Shorter screws could be used for detonator leaf springs. (Schaffer)

Washers needed for informers. (Greisen)

Cable lengths too short? (Hornig)

Headless screws to protect screw holes (not necessary with Scotch wrap).

Need good cover for HE hole while turning over. (Schaffer)

Need proper clevis for attaching tongs to main hoist. (Henderson)

Need better method of getting up tent and securing. (Henderson)

Upper platform should be tested with concrete weight. (Oppenheimer)

It will not be possible to permit any personnel on the assembly platforms other than those actually engaged in assembly operations. However, personnel may observe the operations from beyond the roped off area, and may inspect the assembly at times as noted in the above operations list.

(Signed) N. E. Bradbury

Distribution:

J. R. Oppenheimer
F. Oppenheimer
G. B. Kistiakowsky
Major Ackerman
R. W. Henderson
R. S. Warner
Lt. Schaffer (2)
A. B. Machen
Morrison
Holloway
R. F. Bacher
N. Ramsey
K. T. Bainbridge
Lt. Comdr. Keiller
K. Greisen
D. Hornig
H. Linschitz
R. W. Carlson
John Williams
B. Rossi
R. Wilson

(4) Magee and Hirschfelder, Volume 7 Chapter 4 Los Alamos Technical Series.

## 6.2 NEUTRONS

### 6.2-1 Fast Prompt Neutrons

The cross section for the sulphur (n,p) reaction is almost a step function, rising from 0 to 0.2 barn at 3 Mev. This reaction presents an excellent method for measuring the radial distribution of fast, prompt neutrons above 3 Mev in energy. Delayed neutrons all have energies about 0.6 Mev and thus do not interefere. One measurement was made by E. Klema[5] at Trinity and a great many were made by Linenburger and Ogle[6] at Bikini.

(5) E. Klema, LA 361

(6) Linenburger and Ogle, B Division Report.

The experimental results are all given in Figure 2. The ordinate is distance squared times activity of sample (in arbitrary units) and the abscissa is distance. Klema's Trinity point is only corrected for the difference in atmospheric density, since most of the scattering is done by nitrogen, and the humidity doesn't matter.

Figure 2 is difficult to understand. If the average neutron of the high energy group were degraded below 3 Mev on its first collision, the curve would be a straight line, its intercept at R=0 giving the number of high energy neutrons penetrating the bomb materials. The experimental curve has such great curvature that it would seem to mean that the average neutron of this group must be scattered a great many times (six or more)[7] before being

(7) Hirschfelder and Magee, B Division Report.

is 0.45 $cm^{-1}$.

Fortunately, a more extensive set of measurements using film was obtained at the Bikini air burst test (test "Able") and these are available.[17] Since

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(17) The measurements were made by Dr. Dessauer and Mr. Rouvina of the Radiological Safety Section. The writer is indebted to Mr. Rouvina for the results.

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the two bombs were found by radio chemical means to be identical, a direct comparison can be made. The experimental points are plotted in Figure 5. The ordinate gives distance squared (yards) times Roentgens and the abscissa is distance in yards. The film was not covered with absorbing material as had been done at Trinity. Varying degree of shielding presumably accounts for most of the scattering of points since the films were placed all over the ships and had various and unknown thicknesses of iron between them and the $\gamma$ ray source. This being the case, one should expect that at a particular distance the unshielded radiation intensity is given by the highest reading. One should like to have asymptotically an expression of the form:

$$D^2R = \text{Const. } e^{-D/\lambda}$$

Where D = distance, R = Roentgen and $\lambda$ = means free path.

The straight line drawn in the figure gives what we shall call an "experimental" curve for unshielded radiation intensities at large distances. The point at 3500 yards which is far above the line was taken from a ship which suffered fire damage and so the film was probably ruined by heat.

The two unshielded Trinity film results (see the table above) are also plotted. They are indicated by the capital letter "T". In plotting these points, allowance has been made for the more tenuous character of Trinity air.

There was an X-ray film found at Hiroshima by Dr. Philip Morrison in a hospital at 1550 meters horizontal distance from the burst (or 1815 yards short range). There is considerable uncertainty in the amount of radiation this film

the experimental observation and a point source was used. The experimental curve is adjusted to agree with the calculated at one second. The agreement between the curves is quite good considering the roughness of the calculation. It seems to indicate that the radiation having the long mean free path must be coming from the fission products throughout the time of interest.

6.3-3 Spectrum of Gamma Radiation

It was mentioned earlier that in order to have a mean free path of 340 meters the energy of a gamma ray must be in the vicinity of 5 Mev. This observation only depends upon the validity of the Klein-Nishina formula for the scattering of $\gamma$-radiation, since a primary beam of initially homogeneous radiation in a few mean free paths will come into equilibrium with its scattered radiation. A careful consideration of the possible sources of this high energy radiation leads to the fission products as the most likely source (19). In

(19) Hirschfelder and Magee, B-Division Report

order to account for observed intensities, one needs about 0.72 Mev per fission in this energy region. Before the rising of the ball of fire takes the source of radiation away, there is a total of 1.8 Mev per fission given off. Thus about 40 per cent of the early fission gammas must be in the 5 Mev region.

