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THE NEUTRON SENSITIVE PCP IONIZATION CHAMBER

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Physics Division

THE NEUTRON SENSITIVE PCP IONIZATION CHAMBER

R. K. Abele and J. Gundlach

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A B S T R A C T

A Manual of Operation describing a neutron sensitive ionization chamber, for reactor instrumentation, which yields a current of 100 microamperes when in a neutron flux of 2×10^{10} nv. The instrument is 2 15/16" in diameter and 33" in length. The normally required voltage is + 370 V. The instrument may be removed from operating flux and disassembled immediately without special precautions from radiation.

MANUAL OF OPERATION

I. INTRODUCTION

The Neutron Sensitive Parallel Circular Plate Ionization Chamber has been developed to indicate the neutron flux level near the normal operating power of reactors and to give this indication with a minimum delay caused by neutron transport time. This instrument is thus suited for use in automatic control of reactors and for use in the safety circuitry. The sensitive end of the chamber is designed to make maximum use of a collimated beam of neutrons.[1,2]

II. OPERATION

The PCP chamber can be used with the Sigma Amplifier (Q-947) and in such use is capable of giving "scram" signals to the circuitry in a minimum time. The chamber may be used with the servo control amplifier and its associated equipment and in such use will control the reactor over its normal operating range from 1% to 100% of its design level.[3]

III. DESCRIPTION

A. Reference may be made to Fig. 1. The PCP chamber is 2 15/16" in diameter and 33" in length. An output current electrode consists of four parallel circular plates supported by quartz insulators to a graphite body. Interleaved with this electrode is the high voltage electrode

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1. Time Dependence of Thermal Neutron Flux Due to Instantaneous Epithermal Neutron Group - Greuling and Masket (47-10-170).
2. Analytical Prediction of Ion Chamber Response to Step Discontinuity in MTR Power - Lansing (50-2-32).
3. ORNL-963, MTR Project Handbook.

