This document was prepared in conjunction with work accomplished under Contract No. AT(07-2)-1 with the U. S. Department of Energy.

[redacted]

DPSP-60-2258
RTR-272

UNCLASSIFIED

RECORDS ADMINISTRATION
AFGF

DISTRIBUTION

1. F. P. Allen (RTR)
2. L. G. Anderson
3.-4. H. W. Bellas
5. W. B. Bible
6. T. K. Conlon
7. P. A. Dahlen
8. T. C. Evans
9. L. W. Fox
10. K. W. French
11.-12. W. H. Gambrell
13. W. A. Kropp
14. L. C. Heck
15. A. A. Johnson
16. E. H. Judkins
17. E. O. Kiger
18. F. E. Kruesi
19. H. A. Larson
20. C. T. Axelberg
21. R. H. McKane
22. G. E. McMillan
23. G. Dessauer
24. E. C. Nelson
25. W. M. Olliff
26. W. P. Overbeck
27. R. L. Mellard, Jr.
28. I. R. Smith
29. O. A. Towler
30. C. W. J. Wende
31. W. E. Winter
32. G. W. McManaway
33. PRD Central File
34. 706-C File

This document consists of 13 pages,

No. 33 of 34 copies, Series A.

December 23, 1960

CLASSIFICATION CANCELLED
BY AUTHORITY OF
NAME TITLE DATE

Staff Engineer

RESTRICTED DATA
This document contains Restricted Data As defined in the Atomic Energy Act of 1954. Its transmittal or the disclosure of its contents in any manner to an unauthorized person is prohibited.

TO: A. A. JOHNSON

ION CHAMBER COMPENSATION TESTS

INTRODUCTION

A series of tests were performed under TA 1-922 to determine the need for gamma compensation of the ion chambers used to monitor the neutron flux in the 100 Area reactors. The purpose of this report is to present the results of these tests.

SUMMARY

The gamma background at the chamber during startup was found to be approximately 10^{-10} amps. The gamma current through-out start up is primarily made up of this constant value plus a gamma current which increases in proportion to the neutron flux and whose magnitude is approximately 1 to 2% of that of the neutron current at any given level. The contribution of the gammas to the chamber currents in the tests ranged from 43% to 80% prior to startup, but only accounted for approximately 2% at a power of 40 MW.

The following conclusions have been drawn from the results of the tests:

(1) Gamma compensation is needed for Log N-period systems since they provide the only automatic protection during the approach to criticality. If uncompensated chambers are used the apparent change in relative flux is lower than the actual change (for example, the apparent change is only 30% of the actual change if 70% of the current is gamma current. The amount that the reactor is subcritical, for an increasing flux, would then be over estimated by 1.0/.3 = 3 1/3.)

(2) Gamma compensation is not necessary for the High Level Flux Monitors or the galvanometer system.

[redacted] UNCLASSIFIED

(3) The use of compensated ion chambers should be continued in all positions in order to maintain the versatility of the nuclear instrument system.

The data obtained in the tests is presented in Tables II-VIII. The ratio of uncompensated current to compensated current as a function of neutron current is plotted for representative cases in Figures 3-5.

DISCUSSION

There are presently nine (eight in C Area) Westinghouse or Anton Compensated Ion Chambers located in the biological shield around each of the production reactors. These chambers are used to monitor the neutron flux in the intermediate and power flux regions. They serve as sensing elements for the two log N-period systems, the three High Level Flux Monitors, and the galvanometer circuit. The remaining chambers serve as spares.

The compensated ionization chamber is designed to detect thermal neutrons in the flux range from 2.5×10^2 to 2.5×10^{10} neutrons/cm^2/second. It consists of three coaxial, cylindrical electrodes (see Figure 1). The surfaces of the outer volume are boron coated to make it sensitive to neutrons as well as to gammas. Positive voltage sufficient to saturate the outer volume under all operating conditions is applied to the outer electrode. The compensation adjustment is obtained by applying a negative voltage to the inner electrode which is sufficient to saturate only part of the inner volume. The inner volume is about 5% larger than the outer volume, making it possible to obtain a balance in a uniform gamma flux with only part of the inner volume saturated. The current (conventional) from the outer volume flows into the signal electrode and the current from the inner volume flows away from the signal electrode. The two currents thus subtract, leaving a current proportional to the neutron flux as a signal.

The range of intensity over which neutrons may be detected by an uncompensated chamber is limited by the gamma background in the reactor. Gamma activity in the chamber comes from two sources: the fission process (direct yield and fission products) and induced activities in the reactor materials (fuel cladding, tank wall, etc.). Both fission product activities and induced activities depend on the history of the reactor. The gamma background at any particular power level is then the sum of a constant background from induced activities in the reactor materials and gamma activity which increases essentially linearly with the neutron flux. The constant gamma background was found to be contributing more than 50% of the total current prior to startup in all of the tests except one and was as high as 80% in one case. The gamma current increase, with increasing neutron flux, was found to be approximately 1 to 2% of the neutron current increase. Since the increase is small and an essentially linear function of neutron increase, it could be disregarded and the chambers operated without compensation if the relatively large (compared to pre-startup neutron current) constant gamma background were not present. This constant background introduces considerable error at low power levels (Kilowatt region) into the Log N-period systems (if operated on an uncompensated chamber), which provide automatic protection based on a minimum permissible period for the neutron flux. For example, if the gamma contribution at a particular point is 50%, the apparent period is approximately twice the actual period, and the safety of the reactor is compromised. However, as the reactor power increases, the contribution to the current from the constant gamma background becomes an increasingly smaller portion of the total current and presents no problem at operating power levels.

