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OPERATION AND MAINTENANCE INSTRUCTIONS FOR GAMMA SCINTILLATION MONITOR – MODEL III

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OPERATION AND MAINTENANCE INSTRUCTIONS FOR GAMMA SCINTILLATION MONITOR - MODEL III

INTRODUCTION

The gamma scintillation monitor Model III is designed to continuously monitor and record the gamma activity of a process solution.(1) A standard jet-type sampler is connected in series with a 100 ml annealed glass sample cell over which is placed the gamma scintillation detector. The jet is left on at all times so as to continuously circulate the solution through the sample cell. There is interposed between the sample cell and gamma scintillation detector a three position (stream, background, and standard) turret which can be manually operated at the sample station for purposes of checking the overall instrument operation. A remote meter is located near the sample station so that the counting rate can be observed as the turret is operated. A continuous record of the sample cell gamma activity is obtained on a 24-hour circular chart recorder located at the control gallery.

THEORY

Gamma photons from the sample cell excite the thallium-activated sodium iodide (NaI(Tl)) crystal, producing light flashes which are converted to voltage pulses by the photomultiplier tube, amplified by the pre-amplifier, and counted by the counting rate meter (4).

The 1/2" x 1 3/4" D NaI(Tl) detector crystal is sealed in an aluminum can of 1/32" wall thickness. A glass plate is secured to the top of the can for purposes of completing the moisture tight seal and allowing light to escape from the crystal. This canned crystal is optically coupled to the end of a 5819 type photomultiplier tube by means of a highly polished lucite cylinder (light pipe).

Dow Corning Stopcock Grease (Stores Item No. 10-3A) is used to complete the light coupling from crystal to light pipe and from light pipe to photomultiplier tube. A high proportion of those gamma photons emitted from the sample cell in the direction of the detector are able to pass through the glass cell wall, Figure 1, the lead end cap, the aluminum crystal can, and interact in the NaI(Tl) crystal. Each gamma photon imparts most of its energy to the crystal, and the crystal in turn gives up some of this excitation energy in the form of light pulses (scintillations). These light pulses are transmitted from inside the transparent sodium iodide crystal, through the lucite light pipe, and impinge on the surface of the photomultiplier tube where they result in ejection of electrons. Once the electrons are ejected from the photosensitive surface, they are under the influence of an electrostatic field and are accelerated to the first dynode, etc. Due to secondary emission, the electron current has been multiplied in the order of 100,000 times when the last dynode is reached. The current pulse from the last dynode is passed through a parallel RC circuit forming a voltage pulse with 1/4 microsecond rise time and four microsecond decay time constant. The voltage amplitude of these pulses is directly proportional to the gamma energy absorbed by the NaI(Tl) crystal. This voltage pulse is amplified ten times by the pre-amplifier in the phototube housing and then coupled to the phototube high - voltage cable.

At the counting rate meter the negative-going pulse is taken off the HV cable through a 50 uuf, 5,000 volt coupling condenser and fed to the input of the counting rate meter.

The counting rate meter responds to all pulses exceeding a -0.3 volt amplitude and averages the pulse rate in units of pulses per minute, which is indicated by the meter. In addition to the meter indication, there is a current output (zero to 1 ma) whose value varies directly with the counting rate. It is used to drive both the circular chart recorder and the remote meter.

The photomultiplier high-voltage control located on the counting rate meter serves as a very sensitive pulse amplitude control, because the current gain of the photomultiplier tube varies as the seventh power of the high voltage. For example, an increase in high voltage of 10 volts increases the current gain and thus the pulse amplitude by approximately 10%.

OPERATION

The gamma scintillation monitor Model III has been adjusted to count all gamma photons which transfer 0.1 Mev* or greater to the sodium iodide crystal. A long-lived Cs-137 gamma source has been supplied as part of the turret assembly (Fig. 2) for purposes of checking this setting. The proper operating point is adjusted in the field by varying the high-voltage until the net cesium counting rate is as specified in Table 1.

Typical high-voltage plateaus of a Cs standard are shown in Figure 5. The gross cesium plateau was taken with the Cs standard positioned directly beneath the detector. The HV was varied in 50-volt steps,and after waiting 5 to 10 minutes to reach equilibrium,the corresponding counting rates were read from the circular chart recorder. Next, the background absorber was placed beneath the detector and the background plateau was measured. The difference of these two curves is plotted to show the net Cs high-voltage plateau.

It has been determined in the laboratory by use of a gamma ray spectrometer [2] that the high voltage setting on the net Cs high voltage plateau for which the counting rate is 74% of the counting rate in the flat plateau region, corresponds to an energy threshold of 0.1 Mev. So as to eliminate the necessity of computing a net Cs plateau each time the instrument is adjusted, the net Cs counting rates corresponding to a 0.1 Mev threshold are given below in Table I.

TABLE I

NET COUNTING RATES OF CESIUM STANDARDS WHICH CORRESPOND TO AN ENERGY THRESHOLD OF 0.1 MEV

Cs Standard	Net Counting Rate
Original instrument on A line	________
Second instrument on B line	________

When the high voltage is adjusted for a 0.1 Mev energy threshold the phototube current gain for the absorption of a 0.1 Mev photon is just sufficient to result in an output pulse greater than the input voltage threshold of the counting rate meter and thus record as a gamma event. If, however, the photomultiplier current gain is reduced by decreasing the high voltage, all pulses will be reduced in amplitude, and thus fewer of

*0.1 Mev is equal to 100,000 ev. The electron volt (ev) is a convenient unit of energy used by physicists. Typical fission product gamma photons may have an energy value from 0.01 Mev to 1 Mev.

them will exceed the CRM input threshold and the counting rate will decrease. Conversely, an increase in high voltage will result in an increase in counting rate.

