ANNEX "A"

ESTIMATE OF BLAST AND THERMAL EFFECTS ON MIKE SHOT - OPERATION IVY

by

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CHAPTER I

GENERAL

The large size of the Ike weapon, together with the considerable uncertainty in predicted yield, present unusual problems in estimating blast and thermal effects.

Because of the limited size of available island, we cannot afford the luxury of protecting island installations against any possible yield, and for that matter, it would be imprudent to attempt to do so. Fortunately, the blast and thermal effects scale in such a way that no prohibitive problems are introduced, but every reasonable precaution must be taken and ingenuity used to keep the calculated effects at a minimum.

The Test Director has formulated the policy that personnel protection will be based on an absolute upper estimate of yield; structures or things will be protected on the basis of a reasonably probable yield. The wisdom of this policy is especially evident in blast, where the structural criterion for damage is seldom known better than a factor of 2; for the marginal case at low pressure, experience indicates that the effort required to protect structures is usually much greater than the effort required to repair whatever minor damage might occur.

The most likely value of yield for Mike shot is of the order 5 to 10 MT, and there is a very small probability that the yield may go as high as 50 MT. Both blast and thermal effects are such that the yield of 5 to 10 MT is reasonably safe. It is understood that should the probable yield later appear to be in the order of 50 MT, Los Alamos Scientific Laboratory will so inform all test personnel and the general conclusions of this paper should be reviewed at that time.

CHAPTER 2

BLAST EFFECTS

2.1 General

Certain factors lend simplicity to the estimate of blast effects on the Mike shot. Because it is a surface burst, a reflection factor of 2 has been assumed for these predictions, meaning that the blast wave is a hemisphere whose peak pressures and wavelengths and radii are appropriate to a burst of twice the yield in free air. Because of the large scaled size of the explosion, compared with the shot island, the burst is essentially over water, which is an excellent

reflecting surface in all respects. During the early strong shock phase, the rate of work by the shock front on air as compared to its rate on soil or water is in a ratio more than 100 to 1 in favor of air. It follows that less than 1 per cent of the energy will be transmitted to soil or water during these stages. Recent atomic tests have been concerned with the effect of thermal radiation in attenuating the peak pressures in a blast wave; this effect will be at a minimum on Mike shot because of the glancing angles of incidence of thermal radiation; however, the "Thermal effect" will not be completely absent because the fireball attains a large vertical height in a short time.

Other factors lead to difficulty in estimating the effects. The rise of the fireball and consequent afterwind lead to an attenuation of the blast wave at close distances which is difficult to estimate; this effect is at a maximum because of the low height of burst. Next, considerably higher temperatures may be achieved in this explosion than on an ordinary nuclear explosion; this leads to greater losses in energy through irreversible heating, to a different "partition of energy", to the possibility of a greater fraction of energy appearing as thermal radiation, and to the possibility of a smaller comparable blast yield. Again, the explosion is so large that the atmosphere can no longer be considered as homogeneous; the top of the blast wave will be in rarefied atmosphere at a time when ground pressures are still in the region of practical interest. Considerable blast experimentation will be devoted to this point which may lead to a variation of 25 per cent in yield. Again, atmospheric inversion may focus energy upward or downward at long distances, but for an ordinary bomb, this effect is usually at pressures near 0.1 psi. On Mike shot, the scaled height of these inversion layers are such that some focussing (or defocussing) of energy may occur at pressures of interest. Finally, on the space scale involved here, layers of clouds are close enough to be of some concern both from the standpoint of energy reflection as well as from the standpoint of providing a shield from thermal radiation.

For the most part the uncertainties listed are expected to be in the order of 25 to 50 per cent in blast yield, and small compared to the design uncertainty of 5 to 50 MT, and not sufficiently large to require specific numerical treatment.

For the most part, the data used in making these estimates were taken from IBM problem M, which was assumed to be 10 KT. This is conservative because it implies that blast efficiency of an atomic bomb is 0.65 compared with TNT. The actual efficiency may be as low as 0.5 for a conventional weapon and perhaps lower for a very large weapon. Moreover, experience on structures are usually based on pressure gauge readings, and these are generally lower, perhaps 20 per cent, than the "ideal" values quoted here.

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2.2.1 Peak Overpressure vs Distance

Figure 1 shows the peak reflected overpressure as a function of distance for the yields indicated. Although these values have been taken from the IBM solution (in order to be consistent with other curves which follow) these predictions are in good agreement with predictions made on the basis of Greenhouse tower shots. There is a substantial difference; the tower explosions were on a scale small enough that the pressures recorded were essentially over a land surface. In this case, the explosion occurs over water, the present theory indicates that somewhat higher peak pressures should be observed than if the explosion occured entirely over land. Within the first few miles from the bomb, the peak pressures may be reduced considerably from the value shown here by the thermal effect on the ground prior to shock arrival. At long distances, such as at Parry and Eniwetok, the pressures may be lower or higher for reasons cited in Sec. 2.1 above. However, at long distances, the peak pressure is a slowly varying function of yield, such that an eight-fold increase in yield merely doubles the pressure.

2.2.2 Peak Material Velocity vs Distance

Coincident with the arrival of the shock wave is a wave of material velocity whose peak value as a function of distance is given in Fig. 2. The relationship between peak material velocity and peak pressure is

$$u = \frac{5 \frac{\Delta P}{P_0}}{\sqrt{7(6\frac{\Delta P}{P_0} / 7)}} \cdot C_0$$

where

u = material velocity

C_0 = ambient sound velocity

$\Delta P/P_0$ = overpressure, in atmospheres

The duration of this wind is comparable to the positive duration of the blast pressure.

2.2.3 Pressure vs Time

Figures 3, 4, 5, and 6 give estimates for the pressure vs time wave at selected pressure levels of 1,000, 100, 10 and 1 psi and indicate the variation in the form of the pressure wave at these pressure levels. At high pressures and close in there is no negative phase; pressure decays assymptotically to zero. Moreover, "length of the positive phase" is strongly influenced in this region by the rise of the fireball, which attenuates pressures shortly after shock arrival, and should reduce the

... of the positive phase." within the first few miles the thermal
effect will lead to a marked attenuation of peak pressures and the usual slow
rise in pressure, instead of the ideal curve shown here. At
slightly greater distances, the thermal effect will result in
a "partial shock" rather than a completely slow rise. Still
further, the shock front will be sharp as shown here. At far
distances the negative phase increases and eventually the positive
and negative impulse under the blast wave become equal.

In translating these curves to different yields, both
the distance and time must be increased by $W^{1/3}$, holding pressures
constant. In many cases, the criterion for structural damage is not
simply peak pressure, but the product of the air density and the
square of the material velocity $\frac{1}{2}\rho u^2$, this blast wind results
in a dynamic pressure on structures; the time variation of this
dynamic pressure may be taken as approximately similar to the
pressure-time curves shown here.

2.2.4 Time of Arrival

Figure 1 gives the time of arrival of the shock wave
as a function of distance. These curves are based on calculations
from peak pressures observed on tower shots, but are in good agreement
with the time-of-arrival curve as predicted from the IBM run using this
yield. Unlike peak pressures, the observed time of arrival should be
independent of the type of surface.

