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A THERMAL NEUTRON SURVEY INSTRUMENT

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HEALTH PHYSICS DIVISION

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A THERMAL NEUTRON SURVEY INSTRUMENT

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INTRODUCTION

A thermal neutron survey instrument that is capable of measuring flux values less than 50 neutrons/cm^2/second has been developed. The instrument is very convenient to use, because it does not respond to other types of radiation.

The main reactions resulting in appreciable ionization in tissue due to thermal neutron exposure are the $N^{14}(n,p)C^{14}$ and the $H^1(n,\gamma)D^2$ reactions. Snyder[1] has calculated the maximum permissible flux of thermal neutrons, assuming that the protons have a relative biological effectiveness of ten, while that of the gamma rays is one. He shows that the depth dose curve is a maximum at slightly less than 1 cm inside tissue and based on a tolerance value of 0.06 rem (roentgen-equivalent-man) per 8-hour day for a 5-day week, he finds that the maximum permissible flux is between 1700 and 1950 n/cm^2/sec.

DETECTOR

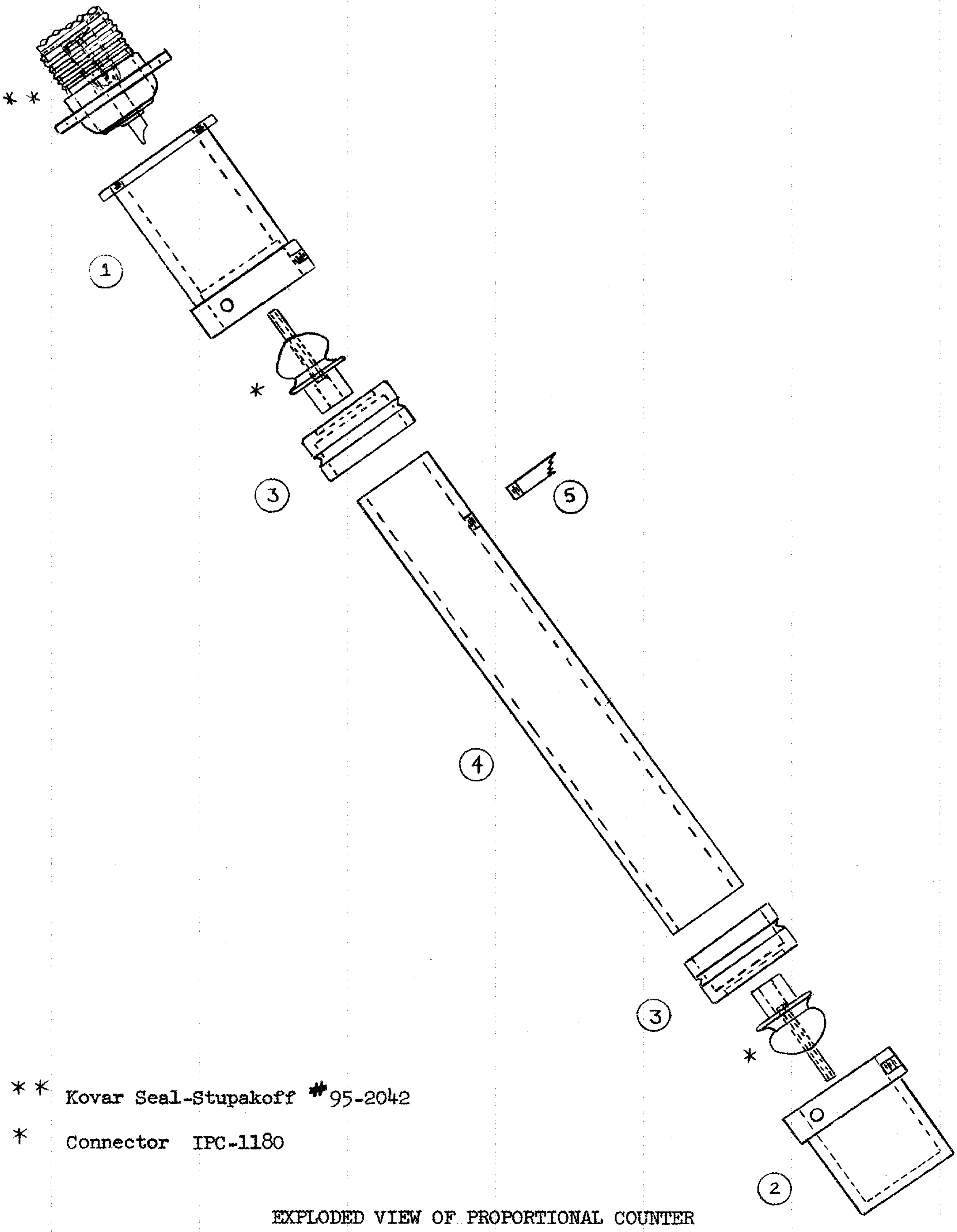
Since flux values less than 100 n/cm^2/sec need to be detected, the use of the $B^{10}(n,\alpha)Li^7$ reaction is suggested. Further, since the energy release of this reaction is 3.9 Mev, the use of B^{10} in a proportional counter permits easy discrimination against gamma radiation. The proportional counter has a radius of 1.2 cm and an active length (determined by using hypodermic tubing on the ends of the center wire) of 5 cm. When BF_3 of the unenriched type is used at a pressure of 4 cm Hg, the sensitivity of the counter is such that a thermal flux of 150 n/cm^2/sec gives an approximate average count rate