6.3-4 Capture Gammas and Contamination

Some of the features of the Trinity Test were due to the location of the point of burst near the ground. During the first fraction of a second an appreciable amount of gamma radiation, for points close to the burst, was due to neutron capture in the ground. No measurements bearing on this point have been made, so it will not be discussed further. Estimates of this effect have been made by Weisskopf[20,21] and calculations of Marshak[22,23] on the rate

(20) V. Weisskopf, LAMS 218

existence of the extremely high temperatures was verified by measurements of Brian O'Brien.(32)

(32) Hirschfelder and Magee, B-Division Report

In Figure 7 the illumination as a function of time (according to the theory discussed in footnote 30) is presented. The ordinate is distance squared times "suns", where the "sun" (☉) is a unit of illumination rather than brightness. The temperatures of the radiating surface are indicated along on the curve. This curve is careful for calculating radiation intensities at all distances and times, in-so-far as atmospheric absorption can be neglected.

6.4-3 Incendiary Effects

Measurements on the incendiary effects were made at Trinity by Marley and Reines.(33) They found that no fires were started in wooden materials which

(33) Marley and Reines, LA 364

were appreciably outside the fire zone, but that charring occurred to beyond 1000 yards. Fir timber was slightly scorched out to distances of 2000 yards.

In an attempt to understand scorching and charring, let us consider a constant source of heat on a surface. It can be shown rather easily that the surface temperature is raised after a titime by the amount:

$$T_s = \frac{2}{\sqrt{\pi}} \frac{Q}{K\rho C} \sqrt{t}$$

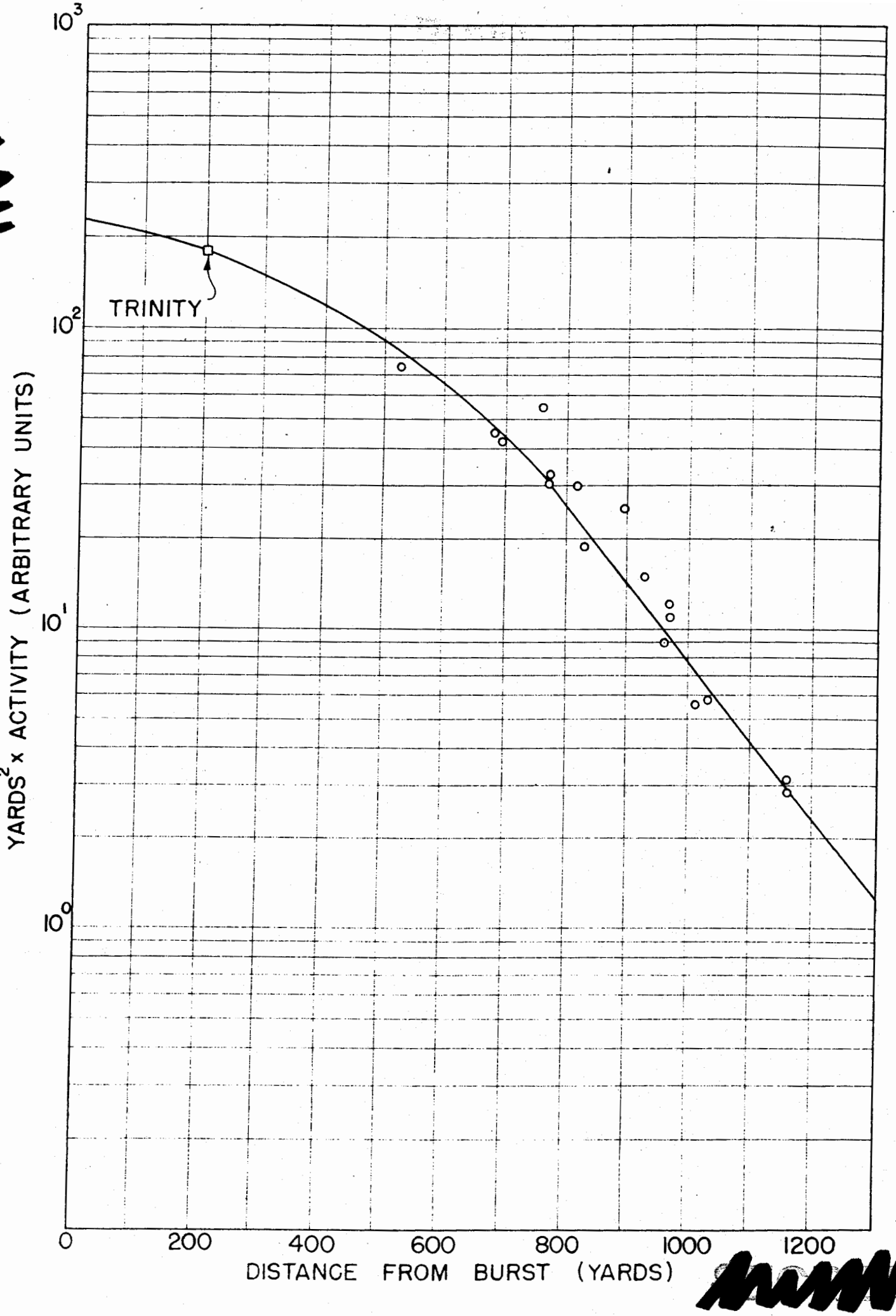
Where: Q = Strength of heat source (cal/cm$^2$ sec)

