SAC200183960000

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

[redacted]

02SA20C000115

(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

(5) E. Klema, LA 361

great many were made by Linenburger and Ogle[6] at Bikini.

(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. [redacted]

degraded below 3 Mev. At present this result is not explained.

The absolute number of fast neutrons represented by Klema's Trinity point is 6.5×10^{21} neutrons through the sphere at 200 meters distance. It is impossible to make a theoretical estimate of the number of fast neutrons per fission which should penetrate the bomb, so an estimate of the efficiency cannot be made from these data.

6.2-2 Slow Neutrons-Space and Time Relations

Slow neutrons come from two sources: (8,9) (1) Prompt neutrons which are

(8) V. Weisskopf, LAMS 218

(9) V. Weisskopf, LAMS 260 and LAMS 260A

first slowed down in the high explosive to about 300 ev and then discharged into the air about 30 to 50 microseconds after the nuclear explosion. These have an average penetration of about 280 meters in air before being absorbed as epi-thermals by nitrogen (i.e., the average value of r^2 is $(280)^2$). (2) Delayed neutrons which are emitted from fission products. The half lives of these neutron emitters is the order of a second or so. These neutrons have an energy of about 0.6 Mev and thus have farther penetration, about 450 meters.

The total flux of slow neutrons per unit logrithmic energy interval as a function of distance was measured by E. Klema[10] at Trinity using activation

(10) E. Klema, LA 362

of cadmium covered gold foils. His results are given in Figure 3. The slow neutron intensity-time relation was measured by Blair, Frisch and Richards[11]

(11) Blair, Frisch and Richards, LA 367

at one 600 meter station using a cellophane "catcher camera". Their results are shown in Figure 4.

Figure 4 shows the space and time discrimination against the first group of neutrons which was expected at 600 meters. Only 20 per cent of the total number are from the prompt neutrons, and their contribution is negligible. after 0.5 second. According to expectation, however, the prompt neutrons should have lasted only about 0.5 second. This discrepancy is not understood at present.

The increase in intensity at 0.6 second is due to the arrival of the shock wave at 600 meters. The deviation of the observed curve from the "expected" in the region 0.6 to 3.5 seconds must be associated with air motion, but a detailed explanation has not been made.

Due to the presence of the ground and the tenuous ball of fire, it is difficult to make absolute calculations of neutron intensities. [redacted] A model experiment [12], however, did demonstrate that the ground and ball of fire effects almost cancel.

00E b(3)

(12) Blair, Frisch and Richards, LA 367

Calculations on the ground effect and neutron intensities in the air as a function of time have been made by Marshak et al [13,14].

(13) Bellman and Marshak, LA 257

(14) Marshak, LA 358

6.3 GAMMA RADIATION

6.3-1 Radial Distribution of Total Radiation

The total gamma radiation at a number of positions was measured by E. Segre et al[15] using X-ray film and paper. Their results are given

(15) E. Segre et al, LA 432

in the following table.

Table 6.3-1

Total Radiation in Roetgens

	400 mS	600 mS	760 mS	1000 mS	600 mN	800 mN
0 cm pb			15000 ±4000	2100 ±300		
0.95 cm pb		4000 ±1000	2100 ±300	920 ± 90		1400 ± 140
1.9 cm pb	19000 ±6000	1600 ± 200	1300 ±130	820 ± 80	12000 ±2500	1000 ± 150
3.8 cm pb	3200 ±600	1100 ±110	650±70	380 ± 60	2600 ±400	510 ± 60
5.7 cm pb	1900 ±500		360±50	200 ± 30	1150 ±100	380 ± 50

In this table 400 mS means 400 meters south, etc. Several different thicknesses of lead shielding were used at each station.

Weisskopf[16] has pointed out the difficulties in interpreting these

(16) V. Weisskopf, LAMS 351

results. In some cases the values (for the same shielding) multiplied by the distance squared increase with distance, whereas there should be exponential attenuation. In some cases the absorption coefficient in lead seems to be as small as 0.1 cm^{-1}, the smallest coefficient for lead at any gamma ray energy 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

(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.

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 γ 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 λ = 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 received, since it was rather poor quality, and the shielding was not certain. We have plotted the point (marked with an H) on the figure after correcting for the different fission yield (8000 tons is assumed).

The equation of the straight line in Figure 5 is:

$$D^2R = 3.70 \times 10^{10} \times 10^{-D/850}$$

This curve established that the mean free path of the radiation at large distances is about 370 yards or 340 meters. Gamma radiation having such a long mean free path in air of normal density must have an energy in the vicinity of 5 Mev. This point will be discussed later.

6.3-2 Time Dependence of Radiation at Distant Points

E. Segre et al [18] attempted to measure the time dependence of the gamma radiation at two stations with ionization chambers. One of them, on the ground at 550 meters, gave a result; the other instrument was destroyed by thermal radiation. Their instruments were designed for a lower yield than was obtained and thus they got saturation for early times. For later times, 10 to 20 seconds, they obtained significant readings. Taking into account the motion of the ball of fire and assuming that all the intensity was coming from fission products, they calculated the fission yield of the bomb quite accurately. They did not present their data in terms of radiation intensity as a function of time.

More extensive measurements of the time variation of radiation intensity was made by Dr. J. Tuck at the Bikini air burst test (test Able). These results indicate quite well that the delayed gamma radiation is due to the fission products. In Figure 6 one of Tuck's records is compared with expectation. The "calculated" curve is obtained from the laboratory measurements of the rate of gamma emission (as given in footnote 2) and the observed rate of rise of the ball of fire. The mean free path was taken as 340 meters in accord[redacted]

(18) E. Segre et al, LA 432

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 γ -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

(21) V. Weisskopf, LAMS 250 and LAMS 250A

(22) Bellman and Marshak, LA 257

(23) Marshak, LA 358

of neutron absorption in the ground are pertinent.

