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CONTACT ELECTRICAL METHOD OF STUDYING IMPLOSION

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ABSTRACT

This report describes a method of investigating the motion of one surface of a metallic wall of any shape propelled by a charge of high explosive in contact with the other surface of the wall. The method consists essentially of observation of the times at which the conducting surface makes electrical contact with wires, "pins", placed normal to the surface with their ends at predetermined distances from the original position of the surface. Thus the results appear as points on a displacement-time curve for the surface. Many pins can be used in a single experiment, the contact with any particular one being identified by the sign and magnitude of the voltage pulse produced. The record of an experiment is an oscillogram obtained with an accurately timed sweep having timing marks on it. A pre-amplifier designed to give different signs and sizes to the pulses from a number of pins is described.

The method suffers from the distinct disadvantage that leads must be brought from the pins to the recording circuit. Thus, for example, the method cannot be used with a full sphere. Using a segment of a sphere, the motion can be followed usefully only to the time at which perturbation waves from the opening reach the region of the sphere where measurements are being made. As an example of this method a number of relatively simple experiments are discussed. Displacement-time waves for steel plates imploded with pentolite and torpex charges are given. Steel plates 1/8" thick attain a velocity of 1.9 mm per microsecond with pentolite and 2.0 mm per microsecond with torpex. Steel plates 1/4" thick imploded with the pentolite charges of the same dimensions attain a velocity of 1.3 mm per microsecond. These curves are given for about 10 mm motion of the plates and over this range show no appreciable difference between torpex and pentolite. A preliminary measurement of the velocity of the shock wave in

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steel shows that it is the same as sound velocity. Use of insulating plates show that the contacts are not caused by air ionization by the shock wave. The displacement times can be measured with an equivalent probable error of a single reading of about 0.1 microsecond.

As experiments with various geometries are completed by this method, the results will be given in brief reports.

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CONTACT ELECTRICAL METHOD OF STUDYING IMPLOSION

THE PRINCIPLE OF THE METHOD

The motion of a metallic surface is determined by observation of the times at which the surface reaches predetermined points in front of it. These points are the ends of wires, "pins". The pins are supported by means of an insulator so that a circuit is completed when the surface strikes the end of each pin. Each pin is associated with an individual circuit which produces a voltage pulse of characteristic magnitude and sign. The voltage pulses are amplified and impressed on the vertical plates of a cathode-ray oscillograph. The single-sweep circuit for the oscillograph is triggered at a suitable time before the first contact is made and the circuit provides timing marks across the sweep. The resulting oscillogram is a stepped line in which the beginning of each step represents the time of contact to a pin. Examples of the scope traces are given in Fig. 1 and Fig. 2.

The particular method of timing the contacts described here is by no means the only possible way, but it is the only way used in these experiments so far.

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Fig. 1. Typical oscillogram with the contact method using pins below a flat steel plate. Four positive and three negative pulses or steps are shown representing seven contacts. The blanking spaces are at 0.5 microsecond intervals.

