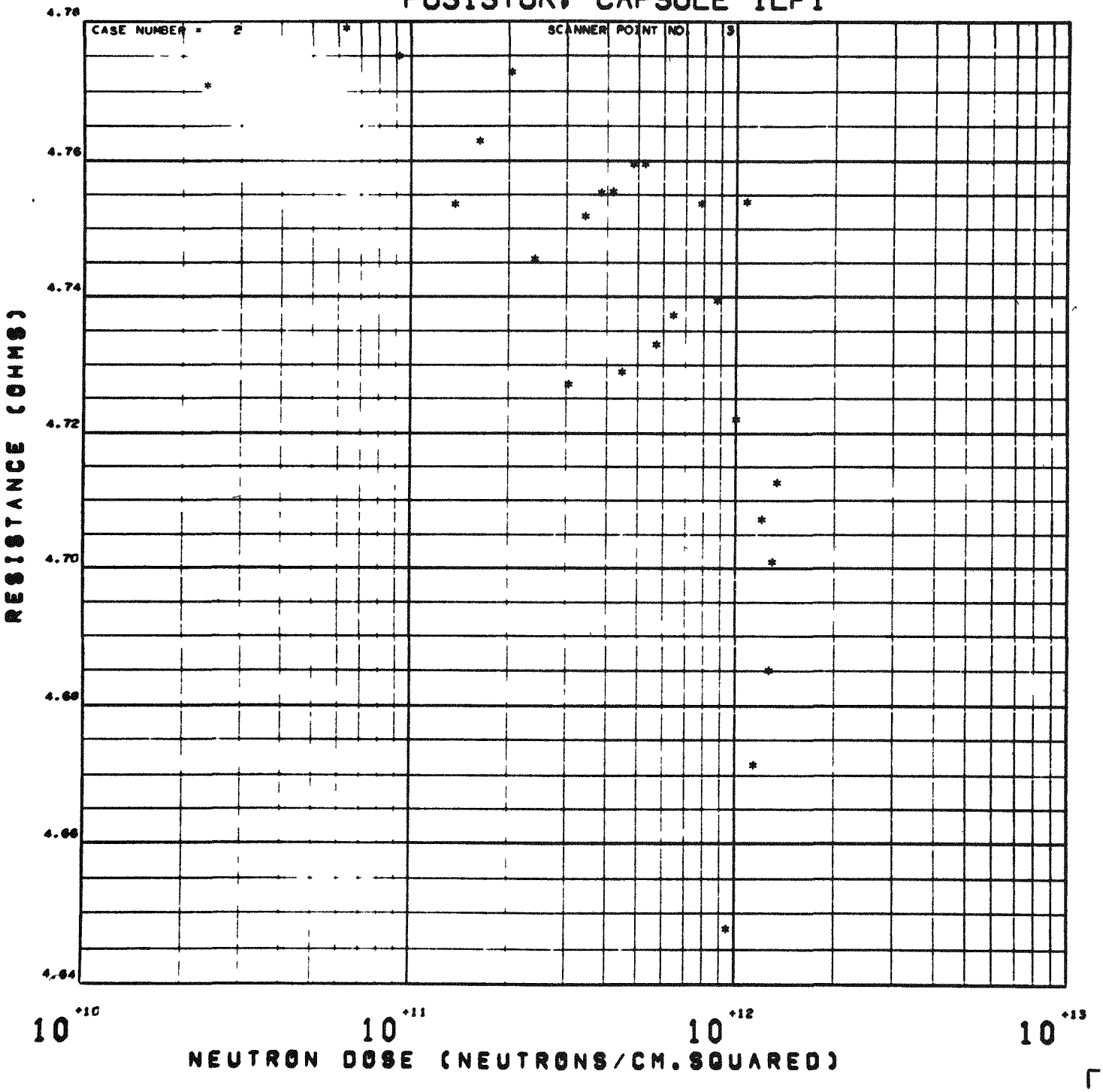
Graph 17

7474-96 L
003 000

FUSISTOR, CAPSULE ILF1



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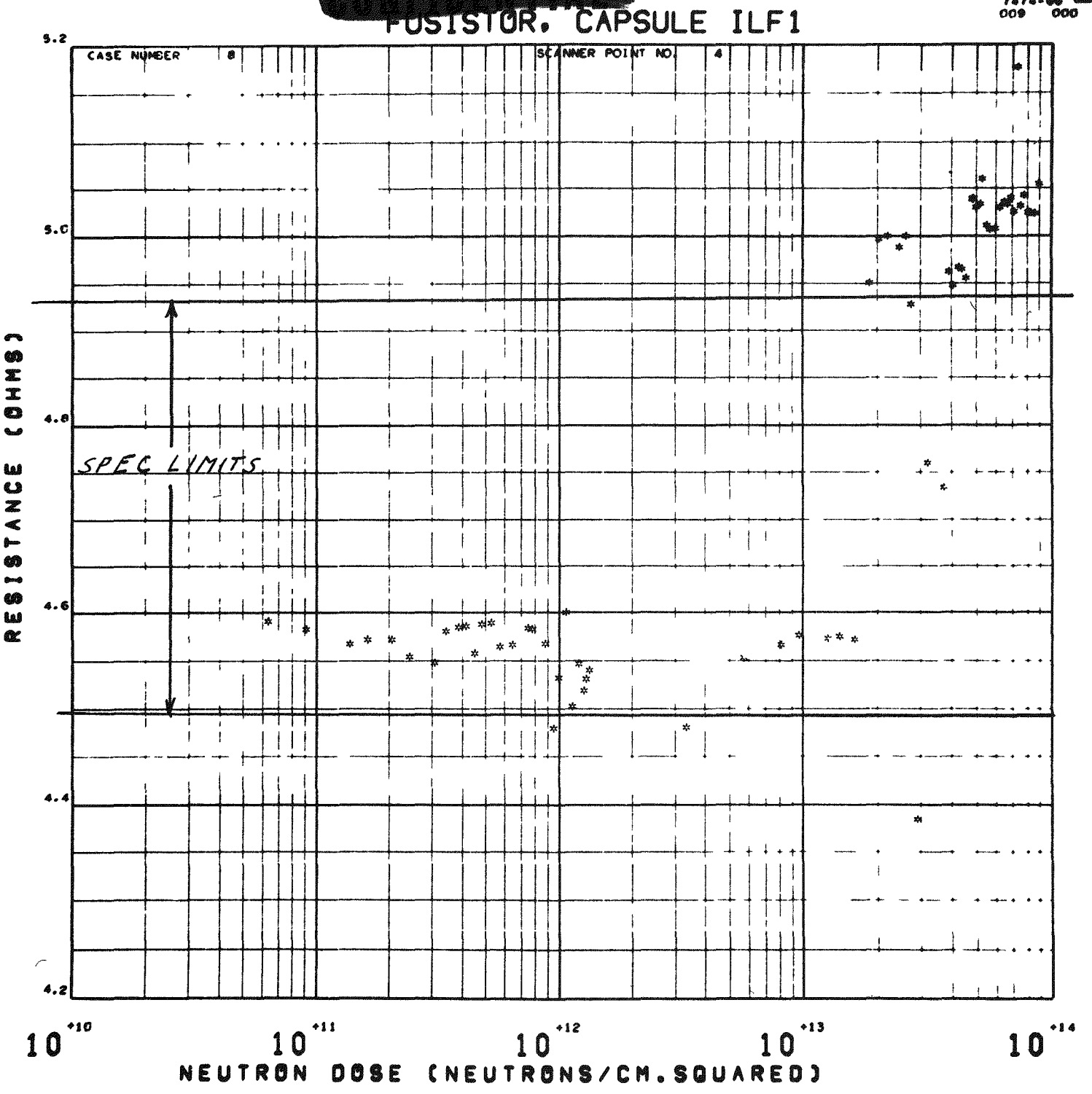
Graph 18

[redacted]

7474-66 L
009 000



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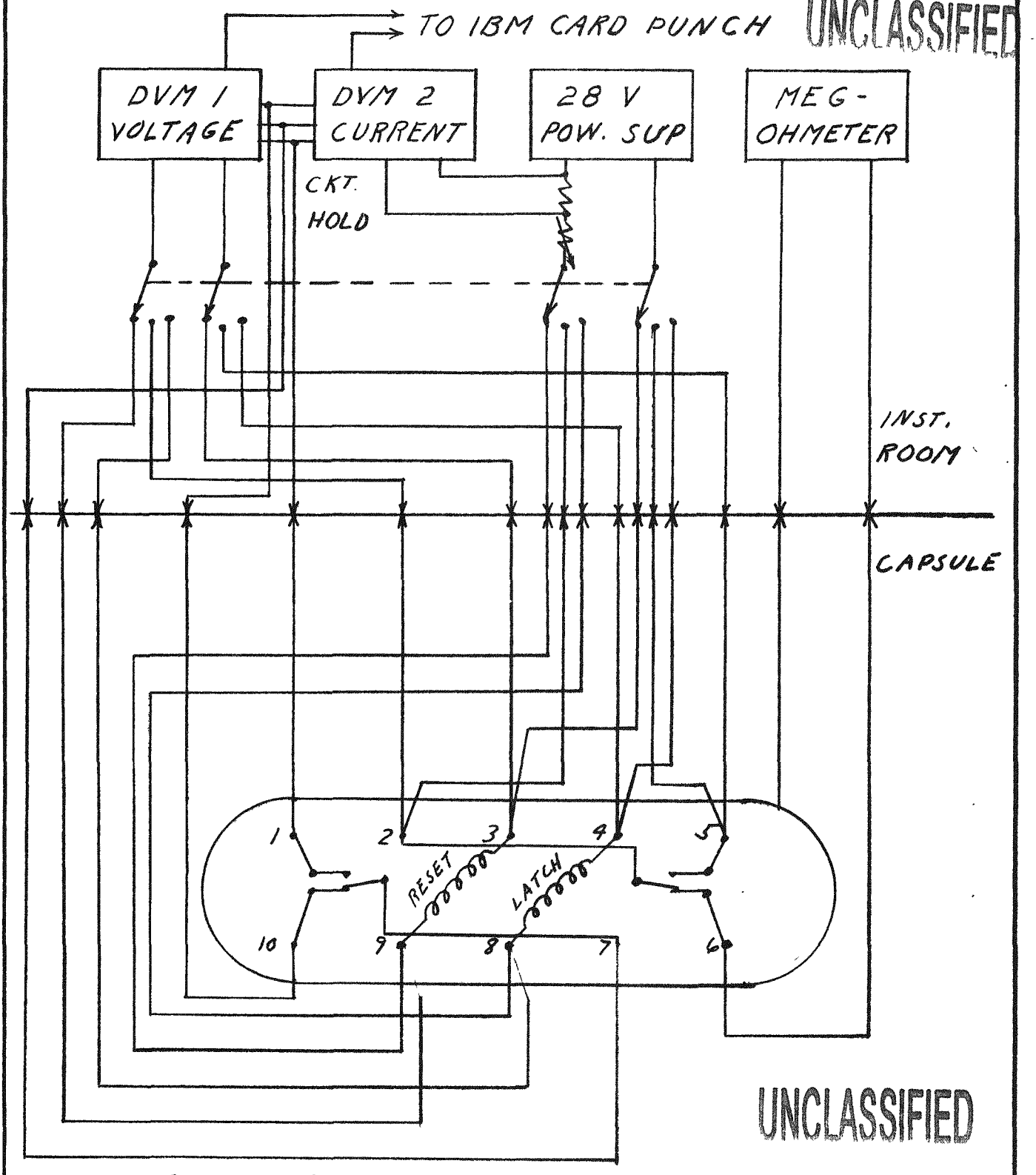
RELAY TEST (TYPICAL)



DVM-1 EI UNITS 3000A AEC 64123, 3400A AEC 64124
DVM-2 EI UNITS 3000A AEC 64098, 3400A AEC NONE
POW. SUP. POWER DESIGNS INC. RMI 48148

6.3 Relays

6.3.1 Test Setup The typical test setup for testing two 6PDT latching relays and two 2PDT latching relays is shown in figure 26.

6.3.2 Results No degradation was noted in the insulation resistance, contact bounce and contact resistance.

Coil resistances were as much as 20% above the spec limit during irradiation. Concurrently the required latch and reset voltages were higher. The increase in voltage requirement for relay actuation will not be detrimental since the voltage available in the NPU is much higher than the 14 volts maximum required to actuate the relays during irradiation.

Table 15 summarizes the post-irradiation electrical characteristics. Pre-irradiation and post-irradiation resistance were similar but the post-irradiation latch and reset voltages differed from pre-irradiation values. Apparently some change in the magnetic characteristics of the relays occurred. This change cannot be rationalized easily since the actuation voltages increased for the 6PDT relays and decreased for the 2PDT relays.

Graphs 19 through 22 show the contact resistance of the two relay types. From the data it appears that a favorable decrease in contact resistance results from irradiation. Most of the scatter in the data is due to the non-repeatibility of contact resistance measurements.

Graphs 23 through 26 show that both latch and reset coil resistances of the 6PDT relays exceeded their specification limit by a maximum of 20% during irradiation. Graphs 27 through 30 show that % reset increase of the latch and reset coil resistances of the 2PDT relays was as much as for the 6PDT relays. Since the 2PDT nominal coil resistance was 700 ohms, their 20% change was well within their specification limit of 10,000 ohms per coil maximum.

Graphs 31 through 34 show that the insulation resistance decreased progressively during irradiation but was always well above the 100 megohm requirement of the specifications.

Graphs 35 through 38 show that both type relays always pulled in and reset well below the specification maximum of 22 volts.

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TABLE 15

Relay		Latch Volts		Latch Coil		Reset Volts		Reset Coil Ohm	
Type	No.	Pre-ir.	Post-ir.	Pre-ir.	Post-ir.	Pre-ir.	Post-ir.	Pre-ir.	Post-ir.
6PDT	A2951	12.4	12.8	197.3	198.4	7.6	8.9	279.2	280.8
6PDT	A2592	13.5	16.4	193.4	194.7	9.2	15.2	286.7	288.6
2PDT	A3041	11.9	8.79	626.6	628.4	10.8	8.35	636.7	636.4
2PDT	A3042	11.6	9.96	624.7	627.8	10.5	8.67	623.5	627.6

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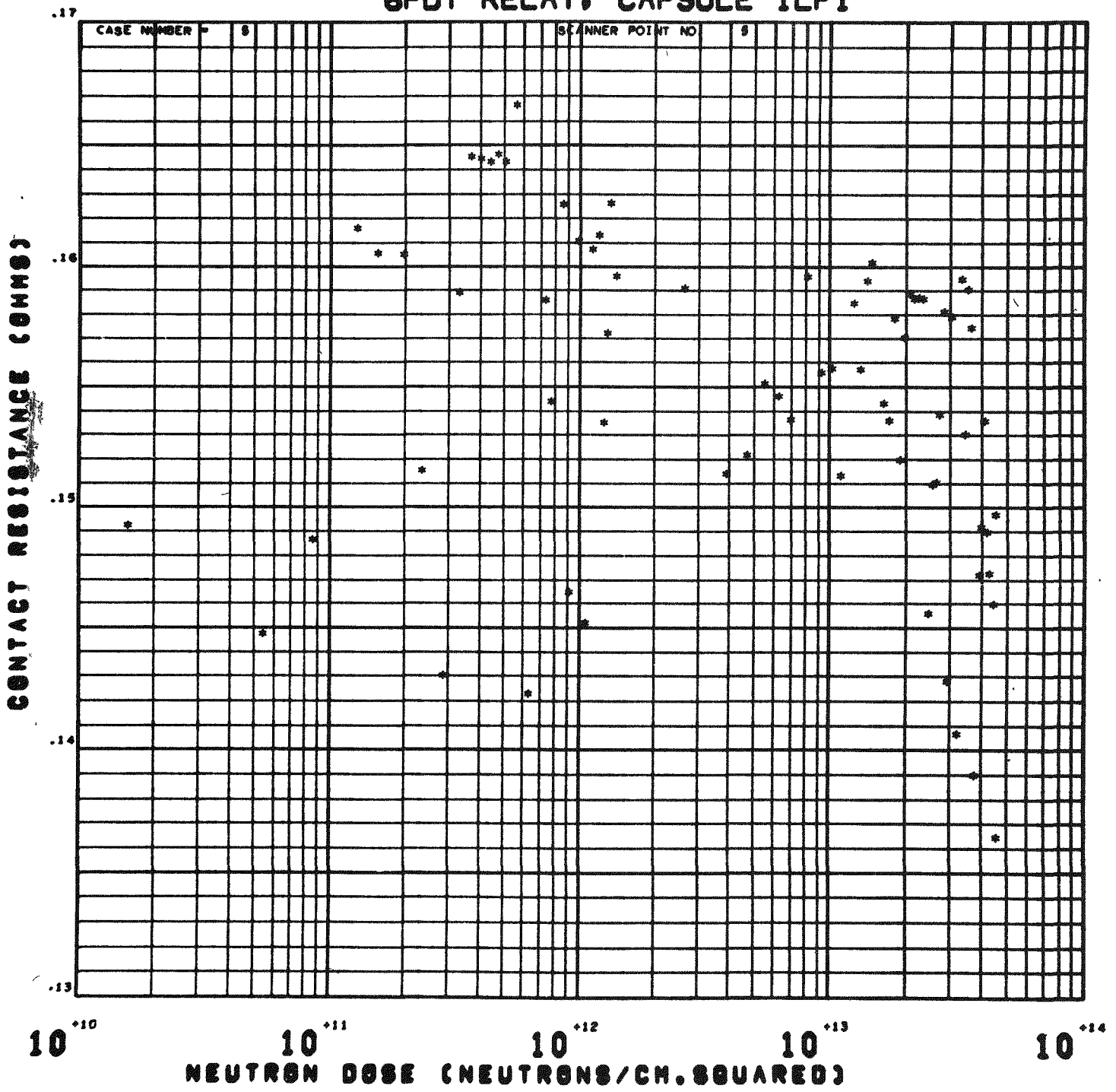
Graph 19

7471-71 L
006 000

6PDT RELAY, CAPSULE ILF1



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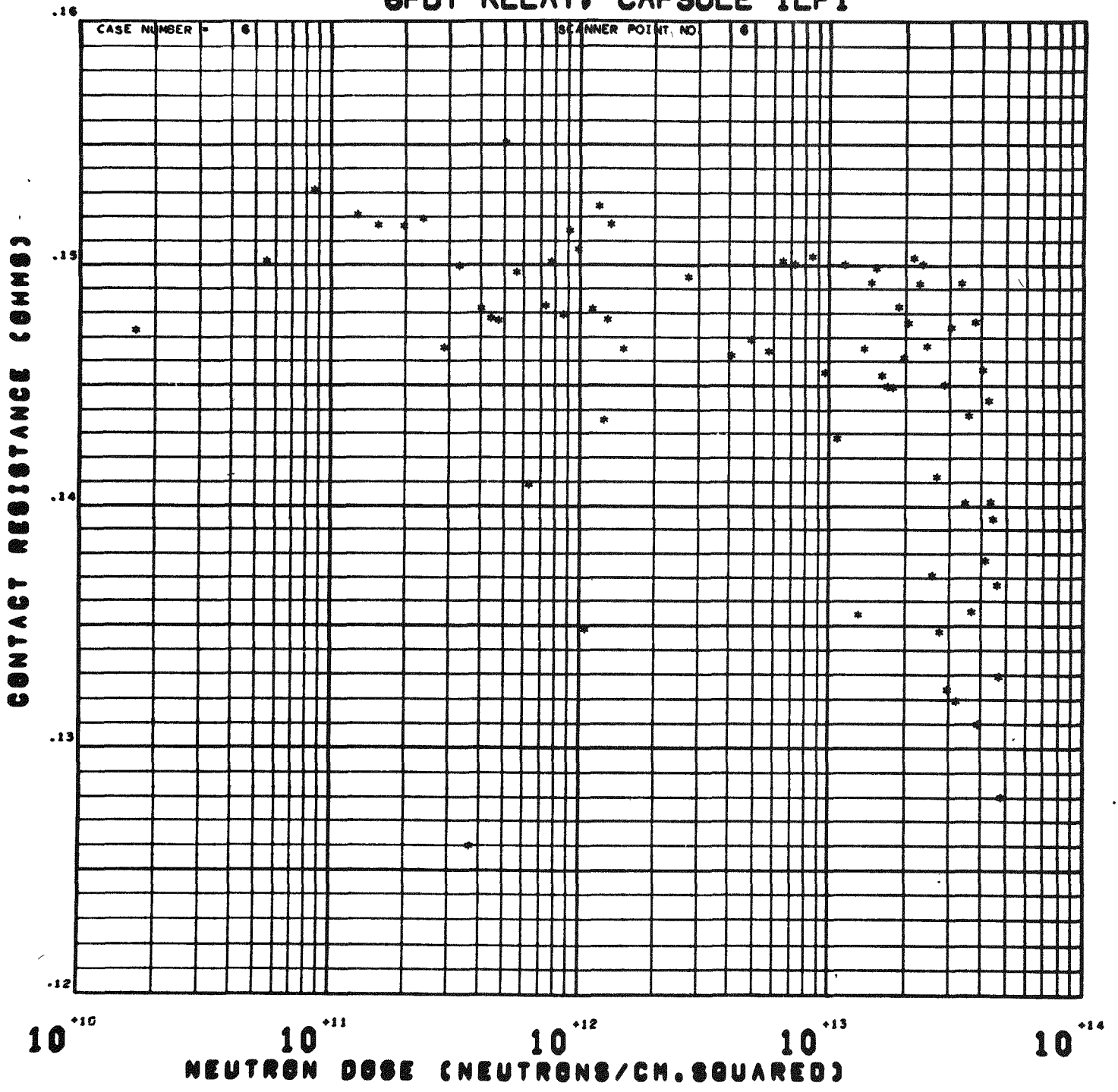
Graph 20

7471-71 L
007 000

6PDT RELAY, CAPSULE ILF1



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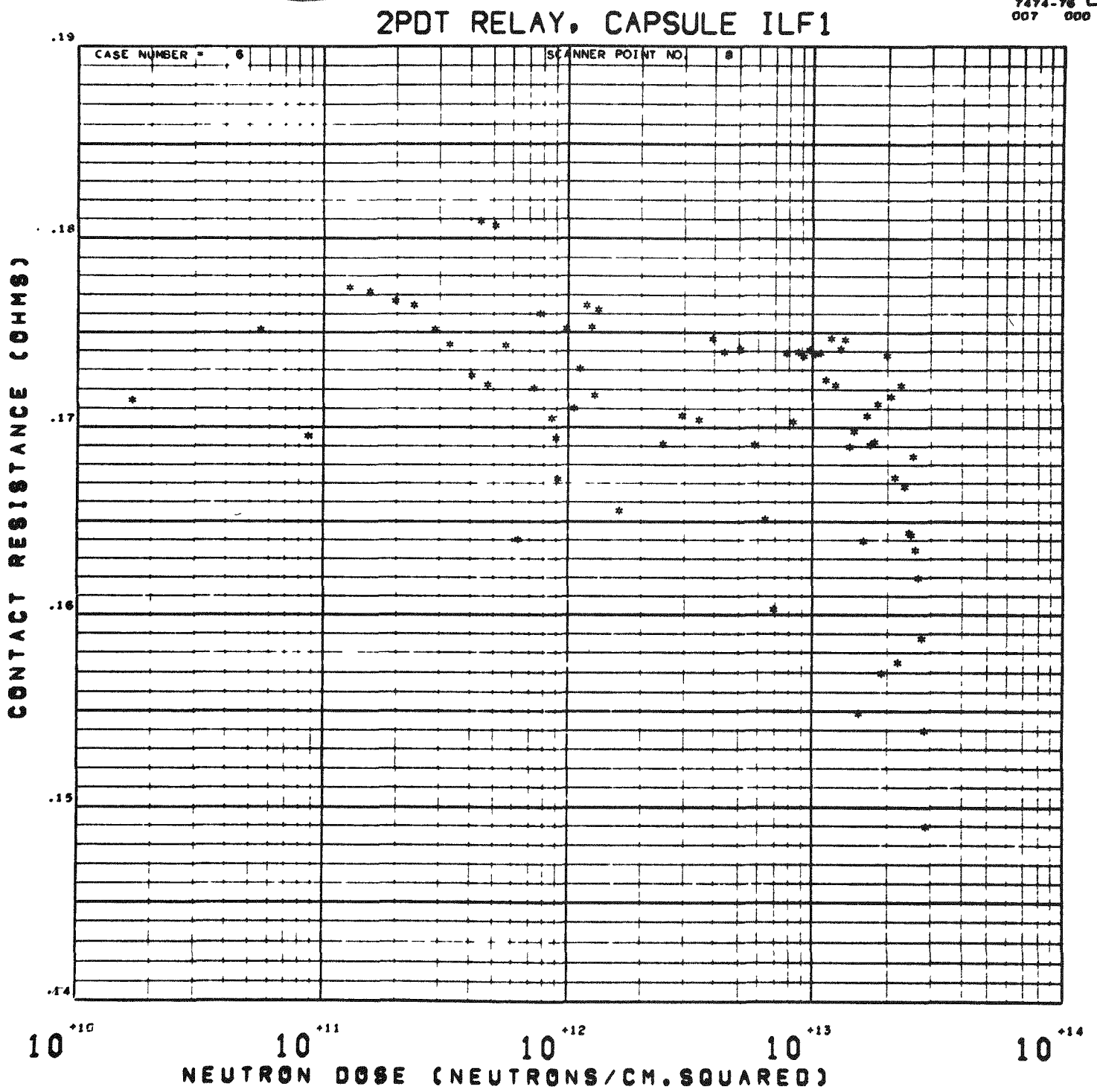
Graph 21

7474-76 L
007 000



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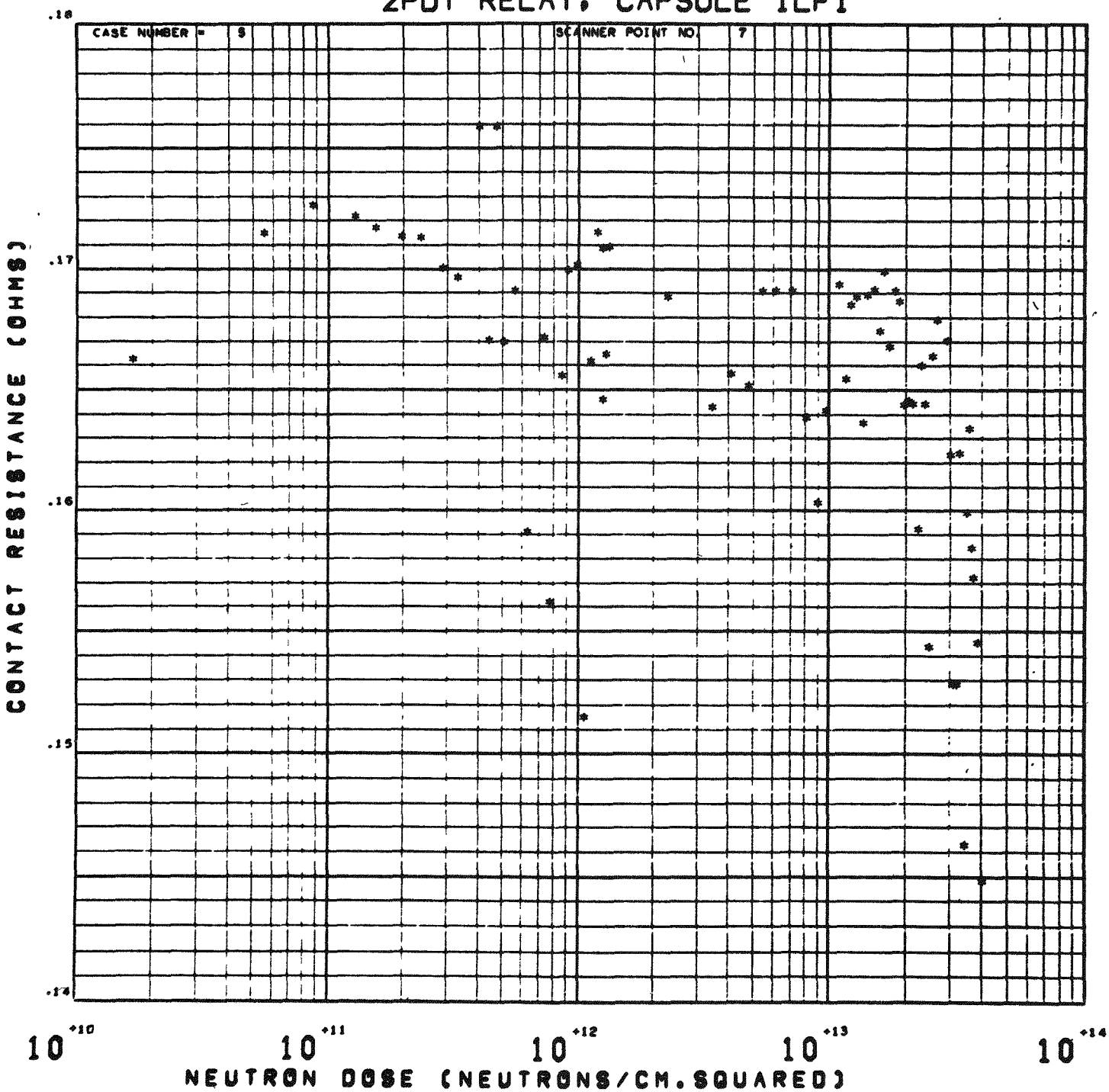
Graph 22

7474-76 L
006 000

2PDT RELAY, CAPSULE ILF1



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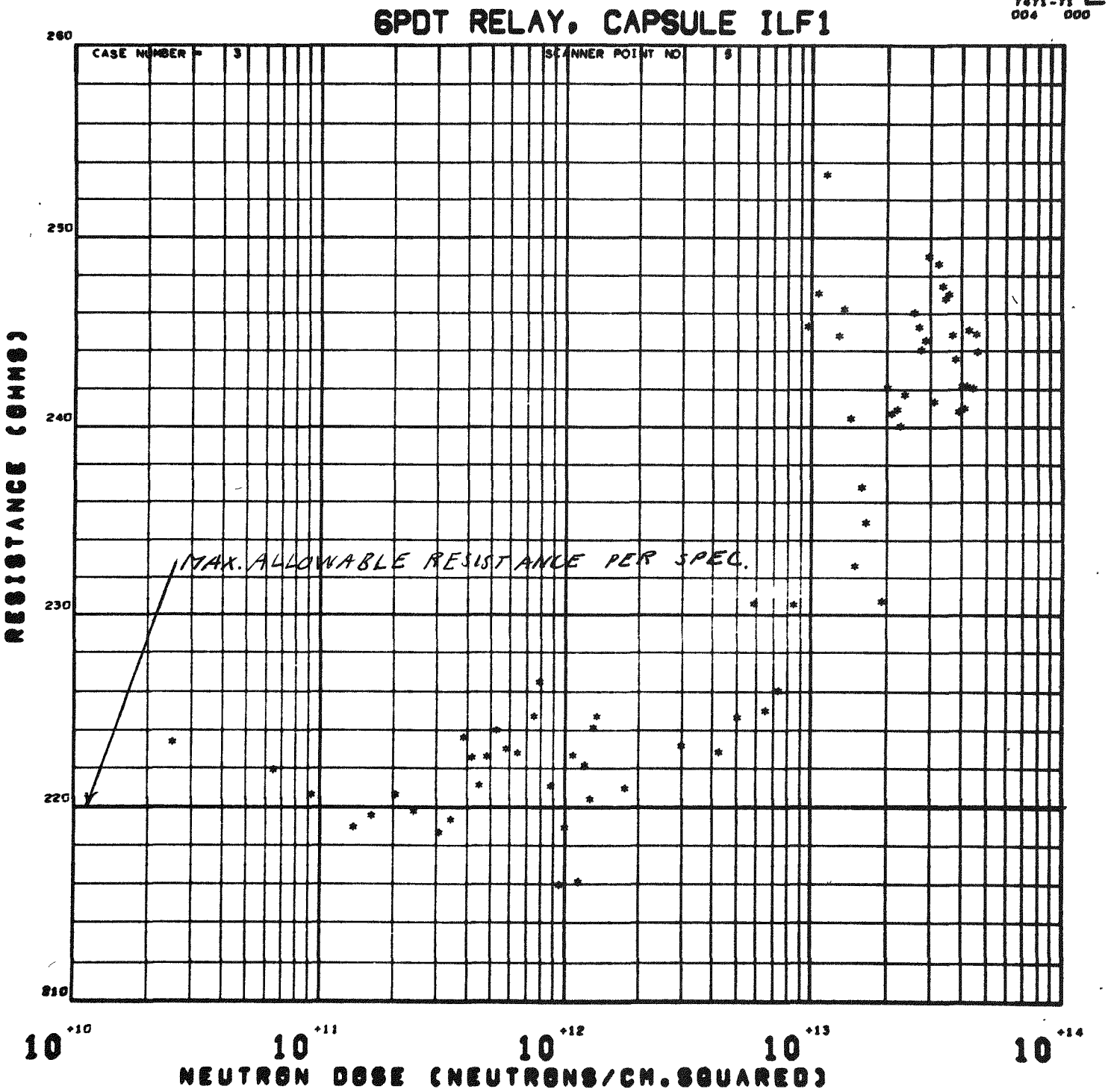
Graph 23

