TN-65-66
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MORE PuBe NEUTRON MEASUREMENTS IN THE ACCELERATOR TUNNEL - SUPPLEMENT TO TN-65-24

In TN-65-24, measurements of the neutron flux in the accelerator tunnel from a PuBe source were reported, but no measurements of dose rate were given. In this note, dose rates as a function of distance down the tunnel are reported. Measurements were taken only in the plain concrete part of the tunnel.

I. GENERAL SETUP

The measurements were made in the 10 foot high, 11 foot wide plain (non-boron) portion of the accelerator tunnel. The source (PuBe with strength 2.05×10^7 n/s) and detectors were always centered in the tunnel (about 5 feet from the walls and about 5 feet from the floor) and moved relative to each other along the beam direction. Four counters were used to take measurements:

(1) A bare BF_3 proportional counter with efficiency for thermal neutrons, $\epsilon = 28$ c/n-cm^{-2}.

(2) A BF_3 counter moderated by 6.3 cm paraffin and surrounded with a 0.032" Cd liner. The efficiency of the moderated counter is fairly constant for neutrons from 20 keV to 10 MeV and was $\epsilon = 13$ c/n-cm^{-2}. (1)

(3) A polyethylene-lined proton-recoil proportional counter whose output is proportional to the energy of the incident neutrons. (2) This counter had dimensions of 12" active length by 2-1/2" diameter. The efficiency of this counter (hereafter referred to as the P.R. counter) was $\epsilon = 1$c/31 MeV-cm^{-2}.

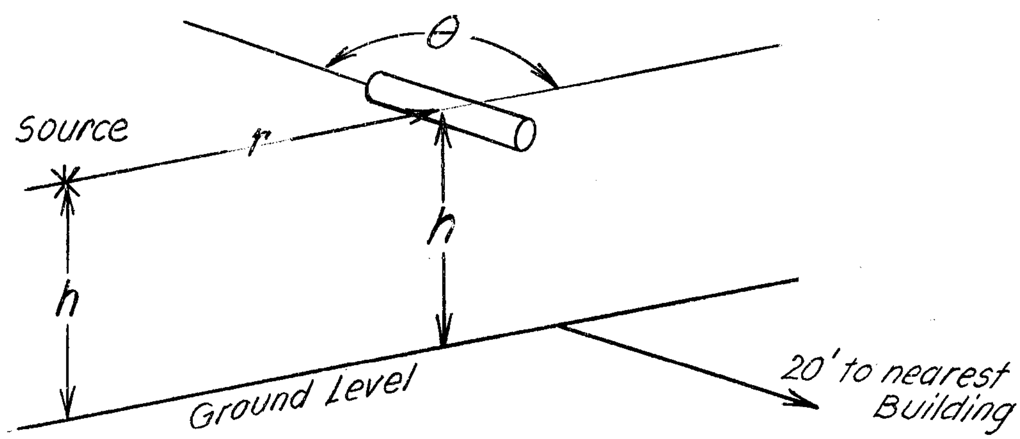
(4) A sphere dosimeter. (3) This is a thermal neutron detector (LiI viewed by a photomultiplier tube) surrounded by a 10" diameter spherical polyethylene moderator. The combination gives a response that is equivalent to the ICRP dose curve

to within ± 10% for the energy range from thermal to 7 MeV. This instrument has the advantage of being non-directional, and serves as a check on possible errors due to the directional dependence of the moderated BF_3 described in TN-65-24.

The background counting rates of both the bare and moderated BF_3 counters were 2 ± 2 c/50 sec, and of the proportional counter and sphere dosimeter less than 1 c/50 sec. Counting rates were usually high enough so that statistics and background were no problem. When they were significant, the statistical error (± N) is shown on the graphs.

II. COUNTER CALIBRATION

The P.R. counter and sphere dosimeter were calibrated in the same manner described in TN-65-24 and shown in the sketch below.



The P.R. counter was in the horizontal plane, and its axis made an angle θ with respect to r. The angular distribution was measured for h = 5' and r = 10'; it was approximately fit by $(1-.63\cos^2\theta)$; that is, the rate at 90° was almost three times the rate at 0° or 180°. This compares with the BF_3 moderated counter fit of $(1-.55\cos^2\theta)$, which indicates the rate for the BF_3 at 90° is about 2 times that at 0° or 180°. The sphere dosimeter's angular response was isotropic in the horizontal plane and within 80% when the dosimeter was placed on its side. The anisotropy arises primarily from the presence of the light pipe, P.M. tube and electronics associated with the dosimeter.

