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AIRPLANE AND MISSILE GENERATED SHOCK WAVES

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5141

ABSTRACT

An approximate theoretical calculation of the overpressures caused by supersonic vehicles, which generate shock waves that intercept the earth, is presented. Estimated values of overpressure on the order of 0.03 psi were found to exist at a distance of five miles from the vehicle.

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Following a request for information concerning overpressures caused by shock waves emanating from airplanes and missiles, to be used in the design of buildings on the Nevada range over which these vehicles will fly, a theoretical calculation was made and the results are presented below. The original request was for an estimate of the overpressures at 100 yards and 2-1/2 miles from an airplane flying at 1.2 Mach number and at 5-1/2 miles from the Mach Five Test Vehicle. In order to provide an answer to the problem in a reasonable period of time only an approximate calculation was made, involving a number of simplifying assumptions which are:

(1) A two dimensional solution was substituted for the correct three dimensional solution in the case of the M5TV. This assumption should be conservative in nature.

(2) A two dimensional solution was used for the wing of the airplane ignoring the effect of the fuselage. At long distances this assumption should not effect the results appreciably since the fuselage bow shock wave is relatively weak compared to the wing bow shock wave.

(3) The actual contours of the vehicles were replaced by a simple wedge of suitable dimensions.

(4) Only the bow shock of the approximating wedge was considered. In the actual case the overpressure caused by the bow shock could be followed by a negative pressure phase and in turn followed by another shock or compression of less strength.

(5) A homogenious atmosphere was assumed. In the actual case gradients in pressure, temperature and density would cause distortion of the shock wave patterns which could either attenuate or magnify the shock strengths.

(6) No differentiation between the overpressure at lateral or vertical or longitudinal direction is attempted. The calculation was made in the plane of maximum overpressure.

Thus, it is obvious that these calculations can only yield orders of magnitude. The enormous amount of effort required to make a rigorous calculation was not felt to be warranted, particularly when even the rigorous calculation would yield poor accuracy at the large distances from the vehicle.

The first case considered is that of an airplane flying in level flight at a Mach number of 1.25. A schematic of wing cross-section and shock wave system used to calculate the overpressure is shown in Figure 1. As indicated in Figure 1, the increase in overpressure as a result of shock reflection is included in the calculation. The calculated overpressure as a function of distance between the wing and ground plane is shown in

Figure 2. It should be noted that the calculated value for a distance of 100 yards is about 1.5 psi. This should be a reasonably accurate value since it is close enough to the airplane to allow accurate calculation. The calculation was not carried beyond a distance of 6000 feet because it becomes impossible to calculate with any degree of accuracy. A hyperbolic curve was fitted to the calculated curve for purposes of extrapolating to greater distances, and is shown on Figure 2. The value of overpressure determined by the equation for a distance of 2-1/2 miles is 0.07 psi. It is interesting to compare an experimentally measured value of 0.014 psi caused by an F-86 flying in a dive at 30,000 feet and a Mach number of 1.05 to the value of 0.032 psi that would be calculated for a distance of 30,000 feet and Mach number of 1.25. While a direct comparison is impossible, it would appear that the formula does yield values of the correct order.

The two dimensional calculation for the M5TV was based on the cross-section and shock configuration shown in Figure 3. A Mach number of 3.5 was chosen since that is the impact Mach number of the M5TV. The results of this calculation are shown in Figure 4, which shows the overpressure as a function of distance from impact in the plane of the trajectory. A formula for extrapolation similar to that given for the airplane is shown in Figure 4 for predicting overpressure at greater distances. The extrapolated value of overpressure at 5-1/2 miles for the M5TV would be 0.031 psi. It should be noted that in this case the angle of the trajectory has a pronounced effect on the magnitude of the overpressure. Less dive angle will increase the overpressure at the same distance from impact significantly.

