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OPERATION CROSSROADS

REPORT OF

BUREAU OF SHIPS INSTRUMENTATION GROUP

SECTION X

Shock Measurements

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Director
Defense Atomic Support Agency
Washington, D. C. 20301

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(6) OPERATION CROSSROADS.

Report of

BUREAU OF SHIPS INSTRUMENTATION GROUP,

SECTION X.

SHOCK MEASUREMENTS [U],

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Director
Defense Atomic Support Agency

(11) 1947, (12) 1v.

10 R. E. Blake, J. P. Walsh I. Vigness.

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ATOMIC ENERGY ACT 1954

Report On

SHOCK MEASUREMENTS

The measurements reported on herein were made by Messrs J.P. Walsh, R.E. Blake, W.M. Mitchell, and Lt. P.T. Egbert, USNR, all of the Naval Research Laboratory. The report was prepared by Mr. R.E. Blake, with the guidance and assistance of Mr. J.P. Walsh and Dr. I. Vigness.

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SECTION I

INTRODUCTION

This report is concerned with the shock motion produced aboard the target ships by the Able and Baker test explosions. Measurements of shock motion are of prime interest in order to determine the motions and forces to which shipboard equipment is subjected.

Approximately 315 shock measurement gages were installed on nine (9) destroyers, eight (8) submarines, two (2) cruisers, three (3) battleships, and three (3) attack transports. Each gage was placed at an actual or potential location of shipboard equipment (turbine, switchboard, electronic gear, radar antenna, etc.) with the purpose of measuring some characteristic of the shock motion (i.e. peak acceleration, velocity-time curve, frequency-response spectrum, etc.). The following types of gages were used:

Gage	Number Used	Symbol
Putty Gage	176	G
Multi-Frequency Reed Gage	47	R'
Motorized Reed Gage	18	R''
Velocity Meter	20	V'
Indenter Gage	46	Q
Shock Displacement Gage	8	O

The material in this report is arranged according to the following outline:

Section II is a discussion of the theory, description, and accuracy of the various gages.

Section III is a discussion of the overall plan or philosophy of the gage locations.

Section IV is a detailed ship-by-ship description of individual gage locations and presentation of the data for each gage. The group of data for each ship is followed by a discussion of that data.

Section V is a discussion of all the data and a comparison of the data from different ships.

Section VI presents the conclusions drawn from the tests.

SECTION II

GAGE CHARACTERISTICS *

Putty Gage.

The putty gage is a mechanical instrument designed to measure the maximum value of the acceleration to which it is subjected. The diagramatic sketch, Figure 1, shows the major features of this gage. In the sketch, Part 1 is a weight which is pressed against the top of the gage frame, 3, by the precompression of the spring, 2. An extension of the weight has a conical point which is about .001 inch from the surface of the plasticine (putty) insert 4.

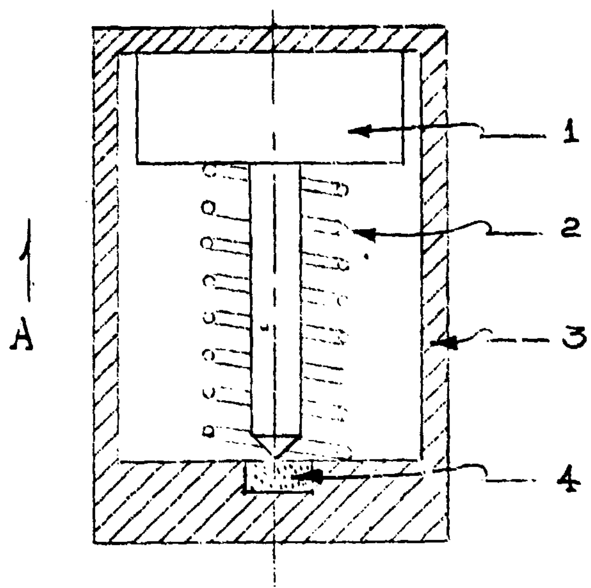


Figure 1 - Single Element of Putty Gage.

When the frame is accelerated in the direction indicated by the arrow, the acceleration and motion of the weight will be identical to that of the frame as long as the force exerted by the spring exceeds the inertia force of the weight against the spring. At some critical acceleration, the weight can no longer be held against the frame and it will then indent the putty. For gradually applied acceleration, the critical acceleration, A_c, is given by the equation $A_c = \frac{F_s}{M_w + \frac{1}{2} M_s}$ where M_w and M_s are the mass of the weight and spring, respectively, and F_s is the precompression force of the spring.

* The theory of some of these gages is taken in part from Reference 1. An addition to Reference 1 will contain the discussion of this section in more complete form. The References are listed at the end of Section III.

The plasticine inserts were in a plastic disk so keyed to the frame that the inserts could be identified after removal of the disk from the instrument. The gages were read by measurement with a travelling microscope of the diameter of the indentations which had been made in the inserts. The maximum acceleration of the gage is assumed to lie between the larget critical acceleration of those elements whick made indentations and the lowest critical acceleration of those elements which did not make indentations. The accelerations reported are interpolations between these two values based upon the size of the indentations made.

Each putty gage used in the tests had eight elements with critical acceleration values ranging from 20 to 2500 g. (g is the acceleration of gravity.) In order to concentrate the critical accelerations of a gage in the neighborhood of the expected reading, two ranges of critical acceleration were standardized upon. These accelerations are tabulated in Column 1 of Tables I and II.

TABLE I

Low Range Putty Gages

Element No.	1 A_c (g)	2 T (Milliseconds)	3 F_s c.p.s.	4 M_s/M_w	5 A_c/A for $T_o/T=1$	6 A_c/A for $T_o/T=1$
1	20	1.38	362	.070	.66	.88
2	50	1.38	362	.070	.77	.95
3	90	1.02	490	.214	.77	.95
4	150	1.02	490	.214	.85	.97
5	300	0.52	970	.519	.74	.94
6	700	0.52	970	1.58	.88	.98
7	1200	0.52	970	1.58	.92	.98
8	1800	0.52	970	1.58	.96	.99

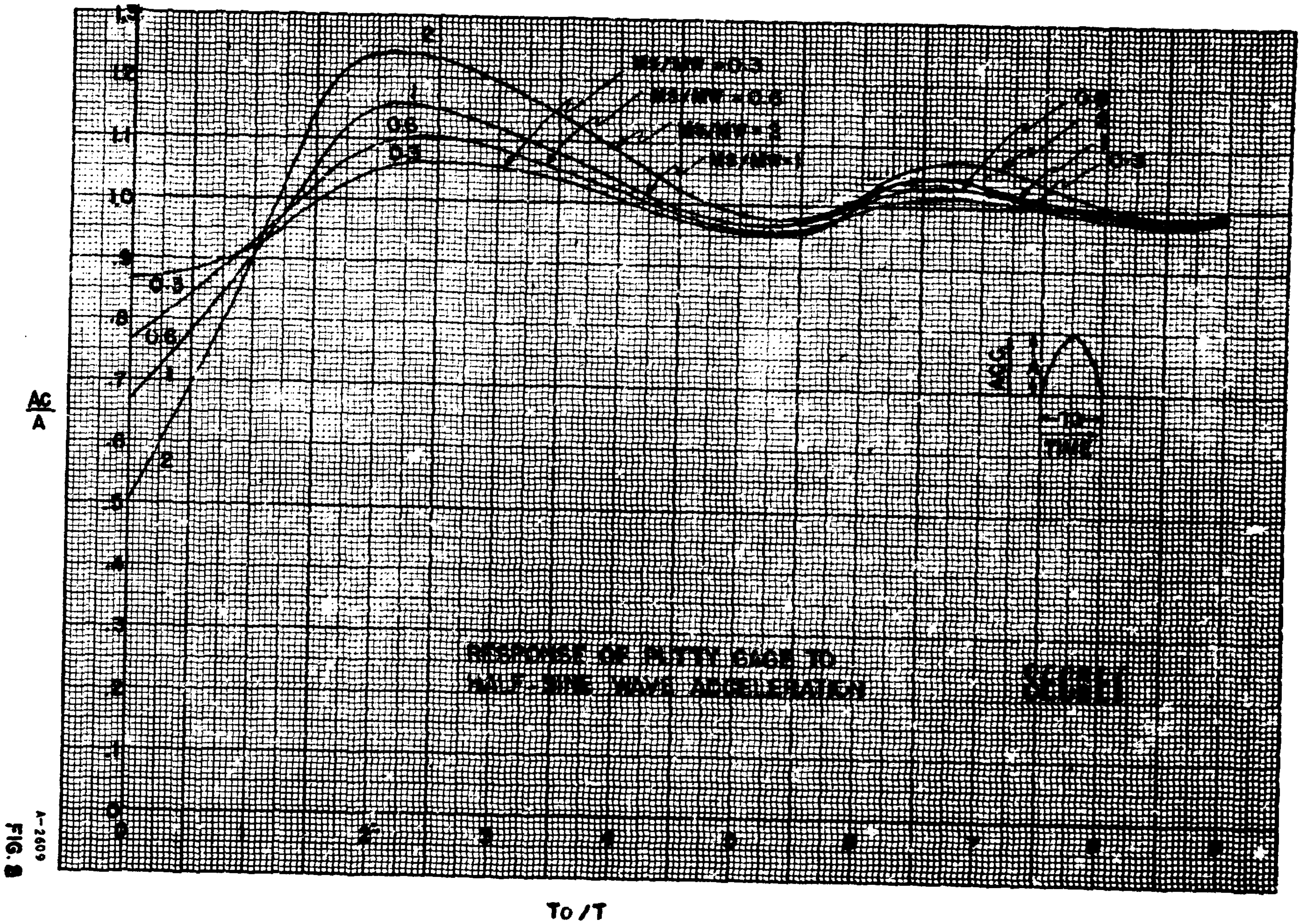
TABLE II

High Range Putty Gages

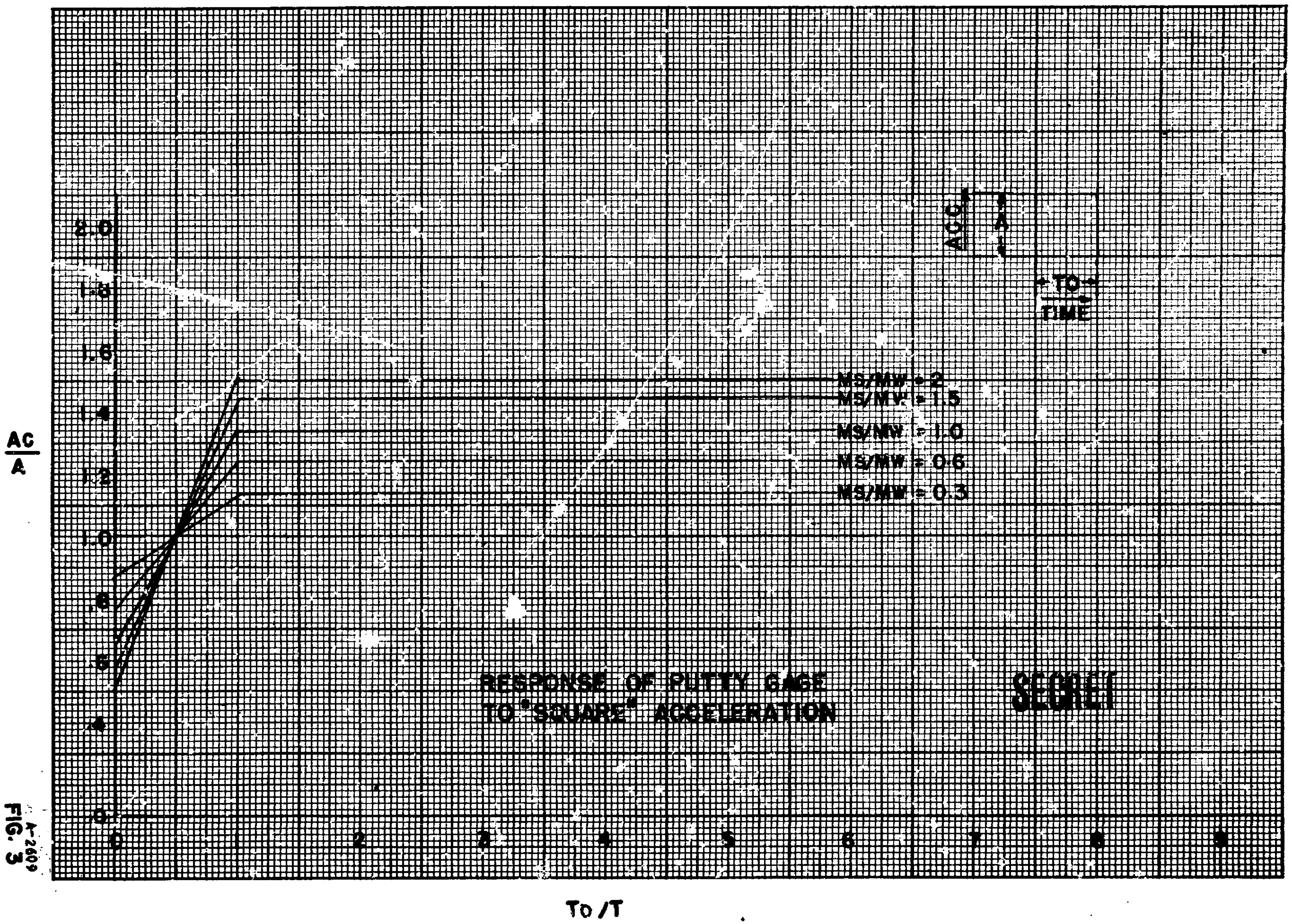
Element No.	1 A_c (g)	2 T (Milliseconds)	3 F_s c.p.s.	4 M_s/M_w	5 A_c/A for $T_o/T=1$	6 A_c/A for $T_o/T=1$
1	50	1.38	362	.070	.77	.95
2	100	1.02	490	.214	.79	.95
3	300	.52	970	.519	.74	.94
4	650	.52	970	.519	.87	.98
5	1000	.52	970	.519	.91	.98
6	1500	.52	970	1.58	.94	.985
7	2000	.52	970	1.58	.97	.99
8	2500	.52	970	1.58	.98	.995

ACCURACY OF THE PUTTY GAGE

The assumption of a gradually applied acceleration in calculation of the critical acceleration is not valid for shock motions when the time required for severe fluctuations of the acceleration is of the same order of magnitude as the transit time of a stress wave through the spring. The curves of Figures 2 and 3 indicate the magnitude of the error to be expected when an acceleration pulse is short. In each curve A_c is computed by the formula of page 2; A is the actual peak acceleration of the gage frame; T is the time required for a longitudinal stress wave to pass from one end of the spring to the other; T_o is the duration of the pulse; and M_s/M_w is the ratio of the mass of the spring to that of the weight. T and M_s/M_w are listed in Columns 2 and 4 of Tables I and II. These curves were derived theoretically, using the assumption that indentation of the putty occurred as soon as the weight lost contact with the frame. Actually, the clearance between the cone point on the weight and the putty surface is about .001", which causes too low a reading for short duration pulses of acceleration. The only analyses available consider the two effects separately. The effect of clearance alone is indicated in Tables I and II by Column 5 (A_c/A when $T_o/T=1$) for a half-sine pulse, and Column 6 (A_c/A when $T_o/T=1$) for a square-wave pulse. If the two effects were combined, we would have curves resembling those of Figure 2 and 3 except A_c/A would be closer to 1 in the region $T_o/T>2$ and A_o/A would be very small as T_o/T approaches zero.


RESPONSE OF PUTTY GAGE TO
HALF-SINE WAVE ACCELERATION
AC/A
To/T
TIME

A-2609
FIG. 8



AC/A
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
0
0
2
3
4
5
6
7
8
9
To /T
MS/MW = 2
MS/MW = 1.5
MS/MW = 1.0
MS/MW = 0.6
MS/MW = 0.3
ACC
A
TO
TIME
RESPONSE OF PUTTY GAGE
TO "SQUARE" ACCELERATION
SECRET

A-2609
FIG. 3

Thus the putty gage shows good accuracy for $T_o/T > 2$ and reads to low for shorter pulses. Fortunately, the stress produced in equipment is not proportional to acceleration when the pulse duration is much shorter than the natural period(s) of vibration of the equipment, but is more nearly proportional to the velocity change produced by the pulse. For this reason, an acceleration of 1000 g. of duration 1/2 millisecond will produce only slightly higher stress in most equipment than 500 g. of 1 millisecond duration. Therefore, the occurrence of low readings for short pulses are not of great practical significance.

A large error can be caused if resonant vibration of a putty gage spring is induced to transient vibration of the supporting structure. There resonant frequencies, F_s, are odd integer multiples of the values in Tables I and II, Column 3. There seems to be no reason why the stress fluctuation in the spring cannot built up to a value equal to the precompression of the spring, in which case an acceleration of less than one half A_c will cause indentation. The occurrence of resonance is expected to have been rare and, in order for it to be misleading, it had to permit premature indentation of particular elements. For example, if plungers 1, 2, 3, and 7 of a gage showed indentation, Number 7 would have been ignored. Also, resonance in spring number 1 is insignificant. Thus, while resonance can cause large errors, such errors are the result of a coincidence and therefore must have occurred in only a few gages.

Accidental indentation could have occurred in the two weeks prior to and after tests during which the gages were being installed or serviced at their test locations. Two cases of accidental indentation were found and corrected just prior to the Baker test, one due to straightening of some bulkheads of a destroyer with a sledgehammer and one due to firing of a small test charge near an APA. The chance that large errors due to jolting of structure near installed gages occurred is believed to be small. Except in the case of the small test charge, accidental indentations which were found did not exceed 100 g.

The error in interpolating between the critical accelerations of the plungers probably did not exceed ±25 per cent of the interval between successive critical accelerations. The putty gages were usually in a group of other types of gage and their readings can be checked against those of the read, indenter, and velocity gages.

REED GAGE.

A multi-frequency reed gage contains eight flat spring steel strips, each of which is firmly clamped to the gage frame at one end and has a brass weight fixed to the other end. The fundamental natural frequencies of vibration of these reeds are 20, 40, 100, 210, 345, 435, 570, and 920 cycles per second, respectively. Motion of the reed tip relative to the gage frame is marked on a sheet of waxed paper fixed to the frame by means of scribers which are fixed to the reed tip. The record on the paper then shows the maximum deflection of the reed tip up and down from its neutral position.

The significance of the reed gage data is derived from the theory of the response of complex elastic (linear) structures to a given shock motion of the foundation of the structure. References 2 and 3 show that the distortion of the elastic structure may be considered to be made up by superposition of the natural modes of vibration of the structure. Also, the amplitude of each mode depends only upon the natural frequency of the mode, a factor depending upon where the shock motion is introduced, and the shock motion. If the elastic distortion of a single-degree-of-freedom system of a certain natural frequency, f_n, for a given shock motion is known, the distortion of a mode of a complex system which has the same natural frequency can be found. Thus, the reed gage records indicate the effect of the shock upon simple structures and comparison of records from different locations indicated the relative damage capacity of the shock at the different locations.

The reed gage record is plotted in this report as the ratio of maximum tip deflection to static deflection versus reed natural frequency. This is usually called a frequency-response curve. The static deflection of a reed is determined from its natural frequency f_n by the formula $\delta_s = \frac{4\pi^2 g}{f_n^2}$ and the maximum tip deflection x up and down for each reed is measured from the record. The ratio x/δ_s corresponding to a particular f_n then is the maximum number of "g" which a simple system having the same f_n would be subjected to by the shock.

The nature of the shock itself can be partially reconstructed from the reed gage record by comparing the frequency-response curve with the known curves for certain simple shocks. An "equivalent" simple shock which will produce roughly the same frequency-response curve can thus be selected. The value which x/δ_s approaches as f_n approaches infinity is the peak acceleration of the shock. Since the reed gage is very inaccurate for high values of f_n, this fact has been used to improve the accuracy of the curve in this region by plotting the peak acceleration found by an adjacent putty gage at about $f_n = 1000$ cps.

The value of f_n at a maximum value of x/δ_s indicates the predominant frequency of the shock. Study of the frequency response curve for several types of simple shocks illustrated in reference 4 shows that the predominant frequency is approximately equal to the reciprocal of twice the duration of a single-pulse shock (half-sine wave, square wave, triangular wave, etc., of acceleration) or is equal to the frequency when the shock is a steady or transient vibration. The predominant frequency found for a reed gage on the shell of a ship should approximate the reciprocal of twice the duration of the explosion pressure wave. The predominant frequency for interior locations in the ship will be lower and indicate to what extent the intervening structure acts as a "shock mount" for interior equipment.

In addition to the frequency-response curves, the 20 and 40 cycle reed amplitudes are tabulated because they approximate the amplitude to be expected of shock mounted equipment and thus supplement the lead (x) gage measurements.

ACCURACY OF REED GAGES

There are several possible sources of deviation of reed gage performance from the theoretical ideal. Most important is the inaccuracy of measurement of the records. From experience in measuring these records, it is estimated that an accuracy of $\pm$ .01" is the best possible. The error in the curves plotted is therefore $\pm .01/\delta_s$. Since δ_s decreases rapidly with increasing f_n, the error probably amounted to several hundred percent for the highest frequency reed. The probable error is tabulated below for each reed.

f_n	Error in g	f_n	Error in g
20	.41	345	123
40	1.64	430	189
100	10.4	570	332
210	45.2	920	868

As mentioned before, the reading of an adjacent putty gage has been plotted on each frequency response curve to indicate the value of x/δ_s which the high frequency reeds should approach.

In a few cases, the amplitude of the low frequency reeds was so great that the scribers went off the edge of the recording paper. This is noted on the curves for the reeds to which this happened. The points plotted represent the distance to the edge of the paper. The actual x/δ_s was, of course, greater than that plotted.

The reeds are not pure single-degree-of-freedom systems as is required by theory since they have many natural frequencies above the fundamental and they are nonlinear at high amplitudes. The record of motorized reed gage R''3 of the DD408 on test Baker shows clearly an example of simultaneous excitation of two natural frequencies of the 20 cps reed. The next higher natural frequency observed is estimated from this record to be 350 cps. Due to the high ratio of the higher frequencies to the fundamental, and as the displacements caused by the higher frequencies are small, it is assumed that the contribution of higher harmonics to a reed is negligible.

It is known that the assumption that the reed tip deflection will be the same as the deflection of a mass-on-weightless-spring system of the same natural frequency is not valid. This error is in addition to the effect described in the preceding paragraph and is due to the fact that the scriber is located at the center of the brass weight while the point at which the mass should be considered to be concentrated is closer to the base of the reed. This error increases as the mass of the reed becomes larger relative to that of the brass weight. The readings used in this report are all actual reed deflections and are therefore larger than would have occurred with the more theoretically desirable mass-on-weightless-spring system. Factors by which the reed deflections should be multiplied to convert to the simple mass-spring system deflections have been obtained from experiments subjecting a reed gage to known simple shocks. While these factors may be subjected to revision, they are tabulated below in Table III to indicate the relative magnitude of error only. It is of interest to note that the factor

f_n	Factor	f_n	Factor
20	.98	345	.68
40	.94	430	.65
100	.86	570	.68
210	.78	920	.614

for the first mode of a simple cantilever (no brass weight) is, by theory, equal to .64. The effect of the higher modes would be to make this factor somewhat greater.

The motion of the reeds was damped by the friction of the waxed paper which tended to reduce the reed amplitude, particularly in the case of resonance of a reed frequency with a transient vibration. The amount of damping is indicated on motorized reed gage records at the end of Section IV, which were made by dropping the gage onto a heavy steel anvil. Measurement of the decrement shows that the decrement per cycle is independent of amplitude, which is characteristic of Coulomb damping. Typical measurements are tabulated below in Table IV for those reeds which could be measured.

TABLE IV

f_n	Decrement/cycle inches	Decrement/second in/sec.
20	.132	2.65
40	.115	4.60
100	.014	1.40
210	.004	.82

The reed gages had about the same chance for accidental excitation as the putty gages.

MOTORIZED REED GAGES

The motorized reed gages are identical to the reed gages, just described, except that the spools of recording paper had electric-motor drives which were started just before the test explosions. The records obtained showed the variation of reed amplitude with time. The time scale was not recorded separately on the paper but could be estimated from the transient vibrations of the reeds.

The records obtained were used to plot frequency-response curves just as was done with the non-motorized gages. Some of the more interesting records are reproduced in Section IV.

The accuracy of the motorized reed-gage record is the same as for non-motorized reed gage except no error due to accidental excitation could occur.

INDENTER GAGE

The indenter gage was designed as a peak-reading accelerometer. Figure 4 shows the essential details of such a gage. The mass M is guided by case C and rests against the hardened steel pins B. The end of B in contact with M is cut off square, but the other end has a 90° conical point and just contacts the flat surface of a soft aluminum plug P.

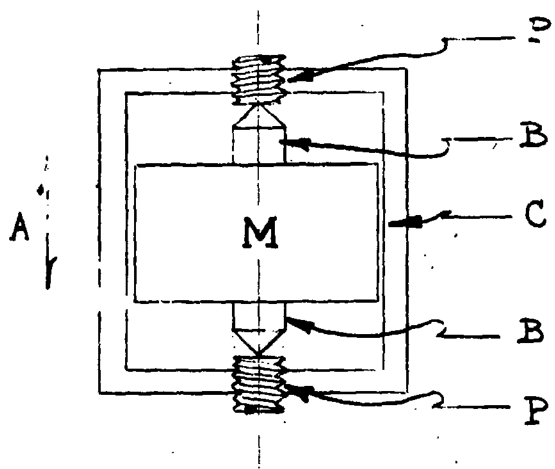


Figure 4

When the case C is accelerated up or down, the inertia of M causes a cone point to be pressed into its aluminum plug. It has been shown for static tests that the depth, d, of penetration of the cone point into the aluminum is related to the applied force F by the formula $F = Rd^2$ where R is an empirical constant. Further, the depth of penetration is uniquely related to the crater diameter of the impression. Assuming that the static law $F = Rd^2$ applies under dynamic loading conditions, we can find the peak acceleration of the mass M from a measurement of crater diameter and a curve of F/M versus crater diameter. However, we are interested in the peak acceleration of the gage case, not that of the internal mass. While the two are equal for a gradually attained steady acceleration, they can be very different for rapidly fluctuating accelerations.

A theoretical analysis of an indenter gage with values of M and R the same as those for the gages used at Bikini has been made by Dr. Paul Symonds of NRL for the case when the gage base undergoes a half-sine wave pulse of acceleration with a peak value of A_p and a duration T. The curves resulting from this analysis are shown in Figure 5.

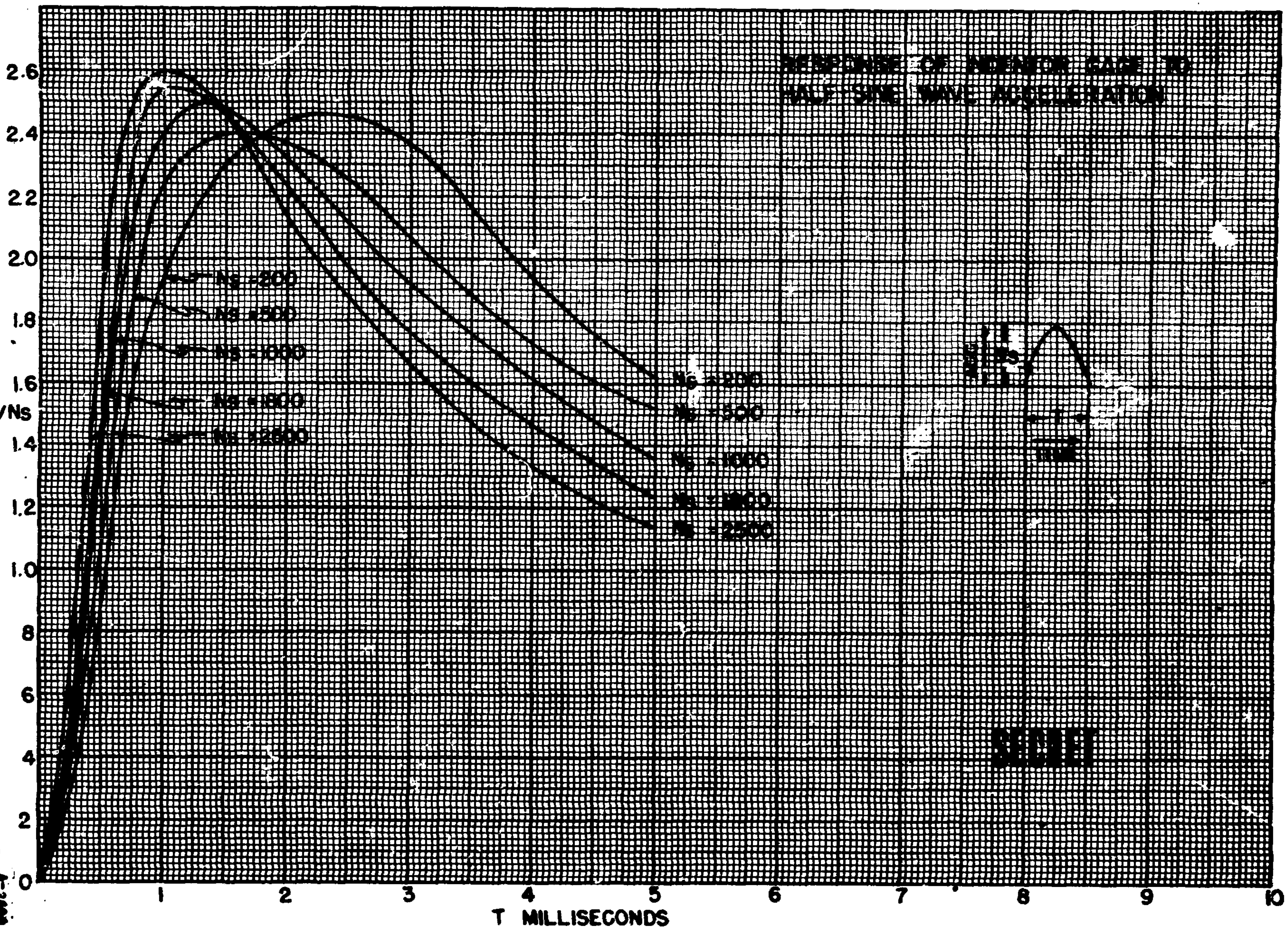

RESPONSE OF INDENTOR CAGE TO
HALF SINE WAVE ACCELERATION
Ns =200
Ns =500
Ns =1000
Ns =1800
Ns =2500
N/Ns
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
8
6
4
2
0
1
2
3
4
5
6
7
8
9
10
T MILLISECONDS
SECRET

FIG. 5 A-2000

The gage reading is too low for T< 1/2 millisecond and is about 2-1/2 times too high for T in the vicinity of 1-4 milliseconds. At larger values of T, the reading approaches the true value.

When the shock consists of a transient vibration, it can be readily seen that the mass M will lose contact with the pin as soon as the acceleration of the base reverses its direction. The mass will "rattle" back and forth between the pins a large number of times. Each impact is theoretically capable to increasing the indentation of the aluminum regardless of how large it may be already. Therefore, no theoretical upper limit can be placed on how much too high the gage will read.

In the gage used, The central mass M was supported by six pins rather than two so that the peak acceleration of the mass would be recorded in both directions for each of the three rectilinear axes of the gage. The orientation of the gage axes relative to those of the ship were recorded. The data tabulated for a gage gives the peak acceleration of the <u>mass</u> calculated by the method outlined above for each of six directions. Each direction gives the bearing and elevation of the acceleration vector. It was not possible to convert these vectors into a set parallel to the principle axes of the ship because it was not determinable whether these vectors were components of some diagonal vector or were the principle vectors of a shock whose direction of motion changed with time.

ACCURACY OF THE INDENTER GAGE

It has been shown in the preceding paragraphs that the indenter gage may be inaccurate for shock motion of the type to be expected. It should be noted however, that the gage will always read too high unless (1) T< 1/2 millisecond, or (2) if the force required for indentation is greater for dynamic than for static loads. It is believed that T was not less than 1/2 milliseconds at the locations where indenter gages were placed. For Baker shot, T would certainly be greater than 5 milliseconds at the locations (in superstructure areas) of the indenter gages. For Able shot, where the blast duration was in the order of a second, it would also be expected that T would be greater than 5 milliseconds. The error involved in above statements will be overshadowed by the other errors already discussed.

Another source of error was the fact that some indentation was unavoidable during assembly of the gage. These usually correspond to about 20 to 50 g so one can be reasonably certain that readings over, say, 100 g were due only to shock.

It should be concluded that the values of acceleration determined from indenter gage readings were somewhat greater than the actual peak accelerations for associated frequencies less than 1000 cps.

SHOCK RECORDING GAGE

The shock recording gage is essentially equivalent to a refined, single-element, motorized reed gage. As shown in the photographs (283-286) of the installed gages, a mass and coil-spring system is used instead of a reed, and motion of the mass relative to the gage frame is marked on a strip of waxed paper which is drawn under the stylus by a motor-driven spool. Time intervals are indicated by firing a spark through the paper at about ten millisecond intervals.

A detailed analysis of these records cannot be made at this time. The acceleration-time curve of the gage base may be obtained from the record by application of the equation $\ddot{X} = w^2 u + \ddot{u}$, where $\ddot{X}$ is the acceleration of the base, w is the natural frequency of the mass-spring system in radians per second, u is the relative motion recorded by the meter, and $\ddot{u}$ is obtained by double differentiation of u with respect to time. Formulas for the velocity, $\dot{X} = W^2 \int u\,dt + \dot{u}$, or the displacement, $X = W^2 \iint u\,dt\,d_t + u$, may be used if preferred. Copies of some of the records are included in this report in Section IV.

VELOCITY METER

The velocity pickup used was originally designed by the British and was extensively used on their "Cameron" trials. Modifications of this instrument were made by the David Taylor Model Basin group and a more detailed description of this instrument can be found in their reports. The essential features of the unit are

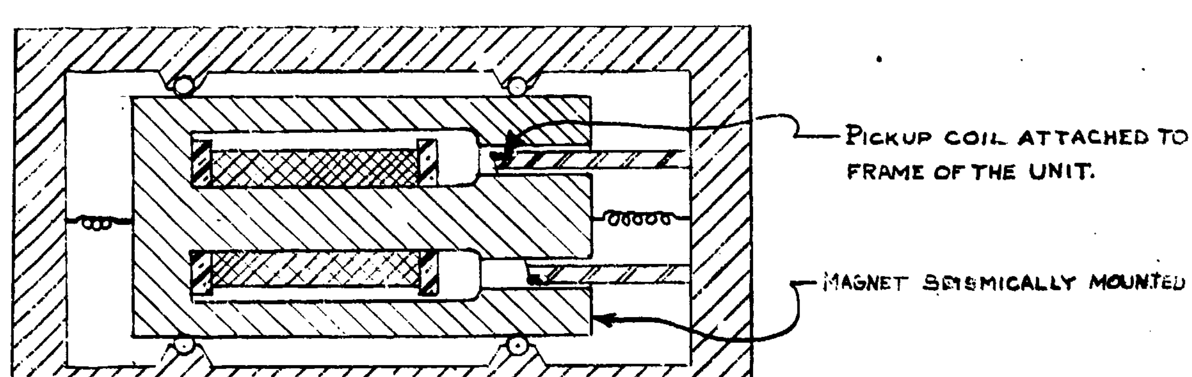


Figure 6. "British Type Velocity Meter."

illustrated in Figure 6. The velocity pickups and their recording systems reported here were operated by personnel from the Bureau of Ships and from the Norfolk Navy Yard.

The system of recording employed was frequency modulation of the signal impressed on a wire recorder. A central or carrier frequency of about 4500 cps. was used. The system of recording and the velocity meter were capable of responding with reasonable fidelity between a frequency range extending from about 10 cps to over 1000 cps. However, it is evident, from the study of the records, that the wire in passing through the recorder suffered transient longitudinal vibrations which effectively caused a considerable background frequency modulation to be impressed upon the record. This background was generally between 15 to 25 per cent of the full scale deflection. As a result, only records for which the real velocity changes were greater than 25 per cent of full scale were noticeable as such. For records in which full scale deflection occurred, the error is estimated to be no greater than 25 per cent. It should be remarked that the principal of recording is excellent and should afford good results if employed with a recorder built with this method in mind.

In inspecting the velocity meter records, the effect of the springs and bottoming of the magnet must be considered. The springs cause a low frequency oscillation of the record at less than 10 cps. When the magnet bottoms against the base of the meter, a sudden reversal of the signal occurs which is rather easy to detect. The stop in the other direction is the relatively flexible top of the meter cover which reverses the signal in a time which is not short relative to the shock motion changes. The magnetic field at the pickup coil drops from full strength to about 50 per cent of full strength as the magnet moves through the last 1/8" to the top stop. The effect of this is to make the meter cover seem even more flexible and make this bottoming difficult to detect. The magnet bottoms after travelling zero or two inch (nominal travel between stops) after a previous bottoming. The travel to a stop from the rest position of the magnet is about one inch. By integration of the velocity-time record, the times at which bottoming will introduce a spurious record can be found. One can also find the direction of motion with respect to the front and back of the pickup unit, by noting whether a velocity results in a hard or soft bottoming of the meter.

SECTION III

INSTRUMENTATION PLAN

<u>Objectives.</u> In order to present the objectives of this work, it is necessary to describe the things that occur in a ship's structure when the ship is subjected to a pressure wave resulting from an explosion. This has been described excellently in Reference 5, Section 3, and it is quoted here:

"When a pressure pulse from a non-contact underwater explosion reaches a ship, its first effect is to cause or tend to cause a certain amount of elastic distortion of the hull. This effect can be sub-divided into two parts. First, the shell plating between frames will be dished inwards, and second, there will be an inward movement of the ship's side or bottom as a whole.

"When the pressure in the pressure pulse is reduced, the elasticity of the shell plating and the ship's framing will tend to cause these items to return to their original shape, provided their elastic limit has not been exceeded and both shell plating and framing will oscillate until their energy is exhausted.

"Internal structures which are connected to the hull will therefore be subjected to forces caused by the movement of the shell plating and framing as a result of underwater explosions. These forces will cause the structures to oscillate, the actual characteristics of the movements depending on the mass and stiffness of the loading structure, the mass of the shell plating, framing and entrained water, and the stiffness of the shell plating and framing.

"Decks and bulkheads which are not in direct contact with the hull below the waterline will receive shock forces via structures linking them to the hull below the waterline. These structures, by virtue of their mass and flexibility, will tend to reduce the shock forces transmitted to such decks and bulkheads."

The objectives of the instrumentation was to determine the characteristics of the motion of the various parts of the ship due to the pressure wave resulting from the explosions of the atomic bombs. Since it is these shock motions of the structures which cause damage to equipment attached to these structures, it is necessary in order to design equipment and shock mountings to determine the shock motions to which equipment is subjected. Summaries of the instrumentation plans for the various types of ships follow.

I. DESTROYERS

The Destroyers chosen for instrumentation were those which were in the westerly string. Two ships, the DD404 and the DD408, were instrumentated much more completely than the other ships in the string. Putty gages, reed gages, and velocity meters were installed throughout these two ships, starting in the aft fire room on the keel top, then on external frame numbers in the same compartment. In the engine room, gages were installed on the following foundations: The main switch board, low pressure turbine, and the turbo-generator. It was considered that these gages would give data that was representative of conditions below the main deck.

The second group of gages installed on the DD404 and 408 were those in the superstructure. Gages were installed on frame numbers on both the first and second superstructure deck level, in the main battery fire control director, and the radar antenna mounting brackets at the top of the fore mast. Only putty gages were installed at the top of the fore mast but in all other locations clusters of gages made up of putty gages, reed gages, and velocity meters were installed. The objective of the instrumentation of the DD404 and DD408 was to determine the characteristics of the shock in various parts of the ship due to the explosion. One sort of thing which this data would yield would be the relation between the shock experienced by equipment which was installed on foundations attached to the hull numbers and the shock experienced by equipment in the superstructure. It was hoped that an empirical relationship could be extablished concerning the characteristics of the shock delivered to the keel as compared to the shock transmitted to various other parts of the ship as one moved up from the keel through the structure to the main battery director and then to the masthead.

In addition to the gage mentioned above, for the B shot, four shock recording gages per ship were added. These gages were located close to the "A" shot gages as follows: One on the keel top, one on an external frame number 5' below waterline, one on frame 5' below main deck, and one on the low pressure turbine foundation.

On the remainder of the ships in this Destroyer string, putty gages and reed gages were installed on the keel and on a frame number in the fire room and two putty gages were installed in the superstructure. The gage locations were selected on each ship to be as much similar to the location on the DD404 and DD408 as possible. These gages were essentially range gages. The results would give data on the shock characteristics as a function of the distance of the ship from the explosion.

Since these range gages were in locations which were similar to those on the ships which had a more complete instrumentation, it was considered possible to draw conclusions concerning the shock characteristics throughout the ship with the data from the range gages and the conclusions drawn on shock propagation through the ships structure as a result of the analysis of the data from the gages on the DD404 and DD408.

II. SUBMARINES

The instrumentation plan for the submarines was similar to the plan for the destroyer instrumentation in that two of the target ships had a relatively large number of gages installed to give data on the transmission of shock through the structure of the ship while the remaining six ships had but two gages, each installed to give data on the intensity of shock as a function of distance from the explosion.

In all eight ships the range gages, one putty gage and one reed gage, were installed on the flange of a hull stiffener in the torpedo room and on the side of the ship which was closer to the explosion. Except for the SS308 and the SS335, this constituted the instrumentation. However, in the cases of the SS308 and SS335, in addition to these range gages, twelve putty gages were installed in each ship to give data on the characteristics of the shock occurring in various parts of the ship. The locations of these gages were as follows: In the engine room on the generator foundation, in the maneuvering room on the supports for the control cubical and also on the control cubical, in the control rooms on bulkhead stiffeners, in the conning tower on the external plates, and on frame and deck beams in the torpedo rooms. The objective of the instrumentation was to obtain data on the characteristics of the shock to which equipment, in the several types of structure of which a ship is composed, was subjected due to the explosion.

CAPITAL SHIPS

The capital ships instrumentated were the battleships USS NEW YORK AND USS NEVADA, and the cruisers USS SALT LAKE CITY and the USS PENSACOLA. These ships were treated individually and not as a group of practically indentical structures as were the destroyers and submarines.

The gages installed were putty gages and reed gages and the locations were chosen with the same view in mind as in the case of the destroyers, namely, to give information concerning the propagation of shock through the structure of the ships.

The gages were installed on the hull well below the waterline on a frame member or some rigid structure attached to the large structural members of the hull in interior compartments above the waterline as well as in the superstructure.

APA INSTRUMENTATION

Very little instrumentation was attempted on the APA's. For the "A" shot, two ships, the APA64 and APA65, has instruments installed, and on the "B" shot the APA87 was added. The instrumentation consisted of putty gages installed on the foundations of equipment. Two gages were installed on external hull frame members, one gage below the waterline and one above the waterline. The others were installed on the following foundations: Main switchboard, main motor, and main generator.

All that was intended to be found from these gages was the peak value of the acceleration which would be guide and check to be used in the analysis of the data from the velocity meters which were adjacent to these putty gages.

REFERENCES

1. I. Vigness, E. W. Kammer, and S. G. Holt, "Shock and Vibration Instrumentation and Measurements, Second Partial Report." RESTRICTED Naval Research Laboratory Report 0-Z645.

2. M. A. Biot and R. L. Bisplinghoff, "Dynamic loads on airplane Structures During Landing" N. A. C. A. Advance RESTRICTED Report No. 4H10.

3. M. A. Biot, "Analytical and Experimental Methods in Engineering Seismology", American Society of Civil Engineers Transactions Paper No. 2183, or Proceedings January, 1942.

4. J. M. Frankland, Ph. D., "Effects of Impact on Simple Elastic Structures" David W. Taylor Model Basin Report 481, RESTRICTED.

5. "Shock Effects from Underwater Explosions" Report on Trials in H. M. S. "Cameron" Carried out by the British Admiralty Shock-in-Ships Committee July, 1942 to September, 1943 BR1314 RESTRICTED.

6. Director of Ship Material, Joint Task Force One, Bureau of Ships Group. "Interim Report for Test Able", and "Interim Report for Test Baker." SECRET

SECTION IV

GAGE LOCATIONS AND DATA

The data is arranged by ships in the following sequence: destroyers, submarines, attack transports, cruisers, and battleships. Ships of a class are in numerical order. Following the data for each ship and class of ships is a discussion of that data.

The following notes explain some of the notation and symbols used in that data.

Note 1. The lowest critical acceleration for the low range putty gage is 20g.; the lowest for the high range gage is 50g. When no indentation was found, the acceleration is recorded as less than 20g. or less than 50g.

Note 2. The orientation of a gage is described as "directed up", "direct to port", etc. "Directed up" means that the gage body is above the mounting base, "directed to port" means that the gage body is to port of the mounting base, etc. A putty gage records only the acceleration vector or its component which is directed in the same sense as the gage.

Note 3. The reed gage deflections are described as "up" meaning toward the top of the gage or "down" meaning toward the mounting base. On the frequency-response curves "up" and "down" refer to the direction toward which the reed deflected even though the accelerations plotted are those of the brass weight and therefore have an opposite direction.

Note 4. Directions indicated in the tables of indentor gage readings are the directions toward which the accerlation vectors are pointed.

Note 5. The following abbreviations and symbols are used:

G	Putty gage
R'	Reed gage
R''	Motorized reed gage
V'	Velocity meter
Q	Indentor gage
O	Shock displacement gage
g	Acceleration of gravity = 32.2 ft/sec.^{2}

f_n	Natural frequency of vibration in cycles per sec.
c.p.s.	Cycles per second
d_s	Static deflection, or the deflection corresponding to a steady acceleration of 1g.
A	Test Able
B	Test Baker

Note 6. Motorized reed gage records for Baker showed several successive shocks but it was not possible to separate the records into a consistent number of pulses. However, the last pulse, due presumably to air blast, was always distinguishable. In preparing frequency-response curves from these records, the maximum amplitudes in the air blast shock record have been labeled "wave 2". Maximum amplitudes due to the preceding group of shocks, presumably water-borne, are labeled "wave 1".

Note 7. The bearing listed for each ship in the comments on that ship is the bearing of the explosion relative to the ship.

Note 8. DSM reports on shock damage to ships are taken from reference 6.

Note 9. Photos of gage locations referred to are in the Photographic Volume of this group of reports.

Note 10. Numbers (1), (2), or (3) following the letter "A" (test Able data) are estimates of the relative shock intensity to be expected at the gage locationand are defined in Section V, DISSCUSSION OF DATA - TEST ABLE.

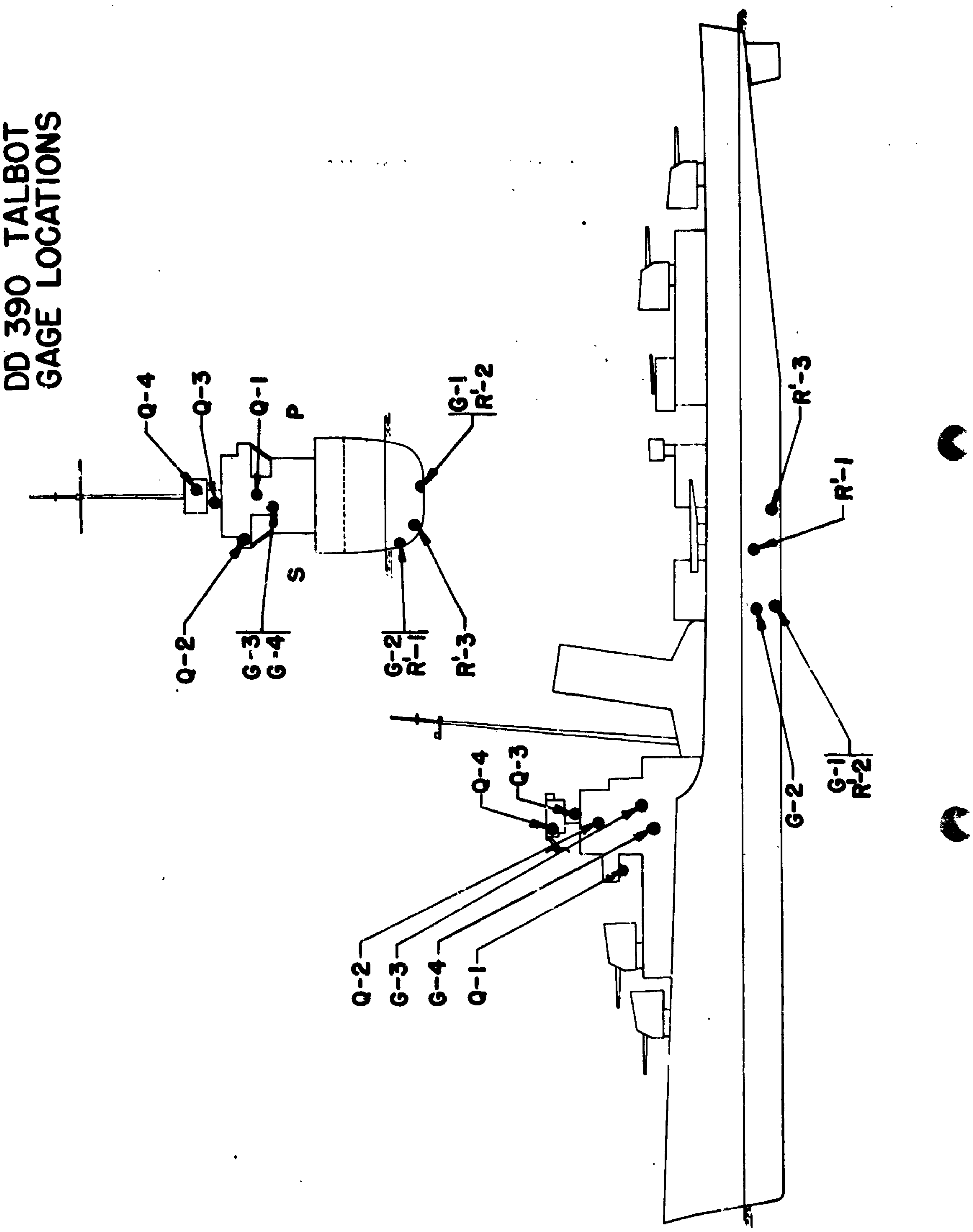

DD 390 TALBOT
GAGE LOCATIONS
Q-4
Q-3
Q-1
P
S
Q-2
G-3
G-4
G-2
R'-1
R'-3
G-1
R'-2
R'-3
R'-1
G-2
G-1
R'-2
Q-4
Q-3
Q-2
G-3
G-4
Q-1

FIG. 7

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DD390 - USS RALPH TALBOT

Putty Gages

G1 - Photo 252. In fireroom compartment B-2-1. Directed up on top of keel at frame 99. Note: Cast iron ballast ingots cover the hull plates for about 2 1/2 ft. either side of keel.

A. (3) 75g. B. 300g.

G2 - Similar to photo 262. In fireroom, compartment B-2-1. Directed inboard normal on flange of Frame 99, 4 ft. below upper grating level on starboard side.

A. (3) less than 50g. B. 60g.

G3 - Similar to photo 291. In C.I.C. room, directed up on deck at frame 62. 5 in. inboard from starboard bulkhead.

A. (2) 60g. B. 100g.

G4 - Photo 253. In passage-way A-0101-36 just forward of ships Office. Directed to port on overhead beam at frame 58. 3 ft. to starboard of ship centerline.

A. (2) 110g. B. 100g.

Reed Gages

R'1 - Similar to photo 260. In fireroom, compartment B-2-1. Directed inboard, normal on flange of starboard frame 100, 4 1/2 ft. below upper grating level.

	20 cps		40 cps	
Graph	Up	Dn	Up	Dn
A. (3) Fig. 8	.105	.10	.02	.04
B. Figure 9	.02	.03	0	0

R'2 - Photo 252. In fireroom compartment B-2-1. Directed up on frame 99 flange. About 1 ft. to starboard of keel centerline.

	20 cps		40 cps	
	Up	Dn	Up	Dn
A. (3) readings all zero.				
B. Figure 10	.10	.07	Record torn	

R'3 - **Photo 254. In fireroom compartment B-2-1. Directed forward on aft starboard support of aft boiler, frame 105.**

A. Readings all zero

B. Readings all zero

Indenter Gages

Q1 - Photo 255. On underside of Mk. 51, 20 mm gun director platform. Directed down at intersection of 3'' I-beam (about frame 55) and 3'' stiffener (on ship centerline). Director platform is just forward of C.I.C. room.

A		B	
Up	85g.	Up	50g.
Dn.	65	Dn	70
40°	760	65°	300
130°	280	155°	390
220°	410	245°	330
310°	615	335°	440

Q2 - Photo 256. On Navigating Bridge deck directed up on deck, 2 in. from base of starboard Mk. 27 torpedo director. Approx. frame 66 1/2.

A		B	
Up	230g.	Up	65g.
Dn	220	Dn	65
75°	1270	60°	40
165°	135	150°	35
255°	1550	240°	65
345°	65	330°	60

Q3 - Photo 257. On top of pilot house. Normal on flange of aft starboard brace of base of Mk. 33 gun director.

A				B			
brg.	19° elev.	28°	250g.	brg.	41°elev.	28°	155g.
brg.	54° elev.	-55°	90	brg.	120°elev.	20°	60
brg.	120° elev.	20°	20	brg.	174°elev.	55°	95
brg.	199° elev.	-28°	260	brg.	221°elev.	28°	220
brg.	246°elev.	55°	70	brg.	300°elev.	-20°	35°
brg.	300°elev.	-20°	20	brg.	356°elev.	55°	80

Q4 - Photo 258. Inside turret of Mk. 33 gun director above pilot house. Directed upon top of port arm of forward U-bracket.

A		B	
Up	50g.	Up	40g.
Dn	30	Dn	30
70°	165	0°	60
160°	40	90°	130
250°	15	180°	85
340°	20	270°	185

COMMENTS

Test Able   Range 3735 ft.   Bearing of burst 139°

The putty and reed gages were not on surfaces exposed to air blast and therefore gave small readings. G4, horizontal within the superstrucuture, probably gave a representative reading (110g.) for interior superstructure locations while readings for locations below the waterline show negligible values. R'1 vertical on the keel shows a low-frequency excitation of about 200-300 cps.

Some indenter gages (Q1, Q2, and Q3) showed very high readings. This is partially in accord with the fact that they were on structures which were struck directly by air blast. Q2 showed its high reading in a direction parallel to the free-air shockwave front which might possibly be due to reflection of the wave from the superstructure. Q2 in particular shows equal high readings in opposite directions which indicates that rattling of the weight caused most of the reading 200-500g. seems to be a reasonable estimate of the peak acceleration of exposed ordnance equipment. Q4 within the gun directer shows a reading of less than 165g. in accord with that of G4 within the superstructure.

Test Baker   Range 5450 ft.   Bearing of burst 265°

The gage locations were planned for direct exposure of the starboard side to the shock waves while the wave actually struck the port side.

The gages below the waterline registered a higher shock at the keel than on the hull away from the blast. The 300g. reading of the keel putty gage is not well substantiated by the adjacent reed gage. However, in consideration of the poor reed gage accuracy at high frequency, the apparent disagreement is explainable if the shock pulse duration is less than 1 millisecond.

The superstructure gages all show vertical accelerations of 100g. or less. Since the 100g. vertical reading occurred on the putty gage in the C.I.C. room and the exposed indenter gages read less vertically, it seems probabe that the origin of the vertical shock was underwater pressure waves. Q1, exposed to air blast, had a 400g. horizontal reading; Q2 was shielded from air blast and had readings below 60g. Q3 was partially exposed to air blast and had a 220g. reading; and Q4 within the gun director had a 130g. reading. These readings indicate that shock due to both air and water blast waves was felt in the superstructure; the horizontal reading due to airborne pressure and the vertical due to waterborne waves. 100-300g. seems a fair figure to assign to shock in exposed ordnance equipment.

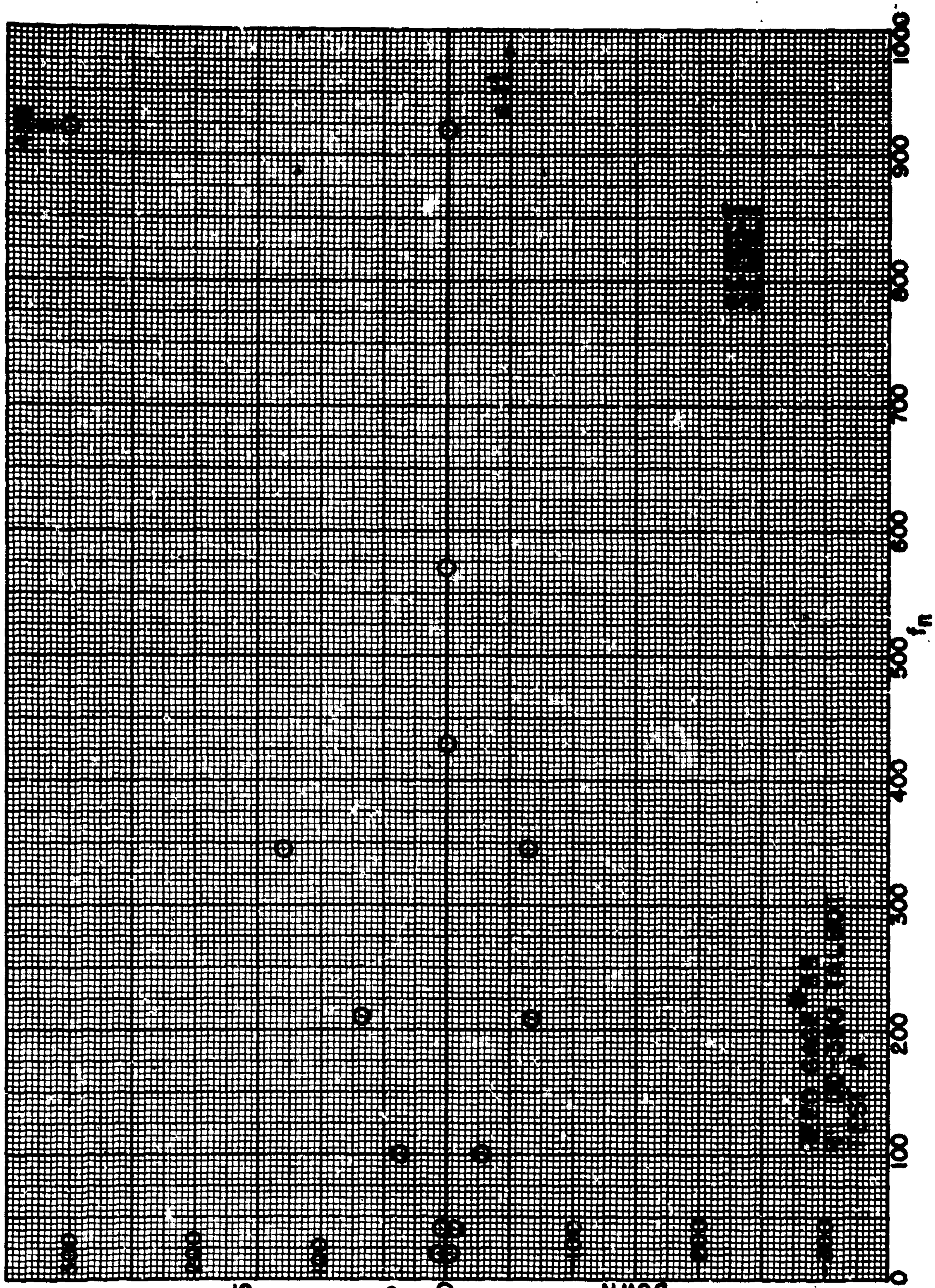
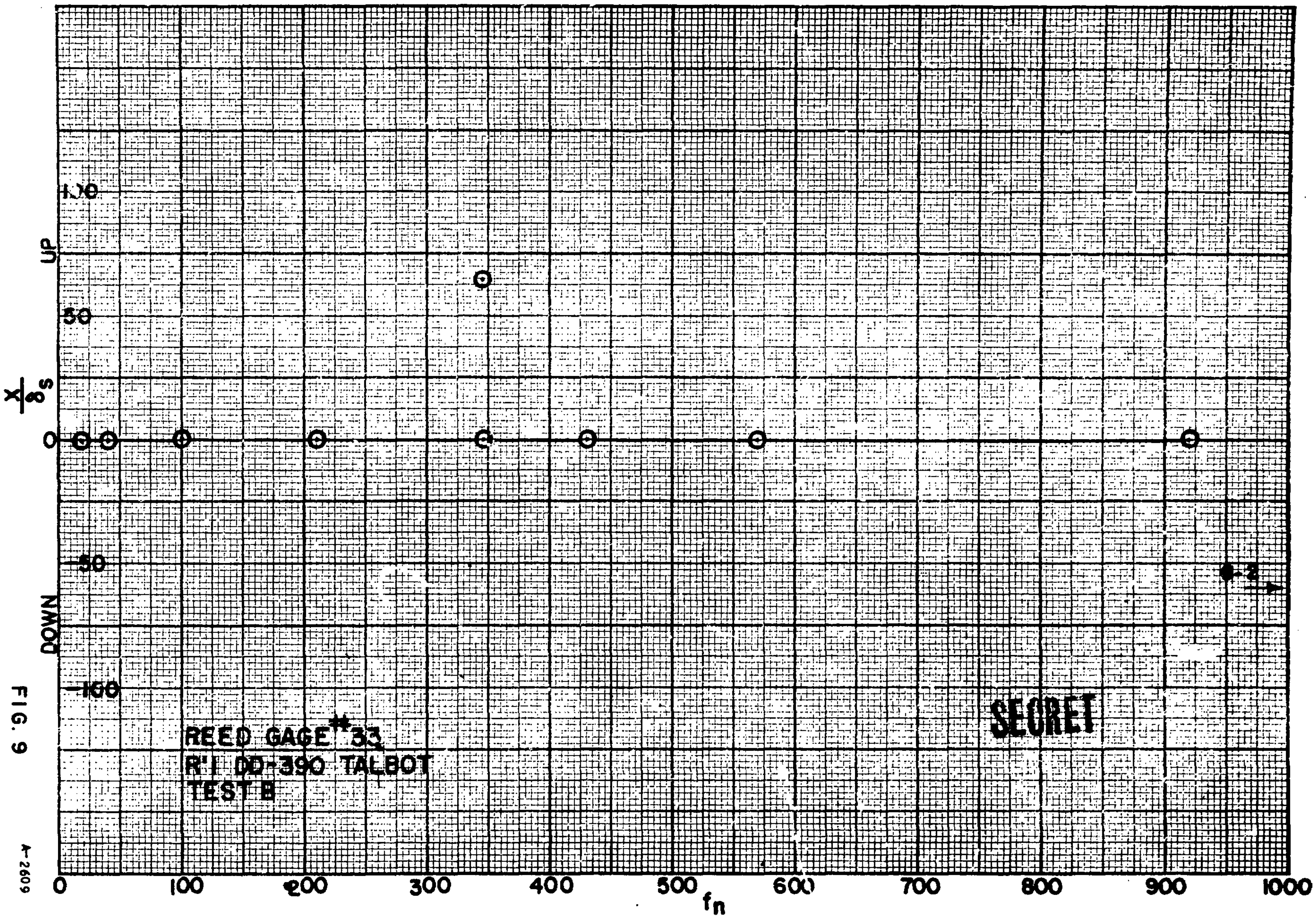

UP
DOWN
0
$\frac{X}{\delta_s}$
f_n
0
100
200
300
400
500
600
700
800
900
1000

FIG. 8



100
UP
50
X/δs
0
-50
DOWN
-100
REED GAGE #33
R'I DD-390 TALBOT
TEST B
SECRET
0
100
200
300
400
500
600
700
800
900
1000
fn

FIG. 9

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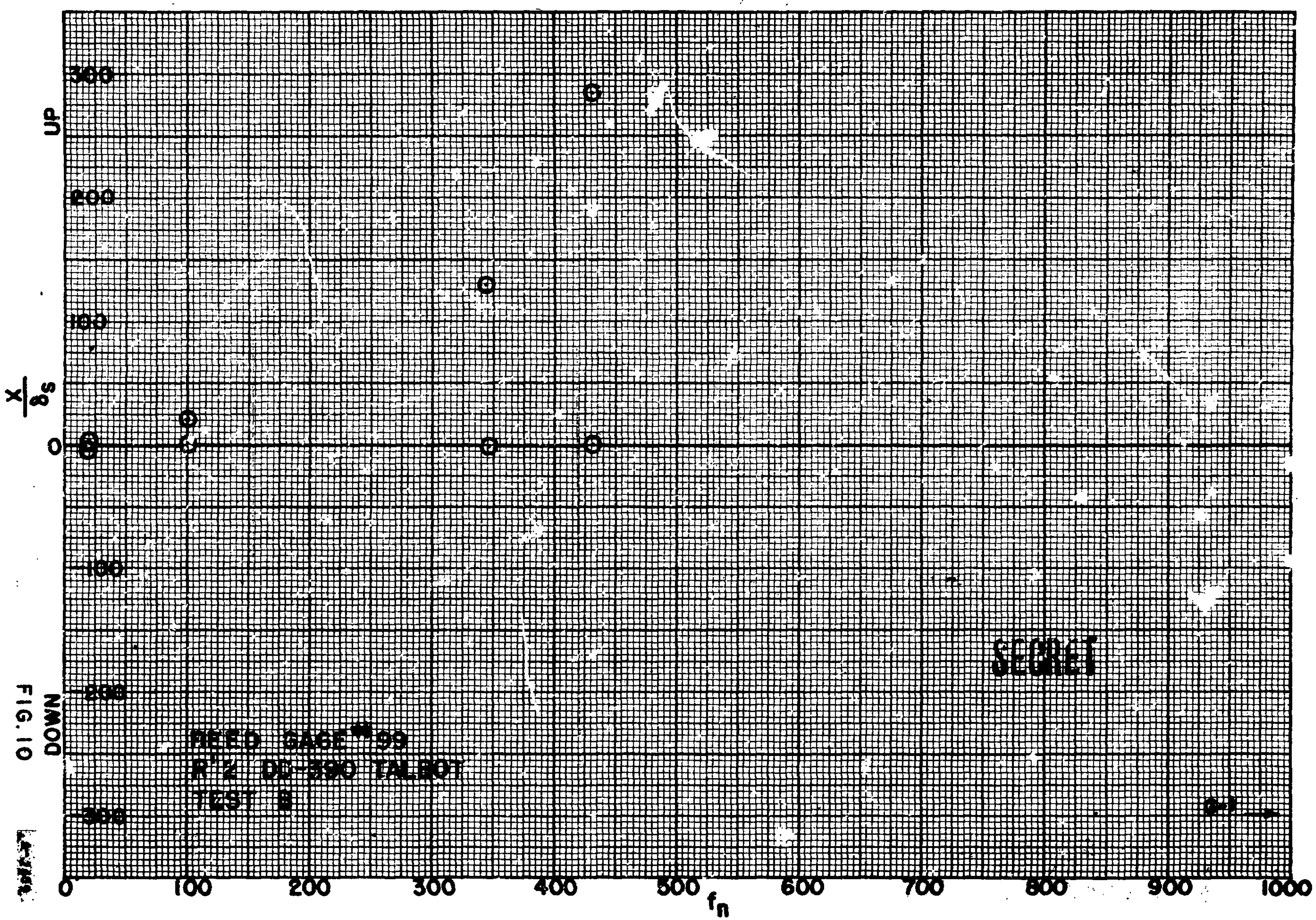


UP
DOWN
300
200
100
0
-100
-200
-300
$\frac{X}{\delta_s}$
0
100
200
300
400
500
600
700
800
900
1000
f_n
REED GAGE #99
R'2 DC-390 TALBOT
TEST B
SECRET

FIG. 10

DD402 - USS MAYRANT

Putty Gages

G1 - Photo 259. In aft fireroom, compartment B-2-1. Directed inboard, normal on flange of starboard frame 101, 4' below upper grating level.

A. Not installed. B. 75g.

G2 - Similar to Photo 262. In aft fireroom, compartment B-2-1. Directed up on top flange of keel, 56 in. forward of bulkhead 104.5.

A. Not installed. B. Less than 50

G3 - Similar to photo 291. In C.I.C. room. Directed up on deck over the beam at frame 59. 6 in. inboard from starboard bulkhead.

A. Not installed. B. 300g.

G4 - Similar to photo 271. In C.I.C. room. Directed to port on bracket on deck over beam at frame 60. 6 in. inboard from starboard bulkhead.

A. Not installed. B. Unreadable

Reed Gages

R'1 - Photo 260. In aft fireroom, compartment B-2-1. Directed inboard, normal on flange of starboard frame 97. 4 ft. 6 in. below upper grating level.

	Graph	20 cps		40 cps	
		Up	Dn	Up	Dn
A.	Not installed				
B.	Figure 12	.47	.495	.17	.135

R'2 - Similar to photo 262. In aft fireroom, compartment B-2-1. Directed up on top flange of keel, 66 in. forward of bulkhead frame 104.5.

A. Not installed

B. Not installed

DD 402 MAYRANT
GAGE LOCATIONS

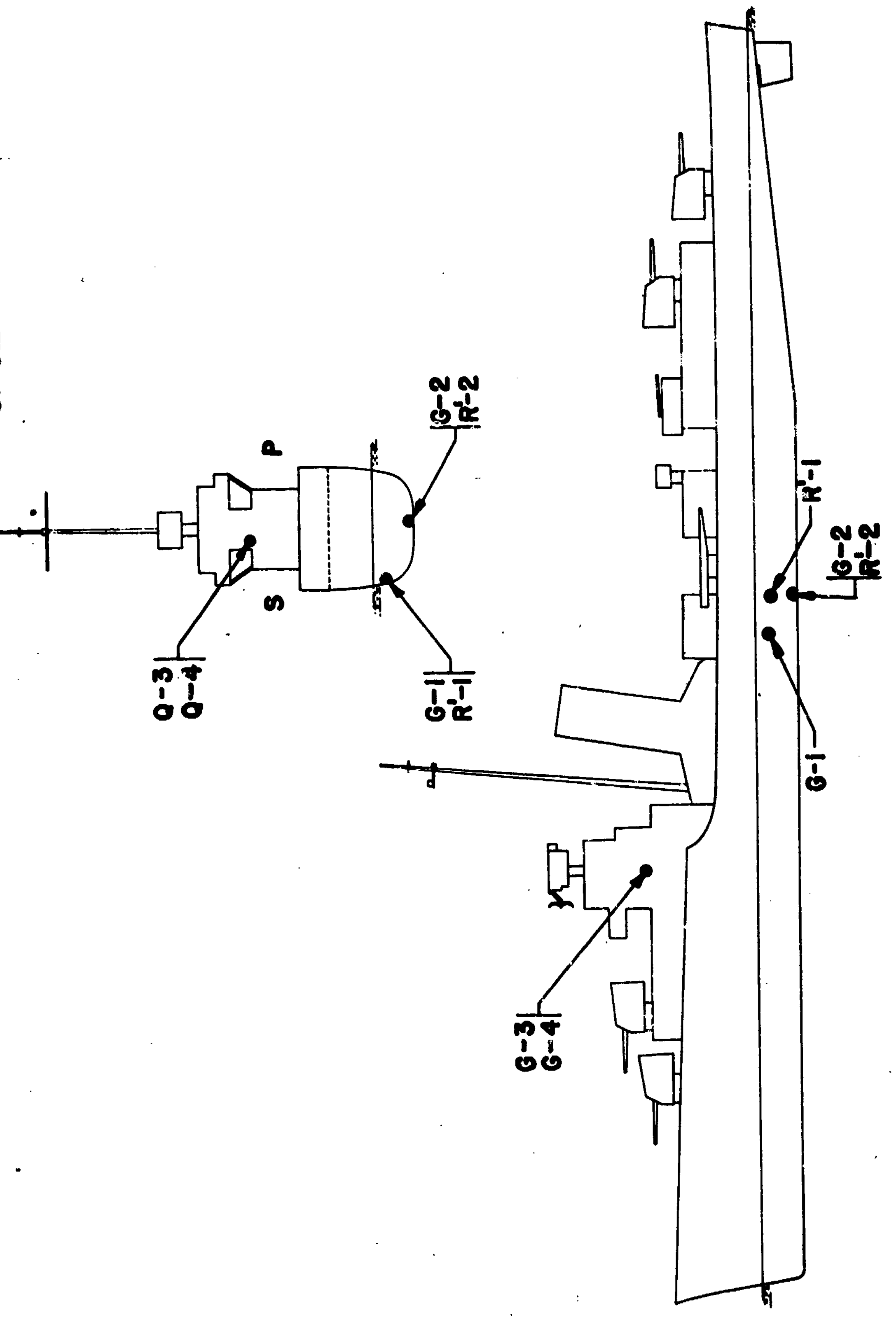


FIG. 11

A-2609

COMMENTS

Test Baker   Range 2600 ft.   Bearing 353°

The instrumentation was planned for starboard exposure to the pressure waves, rather than the port bow.

In view of the high vertical putty gage acceleration of 300g. in the C.I.C. room, and the sizable deflections of R'1 on the hull, it is difficult to explain the low readings of the hull putty gages. D.S.M. reports a dishing of the starboard hull amidships, apparently due to the contact with tugs during decontamination, which makes the R'1 reading unreliable.

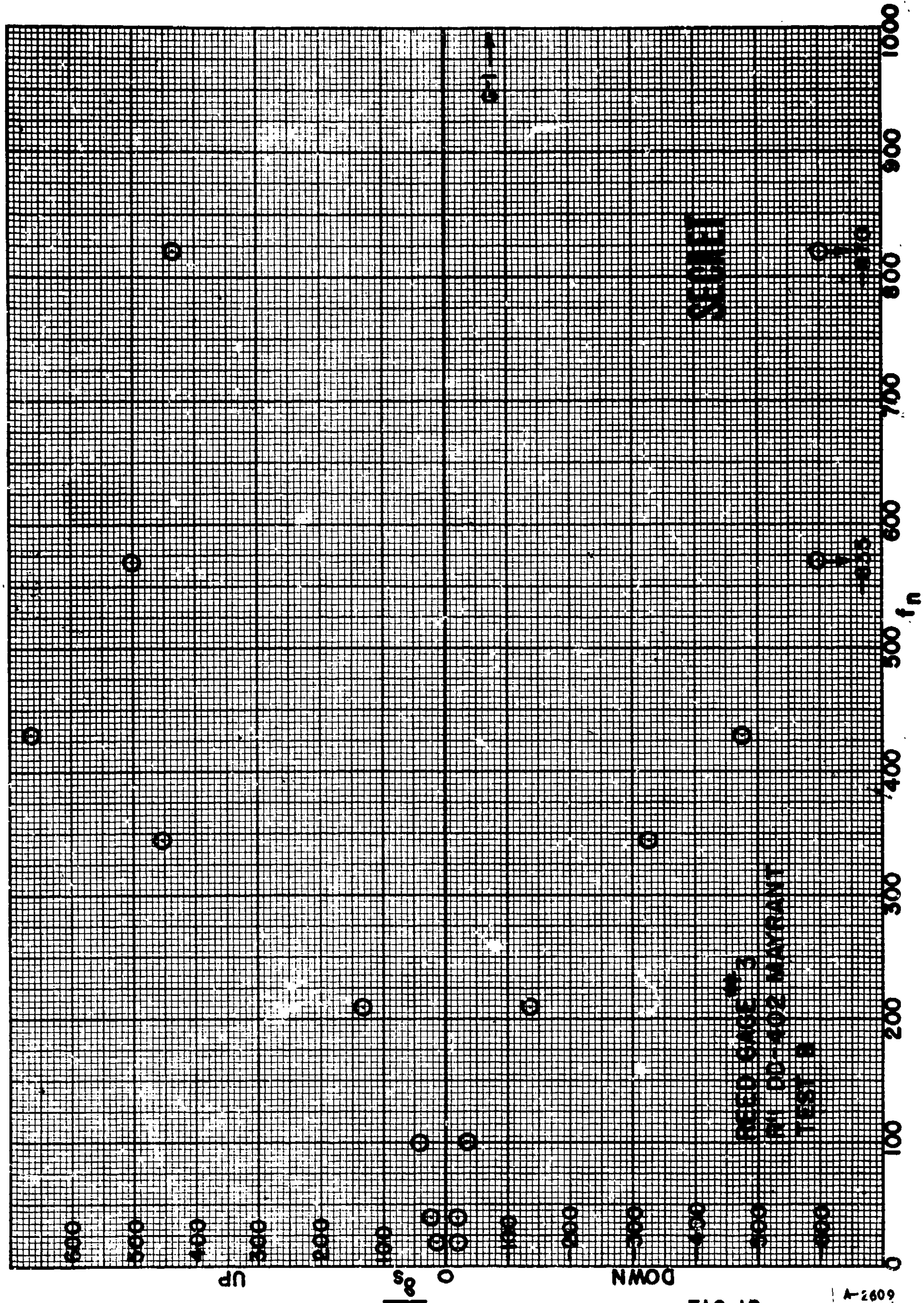

REED GAGE #3
R1 DD-402 MAYRANT
TEST B
SECRET
UP
DOWN
f_n
$\frac{x}{\delta_s}$

FIG. 12

A-2609

DD 403 TRIPPE
GAGE LOCATIONS

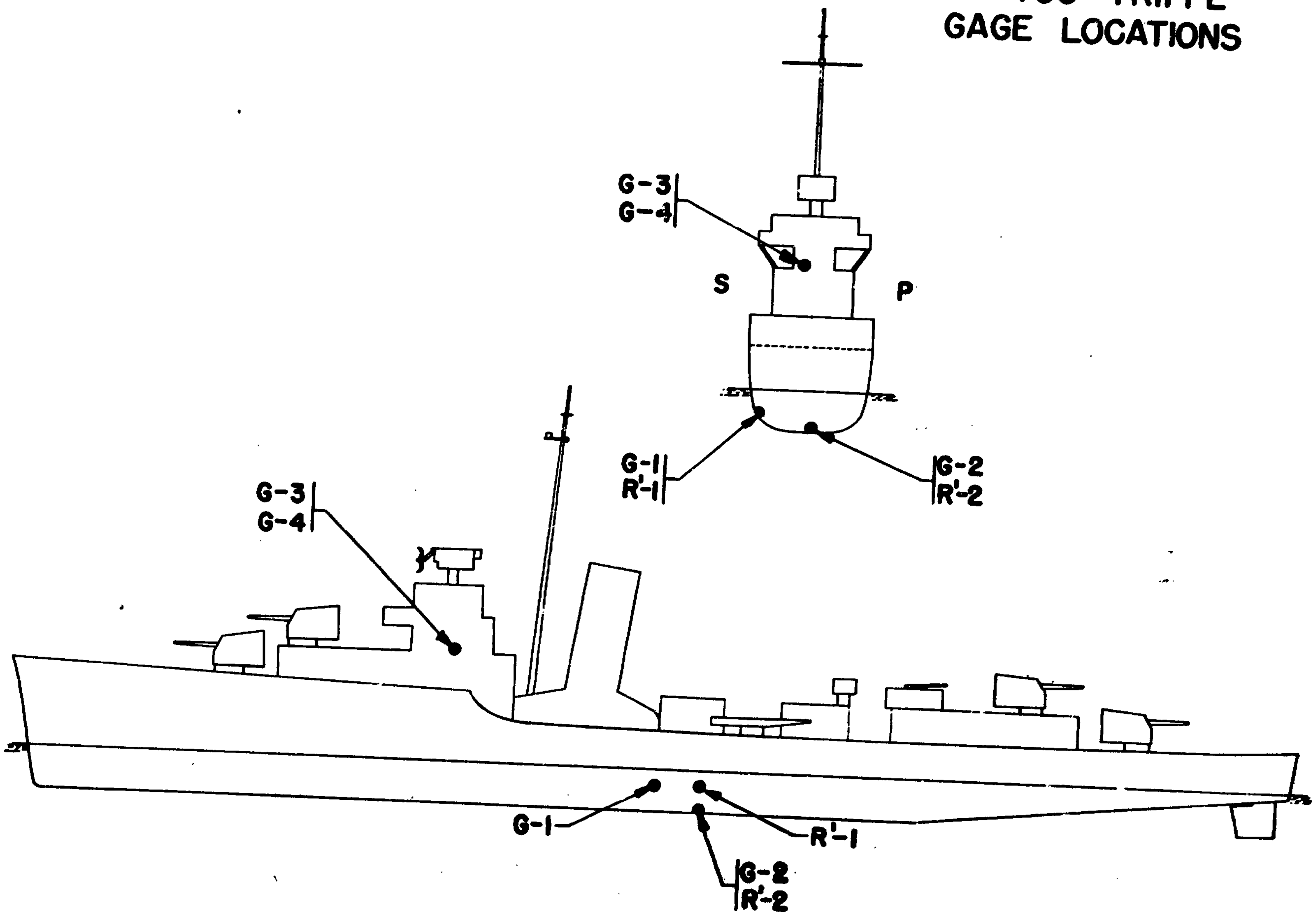


FIG. 13

A-2609

DD403 - USS TRIPPE

Putty Gages

G1 - Photo 262. In aft fireroom, compartment B-2-1. Directed inboard, normal on flange of starboard frame 97. 4 ft. below upper grating level.

A. Not installed B. Less than 50g.

G2 - Photo 263. In aft fireroom, compartment B-2-1. Directed up on top flange of keel. 56 in. forward of frame 104.5.

A. Not installed B. Unreadable

G3 - Similar to photo 292. In C.I.C. room. Directed up on deck at frame 62. 5 in. inboard from starboard bulkhead.

A. Not installed B. Less than 20g.

G4 - Similar to photo 272. In C.I.C. room. Directed to port on bracket on deck at frame 61. 7 in. inboard from starboard bulkhead.

A. Not installed B. Less than 20g.

Reed Gages

R'1 - Similar to photo 261. In aft fireroom, compartment B-2-1. Directed inboard, normal on flange of starboard frame 101. 4 ft. 6 in. below upper grating level.

A. Not installed B. Readings all zero

R'2 - Photo 263. In aft fireroom, compartment B-2-1. Directed up on top flange of keel, 66 in. forward of frame 104.5.

A. Not installed B. Unreadable

COMMENTS

Test Baker Range 4125 ft. Bearing 346°

The instrumentation was placed for starboard exposure to the pressure wave rather than the port bow.

All gages show no shock of intensity adequate to cause any readings. DSM reports no shock effects other than breakage of a few light bulbs.

DD 404 RHIND GAGE LOCATIONS

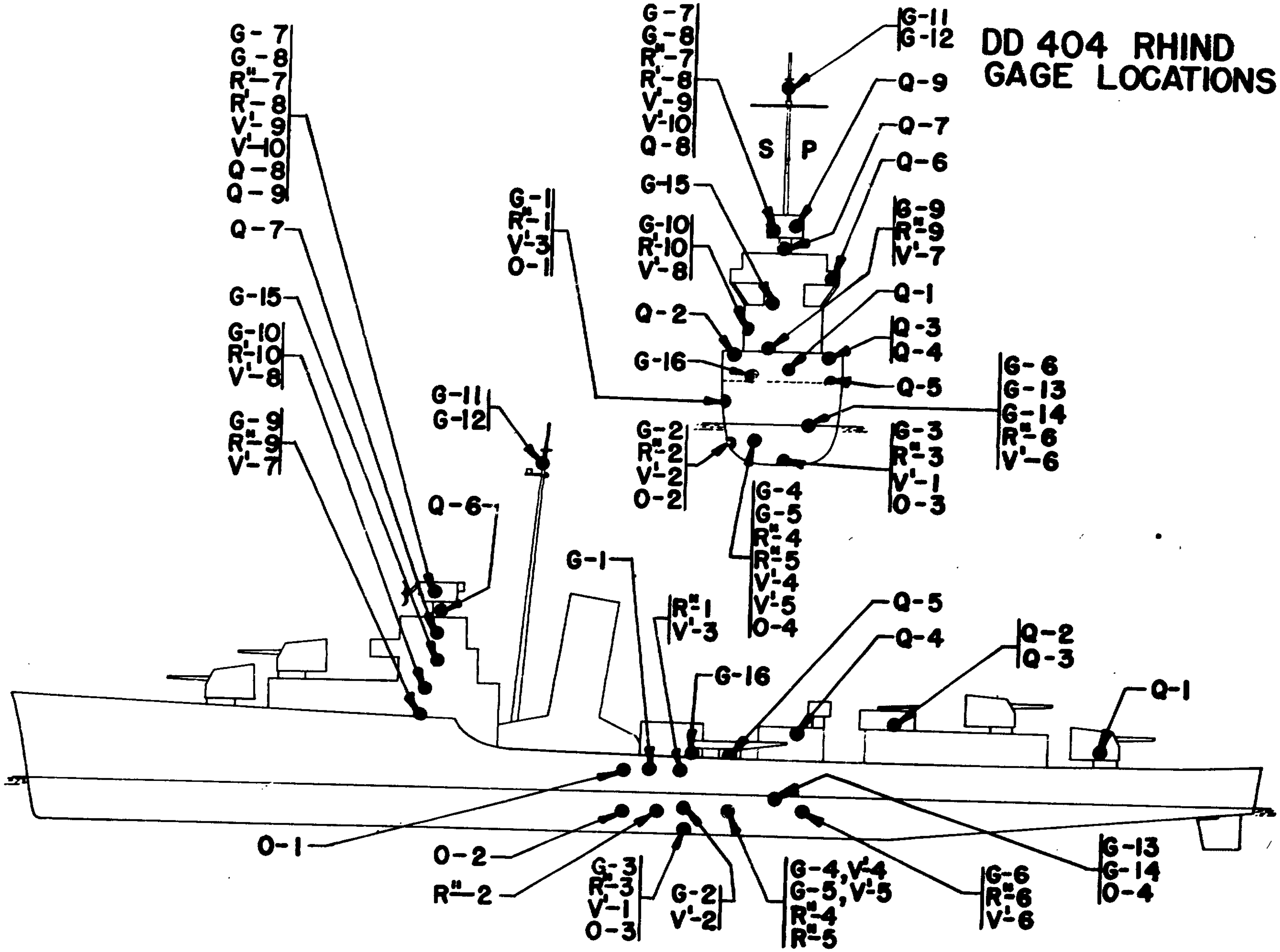


FIG. 14 A

A-2609

DD404 - USS RHIND

Putty Gages

G1 - Photo 263. In aft fireroom, compartment B-2-1. Directed inboard, normal on flange of starboard frame 97. About 5 ft. below main deck.

A. (1) 450g. B. 300g.

G2 - Photo 264. In aft fireroom, compartment B-2-1. Directed inboard, normal on flange of starboard frame 101. 4 ft. below upper grating level.

A. (3) less than 50g. B. Less than 50g.

G3 - Photo 263. In aft fireroom, compartment B-2-1. Directed up on flange of frame 101 about 6 in. to port of keel center line.

A. (3) less than 50g. B. Less than 50g.

G4 - Photo 266. In forward engine room, compartment B-3-1. Directed up on foundation of starboard low-pressure turbine, about 4 ft. below turbine shaft.

A. (3) less than 50g. B. Less than 50g.

G5 - Photo 266. In forward engine room, compartment B-3-1. Directed to port on foundation of starboard low-pressure turbine, about 4 ft. below turbine shaft.

A. (3) less than 50g. B. Less than 50g.

G6 - Photo 267. In forward engine room, compartment B-3-1. Directed up on top flange of short horizontal channel welded between two vertical stiffeners of bulkhead 118. The channel supports the forward end of the I-beam which passes under the starboard end of the main switchboard.

A. (3) less than 50g. B. Less than 50g.

G7 - Photo 268. In main battery director. Directed up on special bracket added on starboard vertical supports of director equipment. Just inside starboard door of director.

A. (2) 110g. B. Less than 20g.

DD404 - USS RHIND

Putty Gages

G8 - Photo 268. In main battery director. Directed to port on same bracket as G7.

A. (2) 100g. B. Less than 20g.

G9 - Photo 269. In Supply Office. Directed up on deck at frame 60, 12 in. from inboard bulkhead.

A. (3) less than 20g. B. Less than 20g.

G10 - Photo 270. In Supply Office. Directed to port on flange of vertical stiffener (frame 60) of starboard bulkhead. 3 ft. 6 in. above deck.

A. (1) 200g. B. 30g.

G11 - No photo. At top of main mast. Directed up on seat bracket about 3 ft. below top of mast.

A. Not recovered - Mast bent.

G12 - No photo. At top of main mast. Directed to port on starboard side of mast about 2 ft. below top of mast.

A. Not recovered - Mast bent.

G13 - Similar to photo 301. In forward engine room, compartment B-3-1. Directed up on port aft corner of inboard turbo-generator base at approx. frame 114. Base is on upper grating level.

A. (3) less than 50g. B. Less than 50g.

G14 - Similar to photo 301. In forward engine room, compartment B-3-1. Directed to port aft corner of inboard turbo-generator base at approx. frame 114. Base is on upper grating level.

A. (3) less than 50g. B. Over 300g.

G15 - Photo 271. In C.I.C. room. Directed to port on bracket on deck at frame 62. 5 in. inboard from starboard bulkhead.

A. (2) 125g. B. 50g.

DD404 - USS RHIND

Putty Gages

G16 - Similar to photo 302. In Engineer's Record Office. Directed up on deck at frame 101. 8 in. inboard from starboard bulkhead.

A. (2) 70g. B. Less than 20g.

Reed Gages

R''1 - Photo 272. Slow speed. In aft fireroom, compartment B-2-1. Directed inboard, normal on flange of starboard frame 101, about 5 ft. below main deck.

Graph	20 cps Up	20 cps Dn	40 cps Up	40 cps Dn
A. (1) Fig. 14 B Fig. 15	.595	.57	.45	.38
B wave 1 Fig. 23 Fig. 24	.03	.02	.02	.02
B wave 2 Fig. 23 Fig. 25	.025	.045	.01	.025

R''2 - Similar to photo 260. Slow speed. In aft fireroom compartment B-2-1. Directed to port, normal on flange of starboard frame 97. 56 in. below upper grating level.

Graph	20 cps Up	20 cps Dn	40 cps Up	40 cps Dn
A. (3) Fig. 16 Fig. 17	.135	.175	.02	.05
B wave 1 p. Fig. 26 Fig. 27	.02	.02	.01	.01
B wave 2 p. Fig. 26 Fig. 28	.02	.025	.01	.02

R''3 - Photo 265. Slow speed. In aft fireroom, compartment B-2-1. Directed up on top flange of keel at frame 101.

Graph	20 cps Up	20 cps Dn	40 cps Up	40 cps Dn
A. (3) Fig. 18 Fig. 19	.05	.02	.02	.015

B. Readings all zero

DD404 - USS RHIND

Reed Gages

R''4 - Photo 266. High speed. In forward engine room, compartment B-3-1. Directed up on foundation of starboard low-pressure turbine. About 4 ft. below turbine shaft.

Graph Record	20 cps Up	20 cps Dn	40 cps Up	40 cps Dn
A. (3) Readings all Zero.				
B. wave 1 Fig.29 Fig.30 Fig.31	.03	.03	.02	.01
B. wave 2 p. Fig.29 Fig.32	.02	.015	0	0

R''5 - Photo 266. High speed. In forward engine room, compartment B-3-1. Directed to port on starboard low-pressure turbine foundation near R''4.

Graph Record	20 cps Up	20 cps Dn	40 cps Up	40 cps Dn
A. (3) Readings all zero.				
B. wave 1 Fig.33 Fig.34	.02	.01	.005	.005
B. wave 2 Fig. 33 Fig.35	.02	.015	.01	.01

R''6 - Photo 267. High speed. In forward engine room, compartment B-3-1. Directed down on underside of fore-and-aft I-beam under starboard end of main switchboard. Gage is at upper grating level about 30'' forward of bulkhead 118.

Graph Record	20 cps Up	20 cps Dn	40 cps Up	40 cps Dn
A. (3) Readings all zero.				
B. wave 1 Fig.36 Fig.37 Fig. 38	.05	.06	.02	.02
B. wave 2 Fig. 36 Fig.39	.025	.035	.02	.02

DD404 - USS RHIND

Reed Gages

R''7 - Photo 273. Slow speed. In main battery director directed up on special bracket added on starboard supports of director equipment. Just inside starboard door of director.

Graph Record	20 cps Up	20 cps Dn	40 cps Up	40 cps Dn
A. (2) Readings all zero.				
B. wave 1 Fig. 4 Fig.41	.02	.04	.02	.02
B. wave 2 Fig.4 Fig.42	.035	.05	.02	0

R''8 - Photo 273. In main battery director. Directed to port on same bracket as R''7.

A. Unreadable

B. Record lost

R''d - Photo 274. In Supply Office. Directed up on deck at frame 60, 30 in. from inboard bulkhead.

Graph Record	20 cps Up	20 cps Dn	40 cps Up	40 cps Dn
A. (3) Fig. 20 Fig. 21	.03	.08	.025	.07
B. wave 1 Fig. 43 Fig.44	.035	.035	.02	.02
B. wave 2 Fig.43 Fig.45	.02	.02	.01	.01

R'10 - Photo 275. In Supply Office. Directed to port on flange of vertical stiffener (frame 63) of starboard bulkhead. About 3 ft. above deck.

Graph Record	20 cps Up	20 cps Dn	40 cps Up	40 cps Dn
A. (1) Fig. 22	1.35	1.59	.57	.715
B. Figure 46	.11	.125	.27	.27

DD404 - USS RHIND

Indenter Gages

Q1 - Similar to photo 306. In aft (No. 4) 5" gun turret. Directed up on deck frame member on starboard edge of breech clearance depression about 2 ft. forward of starboard support of gun. Directions assume gun to be pointed aft.

A		B	
Up	0g.	Up	35g.
Dn	55	Dn	60
25°	48	15°	40
115°	70	105°	25
205°	112	195°	25
295°	22	285°	50

Q2 - Photo 276. On starboard 40 mm gun platform at approximately frame 135. Directed up on deck over the intersection of two beams under the platform. To starboard and aft of gun pedestal.

A		B	
Up	60g.	Up	85g.
Dn	140	Dn	40
40°	150	80°	90
130°	90	170°	70
220°	170	260°	75
310°	85	350°	80

Q3 - Photo 277. On post 40 mm gun platform at approximately frame 135. Directed up on deck at location summetrical about ship centerline with Q2 location.

A		B	
Up	125g.	Up	160g.
Dn	140	Dn	50
19°	725	15°	235
100°	295	105°	70
190°	370	195°	430
280°	160	285°	70

DD404 - USS RHIND

Indenter Gages

Q4 - Photo 278. On port mark 51, 40 mm gun director platform. Directed down at intersection of beams on underside of platform. Director pedestal is over center of rectangle formed by beams on underside of platform; gage is at forward starboard corner of this rectangle.