The test equipment consisted of an extended range Beckman microammeter, Brown recorder and chamber power supplies. A switching arrangement was incorporated in the power supplies so that readings could be taken of compensated current, uncompensated current (neutron plus gamma), gamma current alone, and total current (neutron plus gamma plus gamma, obtained by applying +900 volts to both inner and outer chambers so that the outputs add). A diagram of the switching arrangement is given in Figure 2.

Tests were performed in all of the 100 Areas. The seven tests run included 4 cold clean startups, 2 scram recoveries, and one manual scram.

Readings taken in the tests were restricted to compensated current and uncompensated current because of the relatively high rates of change in current during startup. The ratio of uncompensated current to compensated current was plotted as a function of neutron current. The test data are given in Tables II-VIII and are plotted for the tests on the R-2-3 scram recovery, R-2-3 manual shutdown, and the P-3 startup (Figures 3, 4, and 5).

The gamma contribution to the chamber current at several levels is given in the table below, the numbers in parentheses are the neutron currents in microamps.

TABLE I

Test Performed	Type Load	Gamma Contribution Prior To Start-Up	40 MW	To Chamber Current At Neutron Current of .01 Microamps*	.1 Microamps*
K-1 Start Up	VI-J	80% (7 x 10^{-6})	1.7% (.12)	20%	7%
C-1 Start Up	VII-A	-	2.7% (.70)	7%	3%
C-1 Scram Recovery	VII-A	57% (6.2 x 10^{-5})	1.7% (.88)	8%	3%
L-1 Start-Up	VII-A	77% (2.4 x 10^{-5})	1.7% (.18)	7%	2%
R-2-3 Scram Recovery	VII-A	43% (2.04 x 10^{-4})	1.6% (.31)	6%	2%
P-3 Start-Up	VII-AL	54% (1.1 x 10^{-4})	-	5%	2%

* Obtained from curves

The function of the Log N-Period system is to provide automatic protection against reactor runaway during startup. Six and one-third decades of current are covered by the logarithmic amplifier, providing a convenient indication of reactor power with no range change required. Flux and period information is essential during the approach to critical and the rise to power. The Log N-Period System provides the only automatic safety during the approach to critical and is most important while the reactivity changes have the least effect on neutron flux (over the first 1 to 2 decade increase in flux). In all of the tests except one, the gamma contribution to the current at the chamber was greater than 50% and in one case was as high as 80%. The gamma contribution had decreased to between 3 and 11% by the time the reactor was known to be critical. If uncompensated chambers were used, there would be a considerable amount of error introduced into the signal to the Log N-Period system. For example, since the apparent neutron flux would be greater than the actual flux, a possibly large error would be introduced into estimations of how far the reactor was from critical.

DPSOL's 105-1046E and 1046N specify that during start-up the High Level Flux monitors be set two decades below full power readings. Thus the HLFM setting during startup will normally be on the 3×10^{-7} or 10×10^{-7} range. From Table I, it is seen that at 0.1 microamp the gamma contribution to the total flux was not greater than 7% in any of the tests. Since the HLFM's will not normally be providing protection below .1 to .3 microamps, as explained above, and the gamma contribution at .1 microamps is no greater than 7%, it is concluded that compensation would not be necessary for the HLFM's.

It can be concluded from consideration of the data obtained that:

(1) Compensation is necessary on chambers serving as sensing elements for instruments which provide the primary protection in the approach to criticality. (Log N-Period systems).

(2) Compensation is not necessary on chambers serving as sensing elements for instruments providing protection only above 0.1 microamps (High Level Flux Monitors).

It would, therefore, be possible to install uncompensated ion chambers as sensing elements for the High Level Flux Monitors on a replacement basis. However, this would result in a reduction in the versatility of the nuclear instrument system, and although a financial gain would be realized, it would be small (Anton uncompensated chambers list at $1185 and compensated chambers at $1950). It is concluded that Compensated Ion Chambers should be used in all of the nuclear instrument positions in order to maintain the versatility of the system.

