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C-9

COMPILATION OF COUNTING CORRECTIONS

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Serial No. C-9
June 26, 1946

CLINTON ENGINEER WORKS
CARBIDE AND CARBON CHEMICALS CORPORATION

Laboratory Division

Physics Research Department

COMPILATION OF COUNTING CORRECTIONS

R. L. Macklin
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Part 1

Correction Factor due to Absorption

It has been customary to use solid films of active material in the parallel plate pulse counting chambers. The material is deposited over a constant area on every film and the film weight is allowed to determine the thickness. Since both alpha and fission particles have extremely short ranges in solid material, some of the particles produced in the film will be absorbed by the film and will never escape to the surface to be counted. We shall derive an expression for the total number of disintegrations in the film as a function of number of particles counted.

We shall assume that a certain length $(r - k)$ of the particle's range (r), must remain after the particle leaves the surface of the film in order for it to be counted.

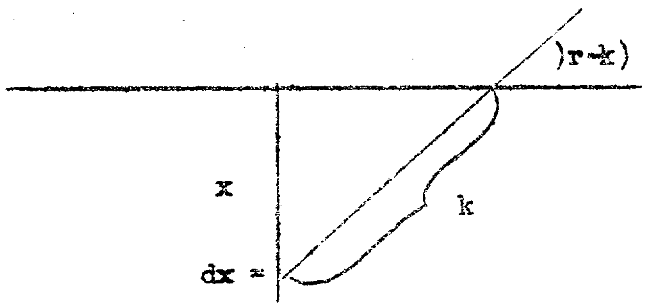
Thus where:

Ao is the number of ionizing particles produced per min. per mm. of film depth.

A is the observed counting rate.

D is the thickness of the film.

r is the range of the particles in the material of the film.



The probability of a particle escaping from the upper surface is the integral of the probability of the particle starting at a depth x multiplied by the probability of escaping from that depth. From the diagram, this second probability is the ratio of the area of the zone subtended by a cone with altitude x on a sphere of radius k, to the area of the entire sphere. Thus:

$$A = A_o \int_o^D \frac{2\pi k(k-x)dx}{4\pi k^2} \approx \frac{A_o}{2k}\int_o^D (k-x)dx$$

$$= \frac{A_oD}{2}\left(1 - \frac{D}{2k}\right) \qquad (1)$$

Equation (1) also gives the observed counting rate as a function of disintegrations occurring for a plate being alpha counted; however, in fission counting, each disintegration produces two fission fragments, and the observed rate will be twice as great. More useful expressions may be obtained by observing the proportionality between thickness and film mass.

Where: m is the mass of the film,

μ the mass absorbtion coefficient.

Ac the number of disintegrations per min per mg. of film.

$$Ac = \frac{2A}{m(1 - \mu m)} \text{ for alpha counting} \tag{2}$$

$$Ac = \frac{A}{m(1 - \mu m)} \text{ for fission counting} \tag{3}$$

It is noted that these expressions are valid only as long as $D < k$. At the point where $k = d$, one half of the fission events (3/4 of the alpha particles) are being lost in the film, and a further increase in film thickness will not increase the counting rate.

Part II

Dead Time Corrections

Experiment has shown the radioactive disintegration of atoms to be a random phenomenon. When counting events which accompany such disintegrations for an insignificant fraction of the half/life of an isotope, the average rate of their occurrence (Ac) may be taken as constant.

Under these conditions the events conform to the well-known Poisson Distribution,

$$P_{k,t} = \frac{x^k e^{-x}}{k!} = \frac{(Act)^k e^{-Act}}{k!} \qquad (1)$$

$P_{k,t}$ is the probability that k events will occur in a time interval t where the average rate (Ac) is x/t.

Many counting devices are characterized by a short period of insensitivity following an event. The minimum time between two events, both of which can be counted by a device, is known as its resolving time or dead time. Thus when counting random events some will not be counted due to their occurrence within the dead time period following another.

