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CORRELATION OF COUNTING RATE AND RADIATION INTENSITY FOR SEVERAL TYPES OF GEIGER COUNTERS

BY

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OAK RIDGE NATIONAL LABORATORY

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CORRELATION OF COUNTING RATE AND RADIATION INTENSITY FOR SEVERAL TYPES OF GEIGER COUNTERS

March 31, 1949

Introduction

A determination of counting rate versus radiation intensity in mr/hr was made for several types of Geiger counters using a 4.87 mg. radium source.

It must be emphasized that the relation herein established between counts per minute and mr/hr is true only for a radium source because the unit mr is an energy unit and because counts per minute is a function of disintegration rate, the ratio of mr to disintegration rate being different for different radioactive nuclei.

Procedure

The measurements were made in a large room to minimize back scattering from the walls to the counter. A 4.87 mg. radium source enclosed in a platinum needle (1/2 mm. wall) was fixed to the top of a 1/4" D. x 12" vertical wooden rod, the bottom end of the rod being terminated in a wood block. The wood block was arranged to slide freely between two ways, one way being calibrated in millimeters. By means of this apparatus the source could be accurately located at a fixed and measured distance from the counter being calibrated. The entire apparatus was elevated two feet above the floor to minimize back scattering from the floor.

The counters to be tested were vertically suspended such that the center of the sensitive volume of the counter was on the same horizontal axis as the center of the source.

The radiation intensity at the counter for different source locations was calculated utilizing the inverse square law plus a small correction for air scattering.

The following types of counters were checked:

Cathode	Cathode Thick	Cathode Outside Diameter	Sensitive Length	Filling
Glass	.006"	3/4" approx.	2 7/8" approx.	.5 cm. Amyl Ac. 9.5 cm. Argon
Glass	.006"	3/4" approx.	2 7/8" approx.	1 cm Ethyl Ether 9 cm Neon
Glass	3/64"	3/4" approx.	2 7/8"	1 cm Ethyl Ether, 9 cm Argon
Brass	1/32"	1" approx.	6"	1 cm Ethyl Alcohol 9 cm Argon

Several counters of each type were calibrated.

Results

The results are best summarized in Table 1 and Figures 1 through 4. It will be noted that departure of the curves from the theoretical plot of counts per minute versus radiation intensity based on inverse square law becomes appreciable at high counting rates. This departure is due mainly to the dead time of the counter. The dead times are on the order of 100 to 200 micro seconds. The ether-argon counters show the shortest dead time. The counting rate for a particular radiation intensity is also dependent on radiation intensity, the sensitive volume of the counter, the wall thickness, and wall material. It will be noted that the volumes of thin and thick wall glass counters are approximately the same, but for the same radiation intensity the thick wall glass counters have a 28% lower counting rate than the thin wall counters. Also although the sensitive volume of the brass counter is about $3\frac{1}{2}$ times that of the thin wall glass counter, the counting rate is only about 2 times that of the thin wall glass. The effect of wall material and thickness on counting rate is evident.

Addenda

Since the results are based upon a calculation of the radiation intensity at various distances it is necessary to amplify the basis of these calculations.

The radium source as received from the Bureau of Standards is reported as having gamma radiation equivalent to that of 4.67 milligrams of radium in radioactive equilibrium and contained in a tube of Thuringian glass .27 mm thick, but since the source is enclosed in a platinum tube of 0.5 mm wall thickness, the gamma radiation from the specimen would be approximately 4.3% greater.[1] Hence the value 4.87 milligrams is used as the source strength in this report.

The source strength I, in milliroentgens per hour at one centimeter for 1/2 mm platinum filter was calculated from $I = 8400M$ where M is source mass in milligrams.[2]

The radiation intensity I, at a distance D_1 centimeters was calculated from the inverse square law: $I = \frac{I}{D_1^2} = \frac{8400M}{D_1^2}$ to which was added a correction for air scattering taken as $.015 \frac{(D_1^2)}{(10^4)} I$, the accuracy of which is believed to be well within 30% of the true correction.