[1] W. S. Snyder, Nucleonics, February, 1950, pp 46-49

of 1 count/second. This means that a flux value as high as 10 times tolerance can easily be detected with no loss of counts with a simple thyratron discriminator circuit.

An exploded view of the proportional counter is shown in Figure 1, while the details of the parts are shown in Figure 2.

Figure 3 is a curve of the count rate plotted against pulse size for the proportional counter just described, when it is filled with unenriched BF_3 at a partial pressure of 4 cm Hg and argon at a partial pressure of 36 cm Hg. The argon prevents excessive loss of alpha particles into the counter walls. If an operating sensitivity of 0.04 volts is chosen, the stability of the amplifier and discriminator need not be closer than from 0.02 volts to 0.08 volts in order to maintain the calibration to within ± 5%

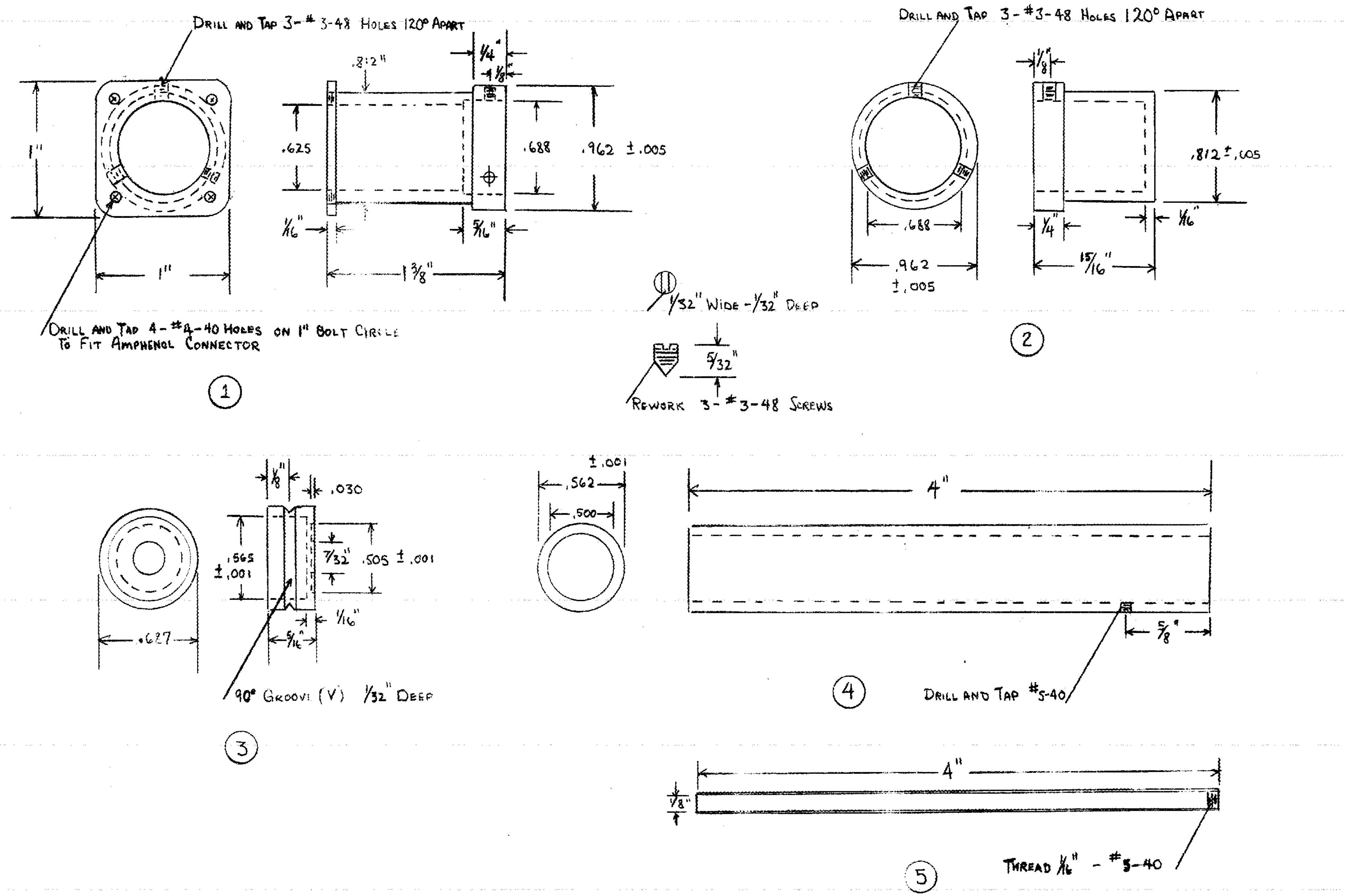