Due to the presence of the dust around the detonation point, a large region of the country side was contaminated with fission products. This topic is discussed by Hirschfelder et al[24].

(24) Hirschfelder et al, LAMS 277

A total of about 1 per cent of the fission products were left in the crater and vicinity. The gamma activity due to this contamination is reported by Aebersold and Moon[25].

(25) Aebersold and Moon, LA 359

6.4 THERMAL RADIATION

6.4-1 Total Radiation

The total radiation was measured by D. Williams and P. Yuster[26], using

(26) Williams and Yuster, LA 353

a thermopile technique. They obtained a value of 3060 metric tons TNT equivalent for the total, the measurement was made at 10,000 yards.

6.4-2 Radiation Intensities - Space and Time Relations

There was no good measurement either of the brightness of the ball of fire or the illumination as a function of time at any distance at Trinity. Measurements of the brightness using the absolute density of fastex film and rough estimates of the temperature by means of a record obtained on a recording spectrograph indicate roughly solar brightness, with little variation as a function of time.(27) These measurements were admittedly unreliable. The

(27) These results were privately communicated to the author by J. E. Mack and F. Geiger. Most of the Trinity photographic observations are presented in LA 531 by J. E. Mack.

theoretical expectation had been that the temperature of the radiating surface should be several hundred thousands of degrees for the first few microseconds, drop to a minimum of about 4500° at about 15 milliseconds,(28) increase for

(28) Later estimates (Magee and Hirschfelder, Volume 7 Chapter 4 Los Alamos Technical Series) of the minimum temperature and later temperatures have been lowered.

less than a second to 10,000° and then cool off more slowly.(29) The minimum

(29) Group T-7 report in "Theoretical Division Progress Report for February 1945" LAMS 221

was corroborated, but the initial high temperatures were not found.

The theory of the radiating body was further developed.(30) The high

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

temperatures initially seemed to be essential, and they were kept in the theory. The theory for the radiation after the first few milliseconds is not in a very good state, and here the "theory" was adjusted to give the correct total radiation as measured by Williams and Yuster.(31) At the Bikini "Able" test the

(31) Williams and Yuster, LA 353

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

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(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

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(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:

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

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

K = Thermal diffusivity (cm^2/sec)

ρ = 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 source for a short time. It seems reasonable to expect a scorching or charring process to have a temperature criterion, either occurring or not depending upon the temperature, and relatively unsensitive to application time.

Let us apply this formula to pine wood, using Figure 7. The constants are taken as:

$$K^2 = 1.4 \times 10^{-3}$$
$$\rho = 0.5$$
$$c = 0.42$$

Assuming that the value of $D^2 \epsilon$ is constant at 4.5×10^9 for 20 milliseconds and then drops abruptly to zero, we get:

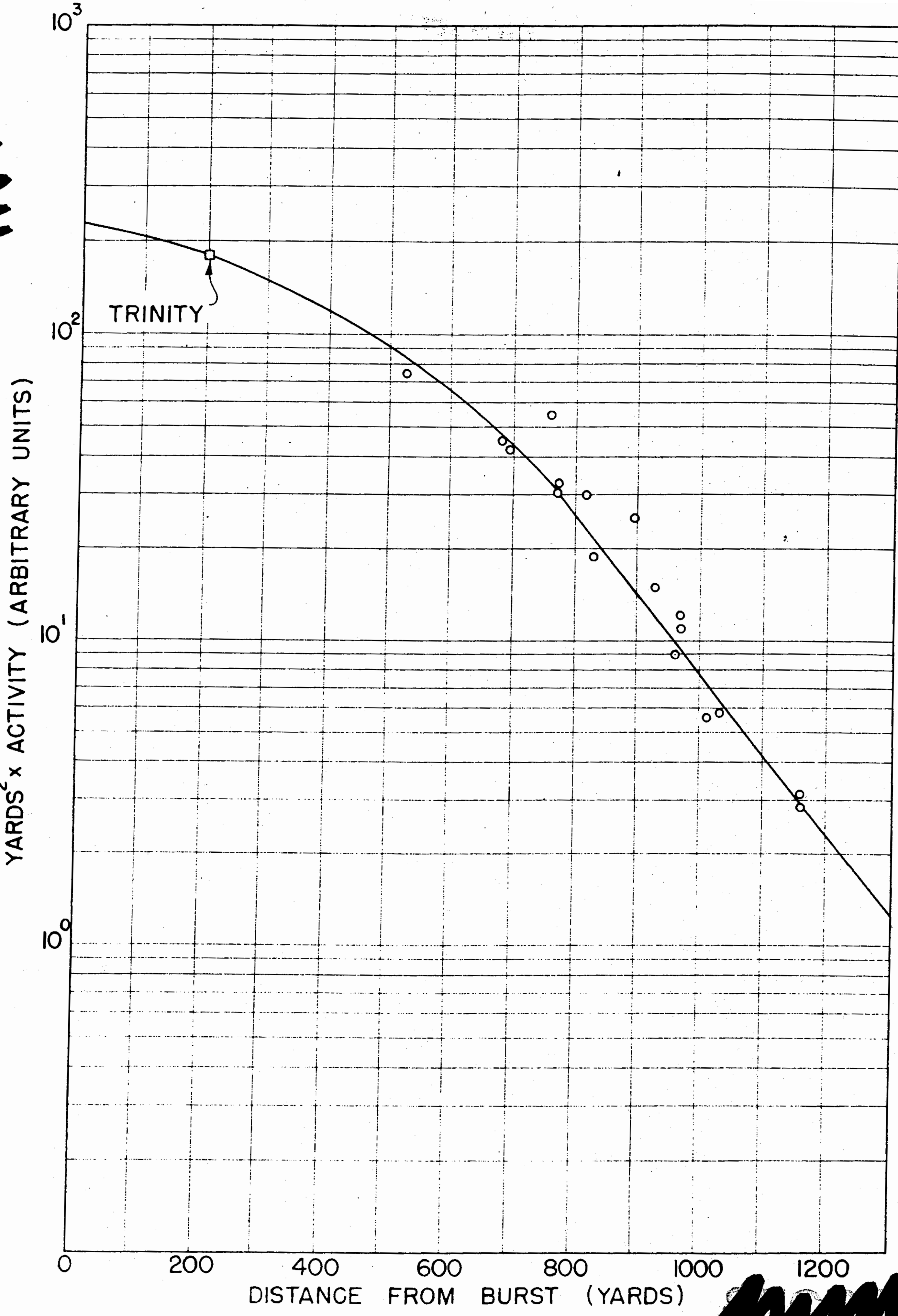
$$\Delta T_s = \frac{9.2 \times 10^8}{D^2} \ {}^{\circ}C \qquad \text{(for distance in yards)}$$