A		B	
Up	50g.	Up	40g.
Dn	70	Dn	80
45°	55	70°	35
135°	50	160°	25
225°	120	250°	30
315°	80	340°	30

Q5 - Photo 279. On main deck about 6" outboard from base of port torpedo tubes. Directed up over main frame member of approx. frame 112.

A		B	
Up	0g.	Up	50g.
Dn	60	Dn	20
30°	50	0°	40
120°	80	90°	20
210°	80	180°	15
300°	50	270°	50

Q6 - Photo 280. At base of port torpedo director on navigation bridge deck. Directed up on deck to starboard and aft of director pedestal over intersection deck reinforcing members.

A		B	
Up	105g.	Up	70g.
Dn	110	Dn	90
5°	170	0°	20
95°	100	90°	35
135°	200	180°	0
275°	130	270°	70

DD404 - USS RHIND

Indenter Gages

Q7 - Photo 281. On pedestal of main 5 in. gun director. Directed aft and up on flange of aft brace of the support tube, 2 in. above top of pilot house.

A							B						
brg.	0°	elev.	-20°	35g.			brg.	0°	elev.	-20°	30g.
"	71°	"	42°	517			"	71°	"	42°	90
"	109°	"	-42°	331			"	109°	"	-42°	48
"	180°	"	20°	112			"	180°	"	20°	50
"	251°	"	-42°	375			"	251°	"	-42°	95
"	289°	"	42°	712			"	289°	"	42°	48

Q8 - Photo 268. Inside main 5 in. gun director turret. Directed up on same bracket as G7 etc.

A		B	
Up	165g.	Up	50g.
Dn	170	Dn	30
70°	520	75°	20
160°	490	165°	30
250°	400	255°	30
340°	550	345°	30

Q9 - Photo 282. Inside main 5 in. gun director. Directed up on 3 in. x 3 in. x 1/8 in. channel which runs forward from forward port corner of the internal director mechanism shell, 30 in. above platform which is just inside port door of director.

A		B	
Up	280g.	Up	180g.
Dn	260	Dn	175
45°	270	45°	310
135°	425	135°	200
225°	345	225°	160
315°	440	315°	125

DD404 - USS RHIND

Shock Displacement Gages

01 - Photo 283. In aft fireroom, compartment B-2-1. Directed to port on flange of starboard shell frame 93. 3 ft. below main deck.

B. Record not reproduced but is available.

02 - Photo 284. In aft fireroom compartment B-2-1. Directed to port on flange of starboard shell frame 93. 4 ft. below upper grating level.

B. Record not reproduced but is available.

03. Photo 285. In aft fire room compartment B-2-1. Directed up on flange of port frame 101 near keel.

B. Record not reproduced but is available.

04 - Photo 286. In forward engine room, compartment B-3-1. Directed up on starboard aft corner of base of starboard turbo-generator at approx. frame 114. Base is at upper grating level.

B. Record not reproduced but is available.

Velocity Meters

V'1 - Photo 287. In aft fireroom, compartment B-2-1. On starboard frame 101, 5 ft. below main deck. Directed to port. Note: Travel to base stop is 1" ± 1/32".

A. (1) Record not distinguishable

B. Record not distinguishable.

V'2 - Photo 264. Aft fireroom, compartment B-2-1. Directed to port on starboard frame 101, below upper grating level. Note: Travel to base stop is 1 1/8" ± 1/32".

A. (3) Record not distinguisable.

B. Record not distinguishable.

DD404 - USS RHIND

Velocity Meters

V'3 - Photo 272. Aft fireroom compartment B-2-1. Directed up on frame 101, about 1 ft. to starboard of keel centerline.

A. (3) Record not distinguishable.

B. Record not distinguishable.

V'4 - Photo 266. Forward engine room, B-3-1. Directed up on starboard low pressure turbine foundation, about 4 ft. below turbine shaft. Note: Travel to base stop is 1 1/16" ± 1/32".

A. (3) Record not distinguishable.

B. Record not distinguishable.

V'5 - Photo 288. Forward engine room, compartment B-3-1. Directed to starboard on starboard low pressure turbine foundation, about 4 ft. below turbine shaft. Note: Travel to base stop is 1" ± 1/32".

A. (3) Record not distinguishable.

B. Record not distinguishable.

V'6 - Photo 289. Forward engine room, compartment B-3-1. Directed down on under side of beam under starboard end of main switchboard, 20" forward of bulkhead 118.

A. (3) Record not distinguishable.

B. Record not distinguishable.

V'7 - Photo 269. Supply Office. Directed up on deck over beam at frame 60, 12" from inboard bulkhead. Note: Travel to base stop is 1" ± 1/32".

A. (3) Record not distinguishable.

B. Fig. 48, Channel 7.

DD404 - USS RHIND

Velocity Meters

V'8 - Photo 270. Supply Office. Directed to port on starboard bulkhead frame 61, about 3 ft. above deck. Note: Travel to base stop is 1" ± 1/32".

A. (1) Fig. 47, Channel 8.

B. Fig. 47, Channel 8.

V'9 - Photo 290. Main battery director. Directed up on gage bracket just inside starboard door. Note: Travel to base stop is 1" ± 1/32".

A. (2) Record not distinguishable.

B. Record not distinguishable.

V'10 - Photo 290. Main gun director. Directed to port on gage bracket just inside starboard door.

A. (2) Fig. 47, Channel 10.

B. Fig. 48, Channel 10.

COMMENTS

Test Able   Range 3038 ft.   Bearing 61°

Putty gages G1, G7, G8, G10, G15 and G16 were the only gages to show any reading. All these were on or very close to bulkheads or structures acted upon directly by the pressure wave. In fact all these structures were dished severely by the pressure. Note that G2 which was about 5 ft. below the waterline was unaffected while G1, 5' above the waterline, read 450g.

Reed gages R"1 and R'10 had high readings in accord with the putty gages adjacent to them. Both show a long duration shock as indicated by their frequency response curves. R'10 was on the Supply Office bulkhead which was ruptured and dished several inches, and indicates an "equivalent shock duration" of 20 milliseconds. R"1 indicates an equivalent duration of 10 and/or 2 milliseconds. The difference in response frequency is tentatively attributed to difference in natural frequency of the structures on which the gages were mounted.

The indenter gage readings are fairly consistent with the other gage readings. Q1, Q2, Q4, and Q5 all had rather low readings apparently because they were tied in closely with heavy rigid mounting bases rather than the light structures with extensive exposed areas which produced large putty and reed gage readings. Q3 at the port side location corresponding to Q4 on the starboard side read high for reasons not apparent. Q6 gave a reasonable reading; Q7 seems rather high. Q8 was adjacent to G7 and G8 and read 50% and 500% higher than these putty gages for the same directions.

Velocity meters V'8 and V'10 indicate shocks in agreement with the similarly placed reed gages and putty gages. V'8 records a velocity change of about 18 ft./sec. in an interval of 10 milliseconds at time equal to .165. In this interval the greatest slope corresponds to about 110g. as compared with 200g. recorded by G8 at the same location. A transient vibration of about 70 cps is discernable. R'10 at this location indicated a disturbance of about 100 cps. The V'10 record is of a quite different nature, presumably because the gage location was not closely connected with exterior surfaces. Interpretation of this wave is difficult since the sudden velocity changes at .12 and .15 seconds are probably due to bottoming of the gage. The rise from .075 to .12 seconds is gradual and corresponds roughly to the natural vibration frequency of the spring supported mass of the velocity meter. Since the adjacent putty gage read 100g., it is concluded that the velocity change produced by the 100g. acceleration was not large enough to be apparent on the velocity meter record.

In summary, 500g. seems to be a fair estimate of the acceleration of structures having a high ratio of directly exposed area to resistance to motion (i.e. mass or rigid connection to massive unexposed members). Locations immediately adjacent to the above but not close to very heavy members registers about 100-200g. Examples of these latter locations are within the gun director, within the Engineer's Record Office, on the deck of C.I.C., etc. Heavy masses such as the 5" guns and the torpedo tube base undergo accelerations less than 100g. and structure over, say, 5 ft. away from the exposed surfaces show accelerations under 100g. even without benefit of adjacent massive items.

Test Baker   Range 6825 ft.   Bearing 318°

The instrumentation was planned for direct exposure of the starboard side to the shock waves, while the port bow was actually closest to the explosion.

The only putty gages to show readings were G1, G10, G14, and G15 of which only G1 and G14 were of significant magnitude. Since the indentations of G14 were very small and a zero reading is indicated by the location and the readings of the other gages, it is considered that the G14 reading should be ignored. The G1 reading also is questionable since the identical location on the DD408 showed no reading and its location was very likely to be struck by a tug or small boat.

All the reed gages showed negligible shock. The motorized gages recorded the underwater and airblast shocks separately on the time scale. The motorized reed gages show a trend which is supported by the velocity meters and other gages in that the keel and hull gages suffered less shock due to the underwater pressure than those in the superstructure. This is a contradiction to the generally accepted rule that the shock in the hull us greater than that above the waterline. This will be discussed in the comments on the destroyers as a class.

While the motorized reed gage records do not permit definite separation of the successive pulses prior to the airblast, they show excitation by these pulses up to 1.3 seconds after the initial excitation. The major pulses are usually apparent however.

V'7, V'8, and V'10 were the only meters to show readings above the background. V'7 and V'10 record low and apparently reliable indications of the successive underwater pressure waves. V'8 shows one definite pulse and vibration probably at the bulkhead natural frequency but it is not certain whether this is due to air or water pressure. Note that these gages were in the superstructure.

Q3 and Q9 were the only indenter gages which recorded a shock. It may be significant that both were on the port side. Q9 is within the gun director and yields a higher reading than the putty gages and the indenter gage on the starboard side of the director or the indenter gage at the base of the director. This suggests that its reading and probably that of Q9 were caused by the airborne pressure wave.

While the shock recorded was low, data was obtained on the variation in shock with location in the ship. Both air and water pressure produced readings but the distribution of the waterborne shock is thus far anamalous.

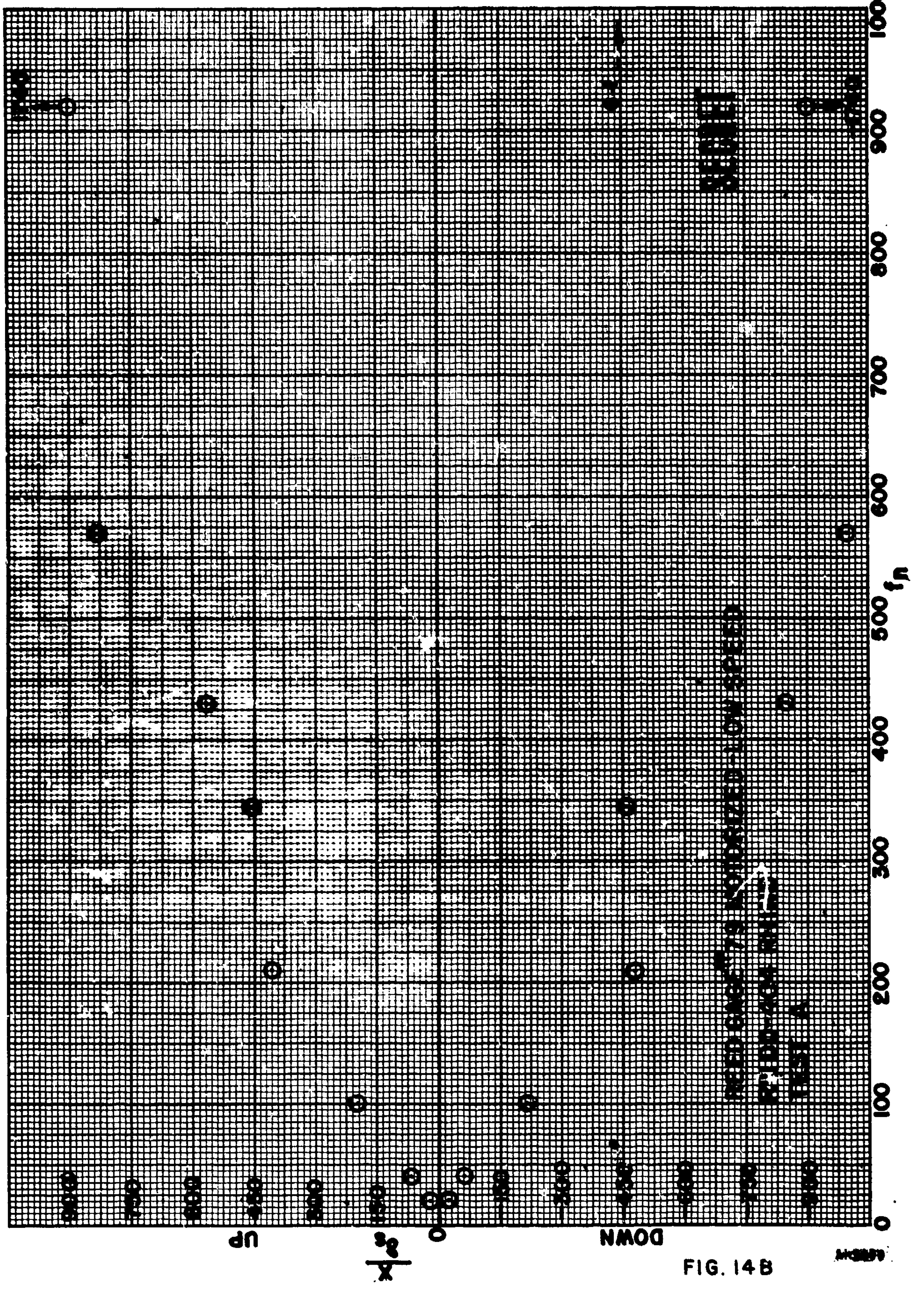
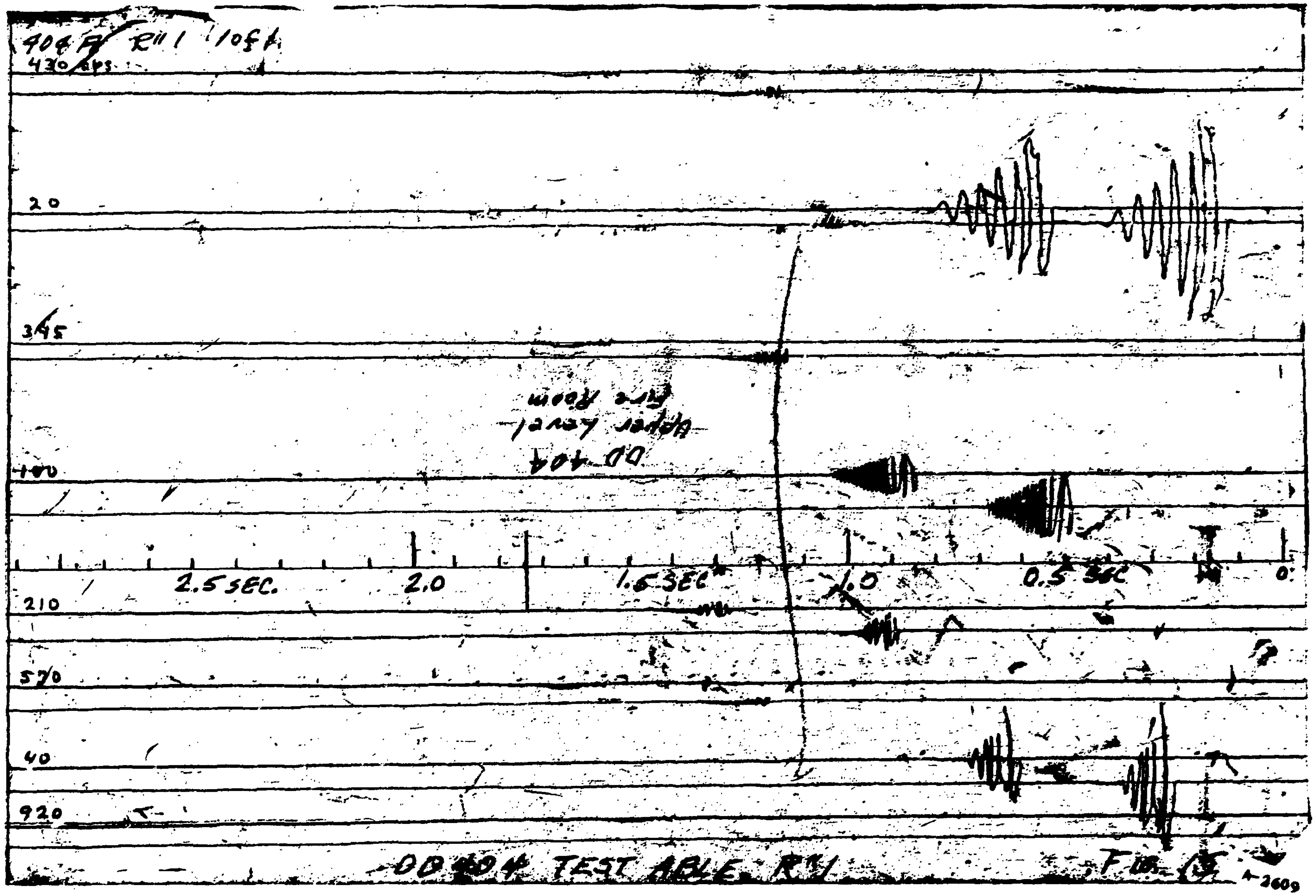
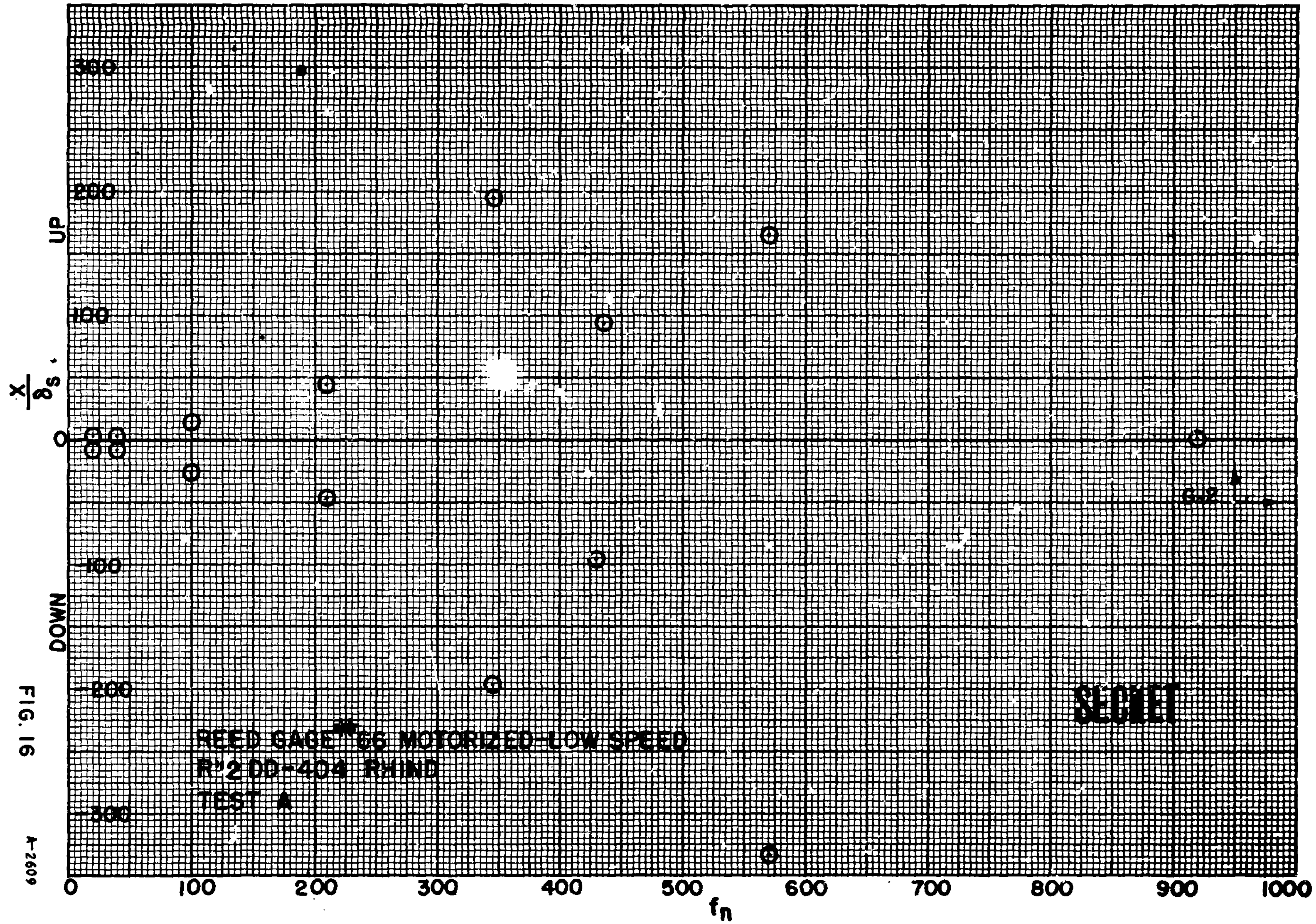


FIG. 14 B


404 R''1 1 of 1
430 eps
20
345
OD 404
Upper Level
Fire Room
400
210
570
40
920
2.5 SEC.
2.0
1.5 SEC
1.0
0.5 SEC
0
OD 404 TEST ABLE R''1
FIG. 15
A-2609



300
200
100
0
-100
-200
-300
UP
DOWN
$\frac{X}{\delta_s}$,
0
100
200
300
400
500
600
700
800
900
1000
f_n
G-2
SECRET
REED GAGE #66 MOTORIZED LOW SPEED
R'2 DD-404 RHIND
TEST A

FIG. 16

A-2609

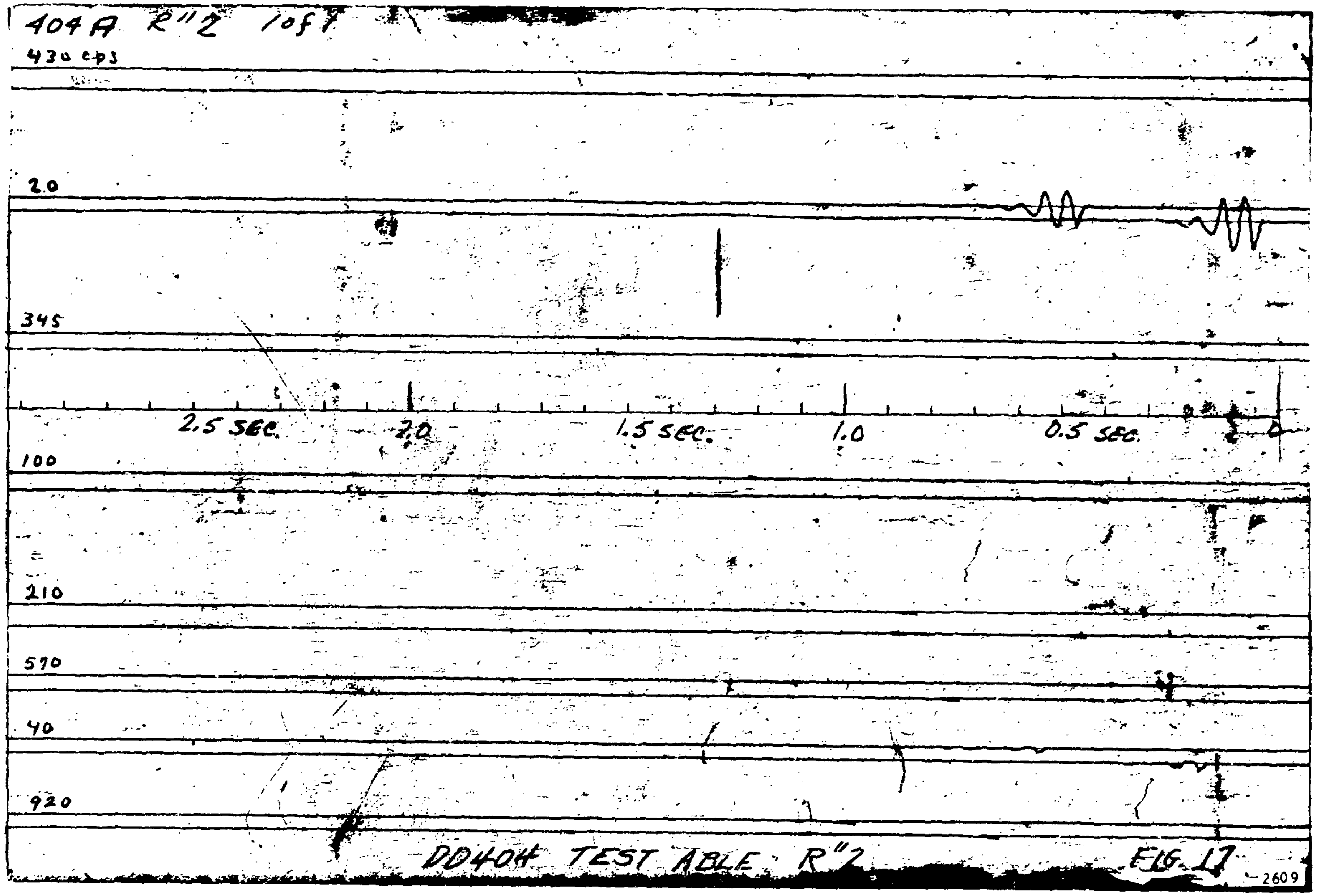
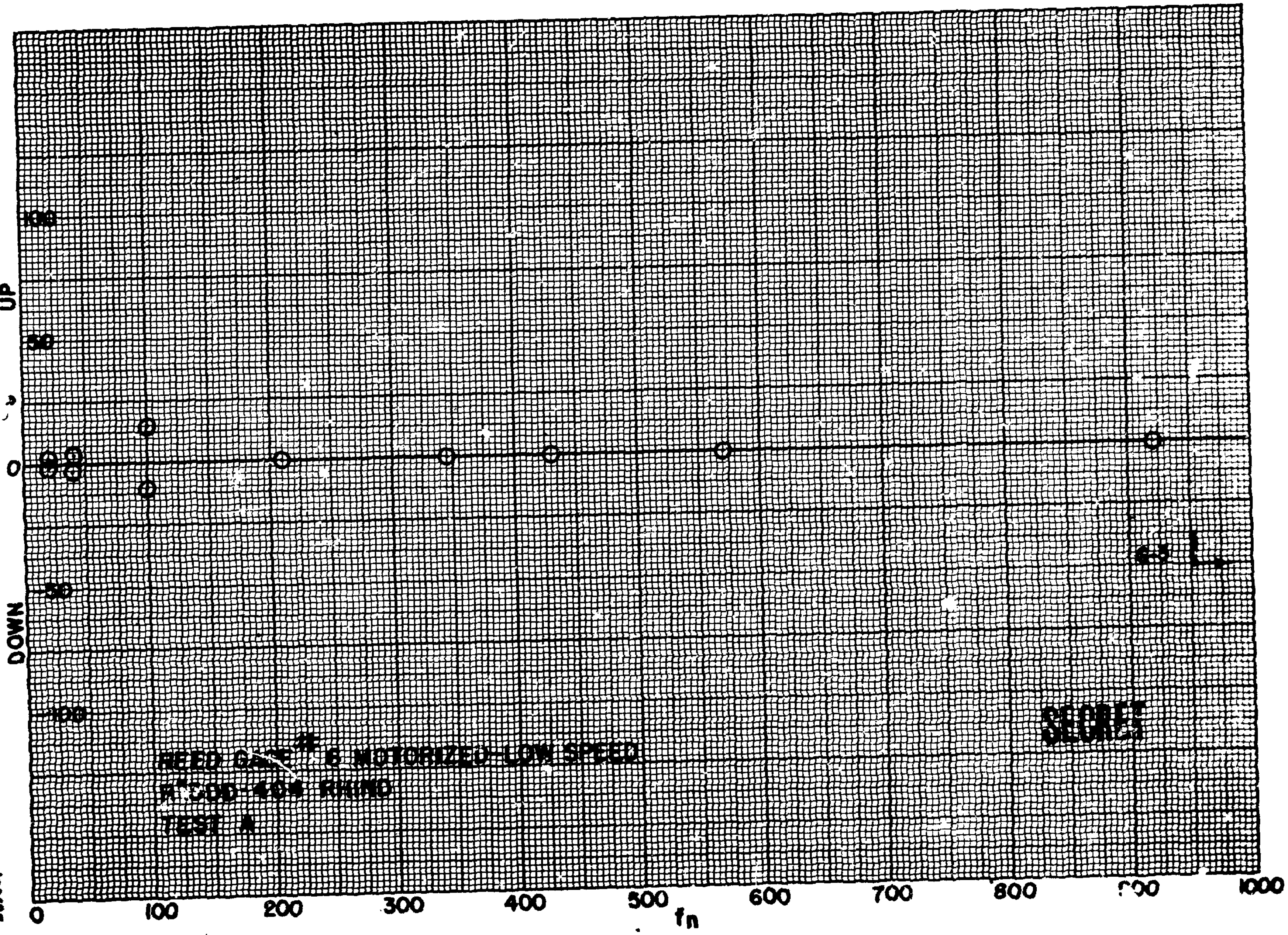
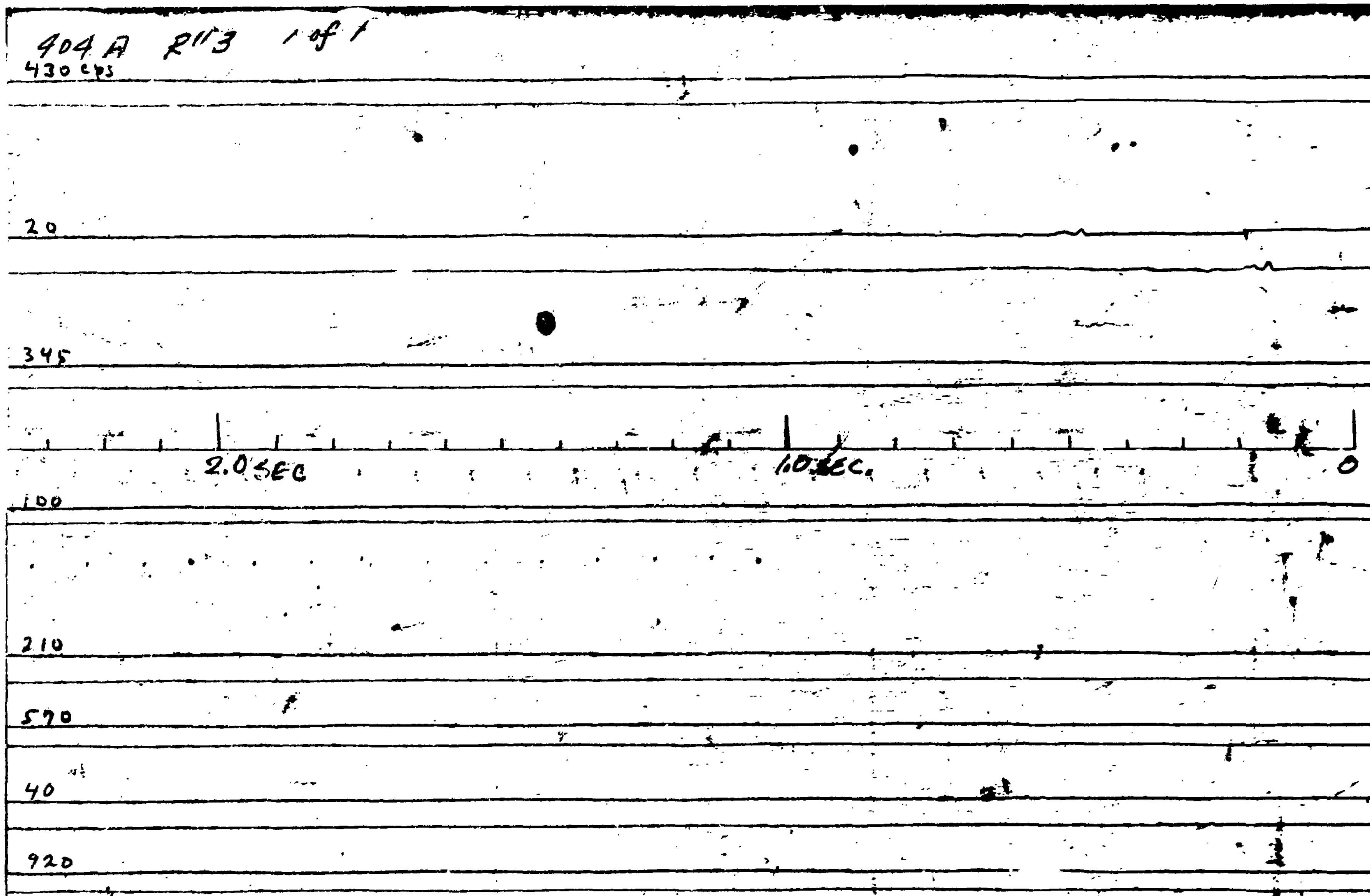

404A R"2 1of1
430 cps
2.0
345
2.5 SEC.
2.0
1.5 SEC.
1.0
0.5 SEC.
100
210
570
40
920
DD404 TEST ABLE R"2
2609

FIG. 17



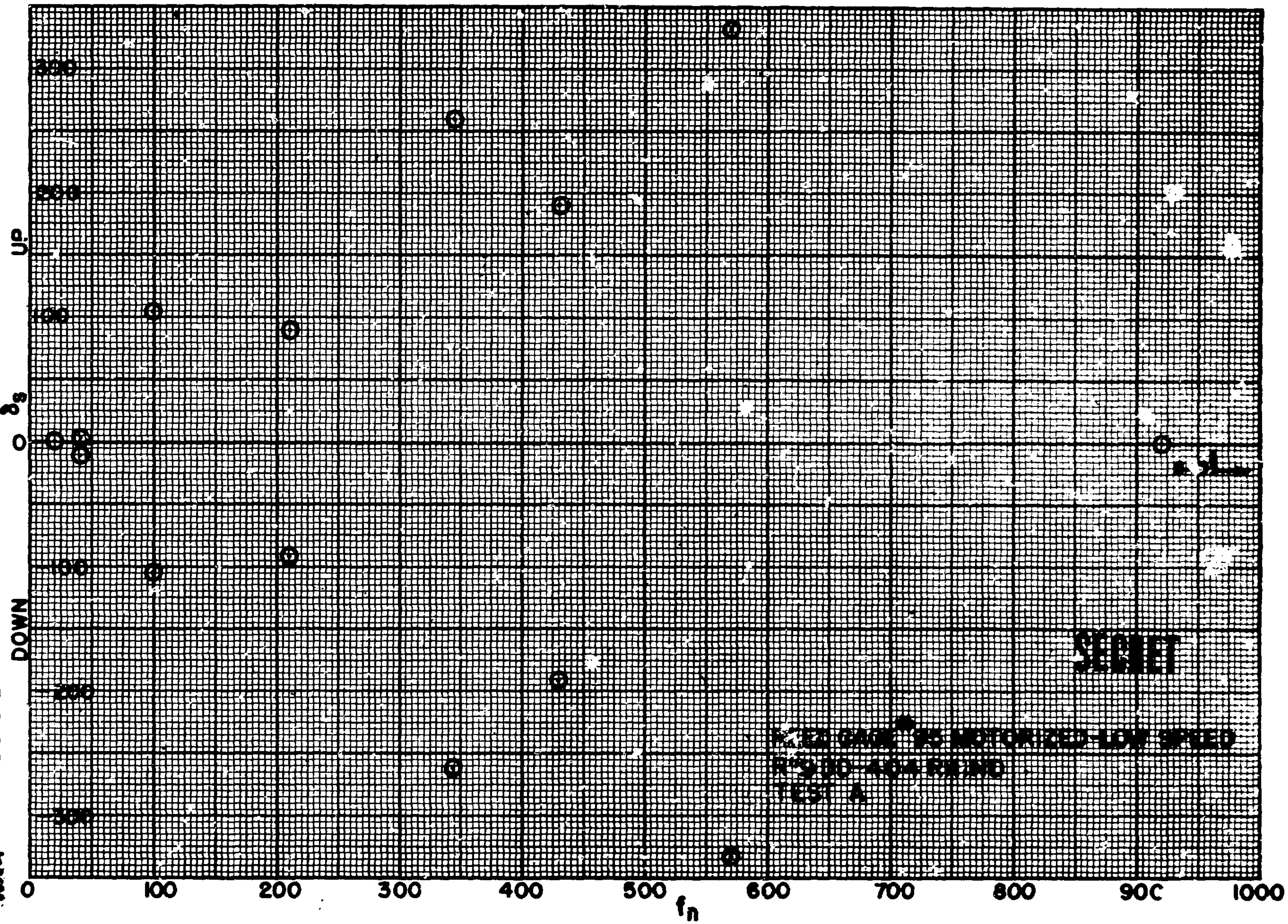
100
UP
50
0
-50
DOWN
-100
REED GAGE # 6 MOTORIZED-LOW SPEED
R COD 404 RHINO
TEST A
SECRET
0
100
200
300
400
500
600
700
800
1000
f_n

FIG. 18



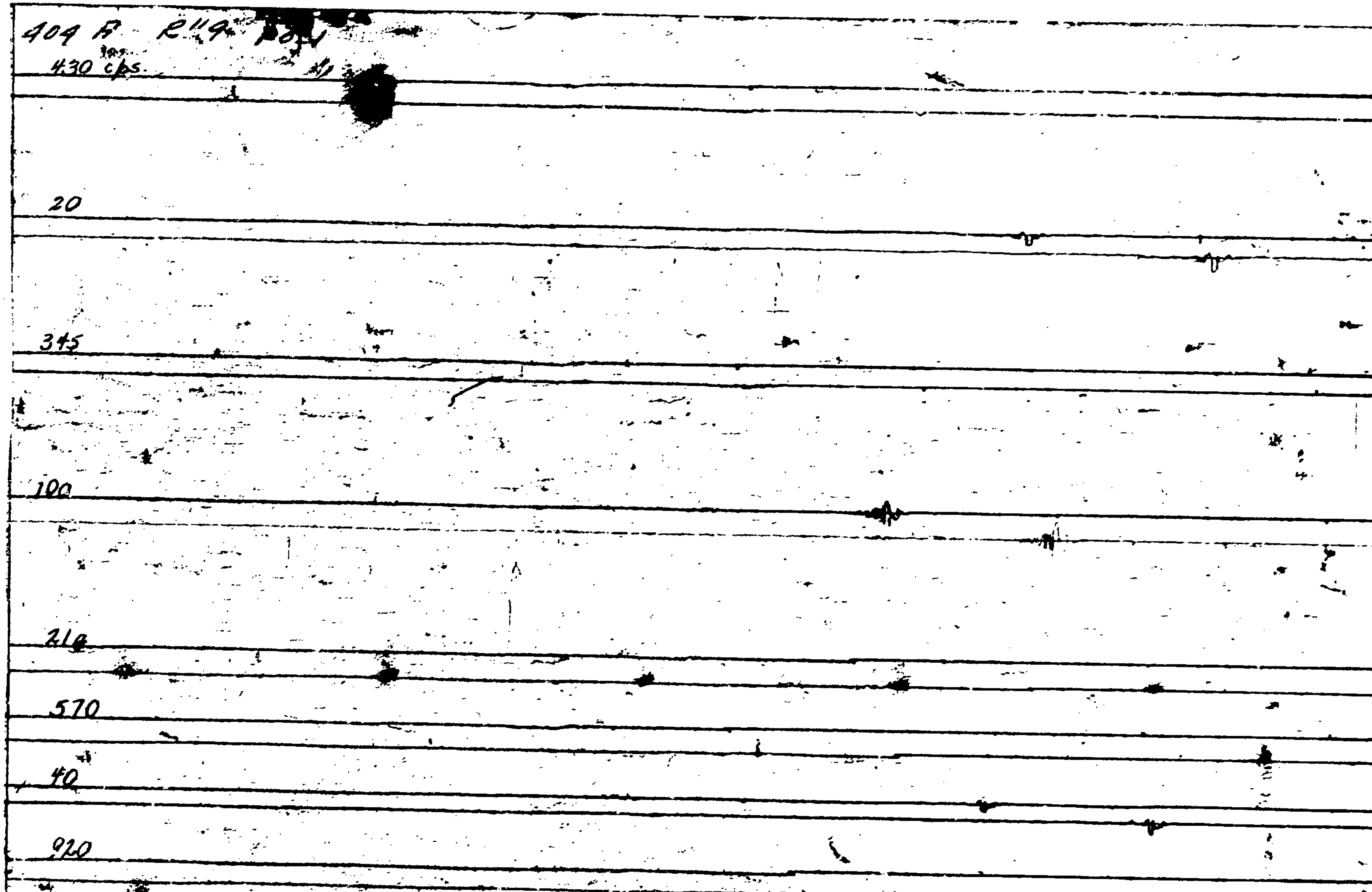
DD404 TEST ABLE R"3 FIG. 19

A-2609



UP
DOWN
0
100
200
300
-100
-200
-300
400
500
600
700
800
90C
1000
f_n
SECRET
TEST A

FIG. 20



DD 404 TEST ABLE R"9

FIG. 21

A-2609

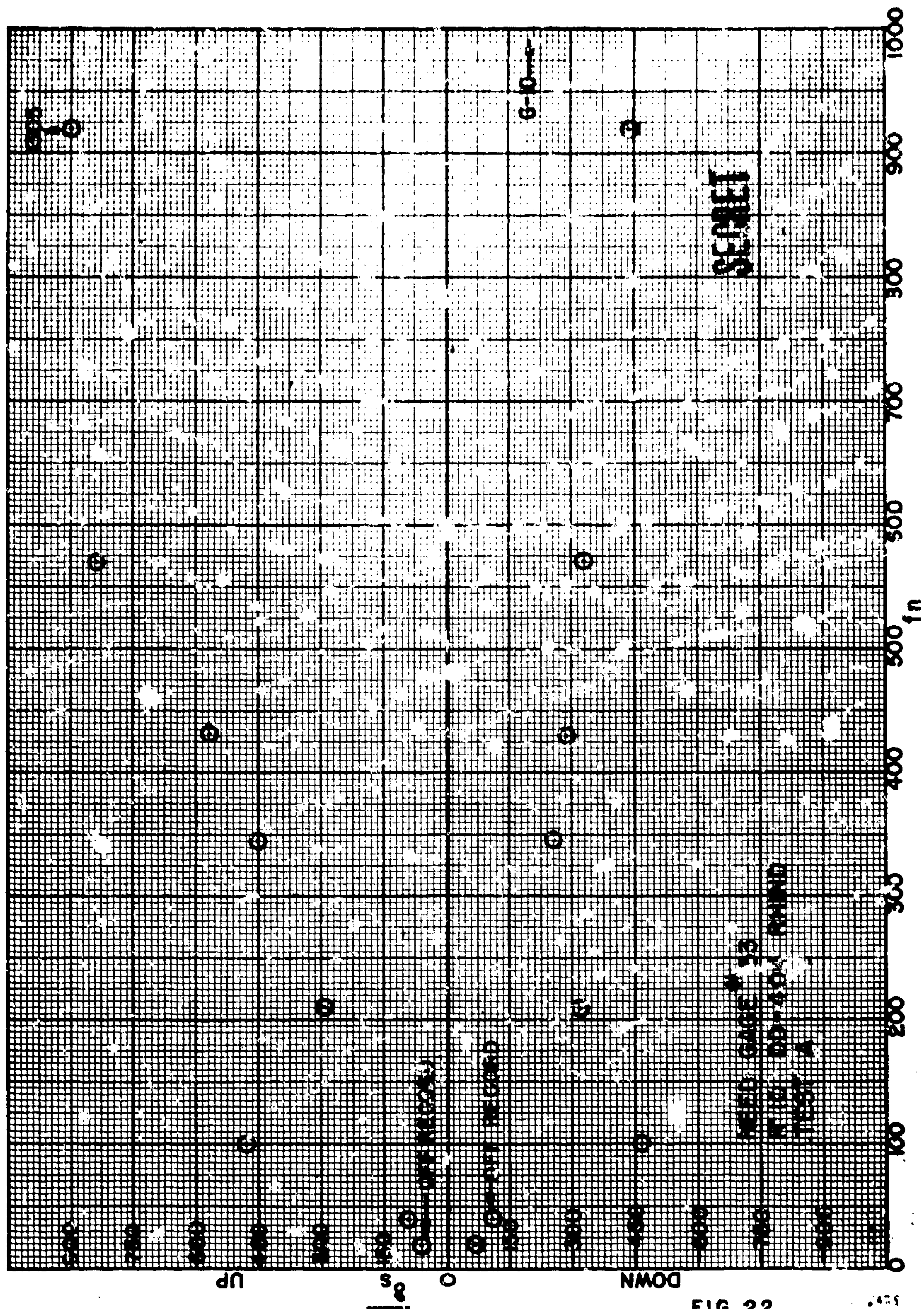


FIG. 22

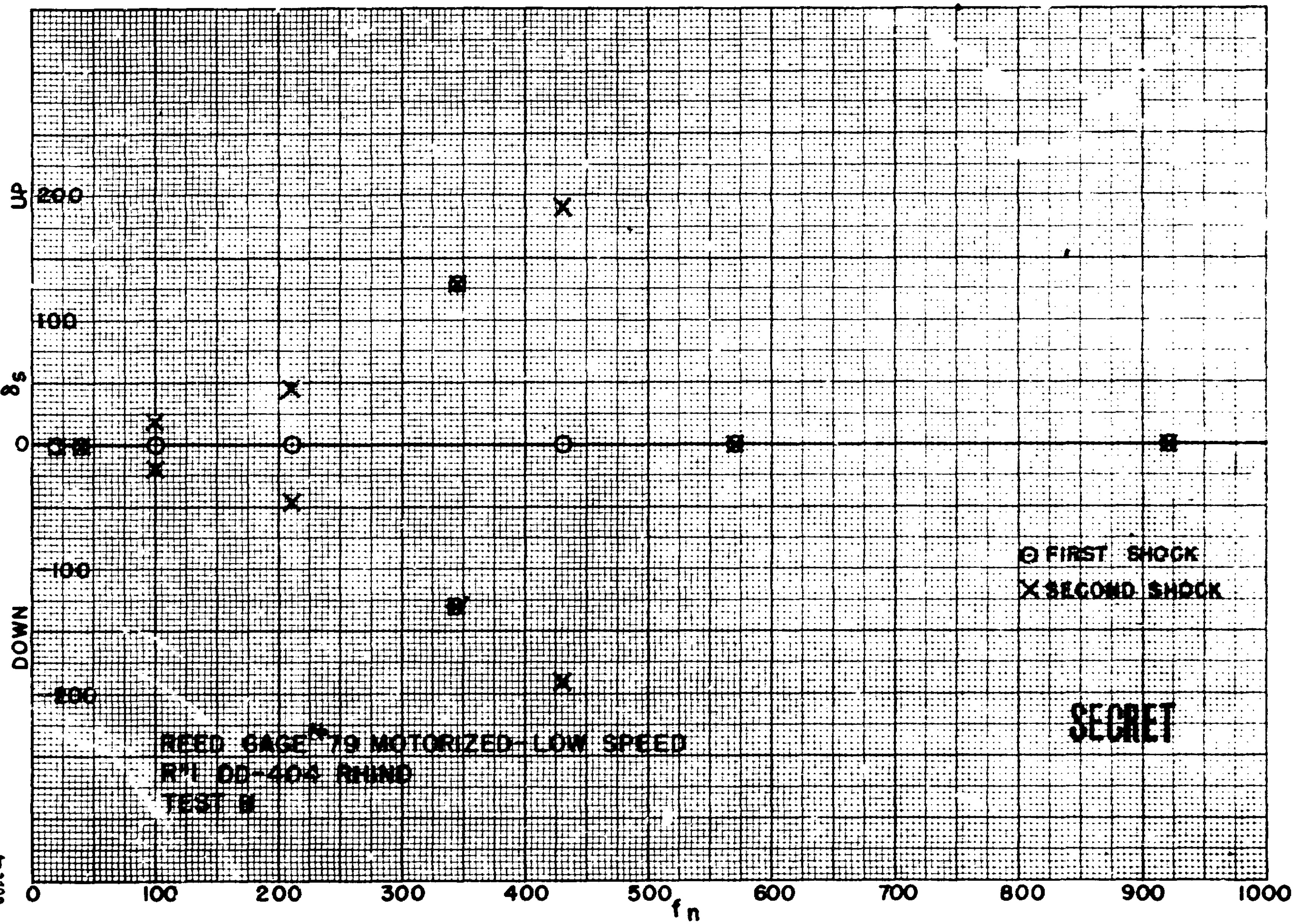
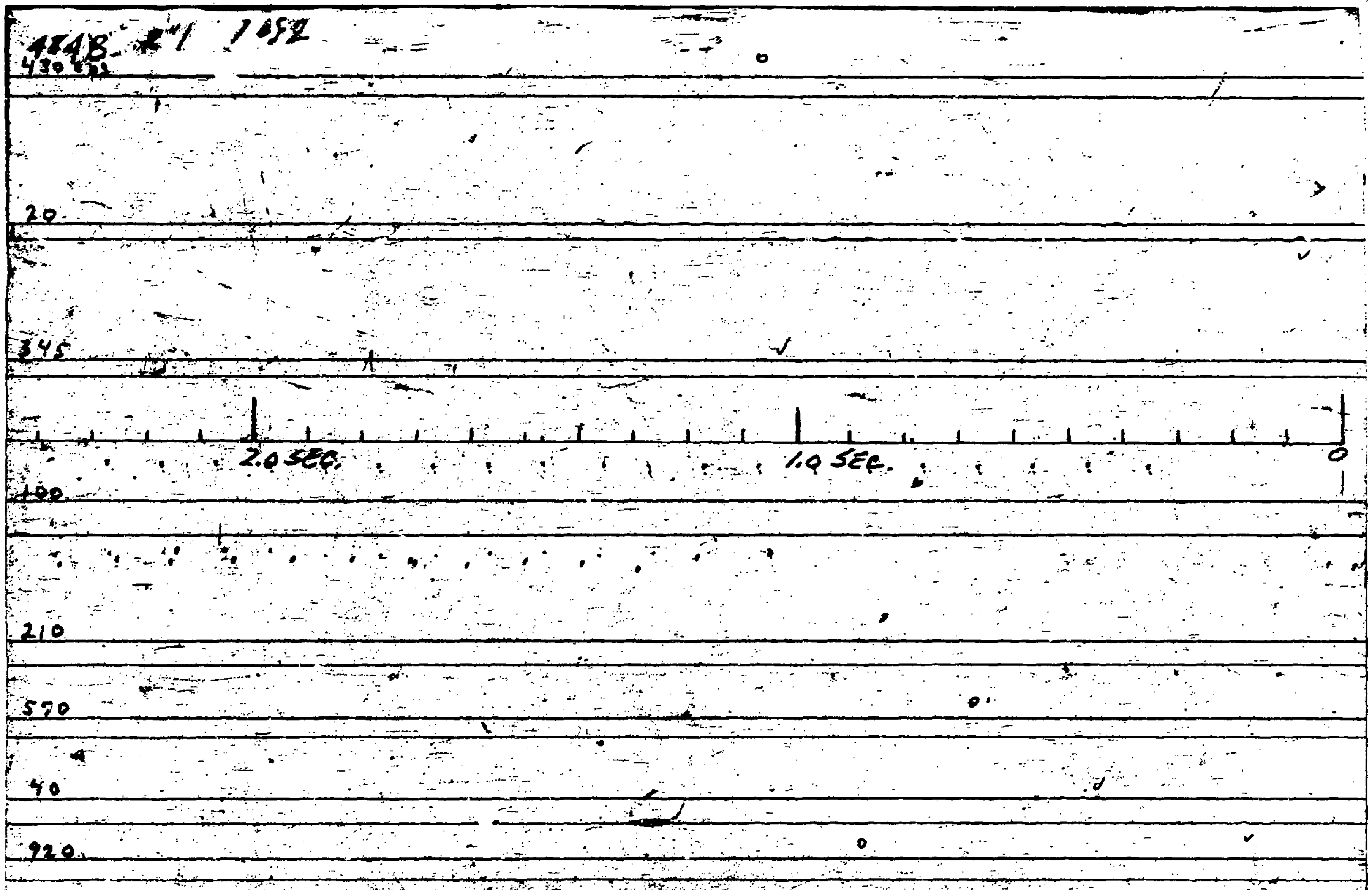

REED GAGE #79 MOTORIZED-LOW SPEED
R'L DD-404 RHIND
TEST II
O FIRST SHOCK
X SECOND SHOCK
SECRET
UP
DOWN
X / δs
200
100
0
100
200
0
100
200
300
400
500
600
700
800
900
1000
fn

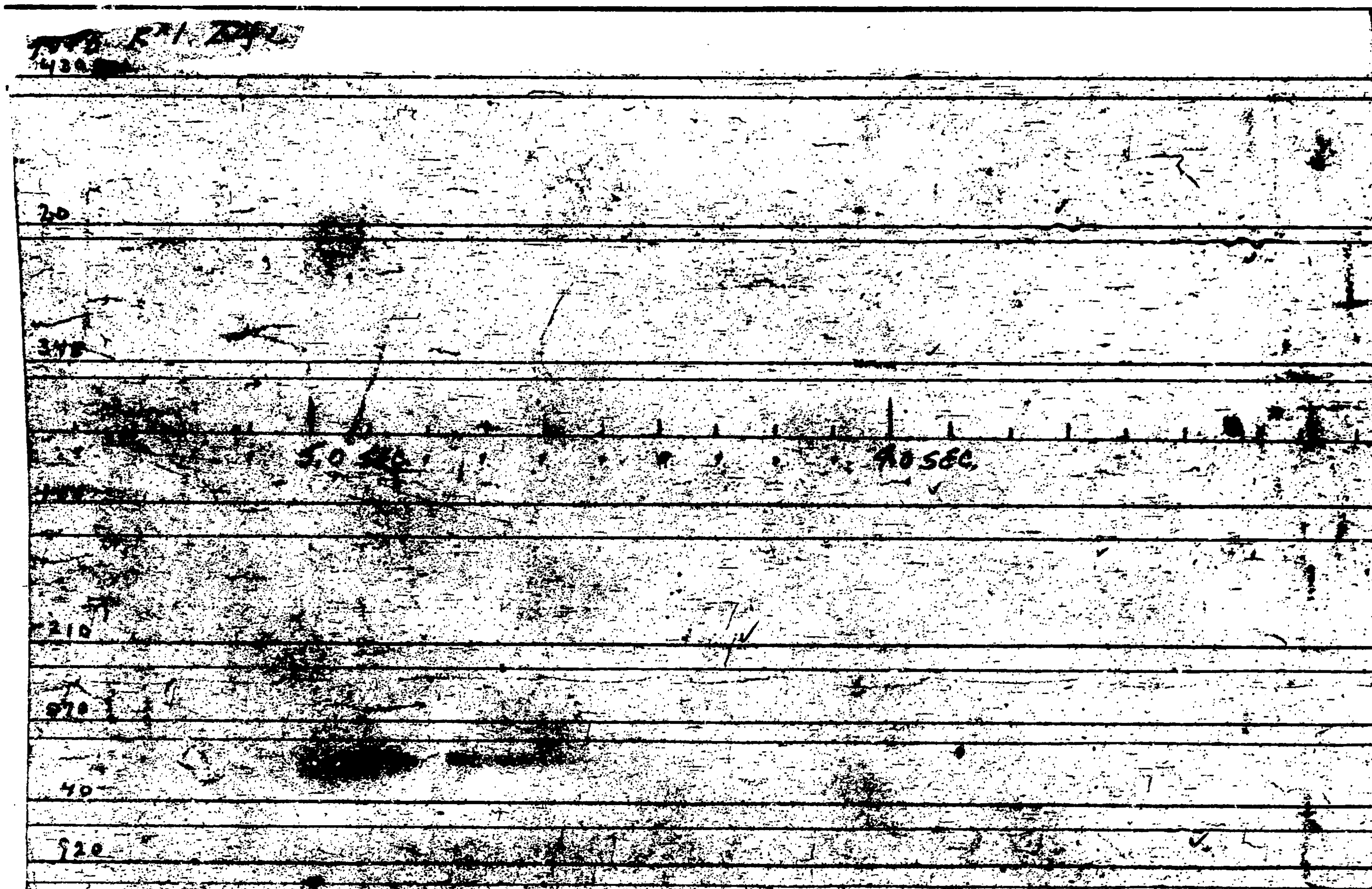
FIG. 23

A-2109



DD 404 TEST BAKER R#1 WAKE I

FIG 24



DD 40 TEST BAKER "P" WAVES A-2609

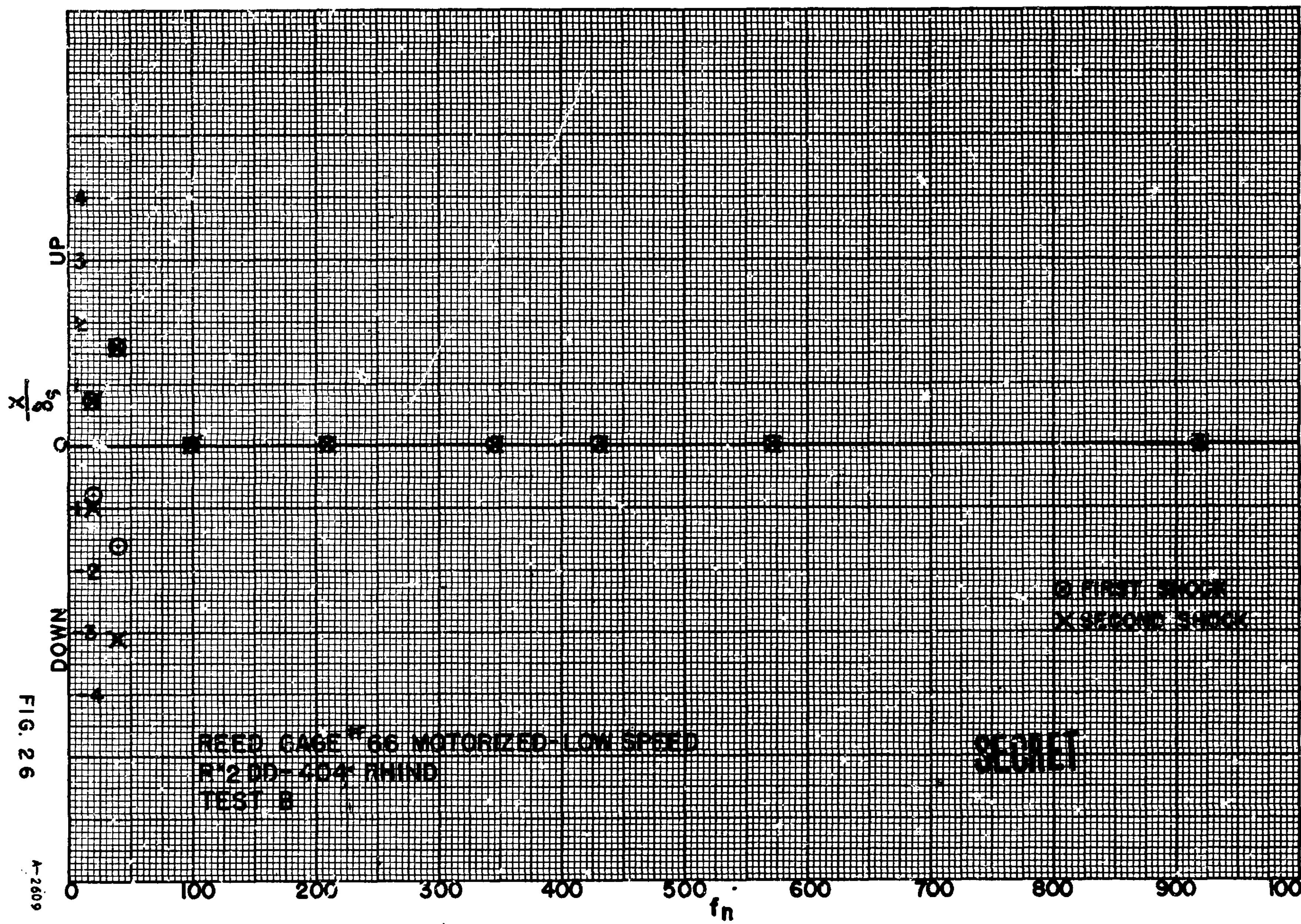
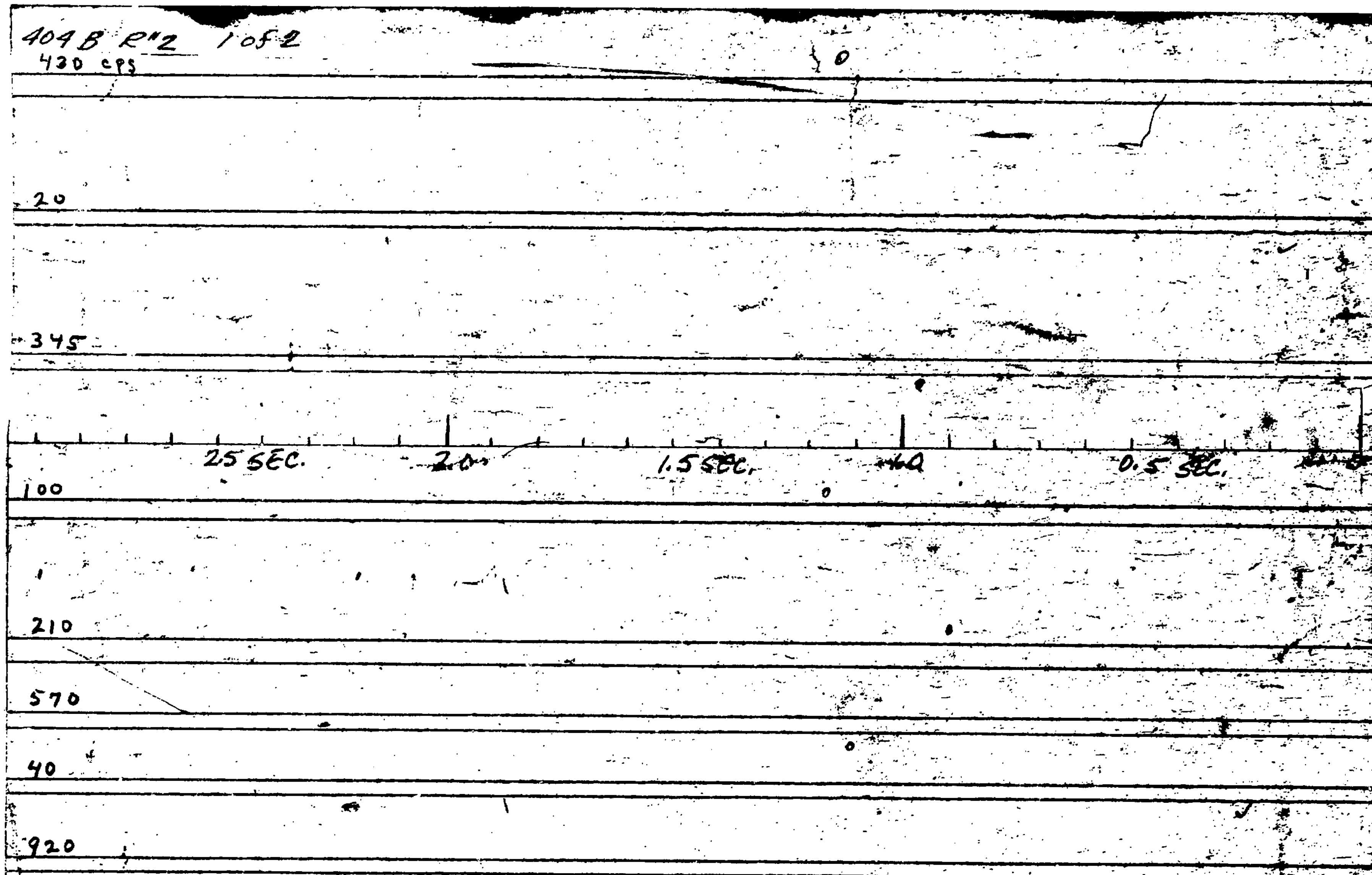

UP
DOWN
X/δ_s
4
3
2
1
0
1
2
3
4
0
100
200
300
400
500
600
700
800
900
1000
f_n
⊙ FIRST SHOCK
X SECOND SHOCK
REED GAGE #66 MOTORIZED-LOW SPEED
R*2 DD-404 RHIND
TEST B
SECRET

FIG. 26

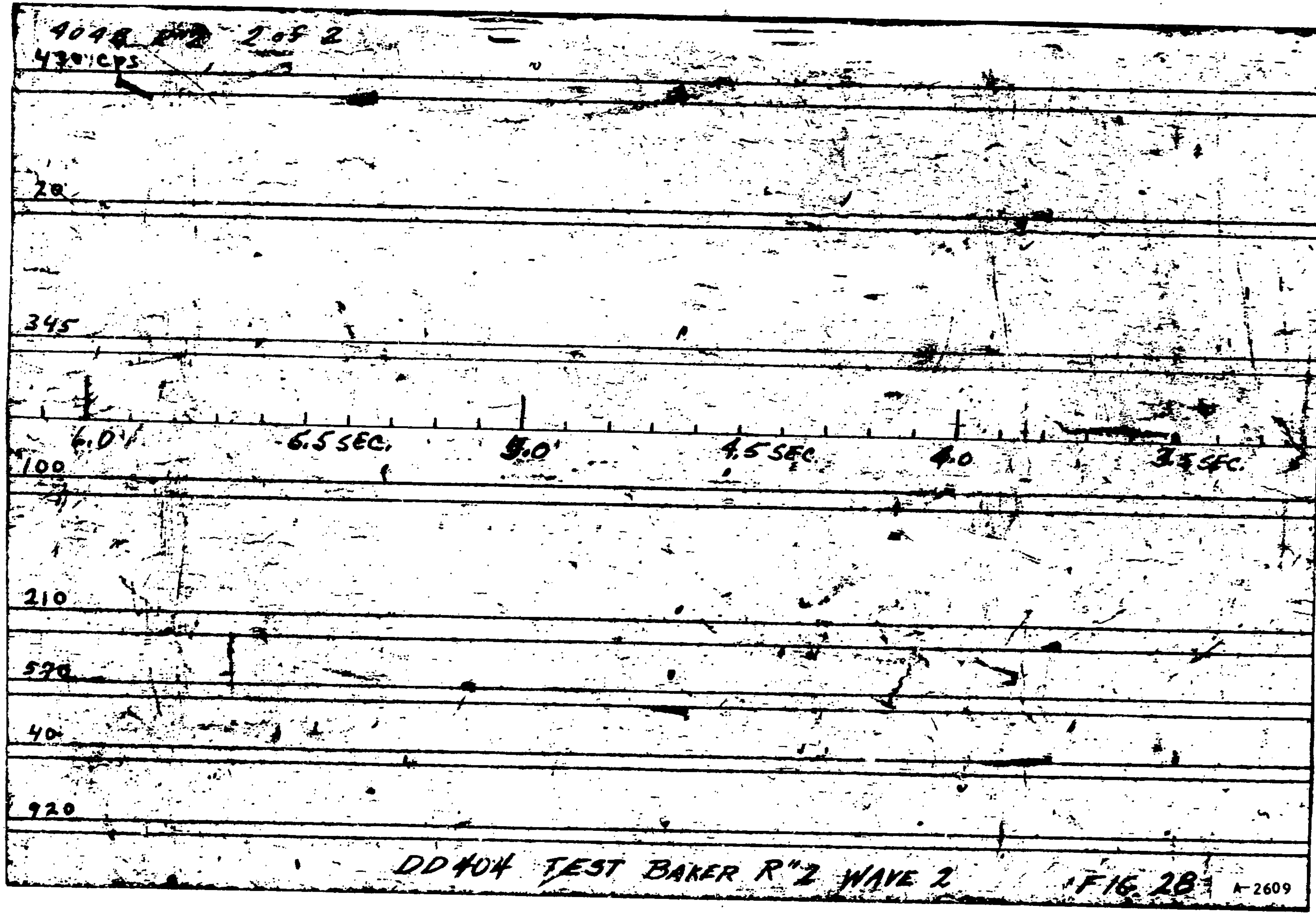
A-2609



DD404 TEST BAKER R"2 WAVE I

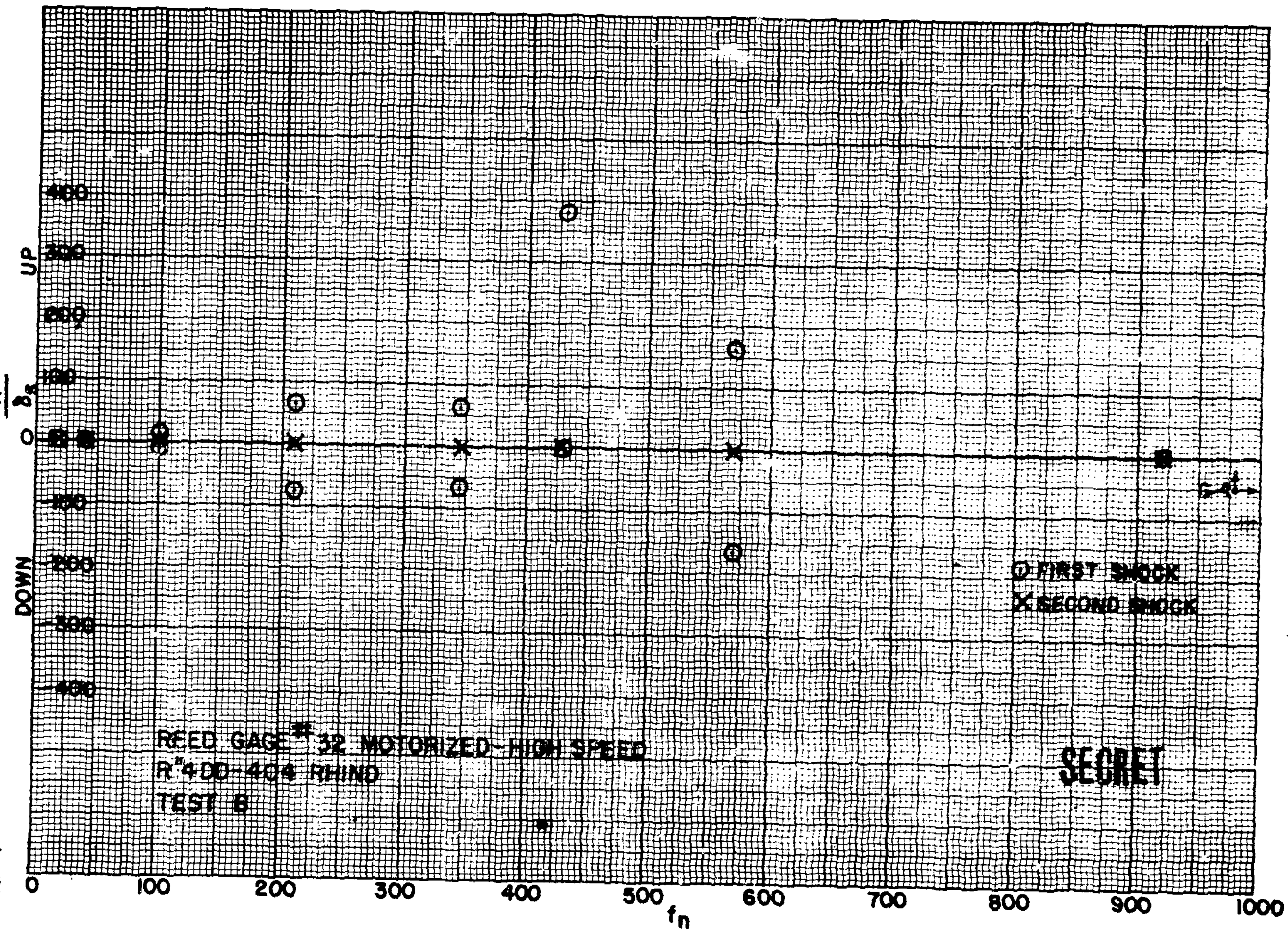
FIG. 27

A-2609



4048 2 of 2
430 CPS
20
345
6.0'
6.5 SEC.
5.0'
4.5 SEC.
4.0
3.5 SEC.
100
210
590
40
920
DD 404 TEST BAKER R"2 WAVE 2

FIG. 28 A-2609



REED GAGE # 32 MOTORIZED-HIGH SPEED
R # 400-404 RHINO
TEST B
FIRST SHOCK
SECOND SHOCK
SECRET
UP
DOWN
f_n
0
100
200
300
400
500
600
700
800
900
1000

FIG. 29

A-2409


404B R#4 1 of 3
930 cps
20
345
180
0.6 sec.
0.5
0.4 sec.
0.3
0.1
0
210
540
49
920
OD 404 TEST BAKER R#4 WAVE 1 PART 1 FIG 30
A-2609

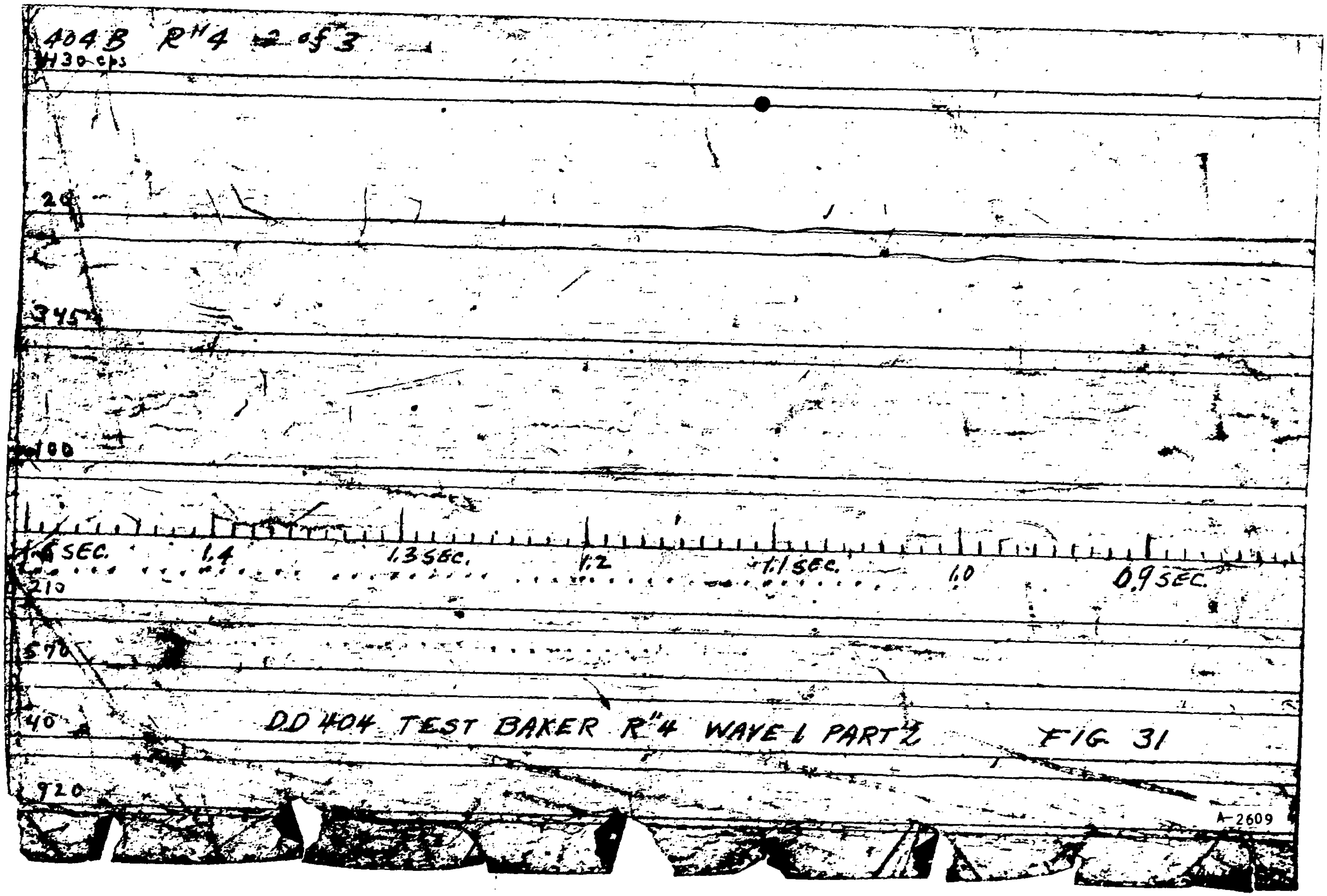
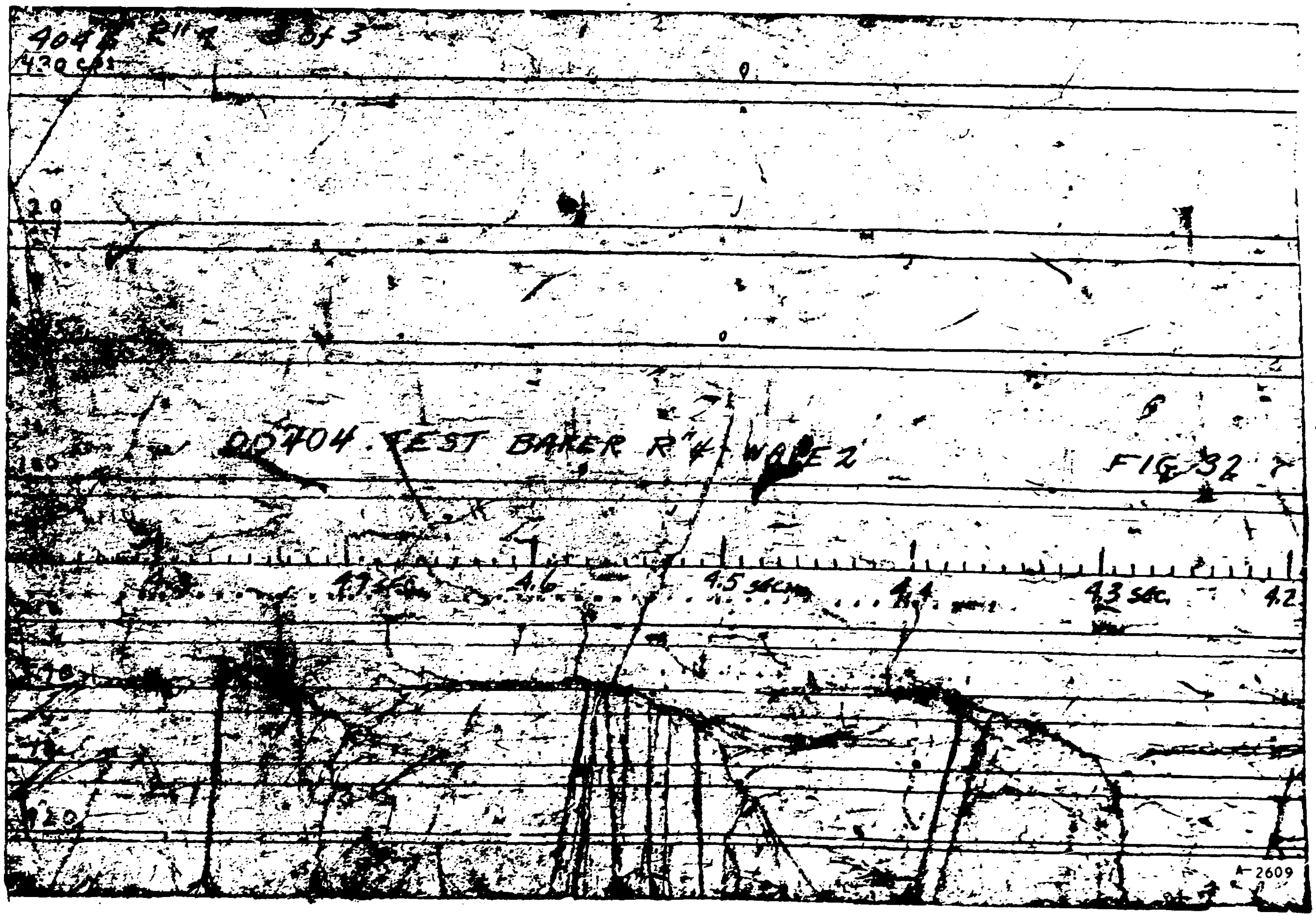

404 B R#4 2 of 3
H 30 cps
20
345
100
1.5 SEC.
1.4
1.3 SEC.
1.2
1.1 SEC.
1.0
0.9 SEC.
210
570
40
920
DD 404 TEST BAKER R#4 WAVE 1 PART 2
A-2609

FIG 31



3 of 3
430 cps
DD704 TEST BAKER R"4 WAVE 2
FIG 32
4.7 sec
4.6
4.5 sec
4.4
4.3 sec.
4.2
A-2609

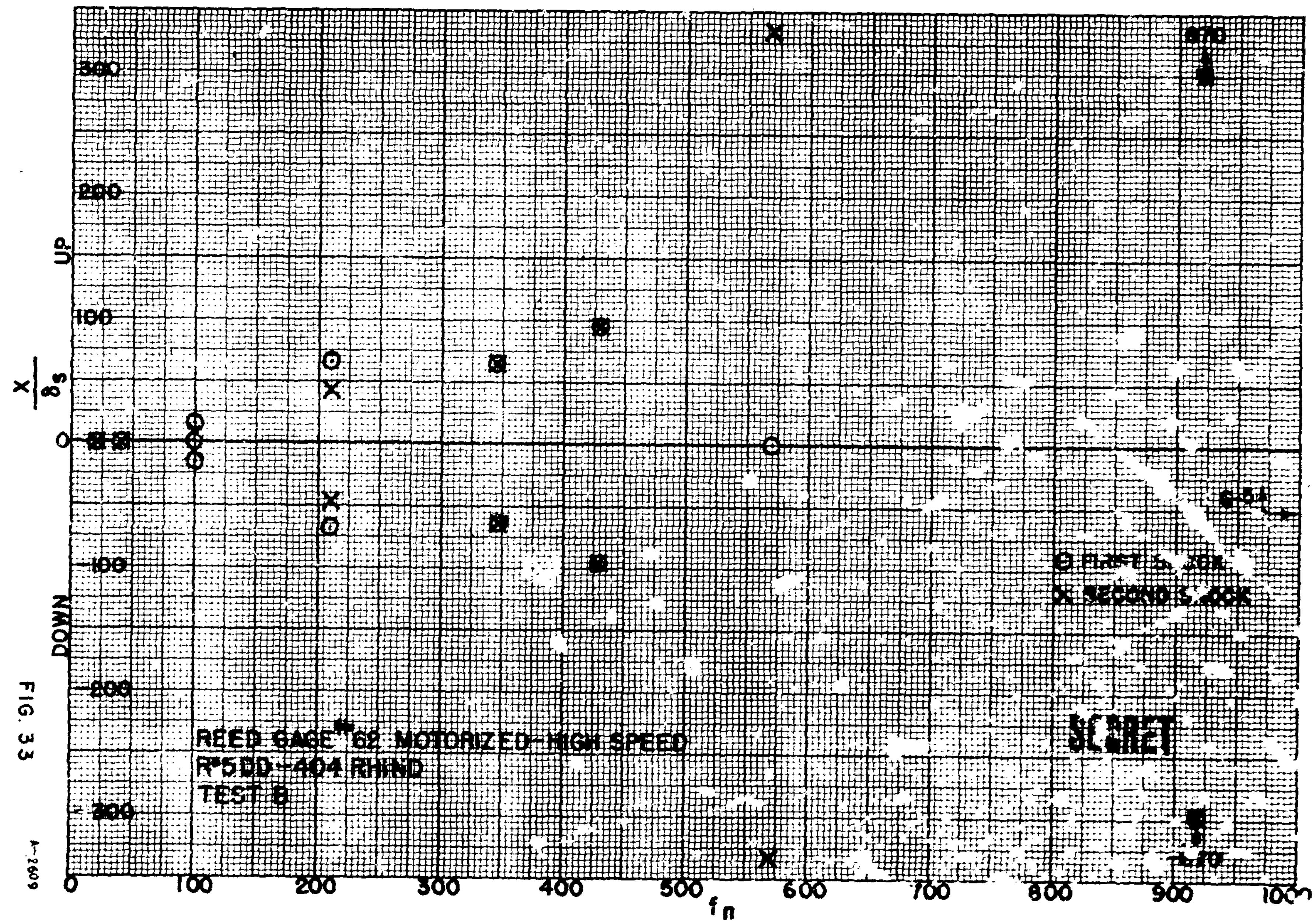

REED GAGE #62 MOTORIZED-HIGH SPEED
R#5DD-404 RHIND
TEST B
SECRET
⊙ FIRSTS
X SECONDS
UP
DOWN
X/δs
fn
0
100
200
300
400
500
600
700
800
900
1000
-100
-200
-300

FIG. 33

A-2609

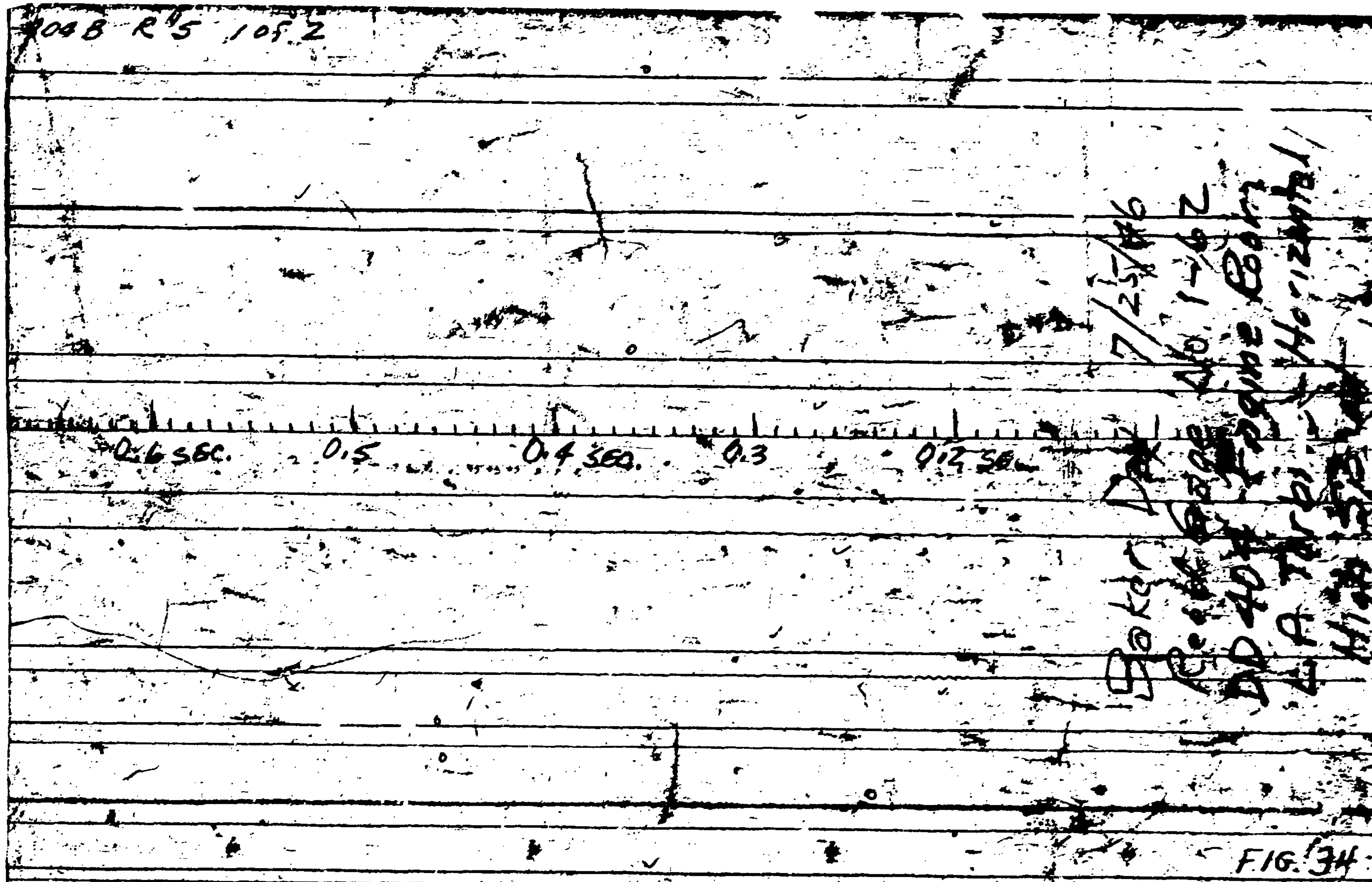
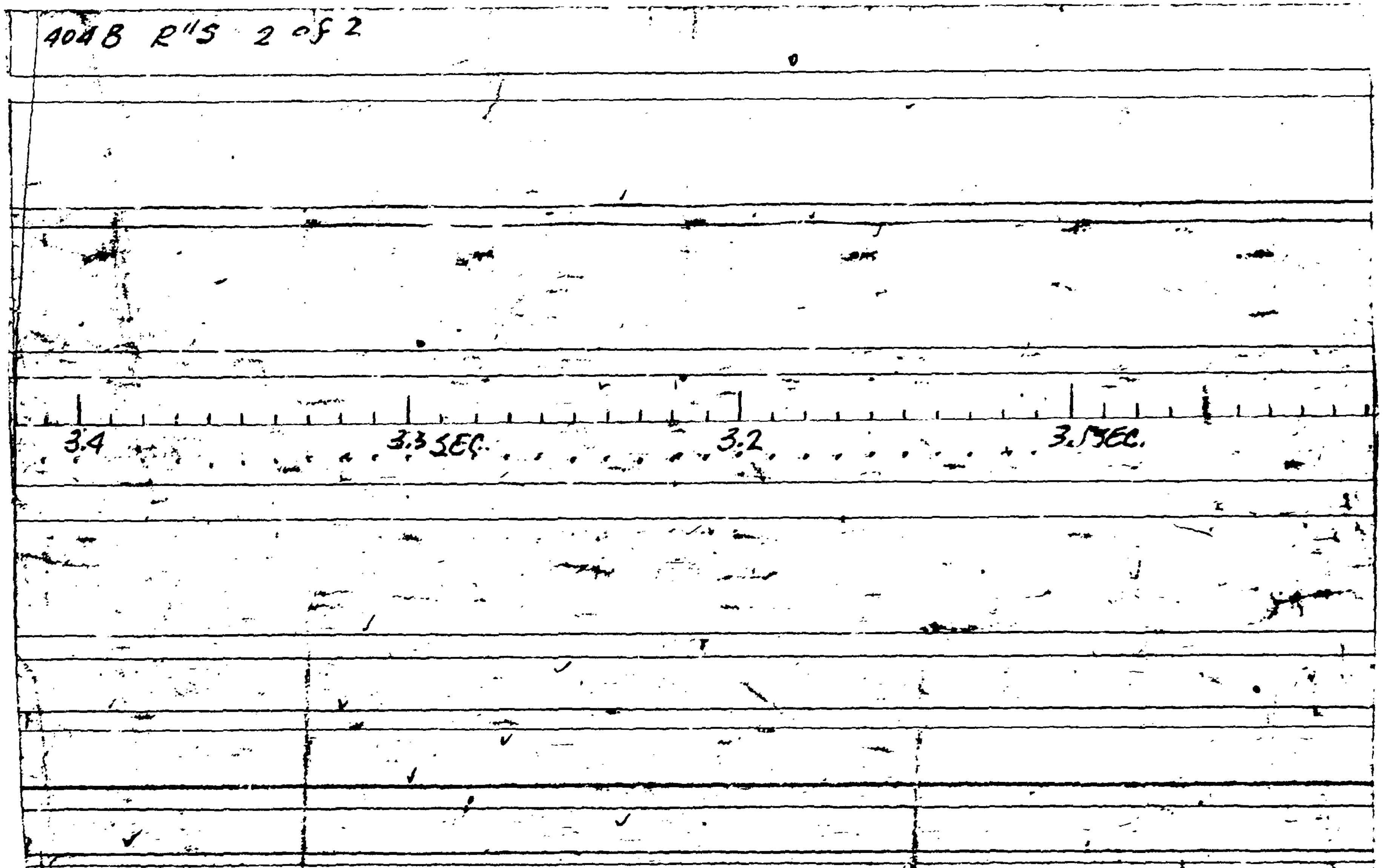