$K$ = Thermal diffusivity (cm$^2$/sec)

$\rho$ = Density (g/cm$^3$)

C = Specific heat (cal/g degree)

The above formula shows that the source strength comes in directly whereas the time is a square root. It is thus relatively better to have an intense



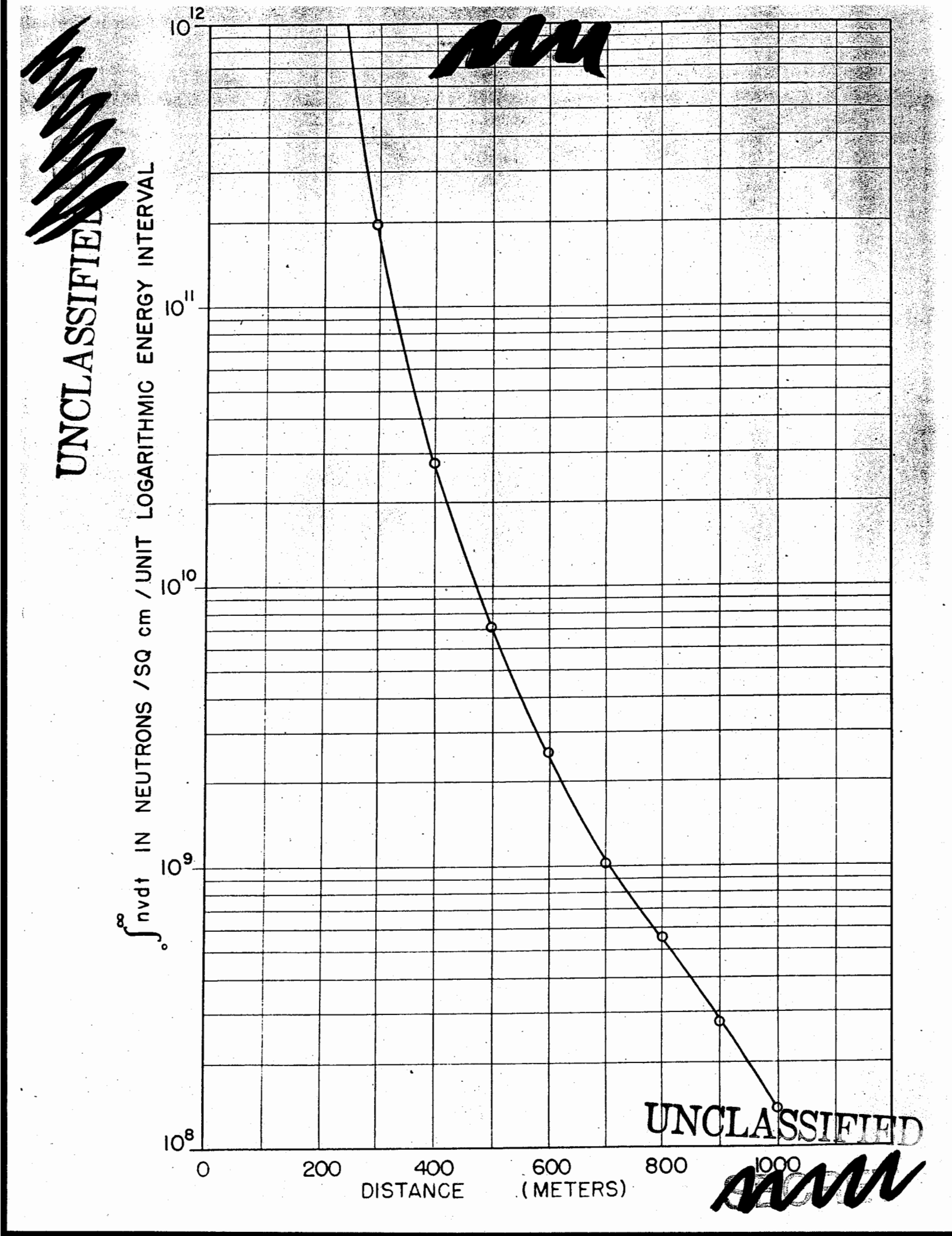

UNCLASSIFIED
$10^{12}$
$10^{11}$
$10^{10}$
$10^{9}$
$10^{8}$
$\int_0^\infty nvdt$ IN NEUTRONS / SQ cm / UNIT LOGARITHMIC ENERGY INTERVAL
0
200
400
600
800
1000
DISTANCE (METERS)
UNCLASSIFIED