It can be seen from Figure 5 that there is a reasonable flat portion on the net high voltage plateau where almost all of the gamma photons are recorded and very few of the phototube noise pulses are recorded. At first glance this would appear to be an ideal operating point. However, due to varying energy spectra of fission product gamma and the requirement that all gamma scintillation counters have a similar yield vs. energy characteristic, it is necessary that these instruments be operated with a fixed energy threshold. The choice of 0.1 Mev as the gamma energy threshold is completely discussed elsewhere (3).

MAINTENANCE

A. NaI(Tl) Crystal and Phototube

The detector crystal is very fragile and must be handled with considerable care. However, when properly handled these crystals are capable of continuous operation in a field of moderate gamma flux for a number of years. If the moisture seal is broken, they will soon deteriorate. Such deterioration will be detected by a slow reduction in light output and thus a decrease in pulse amplitude. If moisture leakage has occurred, a visual inspection will show a yellow cast to the crystal particularly around the edges. A normal crystal is clear with possibly a faint bluish tint. If the crystal has been dropped or jarred, it may be cracked or separated from the glass window. If any of the above effects are noticed, the crystal should be replaced. The most recent price quotation from Harshaw Chemical Company on these crystals is $60 apiece.

The 2" diameter end-window-type photomultiplier tube is also fragile; however, it too is capable of an extremely long life if properly handled. The photomultiplier tube can be damaged by adjusting the high voltage beyond 1350 volts for a 5819 and 1600 volts for a 6292, by jarring the phototube so that the dynode structure is bent or two dynodes become shorted, and by applying HV to the phototube when it is exposed to room light. A defective photomultiplier tube will generally make itself known in one of two rather obvious ways, as follows: 1) the current gain will be greatly reduced; 2) the noise level of the phototube will increase. For example, in Figure 5 the photomultiplier tube noise pulses are not counted until a voltage of 1025 is reached. If this tube were to become noisy, the noise might start to count at a much lower voltage, say 900 or even 800 volts.

Whenever replacing the phototube and crystal assembly, it is important to be sure that sufficient silicone grease is used between adjacent surfaces so that all air pockets are excluded. The side of the lucite light pipe must be clean and free from grease to insure maximum reflection of light from inside the crystal to the photocathode. The silicone grease can be removed by washing with alcohol. A 1/4" thick piece of foam rubber is always placed at the bottom of the crystal and then firmly compressed upon assembly so as to keep the components of light pipe system in firm contact at all times.

B. Pre-Amplifier

The pre-amplifier (Fig. 4) is a pulse amplifier with a gain (amplification) of ten, which is highly stabilized by negative feedback. Normally the pre-amplifier will need very little attention with the exception of tube replacement every few months at most. The negative feedback operates to keep the pulse gain at ten even after the gain of the individual tubes begins to fall off. Thus, when the pulse gain <u>does</u> start to drop below normal, the tubes are probably very low in transconductance and should be replaced immediately. The pre-amplifier has sufficient gain stabalization so that there is negligible difference in pulse gain between operation with the usual 70 foot cable or the 5 foot spare cable located at the counting rate meter.

It is necessary to open the pre-amp housing for some reason and the pre-amp tubes have been in operation for more than a month, it would be very good preventive maintenance to replace both tubes with new tubes which have been selected for above average transconductance. When a pre-amp housing is installed in a sample box it should always be covered with a plastic bag for moisture protection.

C. Counting Rate Meter, Recorder, and Remote Meter

The theory of operation and a detailed maintenance discussion of the General Radio Counting Rate Meter (CRM) Model 1500 B can be found in the instruction manual supplied with each instrument.

The following check list should be followed whenever the CRM is suspected of malfunctioning: NOTE: return c/m range switch to original position after checking.

1. Turn the meter-selector switch to Volts and see if the meter needle comes to the red line. If the reading is within 1/4 minor division of the red line, adjust the high voltage calibrate until the meter reads on the red line. If the meter reading is more than one minor division from the red line, the high voltage circuit is probably defective and should be repaired before going further. (Very likely, tube replacement is required.) After repair of the high voltage circuit, allow the instrument 1/2 hour warm-up before making the final red-line adjustment of the high voltage.

2. Return the meter-selector switch to CPM and turn the coarse Volts switch to zero (counterclockwise from the 400 volt position). Check the zero of the CRM meter utilizing the short button to speed the time constant decay; and adjust to zero if necessary with the CRM zero control. Turn the counts-per-minute selector switch to the 60 cycle Calibrate and after waiting for the meter to come to a steady reading, adjust the calibrate control to 3,600 counts per minute. (Note: do not adjust to red line.) Now check the zero again as there is interaction between the zero and calibrate controls. The response switch can be turned from 4 to 1 to speed the response while calibrating but it must be returned to position 4 when the calibration is completed.