* * Kovar Seal-Stupakoff #95-2042

* Connector IPC-1180

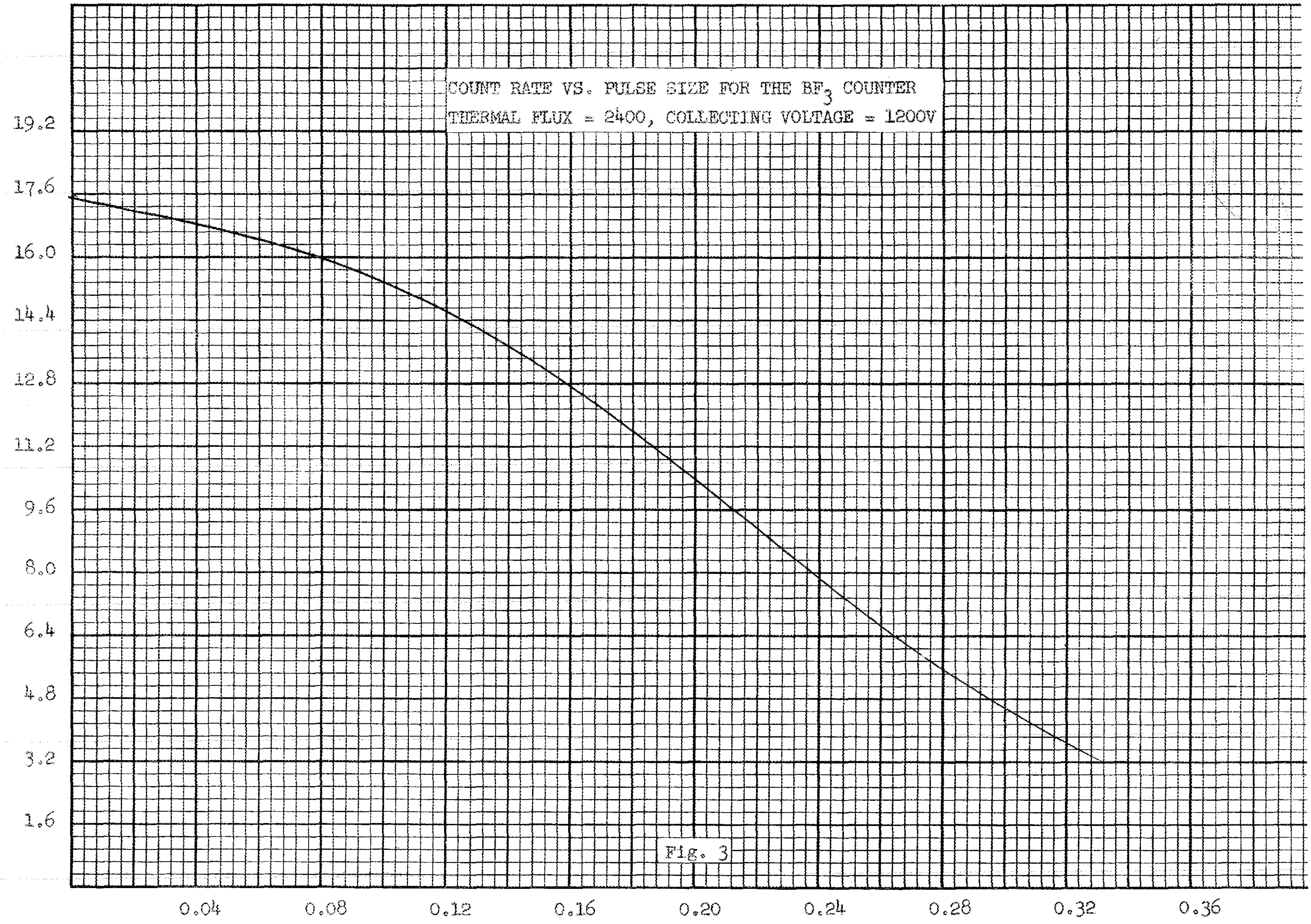
EXPLODED VIEW OF PROPORTIONAL COUNTER

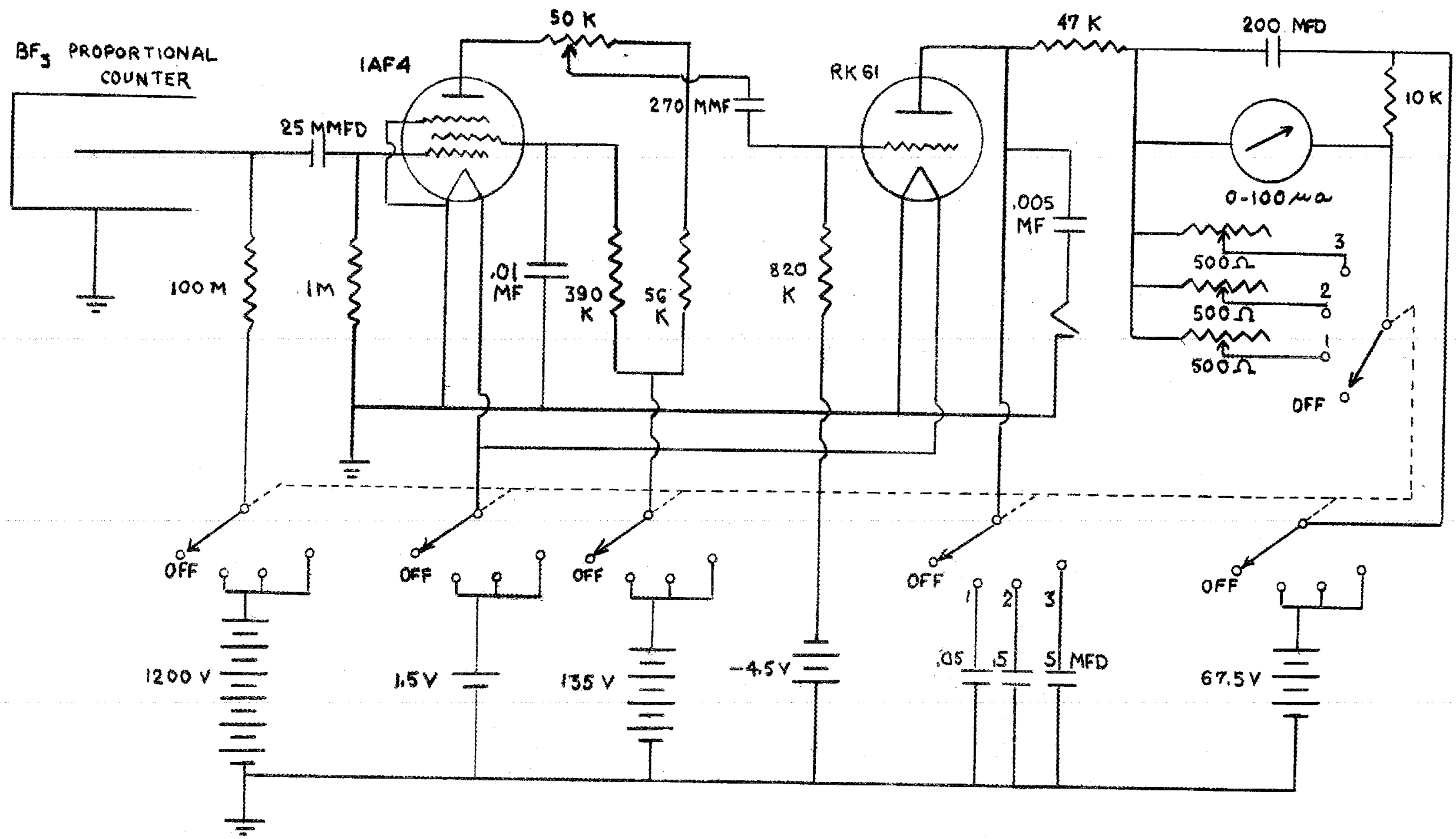
Fig. 1



DETAILS OF PROPORTIONAL COUNTER

Fig. 2


COUNT RATE VS. PULSE SIZE FOR THE BF_3 COUNTER
THERMAL FLUX = 2400, COLLECTING VOLTAGE = 1200V
19.2
17.6
16.0
14.4
12.8
11.2
9.6
8.0
6.4
4.8
3.2
1.6
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
0.36
Fig. 3