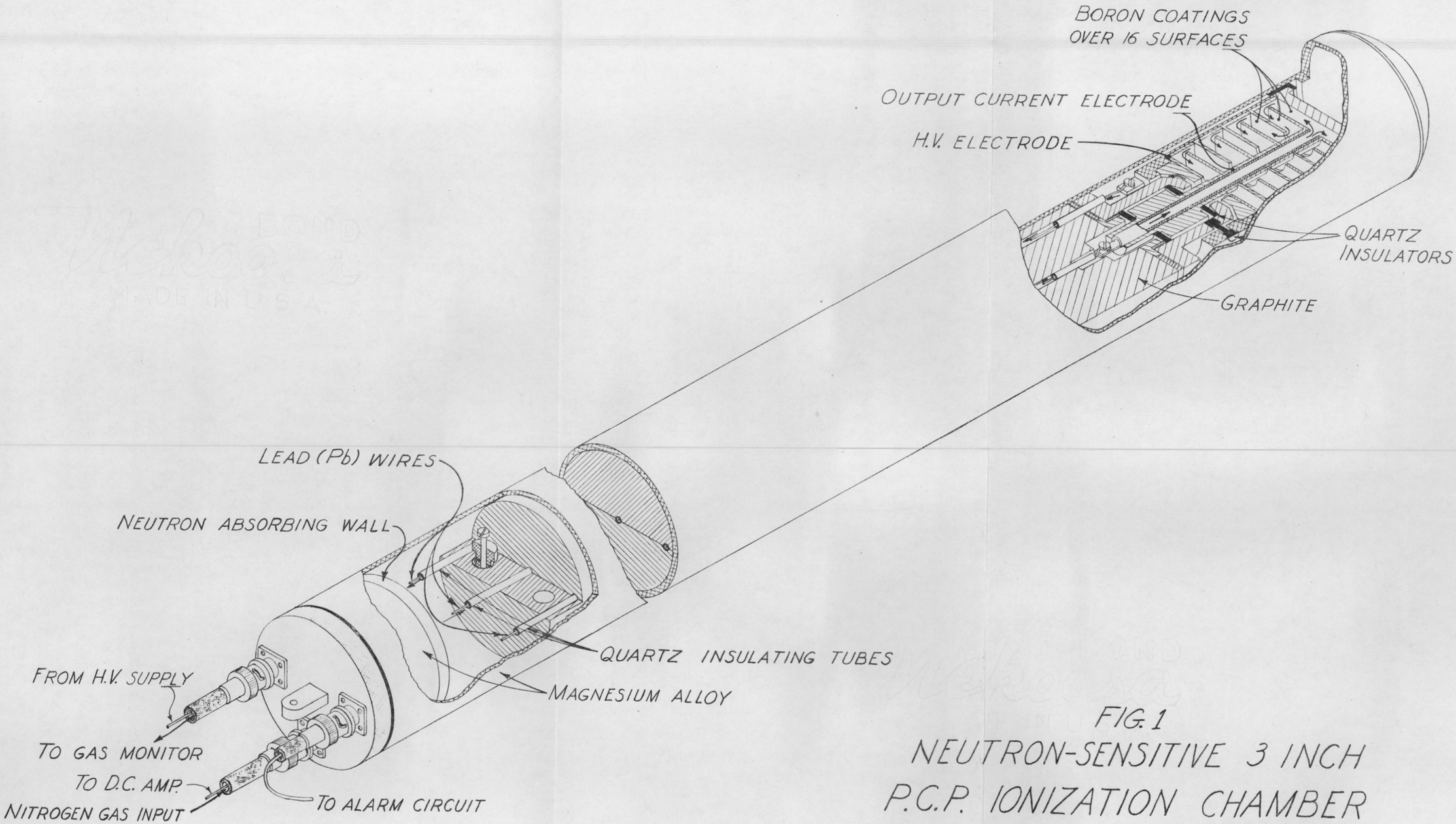

FIG. 1
NEUTRON-SENSITIVE 3 INCH
P.C.P. IONIZATION CHAMBER
LENGTH- APPROX. 33 IN.

Q-975-7

NOT CLASSIFIED

DESCRIPTION A. (Continued)

consisting of five discs which are also supported by quartz insulators to the graphite body. Electrical connections of lead (Pb) wire through quartz tubing are made from this sensitive section through the graphite body, which attenuates the neutron flux at the cable connectors. A cable attachment on the body of the chamber at this end is used to secure the chamber to the reactor structure.

B. BORON COATING

The sixteen parallel surfaces of the output current electrode and the high voltage electrode are coated with Boron 10 to a thickness of .3 mg/cm^2. This results in a total of 154 mg of Boron 10 on the chamber surfaces, and of this amount 122 mg are on surfaces perpendicular to the longitudinal axis of the chamber. These sixteen surfaces give a calculated efficiency of eight times that of a single plate chamber. The graphite electrodes are coated by a method utilizing a colloidal dispersion of boron in oil.[4] The cross sectional area of the PCP chamber results in a sensitivity of approximately .45 microamperes/10^8 nv streaming flux varying to .85 microamperes/10^8 nv for a surrounding flux where neutrons are reflected by material around the chamber (Fig. 4).

C. DETAIL

1. Choice of Materials. Considerable attention must be given to the selection of materials for an ionization chamber used in a reactor.