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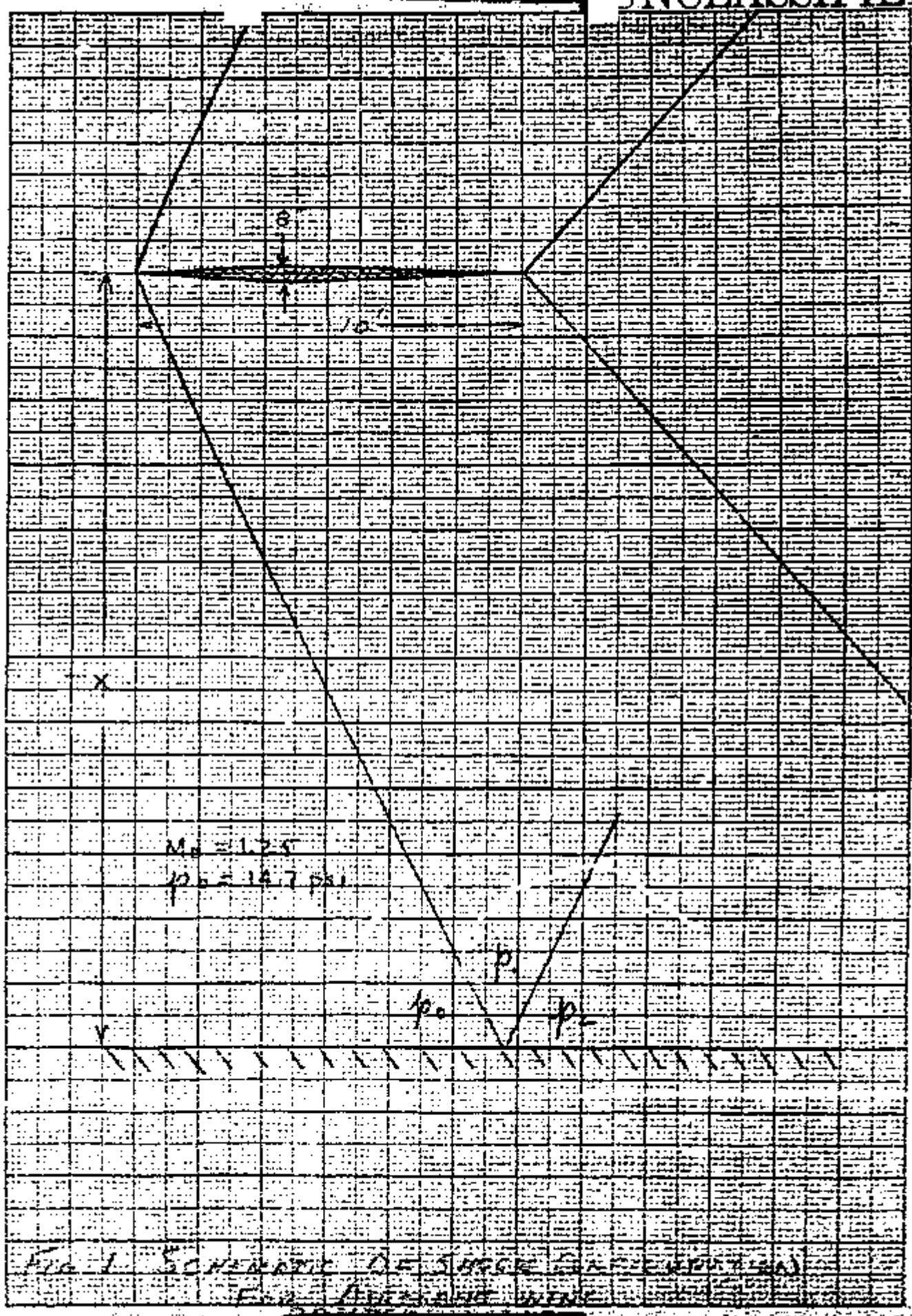