7471-71 L
004 000



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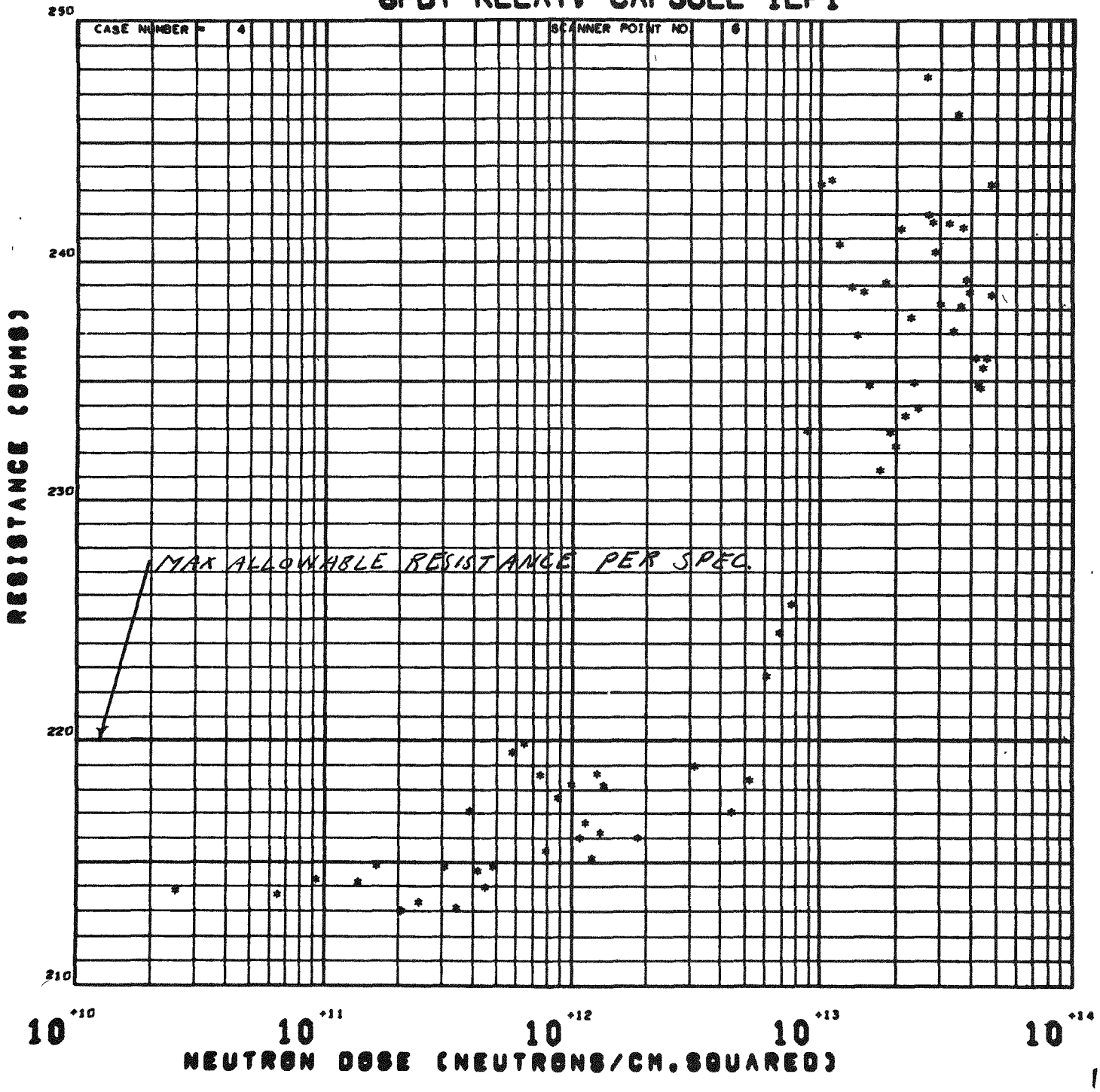
Graph 24

7471-71 L
005 000

6PDT RELAY, CAPSULE ILF1



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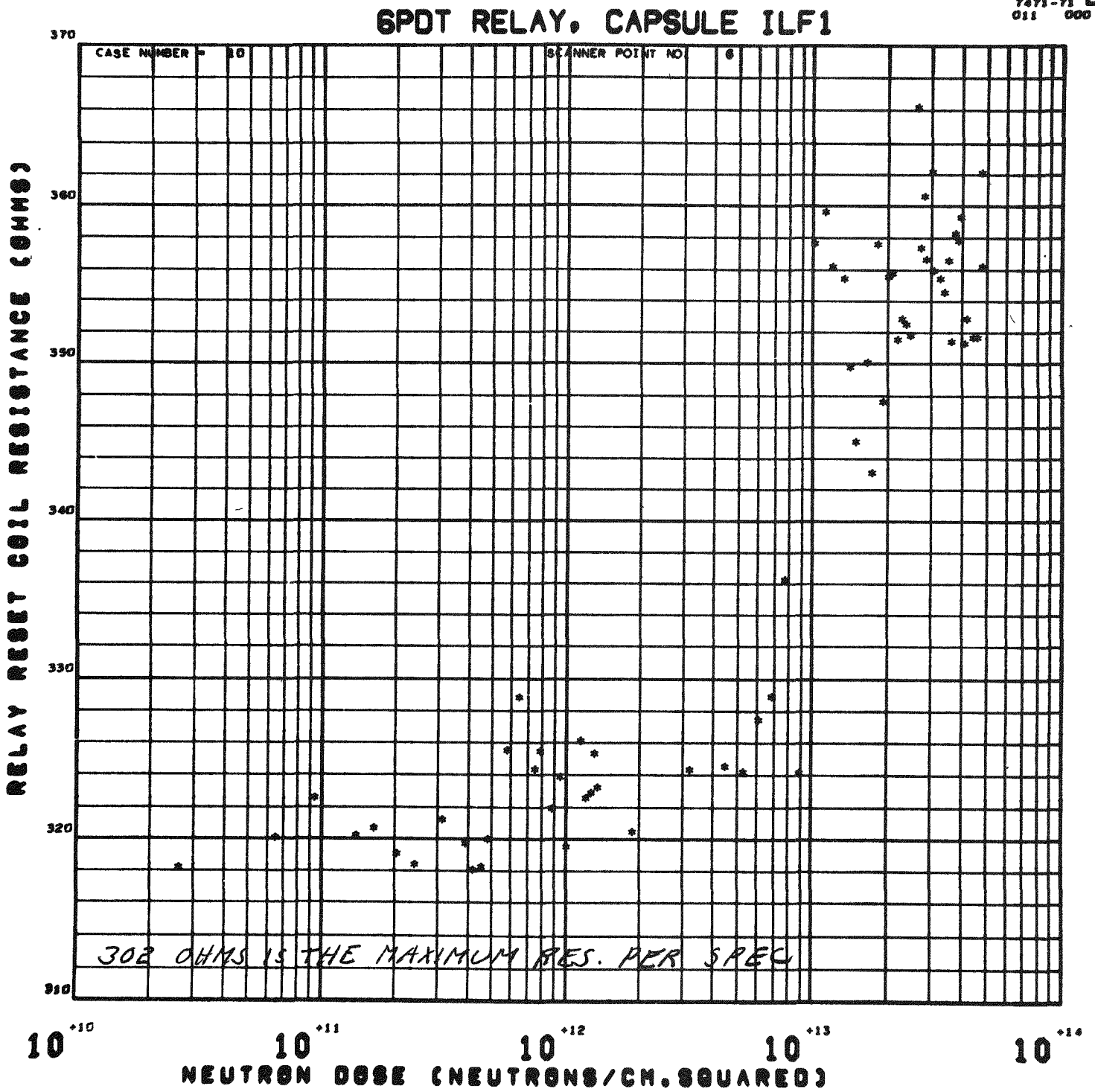
Graph 25

7471-71 L
011 000



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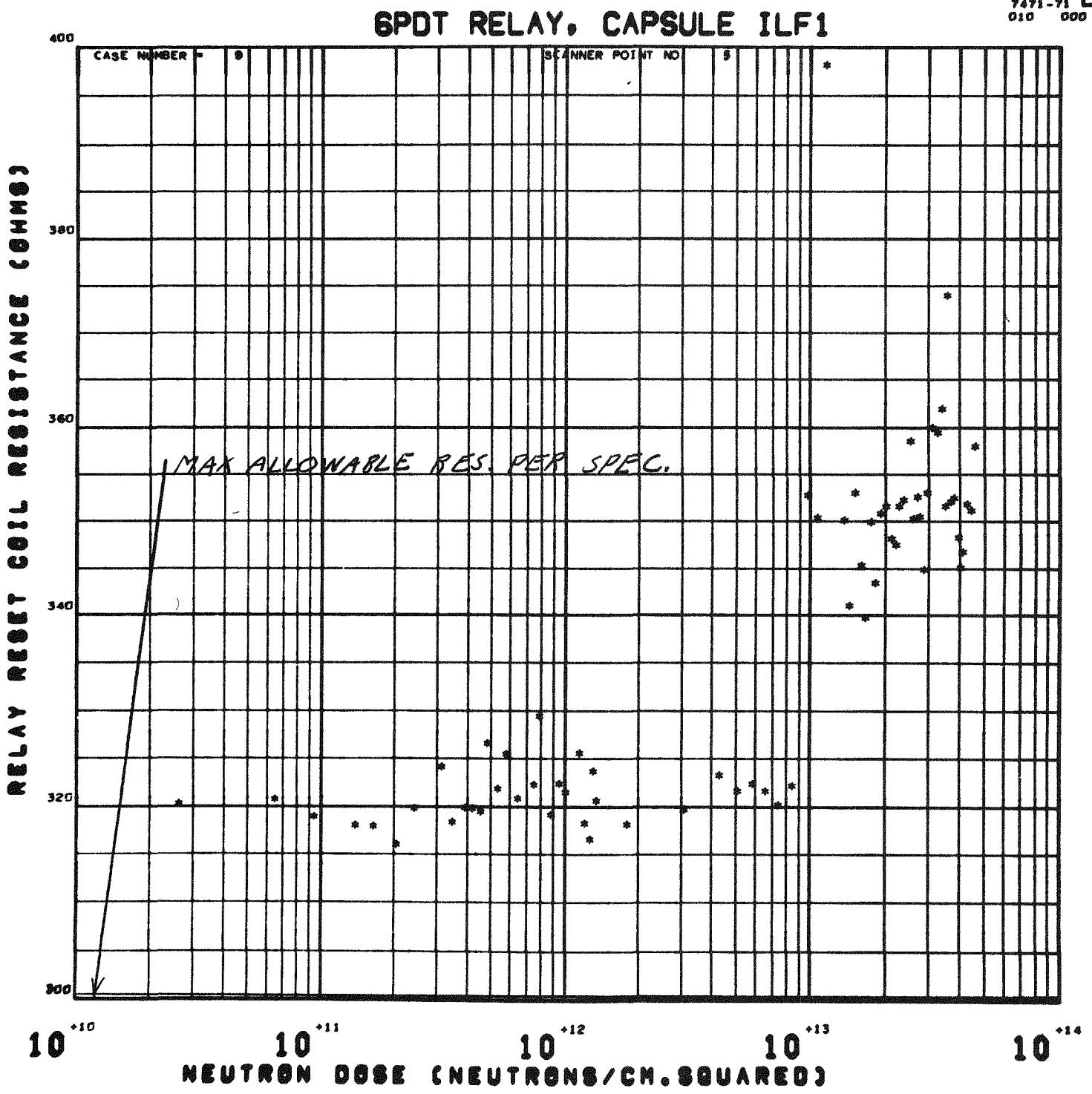
Graph 26

7471-71 L
010 000



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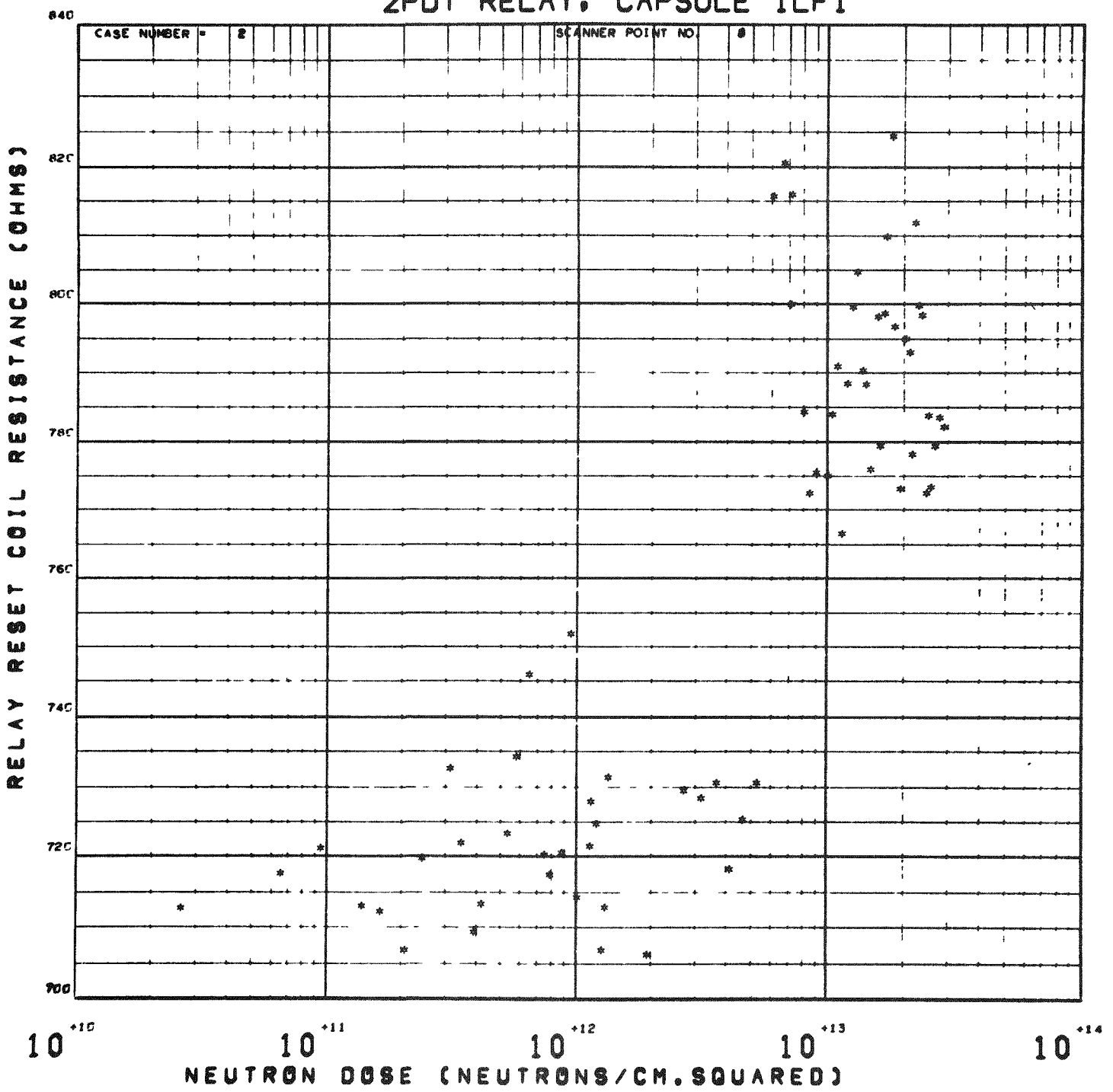
Graph 27

[redacted]

7474-88 L
003 000

2PDT RELAY, CAPSULE ILF1



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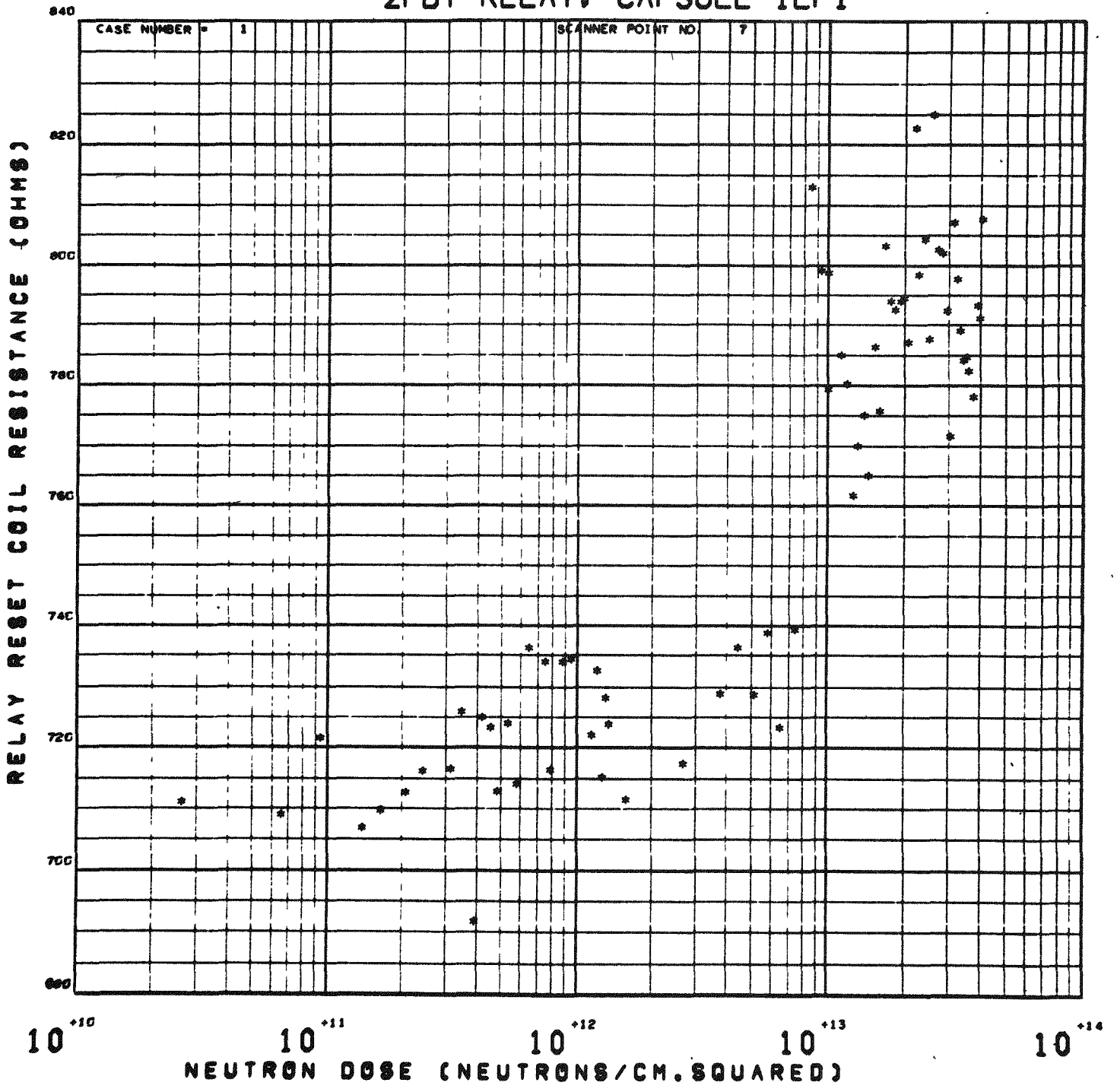
Graph 28

7474-88 L
002 000

2PDT RELAY, CAPSULE ILF1



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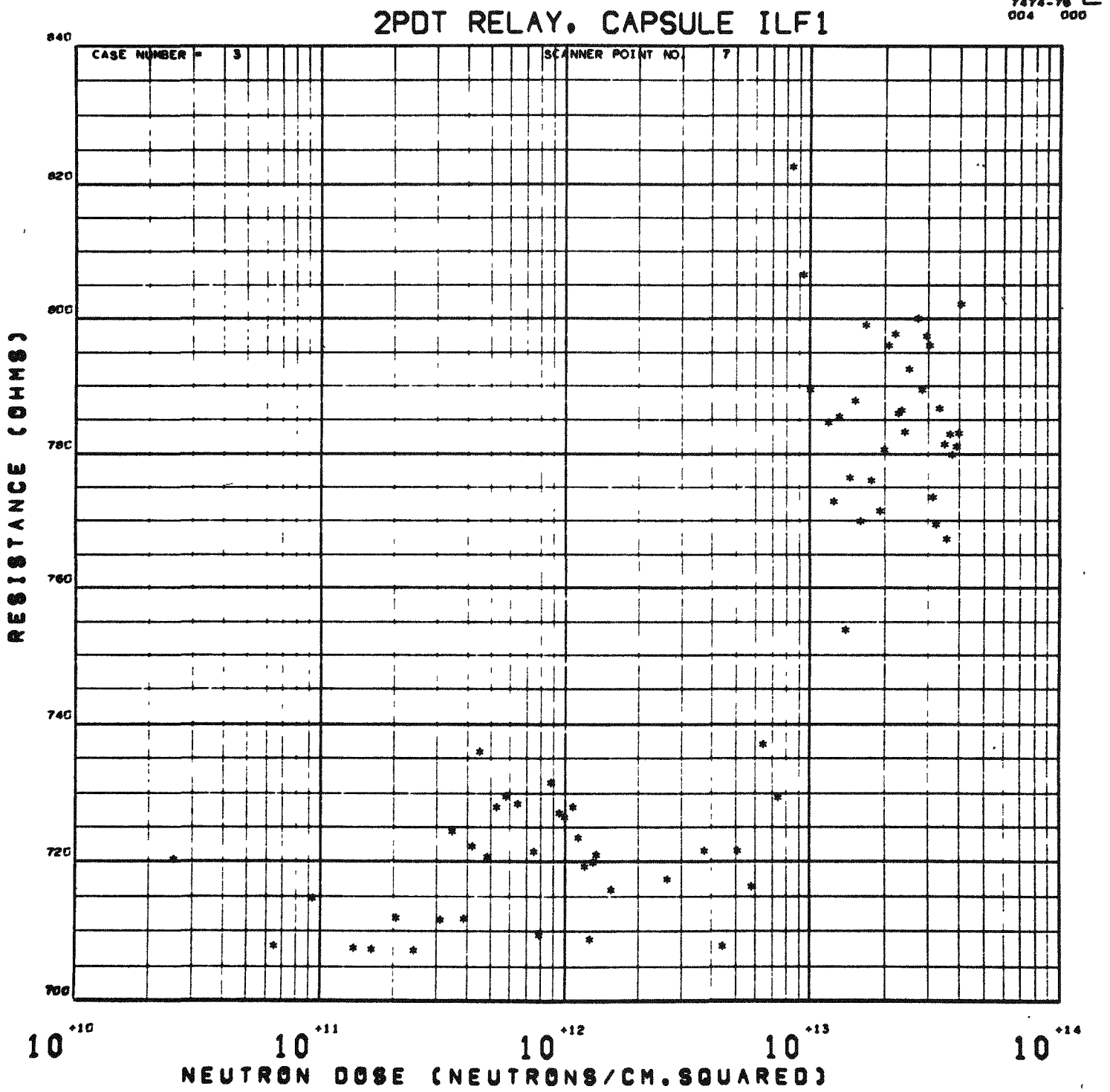
Graph 29

7474-76 L
004 000



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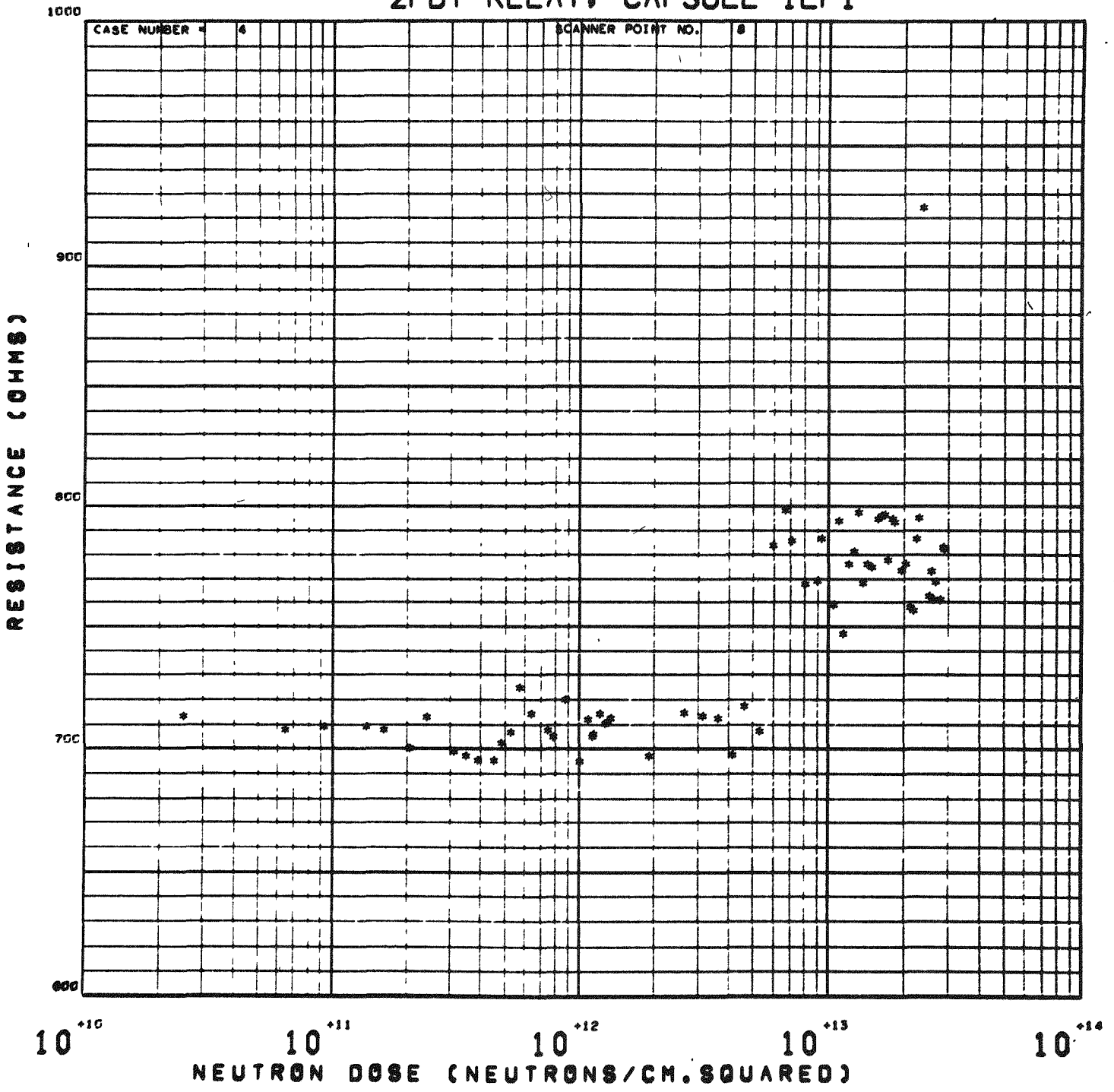
Graph 30

7474-76 L
005 000

2PDT RELAY, CAPSULE ILF1



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Graph 31

7471-71 L
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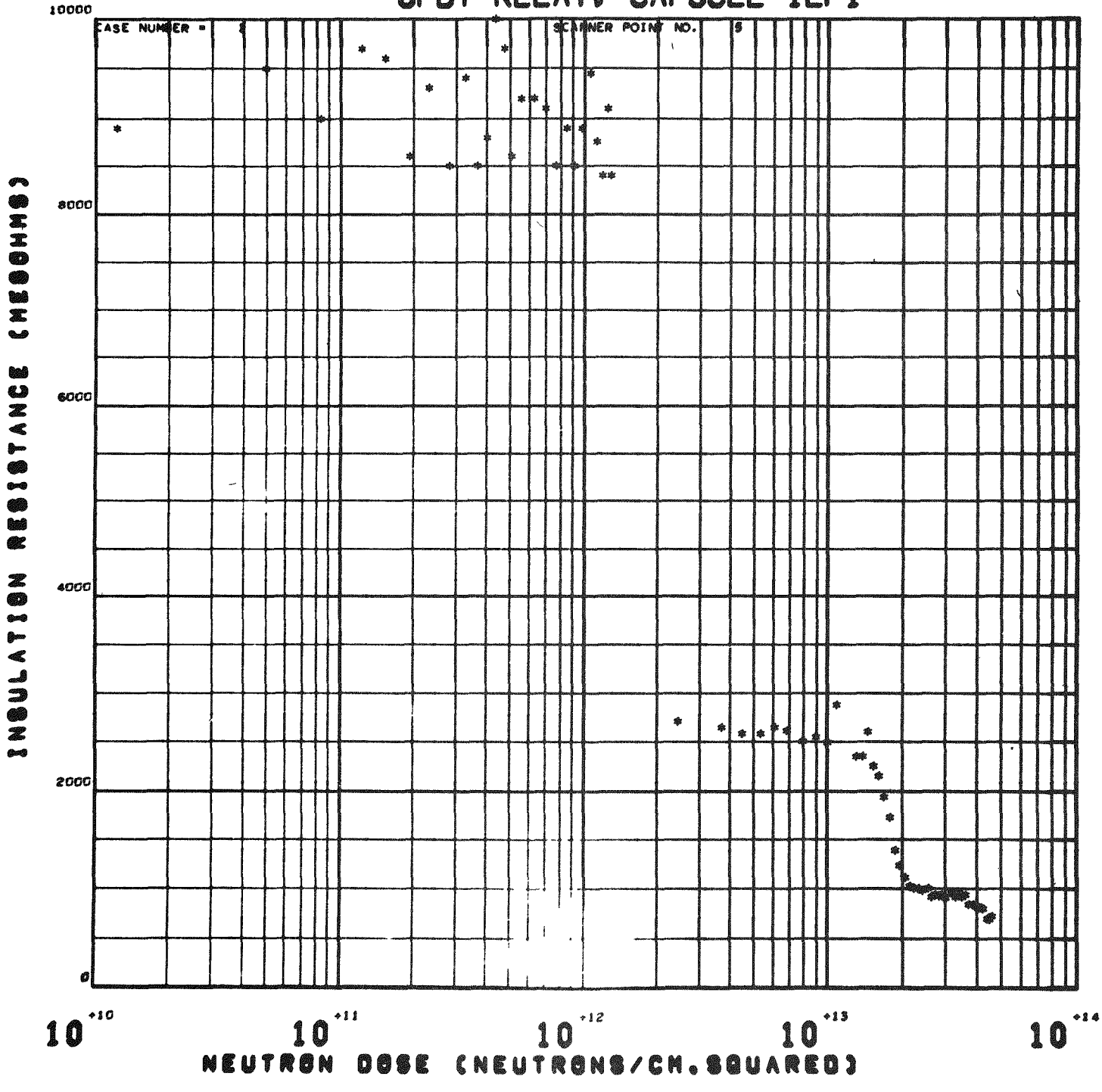
6PDT RELAY, CAPSULE ILF1



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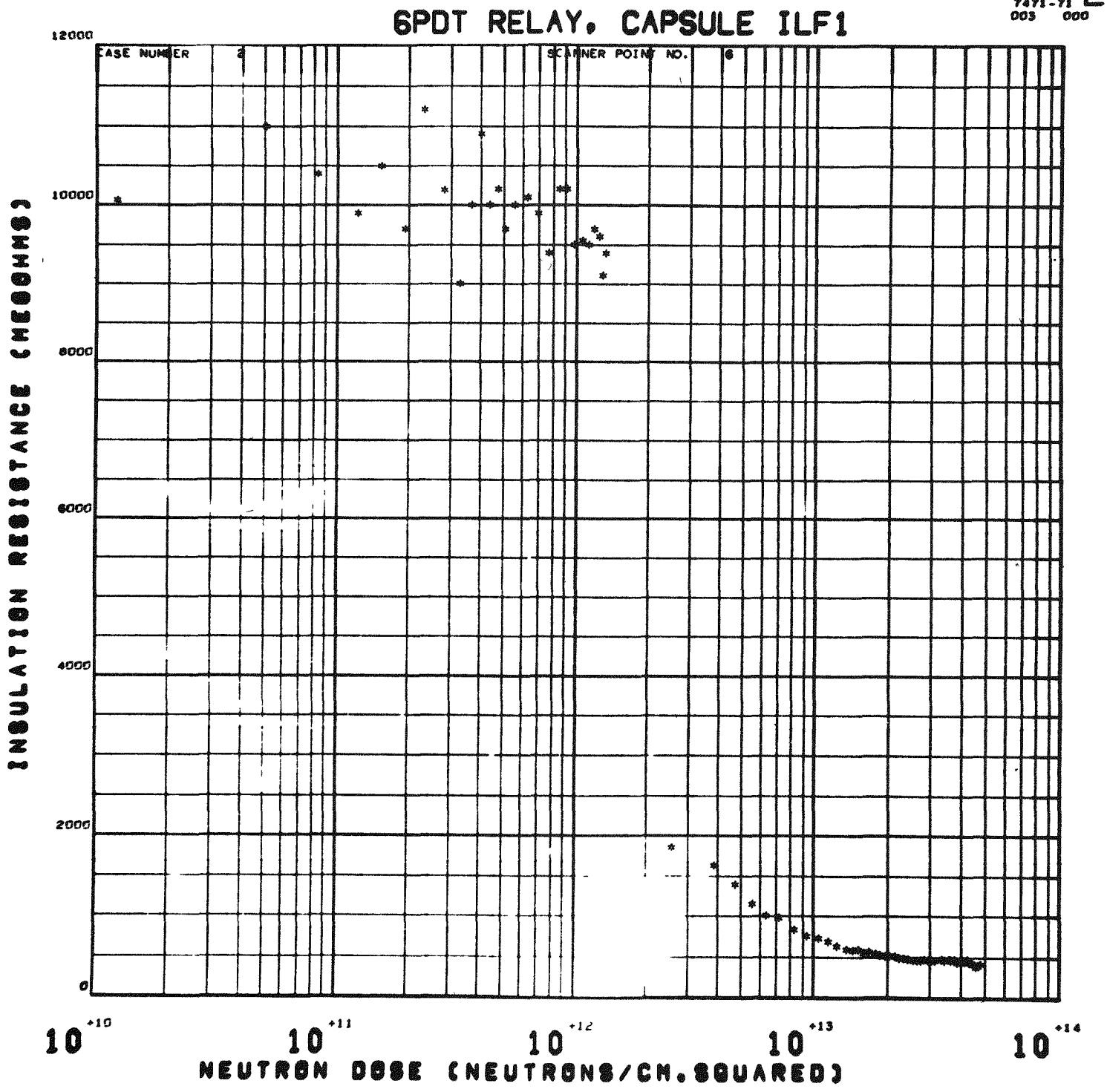
Graph 32