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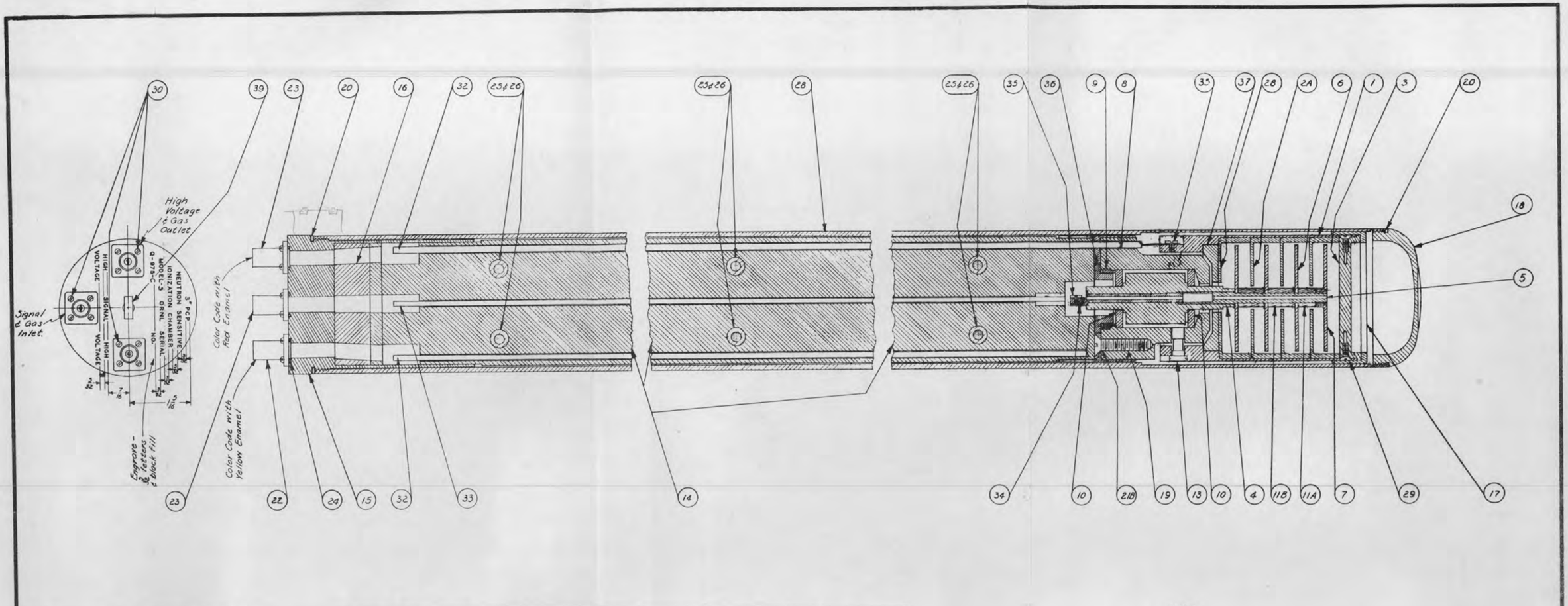
4. ORNL Instrument Department, Q-1045-11. A Boron Coating for Neutron Sensitive Ionization Chambers.

Choice of Materials (continued)

It is required that the materials of a chamber in a moderately high flux be not subject to radiation damage. Further, it is required that the materials be not sufficiently radioactive to contribute appreciably to the ionization current over the range of operation of the reactor and that the combination of cross section and half life of the materials in the chamber be such that the chamber may be disassembled and serviced within a short time after it has been removed from the reactor. In the sensitive end of the chamber only materials of high purity and low thermal neutron cross section are used. Material exposed to the collecting volume is graphite (C-18 or AUC). Magnesium (Dow Chemical Alloy 58135) is used in the supporting structure of the electrodes and the outer casing. Corroding type lead is used wherever electrical connections are made. Quartz and polystyrene are used as insulators. A barrier disc of boron plastic behind the graphite body serves to further reduce the neutron flux at the connector end of the chamber so that conventional brass connectors and cables can be used.

2. Manufacture. The design is such that all parts can be readily made in a machine shop from ORNL Instrument Department drawings titled Q-975-1B, Q-975-1C, Q-975-2B, Q-975-3B, Q-975-4B, Q-975-5B and Q-975-6B.

3. Disassembly. Reference should be made to Fig. 2 or to Q-975-1B, or Q-975-1C. For disassembly proceed as follows: Unscrew end cap (18) and remove insulator (17). Shell (28) can now be removed by unscrewing the threaded joint located at end cap (18). Unscrew end cap (18) and remove insulator (17). The top half of connecting shank (14) is removed by unscrewing 6 screws (25) and lifting the upper section. This exposes