Counting devices generally fall betwen two extreme types. At one extreme each event produces a reaction of duration t and the device fails to count any event occurring while such a reaction is in progress. We shall call this extreme Type I*. Parallel plate pulse counting ionization chambers have been found to very closely approximate Type I. At the other extreme the device goes through a cycle of duration t for each event counted and fails to count any event occurring during such a counting cycle. This behavior is closely approximated by triggering devices such as scaling pairs and blocking oscillators and will be referred to as Type II.

To find the number of counts lost per unit time in a Type I device, we multiply the number of dead time periods per unit time (equal to Ac) by the probable number of events introduced in time t. If one event occurs within time t of the preceding one it will not be counted and thus the probability of losing one count in this way can be determined from (1) as $P_{1,t}$. If two counts occurred within a time t following another they would not be counted. However, the probability of losing the last is included in $P_{1,t}$ as it occurred singly within time t of the second count. Thus the additional loss is (2-1) $P_{2,t}$. Likewise when n counts occur within time t of another, the additional loss is only n-(n-1) $P_{n,t}$. The total number of counts lost (on the average) in unit time may therefore be expressed as

*Skinner - Phys. Rev. 52, 322

$$Ac-A = Ac\,(P_{1,t} + P_{2,t} \ldots + P_{n,t} + \ldots)$$

$$= Ac\left\{Act\,e^{-Act} + \frac{(Act)^2}{2!}e^{-Act} \ldots + \frac{(Act)^n}{n!}e^{-Act} + \ldots\right\}$$

$$= Ac\,e^{-Act}\left(e^{+Act} - 1\right)$$

$$Ac-A = Ac - Ac\,e^{-Act} \qquad (2)$$

whence,

$$A = Ac\,e^{-Act} = Ac\left\{1 - Act + \frac{(Act)^2}{2!} - \frac{(Act)^3}{3!} + \ldots\right\} \qquad (3)$$

While equation (3) serves to determine the observed counting rate we usually wish to determine the average rate Ac of the random events entering the counting device. This may be done by solving the equation for Ac. Using the method of undetermined coefficients:

$$Ac = A\left(1 + At + 3/2\,(At)^2 + 8/3\,(At)^3 + 125/24\,(At)^4 + \frac{108}{10}(At)^5 + \ldots\right) \qquad (4)$$

To find the maximum value of the remainder after the term in $(At)^4$:

$$\frac{Ac}{A} = e^{Ac\ t} = 1 + At + 3/2\,(At)^2 + 8/3\,(At)^3 + \frac{125}{24}(At)^4 + R_4$$

Taking a value of Act slightly larger than any met with in precise counting, say Act = 0.1152020 we find:

$$e^{Ac\ t} = 1.122100 \text{ (whence } At = 0.1026664)$$

$$\frac{Ac}{A} - R_4 = 1 + 0.1026664 + 0.0158106 + 0.0028857 + 0.0005883$$

$$= 1.1219460$$

whence, R_4 = 0.000154 or 0.0137% of the correction.

If this error be considered too large, the next term, $108/10\ (At)^5$ may be included in (4) and the remainder R_5 evaluated. R_5 is 0.000030 for the above conditions or 0.002% of the correction.

To find the number of counts lost in unit time in a type II device we multiply the number of counting cycles (equal to A) of dead time (t) by the probable number of events introduced into the device in time (t). Here the probable number is simply:

$$1\,P_{1,t} + 2\,P_{2,t} + 3\,P_{3,t} + \ldots + n\,P_{n,t} + \ldots)$$

and the total number of counts lost is

$$Ac - A = A\,(1P_{1,t} + 2\,P_{2,t} + 3\,P_{3,t} + \ldots + n\,P_{n,t} + \ldots)$$

$$= A\,e^{-Act}\left(Act + \frac{(Act)^2}{1!} + \frac{(Act)^3}{2!} + \ldots\right.$$

$$= A\,e^{-Act}(Act)\left\{1 + Act + \frac{(Act)^2}{2} + \ldots\right\}$$

$$= A\,Act \qquad (7)$$

whence

$$A = \frac{Ac}{1 + Act} \qquad (8)$$

and

$$Ac = \frac{A}{1-At} \qquad (9)$$

It is perhaps unfortunate that the routine counting chambers do not conform more closely to Type II than Type I. A comparison of the correction formulae for Type II and Type I may be made as follows:

$$\text{Type II} \quad \frac{Ac}{A} - 1 = At + (At)^2 + (At)^3 + (At)^4 + \ldots)$$
$$= Act$$

$$\text{Type I} \quad \frac{Ac}{A} - 1 = At + 3/2\,(At)^2 + 8/3\,(At)^3 + \frac{125}{24}\,(At)^4 + \ldots$$

$$= Act + 1/2\,(Act)^2 + 1/6\,(Act)^3 + \frac{1}{24}\,(Act)^4 + \ldots$$

$$= e^{Act} - 1$$

For Act less than 0.1 as is usually the case, the two corrections are less than 10% and 10.52% respectively. This is rather too large a difference to ignore in precise counting.

If we consider the case where two units, the first with a dead time t, and the second with a dead time s, are operated in series with j scaling pairs between them, two total dead time loss equations are possible. First, if $s < 2^j t$, the second unit cannot possibly receive two counts in a time shorter than s, and thus will faithfully follow each count passed by the first unit. The total dead time loss is then as expressed by equation (2) with the dead time of the first unit.

In the second case, where $s \gg 2^j t$, the loss of the first unit is still given by equation (2), but there will also be a factor due to loss in the second unit. If the first unit should pass 2^j counts on to the scalers in the time s following a count, one time in every 2^j, the scaling pairs will pass one pulse on to the econd unit within the time s of the first. If the first unit were to pass on $2^j + 1$ counts in time s, there would be twice the probability of finding the scaling circuit able to pass on a pulse to the second unit within time s, etc. This will hold true up to the case where 2×2^j are passed on by the first unit. From here on to 3×2^j it will be certain that the second unit will receive one pulse within time s of another, and there will be an increasing probability that it will receive twice that many. Thus to find the total loss due to the second unit, we will sum the probabilities, $Q_{r,s}$ of finding r pulses in the time s following another count, multiplied by the loss which was shown above to accompany such an occurrence. This gives for a Type I device as the number of pulses lost (L) per unit time:

$$L = \frac{A_1}{2^j}\left(Q_{1,s} + Q_{2,s} + Q_{3,s} + \ldots + Q_{n,s} + \ldots\right) \qquad (10)$$

as in (2)

where

$$Q_{1,s} = \frac{1}{2^j} P_{2^j,s} + \frac{2}{2^j} P_{2^j+1,s} + \ldots + \frac{2^j}{2^j} P_{2\cdot 2^j-1,s} + \frac{2^j-1}{2^j} P_{2\cdot 2^j,s} +$$

$$\ldots + \frac{1}{2^j} P_{3\cdot 2^j-2,s}$$

$$Q_{\ ,s} = \frac{1}{2^j} P_{n\cdot 2^j,s} + \frac{2}{2^j} P_{n\cdot 2^j+1,s} + \ldots \frac{2^j}{2^j} P_{(n+1)\,2^j-1,s}$$

$$+ \frac{2^j-1}{2^j} P_{(n+1)\,2^j,s} + \ldots$$

$$\ldots + \frac{1}{2^j} P_{(n+2)\,2^j-2,s}$$

Substituting,

$$L = \frac{A_1}{2^j}\left[\sum_{2^j}^{2\times 2^j-1} \frac{k+1-2^j}{2^j} P_{k,s} + \sum_{2\times 2^j}^{\infty} P_{k,s}\right]$$

The number of counts lost in the second unit will be 2^j times the number of pulses lost. Thus if A_2 is the output rate (including the scaling factor)

$$A_2 = A_1 - 2^j L = A_1 \sum_{2^j}^{2\times 2^j-1} \frac{k+1-2^j}{2^j} P_{k,s} + A_1 \sum_{2\times 2^j}^{\infty} P_{k,s} \quad (11)$$

As it is usually desired merely to limit the loss in the second unit to negligible proportions so that an overall dead time expression may be employed, the obvious extension to a type I device is omitted. Since the loss in a Type I unit will be slightly less (see above) use of the Type II formula (11) merely introduces a slight safety factor.