7471-71 L
003 000



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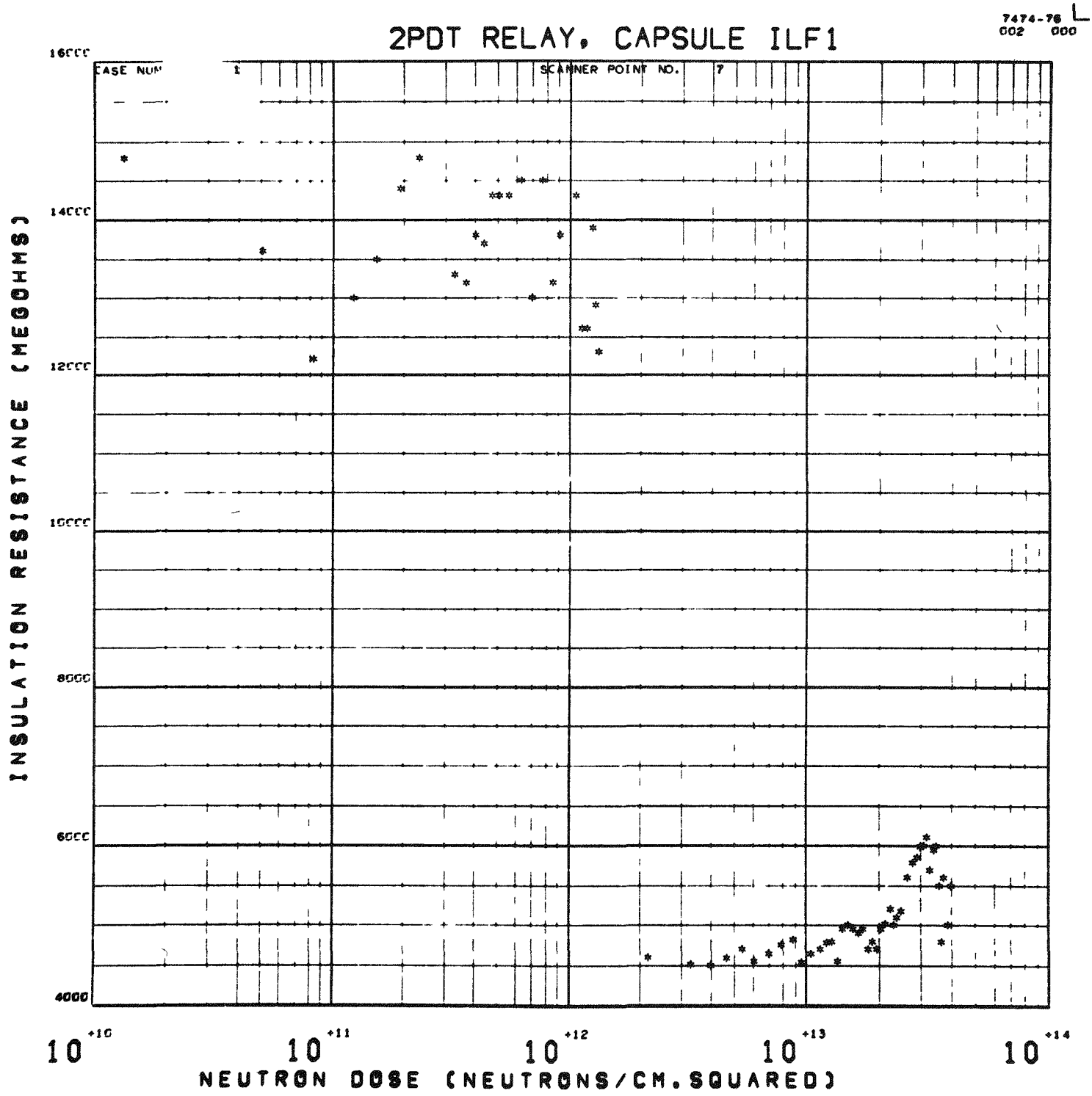
Graph 33

7474-76 L
002 000



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Graph 34

7474-76 L
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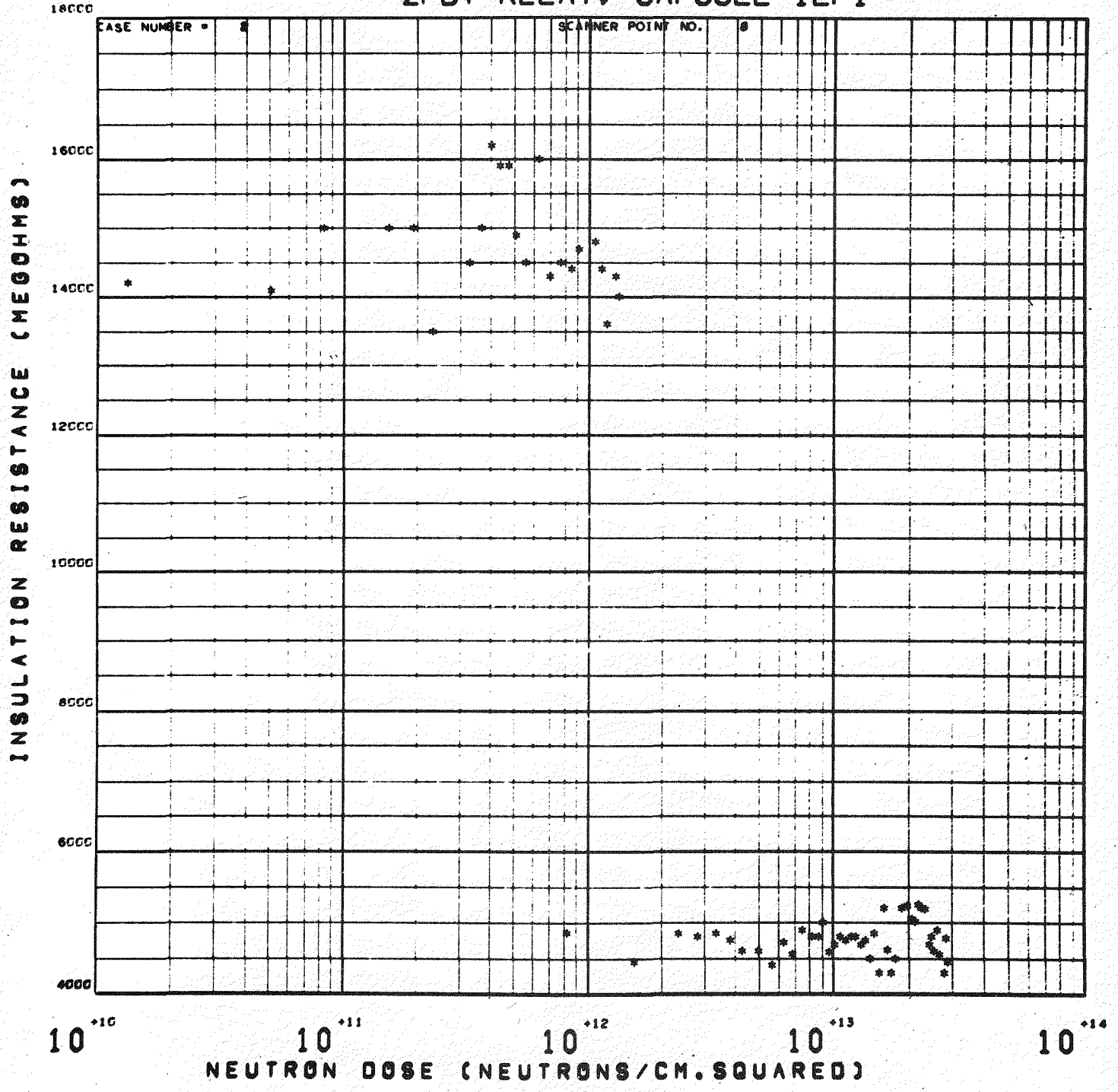
2PDT RELAY, CAPSULE ILF1



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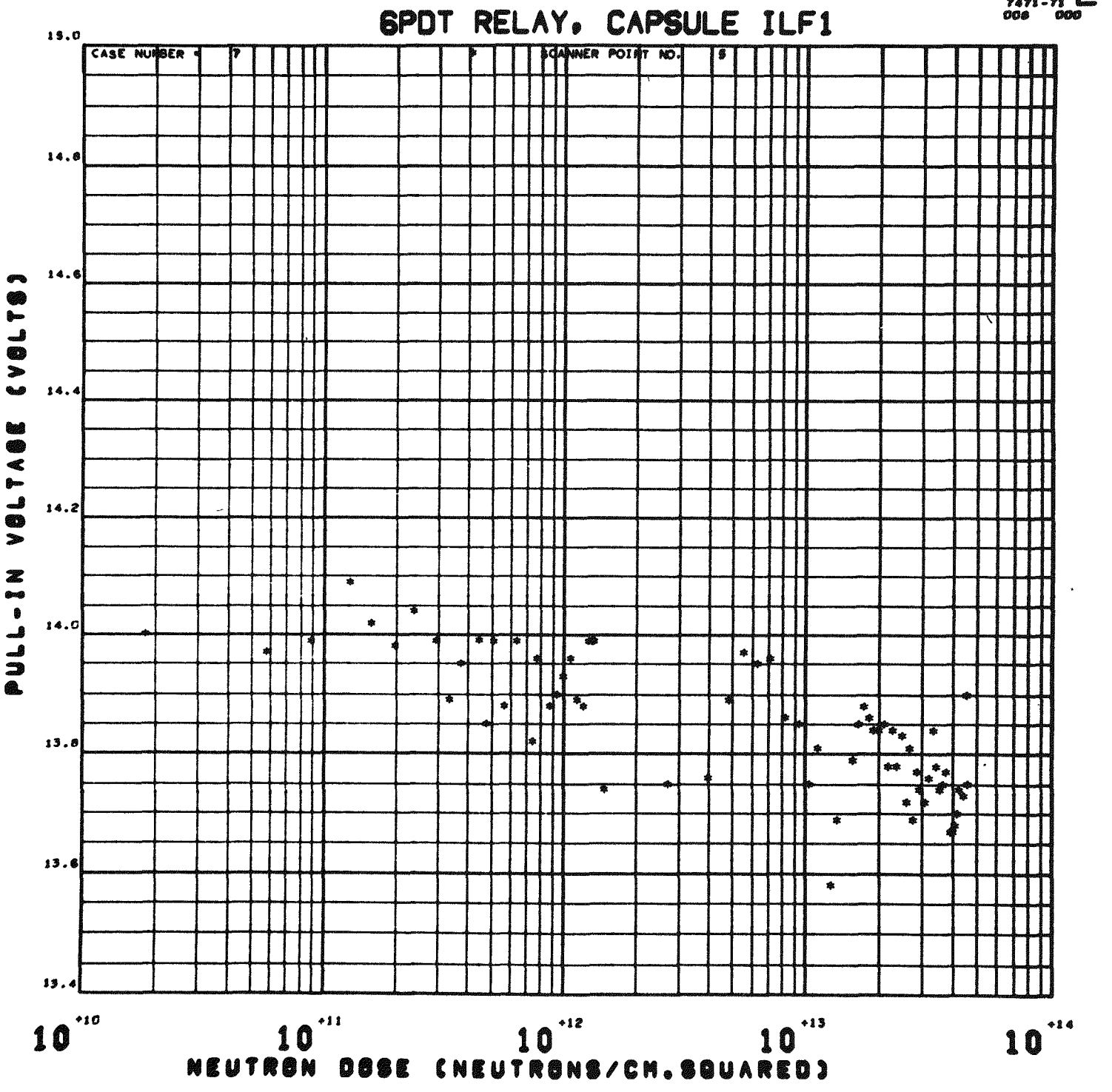
Graph 35

7471-71 L
008 000



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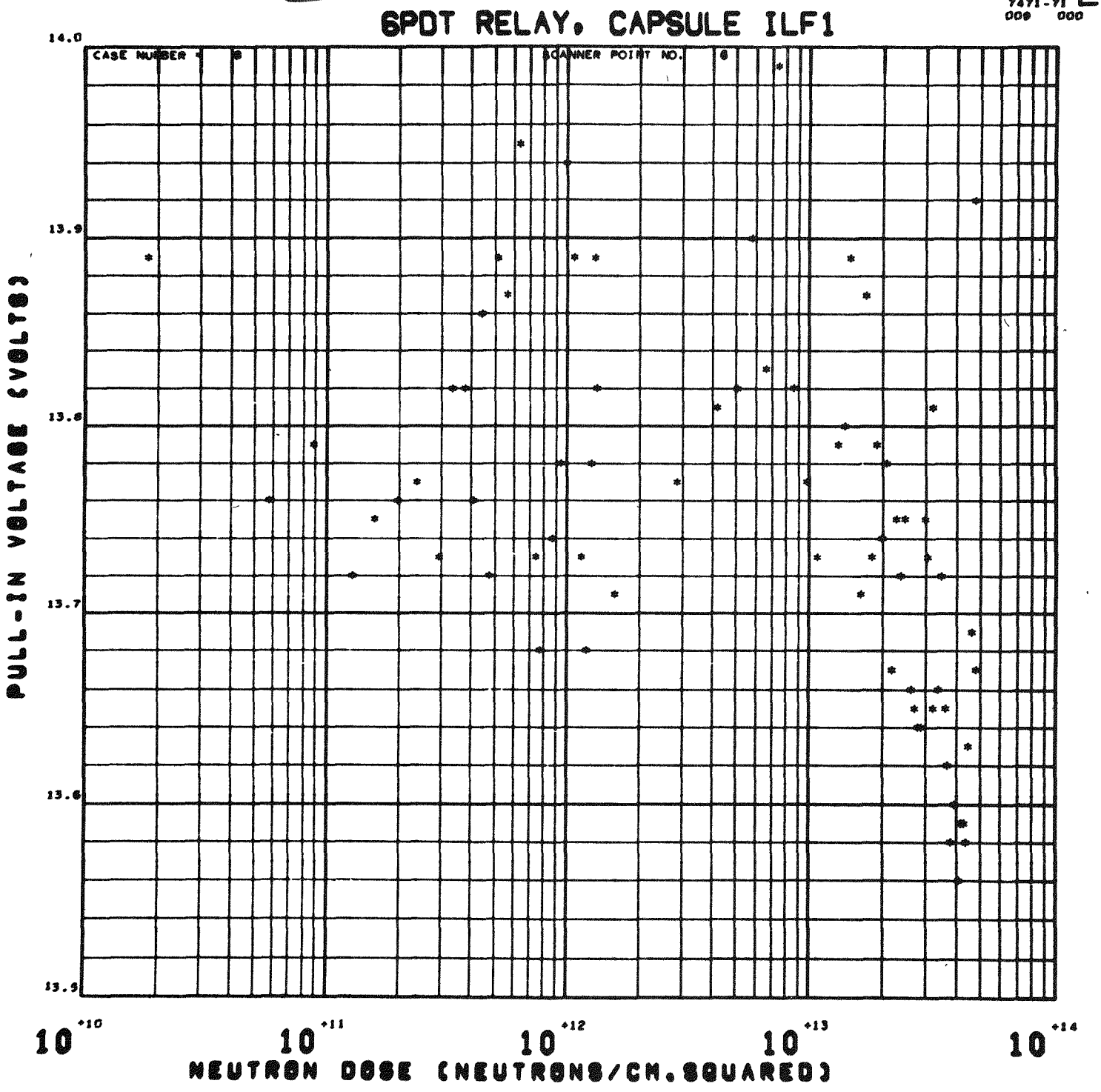
Graph 36

7471-71 L
009 000



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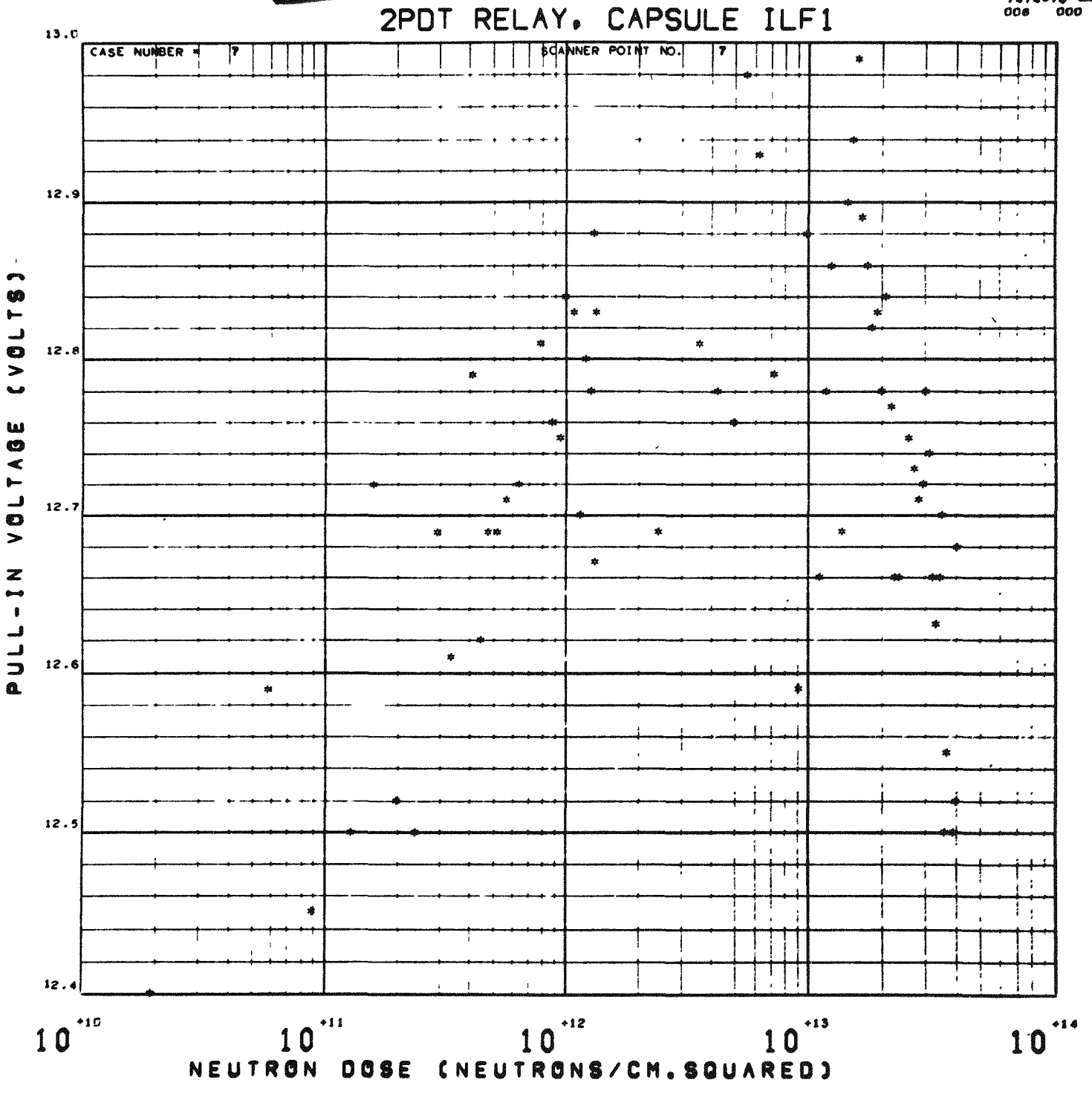
Graph 37

7474-76 L
008 000



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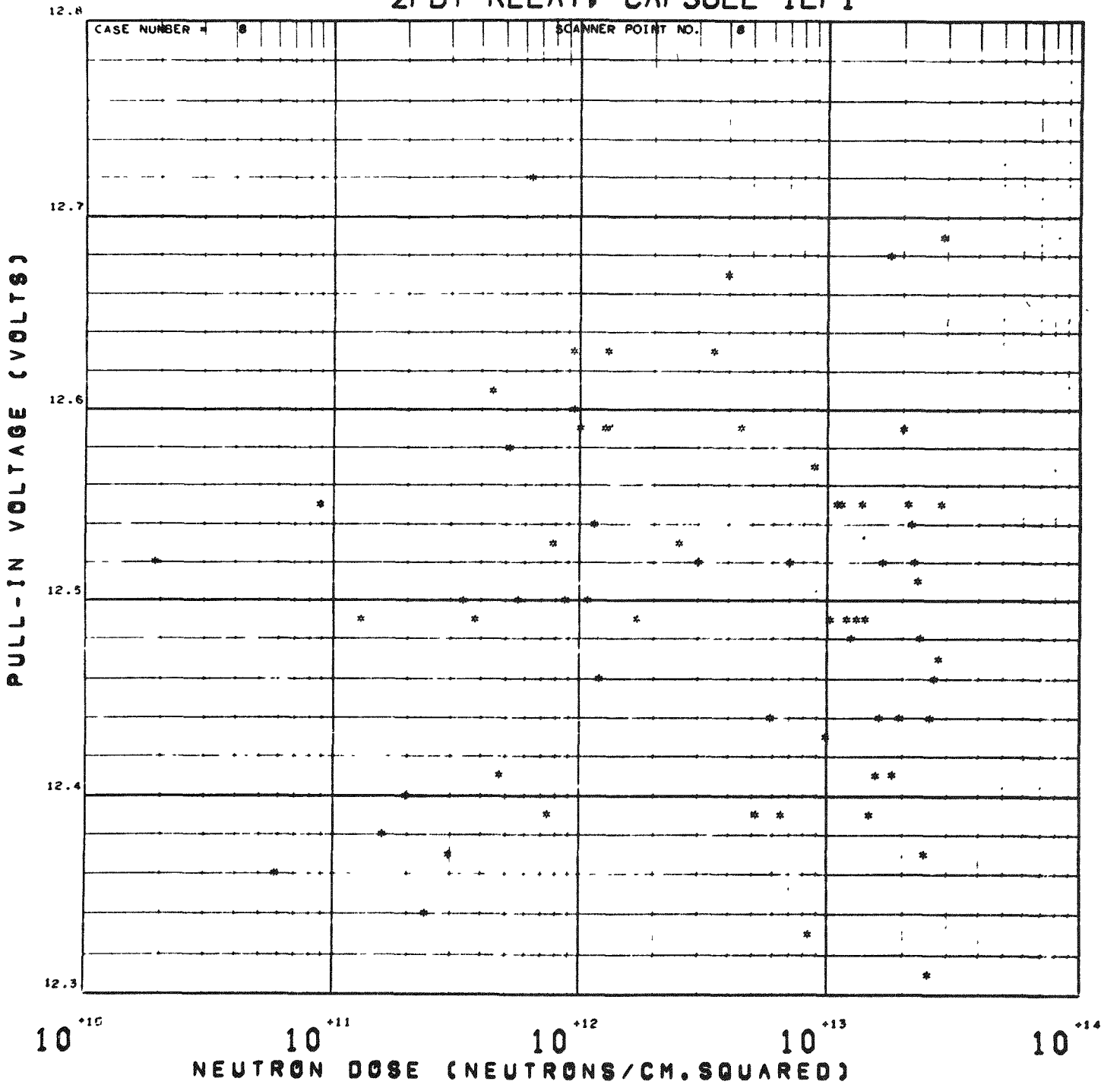
Graph 38

7474-76 L
009 000

2PDT RELAY, CAPSULE ILF1



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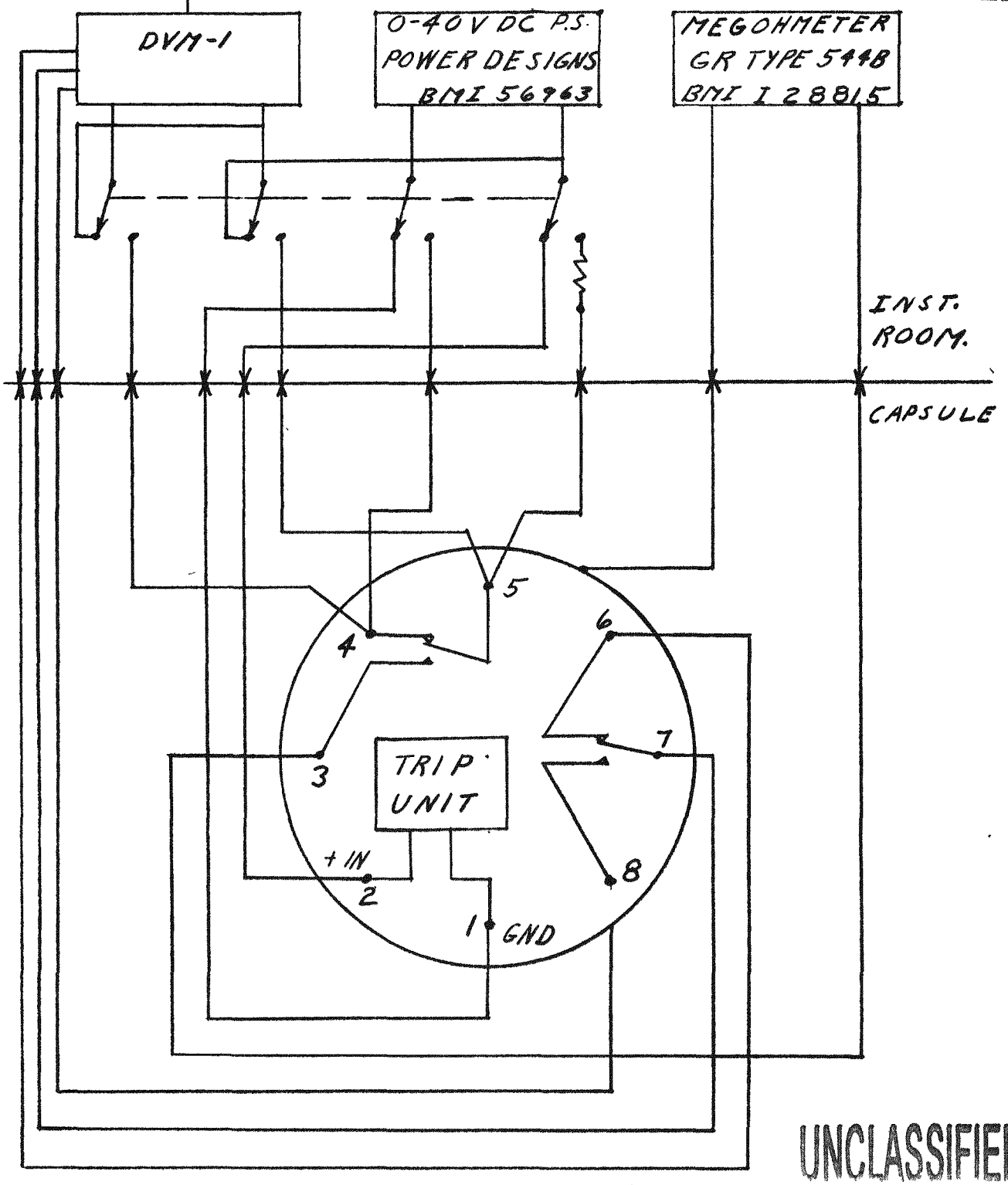
DVM-1 EI POWER UNIT MODEL 3000A AEC 64123
EI DVM MODEL 3400 AEC 64124
→ TO IBM CARD PUNCH

UNCLASSIFIED



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6.4 Low Voltage Trip Device

6.4.1 Test Setup The test setup for the low voltage trip devices is shown in figure 27.

6.4.2 Test Results Insulation resistance and contact resistance did not change significantly due to irradiation. The components tested were manufactured to the following specifications: trip voltage, 22.0 to 22.5 volts and reset voltage, 23.5 to 24 volts. Examination of the pre-irradiation and post-irradiation characteristics in Table 16 show only one marginal deviation from the specification. Table 16 does show a narrowing of the dead band due to irradiation.

TABLE 16

LOW VOLTAGE TRIP DEVICE

No.	Reset Volts Pre-Ir.	Reset Volts Post-Ir.	Trip Volts Pre-Ir.	Trip Volts Post-Ir.	Dead Band Volts Pre-Ir.	Dead Band Volts Post-Ir.
A3271	23.7	23.6	22.1	22.4	1.6	1.2
A3272	23.7	23.6	22.1	22.4	1.6	1.2
A3273	23.9	23.7	22.3	22.6	1.6	1.1
A3274	23.8	23.7	22.2	22.5	1.6	1.2

Graphs 39 through 42 show that the insulation resistance was adequate during irradiation.

Graphs 43 through 46 show a favorable slight decrease in contact resistance during irradiation.

Drop-out and reset measurements during irradiation were extremely erratic. Since both pre-irradiation and post-irradiation data were repeatable and steady, very little confidence can be placed in the data presented in graphs 47 through 50 which show the drop-out voltage and graphs 51 through 54 which show the reset voltage.