3. When both the zero and 3,600 calibrate have been properly adjusted, the circular chart recorder should be checked. Zero the CRM by turning off the high voltage as before and adjust the recorder to zero by use of the mechanical pen adjust. Next, turn the counts per minute selector switch to calibrate and after equilibrium has been reached, the recorder should be adjusted to 60% of full scale by means of the Up Scale Calibrate potentiometer R-108, shown in Figure 3.

4. The remote meter can be adjusted by use of its mechanical zero adjust and the Up Scale Calibrate potentiometer R-109, shown in Figure 3.

OVERALL SYSTEM ADJUSTMENT AND MAINTENANCE

The gamma scintillation monitor is provided with a three-position turret for purposes of checking the overall instrument operation. Whenever the instrument is suspected of malfunctioning, the manually operated turret can be used to determine whether the trouble is in the instrument itself or in some associated component, such as the aspirator jet or sample cell.

Before using the turret, which is located near section 16 in the operating canyon, it is well to check the counting rate meter as outlined under Maintenance, Section C. Having determined that the counting rate meter is operating satisfactorily, it is necessary to enter the canyon, turn off the air pressure to the jet, remove the steel sampler cover, and remove the sheet-metal cover. Now, the manual turret control can be observed and operated.

First, the turret is rotated to the background position, that is, the blank lead absorber is rotated directly under the detector and allowed to remain in this position for ten minutes. The remote meter can be read during this time as a means of checking for normal operation and to make certain the instrument hasn't been turned off, had its range changed, etc. Next, the standard (the lead absorber with a red letter S on the top side) should be rotated beneath the detector and left there for ten minutes. Finally, the turret should be returned to the stream position, the jet turned on by operating the air valve, and the covers and lead stopper replaced.

Upon observing the circular chart record, the background and standard counting rates can be read quite accurately. The net chart deflection (standard minus background) in per cent of full scale multiplied by the counts per minute range will give the net counts per minute of the cesium standard. If this value is within ± 5% of the required value as tabulated in Table I, the instrument is working satisfactorily and the malfunction must be in some other component of the system. If the net Cs-137 standard counts per minute is outside of the ± 5% limit, then there is very likely a defective component in the instrument itself.

The most likely direction for a change in counting rate of the standard is a decrease. From the high voltage plateau of Figure 5 it can be reasoned that a decrease in net counting rate is due to a decrease in pulse gain somewhere in the system from NaI(Tl) crystal to CRM input, or to an increase in CRM input threshold. The first four tubes in the CRM should be checked first. If the malfunction persists after replacing all weak tubes in the CRM, either the phototube, or crystal may be at fault. The spare pre-amp assembly can be connected next as a means of checking by substitution.

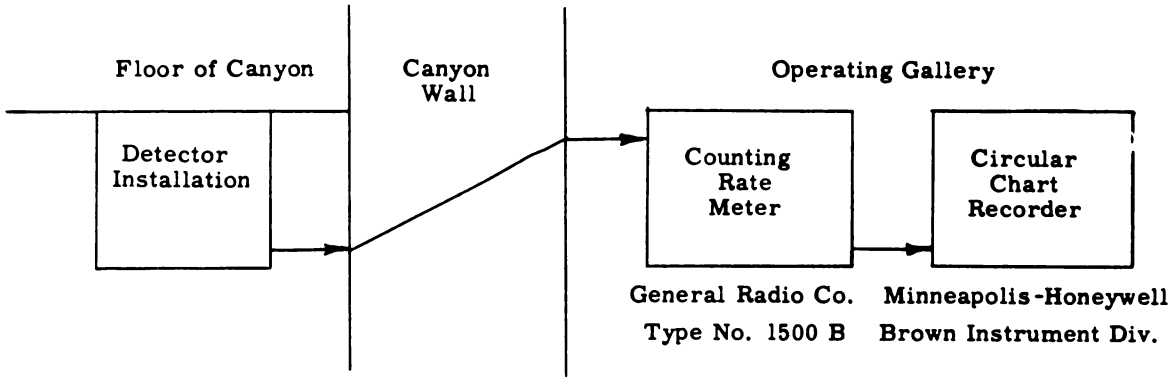
If the net counting rate of the Cs-137 standard exceeds the upper allowable limit, the most likely causes would be a decrease in CRM input threshold , a high voltage supply which exceeds the indicated voltage value, or a noisy phototube.

After repair of the instrument, the high voltage operating point should be checked as mentioned previously and adjusted if necessary. In addition to the suggestion above, the maintenance man will have to combine his understanding of the overall instrument operation as discussed in this report with his own good judgment and troubleshooting ability in order to detect and repair all failures which may occur.