Figure 4

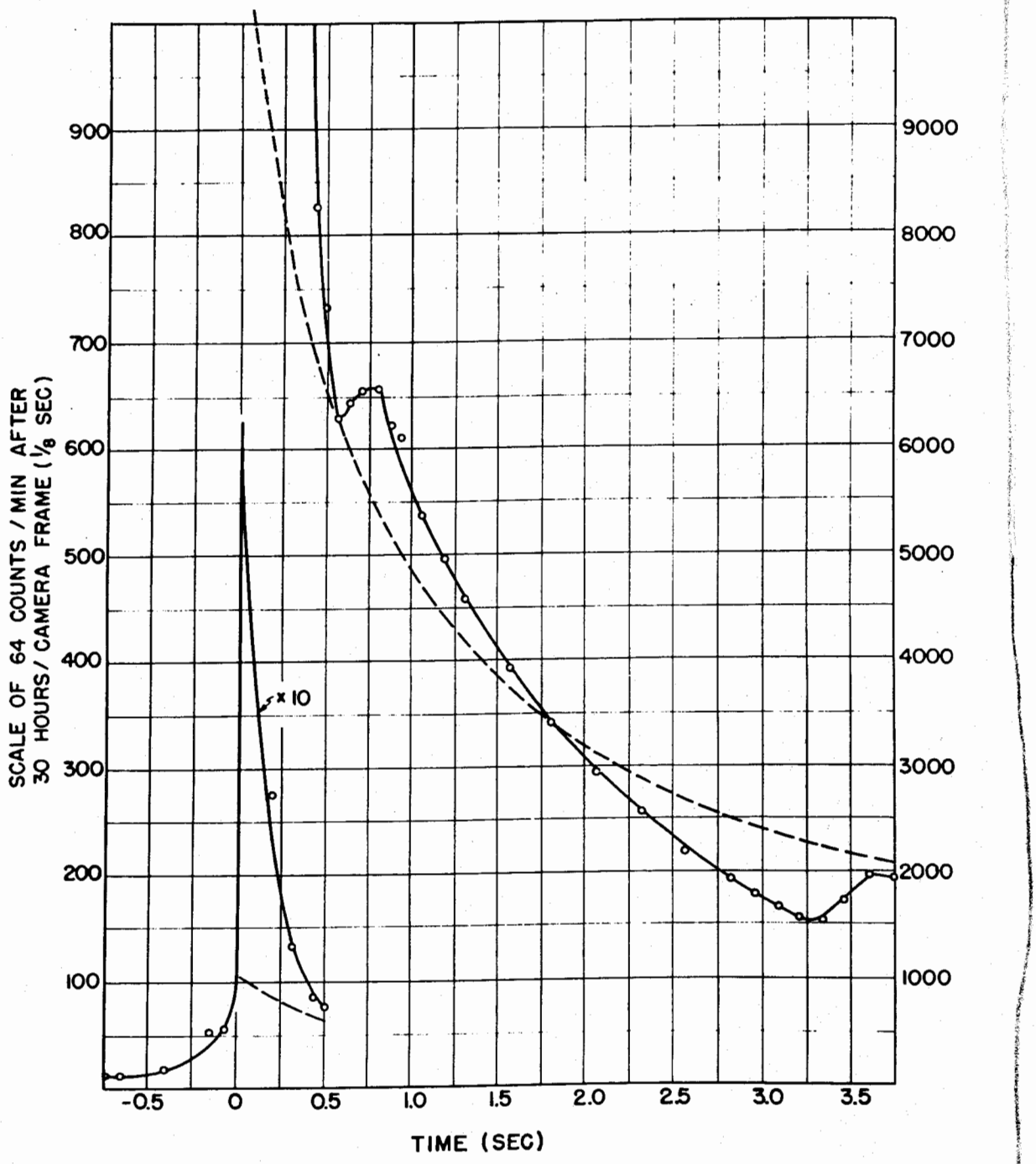
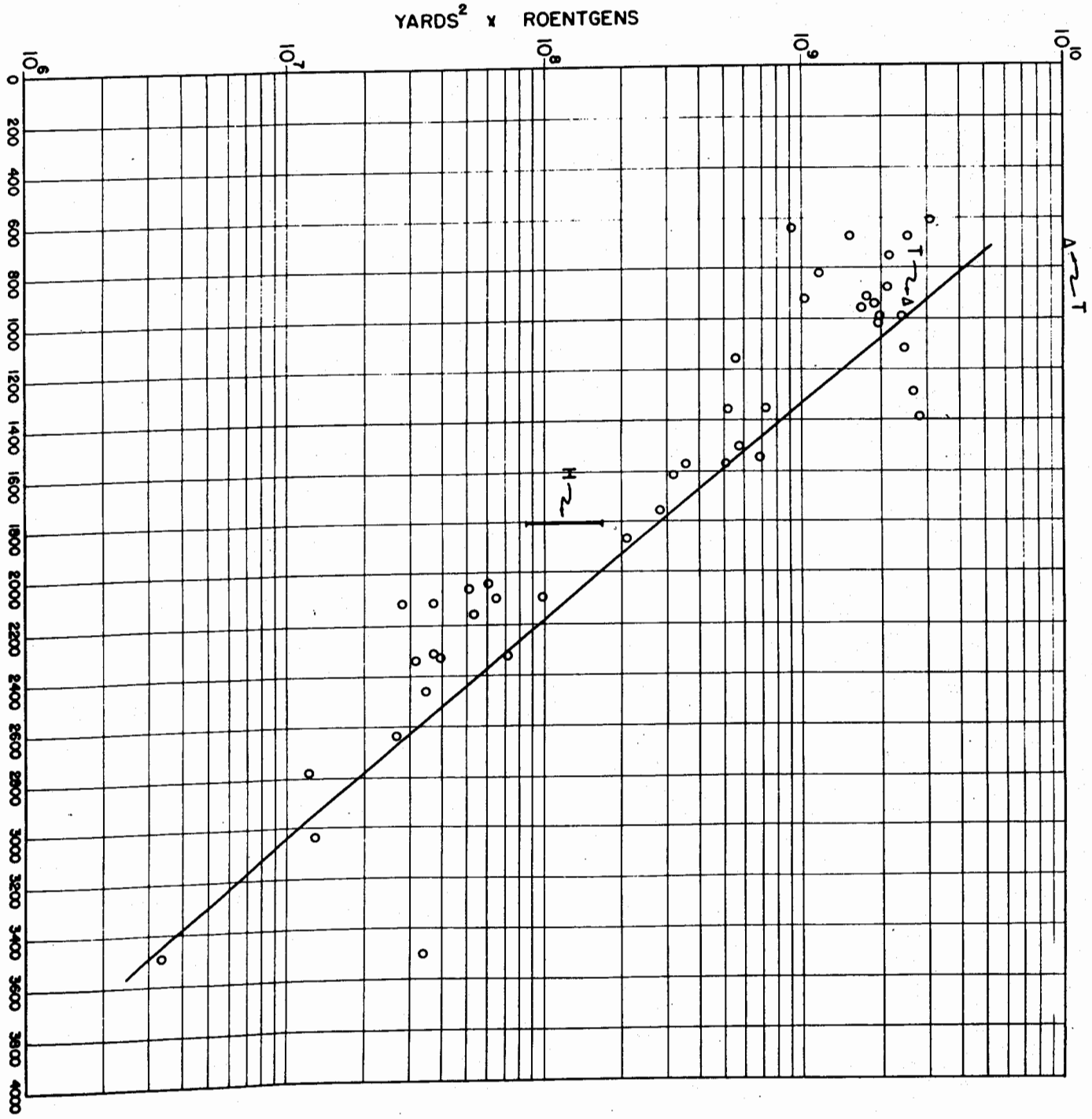