It remains to evaluate $P_{k,s}$ the probability of finding k counts delivered by the first unit within time s following another count. It is evident that since each count coming out of the first unit has associated with it a dead period θ, the total free time that will be left within the time s in which k counts may be passed on to the second unit will be $(s-k\theta)$.

The value θ is dependent upon the type of behavior exhibited by the first unit. If the first unit is of Type II, θ will be identically equal to the dead time t. However, with units of Type I, it is seen that θ will be in general slightly greater than t, since there is a possibility that a count will enter the first unit during some of the t periods and thus extend the length of the dead period. To evaluate θ in this case, we consider that a certain fraction of the counts coming in at rate Ac are lost in the first unit. This fraction, given by equation (2) as $1-e^{-Act}$ represents a total fraction of the time in which no count can be delivered. To find how much of this is to be associated with each count coming out of the first unit on the average we may divide by $A = Ace^{-Act}$. Thus:

$$\theta = \frac{1 - e^{-Act}}{Ac\, e^{-Act}} = \frac{1}{Ac}\left(e^{Act} - 1\right) \qquad (12)$$

It is now seen that the total time interval available to the k counts, $(s-k\,\theta) = S$, must be divided between them on the average in such a way that each individual interval may vary from θ to S, dependently in such a way that the sum of the individual intervals shall always be S. To find this product will in general require a $(k-1)^{th}$ order integration. However, an approximate result could be obtained by allowing some number of intervals to vary dependently over the proper range, and assuming that all of the remaining intervals are of equal length. By induction on such a result, we may obtain the correct form for the general case.

Let the first two intervals be x and y, and each of the remaining intervals be $(s-x-y) / (k-2)$. Then:

$$P_{k,s} = \frac{Ac^{k}\int_{0}^{S}\int_{0}^{S-x} x\, y\, (S-x-y)^{k-2}\, dx\, dy}{(k-2)^{k-2}\int^{S}\int^{S-x} dx\, dy} = \frac{Ac^{k}\int_{0}^{S} x\,(S-x)^{k'}\, dx}{k\cdot(k-1)(k-s)^{k-2}\, 1/2^{\,2}}$$

$$= \frac{Ac^{k}\, S^{k+2}}{(k+2)\,(k+1)\,k\,(k-1)\,(k-2)^{k-2}\, 1/2\, S^{2}} \qquad (13)$$

This equqtion is perfectly rigorous for $k = 3$, for at that point the assumption is correct. For that value of k, the equation is of the form:

$$P_{k,s} = \frac{Ac^{k}\, S^{k}\, (k-1)\,!}{(2\,k-1)\,!} \qquad (14)$$

By an induction on equation (13) it is evident that an expression of the form (14) will be rigorously valid for all values of k from 1 to s/Θ. The value of $P_{k,s}$ of course falls to zero when S becomes zero; that is, when $\Theta = s/k$. This is not precisely correct for units of type I since absolute cut off of counts does not occur until $t = s/k$. This error, which arises since it is necessary to use an average value for Θ, is vanishingly small.

With this limitation, the fraction of counts lost in a unit of dead time s following a unit of dead time t with j scaling pairs between the two is given by:

$$F_2 = \sum_{k=2^j}^{2^{j+1}-1} \frac{Ac^k\,(k-2+1)\,(s-K\theta)^k\,(k-1)!}{2^j\,(2k-1)!}$$

$$+ \sum_{k=2^{j+1}}^{S/\theta} \frac{Ac^k\,(s-k\theta)^k\,(k-1)!}{(2K-1)!} \qquad (15)$$

Where for Type I units, θ is given by equation (12) and for Type II units θ is identically equal to t.

From this equation we may calculate the following table, giving the maximum values of s/θ that will be permissable at various scaling factors so that the second unit will lose less than 0.1% of the counts when $Ac\theta = 0.1$.