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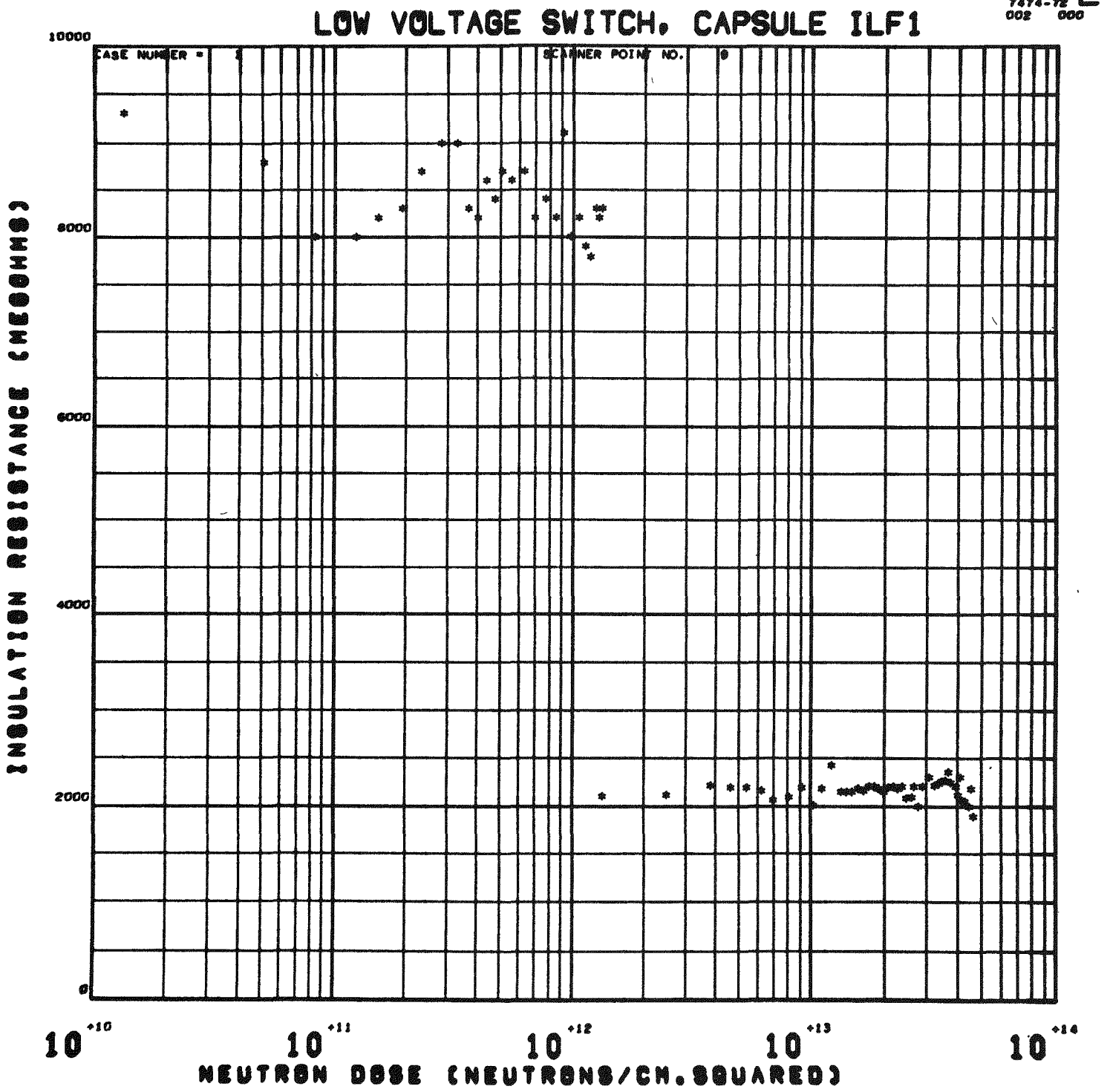
Graph 39

7474-72 L
002 000



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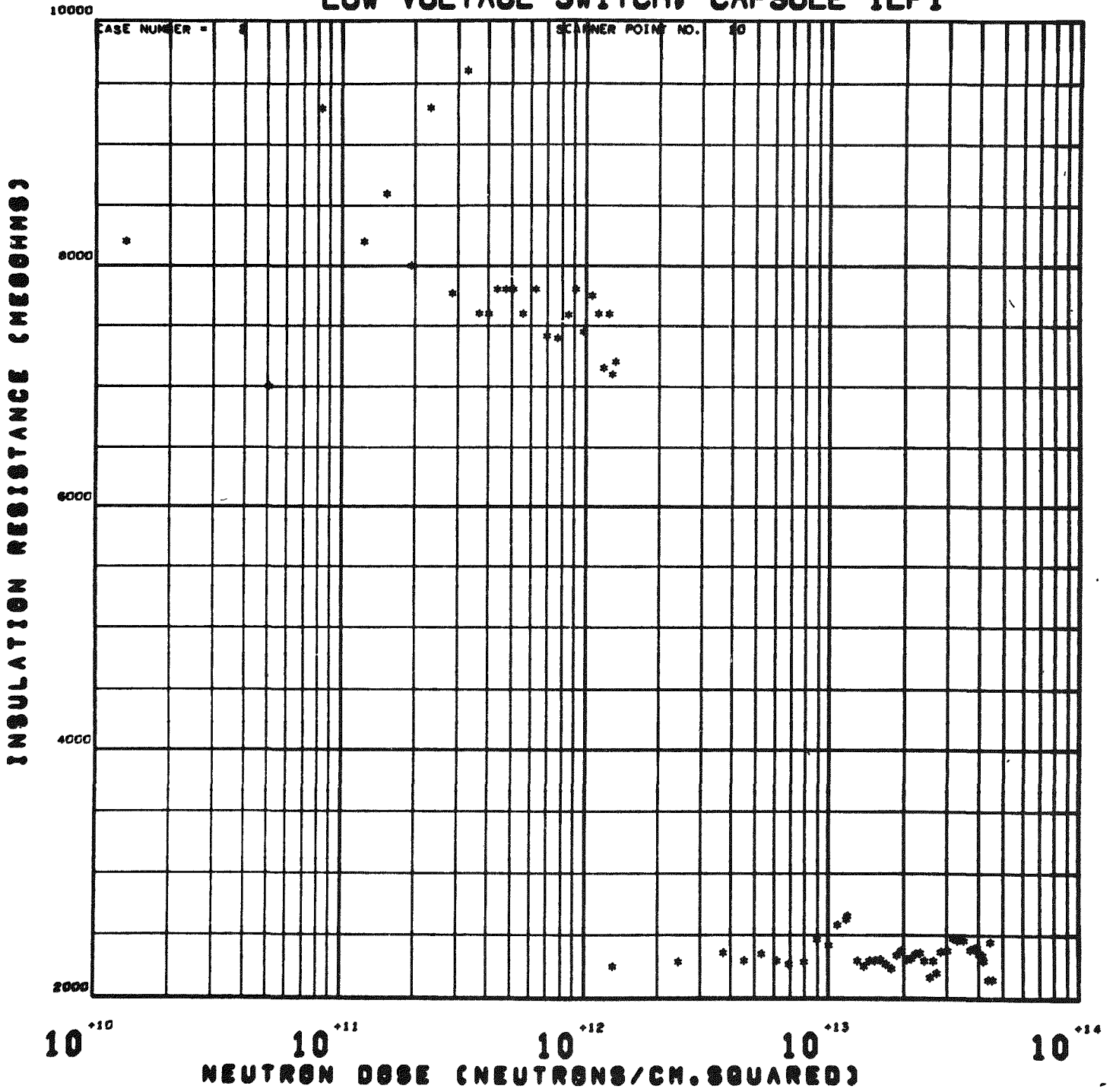
7474-72 L
003 000

LOW VOLTAGE SWITCH, CAPSULE ILF1



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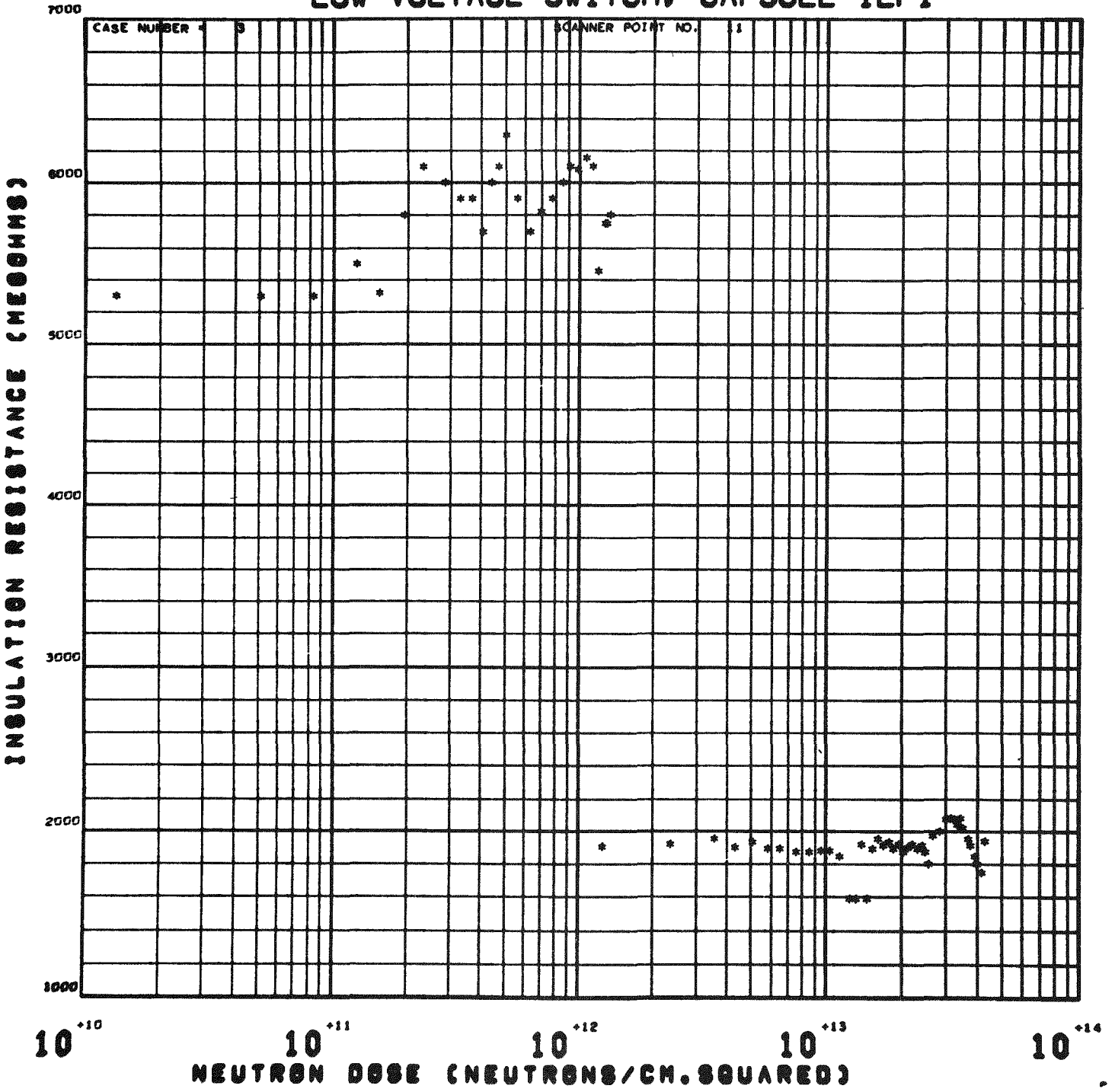
[redacted]

Graph 41

7474-72 L
004 000

LOW VOLTAGE SWITCH, CAPSULE ILF1



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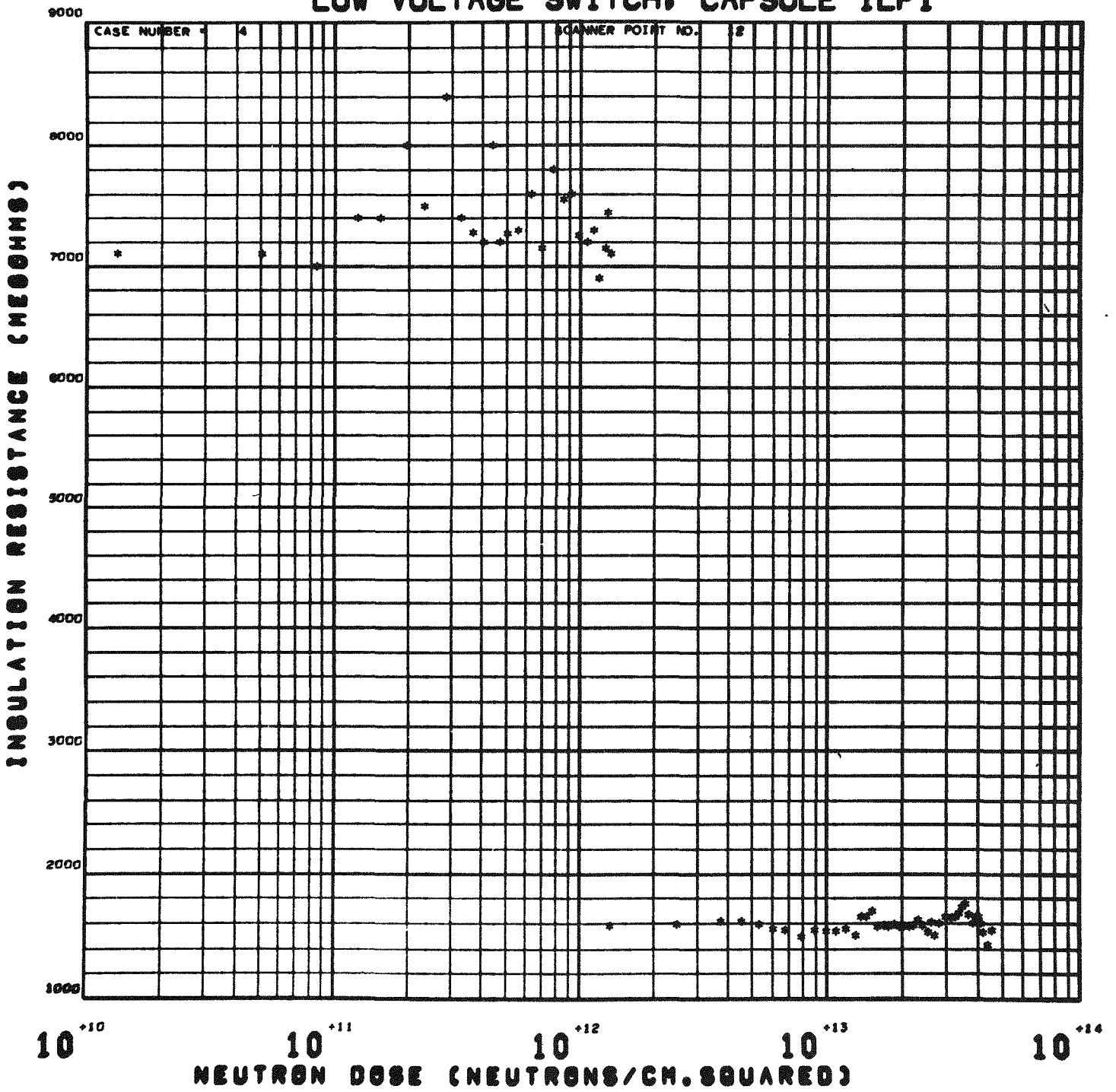
Graph 42

7474-72 L
005 000

LOW VOLTAGE SWITCH, CAPSULE ILF1



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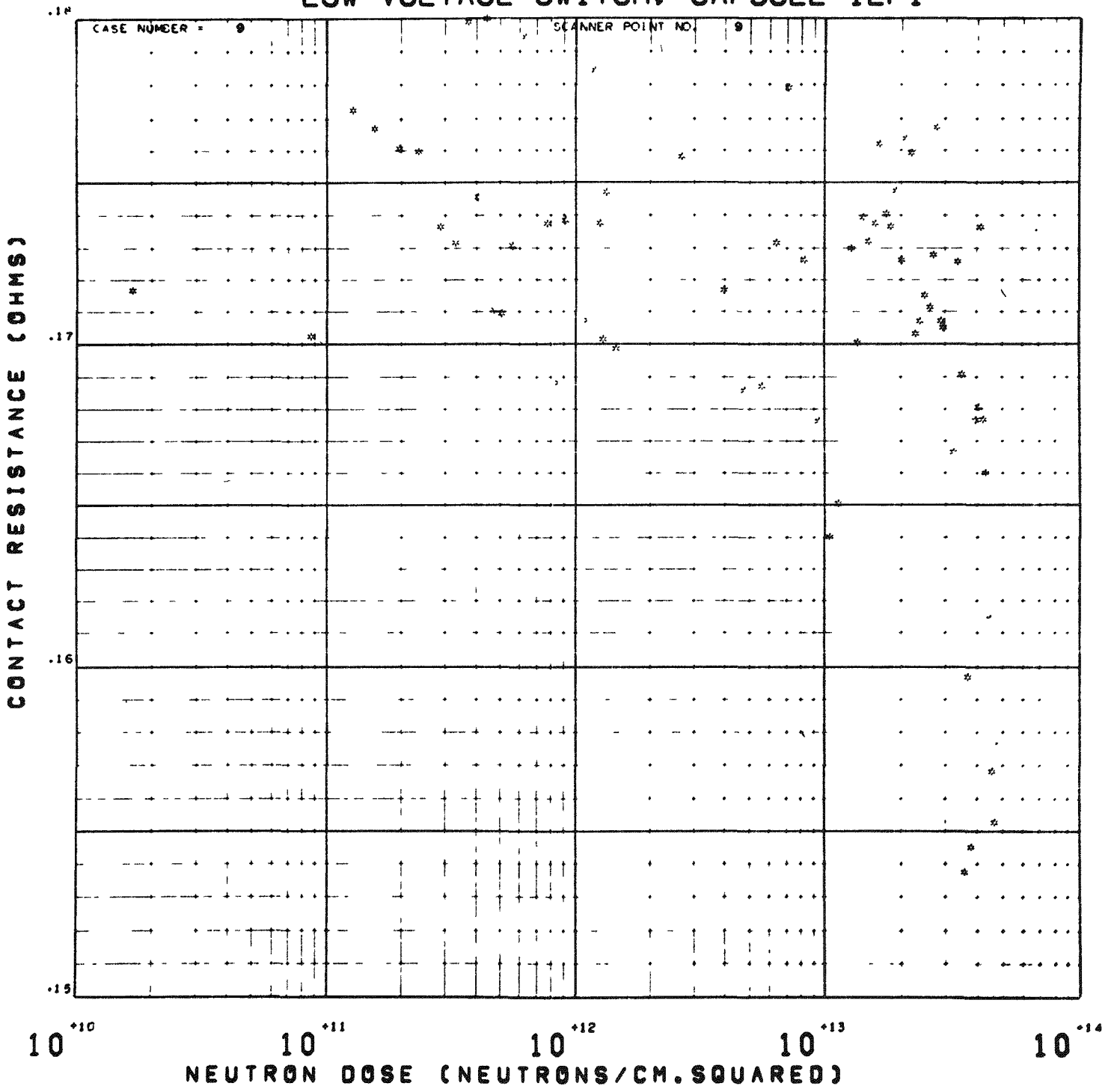
Graph 43

[redacted]

7474-66 L
CIC CCC

LOW VOLTAGE SWITCH, CAPSULE ILF1



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Graph 44

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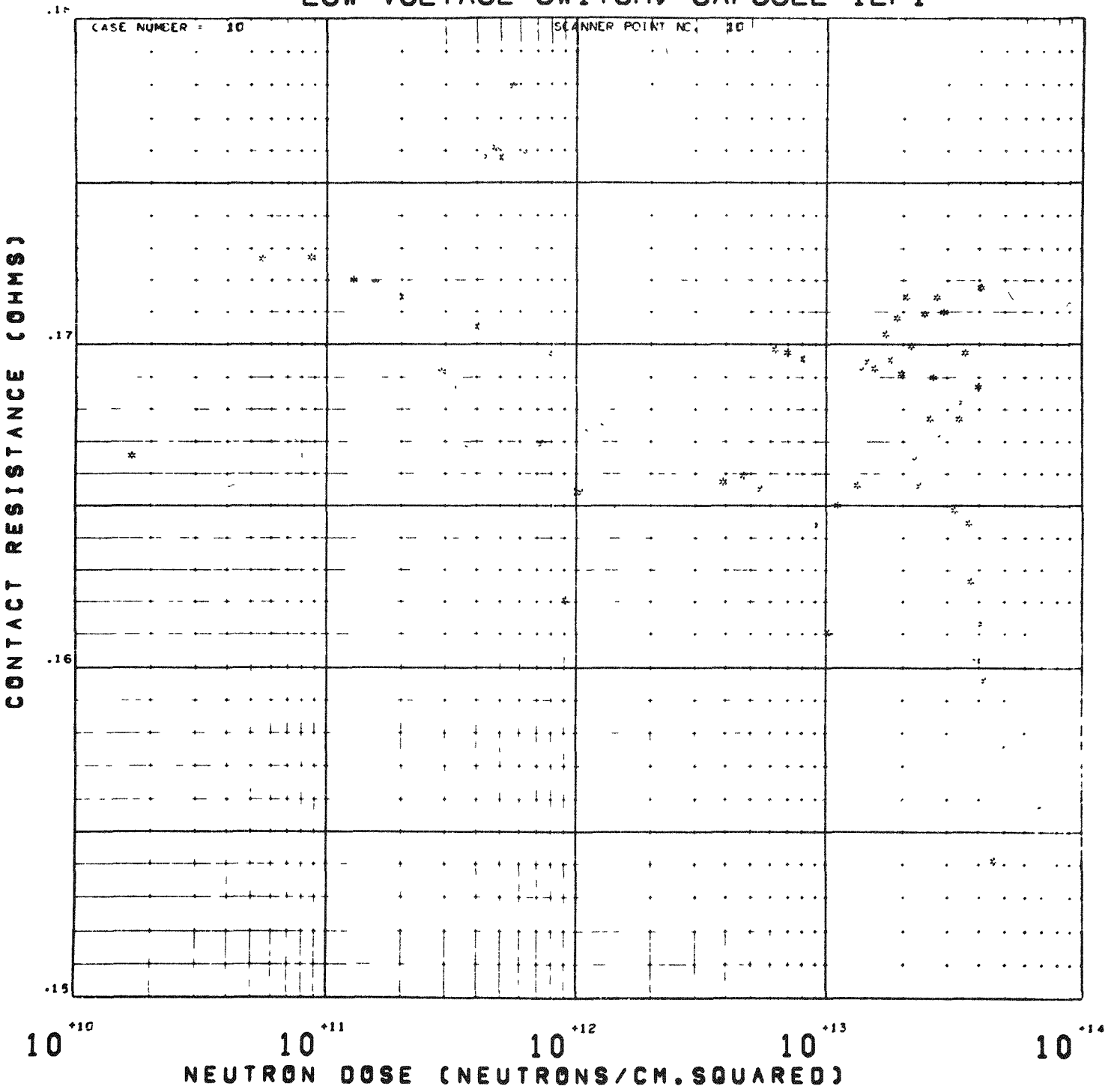
7474-66 L
C11 000

LOW VOLTAGE SWITCH, CAPSULE ILF1



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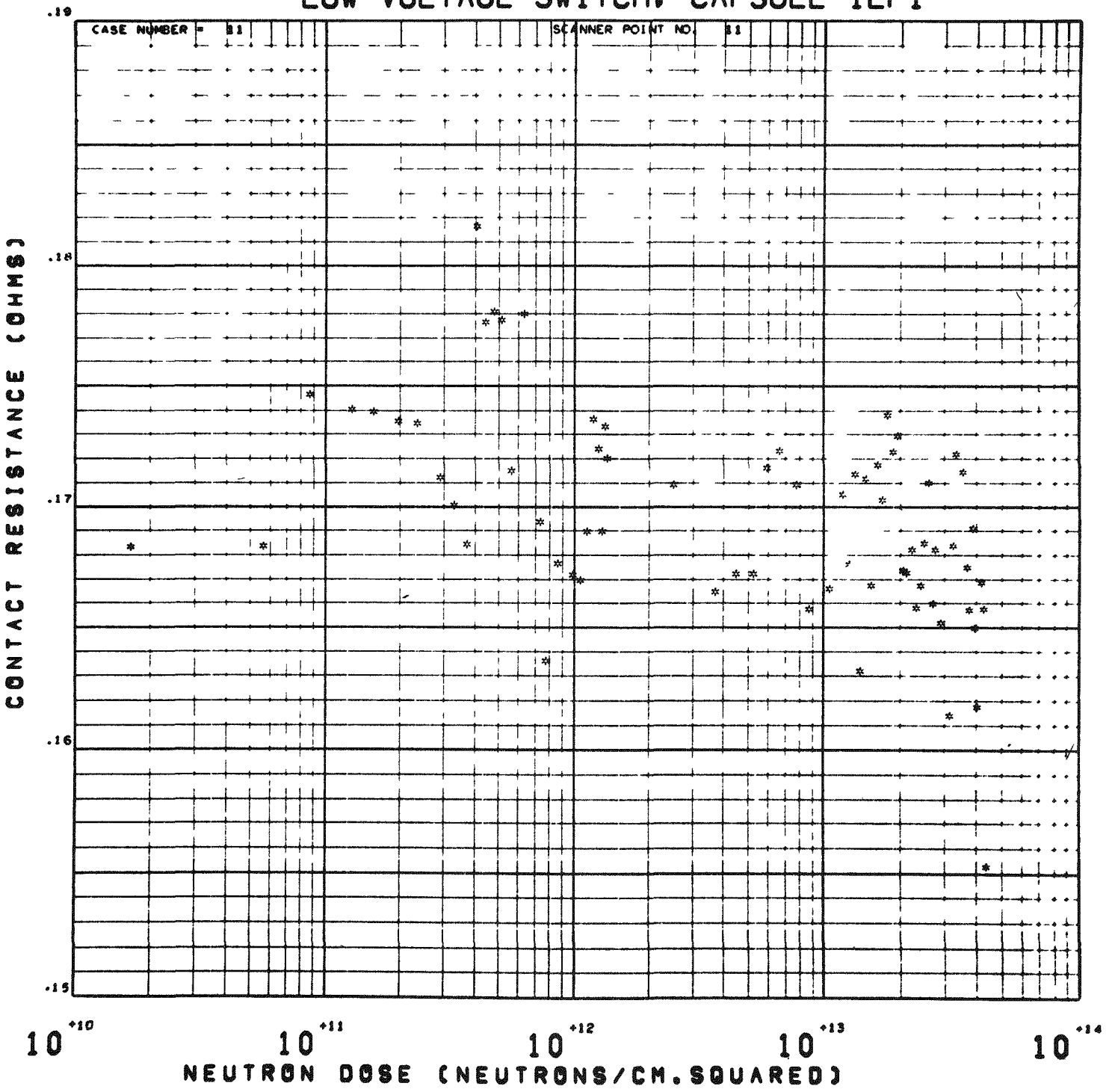
Graph 45

7474-66 L
012 000

LOW VOLTAGE SWITCH, CAPSULE ILF1



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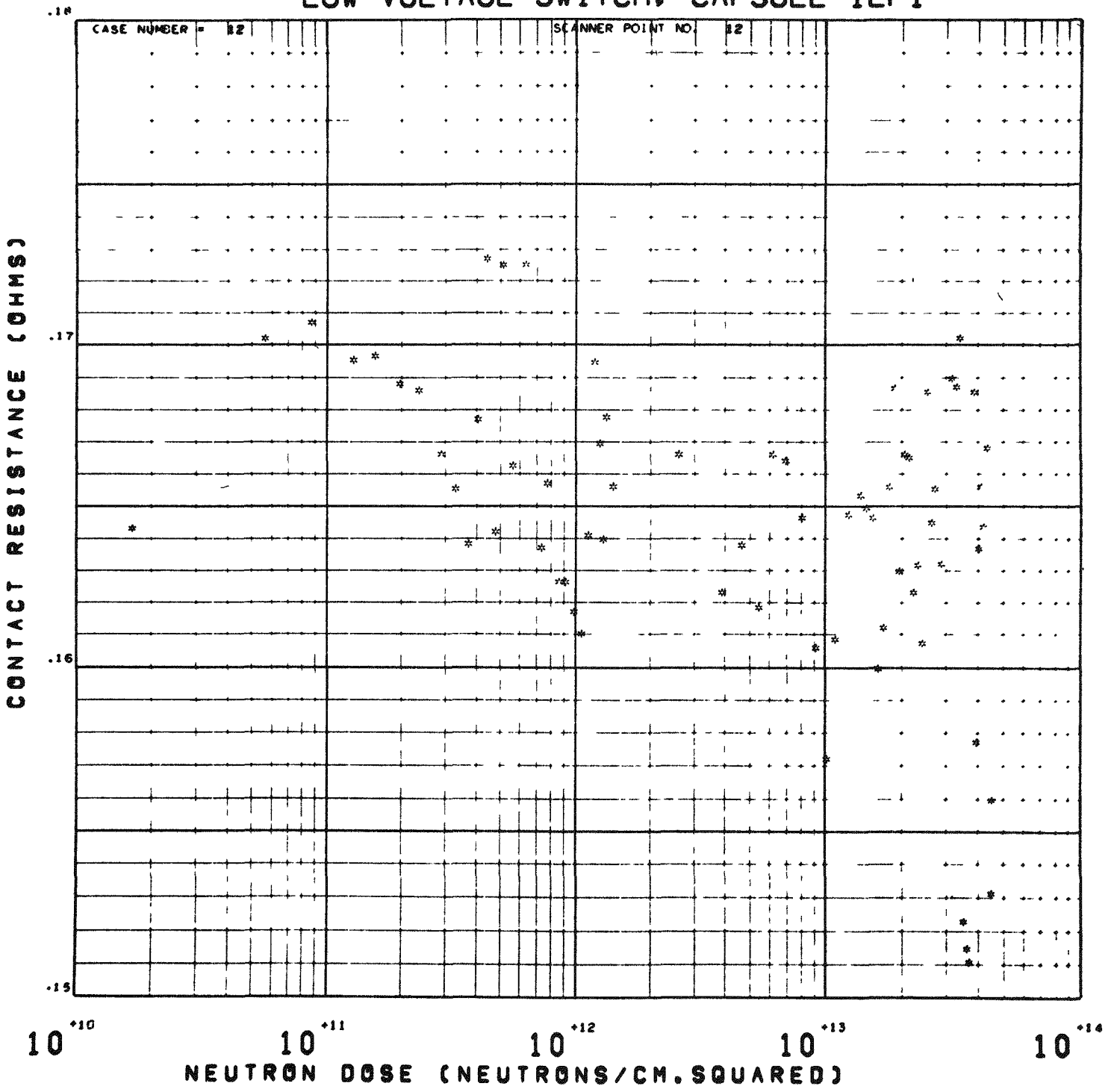
Graph 46

7474-66 L
C13 000

LOW VOLTAGE SWITCH, CAPSULE ILF1



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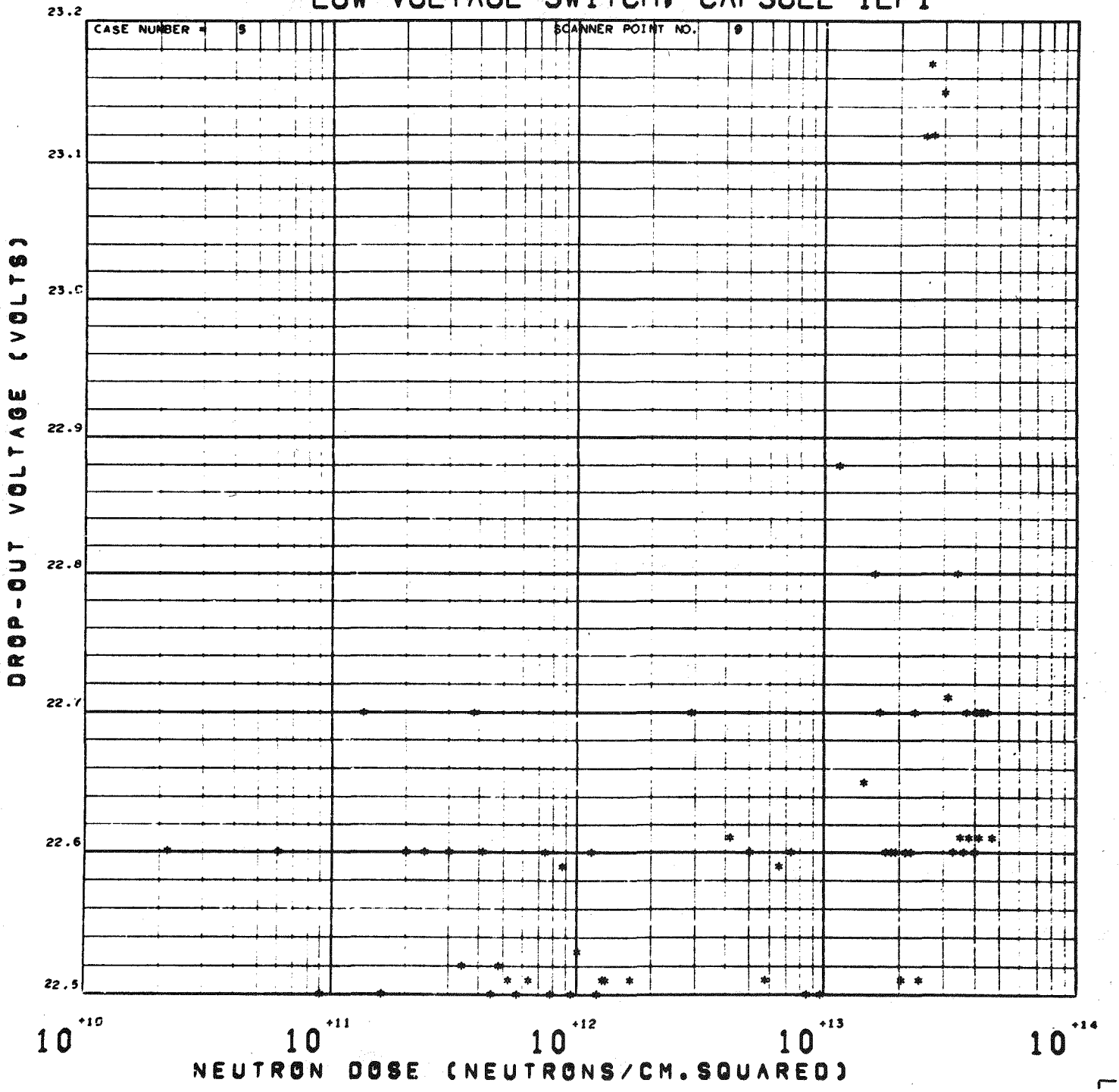
Graph 47

7474-79 L
006 000

LOW VOLTAGE SWITCH, CAPSULE ILF1



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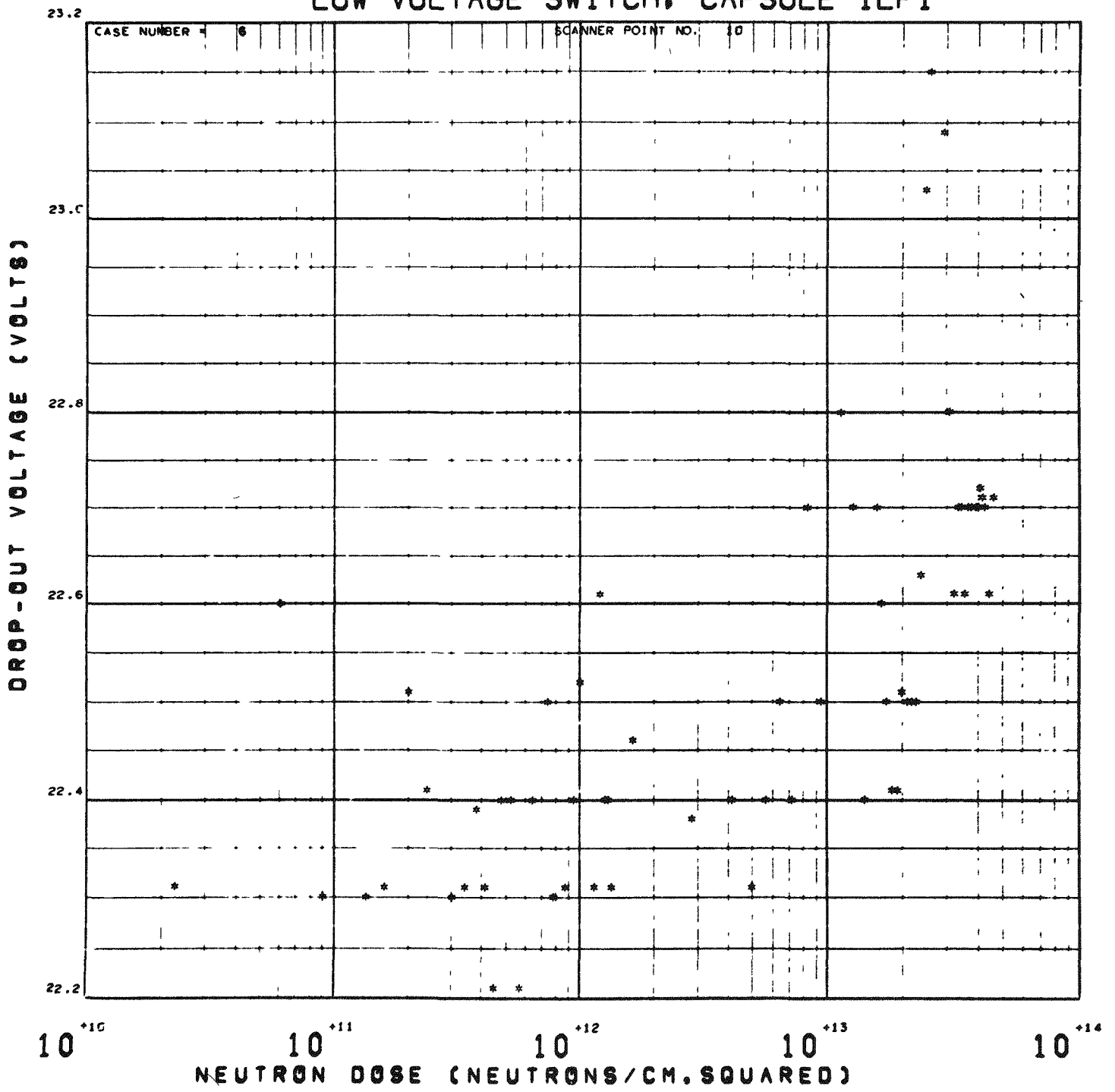
7474-79 L
007 000