RANGE	FLUX FULL SCALE
1	20,000
2	2,000
3	200

CIRCUIT FOR THERMAL NEUTRON SURVEY INSTRUMENT

Fig. 4

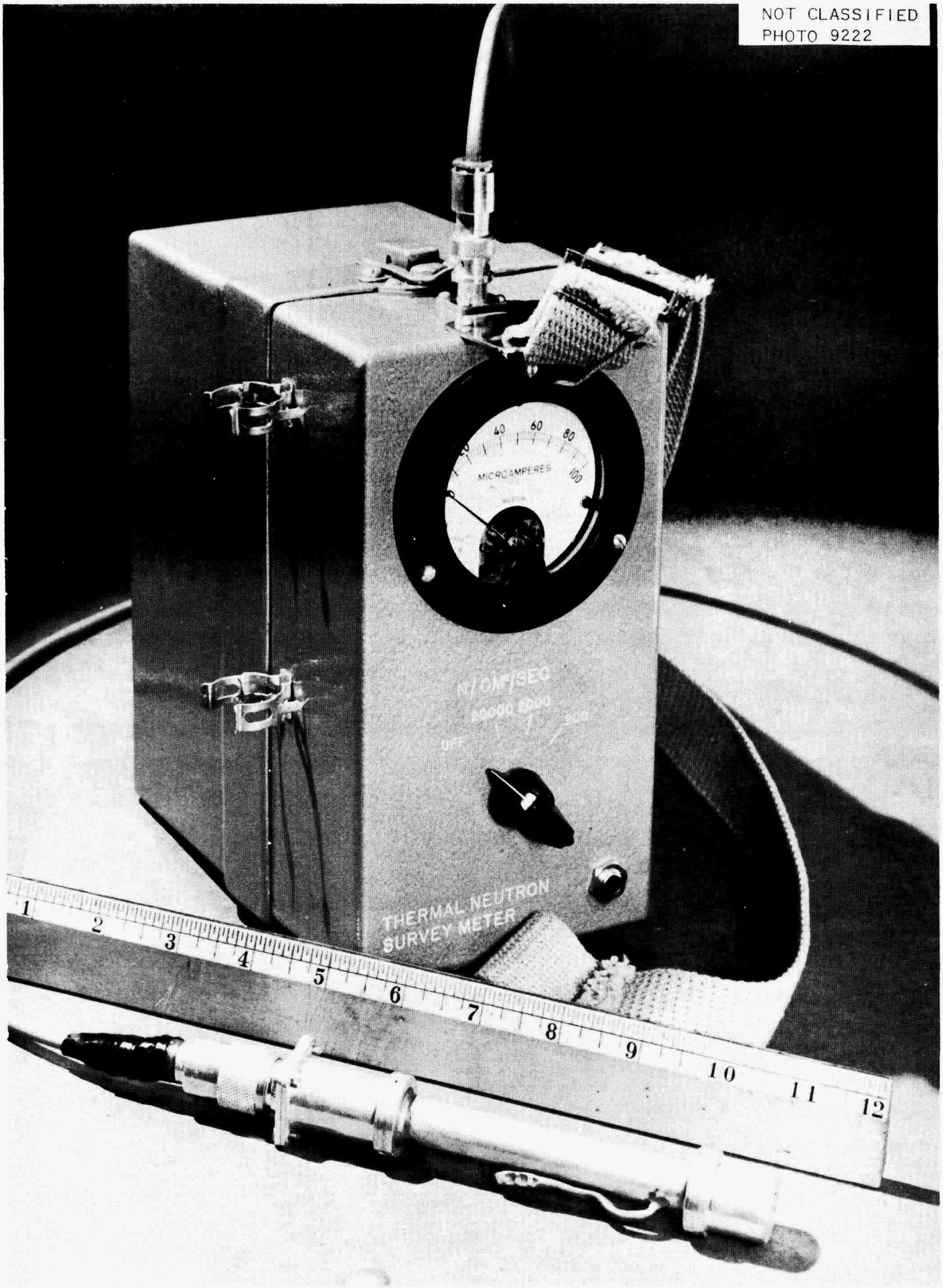
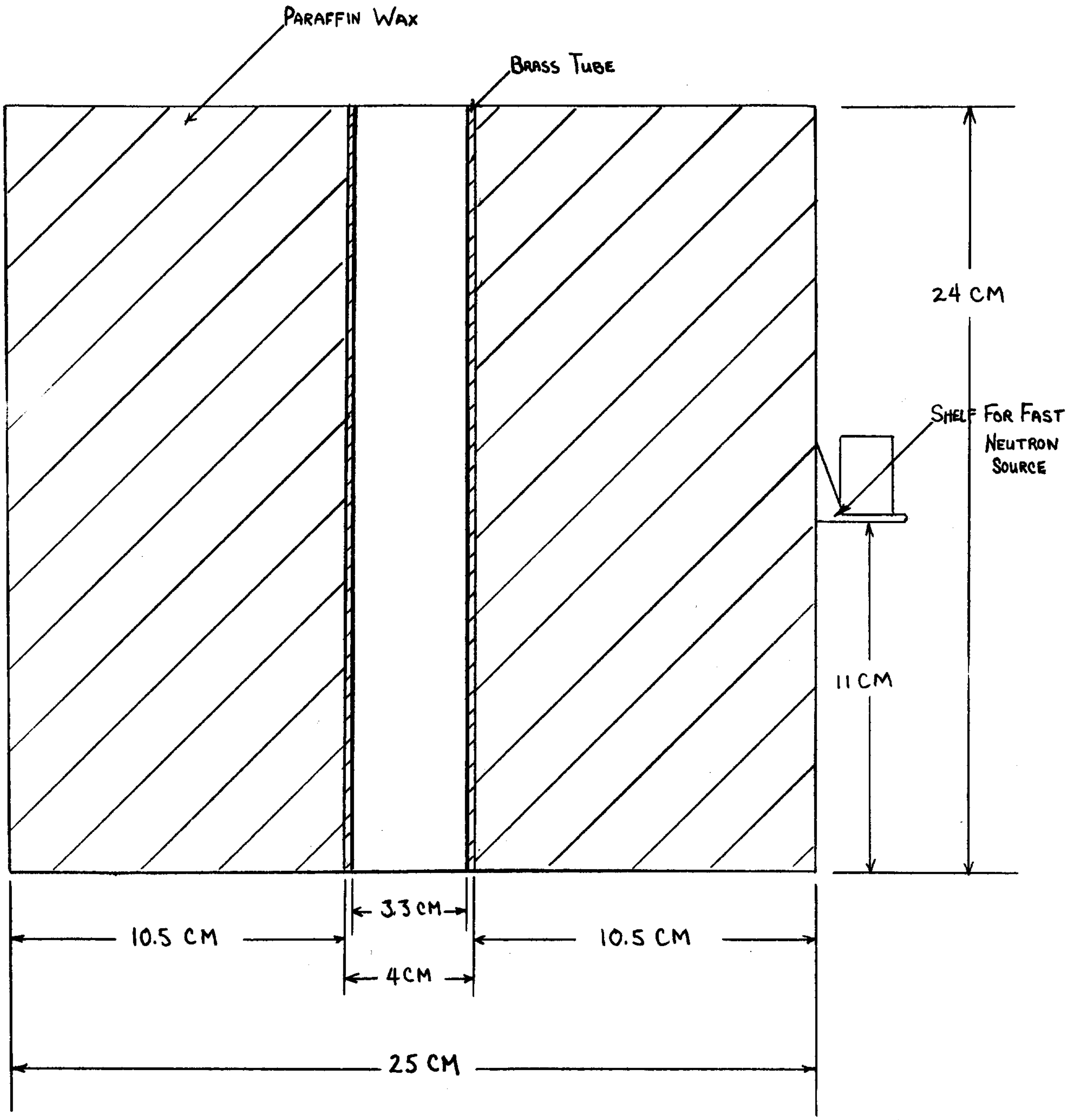