The data <u>counts per minute</u> have been corrected for background radiation.

Where particles arrive at a random means rate <u>P</u> per second and only <u>r</u> per second are recorded because of the counter dead time of $\frac{1}{q}$ second the expression $p = r\left(1 - \frac{r}{q}\right)^{-1}$ holds true.[3]

Figure 5 is a plot of this expression.

Analysis of figures 1 through 4 show that at rate of particle arrival P, the counter dead times are approximately as follows:

Thin wall glass	Amyl - Ac - Argon	190 micro seconds
Thin wall glass	Ether - Neon	130 micro seconds
Thick wall glass	Ether - Argon	120 micro seconds
Brass wall	Alcohol - Argon	200 micro seconds

References

1. National Bureau of Standards Certificate for One Specimen of Radium Salt.

2. Project Handbook - CL-697 Volume II, Chapter 5, Section V A- 1.3.

3. W. B. Lewis - Electrical Counting - Masonvillan Co. 1943 - Pg. 117.

DMDavis:RStepp:REZedler:ac

TABLE 1

Type Counter	Distance	214.7 cm	148.3 cm	102.7 cm	72 cm	50.6 cm	35.7 cm	25.3 cm	17.8 cm
	Intensity	.95 mr/hr	1.92 mr/hr	3.94 mr/hr	7.96 mr/hr	16.04 mr/hr	32.31 mr/hr	64.01 mr/hr	129.3 mr/hr
Thin wall glass *Wall thick. .006" Eff. length 2 7/8" Diam. (I.D.) 11/16" 1/2 cm. Amyl Ac. 9.5 cm. Argon	counts/min. / mr/hr	3794	7644	14995	28570	52773	90553	141289	194852
	counts/min. / mr/hr	3995	3983	3805	3588	3291	2802	2207	1507
*Thin wall glass Wall thick. .006" Diam. (I.D.) 11/16" Eff. length 2 7/8" 1 cm. Ether 9 cm. Neon	counts/min. / mr/hr	3745	7648	14724	29986	56938	103166	171466	256863
	counts/min. / mr/hr	3943	3985	3738	3765	3550	3190	2680	1985
Thick wall glass Wall thick. .06" +Diam. (I.D.) 11/16" Eff. length 2 7/8" 1 cm. Ether 9 cm. Argon	counts/min. / mr/hr	2697	5562	11296	22597	43743	81333	144307	238083
	counts/min. / mr/hr	2848	2896	2868	2840	2728	2516	2254	1841
Brass wall Wall thick. 1/32" +Diam. (I.D.) 15/16" Eff. length 6" 1 cm. Alcohol 9 cm. Argon	counts/min. / mr/hr	7800	15276	29412	53938	92765	146431	207386	255586
	counts/min. / mr/hr	8210	7955	7465	6785	5780	4530	3240	1975