PART NO.	NO. REQ'D	DESCRIPTION	MATERIAL	PART NO.	NO. REQ'D	DESCRIPTION	MATERIAL
28	1	Outer Casing	Magnesium *				
27	2	Screws, 1/4-20 Fillister Head, 2" Long	2S Aluminum				
26	12	Bushing	Magnesium *				
25	6	Fillister Hd. #10-24	Magnesium *				
24	3	"O" Ring, 3/8 x 1/8	Rubber-or-Neoprene				
23	2	Connector, (Gas Adapted, See Q-900-7) IPC-2700	Stores Stock, Modified				
22	1	Connector, IPC-2700	Stores Stock				
21B	2	Special Screw	Magnesium				
21A	2	Special Screw	Magnesium				
20	2	End Cap Gasket	Lead				
19	1	Aligning Sleeve	Magnesium *				
18	1	End Cap	Magnesium *				
17	1	Cap Insulator	Polystyrene				
16	1	Connecting Disc	Magnesium & Boron Poly.				
15	1	End Plug	Magnesium				
14	1	Connecting Shank	Graphite *				
13	3	Insulator	Polystyrene - or - Quartz				
12	2	Screws, #4-40 Flat Hd. 1/4 Long	2S Aluminum -or- Brass				
11B	2	Spacer .5625	Graphite *	40	1	Spanner for collector end plate	24S Aluminum
11A	1	Spacer .375	Graphite *	39	1	Cable Attachment	S.S.
10	2	Insulator	Polystyrene	38	1	Cable-Clevis, 7/16" Open-end Electrline-1S	Stores Stock Item #21-151
9	1	Insulator Clamping Ring	Magnesium *	37	1	Shell Insert	Graphite *
8	1	Ground Shell	Graphite *	36	1	Aligning Sleeve Insert	Graphite *
7	1	Collector End Plate	Graphite *	35	3	Special Screw	Magnesium *
6	3	Collector Plate	Graphite *	34	1	Collector Connector	Magnesium *
5	1	Collector Shaft	Magnesium	33	1	Tubes, 3MM O.D., 2MM I.D. 21 1/2" Long	Quartz
4	1	Collector	Graphite *	32	2	Tubes, 3MM O.D., 2MM I.D. 23 1/2 Long	Quartz
3	1	End Plug	Graphite *	31	1	Screws, 1/4-20, Flat Hd. 1 1/2 Long	2S Aluminum
2	*	Cup* (A 3-Req'd .500) (B 1-Req'd .625)	Graphite *	30	12	Screws, #3-56, Round Hd. 1/4 Long	Brass
1	1	Chamber Shell	Magnesium *	29	3	Screws, #2-56, Flat Hd. 1/4 Long (Special)	Magnesium *

BILL OF MATERIAL

Notes:

1. Magnesium: Dow Chemical Alloy #58135.
   Graphite: Grade C-18 Free Machining Molded.
2. All mating holes (Graphite -to- Magnesium) to be drilled in Graphite at assembly.
3. All graphite plate & cup surfaces (Items 2, 3 & 6) that are exposed to inside of chamber proper to be coated with enriched Boron coating - thickness approx. .3mg/cm²

* See Note #1

Blaw-Knox Item #650-1a

Companion Drawings Q-975-2C, 3C, 4C, 5B & 6B

REVISIONS			
DATE	CODE	CHANGE	CHK.

LIMITS ON DIMENSIONS UNLESS OTHERWISE SPECIFIED
FRACTIONS ±
DECIMALS ±
ANGLES ±

FIRST USED

DESIGNED R. K. Abele
DRAWN BY J. E. Percifal
STARTED 2-14-50
FINISHED 2-16-50
CHECKED 10-16-50 RK Abele
APPROVED

OAK RIDGE NATIONAL LABORATORY
INSTRUMENT DEPARTMENT

FIG. 2
NEUTRON CHAMBER-3" PCP
MODEL-3
-ASSEMBLY-

SCALE Full | Q-975-1C | D

Disassembly (continued)

all electrical connections -- both the solder joints at the connector end and the mechanical joints at the chamber proper. Lead (Pb) wires may be unsoldered from the copper by using a small pencil soldering iron heated to a temperature which just melts 50-50 or 60-40 tin-lead solder. Do not apply heat long enough to melt lead wire.

To disassemble the chamber proper, remove 3 screws (29) and lift out end plug (3). Care should be taken in handling the boron coated parts in the chamber. Collector end plate (7) is now unscrewed. In chambers through serial No. 14 this is done by applying slight pressure with a piece of sponge rubber and turning counter-clockwise. For chambers of serial No. 15 and higher, insert a small spanner wrench in holes of collector end plate and proceed as above. Parts numbered (6),(2A), (2B), (11A), (11B) and (37) are all removed by sliding out through the open end of the chamber. A long pair of tweezers may prove helpful for this operation. If it is necessary to remove chamber shell (1), lead (Pb) wires should be disconnected before pulling out 3 insulators, item (13). A fingernail or tweezer slot is provided in the head of these insulators, but care must be taken to prevent chipping of the quartz.