The hypothesis was tendered for the calibration constant of the BF_3 counter, $\epsilon(c/n\text{-}cm^{-2})$, that it was a function of r/h; that is, the scattered flux, Φ_s , was proportional to the direct flux, Φ_d , and some function of r/h, so that

$$\text{Counts/sec} = \epsilon\, \Phi_{total} = \epsilon\, \Phi_{direct}\ [1 + F(r/h)]\ .$$

Using this hypothesis, the calibration constant for the BF_3's was measured as a function of r/h and the value at $r/h \rightarrow 0$ used. It seems reasonable that some sort of r/h dependence would hold for the P.R. calibration constant even though the exact form is not clear because the calibration constant, ϵ ($c/MeV\text{-}cm^{-2}$), is dependent upon incident neutron energy, and the energy of the scattered neutrons is dependent upon the albedo of the scattering medium as well as scattering angle. The same is true for the sphere dosimeter. Both counters were calibrated at h = 5, 10 and 25 feet with the results shown in Figs. 1 and 2. For the P.R. counter, r/h extrapolated to zero was chosen as 0.032 $c/MeV\text{-}cm^{-2}$, or 1c = 31 MeV/cm^2. To convert flux to energy, the average energy of neutrons from a PuBe source is given as 4.2 MeV. [4] Even though the P.R. counter does not show a true r/h function, the extrapolated value is probably within ± 10%. The calibration of the sphere dosimeter utilized the results of the P.R. counter calibration. The flux at a given r/h was measured with a BF_3 (previously calibrated the same way) and the energy at that spot determined from the P.R. counter measurement. This gave an average energy per neutron at that distance which could be converted to mrem/hr. The sphere dosimeter was then in a known radiation field (mrem/hr), and a calibration figure could be arrived at for each point of measurement. As Fig. 2 shows, the r/h values for 5' and 25' are quite close; a value of 153 mrem/hr was chosen, which agrees with the calibration constant as supplied by the manufacturer and determined by them in a different manner.

III. DOSE MEASUREMENTS IN THE TUNNEL

The source was suspended in the middle of the tunnel; the detectors were placed one above the other and more or less centered in the horizontal plane. For the P.R. counter, h = 5-1/2', for the moderated BF_3, h = 5' and for the sphere dosimeter, h = 3'. The detectors were placed with cylinder axes normal to the source. Figure 3 shows the average neutron energy from PuBe neutrons in the tunnel as measured by the moderated BF_3-P.R. combination as a function of source-detector separation. Average neutron energies at all points of measurement lie between 1 and 2 MeV. The RBE within this range only changes by about 10%, (5) so a value of 8 n/cm^2-sec = 1 mrem/hr was used in converting flux to dose rates. Table I gives the dose rates in the tunnel from both thermal and fast neutrons measured with the bare BF_3 and the BF_3-P.R. combinations, and total dose as measured with the sphere dosimeter.

TABLE I

Source-Detector Separation (feet)	Dose Rate (mrem/hr)				
	Thermal	BF_3-P.R.	$\pm\sqrt{N} \times 100(\%)$	Sphere	$\pm\sqrt{N} \times 100(\%)$
5	0.074	22.5	± 4 %	21.4	---
10	0.057	10.0	8	8.5	---
15	0.041	5.7	10	4.6	2 %
20	0.03	3.5	10	2.6	2
30	0.015	1.6	10	1.17	4
50	0.004	0.42	14	0.35	5.3
100	0.00025	0.052	21	0.063	10

Figure 3 shows that the neutron energy does not drop off, but remains fairly constant at about 1 MeV for at least 100 feet. Also a comparison of the ratio of BF_3-P.R. readings to sphere dosimeter readings, given below in Table II, indicates that end effects in the earlier BF_3 readings, as reported in TN-65-24, were probably fairly small (at least less than 35%).

TABLE II

Distance (feet)	Ratio $\left(\frac{BF_3\text{-P.R.}}{\text{Sphere}}\right)$
5	1.05
10	1.18
15	1.24
20	1.35
30	1.33
50	1.20
100	0.83

Included in this note is the addition of neutron flux data in the tunnel (fast and thermal flux) to Figs. 2 and 3 of TN-65-24 to indicate agreement between measurements, and to provide a few more points in the areas where the change is greatest. For these Figures, Q is an effective source strength defined in terms of the observed flux, Φ_m ,

$$\Phi_m = \frac{Q}{4\pi r^2}$$

and Φ_d the flux if there were no scattering effects.