FIG. 34

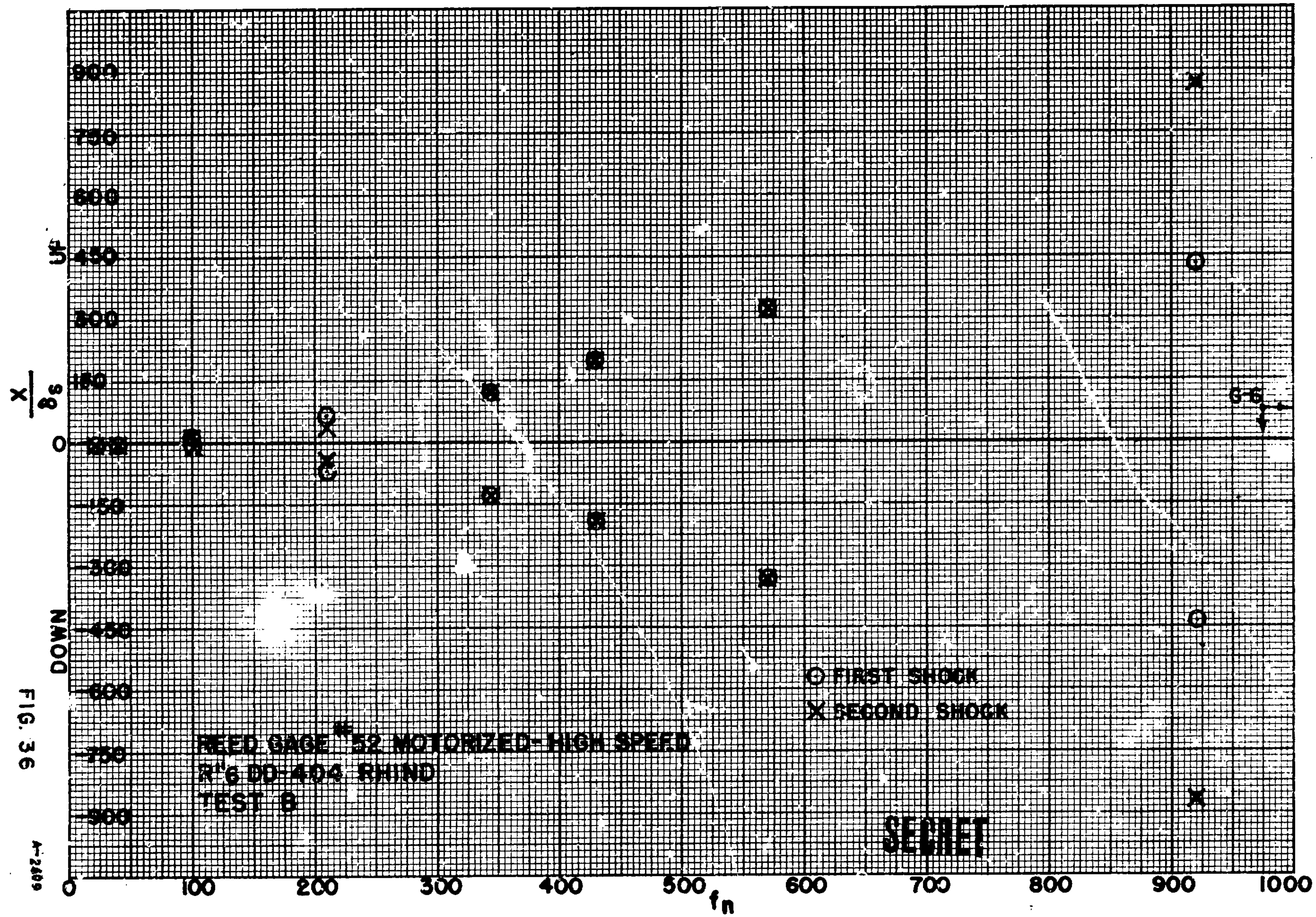
DD404 TEST BAKER R 5 WAVE 1

A-2609



DD 404 TEST BAKER WAVE FIG. 35

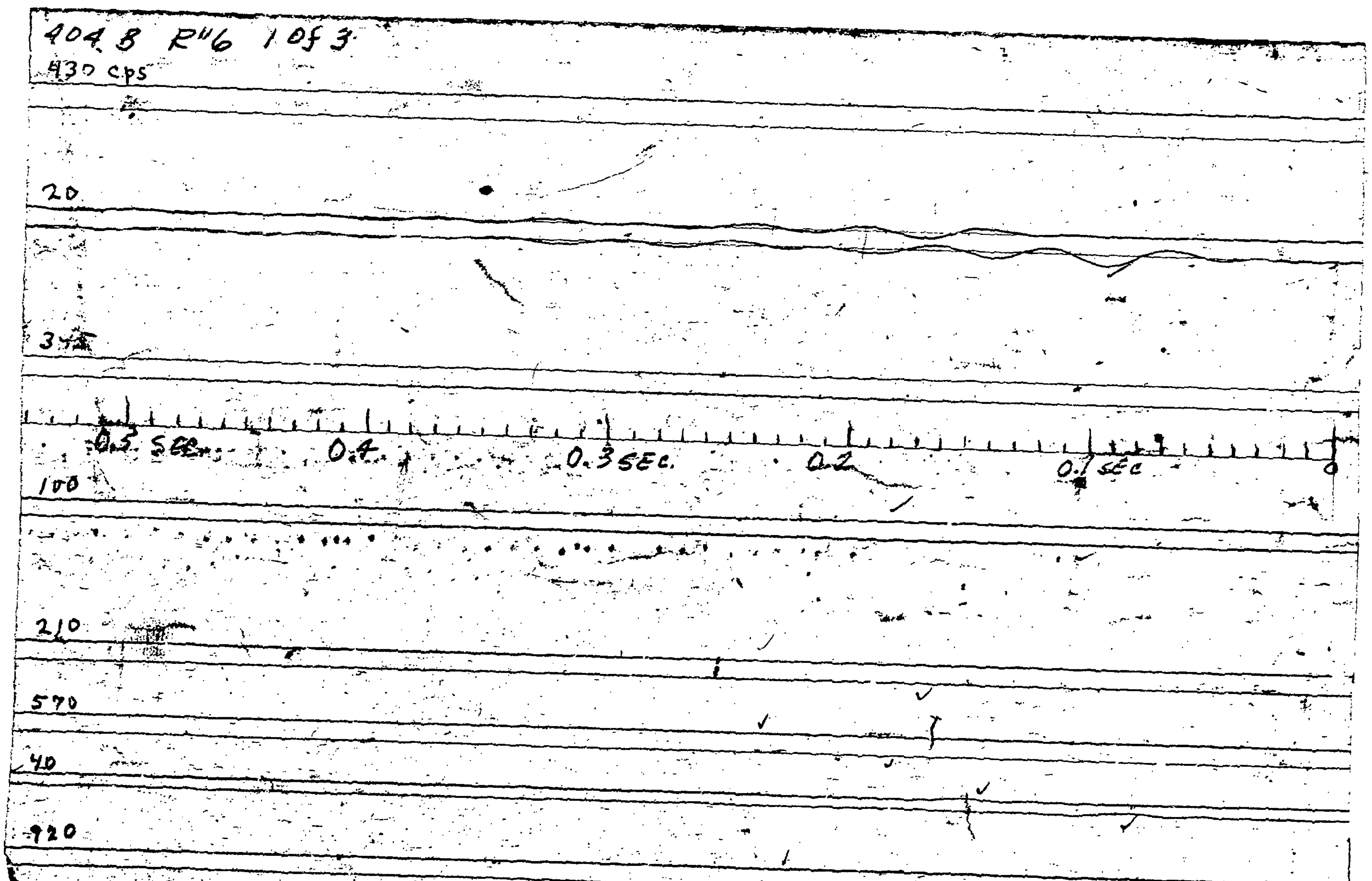
A-2609



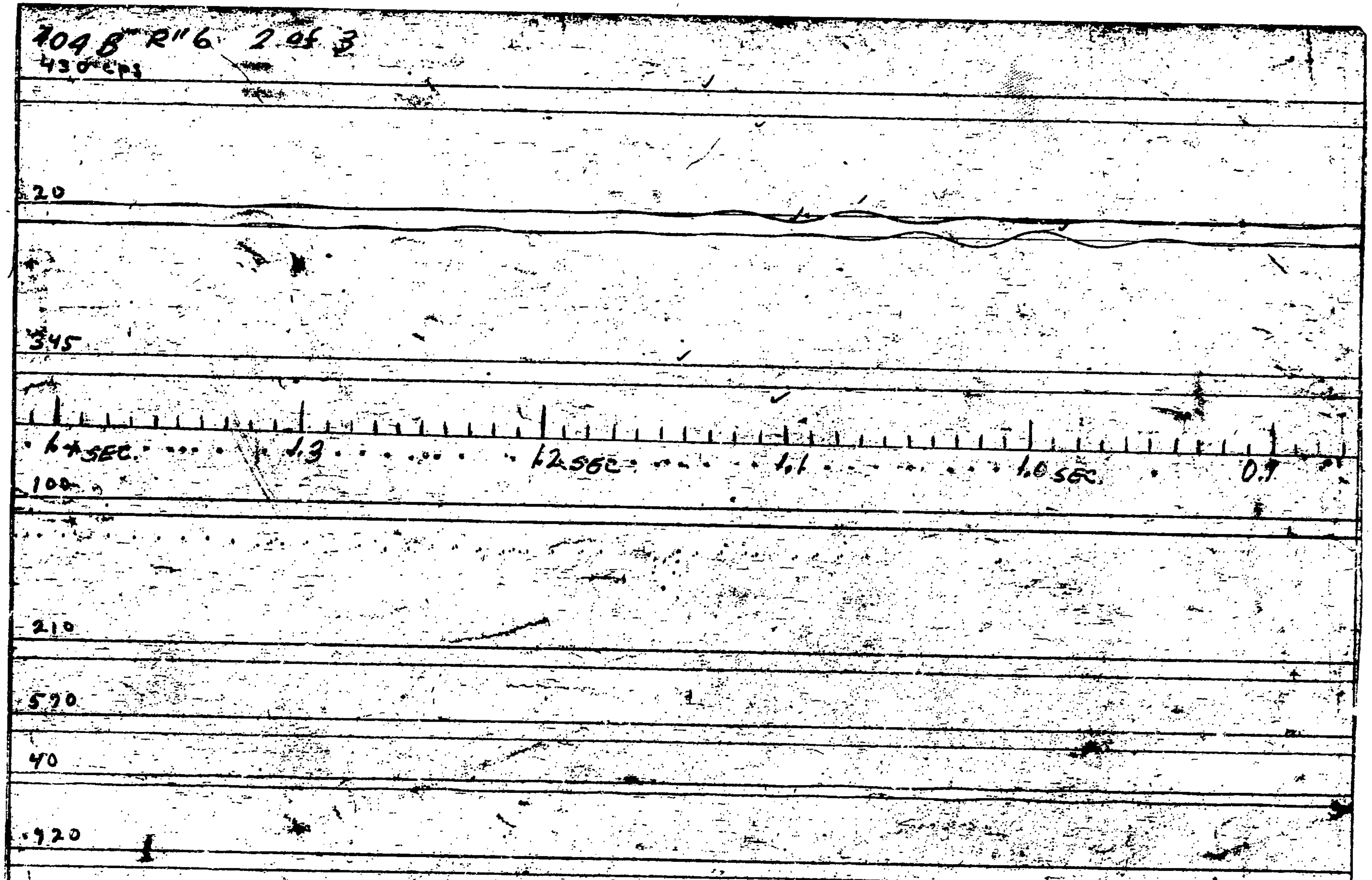
900
750
600
UP
450
300
150
$\frac{X}{g_s}$
0
-150
-300
DOWN
-450
-600
-750
-900
0
100
200
300
400
500
600
700
800
900
1000
f_n
G-6
O FIRST SHOCK
X SECOND SHOCK
REED GAGE #52 MOTORIZED- HIGH SPEED
R'6 DD-404 RHIND
TEST B
SECRET

FIG. 36

A-2409



DD 404 TEST BAKER R"6 "WAVE 1, PART 1 FIG. 37 A-2609

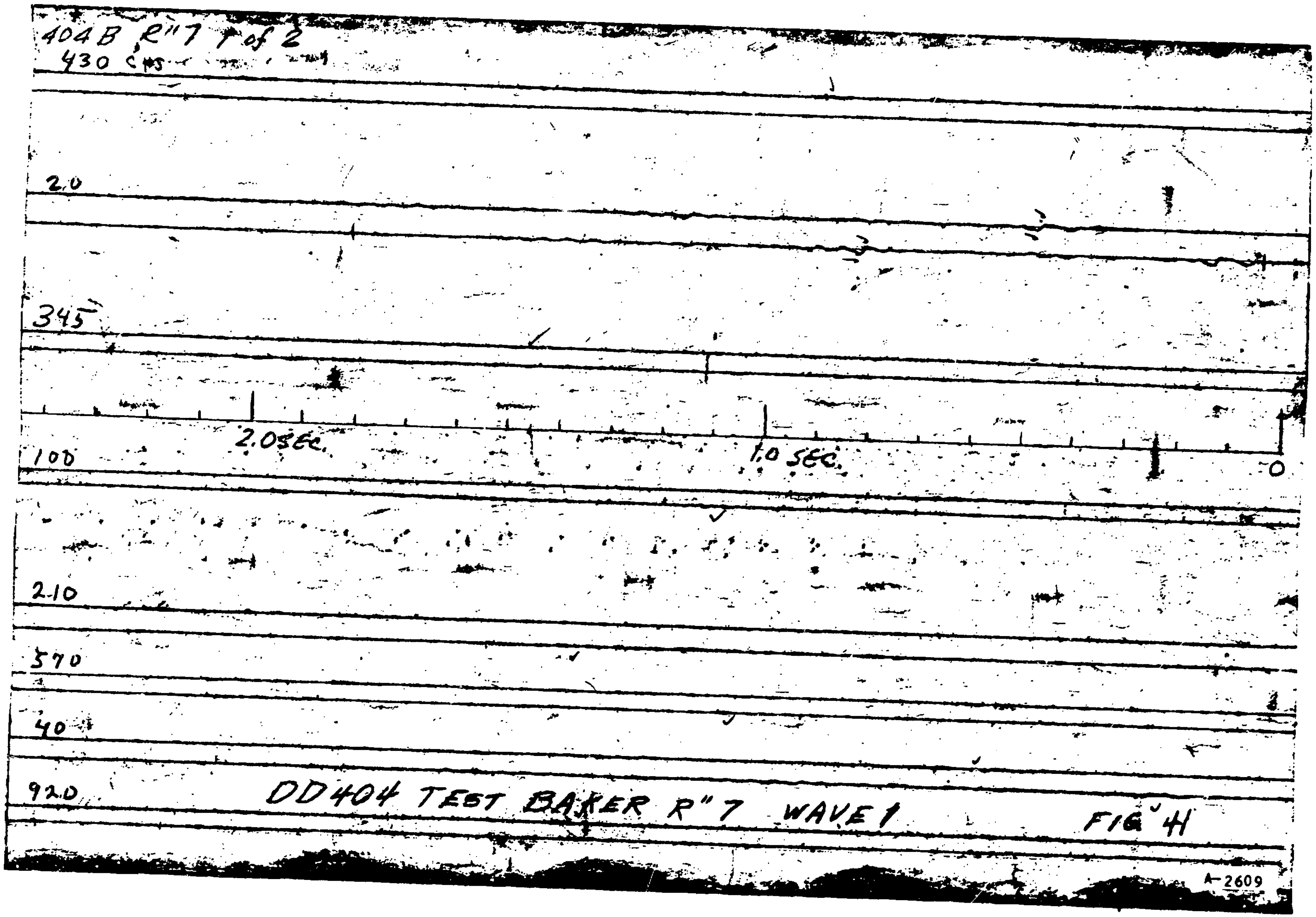


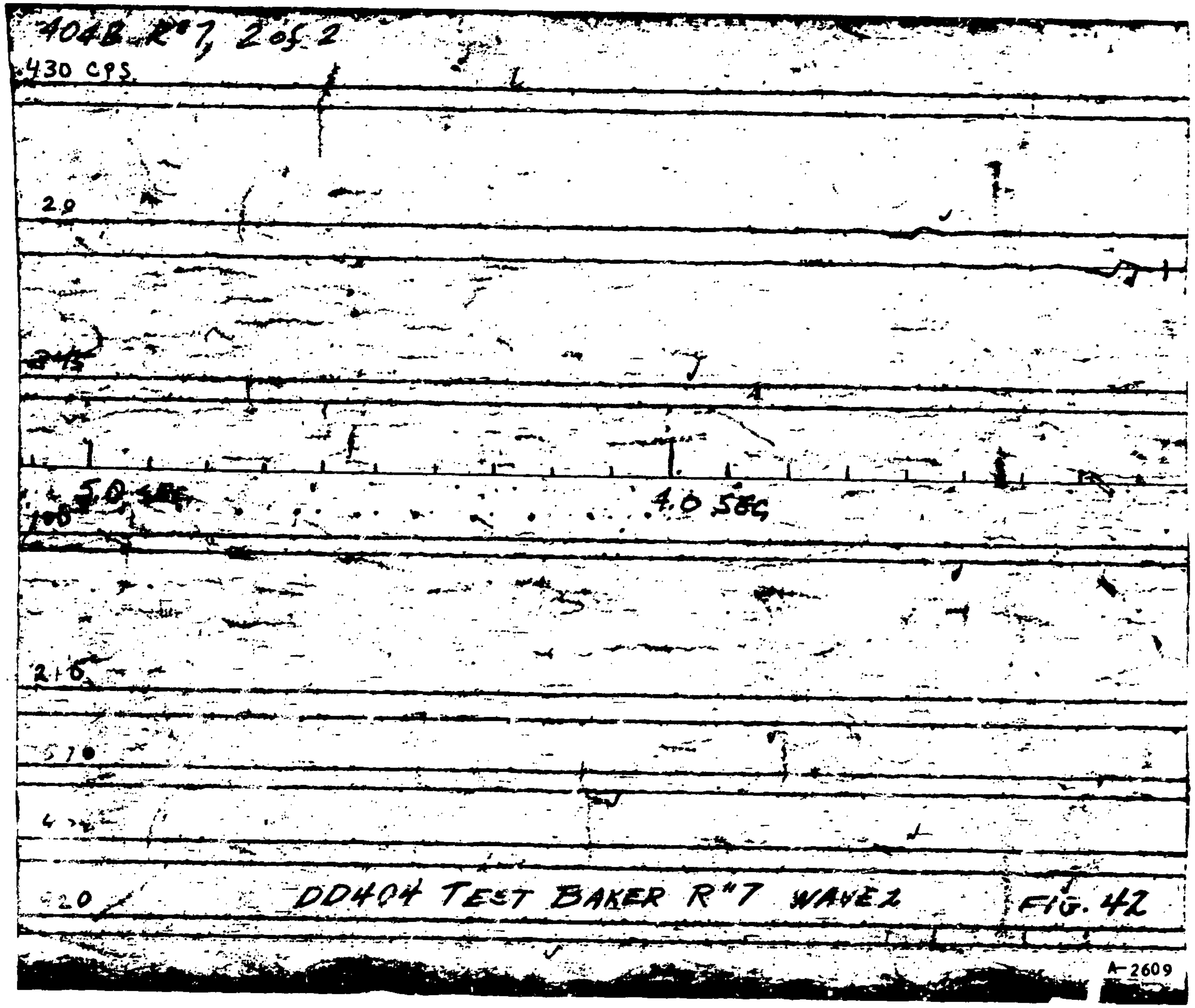
DD 404 TEST BAKER R"6 WAVE 1 PART 2 FIG 38

A-2609

DD 404 TEST BAKER R"6 WAVE 2 FIG. 39

A-2609


404B R"7 1 of 2
430 CPS
2.0
345
2.0 SEC.
1.0 SEC.
0
100
210
370
40
920
OD404 TEST BAKER R"7 WAVE 1
FIG. 41
A-2609



DD404 TEST BAKER R#7 WAVE 2 FIG. 42

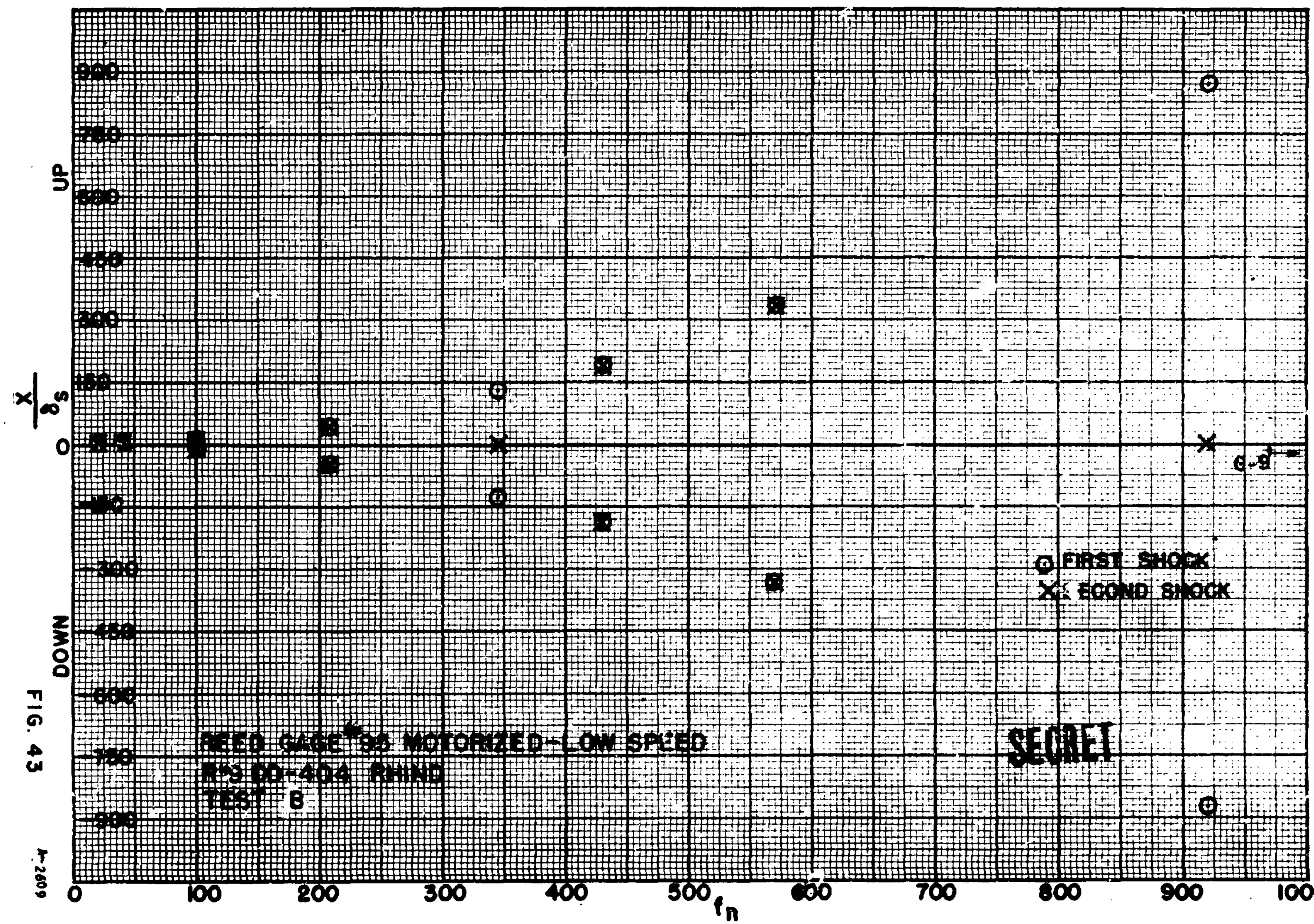
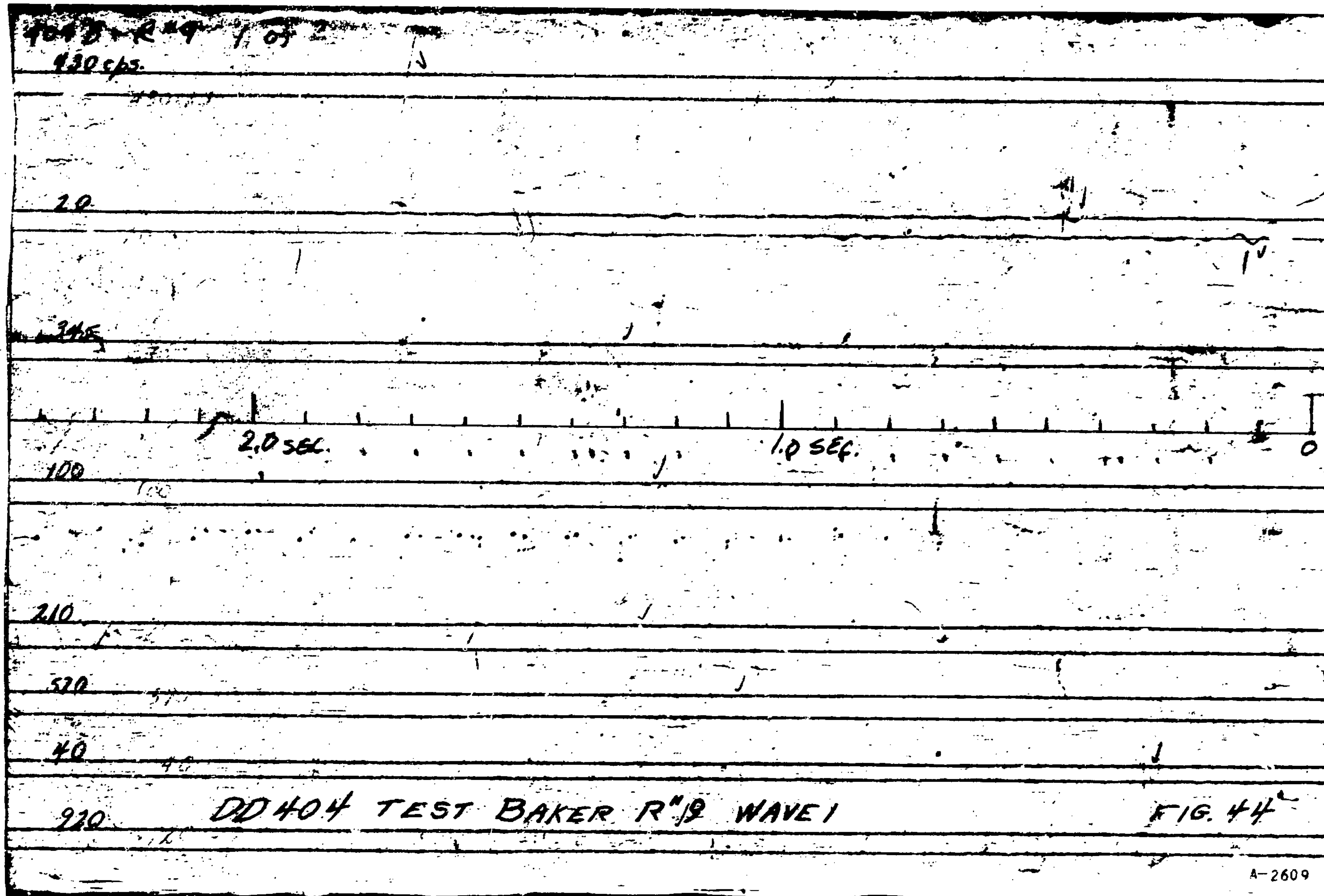

REED GAGE #96 MOTORIZED-LOW SPEED
R#3 DD-404 RHIND
TEST B
FIRST SHOCK
SECOND SHOCK
SECRET
UP
DOWN
$\frac{X}{g_s}$
f_n
900
750
600
450
300
150
0
-150
-300
-450
-600
-750
-900
0
100
200
300
400
500
600
700
800
900
1000

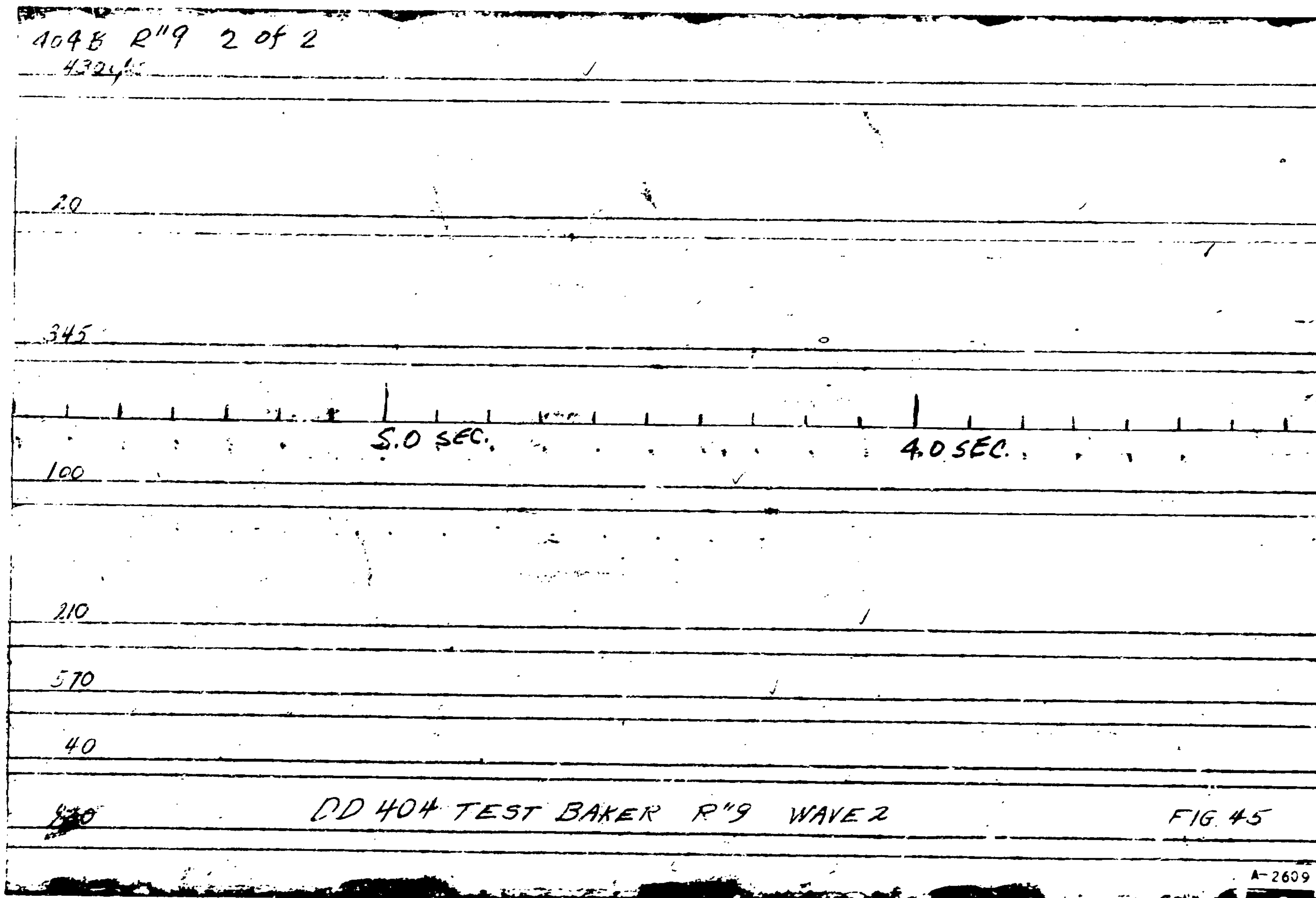
FIG. 43

A-2609



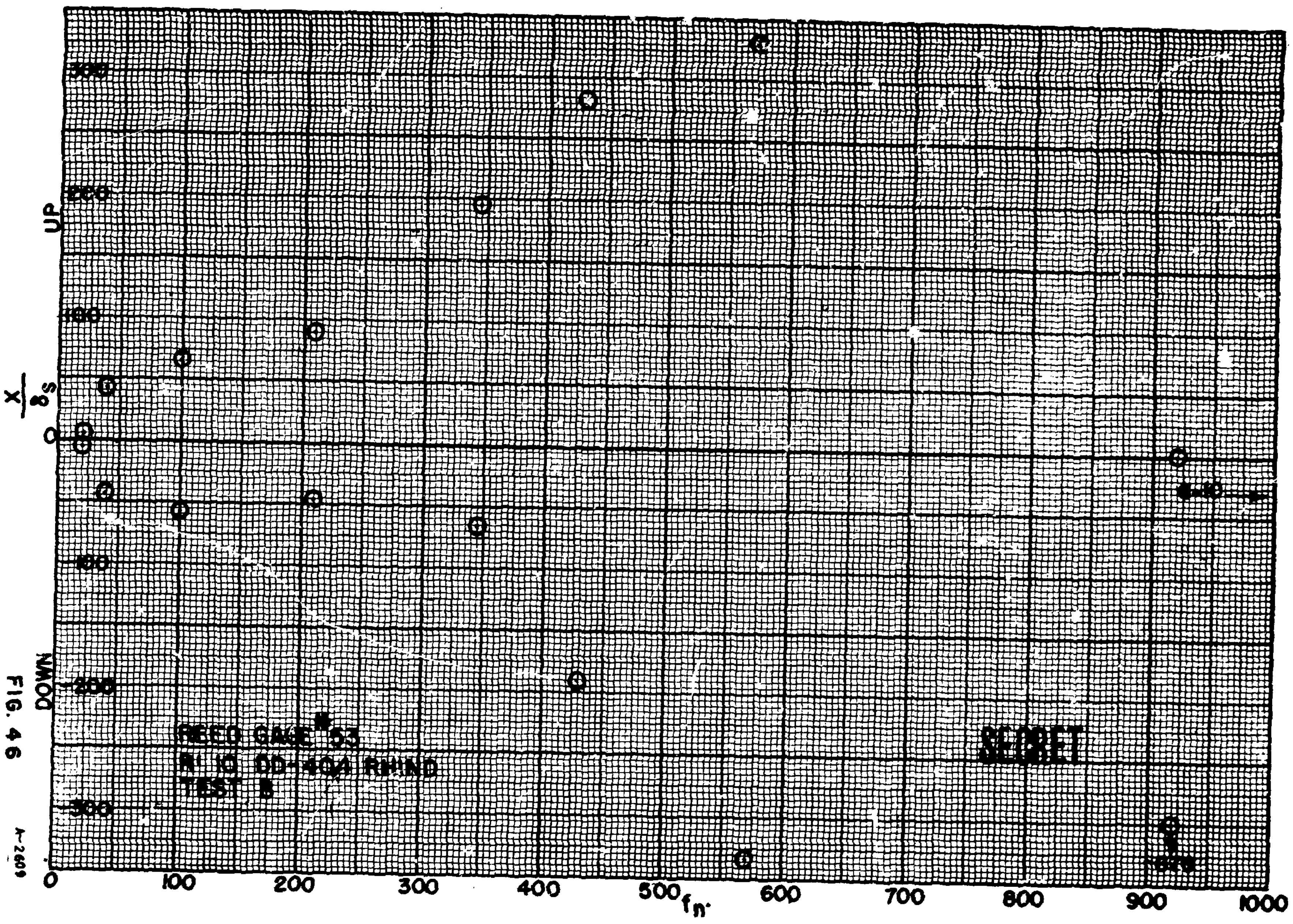
DD 404 TEST BAKER R"19 WAVE 1   FIG. 44

A-2609



404B R"9 2 of 2
20
345
5.0 SEC.
4.0 SEC.
100
210
570
40
DD 404 TEST BAKER R"9 WAVE 2
A-2609

FIG 45



UP
DOWN
300
200
100
0
-100
-200
-300
0
100
200
300
400
500
600
700
800
900
1000
REED GAGE # 53
R' 10 DD-404 RHIND
TEST B
SECRET

FIG. 46

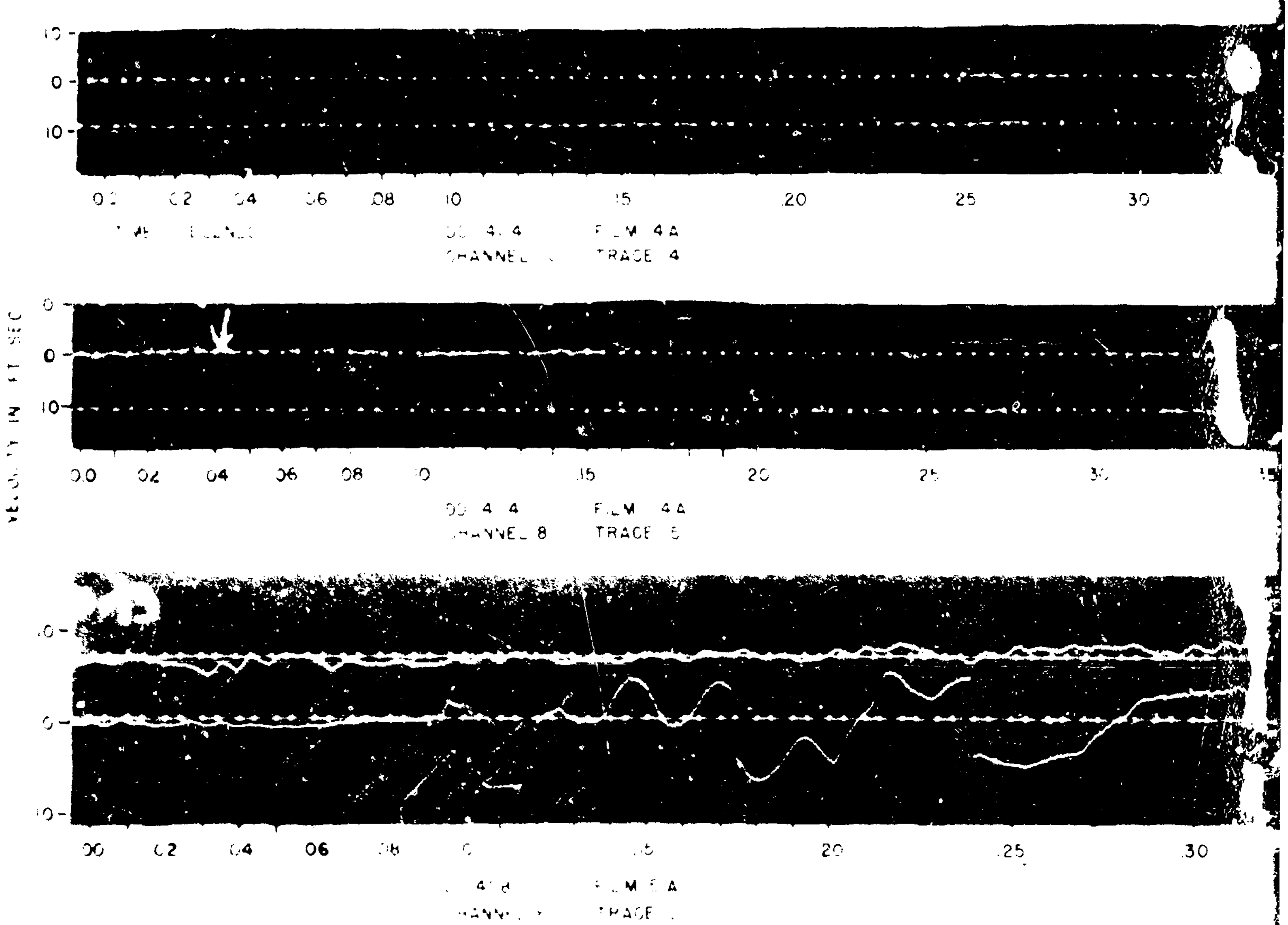
A-2609

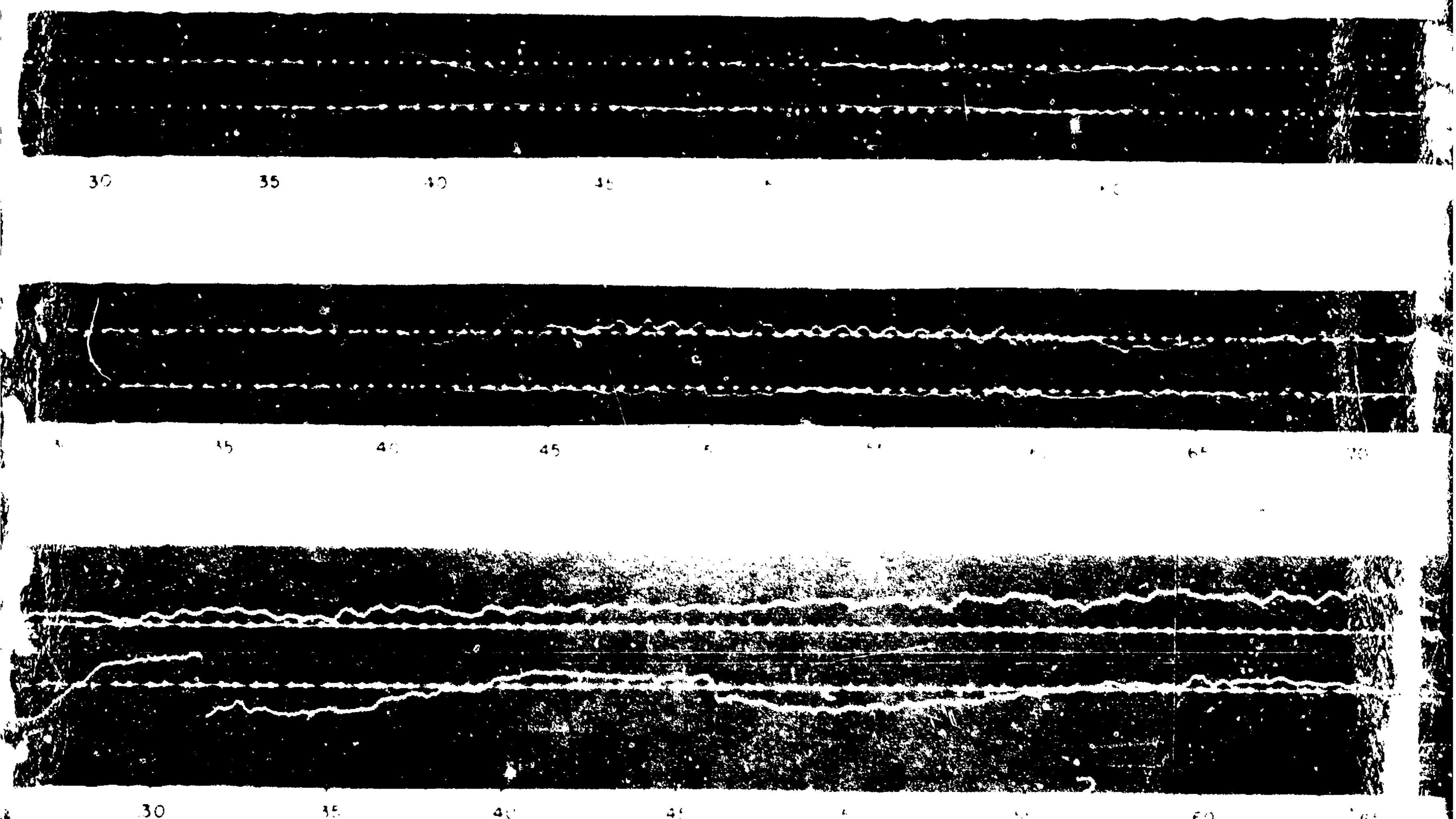
VELOCITY CURVES OBTAINED FROM V' GAGES

FM WIRE RECORDER

TEST ABLE

ZERO TIME CHOSEN ARBITRARILY





2

TOP SECRET

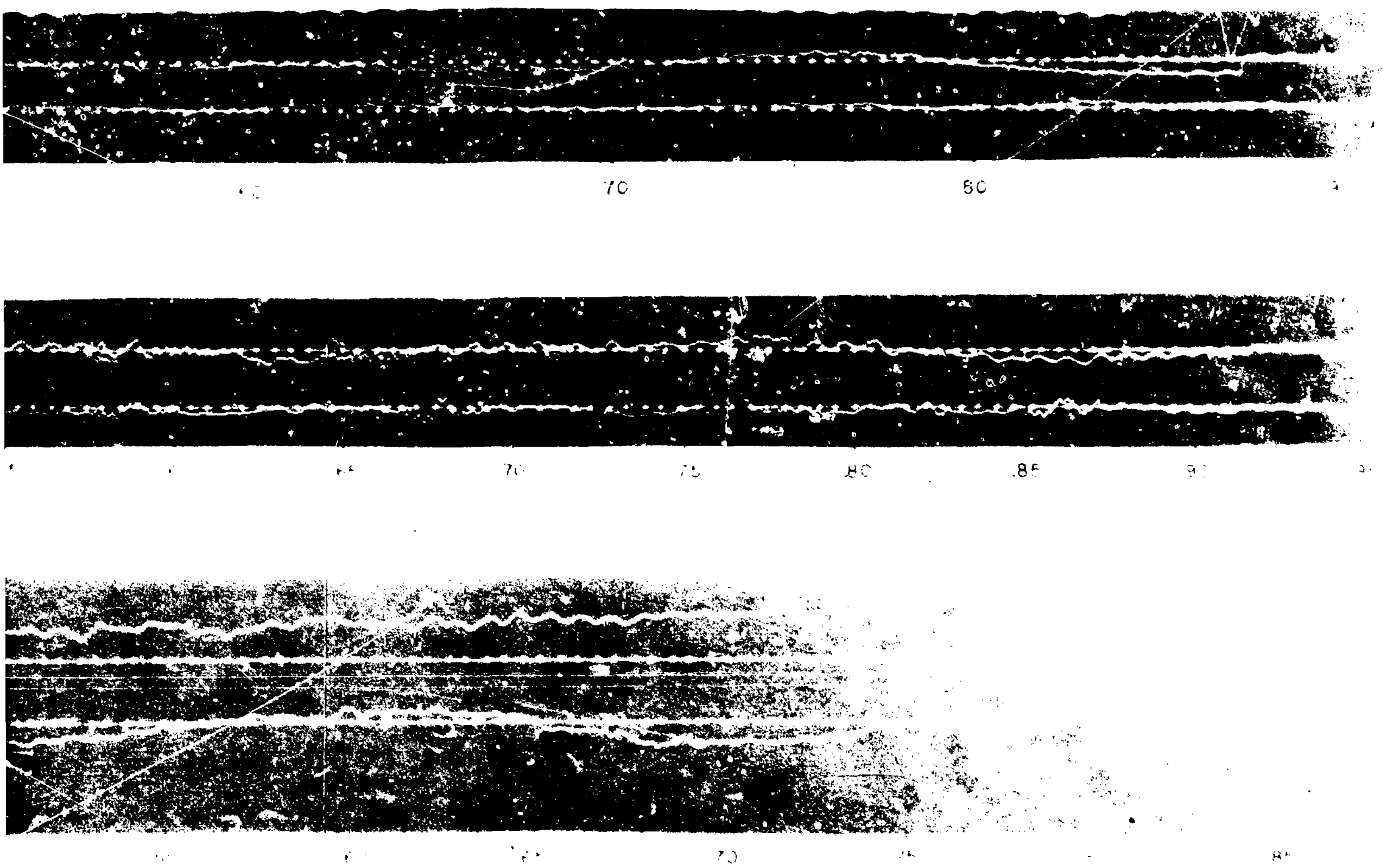


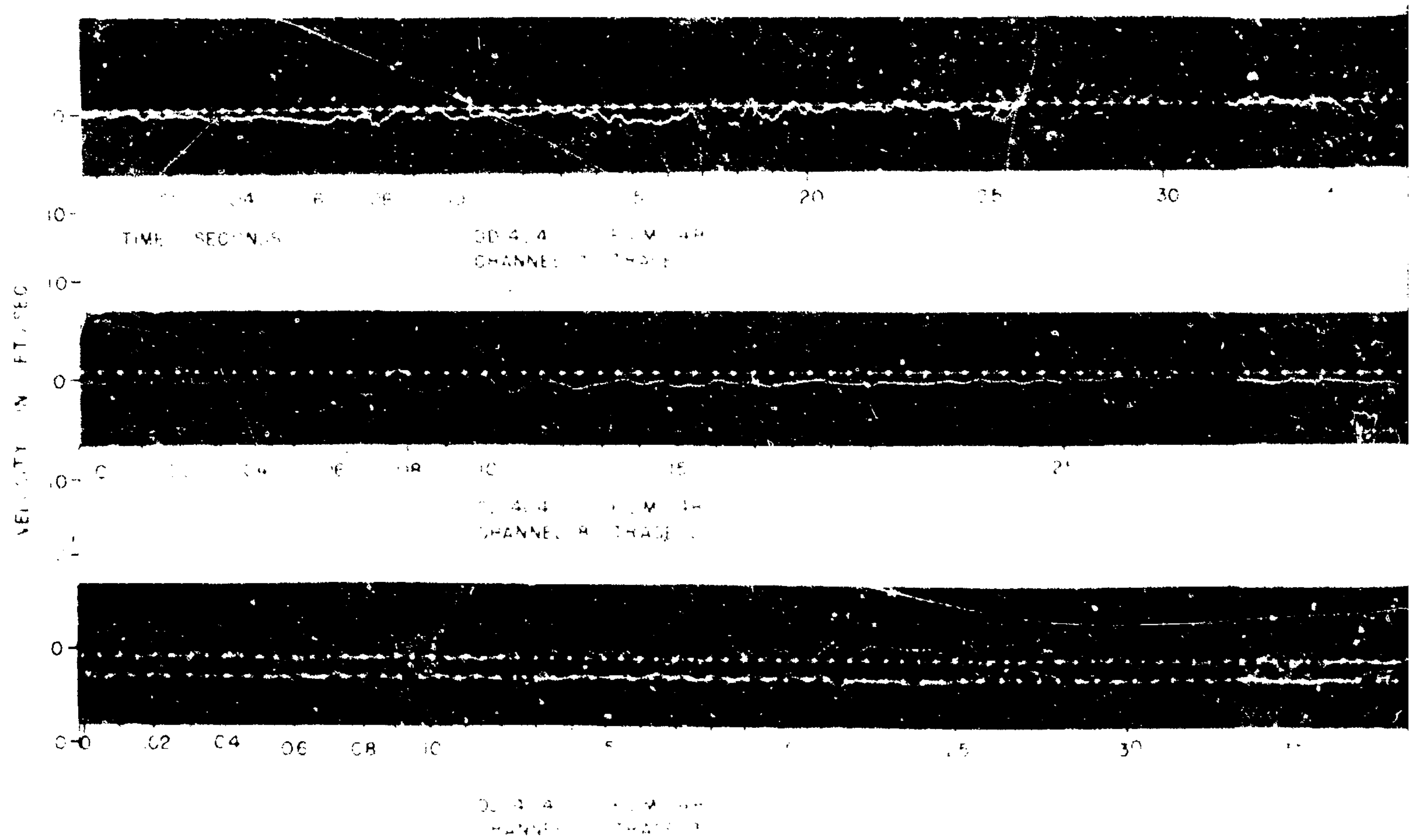
FIG 47

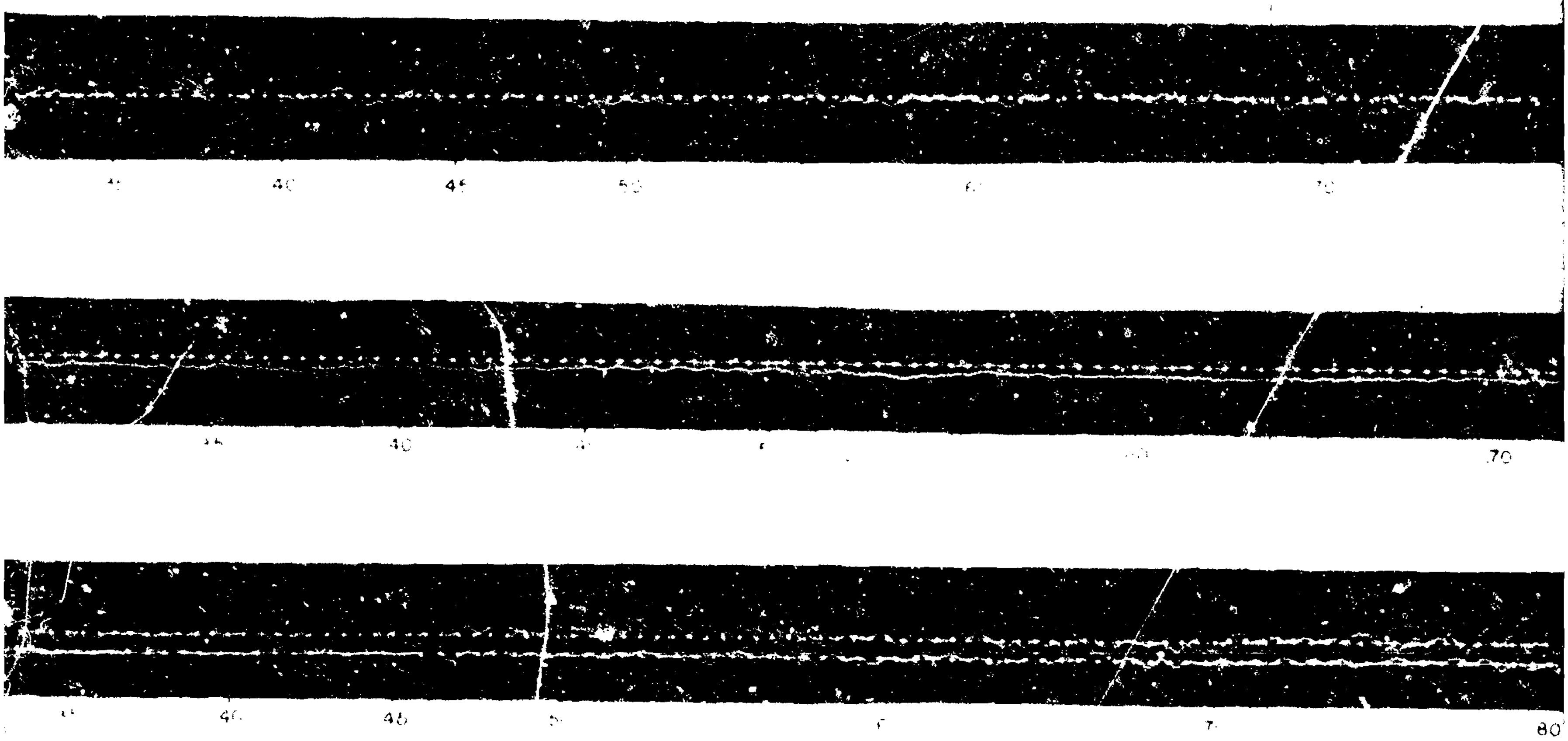
3

VELOCITY CURVES OBTAINED FROM V' GAGES

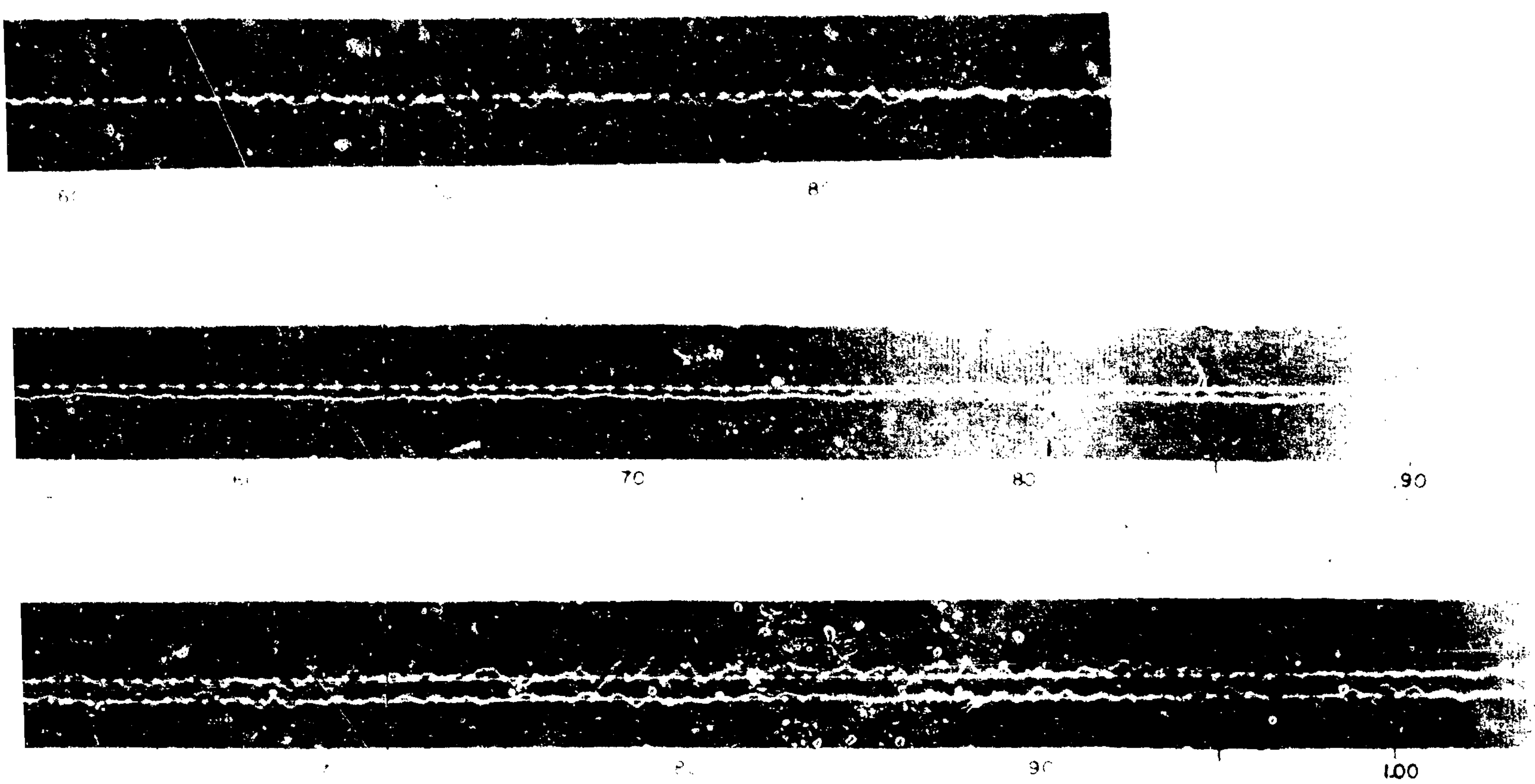
FM WIRE RECORDER

TEST BAKER





2



3

FIG. 48

A-3609

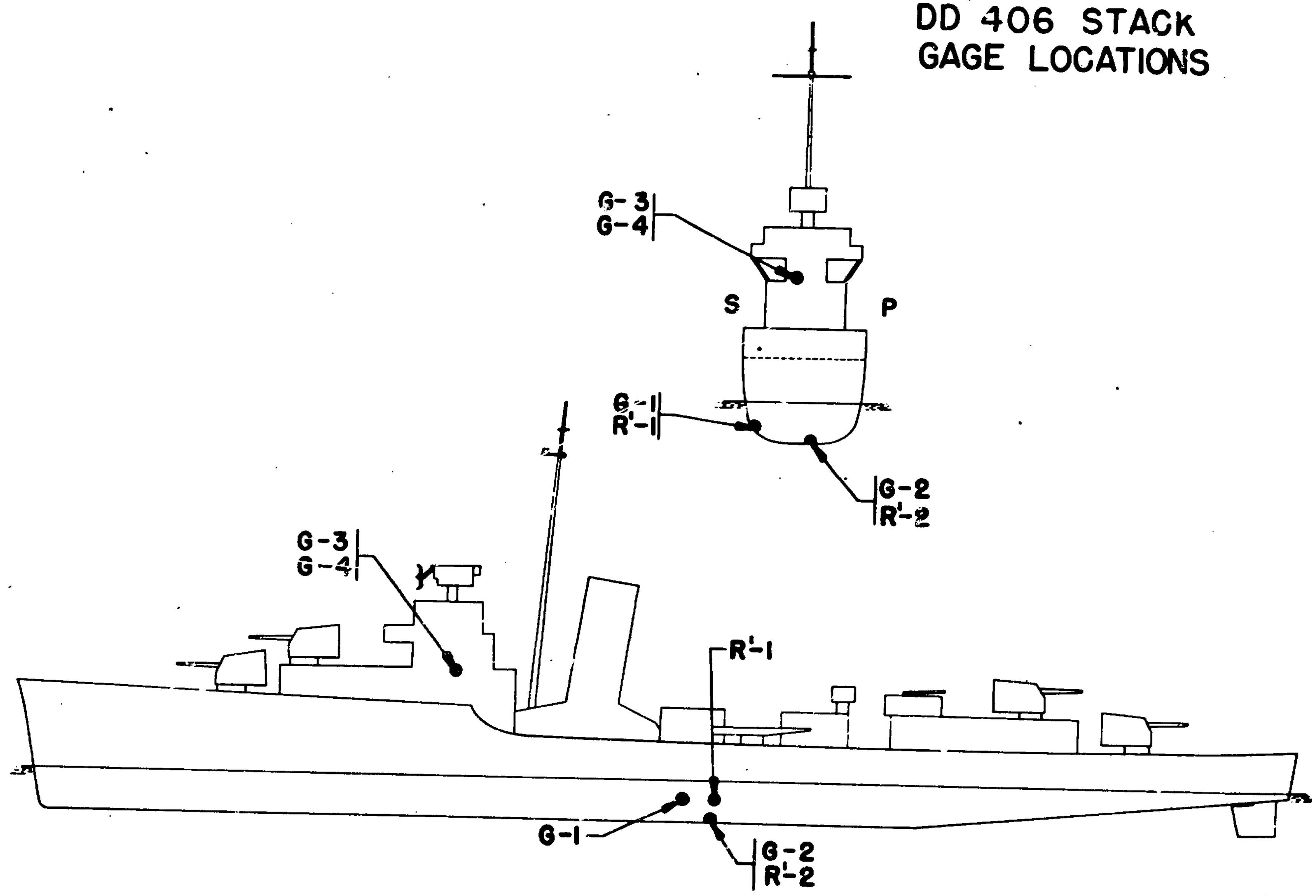


FIG. 49

A-2609

DD406 - USS STACK

Putty Gages

G1 - Similar to photo 261. Aft fireroom, compartment B-2-1. Directed to port on starboard frame 97, 4 ft. below upper grating level.

A. (3) less than 50g. B. Less than 50g.

G2 - Similar to photo 262. Aft fireroom, compartment B-2-1. Directed up on top of keel 10" forward of frame 101.

A. Less than 50g. B. Less than 50g.

G3 - Photo 291. C.I.C. Directed up on deck 5" inboard from starboard bulkhead, just inside starboard door.

A. (2) 90g. B. 30g.

G4 - Photo 292. Supply Office. Directed to port on beam, frame 61, 3 ft. from beam on ship's center line and to starboard.

A. (2) 40g. B. Less than 20g.

Reed Gages

R'1 - Similar to photo 260. Aft fireroom, compartment B-2-1. Directed to port on starboard frame 101, 4 ft. below upper grating level.

	20 cps		20 cps	
Graph	Up	Dn	Up	Dn
A. (3) Fig. 50	.055	.05	.015	.015
B. Fig. 51	.03	.03	0	.02

R'2 - Similar to photo 262. Aft fireroom, compartment B-2-1. Vertical on top of keel at frame 101. Directed up.

	20 cps		20 cps	
Graph	Up	Dn	Up	Dn
A. (3) Readings all zero.				
B. Figure 52	0.65	.055	.005	0

DD496 - USS STACK

COMMENTS

Test Able   Range 3995 ft.   Bearing 31°

The gages below the waterline indicated negligible shock although R'2 on the keel had a slight shock. The putty gages in C.I.C. gave readings of 90 and 40g. in good correlation with the similarly place gages of the DD390 and DD404.

Test Baker   Range 6150 ft.   Bearing 324°

Instruments were placed in expectation of incidence of the pressure wave on the starboard side rather than the port bow. The underwater reed gages indicated slight shock. The only putty gage which had a record was vertical in C.I.C. which supports the anomalous data of the DD404, DD402, etc.

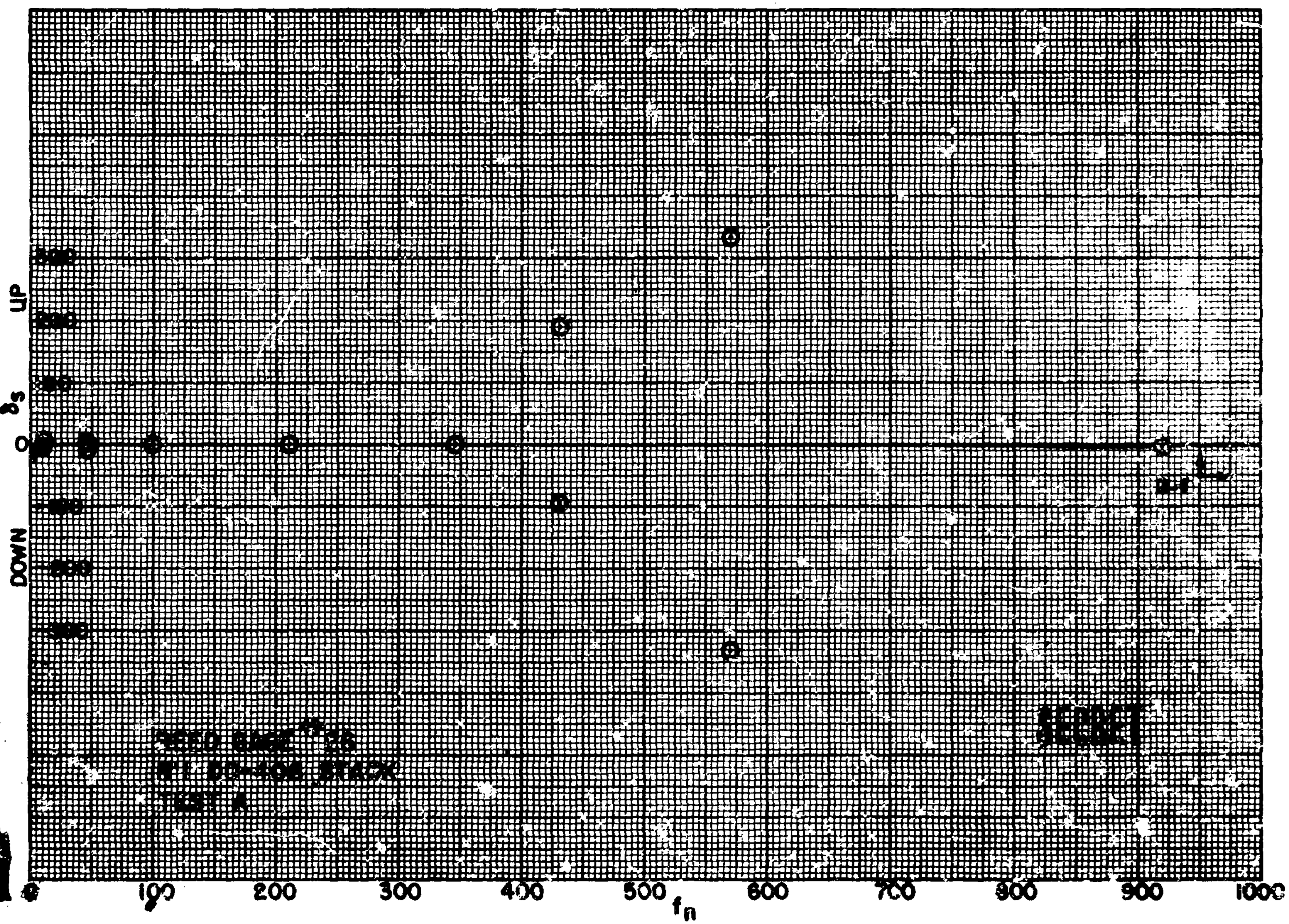


FIG. 50

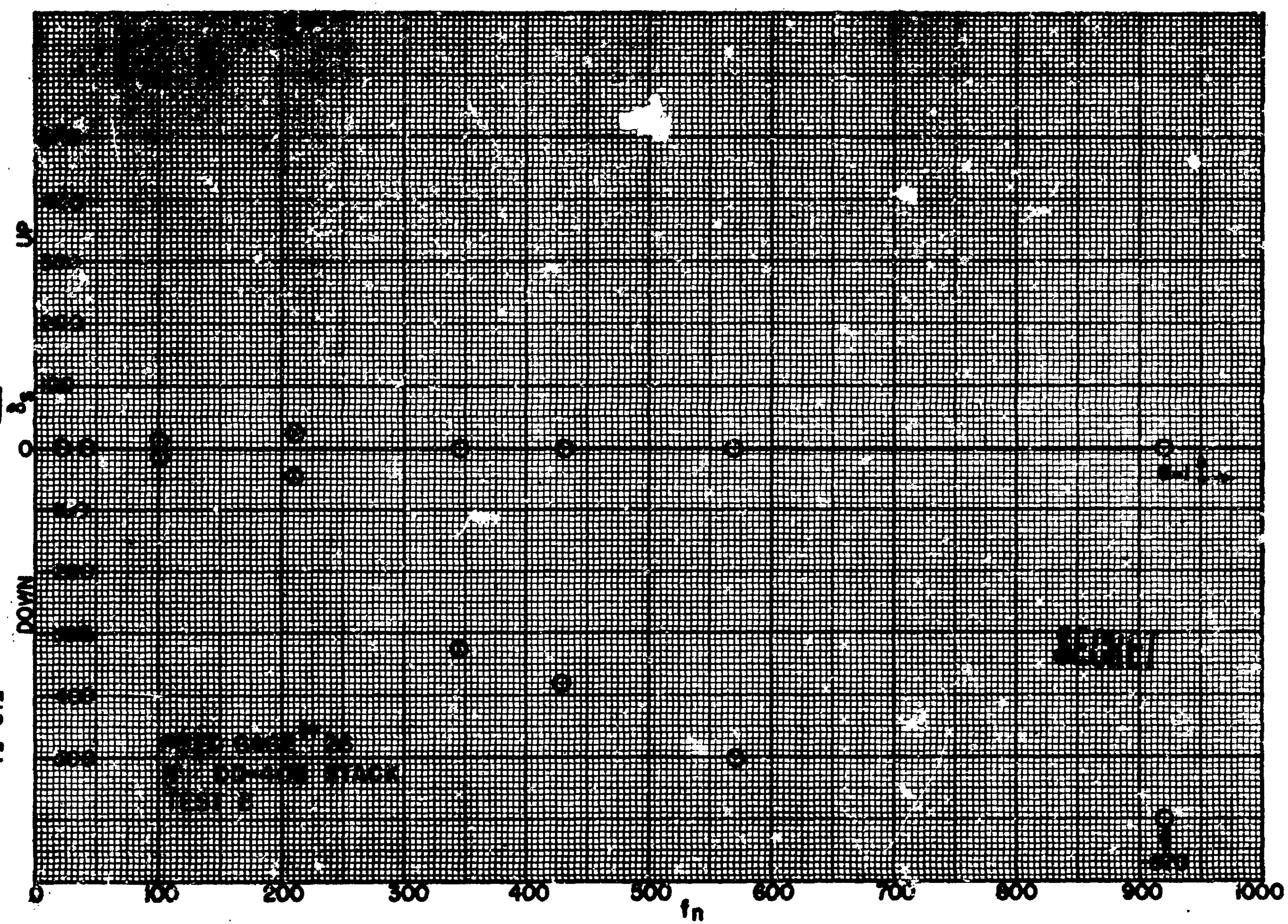


FIG. 51

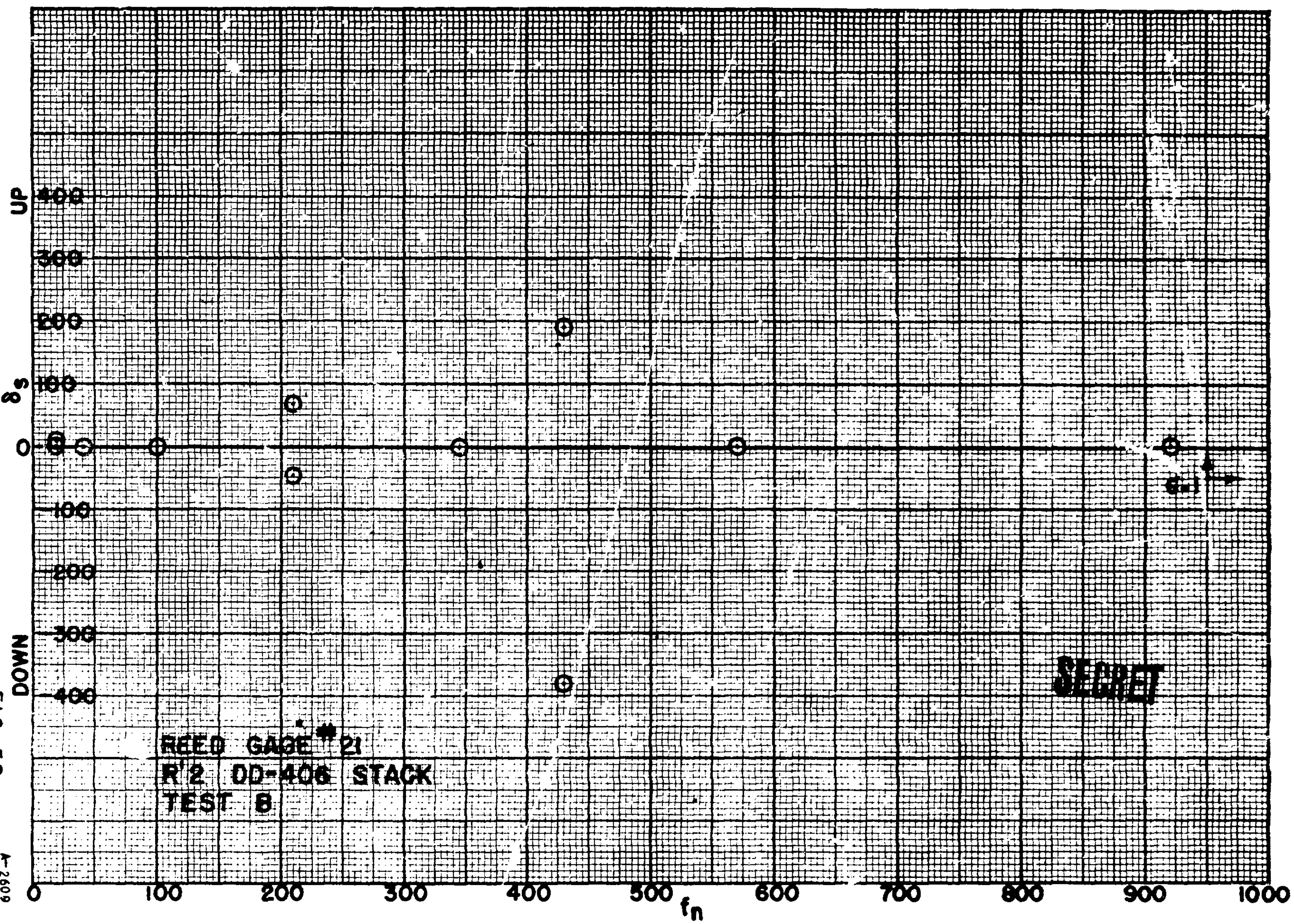

UP
DOWN
x/δs
400
300
200
100
0
-100
-200
-300
-400
0
100
200
300
400
500
600
700
800
900
1000
fn
REED GAGE # 21
R'2 DD-406 STACK
TEST B
SECRET

FIG. 52

A-2609

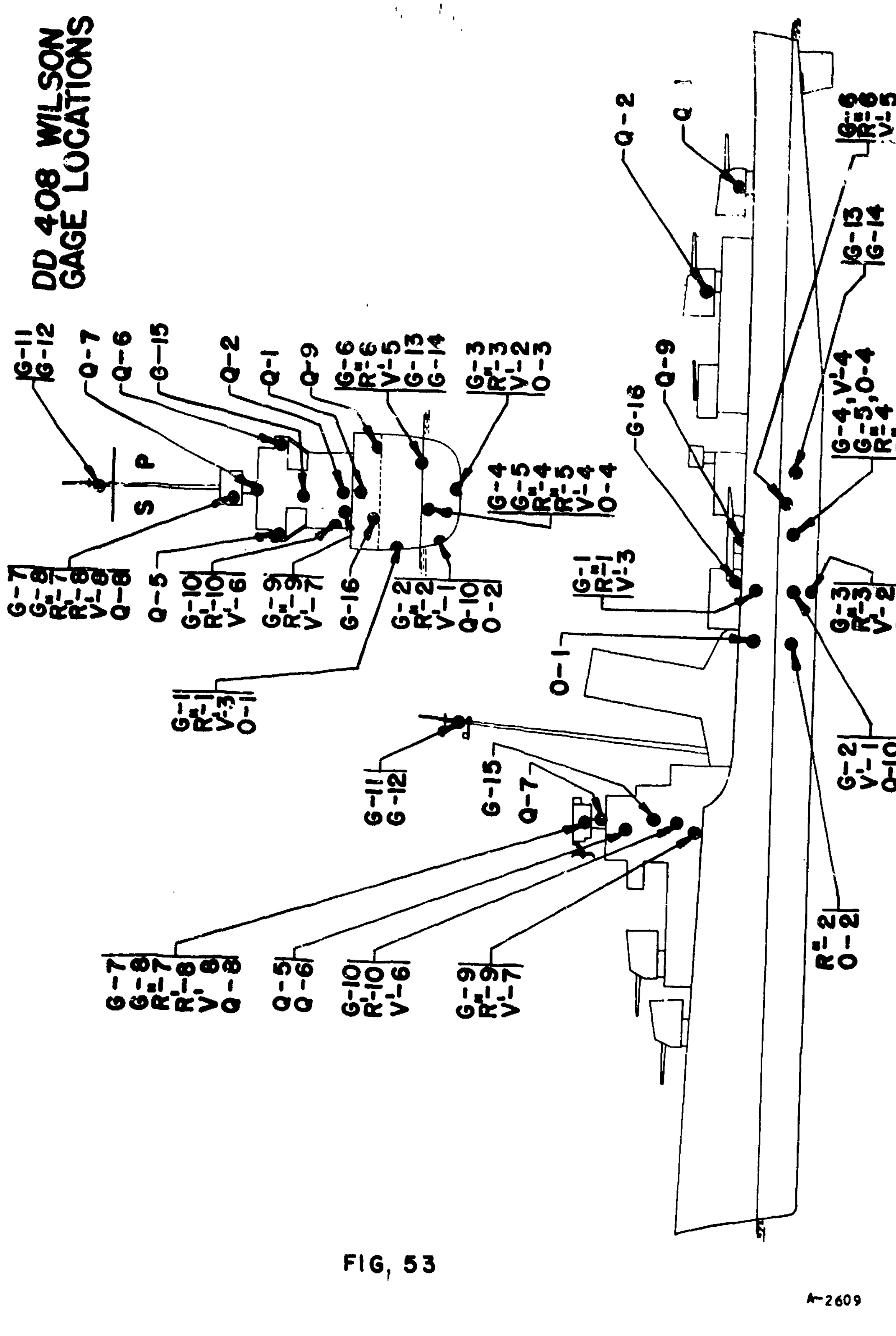


FIG. 53

A-2609

DD408 - WILSON

Putty Gages

G1 - Photo 293. Aft fireroom, compartment B-2-1. Directed to port 68" below main deck on starboard hull frame 101. First frame fwd. of aft bulkhead of aft fireroom.

A. (1) less than 50g. B. Less than 50g.

G2 - Photo 294. Aft fireroom, compartment B-2-1. Normal to hull frame 101 on starboard side of ship 48" below upper grating level.

A. (3) less than 50g. B. Less than 50g.

G3 - Photo 295 and 317. Aft fireroom, compartment B-2-1. Directed up on center line of keel 46" forward of frame 104.5.

A. (3) less than 50g. B. Less than 50g.

G4 - Photos 296 and 297. Forward engine room, compartment B-3-1. Directed up on mounting pad of starboard low pressure turbine foundation.

A. (3) less than 20g. B. Less than 20g.

G5 - Photo 298. Forward engine room, compartment B-3-1. Directed to port on mounting pad of starboard low pressure turbine foundation.

A. (3) less than 20g. B. Less than 20g.

G6 - Photo 299. Forward engine room, compartment B-3-1. Directed down on foundation of main switchboard.

A. (3) less than 20g. B. 40g.

G7 - Photo 300. Main battery director. Directed up on special bracket just inside starboard door.

A. (2) less than 20g. B. Less than 20g.

G8 - Photo 300. Main battery director (Mark 33). Directed to starboard on special bracket just inside starboard door.

A. (2) 40g. B. 30g.

DD408 - WILSON

Putty Gages

G9 - Similar to photo 269. Supply Office. Directed up on deck about 6" from inboard bulkhead. On center line of beam at frame 60.

A. (3) 50g. B. Less than 20g.

G10 - Similar to photo 270. Supply Office. Directed to port 3 ft. above deck on starboard bulkhead at frame 60.

A. (1) 150g. B. 90g.

G11 - No Photo. Directed up on top of mast on antenna foundation.

A. (1) less than 20g. B. Less than 20g.

G12 - No photo. Directed to port on top of mast.

A. Less than 20g. B. Less than 20g.

G13 - Photo 301. (3) Forward engine room. Directed up on turbo-generator base. Inboard turbo-generator on upper grating level at approximate frame 114.

A. (3) less than 20g. B. 60g.

G14 - Photo 301. Forward engine room. Directed to port on inboard turbo-generator base on upper grating level at approximate frame 114.

A. (3) less than 20g. B. 50g.

G15 - Similar to photo 271. C.I.C. Directed to port on deck bracket 5" to port of starboard bulkhead at frame 62.

A. (2) 80g. B. Less than 20g.

G16 - Photo 302. Engineer's record office. Directed up on deck 8" port of starboard bulkhead at frame 101.

A. (2) 30g. B. 40g.

DD408 - WILSON

Reed Gages

R"1 - Photo 293. Slow speed. Aft fireroom, compartment B-2-1. Directed to port on starboard shell frame 101, 52" below main deck.

Graph Record	20 cps Up	20 cps Dn	40 cps Up	40 cps Dn
A. (1) Fig.54 Fig.55	.15	.16	.125	.13
B. wave 1 Fig.62 Fig.63	.025	.015	.02	.02
B. wave 2 Fig.62 Fig.64	.035	.07	.025	.05

R"2 - Photo 303. High speed. Aft fireroom, compartment B-2-1. Directed to port starboard shell frame 93, 59" below upper grating level (third frame forward of aft bulkhead).

Graph Record	20 cps Up	20 cps Dn	40 cps Up	40 cps Dn
A. (3) Fig.56	.055	.045	0	0
B. wave 1 Fig.65 Fig. 66 Fig.67	.025	.025	.01	.01
B. wave 2 Fig.65 Fig.68	.095	.11	.035	.035

R"3 - Photo 317. High speed. Aft fireroom, compartment B-2-1. Directed up on center line of keel at frame 101

Graph Record	20 cps Up	20 cps Dn	40 cps Up	40 cps Dn
A. (3) Readings all zero				
B. wave 1 Fig.69 Fig.70-76	.13	.135	.035	.04
B. wave 2 Fig.69 Fig.77	.025	.025	.02	.02

Reed Gages

R"4 - Photo 296. Slow speed. Forward engine room, compartment B-3-1. Directed up on mounting pad of starboard low pressure turbine.

Graph Record	20 cps		40 cps	
	Up	Dn	Up	Dn
A. (3) Readings all zero				
B. wave 1 Fig.78 Fig.79	.02	.02	.02	.02
B. wave 2 Fig.78 Fig.80	.02	.02	.01	.01

R"5 - Photo 297. Slow speed. Forward engine room, compartment B-3-1. Directed to port on mounting pad of starboard low pressure turbine.

Graph Record	20 cps		40 cps	
	Up	Dn	Up	Dn
A. (3) Readings all zero.				
B. wave 1 Fig.81 Fig.82	.02	.02	.01	.01
B. wave 2 Fig.81 Fig.83	.02	.01	.01	.01

R"6 - Photo 304. Slow speed. Forward engine room, compartment B-3-1. Directed down on foundation of main switchboard.

Graph Record	20 cps		40 cps	
	Up	Dn	Up	Dn
A. (3) Fig. 57 Fig.58	.015	.025	.01	.01
B. wave 1 Fig.84 Fig.85	.035	.025	.02	.02
B. wave 2 Fig. 84 Fig.86	.13	.15	.01	.03

R"7 - Similar to Photo 273. High speed. Main battery director (Mark 33). Directed up on special NRL bracket just inside starboard door.

A. (2) Fig. 59	.13	.15	.01	.03
B. wave 1 Fig.87 Fig.88-94	.035	.025	.02	.02
B. wave 2 Fig.87 Fig.95-96	.07	.11	.025	.025

DD408 - WILSON

Reed Gages

R'8 - Similar to photo 273. Main battery director (Mark 33). Directed to starboard on special NRL bracket just inside starboard door.

Graph Record	Up	Dn	Up	Dn
	20 cps		40 cps	
A. (2) Fig. 60	.168	.165	.045	.025
B. Readings all zero.				

R''9 - Similar to photo 274. High speed. Directed up on deck about 30" to starboard of port bulkhead. On center line of beam under frame 60.

Graph Record	20 cps		40 cps	
	Up	Dn	Up	Dn
A. (3) Readings all zero				
B. wave 1 Fig.97 Fig.98-99	.065	.065	.02	.035
B. wave 2 Fig.97 Fig.100	.02	.02	.02	.015

R'10 - Photo 305. Supply Office. Directed to port 3 ft. above deck on starboard bulkhead frame 63.

Graph Record	20 cps		40 cps	
	Up	Dn	Up	Dn
A. (1) Fig. 61	.67	.77	.97	.65
B. Figure 101	.315	.195	.70	.60

Indenter Gages

Q1 - Photo 306. Number 4, 5" gun. On foundation at standing platform level on starboard side of gun supports. 2 ft. aft on starboard side of breech clearance depression in deck. Directions assume gun to be pointing aft.

A		B	
Up	50g.	Up	55g.
Dn	30	Dn	85

Indenter Gages

Q1 - continued.

A		B	
80°	40	80°	20
170°	25	170°	30
260°	50	260°	20
350°	30	350°	20

Q2 - Similar to photo 306. Number 3, 5" gun. Same position as Q1 with respect to gun.

A		B	
Up	35g.	Up	55g.
Dn	30	Dn	40
80°	40	75°	30
170°	25	165°	15
260°	30	255°	20
350°	25	345°	40

Q3 - Photo 307. Port Mark 51 director. Directed up on starboard side of director foundation at platform level.

A		B	
Up	40g.	Up	35g.
Dn	--	Dn	35
15°	100	15°	40
105°	45	105°	0
195°	--	195°	40
285°	60	285°	55

Q4 - Photo 308. Starboard twin mount 40 mm gun. On underside of foundation at intersection of I-beams on starboard and aft corner of inner square formed by these beams.

A		B	
Up	50g.	Up	20g.
Dn	70	Dn	25
0°	--	45°	20
90	60	135°	50
180°	55	225°	60
270°	45	315°	50

DD408 - WILSON

Indenter Gages

Q5 - Photo 309. Starboard torpedo director. Vertical on platform at base of director on port aft corner of foundation. Navigation bridge.

A		B	
Up	90g.	Up	25g.
Dn	80	Dn	20
10°	110	30°	90
100°	75	120°	65
190°	75	210°	65
280°	90	300°	25

Q6 - Photo 310. Port torpedo director. Vertical on platform at base of director on starboard aft corner of foundation.

A		B	
Up	60g.	Up	110g.
Dn	20	Dn	110
45°	80	45°	50
135°	60	135°	40
225°	70	225°	50
315°	55	315°	30

Q7 - Photo 311. Mark 33 gun director. On deck at base of director near port side of aft brace stiffener. Vertical.

A		B	
Up	30g.	Up	30g.
Dn	30	Dn	55
80°	35	0°	50
170°	40	90°	20
260°	50	180°	25
350°	90	270°	35

Q8 - Similar to photo 273. Main director (Mark 33). Inside starboard door on special NRL bracket

A		B	
Up	95g.	Up	35g.
Dn	55	Dn	65

DD408 - WILSON

Indenter Gages

Q8 - continued

A		B	
80°	95g.	0°	65
170°	40	90°	50
260°	90	180°	50
350°	55	270°	40

Q9 - Photo 312. Port torpedo tubes. On deck 324° clockwise from port about 6'' from foundation column. Vertical.

A		B	
Up	30g.	Up	60g.
Dn	50	Dn	30
75°	25	80°	65
165°	35	170°	90
255°	20	260°	65
345°	30	350°	80

Q10 - Photo 294. Aft fireroom, compartment B-2-1. On shell 4 ft. 8'' below upper grating level at frame 101, starboard side. Normal to flange of frame.

A		B	
Normal inb'd	50g.	Normal inb'd	55g.
Normal outb'd	45	Normal outb'd	25
Up	30	Up	55
*Dn	50	*Dn	45
for'd	75	For'd	--
aft	50	Aft	50

* These directions all in plane tangent to shell

Shock displacement Gages

01 - Photo 315. Aft fireroom, compartment B-2-1. Directed to port on starboard frame 93, 4 ft. below main deck.

B. Record - Fig. 102 a - d

DD408 - WILSON

Shock Displacement Gages

02 - Photo 303 and 316. Aft fireroom, compartment B-2-1. Normal to starboard frame 93, 1 ft. above lower grating.

B. Record not reproduced but is available.

03 - Photo 317. Aft fireroom, compartment B-2-1. Directed up on frame 101 near keel.

B. Record - Fig. 103 a - c

04 - No photo. Forward engine room, compartment B-3-1. Directed to port mounting pad of low pressure turbine foundation.

B. Gage motor failed to operate.

Velocity Meters.

V'1 - Photo 313. Fig. 104 and same as 404 Test Able. Aft fireroom, compartment B-2-1. Normal to starboard shell frame 101, 28" below upper grating level.

A. (3) Record not distinguishable.

B. Record not distinguishable.

V'2 - Photo 317. Aft fireroom, compartment B-2-1. Directed up on top of keel at frame 101.

A. (3) Record not distinguishable.

B. Record not distinguishable.

V'3 - Photo 293. Aft fireroom, compartment B-2-1. Normal to starboard shell frame 101, 5 ft. below main deck.

A. (1) Record not distinguishable.

B. Record not distinguishable.

DD403 - WILSON

Velocity Meters

V'4 - Photo 297. Forward engine room, compartment B-3-1. Directed up on mounting base of starboard low pressure turbine.

A. (3) Record not distinguishable.

B. Record not distinguishable.

V'5 - Photo 314. Forward engine room, compartment B-3-1. Directed down on beam under starboard end of main switchboard.

A. (3) Record not distinguishable.

B. Record not distinguishable.

V'6 - Similar to photo 270. Supply Office. Directed to port on frame 61 of starboard bulkhead 3 ft. above deck.

A. (1) Fig. 47. Channel 6.

B. Fig. 104, Channel 6.

V'7 - Similar to photo 269. Supply Office. Directed up on deck over beam at frame 60. About one foot from inboard bulkhead.

A. (3) Record not distinguishable.

B. Fig. 104, Channel 7.

V'8 - Photo 300. Main Battery Director. Directed up on special NRL bracket.

A. (2) Record not distinguishable.

B. Fig. 104, Channel 8.

COMMENTS

Test Able   Range 4439 ft.   Bearing 24°

Putty gages G8, G9, G10, G15, and G16 were the only one to show readings. They support very well the pattern of putty gage readings on the DD404, though they were but 1/2 to 2/3 as large,

COMMENTS

with the exception that G1 showed no reading instead of the highest.

All indenter gage readings were less than 110g. and are also fairly consistent with DD404 indenter gages.

Reed Gages R''1, R'8, and R'10 were the only reed gages to register more than a negligible shock and are consistent with the DD404 readings and the other gages of the DD408.

V'6 was on the Supply Office bulkhead and was the only velocity meter to give a signal discernable above the background. A steady acceleration of about 35g. average for a duration of 10 milliseconds starting at .095 seconds is followed by a large transient vibration of frequency 43.5 cps. This transient has an amplitude of 2.5 ft/sec which is equivalent to a .11 inches amplitude. Note that bottoming of the meter occurred at the time equal to .103 sec., .116 sec., .172, .202 sec., etc. This meter was adjacent to R'10 and G10. R'10 together with G10 indicates a peak acceleration of 150g. The reed gage indicates a disturbance having a characteristic frequency of about 40 cps, thus agreeing very well with V'6. V'8 on the DD404 in a similar location indicated a 70 cps. transient vibration and a 10 millisecond initial acceleration period

Test Baker Range 5426 ft. Bearing 330°

Instruments were placed in expectation of incidence of the pressure wave on the starboard side rather than the port bow.

Putty gages G6, G8, G10, G13, G14, and G16 showed readings but all of these were less than 100g. Of these, the readings of G13 and G14 are in doubt because they alone were on a base whose temperature was about 200°. Such temperatures seem to cause slight swelling of the putty and cause therefore, small indentations.

Reed gage R'10 alone had a sizable reading which was due to airblast on the bulkhead to which it was attached. Readings of the motorized gages were adequate to indicate a series of shocks prior to the airblast; the last one arriving about 1.2 seconds after the first. R''3 and R''7 had about equal deflections of the 20 and 40 cycle reeds during wave 1 and therefore indicated about equal shocks on the fireroom keel and the deck of the Supply Office.

DD408 - WILSON

COMMENTS

Velocity meter records V'6, V'7, and V'8 were greater than the background. V'6 was on the same bulkhead as G10 (which read 90g) and R'10 which showed a disturbance of about 40 cps and a peak acceleration of about 120g. The transient vibration on the V'6 record is about 38 cps and the initial acceleration is only 17g. V'7 and V'8 are vertical in the superstructure and indicate that the superstructure shocks in accord with V'7 and V'10 of the DD404. All four of these velocity meters indicate a period of .08 seconds between these shocks particularly those in the region .10 to .80 seconds.

All indenter gages recorded less than 100g. except Q6 on the port torpedo director which read 110g., probably as a result of air-blast.

As on the DD404, the shock recorded was negligible. The data seems valuable only in its relation to the problem of shock propagation through a ship and the question as to the origin of the many pulses of shock.