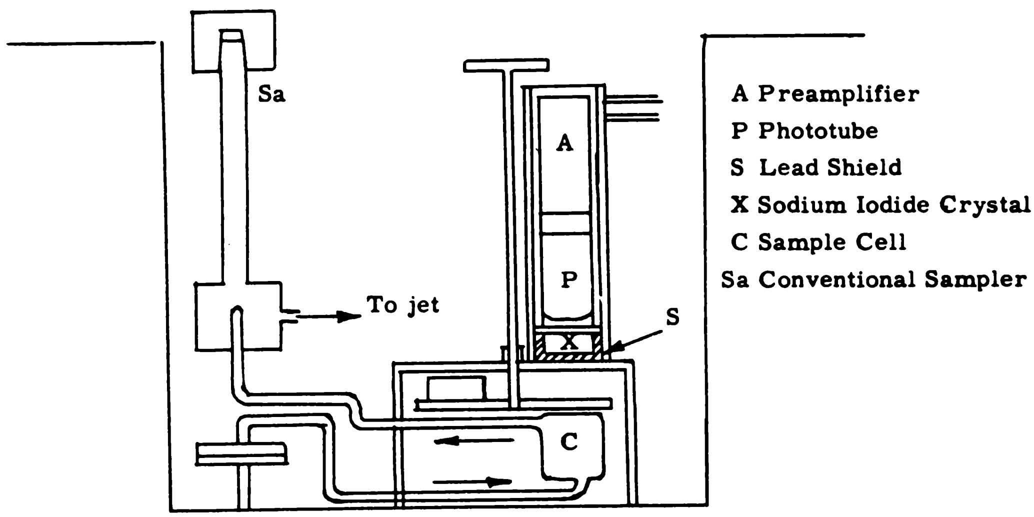
It is strongly recommended that a record be kept of all maintenance adjustments and repairs which are made on the Gamma Monitors. Such notes will be valuable in locolizing a trouble, deciding whether replacement or repair of a component is necessary, and establishing an overall maintenance record.

<u>REFERENCES</u>

(1) Leboeuf, M. B., Connally, R. E., and Upson, U. L., HW-29348 (Secret).
(2) Leboeuf, M. B. and Connally, R. E., HW-27090 (Secret).
(3) Brauer, F. P. and Leboeuf, M. B., HW-28263 (Restricted).
(4) Birks, J.B., Scintillation Counters, New York, McGraw-Hill Book Co., Inc., 1953.