REFERENCES

1. H. DeStaebler and T. Jenkins, PuBe Neutron Measurements in the Accelerator Tunnel, SLAC TN-65-24.
2. Burton J. Moyer, Survey Methods for Neutron Fields, UCRL 1635 (1952).
3. Richard L. Bramblett, Ronald I. Ewing, and T. W. Bonner, A New Type of Neutron Spectrometer, Nucl. Instr. and Methods 9 (1960).
4. W. N. Hess and A. R. Smith, Measurement of Average Neutron Energies for (a,n) Neutron Sources, UCRL 8617 (1959).
5. Protection Against Neutron Radiation up to 30 MeV, NBS 63.

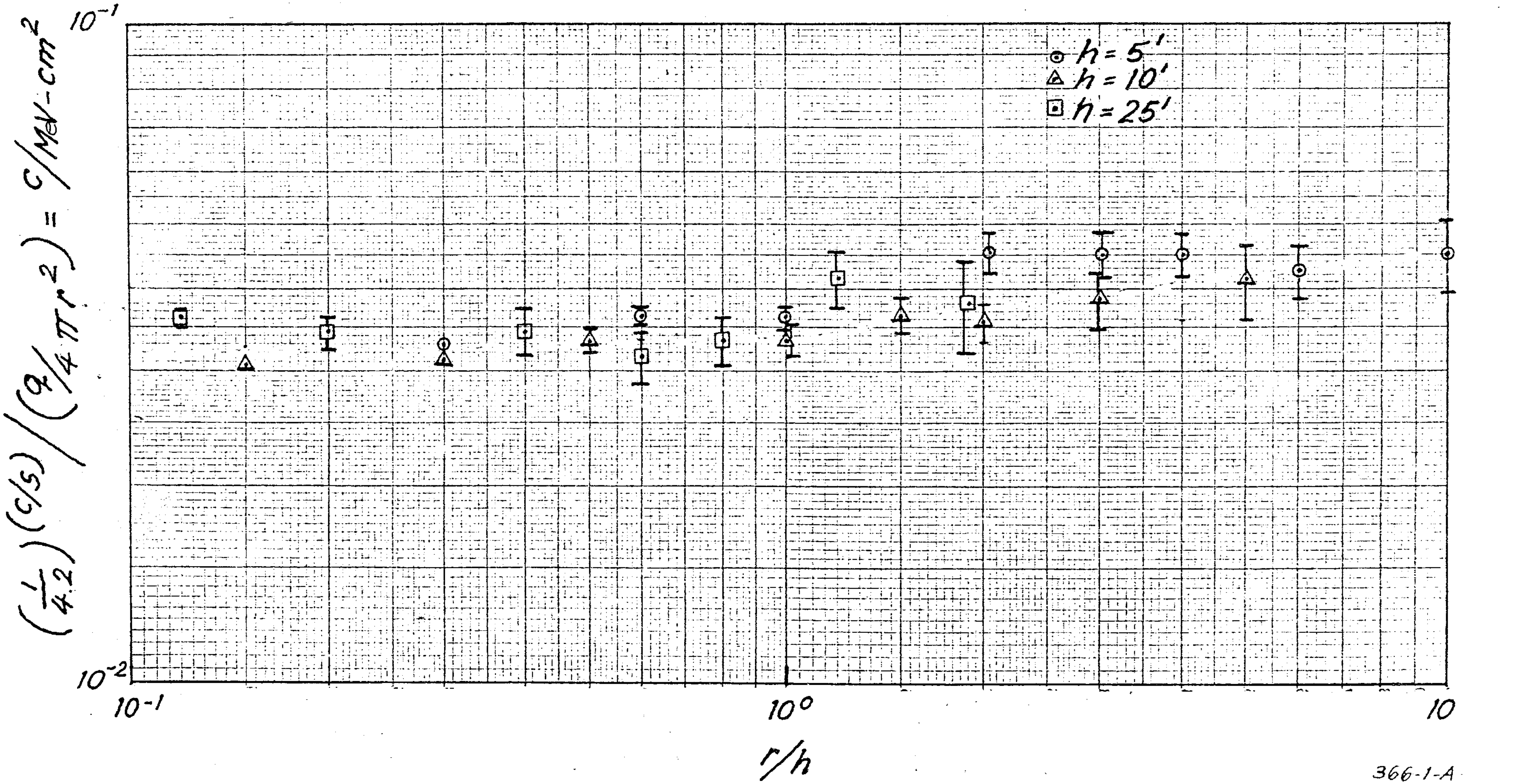


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FIG. 1 -- Response of P.E. Counter to 2.05×10^7 n/s PuBe Neutrons at different heights.