Scaling Pairs to be used	Value of s/θ for no loss in the second unit	Value of s/θ for 0.1% loss in the second unit
1	1	1.01
2	2	3.1
3	4	17.2
4	8	68
5	16	188
6	32	443
7	64	954
8	128	1965
9	256	3989
10	512	8000
11	1024	16000
12	2048	32000

PART III

Split Film Calculations of Dead Time

A. Type I

In order to give a more accurate value for t, the dead time, the familiar split film equation (16) may be extended to include higher order terms of the counting loss equation for a Type I counting device. ***

Where Ao, Bo, and Co are the observed counting rates for the first, and second halves and for the entire film; A, B, and C are the respective actual counting rates, q is the background count, and t is the dead time:

$$Ao = A(1-At + 1/2\ (At)^2 - 1/6\ (At)^3 + \ldots)$$

$$Bo = B(1-Bt + 1/2\ (Bt)^2 - 1/6\ (Bt)^3 + \ldots)$$

$$Co = (A+B-q)\ (1-(A+B)t + 1/2\ (A+B)^2\ t^2 - 1/6\ (A+B)^3\ t^3 + \ldots)$$

$$t' \text{ (first approximation)} = \frac{Ao+Bo - Co-q}{2\ Ao\ Bo} = \qquad (16)$$

$$\frac{\begin{pmatrix}(A+B)-(A^2+B^2)\,t+(A^3+B^3)\,t^2/2-(A^4+B^4)t^3/6+\ldots\end{pmatrix} - \begin{pmatrix}(A+B-q)-(A+B)^2\,t+(A+B)^3\,t^2/2-(A+B)^4\,t^3/6+\ldots\end{pmatrix}-q}{2\,A\,B\begin{pmatrix}1-(A+B)t+(A+B)^2\,t^2/2-(A+B)^3\,t^3/6+\ldots\end{pmatrix}} =$$

$$= t\,\frac{\begin{pmatrix}1-3/4\,(A+B)t+1/6\,(2\,A^2+3\,A\,B+2\,B^2)t^2+\ldots\end{pmatrix}}{\begin{pmatrix}1-(A+B)t+1/2\,(A+B)^2\,t^2+\ldots\end{pmatrix}}$$

setting $t = \alpha\,(t') + \beta\,(t')^2 + \gamma\,(t')^3 + \ldots$

$$t = \alpha\,t' + 1/4\,(A+B)\,\alpha\,(t')^2 + 1/12\,(A^2+B^2)\,\alpha\,(t')^3 + \ldots$$

$$+ \beta\,(t')^2 + 1/2\,(A+B)\,\beta\,(t')^3 + \ldots$$

$$+ \gamma\,(t')^3 + \ldots$$

$$\alpha = 1,\ \beta = -1/4\,(A+B),\ \gamma = 1/24\,(A^2+6\,A\,B+B^2) \cong 1/3\,A\,B$$

$$t = t' - 1/4\,(A+B)\,(t')^2 + 1/3\,A\,B\,(t')^3 + \ldots$$

since $(A+B) = (Ao+Bo) + (Ao^2+Bo^2)t + \ldots$ and $A\,B = Ao\,Bo + \ldots$

$$t \cong t' - 1/4\,(Ao+Bo)\,(t')^2 - 1/4\,(Ao+Bo)t\,(t')^2 +$$

$$1/24\,(Ao^2+6\,AoBo+Bo^2)\,(t')^3$$

B. Type II

$$A_c = \frac{A}{1-At} \qquad B_c = \frac{B}{1-Bt} \qquad C_c = \frac{C}{1-Ct}$$

where A, B, and C are the observed counting rates corrected for extraneous background*** of the two halves (A and B) and of the entire film (C)

Whence:

$$A(1-Bt)(1-Ct) + B(1-At)(1-Ct) = (1-At)(1-Bt)C$$

$$A-ABt - Act+ABCt^2 + B-ABt - BCt + ABCt^2 = C - ACt - BCt + ABCt^2$$

$$ABCt^2 - 2\,ABt + A+B - C = 0$$

and:

$$= \frac{1 \pm \sqrt{1-\frac{C}{AB}(A+B-C)}}{C}$$

***The following derivations will hold strictly for cases where the extraneous background, q, is very small, and will give the greatest precision when Ao and Bo are nearly equal.