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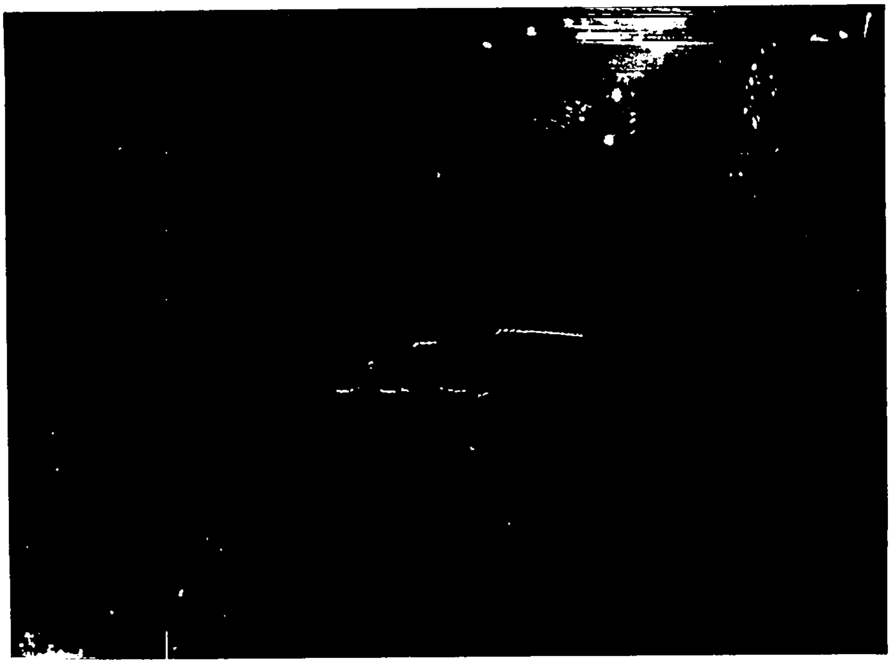

Fig. 2. Typical oscillogram with contact method. There are six positive and five negative steps representing contacts to eleven pins placed under a flat steel plate. In this case the charge was a conical lens and the object of the shot was to determine the flatness of the detonation wave. The blanking spaces are at 0.5 microsecond intervals.

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THE SPECIFIC CIRCUITS

Fig. 3 shows in schematic and block form the circuits[1)] used. We suppose that a charge of high explosive, D, is to be used to propel a metal plate, A, so that it will strike the pins B and C. The primacord, G, is detonated by means of a cap. The detonation wave causes a short between two pins through the primacord at E. This causes a pulse to be fed from a cathode-follower circuit, F, through a long line to the sweep trigger circuit, T,D. The latter circuit contains an adjustable delay so that a pulse to initiate the sweep is fed from the delay circuit at any predetermined time after the tripping signal arrives. This pulse actuates the sweep and intensifier circuits, starting a single sweep which can be photographed. The timing circuit, T, feeds pulses from a crystal-controlled oscillator into the intensifier circuit so as to blank out the trace with the period of the oscillator. The sweep circuit is provided with a thyratron clamp to prevent multiple sweeps, a reset button for single sweeps and a manual-operation trigger button for testing. The sweep circuit can be switched to repetitive sweeps and these can be locked in with a pulsed oscillator in T, in order to measure and adjust the sweep speed, trigger delay, sweep length, etc. The sweep speeds are continuously adjustable from about 2 microseconds per inch to many milliseconds per inch. The delay is adjustable from about 0.2 to 50 microseconds.

When a contact is made between plate A and a pin such as B a small condenser in the pre-amplifier, PA, is charged. This condenser circuit has a long time constant so that the condenser remains charged for the duration of the experiment even if contact is broken between A and B at some later time. The pre-amplifier sends a signal representing this charging of the condenser through a long line into the intermediate amplifier IA. Since the identification of the pins is most important, a detailed circuit diagram of the pre-amplifier is shown in Fig. 4.

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1) All the circuits except PA and F in Fig. 3 were designed and built by Group G-4, and they will not be described in detail here. Without this excellent electronic gear it would be very much more difficult to use the contact method.