Detail of Detector Installation



Block Diagram and Detail of Continuous
Gamma Activity Monitor

FIGURE 1

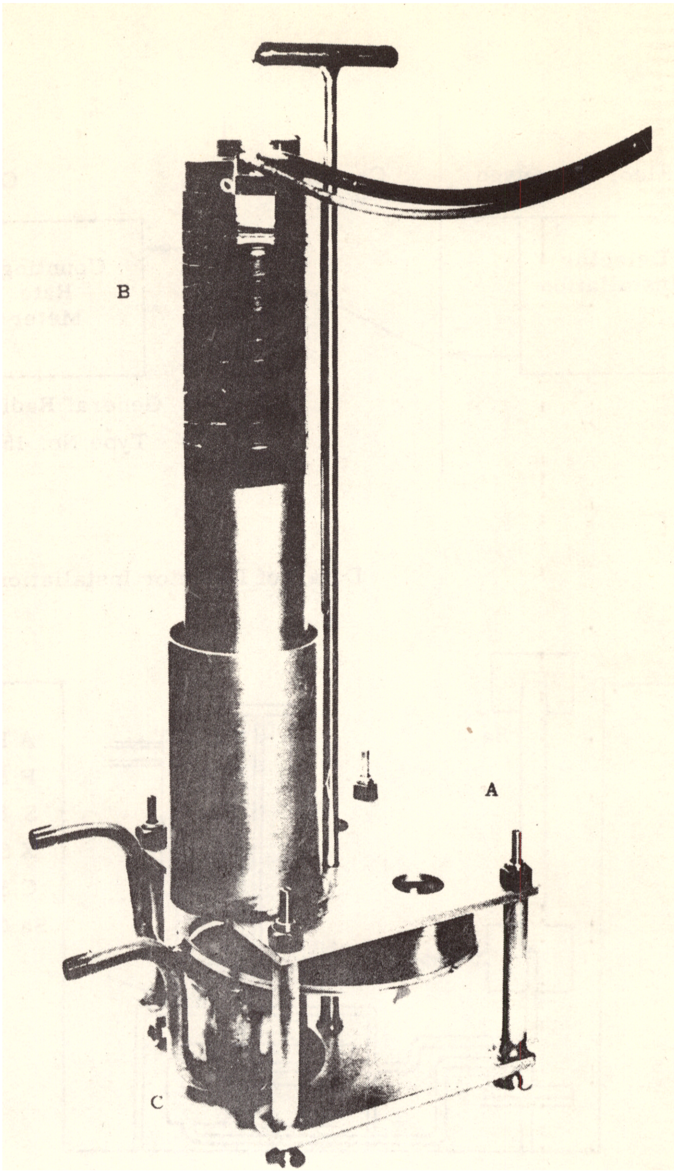


FIGURE 2

DETECTOR ASSEMBLY
GAMMA MONITOR MODEL III

A. Turret Reference HW Drawings H-4-2339, 40, and 41.

B. General Electric Radiation Probe Cat. No. 12C19661.

C. Sample Cell, Stainless Steel.

RESISTORS

R-4	=	0.56 Megohms	±10%		REC-20BF
R-5	=	0.22 Megohms	±10%		REC-20BF
R-6	=	0.33 Megohms	±10%		REC-20BF
R-7	=	1 Megohm	±10%		REC-20BF
R-8	=	0.1 Megohm	±10%		REC-20BF
R-9	=	0.27 Megohms	±10%		REC-20BF
R-10	=	270 K Ohms	±10%		REC-20BF
R-11	=	0.1 Megohm	± 1%	C.C.Co.	X-1/2
R-12	=	0.27 Megohms	±10%		REC-20BF
R-13	=	2 K Ohms	±10%		POSW-862
R-14	=	0.39 Megohms	± 5%		REC-20BF
R-15	=	4 K Ohms	± 5%	C.C.Co.	X-1/2
R-16	=	20 K Ohms	± 2%	C.C.Co.	X-1
R-17	=	1 Megohm	±10%		REC-20BF
R-18	=	10 Megohms	± 1%	C.C.Co.	X-1/2
R-19	=	10 Megohms	± 1%	C.C.Co.	X-1/2
R-20	=	10 Megohms	± 1%	C.C.Co.	X-1/2
R-21	=	500 Ohms	± 2%	C.C.Co.	X-1/2
R-22	=	12 K Ohms	± 2%	C.C.Co.	X-1
R-23	=	500 Ohms	± 5%	C.C.Co.	X-1/2
R-24	=	700 Ohms	± 5%	C.C.Co.	X-1/2
R-25	=	2 K Ohms	±10%		POSW-862
R-26	=	2 K Ohms	± 1%	C.C.Co.	X-1/2
R-27	=	13 K Ohms	± 1%	C.C.Co.	X-1/2
R-28	=	25 K Ohms	± 1%	C.C.Co.	X-1/2
R-29	=	115 K Ohms	± 1%	C.C.Co.	X-1/2
R-30	=	150 K Ohms	± 1%	C.C.Co.	X-1/2
R-31	=	750 Ohms	± 5%		REW-3C
R-32	=	2 K Ohms	±10%		POSW-862
R-33	=	2 K Ohms	±10%		POSW-862
R-34	=	2 K Ohms	±10%		POSW-862
R-35	=	1 Megohm	±10%		POSC-7
R-36	=	2.2 K Ohms	±10%		REC-20BF
R-37	=	150 Ohms	±10%		REW-3C
R-38	=	1 K Ohm	± 5%		REPO-1078
R-39	=	10 K Ohms	±10%		REC-41BF
R-40	=	3 K Ohms	± 5%		REPO-31
R-41	=	150 Ohms	±10%		REW-3C
R-42	=	150 K Ohms	±10%		REC-20BF
R-43	=	0.15 Megohm	± 5%		REC-20BF
R-44	=	0.16 Megohm	± 5%		REC-20BF
R-45	=	0.18 Megohm	± 5%		REC-20BF
R-46	=	0.18 Megohm	± 5%		REC-20BF
R-47	=	0.18 Megohm	± 5%		REC-20BF
R-48	=	0.20 Megohm	± 5%		REC-20BF
R-49	=	0.22 Megohm	± 5%		REC-20BF
R-50	=	56 Ohms	±10%		REW-3C
R-51	=	100 Megohms	±10%		REW-3
R-52	=	10 Megohms	±10%		REC-20BF
R-53	=	1 Megohm	±10%		REC-20BF
R-54	=	80 K Ohms	± 1%	C.C.Co.	X-1/2
R-55	=	50 K Ohms	± 2%		301-465
R-56	=	56 Ohms	±10%		REW-3C
R-57	=	270 K Ohms	± 1%	C.C.Co.	X-1/2
R-58	=	200 K Ohms	± 2%		471-407
R-59	=	0.2 Megohms	± 1%	C.C.Co.	X-1/2
R-60	=	0.2 Megohms	± 1%	C.C.Co.	X-1/2
R-61	=	0.2 Megohms	± 1%	C.C.Co.	X-1/2
R-62	=	0.2 Megohms	± 1%	C.C.Co.	X-1/2
R-63	=	0.2 Megohms	± 1%	C.C.Co.	X-1/2
R-64	=	0.2 Megohms	± 1%	C.C.Co.	X-1/2
R-65	=	0.2 Megohms	± 1%	C.C.Co.	X-1/2
R-66	=	1 Megohm	±10%		REC-20BF
R-67	=	2 K Ohms	±10%		POSW-862
R-68	=	2 K Ohms	±10%		POSW-862
R-70	=	56 K Ohms	±10%		REC-20BF
R-71	=	0.33 Megohm	±10%		REC-20BF
R-72	=	1 K Ohm	±10%		REC-20BF
R-73	=	250 K Ohms	±10%		POSC-11
R-74	=				
R-75	=	0.47 Megohm	± 5%		REC-20BF
R-76	=	10 K Ohms	±10%		REC-20BF
R-77	=	18 Ohms	± 2%	C.C.Co.	X-1/2
R-78	=	27 Ohms	± 2%	C.C.Co.	X-1/2
R-79	=	700 Ohms	±10%		POSW-862
R-80	=	15 Ohms	±10%		REW-3C
R-81	=	200 K Ohms	± 5%		REC-20BF
R-82	=	100 K Ohms	± 5%		REC-20BF
R-83	=	1 Megohm	±10%		REC-20BF
R-84	=	0.56 Megohm	±10%		REC-20BF
R-101	=	10 Megohms	±10%		REC-20BF
R-102	=	2.7 Megohms	±10%	IRC	BTAV
R-103	=	2.7 Megohms	±10%	IRC	BTAV
R-104	=	10 Megohms	±10%		REC-20BF