2.2.5 Positive Duration

Figure 8 shows the duration of the positive phase of the
blast wave as a function of distance from the bomb. The upward
swing of this curve at short distances is associated with the lack
of a negative phase at this point. Where accurate estimates of the
pressure decay is required at close-in distances, the pressure-time
curves may be fitted by a power law or semi-logarithmic plot. For
example, the curve shown for 1,000 psi can be fitted initially by

$$P \sim 1/t^{0.68} \text{ and later by } P \sim 1/t^{0.8} \text{ or } P \sim P_0 e^{-KT}.$$

2.2.6 Positive Impulse vs Distance

Figure 9 shows the positive impulse, or $\int p\,dt$ as a
function of distance. If further information is desired, such as the
negative impulse, these values can be derived upon request.

2.3 Protection from Blast

2.3.1 General Rules

As pointed out earlier, every reasonable precaution must
be taken against the blast effects and every method which ingenuity
suggest should be used, but no prohibitive problems are presented by
blast. It is impossible to point out here the criterion for all types
of structures, but the following discussion shows the general character
of the clonclusions which may be expected. It is suggested that test
personnel consider their individual structures on the basis of the
field variables given in Figs. 1 thru 10.

2.3.2 Previous Experience

Some estimates for the damage on structures at different pressure levels are given in "Effects of Atomic Weapons"; a more complete table is available in Par. 48 and Table 9 of "Capabilities of Atomic Weapons", Department of the Army, Tech Manual TM-23-200, Department of the Navy, OPNAV-P-36-00100, Department of the Air Force, AFOAT 385.2, July 1951.

It should be noted that structures fail from two causes; from peak pressure and from the winds following the blast wave. From the standpoint of pressures, the Mike shot presents no pressures much beyond present experience. According to Fig. 1, pressures on Parry and Aniwetok will be about 0.75 psi; pressures of 0.3 psi were observed on Parry and Aniwetok from Dog and George shots during Operation Greenhouse. A pressure of 0.8 was observed on Bijirii from Dog shot. In both cases, numerous structures were involved, which should furnish pertinent data. The reason for this small increase in peak pressure is because the increase in yield ($P \sim W^{1/3}$) is offset by the greater distance. (Elugelab is approximately 22 miles from Parry, compared with 9 miles on Runit.) With respect to wind loading, the situation is more serious because the positive durations scale like $W^{1/3}$, and are not offset by an increase in distance. The positive durations for 5 MT are 10 times longer than for 5 KT at the same distance.

2.3.3 Structures

Some general conclusions may be drawn with regard to structures. All ordinary window or plates glasses, especially in sizes over 12 in. are nearly bound to break, on Parry and Aniwetok. Where possible, walls facing the blast wave should be removed as well as walls directly behind it, in order to allow pressures to build up more rapidly within the structure, and to relieve the force from normal reflection of the blast. If this is not feasible all windows and doors should be left open. No canvas can be used unless it is strongly secured with at least grommet-type fastening; plenty of slack should be allowed, without taut surfaces; no large unsupported separations of canvas should be draped over frame work. All tents should be struck, (although tents were observed to surve at Nevada Test Site at approximately this pressure level, but much shorter duration). The use of berms or sandbagging to protect structures is of doubtful value; the waveform is so long that the peak pressure can build up behind the berm before any depreciably decay has occured; of course, some protection is afforded from the dynamic wind.

Small plywood structures have been observed to withstand 2 psi during some previous tests and although they failed at slightly higher pressures, they did so through multiple reflections from corners. Door frames and hinges fail readily if exposed to the blast much above 1 psi. Holmes and Narver reports no damage on the hanger at Aniwetok from 0.3 psi on previous shots. At the 0.8 psi level they report that structures bowed on a large wall facing the blast.

It is noted that structures do not fail at some critical pressure level, but that over a range of pressures (perhaps a factor of 3), the damage is somewhat proportional to the pressure. The observation on structures at low pressure levels can be extrapolated with some degree of confidence without expecting a sudden and complete collapse. In most cases, there is always some weak element on a structure which will fail first; such as blowing in of a panel; in stress.

2.3.4 Vehicles

There is of no apparent requirement to evacuate vehicles from Parry to Eniwetok nor any appreciable advantage in doing so. All canvas tops should be removed from the vehicles. Windshields should be lowered flat or removed entirely. The vehicle should face directly away or toward the blast although it is felt that better protection for the radiator and headlights is afforded if the vehicle is facing away from the blast.

2.3.5 Aircraft

All aircraft should be evacuated wherever possible. For small aircraft (including helicopters) which cannot be evacuated, the main wings should be removed, and if left in the open, the aircraft should face toward the blast.

2.3.6 Boats

No damage is expected to hulls or any part of water craft which is usually subjected to wave action. The .7 psi level is equivalent to a head of a 1/2 foot of water which such boats habitually withstand. The superstructures of these craft are more susceptible to blast damage but we recall that the unbalanced peak pressure is of very short duration, small objects being rapidly engulfed by the pressure wave; for example, a mast of 3 in. in diameter will feel the peak pressure for approximately 1/4 of a millisecond. Following the peak pressure the blast winds will be of the order of 40 to 50 miles per hour at Parry or Eniwetok but these craft habitually withstand these winds.

2.3.7 Storage Tanks **BEST AVAILABLE COPY**

Storage tanks for fluids should be left full, both to add mass as well as to prevent the plates from buckling in.

CHAPTER 3

THERMAL EFFECTS

3.1 General

Like blast, an estimate of thermal effects required answers to certain uncertainties which will be settled by some of the experiments on the Operation itself. Fortunately, again, the estimates for thermal radiation are sufficiently low that no prohibitive problems are introduced.

There is an uncertainty in scaling radiation which involves whether the thermal yield is proportional to radiochemical yield or proportional to some lower power such as $W^{.73}$. In this paper, the theoretical upper limit is assumed and this in itself may give values 2 to 7 times higher than actually obtained. There is also an uncertainty regarding the transmission of air, because the fireball rises rapidly to great heights. Near the surface of the water, transmission is quite low, but several hundred feet above the water the transmission increases markedly. The transmission assumed here is for very clear air and considered reasonably safe. Although Klugelab is several hundred feet below the horizon at Eniwetok, no protection is afforded from thermal radiation because the fireball rapidly grows to a diameter many times this value.

A distinctive feature of the thermal radiation on this explosion will be the long time scales involved, nearly 10 times that from a 5 KT bomb. It may be possible to see the light minimum and the subsequent increase to maximum radiation, around 2 seconds. The thermal radiation will persist for some 30 seconds instead of the 3 seconds for conventional size weapons. Personnel should be warned that it is necessary to keep on the dark goggles for much longer periods of time than for conventional size weapons.

3.2 Total Thermal Radiation vs Distance

Figure 10 shows the total thermal radiation in calories/cm^2 as a function of distance from the bomb. These curves have been derived using the assumption that the total thermal radiation will represent 1/3 of the total yield. The dotted lines represent the values of total thermal radiation which would be received if one completely neglected absorption of thermal radiation by air. The full lines are based on a transmission of 80 per cent per mile, and corresponds to a very clear atmosphere. The full lines are considered reasonable estimates for structures near the ground. The dotted lines are an exaggerated upper limit, more appropriate to high flying aircraft.

3.3 Temperatures of Surfaces Exposed to Thermal Radiation

Both the "Effect of Atomic Weapons" and "Capabilities of Atomic Weapons" contain tables which give the critical energies in calories/cm^2 for a number of common materials such as wood, cloth, rubber, and plastics. The long duration of thermal radiation of this weapon has the effect of increasing these critical energies by a factor of 3 above the critical energy required on a conventional size weapon. The total thermal radiation occurs over longer periods of time, this permits correspondingly longer periods for heat to be conducted away from the surface and into the interior of their radiated object. For substances which are not shown in such tables the average surface temperature may be estimated roughly from the following equation:

$$T_s = \frac{aQ_T}{y^{1/6}} \sqrt{\frac{1}{h\rho\sigma}} \cos\theta$$

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    a = absorptivity of the surface

    T_s = surface temperature, degrees centigrade

    W = radiochemical yield, kilotons

    h = specific heat, cal/gm deg   SAN BRUNO FRC

    $/$ = density, gm/cm^3

    σ = thermal conductivity, cal/cm, deg, sec

    Θ = angle of incidence of thermal radiation of the surface.