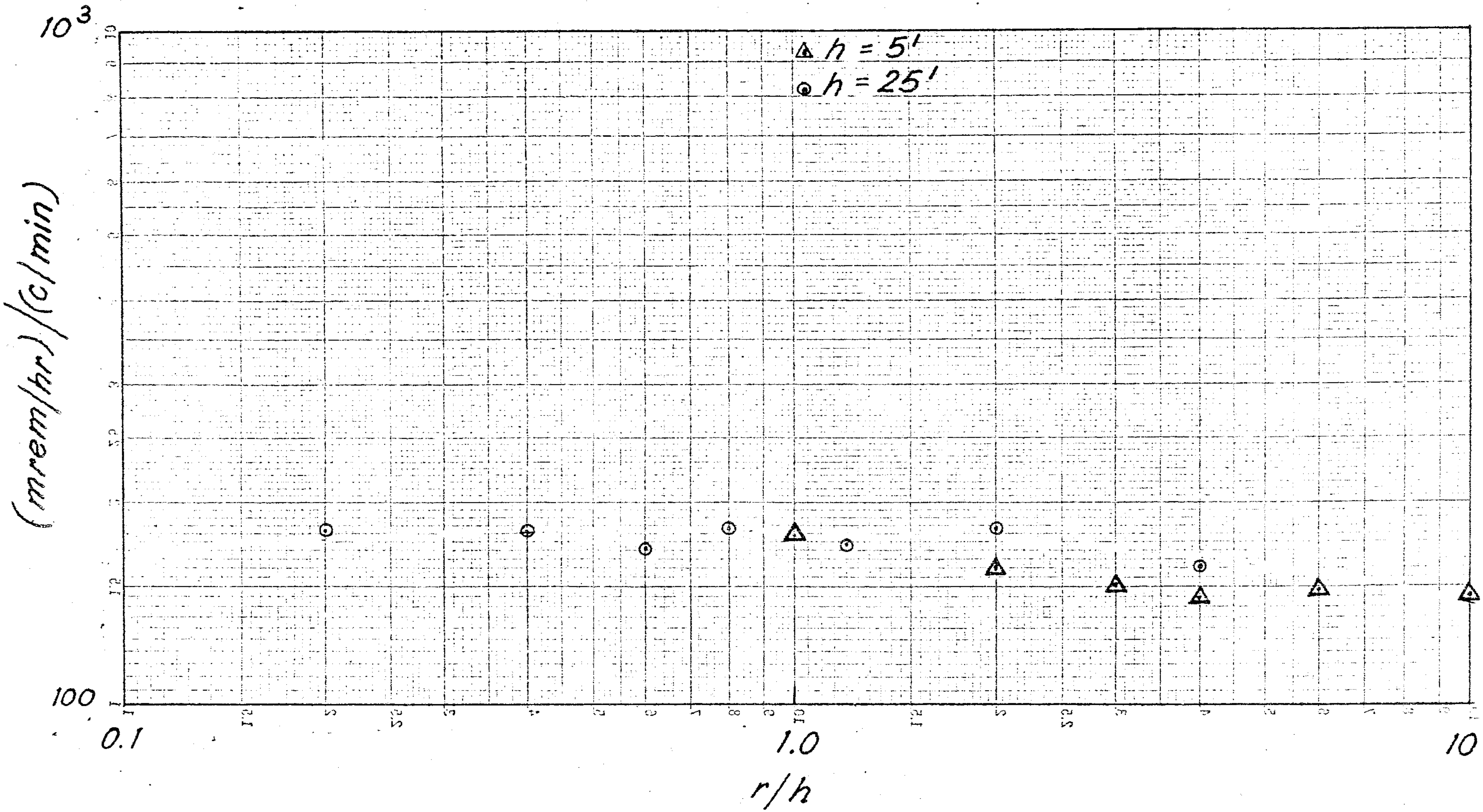