Figure 5. Photograph of the Complete Survey Instrument



THERMAL NEUTRON CALIBRATION UNIT

Fig. 6

flux ($n_t/cm^2/sec$) is obtained by multiplying the strength (n_f/sec) of the fast neutron source by 1.85×10^{-4} cm^{-2}. This conversion was determined by measuring the thermal neutron flux with the indium foil technique[2].

ASSEMBLY

Since the operation of this counter is dependent upon the proper assembly of the parts, and the close attention given to details in the assemblying and filling, the procedure for so doing is given in considerable detail.

A. Counter Body

1. Clean all parts with an organic solvent, rinse with alcohol and distilled water. (Do not use CCl_4)
2. Assemble end caps and filling tube with counter body, using soft solder. The filling tube should be bent into the desired position before soldering. Solder flux should be used sparingly on all joints.
3. Clean inside again before proceeding. It is extremely important that no trace of flux or solvent remain to react with the BF_3 as this will cause poor operation of the counter.
4. Cut glass tube of two Kovar seals to 3/8" length and fire polish the ends. Clean thoroughly and solder the seal into the end cap with soft solder. Before putting the second seal in, run a clean, straight nickel lead wire (about 0.015") through the two seals and put a slight bend on both ends to keep it from falling out. It should be about 4 inches longer than the counter. Be careful not to get flux inside the counter.

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[2]C. W. Tittle, Nucleonics, 8, No. 6, 5-9 June (1951)

B. Central Wire

Assembly of the central wire is shown in Fig. 7.

1. Place the end of 0.10" stainless steel tubing through the jaws of a small pin vise. Nick the tubing all around by holding it against a razor blade and rotating. Break the end off by gentle bending, since if it is cut through with the razor blade the hole will be burred. Flare the hole with a sharp pointed tool such as a ground dental tool. Pull 7/8" of tubing through the pin vise, cut off the same way, and ream the end. After two lengths have been cut and reamed, a piece of 0.002" tungsten wire about 2 inches long is spot welded to the end of a spool of 0.001" stainless steel wire[3] to serve as a needle and the pieces of tubing are threaded on the wire.

