NUCLEARULE

CALCULATOR

OPERATION AND MAINTENANCE MANUAL

NUCLEAR-CHICAGO CORPORATION

CHICAGO 10, ILLINOIS

PRINTED IN U.S.A. NOVEMBER 1958 REVISION

TABLE OF CONTENTS

SECTION I. DESCRIPTION

GENERAL

The NUCLEARULE is a circular slide rule which is of constant use to those making measurements of radioactivity with standard detection instruments. Such information as COUNTS PER MINUTE, PROBABLE ERROR, or the time needed for a count within STANDARD ERROR, are easily calculated, as are COINCIDENCE LOSS and DECAY OF ACTIVITY.

GENERAL DESCRIPTION

One side of the rule, called Side I, gives the relationships between the register reading COUNTS of a scaler, the SCALE FACTOR of the scaler, the elapsed TIME in making the count, the COUNT RATE, and an approximation of the various statistical errors.

The other side of the Rule, called Side II, gives (1) the relationships between COUNT RATE, RESOLUTION TIME, and COINCIDENCE LOSS; and (2) the ACTIVITY of a source as a function of the number of HALF LIVES or as a function of the number of half thicknesses of absorbers.

THEORY OF OPERATION

Side I

On Side I of the NUCLEARULE appear scales corresponding to

REGISTER READING
SCALE FACTOR
PROBABILITY (%)
FRACTIONAL ERROR (%)
COUNTS PER MINUTE (cpm)
TIME (minutes)

and a multiplication factor designated as the "k CIRCLE". One setting of the Rule permits the determination of all these quantities.

If among the pairs of quantities both quantities of any pair are known and a quantity of a second pair is known, then this side of NUCLEARULE will determine the unknown quantity of the second pair.

REGISTER READING SCALE FACTOR	Refers to the final register reading and the scale factor used for a particular count.
PROBABILITY (%) FRACTIONAL ERROR (%)	Refers to the probability that successive counts under identical conditions will be within this fractional error.
COUNTS/MINUTE TIME (minutes)	Refers to the average count rate during the total duration of the particular count.

Since the REGISTER READING and the SCALE FACTOR are adjacent, by setting the SCALE FACTOR against the reading now on the scaler (if under 250) the COUNTS PER MINUTE may be read opposite TIME for whatever length of time the count was recorded. Register reading values between 100 and 250 must be interpolated between markings. Readings above 250 should be divided by 10 and calculated, the answer multiplied by 10.

The capital "K" indicates that one should multiply by a factor of 1,000; i.e. 5K means 5 times 1,000 or 5,000.

The small "k" also indicates that the number should be multiplied by 1,000 if the k CIRCLE is black.

IF TIME on the NUCLEARULE is not a value from one to ten minutes, or if the appropriate **count rate** is not shown in the window after the other settings are made, then the scales may be extended by reference to the following table:

TIME (minutes)	MULTIPLY BY
.01 – .1	X100
.1 – 1.	X10
1 – 10	X1
10 – 100	X1/10
100 – 1000	X1/100

Error can be avoided in extending this range if it is kept in mind that the product of the COUNT RATE and TIME obtained by using the scale should equal the product of the COUNT RATE and the TIME directly indicated.

The PROBABILITY (%) scale gives the probability for a statistical variation equal to or less than the value indicated on the FRACTIONAL ERROR (%) scale. Fractional errors corresponding to 50% probability are referred to as the PROBABLE ERROR; to 68.3% the STANDARD ERROR; and to 90%, the RELIABLE ERROR. The values are marked in red directly on the PROBABILITY (%) scale. If, instead of probabilities for certain errors, the value of the PROBABLE ERROR, STANDARD ERROR, or RELIABLE ERROR is desired, these values may be read directly on the FRACTIONAL ERROR scale opposite the appropriate initials in red on the PROBABILITY SCALE.

The PROBABILITY and FRACTIONAL ERROR scales can be used by themselves for any data following a normal error curve distribution; e.g., if the **standard error** is known, the **probability** for any other maximum error can be read off directly.