This is for absorption of all of the radiant energy. If 400° C is selected as a "charring temperature" we get that D = 1520 yards. This is about the limit to which there was an appreciable effect observed.

[redacted] UNCLASSIFIED

Figure 2

[redacted] UNCLASSIFIED



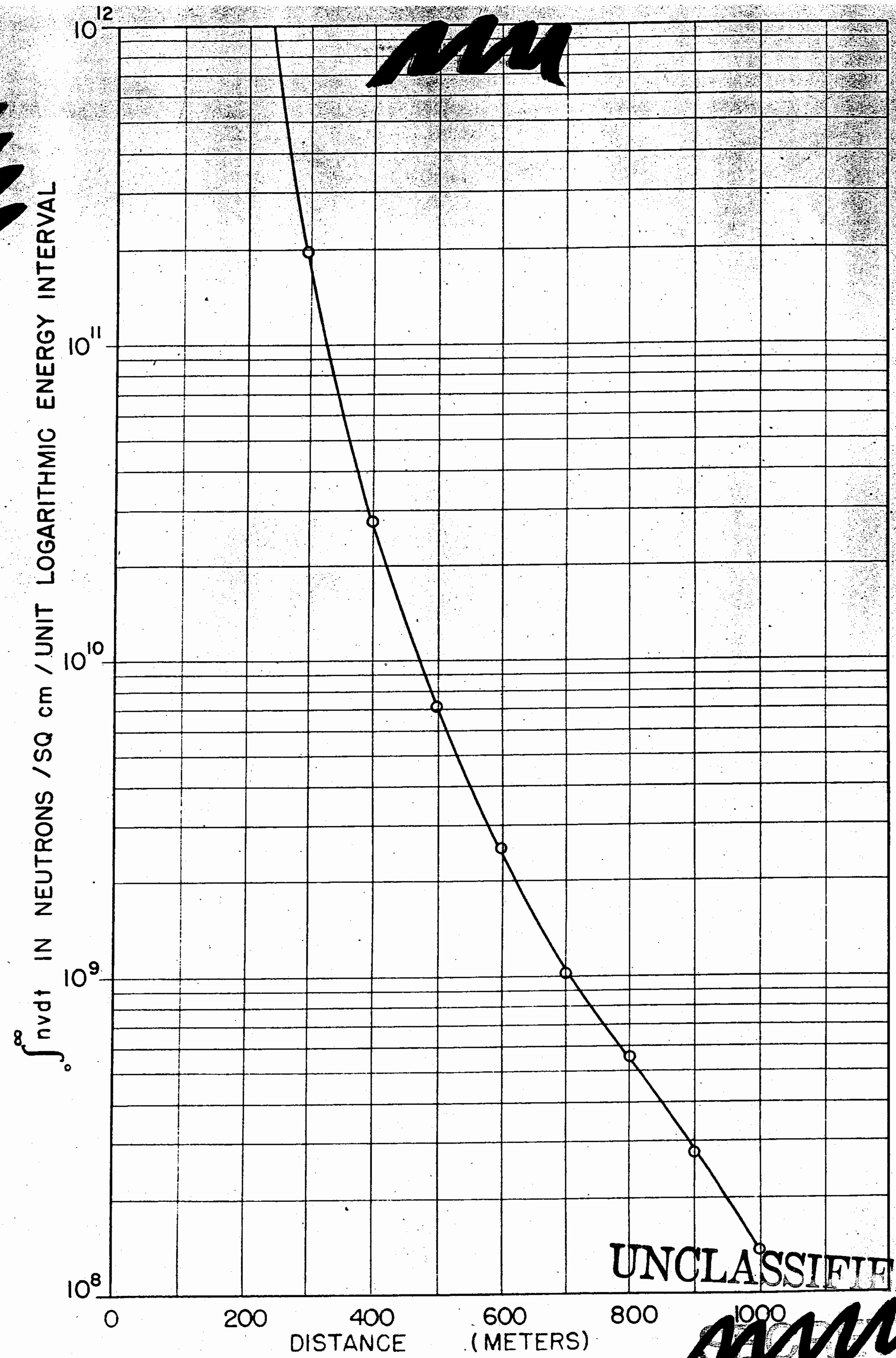
10^3
10^2
10^1
10^0
TRINITY
YARDS^2 x ACTIVITY (ARBITRARY UNITS)
0
200
400
600
800
1000
1200
DISTANCE FROM BURST (YARDS)

Figure 3

UNCLASSIFIED

[redacted]