R. L. Mellard, Jr.

RLM/njg

COMPENSATED IONIZATION CHAMBER

CROSS SECTION & ASSOCIATED CIRCUIT

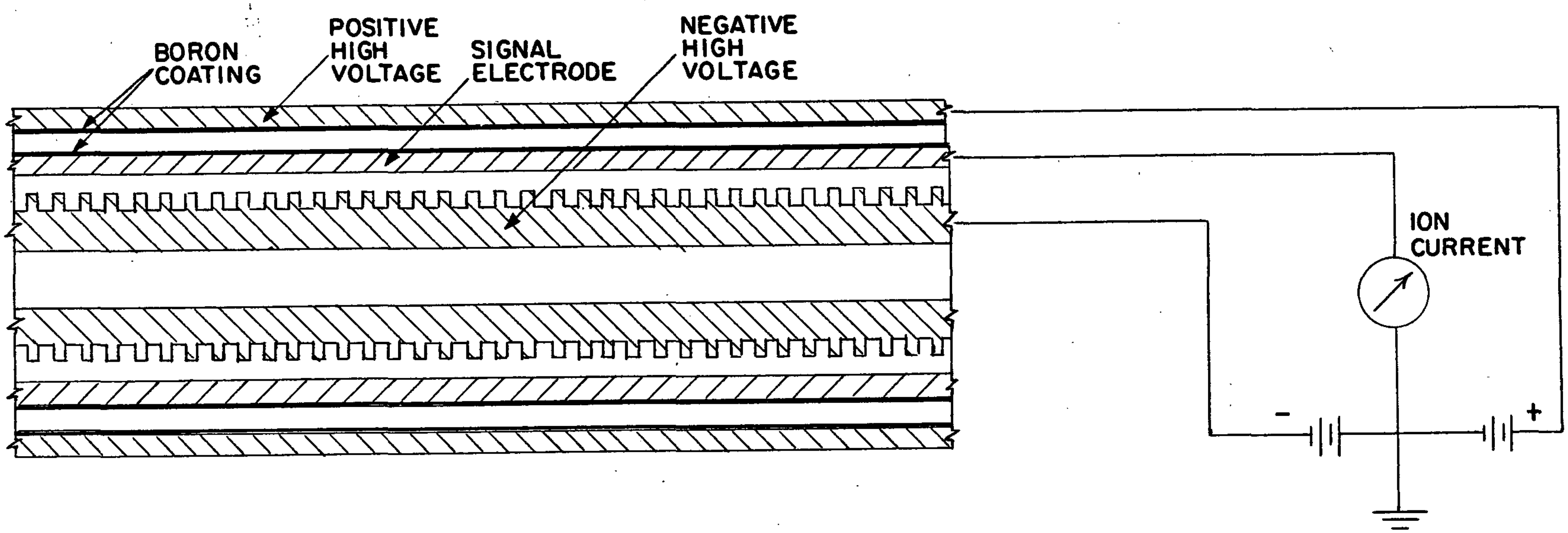