LOW VOLTAGE SWITCH, CAPSULE ILF1



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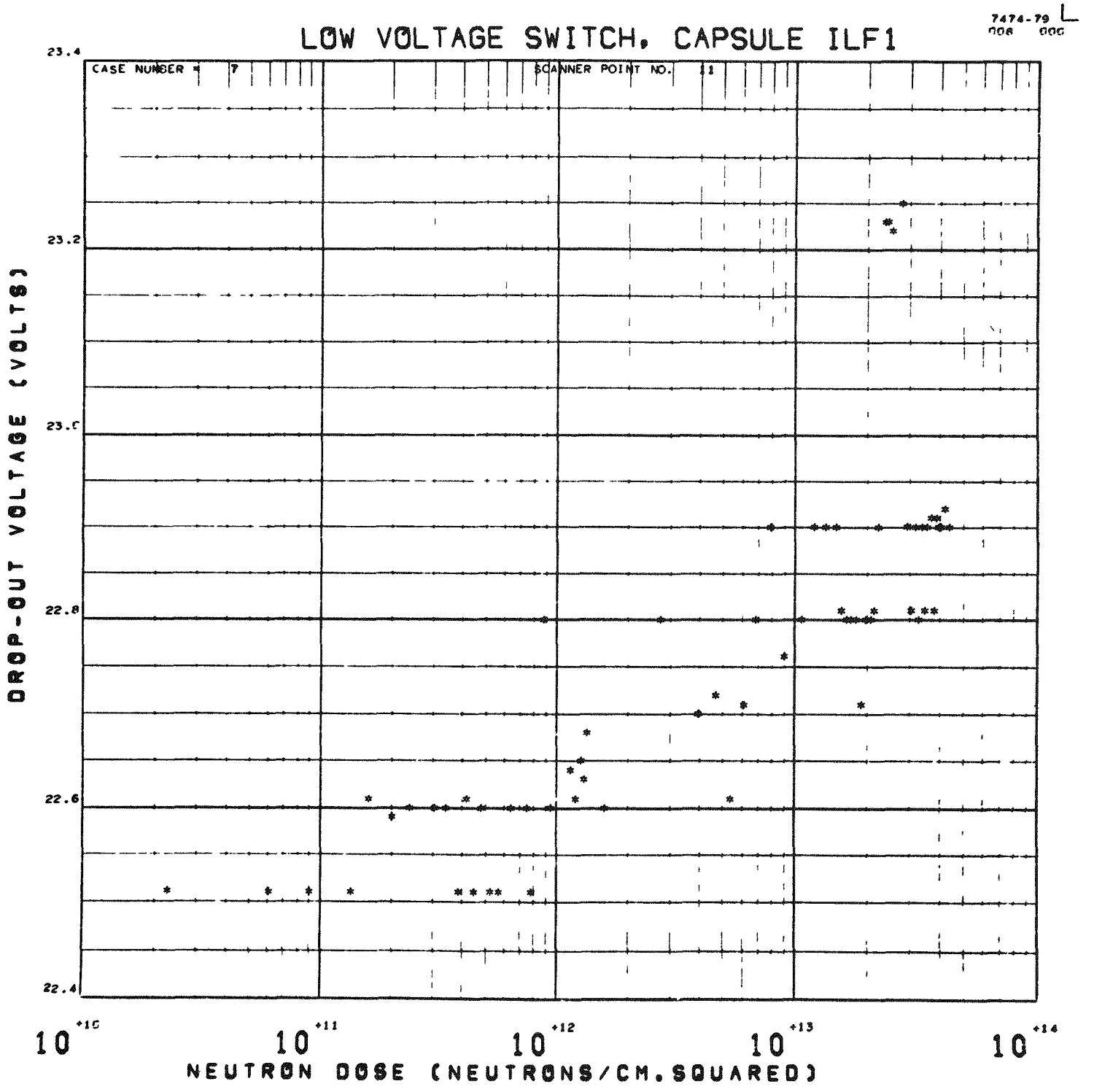
Graph 49



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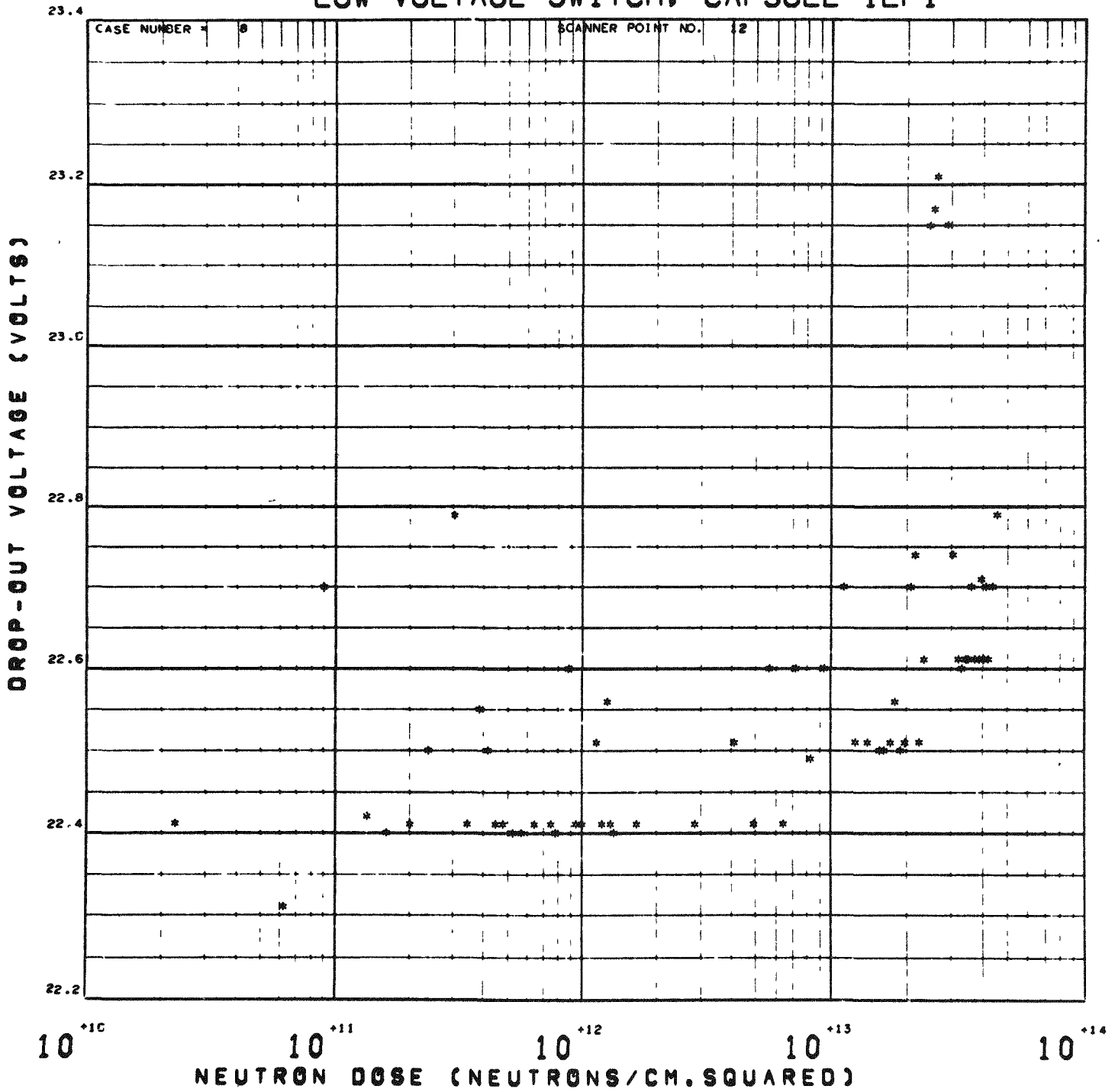
Graph 50

7474-79 L
009 000

LOW VOLTAGE SWITCH, CAPSULE ILF1



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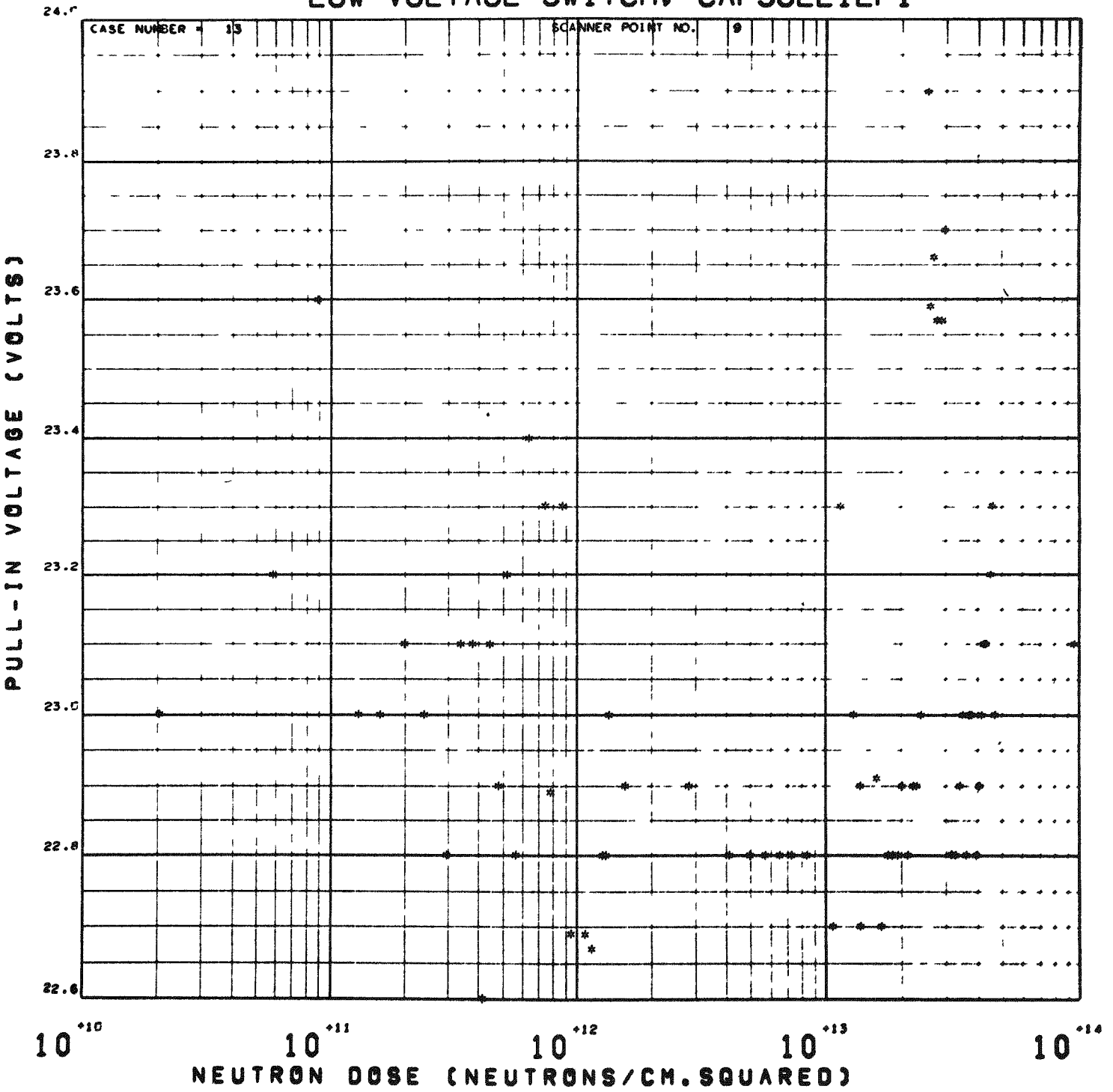
Graph 51

7474-66 L
014 000

LOW VOLTAGE SWITCH, CAPSULEILF1



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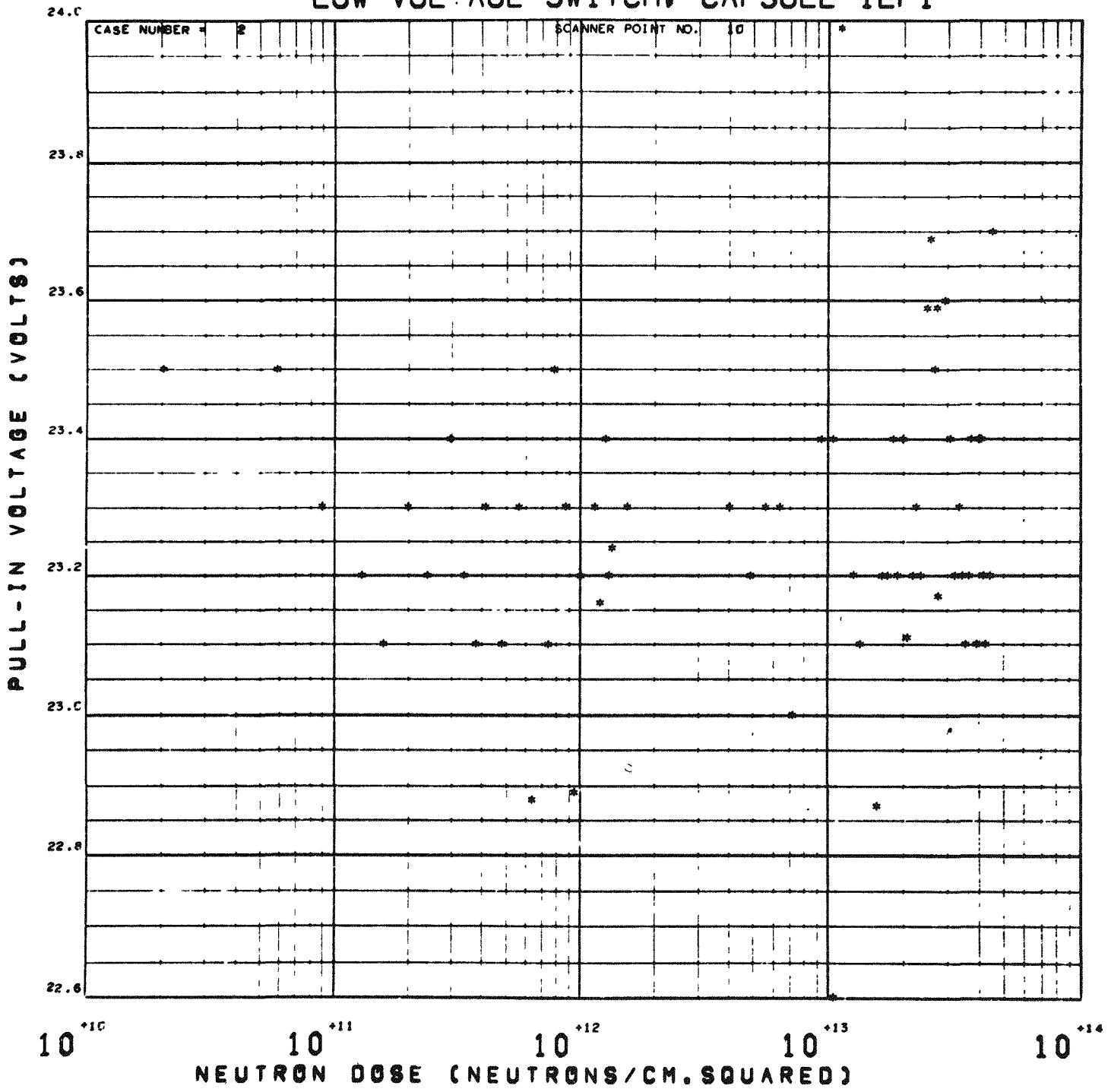
Graph 52

7474-79 L
003 000

LOW VOLTAGE SWITCH, CAPSULE ILF1



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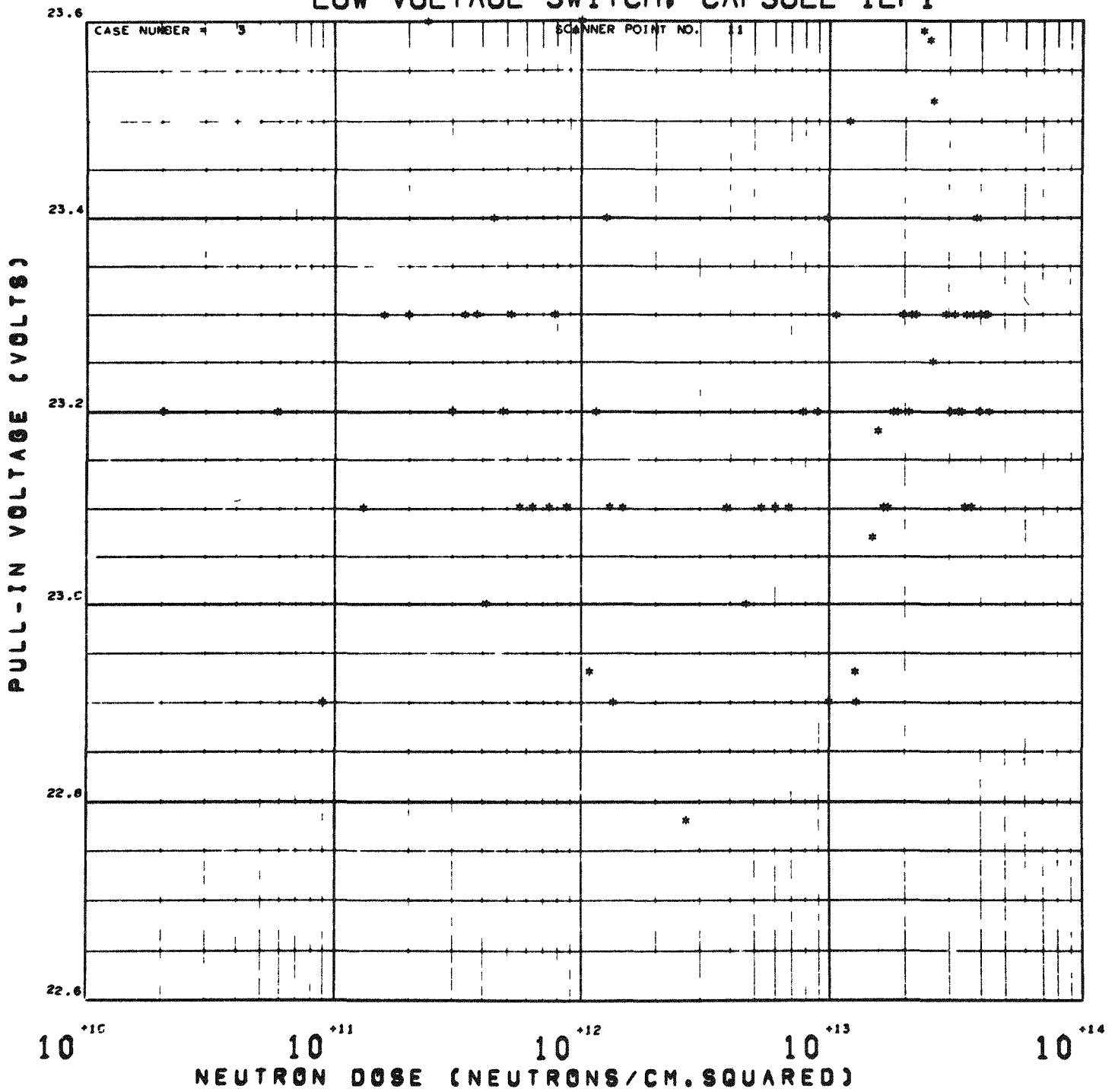
Graph 53

7474-79 L
004 000

LOW VOLTAGE SWITCH, CAPSULE ILF1



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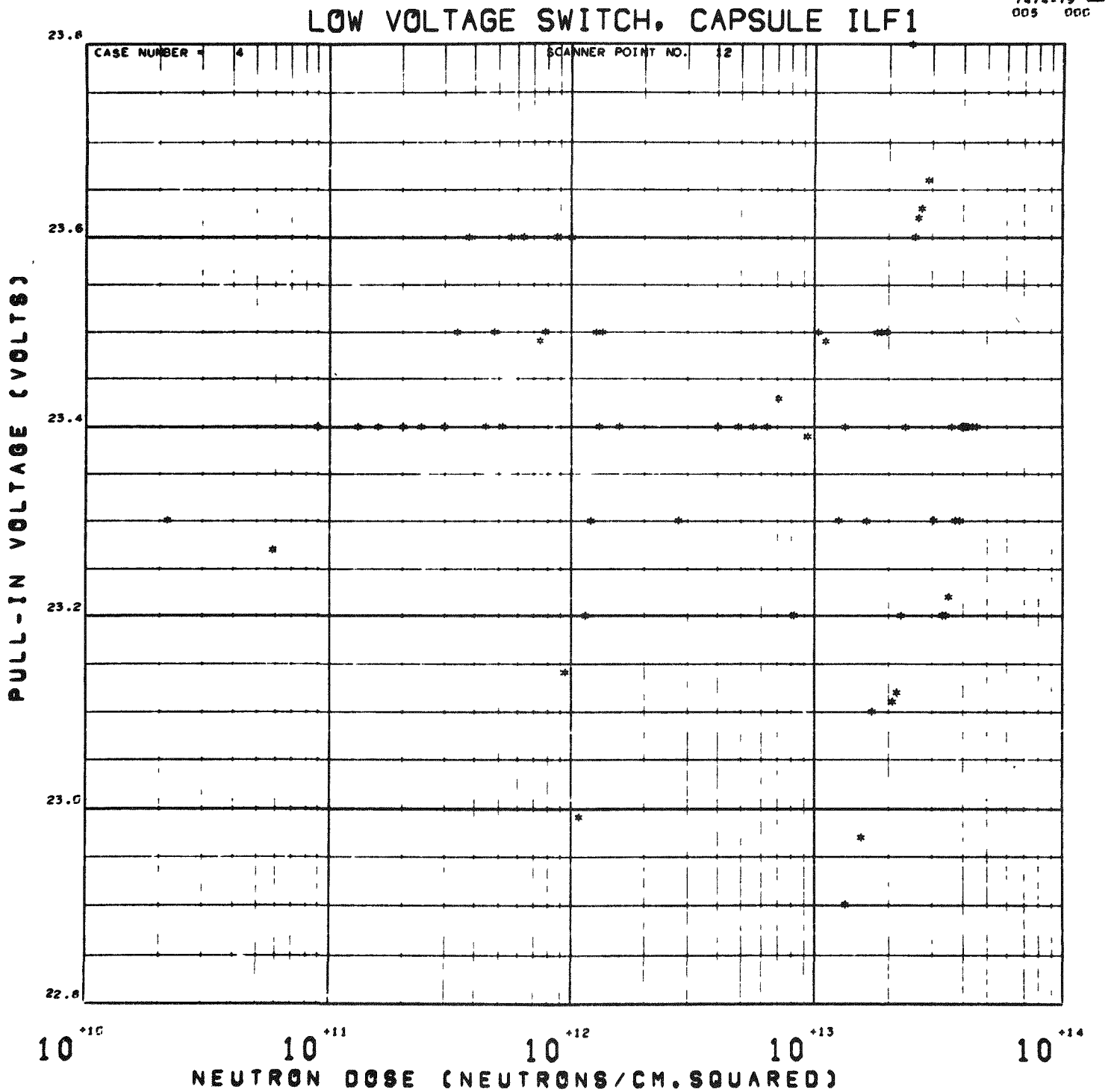
Graph 54

7474-79 L
005 000



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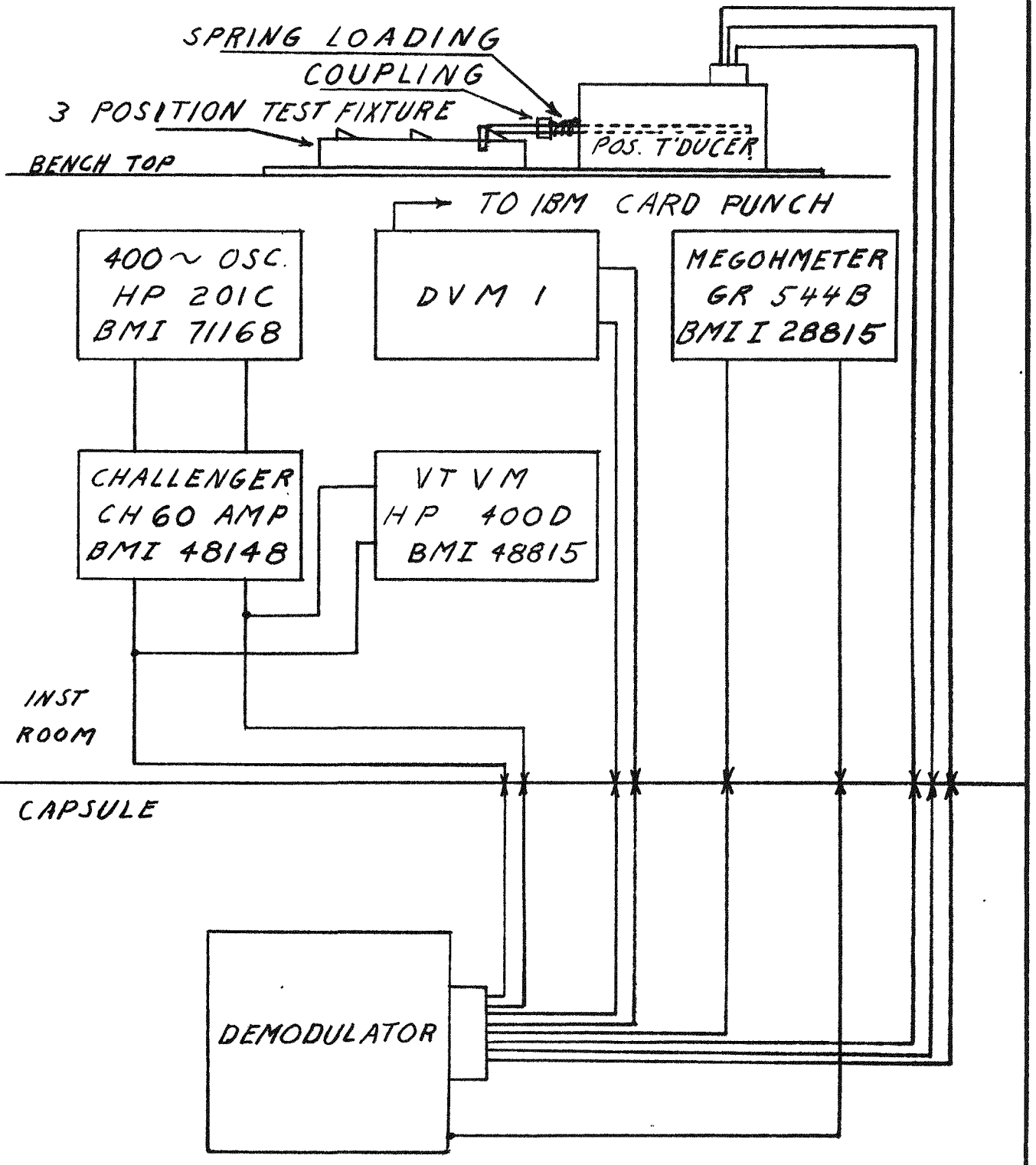
DVM I EI MODELS 3000A AEC 64123, 3400 AEC 64124



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6.5 Expansion Compensator Position Demodulator

6.5.1 Test Setup Figure 28 shows the test setup. Only the demodulator was irradiated. The position transducer was installed in the instrument room in a test fixture. The electrical output was monitored during irradiation at three mechanically repeatable core positions (null, 1", and 2"). The electrical outputs at each position after temperature stabilization of 140°F in a negligible flux position were 0.8 mv., 27.9 mv., and 56.9 mv. respectively.

Graphs 56 through 58 show the outputs for each of the three transducer positions. Most of the scatter in the data is due to poor voltage and frequency regulation of the test.

6.5.2 Test Results Table 17 compares the pre-irradiation and post-irradiation electrical outputs at ambient temperature. No significant change or trend is evident.

TABLE 17

EXPANSION COMPENSATOR POSITION DEMODULATOR

Core Position in Inches	Pre-irrad. mv. out	Post-irrad. mv. out
0.0	0.0	0.0
0.2	4.8	5.04
0.4	10.9	9.91
0.6	16.2	15.00
0.8	20.5	20.46
1.0	26.2	25.86
1.2	31.6	31.54
1.4	36.7	36.43
1.6	42.3	42.42
1.8	47.6	47.54
2.0	52.6	53.01

Graph 55 shows that the insulation resistance was always much greater than the specification requirement of 10^7 ohms.