To obtain access to the signal insulators (10), ground shell (8) is slid out of aligning sleeve (19) after removing exposed screws ~~(21B).~~ Aligning sleeve insert (36) can then be pulled out and insulator clamping ring (9) unscrewed. Parts (4), (5), and (10) will come out as a unit.

End plug (15) is held to shank (14) by one large screw running axially to the shank and two small screws through the sides of (15). The

Disassembly (continued)

connectors are held in place by 4 screws each.

4. Assembly. For assembly, the above procedure is reversed. Before reassembly all insulators (this includes quartz tubing items (32) and (33)) should be cleaned and all dust and lint removed from all parts. The small insulated copper wire connection between the connectors and the lead (Pb) wires is a piece of RG-29/U cable from which the cover and braid have been removed. This insulation, if in good condition, can be cleaned with ethyl alcohol on a lintless cloth. All insulators can be cleaned by washing in a good detergent, rinsing and then re-rinsing with distilled water and finally drying in a vacuum oven at 60°C. If this process cannot be accomplished, an alcohol wash may suffice providing insulators show no smears or deposits when dry. After insulators are cleaned they should not be handled on their insulating surfaces with the hands. If any resoldering is done all excess flux (if used) must be removed. Alcohol will do for this operation.

5. Laboratory Testing. Before the complete assembly is inserted in casing (28) and end plug (3) is in place, a continuity test with an ohm meter can be made from the signal connector to end plate (7) and from both high voltage connectors to the H.V. Electrode Assembly (1). A check between all connectors and ground and between signal and high voltage can be made to see that no shorting has occurred. After the assembly is in casting (28) all connectors should be checked again for shorts to ground or to each other. A continuity of less than 10 ohms should be detected between the two high voltage connectors which are both attached to the H.V. Electrode.

Laboratory Testing (continued)

The signal lead should show an impedance of at least 10^{11} ohms to ground. With + 500 volts placed on the high voltage connector, signal current should be less than 10^{-9} amperes. If the chamber does not pass this test the insulators may be defective or unclean, or there may be lint or other foreign material causing the high leakage current. Cleanliness cannot be overstressed in the assembly of this chamber.

If it is desired to test that the chamber produces a current under radiation, it may be connected to an electrometer with an input resistor of approximately 10^{11} ohms. A small gamma source can then be used to produce an ionization current. Rough calculations of the current expected can be made, based on the collecting volume of approximately 140 cubic centimeters. If a Radium-Beryllium or Polonium-Beryllium neutron source is available, the chamber will show sensitivity to neutrons provided paraffin or other hydrogeneous material is placed around the chamber and the source.

IV. INSTALLATION

A. LOCATION IN REACTOR

A location should be chosen such that the forward end of the chamber is in a flux of approximately 2×10^{10} nv. The chamber should receive a streaming flux of neutrons. The usual considerations of effect of nearby experiments on flux suppression should apply here. Temperature of the instrument is limited to 80°C. No other precautions are necessary.

B. DESIGN OF INSTRUMENT HOLE

It is usually desirable to provide for moving the chamber while the reactor is in operation, so that adjustments in output current can be made.

DESIGN OF INSTRUMENT HOLE (continued)

A suitable shielding plug, with provisions for cable enclosure, to prevent radiation streaming is required.

C. INSTALLATION SCHEME

1. Voltage Supply. Reference may be made to Fig. 3. The positive voltage on the H. V. electrode should be in excess of that amount necessary to achieve a significant degree of saturation (Fig. 4); 370 v is currently in use. The ordinary power supply is usually adequate from considerations of regulation and noise. An additional connection is made directly to the high voltage electrode of the chamber to monitor the positive voltage supply and thus insure reliable operation.

2. Gas Flow. A flow of dry Nitrogen gas through the chamber is required when used in neutron fluxes near 10^{10} nv. (100 μa chamber current) to avoid the change in saturation characteristics due to contamination of the chamber filling gas. Accordingly, the gas is led into the chamber through the signal cable and is returned through one of the H.V. cables. The required gas flow is less than 1 cc. per second.