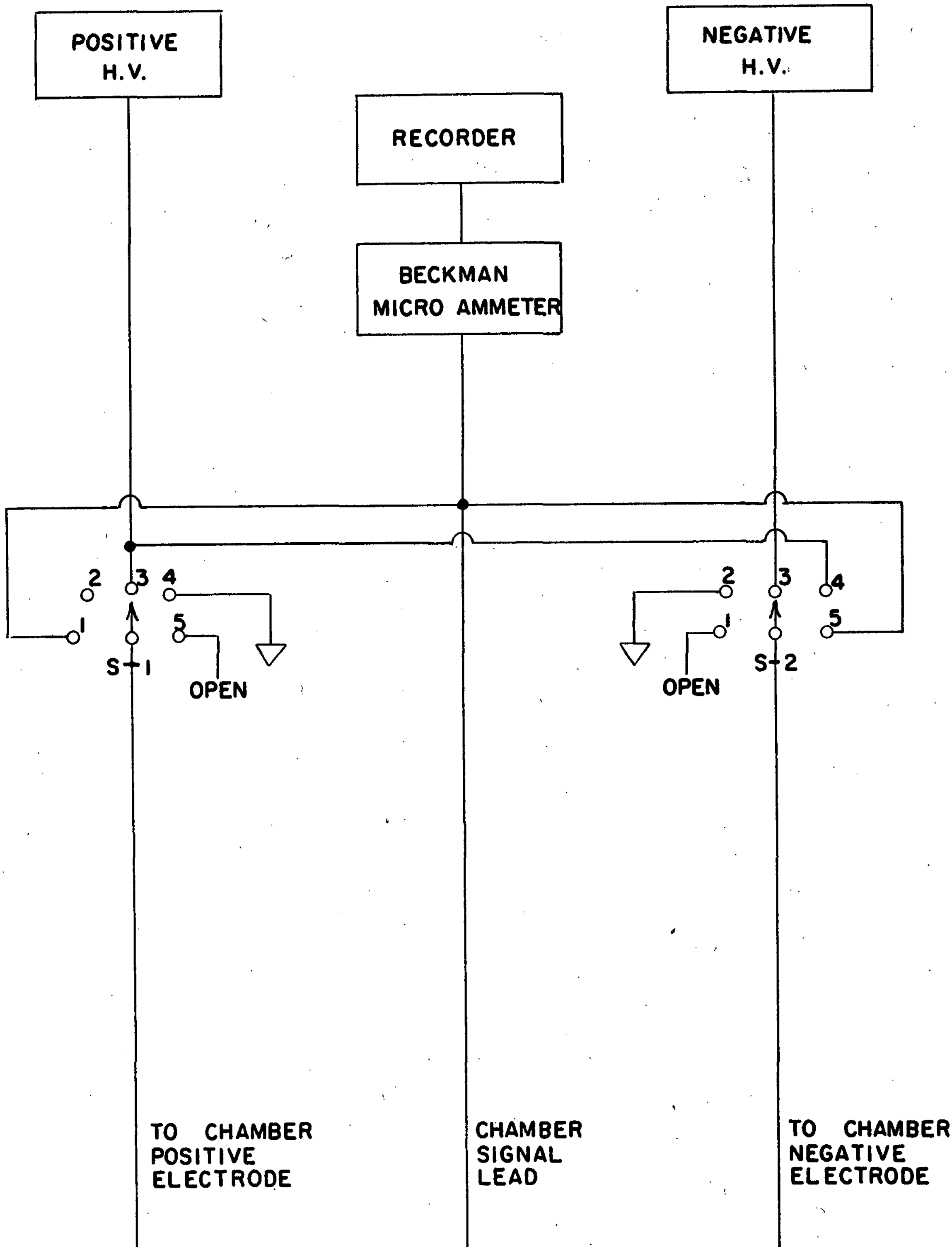
FIGURE 1

P-60-2258

[redacted]-60-2258

FIGURE 2

CIC TEST EQUIPMENT



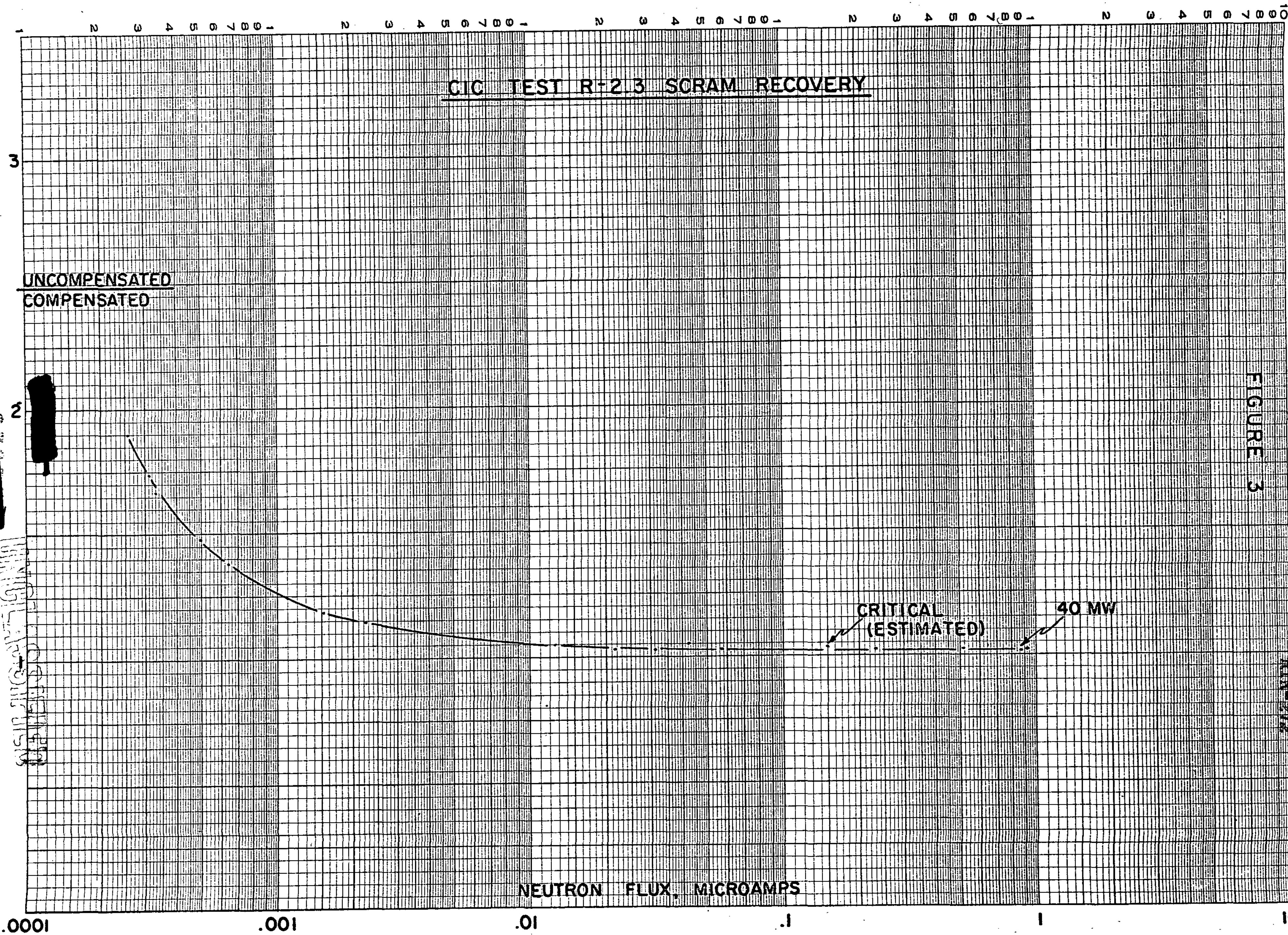