[redacted]



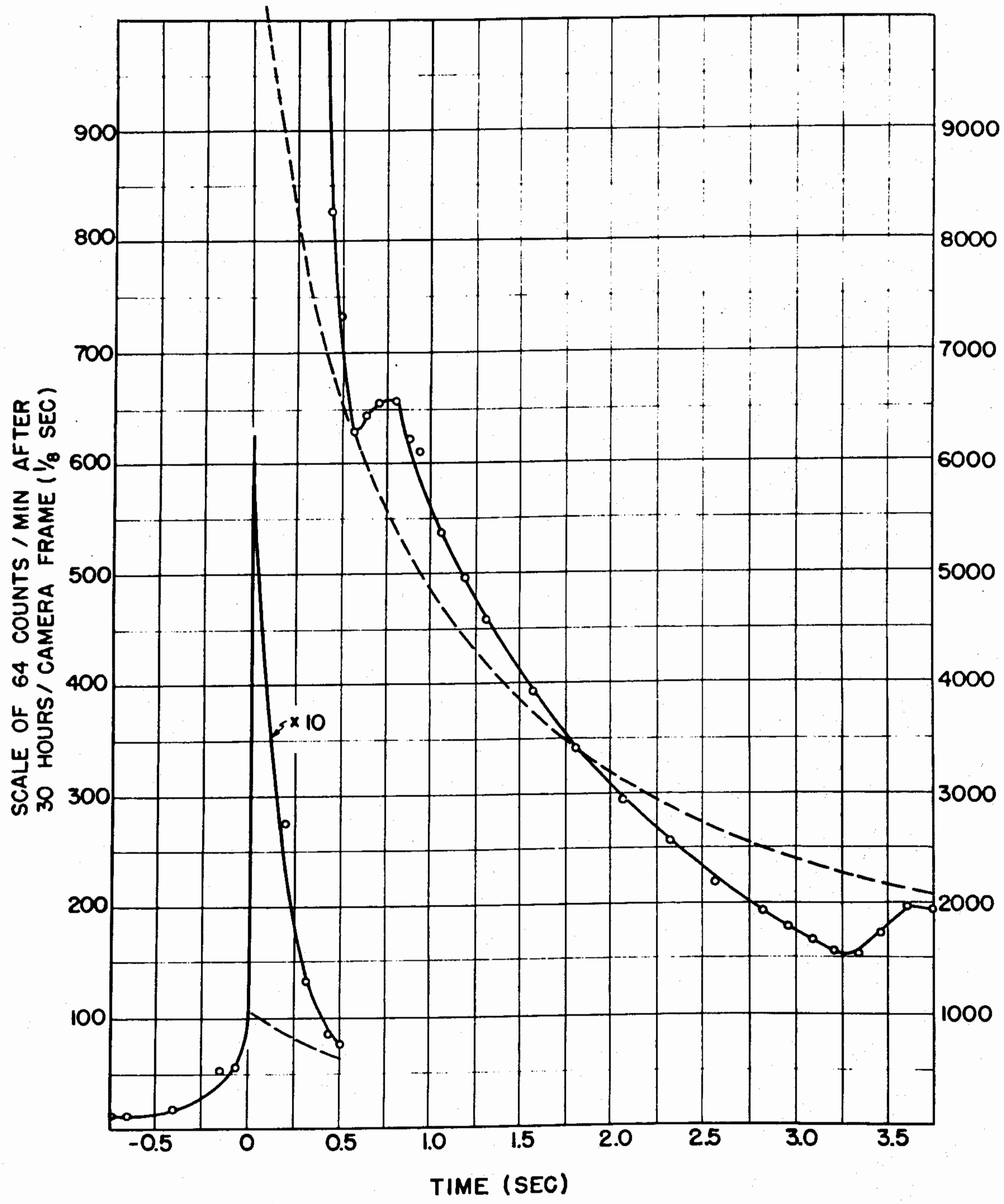
[redacted]

[redacted]

Figure 4

[redacted]