3. Coaxial Cables. Three RG-62/U coaxial cables with quick disconnect connectors are used to supply the positive voltage to the chamber, to monitor the positive voltage, and to return the signal current to the measuring instrument. The two positive voltage cables are interchangeable except for gas flow. The hollow construction of this low capacity cable enables it to carry the gas flow in addition to the electrical currents. The cable connectors IPC-28000 and the associated jacks IPC-27000 on the chamber and measuring instrument are modified[5] for introducing the gas

5. ORNL Instrument Department, Q-900-7A. Connector Modifications for Gas Flow.

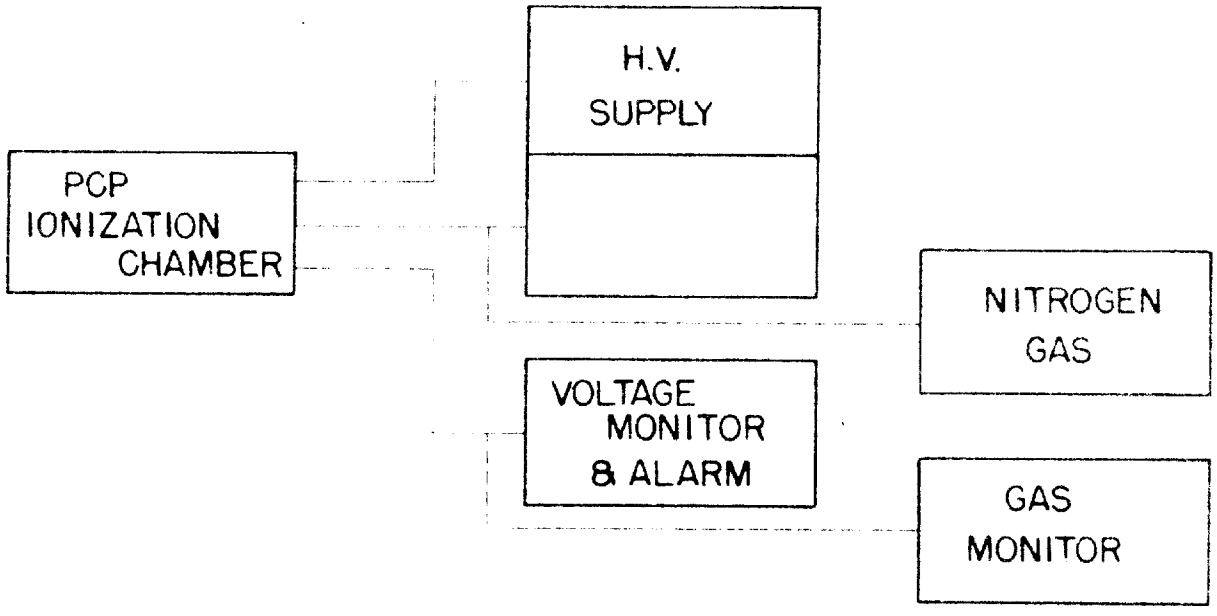


FIG. 3

UNCLASSIFIED
DWG. 11976

Coaxial Cables (continued)

flow into the cable and chamber. Maximum cable lengths may be determined for each individual application depending on the desired response time. In general 100 ft. is not excessive.