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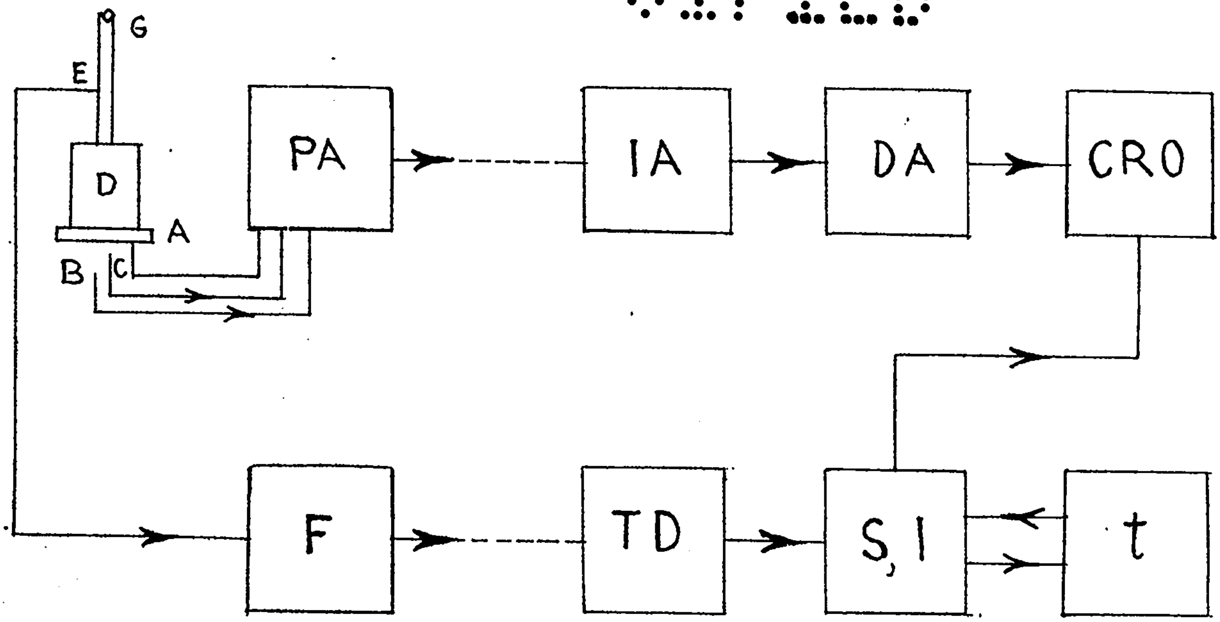