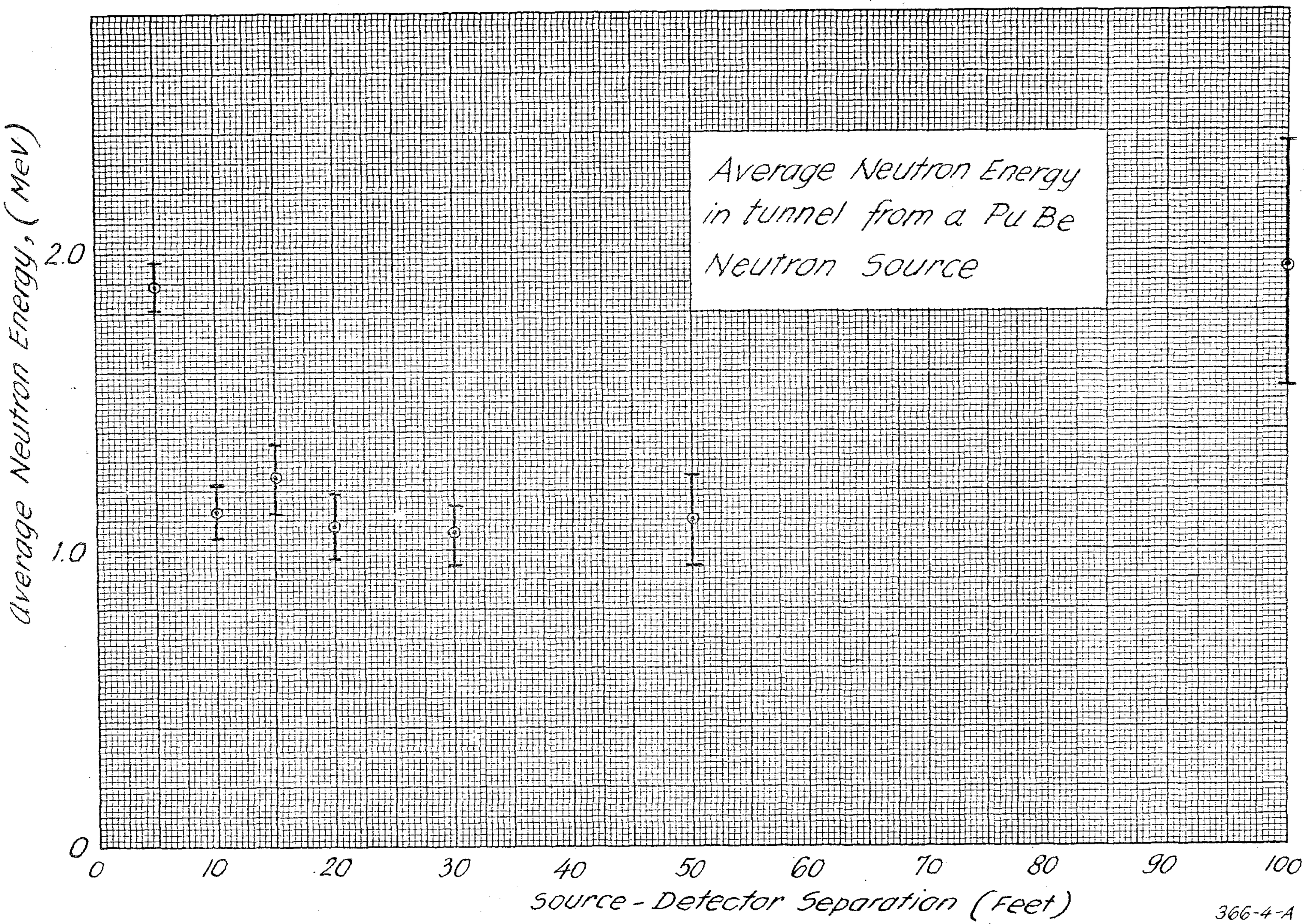