* Data are average results for 3 counters

+ Data are average results for 2 counters

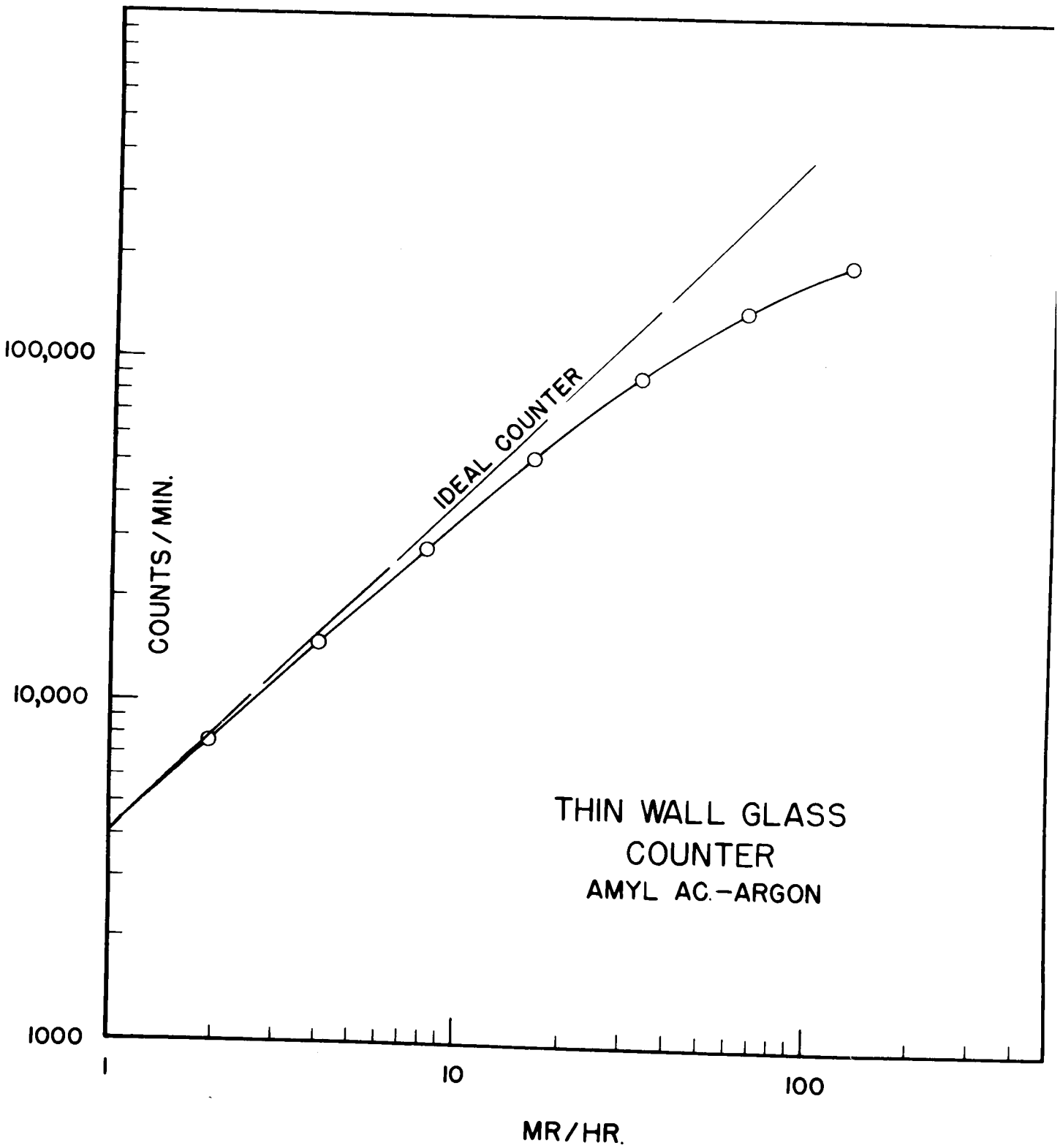
100,000
10,000
1000
COUNTS / MIN.
IDEAL COUNTER
THIN WALL GLASS
COUNTER
AMYL AC.-ARGON
1
10
100
MR/HR.