FIGURE 3

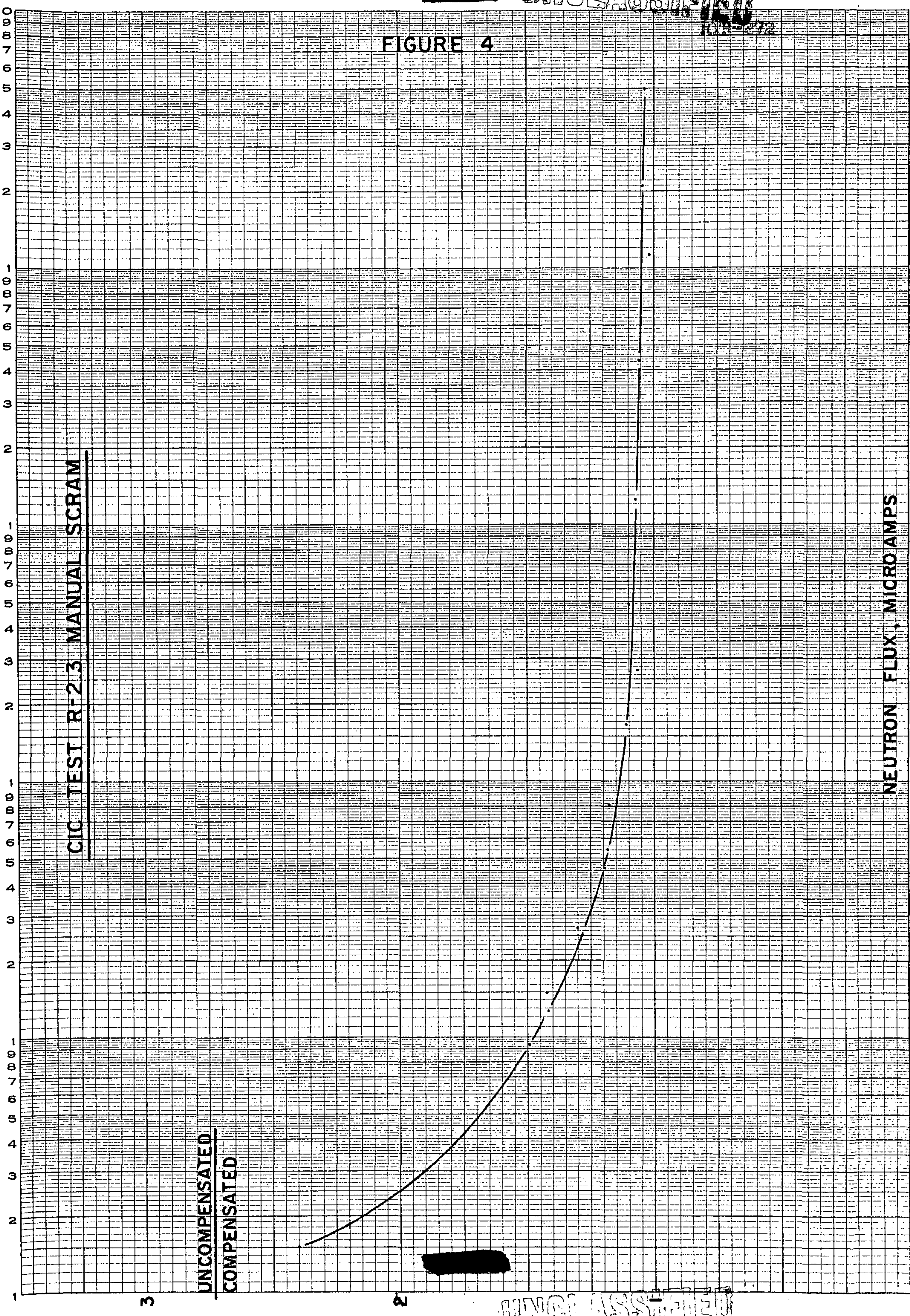
[redacted]

[redacted]

0-2258

[redacted] UNCLASSIFIED DPSP-60-2258

FIGURE 4



[redacted]