Fig. 1 Schematic of Shock Configuration for Average Wing

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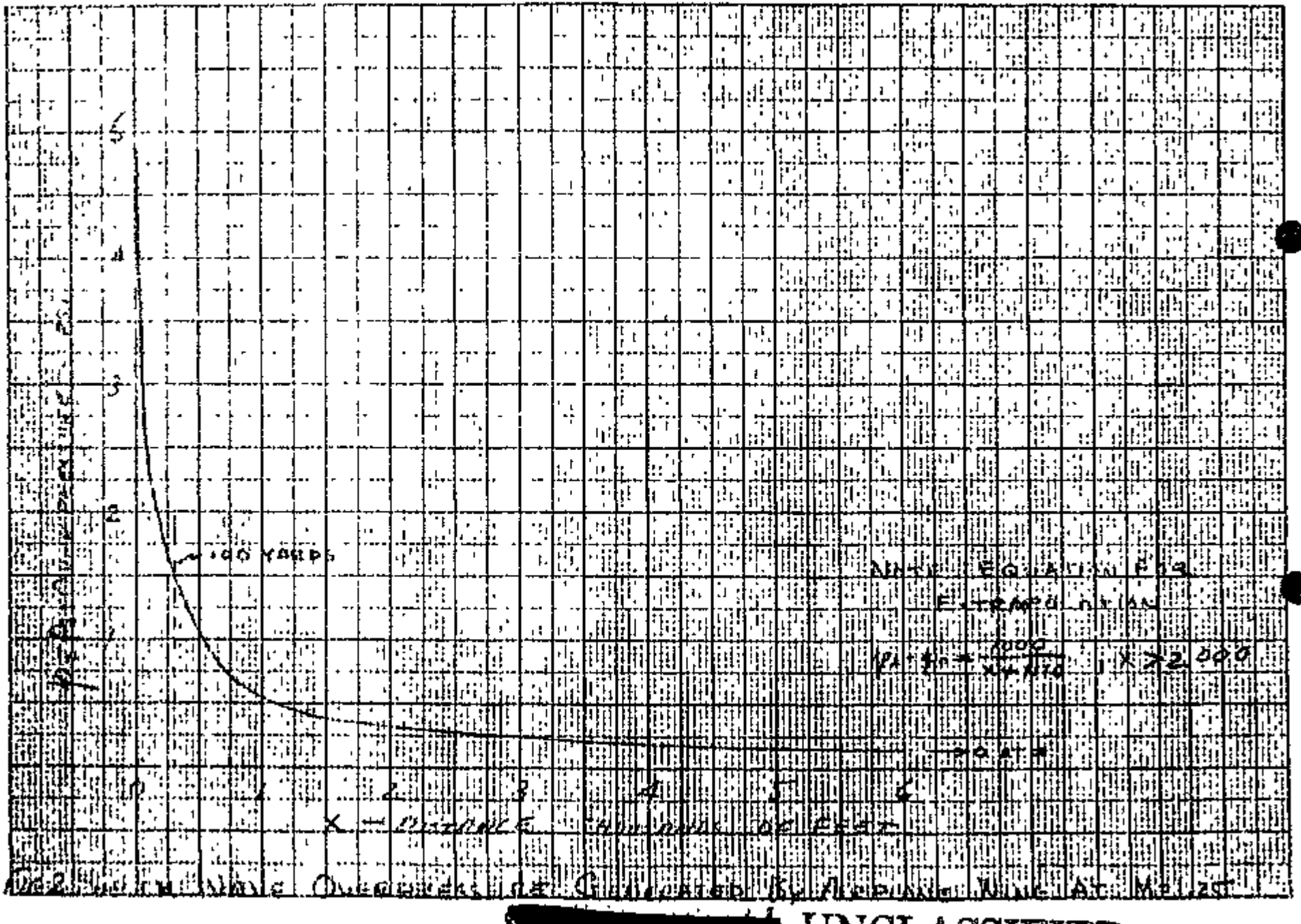