SCALE OF 64 COUNTS / MIN AFTER
30 HOURS / CAMERA FRAME (1/8 SEC)
900
800
700
600
500
400
300
200
100
9000
8000
7000
6000
5000
4000
3000
2000
1000
x 10
-0.5
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
TIME (SEC)

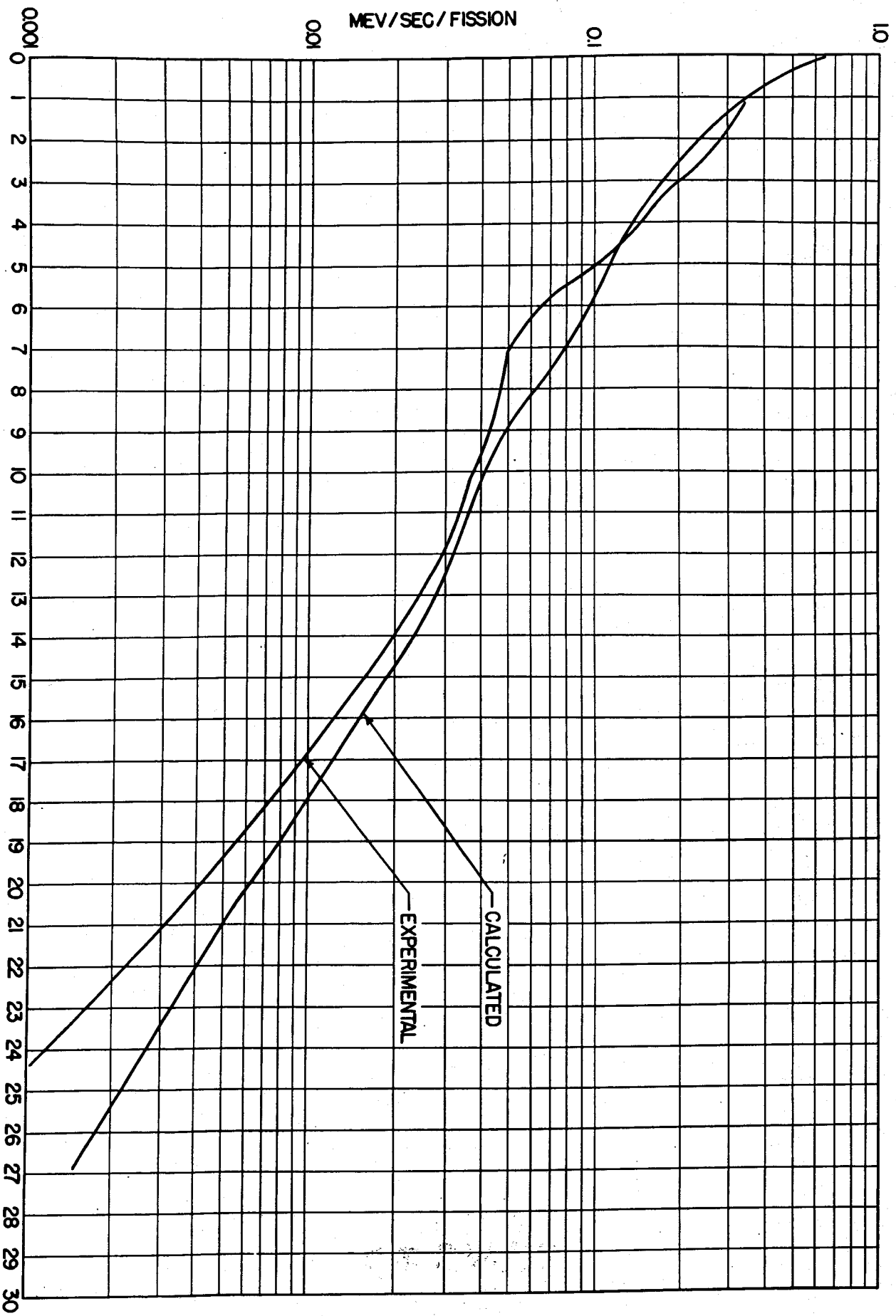
Figure 5

UNCLASSIFIED



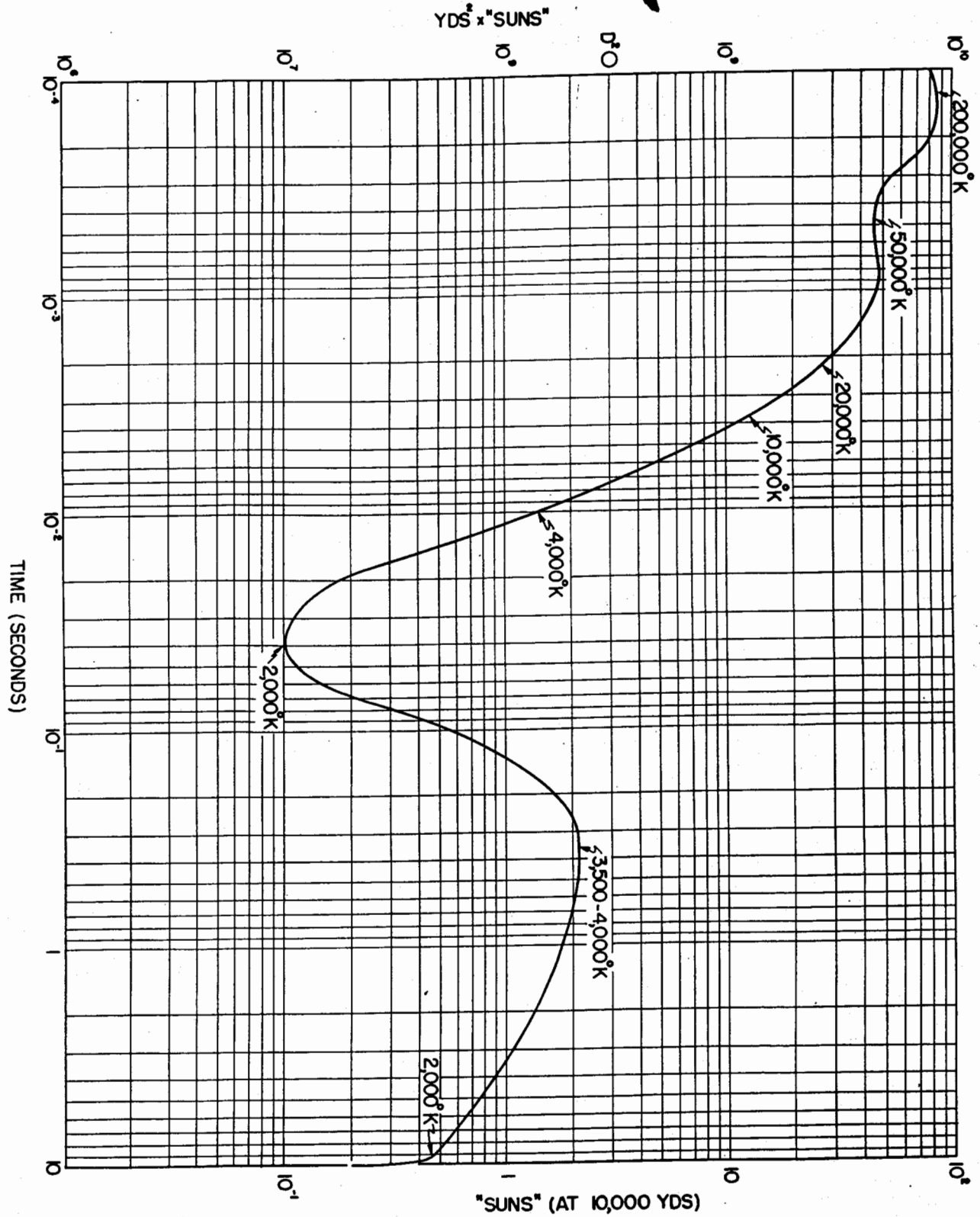

UNCLASSIFIED

Figure 6




UNCLASSIFIED

Figure 7


YDS² x "SUNS"
10⁶
10⁷
10⁸
10⁹
10¹⁰
10⁻⁴
10⁻³
10⁻²
10⁻¹
1
10
200,000°K
50,000°K
20,000°K
10,000°K
4,000°K
2,000°K
3,500-4,000°K
2,000°K
TIME (SECONDS)
10⁻¹
1
10
10²
"SUNS" (AT 10,000 YDS)

detector was destroyed by the initial radiation flash before a record was obtained. The other detector gave results not in disagreement with the radiochemical determination of efficiency and the average of three records was 21 per cent for the gamma-ray determined efficiency. No probable error was placed on this result. In addition to the ionization chamber measurements they also made measurements of the total radiation in $\gamma$ units at various distances from the bomb and under several amounts of lead shielding, using the blackening of photographic materials.