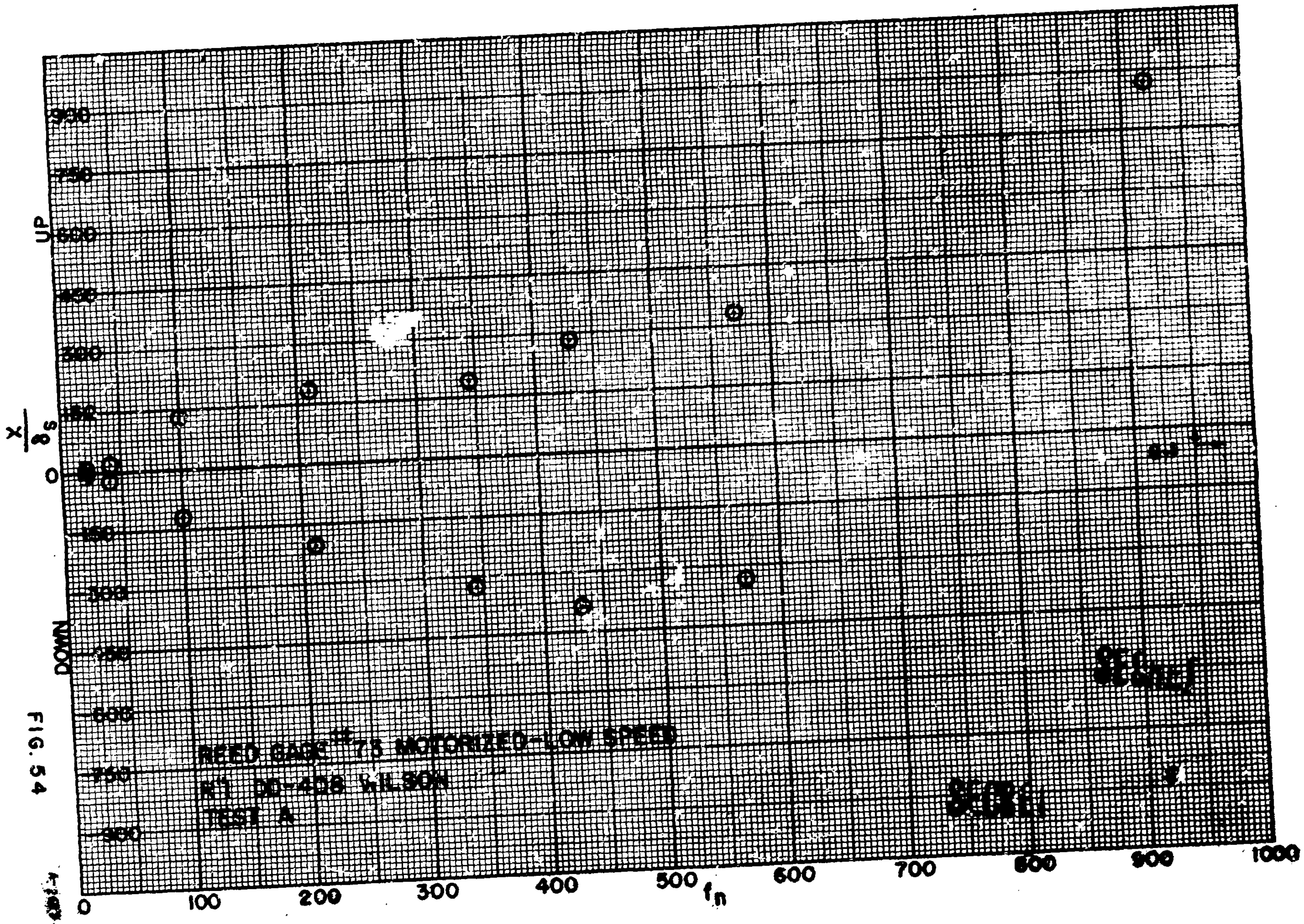
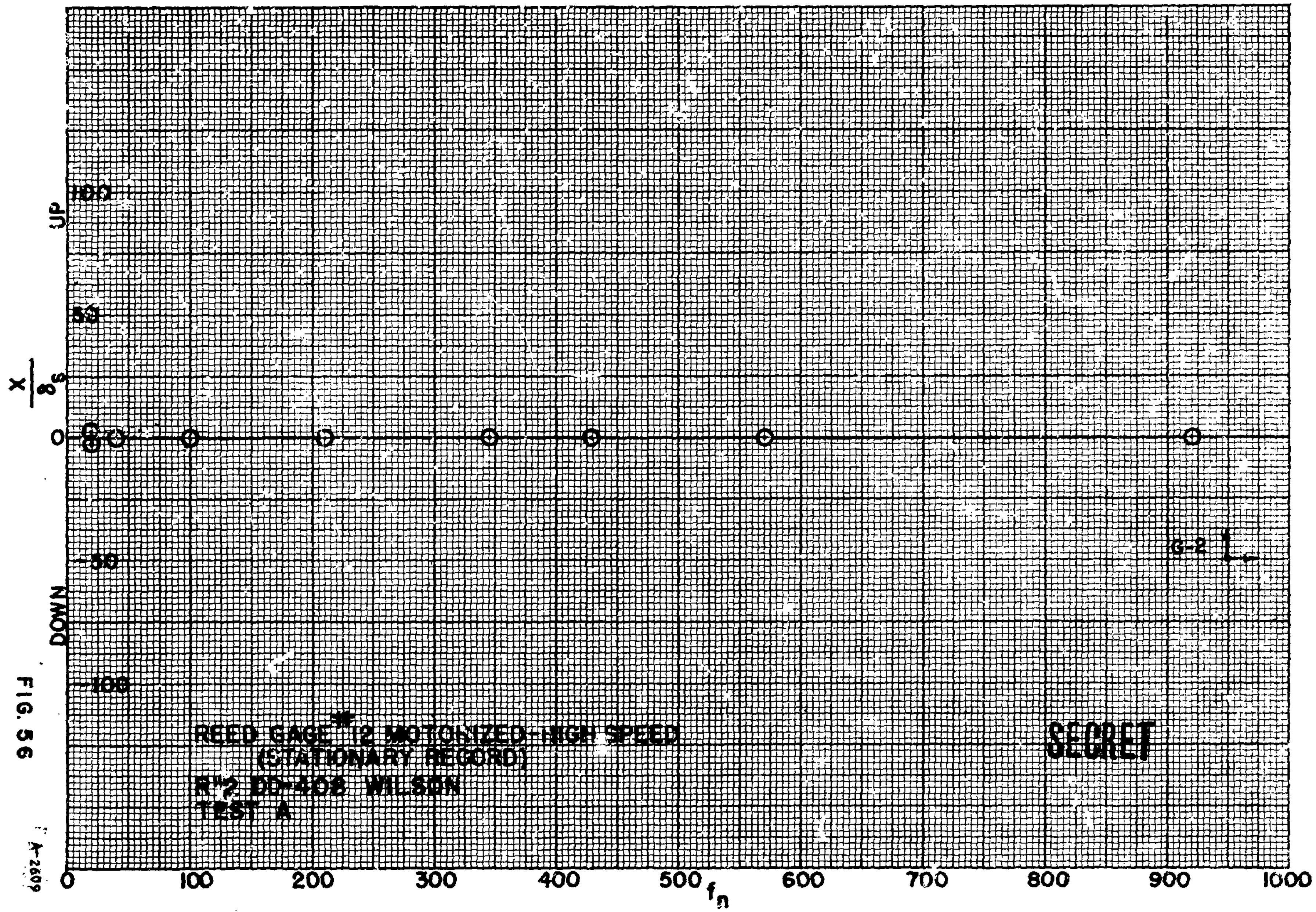

REED GAGE # 75 MOTORIZED-LOW SPEED
RT DD-406 WILSON
TEST A
UP
DOWN
X/g_s
f_n
900
750
600
450
300
150
0
-150
-300
-450
-600
-750
-900
100
200
300
400
500
600
700
800
900
1000

FIG. 54

DP 408
Upper Level Fireroom
20
345
100
210
528
40
120
2.5
2 sec.
1.5
1 sec.
0.5
0

FIG. 55 A-2609



UP
100
50
X/δs
0
-50
DOWN
-100
REED GAGE # 12 MOTORIZED-HIGH SPEED
(STATIONARY RECORD)
R"2 DD-408 WILSON
TEST A
SECRET
G-2
0
100
200
300
400
500
600
700
800
900
1000
fn

FIG. 56

A-2609

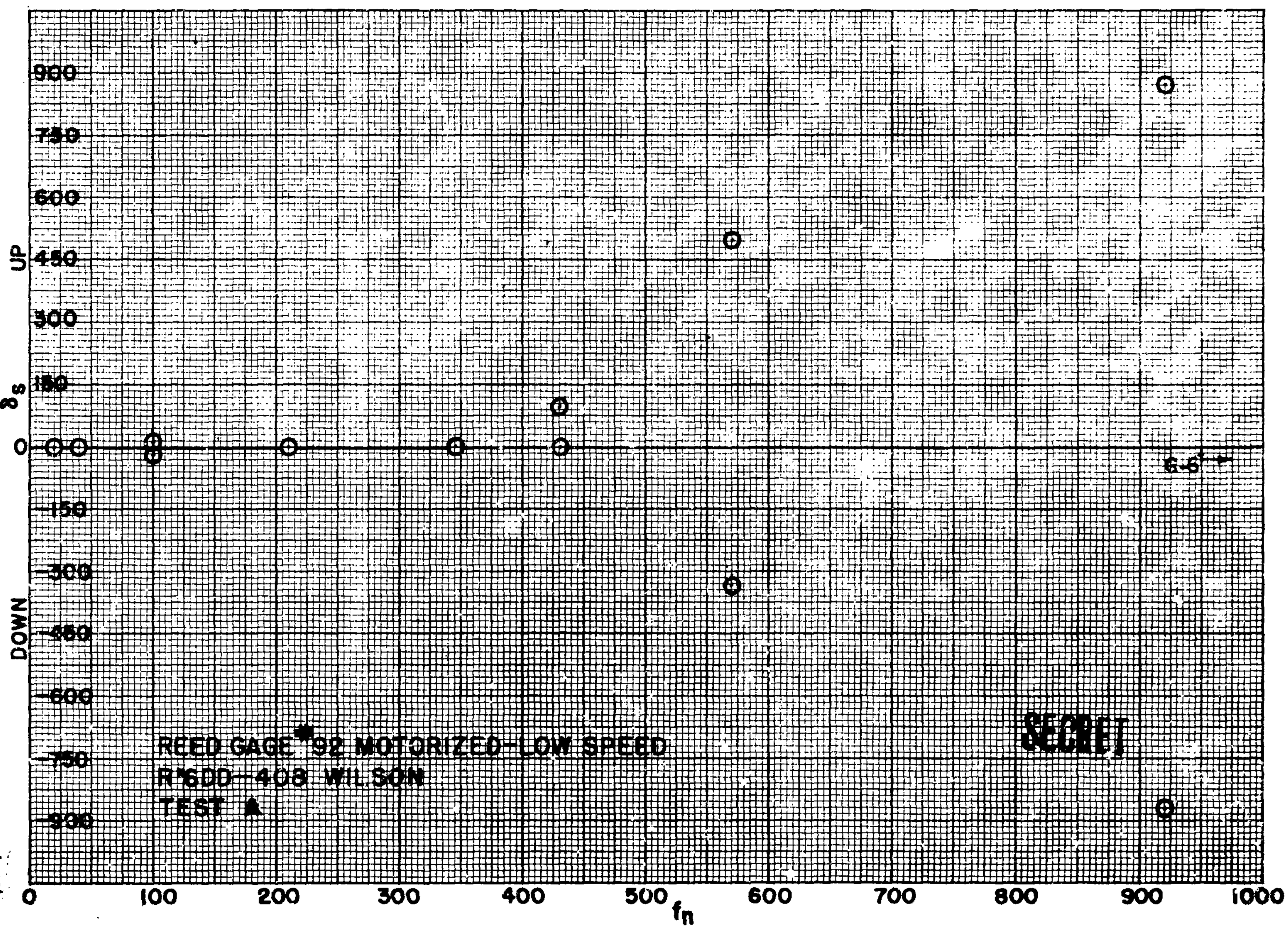
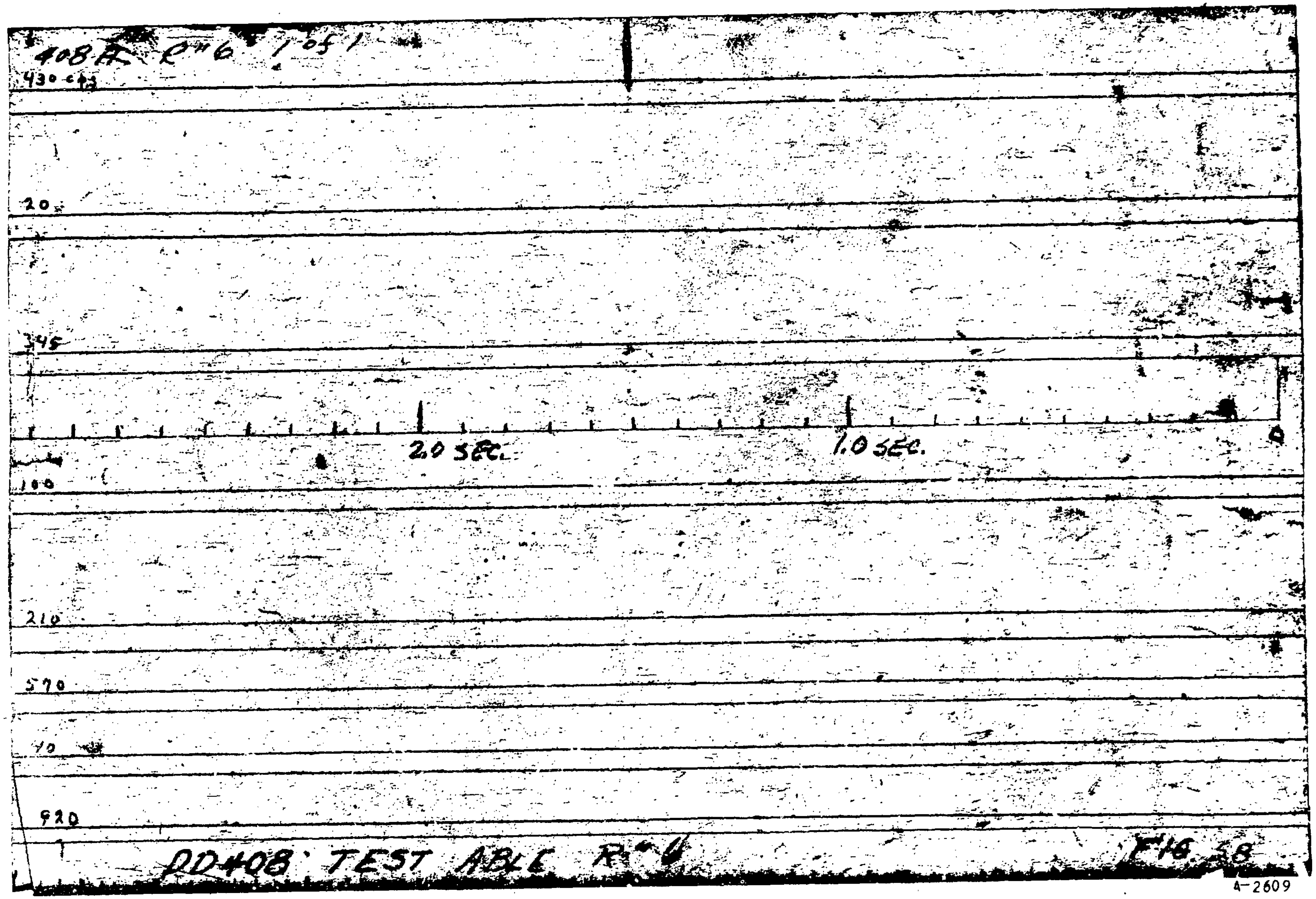

UP
DOWN
X / δs
900
750
600
450
300
150
0
-150
-300
-450
-600
-750
-900
0
100
200
300
400
500
600
700
800
900
1000
fn
6.5
REED GAGE #92 MOTORIZED-LOW SPEED
R#600-408 WILSON
TEST A
SECRET

FIG. 57

A-2609



408 R #6 1 of 1
430 cps
20
345
2.0 SEC.
1.0 SEC.
100
210
570
70
920
DD408 TEST ABLE R #6
FIG. 38

A-2609

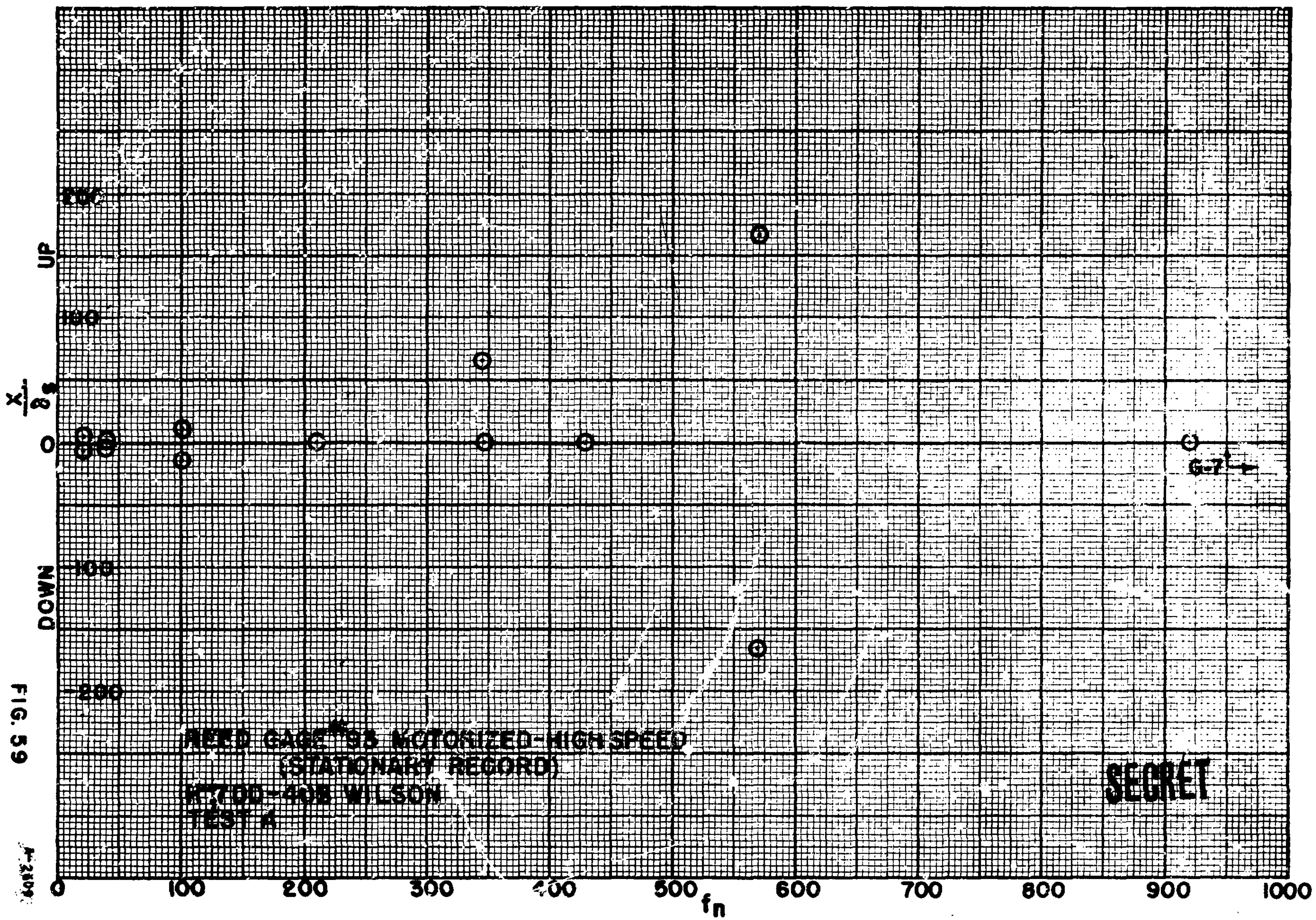
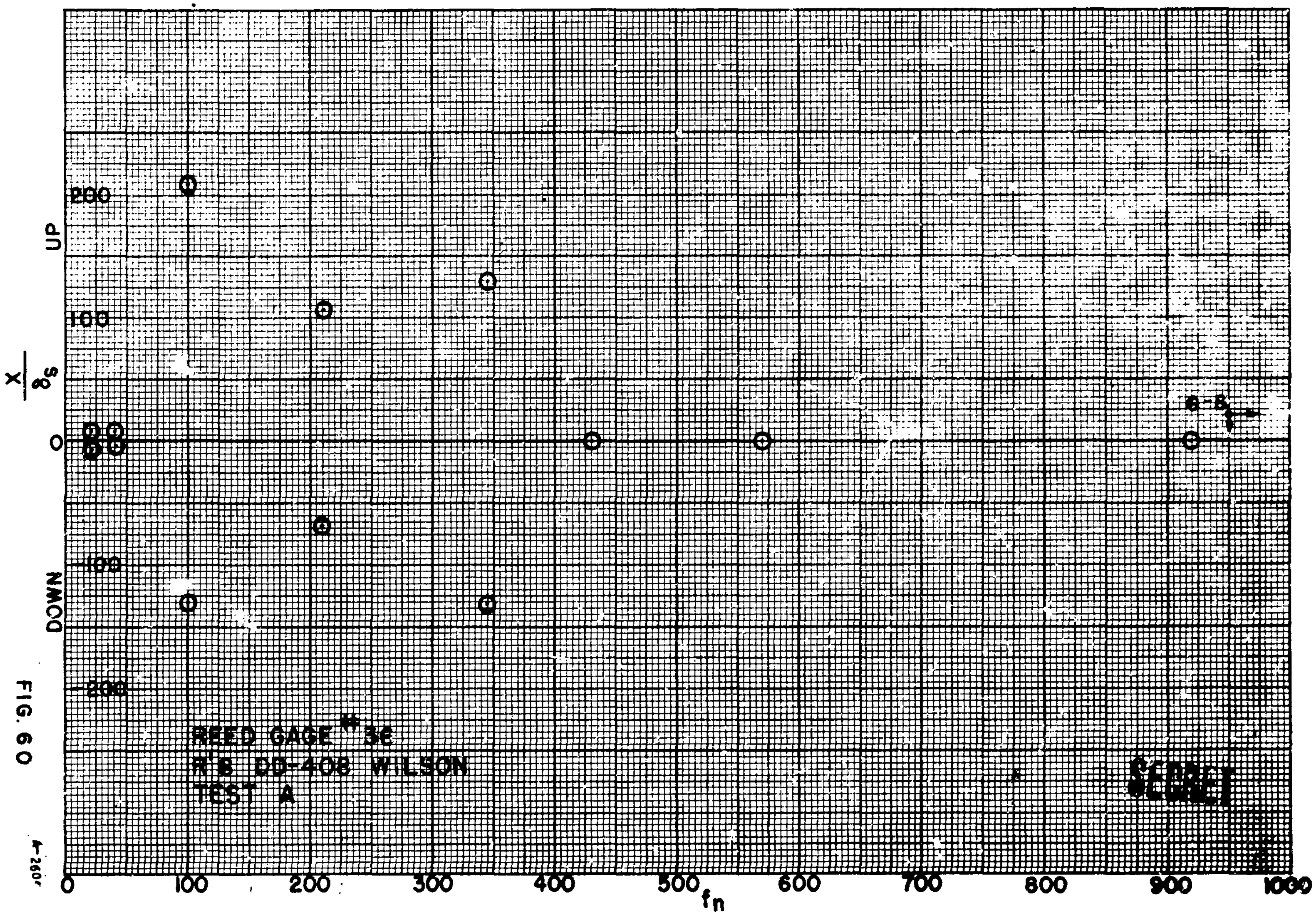

REED GAGE #95 MOTORIZED-HIGH SPEED
(STATIONARY RECORD)
TEST A
SECRET
UP
DOWN
200
100
0
-100
-200
0
100
200
300
400
500
600
700
800
900
1000
fn
G-7

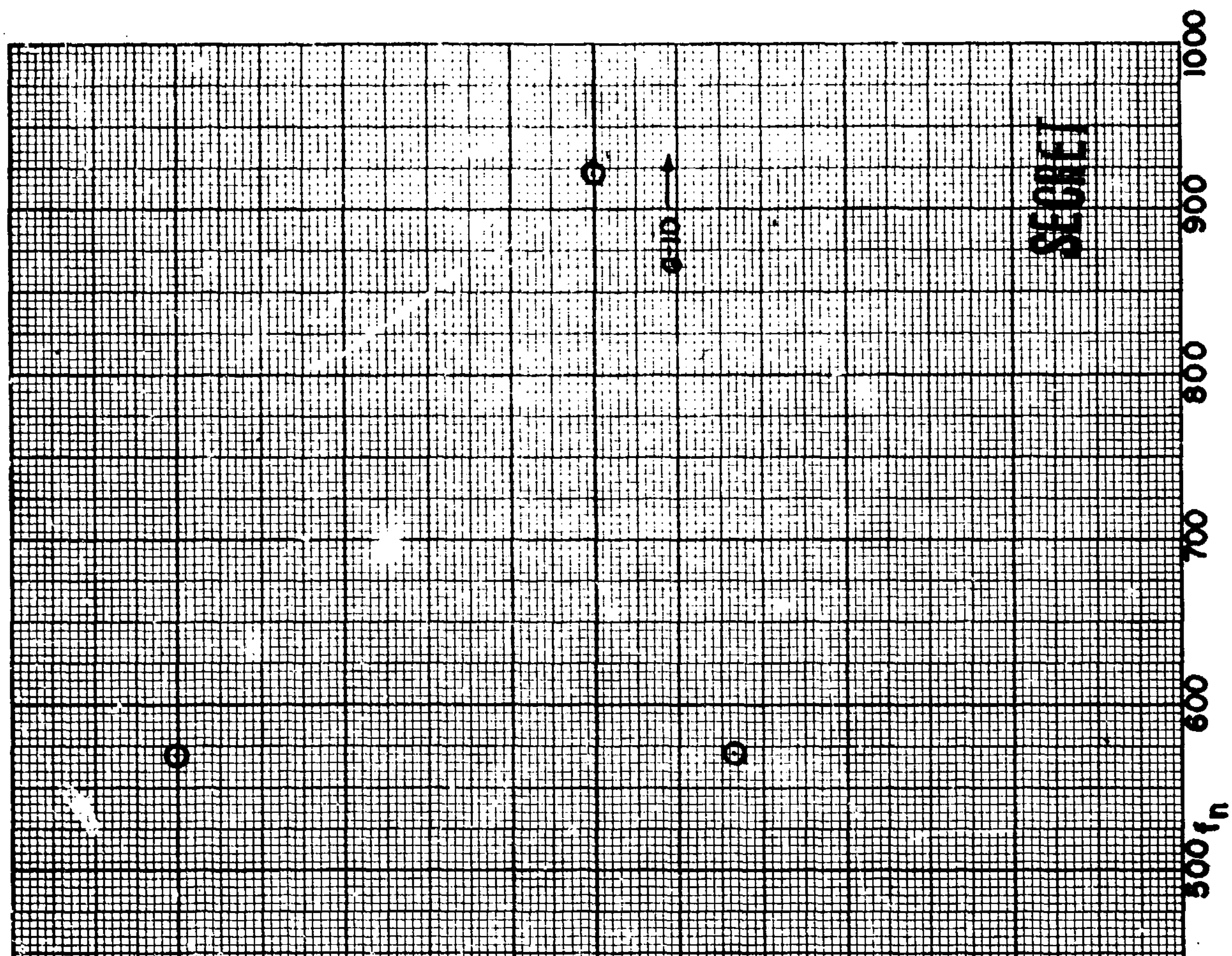
FIG. 59



UP
DOWN
200
100
0
-100
-200
0
100
200
300
400
500
600
700
800
900
1000
f_n
$\frac{X}{\delta_s}$
REED GAGE # 3E
R'B DD-408 WILSON
TEST A
SECRET

FIG. 60

A-260r



SECRET
REED GAGE #3
R 10 DD-408 WILSON
TEST A
OFF RECORD
off
UP
DOWN
0
$\frac{s_3}{X}$
500
400
300
200
100
-100
-200
-300
-400
-500
0
100
200
300
400
500 f_n
600
700
800
900
1000

FIG. 61

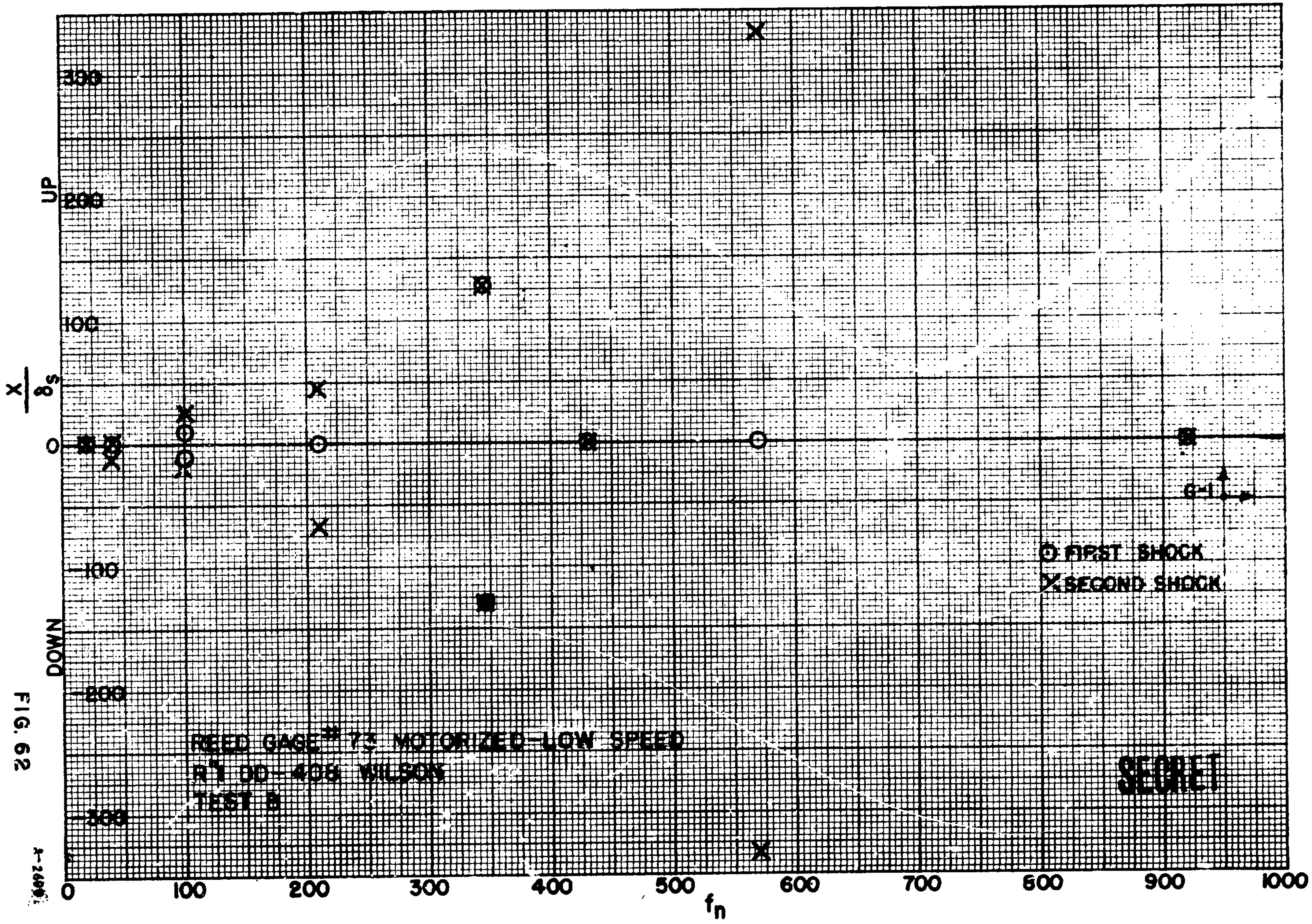
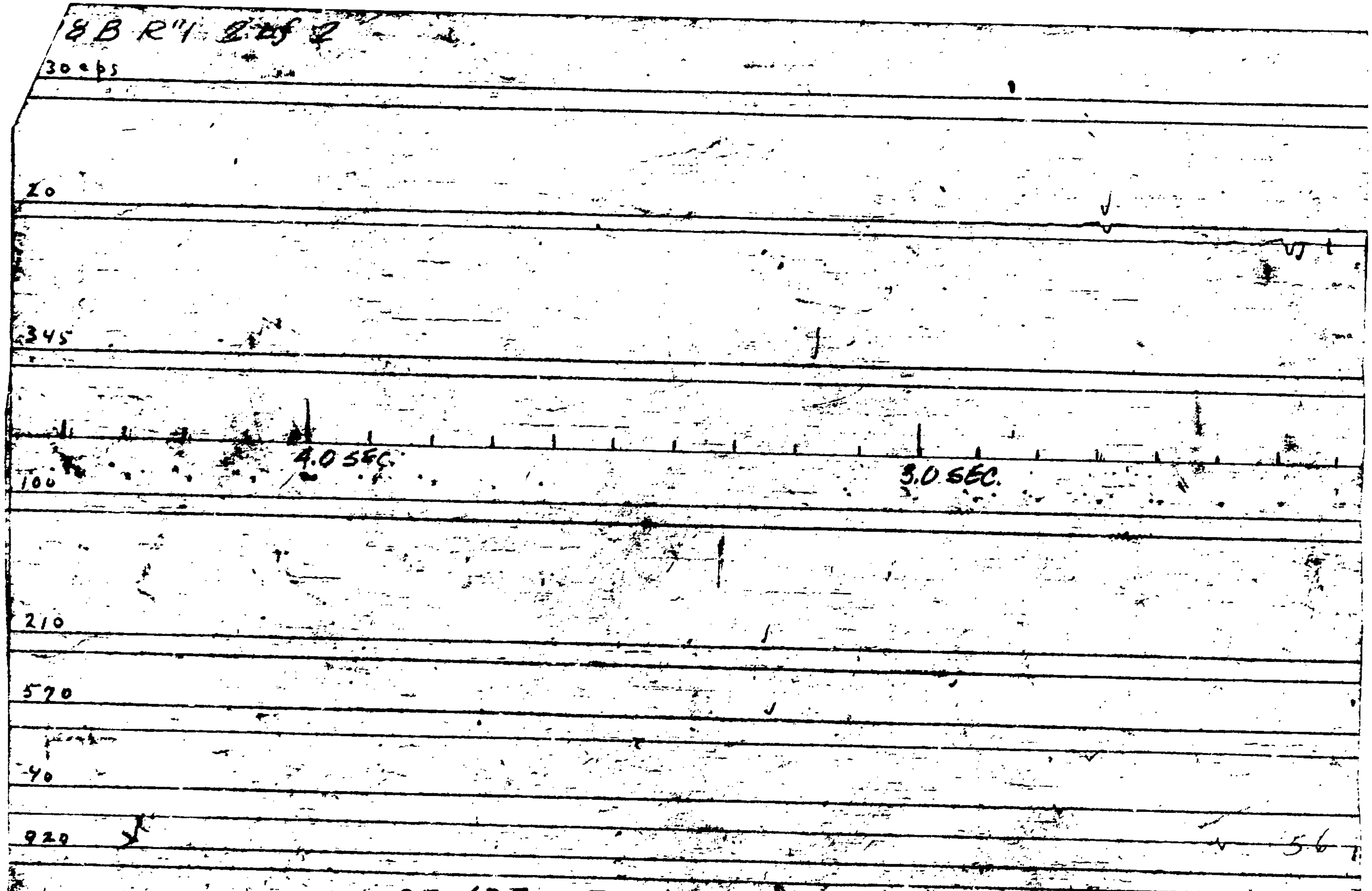

UP
DOWN
X/δs
300
200
100
0
-100
-200
-300
0
100
200
300
400
500
600
700
800
900
1000
fn
G-1
O FIRST SHOCK
X SECOND SHOCK
REED GAGE # 73 MOTORIZED-LOW SPEED
R-1 DD-408 WILSON
TEST B
SECRET

FIG. 62

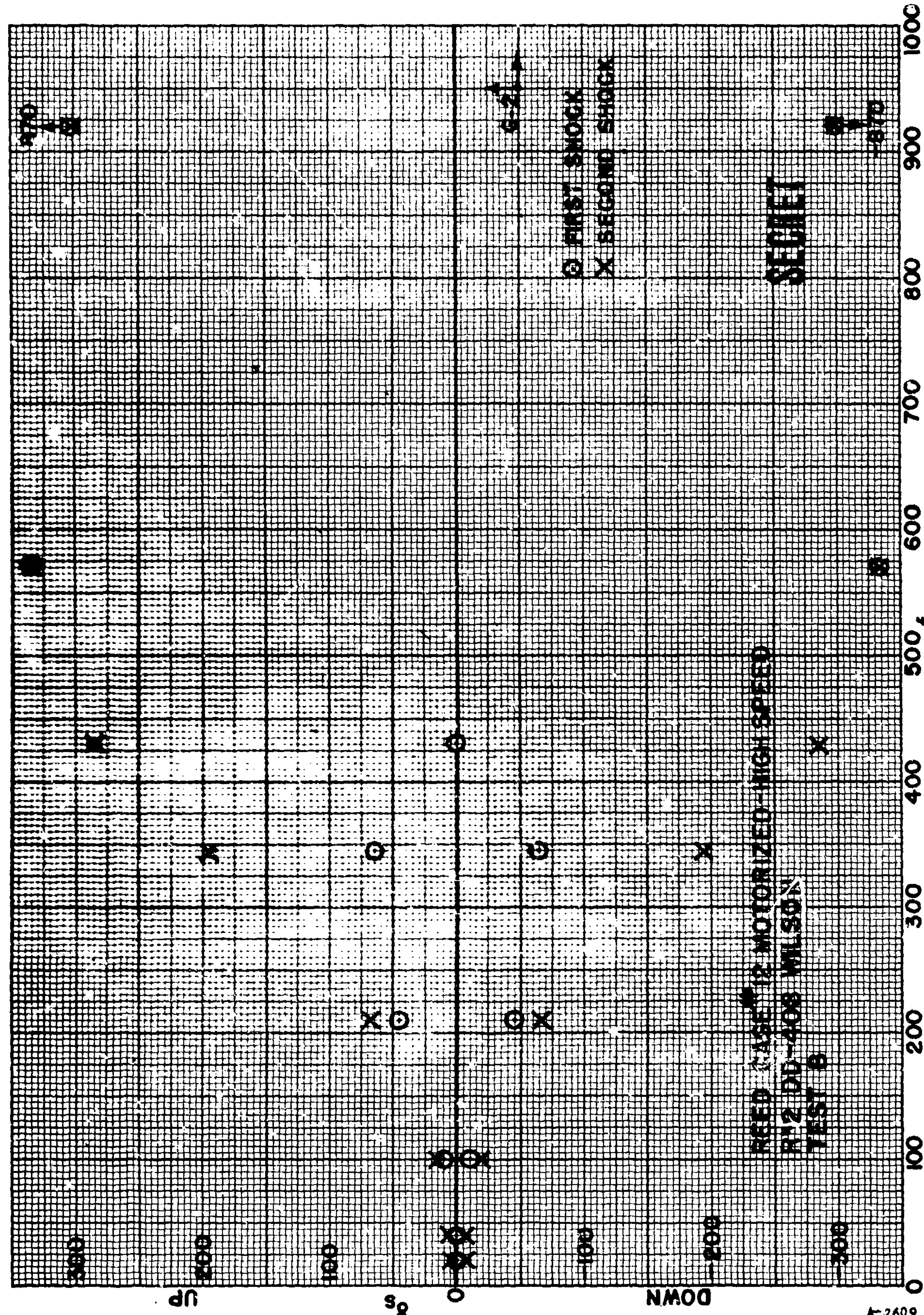
DD408 TEST BAKER R7 WAVE 1 FIG. 63

A-2609



DD 408 TEST BAKER R"1 WAVE 2 FIG. 64

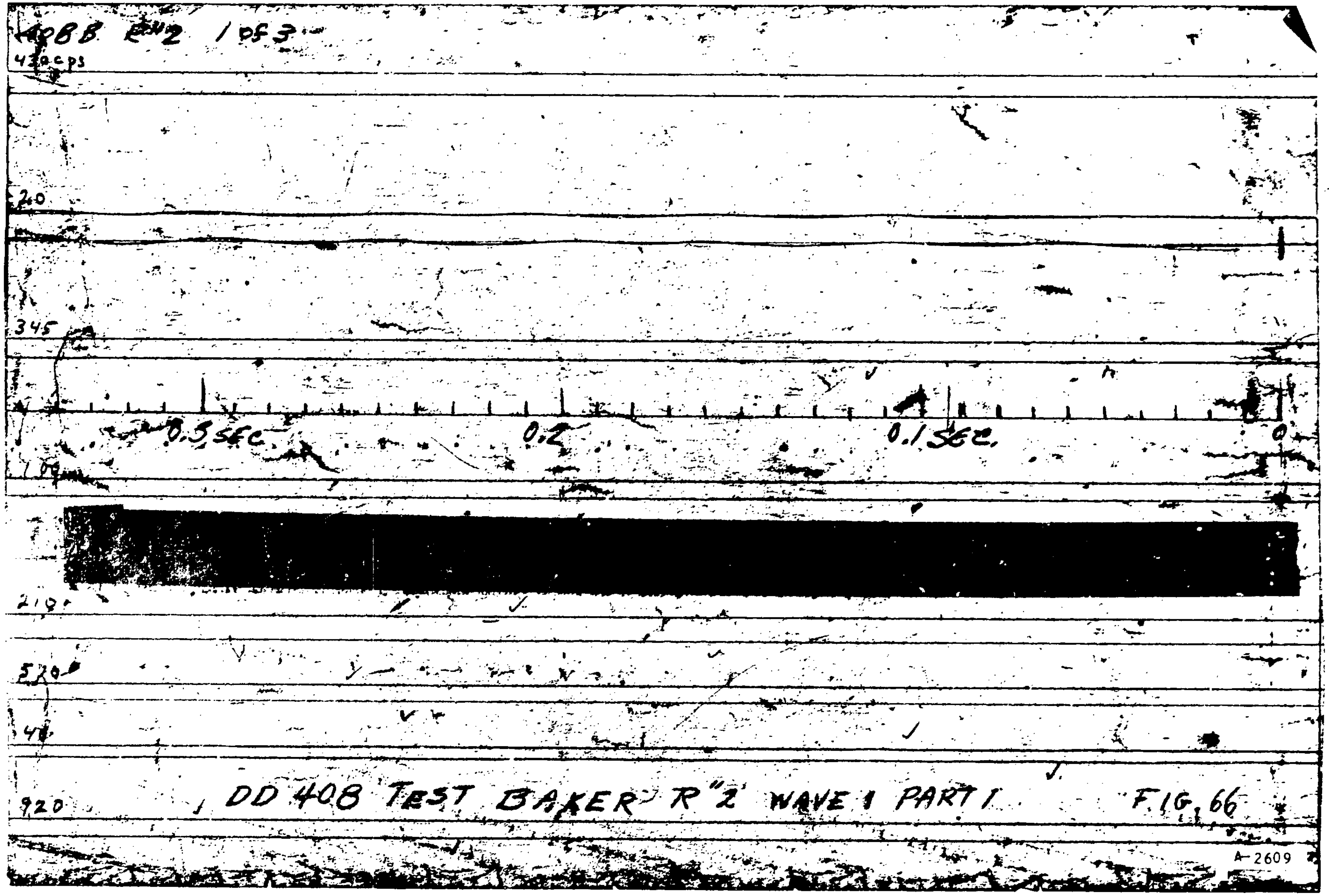
A-2609



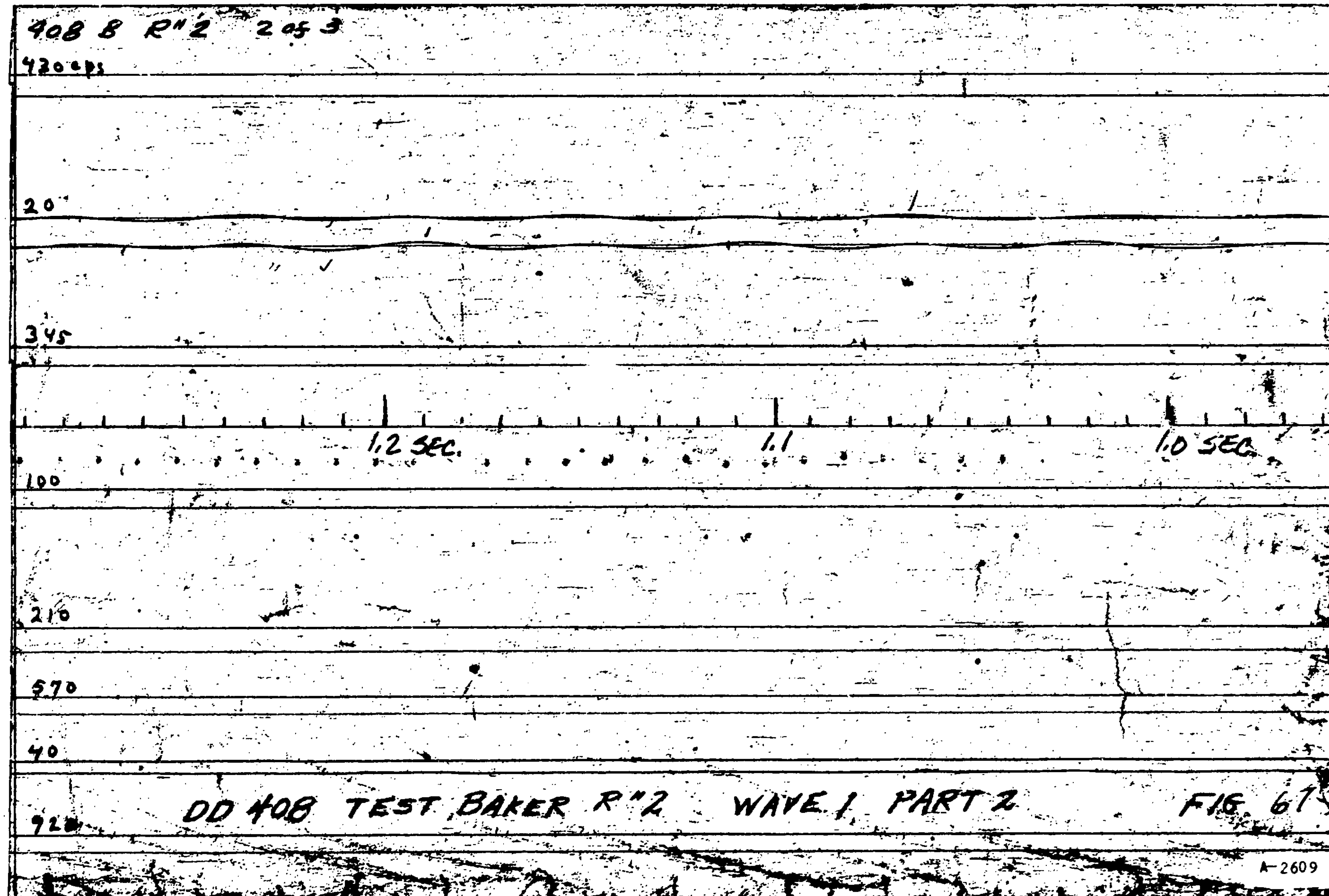
REED CASE #12 MOTORIZED-HIGH SPEED
R"2 DD-408 WILSON
TEST B
⊙ FIRST SHOCK
X SECOND SHOCK
SECRET
UP
DOWN
X/g_s
f_n
870
-870
G-2

A-2609

FIG. 65

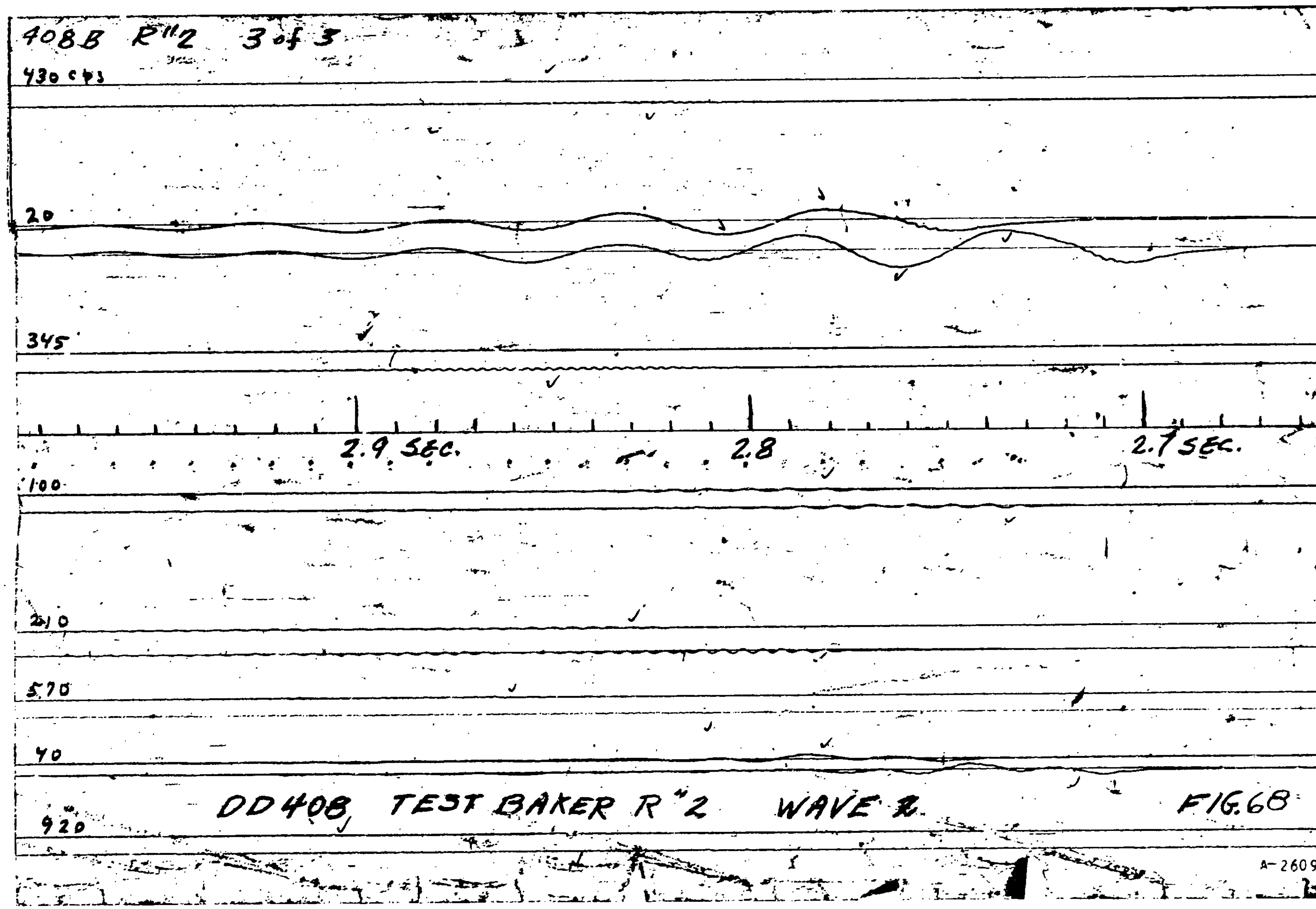


DD 408 TEST BAKER R"2 WAVE 1 PART 1 FIG. 66



DD 408 TEST BAKER R"2 WAVE 1 PART 2

FIG. 67



408B R"2 3 of 3
430 cps
20
345
2.9 SEC.
2.8
2.7 SEC.
100
210
570
40
920
DD408 TEST BAKER R"2 WAVE 2
FIG.68
A-2609

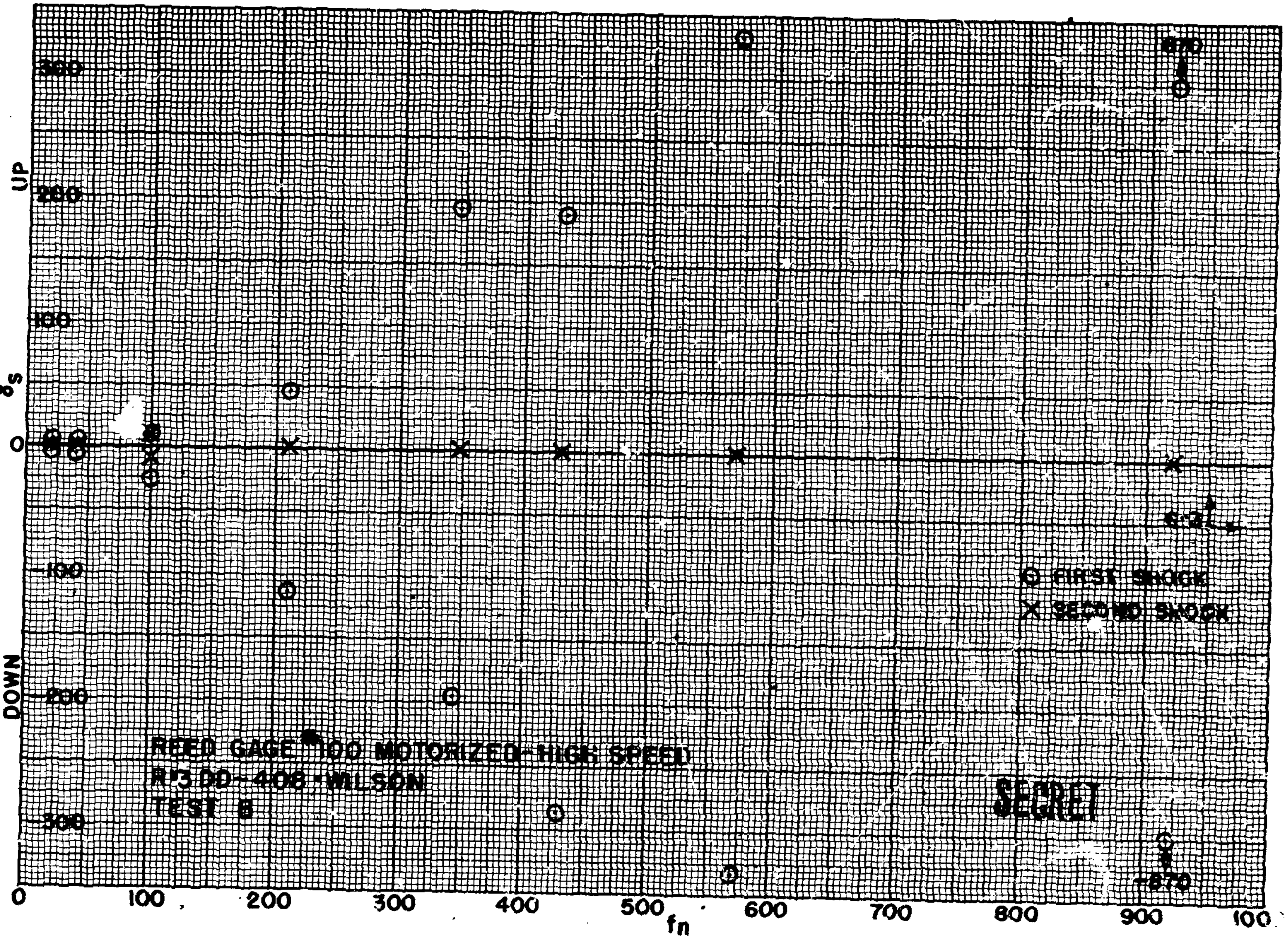
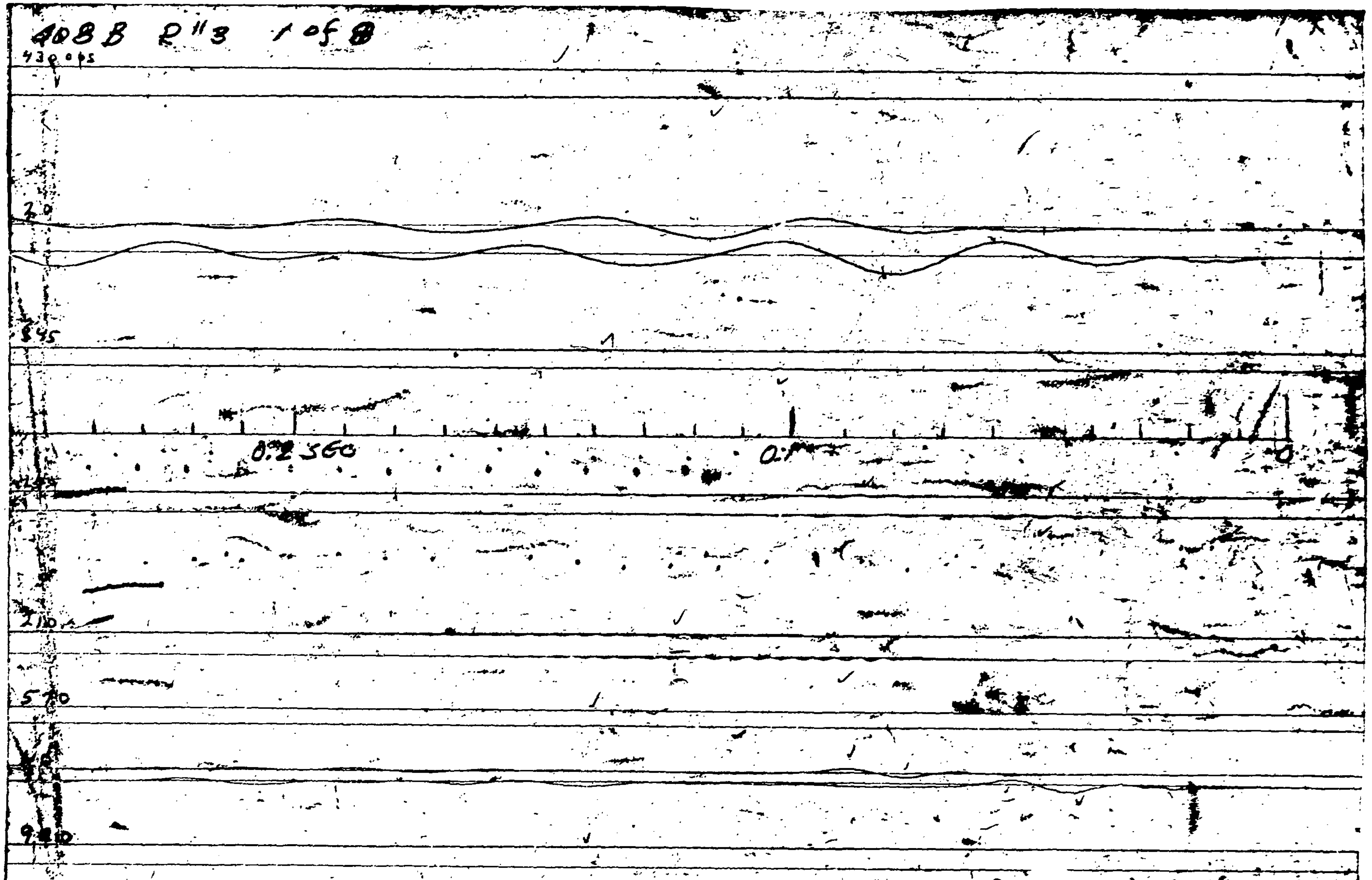

REED GAGE 100 MOTORIZED-HIGH SPEED
R-3 DD-406-WILSON
TEST B
○ FIRST SHOCK
X SECOND SHOCK
SECRET
870
-870
UP
DOWN
300
200
100
0
-100
-200
-300
0
100
200
300
400
500
600
700
800
900
100
f_n
$\frac{X}{\delta_s}$

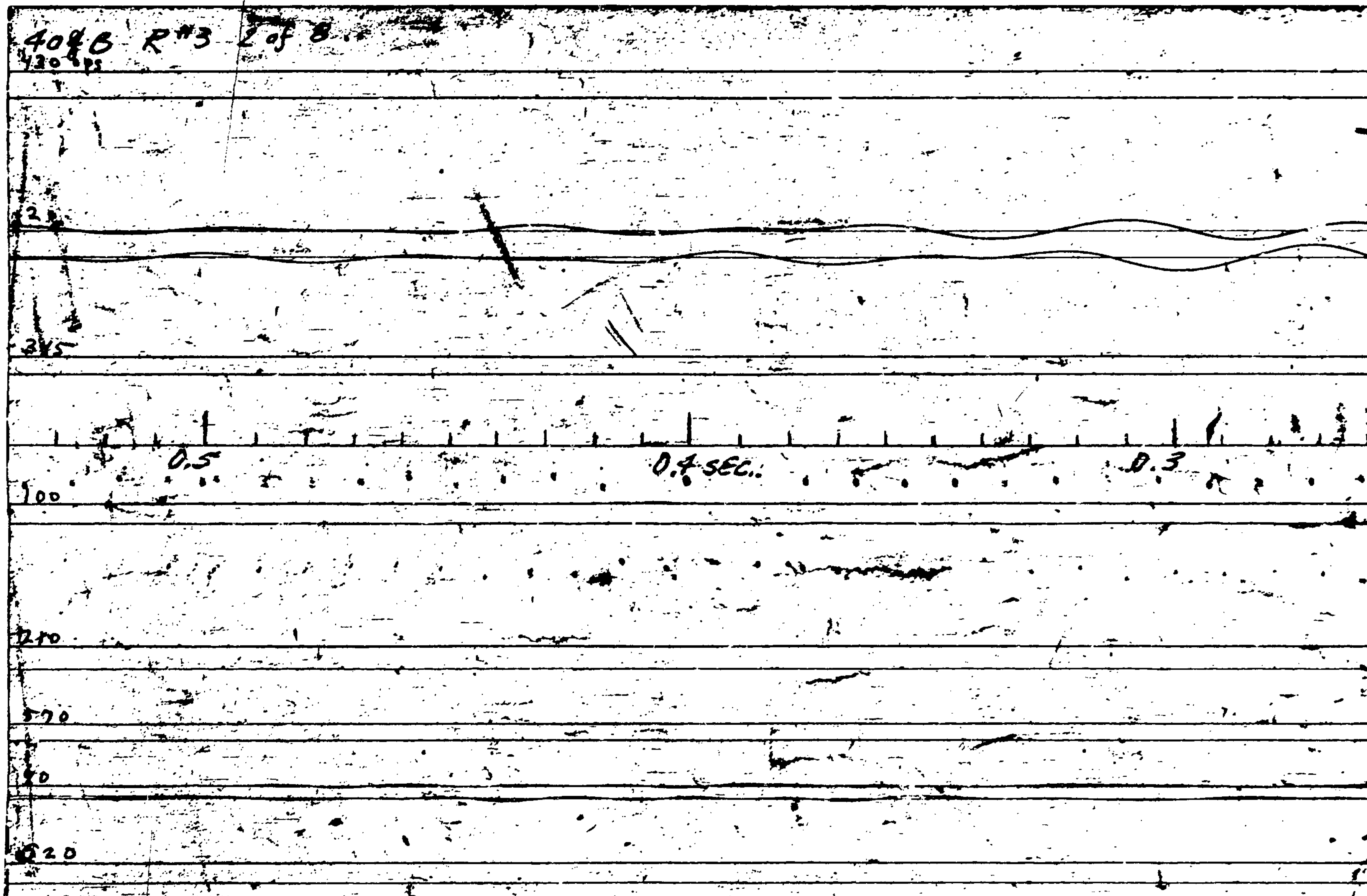
FIG. 69

A-2609



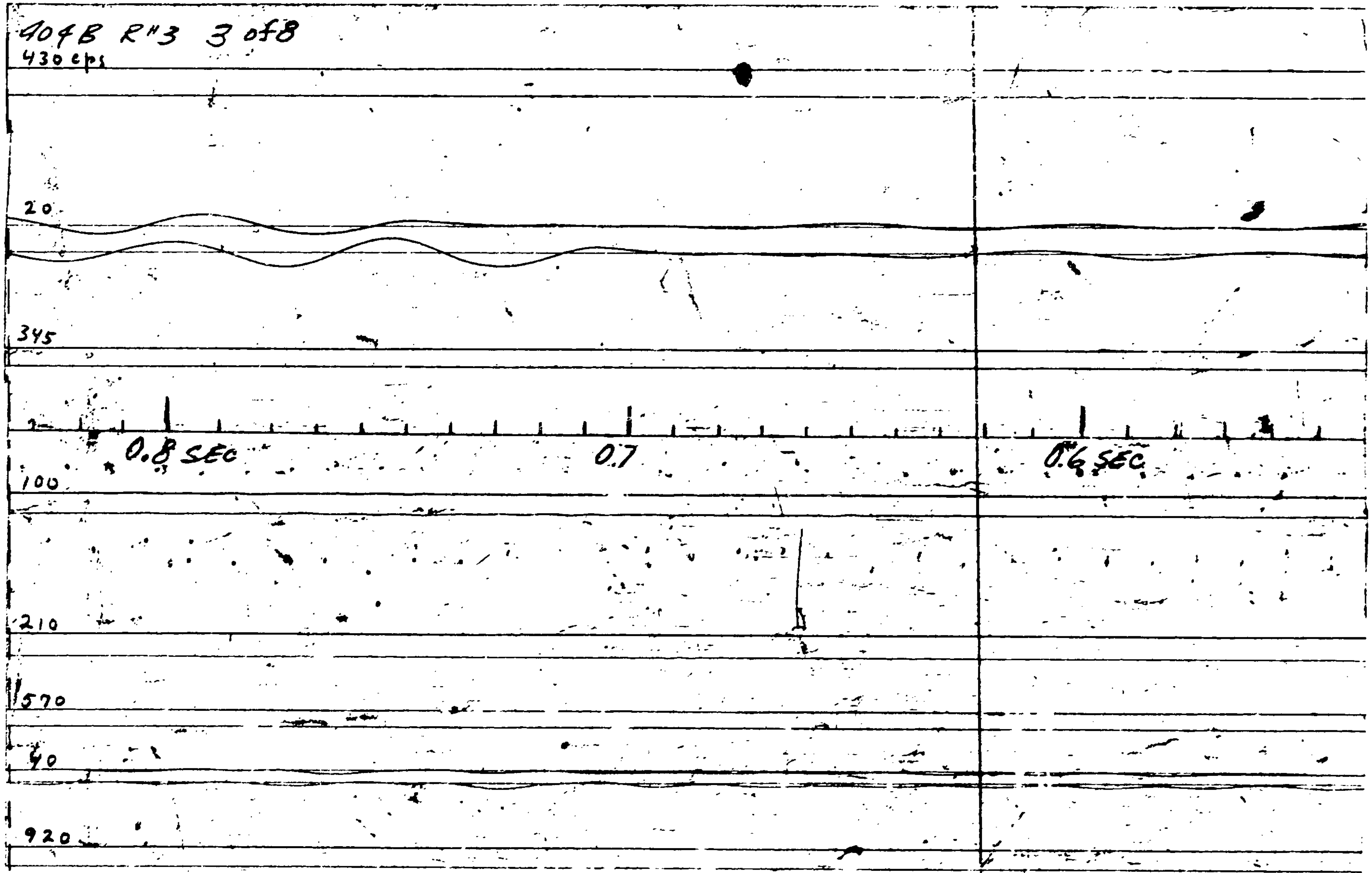
DD408 TEST BAKER R"3 WAVE 1 PART 1 FIG 10

A-2609



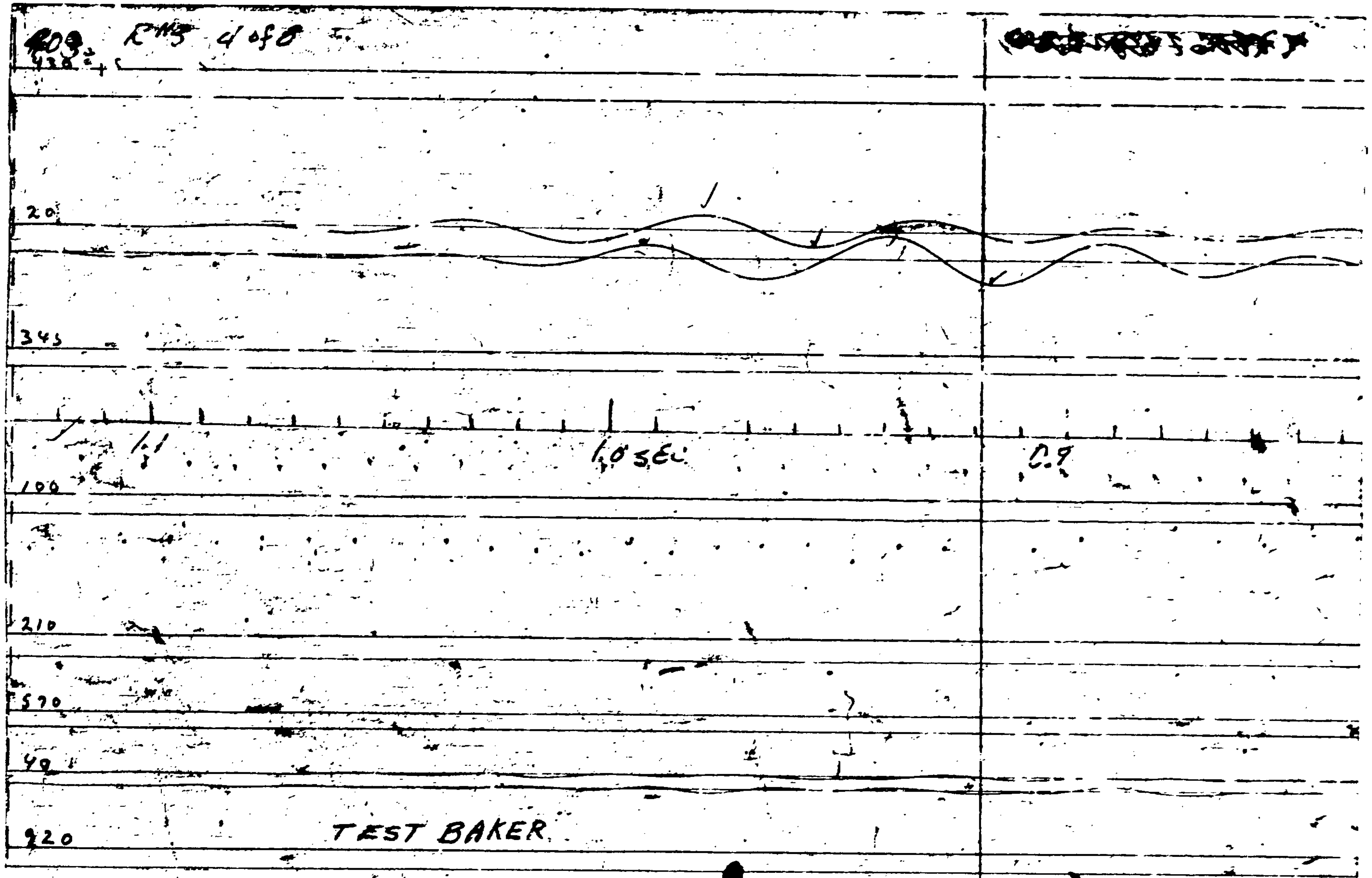
DD 408 TEST BAKER R#3 WAVE L PART 2 FIG 71

A-2609



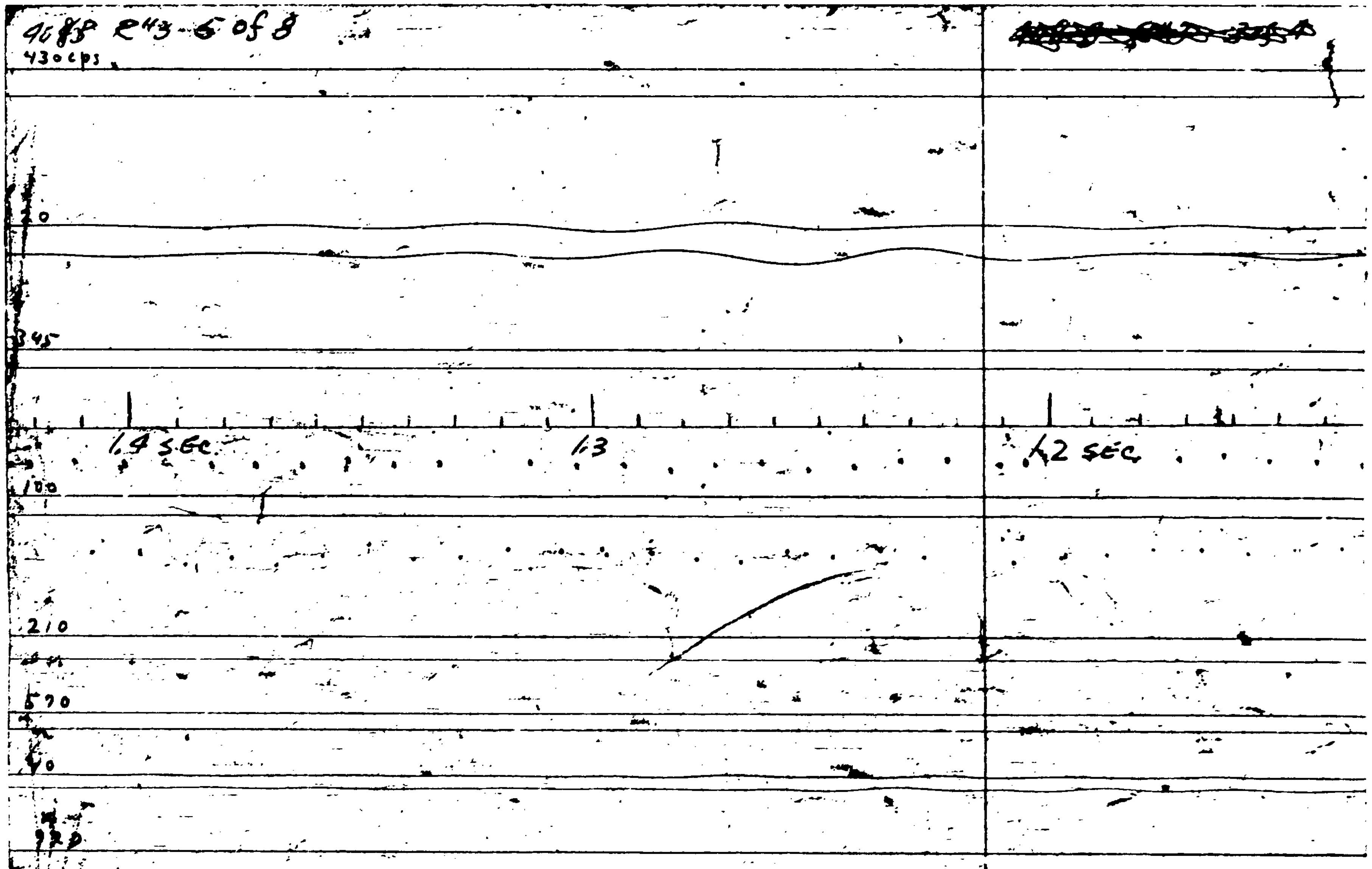
DD408 TEST T^YER R"3 WAVE 1 PA. 3

FIG. 72
A-2609



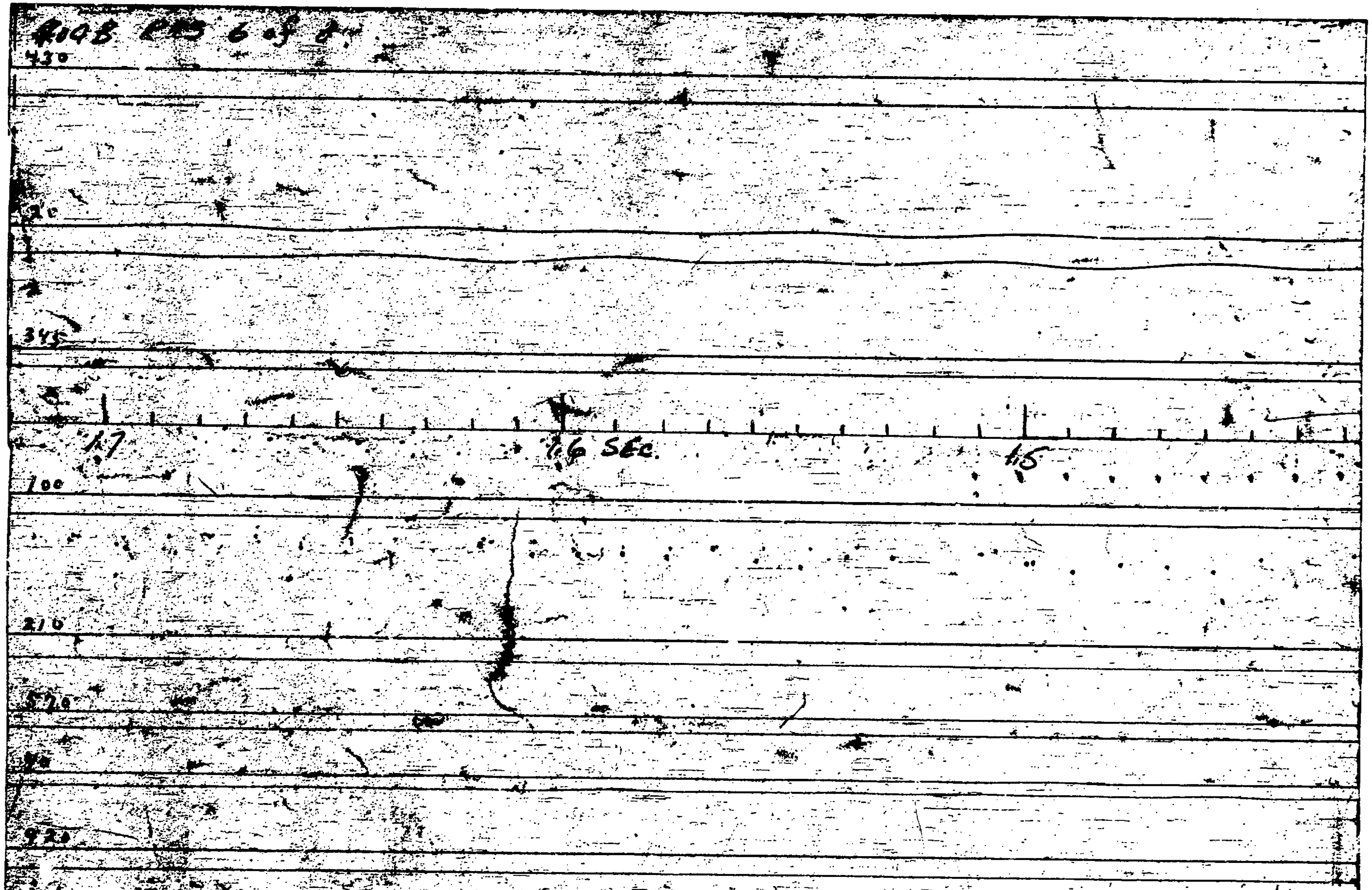
DD 408 R"3 WAVE 1 PART 4

FIG. 73 A-26



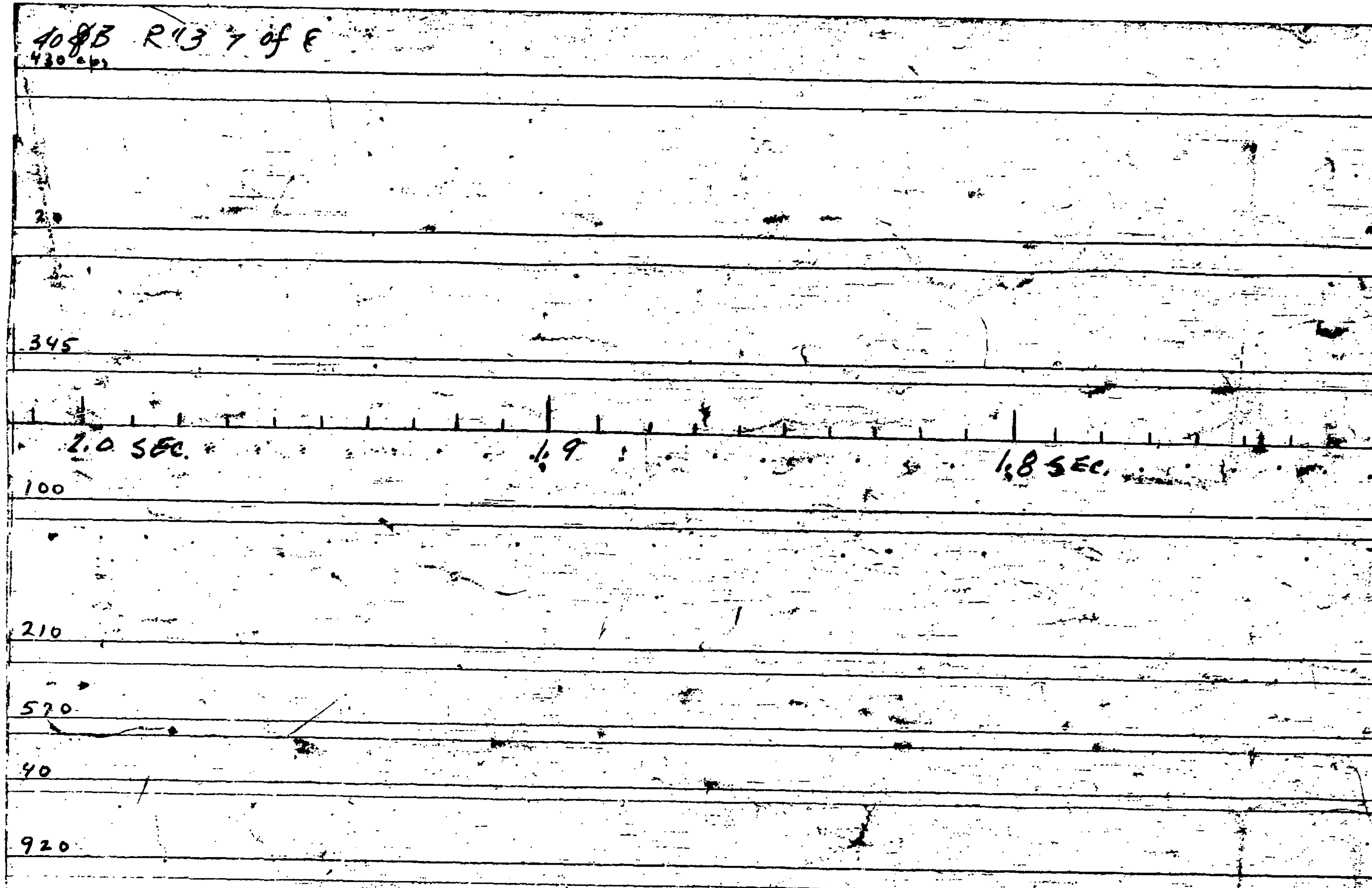
DD 408 R"3 TEST BAKER WAVE PART 5 FIG 74

A-2609



DD-408 TEST BAKER R"3 WAVE 1 PART 6 FIG 75

A-2609



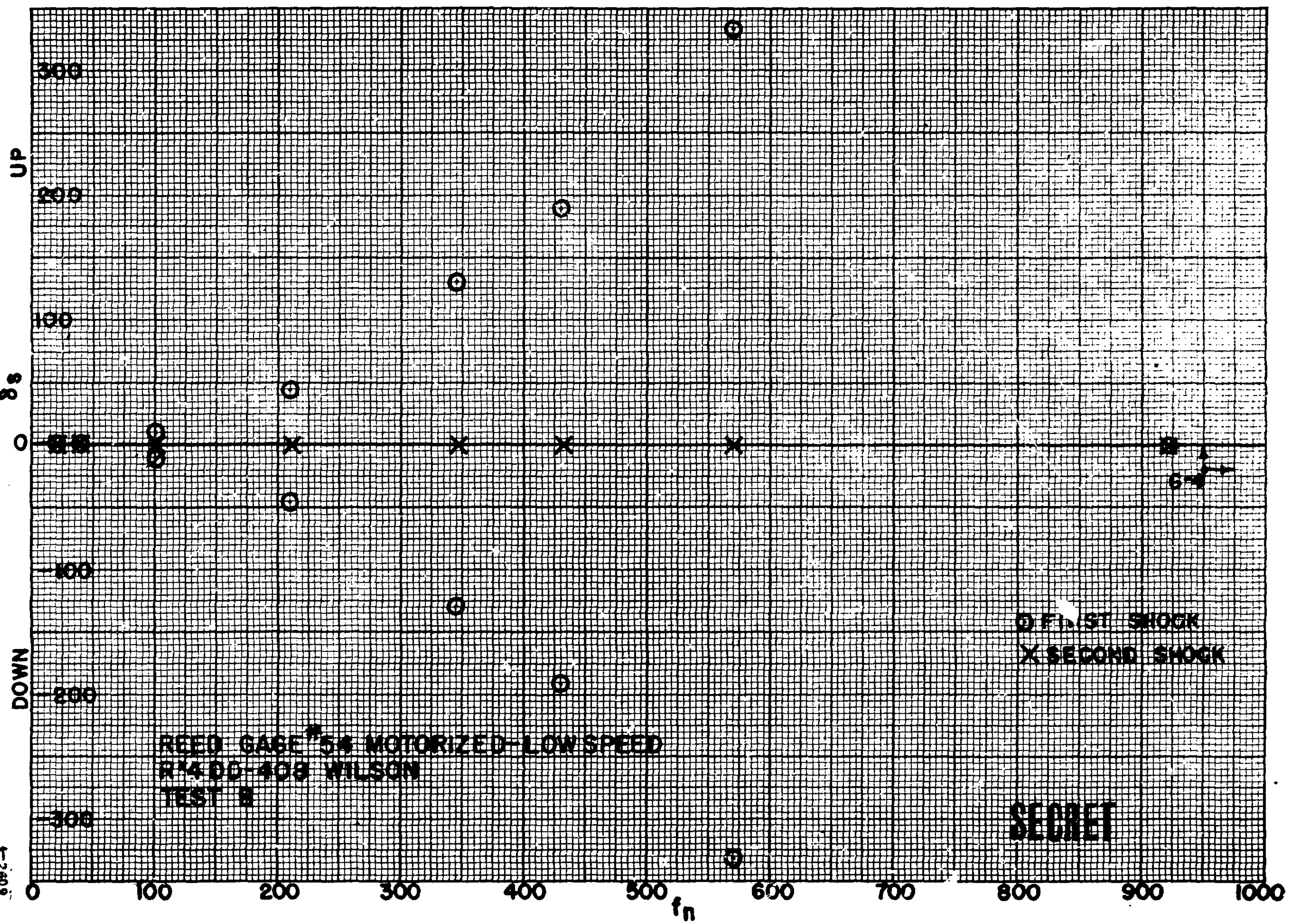
DD 408 TEST BAKER R"3 WAVE I PART 7

FIG. 76

A-2609

DD 408 TEST BAKER R"3 WAVE 2 FIG. 77

A-2609

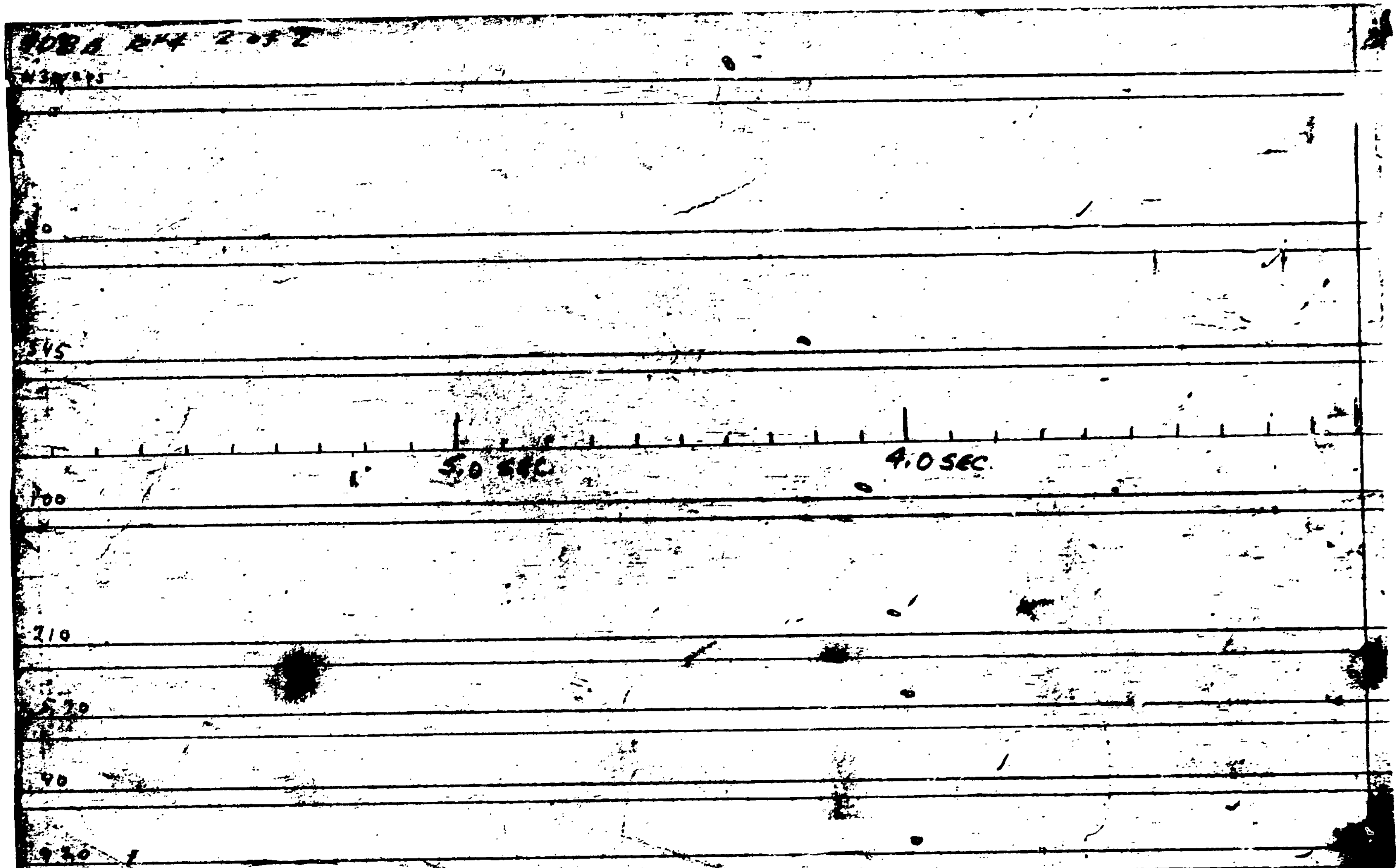


UP
DOWN
$\frac{X}{\delta_s}$
300
200
100
0
-100
-200
-300
0
100
200
300
400
500
600
700
800
900
1000
f_n
⊙ FIRST SHOCK
X SECOND SHOCK
REED GAGE #54 MOTORIZED-LOW SPEED
R*4 DD-408 WILSON
TEST B
SECRET

FIG. 78

A-2609


2.0 SEC.
1.0 SEC.
0
DD 408 TEST AKER R#4 WAVE 1
FIG. 79
A-2609



DD 408 TEST BAKER R"4 WAVE 2 FIG. 80

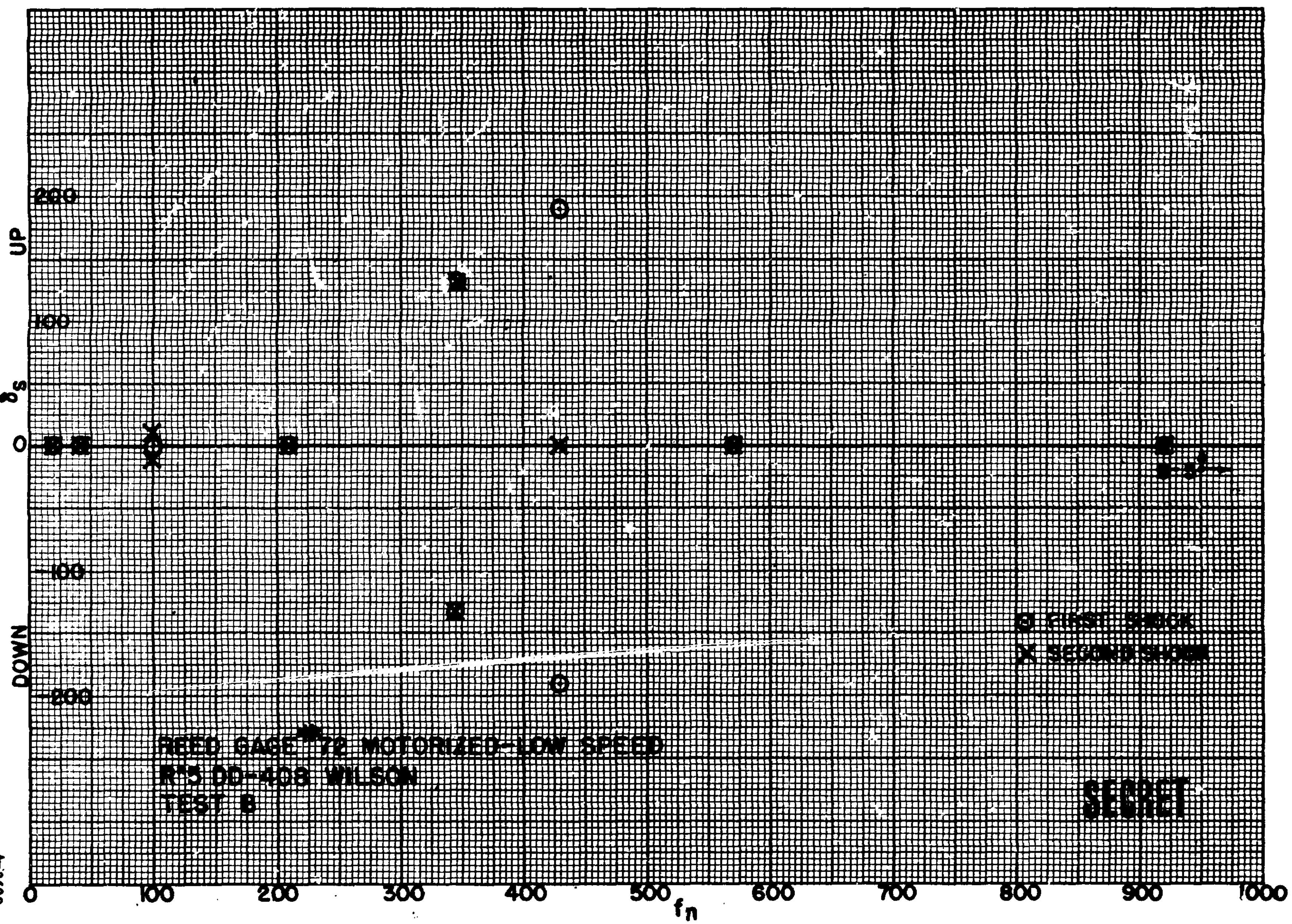
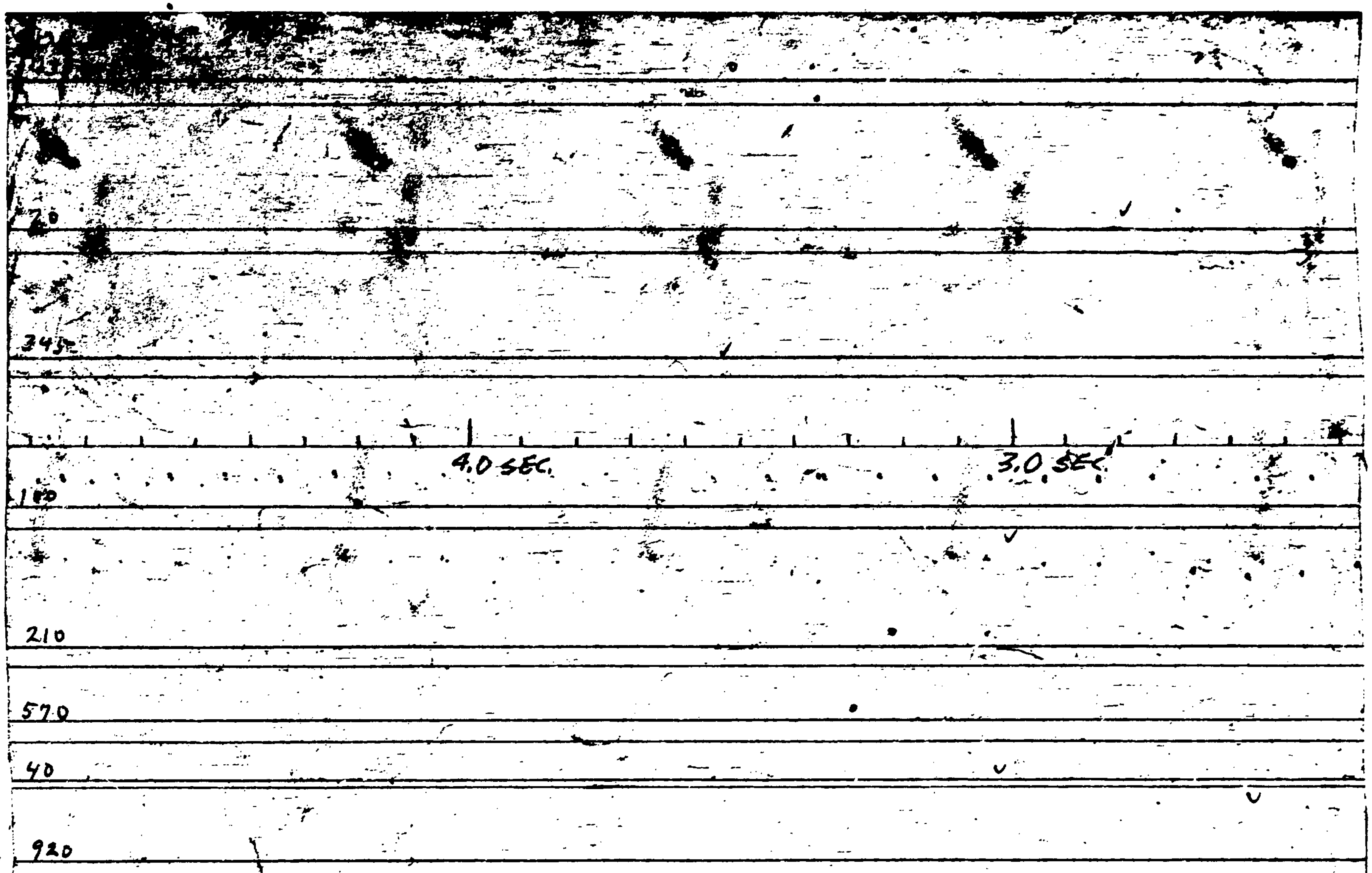