Based on this equation and a yield in the order of 5 MT, Table 1 shows the relationship between the surface temperature and the total thermal radiation, for surface directly exposed to the radiation, where T_s is the rise in surface temperature in $^\circ C$, and Q_T IS THE TOTAL incident thermal radiation in cal/cm^2, as given in figure 10.

TABLE 1

Copper	T_s = 0.1 Q_T
Aluminum	0.1
Steel	0.4
Cement	5
Asbestos	10
Rubber	18
Wood	18

The equation above is not strictly correct because it assumes that the thermal radiation rate is proportional to $1/t^2$. This is reasonable approximation after 2 seconds but prior to this time, the radiation rate varies in such a way that the surface temperatures may momentarily go to a value perhaps 3 times those estimated from the above equation.

Table 1 shows that the most critical materials are rubber and wood. For 5 MT yield, however, the temperature rise will be neglible for such materials on Parry and Eniwetok.

FIGURE I
PEAK PRESSURE VS DISTANCE
SURFACE BURST
IDEAL SURFACE

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ENGEBI

0.5 MT   5 MT   50 MT

RUNIT

PARRY

ENIWETOK

PEAK PRESSURE, PSI

DISTANCE — 1000 FEET

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FIGURE 2
PEAK MATERIAL VELOCITY VS
DISTANCE
SURFACE BURST
IDEAL SURFACE
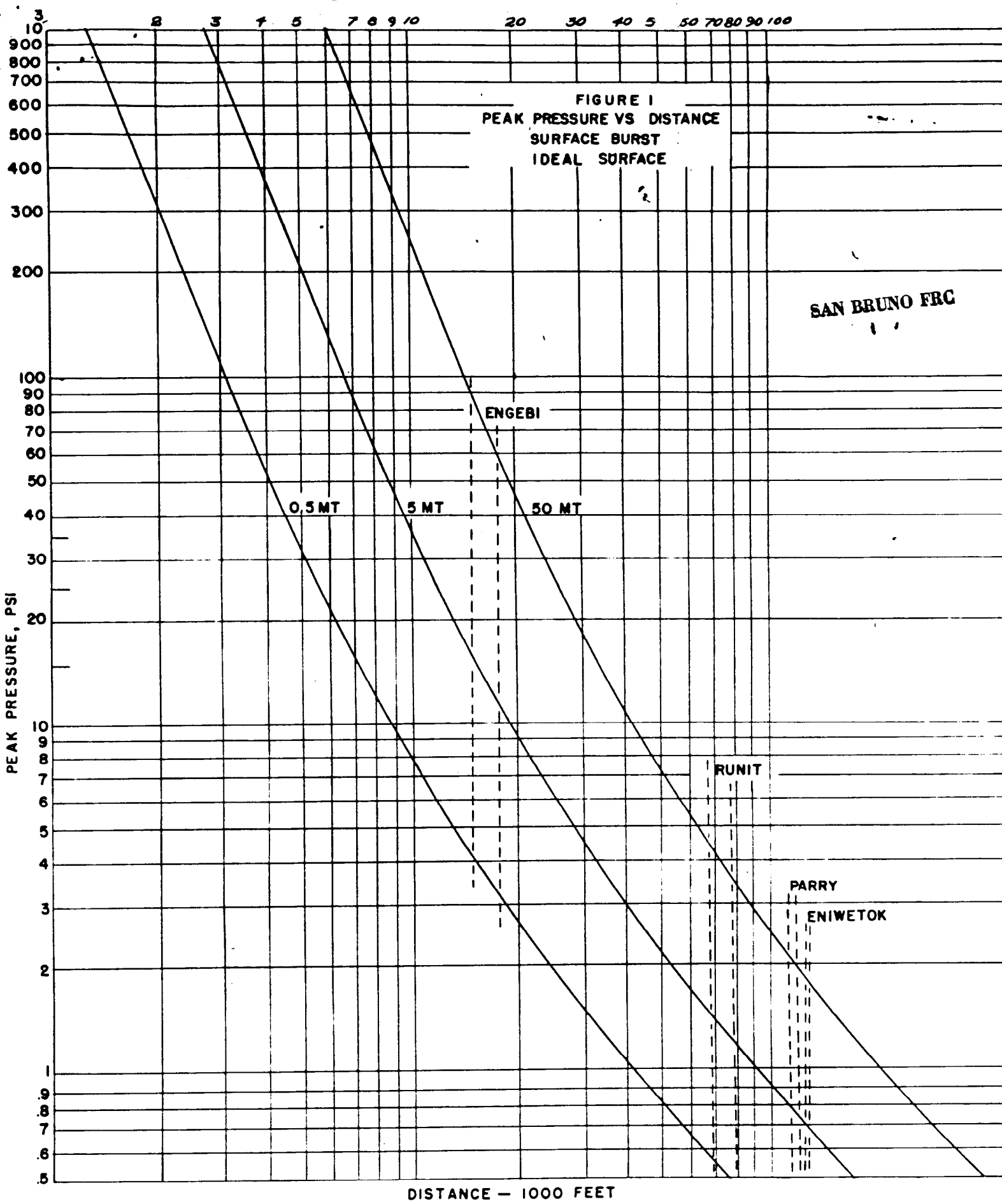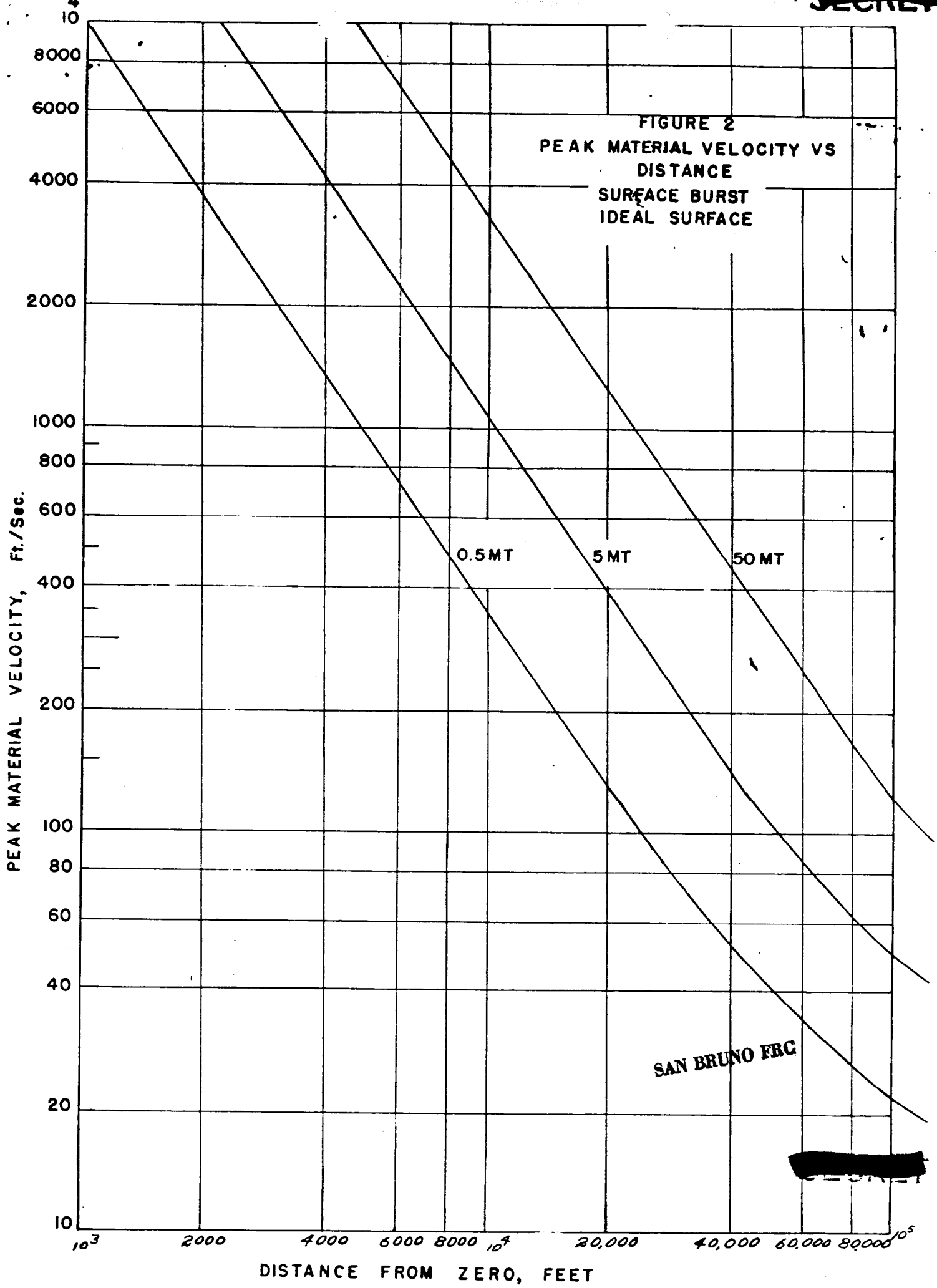
FIGURE 3
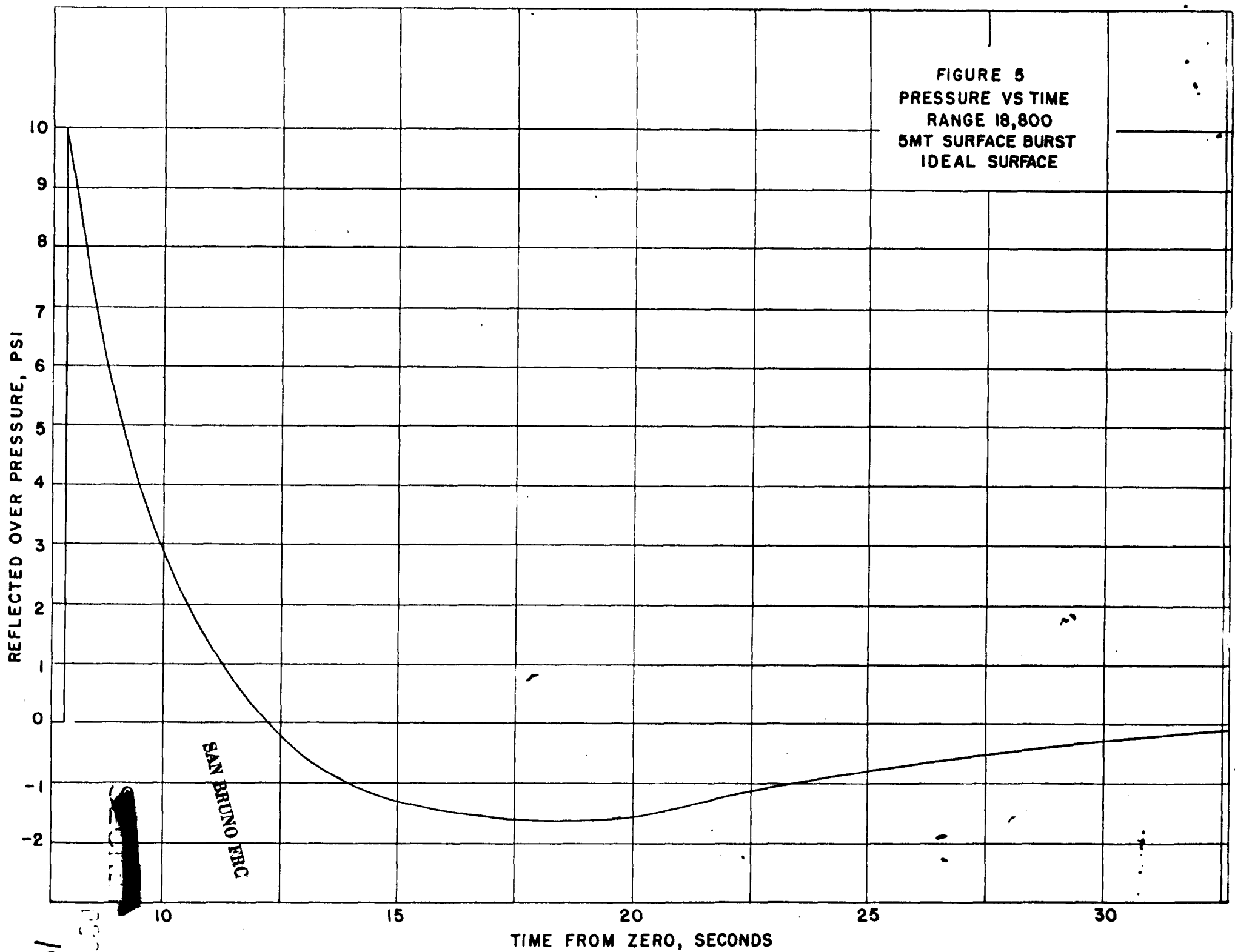PRESSURE VS TIME
5MT SURFACE BURST
RANGE 2750'
IDEAL SURFACE
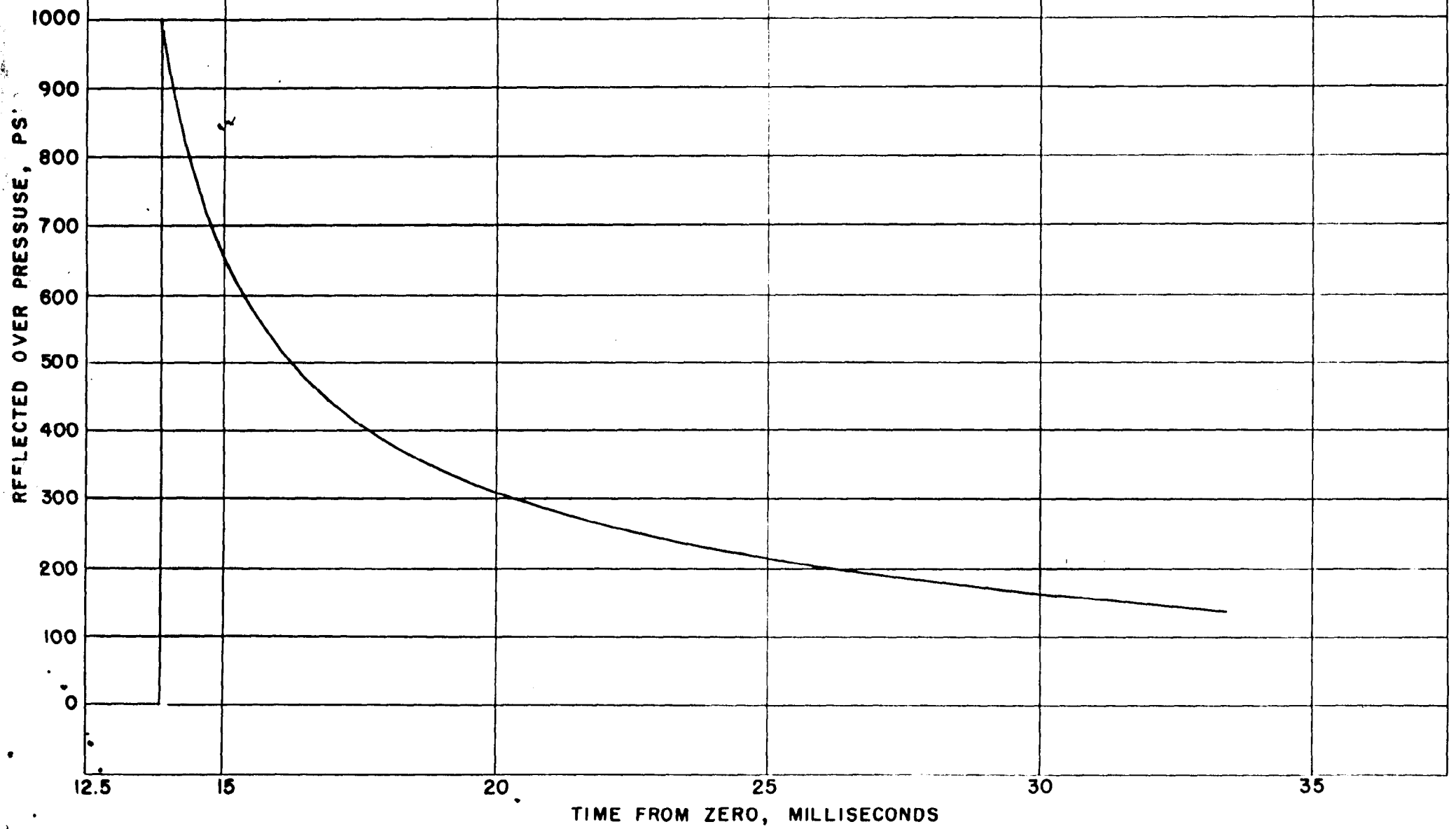
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FIGURE 4
PRESSURE VS TIME
RANGE 6500'
5MT SURFACE BURST
IDEAL SURFACE
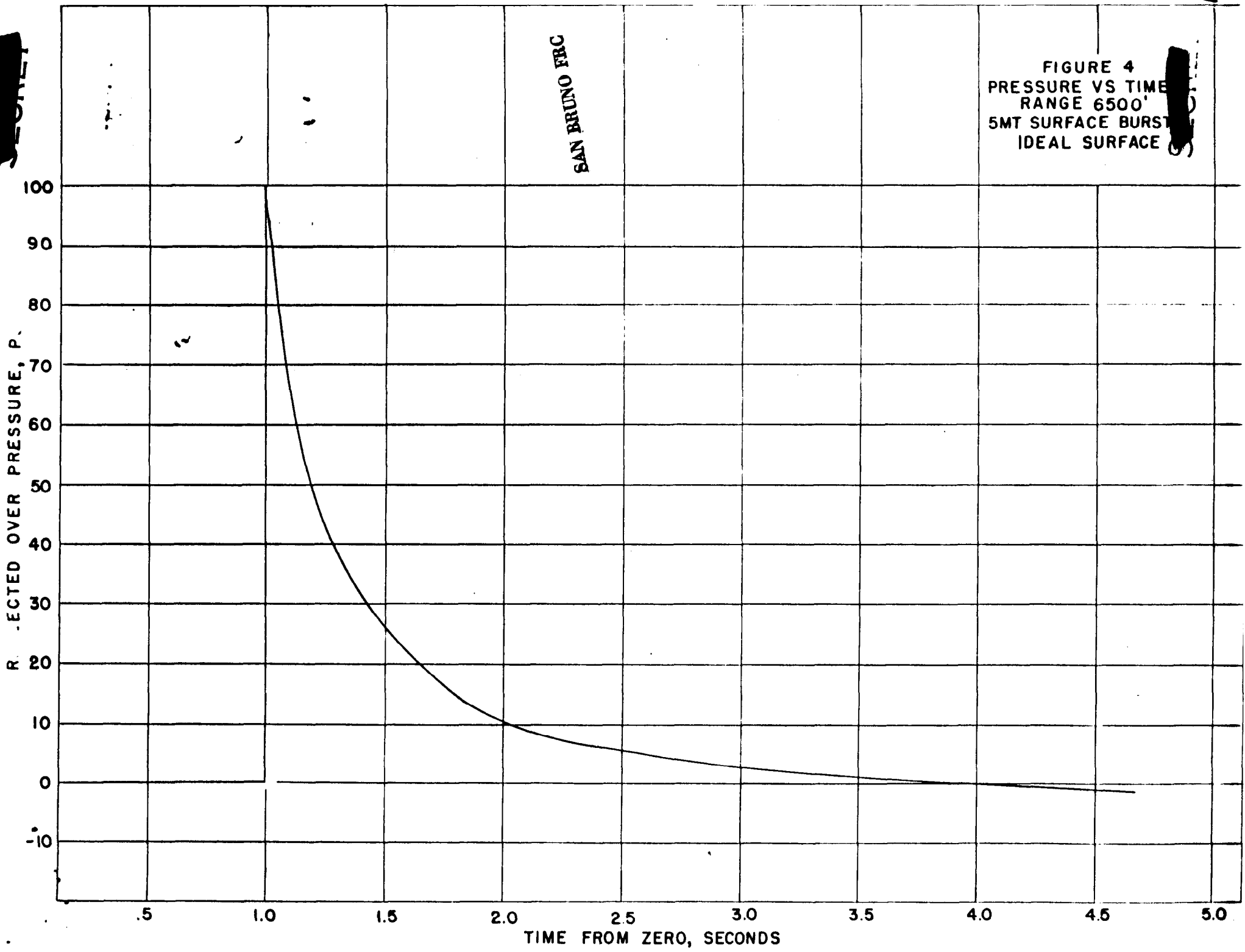
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FIGURE 5
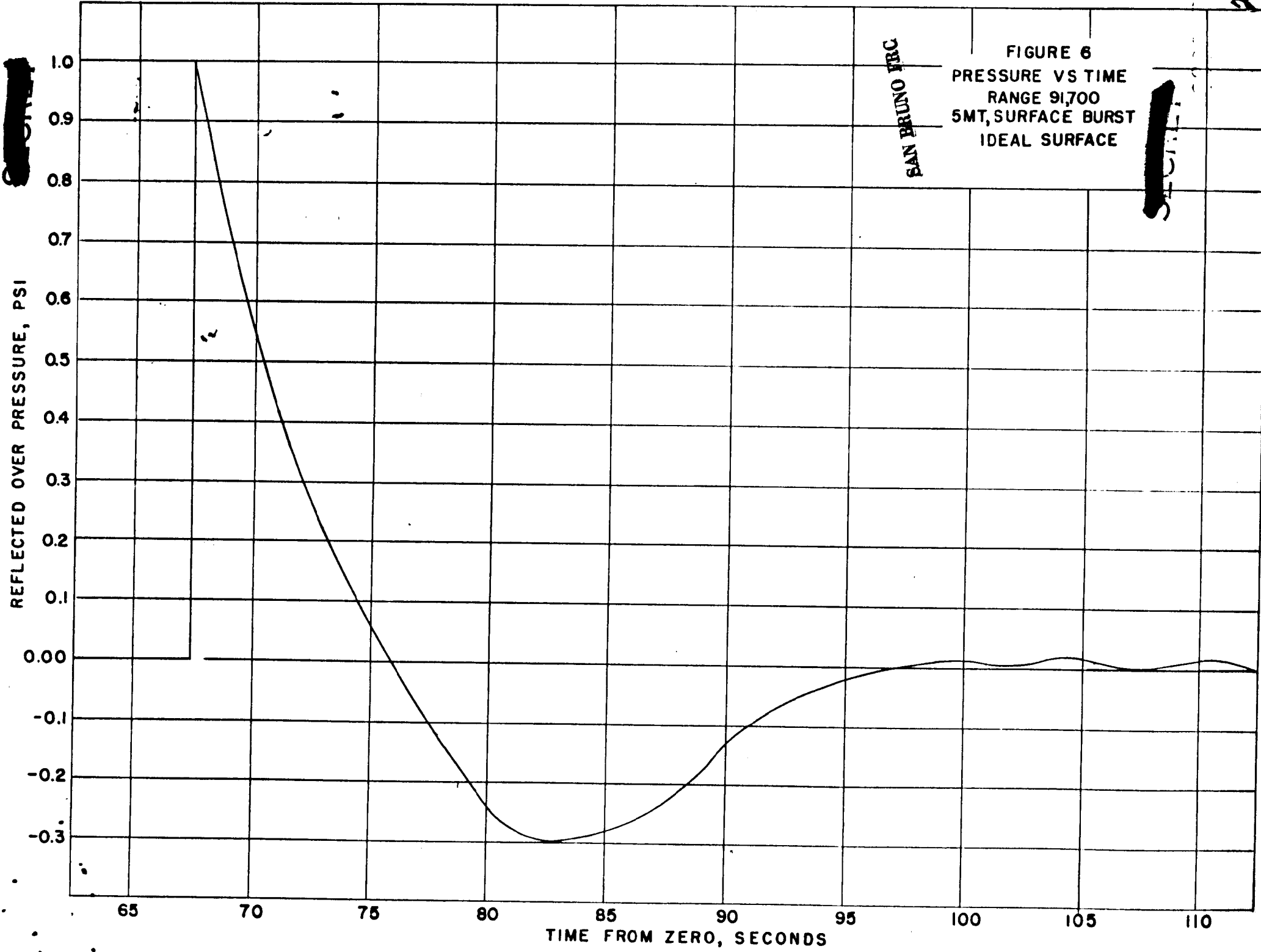PRESSURE VS TIME
RANGE 18,800
5MT SURFACE BURST
IDEAL SURFACE