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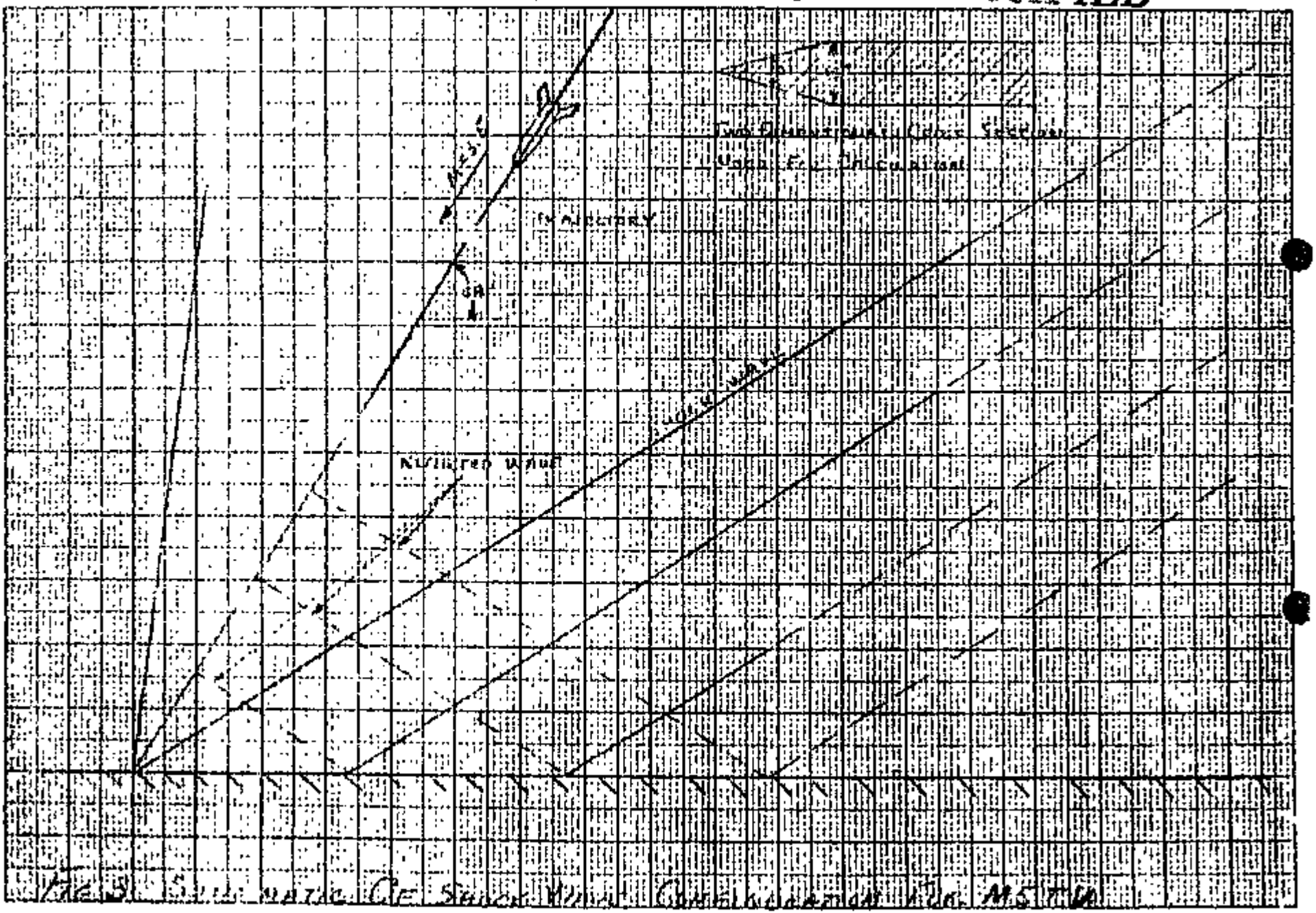