REED GAGE #72 MOTORIZED-LOW SPEED
R#5 DD-408 WILSON
TEST B
⊙ FIRST SHOCK
X SECOND SHOCK
SECRET
UP
DOWN
X / δs
200
100
0
-100
-200
0 100 200 300 400 500 600 700 800 900 1000
fn

FIG. 81

A-2609

DD408 TEST BAKER R"5 WAVE FIG. 82

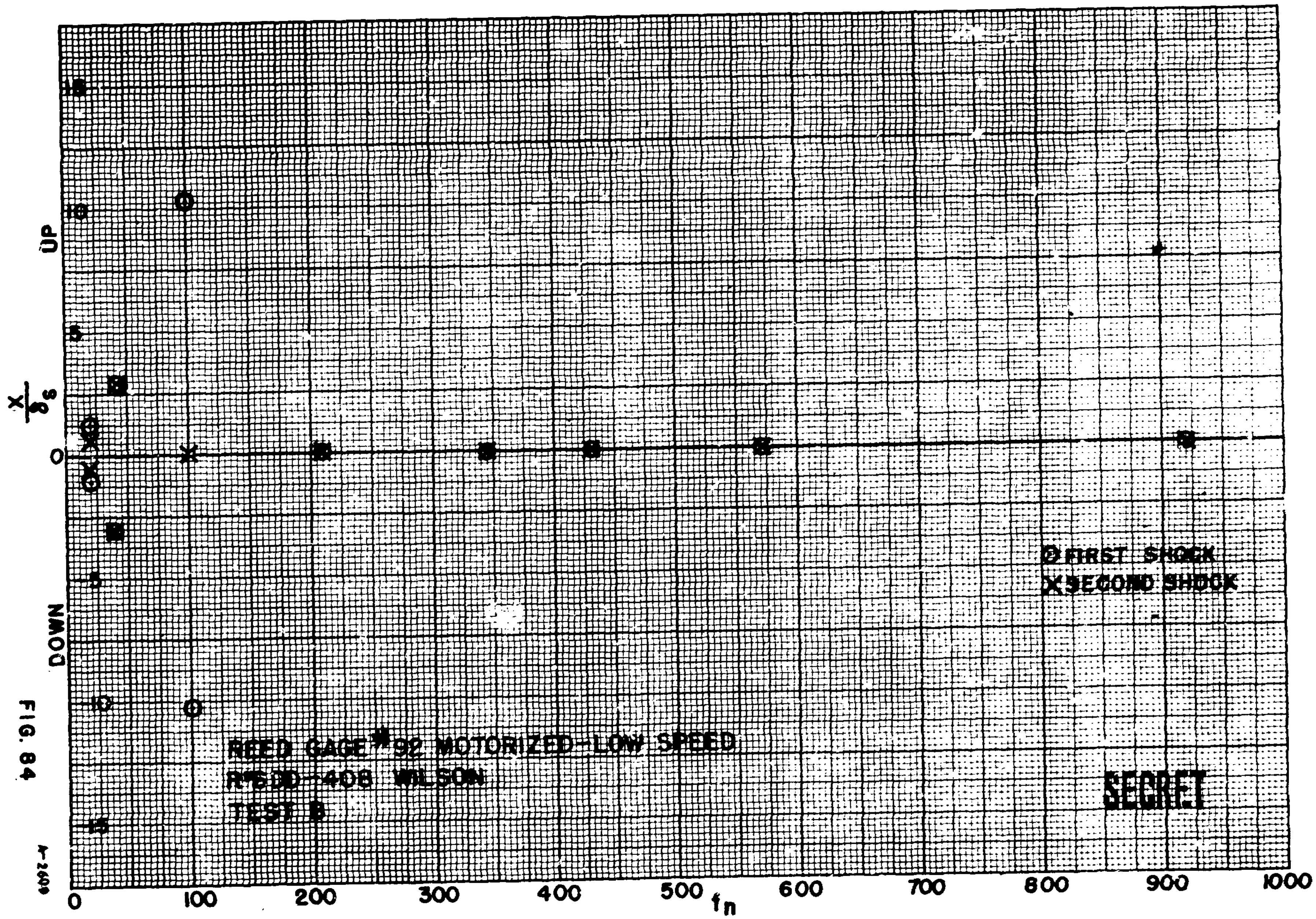
A-2609



DD 408. TEST BAKER R° 5 WAVE 2

FIG. 83

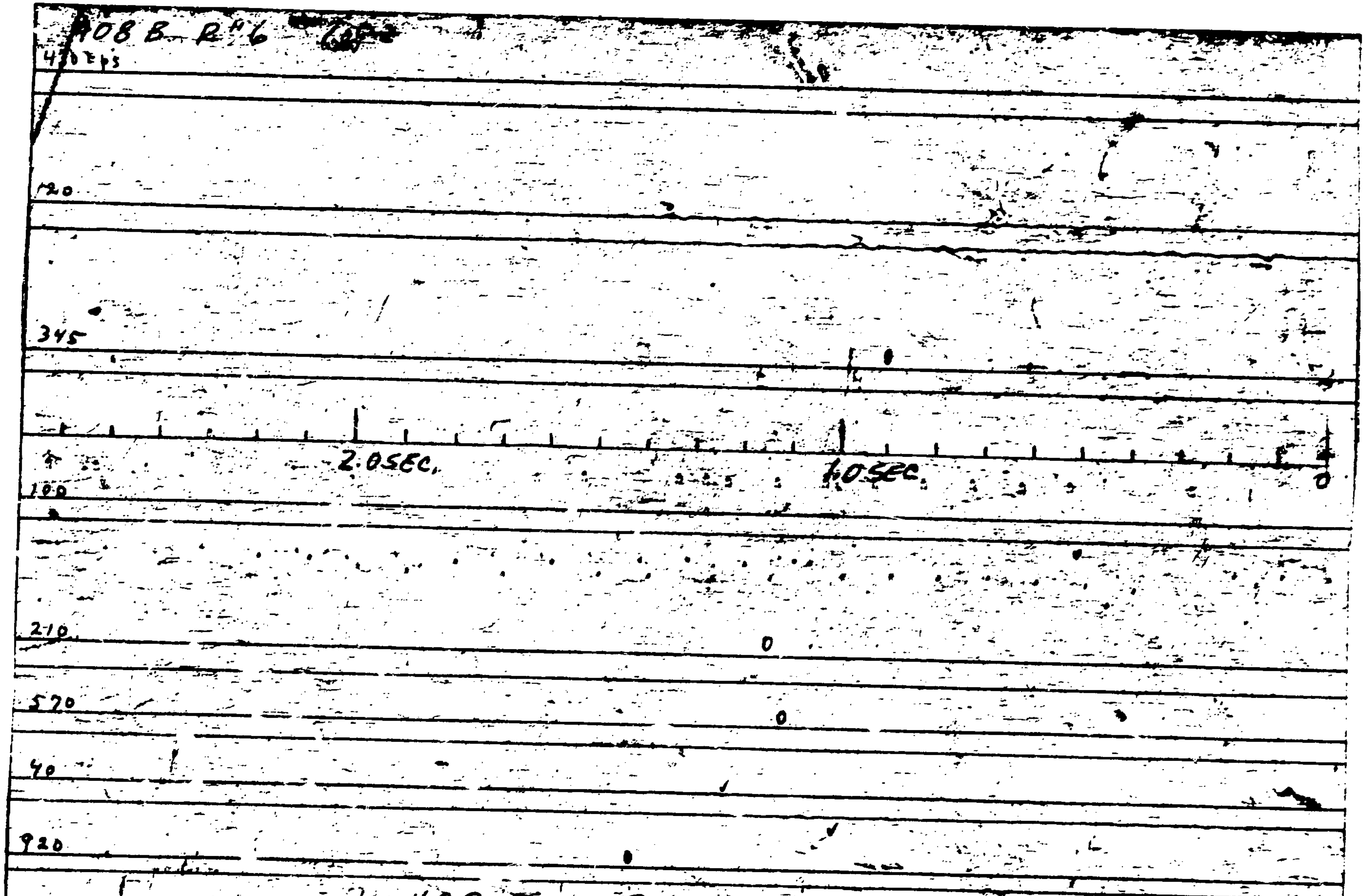
A-2609



15
10
UP
5
X/δs
0
5
DOWN
10
15
0
100
200
300
400
500
fn
600
700
800
900
1000
⊙ FIRST SHOCK
X SECOND SHOCK
REED GAGE #92 MOTORIZED-LOW SPEED
R#SID-408 WILSON
TEST B
SECRET

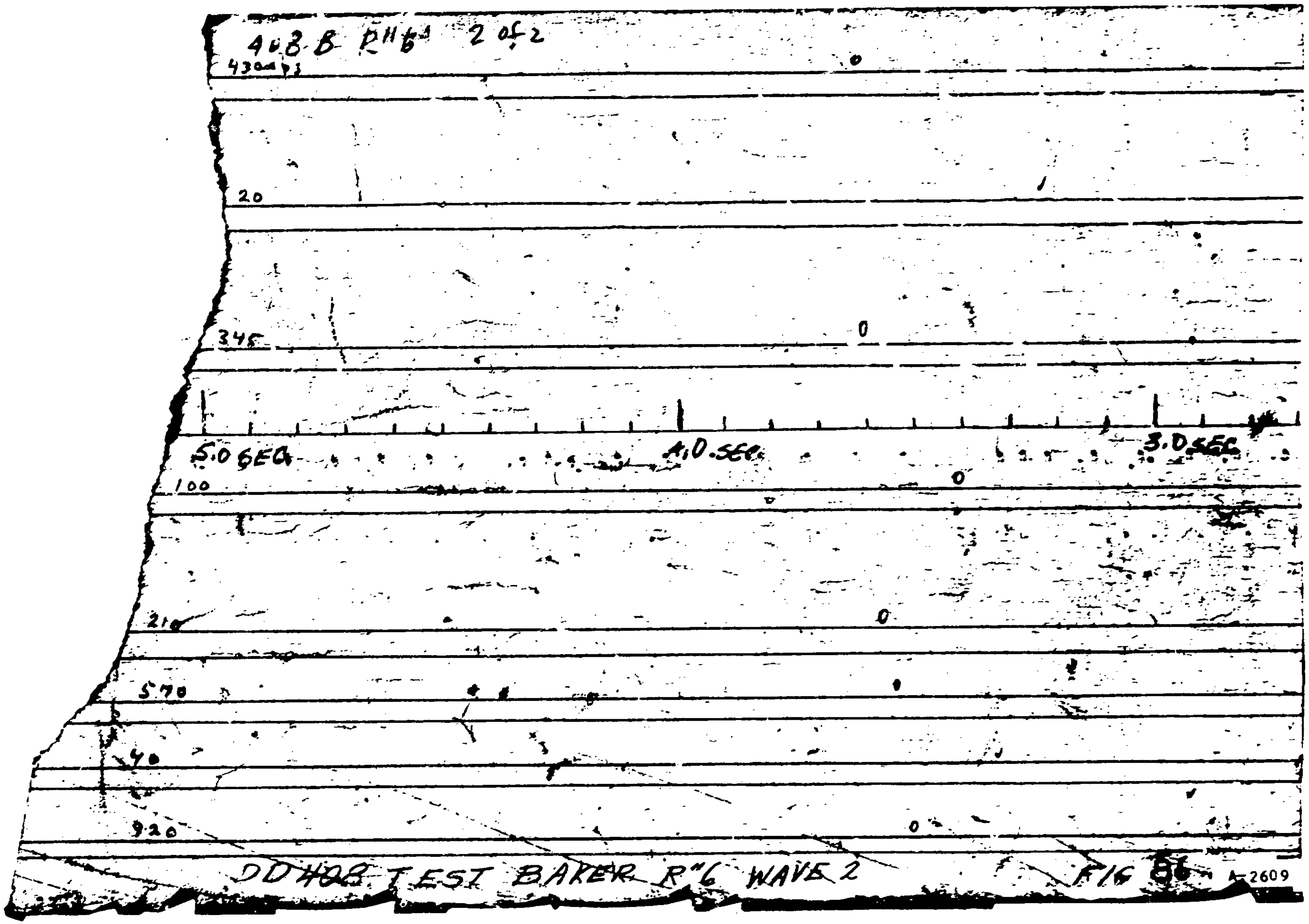
FIG. 84

A-2609

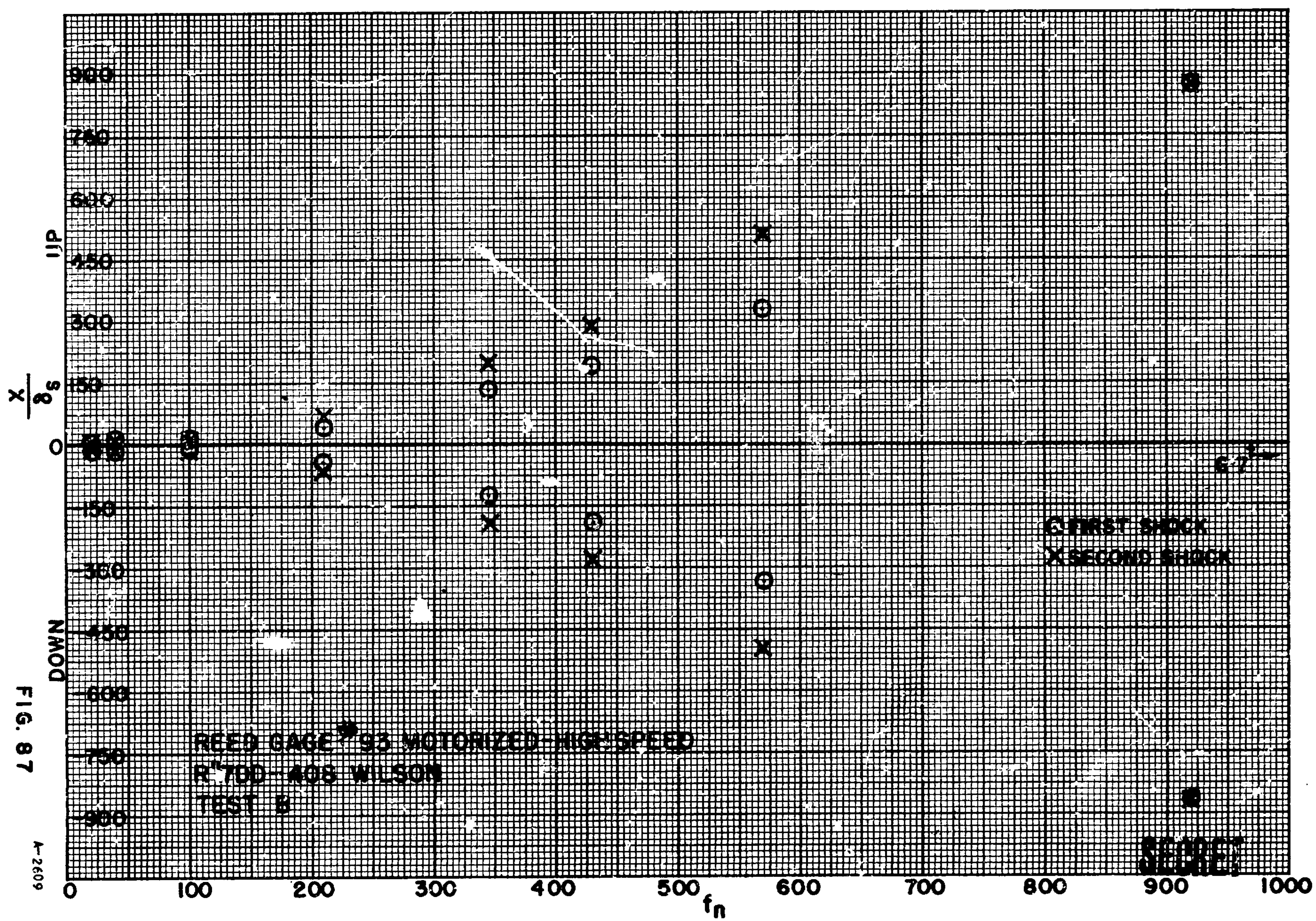


DV 408 TEST BAKER R"6 WAVE 1 FIG. 85

A-2609



408 B
2 of 2
430
20
345
5.0 SEC
4.0 SEC
3.0 SEC
100
210
570
40
920
DD 408 TEST BAKER
WAVE 2
FIG 86
A-2609



UP
DOWN
$\frac{X}{\delta_s}$
900
750
600
450
300
150
0
150
300
450
600
750
900
0
100
200
300
400
500
600
700
800
900
1000
f_n
6.7
O FIRST SHOCK
X SECOND SHOCK
REED GAGE # 93 MOTORIZED-HIGH-SPEED
R" 700 - 408 WILSON
TEST B
SECRET
A-2609

FIG. 87

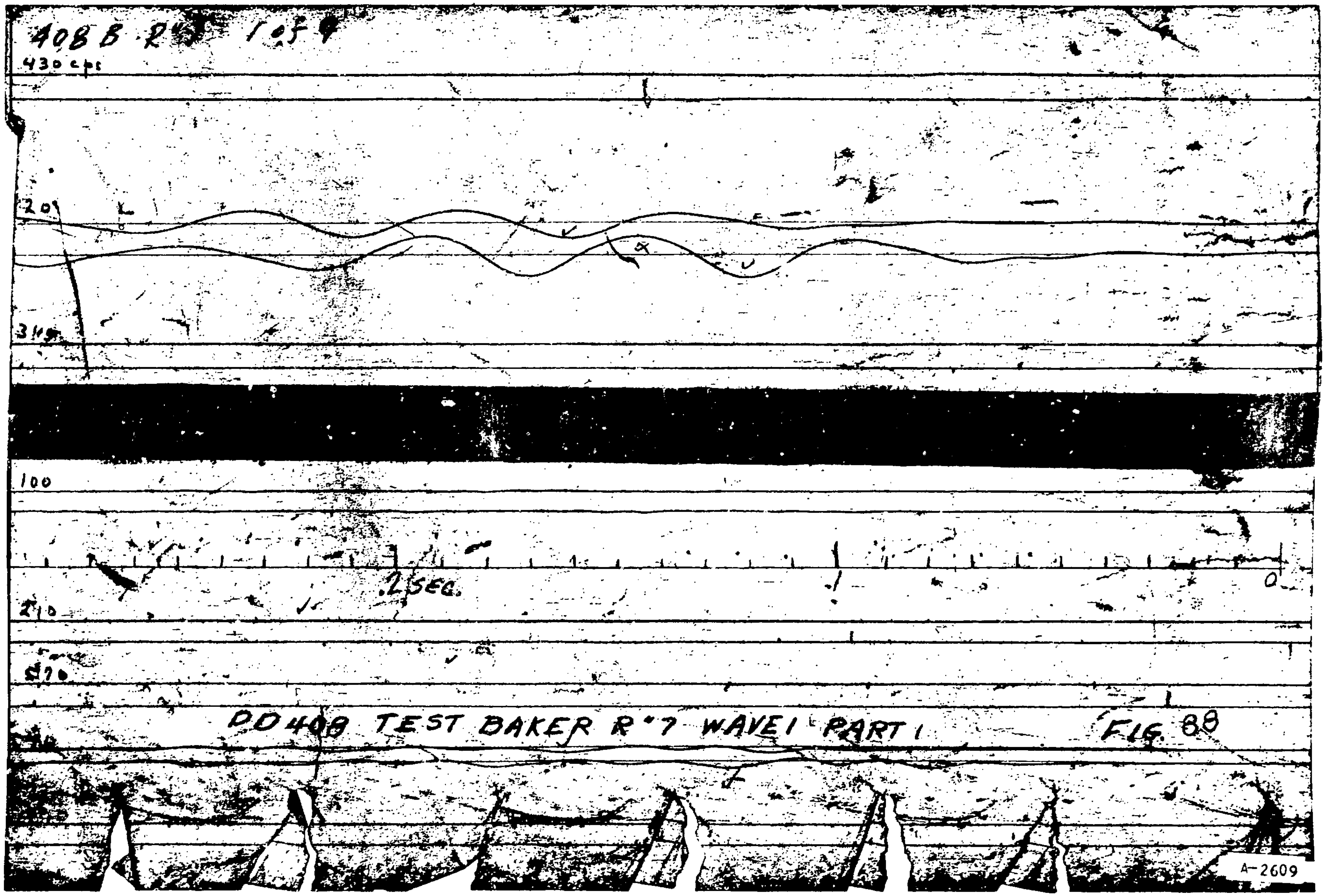
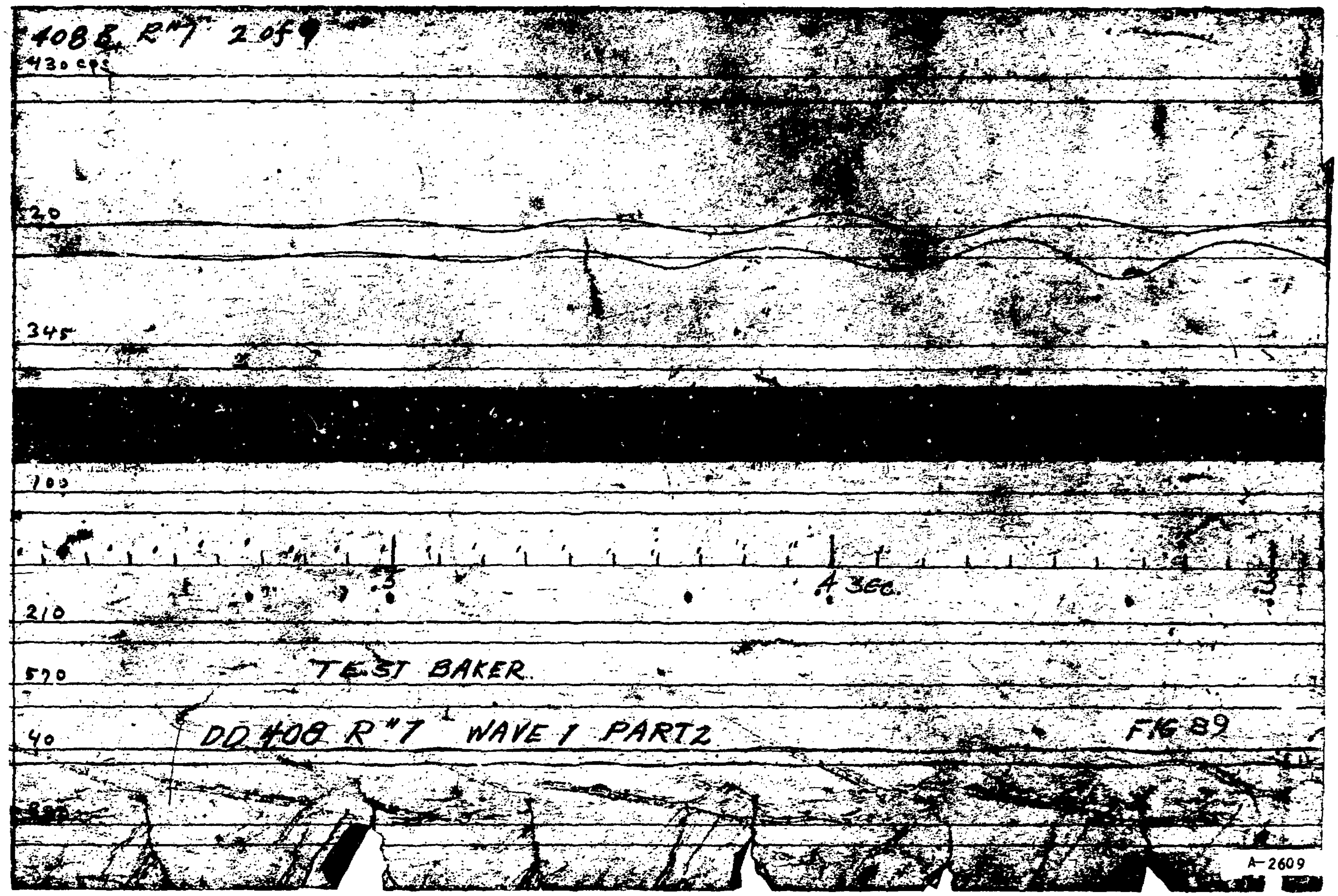
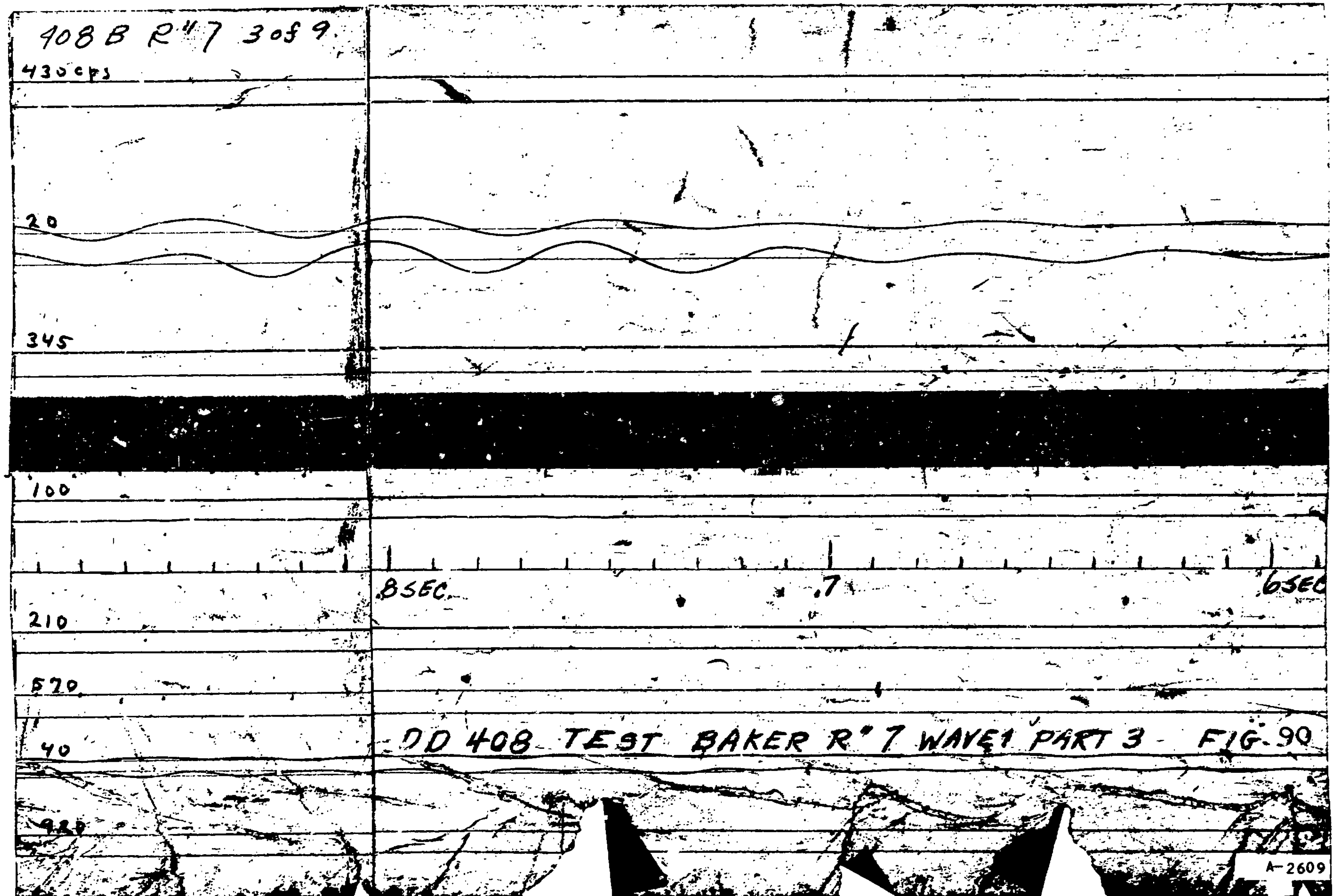
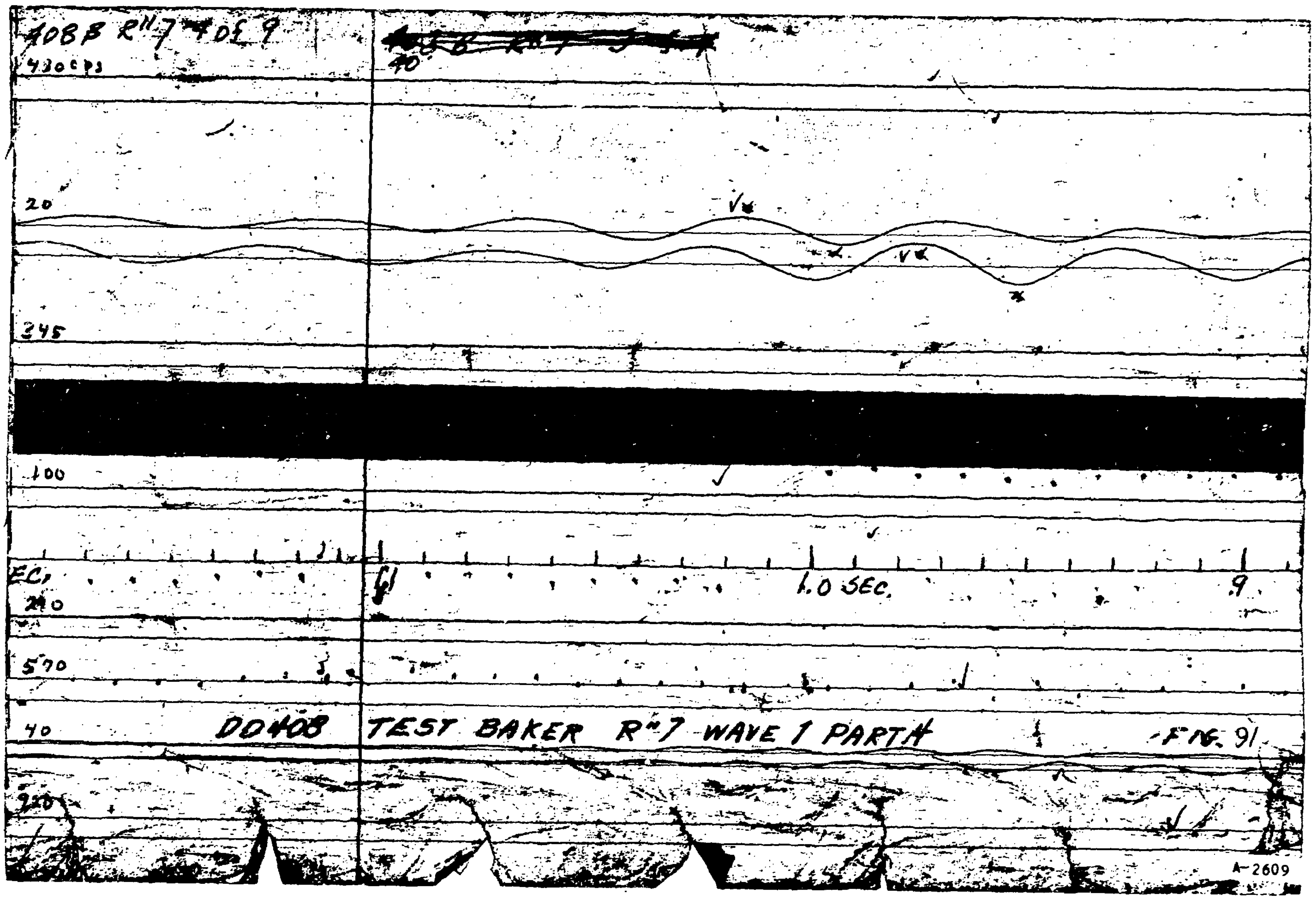
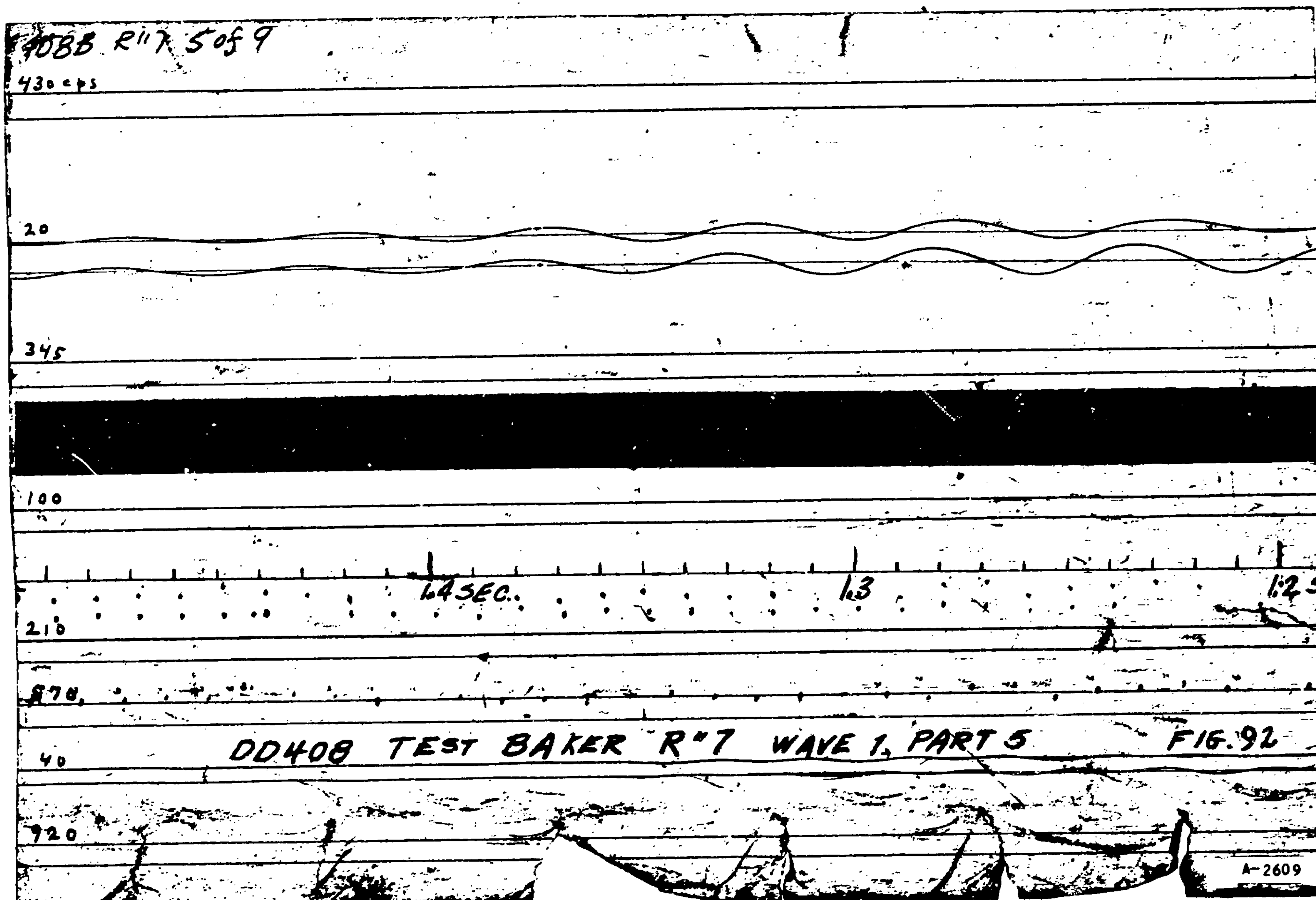

408 B R 1 of 4
430 cps
20
34
100
.2 SEC.
0
210
PD 408 TEST BAKER R°7 WAVE 1 PART 1
A-2609

FIG. 88

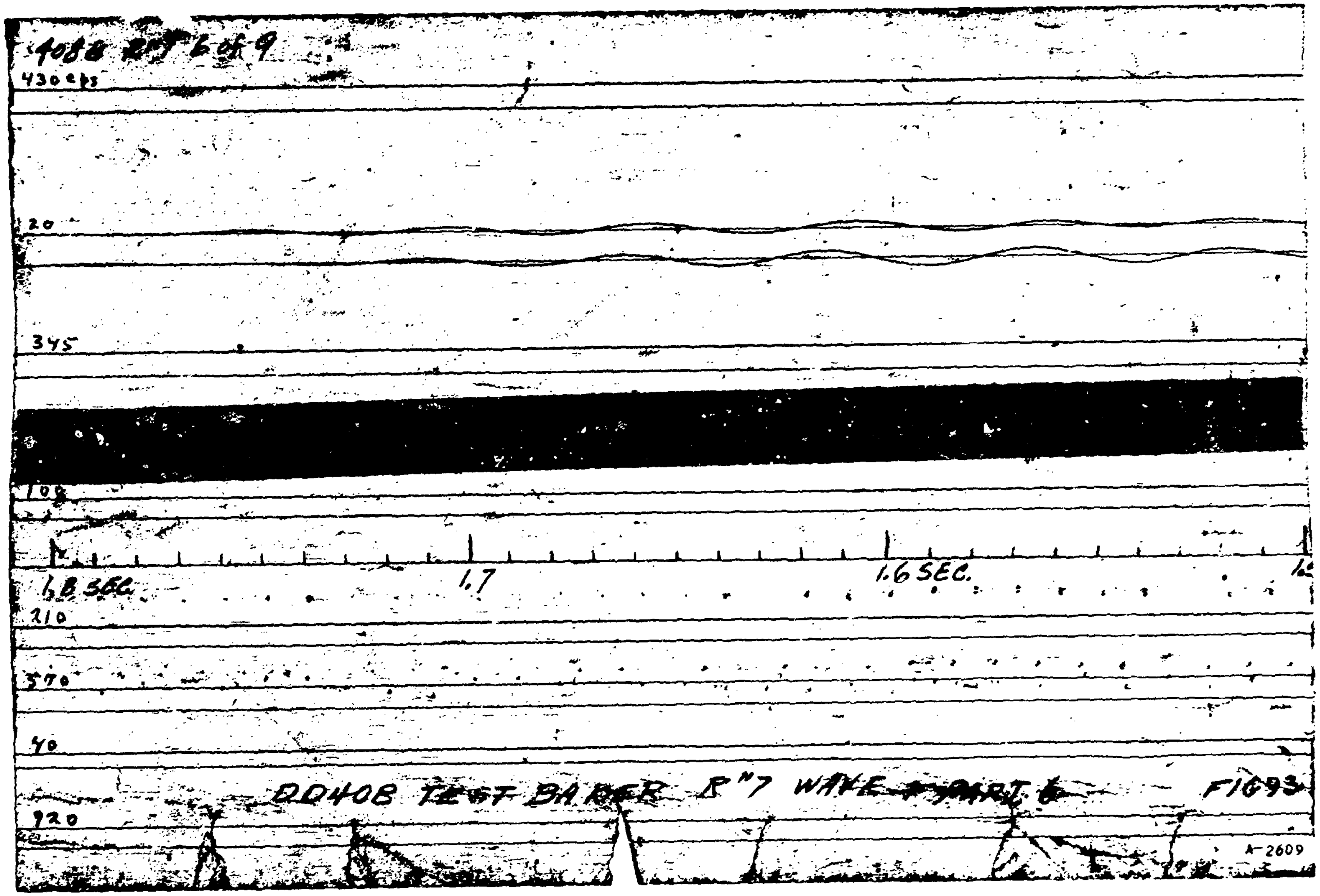

408 B R#7 2 of 9
430 cps
20
345
100
210
570
40
.3
.4 sec.
TEST BAKER
DD 408 R#7 WAVE 1 PART 2
FIG 89
A-2609

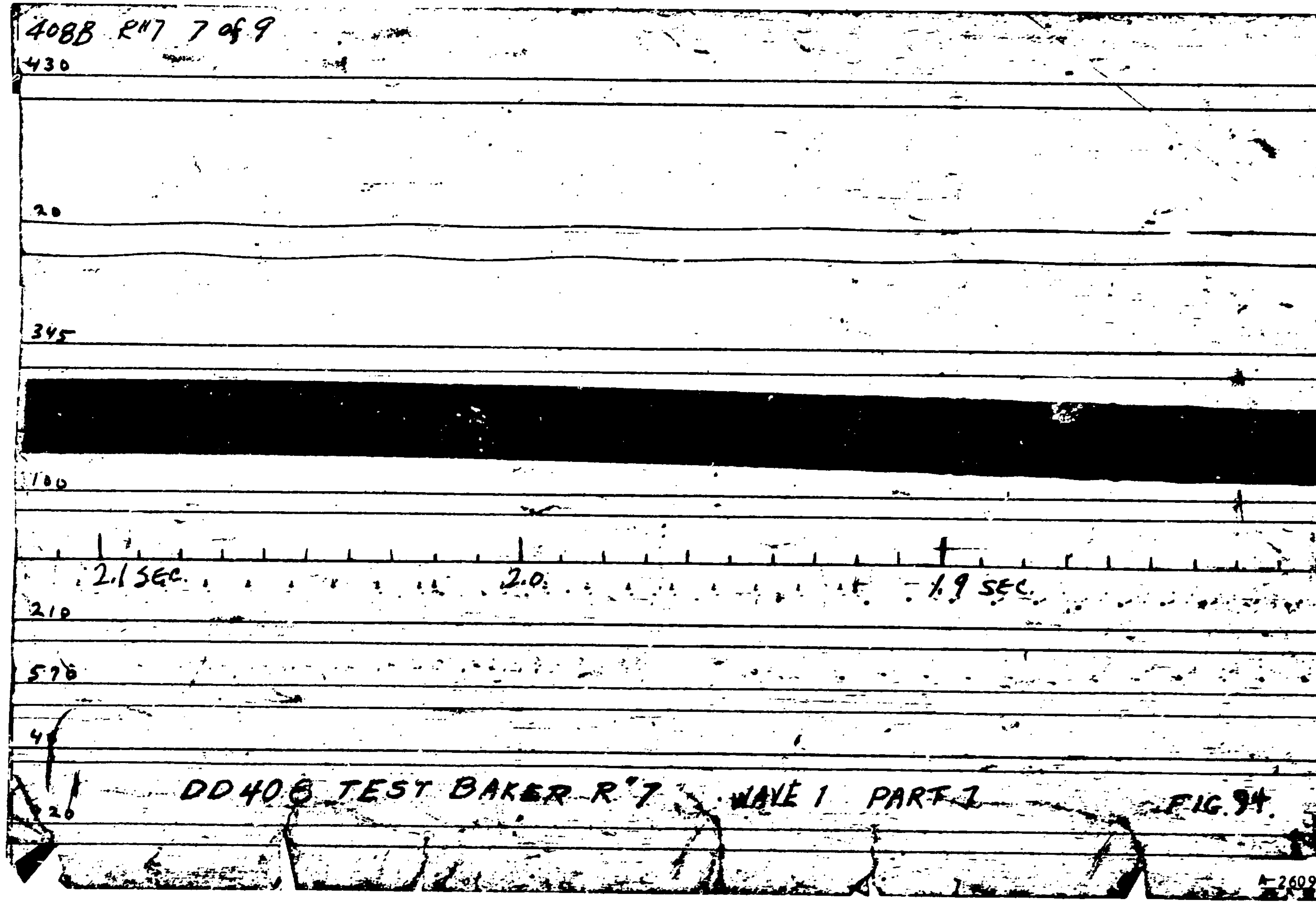

408 B R# 7 3 of 9
430 cps
20
345
100
.8 SEC
.7
.6 SEC
210
570
40
920
DD 408 TEST BAKER R# 7 WAVE 1 PART 3 - FIG. 90
A-2609

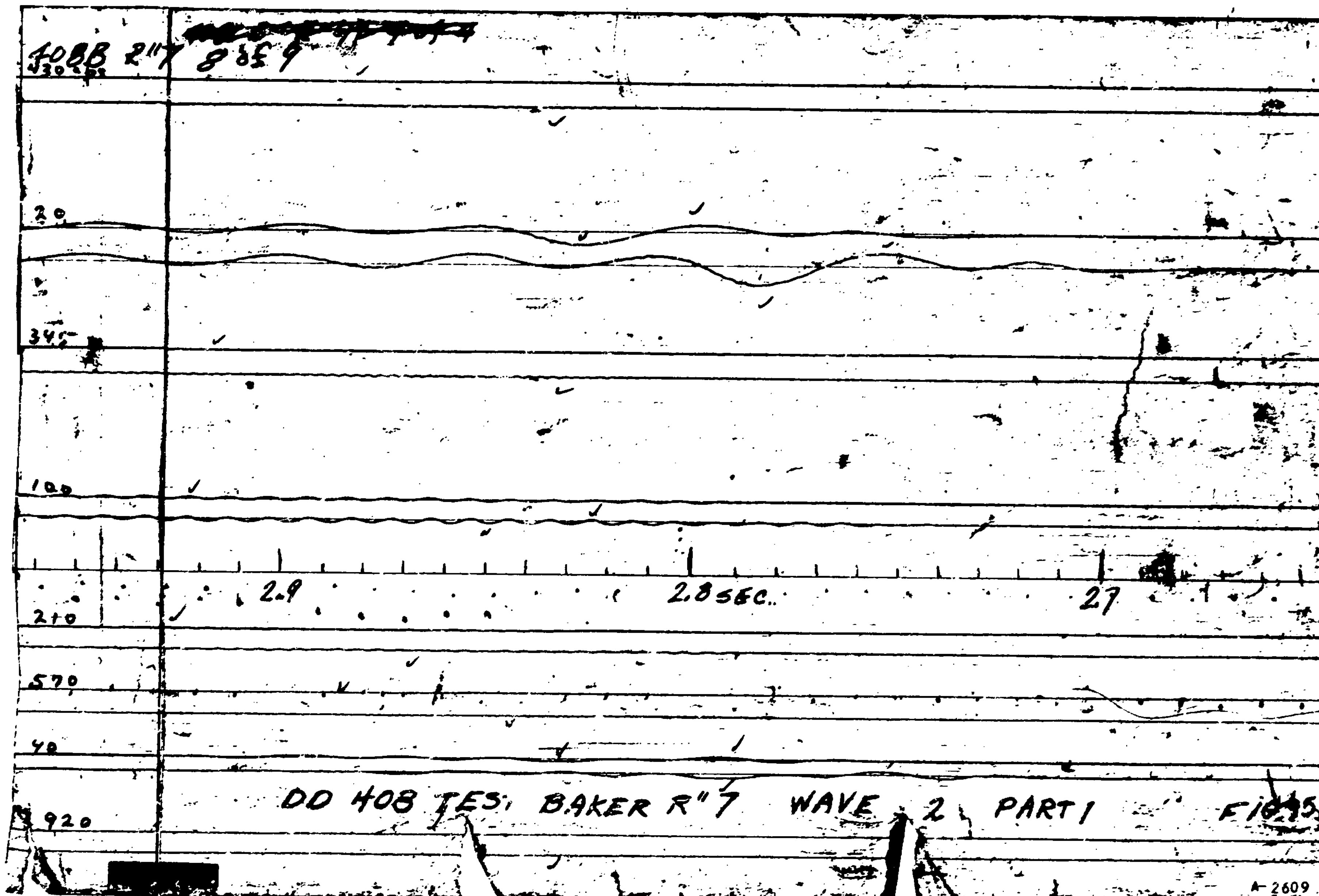

408B R"7 4 OF 9
430 CPS
40
20
345
100
1.0 SEC.
9
210
570
40
DD408 TEST BAKER R"7 WAVE 1 PART A
FIG. 91
A-2609



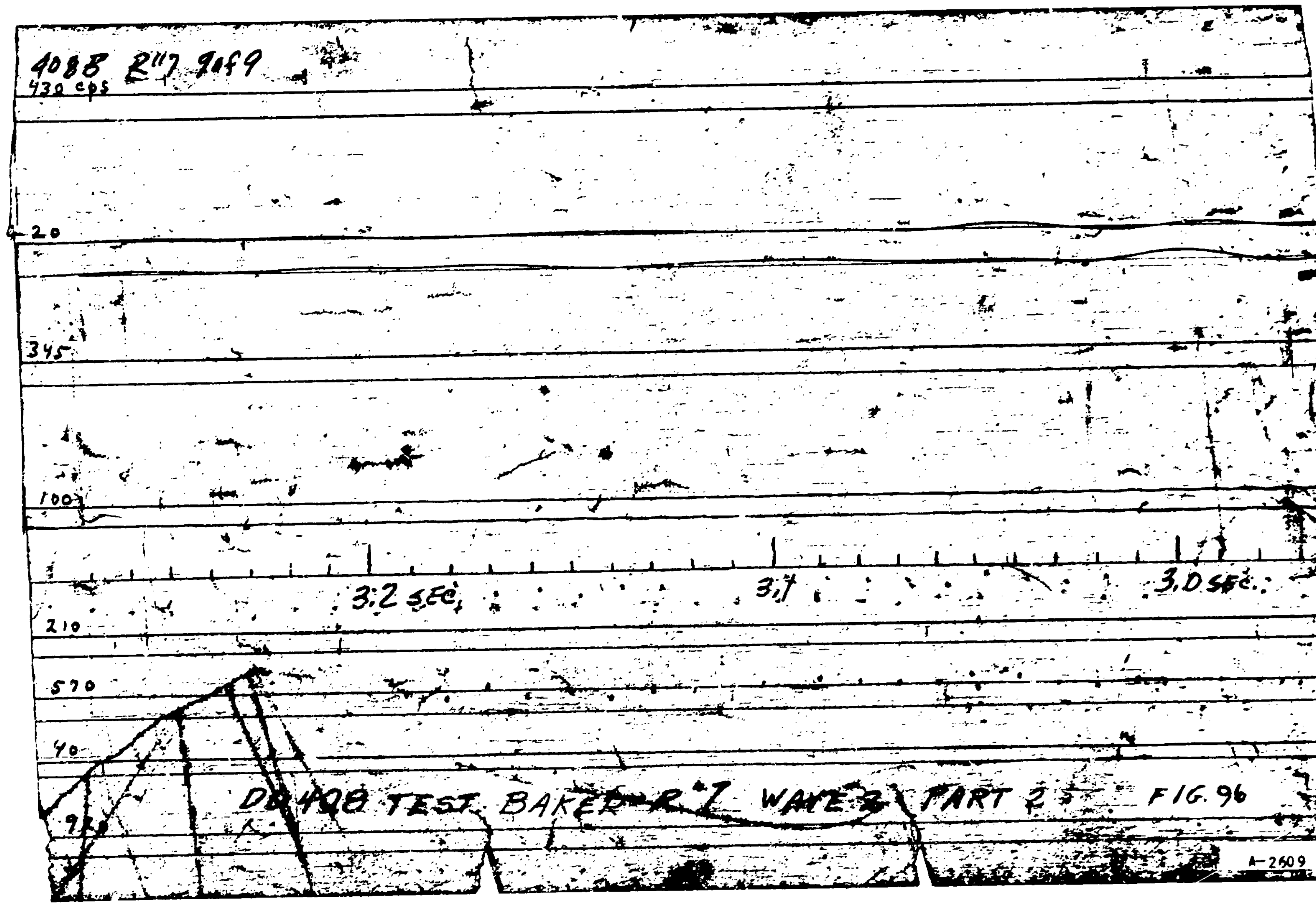
DD408 TEST BAKER R#7 WAVE 1, PART 5
FIG. 92


430 cps
20
345
1.8 SEC.
1.7
1.6 SEC.
210
570
40
920
FIG 93
A-2609

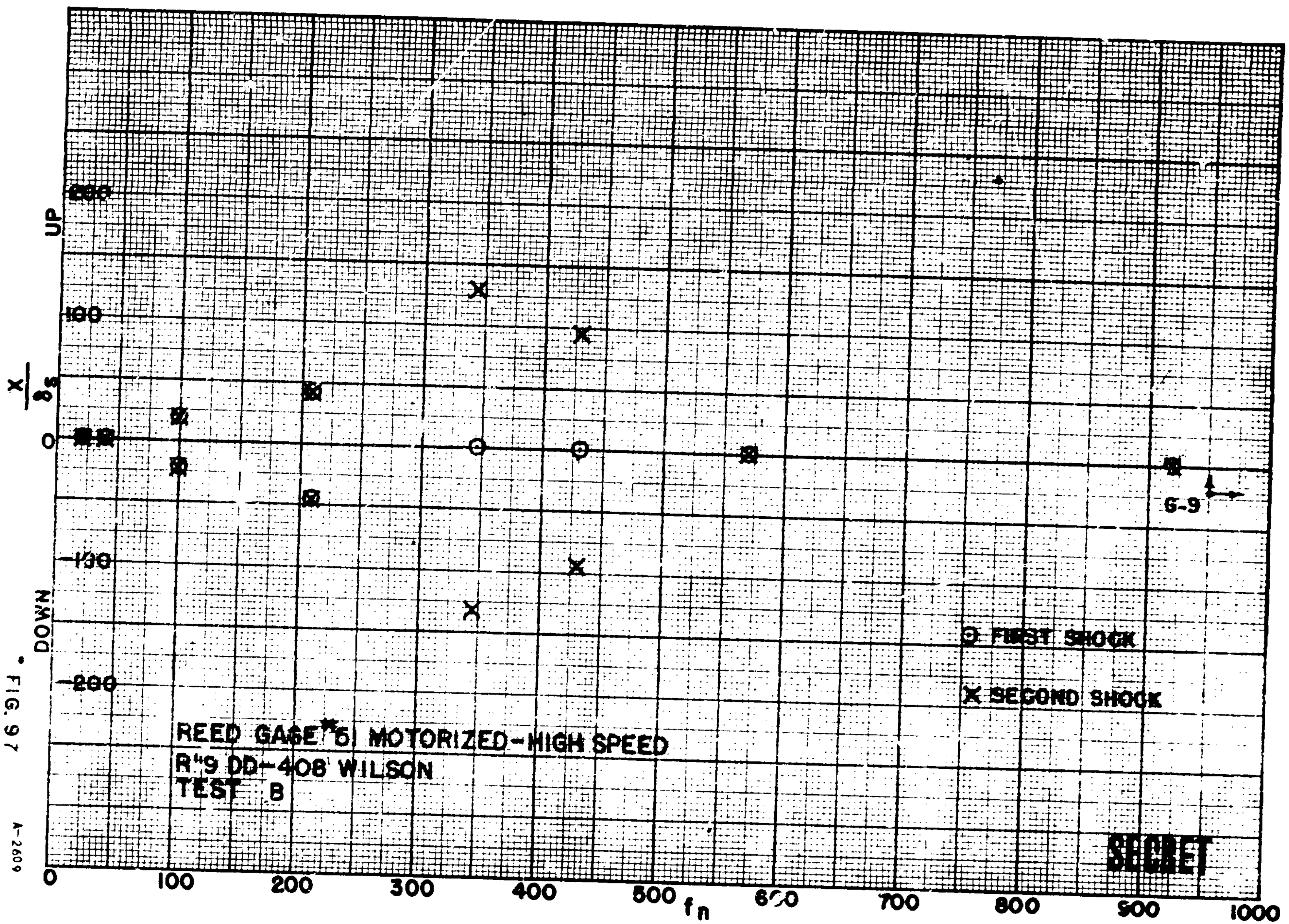

408B R"7 7 of 9
430
20
345
100
2.1 SEC.
2.0
1.9 SEC.
210
570
4
20
DD 408 TEST BAKER R"7 WAVE 1 PART 1
A-2609
FIG. 94.



408B 2"7 8 35 9
20
345
100
2.9
2.8 SEC.
27
210
570
40
920
DO 408 TES: BAKER R"7 WAVE 2 PART I
A-2609



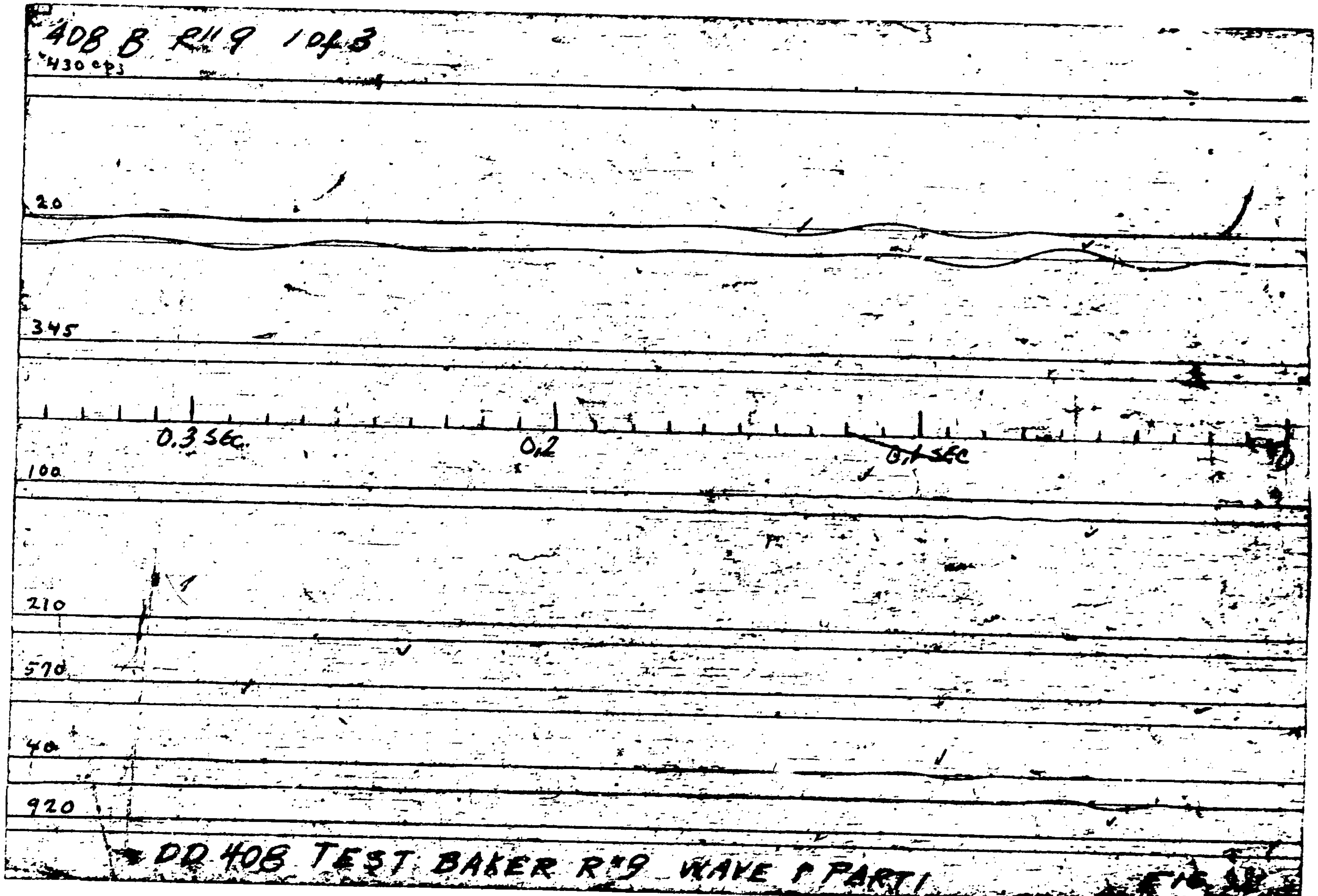
4088 R"7 9 of 9
430 cps
20
345
100
3.2 SEC.
3.1
3.0 SEC.
210
570
40
DD 408 TEST BAKER R 7 WAVE 3 PART 2
FIG. 96
A-2609



UP
200
100
X/δs
0
-100
DOWN
-200
0
100
200
300
400
500
600
700
800
900
1000
fn
FIRST SHOCK
SECOND SHOCK
G-9
REED GAGE #5 MOTORIZED-HIGH SPEED
R"9 DD-408 WILSON
TEST B
SECRET

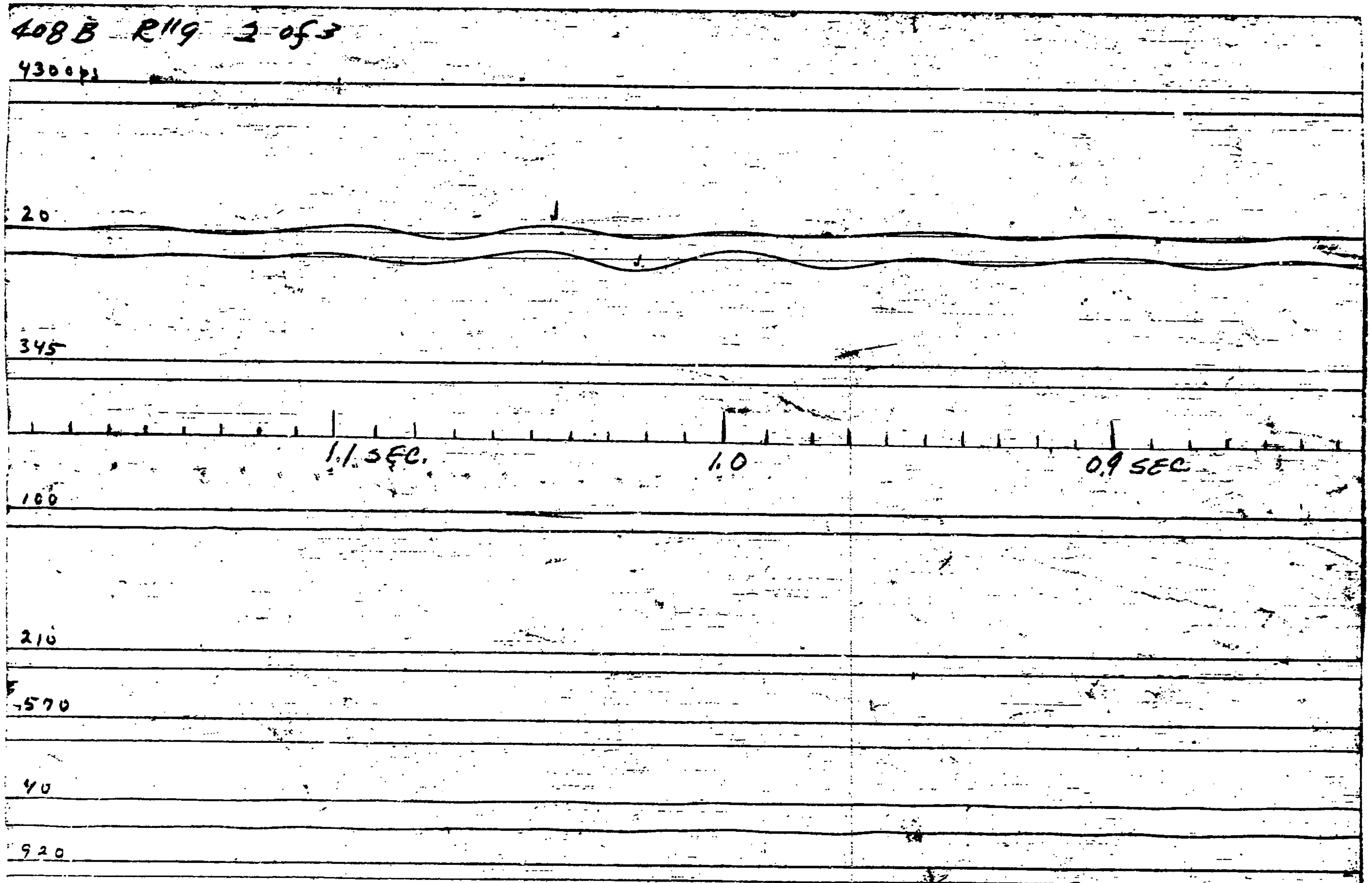
FIG. 97

A-2609



408 B R#9 1 of 3
430 cps
20
345
0.3 SEC.
0.2
0.1 SEC
100
210
570
40
920
DD 408 TEST BAKER R#9 WAVE P PART I

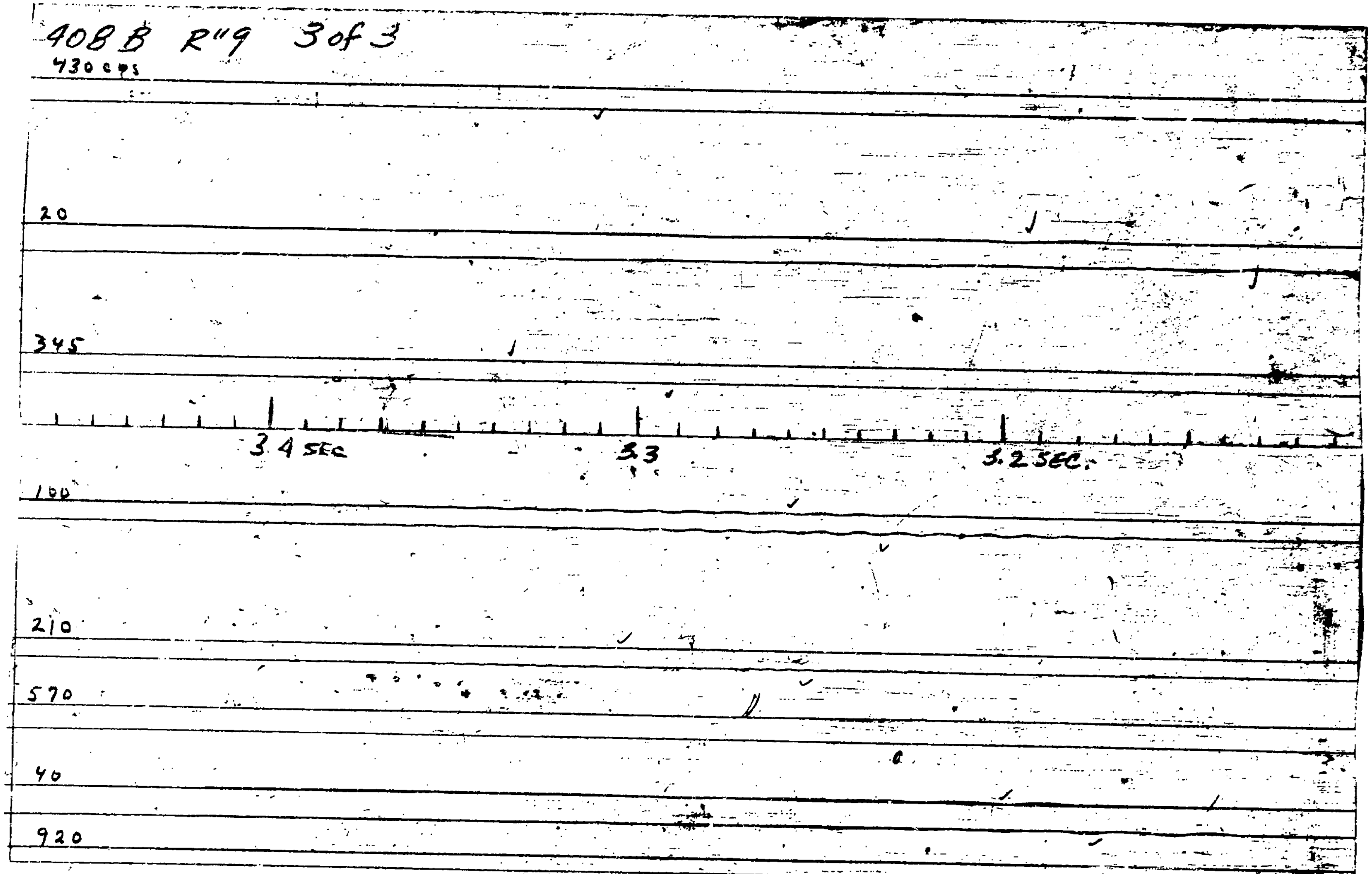
A-2609



OD 408 TEST BAKER R"9, WAVE 1 PART 2

FIG. 99

A-2609



DD 408 TEST BAKER R"9 WAVE 2

FIG 100 A-2609

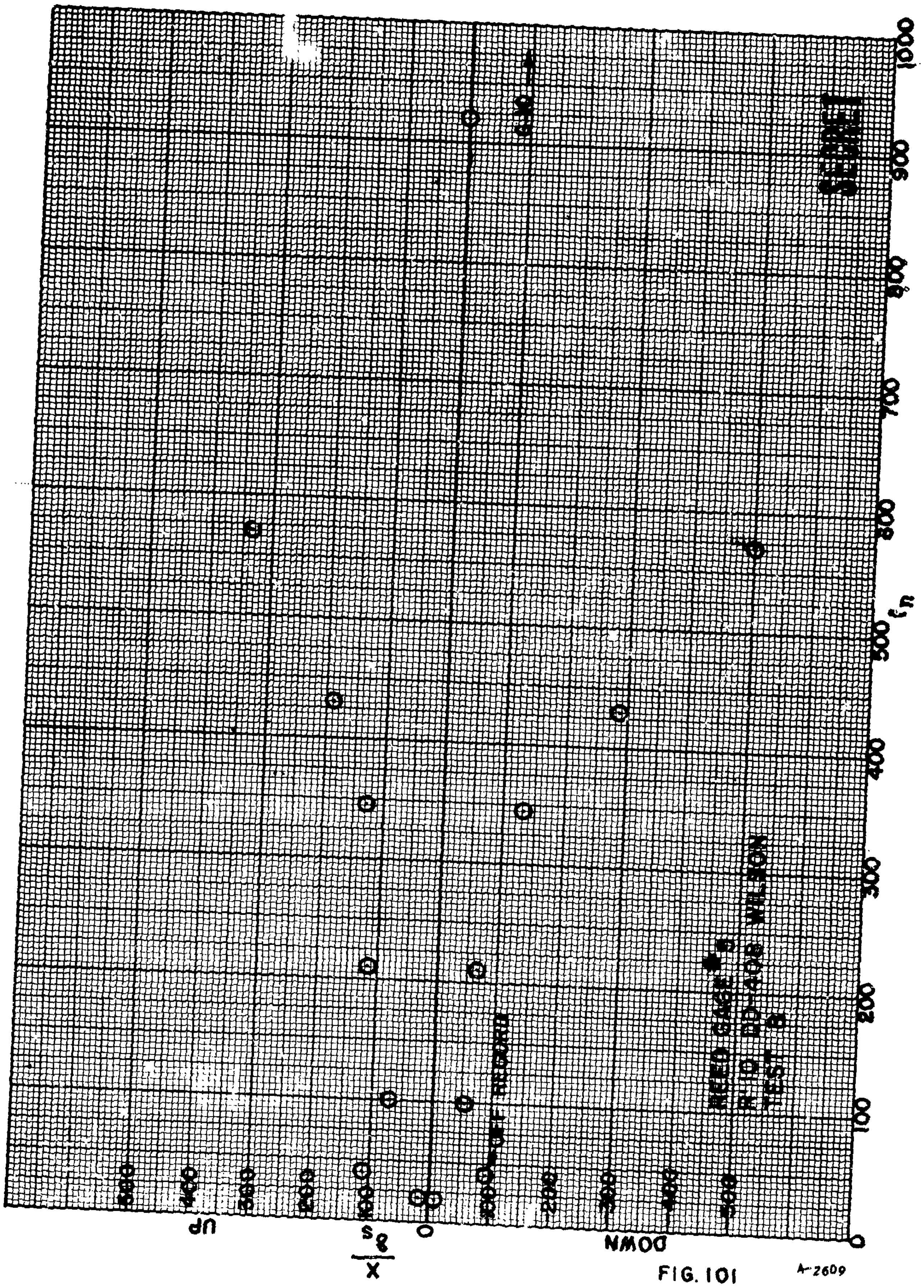


FIG. 101

A-2609

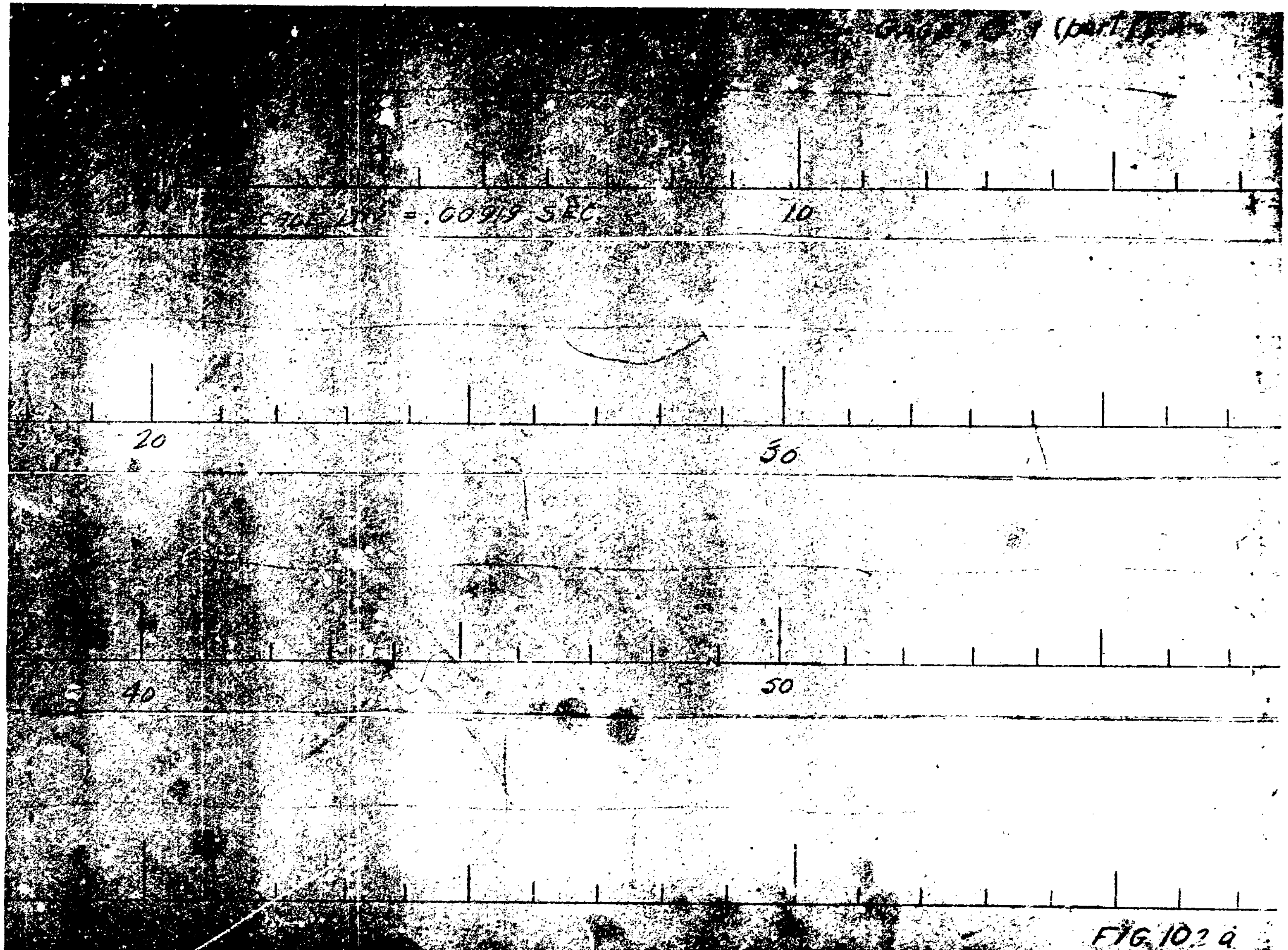
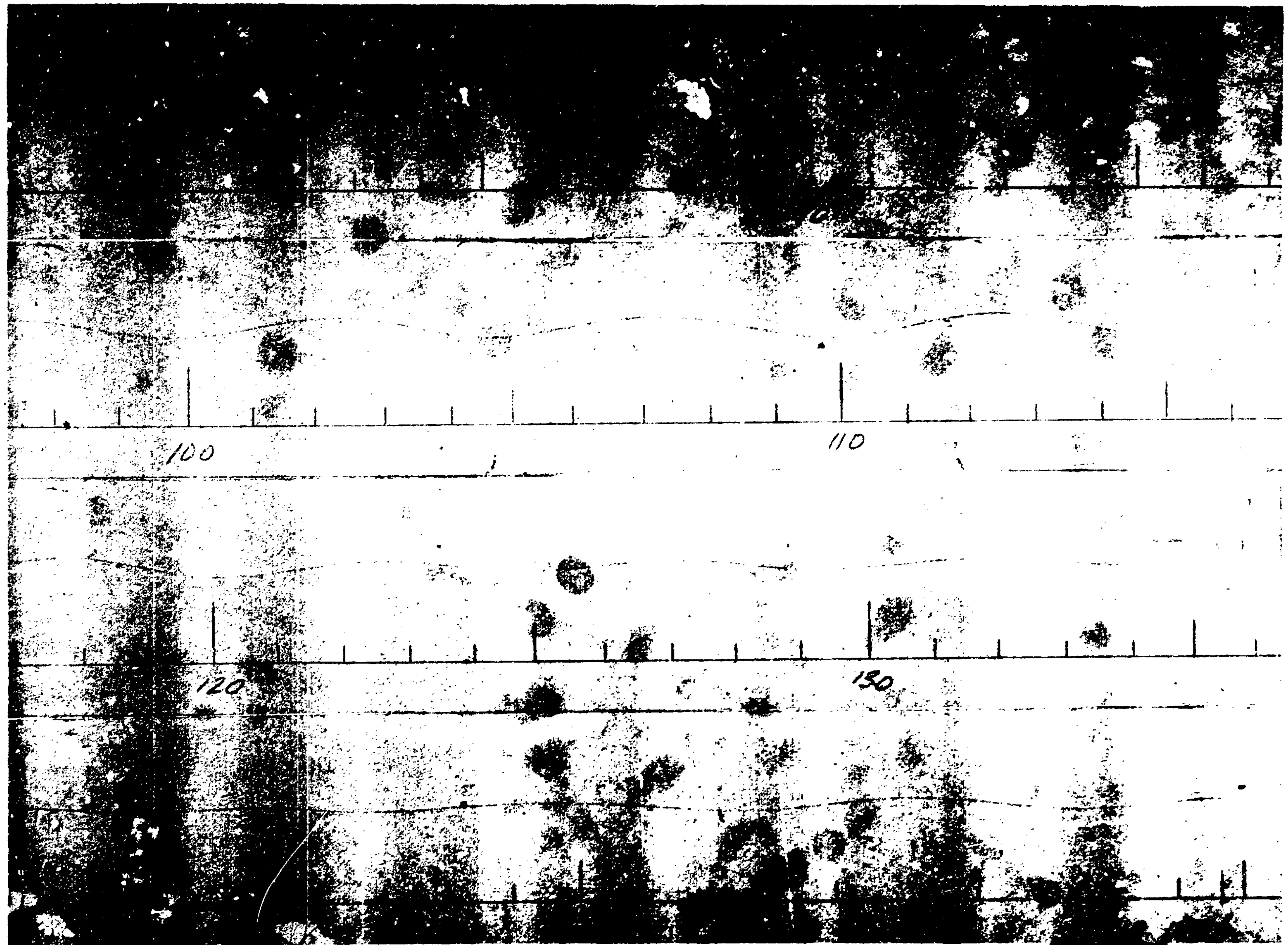
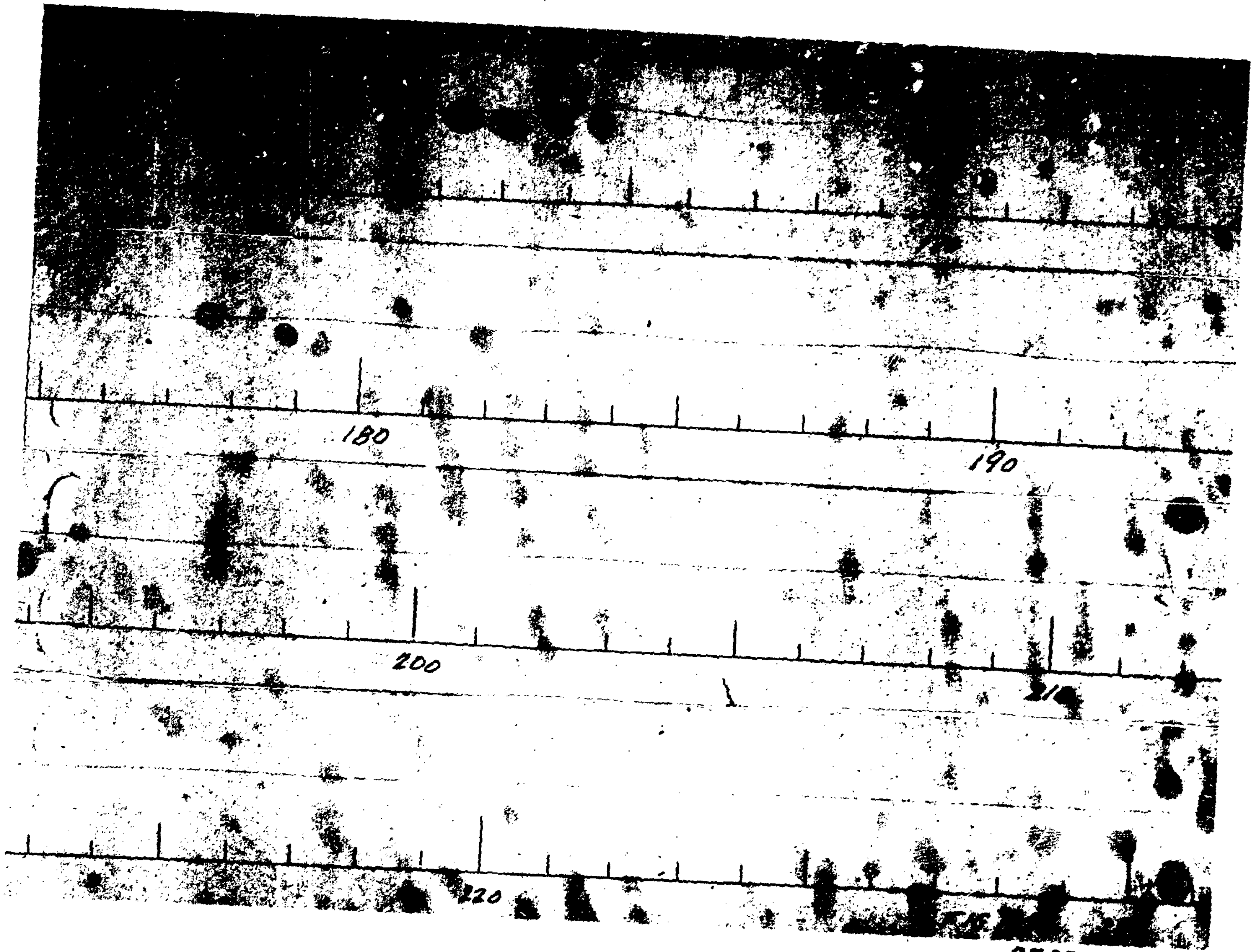


FIG. 102 a

SECRET

A-2609


100
110
120
130



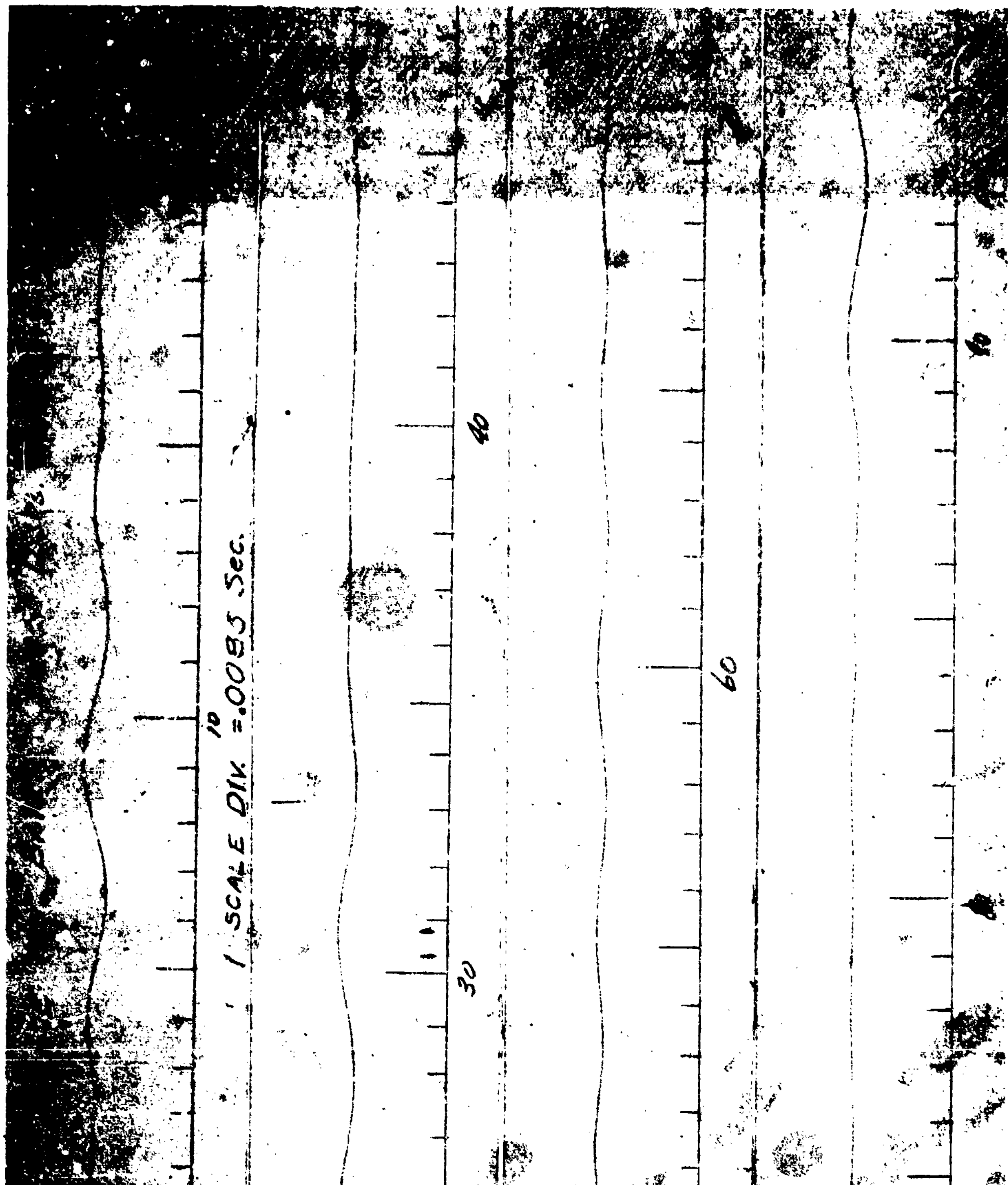
SECRET

A-2609

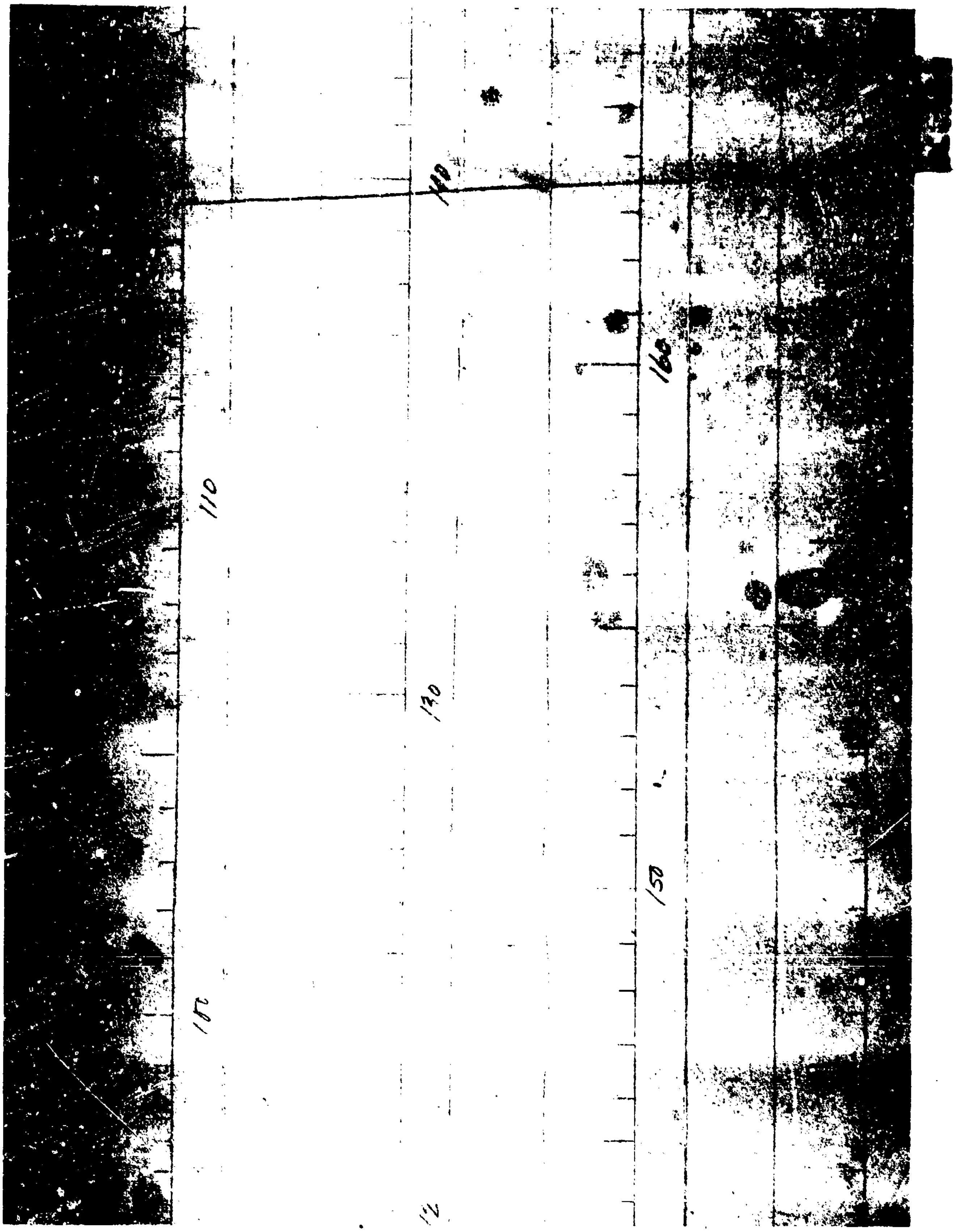
A-2609

SECRET

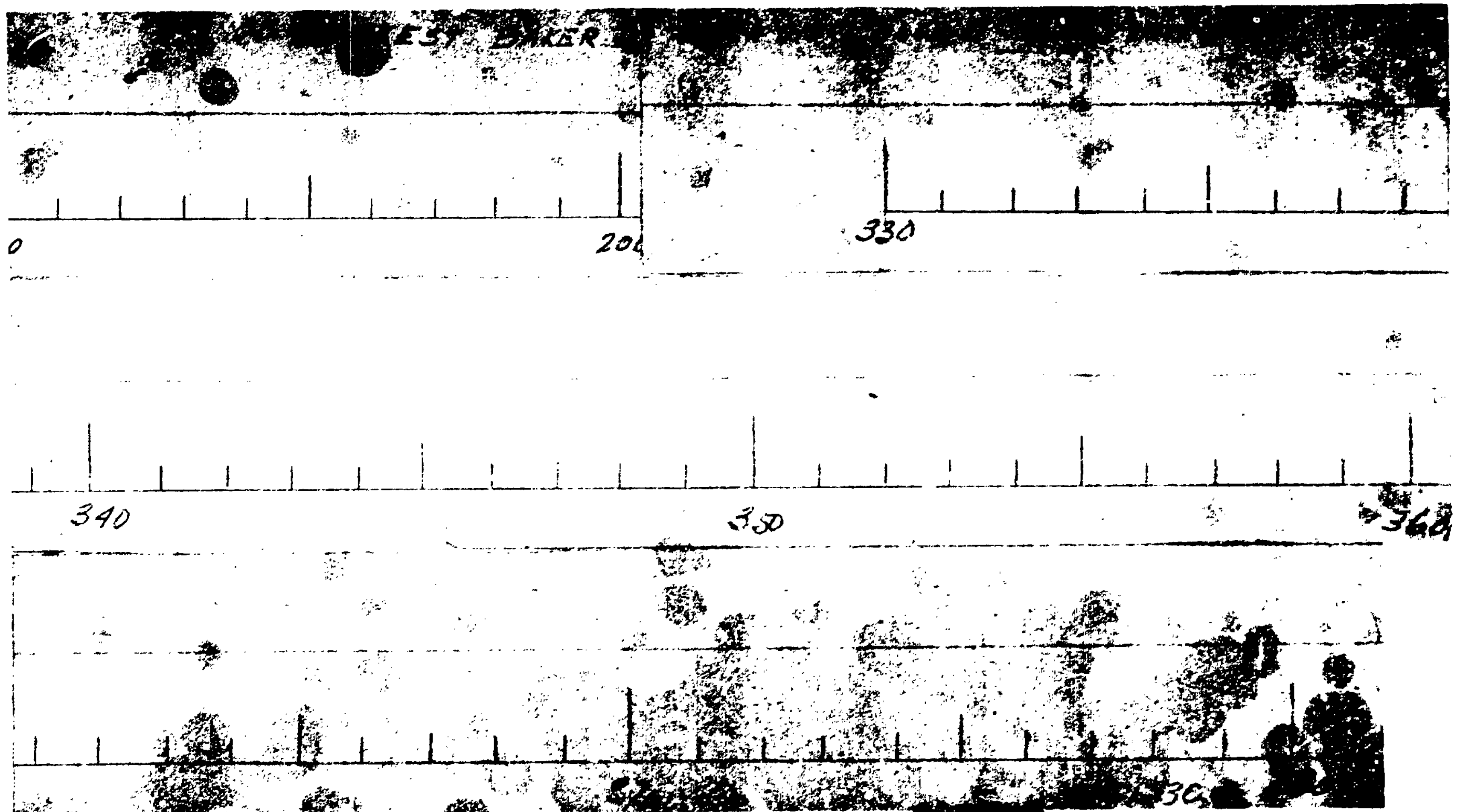
SECRET



A-2609



[illegible]



SECRET

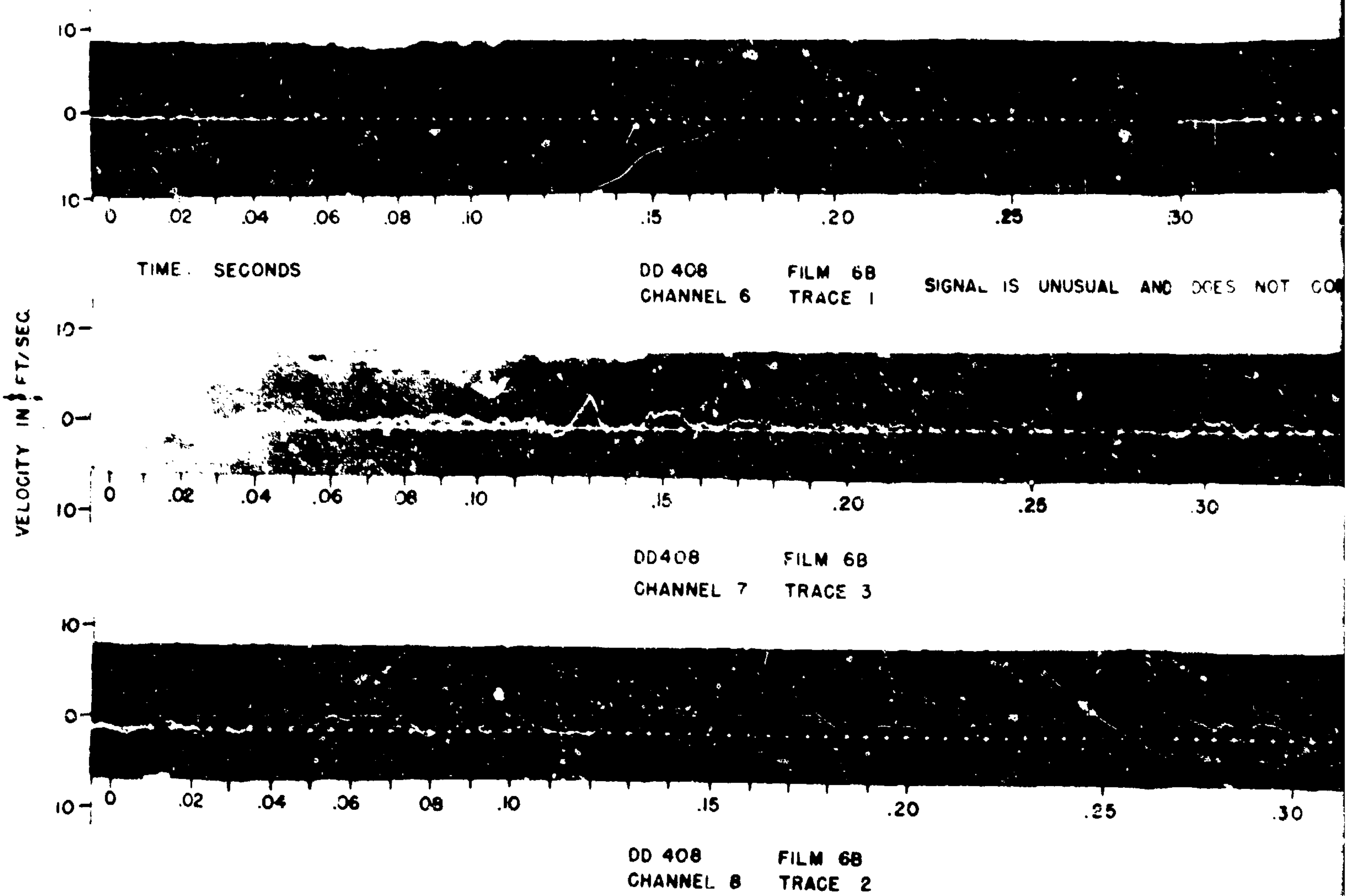
A-2609

VELOCITY CURVES OBTAINED FROM V' GAGES

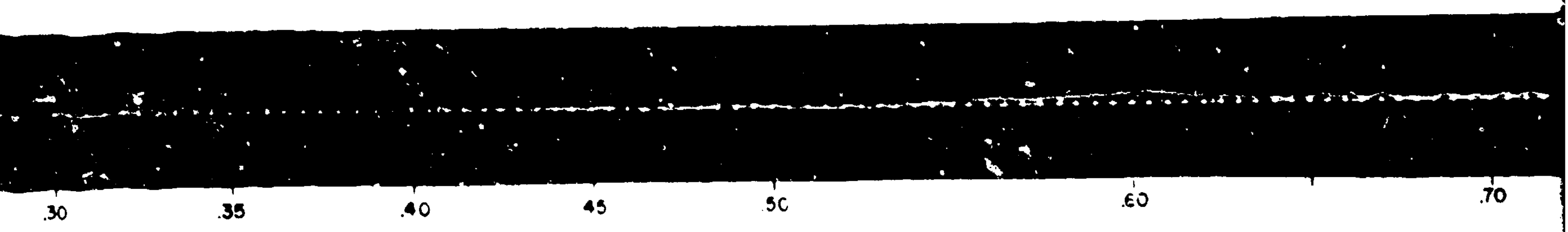
FM WIRE RECORDER

TEST: BAKER

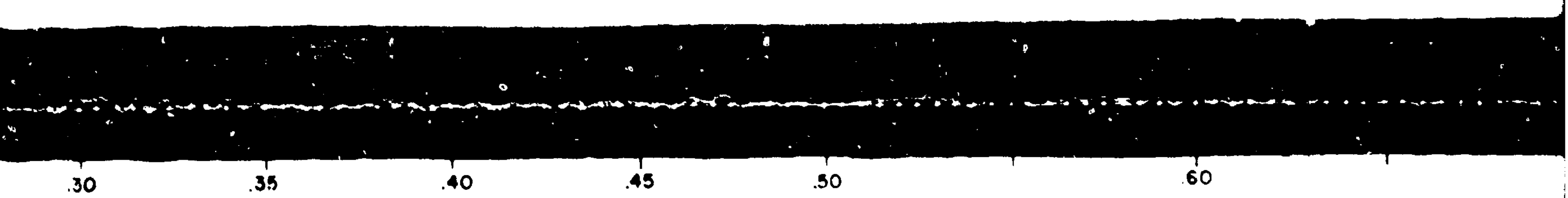
ZERO TIME CHOSEN ARBITRARILY

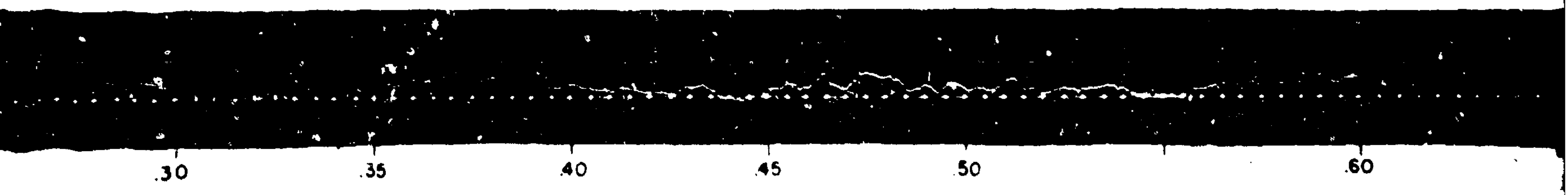


1



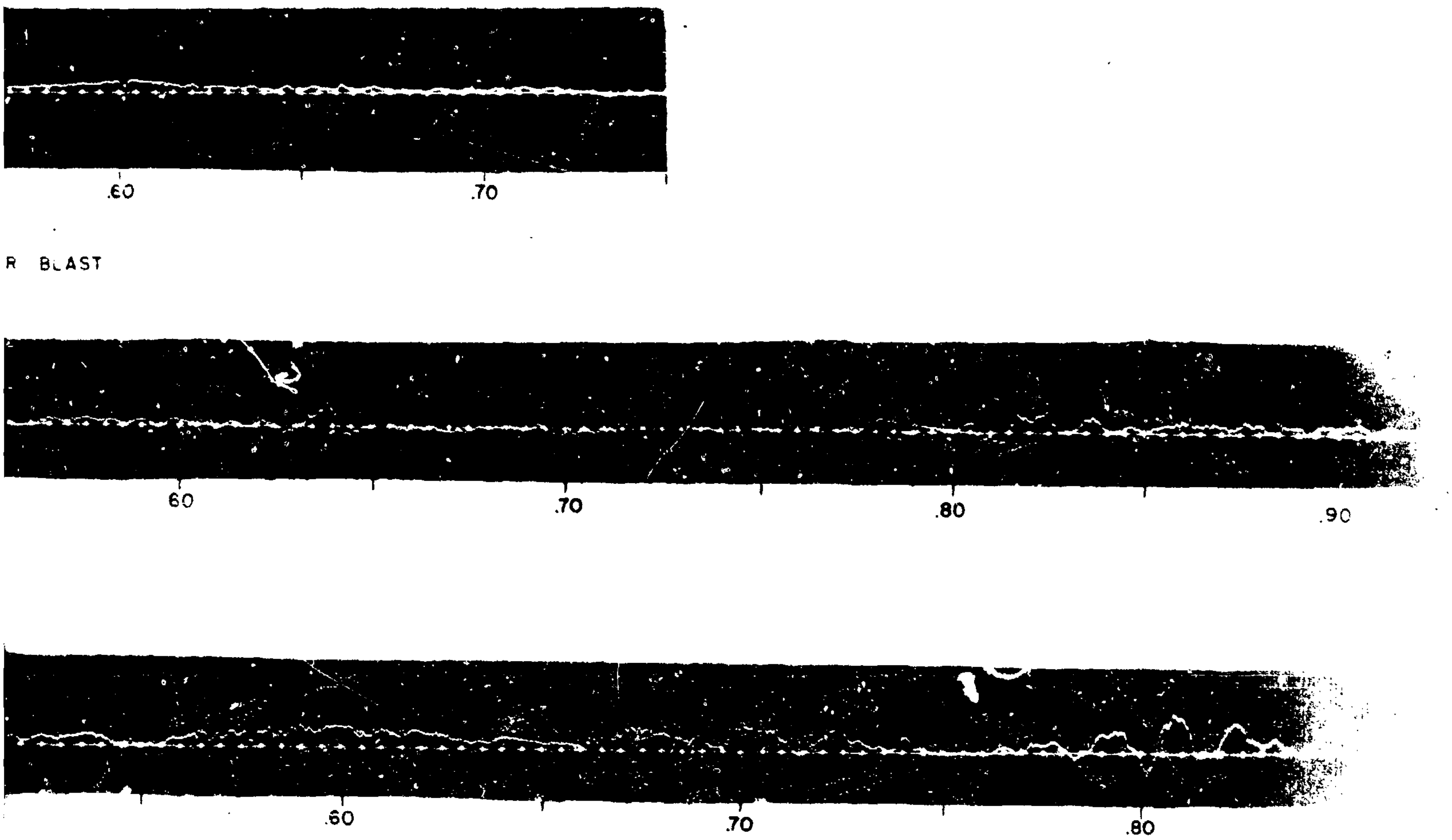
AND DOES NOT COME IN AT THE RIGHT TIME FOR BLAST BEGINNING - LIKELY DUE TO AIR BLAST





2

TOP SECRET



3

FIG. 104

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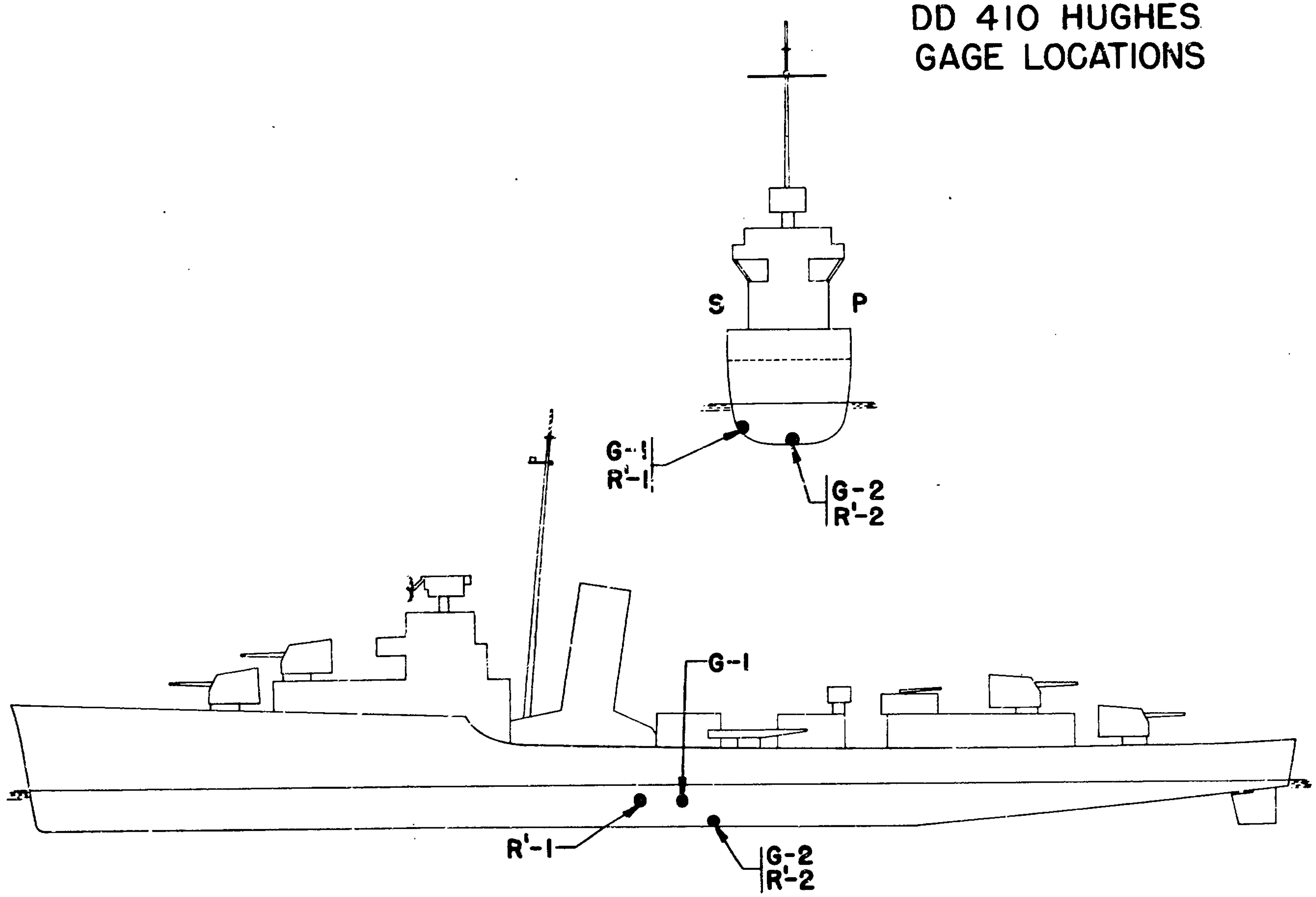


FIG. 105

DD410 - HUGHES

Putty Gages

G1 - Similar to photo 261. Aft fireroom, compartment B-2-1. Directed to port on frame 97 starboard 4 ft. below upper grating level.