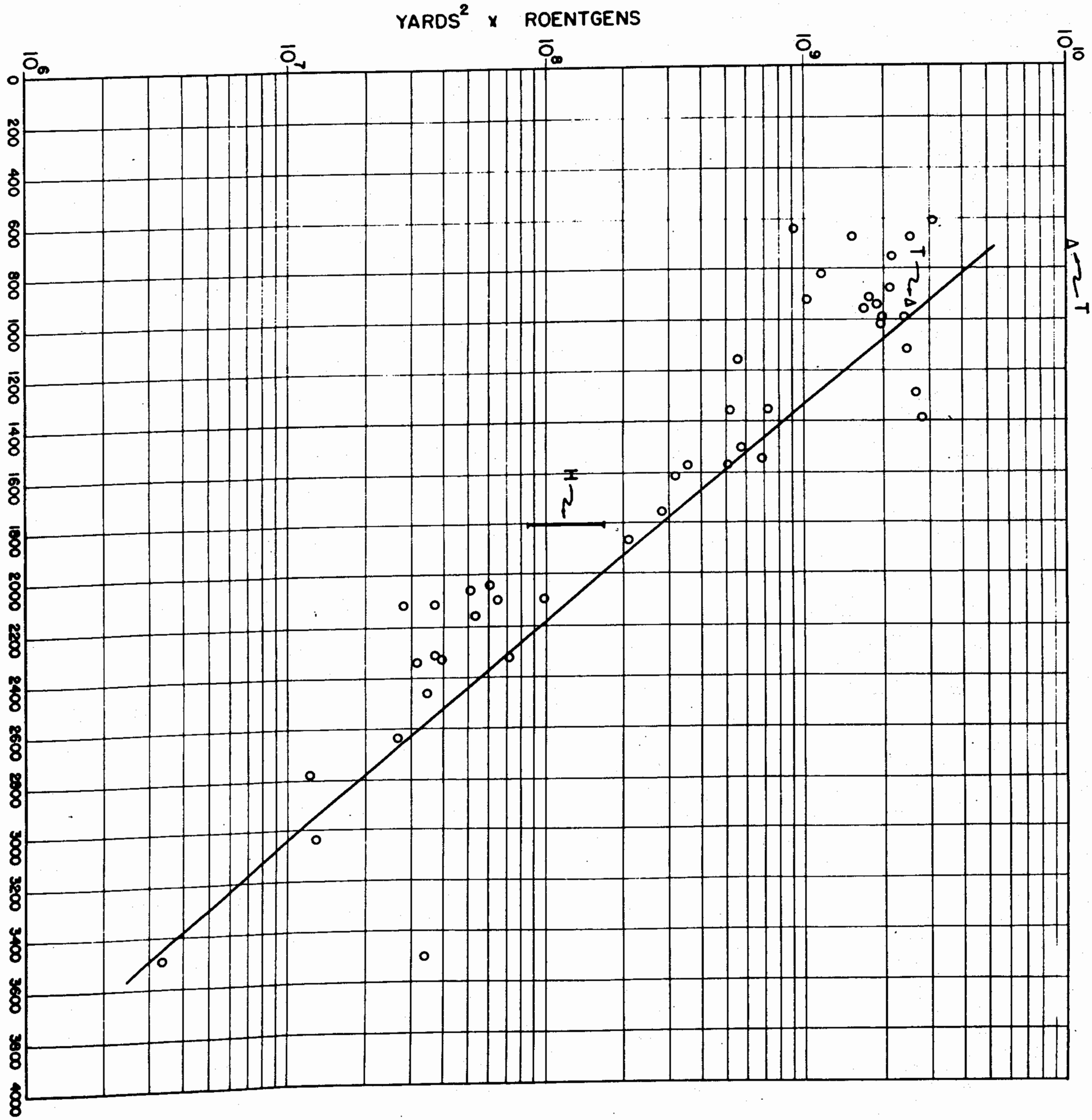
UNCLASSIFIED



UNCLASSIFIED

Figure 5

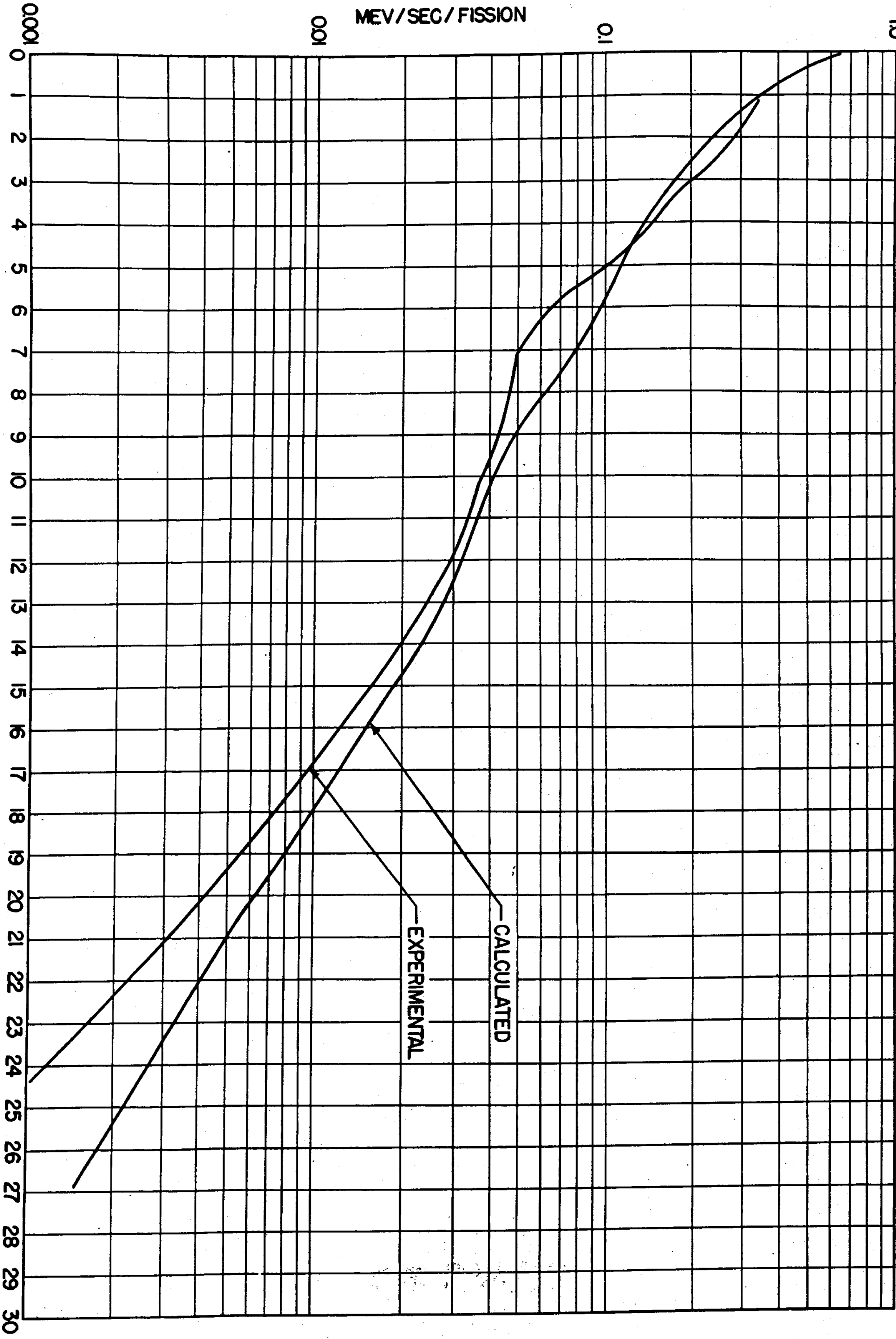
[redacted] UNCLASSIFIED



[redacted] UNCLASSIFIED

Figure 6

[redacted] UNCLASSIFIED

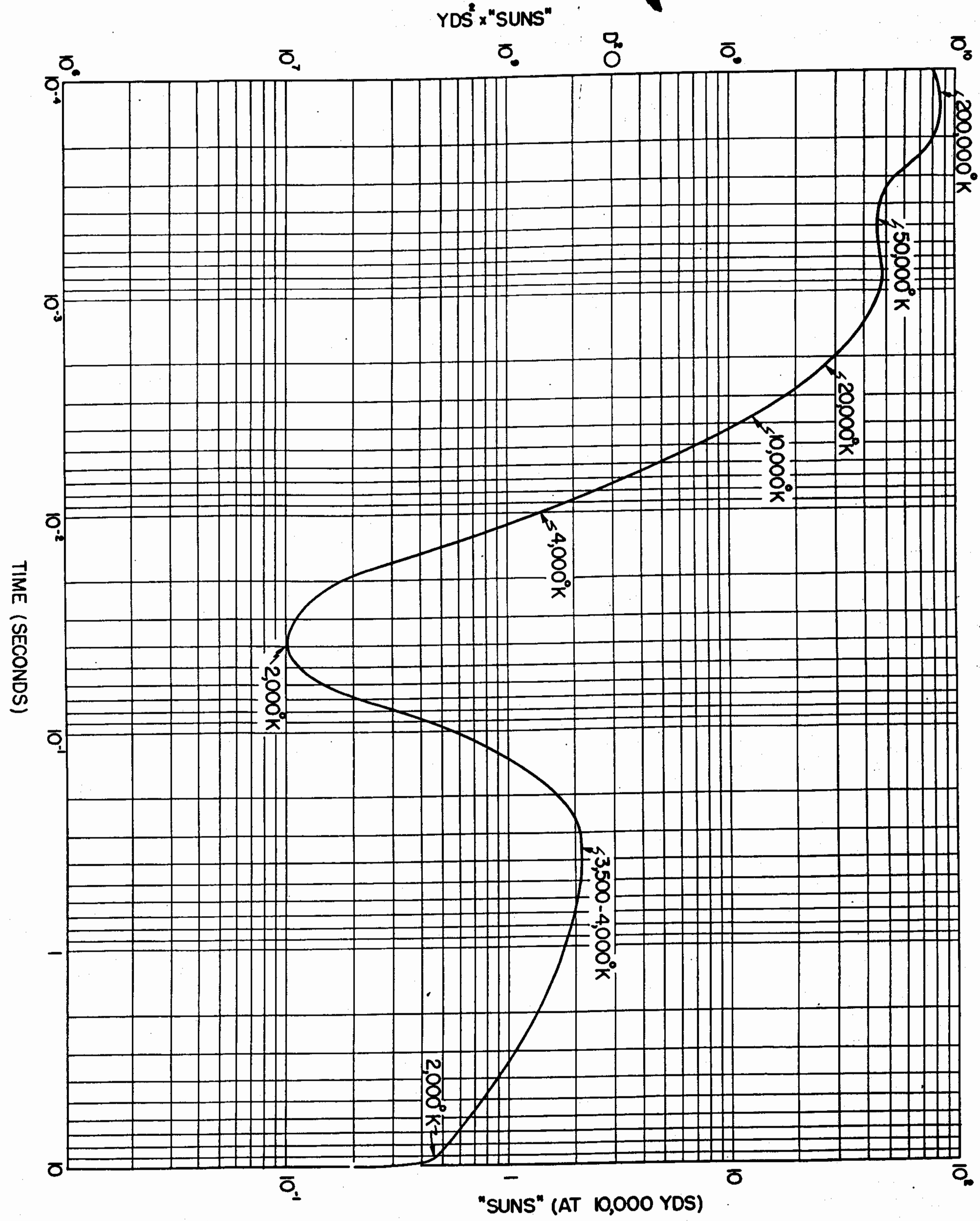


UNCLASSIFIED [redacted]

Figure 7

[redacted] UNCLASSIFIED

[redacted] UNCLASSIFIED



UNCLASSIFIED [redacted]

CHAPTER 7

SUMMARY OF NUCLEAR PHYSICS MEASUREMENTS

Robert R. Wilson

The immediate purpose of the nuclear physics measurements was to determine the efficiency of the fast chain reaction to be tested at Trinity. The experiments were also designed in a manner that would give the greatest insight into the nuclear phenomena occuring during the explosion. Particulary in the event of a failure or of a resulting low efficiency would such measurements be crucial.

The experimental problems posed were extremely difficult. Most measurements were designed to give results for an efficiency varying from that equivalent to an energy release from 10,000 to 50,000 tons of TNT. It was necessary to place most of the equipment in a position where it had to withstand the heat and shock wave from the bomb, or alternatively to send its data to a distant recording station before it was destroyed. We can understand the difficulty of transmitting signals during the explosion when we consider that the gamma-rays from the reaction will ionize the air and other material within hundreds of yards. Fermi has calculated that the ensuing removal of the natural electrical potential gradient in the atmosphere will be equivalent to a large bolt of lightning striking that vicinity. We were plagued by the thought that other such phenomena might occur in an unpredictable or unthought of manner. All signal lines were completely shielded, in many cases doubly shielded. In spite of this many records were lost because of spurious pickup at the time of the explosion that paralyzed the recording equipment. Much of the recording was done photographically in reinforced concrete earth covered shelters placed at a distance of about 1000 yards from the bomb. Deeply buried shielded cables brought the signals to the shelters. Even here the tremendous gamma-ray emission blackened the photo plates except where the plates were surrounded by thick Pb shields within the shelters. In many cases the dirt was blown from the shelters by the outgoing wind.