Moon also made measurements on the delayed gamma-rays[4] at longer times particularly for the purpose of giving information to parties entering the radioactive region after the explosion. He also made an attempt to photograph the distribution of fission products in space as a function of time using the gamma-rays from the products and a pinhole camera.[5]

The radiant energy was successfully measured by D. Williams and P. Yuster using a thermopile technique.[6] They found 3060 metric tons of TNT equivalent as the value for the total radiant energy emitted.

The members of J. Williams group made measurements on the number of delayed neutrons from the fission products resulting from the explosion. Their technique consisted of measuring the activity of a cellophane tape which had been passed rapidly between two $U^{235}$ plates.[7] The activities of the fission fragments caught in the cellophane gave a time-differentiated neutron record. Three cellophane catcher cameras were constructed. One was air-borne 300 meters out and 300 meters up; the other two were ground stations, one at 300 meters and the other at 600 meters from the bomb. Only the 600 meter station survived the radiation and the blast to give record.

The low and unknown density distribution in the ball of fire and the large soil effect at 600 meters made difficult the interpretation of the observed neutron density in terms of efficiency. A scaled mock-up of the ground plus ball of fire hole has been studied and the results indicated that at 600 meters

CHAPTER 10

SUMMARY OF TRINITY EXPERIMENTS

JULY 16, 1945 FISSION BOMB

MAY 7, 1945 100 TON

INDEX OF REPORTS

| Measurements | In Charge | Equipment or Method |
|---|---|---|
| I. IMPLOSION | | |
| 1. Detonator Asimultaneity | K. Greisen<br>E. W. Titterton | Detonation wave operated switches and fast scopes |
| 2. Shock wave transmission time | D. Froman<br>H. Sutton | Interval from firing of detonators to nuclear explosion recorded on fast scope |
| 3. Multiplication factor ($\alpha$) | a/R. R. WILSON | Electron multiplier chambers and time expander |
| | b/R. R. WILSON | Two chamber method |
| | c/B. Rossi | Single coaxial chamber, coaxial transformers and direct deflection high speed oscillograph |
| II. ENERGY RELEASE by Nuclear Measurements | R. R. WILSON | |
| 1. Delayed gamma rays | E. Segre | Ionization chambers, multiple amplifiers, Heiland recorders, ground and balloon sites |
| 2. Delayed neutrons | H. T. Richards a/ | Cellophane catcher and 25 plates, on ground and airborne |
| | b/ | Gold foil detectors to give integrated flux |
| | c/ | Sulphur threshold detectors - 8 units |
| 3. Conversion of Pu to fission products | a/H. L. Anderson | Determination of ratio of fission products to Pu |
| | b/D. Frisch<br>J. M. HUBBARD | Collection of fission products and Pu or 25 on filters from planes at high altitude |

| Results | Report | Ser. No. of Rpt. | Used in 100T | In Charge | Report | Ser. No. of Rpt. |
|---|---|---|---|---|---|---|
| Records fogged by gamma rays | LA-437 | 26 | - | - | - | |
| [redacted] DOE b(3) | | | | | | |
| | LA-432 | 31 | Equip. Test | M. Blair | Informal | 59 |
| Record obtained from 600 m station. Energy release consistent with H. Anderson figure | LA-367 | 32 | - | - | - | - |
| No. of neutrons per $cm^2$ per unit logarithmic energy interval was measured for 7 stations, 300-1000 meters | LA-362 | 33 | - | - | - | - |
| Two of 8 units recovered. Give n flux for energies 3 Mev at 200 m | LA-361 | 34 | - | - | - | - |
| 17.4 + 0.3% efficiency = 18,600 tons TNT | LA-356 | 35 | Tracer Test | Anderson Sugarman | LA-282 LA-282A LA-290 | 60 60A 61 |
| No results from TR shot dust after it circled world. Indications from Hiroshima. Nothing from Nagasaki | LA-418 also Bainbridge Russo Hubbard rpts. & LAMS-277 | 36A 36B 36C 36D 56 | - | - | - | - |

| Results | Report | Ser. No. of Rpt. | Used in 100T | In Charge | Report | Ser. No. of Rpt. |
|---|---|---|---|---|---|---|
| | | | | 100 TON SHOT | | |
| General blast considerations | LA-316 | 13 | Yes | W. D. Kennedy | LAMS-247 | 12 |
| No records. Traces thrown off scale by radiation effects. | LA-366 | 37 | Yes | Walker | LA-286 | 62 |
| No TR records. Shot had to be fired when planes out of position. 100 ton records and combat records | | | Yes | Waldman | Report to Parsons | 63 |
| Obtained velocity of sound for a small charge and then excess velocity for bomb. Yield 10,000 T | LA-352 | 38 | Yes | Barschall | LA-291 | 64 |
| | | | Yes | Not armed | | |
| | | | - | - | - | - |
| Blast pressure values low compared to all other methods | LA-350 | 39 | - | - | - | - |
| | LA-350 above | | - | - | - | - |
| Highest pressure range | LA-431 | 40 | - | - | - | - |
| 9900 ± 1000 ton TNT equivalent | LA-354 | 41 | Yes | Hoogterp | LA-288 | 65 |
| Consistent with 10,000 tons | LA-360 | 42 | - | - | - | - |
| Consistent with 10,000 tons | LA-355 | 43 | Yes | Jorgensen | LA-284 | 66 |