SIDE II

On Side II of the NUCLEARULE appear scales corresponding to

ACTIVITY
COUNTS/MINUTE (cpm)
NUMBER 1/2 LIVES
COINCIDENCE LOSS
RESOLUTION TIME

The ACTIVITY and the NUMBER 1/2 LIVES scales are in red because they are used together and are not used in conjunction with any other scales. The one and one thousand on the ACTIVITY scale coincide. The NUMBER 1/2 LIVES scale goes from 0 to 9.96. The division from 9.9 counterclockwise to 0 represents only 0.06 half lives and is 0.6 the size of the other divisions which represent 0.1 half lives.

If the initial activity and the number of half lives are known, set the 0 on the NUMBER 1/2 LIVES scale to the initial activity on the ACTIVITY scale. Follow counter-clockwise around the rule with increasing number of half lives until the known amount is reached. If while following around, the red line above the 1 on the ACTIVITY SCALE is crossed, the units for the activity must be reduced by a factor of 1000, i.e., if the initial activity is curies, then switch to millicuries; if the initial activity is in millicuries, then switch to

microcuries, etc. If the desired number of half lives is less than 9.96, simply read the final activity on the ACTIVITY scale opposite the NUMBER 1/2 LIVES, remembering the switch in units if necessary.

If the number of half lives is greater than 9.96, two methods may be used. One is quite simple, although it is approximate and introduces an error of 2.4% for each ten half lives. To apply it, divide the activity by 1000 (switching units) for each ten half lives. Then use the rule in the fashion outlined in the preceding paragraph to obtain the reduction following the last multiple of ten half lives.

The other method which introduces no error other than in the reading of the rule consists in breaking the long interval up into shorter intervals each of which is less than 9.96 half lives and applying the standard procedure to each of the smaller intervals. (See Examples)

For the other combinations of known quantities, the same general method may be applied by starting at different points in the procedure and working backwards. Since the absorption of gamma radiation in matter follows the same exponential decay as the decay of radioactivity in time, the identical procedure can be used to determine this absorption by interpreting INITIAL ACTIVITY as the strength of radiation before the absorbers, and the NUMBER 1/2 LIVES as the number of half thicknesses for the particular material and gamma energy involved.

Order of magnitude results can be obtained for beta radiation by this same procedure although no attempt should be made to obtain accurate results when replacing the actual beta absorption curves with this exponential absorption curve. The numbers on the ACTIVITY scale can be interpreted in any units proportional to the activity of the source or the radiation at a particular point, i.e., rutherfords, counts/minute, or curies, which has been used for purposes of explanation here.

The calculation of the COINCIDENCE LOSS from a counting setup, when the coincidence loss is a large percentage of the total count is a relatively complex determination that is unique with each setup. However, when this loss is not great, it may be considered as resulting from a fixed RESOLUTION TIME for the particular set of conditions. Under the assumption then, that this loss is small, the amount of the COINCIDENCE LOSS is equal to the product of the RESOLUTION TIME and the COUNT RATE, providing both are expressed in the same system of units. If, as is most common for GM tube work, we express the RESOLUTION TIME in microseconds and the COUNT RATE in counts per minute, then the COINCIDENCE LOSS in percent is the product of the RESOLUTION TIME and the COUNT RATE, divided by 600,000. The NUCLEARULE performs this entire calculation in one setting of the rule.

If the count rate is one of the known quantities, set the black arrow (situated at 0 on the red NUMBER 1/2 LIVES scale) opposite the COUNT RATE. The unknown quantity can then be read off directly opposite the other known quantity. If the **count rate** is the unknown quantity, set the COINCIDENCE LOSS opposite the RESOLUTION TIME, and read the count rate on the COUNT/MINUTE scale opposite the black arrow. Since the "K's" on the COUNT/MINUTE scale indicate a multiplication factor of 1000, i.e., 5K represents 5000.

EXAMPLES

ACTIVITY AFTER DECAY: On Side II set cpm on the upper scale at ZERO on the second scale labeled NUMBER 1/2 LIVES and read the counts after decay opposite any elapsed number of HALF LIVES.

EXAMPLE: Set 700 cpm opposite ZERO on the second scale and read opposite 1 **half life**, 350 cpm; opposite 2 HALF LIVES read 175 cpm.

COINCIDENCE LOSS: On Side II set ZERO on second scale against COUNTS PER MINUTE on the upper scale and against known RESOLUTION of the machine (usually supplied by the manufacturer) read COINCIDENCE LOSS.