PART IV

Calculation of Dead Time From Sources of Known Activity Radio

In counting systems where the geometry of sample placement is not critical, the split film method is not essential. It is needed for instance, where the sample activity follows the inverse square law.

Two samples made of the same material but differing in weight provide a more rapid method of calculating dead time. If absorption losses are present they must be known, of course, before the counting activity ratio can be determined. Therefore we shall refer to the function M defined as m(1-u m). (See report C-9, Part I).

The observed counting rate of a Type I counter is then

$$r = n\,M\,e^{-nMt} \qquad (1)$$

Using two samples (1 and 2) the ideal counting rate n for unit M can be derived.

$$n\,M_1\,t = \ln \frac{n\,M_1}{r_1} \qquad (2a)$$

$$n\,M_2\,t = \ln \frac{n\,M_2}{r_2} \qquad (2b)$$

$$M_2 \ln \frac{nM_1}{r_1} = M_1 \ln \frac{nM_2}{r_2} \tag{3}$$

$$n^{M_2} \left(\frac{M_1}{r_1}\right)^{M_2} = n^{M_1} \left(\frac{M_2}{r_2}\right)^{M_1} \tag{4}$$

$$n^{(M_2-M_1)} = \left(\frac{M_2}{r_2}\right)^{M_1} \left(\frac{M_1}{r_1}\right)^{-M_2} \tag{5}$$

$$n = \left(\frac{r_1}{M_1}\right)^{\frac{M_2}{M_2-M_1}} \left(\frac{r_2}{M_2}\right)^{\frac{M_1}{M_1-M_2}} \tag{6}$$

Solving (2a and 2 b) for t in terms of n (from 6):

$$n\, t\, (M_2-M_1) = \ln \left(\frac{r_1 M_2}{r_2 M_1}\right) \tag{7}$$

$$t = \frac{\ln \left(\frac{r_1 M_2}{r_2 M_1}\right)}{n\,(M_2-M_1)} \tag{8}$$

The value of t may also be found from the t correction formula (See report C-9, Part II) or graph. The t correction is simply.

$$\frac{n M_1}{r_1} \quad \text{or} \quad \frac{n M_2}{r_2} \tag{9}$$

The formula or graph gives the value of $r_1 t$ or $r_2 t$ whence t is found upon dividing by the indicated observed counting rate.

Similarly for a Type II counter

$$r_1 = \frac{nM_1}{1+nM_1 t} \quad \text{or} \quad 1+nM_1 t = \frac{nM_1}{r_1} \qquad (10a)$$

$$r_2 = \frac{nM_2}{1+nM_2 t} \quad \text{or} \quad 1+nM_2 t = \frac{nM_2}{r_2} \qquad (10b)$$

whence

$$n\ t\ (M_2 - M_1) = n \left(\frac{M_2}{r_2} - \frac{M_1}{r_1}\right) \qquad (11)$$

and

$$t = \frac{r_1 M_2 - r_2 M_1}{r_1 r_2\ (M_2 - M_1)} \qquad (12)$$

The sensitivity of these formulas is closely proportional to the difference in the counting activity of the two samples up to $r_2 t$ values of 0.15. Thus it is advisable to have as large a difference in counting rates as practicable. With limited counting time it becomes desirable to sacrifice some sensitivity by increasing the counting rate of the lighter sample to a point where the increased precision of the average random counting rate combines with the sensitivity of the formula to make the overall uncertainty in t a minimum.