FIGURE 3
Schematic Representation of the Circuits

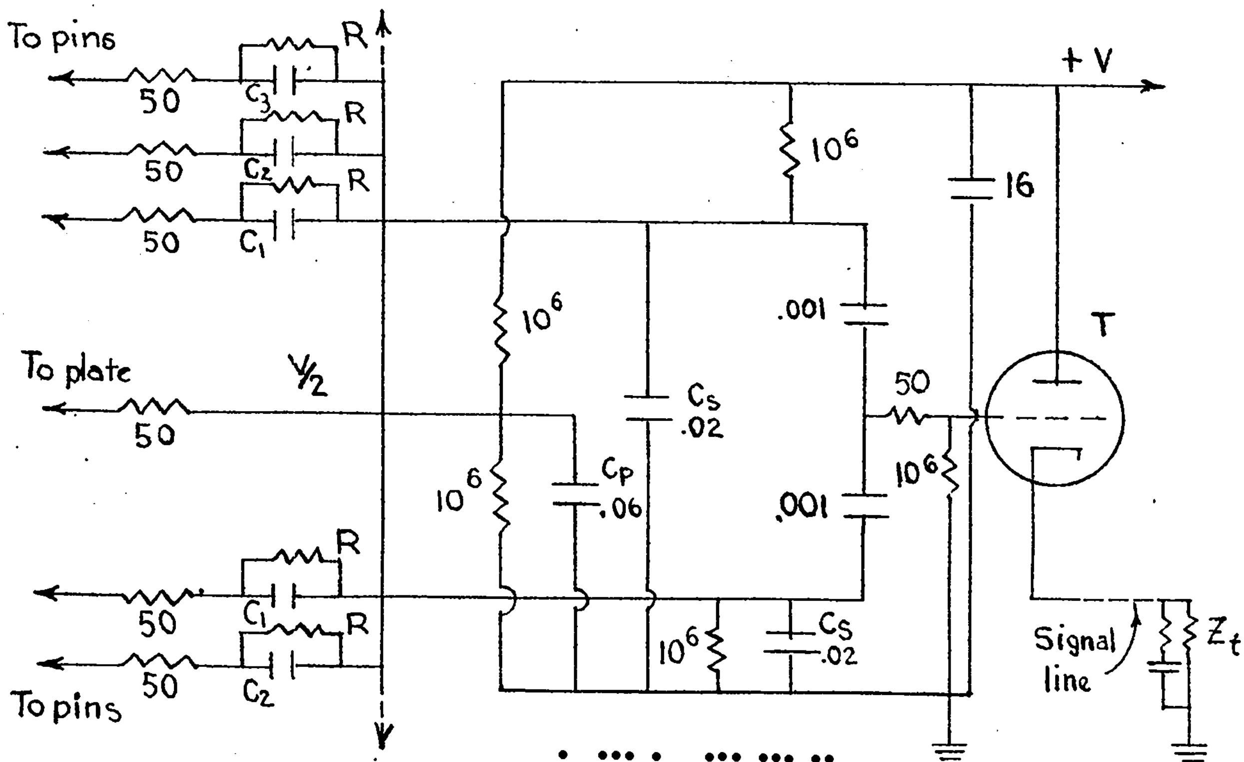

FIGURE 4

The Pre-Amplifier (Resistances are in ohms; capacities in microfarads)

In Fig. 4 each condenser-resistor network, C_1, C_2, etc., is connected to a pin. In practice twelve of those have been used, six in the upper and six in the lower set. The value of R is 2.5 megohms and the values of the condensers C_1, C_2, -- vary from 50 to 150 micro-microfarads in equal steps. When the plate is connected to any pin the left-hand plate of its small condenser, say C_1, changes potential by either $-V/2$ or $+V/2$ since C_p is large compared with C_1 if the condenser C_1 is in the upper or lower bank, respectively. The charge for the right-hand plate is derived from the condenser C_s connected to the corresponding bank. Thus the potential of C_s changes by $\mp(C_1/C_s)V/2$ and about half this voltage is impressed on the grid of the cathode follower, T, through the .001 coupling condenser. Only half the voltage appears at the grid because of the shunting action of the coupling condenser in series with C_s in the other bank. The values of the condensers C_1, C_2, etc., are sufficiently small compared with C_s and C_p so that the pulse appearing at the grid of T, when contact is made to a given small condenser, is practically independent of any possible combination of previous contacts. This makes the pulse size specific for the particular pin connected to the condenser. The 50-ohm resistors shown in Fig. 3 prevent oscillations but do not increase the rise time above that of the main amplifier. By alternating the signs of successive pulses it is possible to get large steps on the record without either going off the scope or overloading the amplifiers. Tube T is a cathode follower whose load impedance, Z_t, is at the end of a long coaxial cable. This impedance has a DC resistance of the proper value to bias the tube correctly and is precisely adjusted to the characteristic impedance of the line. This adjustment must be done with considerable care in order to prevent troublesom reflections in the line. Z_t is actually in the chassis with the intermediate amplifier, IA.

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The intermediate amplifier, IA in Fig. 2, is a stabilized feed-back linear amplifier, with a maximum voltage gain of about 10,000 and a rise time of 0.15 microseconds. DA is a push-pull driver amplifier for the oscilloscope, CRO. The oscilloscope circuit supplies especially high accelerating voltages to produce sufficient light intensity to photograph fast sweeps. The camera used for recording the traces is equipped with an F 1.5 coated lens of 7 cm focal length, but an F2 lens can be used for all but the fastest sweeps.

DISCUSSION OF THE CONTACT METHOD AND REPRODUCIBILITY OF RESULTS

The contact pins are mounted on the ends of fine-threaded screws which pass through tapped holes in an insulator rigidly supported relative to the initial position of the metal surface whose motion is to be studied. The screw supports are made sufficiently long so that a shock wave in the support cannot reach the pin before the plate[2]. The electrical connection to the plate can be made by means of a wire supported like the pins but in contact with the plate, or by means of a wire soldered to the plate. Care is taken that the blast wave does not reach this wire before the plate reaches the last pin. Wire of soft copper or fuse wire is found suitable for making this connection but other metals may be as good. The pins are of piano wire about 0.02" in diameter, soldered into a small hole in the end of the screw. The distance of the end of a pin from the plate is set either by screwing the pin down on a thickness gauge between it and the plate, or by unscrewing the screw a counted number of turns from contact with the plate. Contact with gauge or plate is determined electrically.