EXAMPLE: Set 2.5K (2,500) on the upper scale against ZERO on the second scale and read 4.17 COINCIDENCE LOSS against 100 microseconds RESOLUTION TIME.

PROBABLE ERROR: On Side I set REGISTER READING on the upper scale opposite the SCALE FACTOR on the second scale and read for FRACTIONAL ERROR on the fourth scale. This is the percent PROBABLE ERROR.

EXAMPLE: Set register reading of 100 on upper scale opposite a scale factor of 100 (which multiple gives you 10,000 counts). Opposite the red letters "P.E." on the third scale read (approximately) 0.676%. This figure is the percent PROBABLE ERROR for 10,000 counts.

COUNTS PER MINUTE: On Side I set the REGISTER READING on the upper scale opposite the SCALE FACTOR on the second scale and read the bottom scale to find a time span in which a number of counts were taken. Opposite the unit one on the TIME scale read the number of COUNTS PER MINUTE if all counts were taken in one minute; opposite the given time span in which the total counts were taken, read COUNTS PER MINUTE for any one minute within that given span of time.

EXAMPLE: On Side I set the REGISTER READING at 250 on the upper scale opposite the SCALE FACTOR of 100 on the second scale and read the bottom scale to find a time span in which a number of counts were taken. Opposite the unit 1 on the TIME scale read the number of COUNTS PER MINUTE as 25,000, if all counts were taken in one minute; opposite the given time span in which the total counts were taken, (take 3 minutes) read COUNTS PER MINUTE for any one minute within that given span of time. The reading is 8,333 cpm.

ACTIVITY AFTER LONG DECAY: (an approximate method): If the number of HALF LIVES is greater than 10, as in the following example, consider that the activity at the end of 10 half lives is reduced by a factor of 1,000. Set the ZERO of the NUMBER of HALF LIVES scale opposite the reduced activity on the ACTIVITY scale and read counterclockwise to the number of half lives remaining. Read opposite HALF LIVES the final ACTIVITY.

EXAMPLE: If the initial activity were 50 millicuries and the number of half lives that have elapsed are 14.3, then reduce the 50 millicuries by 1,000 for ten half lives to get 50 microcuries. Then set the ZERO of the NUMBER HALF LIVES at 50 and read counterclockwise to 14.3 minus 10 half lives, or, at 4.3 half lives. Read opposite 4.3 half lives the final ACTIVITY of 2.53 microcuries (within 2.4% error).

EXACT METHOD: If one does not want to tolerate the 2.4% error, one may break down the 14.3 half life decay into two smaller ones, say a 9 and a 5.3 half life, and calculate twice, taking the result of the result of the first calculation for the rule setting of the second.

EXAMPLE: Set the ZERO on the NUMBER HALF LIVES scale at 50 (millicuries) and read counterclockwise to 9 half lives. Read opposite 9 half lives an activity of 98 microcuries. NOTE: when we cross 1 on the ACTIVITY scale we must divide by 1,000. Reset the ZERO to 98 and again read counterclockwise, to 5.3 half lives. We obtain a final ACTIVITY of 2.48 microcuries (accurate).

ORIGINAL ACTIVITY (an approximation): On Side II set the COUNTS PER MINUTE of the top scale against the number of HALF LIVES that have elapsed and read clockwise on the second scale to ZERO. Read opposite ZERO on the top scale the ORIGINAL ACTIVITY.

EXAMPLE: Set 100 COUNTS PER MINUTE on the top scale against 4 half lives and read clockwise to ZERO. Read opposite ZERO the ORIGINAL ACTIVITY of 1.6K (which is 1,600).

MAINTENANCE

Cleaning and Decontaminating

The slide rule may be cleaned and decontaminated easily by washing with soap and water. Organic solvents should not be used on the slide rule or its carrying case because of the possibility of damaging the plastic.

Accuracy

The accuracy of the rule is determined principally by the exactness of the concentricity of the various discs. Initially, this alignment is carefully checked so that an accuracy on all the logarithmic scales of .25% is maintained. Moisture will not cause changes in the dimensions, although extended exposure to high temperatures may. If the rule is not subjected to elevated temperatures nor unnecessary shearing stress, its original accuracy will be maintained.