A. (3) less than 50g. B. -----

G2 - Similar to photo 262. Aft fireroom, compartment B-2-1. Directed up on top of keel at frame 100.

A. (3) less than 50g. B. -----

Reed Gages

R'1 - Similar to photo 260 Aft fireroom, compartment B-2-1. Directed to port on frame 93 starboard, 4 ft. below upper grating level.

Graph	20 cps		40 cps	
	Up	Dn	Up	Dn
A. (3) Fig. 106	.06	.04	.01	.01

B. Not recovered.

R'2 - Similar to photo 262. Aft fireroom, compartment B-2-1. Directed up on frame 100 about 10" port of keel center line.

Grpah	20 cps		40 cps	
	Up	Dn	Up	Dn

A. (3) Readings all zero

B. Not recovered.

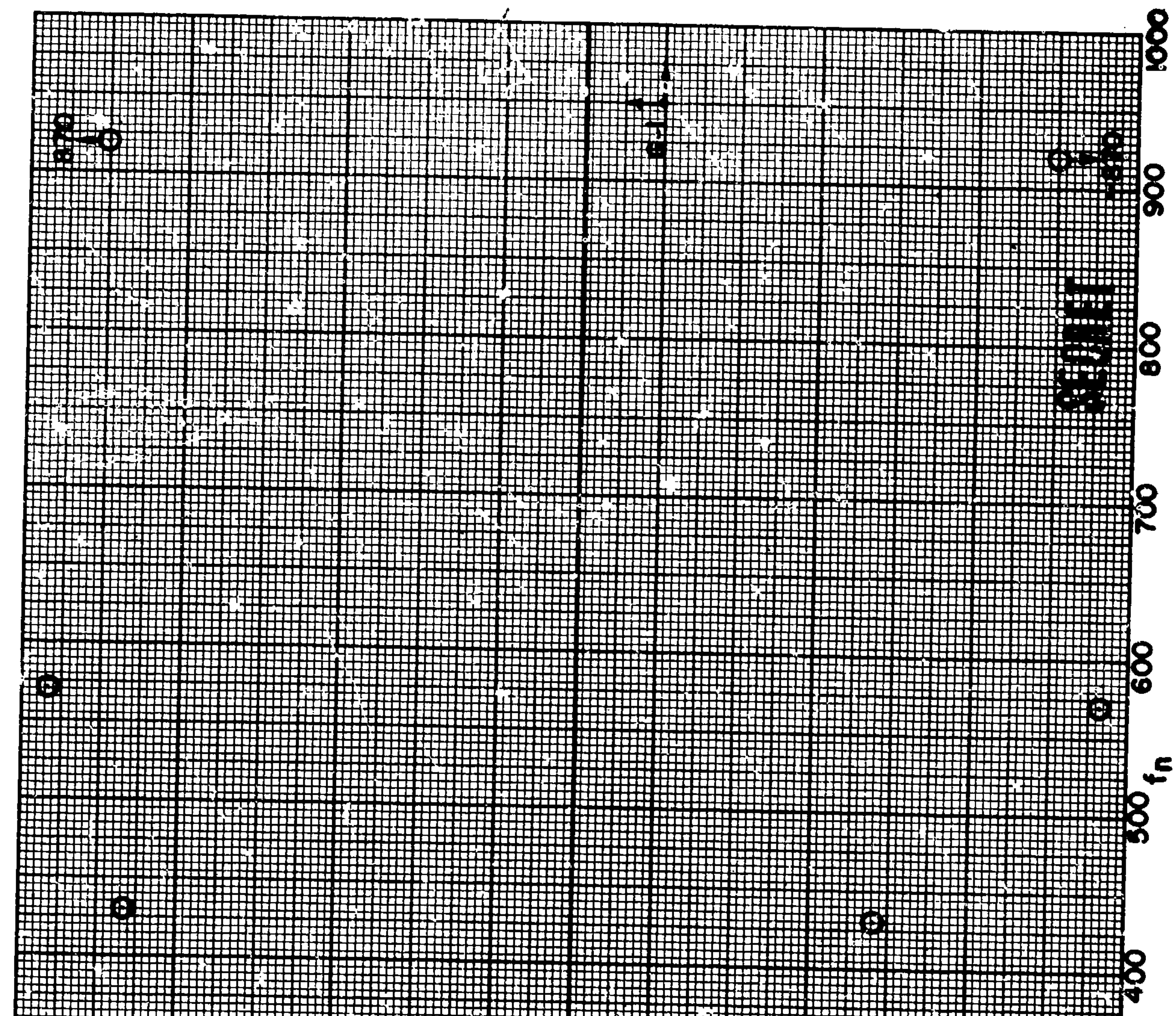
COMMENTS

Test Able Range 3084 ft. Bearing 192°

All gages showed very slight shock since they were all below the water line, and the ship was stern to the explosion.

Test Baker Range 1900 ft. Bearing 91°

These gages were not recovered due to flooding. This was unfortunate since the ship was properly oriented and sustained high shock damage while receiving just enough hull damage to flood slowly



REED GAGE No 37
SD-410 HUGHES
TEST A
SECRET
f n
0
100
200
300
400
500
600
700
800
900
1000
UP
DOWN
Sg
X

FIG. 106

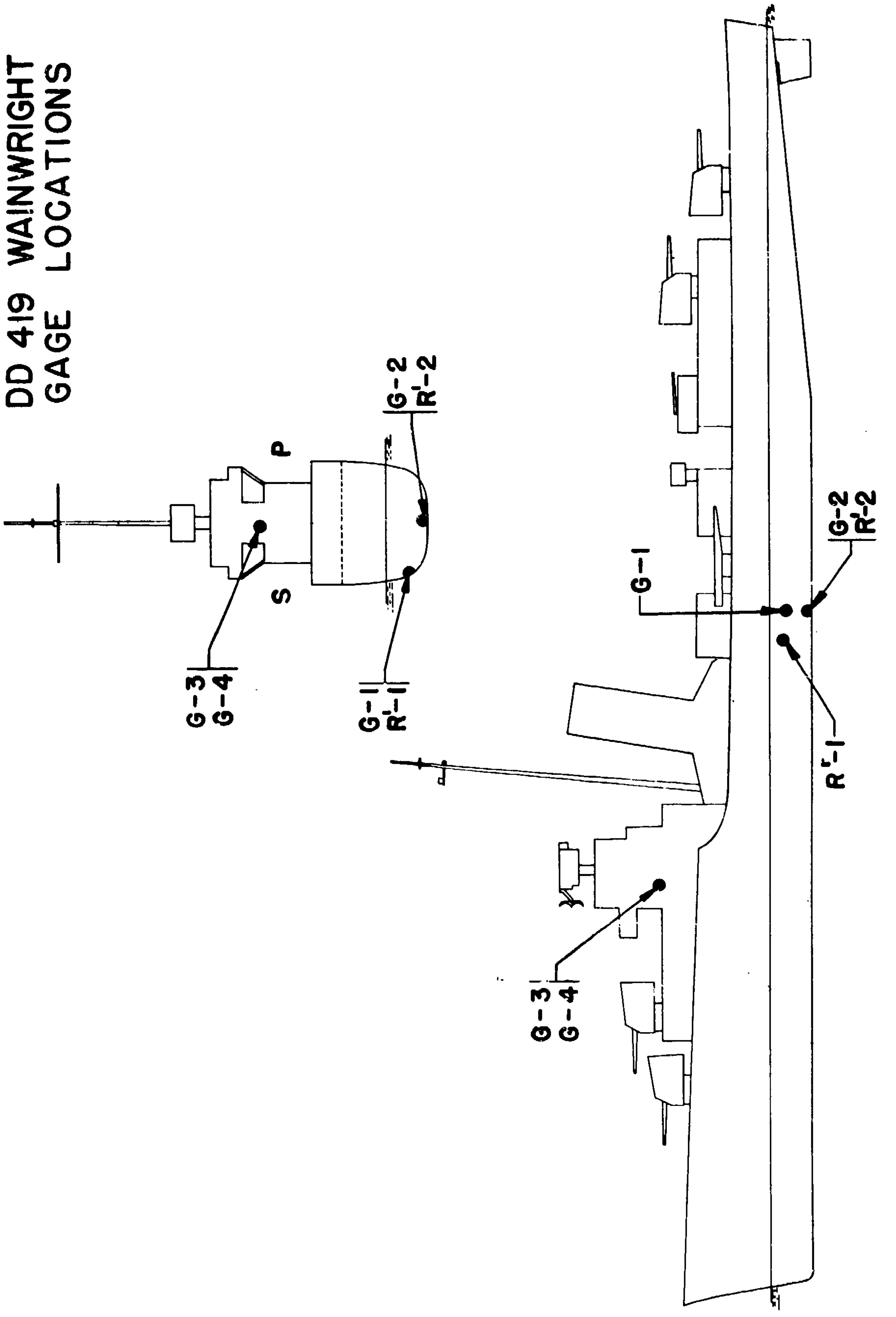


FIG. 107

A-2609

DD419 - WAINWRIGHT

Putty Gages

G1 - Similar to photo 261. Aft fireroom, compartment B-2-1. Athwartships on starboard frame 101, 4 ft. below upper grating level. Directed to port.

A. (3) less than 20g. B. Less than 20g.

G2 - Similar to photo 262. Aft fireroom, compartment B-2-1. Vertical on top of keel at frame 101. Directed up.

A. (3) less than 20g. B. Less than 20g.

G3 - Photo 318. C.I.C. Vertical on deck at frame 56, 23" inboard from starboard bulkhead. Directed up.

A. (2) 40g. B. Less than 20g.

G4 - Photo 318. C.I.C. Athwartships on deck at frame 56, 4" inboard from starboard bulkhead. Directed to port.

A. (2) 40g. B. Less than 20g.

Reed Gages

R1 - Similar to photo 260. Aft fireroom, compartment B-2-1. Athwartships on starboard frame 97, 4 ft. below upper grating level. Directed to port.

	Graph	20 cps Up	20 cps Dn.	40 cps Up	40 cps Dn
A.	(3) Readings all zero.				
B.	Fig. 108	.02	0	0	.015

R2 - Similar to photo 262. Aft fireroom, compartment B-2-1. Vertical on top of keel 24" forward of frame 101. Directed up.

A. (3) Readings all zero.

B. Mutilated. Readings probably all zero.

COMMENTS

Test Able Range 6477 ft. Bearing 342°

40g. was recorded by the two superstructure putty gages while all the gages below the waterline registered no shock.

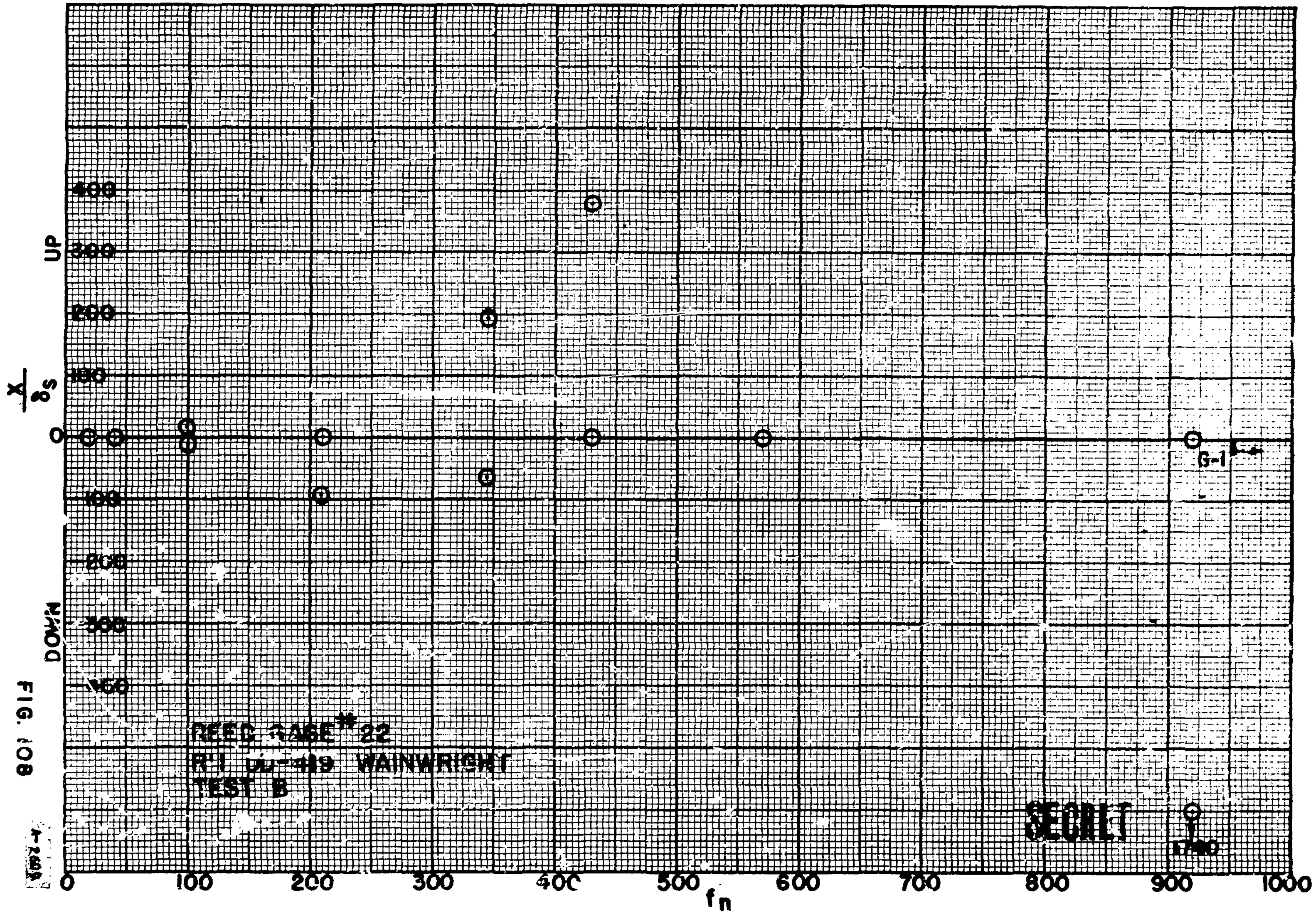


FIG. 108

A-2608

COMMENTS ON DESTROYERS

ABLE

The DD404 was subjected to 12 psi airblast pressure as compared to the 21 psi which sank the DD367. It seems reasonable to assume that 15 to 17 psi is the maximum at which the shock measurements would be of interest. As a first approximation to the shock on a destroyer at a range corresponding to, say 16 psi, the DD404 readings should be multiplied by a factor of about 1.3. This is of course the pressure ratio but it seems to be fairly well substantiated by the range vs. reading plots, figures 171 and 172 and the assumption that the peak acceleration is proportional to the peak pressure.

BAKER

All destroyers instrumented were turned approximately 90° to starboard of the planned headings. This resulted in exposure of the port bow rather than the starboard side in the cases of the DD's 40[illegible], 403, 404, 406, 408, and 419. The records were far smaller than indicated by the few ships of other types which were oriented as planned and they do not yield a clear picture of the change in shock as it is propagated through the ship.

Comparison of the gage readings for [illegible] does indicate quite consistently that superstructure [illegible] sustained slightly greater shock than the hull in the vicinity of [illegible]. The hull gages were on the keel and 5 feet below the wa[illegible] starboard frame member. It seems certain however, that the hull at frame 60 and forward must have received far greather shock than the hull at frame 100. This is supported by the theory presented in section 1 of reference 5. Hull plating normal to the direction of propagation of a shock front is subjected to a greater impulse from the shock wave than plating inclined to the direction of propagation. Plating on the "shielded" starboard side is affected only by the diffracted wave. Also, the wave which reached the keel at frame 100 traveled almost parallel to the keel. It must have been diminished in doing so by the yielding of the hull plates in a fashion similar to the surface cutoff which occurs at an air-water boundary. These effects were thoroughly demonstrated by the British tests of the destroyer H.M.S. "Cameron," reference 5 and are believed to be the proper explanation of the data.

The velocity meters and motorized reed gages yield data as to the time of arrival of the many shocks.

SS 184 SKIPJACK GAGE LOCATIONS

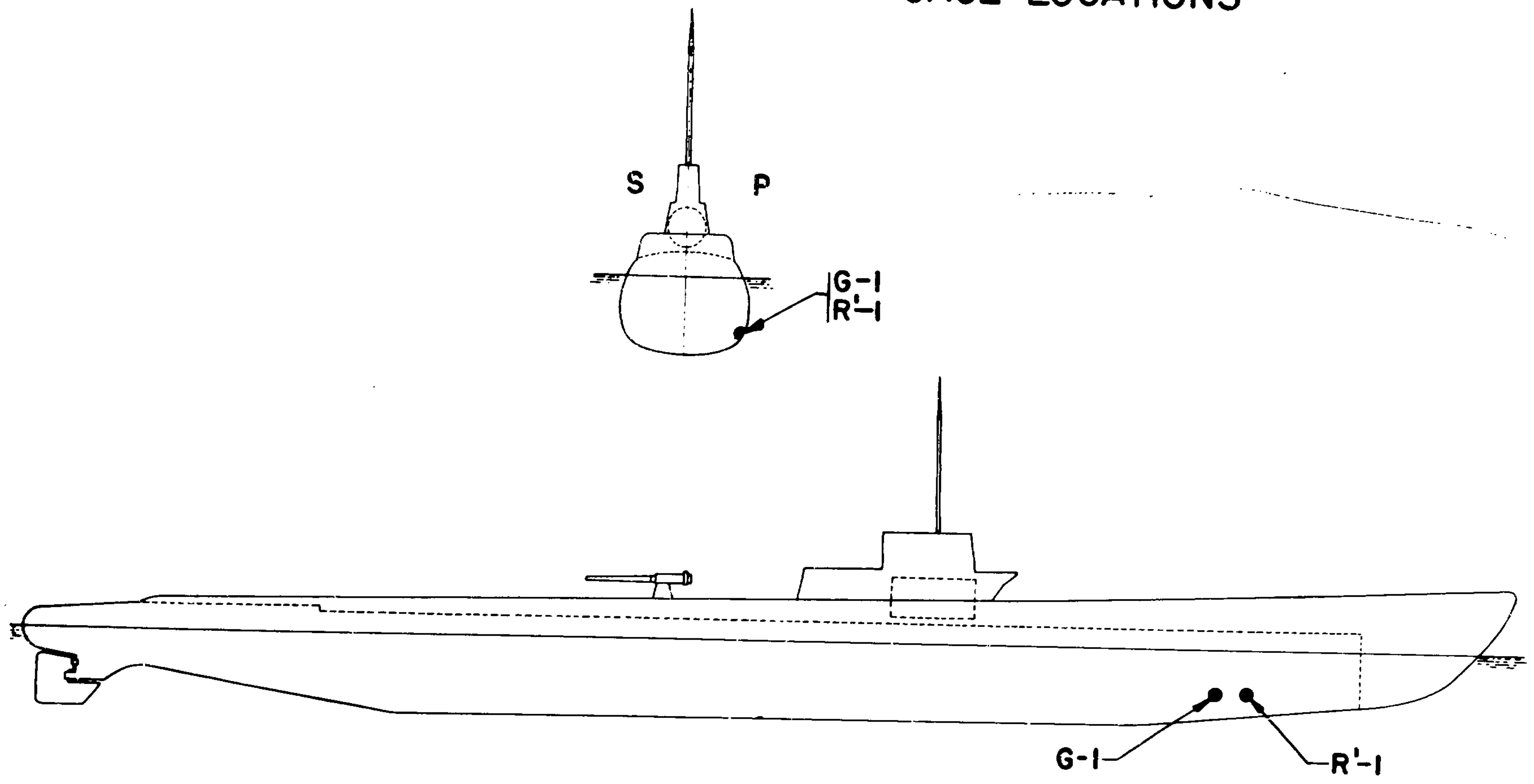


FIG. 109

A-2609

SS184 - SKIPJACK

Putty Gages

G1 - Photo 319. Forward torpedo room. Athwartships, on port frame 27, 12" above deck. Directed to starboard.

A. (3) less than 50g. B. ---

Reed Gages

R'1 - Photo 320. Forward torpedo room. Fore and aft on port frame 26, 12" above deck.

Graph	20 cps		40 cps	
	Up.	Dn.	Up.	Dn.
A. (3) Readings all zero.				
B. Sunk				

COMMENTS

Able Range 3612 ft. Bearing 212°
The gages did not record any shock.

Baker Range 2425 ft. Bearing 226°
The submarine was submerged for this test and was sunk.

SS 196 SEARAVEN GAGE LOCATIONS

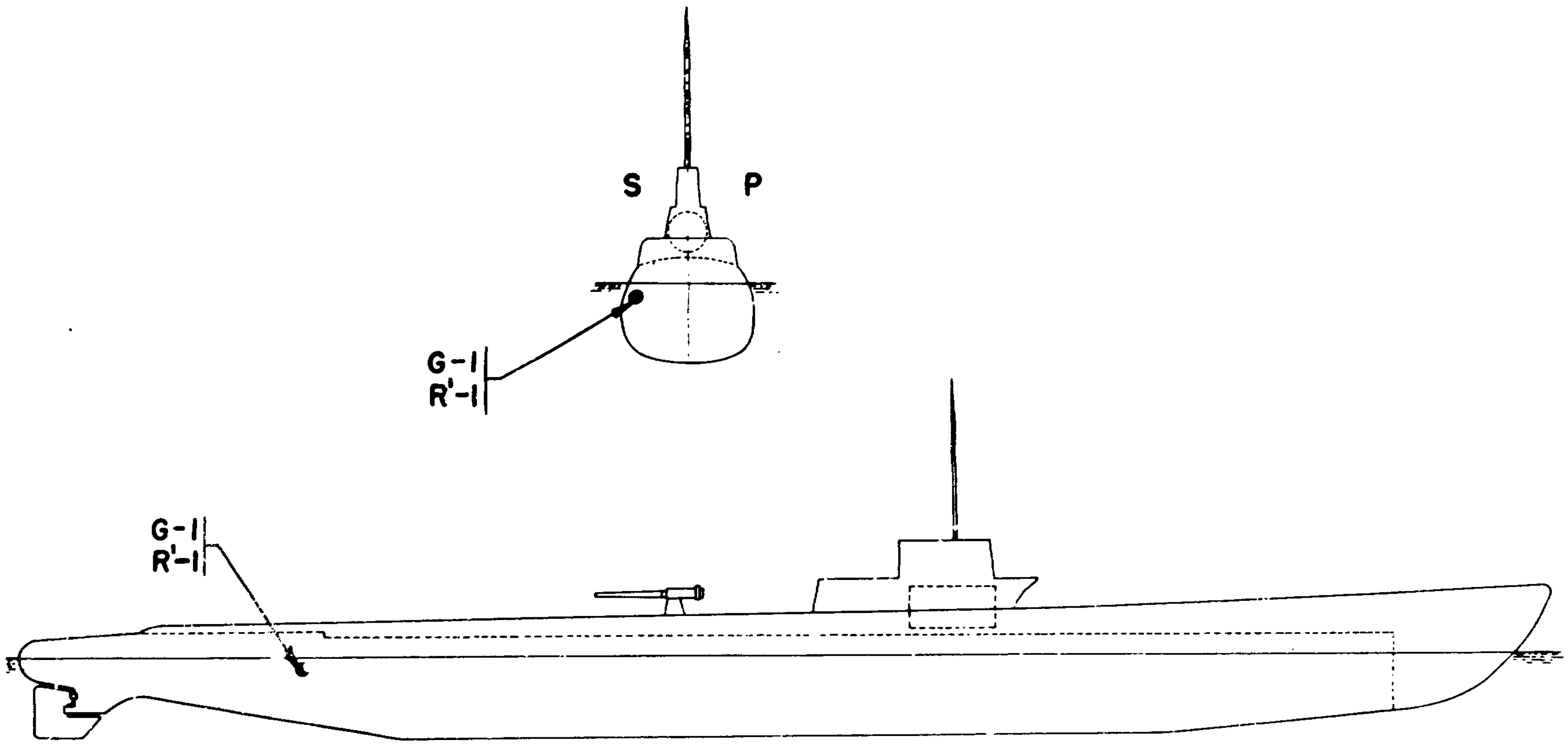


FIG. 110

A-2609

SS196 - SEA RAVEN

Putty Gages

G1 - Photo 321. After torpedo room. Athwartships on web of vertical starboard stiffener on aft side of bulkhead 164, 5' above deck. Directed to port.

A. (3) less than 50 g. B. 200g.

Reed Gages

R'1 - Photo 321. Aft torpedo room. Athwartships on web of vertical starboard stiffener on aft side of bulkhead 164, about 5 ft. above deck. Directed to port.

Graph	20 cps		40 cps	
	Up.	Dn.	Up.	Dn.
A. (3) Readings all zero.				
B. Fig. 111.	.06	.05	.06	.065

COMMENTS

Able Range 5568 ft. Bearing 126°
The gages did not record any shock

Baker Range 4350 ft. Bearing 140°

The submarine was submerged to 80 ft. keel depth. A few minor evidences of shock are reported by DSM. The gage locations probably recorded the maximum shock on this ship except for locations on the hull or hull frame numbers. The reed gage indicates a critical frequency of about 300 cps.

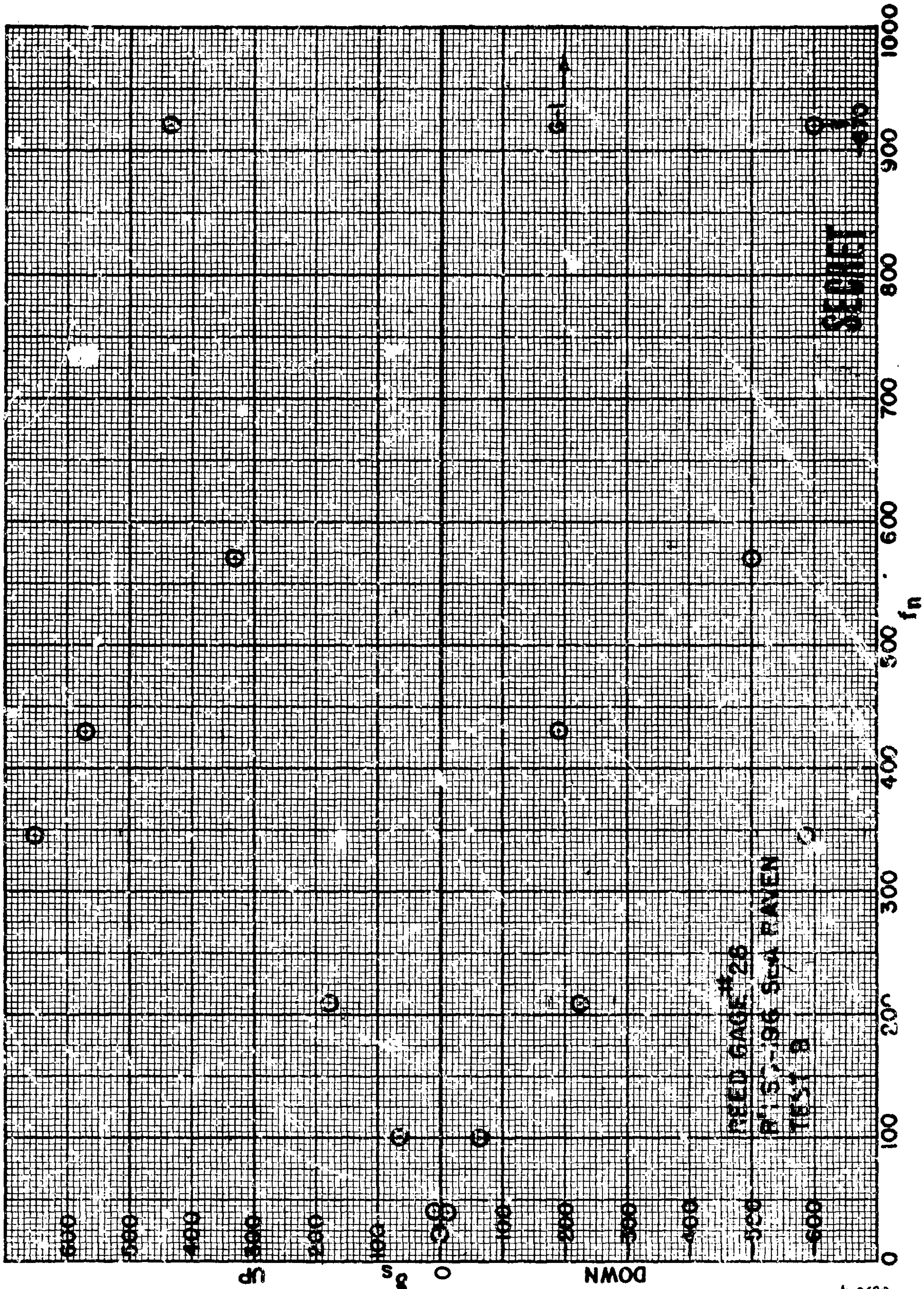


FIG. III

A-2609

SS 203 TUNA
GAGE LOCATIONS

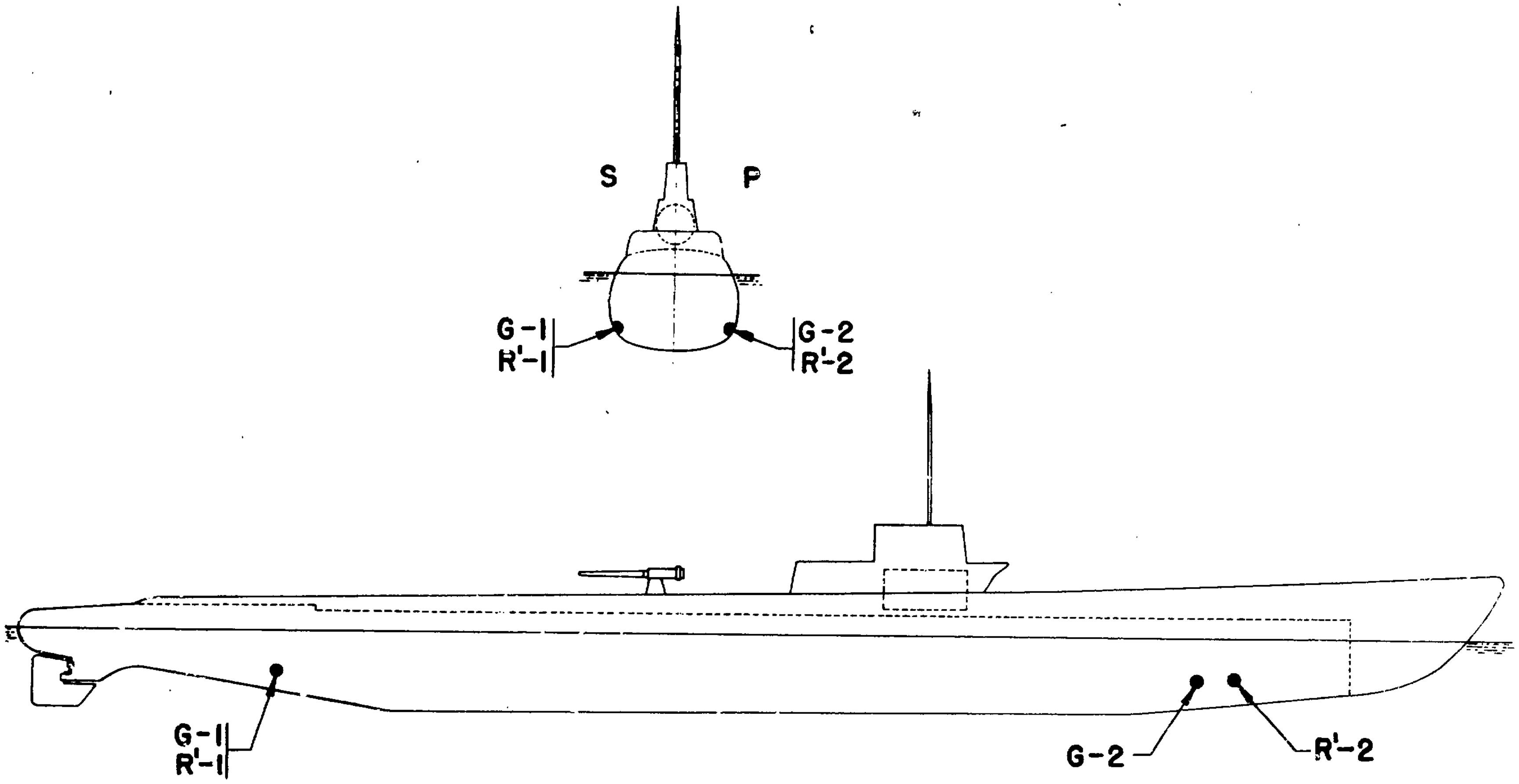


FIG. 112

A-2609

SS203 - TUNA

Putty Gages

G1 - Photo 322. Aft torpedo room. Athwartships on starboard frame 112, 36" above deck. Directed to port.

A. (3) less than 50g. B. Not installed.

G2 - Photo 323. Forward torpedo room. Athwartships on port frame 32, 3" above deck. Directed to starboard.

A. Not installed. B. 250g.

Reed Gages

R'1 - Similar to photo 347a. Aft torpedo room. Athwartships on starboard frame 113, 48" above deck. Direct to port.

Graph	20 cps		40 cps.	
	Up.	Dn.	Up.	Dn.
A. (3) Readings all zero.				
B. Not installed.				

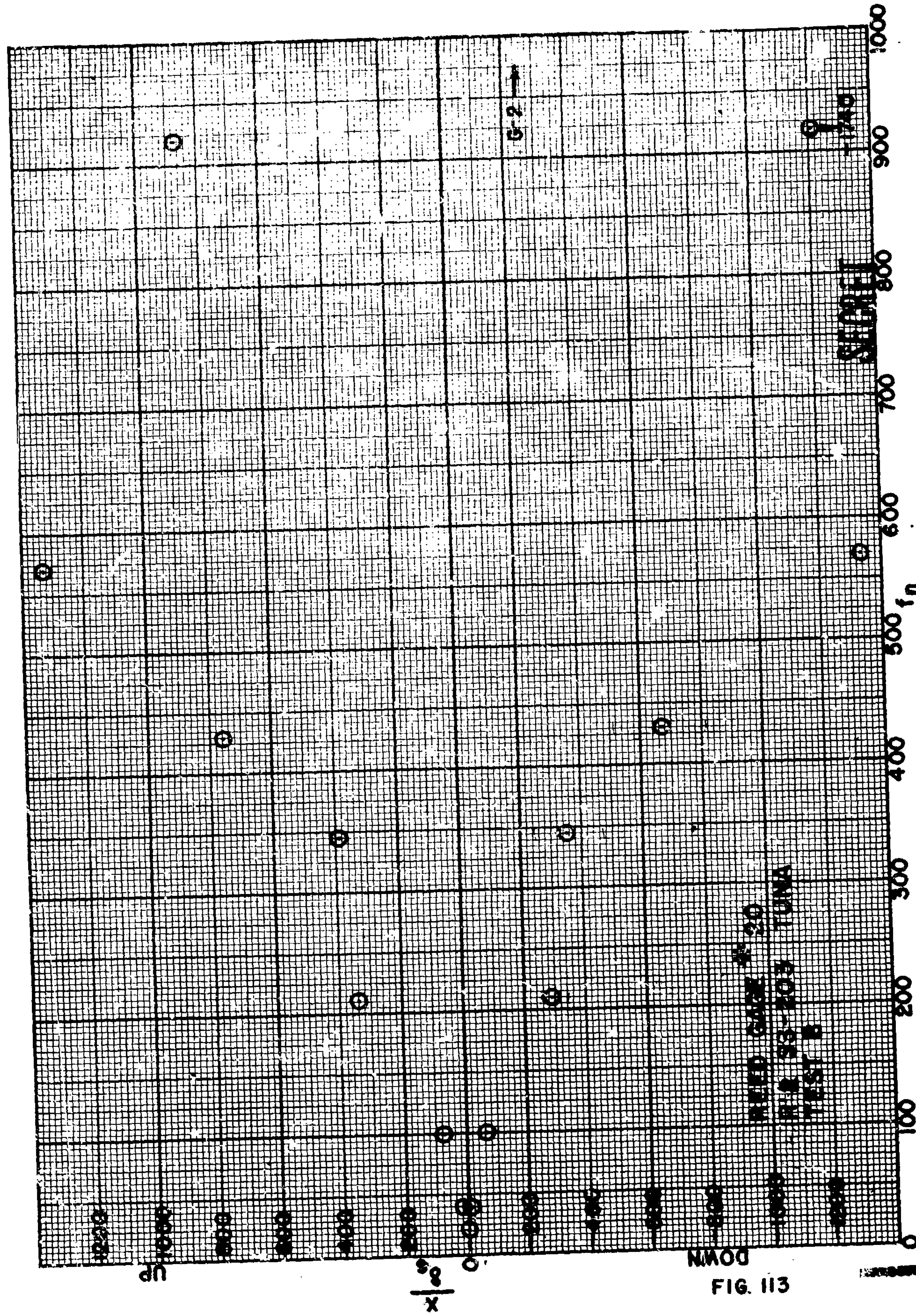
R'2 - Photo 324. Forward torpedo room. Athwartships on port frame 27, 24" above deck. Directed to starboard.

Graph	20 cps		40 cps	
	Up.	Dn.	Up.	Dn.
A. Not installed.				
B. Fig. 113.	.055	.05	.07	.06

COMMENTS

Able Range 5790 ft. Bearing 47°
The gages did not record any shock.

Baker Range 5525 ft. Bearing 341°
The submarine was submerged to 80 ft. keel depth. A few minor evidences of shock are reported by DSM. The gages probably recorded the maximum shock in the vessel due to their location. The reed gage indicates a critical frequency at 210 cps and possibly another at 600 cps.



REED GAGE # 20
R & S3-203 TUNA
TEST B
SECRET
G-2
+1740
UP
DOWN
$\frac{X}{\delta_s}$
f_n

FIG. 113

SS 305 SKATE
GAGE LOCATIONS

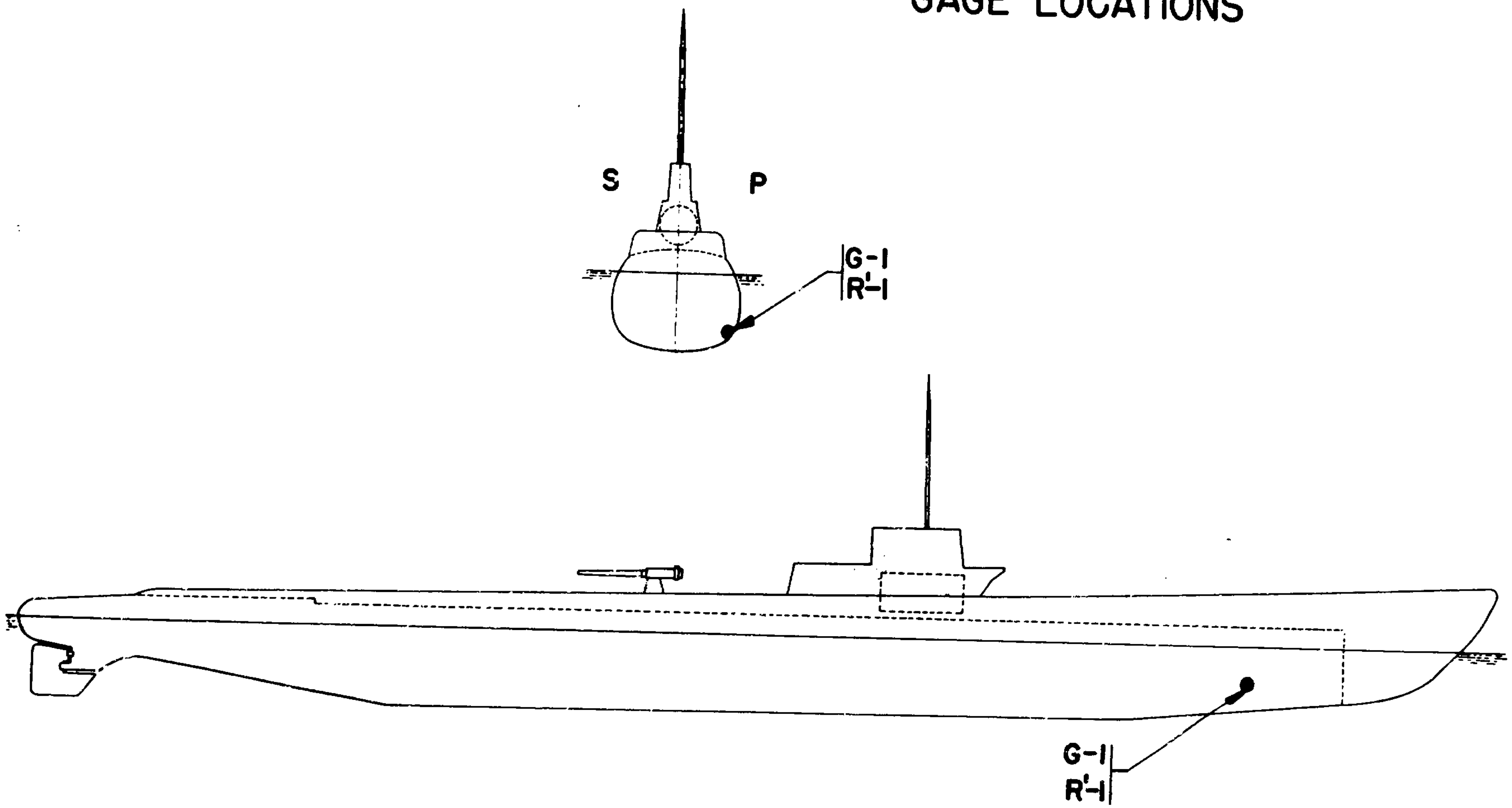


FIG. 114

A-2609

SS305 - SKATE

Putty Gages

G1 - Photo 325. Forward torpedo room. Athwartships on port frame 31, 6" above deck. Directed to starboard.

A. (3) less than 50g. B. more than 2500g.

Reed Gages

R'1 - Similar to Photo 347a. Forward torpedo room. Athwartships on port frame 30, 24" above deck. Directed to starboard.

Graph	20 cps		40 cps	
	Up.	Dn.	Up.	Dn.
A. Fig. 115	.10	.25	.06	.10
B. Fig. 116	.07	.06	.085	.075

COMMENTS

Able Range 1449 ft. Bearing 211°

DSM reports a few evidences of shock including 6 broken light bulbs in the after torpedo room and distorted torpedo tube cradles. The gages were not well placed for recording the maximum shock since they were slightly below the waterline at the port bow. The reed gage record indicates a peak response at 350 cps.

Baker Range 1875 ft. Bearing 325°

The submarine was on the surface for this test. DSM reports shock damage to batteries, hard-rubber battery ventilation ducts, the master gyro, and auxiliary gyro compass. The shock damage was confined to these few items. The gages recorded the maximum shock in the submarine because of their position on the hull at a point closest to the bomb. They show far heavier shock than any other NRL gages because the other gages at this range or closer were shielded. While the peak acceleration was over 2500g, the time duration was very short. The reed gage indicates a duration of less than half a millisecond. This short duration, also indicated by the small size of all the putty gage indentations, in addition to the relatively shock proof construction of a submarine, apparently accounts for the small shock damage.

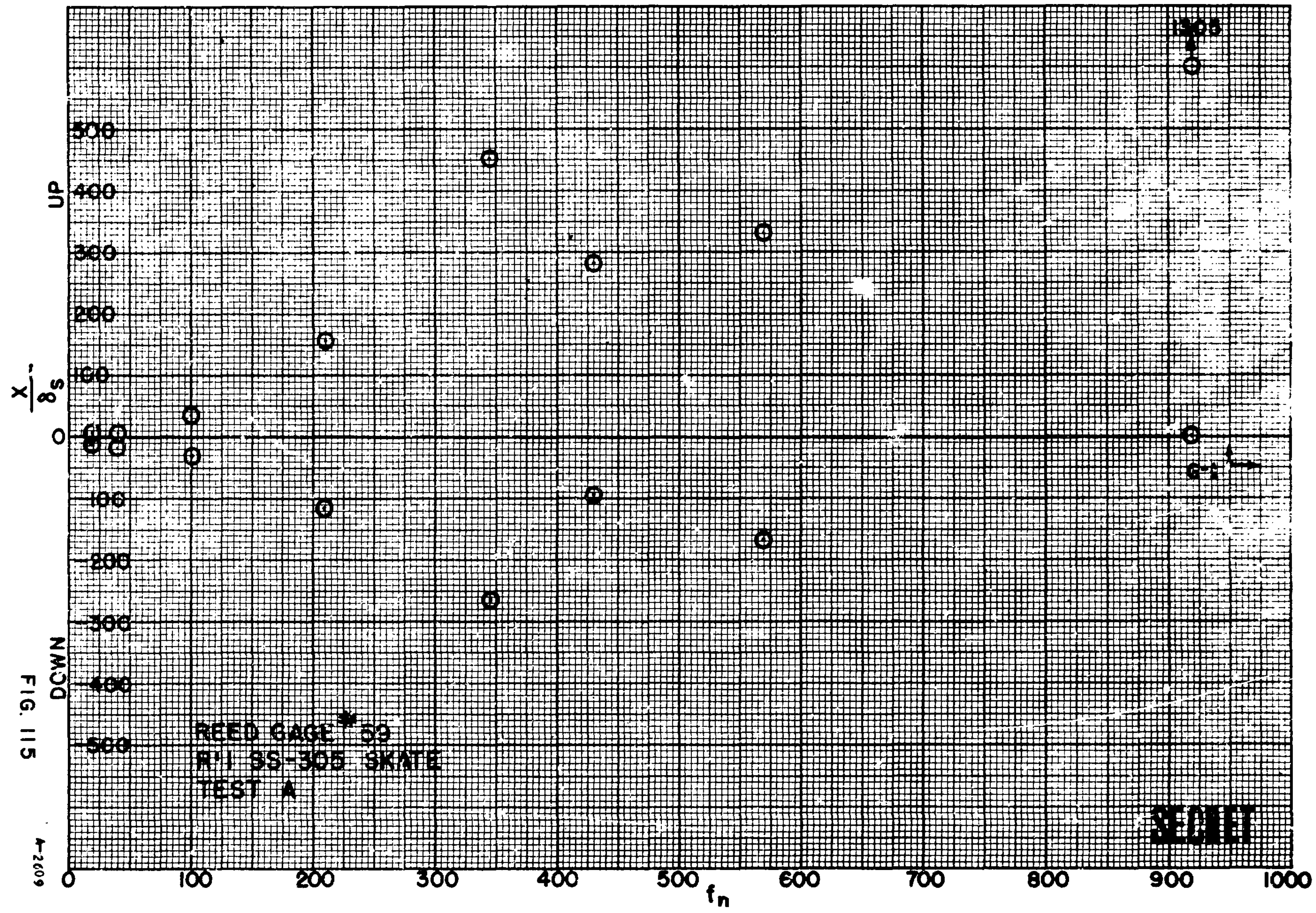


FIG. 115

A-2609

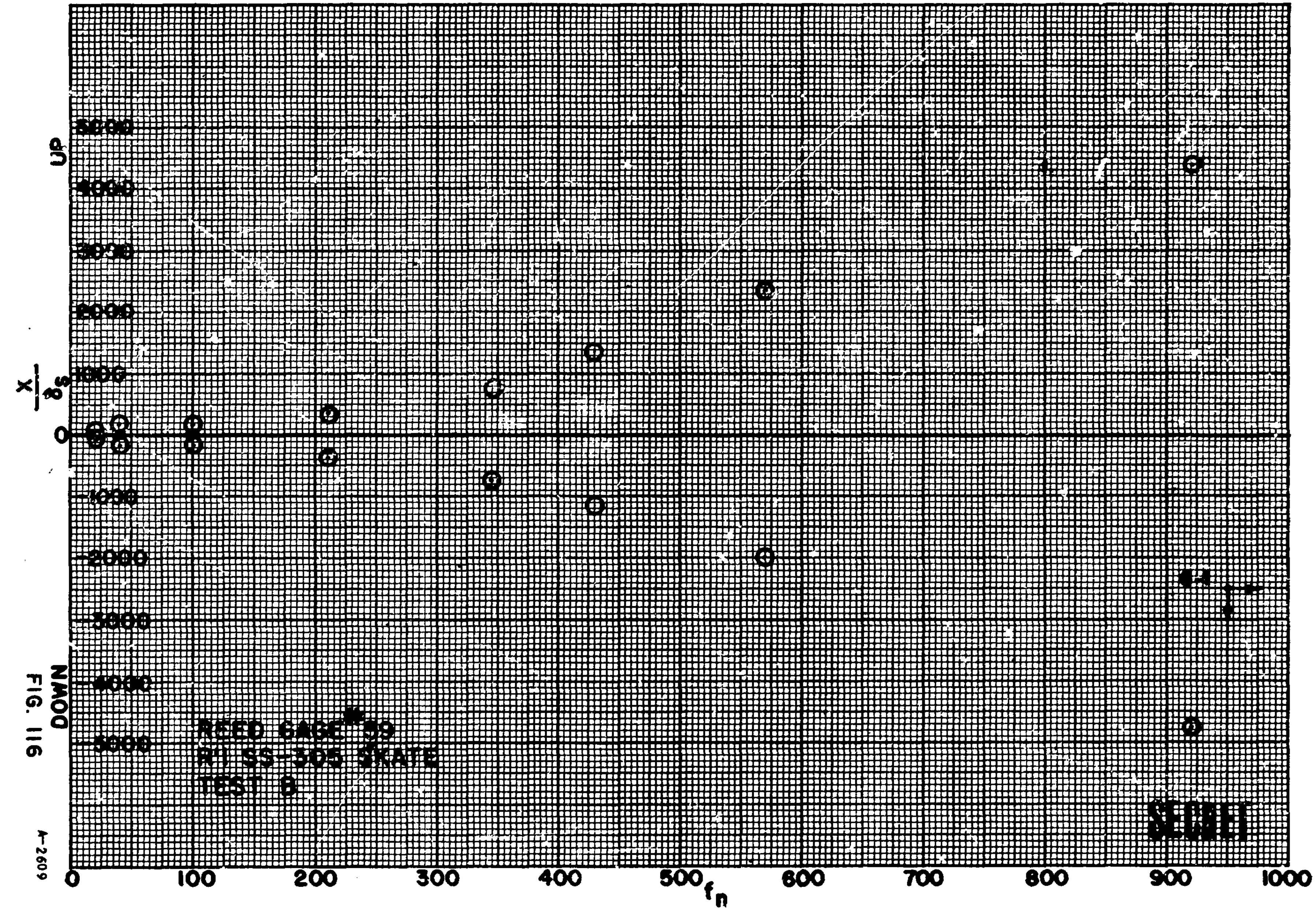

UP
DOWN
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
0
100
200
300
400
500
600
700
800
900
1000
f_n
REED GAGE #59
R/1 SS-305 SKATE
TEST B
SECRET
A-2609

FIG. 116

SS 308 APOGON
GAGE LOCATIONS

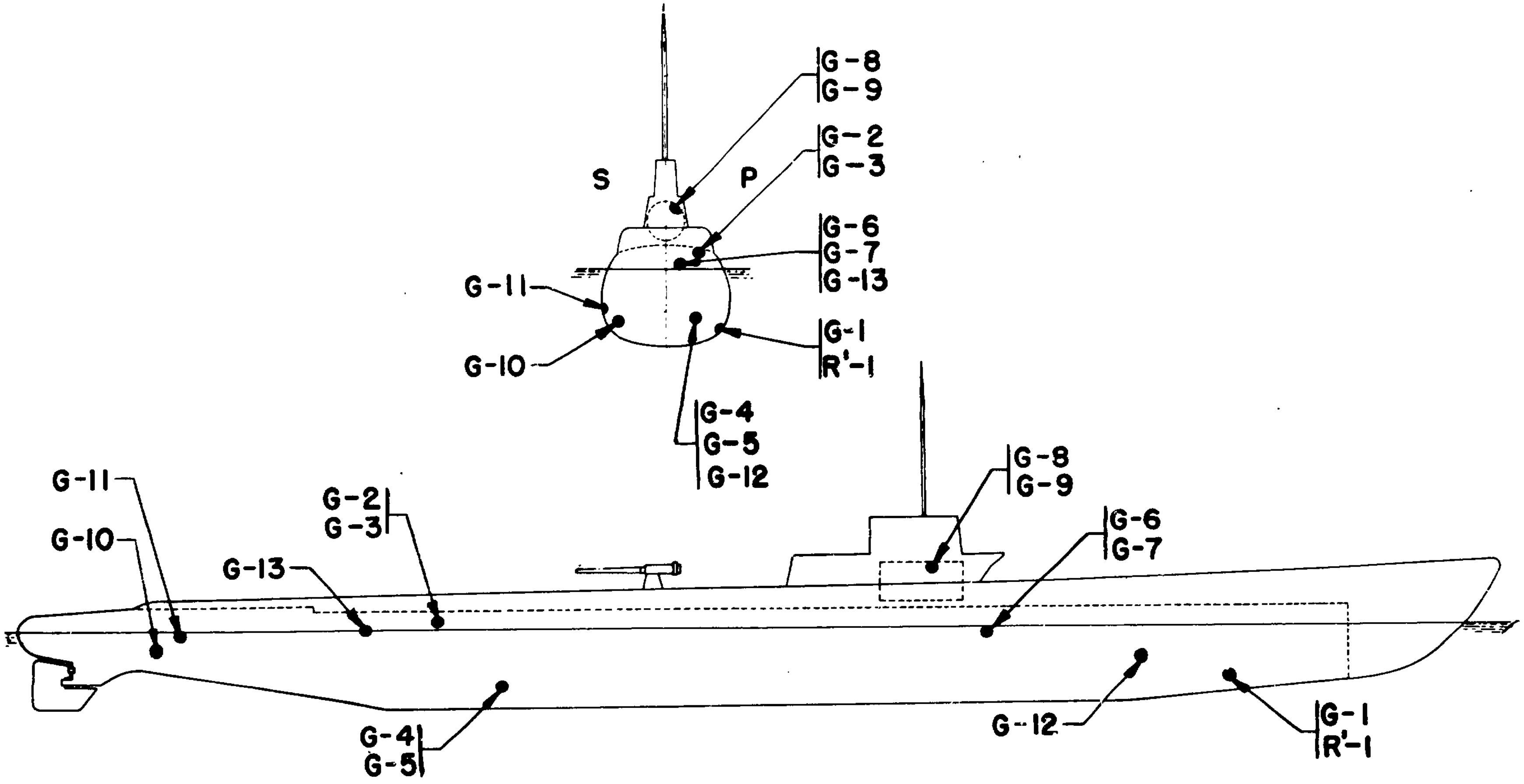


FIG. 117

A-2609

SS308 APAGON

Putty Gages

G1 - Photo 326. Forward torpedo room. Athwartships on port frame 29, 23" above deck. On flange of shell stiffener. Directed to starboard.

A. (3) 200g. B. ---

G2 - Photo 327. Upper port control cubicle brace, at approximate frame 100.5. Vertical. In maneuvering room. Directed down.

A. (2) less than 50g. B. ---

G3 - Photo 327. Upper port forward brace of control cubicle. Approximate frame 100.5. Athwartships. Maneuvering room. Directed to starboard.

A. (2) 100g. B. ---

G4 - Photo 328. Main generator number 4. Vertical on flange of inboard aft brace of generator foundation. Approximate frame 98. Aft engine room. Directed up.

A. (3) less than 20g. B. ---

G5 - Photo 328. Number 4 main generator. Athwartships on web of inboard aft brace of generator foundation. Approximate frame 98. Aft engine room. Direct to starboard.

A. (3) less than 20g. B. ---

G6 - Photo 329. Control room. Vertical on web of heavy vertical stiffening beam on aft side of bulkhead 47-1/3, 5 ft. from deck. Beam is just to starboard of ladder. Directed down.

A. (3) less than 50g. B. ---

G7 - Photo 330. Control room. Athwartships on web of vertical stiffening beam on aft side of bulkhead 47-1/3, 5 ft. from deck. Beam is just to port of ladder. Directed to starboard.

A. (3) 40g. B. ---

SS308 - APAGON

Putty Gages

G8 - Photo 331. Conning tower. Forward and aft on pad eye on upper port shell at approximate frame 52, 6 ft. above deck. Directed forward.

A. (3) less than 50g. B. ---

G9 - Conning tower. Vertical on pad eye on upper port shell at approximate frame 52.

A. Not installed. B. ---

G10 - Photo 332. Aft torpedo room. Vertical on deck over beam at frame 119, 6" from starboard frame of shell. Directed up.

A. (3) less than 50g. B. ---

G11 - Photo 333. Aft torpedo room. Athwartships on port frame 117, 24" above deck. Directed to starboard.

A. (3) less than 50g. B. ---

G12 - Photo 334. Forward torpedo room. Vertical on inboard sound gear bracket. Frame 34.5, 18" above deck, 30" port of center line of ship. Directed up.

A. (3) [illegible]g. B. ---

G13 - Photo 335. Inside shock mounted control cubicle. Vertical on beam at upper door edge of cubicle at approximate frame 103. Inside of control cubicle. Directed down.

A. (3) 90g. B. ---

Reed Gages

R-1 - Photo 326. Forward torpedo room. Athwartships on shell port frame 30, 24" above deck. Directed to starboard.

Graph	20 cps		40 cps	
	Up.	Dn.	Up.	Dn.

A. (3) Readings all zero.
B. Not recovered.

SS308 - APAGON

COMMENTS

Able Range 3093 ft. Bearing 201°

The gage readings are approximately what should be expected at this range. However, the pattern of the readings is not consistent with what one might predict. In particular, G1 was apparently well shielded but gave the highest reading, which, however, was not confirmed by the adjacent reed gage. G13 on the shock mounted control cubicle was not expected to show any shock.

Baker Range 2600 ft. Bearing 305°

This submarine was submerged for this test and was sunk.

SS 335 DENTUDA GAGE LOCATIONS

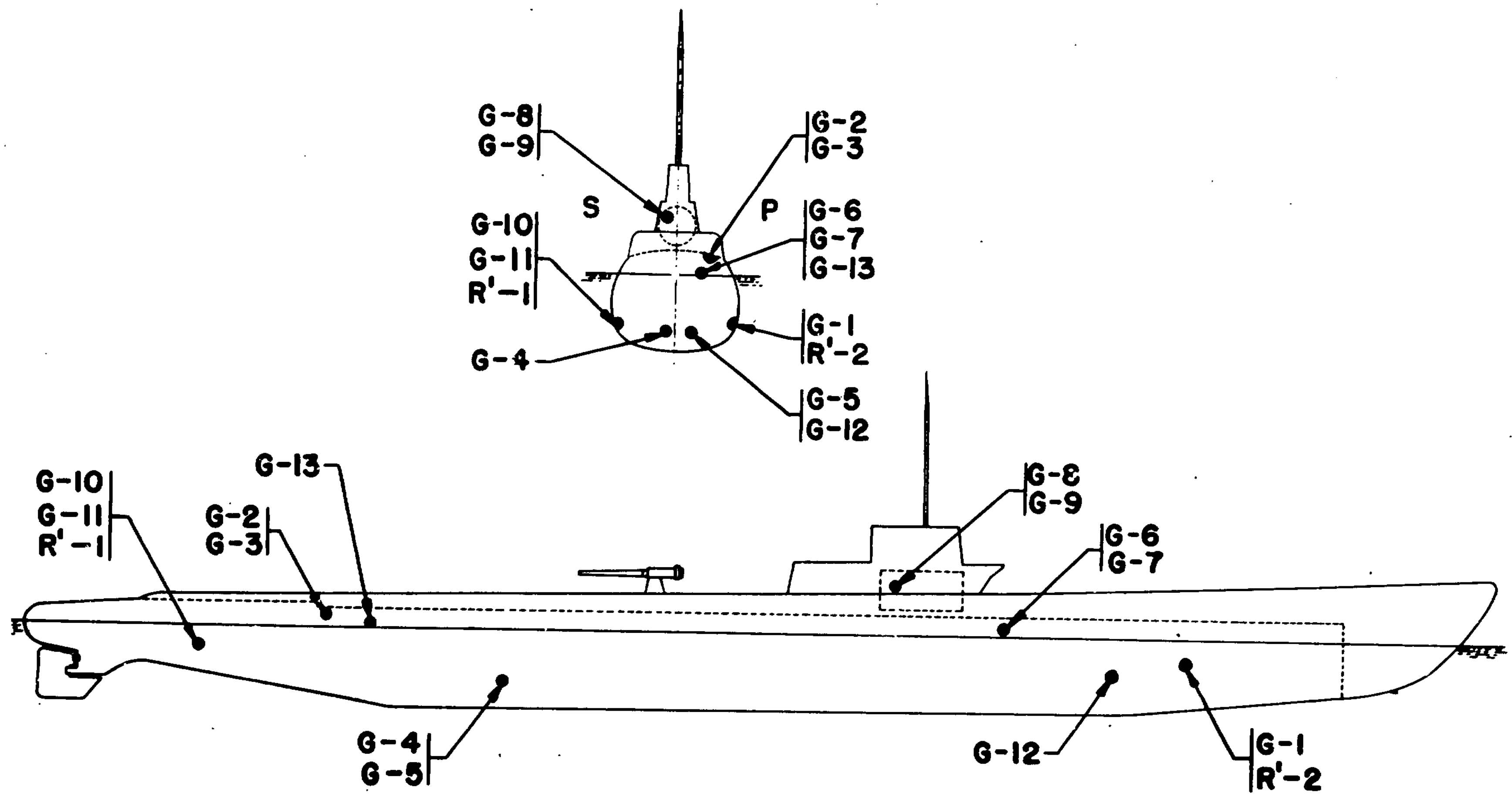


FIG. 118

A-2609

SS335 - DENTUDA

Putty Gages

G1 - Photo 336. Forward torpedo room. Athwartships on port frame 31, 32" above deck. Directed to starboard.

A. (3) less than 50g. B. less than 50g.

G2 - Photo 337. Control cubicle. Vertical on aft port top brace of control cubicle. Approximate frame 104. Directed down.

A. (2) less than 50g. B. 100g.

G3 - Photo 337. Control cubicle. Athwartships on aft port top support of control cubicle at approximate frame 104. Directed to starboard.

A. (2) less than 50g. B. 150g.

G4 - Photo 338. Aft engine room. Vertical on inboard side of Number 3 main generator base at approximate frame 97. Directed up.

A. (3) less than 20g. B. 80g.

G5 - Photo 339. Aft engine room. Athwartships on inboard aft corner of No. 4 main generator base. Approximate frame 97.5. Directed to starboard.

A. (3) less than 20g. B. 80g.

G6 - Photo 340. Control room. Vertical on web of vertical stiffening beam of bulkhead 47.5. Second beam inboard from port shell. Directed down.

A. (3) less than 50g. B. 40g.

G7 - Photo 340. Control room. Athwartships on web of vertical stiffening beam of bulkhead 47.5. Second beam inboard from port shell. Directed to starboard.

A. (3) 125g. B. 110g.

G8 - Photo 341. Conning tower. Vertical on SJ radar-training hand wheel bracket. Upper starboard shell of conning tower. About 4 ft. forward of aft bulkhead. Directed down.

A. (2) less than 50g. B. 200g.

Putty Gages

G9 - Photo 341. Conning tower. Forward and aft on SJ radar-training hand wheel bracket. Upper starboard shell of conning tower.

A. (3) less than 20g. B. 250g.

G10 - Photo 342. Aft torpedo room. Athwartships on starboard frame 118, 6'' above deck. Directed to port.

A. (3) less than 50g. B. 250g.

G11 - Photo 343. Aft torpedo room. Vertical on deck at frame 119, about 10'' from starboard frame of shell. Directed up.

A. (3) less than 50g. B. less than 50g.

G11 - Photo 344. Forward torpedo room. Vertical on deck at frame 34. Directed up.

A. (3) less than 50g. B. 60g.

G13 - Photo 345. Inside shock mounted control cubicle. Vertical on underside of beam at port top edge of cubicle. Approximate frame 102. On first overhead beam port of port edge of cubicle. Two inches inside cubicle. Directed down.

A. (3) less than 20g. B. less than 20g.

Reed Gages

R'1 - Similar to photo 347a. After torpedo room. Athwartships on starboard frame 118, 18'' above deck. Directed to port.

A. (3) Readings all zero.
B. Not installed.

R'2 - No photo. Forward torpedo room. Athwartships on port frame 30, 24'' above deck.

<table>
<tr><td>Graph</td><td colspan="2">20 cps</td><td colspan="2">40 cps</td></tr>
<tr><td></td><td>U</td><td>Dn.</td><td>Up.</td><td>Dn.</td></tr>
<tr><td>A. Not installed</td><td></td><td></td><td></td><td></td></tr>
<tr><td>B. Fig. 119</td><td>.125</td><td>.155</td><td>.10</td><td>.06</td></tr>
</table>

COMMENTS

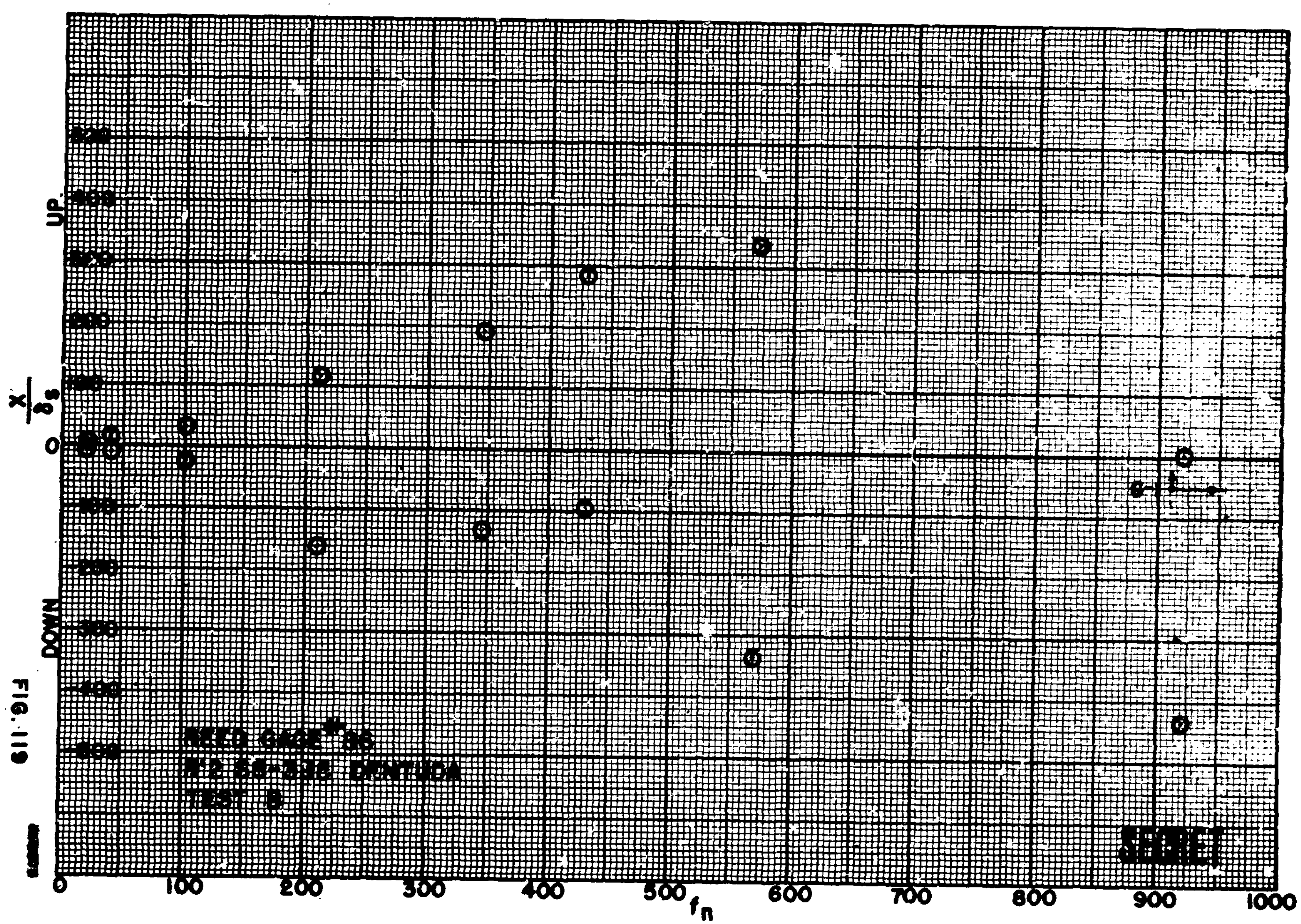
Able | Range 5844 ft. | Bearing 101°

The only gage recording was G7. Because of its position and the failure of the other gages to indicate any shock, the dependability of this reading seems doubtful.

Baker | Range 4525 ft. | Bearing 31°

This submarine was submerged to about 80 ft. keel depth. [illegible] report only the opening of a hull flapper valve as being probably due to shock.

The highest putty gage readings are on gages on the hull frame. These gages are G2, G3, G8, G9, and G10. G1 on the portside hull was shielded and showed no shock. G13 on the shock mounted control cubicle did not record a shock while other internal positions indicated about half the peak acceleration of the shell gages. The R'1 readings are too small to indicate a critical frequency with any accuracy although a critical frequency of 210 cps is possible. R'1 was adjacent to G1 and was shielded from the direct shock.



UP
DOWN
0
100
200
300
400
500
600
700
800
900
1000
f_n
$\frac{X}{\delta_s}$
REED GAGE #36
TEST B
SECRET

FIG. 119

SS 384 PARCHE
GAGE LOCATIONS

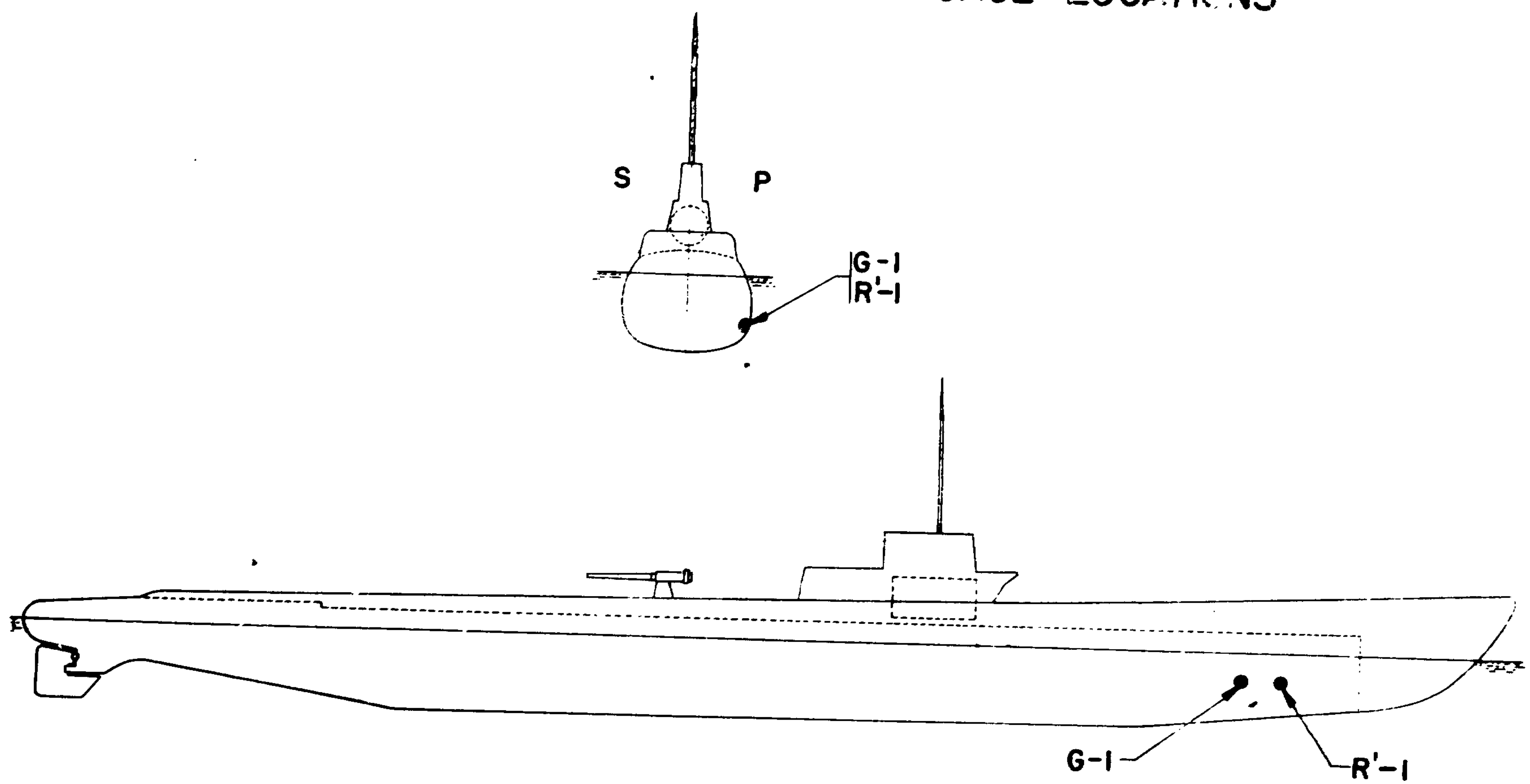


FIG. 120

A-2609

SS384 - PARCHE

Putty Gages

G1 - Photo 346. Forward torpedo room. Athwartships on port frame 30, 3 ft. above deck. Directed to starboard.

A. (3) less than 50g. B. 200g.

Reed Gages

R'1 - Similar to Photo 347a. Forward torpedo room. Athwartships on port frame 28, 2[illegible]" above deck. Directed to starboard.

Graph		20 cps		40 cps	
		Up.	Dn.	Up.	Dn.
A. (3)	Readings all zero.				
B.	Fig. 121	.02	.02	.04	.025

COMMENTS

Able Range Bearing 270°

The gages indicated no shock.

Baker Range 4850 ft. Bearing 212°

This submarine was on the surface and received no shock damage, according to DSM. The peak acceleration indicated by the putty gage is 200g. The reed gage indicates a duration of acceleration of less than a millisecond. The duration apparently was too short for the putty gage to record the full peak acceleration.

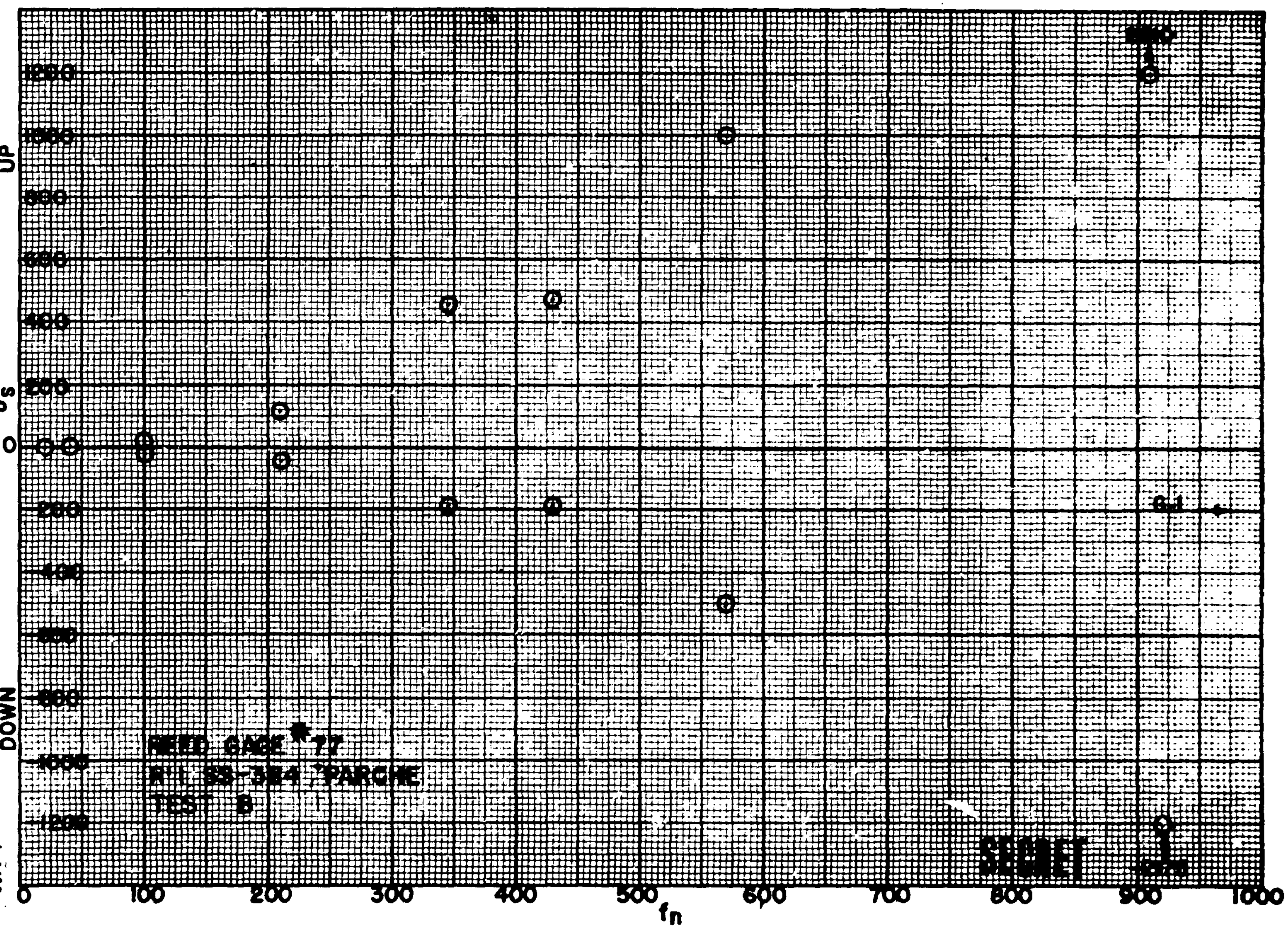


FIG. 121

A-2699

SS 386 PILOTFISH
GAGE LOCATIONS

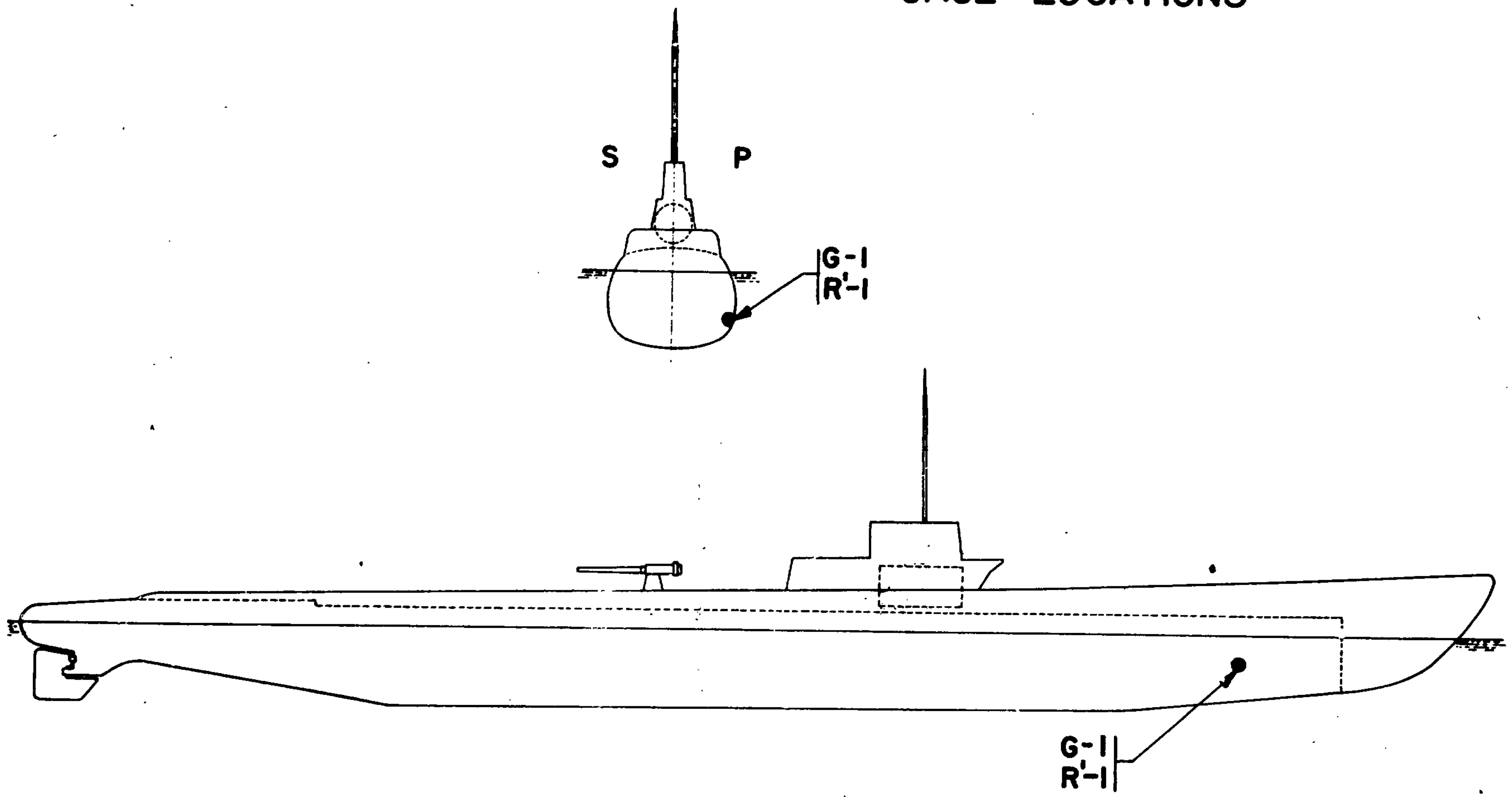


FIG. 122

A-2609

SS386 - PILOTFISH

Putty Gages

G1 - Photo 347. Forward torpedo room. Athwartships on port frame 31, 3" above deck. Directed to starboard.

