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JULY 16TH NUCLEAR EXPLOSION:

SOUND VELOCITY AND EXCESS VELOCITY OF THE SHOCK WAVE

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ABSTRACT

[redacted]

The velocity of sound at the time of the nuclear explosion at Trinity was measured to be 1130 ft/sec. The excess velocity of the blast wave was determined at various distances and the corresponding peak pressures were computed. The calculated pressures are close to those expected for an explosion of 10,000 tons of TNT.

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The present measurements are analogous to those described in LA-291 for the 100-ton test. The apparatus used was modified, however, in order to eliminate the difficulties due to the disturbances which spoiled the records of the 100-ton test.

The velocity of sound was determined by observing the sound from a 5-lb charge of pentolite fired near the nuclear explosive 3.0 sec before t_0 (firing time of the nuclear explosive).

The field lay-out was the following: The nuclear explosive was located at a height of 35 yards above a point denoted as "0". For the location of the field stations the line which is defined by 0 and the north shelter (A) was used as reference. Five microphones (north stations) were located on a line through 0 at an angle of 15° west of 0A. The distance of the stations from 0 were 400, 500, 700, 1000 and 1400 yards. Five more microphones were located at the same distances from 0 and on the same line through 0 on the opposite side from 0 (south stations). The 5-lb charge was located on a line through 0 perpendicular to the line of the stations. The charge was suspended 15 ft above a point 50 yards east of 0. The distances of the microphones from the nuclear explosive and from the 5-lb charge are summarized in Table I.

The signals from the north stations were recorded at shelter A (10,000 yards north), those from the south stations at B (10,000 yards south). The signals were transmitted over twisted pairs (W 110 B) to the recording stations. The wires were laid in ditches up to a distance of 1500 yards from 0, and were strung on insulators over a pole line from there to the shelters.

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Five-inch permanent-magnet speakers were used again as microphones. Their mounting was identical with that described in LA-291. The cone of each speaker was covered with a heavy coat of aluminum paint as a protection from radiation. Fig. 1 is a photograph of one of the microphones as used in the field.

In the electronic equipment for the 100-ton test, signals from five loud-speaker microphones were amplified, limited and mixed for presentation on one five-inch scope, with provision for clamping each channel for a suitable time after the reception of a large signal. This method worked well for signals from the five-pound charge used to determine the sound velocity, but failed for the 100-ton charge because of electrical disturbances of uncertain origin. Following this experience, the equipment was re-designed to have five independent channels from five speakers through five amplifiers to the horizontal deflection plates of five three-inch scope tubes suitably arranged for photography with a single General Radio Oscilloscope Camera. Timing marks were generated from an electrically driven 1000-cps/sec tuning fork, and the scope traces simultaneously blanked for about 0.1 millisecond every 1 millisecond. In addition, a longer blank was inserted at t_o (firing time of the nuclear explosive) by means of a trigger signal. At the same time the gain of each amplifier was reduced by a factor of 10 by the closure of two relays.

The following precautions were taken in the design of the equipment:

1) A double copper-oxide rectifier in series with a small resistor was placed across the twisted-pair transmission line connected to the speaker to the line-matching transformer. This arrangement served as a nonlinear resistance to limit large electrical surges on the line although permitting small signals to pass without much attenuation. It was hoped that by this

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means disturbances due to cross talk between lines would be eliminated. A box containing the rectifiers and resistor was buried near each station.

The factor-of-ten reduction of amplifier gain following t_o was chosen after measuring the limiting properties of the copper oxide unit and the maximum output to be expected from the loudspeaker microphone.

2) The twisted pairs from speaker to shelter were used as balanced lines to help eliminate pickup between line and ground. The best shielded audio input transformers obtainable were used to couple the lines to the first-amplifier grids.

3) The amplifier was made virtually overload proof by partial direct coupling.

4) The maximum output of the amplifiers was chosen so as to keep the scope trace on the screen and thus to preserve the timing blanks.