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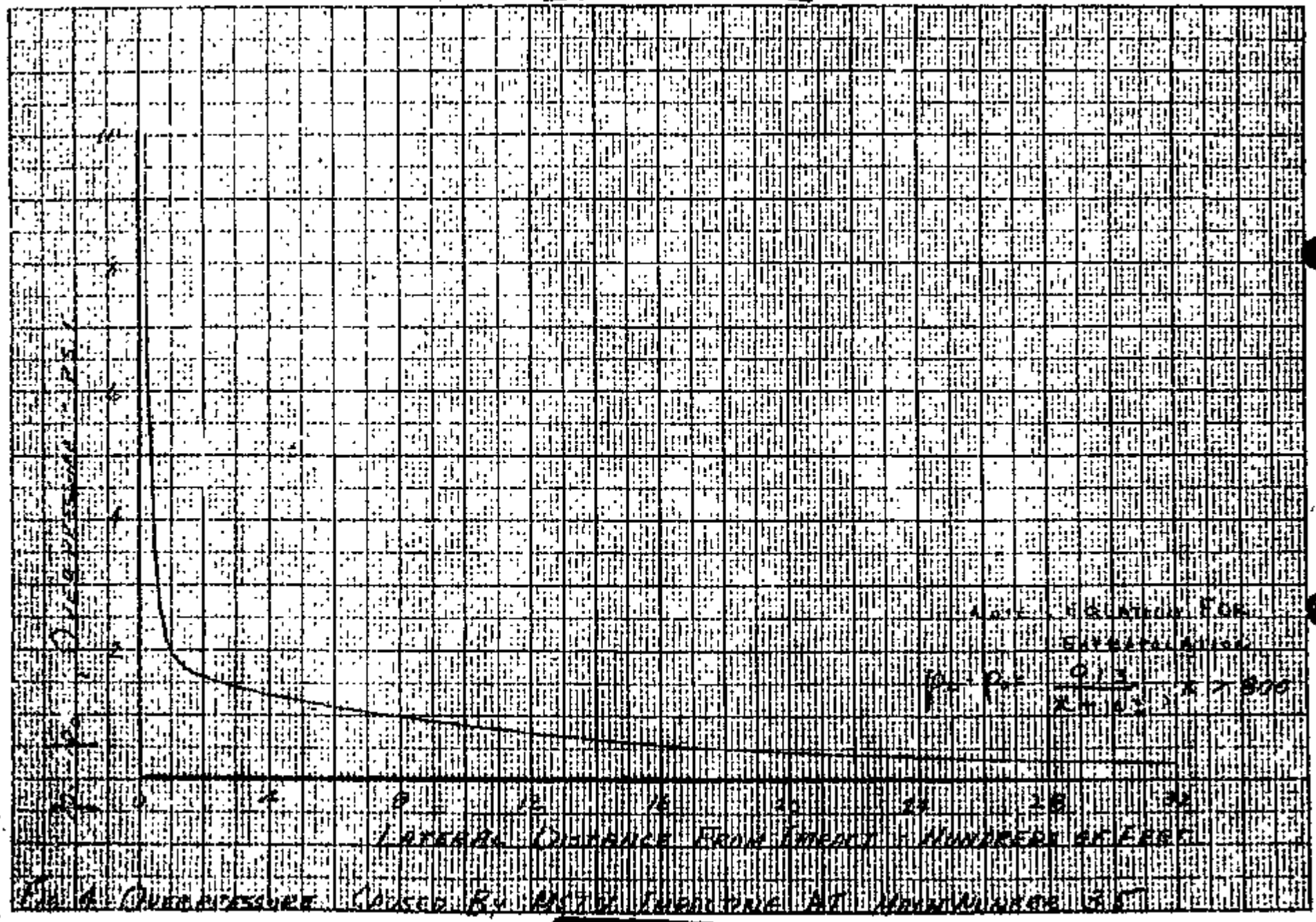

FIG. 4 OVERPRESSURE CAUSED BY [illegible] IMPACTING AT [illegible]

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