| Results | Report | Ser. No. of Rpt. | Used in 100T | In Charge | Report | Ser. No. of Rpt. |
|---|---|---|---|---|---|---|
| | | | - | - | - | - |
| 19,000 tons total yield | | | - | - | - | - |
| Extrapolation from small charge and 100 T data gives 7000 tons | LA-351 | 44 | Yes | Houghton | LA-287 | 67 |
| Approximately 15,000 tons | LA-438 | 45 | - | L.D. Leet prognosis | LA-439 | 68 |
| 10,000 ± 5000 tons | LA-365<br>LA-365A | 46<br>46A | Yes | Penney | LA-283<br>LA-292 | 69<br>70 |
| No effect at these distances | None | - | Yes | See Leet report | LA-439 | 68 |
| Risk of fire produced by radiant energy is small | LA-364 | 47 | - | - | - | - |
| (General prospectus) | LAMS-165<br>LA- 531 | 48<br>49 | | | | |
| Two plots of cloud obtained. Radar reflection not favorable. | Weisskopf-Purcell report | 50 | - | - | - | - |

TRINITY EXPERIMENTS

| Measurements | In Charge | Equipment or Method |
|---|---|---|
| IV. GENERAL PHENOMENA (cont.) | | |
| 2. Rise of Column | J.E.MACK a/ | Four 100 frames/sec Mitchells One 24 frames/sec 16 mm |
| | b/ | Two pinhole cameras |
| and Ball of Fire | c/F.B.Moon | Two gamma ray cameras |
| 3. Mushrooming and lateral movement | J.E.MACK a/ | Two Fairchild 9x9" aero view cameras at N-10,000 and W-10,000 |
| | b/ | Two Fairchild cameras 20 miles NE for stereo-photos |
| | c/ | Two Fairchild cameras 20 miles E for stereo-photos |
| and Rise of Column | d/Capt. M.Allen | Day or night position plotting by searchlight equipment |
| 4. Blast Cloud Effects | F.Reines analysis | J.E.Mack photos J.Aeby photos |
| RADIATION CHARACTERISTICS | | |
| 1. Spectrographic | J.E.MACK a/ | Two Hilger high-time resolution $10^{-5}$ sec spectrographs |
| | b/ | Two Bausch & Lomb $10^{-}$ sec spectrographs |
| 2. Total Radiation | D.Williams J.E.MACK | Two thermocouples and recording equipment |
| 3. Photometric | J.E.MACK a/ | Two units - moving film and filters |
| | b/ | Six photocells and filters recording on drum oscillograph |

| Results | Report | Ser. No. of Rpt. | Used in 100T | In Charge | 100 TON SHOT Report | Ser. No. of Rpt. |
|---|---|---|---|---|---|---|
| | | | - | - | - | - |
| | | | - | - | - | - |
| | LA-430 | 51 | - | - | - | - |
| | | | - | - | - | - |
| | | | - | - | - | - |
| | | | - | - | - | - |
| The first 18 miles of the main cloud path height was triangulated | Allen & L-8 crew reports | 52 | - | - | - | - |
| | LA-448 | 53 | - | - | - | - |
| | LA-531 | 54 | - | - | - | - |
| | | | - | - | - | - |
| | LA-353 | 55 | Yes | J.E.MACK | - | - |
| | | | - | - | - | - |
| | | | - | - | - | - |

| Results | Report | Ser. No. of Rpt. | Used in 100T | In Charge | Report | Ser. No. of Rpt. |
|---|---|---|---|---|---|---|
| These units were extremely valuable in giving the distribution of radioactive products immediately after the shot until safe stable conditions were assured | | | Yes | Moon | Trial for blast effects only | - |
| About 4 hours after shot ionization data from these chambers was radioed back to the control shelter | | | Yes | Anderson Hempelmann | Trial of tanks & rockets | - |
| Local TR ionization and at remote points to 200 miles was measured for dust-deposited fission products | LAMS-277 | 56 | - | - | - | - |
| See II-3-b above | LA-418 Bainbridge Hubbard reports | 36A 36B 36D | - | - | - | - |
| After 4 weeks, approx. 15 R/hr at edge of scoured crater, 0.02 R/hr at 500 yards | LA-359 | 57 | Yes | Anderson | LA-282<br>LA-282A<br>LA-290 | 60<br>60A<br>61 |
| See complete report. Weather data obtained up to 45 minutes prior to shot at Point 0 to 20,000 ft. and 25 minutes after shot. Low level smoke studies made in event of a fizzle. | LA-357 | 58 | Yes | Hubbard | LA-285 | 71 |