5) The upper-frequency response of the amplifier was limited to a half-power point of 1500 cps consistent with determining times to .1 to .2 milliseconds. This reduced interference from higher-frequency strays picked up by the long unshielded transmission lines.

For convenience, a simple sweep circuit could be switched on to the vertical deflection plates of all scopes 1) to observe the appearance of the blanking signals, 2) to observe the nature of electrical disturbances, and 3) to prevent burning the scope screen prior to an actual run, but permitting the spot to be focussed. Switches on the amplifier chassis permitted an audio oscillator of known balanced output voltage to be connected to any, or all of the channels. This permitted the gains of the various channels to be set as well as providing a rapid check on the operation of the equipment from the input terminals to the final scope trace.

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Circuit diagrams for the amplifier, scope, and blanking circuits are shown in Figs. 2, 3, and 4 of this report. Not included are diagrams for the power supplies, sweep circuit, and audio oscillator. The sequence of events during the test was as follows: The 5-lb charge was fired at $t_o - 3.00$ sec, the General Radio recorder was turned on at $t_o - 2.5$ sec, the signal from the 5-lb charge reached the first microphone at approximately $t_o - 2$ sec, and the fourth microphone at approximately $t_o - 0.4$ sec. At t_o (at station A: $t_o - 42$ msec) the scope beams were blanked out for about 2 msec and the gain of the amplifiers was reduced.

The times at which the signals were recorded are given in Table I. An arbitrary zero is used on each record for counting times. The record showed no distinct signal for the shock wave registered by the first microphone on the south. It must be assumed that this microphone was destroyed by the intense radiation. The signal from the first station on the north was relatively very small indicating that at least the cone of the speaker had been burned. The signals from the 500-yard stations were also smaller than expected. These stations had probably also been damaged. Figs. 5 and 6 show prints of several sections of the records.

The velocities computed from the data in Table I are summarized in Table II. The effect of the excess velocity from the 5-lb charge is negligible at 400 yards. The average sound velocity towards the north is 1137.5 ft/sec, towards the south 1122.5 ft/sec. This yields 1130 ft/sec for the sound velocity in still air corresponding to an air temperature of $21^{o}C$, and a component of wind velocity in the direction of the north stations of 7.5 ft/sec.

Using the equation of Rankine and Hugoniot one obtains from the measured

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velocities the peak pressures quoted in Table II on the basis of a barometric pressure of 12.3 psi. If one assumes that the pressures are correct for the midpoint between two stations, one finds that the pressure varies in the region of the measurements roughly as $r^{-1.8}$. Using this relationship the distances were computed for which the average velocity is equal to the velocity of the shock wave. These distances are listed in the last column of Table II.

Fig. 7 shows a plot of peak pressure vs. distance as determined from the present measurements. In addition the relationship between peak pressure and distance as predicted in LA-316 for 10,000 tons of TNT is plotted. On the basis of the fair agreement of the two curves one would conclude that the blast from the nuclear explosive was of the same order of magnitude as that expected from 10,000 tons of TNT.

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TABLE I

NORTH STATIONS

[redacted]

	Distance from 5-lb charge ft.	Arrival time of sound wave msec.	Distance from nuclear explosive ft.	Arrival time of shock wave msec.
1	1209.3	0028.3	1204.2	2177.9
2	1507.5	0290.2	1503.3	2307.5
3	2105.5	0816.0	2102.5	2625.6
4	3004.2	1606.2	3002.2	3190.3
5			4201.3	4055.8

t_o - 42 msec -- 1956.7 msec.

t_o -- 1998.7 msec.

SOUTH STATIONS

	Distance from 5-lb charge ft.	Arrival time of sound wave msec.	Distance from nuclear explosive ft.	Arrival time of shock wave msec.
1	1209.8	0077.4	1204.7	
2	1507.7	0343.0	1503.5	2336.3
3	2105.7	0876.7	2102.8	2650.0
4	3003.7	1677.8	3001.7	3239.6
5			4201.4	4113.7

t_o - 2034.8 msec.