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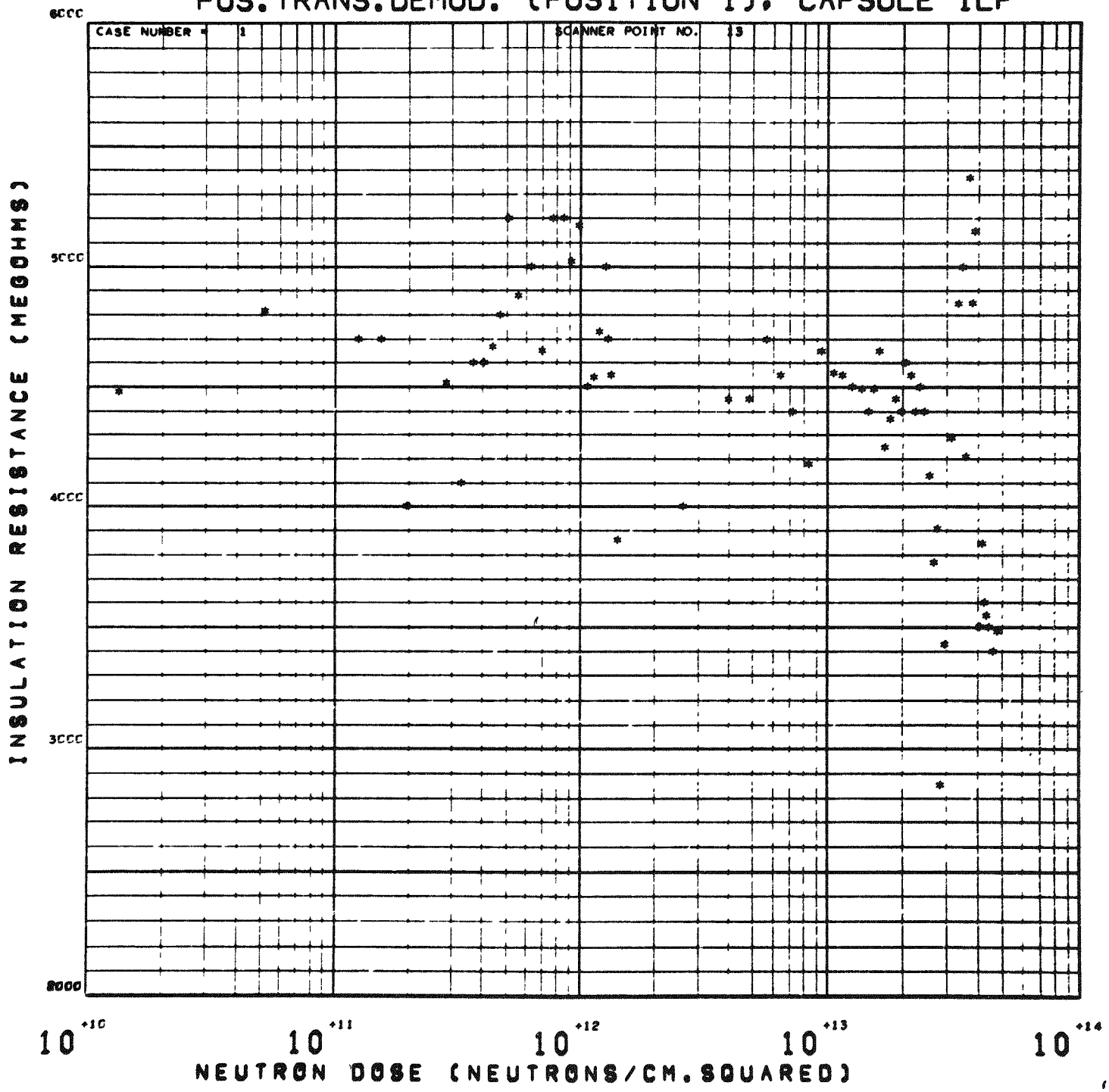
Graph 55

[redacted]

7474-79 L
002 000

POS. TRANS. DEMOD. (POSITION 1), CAPSULE ILF



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7474-79 L
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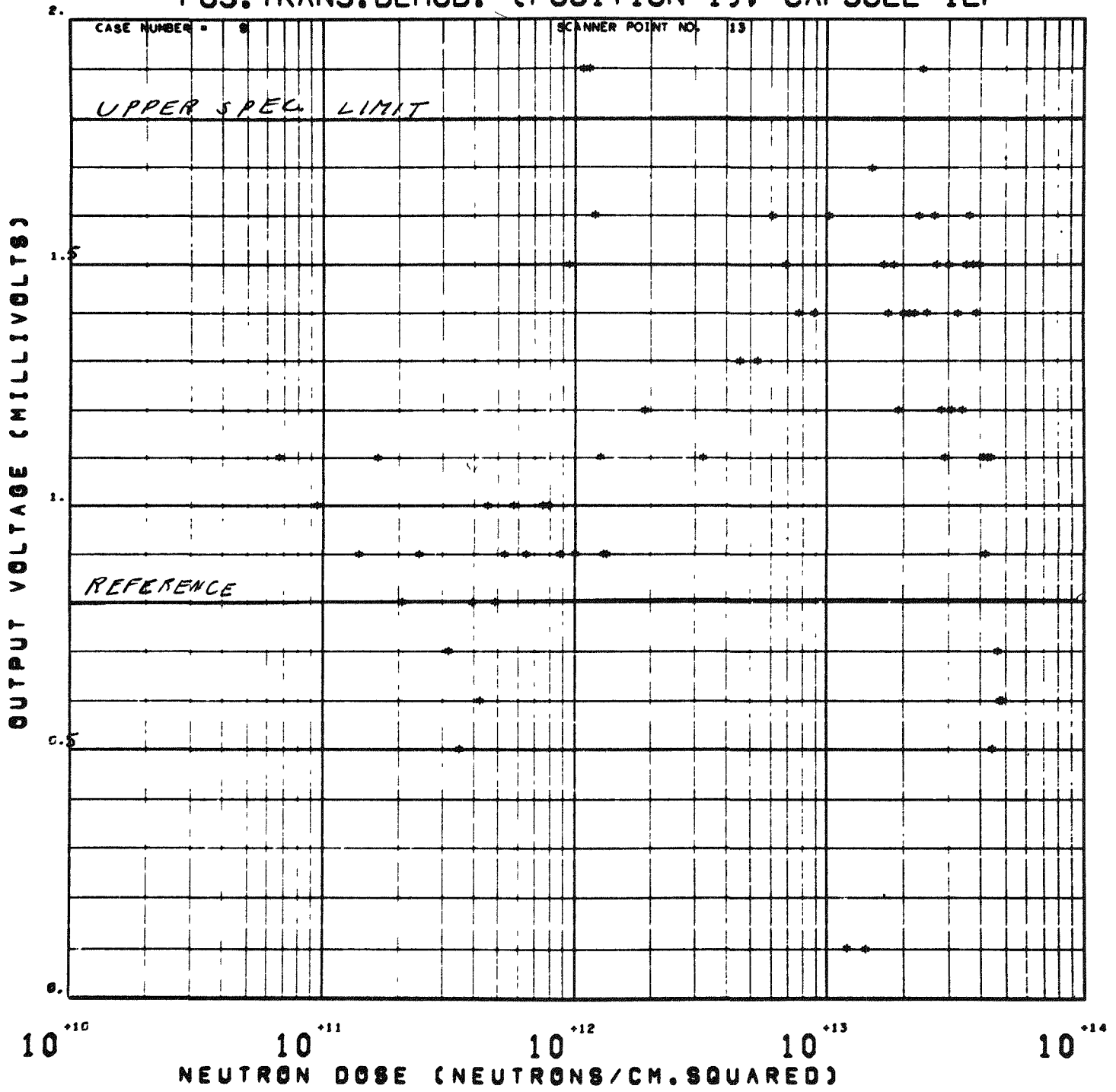
POS. TRANS. DEMOD. (POSITION 1). CAPSULE ILF



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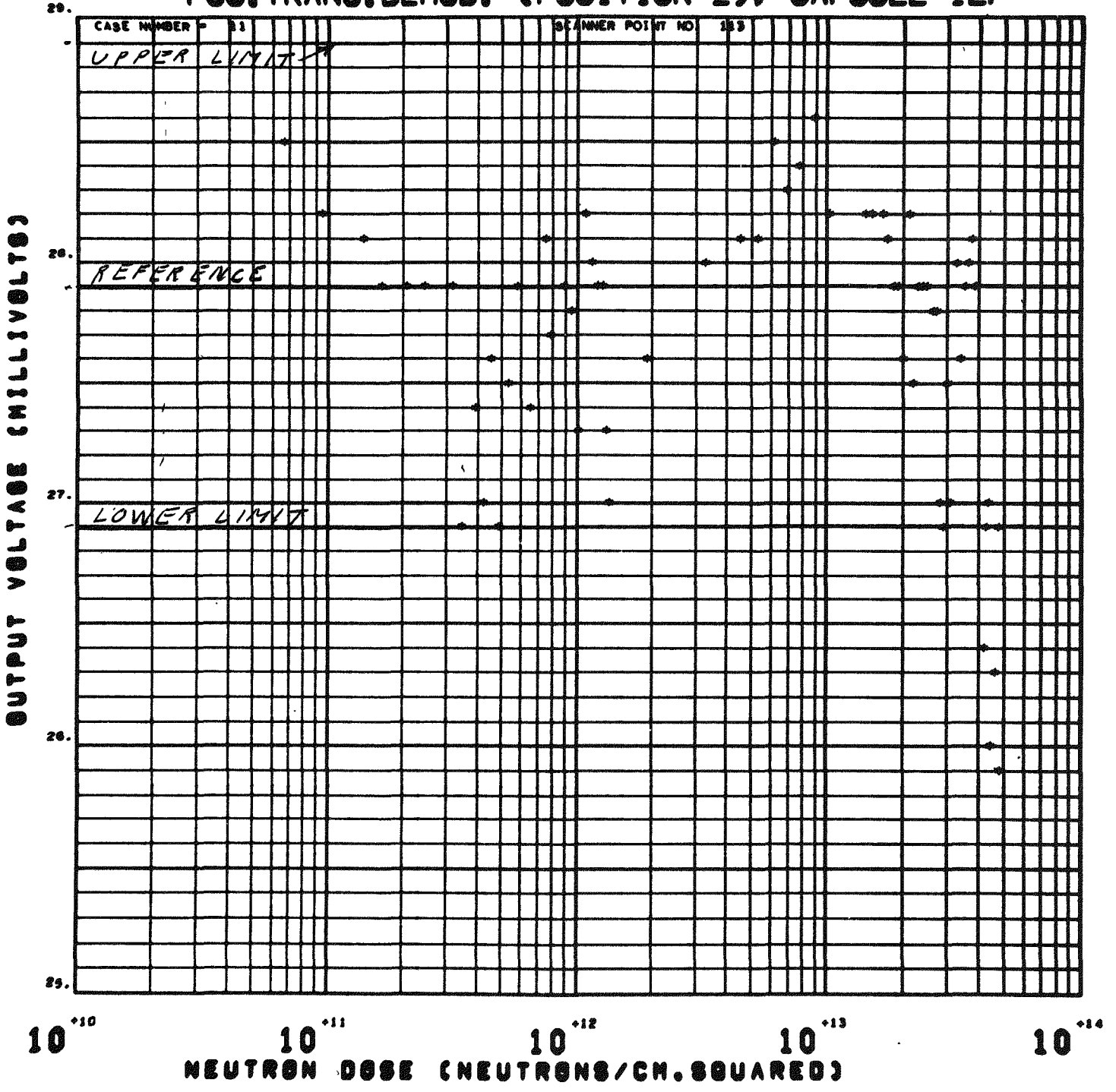
[redacted]

Graph 57

7471-71 L
012 000

POS. TRANS. DEMOD. (POSITION 2). CAPSULE ILF



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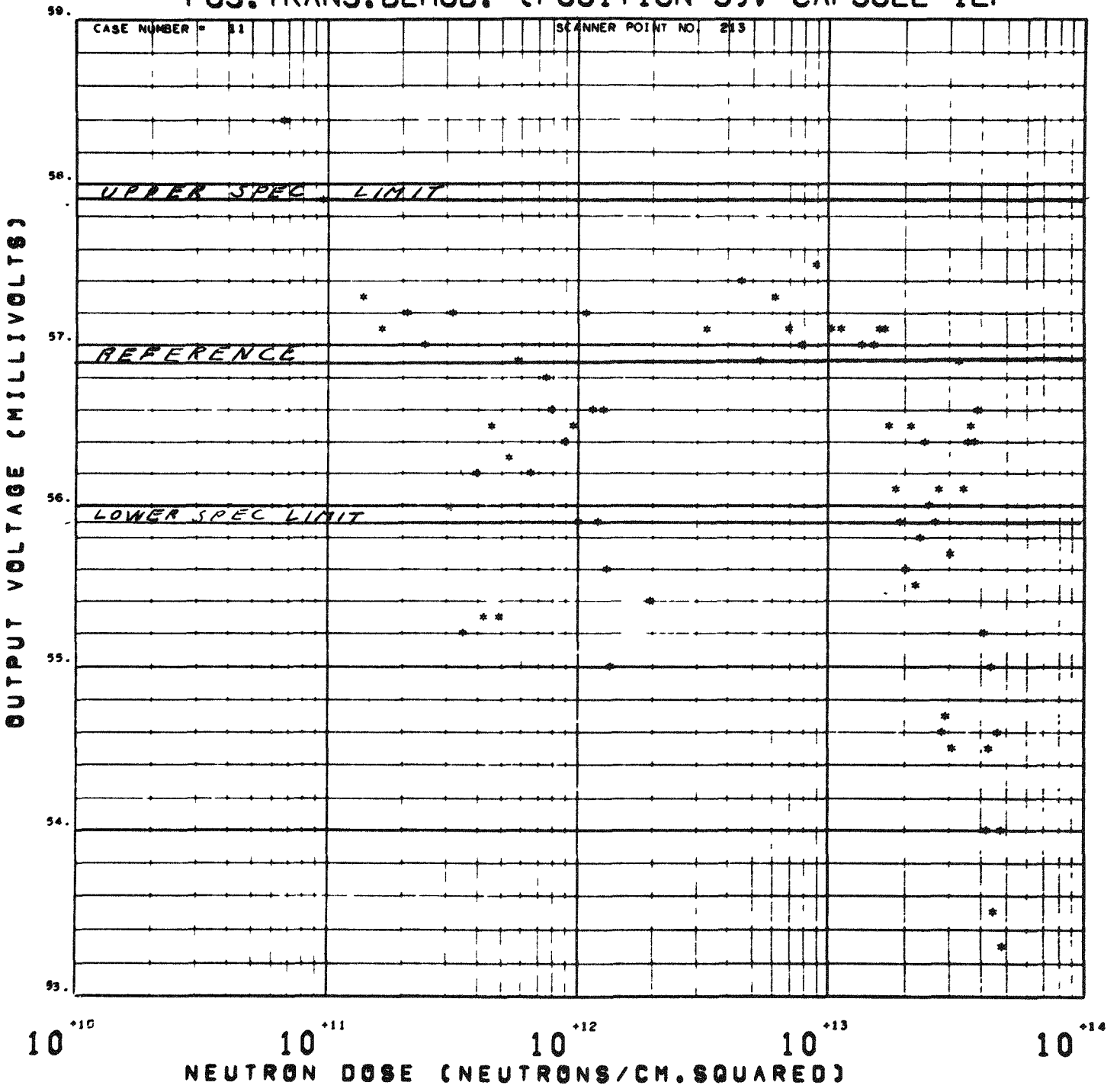
[redacted]

7474-76 L
012 000

POS. TRANS. DEMOD. (POSITION 3). CAPSULE ILF



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6.6 Resistance Thermometer Sensor and Bridge

6.6.1 Test Setup The test setup is shown in figure 29 using an RT 6, 0 to 300°F range, and an RTD bridge.

6.6.2 Test Results The temperature indicated by the RTD during irradiation was consistently 3 to 5° higher than the temperature indicated by two TC's fastened to the sensor.

Both the sensor and bridge were within specification in post-irradiation calibration. Comparison of post-irradiation and pre-irradiation calibration shows a slight shift toward a higher mv hence temperature indication after irradiation.

Graph 59 shows that the insulation resistance was always well above the specification requirement of 10^8 ohms.

Graph 60 shows the millivolt output and the corresponding nominal temperature during irradiation. A good correlation between the RTD temperature and the two TC's on the sensor was not obtained.

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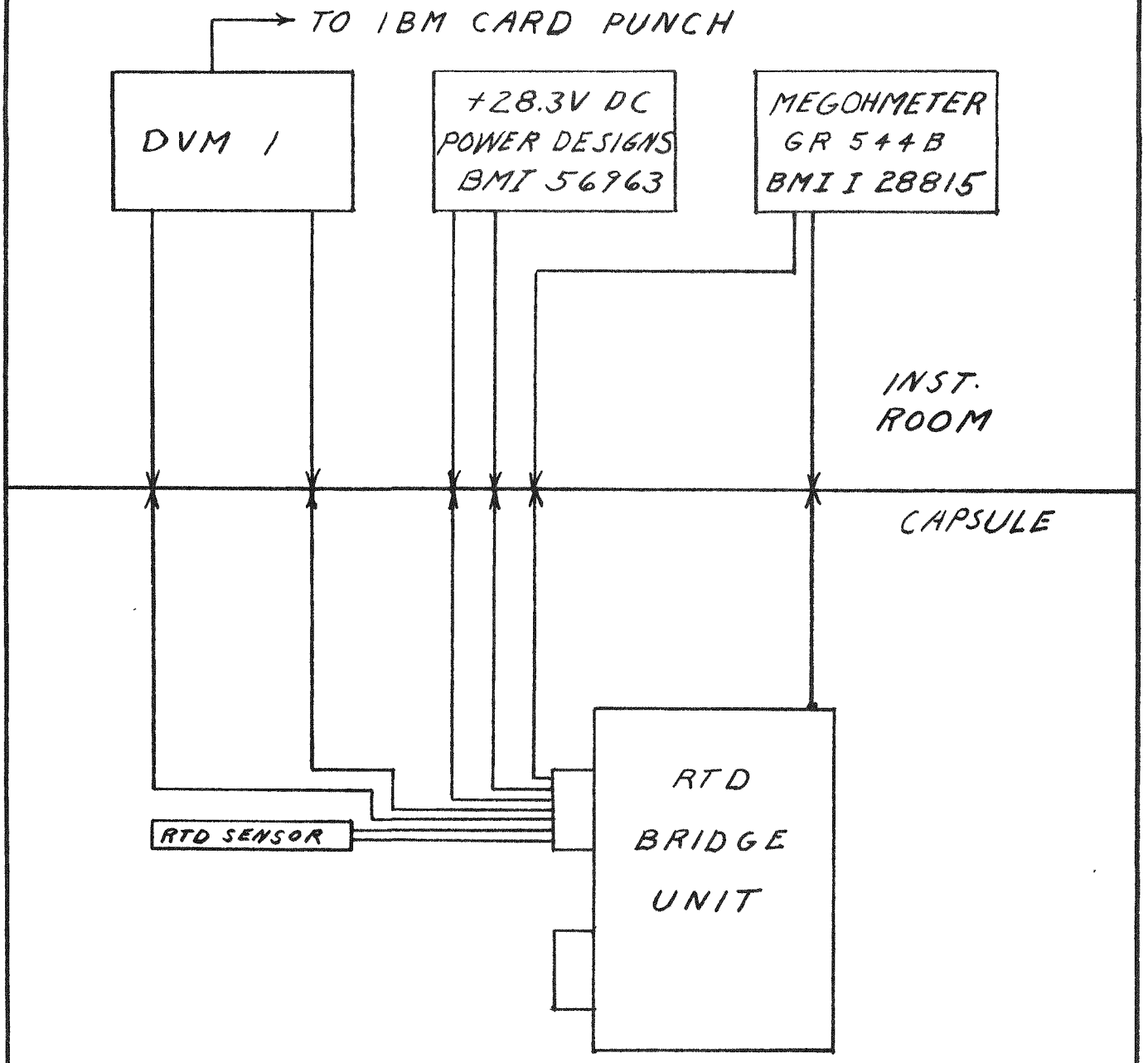

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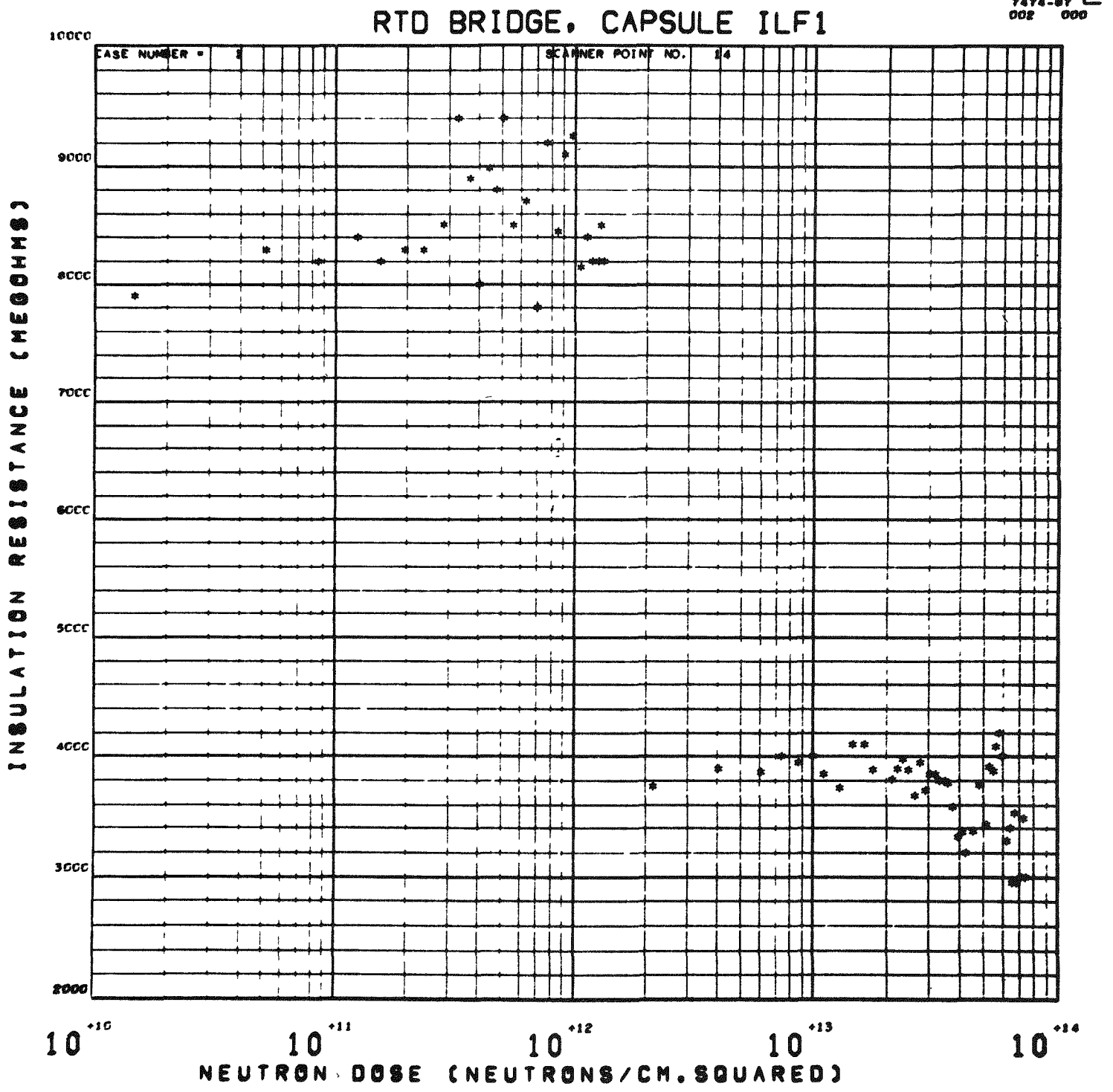
Graph 59

7474-87 L
002 000



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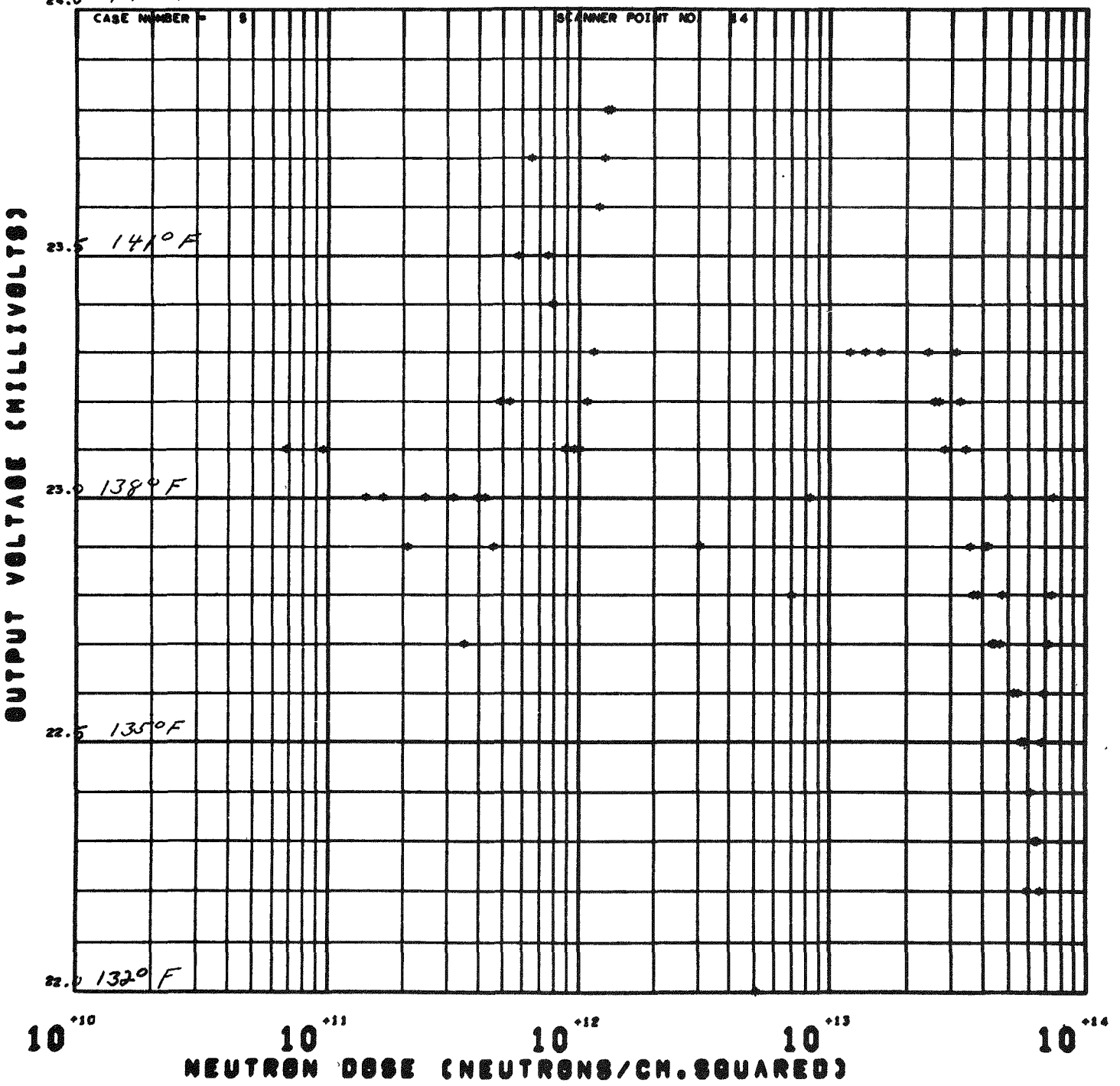
7474-72 L
006 000

RTD BRIDGE, CAPSULE ILF1



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6.7 Low Level Neutron Detection System

6.7.1 Test Setup Figure 30 shows the test setup used.

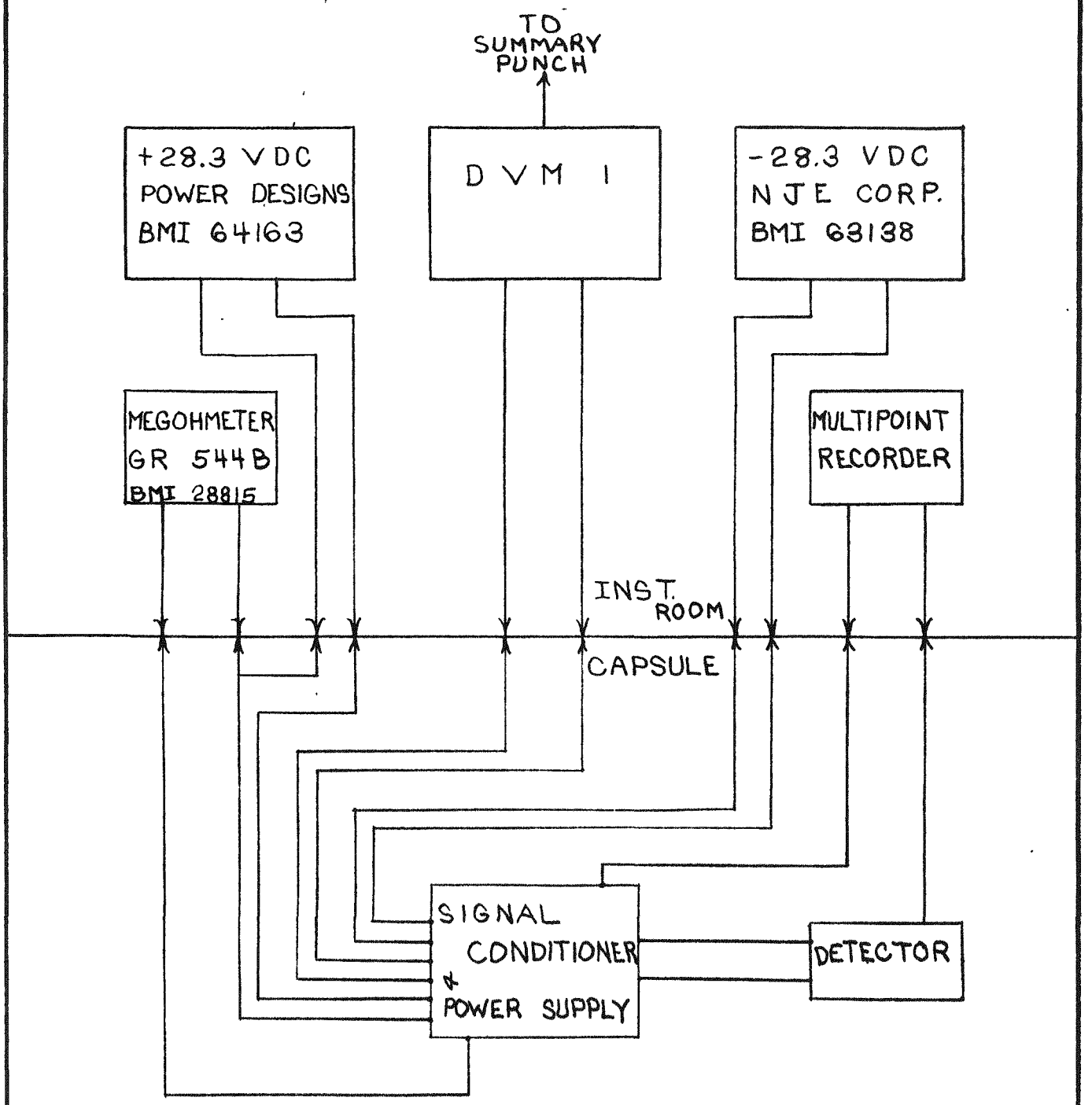
6.7.2 Results This system did not operate properly in the capsule prior to irradiation. The output in a negligible neutron flux field was 67 mv and could not be corrected to achieve zero output. This high output apparently was due to electrical noise capacity coupled through the detector into the system (3.6)

During early phases of irradiation the output remained at 70 mv for neutron flux rates of 0, 1.3×10^7NV, and 2.6×10^8mv. The pre-irradiation calibration check of the system indicated an output of 50 mv for a flux rate of about 4.4×10^5NV. During irradiation at approximately 1.5×10^{13}NVT, rapid degradation of the output started as shown on graph 61.

Post-irradiation testing indicated that the output of the power supply was within specifications and the failure was in the signal conditioner.

Graph 62 shows that the insulation resistance of the low level neutron signal conditioner and the power supply remained adequate during irradiation.

TEST SETUP FOR LOW LEVEL NEUTRON SYSTEM, GAMMA SYSTEM AND HIGH LEVEL NEUTRON SYSTEM. (DETECTOR SIMULATED BY RESISTOR IN HIGH LEVEL SYSTEM.)



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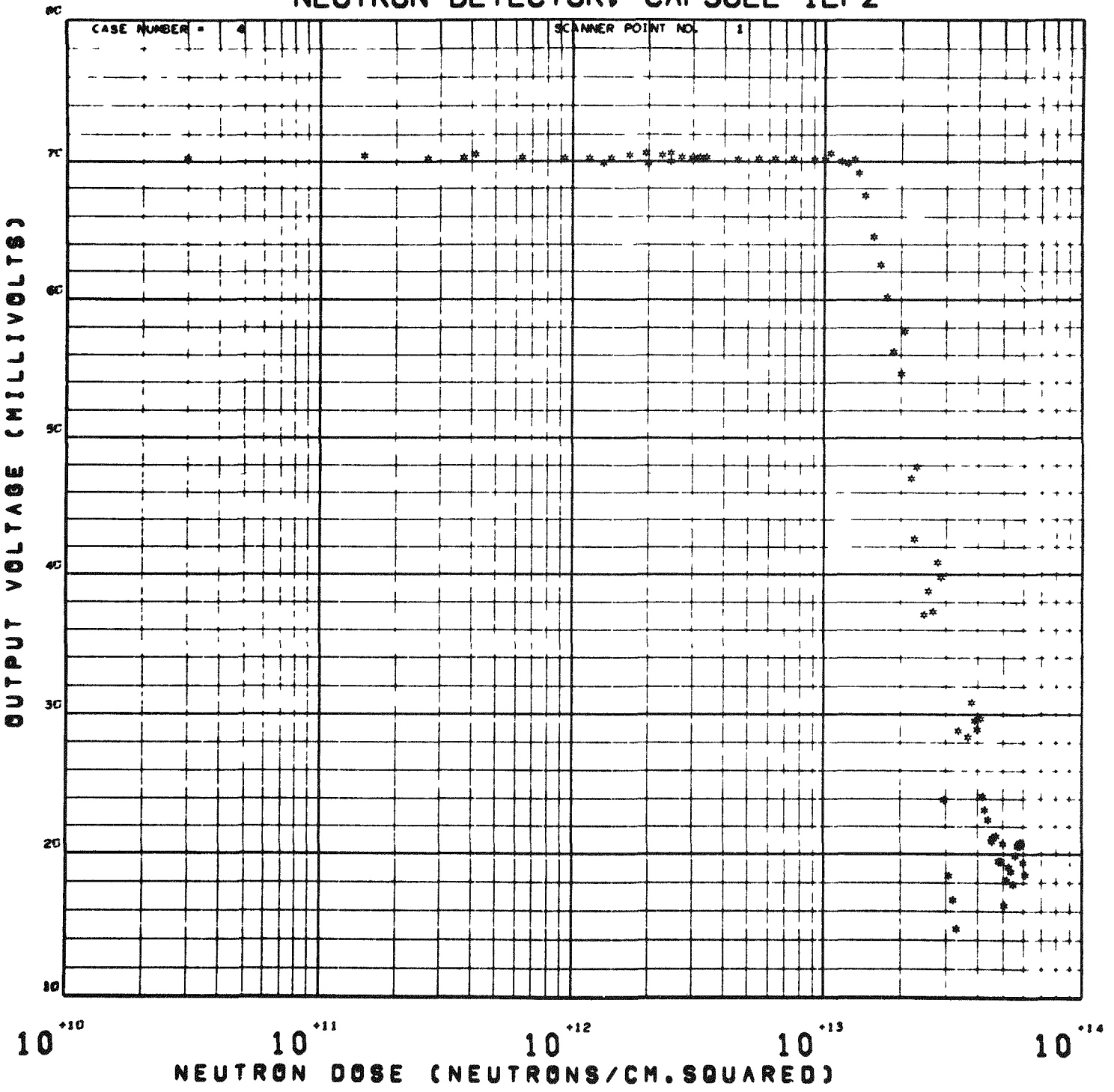
Graph 61

7474-67 L
005 000

NEUTRON DETECTOR, CAPSULE ILF2



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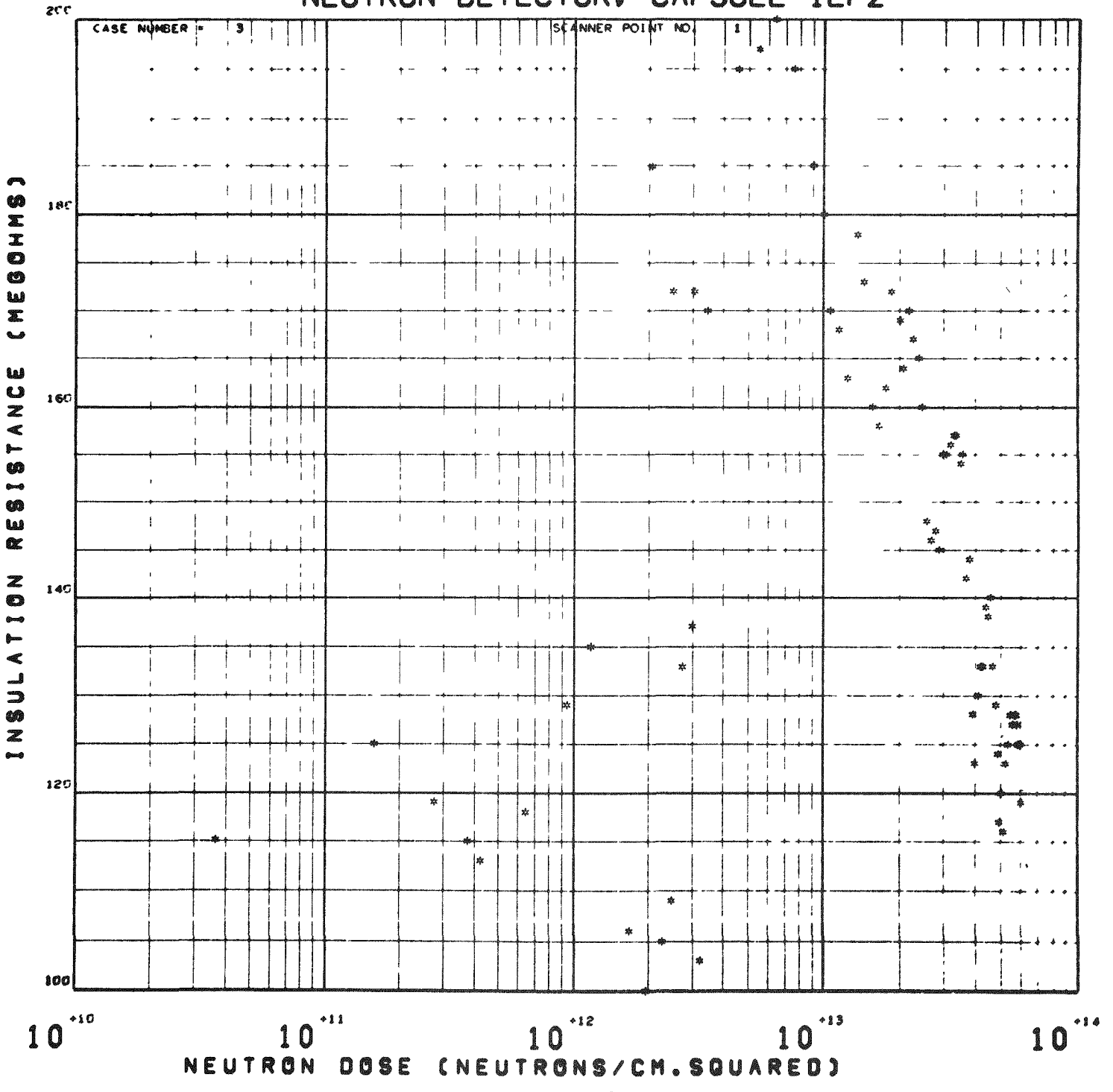
[redacted]

Graph 62

7474-67 L
004 000

NEUTRON DETECTOR, CAPSULE ILF2



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6.8 High Level Neutron Power Supply

6.8.1 Test Setup The test setup was identical to the one shown on figure 30 except that the detector was simulated by a 2.7×10^6 ohm resistor mounted outside the capsule.