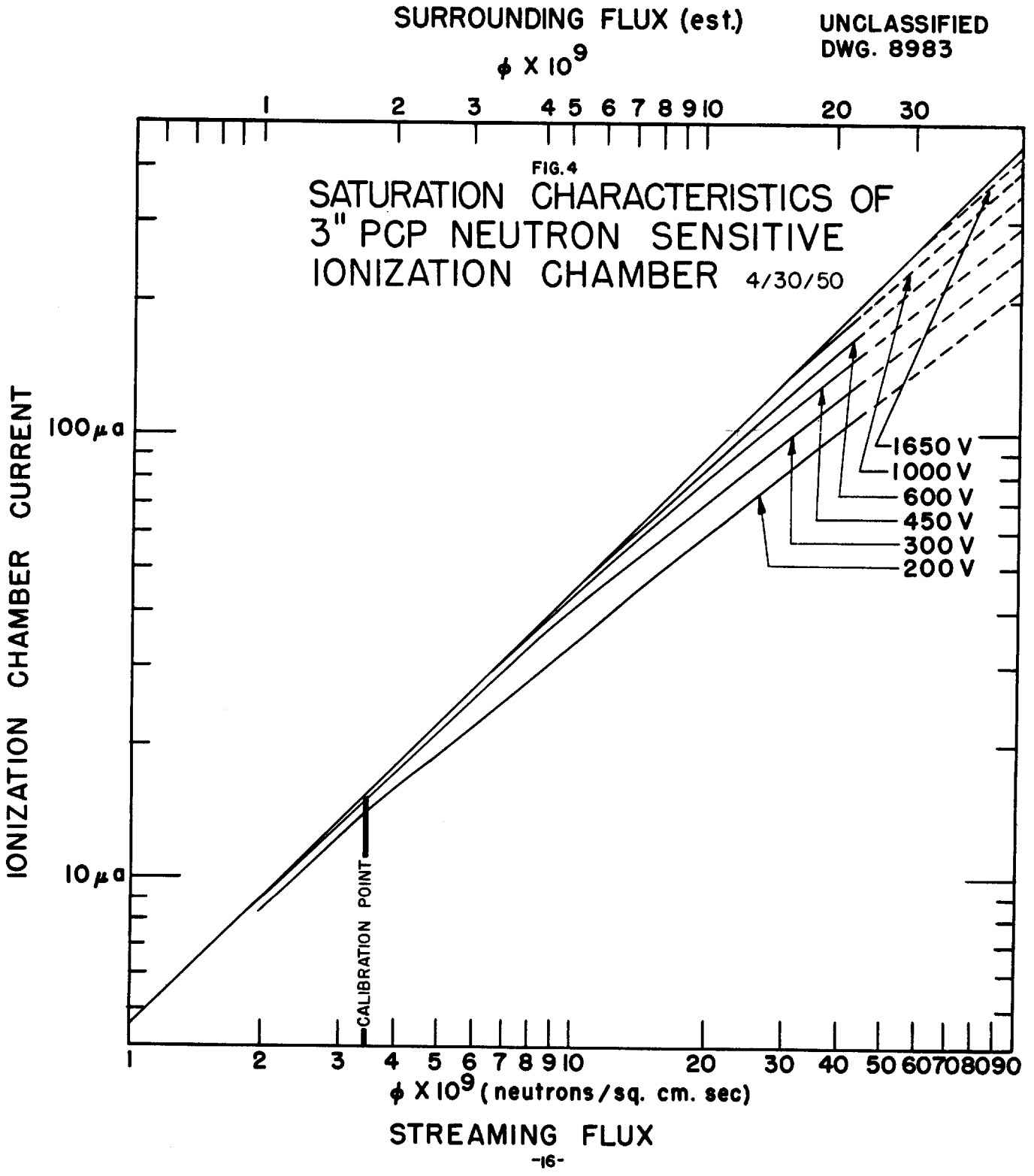
V. TECHNOLOGY

A. RADIATION HAZARD

The chamber may safely be serviced or repaired immediately on removal from the reactor after a cursory check for radiation. Abnormal radiation may be caused by surface contamination or by wrongful substitution of material.

B. SATURATION CHARACTERISTICS

Fig. 4 shows the approximate saturation characteristics for the PCP Ionization Chamber in a surrounding flux. A comparison with a streaming flux is indicated, but the saturation characteristics are expected to be somewhat poorer. The graph was made by assuming linearity of output current up to 150 microamperes at 1650 v on the H.V. Electrode.


SURROUNDING FLUX (est.)
φ X 10^9
UNCLASSIFIED
DWG. 8983
FIG. 4
SATURATION CHARACTERISTICS OF
3" PCP NEUTRON SENSITIVE
IONIZATION CHAMBER 4/30/50
IONIZATION CHAMBER CURRENT
100 μa
10 μa
1650 V
1000 V
600 V
450 V
300 V
200 V
CALIBRATION POINT
φ X 10^9 (neutrons/sq. cm. sec)
STREAMING FLUX