*Part of P-1 socket

CONDENSERS

C-1	=	0.25 µf	±10%		COM-5
C-2	=	0.00005 µf	±10%	2500 WV	COM-45-B
C-3	=	0.00005 µf	±10%	2500 WV	COM-45-B
C-4	=	0.002 µf	±10%		COM-30B
C-5	=	0.25 µf	±10%		COL-43
C-6	=	0.0001 µf	±10%		COM-20B
C-7	=	0.25 µf	±10%	Part of	COLB-16
C-8	=	0.0001 µf	± 2%		COM-20E (3M)
C-9	=	0.0001 µf	± 2%		COM-20E (3M)
C-10	=	0.25 µf	±10%	Part of	COLB-16
C-11	=	0.0002 µf	±10%		COM-20B
C-12	=	1 µf	±10%		ZCOP-1
C-13	=	20 µf		450 WV	COED-9
C-14	=	20 µf		450 WV	COED-9
C-15	=	20 µf		450 WV	COED-9
C-16	=	20 µf		450 WV	COED-9
C-17	=	0.1 µf	±10%		COL-35
C-18	=	0.25 µf	±10%		COL-36
C-19	=	0.0002 µf	±10%		COM-20B
C-20	=	0.00025 µf	±10%		COM-20B
C-21	=	30 µf		150 WV	COE-8
C-22	=	0.01 µf	±10%	1200 WV	COM-50-B
C-23	=	1 µf	±10%		ZCOP-1
C-24	=	0.001 µf	±10%		COM-20B
C-25	=	0.05 µf	±10%		COM-50B
C-26	=	0.05 µf	±10%		COM-50B