FIG. 2 -- Response of sphere Dosimeter to 2.05 × 10⁷ PuBe Neutrons with source and Detector at different heights.

366-3-A


Average Neutron Energy in tunnel from a Pu Be Neutron Source
Average Neutron Energy, (MeV)
2.0
1.0
0
0
10
20
30
40
50
60
70
80
90
100
Source - Detector Separation (Feet)

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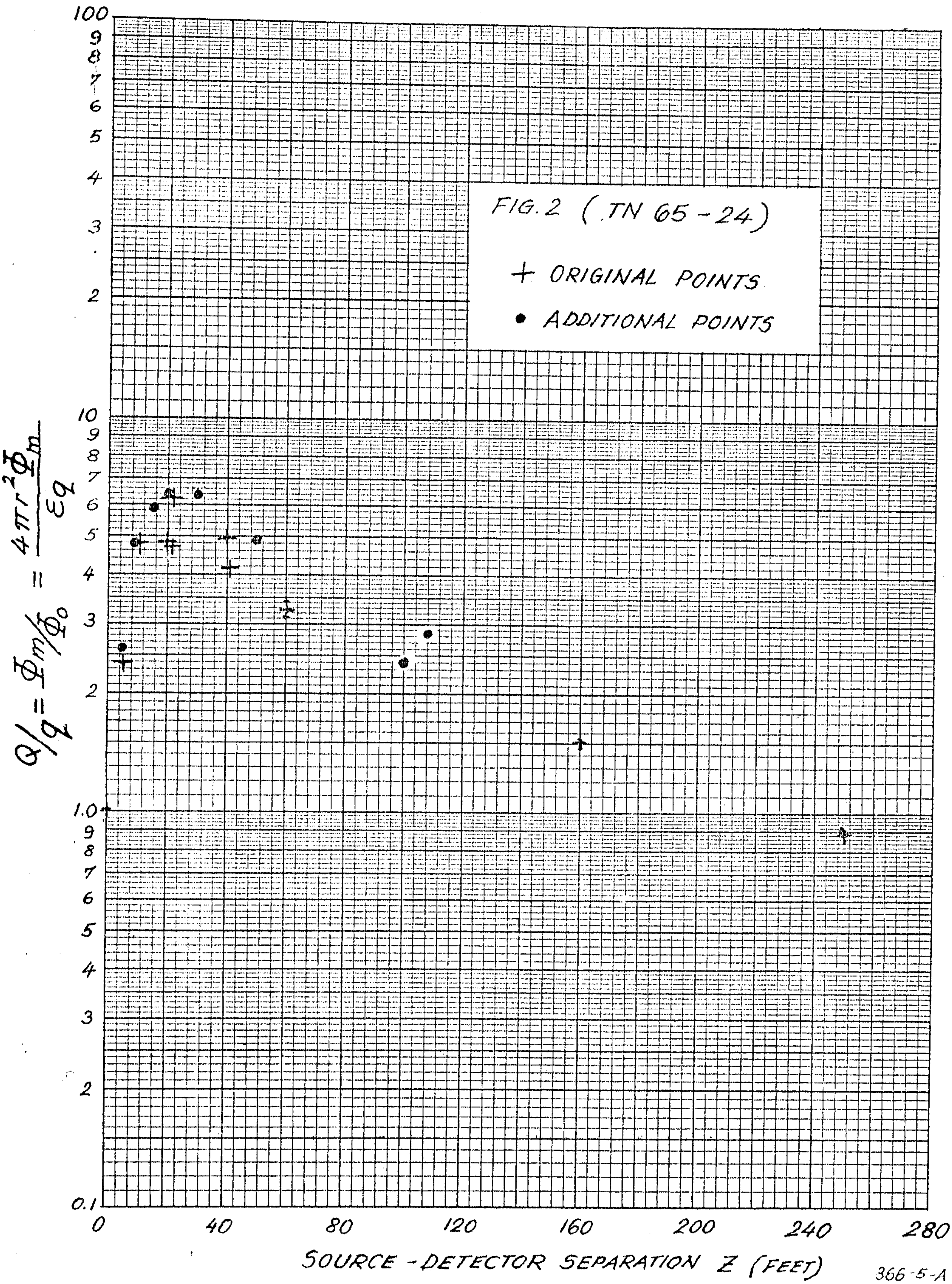