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2) The word "plate" is used for convenience to describe the metallic wall of any shape.

In order to test the method and to measure the over-all reproducibility, a number of similar shots using flat plates were made. The plates used were 4" steel squares. A $2\frac{1}{2}$"-diameter circular groove was cut nearly through the plate and a cylinder of high explosive $2\frac{1}{2}$" in diameter and 3" high was set on the circle. The H.E. was detonated by means of a booster on its axis.

A number of pins, usually six or seven, were set on a circle of 3/16" radius about the axis of the cylindrical charge under the plate. The pin spacing from the plate varied from less than 0.01 to 9.5 mm. Thus, in any particular shot, the ends of the pins were on a spiral about the axis of the cylindrical charge and, although the detonation wave in the H.E. was spherical rather than plane, it would arrive at all points of the plate surface directly above the pins at the same time.

Fig. 5 shows the displacement-time results obtained with ten 1/8" steel plates using pentolite for the H.E. The horizontal lines plotted show the probable errors of the points. For some points on the curve there were several observations and for other points only a few. Fig. 6 shows similar data using torpex for the H.E. No appreciable difference can be seen in the motions of plates propelled by pentolite and torpex. There is a slight suggestion that the acceleration period with torpex is a little greater than with pentolite but the difference is within experimental error. Fig. 7 shows similar data with pentolite but with $\frac{1}{4}$" steel plates. In this case some of the sweeps were timed by using an L-C-type oscillator which was probably temperature sensitive. The fluctuations in these data and the deviations from the curve show the necessity of using a precise timing device such as a crystal-controlled oscillator. In Fig. 7 the point plotted in the lower left-hand corner was obtained by observing the time at which the detonation reached the top of the plate. This was done by placing a thin aluminum foil and a thin insulating membrane between the charge and the

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plate. The foil was then connected to the pre-amplifier in the same way as a pin and a pulse was received from it when it made contact with the plate. The velocity of the shock wave through the $\frac{1}{4}$" steel plate obtained in this way is, within experimental error, the same as the velocity of sound in steel. This point is being investigated further with plates of various thicknesses.

A number of tests were made in order to be sure that the contacts to the pin ends were made by the metal plate itself and not by the shock wave in air preceding it. It was thought unlikely but possible that the air might be highly ionized in the shock front. Probably the most conclusive test was made by using a mica plate instead of a steel one. In place of the pins; two thin metal sheets were used parallel to the plate and quite close together. No contact or conduction between the metal plates was observed during the motion of the mica over an appreciably larger distance than the initial spacing of the mica from the plates. When pins were used instead of the metal plates, conduction between them was observed. This was probably caused by the pins' puncturing the mica and entering the hot explosive gases above it.

From the data obtained in the steel-plate shots, the probable error in a single observation of the time of arrival of the plate a given distance from its initial position was calculated to be slightly less than 0.1 microsecond. This includes the error in setting the pin at the proper spacing and in reading the values from the oscillogram but does not include systematic errors. The only systematic error apparent is that of the oscillator producing the timing marks. According to the manufacturers' specifications the error in the crystal frequency could not introduce more than $\frac{1}{4}$% in the timing. For periods of the order of 10 or 20 microseconds this error is entirely negligible.