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J. Lamb / 1034A

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April 26, 1946

CLINTON ENGINEER WORKS
CARBIDE AND CARBON CHEMICALS CORPORATION

Laboratory Division
Radiation Research Section

SUMMARY OF PRECISE, SIMPLIFIED METHOD OF CALCULATING ENRICHMENTS BY COUNTING FILM FISSIONS

Classification changed to UNCLASSIFIED (level and category)

Sam W. Hall 10/19/95
ADC or ADD signature (first reviewer) Date

Thomas W. Sillery 10/20/95
ADD signature (final reviewer) Date

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This document has been approved for release to the public by:
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LABORATORY DIVISION

RADIATION RESEARCH SECTION

Serial No. C-10
File Index No. KB-2
April 26, 1946

To: Mr. J. A. Klacsmann

SUMMARY OF PRECISE, SIMPLIFIED METHOD OF CALCULATING ENRICHMENTS BY COUNTING FILM FISSIONS

A In terms of the counting corrections developed in Report C-9 the corrected specific counting rate of a film may be found from the formula

$$n = r\frac{(t\ \text{corr.})}{(u\ \text{corr.})} - c \qquad (1)$$

Subtraction of the term c is necessary to make n directly proportional to f.

$$f = f_o\ n/n_o \qquad (2)$$

B For routine calculation the average value of u over a long period would probably be more reliable than one determined at an individual calibration. A ten per cent uncertainty in the estimate of u produces less than one one hundredth of a per cent uncertainty in f provided the same estimate of u is used throughout the calculations and the actual value of u remains constant. A one per cent variation in the value of u between calibrations introduces less than

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0.015 per cent error in the result (f) of any analysis (based on a 5 mg. calibration film). Thus small variations in u are insignificant as well as hard to detect in a limited calibration period. Hence, it is suggested that the entire term

$$m\ (1-um) \qquad (3)$$

be read graphically or tabulated for routine operation. In case it is possible to use films of a constant weight the value of f will be unaffected by this term and its use may be avoided in calculating f.

The t correction should certainly be obtained graphically during routine calculations. Graphs of a t correction vs r at ten microsecond intervals in the range 350 to 450 microseconds being adequate for the counting circuits now in use. Over night runs of split films can be used to evaluate the deadtime (t) as shown in report C-9. The frequency of t determinations is goveren by the magnitude and period of drift of this quantity. As routine counting circuits have run for months without recalibration it is not anticipated that t will need to be redetermined as often as the calibration.

C A high counting rate "check", or "verification" film should be counted daily or oftener to detect changes in calibration and correction terms. The higher the counting rate (r_v) of this film the more sensitive it becomes to changes in t. Likewise a mass (m_v) as far removed from the mass of the calibrating standards (m) as any being used for unknowns gives maximum sensitivity of r_v to changes in u. Immediately upon recalibration or redetermination of correction constants the verification film should be run, its assay (f) calculated and compared with its posted value. For routine daily checks where the calibration and correction constants remain the same it is sufficient to compare r_v with its posted value.

D The calibration standard consists of a set of films having the same weight (m_s) and a convenient counting rate (r_s). This set must first be carefully compared with a like set of normal films to determine its assay f_s. Formulas (1) and (2) apply.

To calibrate a counting unit the set of standard films is counted giving r_s. From (1) n_s is calculated. The quotient f_s/n_s may then be determined and used as the calibration constant for assaying unknown samples. The complete expression for f then becomes:

$$f = \left(f_s / m_s \right) \left(r \frac{\text{t corr.}}{\text{u corr.}} - c \right) \qquad (4)$$

Glossary

Sample subscripts	(o) Normal	(s) Standard	(v) Verification	( ) Unknown
Observed Counting Rate (per minute)	r_o	r_s	r_v	r
Film weight (mg U_3O_8)	m_o	m_s	m_v	m
Corrected specific Counting Rate (per minute) (per mg U_3O_8)	n_o	n_s	n_v	n
Wt. % U_{235}	f_o	f_s	f_v	f

t — Corrected overall deadtime of counting system obtained from

t* — Approximate deadtime determined by split film experiments. (For calculation of t see report C-9 Counting Corrections.)

u — Absorption coefficient

t corr. — Deadtime correction

$$1 + rt + 3/2\ (rt)^2 + 8/3\ (rt)^3 + \dots$$

as in report C-9.

u corr. — Absorption correction

$$m\ (1-um)$$

from report C-9

c — Extrapolated fission counting rate of U_{238} per milligram U_3O_8 per minute.