It was difficult to keep the number of experiments within bounds. Most physicists yielded to temptation and conceived of experiment after experiment. A screening board consisting of E. Fermi, V. Weisskopf, and R. Wilson considered each proposed experiment with respect to its feasibility and possibility of giving cogent information. Even so, considering the short time in which to prepare the experiments, perhaps too many were attempted.

The theoretical work[1] by V. F. Weisskopf on what nuclear phenomena might be produced by the fast chain reaction was of great assistance to those designing the experiments.

It was reocngnized from the beginning that the most promising measurement of the nuclear efficiency would come from the radiochemical determination, and hence the greatest effort was put into this experiment under Anderson's direction. This proved to be so, and they obtained the value of 17.4 $\pm$ 3 per cent. This efficiency determination was made by radiochemical analysis for fission products and Plutonium, of solutions of active dirt collected in the vicinity of the explosion. Experimental details will not be given here as the original reports of the various experiments are to be appended.

Segre's group made observations on the delayed gamma-rays from the fission products by means of ionization chambers several milliseconds after the explosion[3]. They had two stations: one on the ground at 550 meters from the bomb and another one at the same distance but lifted by a balloon to an elevation such that the line joining the balloon with the bomb made a 45° angle with the horizontal. The purpose of the latter station was to get away from the effects due to the earth thrown into the air by the explosion. Unfortunately the air-borne 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 γ 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 the hole produced by the ball of fire nearly compensated for the reduction in intensity produced by the coil. It is perhaps fortuitous that such considerations give a value of the efficiency, 21 per cent, that agreed so closely with the radiochemical determination.

E. Klema[8] determined the number of neutrons per square centimeter per unit logrithmic energy interval as a function of distance from the bomb by measuring the activation of cadmium - covered gold foils which had been calibrated in a graphite block. His values were in good agreement with those obtained by the catcher cameral technique after the latter had been integrated over the time. Klema[9] also measured the number of fast neutrons from the nuclear explosion at a point 200 meters distant using sulphur as the detector.

Both in the case of delayed neutron measurements and of delayed gamma-ray observations, more reliable results would have been obtained had the nuclear efficiency been somewhat lower.

The above experiments were primarily directed toward obtaining the nuclear efficiency. The following measurements were more of a diagnostic character for they did not directly give information on the efficiency. On the other hand they did give an insight into the operation of the bomb that is important and which would have been particularly important had a low efficiency resulted. These measurements were concerned with, α , the rate of multiplication of the neutrons during the early stages of the chain reaction.

A simple measurement that has come bearing on α was made by R. Sutton.[10] [redacted] DOE b(3)

Before this, Froman had measured the time interval between detonation of the explosive and the appearance of the shock wave at the inner boundary of the Uranium tamper on a full scale hemispherical model. [redacted] DOE b(3) Now α is a sensitive function of the time and the efficiency depends on α [2].

[redacted]

DOE b(3)

These limits are considerably wider than the limits of error of Sutton's or Froman's measurements. Thus the measurements indicate that the reaction was set off by the initiator at about the right time and at about the time that was expected. Had something gone wrong it is likely that this experiment would have indicated where the trouble would be found.

Direct measurements of the initial multiplication rate were made by members of B. Rossi's and R. Wilson's groups. The nuclear reaction is accompanied by direct emission from the bomb of neutrons and gamma-rays, the latter arising mainly from capture of neutrons in the outer layer of the tuballoy tamper. The neutrons are slowed down and delayed in the high explosive, hence they are unsuited for studying the time dependence of the reaction. It was therefore decided to measure α by measuring the rate of increase of the gamma-ray intensity.

In the method suggested by Wilson,[11] it was hoped the α could be measured at various times after initiation

[redacted]

DOE b(3)

[redacted] Banks of commercial electron multiplier tubes were used for detectors. Signals from these, placed at various distances from the bomb, were fed into modified oscillographs which gave out voltage pulses which were inversely proportional to α, also the signals were fed into electronic timers which sent out voltage pulses which were proportional to the time between signals. [redacted]

Rossi's method gave considerably more reliable results. It made use of a large air ionisation chamber detector placed very close to the bomb. The signal from it was fed into a long specially designed tapered coaxial line that multiplied the signal. The line lead directly to a high voltage oscillograph where the trace produced by the signal was photographed. [redacted] It was fortunate that alternative methods were chosen for the measurements. For future tests probably all the methods could be successfully used on the basis of the experience gained at Trinity and if a longer time were available for preparations.

References

1.	V. F. Weisskopf	LAMS 218	Neutron and Gamma Ray Effects after the Nuclear Explosion. I
	V. F. Weisskopf	LAMS 250	Neutron and Gamma Ray Effects after the Nuclear Explosion, II
2.	H. L. Anderson N. Sugarman	LA 356	Determination of Nuclear Efficiency.
3.	O. Chamberlain, et al	LA 432	Delayed Gamma Ray Measurements at Trinity
4.	P. B. Moon P. Abersold, P. Moon	LA 433 LA 359	Measurement of Delayed Ionization by Distant Recording Instrument Radiation Survey of Trinity Site Four Weeks after the Explosion.
5.	I. Halpern P. B. Moon	LA 430	Attempt to Obtain Gamma Ray Kinephotographs.
6.	D. Williams P. Yuster	LA 353	Total Radiation
7.	J. Blair, et al	LA 367	Neutron Measurements with Cellophane Catcher Camera.
8.	E. Klema	LA 362	Neutron Measurements with Gold Foil Detectors.
9.	E. Klema	LA 361	Fast Neutron Measurements Using Sulphur as the Detector.
10.	R. Sutton	LA 363	Measurement of Implosion Time.
11.	R. Wilson	LAMS 232	Methods of Measuring Initial Multiplication Rate.