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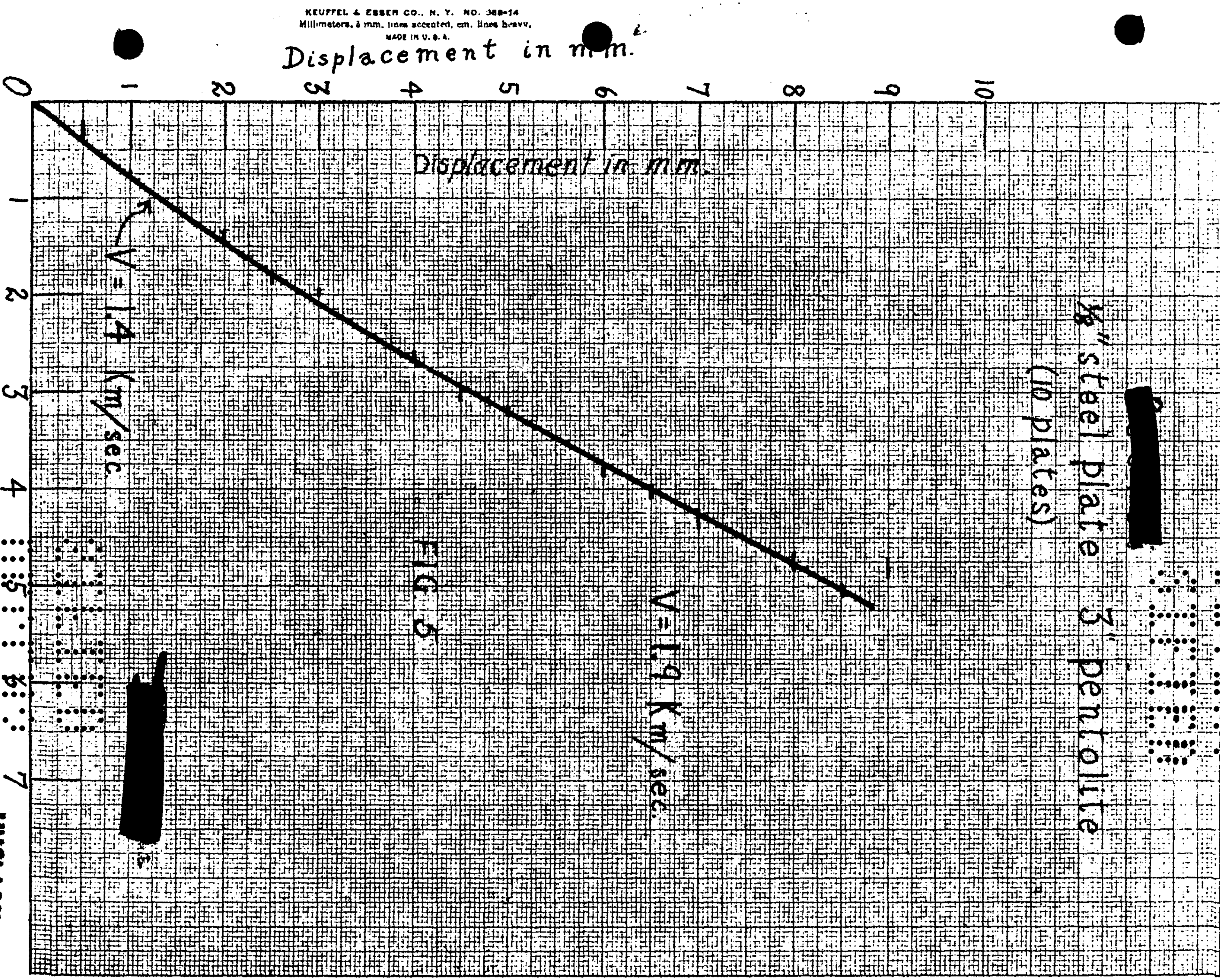