6.8.2 Results An intermittant low insulation resistance (10,000 ohms) between the +28 volt lead and the power supply case was noted in pre-irradiation electrical checkout of the capsule. The insulation resistance of the power supply was measured and was in the order of 10^{10} ohms. The intermittant low resistance appeared to be in the capsule wiring but could not be found in the cursory search the schedule permitted. (3.6) The insulation resistance shown in graph 63 is not realistic. An ohmeter was used to measure insulation resistance to prevent any possibility of component burnout due to the application of high voltage. In post-irradiation tests the insulation resistance of the power supply was 2×10^{10} ohms.

As shown in graph 64, the output voltage dropped from 490 volts to 23 volts at about 6×10^{12}NVT.

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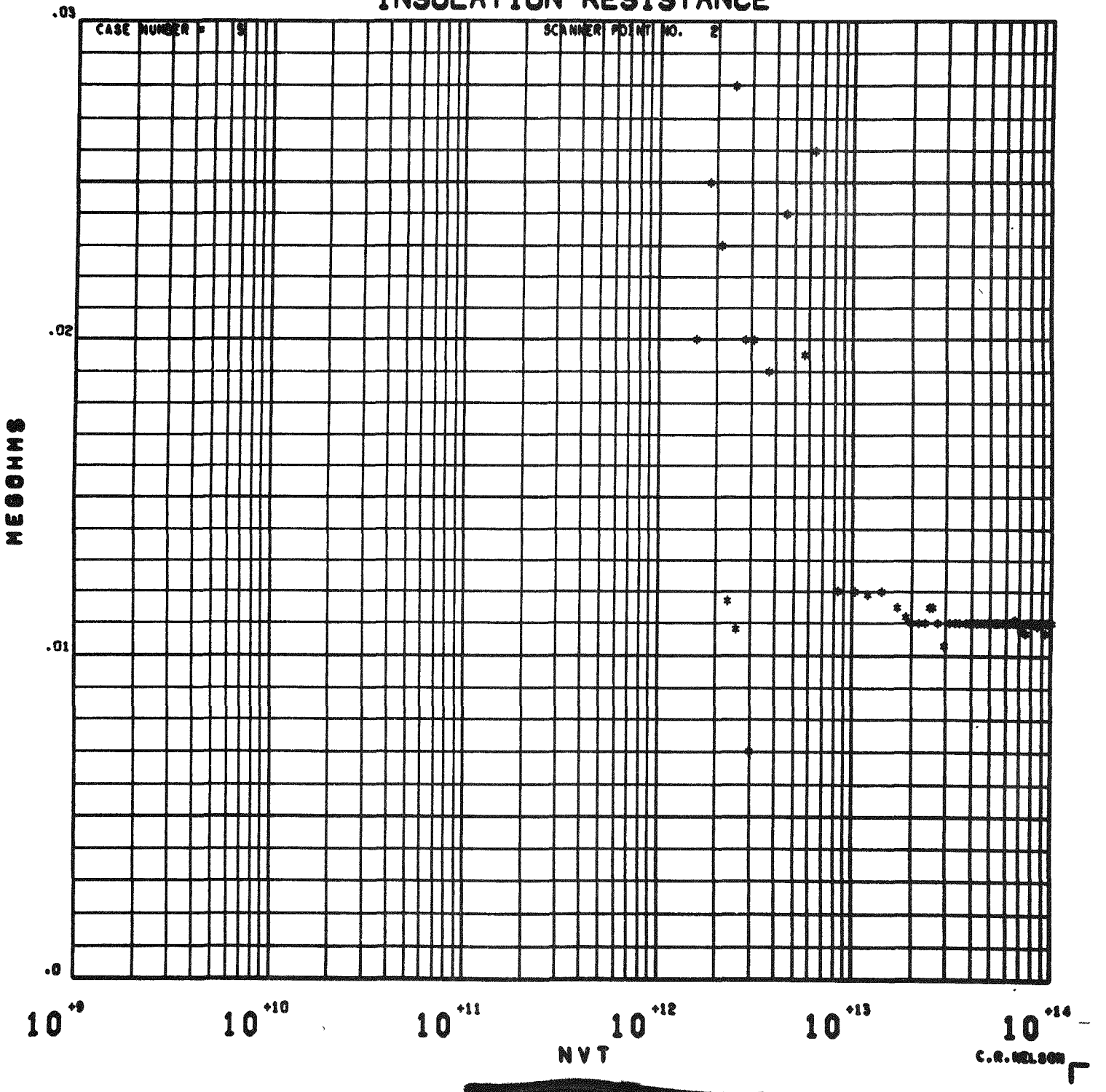
Graph 63

7474-98 L
004 000

INSULATION RESISTANCE



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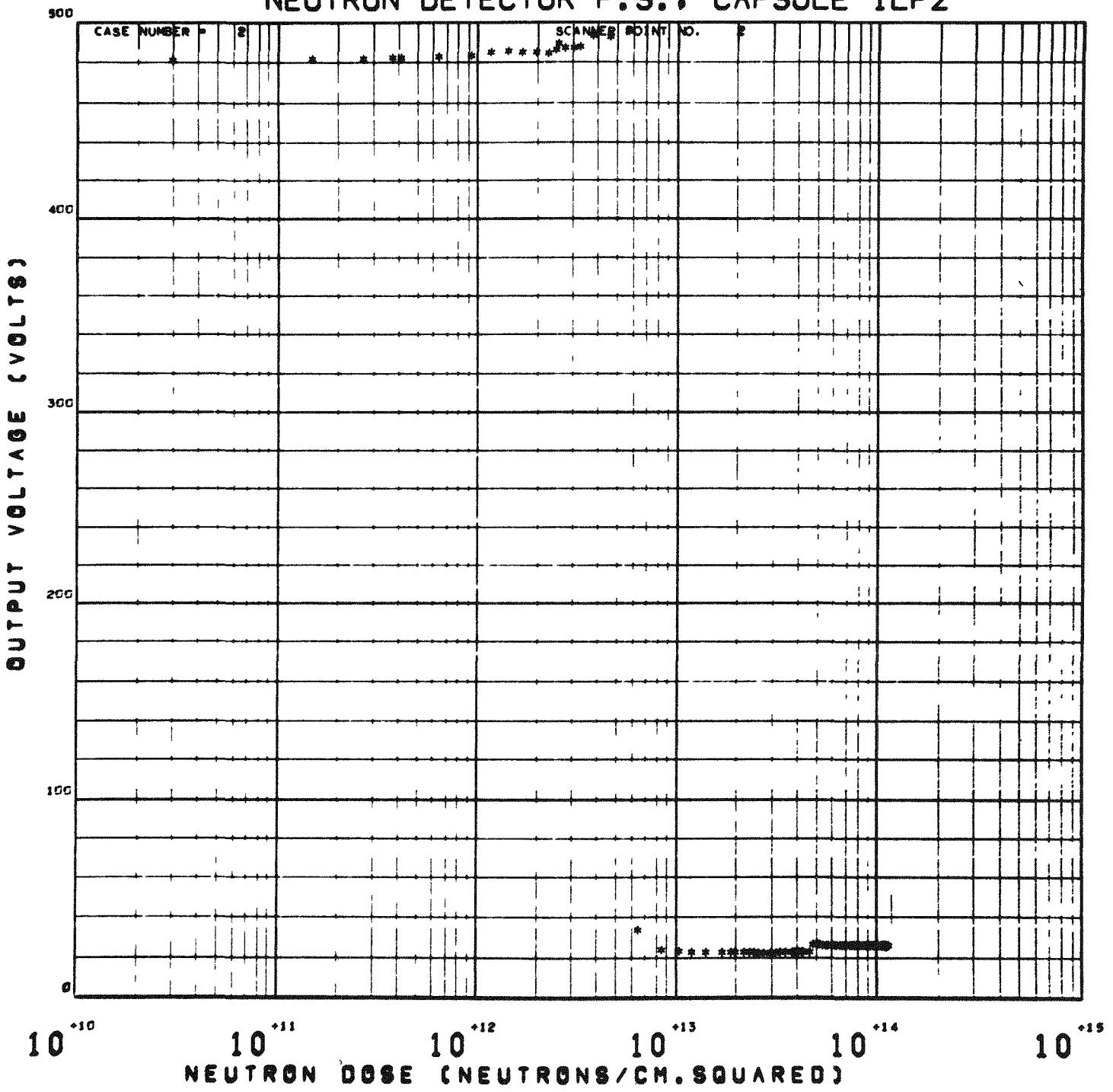
[redacted]

Graph 64

7474-78 L
003 000

NEUTRON DETECTOR P.S., CAPSULE ILF2



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6.9 Gamma Detection System

6.9.1 Test Setup The test setup is shown in figure 30.

The gamma fluxes at both irradiation positions were beyond the range of the gamma detection system. To determine if any degradation occurred, the capsule was periodically moved to a reference position within the range of the gamma system and the electrical output of the gamma system recorded.

6.9.2 Results As shown on graph 64, the insulation resistance was adequate during irradiation.

The gamma rates at the two flux positions used are about 10^7 R/hr and 10^8 R/hr which are factors of about 10^3 and 10^4 higher than the 8,000 R/hr range of the system. Hence the output reading of 103 mv shown on graph 66 is meaningless. The 25 mv outputs are readings in the reference position which was within the range of the gamma system. No degradatinn is evident.

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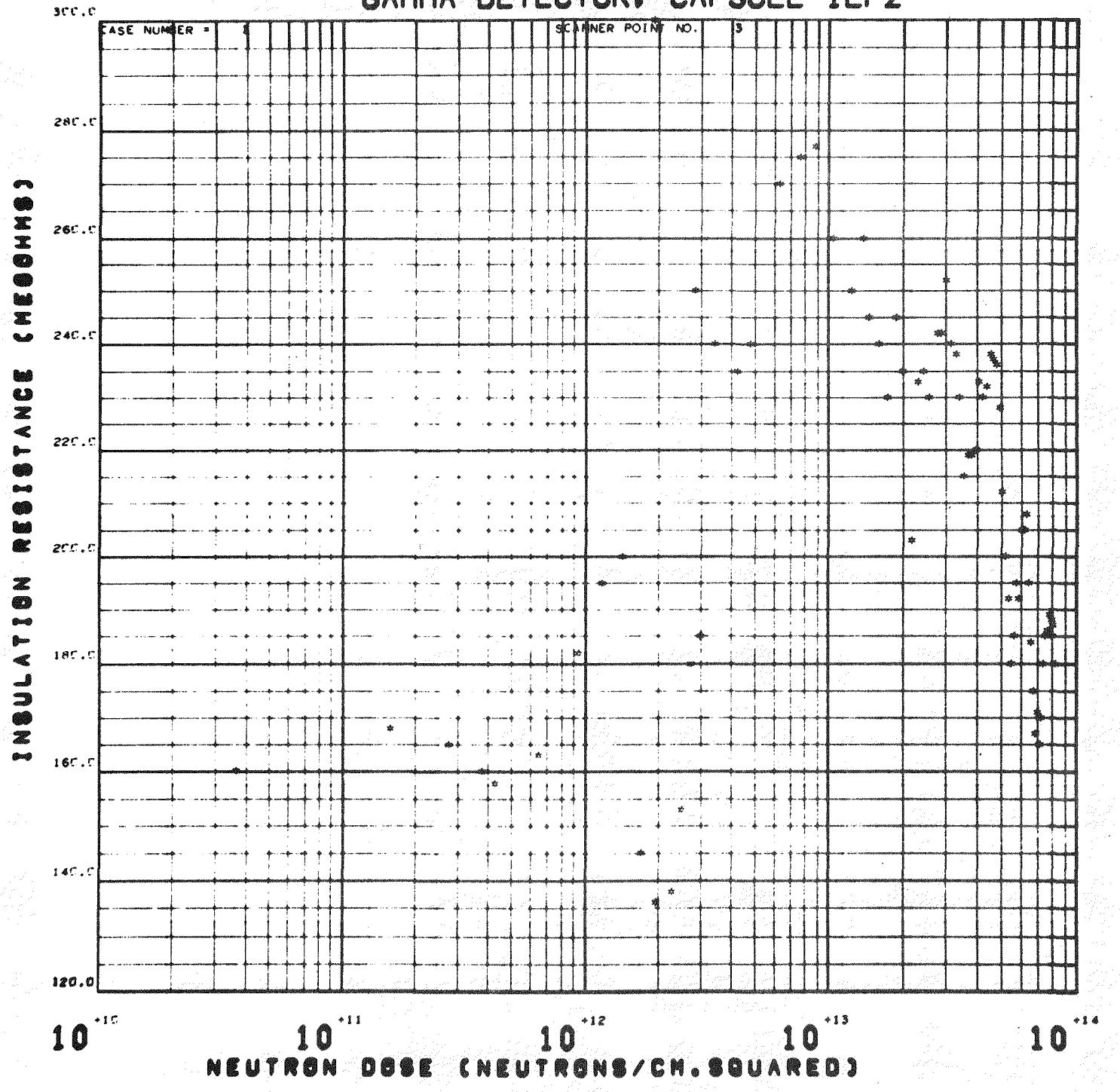
Graph 65

7474-69 L
002 000

GAMMA DETECTOR, CAPSULE ILF2



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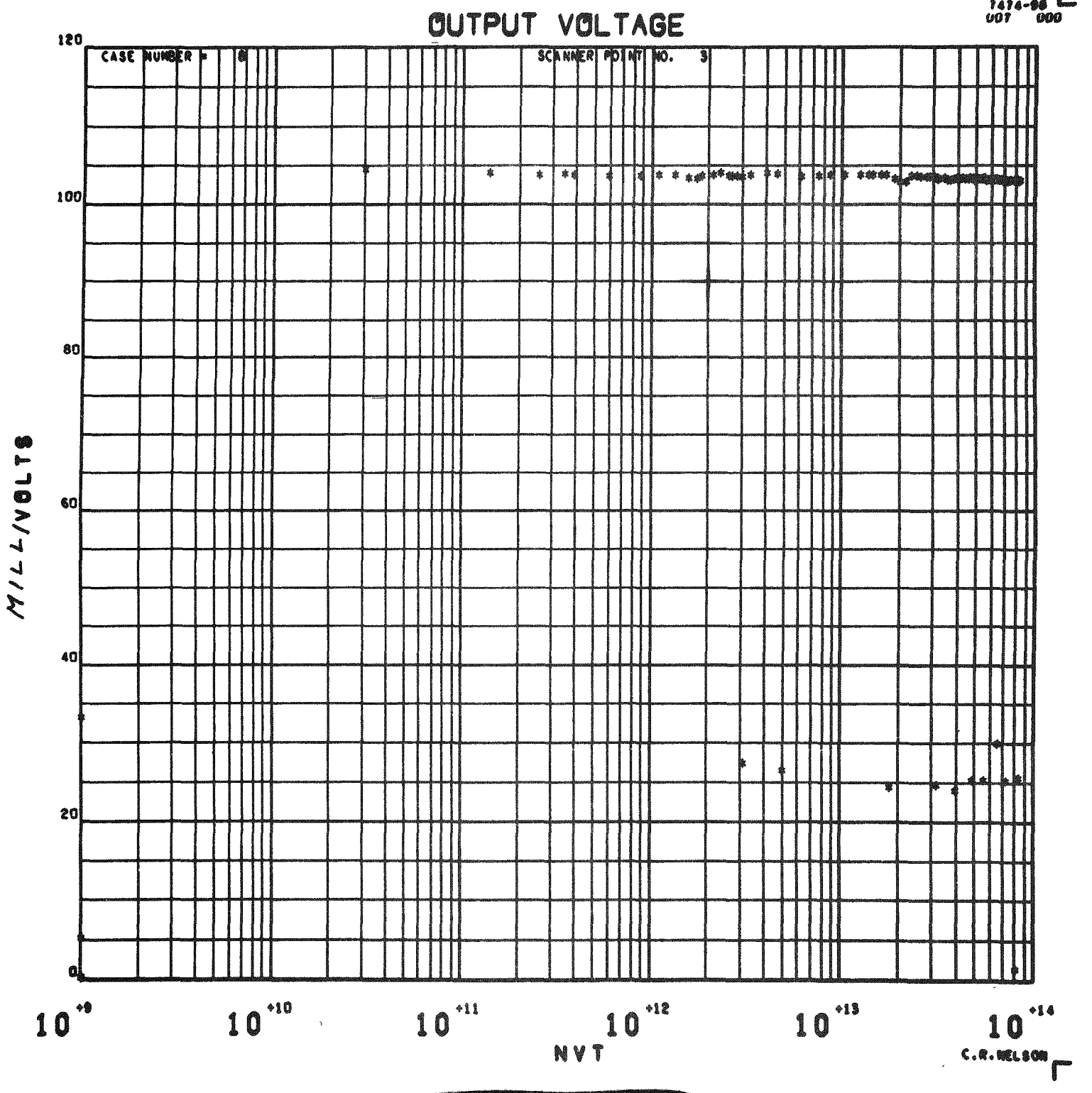
Graph 66



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6.10 Converter Impedance Measuring Device Several diodes in the CZ device were inadvertently burned out when a wiring short developed in the capsule during pre-irradiation testing. With the CZ device inoperative the only measurement that could be made was insulation resistance which was below the minimum specification requirement initially but increased during irradiation as shown in graph 67. The post-irradiation and pre-irradiation insulation resistance was about 10^{10} ohms.

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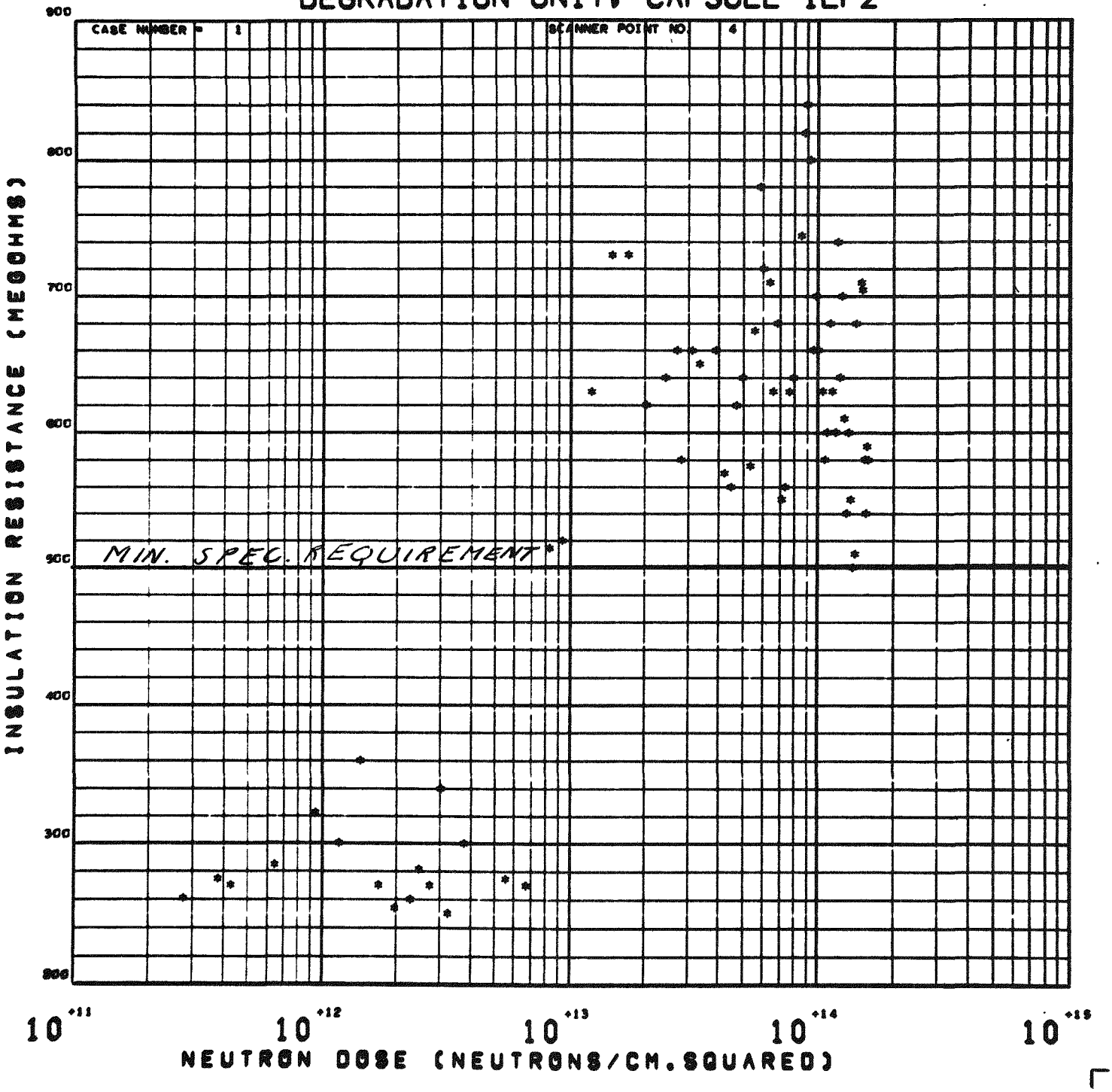
Graph 67

7474-74 L
002 000

DEGRADATION UNIT, CAPSULE ILF2



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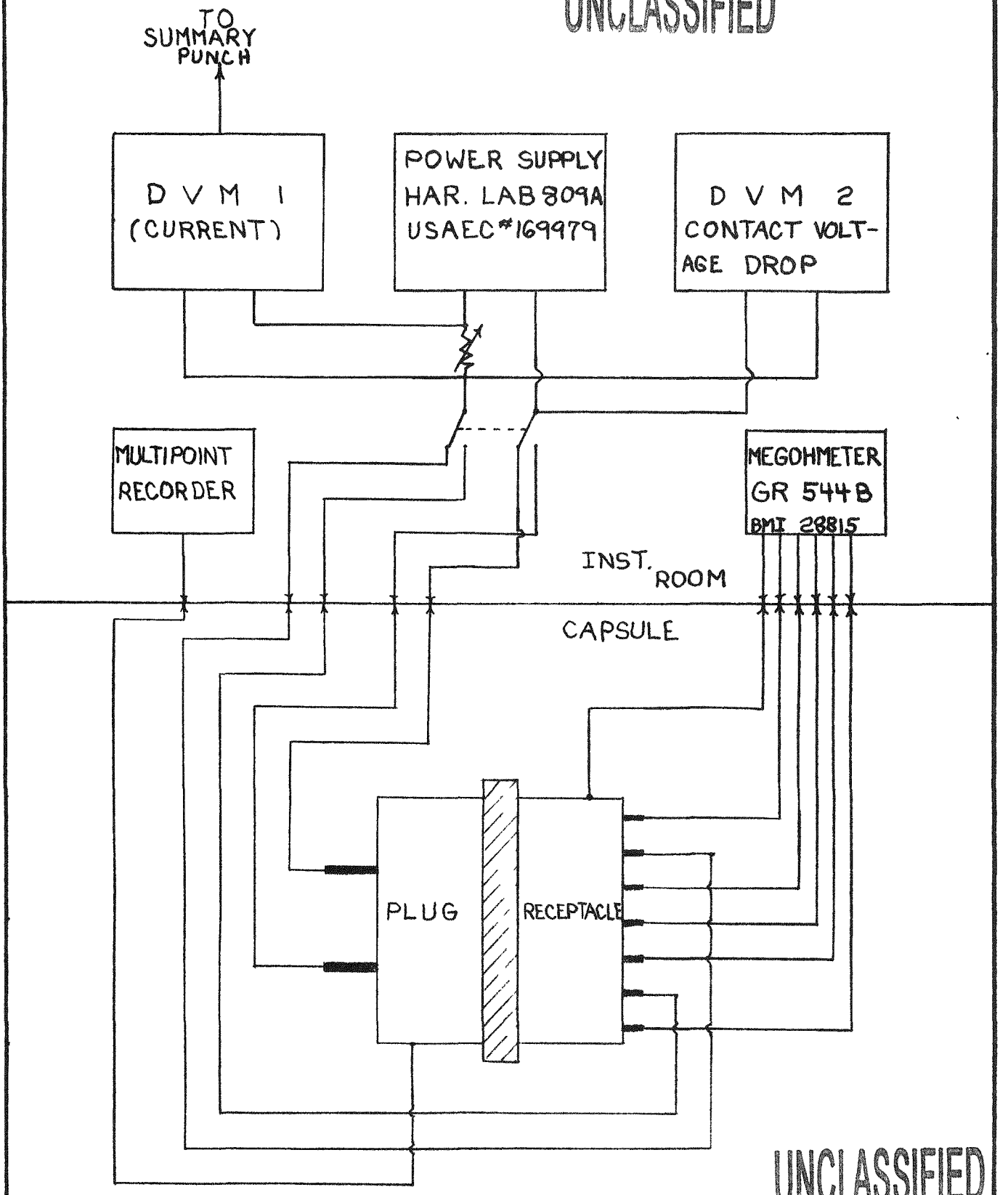

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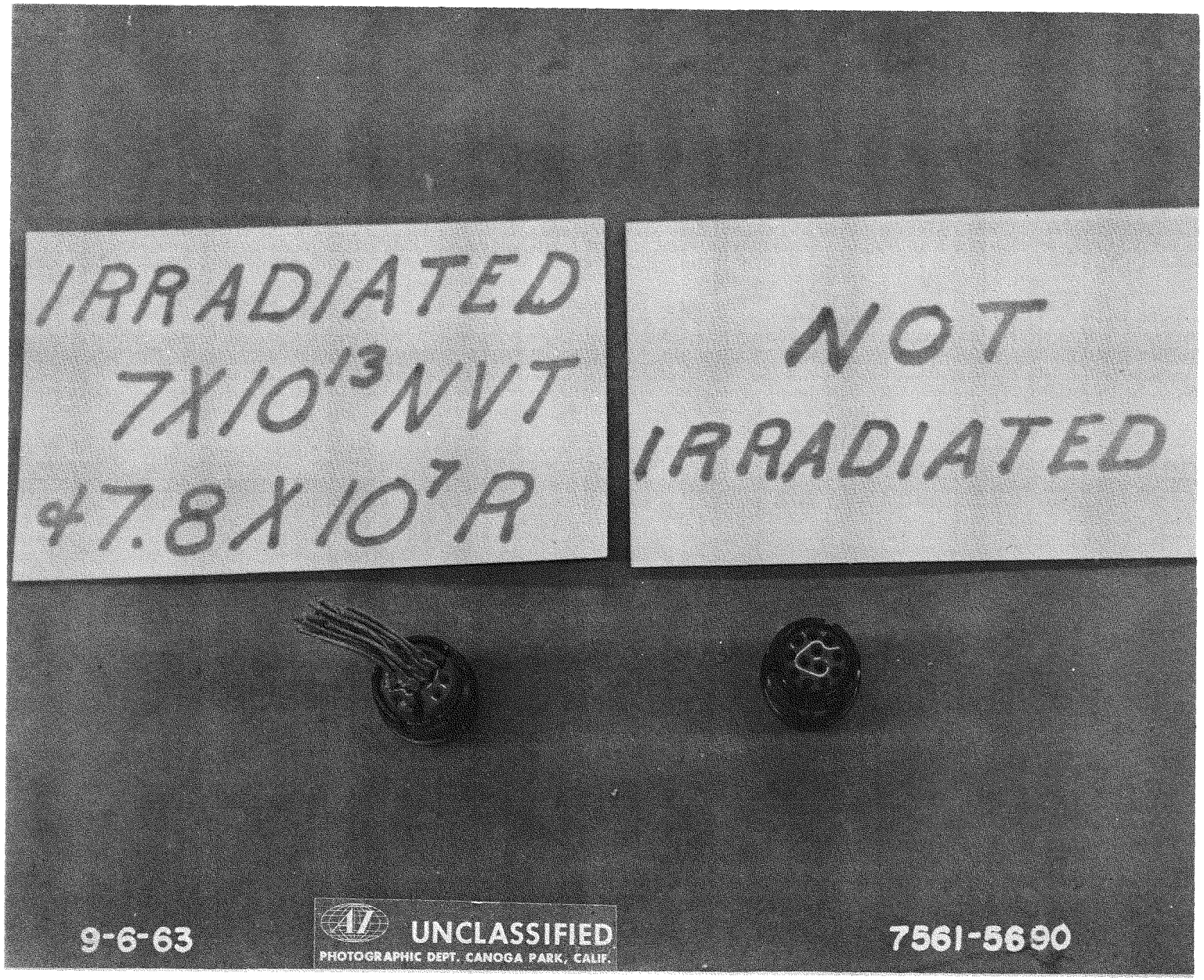
IRRADIATED
7X10^13 NVT
+7.8X10^7 R
NOT
IRRADIATED
9-6-63
UNCLASSIFIED
PHOTOGRAPHIC DEPT. CANOGA PARK, CALIF.
7561-5690

FIGURE 32

6.11 Connector

6.11.1 Test Setup A typical instrument compartment connector with silicone rubber insert material was irradiated using the test setup shown in figure 31.

6.11.2 Test Results As shown on graphs 68 through 72 the insulation resistance during irradiation was adequate. Graphs 73 and 74 show that no significant change in contact resistance occurred during irradiation.

No degradation of electrical characteristics occurred for this test connector and other connectors used in irradiation tests. Considerable embrittlement of the silicone rubber insert material of all connectors was noted. After irradiation pieces of the normally pliable silicone rubber could be extracted using a fingernail. Figure 32 compares an irradiated connector with one not irradiated and clearly shows the degree of embrittlement. The cracks and breaks occurred when the solid wire leads were worked during capsule disassembly.