[redacted]

TABLE II

NORTH STATIONS

[redacted]

Interval	Midpoint yds	Sound Velocity ft/sec	Shock Velocity ft/sec	Peak Pressure psi	Adjusted midpoint yds
1-2	450	1138.6	2307.8	45.2	448.7
2-3	600	1137.3	1883.7	25.3	593.2
3-4	850	1137.3	1593.2	14.0	838.4
4-5	1200		1385.4	7.0	1185.1
1-4		1137.5			

SOUTH STATIONS

Interval	Midpoint yds	Sound Velocity ft/sec*	Shock Velocity ft/sec*	Peak Pressure psi	Adjusted midpoint yds
1-2	450	1123.2			448.8
2-3	600	1122.1	1913.1	27.2	593.3
3-4	850	1122.5	1526.7	12.2	838.4
4-5	1200		1374.3	7.1	1184.9
1-4		1122.5			

* Velocities corrected for tuning fork frequency of 1001.4 cps.

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Fig. 1. Loudspeaker-microphone used in the measurement of sound velocity and excess velocity.

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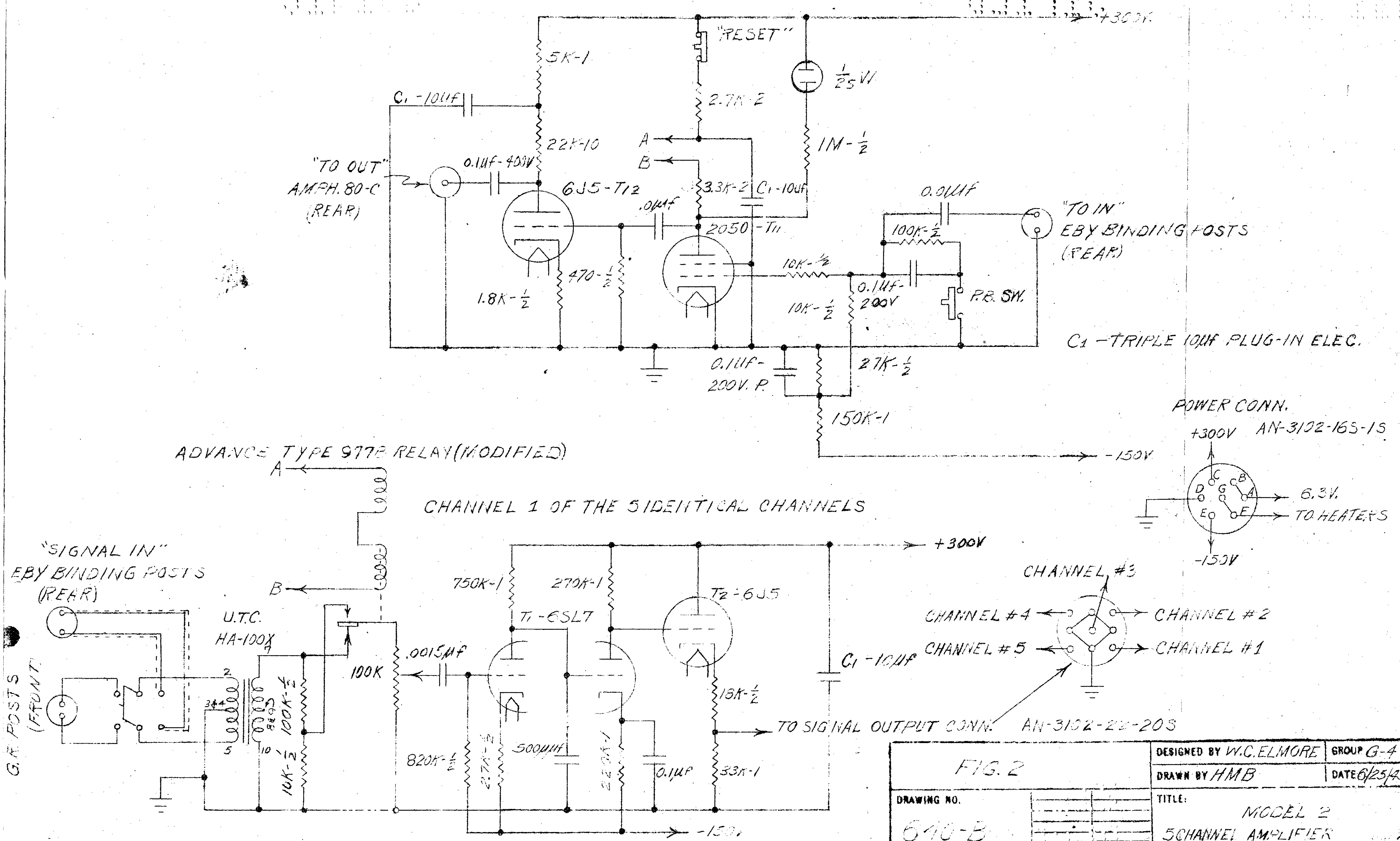