UNCLASSIFIED

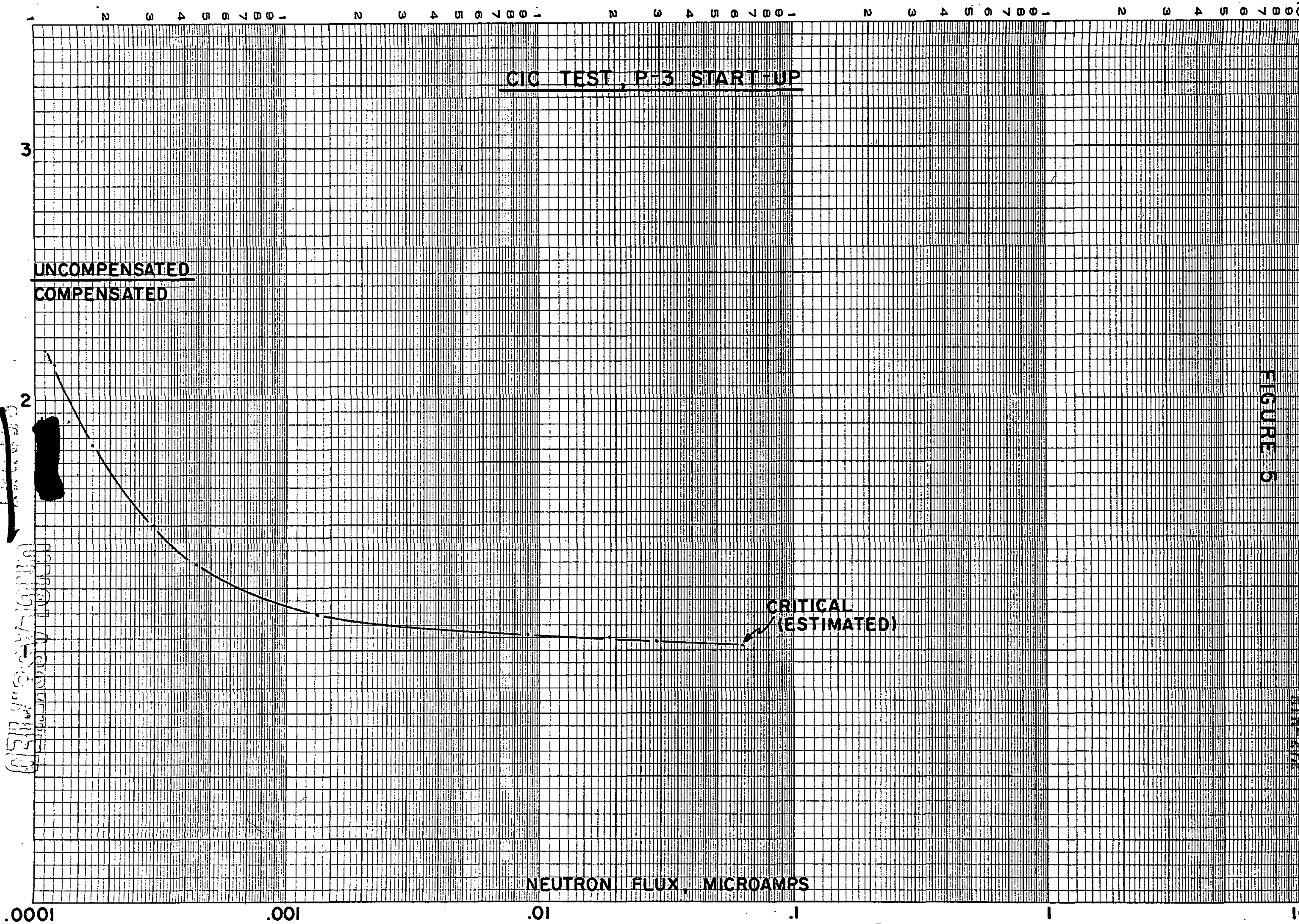

CIC TEST, P-3 START-UP
UNCOMPENSATED
COMPENSATED
3
2
1
CRITICAL
(ESTIMATED)
NEUTRON FLUX, MICROAMPS
.0001
.001
.01
.1
1
10

FIGURE 5

DATA FROM CIC COMPENSATION TESTS

TABLE II

CIC Test, K-1 Start-Up

The chamber used in this test was located in the C-3 position and was installed in October 1954. The CIC for the Log N used was in the B-3 position.

Date	Time	Log N Reading	Microammeter Reading: Compensated Range	Compensated %	Uncompensated Range	Uncompensated %	$\frac{n+\gamma}{n}$
8/11/60	2:53 AM	.0001	10×10^{-11}	7	10×10^{-11}	35	5.0
	5:30 AM	.0003	10×10^{-11}	40	3×10^{-10}	48	3.60
	5:34	.003	10×10^{-10}	65	3×10^{-9}	37	1.76
	5:37	.01	10×10^{-9}	10	3×10^{-9}	94	*
	5:40	.04	3×10^{-8}	30	3×10^{-8}	40	1.33
crit (est.)	5:43	.2	10×10^{-8}	50	10×10^{-8}	55	1.10
	5:45	.4	10×10^{-8}	90	10×10^{-8}	95	1.06
40 MW Stop	5:48	.7	3×10^{-7}	39.5	3×10^{-7}	40.2	1.02
	8:30	1.0	3×10^{-7}	64	3×10^{-7}	68	1.06
	8:35	2.0	10×10^{-7}	35.5	10×10^{-7}	36	1.01
	8:42	3.0	10×10^{-7}	54	10×10^{-7}	56.5	1.05
	8:47	4.0	10×10^{-7}	73	10×10^{-7}	76	1.04
	8:52	5.0	10×10^{-7}	94.5	10×10^{-7}	96.5	1.02
	9:00	6.5	3×10^{-6}	43.5	3×10^{-6}	45.5	1.05
	9:07	8.0	3×10^{-6}	53.2	3×10^{-6}	54.5	1.02
	9:13	9.0	3×10^{-6}	60	3×10^{-6}	62.5	1.04
800 MW	9:18	10.1	10×10^{-6}	25	10×10^{-6}	26	1.04
	3:33 PM	10.5	10×10^{-6}	27.8	10×10^{-6}	29	1.04

*This reading of compensated current appears to be in error.

TABLE III

CIC Test, C-1 Start-Up

The chamber used in this test was located in the C-3 position, and was installed in February, 1955. The CIC sensing element for the Log N used was in the A-3 position.