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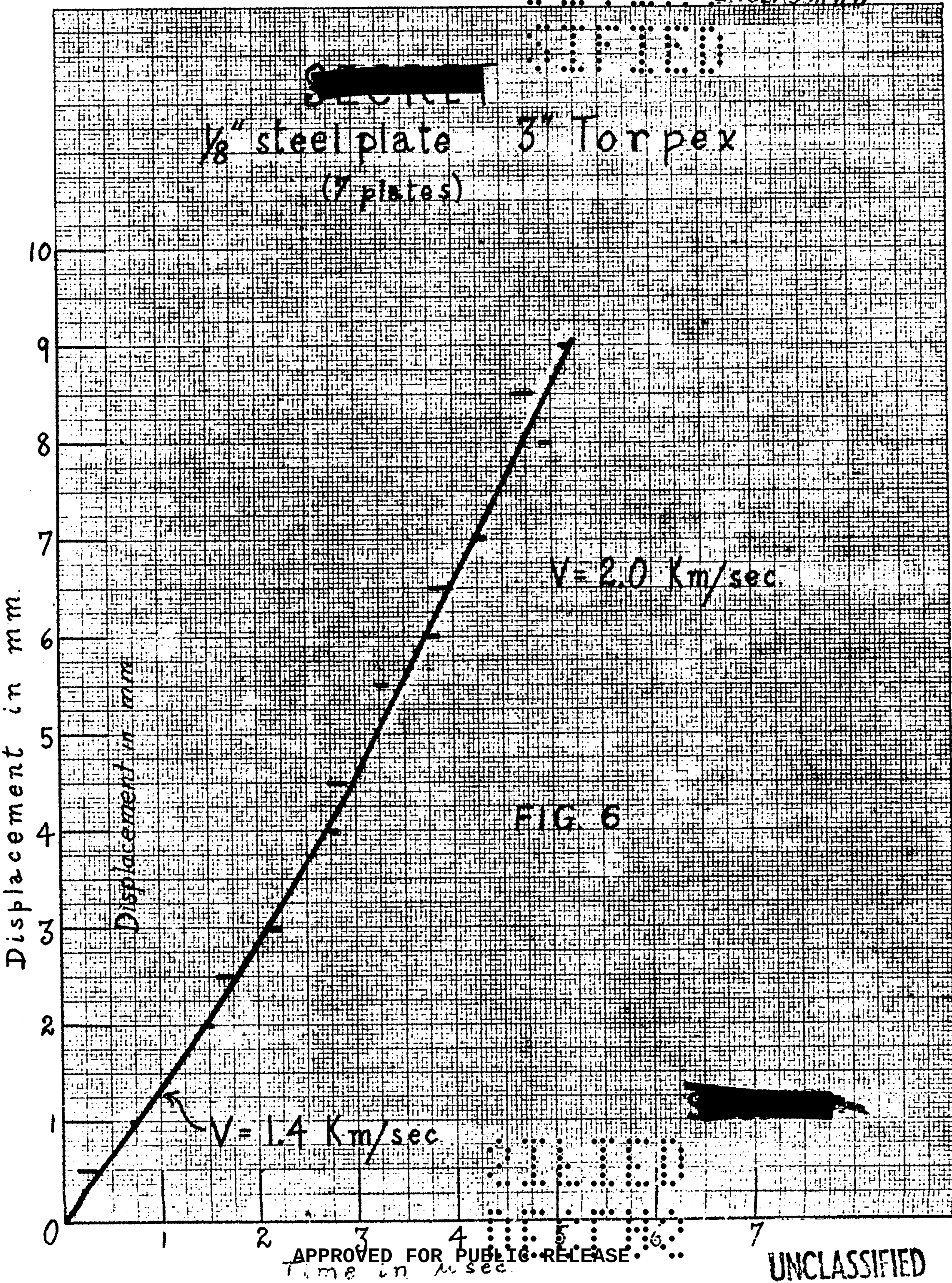
[redacted]
1/8" steel plate 3" Torpex
(7 plates)
Displacement in mm.
V= 2.0 Km/sec
V= 1.4 Km/sec
0
1
2
3
4
5
6
7
8
9
10
Time in μsec