A. (3) less than 50g. B. ---

Reed Gages

R'1 - Photo 347a. Forward torpedo room. Athwartships on port frame 30, 24" above deck. Directed to starboard.

Graph	20 cps Up.	20 cps Dn.	40 cps Up.	40 cps Dn.
A. (3) Readings all zero.				
B. Not recovered.				

COMMENTS

Able Range 6582 ft. Bearing 76°

The gages indicated no shock.

Baker Range 950 ft. Bearing 186°

This submarine was submerged to a keel depth of about 56 ft. and was sunk.

COMMENTS ON SUBMARINES

Able

Shock was indicated only on the SS305 and the SS308. These few readings do not show any apparent pattern. The minor shock damage of the SS305 probably reflects the relatively sturdy construction of submarines.

Baker

The surviving submerged submarines SS196 and SS335 were at about 4400 ft. range. The SS196 reed gage showed a critical frequency of about 350 cps; the SS335 gage is not so definite but seems to indicate a frequency of about 210 cps. The putty gages read 200 and less than 50g, respectively. The SS335 reed gage and its adjacent putty gage were on the side away from the explosion. The highest SS335 putty gage reading was 250g. The other submerged submarine, the SS203 at 5525 feet, had a 250g. putty gage reading and a reed gage critical frequency of 210 cps. and possibly another at 500cps.

The SS384 on the surface at 3850 ft. received about the same peak acceleration as the submerged submarines at the same range but the critical frequency was over 1000 cps. Thus it appears that the surfaced submarine experienced approximately the same peak pressure as those submerged at the same range but the duration was much less.

In the case where the acceleration is of short duration it is preferable to plot velocity vs. f_n rather than acceleration. The velocity plotted is the instantaneous velocity change required to produce the reed deflections measured and is calculated by the formula $V = \frac{2\pi}{12} f_n X$, where V is in feet per second and X is the reed deflection in inches. This has been done and the results plotted on figure 123 show that the shock was not of the nature of a simple instantaneous velocity change. The points plotted represent the "down" reed deflection which is the direction first taken by these reeds as the hull is pushed in by the pressure wave.

A plot of reed deflection vs. natural frequency is shown in figure 124. The equivalent simple shock for the SS305 seems to be an instantaneously completed displacement of about .07 inches; the SS384 equivalent shock is an instantaneous displacement of .015 inches. Both of these submarines were on the surface. The submerged submarines do not have quite as simple an equivalent shock since the amplitude falls with increasing frequency though not fast enough for a sudden velocity.

change shock. It should be remembered that these equivalent shocks are simply those which will produce approximately the same reed deflections; they are not necessarily the same as the actual shocks.

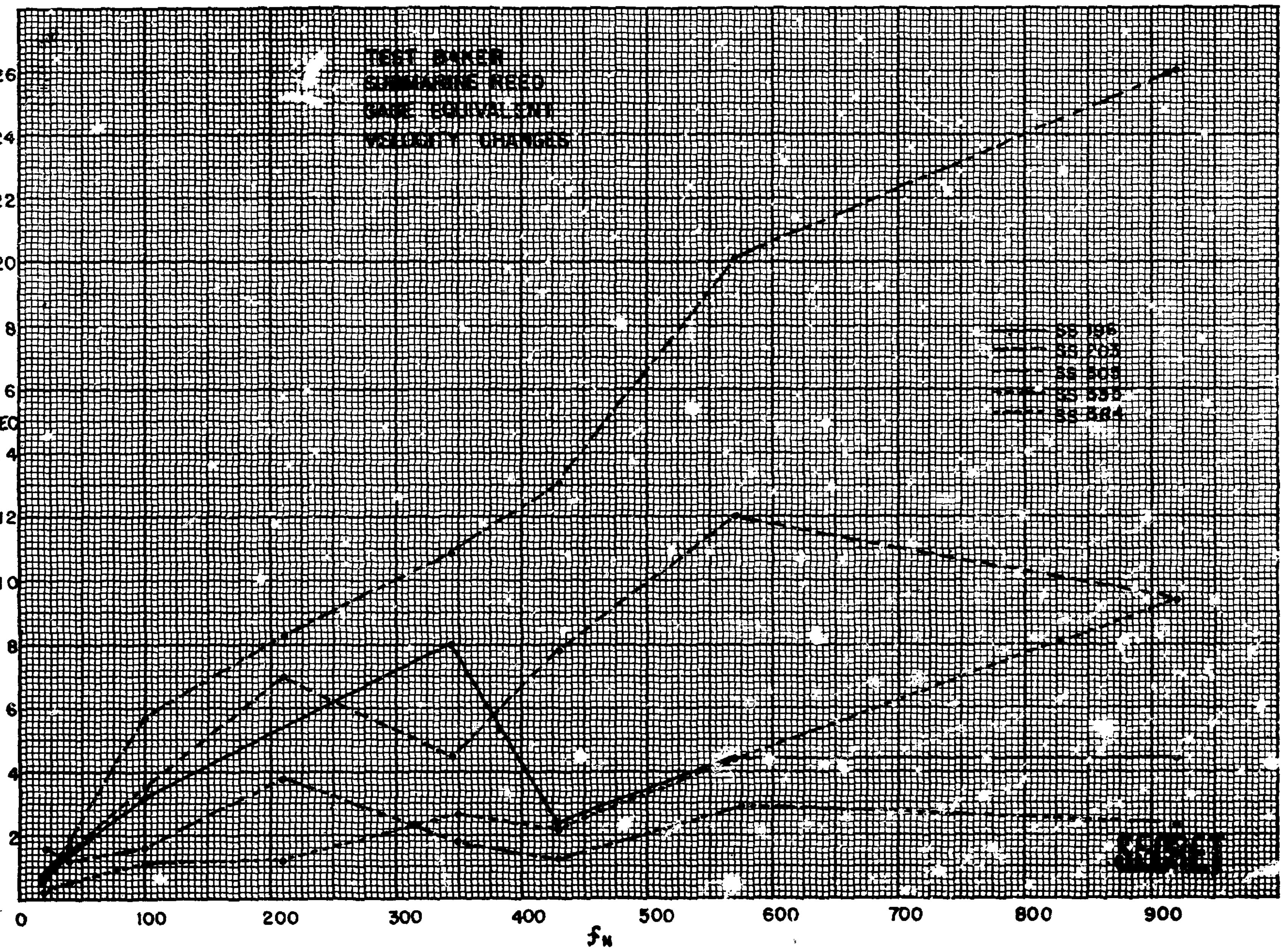


FIG. 123

A-2609

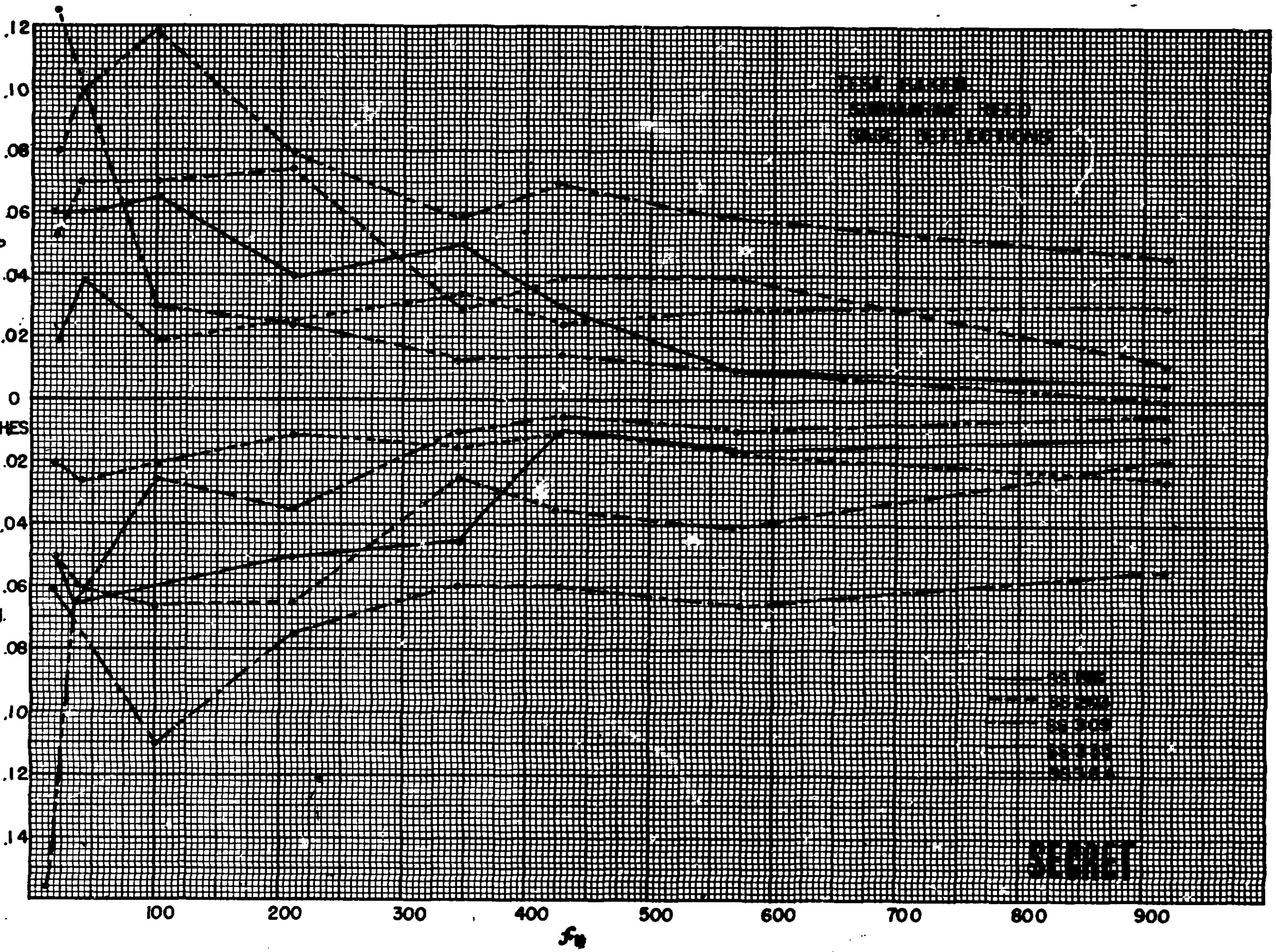


FIG. 124

A-2609

APA 64 BRACKEN
GAGE LOCATIONS

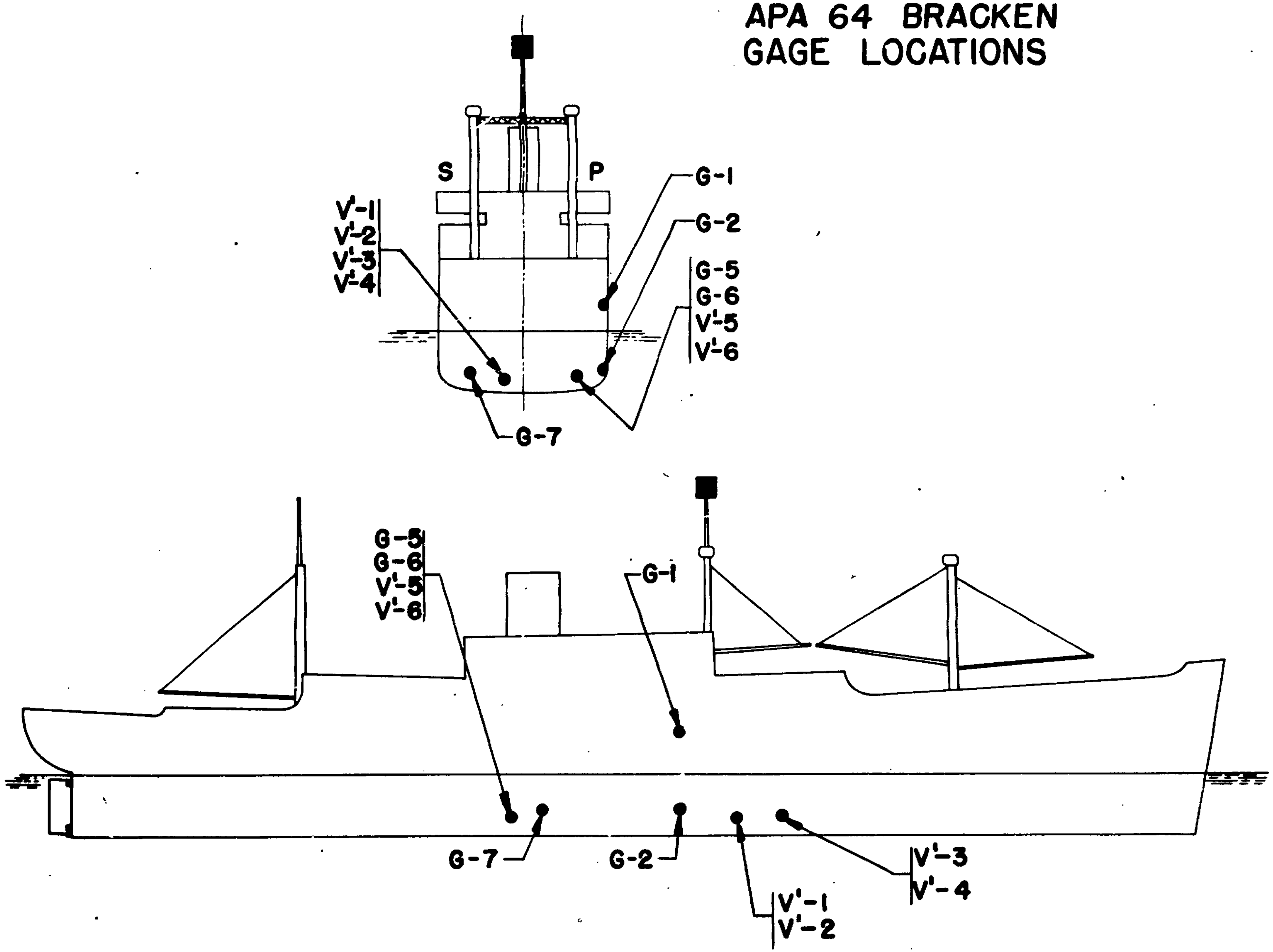


FIG. 125

APA64 - BRACKEN

Putty Gages

G1 - Similar to Photo 35[illegible]. Dry provisions. Directed to starboard on vertical stiffening frame 58 on port shell 56'' below main deck.

A. (1) 70g. B. less than 50g.

G2 - Similar to Photo 353. Ammunition stowage. Directed to starboard on vertical stiffening frame 58, 45'' below 2nd platform.

A. ([illegible]) less than 50g. B. less than 50g.

G5 - Photo 348. Aft machinery space. Directed up on port side of main motor foundation.

A. (3) less than 20g. B. less than 20g.

G6 - Photo 348. Aft machinery space. Directed to starboard on port side of main motor foundation.

A. (3) less than 20g. B. less than 20g.

G7 - Similar to Photo 356. Aft machinery space. Directed up on starboard end of main switchboard foundation.

A. (3) less than 20g. B. less than 20g.

Velocity Meters

V'1 - Photo 349. In forward hold on foundation of forward Bureau of Ships turbo-generator.

A (3) Record not distinguishable. B. Fig. 126, Channel 1.

V'2 - Photo 349. In forward hold on foundation of forward Bureau of Ships turbo-generator.

A. (3) Record not distinguishable. B. Record not distinguishable.

V'3 - Photo 350. In forward hold on foundation of BuShips switchboard.

A. (3) Record not distinguishable. B. Fig. 126, Channel 3.

V'4 - Photo 351. In forward hold on foundation of BuShips switchboard.

A. (3) Record not distinguishable. B. Fib. 126, Channel 4.

Velocity Meters

V'5 - Photo 348. In aft engine room on foundation port main motor.
A.(3) Record not distinguishable. B. Record not distinguishable.

V'6 - Photo 348. In aft engine room on foundation of port main motor.
A.(3) Record not distinguishable. B. Record not distinguishable.

COMMENTS

Able Range 6480 ft. Bearing 191°

No velocity meter records were discernable above the "noise" background. The only gage above the waterline, G1, recorded 70g on the port hull.

Baker Range 4475 ft. Bearing 164°

The gage locations were planned for direct exposure of the port side to the pressure wave rather than the starboard side.

None of the putty gages recorded any shock. The velocity meters V'1, V'3, and V'4 had very light shock indications. The Taylor Model Basin velocity meter records for this ship are supplementary to these and allow a reasonable study of the shock. On the T.M.B. records V6, V8, V10, and V11 alone show a sudden velocity change at the start of the underwater shock. These were underwater hull or keel gages. The port hull gages V5 and V7 do not show a sudden start which indicates that the port hull was shielded from the direct pressure wave. The V6, V8, V10, and V11 records do not resemble a simple instantaneous velocity change. The initial acceleration is followed (particularly in the V6, V10, and V11 records) within a few milliseconds by a deceleration of the same order of magnitude whose effect is to stop the motion after a short travel. This is similar to the equivalent shocks for the submarine reed gage records. These records are also characterized by high frequency vibrations which are not so noticeable in the other records. It is not surprising that high natural frequency modes are excited by the short duration, rapidly fluctuating pressure. It is probably important to note the tendency for the sudden changes to be eliminated as the shock passes through the ship's structure. At interior locations, the shock is characterized by lower frequency vibrations and lower accelerations of longer duration.

The Taylor Model Basin,V6, V8, V10, and V11 records illustrate the loss of pressure by a wave passing parallel to the keel (noted in the destroyer data) since the APA64 keel was directed 16° from the explosion. The initial changes in velocity reported by

Taylor Model Basin are V6 - .80ft/sec., V8 - .48ft/sec., V10-1.75ft/sec., and V11 - .86 ft/sec. From consideration of the location alone, the theory requires that V11 exceed V8, and V10 exceed V6, which is the case. Also the starboard hull gage V6 reading should and does exceed the keel gage V8 reading which in turn exceeds the port hull gage reading of .12ft/sec. While difference in structure may well account for the pattern of these readings, they at least do not refute the theory outlined in the discussion of the destroyer readings.

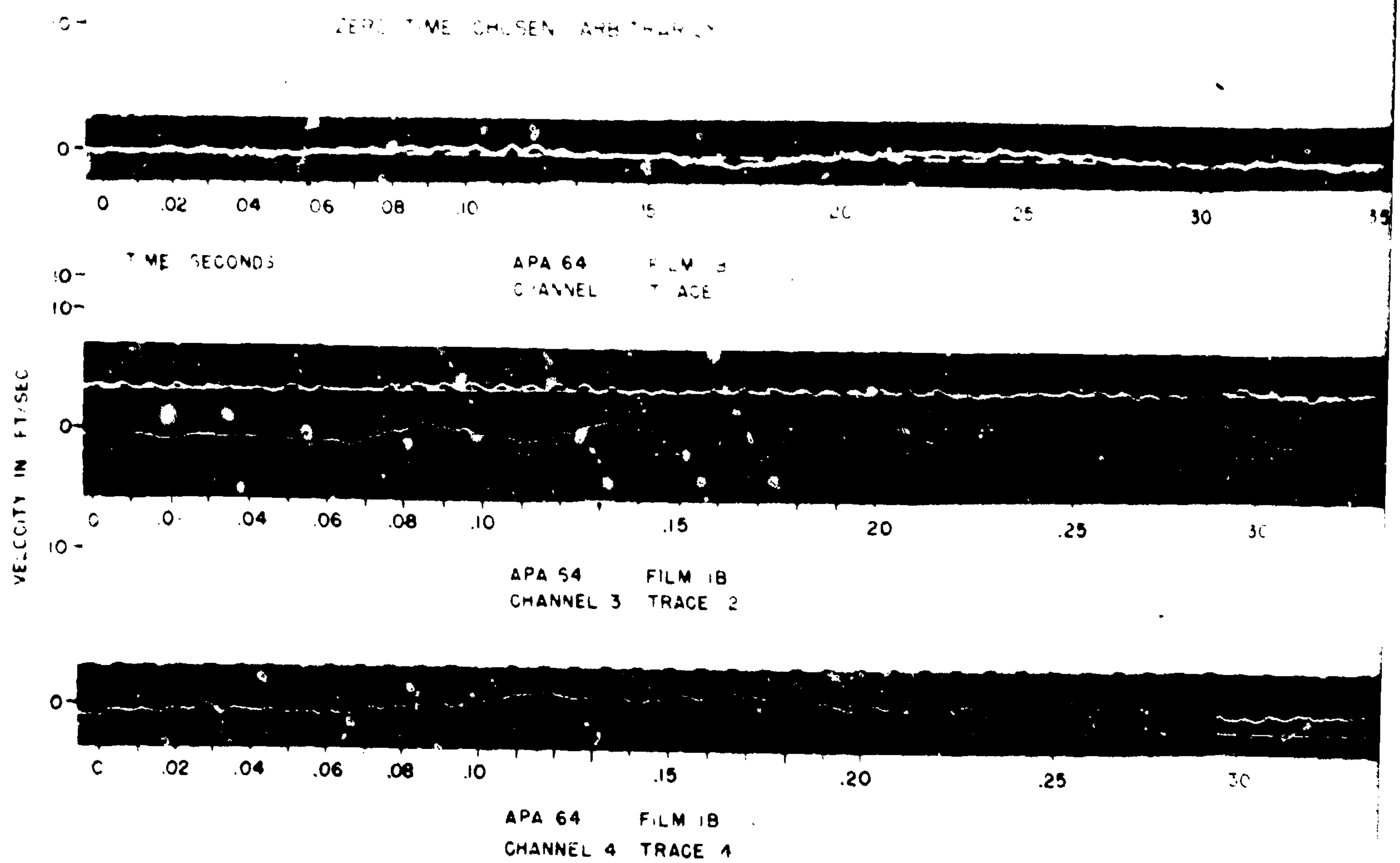
The Taylor Model Basin airblast records are also interesting. The locations showing the greatest excitation are of course those exposed to the direct air pressure. The relative absence of high frequency components and the similarity to the airblast records of the DD404 and DD408 is noteworthy.

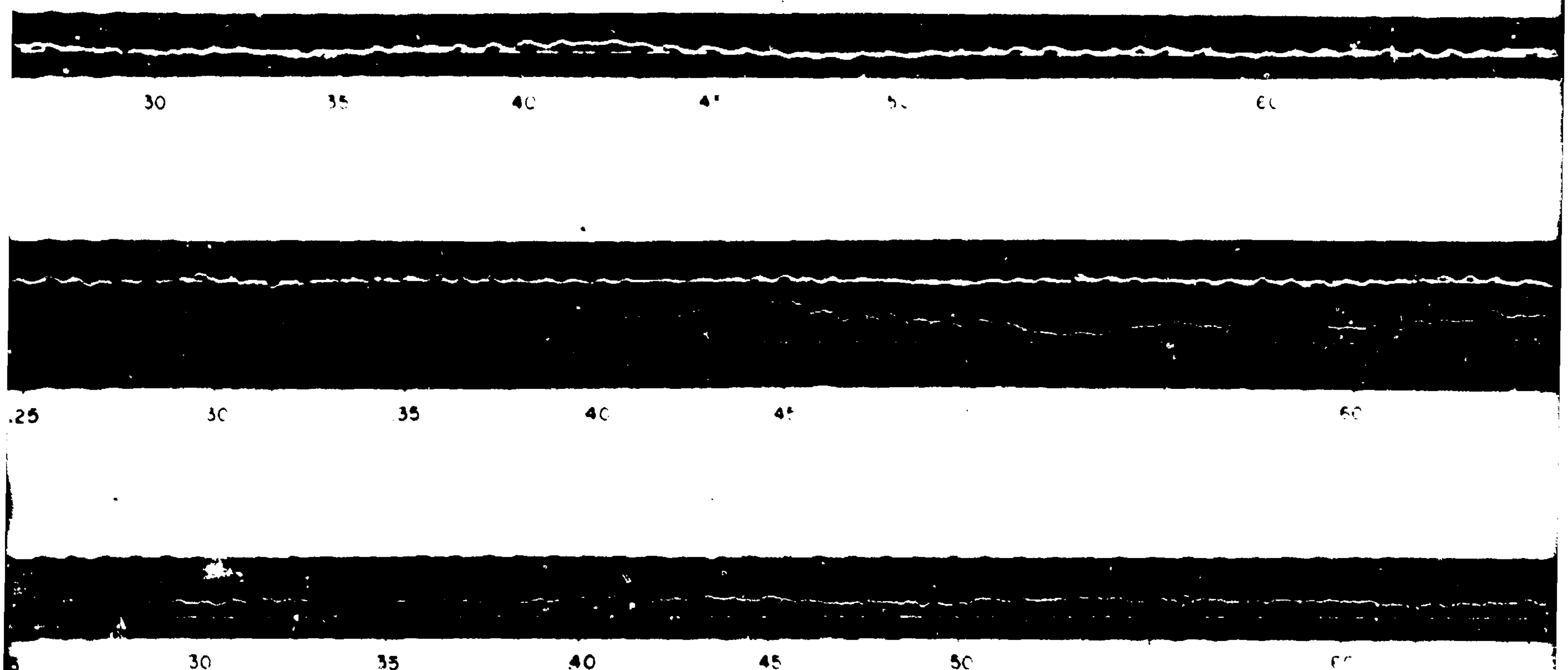
VELOCITY CURVES OBTAINED FROM V' GAGES

FM WIRE RECORDER

TEST: BAKER

ZERO TIME CHOSEN ARBITRARILY





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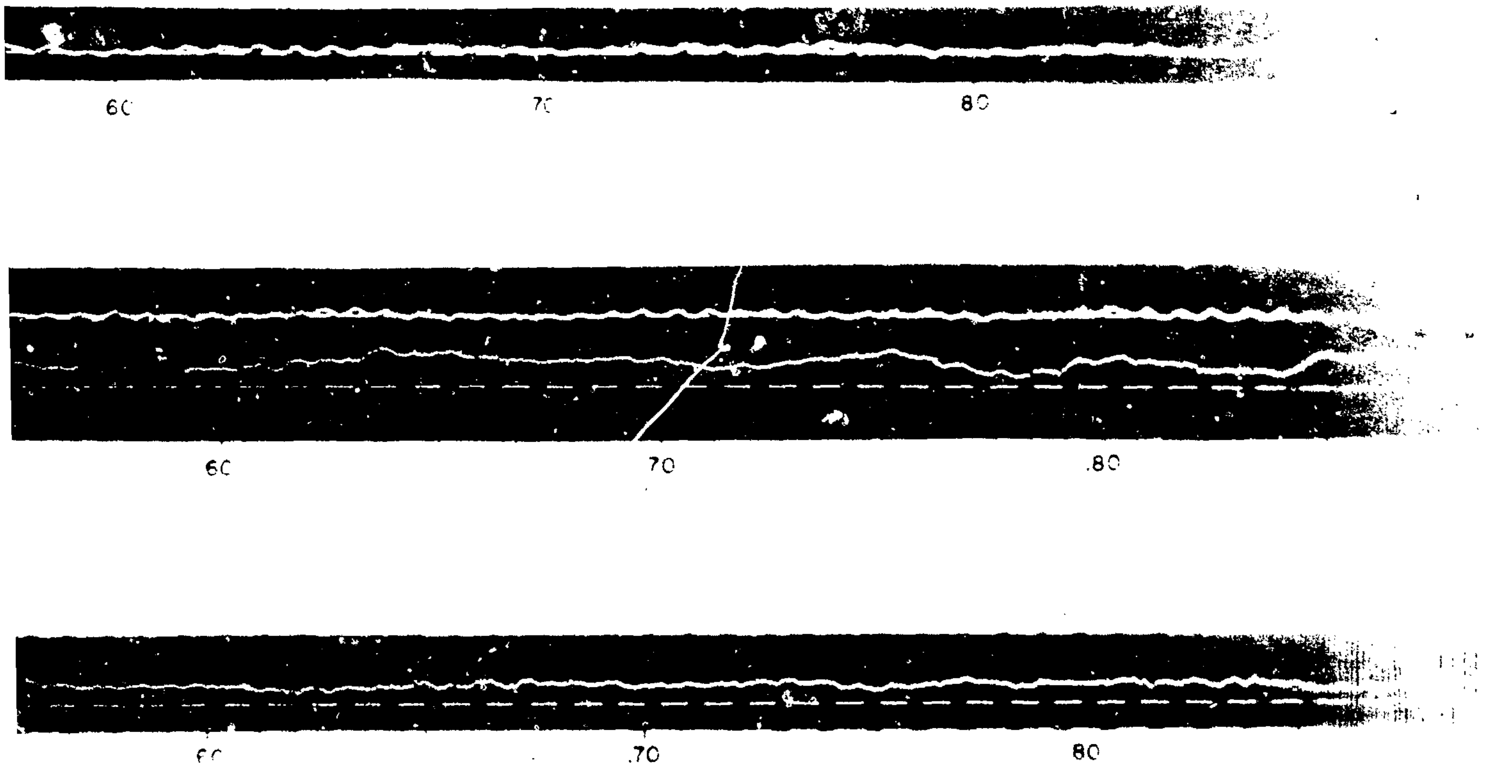
TOP SECRET



3

FIG.12 6

APA 65 BRISCOE GAGE LOCATIONS

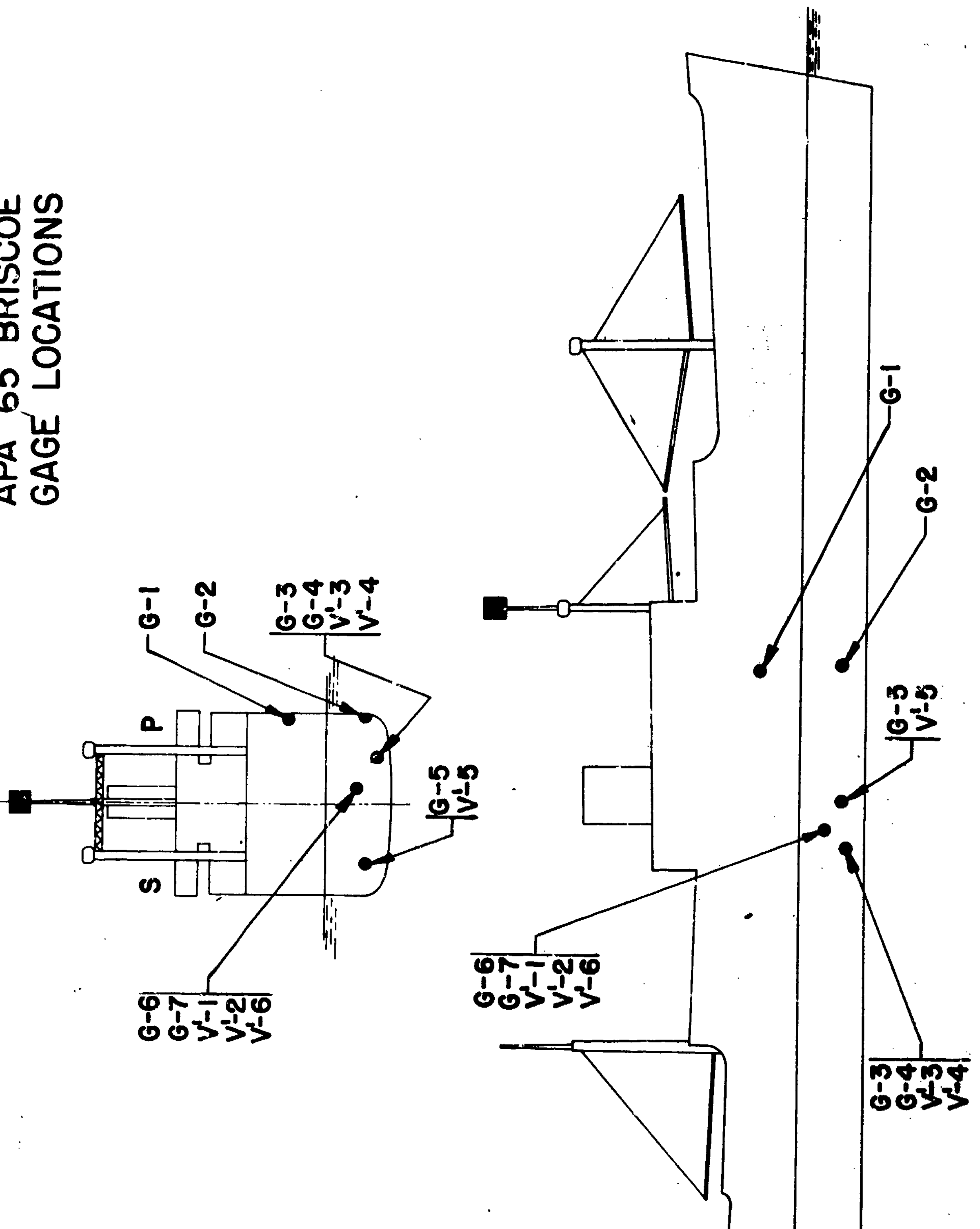


FIG. 127

A-2609

Putty Gages

G1 - Photo 352. Dry provisions. Directed to starboard on port shell vertical stiffener about 3 ft. above deck and 69" below main deck bin.
A. (1) less than 50g. B. 75g.

G2 - Photo 353. Ammunition stowage. Directed to starboard on port shell frame 62" below second platform at frame 58.
A. (3) less than 50g. B. 700g.

G3 - Photo 354. Aft machinery space. Directed up on main port motor foundation.
A. (3) less than 50g. B. 250g.

G4 - Photo 355. Aft machinery space. Directed to starboard on port main motor foundation.
A. (3) less than 50g. B. 200g.

G5 - Similar to photo 348. Aft machinery space. Directed up on main switchboard foundation. On I-beam at starboard end of switchboard at switchboard deck level.
A. (3) less than 20g. B. 250g.

G6 - Similar to photo 348. Aft machinery space. Directed up on port side of main generator foundation.
A. (3) less than 50g. B. less than 50g.

G7 - Photo 356. Aft machinery space. Directed to starboard between generator and turbine on main generator foundation.
A. (3) less than 50g. B. less than 50g.

Velocity Meters - Fig. 128 and 129.

V'1 - Photo 355. In aft engine room. Directed to port on foundation of main turbo-generator.
A. (3) Record not distinguishable. B. Fig. 128, Channel 1.

V'2 - Photo 354. In aft engine room. Directed up on foundation of main turbo-generator.
A. (3). Record not distinguishable. B. Fig. 128. Channel 3.

V'3 - Similar to photo 348. In aft engine room. Directed to port on foundation of port main motor.
A. (3) Record not distinguishable. B. Fig. 123. Channel 2.

APA65 - BRISCOE

Velocity Meters

V'4 - Similar to photo 318. In aft engine room. Directed up on foundation of port main motor.

A. (3) Record not distinguishable. B. Fig. 128. Channel 4.

V'5 - Photo 356. In aft engine room. Directed down of underside of beam supporting starboard end of main switchboard.

A. (3) Record not distinguishable. B. Fig. 129. Channel 5.

V'6 - No photo. In aft engine room. Directed up on foundation of auxiliary generator.

A. (3) Record not distinguishable. B. Fig. 129. Channel 6.

COMMENTS

Able Range 5136 ft. Bearing 181°

All putty gage and velocity meter shocks were below the minimum settings of these gages.

Baker Range 1725 ft. Bearing 240°

This is one of the few ships which were oriented as planned and at a fairly close range. It had a large number of gages so that considerable data is available.

Consider first the TMB port hull gages below the waterline, V6 and V12. The first pulse of each consists of a high acceleration followed within one or two milliseconds by a high deceleration. The initial velocity change of V6 is 5 ft/sec. The V6 record, when integrated roughly, shows a displacement under this pulse of about .15 inches. The total displacement at the time of deceleration is about .45 inches which rules out the possibility that the meter bottomed at this time. The putty gage G2 was adjacent to V6 and indicated 700g. About 20 milliseconds after the start of the first pulse, another positive acceleration occurs. Since the displacement is approximately .70 inches at this time and since V12 does not have such a pulse, it seems likely that this was bottoming of the gage. The next large velocity change occurs at a displacement (magnet relative to pickup coil) of about 1.40 inches. This is a distance of about 2.1 inches from the previous large velocity change and shows both to be due to bottoming. The next change is apparently a shock motion since it occurs

1.40 inches from the last bottoming. Thus the only large velocity changes due to the initial shock front seem to be the initial acceleration and deceleration. Following these, the velocity changes from 4.5 ft/sec. to zero in an interval of over 150 milliseconds. The first triangular pulse of the V12 record has a duration of 2 milliseconds and a peak value of 10 ft/sec. The displacement caused by this pulse is therefore .12 inch. A transient vibration at high frequency follows this pulse. The similarity of the V12 record and the start of the V6 record with the V10 and V6 records on the APA64 shows reasonable correlation.

TMB gages V8 and V14 were over the keel on the double bottom. These have an initial velocity change of 1.5 and 3 ft/sec. respectively which occurs in a time of one millisecond or less. Unlike the port hull gages, however, a large deceleration does not follow and the resulting displacements are about .80 to 1.0 inches respectively. Up to at least .20 seconds after the first sharp change, the succeeding large velocity changes are due to bottoming. Later shocks will be considered with the other records.

All NRL velocity meters were in the aft engine room on the foundations of large pieces of equipment. V'3 indicated very slight athwartships disturbance of the port main motor foundation; V'1 indicated adequate athwartships motion of main turbo-generator to cause several bottomings of the gage but the excitation has low frequency and low acceleration except at the start of the record. At the start, a high frequency excitation occurs resembling the port hull records. The initial velocity change is 1.1 ft/sec. Of the vertical gages, V'4 records a sudden initial velocity change of 2.2 ft/sec. accomplished in an interval of about 5 milliseconds; on the auxiliary turbo-generator; V'5 is also similar in recording a 3 ft/sec. initial velocity change of 2 ft/sec. in an interval of 5 milliseconds; on the auxiliary turbo-generator; V'5 is also similar in recording a 3 ft/sec. initial velocity change in an interval of about 8 milliseconds on the main switchboard foundation. The trend indicated is that the heavy machinery and the interposition of structure between the hull and the gage location decreases the initial velocity change and increases its duration.

TMB gages V5, V7, and V13 on the starboard hull and V4 on the port hull above the waterline have initial excitations of less than 1 ft/sec. and have no simple characteristics. V3 and V9 were vertical in the superstructure and their records strongly resemble the vertical keel gage records. V3 has an initial velocity change of 2 ft/sec. acquired in 8 milliseconds, V9 has an initial velocity change of 6 ft/sec. acquired in 13 milliseconds.

The velocity meters indicate several other shocks besides the initial shock and that due to airblast. The most obvious one occurs about .24 seconds after the initial shock, though there are many others. An attempt to deduce the direction from which the shock came follows. Two shocks are considered which start at approximately .21 and .24 seconds after the start of the first pulse. In the tabulation, the approximate velocity change associated with each meter location is given together with the initial velocity change.

APA 65 - BRISCOE

Meter	Location	Velocity Change: .21 sec. Shock	.24 sec. Shock	Initial Shock
V3	Vertical on deck of superstructure forward.	4.0	2.5	2.0
V4	Horizontal on port hull forward above W.L.	0.8	0.5	1.0
V5	Horizontal on starboard hull forward above W.L.	0.7	1.0	1.0
V6	Horizontal on port hull forward below W.L.	2.0	2.5	5.0
V7	Horizontal on starboard hull forward below W.L.	2.0	4.0	1.0
V8	Vertical on keel forward	2.5	2.0	1.5
V9	Vertical on deck of superstructure forward.	7.0	4.0	6.0
V12	Horizontal on port hull aft below W.L.	1.5	2.5	10.0
V13	Horizontal of starboard hull aft below W.L.	2.0	6.0	1.0
V14	Vertical on keel aft	4.0	6.0	3.0
V'2	Vertical on turbo-gen.	1.0	1.0	2.2
V'4	Vertical on port main motor	2.5	1.0	1.5
V'5	Vertical on main switchboard	2.0	1.5	3.0
V'6	Vertical on auxiliary gen.	1.0	1.0	2.0

With the added fact that the above velocity changes at .21 and .24 sec. were more abrupt on the vertical meters than on the horizontal, the indication here is that the later shock waves came from below rather than from the port side.

It seems possible to deduce the direction of a velocity from the fact that bottoming on the base of the meter is more abrupt than that at the top. V6 on the port hull indicates that the first motion of the starboard hull was in but after a few milliseconds the motion was out and continued in that direction for several hundred milliseconds (apparently 6 inches) at which time a strong pulse accelerated the hull out again. V8 and V14 on the keel started up an continued to move up for several hundred milliseconds. V3 and V9 in the superstructure were hung upside down. The superstructure therefore moved up for several milliseconds at the start. The NRL vertical velocity meters show all the locations on equipment bases to have moved up initially.

The airblast records of the TMB velocity meters show large velocity changes on structures exposed to the air pressure. The transient vibrations are of lower frequency and the velocity changes are more gradual than those due to waterborne shock.

The putty gage G1 adjacent to V4 recorded 700g, which was the second largest putty gage reading of the Baker test. It is noteworthy that this was one of the few hull putty gages at a proper location to record peak hull acceleration. Accelerations on machinery foundations were higher than usual, being 200-250g.

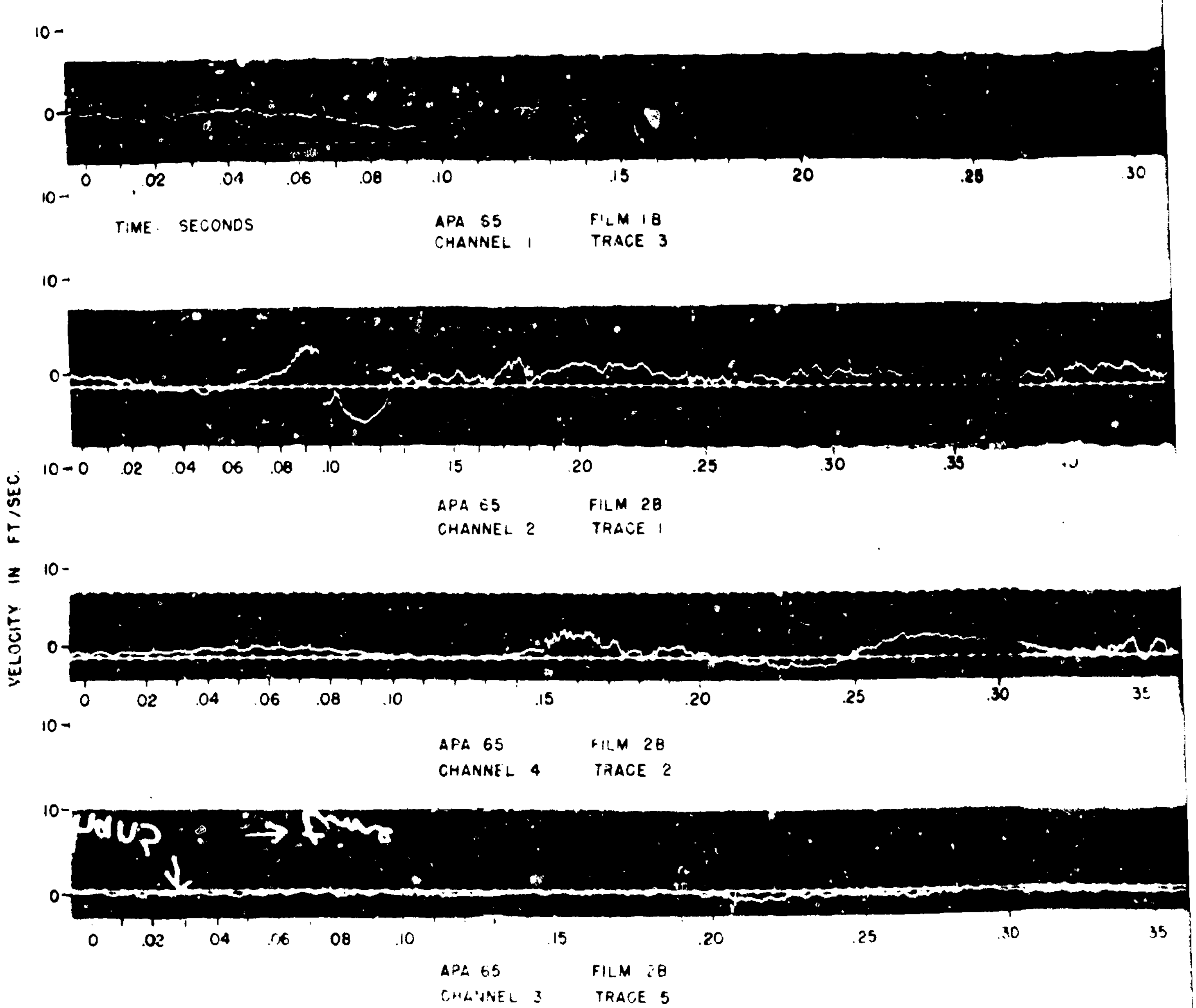
The DSM report terms the shock moderate. Many light bulbs were broken, some machinery foundation bolts were stretched though no machinery appeared to be inoperable, the master gyro was inoperative, and much loose gear and floor gratings were dislodged. Apparently this shock was in the vicinity of the lower limit of shock which causes damage.

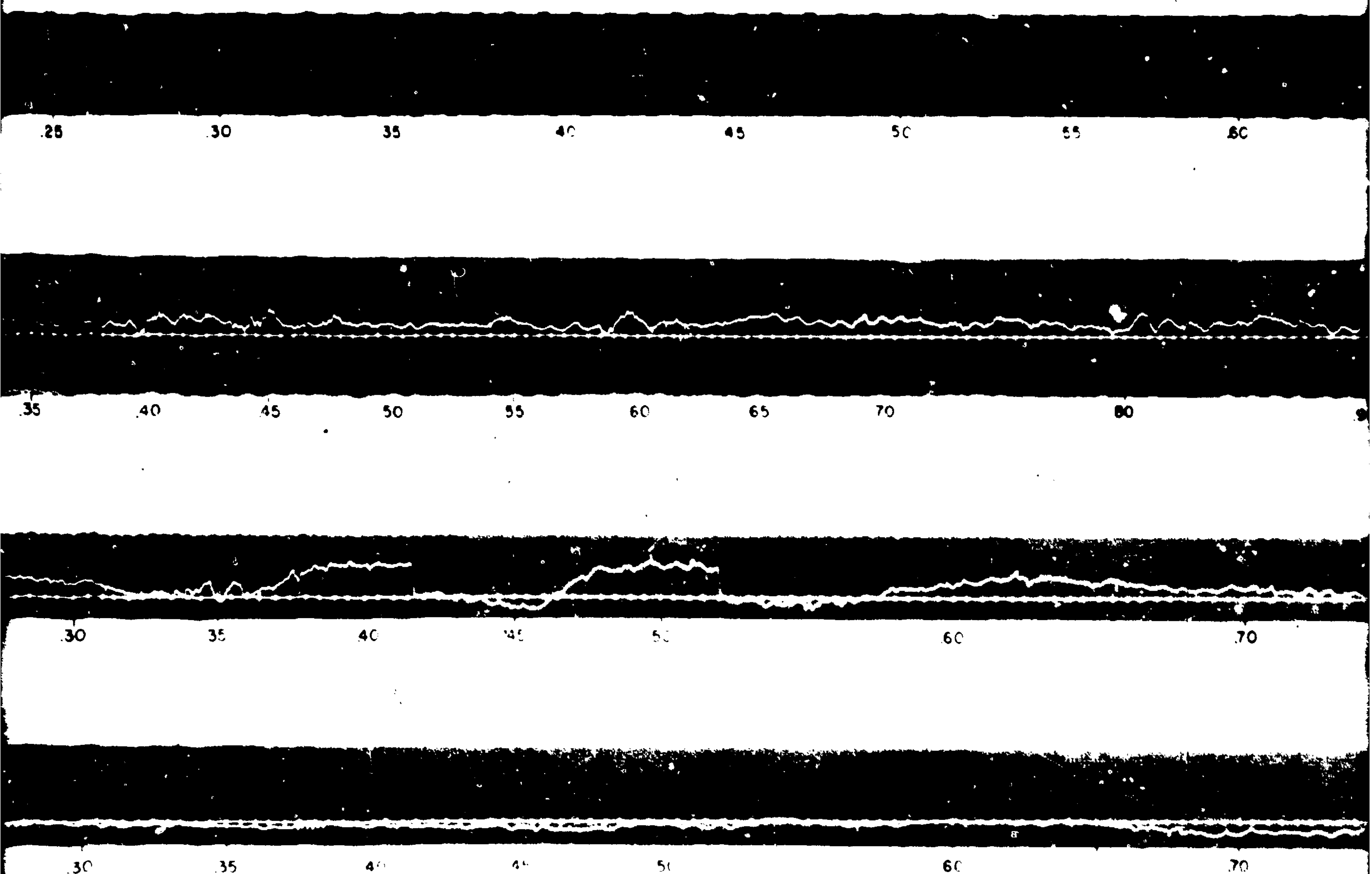
VELOCITY CURVES OBTAINED FROM V' GAGES

F M WIRE RECORDER

TEST: BAKER

ZERO TIME CHOSEN ARBITRARILY





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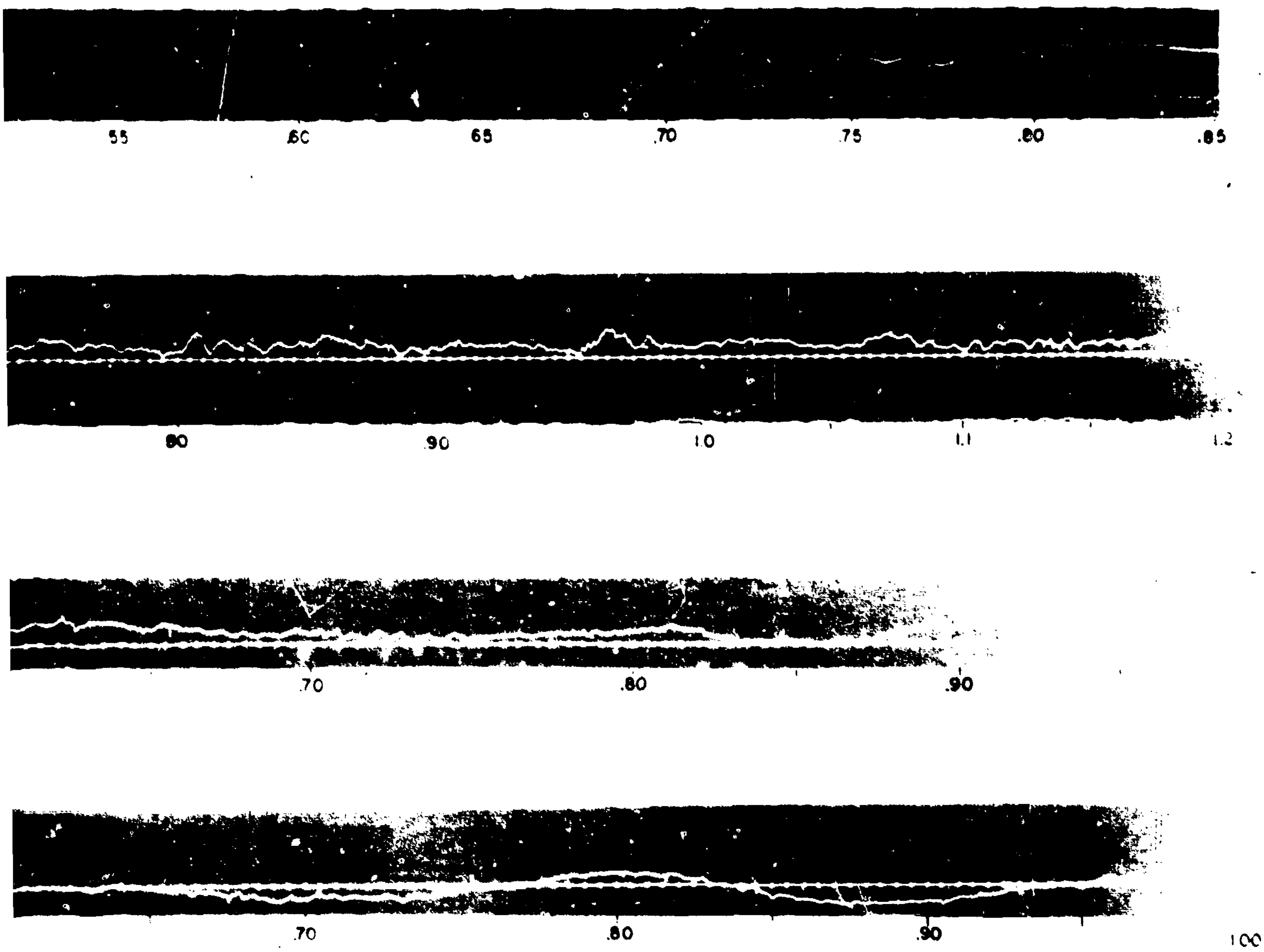

FIG. 128

A-2609

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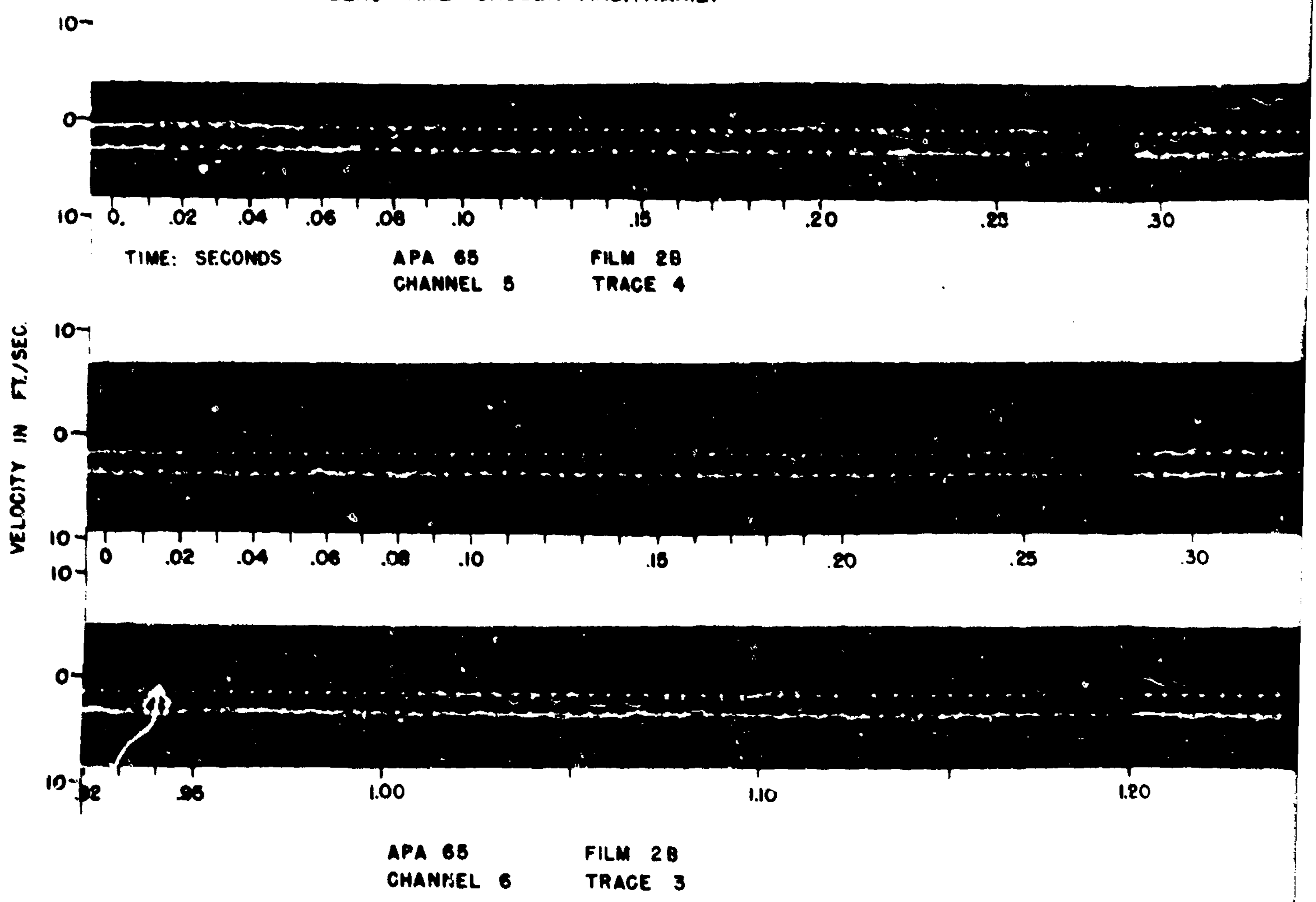
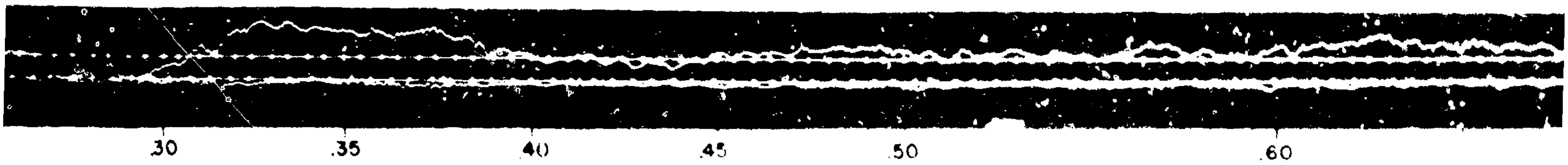
VELOCITY CURVES OBTAINED FROM V' GAGES

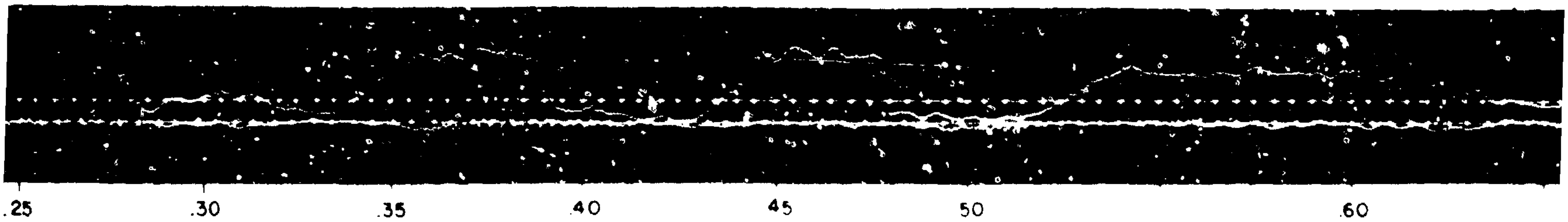
FM WIRE RECORDER

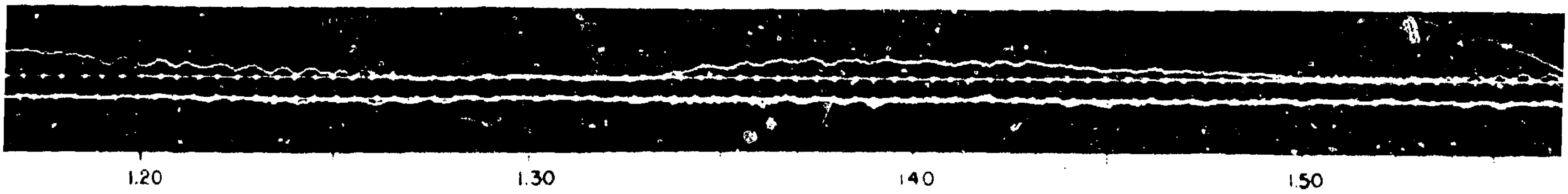
TEST: BAKER

ZERO TIME CHOSEN ARBITRARILY









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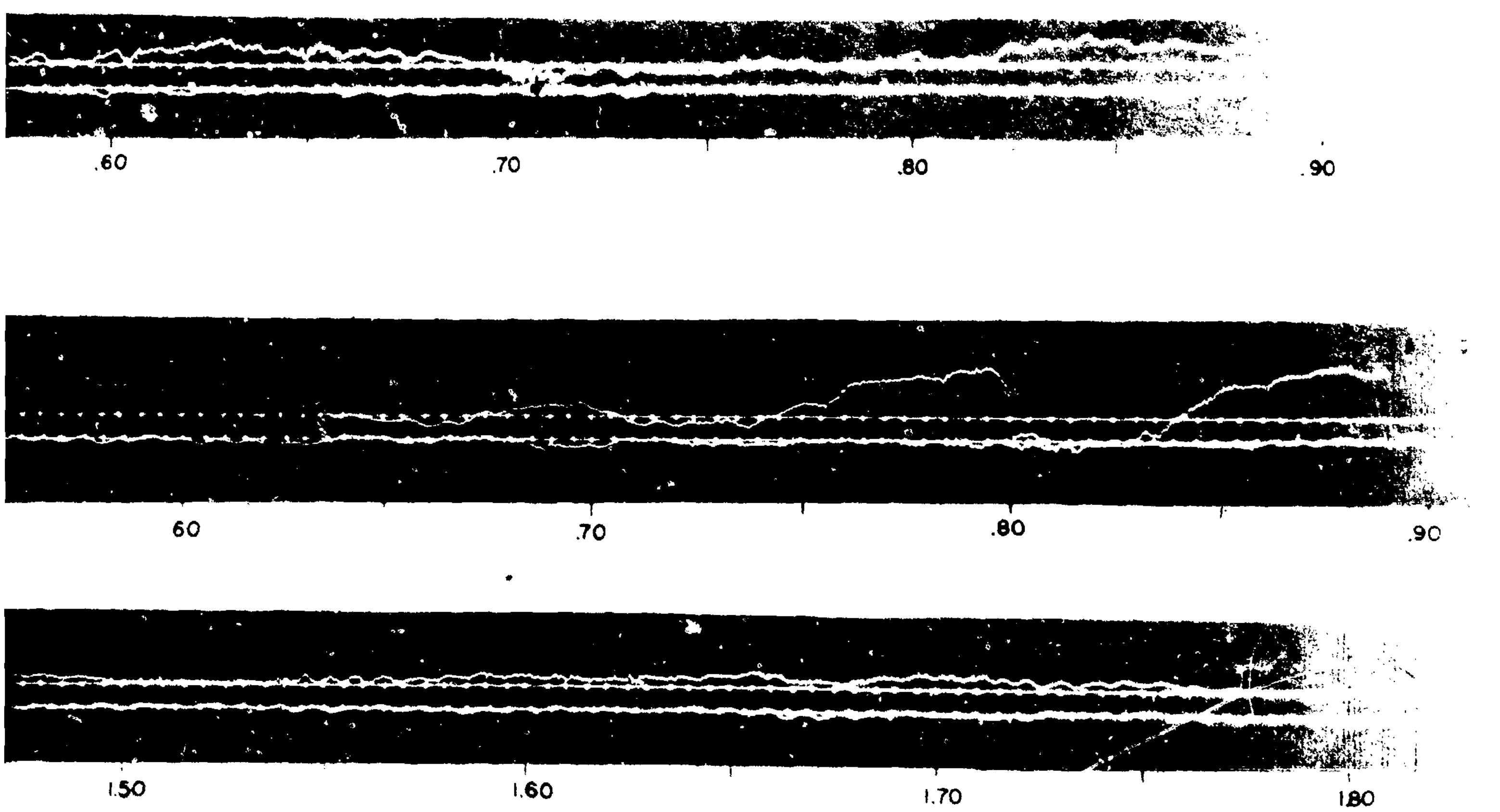

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FIG. 129

A-2609

APA 87 NIAGARA GAGE LOCATIONS

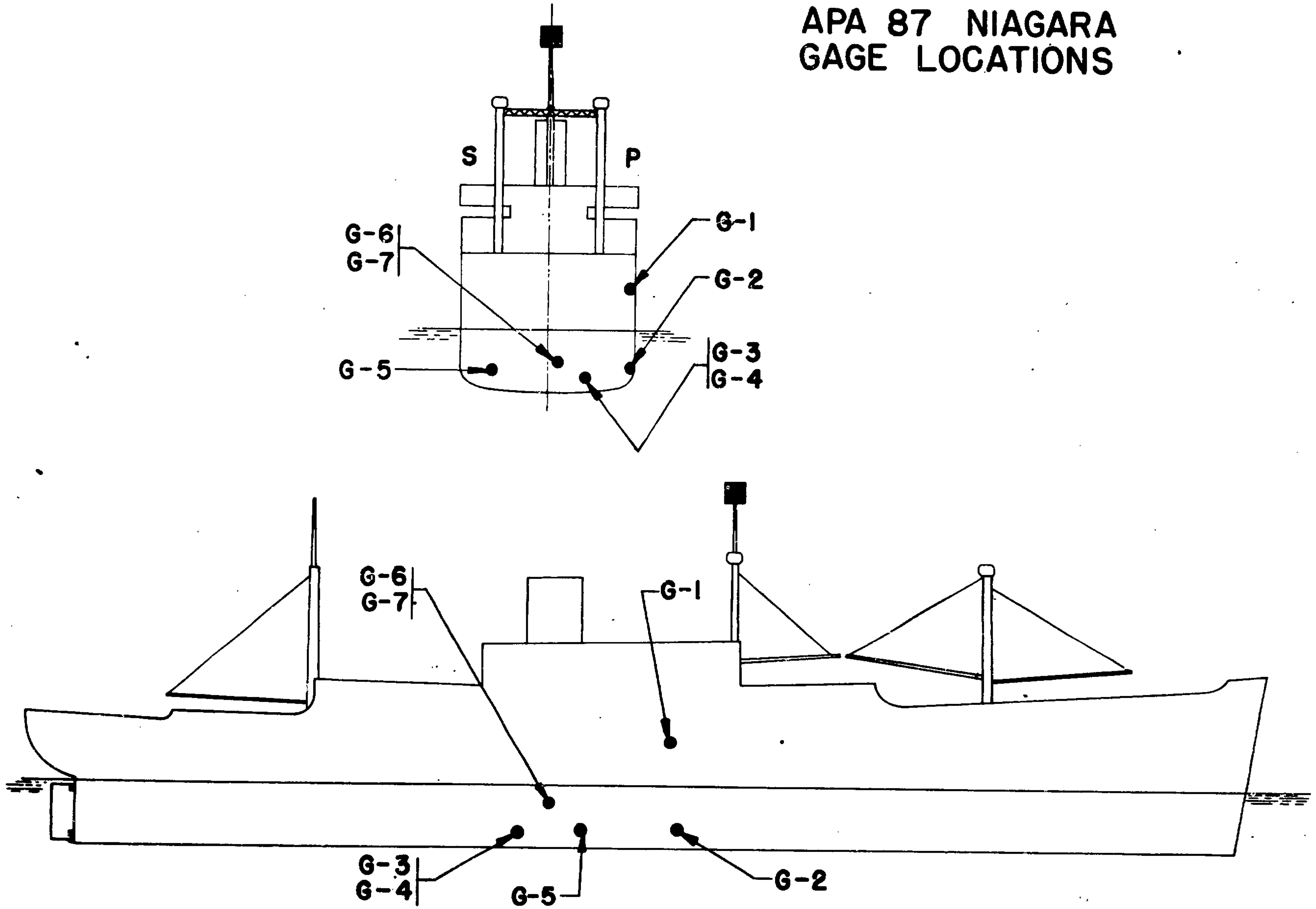


FIG. 130

A-2409

APA87 - NIAGARA

Putty Gages

G1 - Similar to photo 352. Dry provisions. Directed to starboard on port stiffener flange 56'' below main deck at frame 58.

A. Not installed. B. less than 50g.

G2 - Similar to photo 353. Ammunition stowage. Directed to starboard on vertical stiffening frame 58, 45'' below 2nd platform.

A. Not installed. B. less than 50g.

G3 - Similar to photo 348. Aft machinery space. Directed up on main port motor foundation.

A. Not installed. B. less than 50g.

G4 - Similar to photo 348. Directed to starboard at same location as G3.

A. Not installed. B. 100g.

G5 - Similar to photo 356. Aft machinery space. Directed up on main switchboard foundation. On I-beam at starboard end of switchboard at switchboard deck level.

A. Not installed. B. less than 50g.

G6 - Photo 35? Aft machinery space. Directed up on port side of main generator foundation.

A. Not installed. B. less than 50g.

G7 - Similar to photo 355 Aft machinery space. Directed to starboard between generator and turbine on main generator foundation.

A. Not installed. B. 300g.

COMMENTS

Baker Range 9375 ft. Bearing 201°

Due to the range of this ship, the location of G4 and G7, and the small indentations in the putty, the validity of these readings seems questionable.

BB 34 NEW YORK GAGE LOCATIONS

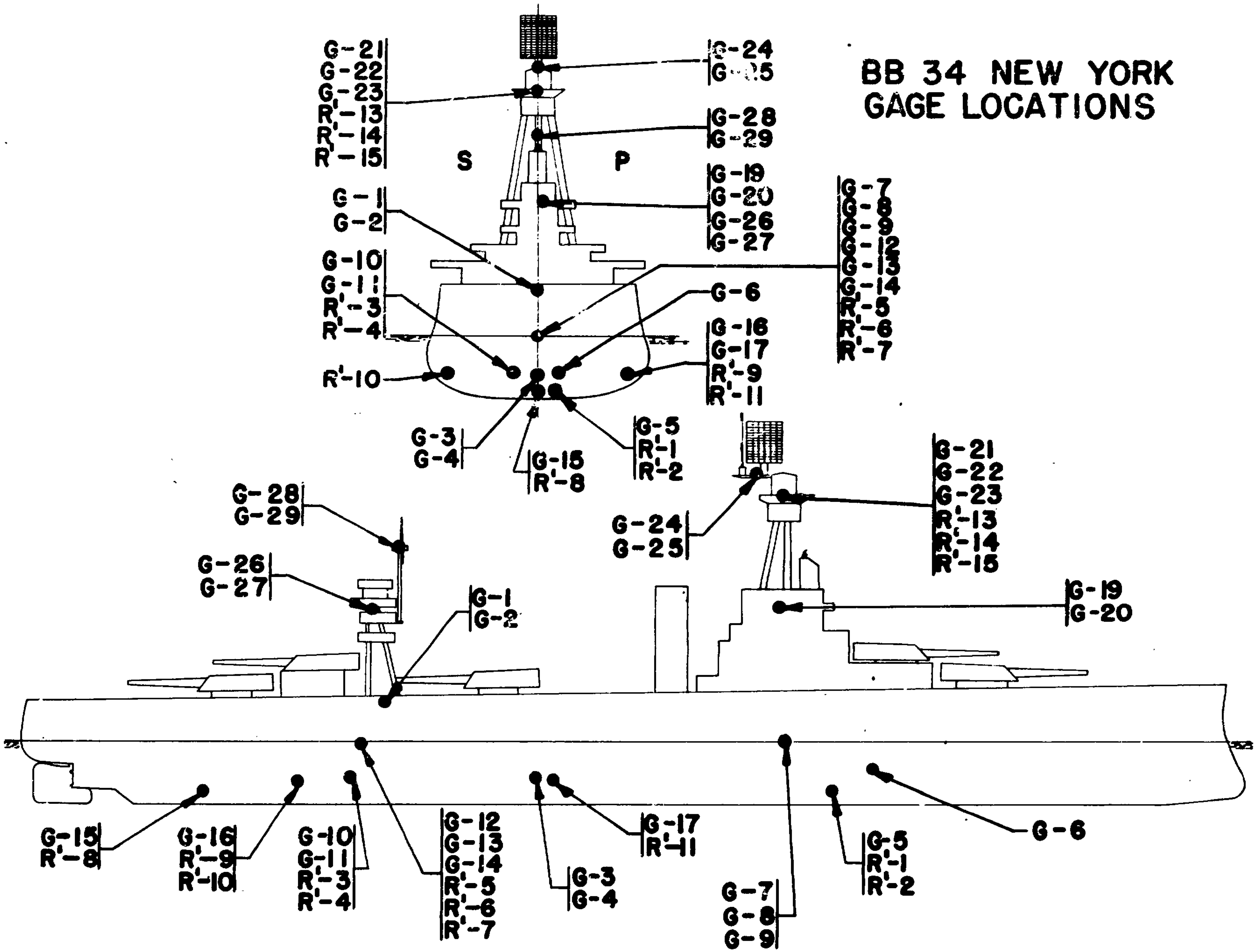


FIG. 131

A-2609

BB34 - NEW YORK

Putty Gages

G1 - Photo 358. General mess scullery. Directed up on channel bracket on under side of main deck at frame 98.

A. (2) 30g. B. 50g.

G2 - Photo 358. Directed to port on web of deck beam overhead in general mess scullery at frame 98.

A. (3) less than 20g. B. less than 20g.

G3 - Photo 359. Aft dynamo room, compartment C-24. Directed up on deck of second platform just port of center line at frame 82.

A. (3) less than 20g. B. ---

G4 - Photo 359. Aft dynamo room, compartment C-24. Directed to starboard on dynamo foundation near G3.

A. --- B. ---

G5 - Photo 360. Dynamo condenser room, compartment A-22. Directed to starboard on brace of aft bulkhead.

A. (3) less than 50g. B. less than 50g.

G6 - Photo 361. Forward dynamo room, compartment A-39. Directed up on deck near port generator on second platform at frame 42.

A. (3) 50g. B. 50g.

G7 - Photo 362. Main radio station, compartment B-102. Directed up on third deck on center line of ship at frame 51-1/2.

A. (3) less than 20g. B. 40g.

G8 - Photo 362. Same as G7 except that it is directed to starboard.

A. (3) less than 20g. B. 20g.

Putty Gages

G9 - Photo 362. Main radio station, compartment B-102. Directed forward on deck.

A. (3) 30g. B 30g.

G10 - No photo. Starboard engine room, compartment C-1. Directed to starboard on archway above second platform 6 ft. starboard of centerline at frame 104.

A. (3) less than 20g. B. 30g.

G11 - No Photo. Directed up at same location as G10.

A. less than 50g. B. less than 50g.

G12 - Photo 363. Radio transmitter room, compartment C-103. Directed up on third deck near center line at frame 101.

A. (3) less than 20g. B. less than 20g.

G13 - Photo 363. Directed to starboard at same location as G12.

A. (3) less than 20g. B. less than 20g.

G14 - Photo 363. Directed forward at same location as G12.

A. (3) less than 20g. B. less than 20g.

G15.- Photo 364. Marine stores, compartment D-11. Directed up in hold on archway at center line of ship at frame 120.

A. (3) less than 20g. B. not recovered.

G16 - Photo 365. GSK main issue room, compartment D-17-P. Directed to starboard on vertical stiffener of port bulkhead above second platform at frame 105.

A. (3) less than 20g. B. 90g.

G17 - Photo 366. 5" shell and handling room, compartment B-19-MP. Directed up on archway above second platform at frame 77-1/2.

A. (3) less than 20g. B. 90g.

G19 - Photo 367. Chart house. Directed up on deck near radar armored tube at navigation bridge level at frame 51.

A. (2) less than 20g. B. 20g.

G20 - Photo 367. Directed to port at same location as G19.

A. (2) 70g. B. 30g.

G21 - Photo 368. Main battery control. Directed up on deck at center-line and frame 51-1/2.

A. (2) less than 20g. B. less than 20g.

G22 - Photo 369. Directed to starboard at same location as G21.

A. (2) less than 20g. B. less than 20g.

G23 - Directed forward at same location as G21.

A. (2) less than 20g. B. less than 20g.

G24 - Photo 370. Radar platform. Directed to starboard on web of beam under platform above main battery control at frame 54.

A. (1) 100g. B. 90g.

G25 - Photo 371. Radar platform. Directed up on deck of platform on top of centerline I beam support of platform just aft of radar antenna base at frame 54.

A. (1) 100g. B. ---

G26 - Photo 372. Surface lookout. Directed up on upper side of flange of overhead 18" brace between center post and forward-starboard member of tripod at frame 101.

A. (2) 60g. B. 60g.

G27 - Photo 372. Surface lookout. Directed to starboard on bulkhead stiffener 6 ft. above deck just inside door at frame 100.

A. (2) 60g. B. 30g.

G28 - Photo 373. Aft radar platform. Directed up on deck at frame 97.

A. (1) less than 20g. B. less than 20g.

G29 - Photo 373. Directed to starboard at same location as G28.

A. (1) less than 20g. B. less than 20g.

BB34 - NEW YORK

Reed Gages

R'1 - Photo 360. Dynamo condenser room, A-22. Directed to starboard stiffening bracket to port of centerline above hold at frame 47.

Graph	20 cps Up.	20 cps Dn.	40 cps Up.	40 cps Dn.
A. (3) Readings all zero.				
B. Fig. 134.	.145	.085	.085	.095

R'2 - Photo 360. Directed up at same location as R'1.

Graph	20 cps Up.	20 cps Dn.	40 cps Up.	40 cps Dn.
A. (3) Readings all zero.				
B. Fig. 135.	.12	.10	.025	.045

R'3 - No Photo. Starboard engine room, C-1. Directed to starboard archway above second platform at frame 104, 6 ft. starboard of centerline.

Graph	20 cps Up.	20 cps Dn.	40 cps Up.	40 cps Dn.
A. (3) Readings all zero.				
B. Fig. 136.	.03	.025	.04	.05

R'4 - No photo. Directed up at same location as R'3.

Graph	20 cps Up.	20 cps Dn.	40 cps Up.	40 cps Dn.
A. (3) Readings all zero.				
B. Fig. 137.	.155	.145	.02	.06

R'5 - Photo 363. Radio transmitter room, C-103. Directed up on deck near centerline at frame 101.third deck.

Graph	20 cps Up.	20 cps Dn.	40 cps Up.	40 cps Dn.
A. (3) Readings all zero.				
B. Fig. 138	.125	.11	.03	.025

R'6 - Photo 363. Directed to starboard at same location as R'5.

Graph,	20 cps Up.	20 cps Dn.	40 cps Up.	40 cps Dn.
A. (3) Readings all zero.				
B. Fig. 139	.025	.025	.01	C

R'7 - Photo 363. Directed aft at same location as R'5.

Graph	20 cps Up.	20 cps Dn.	40 cps Up.	40 cps Dn.
A. (3) Fig. 132	.025	.045	0	0
B. Fig. 140	.105	.035	.01	.05

R'8 - Photo 364. Marine stores. On archway in hold at centerline of ship and frame 120. Directed up.

Graph	20 cps Up.	20 cps Dn.	40 cps Up.	40 cps Dn.
A. (3) Readings all zero.				
B. Not recovered.				

R'9 - Photo 365. GSK main issue D-17-P. Directed to starboard, on port bulkhead stiffener above second platform of frame 105.

Graph	20 cps Up.	20 cps Dn.	40 cps Up.	40 cps Dn.
A. (3) Readings all zero.				
B. Fig. 141.	.05	.06	.03	.055

R'10 - Photo 374. GSK main stores, compartment D-17-S. Directed to port on starboard bulkhead stiffener above second platform at frame 108,

Graph	20 cps Up.	20 cps Dn.	40 cps Up.	40 cps Dn.
A. (3) Readings all zero.				
B. Fig. 142.	.05	.07	.045	.045

R'11 - Photo 366. 5" magazine, compartment B-19-MP. Directed up on top of archway above second platform at frame 77-1/2.

Graph	20 cps Up.	20 cps Dn.	40 cps Up.	40 cps Dn.
A. (3) Readings all zero.				
B. Fig. 143.	.11	.10	.01	.03

R'12 - Not installed.

R'13 - Photo 368. Main battery control room. Directed up on deck at centerline of ship at frame 51-1/2.

Graph	20 cps		40 cps	
	Up.	Dn.	Up.	Dn.
A. (2) Fig. 133	.025	.92	.01	.02
B. Fig. 144	.205	.145	.045	.0[illegible]

R'14 - Photo 369. Directed to port at same location as R'13.

Graph	20 cps		40 cps	
	Up.	Dn.	Up.	Dn.
A. (2) Readings all zero.				
B. Records lost.				

R'15 - Photo 368. Directed forward at same location as R'13.

Graph	20 cps		40 cps	
	Up.	Dn.	Up.	Dn.
A. (2)	.01	0	0	0
B. Fig. 145	.04	.06	.015	.02

COMMENTS

Able Range 5187 ft. Bearing 59°

With the exception of G6 and G9, the putty gages which had readings were above the waterline in reasonably exposed structures. Of the putty gages above the waterline, G20 alone was directed to port; all others were so directed that the components of acceleration away from the burst were not measured. Therefore, the readings are too low to be representative of the maximum shock accelerations on this ship.

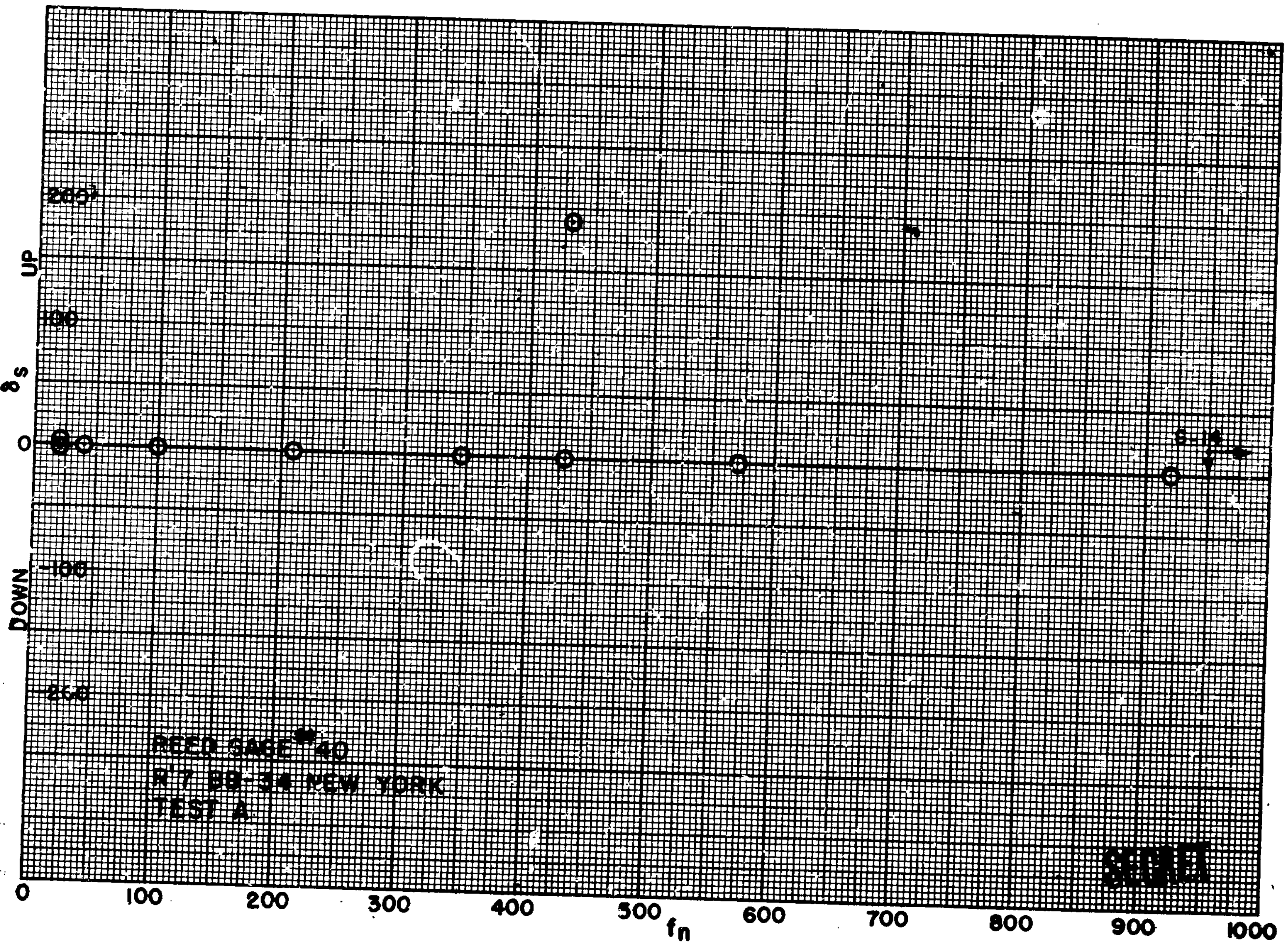
The only reed gages in the superstructure were R'13, R'14, and R'15. Of these, R'13 and R'15 gave very slight readings. R'7 had slight readings in the aft radio room.

Baker Range 2725 ft. Bearing 183°

Due to the orientation of this ship, it is to be expected that the gage readings were lower than they would have been had the ship been broadside to the burst. D.S.M. reports abundant evidence of shock particularly aft of the boiler rooms, that is, aft of the G17,R'11 location. Several hull seams opened in the vicinity of G15 and R'8, flooding the compartment in which they were located.

All the putty gage readings were under 100g which may seem surprising in view of the shock damage. However, the only putty gage not on the shell of a ship to give a reading over 100g. was the vertical putty gage in the DD402 superstructure. Since the New York putty gages can be regarded as "interior" gages, their readings are not unusual. The existence of higher accelerations in the towers than occurred at the base of the towers seems to indicate appreciable air blast. This indication is supported by the reed gage records.

The reed gage records do not indicate any marked predominant frequencies. Most records are of such low amplitude that the probable error is adequate to account for apparent peaks. The largest 20 cycle reed deflection was .155 inches and the largest 40 cycle reed deflection was .095 inches. These are deflections which would be caused by instantaneous velocity changes of 2.3 and 2.9 ft./sec. respectively, so in terms of velocity change the shock is considered to be fairly low. It is suggested that more damage occurred than would have occurred in a more modern ship which would in part account for the apparent discrepancy between gage readings and damage reported.