2. When two pieces of tubing are on the wire, cut off the tungsten and spot weld the stainless wire to the end of the nickel lead wire through the counter body at point A, having cut off the bend on this end of the nickel wire. Apply a slight tension to the wire by moving the spool back and slide a piece of tubing up to the weld. Solder the tubing to the 0.001" wire and the 0.001" wire to the lead wire, near point A.

3. Slide the scale drawing of the cross section of the counter (Fig. 8) under the taut wire so that the unsoldered end of the tubing is over the point B on the drawing. Slide up the next piece of tubing so that it is positioned with its free end at point C. Spot weld another piece of straight, clean 0.015" nickel wire to the stainless wire near point D and solder it, and the tubing at D. Cut the wire loose from the spool at point F.

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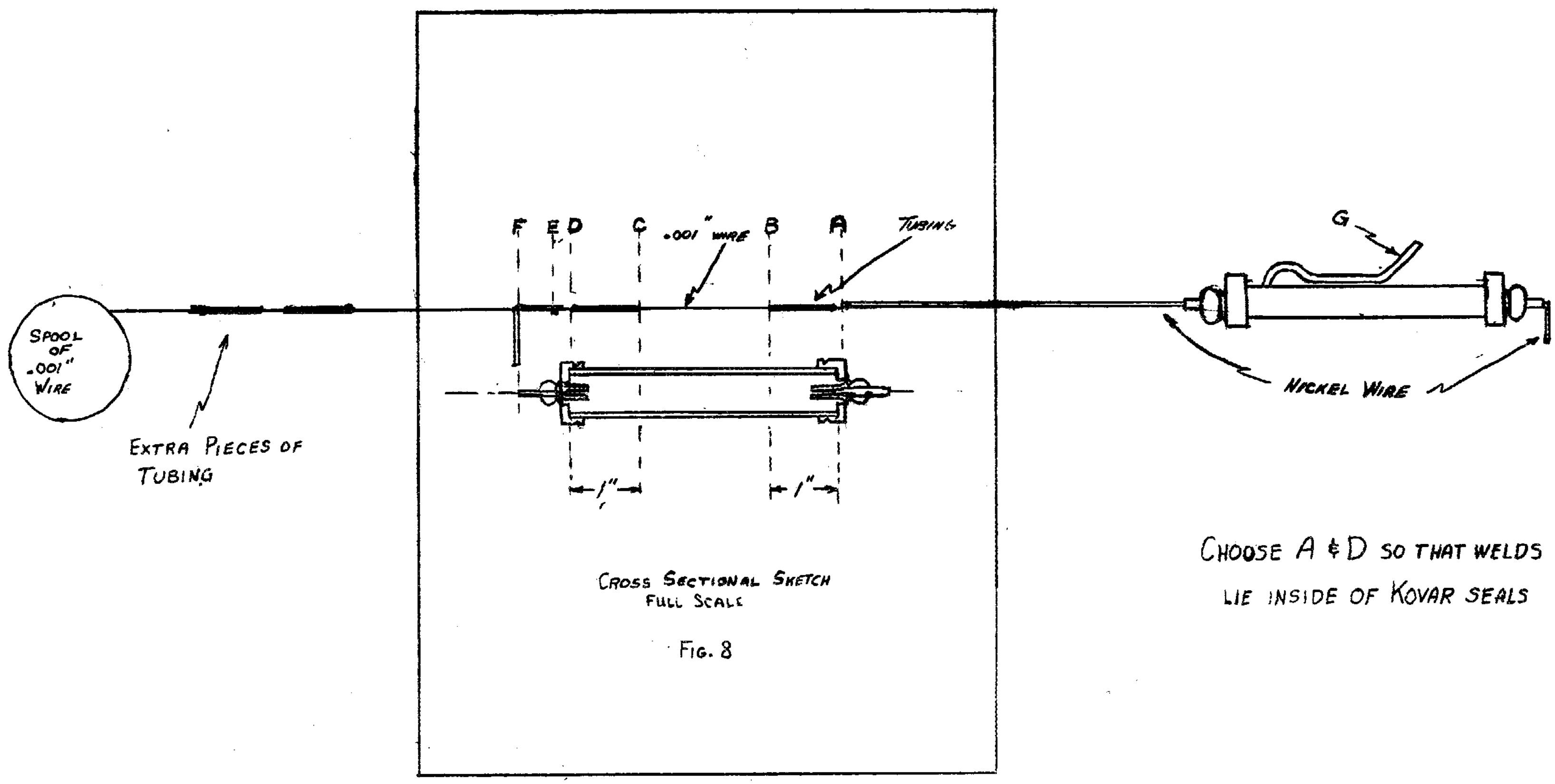
[3]Stainless Steel No. 302, sold by Sigmund Cohn & Co., 44 Gold Street, New York City, is suitable.