FIG. 2

DESIGNED BY W.C. ELMORE GROUP G-4
DRAWN BY HMB DATE 6/25/45
DRAWING NO. 640-B
TITLE: MODEL 2 5 CHANNEL AMPLIFIER
CHANGE DATE

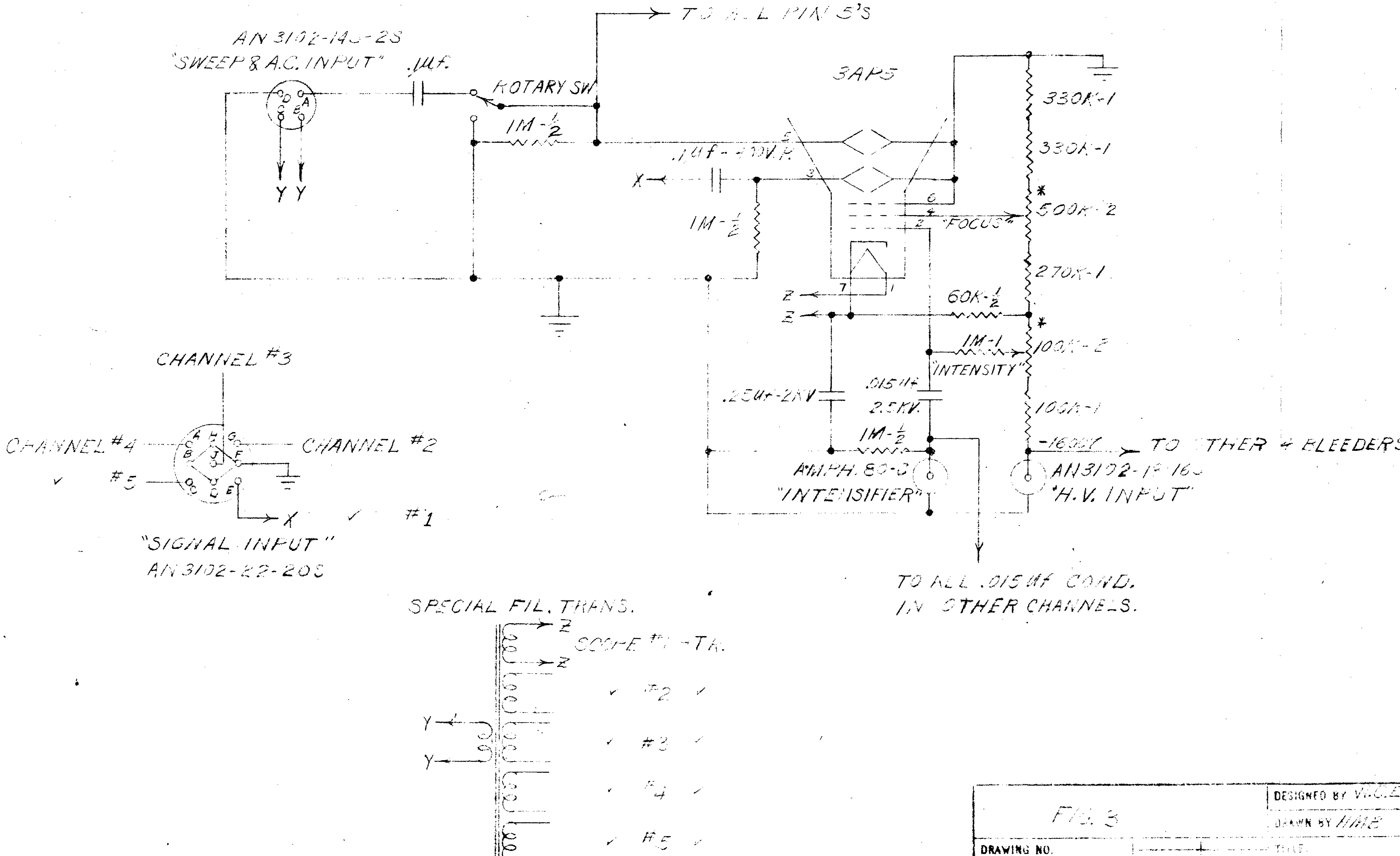


FIG. 3

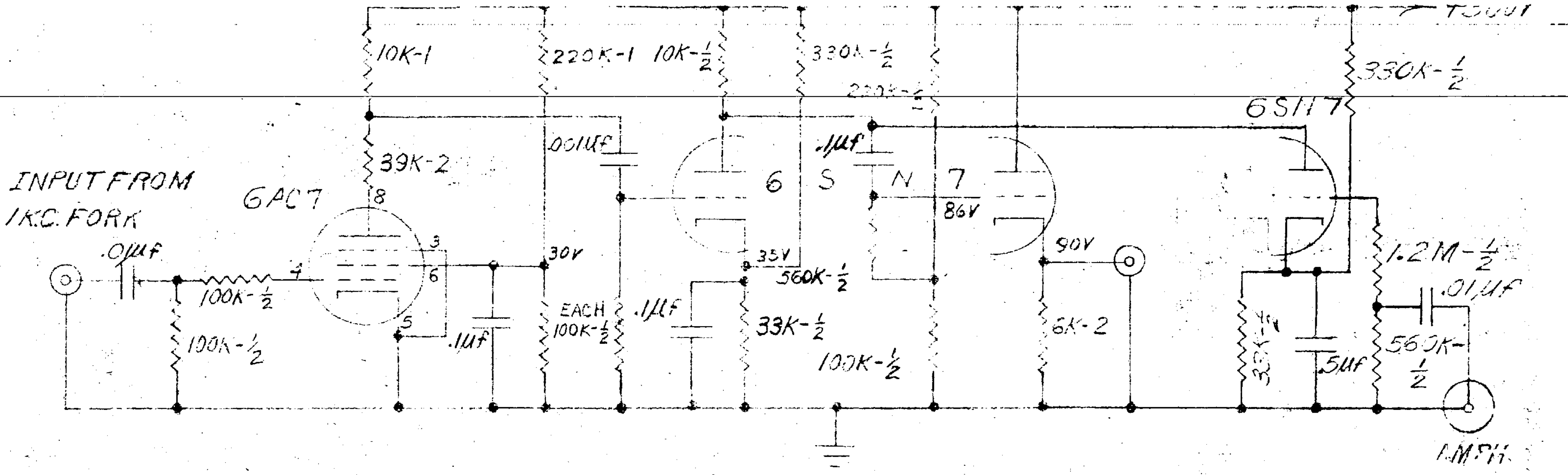
DESIGNED BY W.C. ELMORE

DRAWN BY HMB

DRAWING NO. 640-A

TITLE 5 BARREL SCOPE UNIT FOR 5 CHANNEL AMPLIFIER