Fig. 1

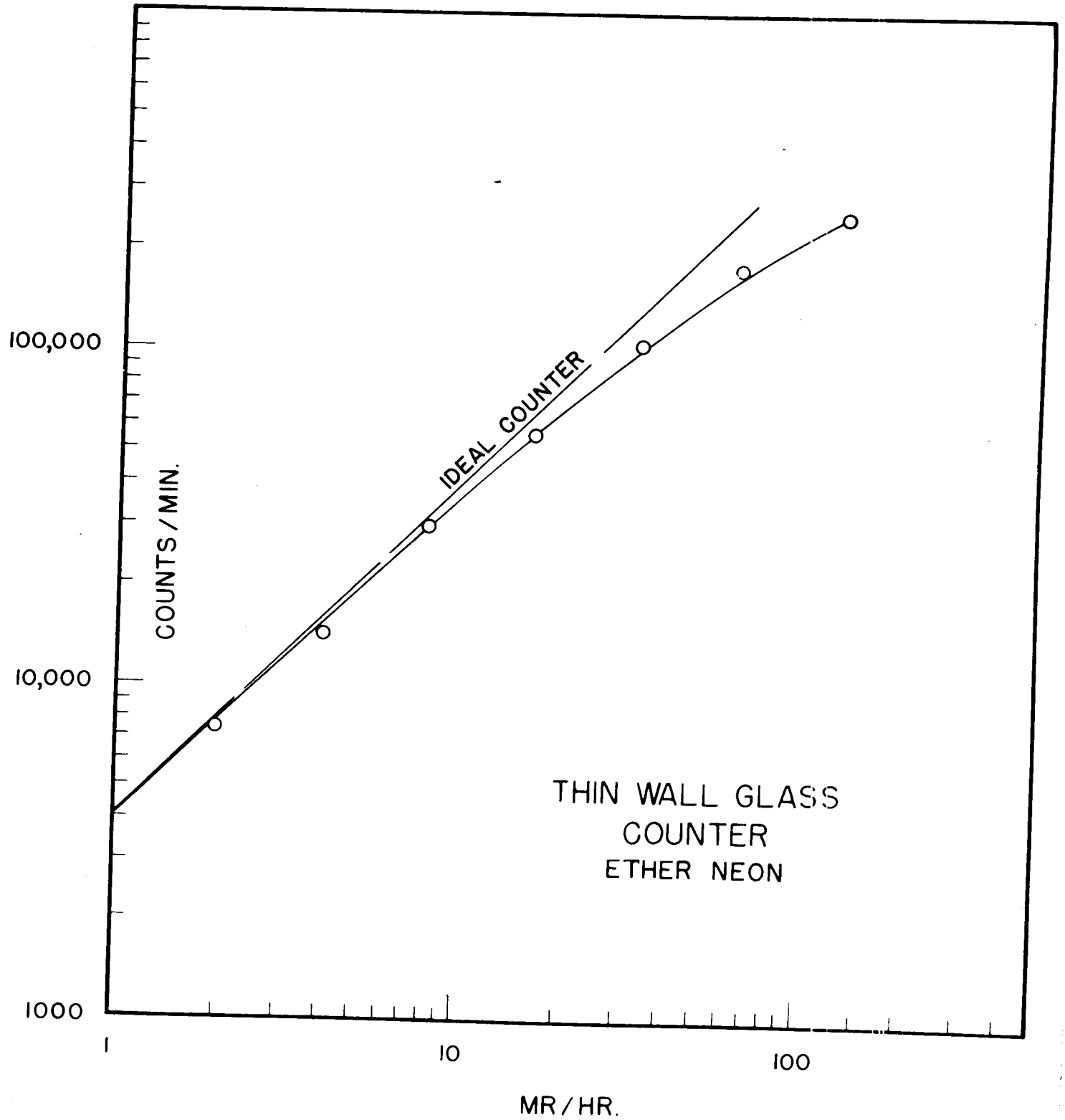
100,000
10,000
1000
COUNTS / MIN.
IDEAL COUNTER
THIN WALL GLASS
COUNTER
ETHER NEON
1
10
100
MR / HR.