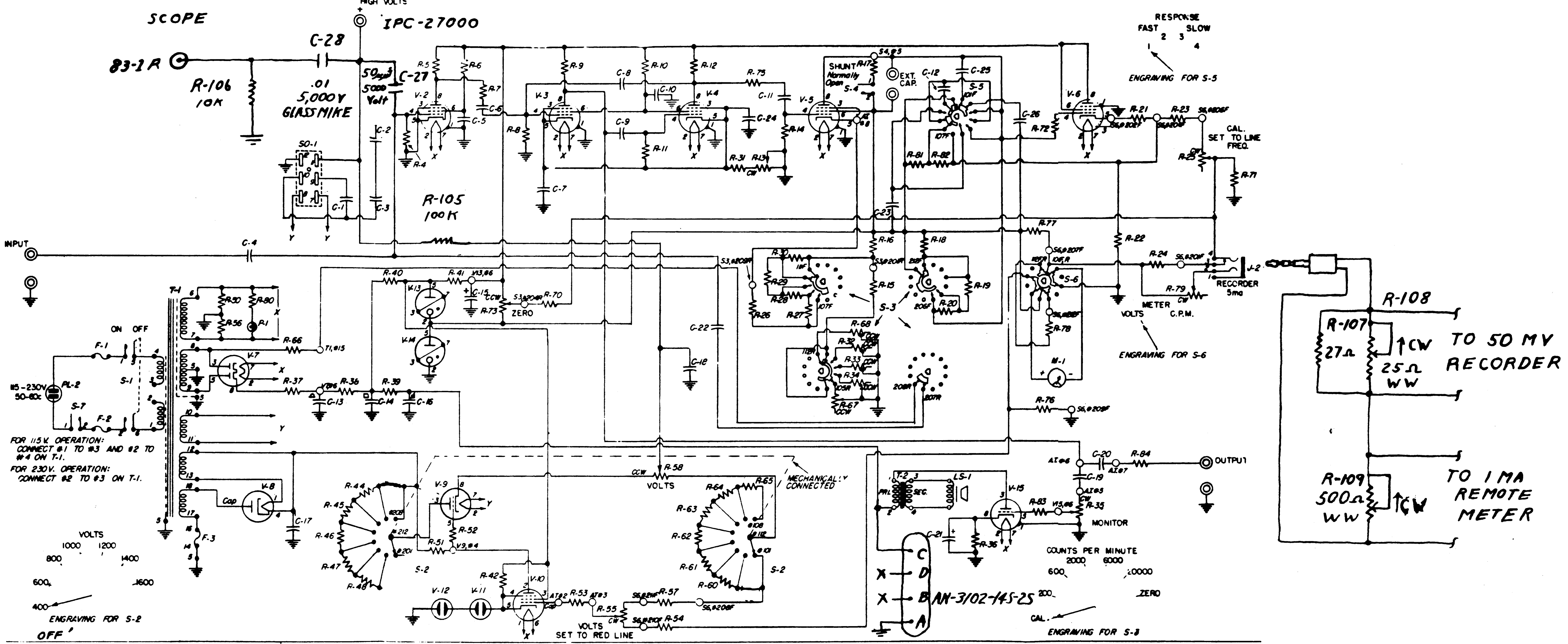
MISCELLANEOUS

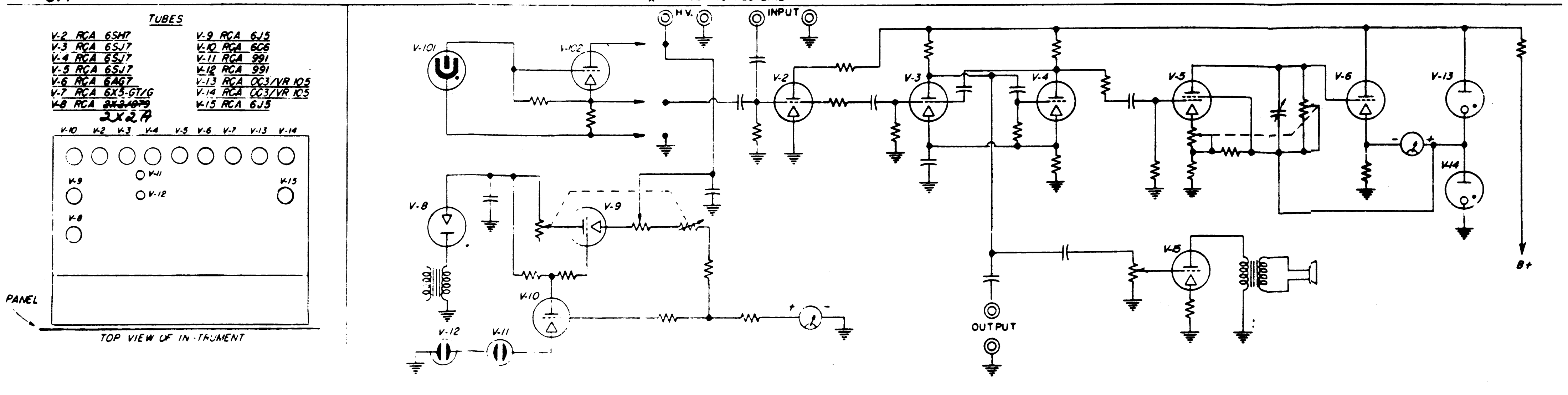
S-1	=	Switch	SWT-333
S-2	=	Switch	SWRW-22-2
S-3	=	Switch	SWRW-56
S-4	=	Switch	SWP-809
S-5	=	Switch	SWRW-57
S-6	=	Switch	SWRW-58
S-7	=	Switch	SWP-444
T-1	=	Transformer	365-429-4
T-2	=	Transformer	746-411
M-1	=	Meter	580-317-2
LS-1	=	Loud Speaker	4SP-5
J-2	=	Jack	CDSJ-1839
SO-1	=	Socket	1500-25
PL-1	=	Plug	CDMP-465-6
PL-2	=	Plug	CDPP-562A
P-1	=	Pilot Light 6-8V Mazda	2LAP-330

For 115V operation:
- F-1 = 1 amp SlowBlow 3AG } OR FUF-1
- F-2 = 1 amp SlowBlow 3AG
- F-3 = 1/16 amp SlowBlow 3AG

For 230V operation:
- F-1 = 0.5 amp SlowBlow 3AG } OR FUF-1
- F-2 = 0.5 amp SlowBlow 3AG
- F-3 = 1/16 amp SlowBlow 3AG