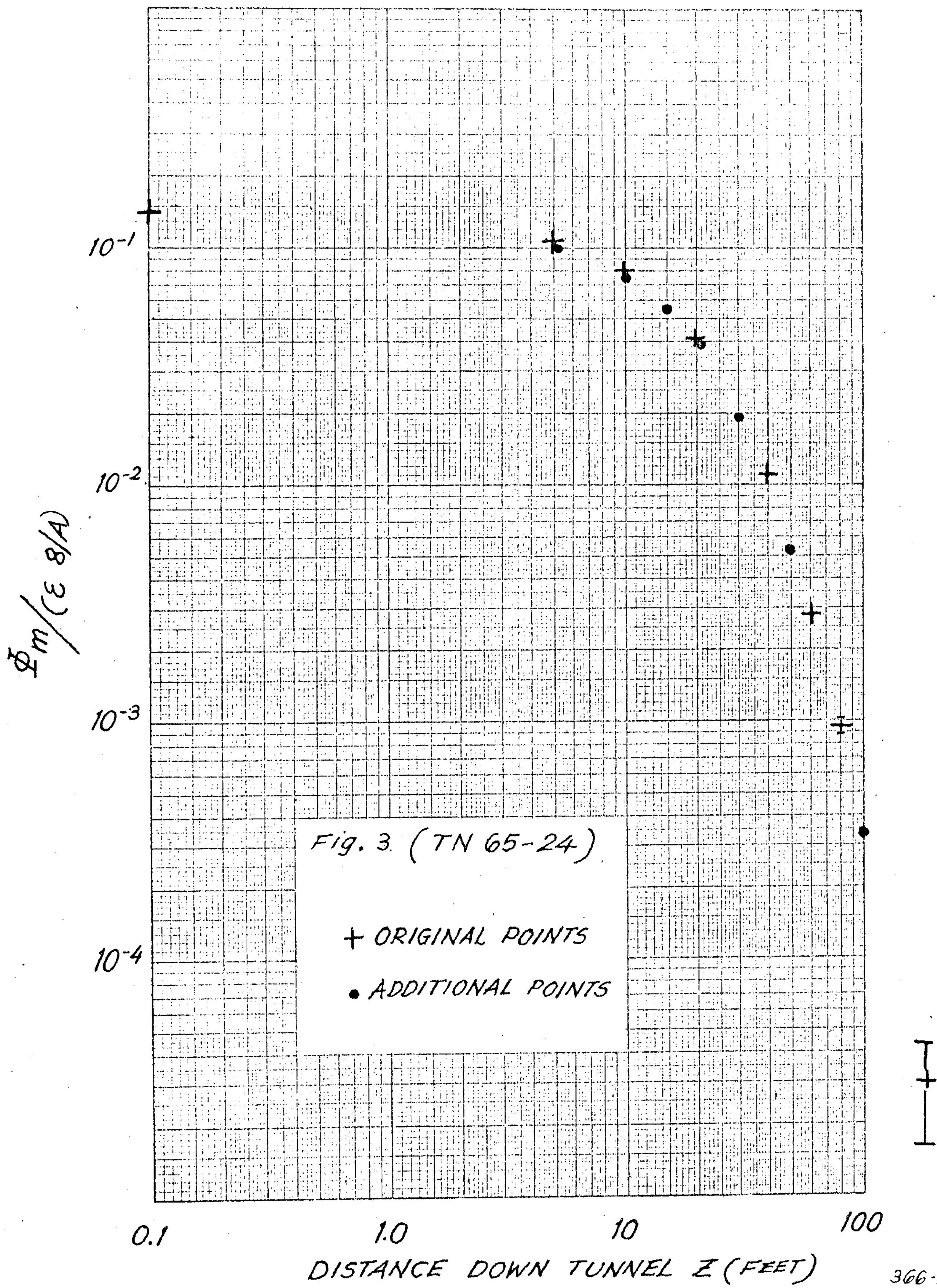


FIG. 2 (TN 65-24)
+ ORIGINAL POINTS
• ADDITIONAL POINTS
$Q/q = \Phi_m/\Phi_o = \frac{4\pi r^2 \Phi_m}{\varepsilon q}$
100
9
8
7
6
5
4
3
2
10
1.0
0.1
0
40
80
120
160
200
240
280
SOURCE - DETECTOR SEPARATION Z (FEET)

366-5-A


10⁻¹
10⁻²
10⁻³
10⁻⁴
Φm/(ε δ/A)
0.1
1.0
10
100
DISTANCE DOWN TUNNEL Z (FEET)
Fig. 3. (TN 65-24)
+ ORIGINAL POINTS
• ADDITIONAL POINTS

366-2-A