Fig. 2

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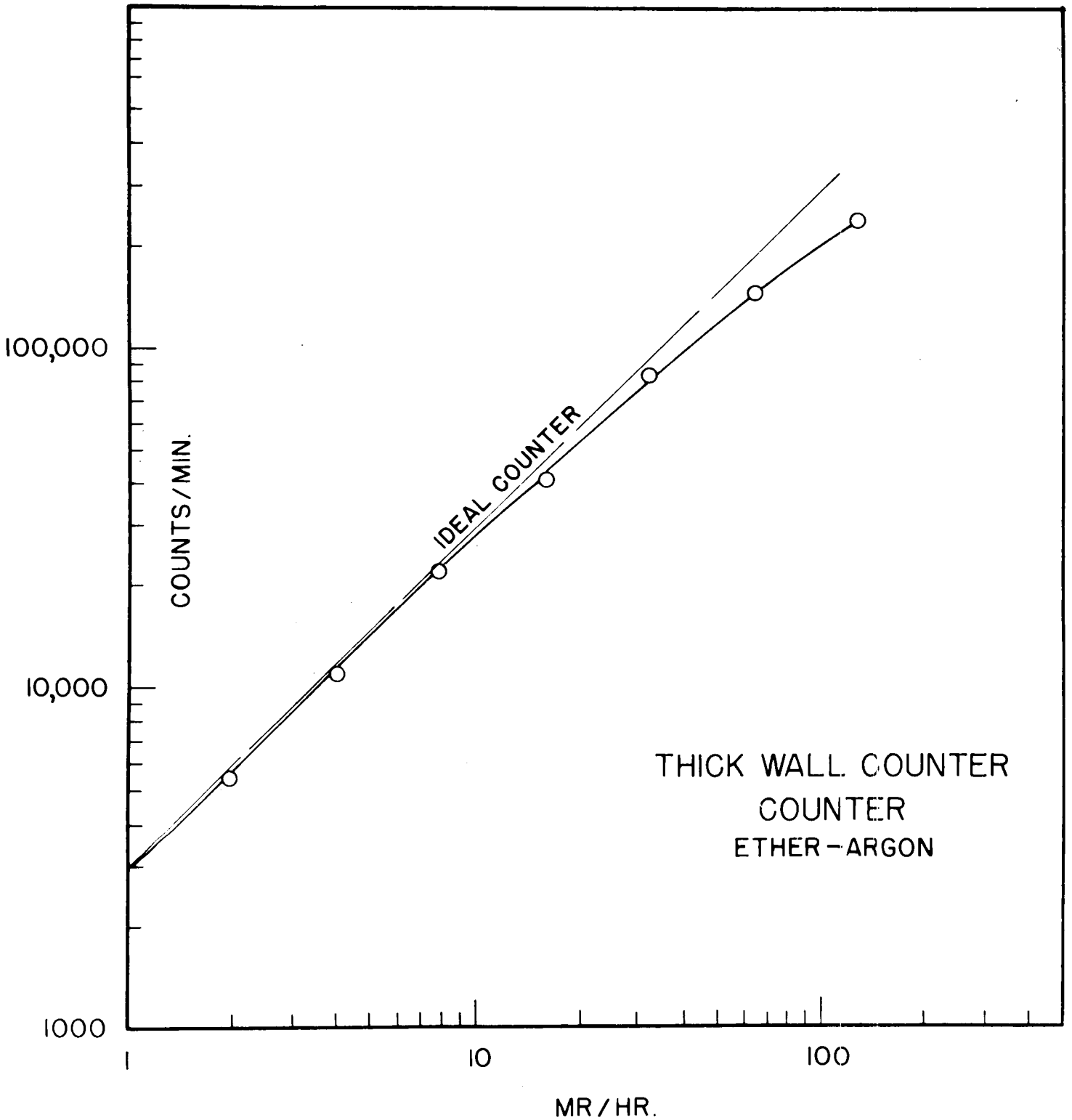