REFLECTED OVER PRESSURE, PSI
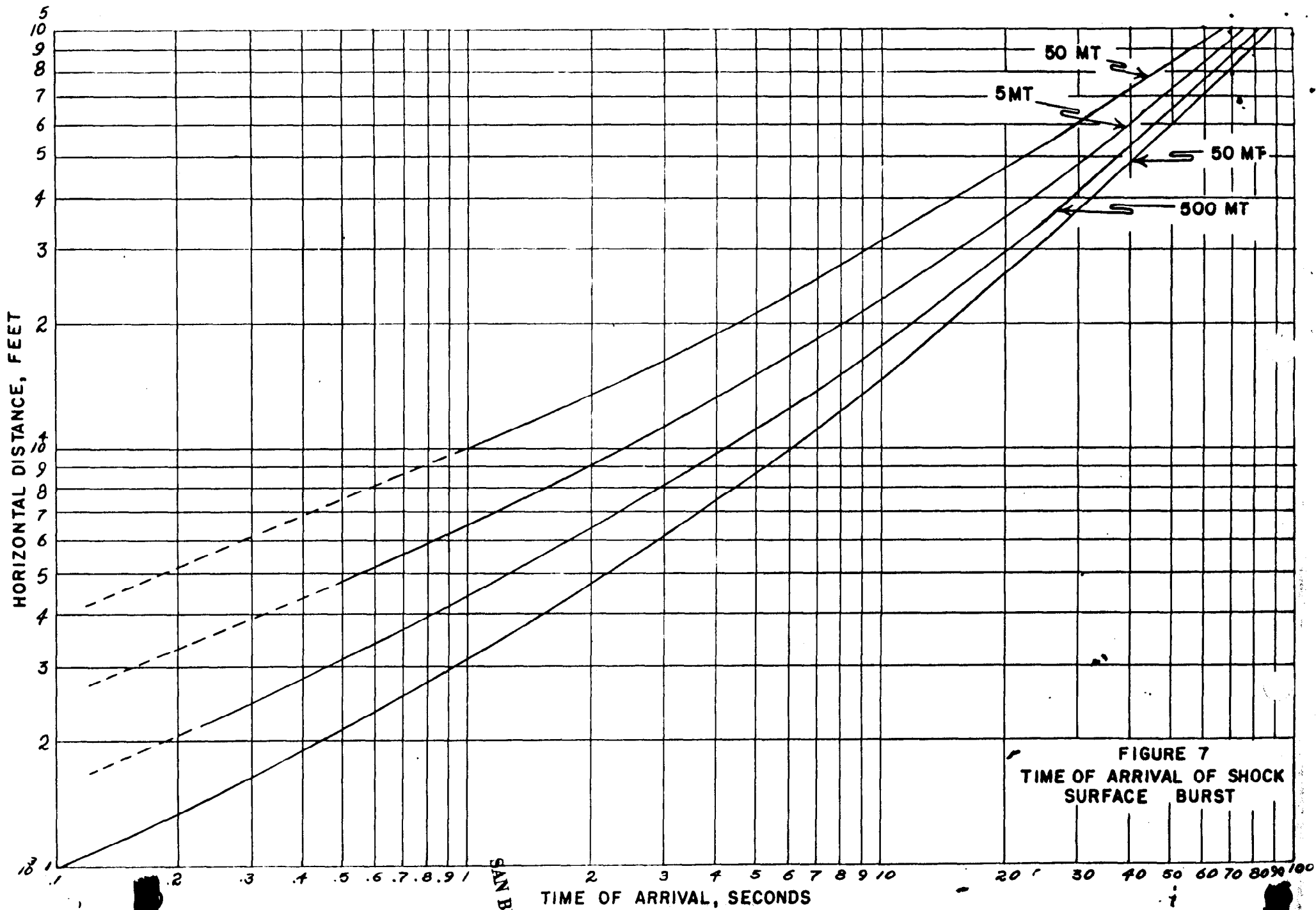
TIME FROM ZERO, SECONDS

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FIGURE 6
PRESSURE VS TIME