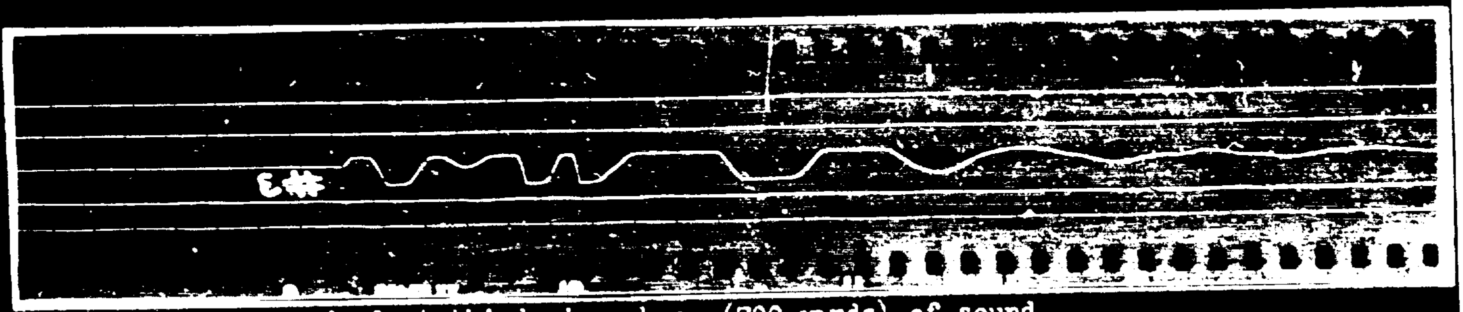
CHANGE DATE



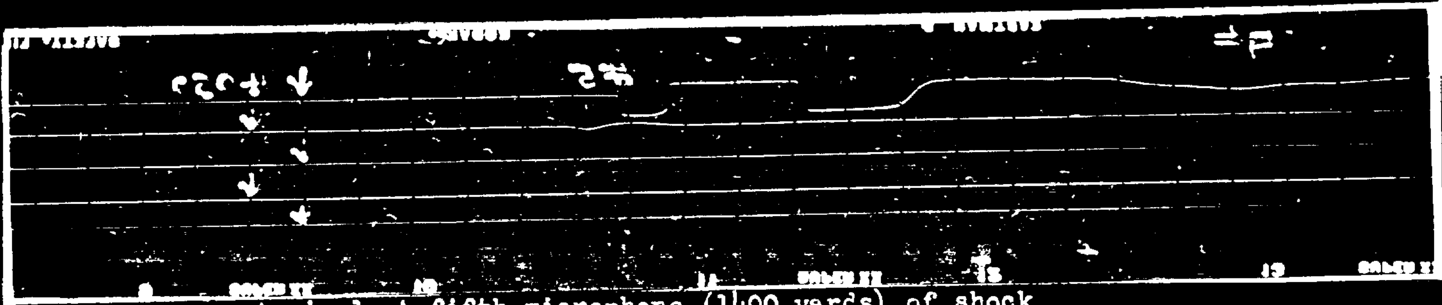
NOTE –
USE WITH MODEL 50 POWER SUPPLY, DWG. NO. 390

FIG. 4	DESIGNED BY TITTERTON — GROUP G-4
	DRAWN BY HMB — DATE 4/3/45
564 REV. — REV. (CHANGE) 6/18/45 (DATE)	TITLE: 1000 CYCLE BLANKING CIRCUIT

North Stations



Arrival at third microphone (700 yards) of sound wave from 5-lb charge.



Arrival at fifth microphone (1400 yards) of shock wave from nuclear explosion.

Blanking marks on traces appear every millisecond. The trace from the first station is at the bottom of the record; the others follow in order. Time increases from left to right.