Fig. 3

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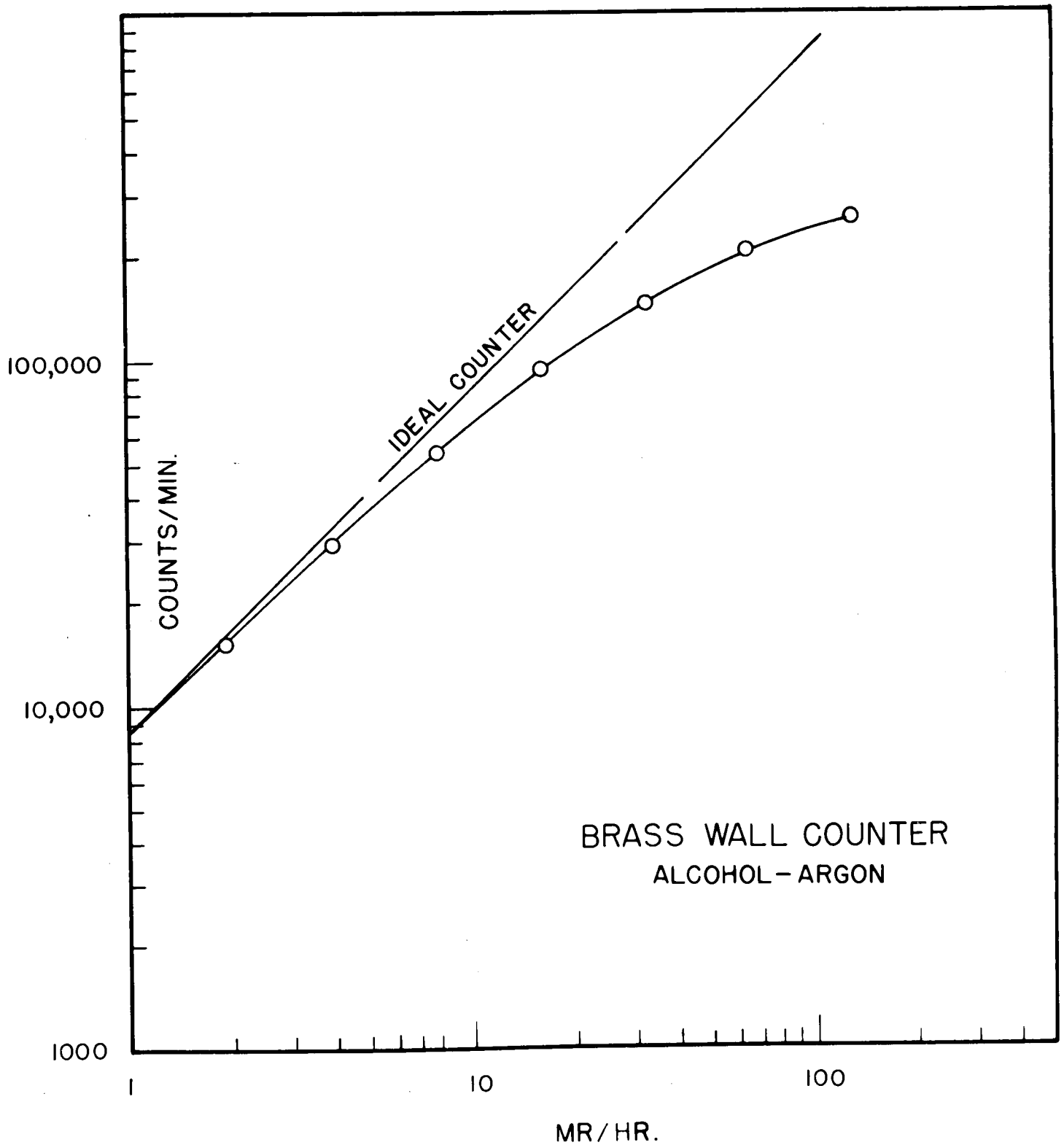