FIG 6

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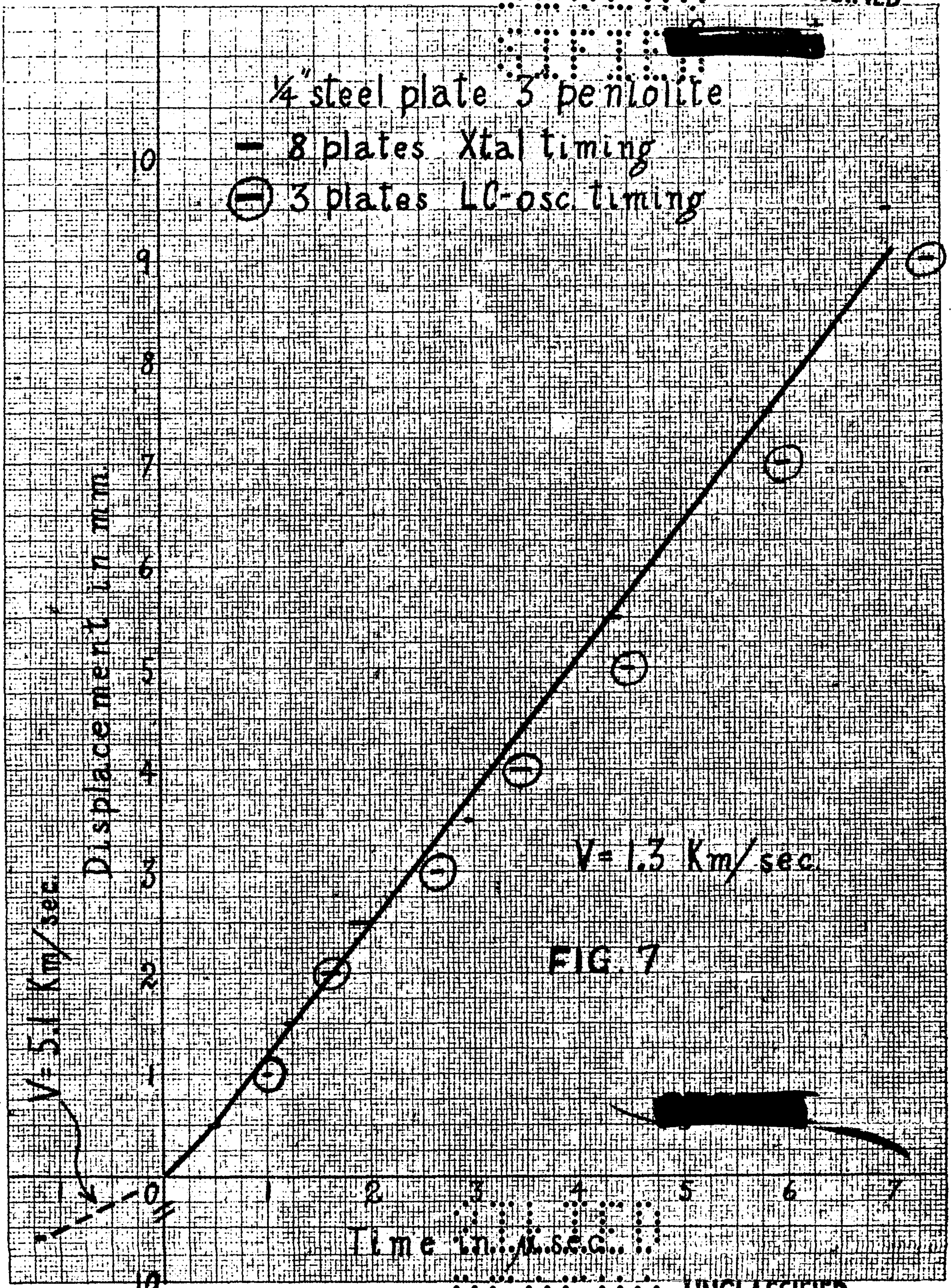

FIG. 7

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