Fig. 5

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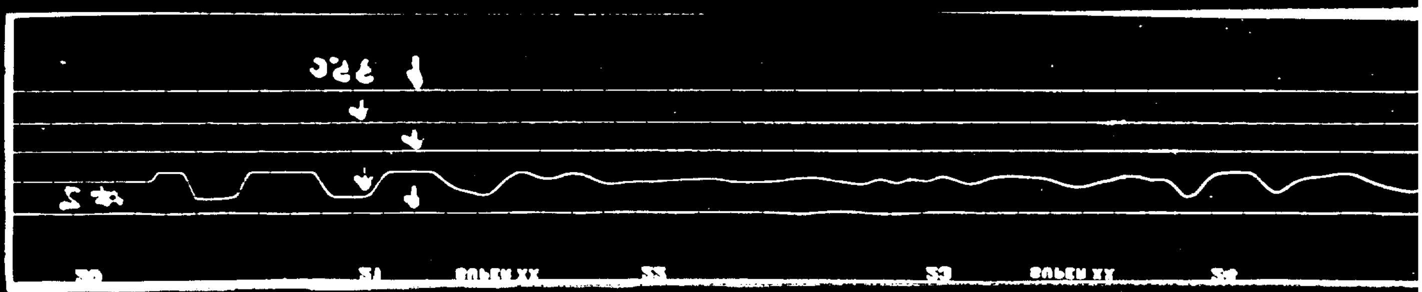
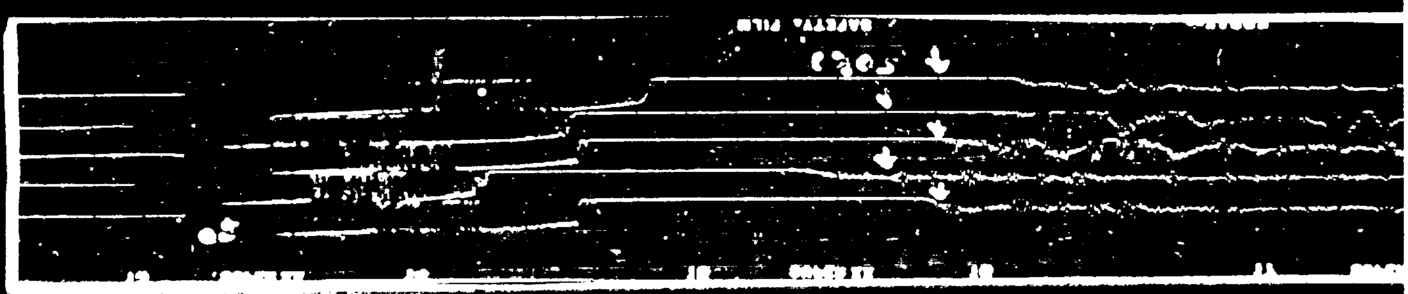
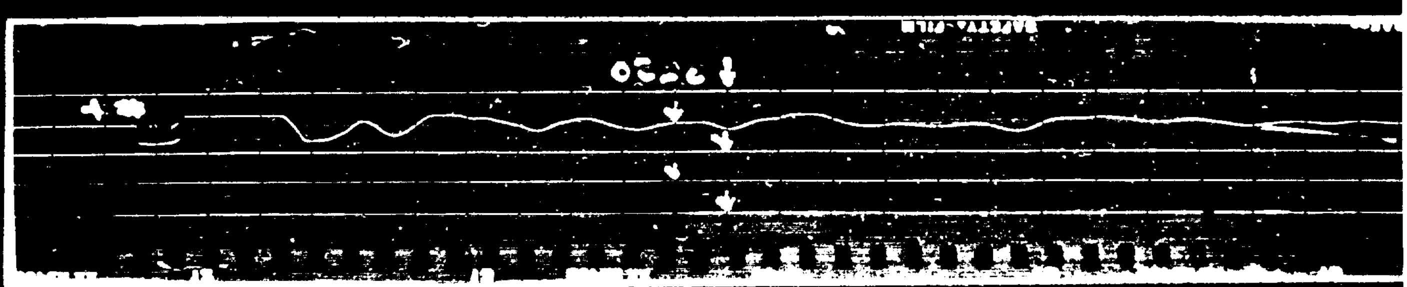
South Stations



Arrival of sound wave from 5-lb charge at second microphone (500 yards).



Blanking signal and pickup at t_0 (firing time of nuclear explosive). The gain was reduced about ten milliseconds after t_0; in the process, the amplifiers were disconnected for seven milliseconds.