METHOD OF ASSEMBLY
FIG. 7

D.J.K.
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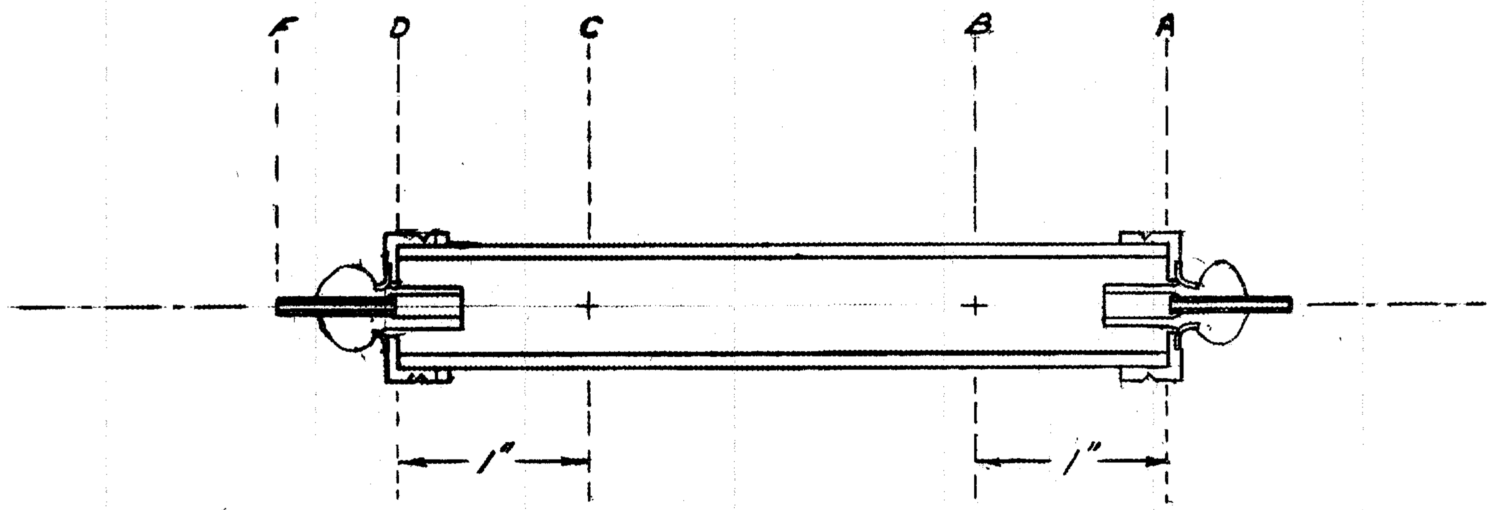

CROSS SECTIONAL SKETCH - FULL SCALE

FIG. 8

D.J.K. - 10-23-51

4. Bend the second piece of lead wire at point F on the drawing showing the tip of the Kovar seal.

C. Final Assembly

1. Transfer the counter and its trailing wire to a ring stand with the wire hanging downward. Clean the wire with a camel's hair brush and alcohol to remove flux and lint. Pull the wire carefully up into the counter until the bend in the nickel lead wire hits the end of the seal at F, and invert the assembly. Hang a small weight on the bottom end of the wire to test the weld.
2. Soft solder the top nickel wire to the Kovar tube first. Then with the weight still applied, solder the bottom nickel wire in.
3. Trim the lead wires and assemble the end shields.

D. Filling of Counter

1. The counter should be exhausted to high vacuum for at least six hours. Baking out the counter is not necessary.
2. Introduce unenriched BF_3 into evacuated manifold and condense it in a small bulb by immersing the bulb in liquid nitrogen. Open the system, including the small bulb still immersed in liquid nitrogen, to vacuum and pump for two minutes. Close manifold and remove the liquid nitrogen allowing the BF_3 to expand into the manifold.
3. Fill the counter to 4 cm of Hg.
4. Shut off counter and recondense BF_3 into original flask.
5. Pump manifold clean.
6. Fill manifold with argon to 40 cm of Hg. Then open counter and adjust final pressure to 40 cm of Hg.
7. Seal off counter.

8. Crimp copper filling tube at point G close to counter body and cut. Soft solder over cut as precaution against leakage.

E. General

1. Pretinning the lead wires where they will meet the seals is helpful.
2. Use of two solders with different melting temperatures will facilitate the assembly of the counter body, end caps, and seals.
3. Use DeKhotinsky cement to seal copper tubing to glass exhaust manifold.

ACKNOWLEDGEMENTS

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