Figure 3. Wiring Diagram for Type 1500-B Counting-Rate Meter





CONVERTED FOR

Elementary Schematic Diagram

GAMMA SCINTILLATION MONITOR MODEL III

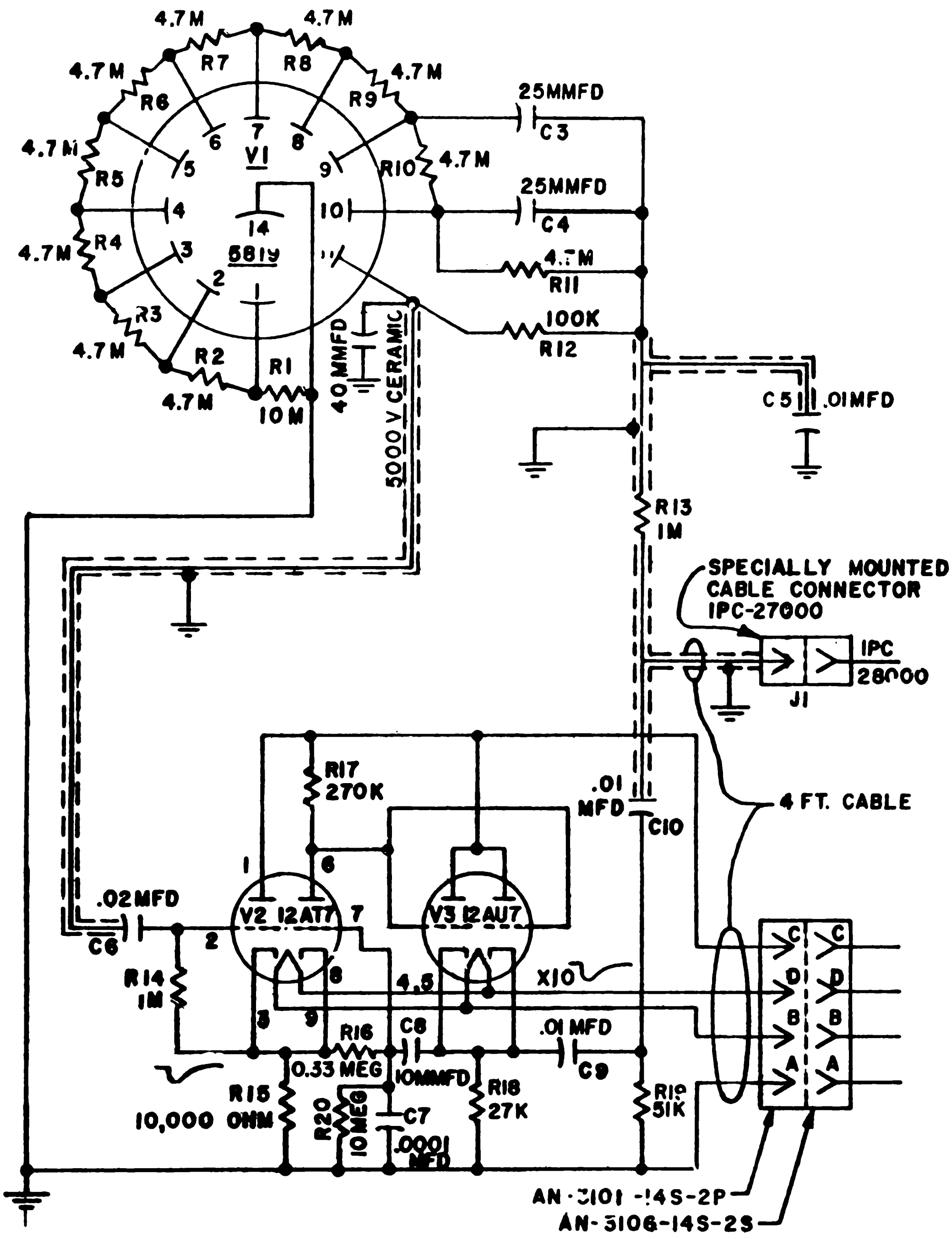


FIGURE 4

GENERAL ELECTRIC PORTABLE RADIATION PROBE CONVERTED FOR THE GSM MOD. III

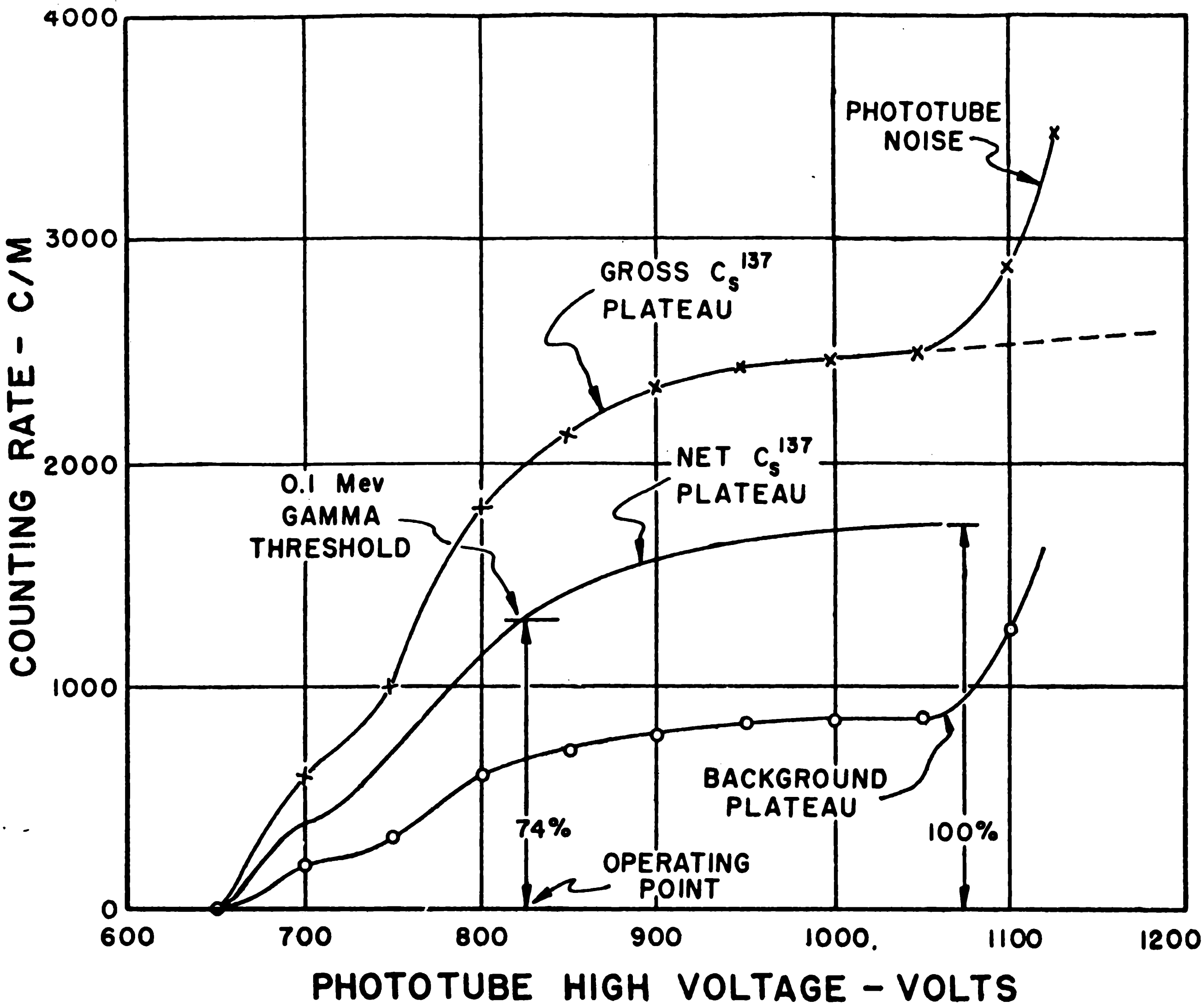


Figure 5.

TYPICAL HIGH VOLTAGE PLATEAUS
FOR THE GSM MODEL III