Arrival of shock wave from nuclear explosion at fourth microphone (1000 yards).

Fig. 6

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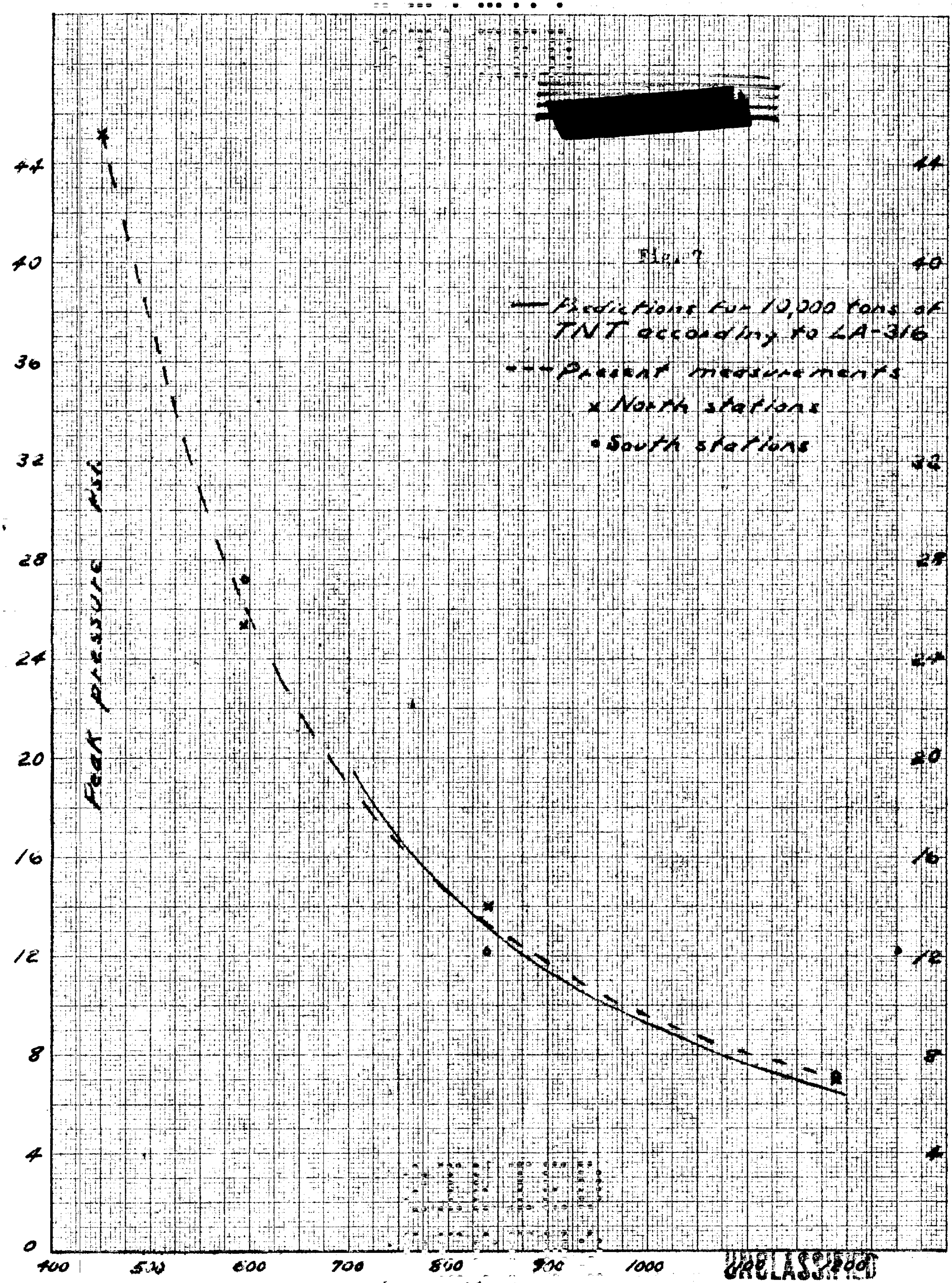

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