Fig. 4

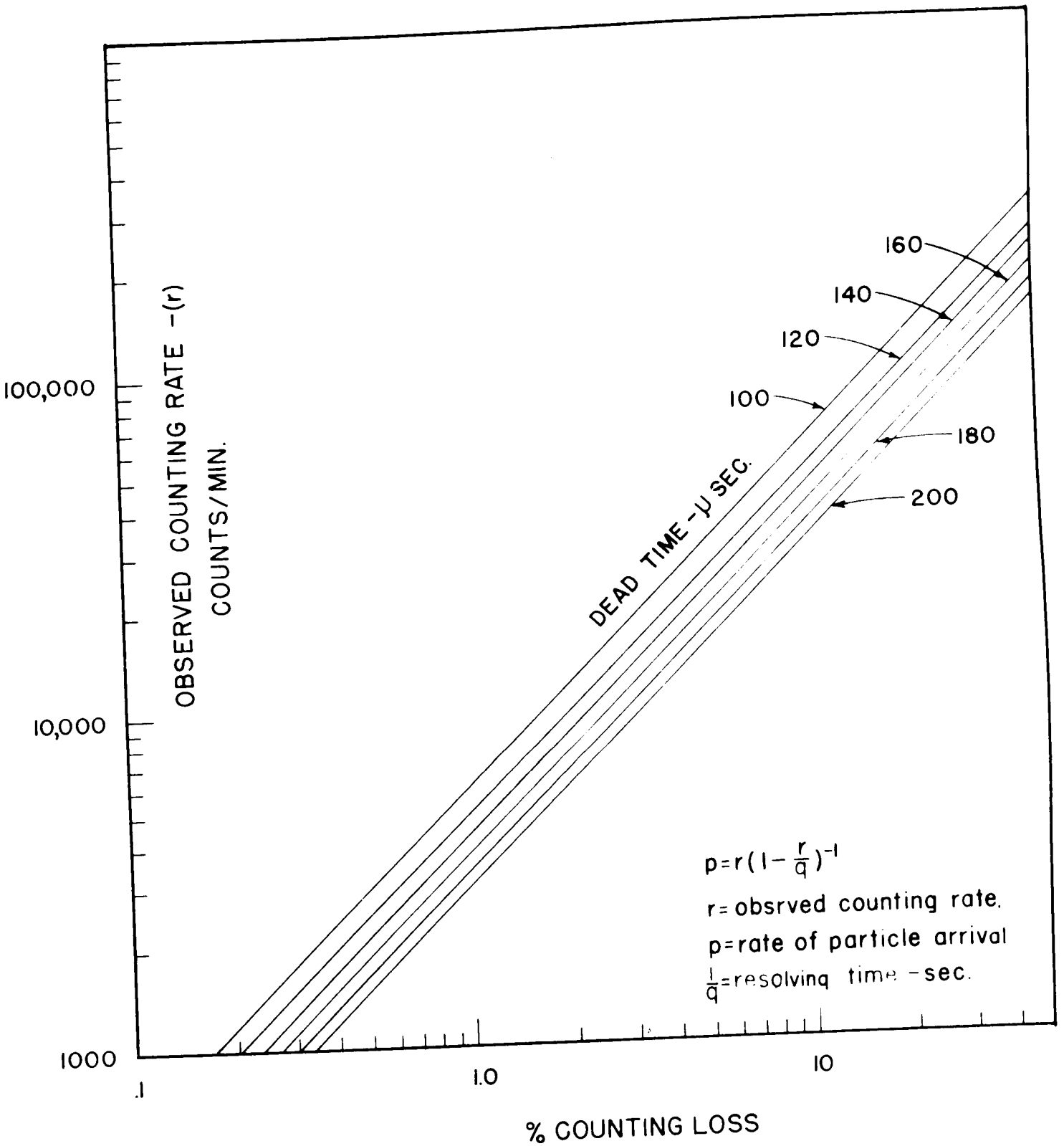
OBSERVED COUNTING RATE -(r)
COUNTS/MIN.
100,000
10,000
1000
.1
1.0
10
% COUNTING LOSS
DEAD TIME - μ SEC.
100
120
140
160
180
200
$p = r(1 - \frac{r}{q})^{-1}$
r = obsrved counting rate.
p = rate of particle arrival
$\frac{1}{q}$ = resolving time - sec.

Fig. 5