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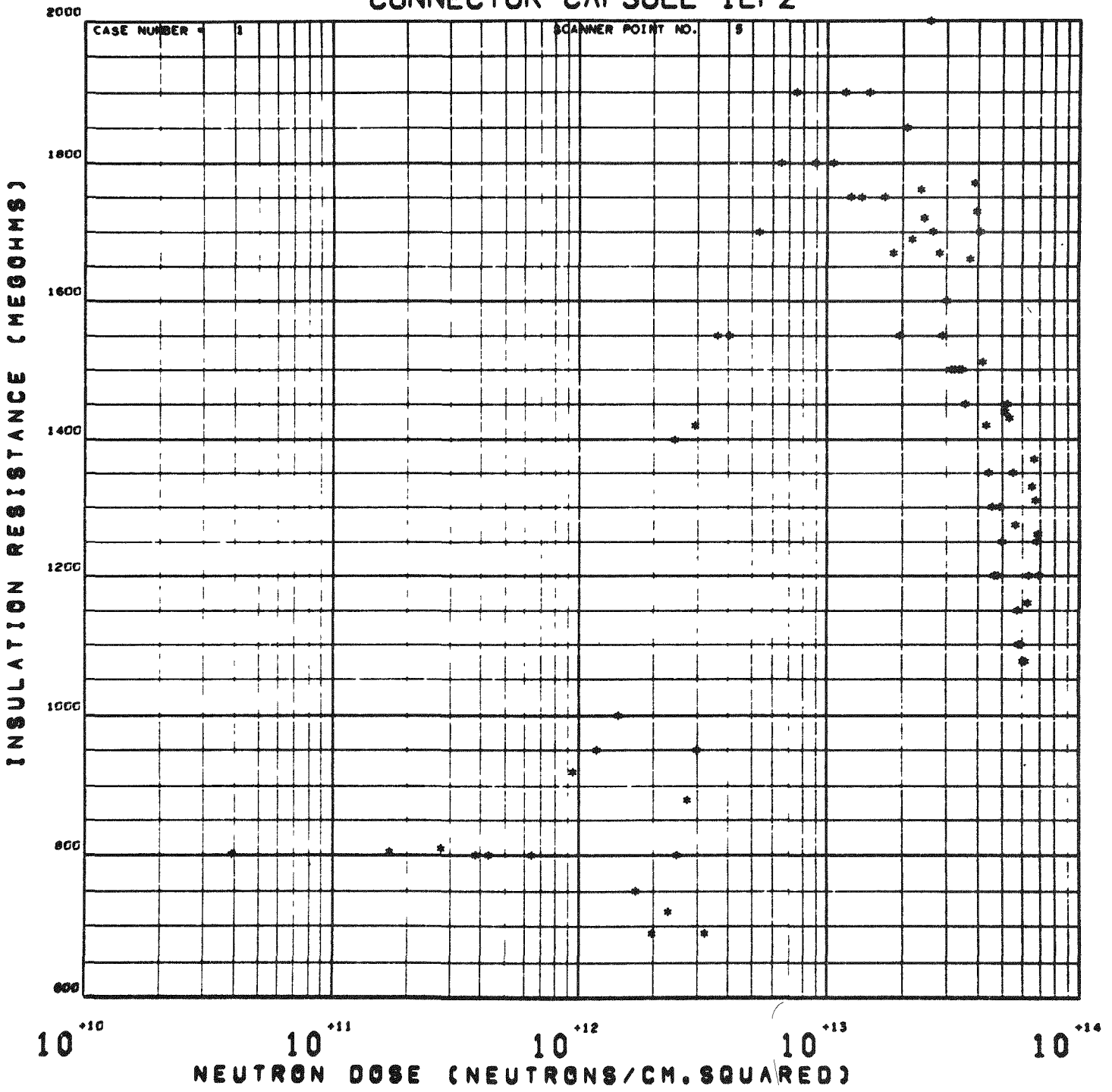
Graph 68

7474-84 L
002 000

CONNECTOR CAPSULE ILF2



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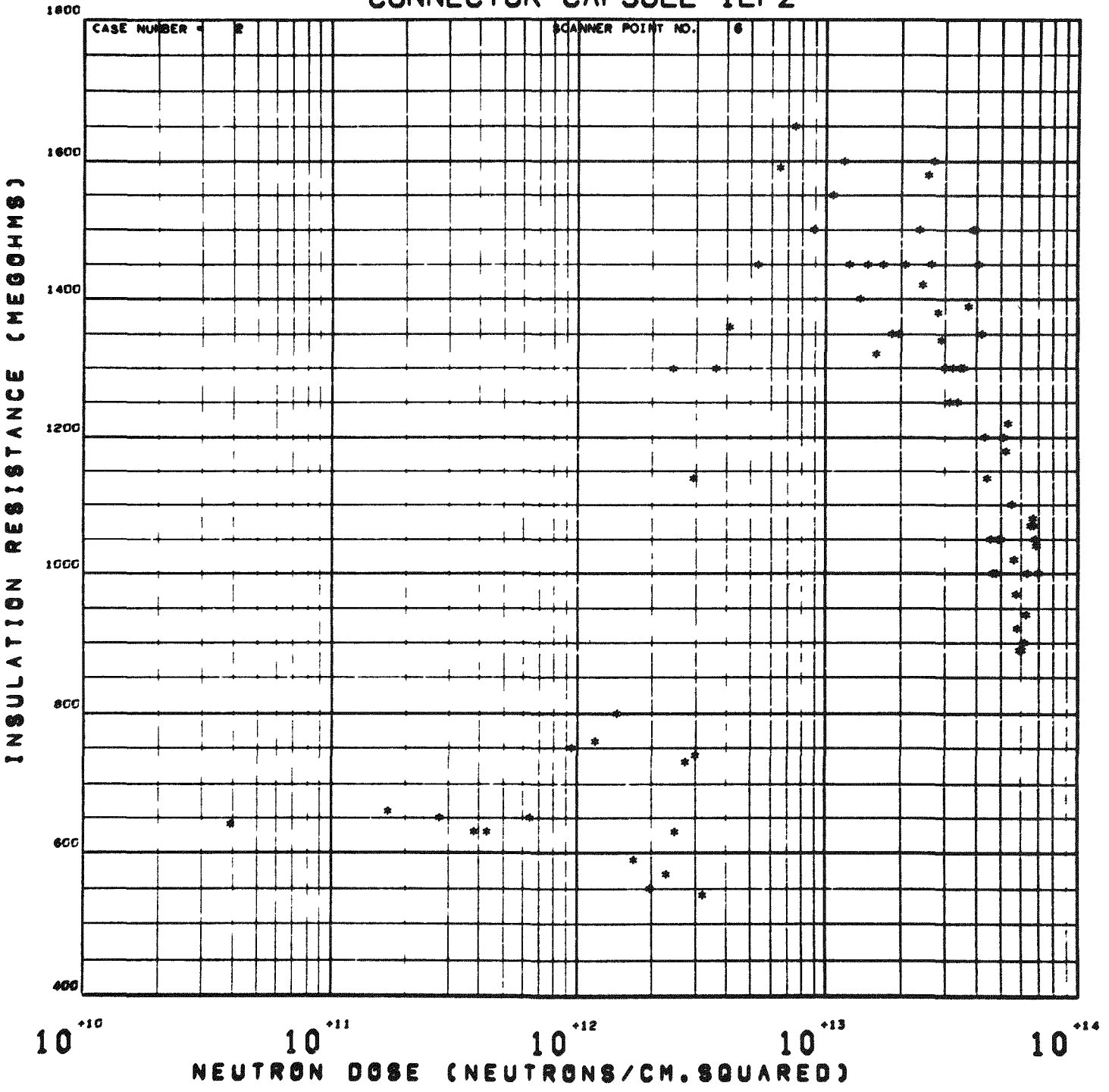
Graph 69

7474-84 L
003 000

CONNECTOR CAPSULE ILF2



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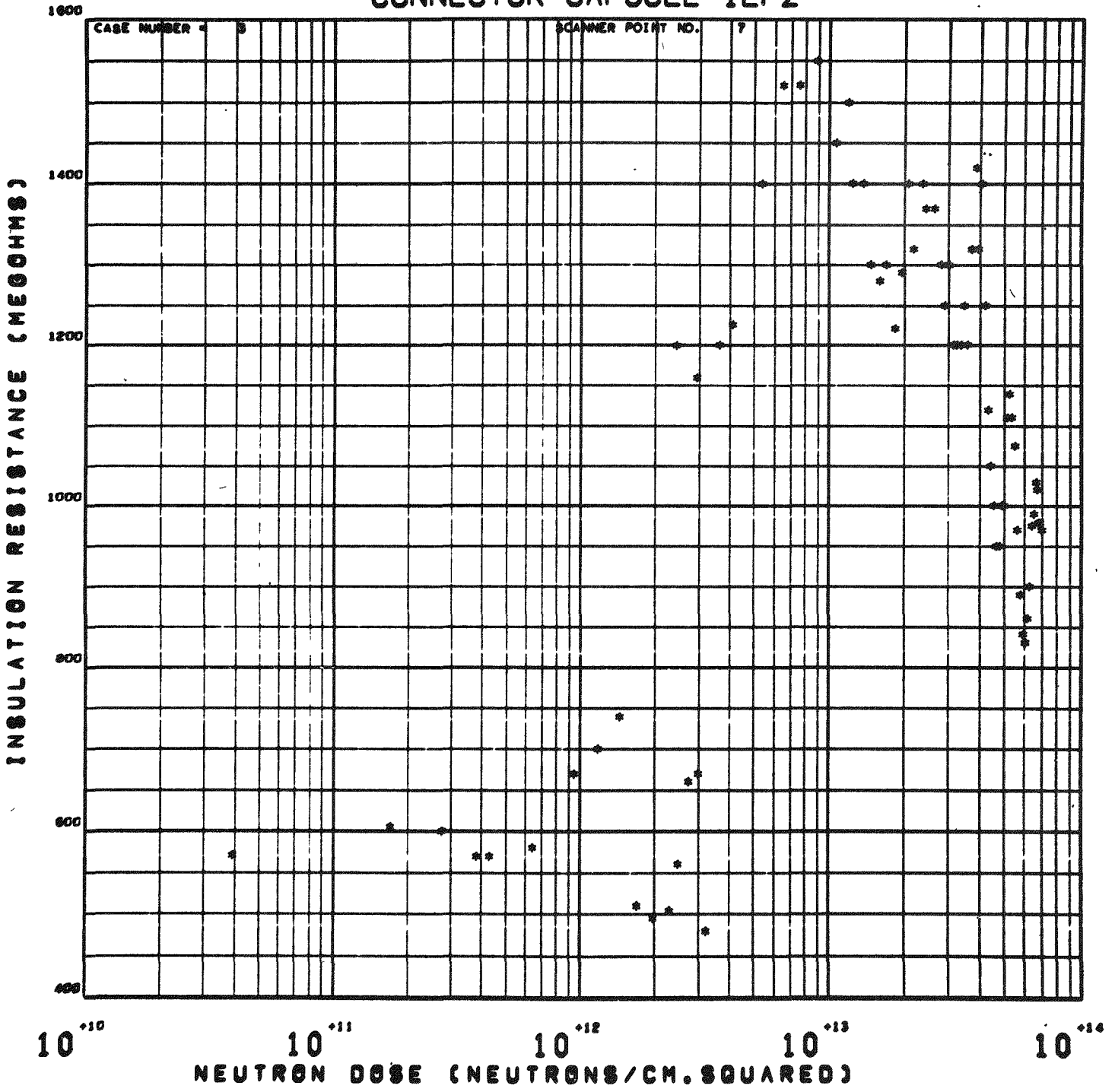
Graph 70

7474-84 L
004 000

CONNECTOR CAPSULE ILF2



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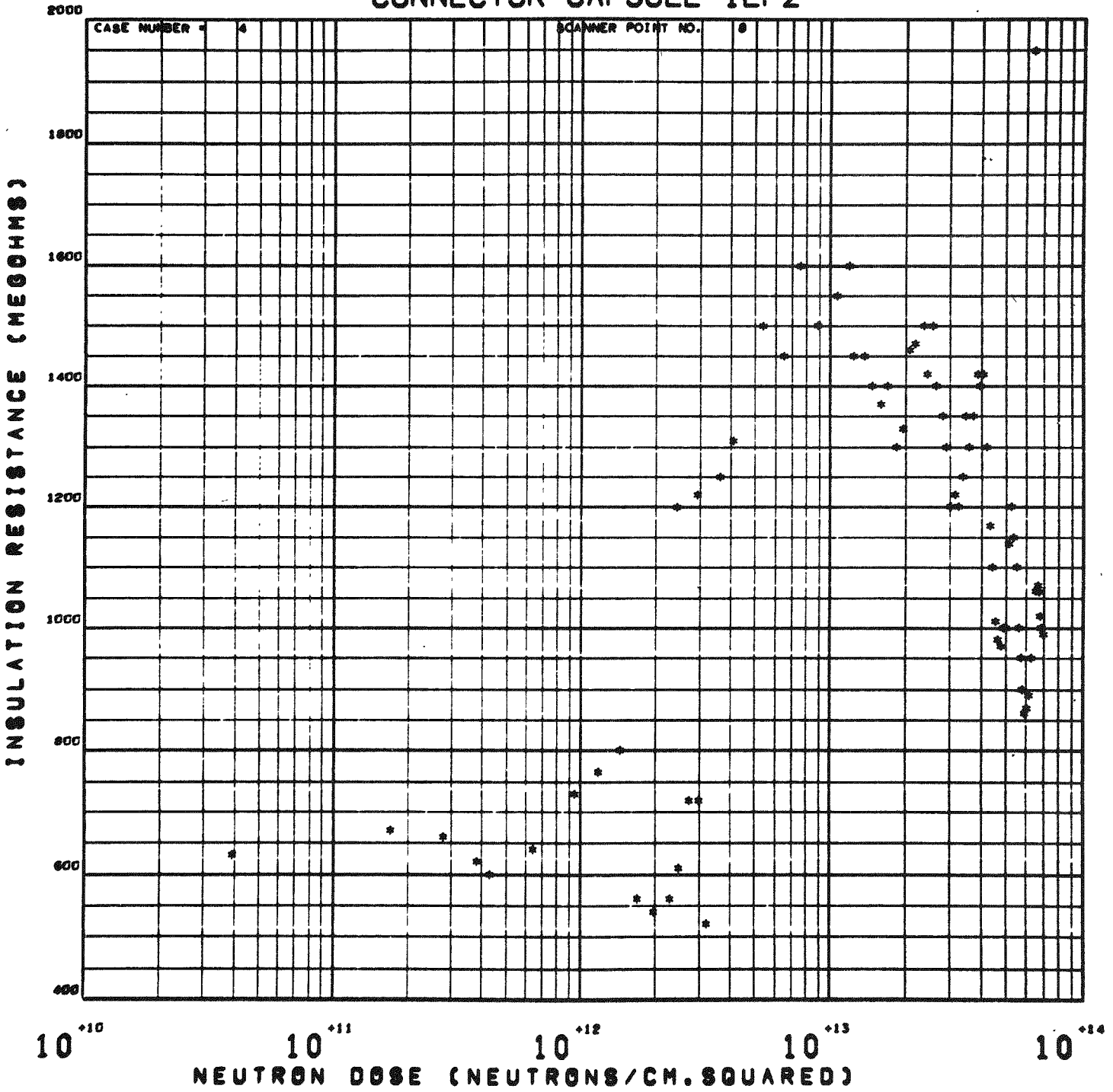
[redacted]

Graph 71

7474-84 L
005 000

CONNECTOR CAPSULE ILF2



[redacted]

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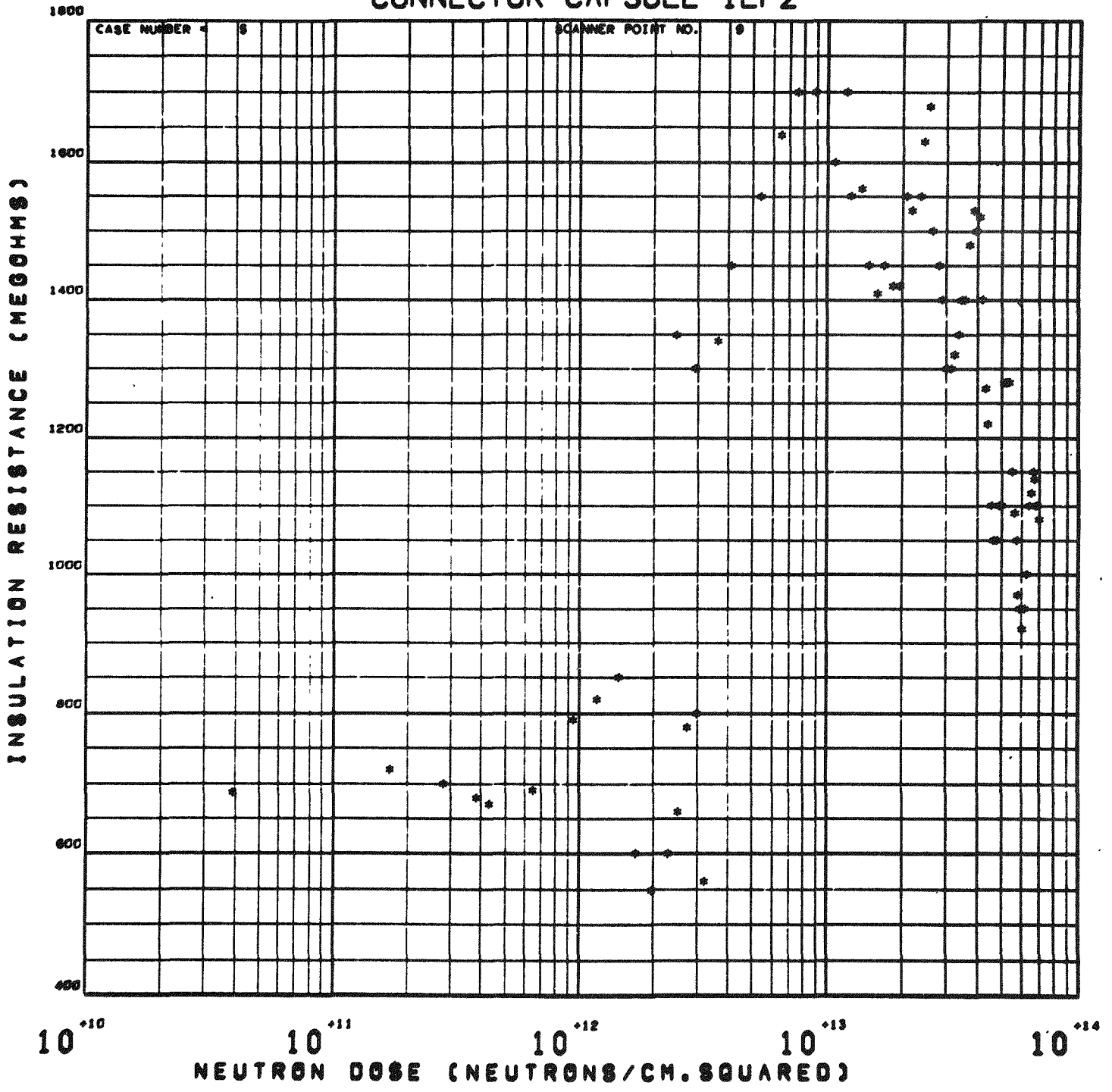
[redacted]

Graph 72

7474-84 L
006 000

CONNECTOR CAPSULE ILF2



[redacted]

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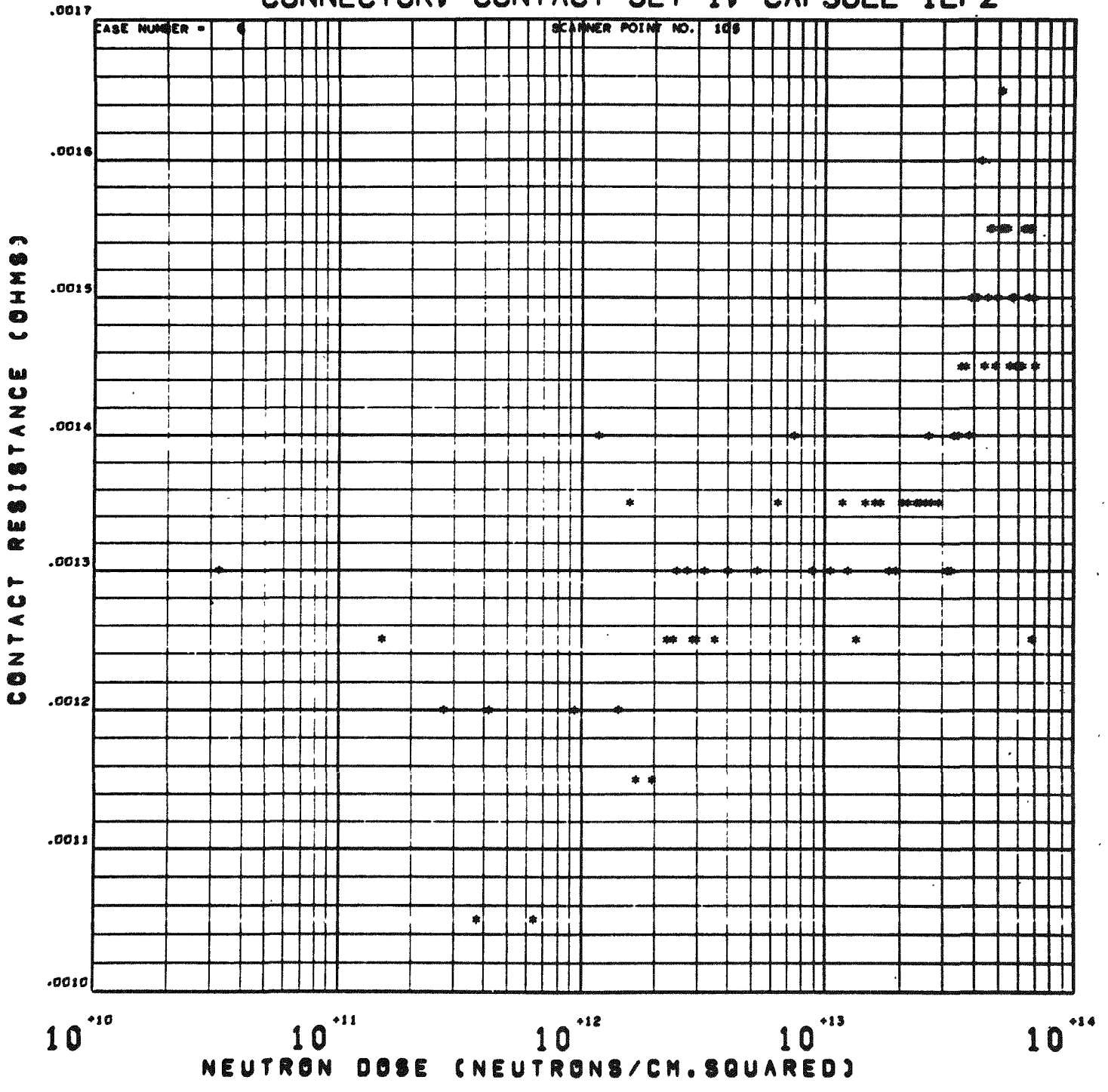
Graph 73

7474-84 L
007 000

CONNECTOR, CONTACT SET 1, CAPSULE ILF2



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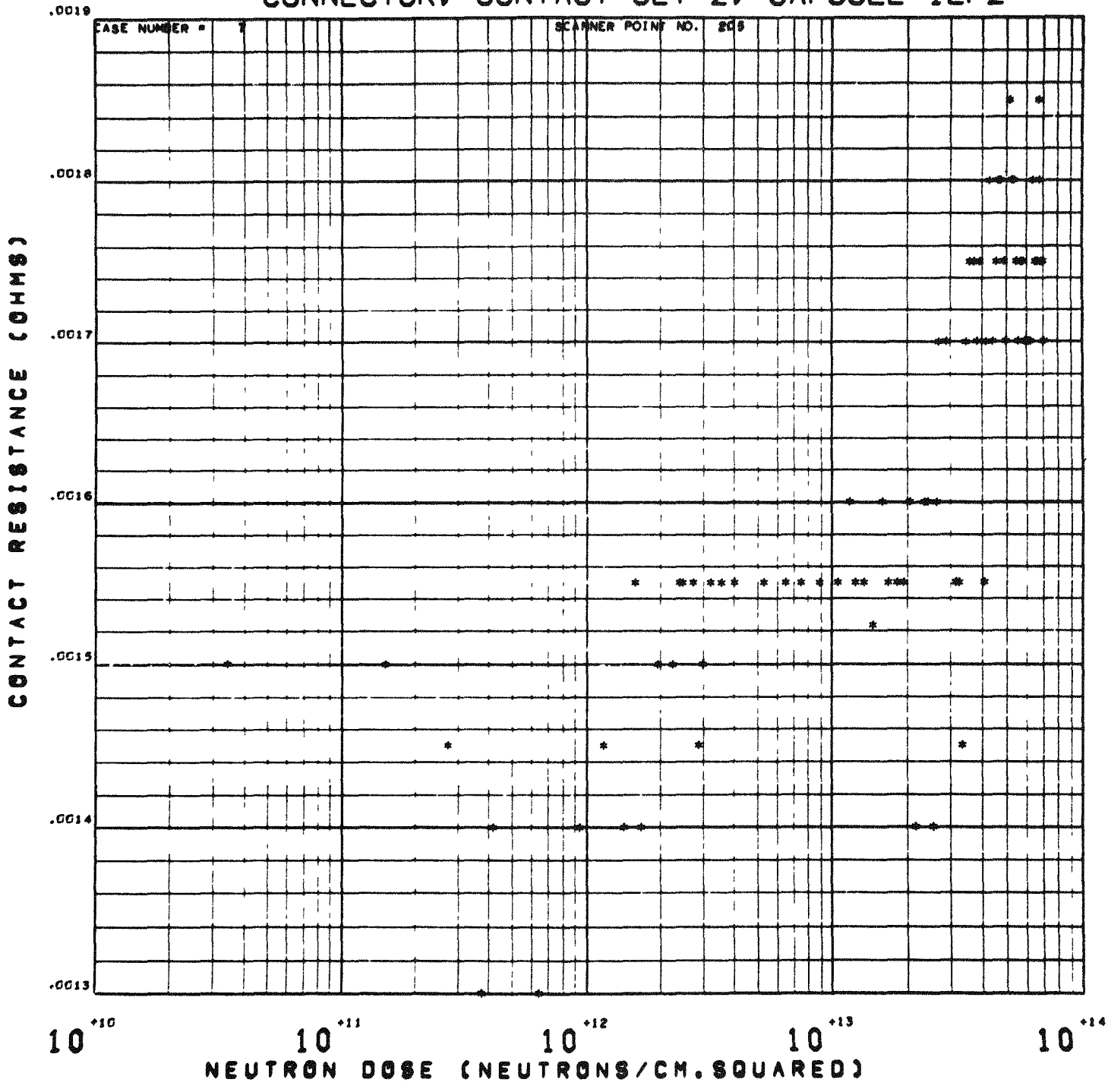
Graph 74

[redacted]

7474-75 L
008 000

CONNECTOR, CONTACT SET 2, CAPSULE ILF2



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7.0 Conclusions and Recommendations

The high level neutron power supply and the low level neutron system which failed at Battelle have been retested and test results will be published when data is reduced. The cause of the failure of these two components should be determined by analysis, electrical checks and dissecting if necessary.

The degree of connector insert embrittlement after 7×10^{13} NVT warrants additional testing to an exposure of 5×10^{14} NVT which is the order of magnitude found at the outer periphery of the instrument compartment where many of the connectors are located.

In any subsequent testing the exposure should be increased by at least a factor of two to compensate for the large dose gradients across a component and within the capsule.

More emphasis should be placed on orientation of the components to approximate the orientation in the instrument compartment.

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APPENDIX I

Heat Transfer Considerations by W. G. Rieder, Battelle Memorial Institute

The hexagonal baffle array, surrounded by the water coil, was the configuration selected for this experiment after consideration of previous array configurations and possible alternatives. For this experiment, the water coil temperatures necessary for obtaining the desired sample temperatures in each position, the sample temperature gradients, and the transient effects due to the fusistor-firing-time tests were analyzed.

Calculations of the Desired Water Coil Temperature

An estimate of the water coil temperature needed to maintain the baffle at 130 F was made with the following assumptions:

(1) All heat is transferred from the baffle assembly by radiation to the water coil (effective emissivity = 0.5).

(2) The gamma heat generation rates at the for the two desired experiment positions are:

(a) γ_{II} = 0.00185 watts/gm
(b) γ_{III} 2 0.000267 watts/gm

The pertinent equation for the water coil temperature is:

$$T_C^4 = T_B^4 - \frac{\gamma \times m}{1730\ A_B\ \varepsilon_{BC}} \times 10^{12}$$

(This is a rearranged form of the radiation equation with the Stefan-Boltman constant in BTU/hr ft^2 R^4.)

where γ = gamma heat generation rate (BTU/hr per unit mass)
m = total mass of samples, tiers, baffle, and leads internal to the baffle

A_B = area of baffle (ft^2)

ε_{BC} = effective emissivity

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for Position III

$\gamma_{III} = 0.000267$ watts/gm

$m = 2000$ gm

$A_B = 195 \text{ in}^2$

$\varepsilon_{BC} = 0.5$

$T_B = 590°R$

$$T_{C_{III}}^4 = 590^4 - \frac{0.000267 \times 2000 \times 3.41 \times 144}{1730 \times 195 \times 0.5} \times 10^{12}$$

$$T_{C_{III}}^4 = [0.120 - 0.00155] \times 10^{12}$$

$$T_{C_{III}} = 126 \text{ F}$$

for Position II

$\gamma_{II} = 0.00185$ watts/gm

$$T_{C_{II}}^4 = [0.120 - 0.0108] \times 10^{12}$$

$$T_{C_{II}} \simeq 114 \text{ F}$$

Estimate of Sample Temperature Gradient

The following calculations give only surface temperature gradients of the specimens since information concerning the internal structure of these specimens was not available. However, the estimates should be realistic for specimens having adequate internal heat transfer paths. Only the analysis of the low-voltage-switch is presented. Assuming the following:

(1) negligible heat transfer between case and internal structure,
(2) uniform volumetric gamma heat generation only,
(3) unidirectional heat flow,
(4) heat sink at one end only (the mounting base),
(5) negligible radiation from surface,
(6) constant cross-sectional area of the case,

a total temperature difference from one end of the sample case to the other may be computed from the equation:

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$$\Delta T = \frac{L^2 \gamma_{II} \rho_s}{2 \; k_s}$$

where L = length of sample (in direction of heat flow)

γ_{II} = gamma heat generation rate (BRR Position II)

ρ_s = density of sample case (assumed to be stainless steel)

k_s = thermal conductivity of sample case.

For the low-voltage-switch

L = 1.75 in.

γ_{II} = 0.00185 watts.gm

ρ_s = 8 gm/cc

k_s = 11 BTU/hr ft °F

$$T = \frac{1.75^2 \times 0.00185 \times 8 \times 16.39 \times 3.413 \times 12}{2 \times 11}$$

$$\Delta T \cong 0.1°F$$

On the basis of this estimate, and considering the fact that all samples except the fusistor, which will be considered separately, are securely bolted to the tiers, it may be assumed that the samples, tiers, and baffle will be approximately isothermal.

Transient Effects Due to Fusistor-Firing-Time Test

During the test it is necessary to dissipate 186 watts of electrical power in a fusistor under test for periods which may extend to 10 sec. Since the total gamma heat generation is only about 4 watts, the thermal equilibirium should be upset significantly. To simplify the transient heat transfer analysis, two extreme cases will be examined: (1) the fusistor is assumed to be completely thermally insulated, (2) the whole array (including fusistor) is assumed to be isothermal. The first case yields the highest possible temperature the fusistor could attain, while the second case gives the highest temperature the rest of the array could attain.

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Case (1)

Heat balance:

$$\frac{dQ_{in}}{dt} = \frac{d\,Q_F}{dt} + \frac{d\,Q_{out}}{dt} \qquad (1)$$

where $\frac{d\,Q_{in}}{dt}$ = power input to fusistor.

$\frac{d\,Q_F}{dt}$ = time rate of thermal energy build up in fusistor

$\frac{d\,Q_{out}}{dt}$ = power transported from the fusistor.

During the fusistor test these quantities are assumed to have the following values:

$$\frac{d\,Q_{in}}{dt} = q_e = \text{(constant = 186 watts)}$$

$$\frac{d\,Q_F}{dt} = \frac{d\,Q_F}{d\,T_F}\,\frac{d\,T_F}{dt} = C_F\,\frac{d\,T_F}{dt}$$

where C_F = total heat capacity of the fusistor (0.0044 BTU/°F)

T_F = fusistor temperature (fusistor assumed to be isothermal)

$\frac{d\,Q_{out}}{dt}$ = 0 (fusistor assumed to be perfectly insulated)

Substituting these values into Equation (1), one has:

$$q_e = C_F\,\frac{d\,T_F}{dt} + 0$$

$$\int_{T_{F_o}}^{T_F} d\,T_F = \frac{q_e}{C_F}\int_o^t dt$$

$$T_F = \frac{q_e}{C_F}\,t + T_F$$ [redacted]

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let $q_e = 186 \times 3.413/3600 = 0.177$ BTU/sec

C_F 0.0044 BTU/°F

$T_F° = 130°F$

$$T_F = 40t + 130 \qquad (2)$$

Equation (2) gives the fusistor temperature (°F) as a function of time (sec), assuming that the fusistor is perfectly insulated. For a test duration of 10 sec the fusistor may increase in temperature to 530 F.

Case (2)

An expression similar to Equation (1) may be written for the entire sample array.

$$\frac{d\,Q_{in}}{dt} = \frac{d\,Q_A}{dt} + \frac{d\,Q_{out}}{dt}$$

where $\frac{d\,Q_{in}}{dt} = q_e + q_r = (\text{constant} = 190 \text{ watts})$

$$\frac{d\,Q_A}{dt} = \frac{d\,Q_A}{dT_A}\,\frac{dT_A}{dt} = C_A\,\frac{dT_A}{dt}$$

where C_A = total heat capacity of array (0.58 BTU/°F)

T_A = array temperature

$$\frac{d\,Q_{out}}{dt} = 0$$

(Note that in this case the heat transferred from the baffle is known within reason and could be included in the calculation, however, as the following will show, the small resultant value of T_A obtained by setting $\frac{d\,Q_{out}}{dt} = 0$, indicates that the added complication of a nonlinear differential equation, which is required for a non-zero value of $\frac{d\,Q_{out}}{dt}$, is not warranted here.)

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from (3)

$$q_e + q_r = C_A \frac{d\,T_A}{dt} + 0$$

$$\int_{T_A^\circ}^{T_A} d\,T_A = \frac{(q_e + q_r)}{C_A} \int_0^t dt$$

$$T_A = \frac{q_e + q_r}{C_A}\, t + T_A^\circ$$

$$q_e + q_r = 190 \times 3.413/3600 = 0.180 \text{ BTU/sec}$$

$$C_A \approx 0.58 \text{ BTU/°F}$$

$$T_A^\circ = 130°\text{F}$$

$$T_A = 0.31\, t + 130 \qquad (4)$$

Equation (4) gives the temperature (°F) of the sample array as a function of time (sec) assuming that the array is isothermal and perfectly insulated. If the test is run for 10 sec, T_A may go as high as 133°F.

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