RANGE 91,700
5MT, SURFACE BURST
IDEAL SURFACE
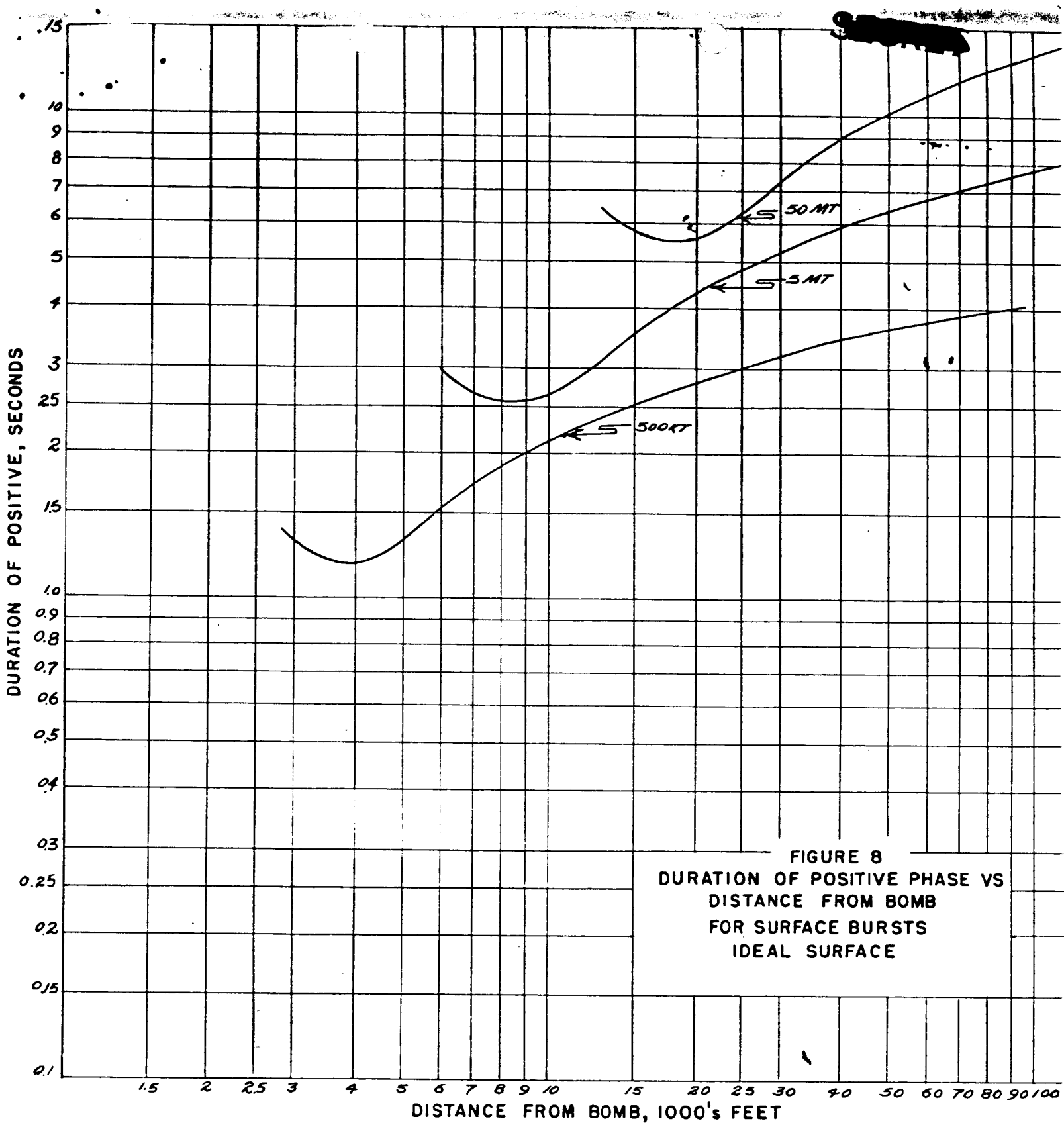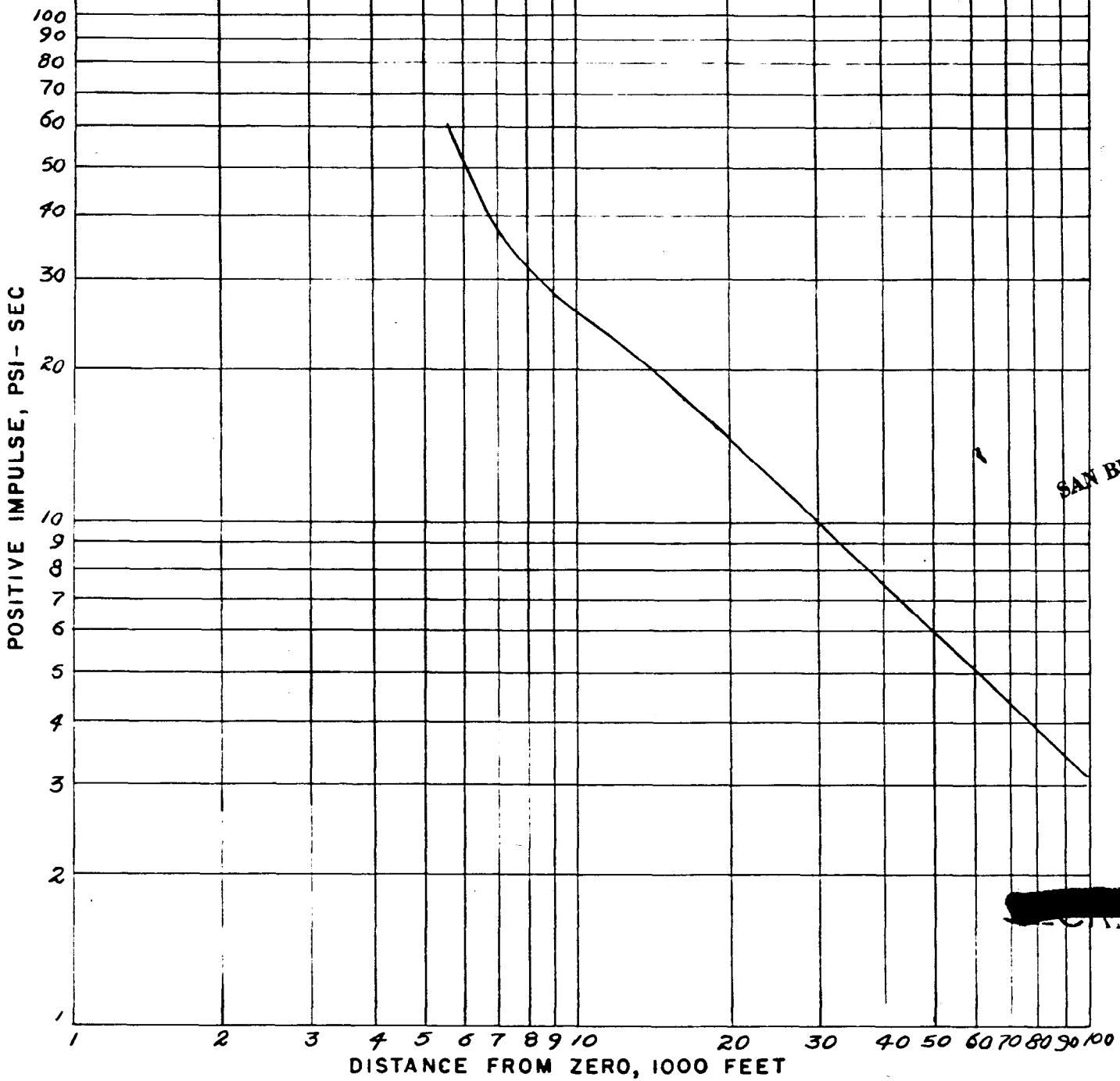
FIGURE 7
TIME OF ARRIVAL OF SHOCK
SURFACE BURST