Date	Time	Log N Reading	Compensated Range	Compensated %	Uncompensated Range	Uncompensated %	$\frac{n+\gamma}{n}$
8/28/60	1:05 PM	.003	3×10^{-8}	40	3×10^{-8}	44	1.10
	1:07	.008	10×10^{-8}	35	10×10^{-8}	38	1.09
	1:09	.02	3×10^{-7}	36	3×10^{-7}	39	1.08
	1:11	.06	10×10^{-7}	35	10×10^{-7}	37	1.06
40 MW	1:13	.15	10×10^{-7}	70	10×10^{-7}	72	1.03
	1:15	.25	3×10^{-6}	42	3×10^{-6}	42.5	1.02
	1:18	.3	3×10^{-6}	53	3×10^{-6}	53.5	1.01
	1:22	.4	3×10^{-6}	65	3×10^{-6}	65.8	1.01
	1:25	.5	3×10^{-6}	82	3×10^{-6}	83	1.01
	1:31	.7	10×10^{-6}	31	10×10^{-6}	31.5	1.02
	1:35	.8	10×10^{-6}	41	10×10^{-6}	41.5	1.01
		1.0	10×10^{-6}	46.5	10×10^{-6}	47.5	1.02
		2.0	3×10^{-5}	30	3×10^{-5}	30.5	1.02
		3.0	3×10^{-5}	37	3×10^{-5}	37.5	1.01
600 MW		3.5	3×10^{-5}	48.5	3×10^{-5}	49	1.01

TABLE IV

CIC Test, C-1 Scram Recovery

The chamber used in this test was located in the C-3 position and was installed in October, 1954. The CIC sensing element for the Log N used was located in the B-3 position.

Date	Time	Log N Reading	Compensated Range	Compensated %	Uncompensated Range	Uncompensated %	$\frac{n+\gamma}{n}$
9/8/60	5:15 PM	.0002	3×10^{-10}	24	3×10^{-10}	56	2.83
	7:02	.0004	10×10^{-10}	62	3×10^{-9}	31	1.50
	7:11	.0005	10×10^{-10}	89	3×10^{-9}	39	1.31
	7:20	.001	3×10^{-9}	32	3×10^{-9}	40	1.25
	7:23	.002	3×10^{-9}	62	3×10^{-9}	73	1.18
	7:26	.005	10×10^{-9}	39	10×10^{-9}	44	1.13
	7:30	.01	3×10^{-8}	40	3×10^{-8}	45	1.12
	7:33	.02	3×10^{-8}	90	3×10^{-8}	95	1.06
	7:35	.06	10×10^{-8}	51	10×10^{-8}	54	1.06
	7:36	.1	3×10^{-7}	40	3×10^{-7}	41	1.03
	7:38	.2	3×10^{-7}	78	3×10^{-7}	80	1.03
	7:40	.5	10×10^{-7}	51	10×10^{-7}	52	1.02
40 MW	7:50	.6	3×10^{-6}	29.5	3×10^{-6}	30	1.02
	7:54	.8	3×10^{-6}	32	3×10^{-6}	32.2	1.01
	7:58	1	3×10^{-6}	40	3×10^{-6}	40.5	1.01
	8:00	2	3×10^{-6}	48.5	3×10^{-6}	49	1.01
	8:03	3	3×10^{-6}	87	3×10^{-6}	88	1.01
	8:05	4	3×10^{-6}	39	3×10^{-6}	39.5	1.01
	8:08	7	3×10^{-6}	61.5	3×10^{-6}	62	1.01
		8.5	3×10^{-6}	84	3×10^{-6}	85	1.01

TABLE V

CIC Test, L-1 Start-Up

The chamber used in this test was located in the B-2 position. The exact date of installation was not known, but it was prior to August, 1956. The CIC sensing element for the Log N used is located in the A-3 position.

Date	Time	Log N Reading	Compensated Range	Compensated %	Uncompensated Range	Uncompensated %	$\frac{\eta+\gamma}{\eta}$
9/24/60	Prior to Start-up	.0004	3×10^{-10}	8	3×10^{-10}	35	4.38
	2:54 AM	.001	3×10^{-10}	68	10×10^{-10}	60	2.94
	2:56	.004	3×10^{-9}	42	3×10^{-9}	62	1.48
	2:58	.01	10×10^{-9}	40	10×10^{-9}	51	1.28
	3:00	.02	3×10^{-8}	37	3×10^{-8}	42	1.14
	3:01	.04	3×10^{-8}	80	3×10^{-8}	86	1.08
Crit (est.)	3:03	.07	10×10^{-8}	35	10×10^{-8}	38	1.09
	3:04	.09	10×10^{-8}	63	10×10^{-8}	66	1.05
	3:05	.15	10×10^{-8}	90	10×10^{-8}	93	1.03
	3:07	.28	3×10^{-7}	53	3×10^{-7}	55	1.04
40 MW	3:15	.28	3×10^{-7}	60	3×10^{-7}	61	1.02

TABLE VI

CIC Test, R-2.3 Start-Up

The chamber used in this test was located in the B-3 position and was installed in April, 1955. The CIC sensing element for the Log N used was located in the D-3 position.