DOE
b(3)

[redacted]

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 E. W. Titterton	Detonation wave operated switches and fast scopes
2. Shock wave transmission time	D. Froman H. Sutton	Interval from firing of detonators to nuclear explosion recorded on fast scope
3. Multiplication factor (α)	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 J. M. HUBBARD	Collection of fission products and Pu or 25 on filters from planes at high altitude

[redacted]

Results	Report	Ser. No. of Rpt.	Used in 100T	In Charge	Report	Ser. No. of Rpt.
Records fogged by gamma rays	LA-437	26	-	-	-	DOE b(3)
[redacted]						
	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	-	-	-	-

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TRINITY EXPERIMENTS

Measurements	In Charge	Equipment or Method
III. DAMAGE, BLAST AND SHOCK	J.H.MANLEY	
BLAST	J.O.Hirschfelder	
1. Piezo	R.L.Walker	Quartz piezo gauges - 22 units
2. Condenser	a/W.C.Bright	Condenser gauges, frequency modulation type C.I.T.-8 units
	b/B.Waldman	Condenser gauges C.I.T. type dropped from B-29 planes - 6 units, 2 planes
3. Excess velocity	a/H.H.Barschall	Moving coil loudspeaker pick-up - 10 stations
	b/	From piezo time records
	c/J.E.MACK	Optical method. Blast-operated switches and torpex flash bombs
	d/J.E.MACK	Schlieren method - 1 station
4. Peak pressure	a/H.Sheard D.Littler	Spring loaded piston gauges - 8 units, intermediate pressure range 2.5 to 10 psi
	b/H.Sheard D.Littler	Same gauges - 12 units, above ground and in slit trenches, 20 to 150 psi in range
	c/W.G.Penney F.Reines	Crusher type gauges
	d/J.C.Hoogterp	Aluminum diaphragm "box" gauges - 52 units 1 to 6 lb. range
5. Remote pressure barograph recorders	J.H.MANLEY	19 Friez ML-3&A #792 barographs
6. Impulse gauge	T.Jorgensen	12 mechanically recording piston liquid and orifice gauges, 4 each for 3 yield values

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Section 10
JULY 16 NUCLEAR EXPLOSION

Results	Report	Ser. No. of Rpt.	Used in 100T	In Charge	Report	Ser. No. of Rpt.
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-369	42	-	-	-	-
Consistent with 10,000 tons	LA-355	43	Yes	Jorgensen	LA-284	66

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TRINITY EXPERIMENTS

Measurements	In Charge	Equipment or Method
III. DAMAGE BLAST (cont.)		
7. Mass velocity	J.E.MACK	Suspended primacord and magnesium flash powder viewed by Fastaxes
8. Shock wave expansion	(H.Bethe) J.E.MACK	Fastax cameras at 800 yd. stations
EARTH SHOCK	J.H.MANLEY	
1. Geophone	H.M.Houghton	12 velocity type moving coil strong motion geophones
2. Seismographs - Leet	L.D.Leet	5 Leet 3 component strong motion displacement seismographs
3. Permanent earth displacement	W.G.Penney F.Reines	Steel stakes for level and vertical displacement measurements
4. Remote seismographs	G-2	Tucson, El Paso, Denver observations
IGNITION OF STRUCTURAL MATERIALS		
1. Roofing and wall materials	W.G.Marley F.Reines	Roofing, wood, and excelsior on stakes
IV. GENERAL PHENOMENA		
1. Behavior of Ball of Fire	J.E.MACK	
	a/	Six 8000 frames/sec Fastaxes
	b/	Two 4000 frames/sec Fastaxes
	c/	Two 800 frames/sec Fastaxes
	d/	Fifteen color cameras, standard 16 mm
	e/	One Cine-Special 24 frames/sec
	f/Lt.C.D.Curtis	Two SCR-584 radars

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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 LA-365A	46 46A	Yes	Penney	LA-283 LA-292	69 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 LA-531	48 49				
Two plots of cloud obtained. Radar reflection not favorable.	Weisskopf-Purcell report	50	-	-	-	-

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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

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Section 10
JULY 16 NUCLEAR EXPLOSION

Results	Report	Ser. No. of Rpt.	Used in 100T	In Charge	100 TON SHOT Report	100 TON SHOT 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	-	-
			-	-	-	-
			-	-	-	-

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TRINITY EXPERIMENTS

Measurements	In Charge	Equipment or Method
V. POST-SHOT RADIATION MEASUREMENTS		
1. Gamma ray sentinels	P. B. Moon	Sixteen ionization chambers which recorded at 10,000 yard shelters
2. Portable chamber observations in high gamma flux region	H. L. Anderson	Observations were made from the tanks using portable ionization chambers, standard design
3. Dust-borne product survey	L. H. Hempelmann	Portable alpha, gamma ionization chambers and Geiger counters
4. Airborne products	J. M. HUBBARD D. Frisch	B-29 planes equipped with special air filters
5. Detailed crater survey	P. B. Moon	Ionization chambers and Watts-type amplifiers
VI. METEOROLOGY	J. M. HUBBARD	Complete instrumentation and weather information

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 LA-282A LA-290	60 60A 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