HORIZONTAL DISTANCE, FEET

TIME OF ARRIVAL, SECONDS

50 MT

5 MT

50 MT

500 MT

FIGURE 8
DURATION OF POSITIVE PHASE VS
DISTANCE FROM BOMB
FOR SURFACE BURSTS
IDEAL SURFACE

DISTANCE FROM BOMB, 1000's FEET

DURATION OF POSITIVE, SECONDS

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FIGURE 9
POSITIVE IMPULSE ($\int P dt$)
VS
DISTANCE
5MT SURFACE BURST
IDEAL SURFACE

POSITIVE IMPULSE, PSI- SEC

DISTANCE FROM ZERO, 1000 FEET

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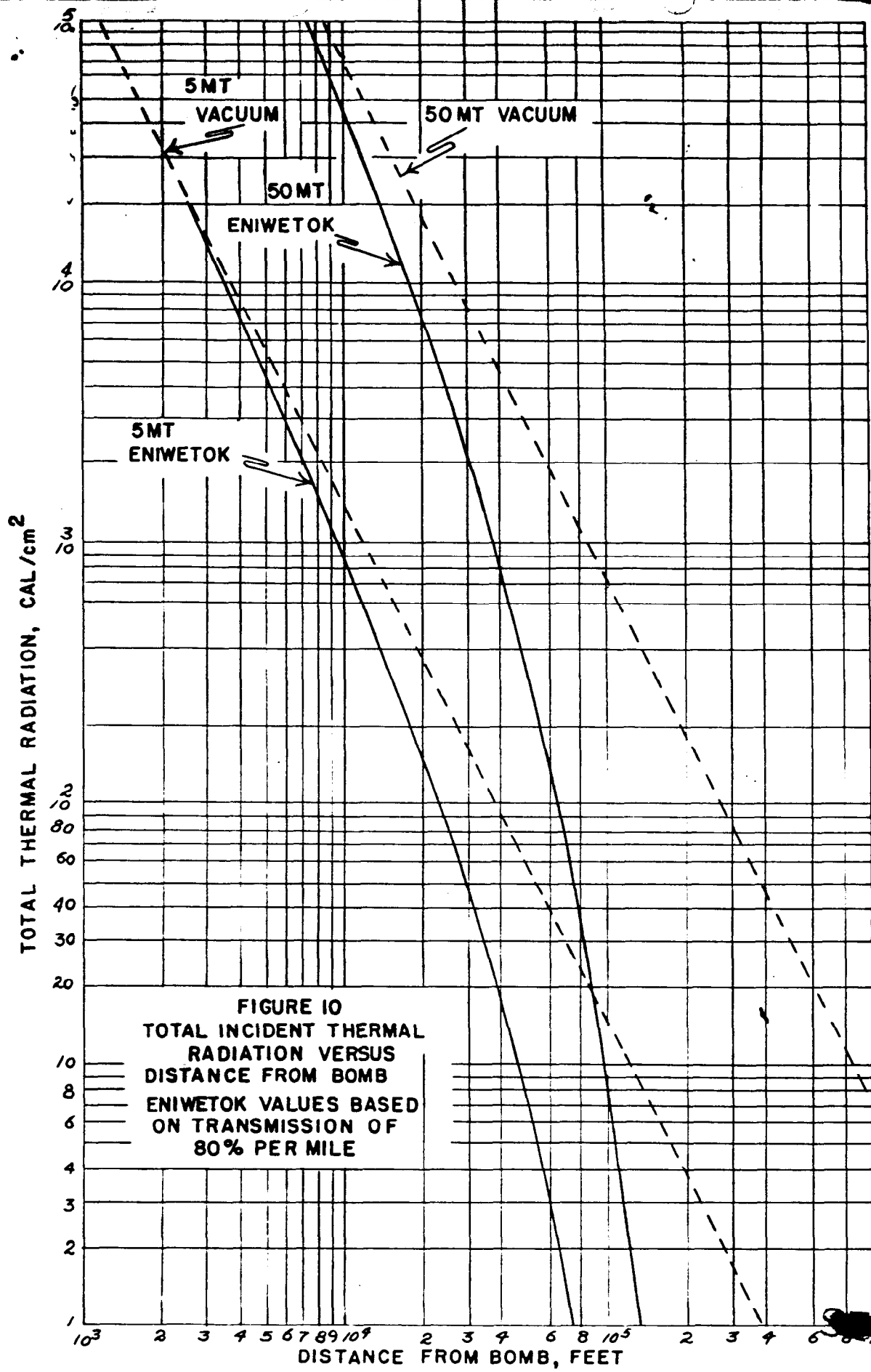
FIGURE 10
TOTAL INCIDENT THERMAL
RADIATION VERSUS
DISTANCE FROM BOMB
ENIWETOK VALUES BASED
ON TRANSMISSION OF
80% PER MILE

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EVACUATION PLANS CONFERENCE
9-10 June

- AGENDA -

J- 12076

9 June 1952

Principal Organizations Represented:

Hq. JTF-132 - Maj. Gen. Clarkson
Hq. TG 132.1 - Mr. S. W. Burriss
SFOO - Mr. Paul Spain
Holmes & Narver - Mr. D. L. Narver, Sr.
Scripps Institution of Oceanography - Dr. Roger Revelle
Cambridge Corporation - Mr. Roger Warner
LASL - Representatives of Technical Divisions and Classification Office
Sandia Corporation - Dr. Everett Cox
University of Maryland, Institute of Fluid Dynamics - Prof. J. B. Diaz

9 June

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1030 - P' Conference Room - Meeting of Scripps Institution personnel with Dr. George White of T-Division, LASL to discuss theoretical considerations and analysis of water wave studies (non-Q cleared personnel).

1100 - Room 117, B-Bldg. - Meeting of personnel of SFOO, Holmes and Narver, and LASL (Lt. Col. F. Porzel) to discuss blast effects of specific structures and equipment.

1330 - P' Conference Room - Meeting of personnel of Holmes and Narver, Scripps Institution, and LASL (George White) to discuss water wave effects of specific structures and equipment.

1500 - Room 117, B-Bldg. - Meeting of Mr. Narver, Paul Spain, Harry Allen, and Duncan Curry to discuss property and transportation matters pertaining to Task Group 132.1 activities.

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10 June

All meetings in S-Bldg. Conference Room located in the Tech Area.

With a view of all participants understanding the limited objective of this meeting attention is invited to the message addressed to Commander, JTF-132 from Commander, Task Group 132.1 (this message to be read by the chairman).

0900-0910 - Dr. Alvin Graves - Operation objectives of IVY.

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0910-0920 - S. W. Burriss - Objectives of this conference.

0920-1000 - Lt. Col. F. Porzel - Blast and Thermal Effects.

1000-1020 - Lt. Col. F. Porzel - Question period covering Blast and Thermal Effects.

1020-1040 - INTERMISSION.

1040-1130 - Dr. Roger Revelle - Water wave analysis and theoretical predictions. - This presentation will include a short question period. Dr. White and Prof. Diaz will assist in the question period.

1130-1200 - Dr. B. R. Suydam - Radio-active Particulate Fall Out - This presentation will include a question period. Dr. Shipman and Dr. Tom White will be present for the question period.

1330-1430 - Cmdr. R. H. Maynard - Radiological Safety Considerations - Presentation to include a discussion period.

1430-1445 - INTERMISSION

1445-1500 - Phil Hooper - TG 132.1's Concept of Operations.

1500-1520 - Mr. Narver - H&N's problems.

1520-1530 - Mr. Roger Warner - Problems confronting the Cambridge Corp. with dewar evacuation and allied handling.

1530-1600 - Knickerbocker - Headquarters, JTF-132's problems.

1600-1700 - Discussion

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