Date	Time	Log N Reading	Compensated Range	Compensated %	Uncompensated Range	Uncompensated %	$\frac{\eta+\gamma}{\eta}$
9/28	9:55 PM	.0003	3×10^{-10}	68	10×10^{-10}	35	1.72
	10:30	.00034	3×10^{-10}	78	10×10^{-10}	40	1.71
	10:45	.00038	3×10^{-10}	86	10×10^{-10}	49	1.90
	11:00	.00046	10×10^{-10}	31	10×10^{-10}	54	1.74
	11:15	.00047	10×10^{-10}	33	10×10^{-10}	55	1.67
	11:30	.0008	10×10^{-10}	50	10×10^{-10}	74	1.48
	11:35	.001	10×10^{-10}	64	10×10^{-10}	88	1.38
	11:45	.003	3×10^{-9}	51	3×10^{-9}	60	1.18
	11:50	.005	3×10^{-9}	75	3×10^{-9}	86	1.15
	11:53	.013	10×10^{-9}	64	10×10^{-9}	70	1.10
	11:57	.025	3×10^{-8}	42	3×10^{-8}	44	1.05
	11:58	.04	3×10^{-8}	72	3×10^{-8}	74	1.03
	12:00 M	.05	10×10^{-8}	31	10×10^{-8}	32	1.03
9/29	12:03	.08	10×10^{-8}	42	10×10^{-8}	44	1.05
	12:05	.1	10×10^{-8}	57	10×10^{-8}	58.5	1.03
Crit (est.)	12:09	.2	10×10^{-7}	15	10×10^{-7}	15.5	1.03
	12:10	.4	10×10^{-7}	23	10×10^{-7}	23.5	1.02
	12:13	.9	10×10^{-7}	51	10×10^{-7}	52	1.02
	12:20	1.5	10×10^{-7}	29.4	10×10^{-7}	29.7	1.01
40 MW	12:25	1.5	10×10^{-7}	31	10×10^{-7}	31.5	1.02

TABLE VII

CIC Test, R-2.3 Manual Scram

Date	Time	Log N Reading	Compensated Range	Compensated %	Uncompensated Range	Uncompensated %	$\frac{n+\gamma}{n}$
9/29	9:55 AM	60	Off	Scale			
(1200 MW)	10:03	48	3×10^{-5}	98.5	3×10^{-5}	99	1.005
	10:08	36	3×10^{-5}	83.5	3×10^{-5}	84	1.006
	10:10	28	3×10^{-5}	66.4	3×10^{-5}	67	1.009
	10:12	20	3×10^{-5}	47.5	3×10^{-5}	48	1.011
	10:18	7	3×10^{-5}	16.8	3×10^{-5}	17.3	1.03
	10:20	3	3×10^{-5}	7.0	3×10^{-5}	7.3	1.04
97 MW	10:21	1.5	10×10^{-6}	11.4	10×10^{-6}	11.6	1.02
	10:23	0.5	10×10^{-6}	4.4	10×10^{-6}	4.6	1.05
	10:26	0.15	3×10^{-6}	4.2	3×10^{-6}	4.5	1.07
	10:28	0.08	10×10^{-7}	4.9	10×10^{-7}	5.4	1.10
	10:29	0.035	3×10^{-7}	9	3×10^{-7}	9.5	1.06
	10:32	0.02	3×10^{-7}	5.5	3×10^{-7}	6.1	1.11
Zero Power	10:36	0.012	3×10^{-8}	27	3×10^{-8}	31.5	1.17
	10:45	.009	3×10^{-8}	18.2	3×10^{-8}	21.5	1.18
	10:54	.006	3×10^{-8}	15.5	3×10^{-8}	18.5	1.19
	11:30	.0038	10×10^{-9}	26.5	10×10^{-9}	34.5	1.30
	12:30 PM	.0022	10×10^{-9}	15	10×10^{-9}	21.5	1.43
	1:00	.00175	3×10^{-9}	43	3×10^{-9}	61	1.42
	2:00	.001	3×10^{-9}	31.5	3×10^{-9}	47	1.49
9/30	8:15 AM	.00016	3×10^{-9}	5	3×10^{-9}	12	2.40

TABLE VIII

CIC Test, P-3 Start-Up

The chamber used in this test was located in the A-3 position and was installed in April, 1958. The CIC sensing element for the Log N used was located in the C-3 position.

Date	Time	Log N Reading	Compensated Range	Compensated %	Uncompensated Range	Uncompensated %	$\frac{n+\gamma}{n}$
10/5/60	8:20 PM	.00024	10×10^{-10}	11	10×10^{-10}	24	2.18
	10:45	.00022	10×10^{-10}	11	10×10^{-10}	24	2.18
	11:22	.00023	10×10^{-10}	12	10×10^{-10}	25.5	2.13
10/6/60	12:00 M	.00027	10×10^{-10}	17	10×10^{-10}	31	1.82
	12:22 AM	.00044	10×10^{-10}	30	10×10^{-10}	45	1.50
	12:25	.0006	10×10^{-10}	44	10×10^{-10}	59	1.34
	12:30	.0008	10×10^{-10}	58	10×10^{-10}	72	1.24
	12:32	.001	3×10^{-9}	34	3×10^{-9}	40.5	1.19
	12:35	.0015	3×10^{-9}	44	3×10^{-9}	50	1.14
	12:40	.009	10×10^{-8}	9	10×10^{-8}	9.5	1.06
	12:45	.02	10×10^{-8}	19	10×10^{-8}	20	1.05
	12:47	.03	10×10^{-8}	29	10×10^{-8}	30	1.03
	12:55	.05	10×10^{-8}	63	10×10^{-8}	64	1.02

[redacted]