UP
DOWN
$\frac{X}{\delta_s}$
200
100
0
-100
-200
0
100
200
300
400
500
600
700
800
900
1000
f_n
REED GAGE #40
R'7 BB-34 NEW YORK
TEST A
SECRET

FIG. 132

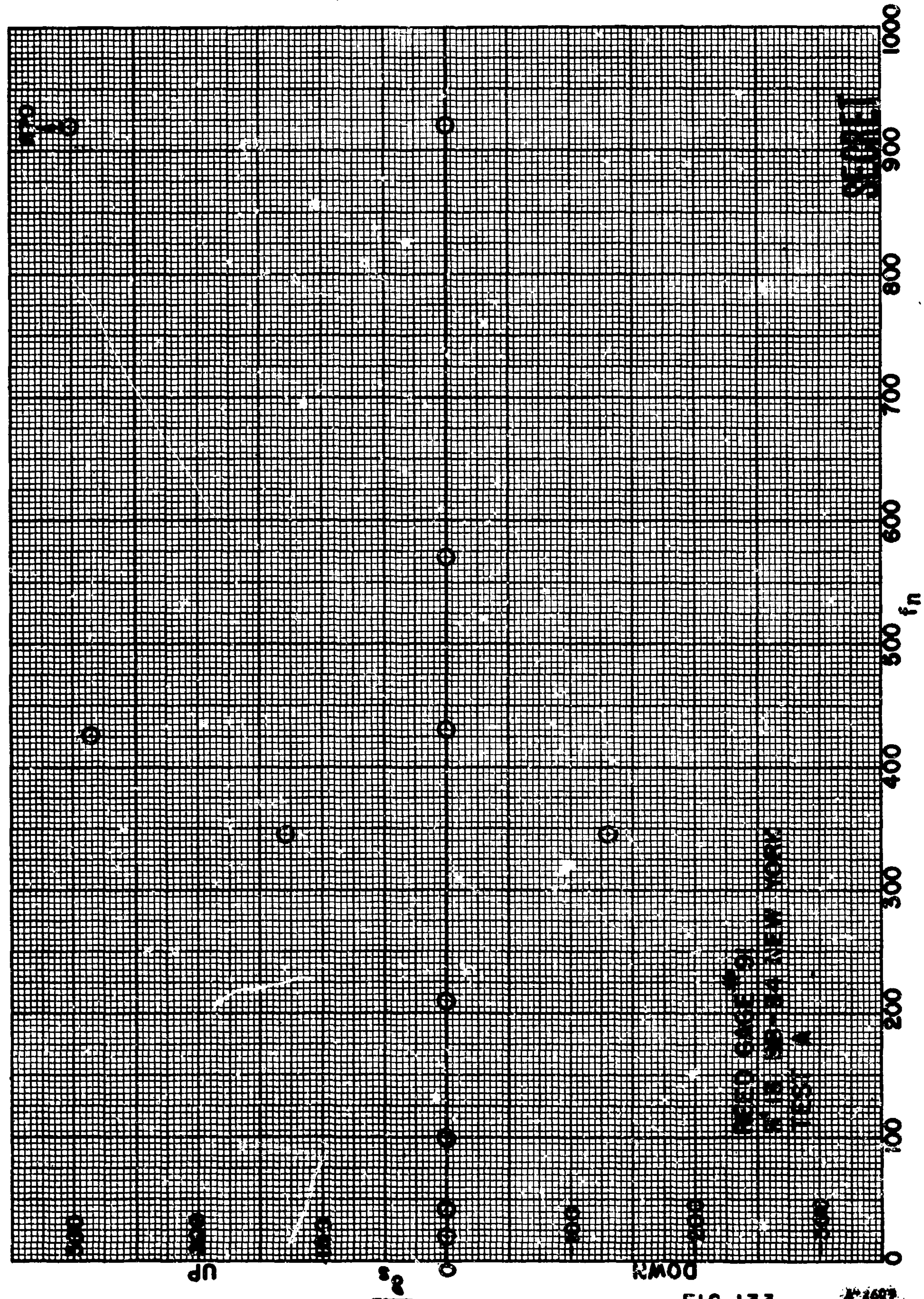

SECRET
REED GAGE #9
K-15 SD-34 NEW YORK
TEST A
UP
DOWN
$\frac{s_2}{X}$
f_n
0
100
200
300
400
500
600
700
800
900
1000

FIG. 133

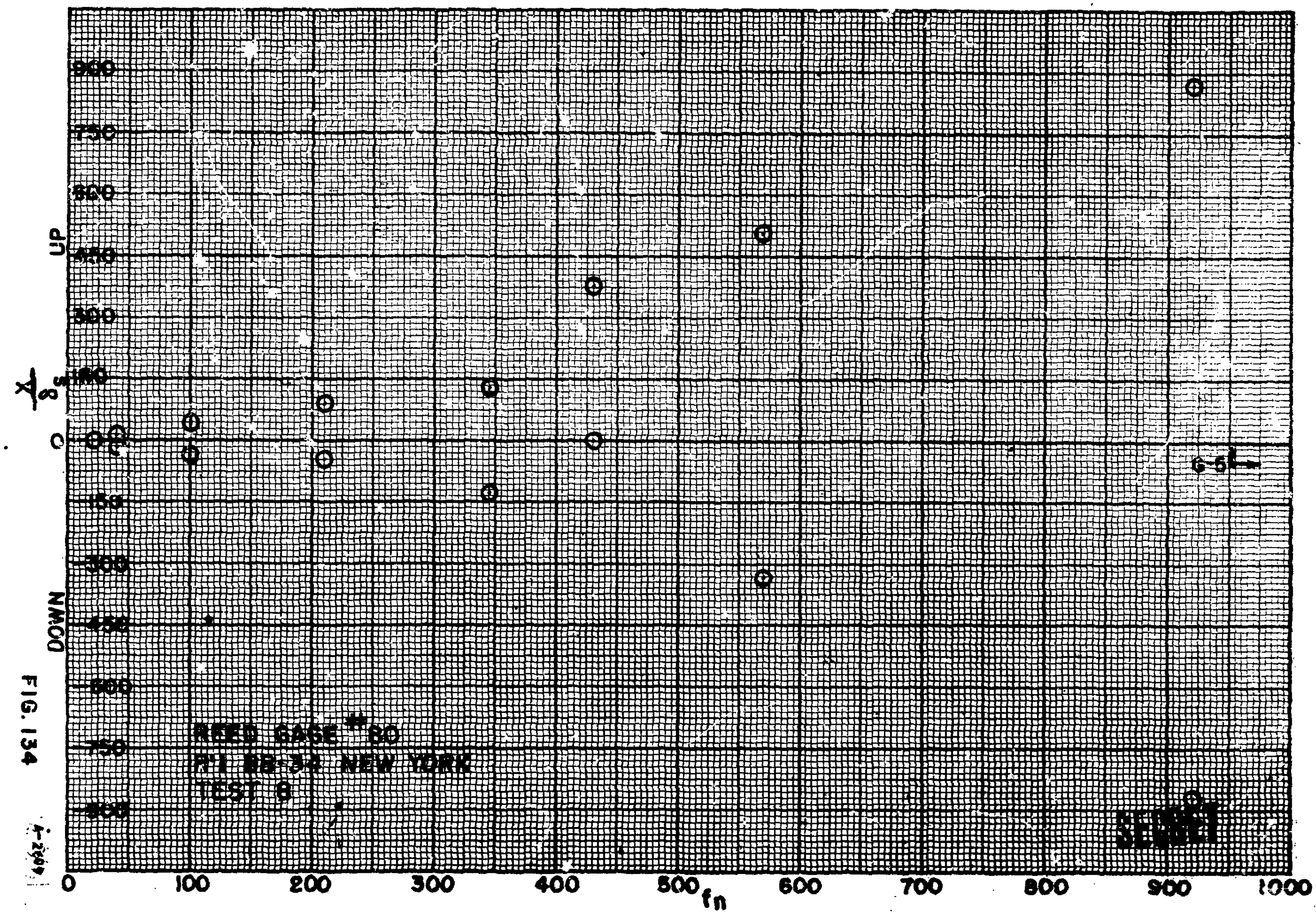
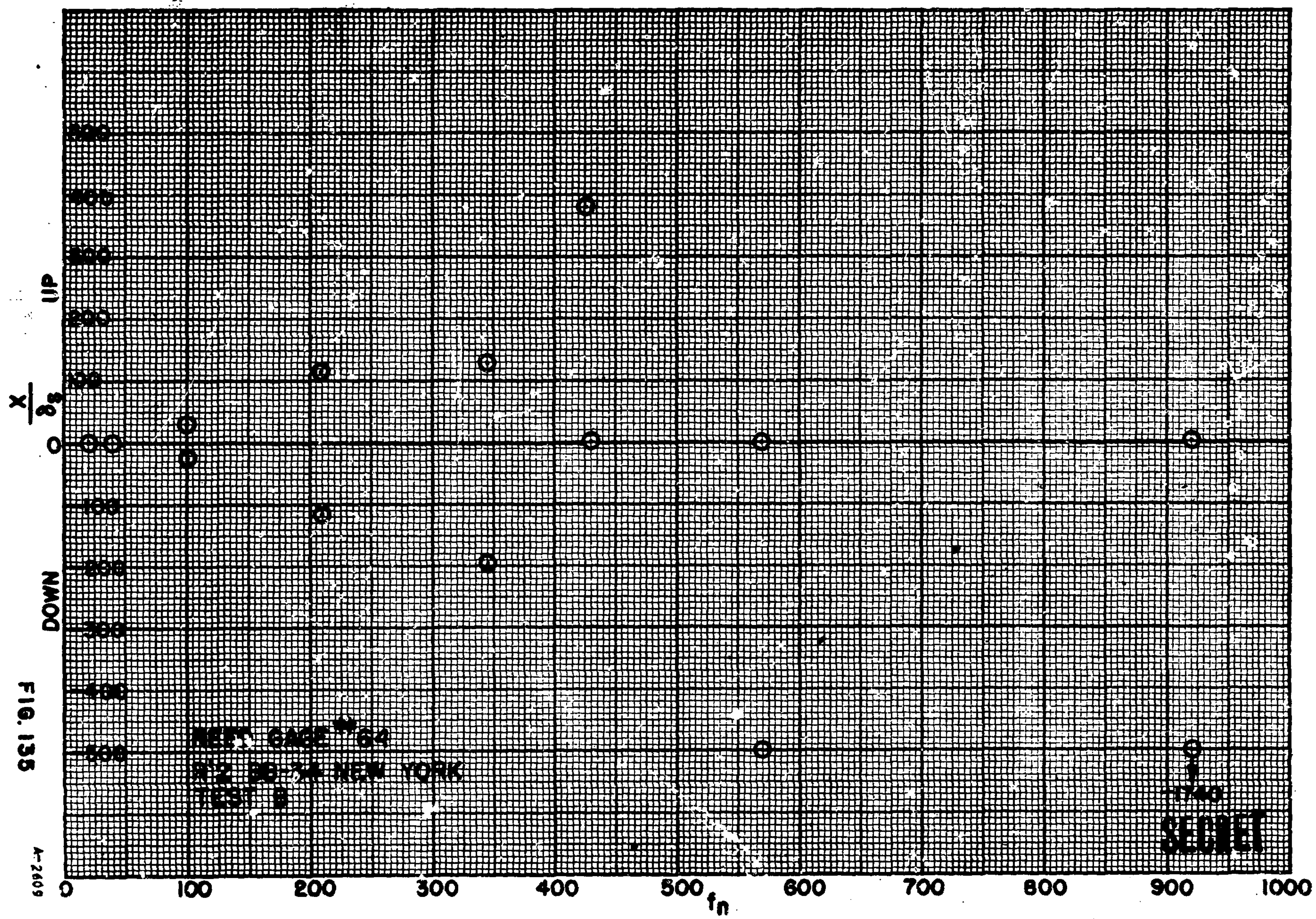


FIG. 134

A-2609



UP
DOWN
500
400
300
200
100
0
100
200
300
400
500
GAGE
64
NEW YORK
TEST B
1740
SECRET
0
100
200
300
400
500
600
700
800
900
1000
f_n
$\frac{X}{\delta_s}$
A-2609

FIG. 135

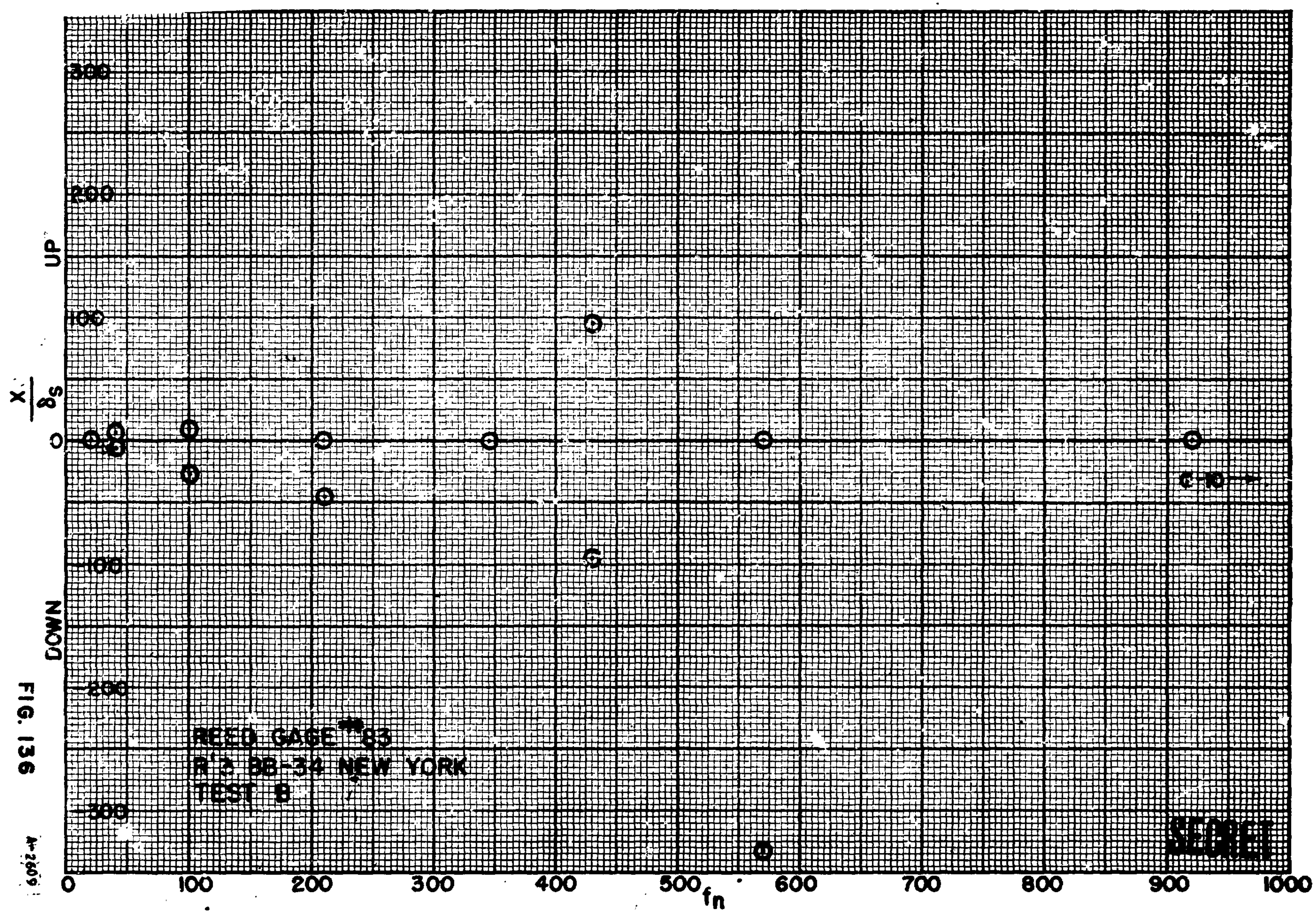
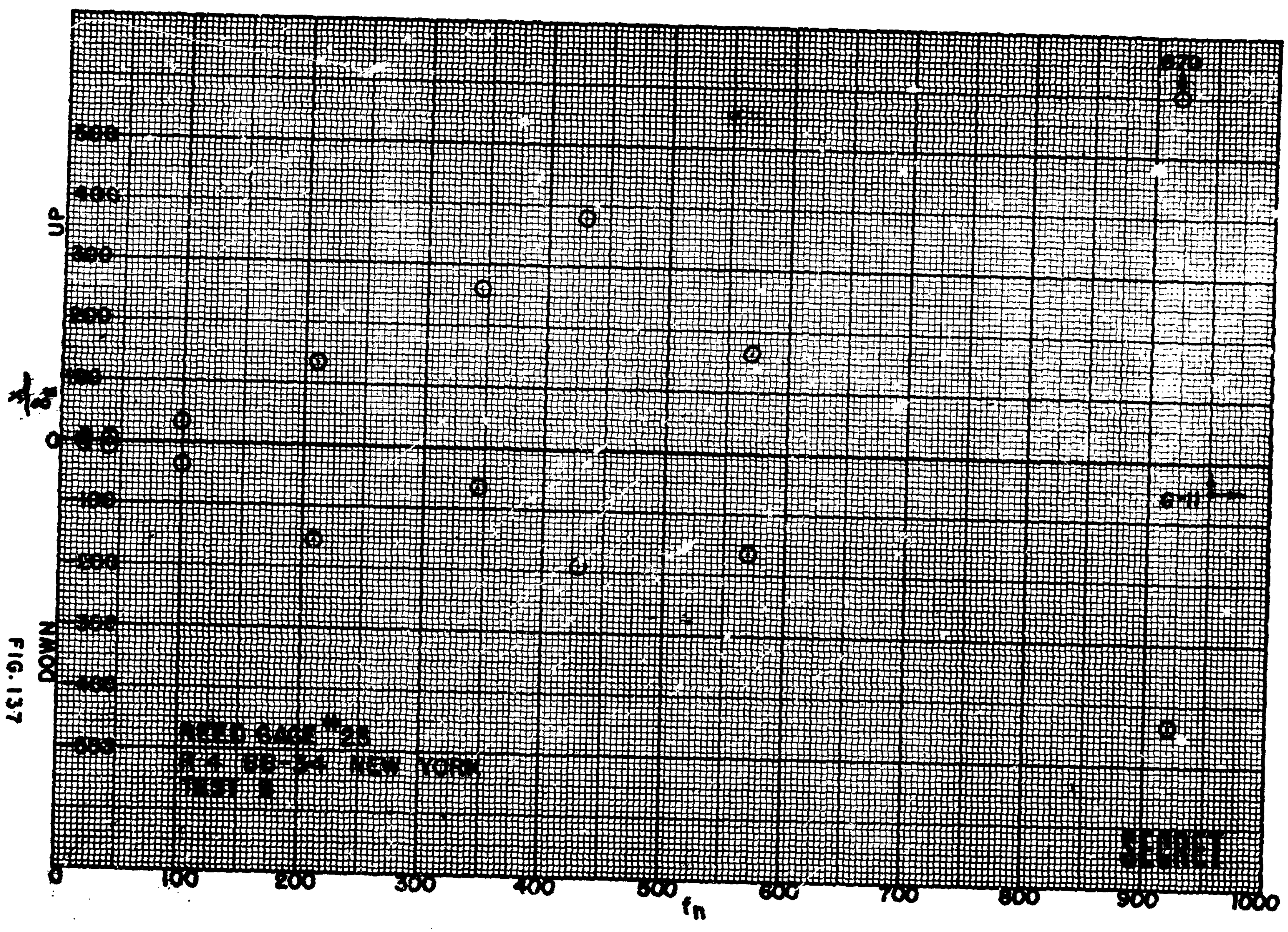


FIG. 136

A-2609



UP
DOWN
500
400
300
200
100
0
-100
-200
-300
-400
-500
0
100
200
300
400
500
600
700
800
900
1000
fn
REED GAGE #25
R-4 GB-24 NEW YORK
TEST B
SECRET

FIG. 137

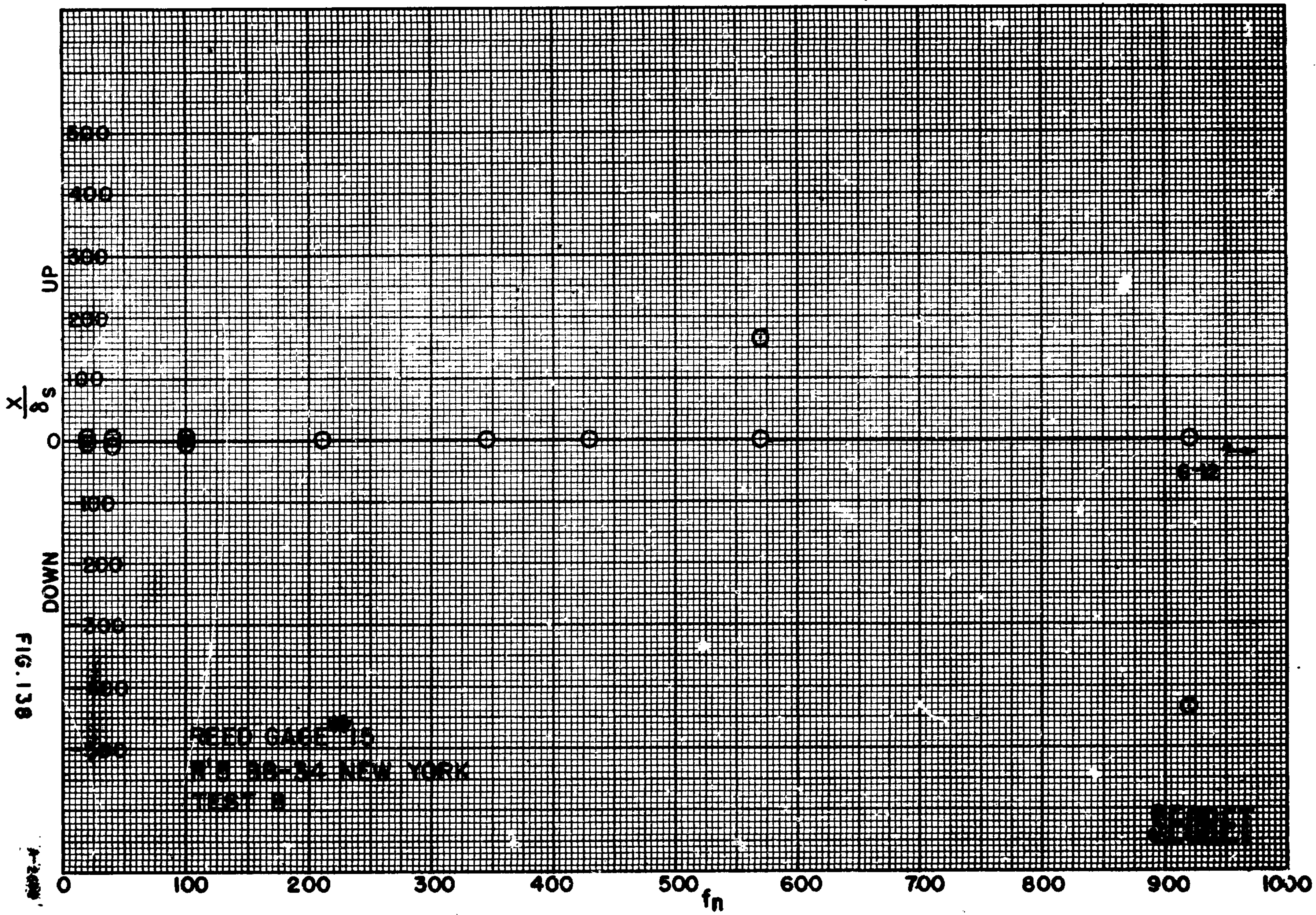
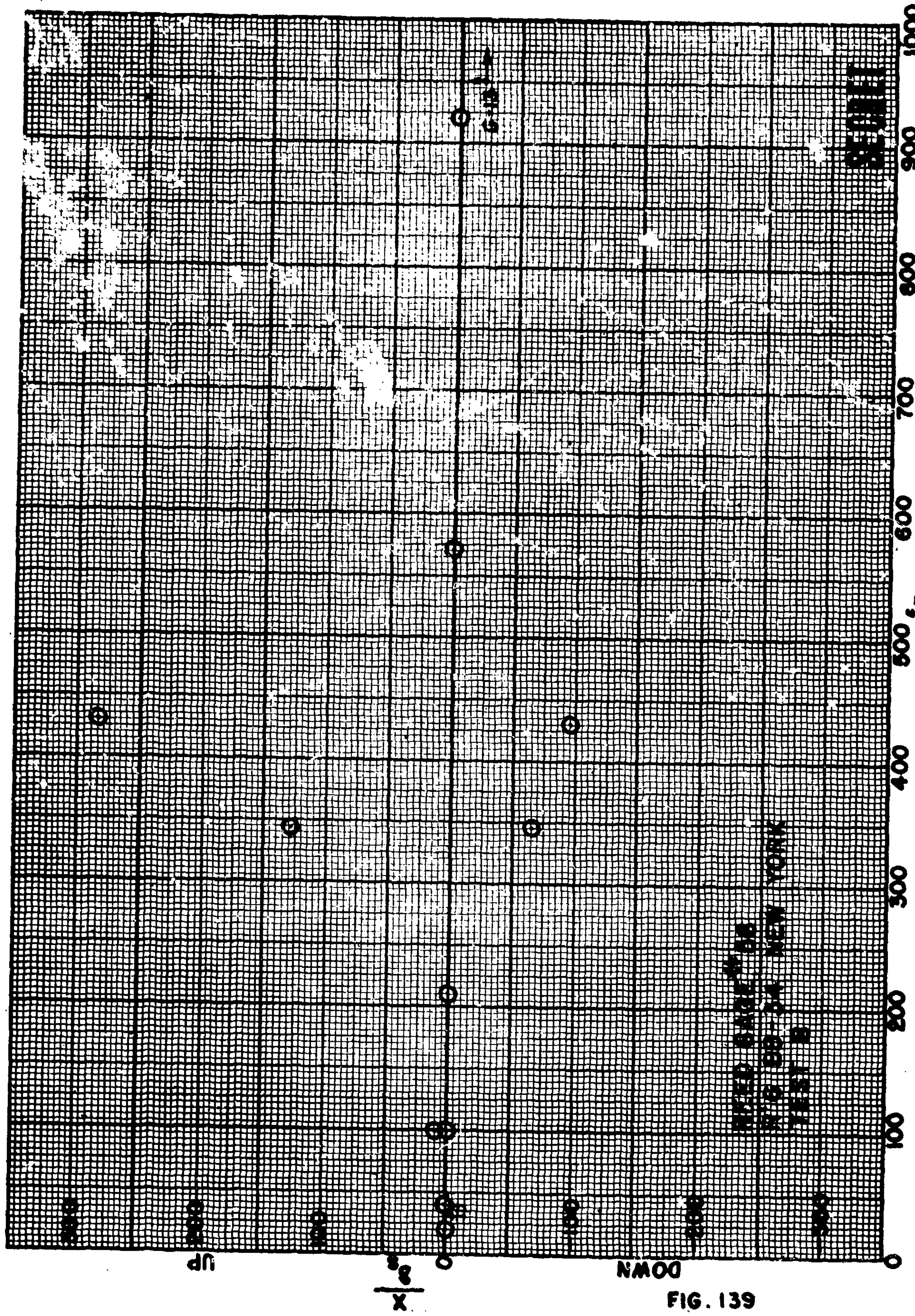

REED GAGE 15
BB-34 NEW YORK
TEST B
UP
DOWN
$\frac{X}{\delta_s}$
500
400
300
200
100
0
100
200
300
400
500
0
100
200
300
400
500
600
700
800
900
1000
f_n

FIG. 138



SECRET
NEW YORK
TEST B
0
100
200
300
400
500
600
700
800
900
1000
f_n
UP
DOWN
$\frac{s_g}{X}$

FIG. 139

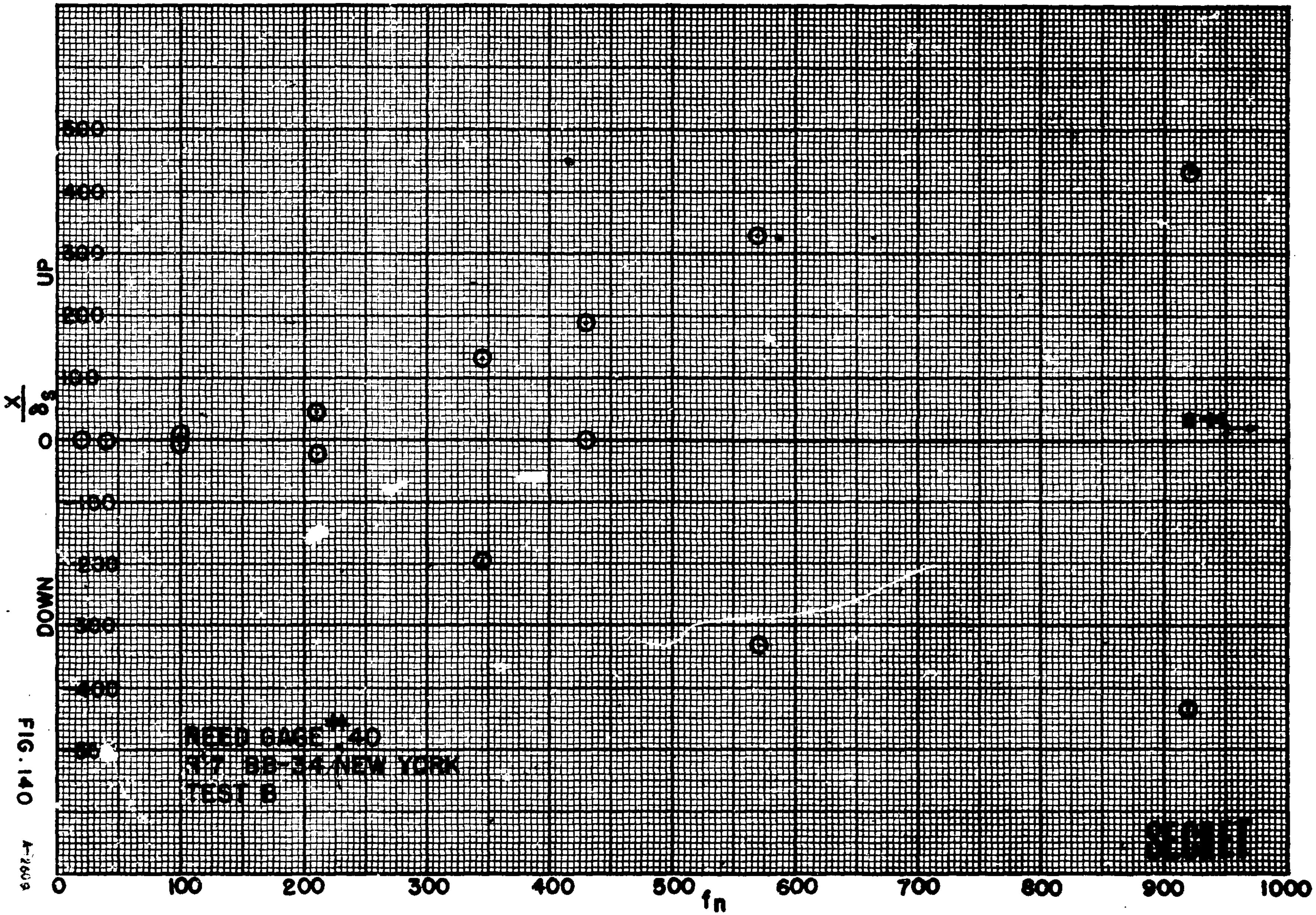


FIG. 140

A-2609

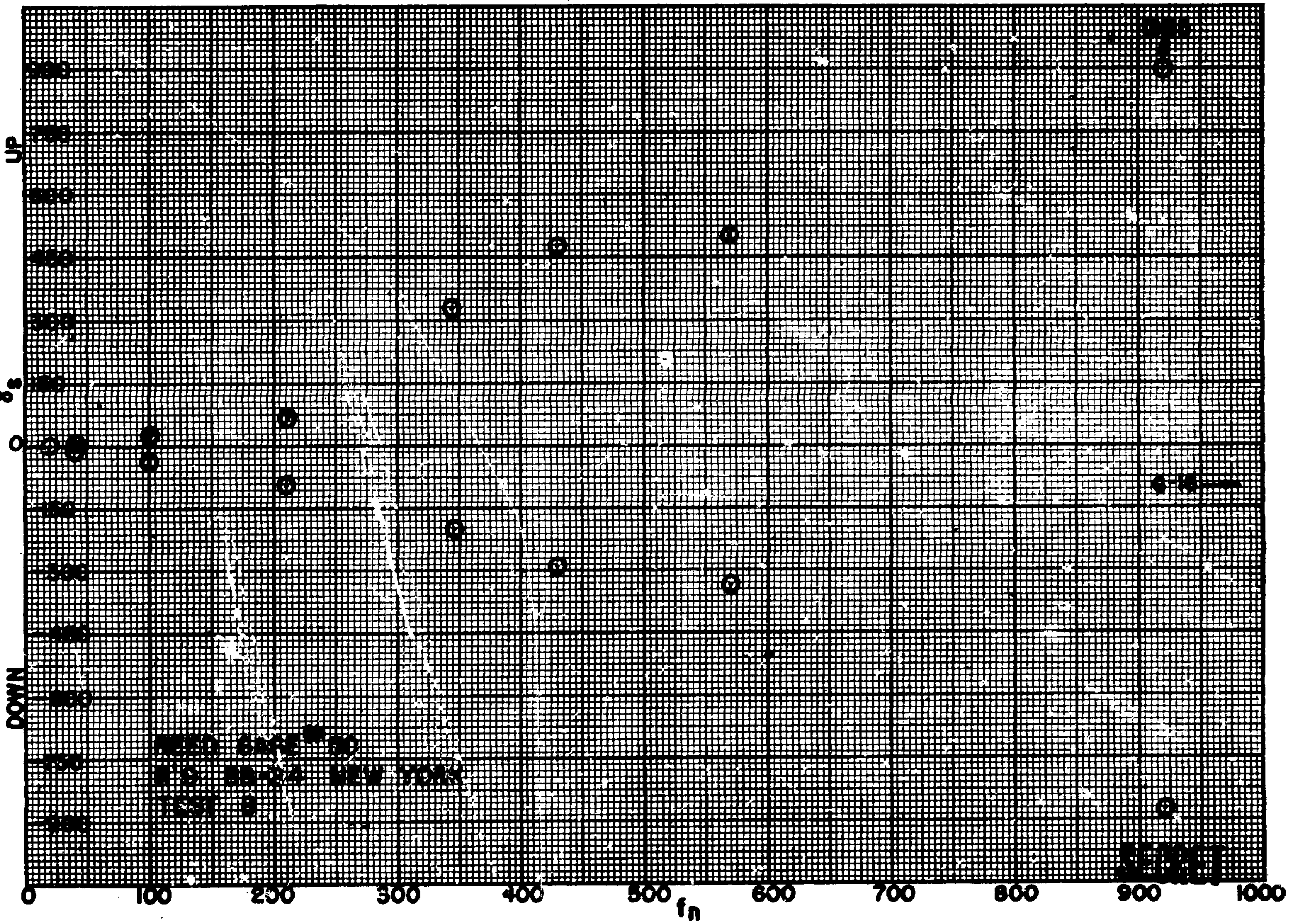


FIG. 141

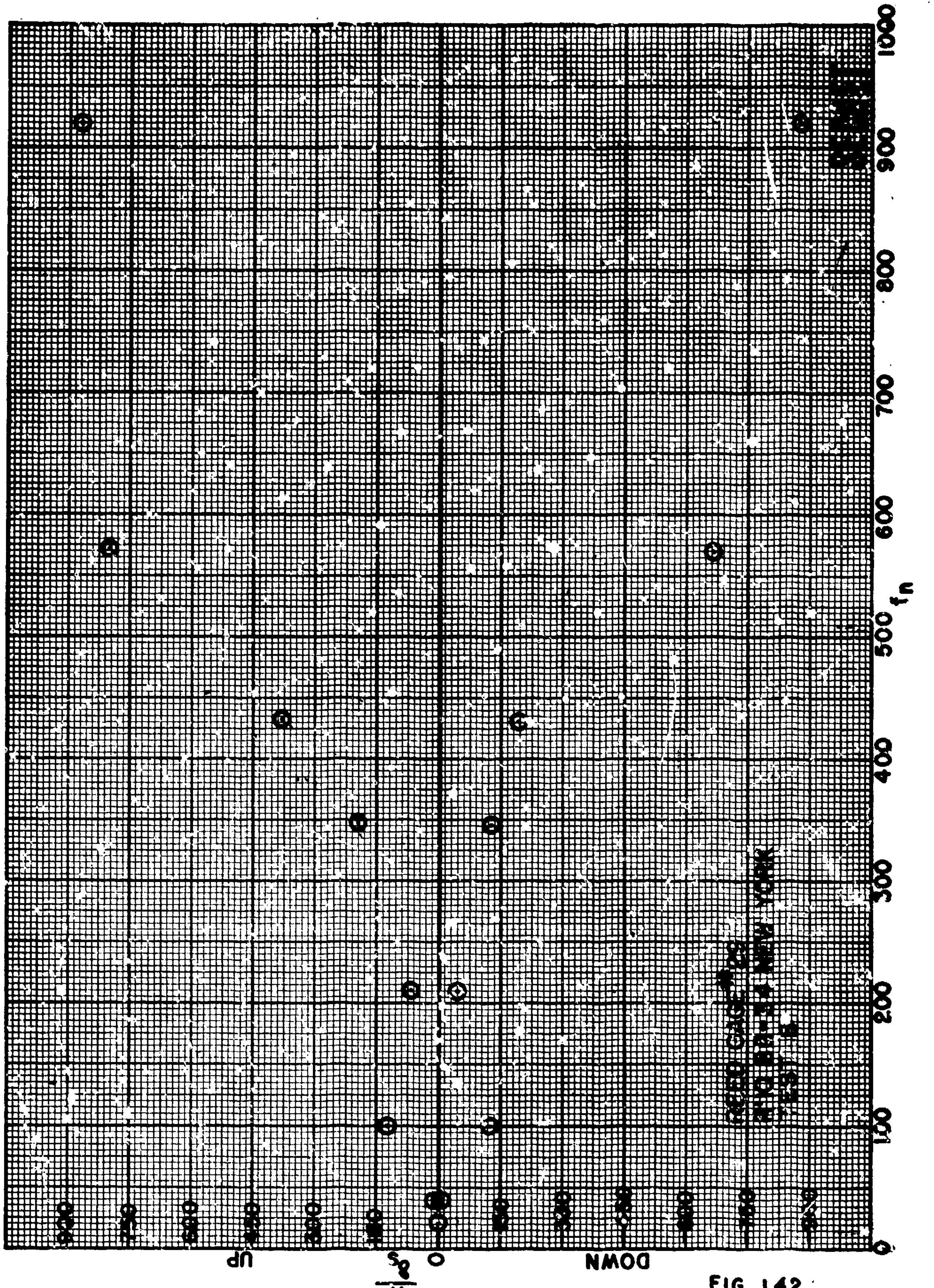


FIG. 142

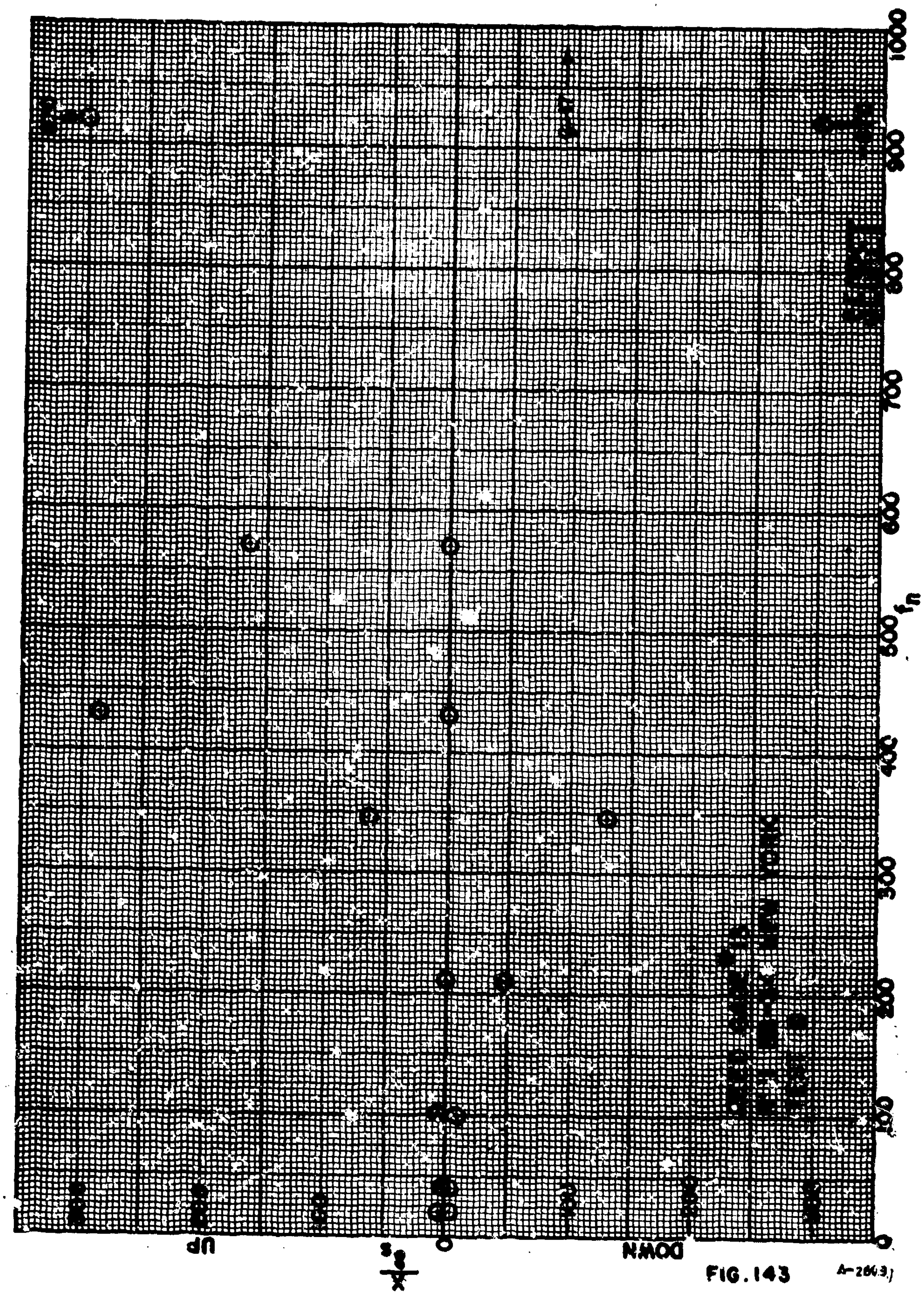


FIG. 143

A-26631

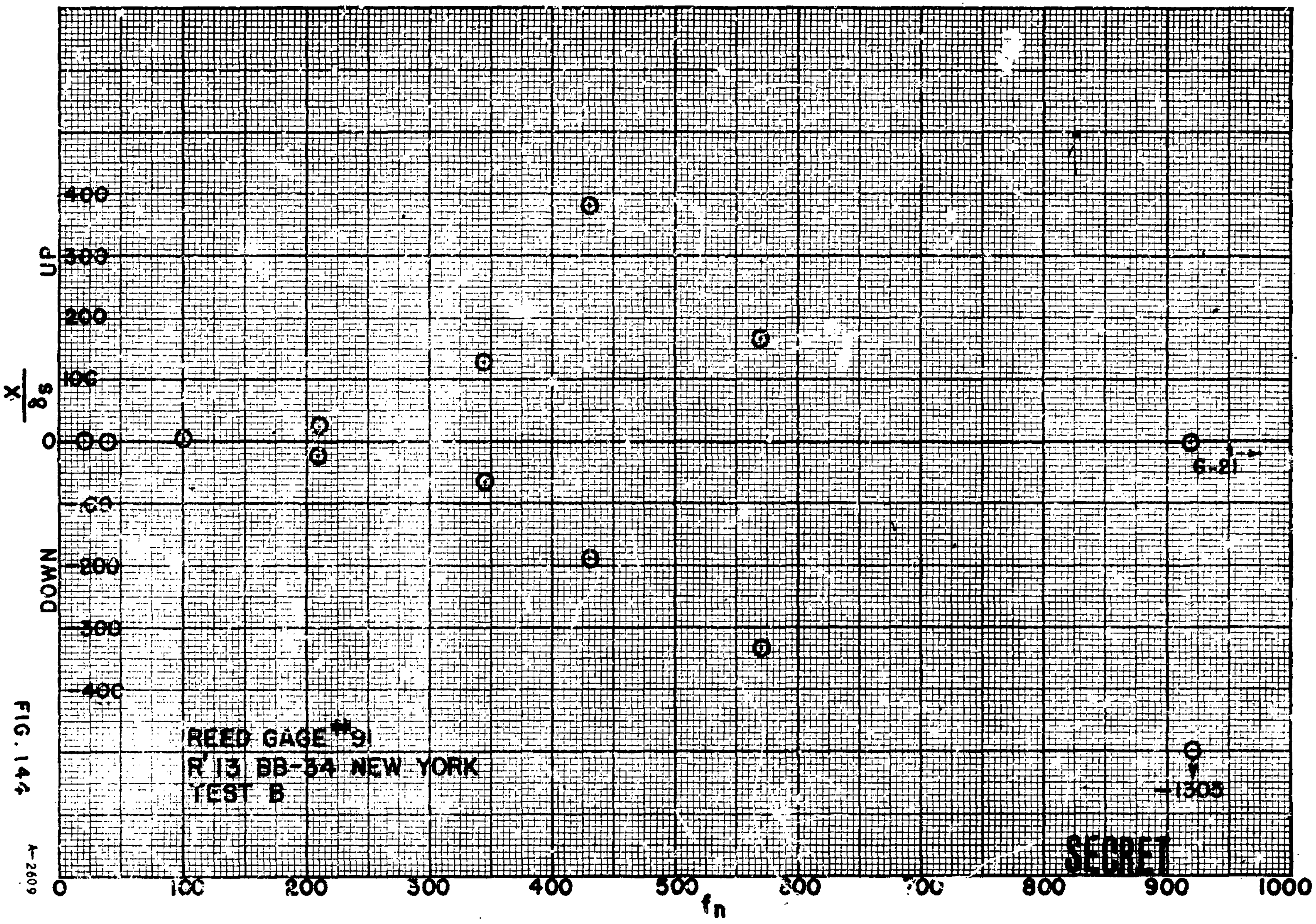


FIG. 144

A-2609

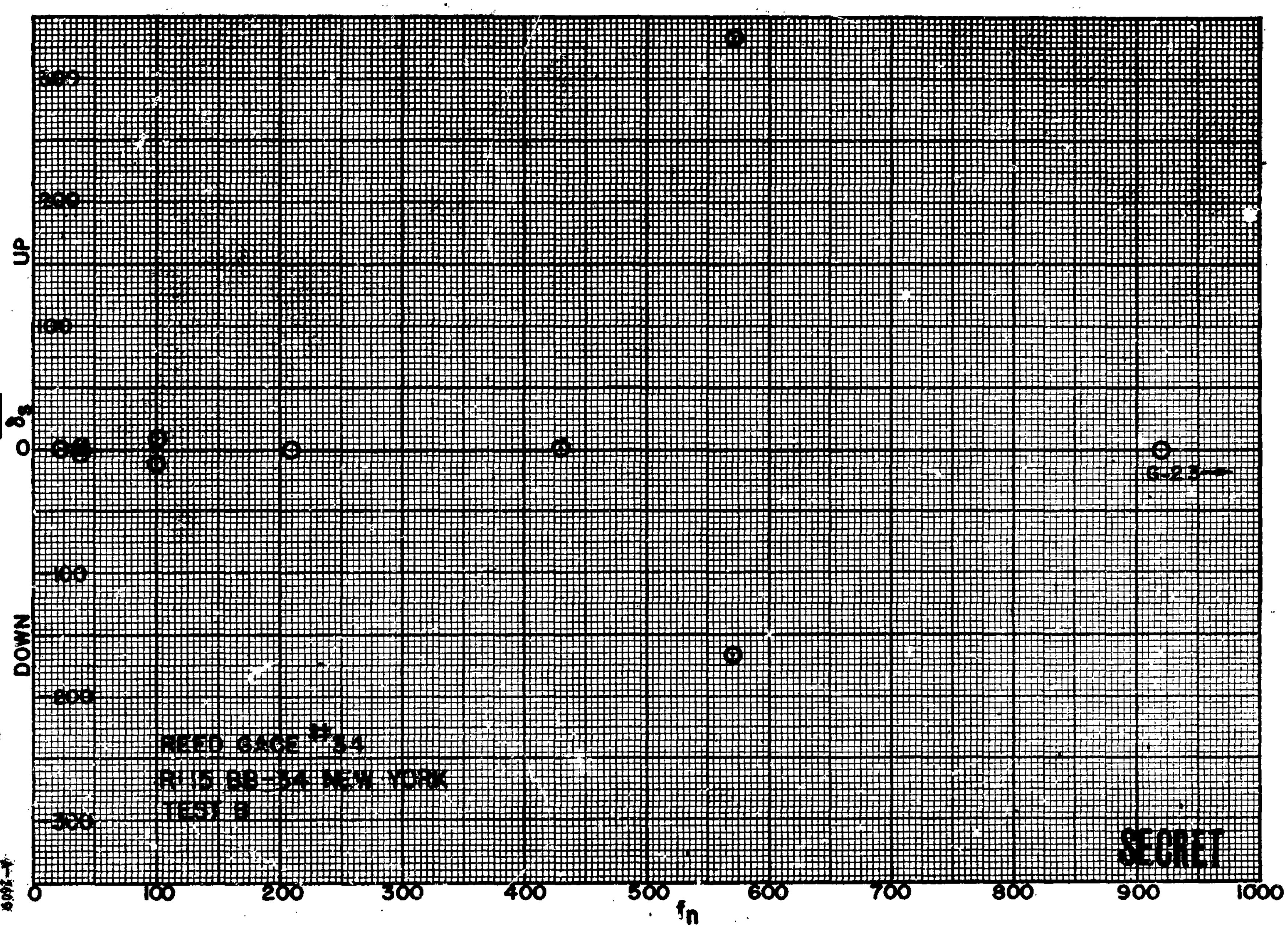


FIG. 145

A-2609

BB 36 NEVADA GAGE LOCATIONS

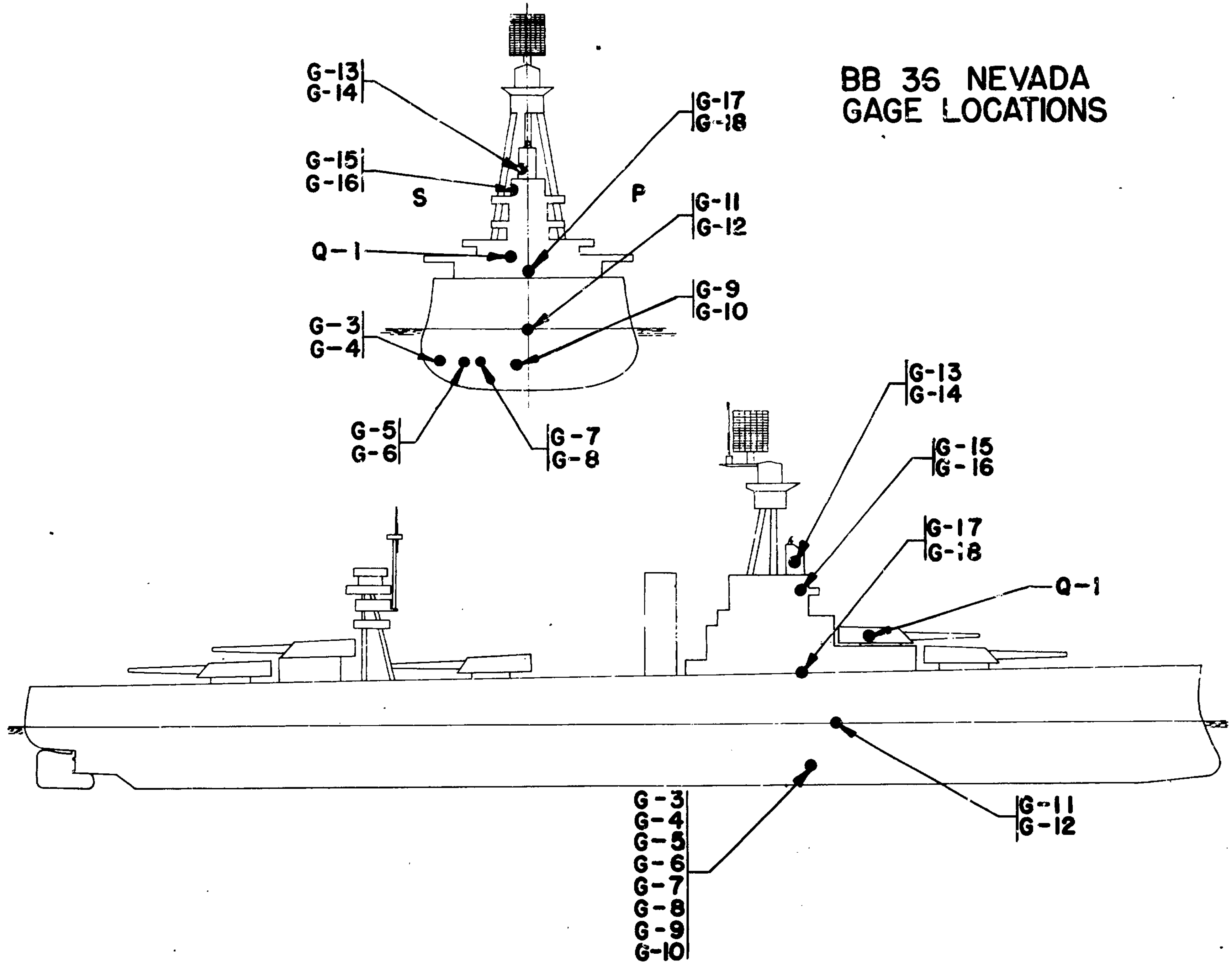


FIG. 146

BB36 - NEVADA

Putty Gages

G3 - Photo 375. Compartment A-539-E. Directed up on stiffener on starboard bulkhead at frame 58, 3' above 2nd platform.

A. (3) Less than 20g. B. 90g.

G4 - Photo 375. Same as G3 except directed to port 4' above 2nd platform.

A. (3) Less than 20g. B. 90g.

G5 - Photo 376. Compartment A-539-E. Directed to port on vertical stiffener on frame 60 (after bhd. of compartment), 22" above second platform. Second stiffener starboard of port bulkhead of compartment.

A. (3) Less than 20g. B. 50g.

G6 - Photo 376. Directed up 34" above 2nd platform, otherwise, same as G5.

A. (3) Less than 20g. B. 50g.

G7 - Photo 377. Compartment A-539-E. Directed up on port bulkhead stiffener at frame 59, 4' above second platform.

A. (3) Less than 20g. B. 40g.

G8 - Photo 377. Directed to starboard 5' above 2nd platform. Otherwise same as G7.

A. (3) Less than 20g. B. 20g.

G9 - Photo 378. Compartment A-543-E. Directed to port on stiffener on after bulkhead of compartment (frame 60), 2' starboard of ship, 6' above second platform.

A. (3) Less than 20g. B. 20g.

G10 - Photo 378. Directed up 7' above 2nd platform. Otherwise, same as G9.

A. (3) Less than 20g. B. 20g.

BB36 - NEVADA

Putty Gages

G11 - Photo 379. Compartment A-327-C. Directed up on stiffener on aft bulkhead (approx. frame 55 1/2) at centerline of ship 10" above 3rd deck.

A. (3) 60g. B. Less than 20g.

G12 - Photo 379. Directed to port 18" above 3rd deck. Otherwise, same as G11.

A. (3) Less than 20g. B. Less than 20g.

G13 - Photo 380. 5" battery director. Directed to port on starboard side 14" above deck on transverse centerline about frame 61.

A. (1) 90g. B. 40g.

G14 - Photo 380. Directed up 20" above deck. Otherwise, same as G13.

A. (1) 200g. B. Less than 20g.

G15 - Photo 381. Main battery F. C., compartment A-0601-. Directed up on starboard stiffener, 5' forward of aft bulkhead, 4' above deck.

A. (1) Less than 20g. B. --

G16 - Photo 381. Directed to port 5' above deck. Otherwise same as G15.

A. (1) 40g. B. 30g.

G17 - Photo 382. Compartment A-0114-L (mid ships). Directed to port on starboard bulkhead stiffener at frame 62, 9' starboard of centerline of ship and 3' above deck.

A. (3) Less than 20g. B. Less than 20g.

G18 - Photo 382. Directed up 4' above deck. Otherwise, same as G17.

A. (3) Less than 20g. B. 20g.

INDENTER GAGES

Q 1 - Photo 383. #2 Turret, Starboard gun. Below shell table. Vertical

A		B	
Up	165g.	Up	45g.
Dn.	100	Dn	50
30°	175	0°	85
120°	190	90°	70
210°	325	180°	85
300°	175	270°	90

COMMENTS

Able Range 2376 ft. Bearing 192°

Putty gages G11, G13, G14, and G16 alone had readings. The G11 reading is either spurious or not representative of its type of location. G13, G14, and G16 were on exposed superstructure bulkheads. Q 1 within the massive #2 14" gune turret gives much higher readings for no apparent reason. Damage due to blast pressure was fairly severe and some shock damage was reported by DSM.

Baker Range 3100 ft. Bearing 90°

The bearing of the explosion from this ship was as planned. DSM reports a fairly large amount of shock including many loosened foundation bolts, floor plates and loose gear dislodged, dislodging of finder relays in the automatic telephone switchboard, excessive spilling of the gyro-compass mercury, broken pipe hangars, and shearing of the hold-down clip bolts of turret No. 2.

Putty gages G3, 6, 7, 10, 11, 14, 15, and 18 were directed up, G4, 5, 9, 12, 13, 16 and 17 were directed to port, and G8 was directed to starboard. The readings illustrate very well the decrease in peak acceleration with distance from the starboard shell. The G13 and G16 readings are probably due to airblast; the G18 reading may be due to either air or water pressure.

The indenter gage Q 1 in the No. 2 turret starboard side had a maximum reading of 90g.

P4

BB 38 PENNSYLVANIA

Indenter Gages

Q1 - Photo 384. Top of aft Mark 34 director. Directed up on armor plate top below antenna at approx. centerline of director.

	A		B
Up	150g.		Not installed.
Dn	25		
0°	85		
90°	55		
180°	65		
270°	90		

Q2 - Photo 385. Starboard aft 5"/38 gun turret. Mount 7. Directed up on deck over light deck beam.

	A		B
Up	70g.	Up	245
Dn	30	Dn	185
20°	65	0°	310
110°	140	90°	515
200°	20	180°	150
290°	35	270°	445

Q 3 - Photo 386. Directed up on top of starboard Mark 37 director near base of antenna foundation.

	A		B
Up	60g	Up	30g.
Dn	25	Dn	-
15°	45	70°	30
105°	40	160°	15
195°	70	250°	25
285°	50	340°	25

Q4 - Photo 387. Inside starboard Mark 37 director. Directed up on top of beam between control officer's seats.

	A		B
Up	35g.	Up	30g.
Dn	25	Dn	25
80°	70	0°	30
170°	45	90°	30
260°	-	180°	-
350°	45	270°	25

Q 5 - Photo 388. Space A-704. Main deck, directed down on frame 82 overhead I-beam, 15' inboard of starboard side.

A	B	
Not installed.	Up	25g
	Dn	45
	0°	20
	90°	25
	180°	-
	270°	20

Q6 - Photo 389. Compartment C-501-MS. Directed down on overhead I-beam, frame 83, 3rd deck in ammunition passageway.

A	B	
Not installed.	Up	25g.
	Dn	45
	0°	20
	90°	25
	180°	-
	270°	20

COMMENTS

Able Range 5229 ft. Bearing 208°

Indenter gages Q1 and Q2 had one reading apiece which were due to shock and they are apparently free from rattling.

Baker Range 3550 ft. Bearing 132°

All gages except Q2 have very low readings. Q2 apparently rattled under a fairly strong shock.

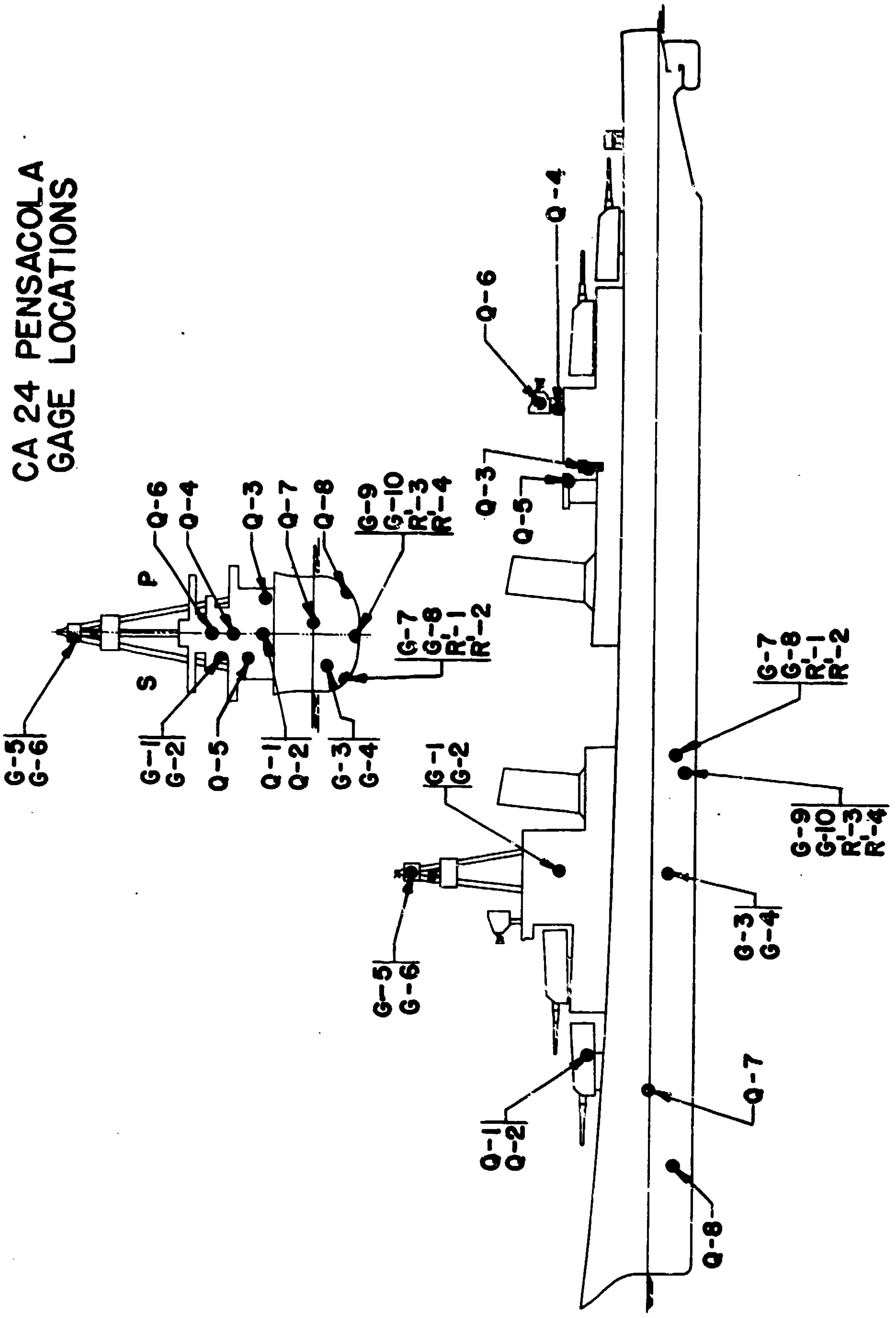


FIG. 147

A-2609

CA24 - PENSACOLA

Putty Gages

G1 - Photo 390. Main radio room. Directed up on deck 42" inboard of starboard outboard bulkhead at frame 45.

A. (2) Less than 20g. B.

G2 - Photo 391. Main radio room. Directed to port on vertical stiffener on starboard bulkhead 39" above deck. Frame 44.

A. (1) Less than 20g. B. 40g.

G3 - Photo 395. Gyro-compass room, compartment A-422-E. Directed up on vertical stiffener on starboard bulkhead, 4'6" above deck at frame 43.5.

A. (3) Less than 20g. B. 40g.

G4. Gyro-compass room, compartment A-422-E. Directed to port on vertical stiffener on starboard bulkhead, 5'6" above deck at frame 43.5.

A. (3) Less than 20g. B. 45g.

G5. Main battery fire control room, compartment A-0601c. Directed up on vertical stiffener on starboard bulkhead 18" above deck, 40" forward of frame 47.

A. (1) 80g. B. 30g.

G6. Main battery fire control room, compartment A-0601C. Directed to port on vertical stiffener on starboard bulkhead 30" above deck.

A. (1) 100g. B. 45g.

G7. Forward fire room, compartment B-1. Directed up on bracket on starboard inner bottom, 4' above lower grating level at frame 50.

A. (3) 50g. B. 250g.

G8. Forward fire room, compartment B-1. Directed up on bracket on starboard inner bottom, 4' above lower grating level at frame 50.

A. (3) Less than 50g. B. 200g.

G9. **Forward fire room, compartment B-1. Athwartships on top of keel aft of frame 48.**

A. (3) Less than 50g. B. 75g.

G10. Same as G9 except directed up.

A. (3) Less than 50g. B. not recovered.

Reed Gages.

R'1. Forward fire room, compartment B-1. Directed up on bracket on starboard inner bottom 4' above lower grating level at frame 49.

Graph	20 cps. Up	20 cps. Dn	40 cps Up	40 cps Dn
A. (3) Readings all zero.				
B. Fig. 148.	.88	.79	.34	.31

R'2. Forward fire room, compartment B-1. Directed to port on bracket on starboard inner bottom 4' above lower grating level at frame 49.

Graph	20 cps. Up	20 cps. Dn	40 cps Up	40 cps Dn
A. (3) Readings all zero.				
B. Fig. 149.				

R'3. Forward fire room, compartment B-1. Directed up on top flange of keel saddle on centerline of keel aft of frame 48.

A. Not recovered.

R'4. Forward fire room, compartment B-1. Athwartships of top flange of keel saddle on centerline of keel aft of frame 48.

A. Not recovered.

Indenter Gages

Q1 - Photo 396. Forward 8" turret. Vertical on top of 12" beam under starboard shell tray.

A		B	
Up	270g.	Up	360g.
Dn	160	Dn	260
70°	395	60°	845
160°	130	150°	705
250°	380	240°	770
340°	485	330°	705

Q2 - Photo 396. Forward 8" turret. Athwartships on starboard side of starboard tray.

A		B
Up	325g.	Not installed
Dn	320	
0°	50	
90°	145	
180°	80	
270°	145	

Q3 - Photo 397. Mark 63 director foundation. On starboard horizontal support 6'8" above deck. Deck above well deck port side aft.

A					B				
brg.	0°	elev.	0°	430g.	brg.	62°	elev.	12°	275g.
"	90°	"	25°	260	"	90°	"	65°	150
"	90°	"	-65°	115	"	122°	"	22°	815
"	180°	"	0°	405	"	208°	"	-12°	330
"	270°	"	-25°	170	"	270°	"	-65°	225
"	270°	"	65°	110	"	302°	"	-22°	875

Q4 - Photo 398. Mark 33 director aft. On forward vertical stiffener at foundation column 1'11" above deck.

A		B	
Up	55g.	Up	230g.
Dn	80	Dn	260
0°	70	0°	155
90°	-	90°	350
180°	75	180°	160
270°	110	270°	860

Q5. Starboard Mark 51 director. On deck of search light platform over intersection of I-beams.

A		B	
Up	225g.	Up	210g.
Dn	50	Dn	180
80°	110	60°	125
170°	90	150°	155
260°	100	240°	125
350°	55	330°	-

Q6 - Photo 399. Aft mark 33 director. Inside starboard door on forward cross brace about 30'' above deck of director.

A		B	
Up	55g.	Up	60g.
Dn	50	Dn	45
70°	55	20°	-
160°	40	110°	-
250°	50	200°	40
340°	50	290°	-

Q7 - Photo 400. Compartment A-203-1L. On deck just outside barbette wall of #1 turret at frame 21.

A

Not installed.

B	
Up	260g.
Dn	190
60°	150
150°	260
240°	90
330°	445

COMMENTS

Able Range 2694 ft. Bearing 172°

The gages below the waterline had not shock indications. G5 and G6 recorded 80g. up and 100g. to port on the starboard bulkhead of the main battery fire control tower. It is surprising that G1 did not record a shock on the starboard bulkhead of the room.

The indenter gage readings are difficult to understand. Both Q1 and Q2 inside the forward 8'' gun turret had high readings. The readings of the two gages are not at all consistent with one another in indicating the direction of maximum shock though both are of the same approximate magnitude. It is not clear why this turret should have such high readings. Q3, Q4 and Q5 were located externally on ordinance equipment pedestals. The 405g. and 430g. readings of Q3 were in opposite directions and apparently due to rattling of the weight. It seems reasonable to assign a value to these locations of 100 and 250g. In contrast with the readings inside the forward 8' turret, the reading inside the aft mark 33 director turret was not over 55g.

Baker Range 2200 ft. Bearing 357°

The instrumentation was planned for exposure of the starboard side to the pressure wave rather than bow-on exposure. Due to the close range of this ship, there was tremendous shock damage, as reported by D.S.M.

Putty gage accelerations in the superstructure and in the gyro compass room were about 50g. D.S.M. reported the gyro-compass springs to be broken. G7 and G8 were on the inner hull plating and recorded 250 and 200g. respectively. D.S.M. reported extensive shock damage in the boiler rooms and machinery spaces at locations comparable to these latter two gage locations. G9, athwartships on the keel saddle read 75g. which is to be expected since the major shock component must have been vertical at that location.

The two reed gage records recovered were R'1 vertical and R'2 directed to port at locations comparable to G7 and G8. Since these gages are of particular interest, the deflections of the reeds and the equivalent velocity changes are tabulated below.

	DEFLECTION-INCHES				VELOCITY CHANGE-FT./SEC.			
f cps	R'1		R'2		R'1		R'2	
	Up	Dn	Up	Dn	Up	Dn	Up	Dn
20	.88	.79	.34	.36	9.2	8.3	3.6	3.8
40	.34	.31	.15	.20	7.1	6.5	3.1	4.2
100	.145	.12	.13	.16	7.6	6.3	6.8	8.4
210	.08	.08	.04	.05	8.8	8.8	4.4	5.5
345	.025	.025	.05	.055	4.5	4.5	9.0	9.9
430	.03	.03	.065	.07	6.8	6.8	14.7	15.8
570	.03	.04	.045	.05	9.0	11.9	13.4	14.9
920	.03	.03	.01	.015	14.4	14.4	4.8	7.2

The R'1 and R'2 frequency response curves are not similar in shape, though one would expect them to be since presumably the gages were subjected to components of the same shock motion. R'1 indicates exciting frequencies of 200 cps. and over 1000 cps., R'2 indicates exciting frequencies of 100-200 cps. and 600 cps. The only simple explanation requires that the point of attachment of R'1 be stiffer than that of R'2 but this is not completely satisfactory.

The accelerations of Q1 are very high but seem to be due to rattling. D.S.M. reports that the turret in which this gage was located lifted from its training race by breaking the turret hold-down clips and landed heavily on the race. Therefore these readings are due to special secondary shock conditions. Q3 had high readings also apparently due to rattling; Q4 read 860g. acceleration to port and 350g. to starboard on the base of the mark 33 director aft. Q6 inside this director read only 60g. The reading of Q5 is lower than those of Q3 and Q4 and support the writer's belief that the Q3 and Q4 readings are not representative of this type of location. Q7 does not seem to have unreasonable readings but the impact of the No. 1 turret on its race could have caused the readings.

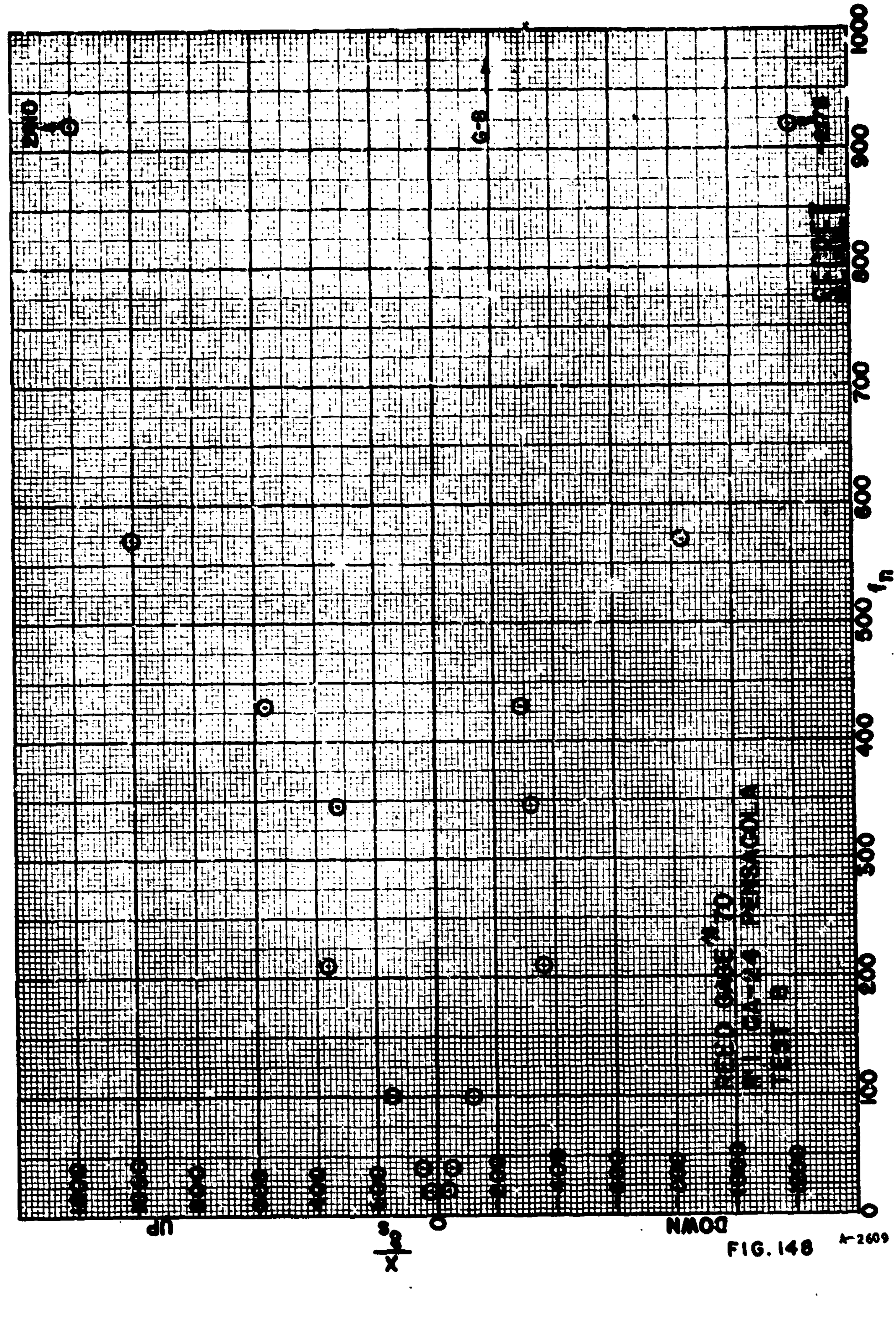


FIG. 148 A-2609

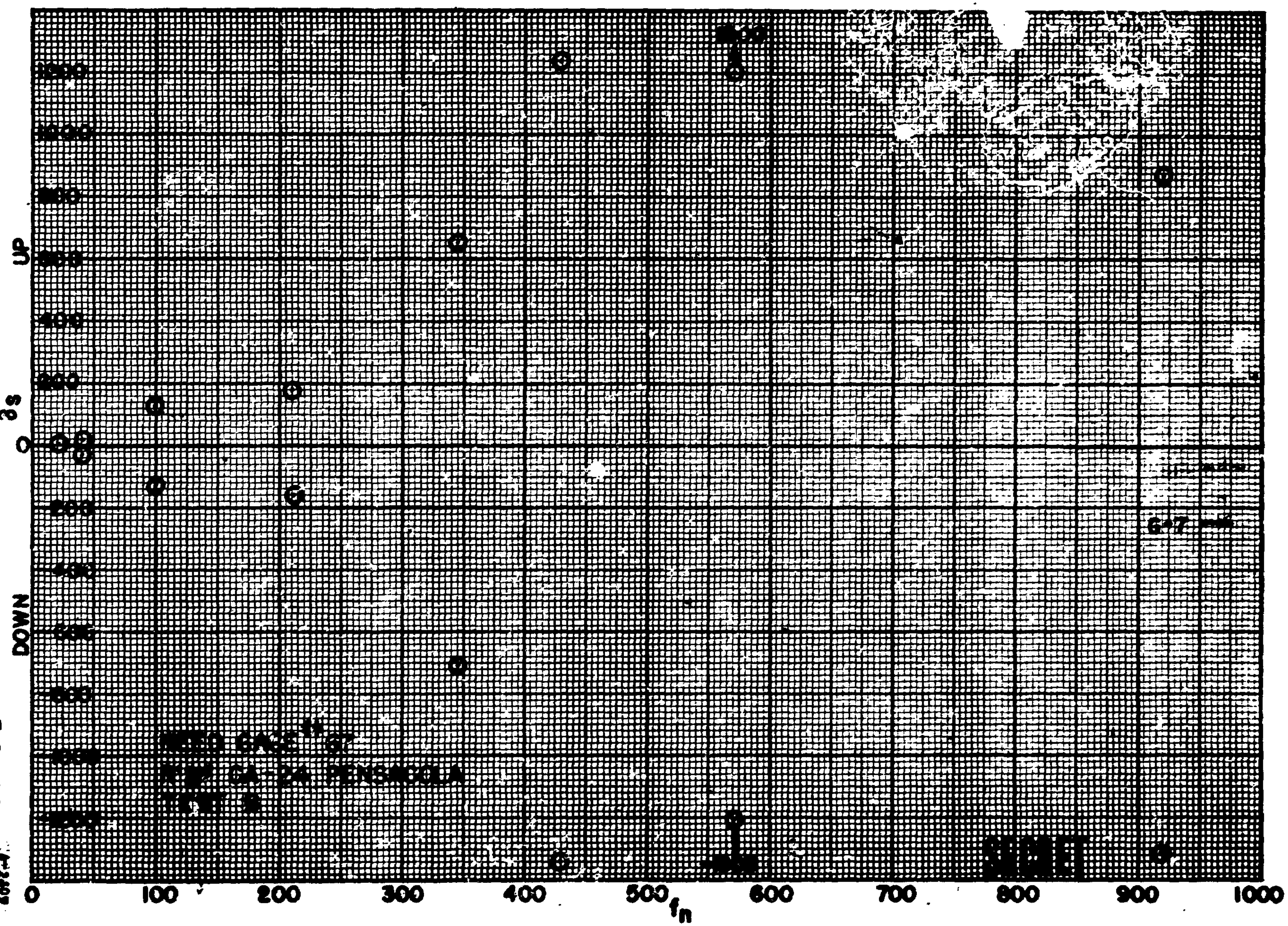
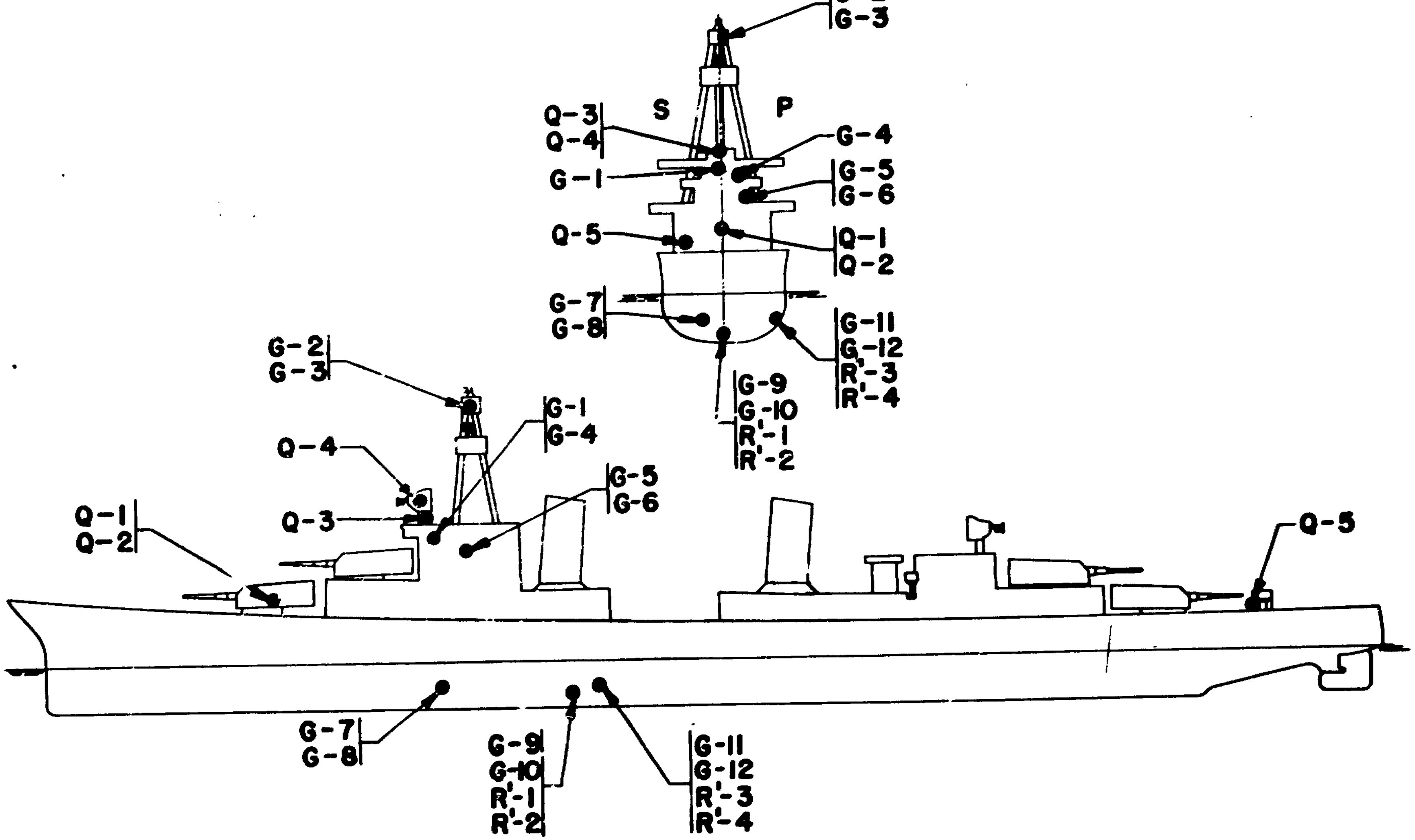


FIG. 142

CA 25 SALT LAKE CITY GAGE LOCATIONS



A-2609

FIG. 150

Putty Gages

G1 - Photo 402. Pilot House. Directed up on longitudinal, stringer 6" aft of frame 41, under navigation bridge deck, about 18" to starboard of centerline.

A. (1) 130g. B. 40g.

G2 - Photo 403. F.C. Station. Directed up on port bulkhead 42" above deck and 24" aft of transverse centerline of fire control (main gun director).

A. (1) NG B. Less than 20g.

G3 - Photo 404. F.C. Station. Directed to starboard on port bulkhead 12" forward of transverse centerline of fir control station (main gun director), 60" above deck.

A. (1) NG B. 45g.

G4 - Photo 406. In pilot house of conning tower. On port bulkhead 24" forward of after bulkhead of pilot house (frame 4), 4 ft. above emergency platform. Directed to starboard.

A. (1) 250g. B. Less than 20g.

G5 - Photo 407. Main radio room. Directed to starboard on vertical stiffener at frame 45, 5 ft. above platform. Stiffener is on port bulkhead.

A. (1) 70g. B. Less than 20g.

G6 - Photo 407. Main radio room. Directed up on vertical stiffener on port bulkhead at frame 45, 4 ft. above platform.

A. (2) 50g. B. Less than 20g.

G7 - Photo 408. Gyro-compass room, compartment A-422-E. Directed to starboard on flange of stiffener on port bulkhead at frame 44, 5 ft. above deck.

A. (3) 70g. B. Less than 20g.

G8 - Photo 407. Gyro-compass room, compartment A-422-E. Directed up on flange of stiffener on port bulkhead at frame 44, 4 ft. above deck.

A. (3) Less than 20g. B. Less than 20g.

G9 - No photo. Compartment B-1. Directed up on top flange of keel saddle just above I-beam on centerline of ship aft of frame 48.

A. (3) Less than 50g. B. 75g.

G10 - No photo. Directed to starboard at same location as G9.

A. (3) Less than 50g. B. Less than 50g.

G11 - Photo 409. Forward fireroom, compartment B-1. Directed up on bracket on port inner bottom at frame 50, 5 ft. above lower grating level.

A. (3) Less than 50g. B. Less than 50g.

G12 - Photo 409. Forward fireroom, compartment B-1. Directed to starboard on bracket on port inner bottom at frame 50, 5 ft. above lower grating level.

A. (3) Less than 50g. B. Less than 50g.

Reed Gages

R'1. Compartment B-1. Directed up on top flange of keel saddle just above I-beam at centerline of ship and aft of frame 48.

Graph	20 cps		40 cps	
	Up	Dn	Up	Dn
A. (3) Readings all zero.				
B. Fig. 153.	.305	.245	.055	.055

R'2. Direct to starboard at same location as R'1.

Graph	20 cps		40 cps	
	Up	Dn	Up	Dn
A. (3) Fig. 151.	.005	.015	0	0
B. Fig. 154	.165	.09	.13	.13

R'3. Forward fireroom, compartment B-1. Directed to starboard on bracket on inner bottom at frame 50 on port side, about 4 ft. 6 inches above lower grating level.

Graph	20 cps		40 cps	
	Up	Dn	Up	Dn
A. (3) Fig. 152	.045	.035	0	0
B. Fig. 155	.04	.05	.035	.035

R'4. Forward fireroom, compartment B-1. Directed up on bracket on port inner bottom at frame 51, about 5 ft. above lower grating level.

Graph	20 cps		40 cps	
	Up	Dn	Up	Dn
A. (3) Readings all zero.				
B. Fig. 156	.08	.10	.02	.035

Indenter Gages

Q1. No. 1, 8" turret. Directed up on fore and aft channel under port shell tray.

A		B	
Up	125g.	Up	190g.
Dn	30	Dn	190
20°	75	0°	170
110°	75	90°	985
200°	60	180°	150
290°	75	270°	955

Q2. No. 1, 8" turret. On port shell tray about 30" above deck. On starboard side of shell tray. Directed to starboard.

A						B					
brg.	0°	elev.	-10°	265g.		brg.	0°	elev.	45°	390g.
"	0°	"	80°	240		"	0°	"	-45°	300
"	90°	"	0°	310		"	90°	"	0°	225
"	180°	"	10°	240		"	180°	"	45°	215
	180°	"	-80°	400		"	180°	"	-45°	300
	270°	"	0°	310		"	270°	"	0°	-

Q3. Forward 5" director (Mark 33). Normal to flange of starboard aft rib of cylindrical support base.

		A						B		
brg.	9°	elev.	55°	300g.		brg.	38°	elev.	19°	250g.
"	56°	"	-28°	470		"	88°	"	-62°	60
"	135°	"	20°	100		"	135°	"	20°	35
"	189°	"	-55°	110		"	218°	"	-19°	280
"	236°	"	28°	690		"	268°	"	62°	155
"	315°	"	-20°	45		"	315°	"	-20°	60

Q4. Main Battery director (Mark 33). Inside starboard door of director on athwartships beam approximately 30" above deck of director. Beam is about 18" aft of forward bulkhead. Directed up.

A			B	
Up	80g.		Up	120g.
Dn	120		Dn	55
0°	210		45°	130
90°	90		135°	165
180°	80		225°	115
270°	190		315°	210

Q5. Starboard Mark 51, 40 mm gun director. Directed to port beam under director 4 ft. above deck.

		A						B		
brg.	0°	elev.	-45°	310g.		brg.	0°	elev.	45°	110g.
"	0°	"	45°	340		"	0°	"	-45°	115
"	90°	"	0°	540		"	90°	"	0°	65
"	180°	"	45°	-		"	180°	"	45°	140
"	180°	"	-45°	290		"	180°	"	-45°	100
"	270°	"	0°	520		"	270°	"	0°	115

COMMENTS

Able Range 3054 ft. Bearing 228°

G2 and G3 read very high but this was due to the impact of a bulwark as shown in photo 405 so the readins are not reported. G1 read 130g. and was on the underside of the navigation bridge deck which was exposed to the external pressure. G4 read 250g. on a rather light bulkhead and read 70g. The G7 reading of 70g. to starboard in the gyro-compass room deep inside the ship is surprising though DSM reports that mercury spilled from the gyro-compass.

Since the occurrence of a 70g. acceleration throughout the ship at locations so remote from the pressure should mean considerable shock damage, it is suggested that this shock was real and due to the presence of the footing of the forward leg of the tripod mast.

Other gages below the waterline had zero readings except the 20 cps. reeds of R'2 and R'3 in the fireroom were slightly disturbed.

The Q1 and Q2 readings inside the No. 1 turret illustrate the wide variations of readings obtained at locations only a few feet apart. Q3 and Q4 show higher readings on the exposed base of the mark 33 director than were found inside the director. This agrees with the CA24 readings on a mark 33 director. Most of the indenter gages have equal readings in opposite directions which is presumable due to rattling of the internal weight so the readings are not very reliable.

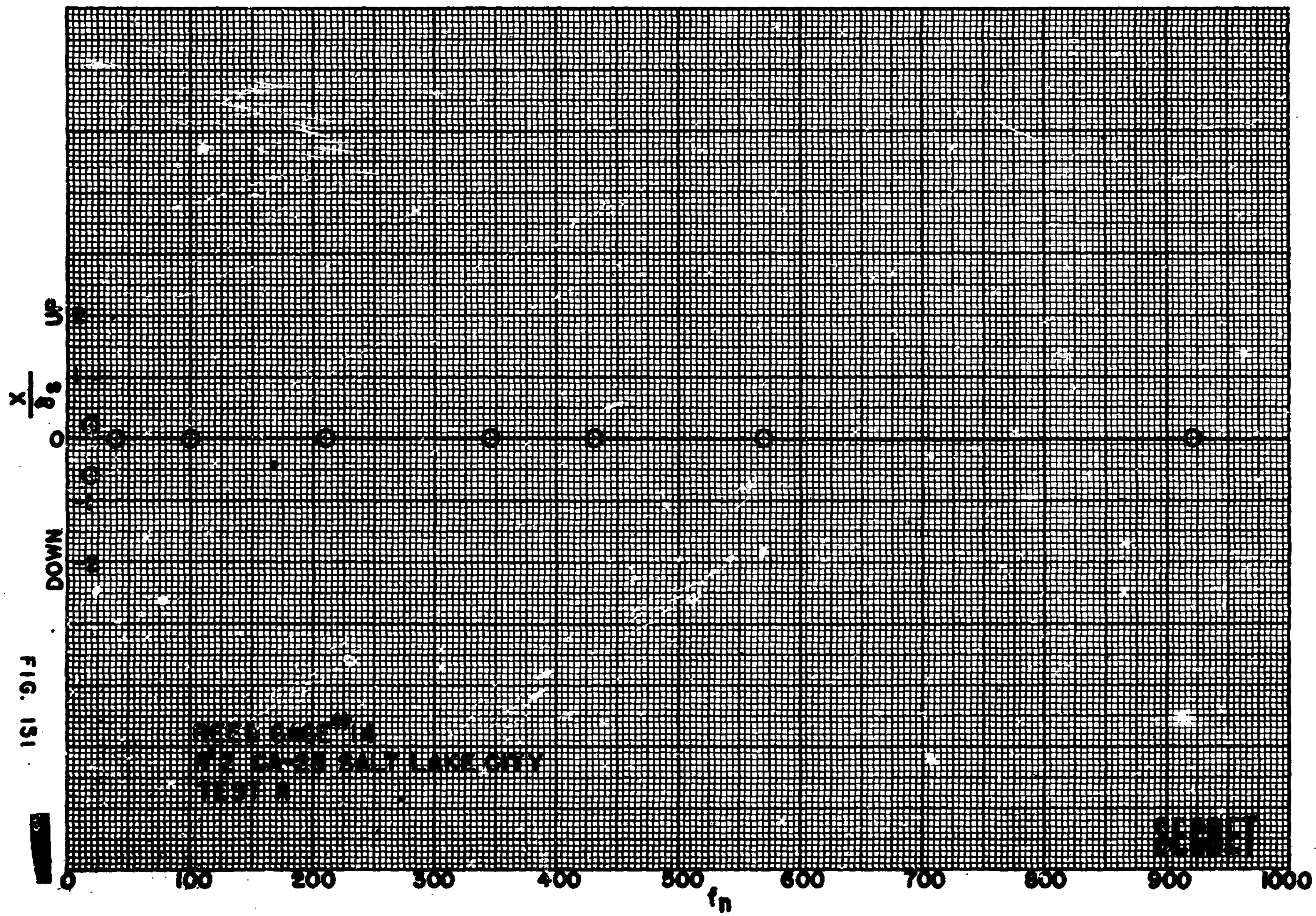
Baker. Range 3550 ft. Bearing 132°

The instrumentation on this ship was planned for portside exposure to the pressure wave rather than starboard. DSM reports moderate shock effects in that floor plates were generally displaced, the turbines were shifted, some valve stuffing glands leaked, and some electronic equipment and the forward AA directors were damaged.

The putty gages G1 and G3 were presumably affected by air blast since the only other putty gage affected was G9 vertical on the keel saddle which read 75g. The failure of G11 and G12 to give readings illustrates the shielding of the port hull plating from a pressure wave coming from the starboard side.

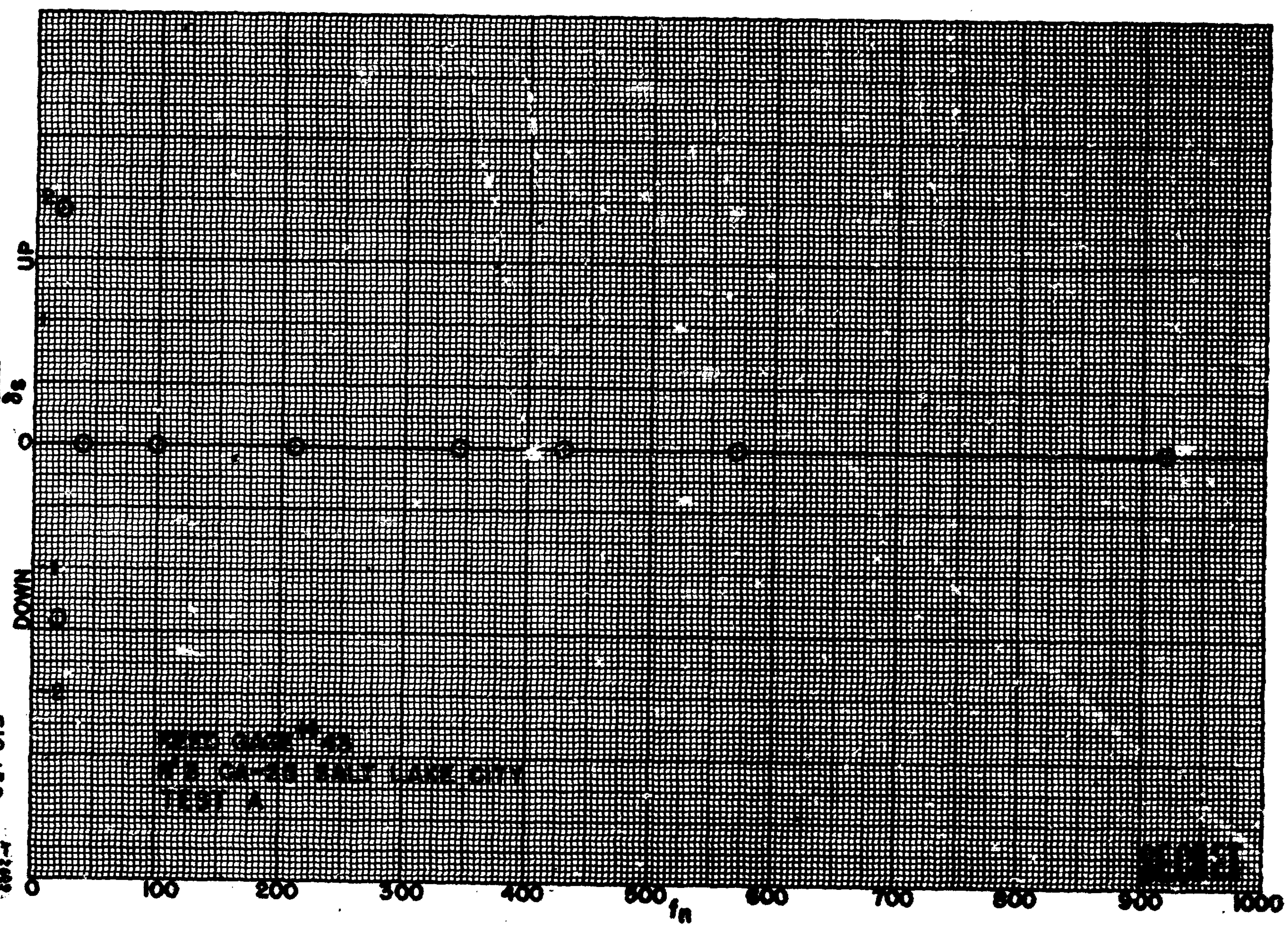
The reed gage records also illustrate this shielding. The R'3 and R'4 records on the port inner shell have small deflections. R'1 vertical on the keel saddle has a frequency response curve which has the appearance of the curve which would result from a strong vibration at about 920 cps. The equivalent shock for the reeds of frequencies below 300 cps. is on the order of 3 ft/sec. impulsive velocity change. R'2 directed to starboard on the keel saddle had predominant frequencies at 100 and 600 cps.

The indenter gage readings are presumably due to airblast. Q1 and Q2 inside the No. 1 turret are not in good agreement. Q4 does not show low readings inside the mark 33 director in comparison with Q3 on the director support. Q5 has moderate readings.



DECK GAGE #14
#2 CA-28 SALT LAKE CITY
TEST 8
SECRET
UP
$\frac{X}{g_s}$
0
DOWN
0
100
200
300
400
500
600
700
800
900
1000
f_n

FIG. 151



UP
X/δs
0
DOWN
0
100
200
300
400
500
600
700
800
900
1000
fn
PRESS. GAGE #43
N.S. CA-28 SALT LAKE CITY
TEST A

FIG. 152

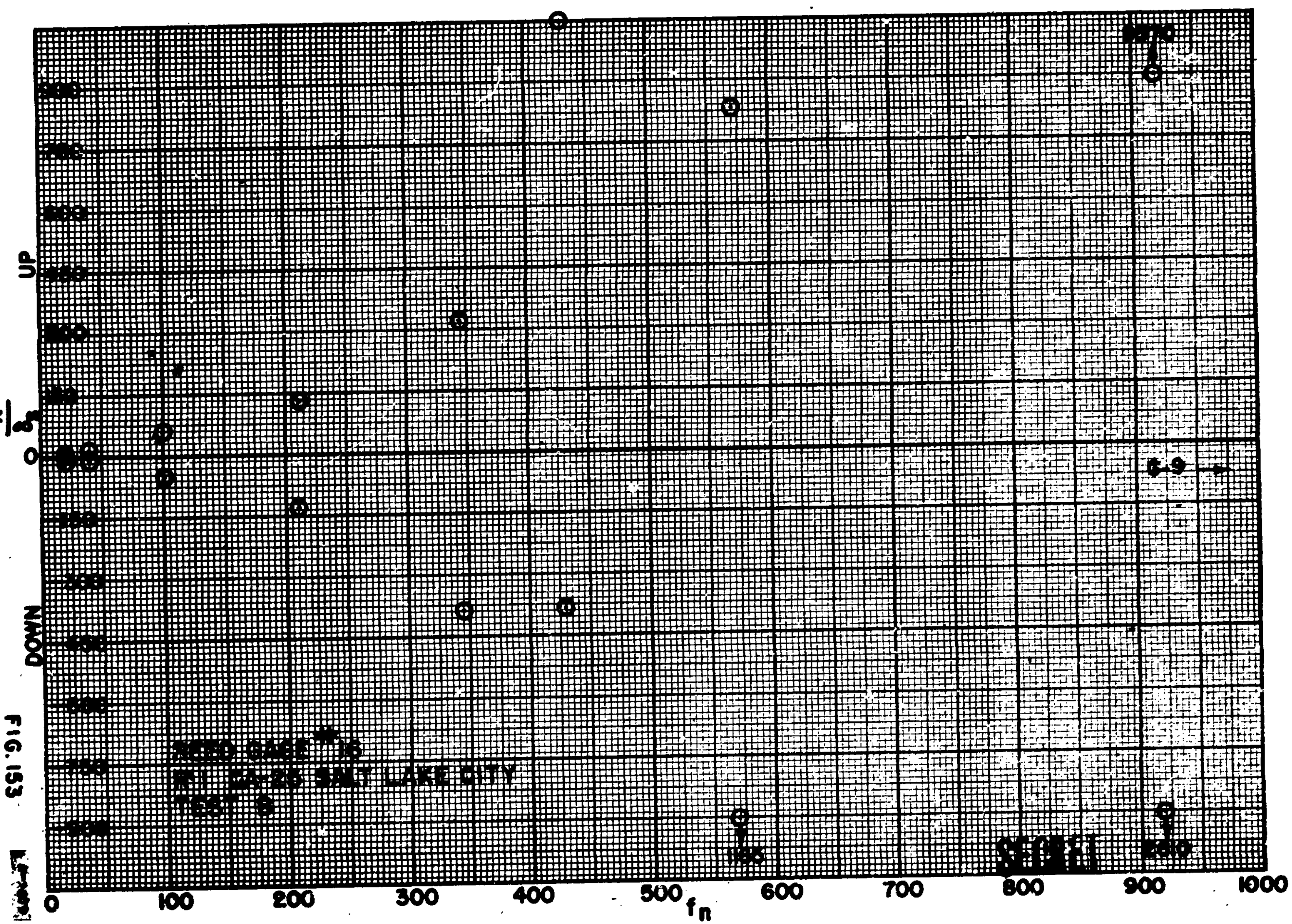

UP
DOWN
0
SALT LAKE CITY
0
100
200
300
400
500
600
700
800
900
1000
f_n

FIG. 153

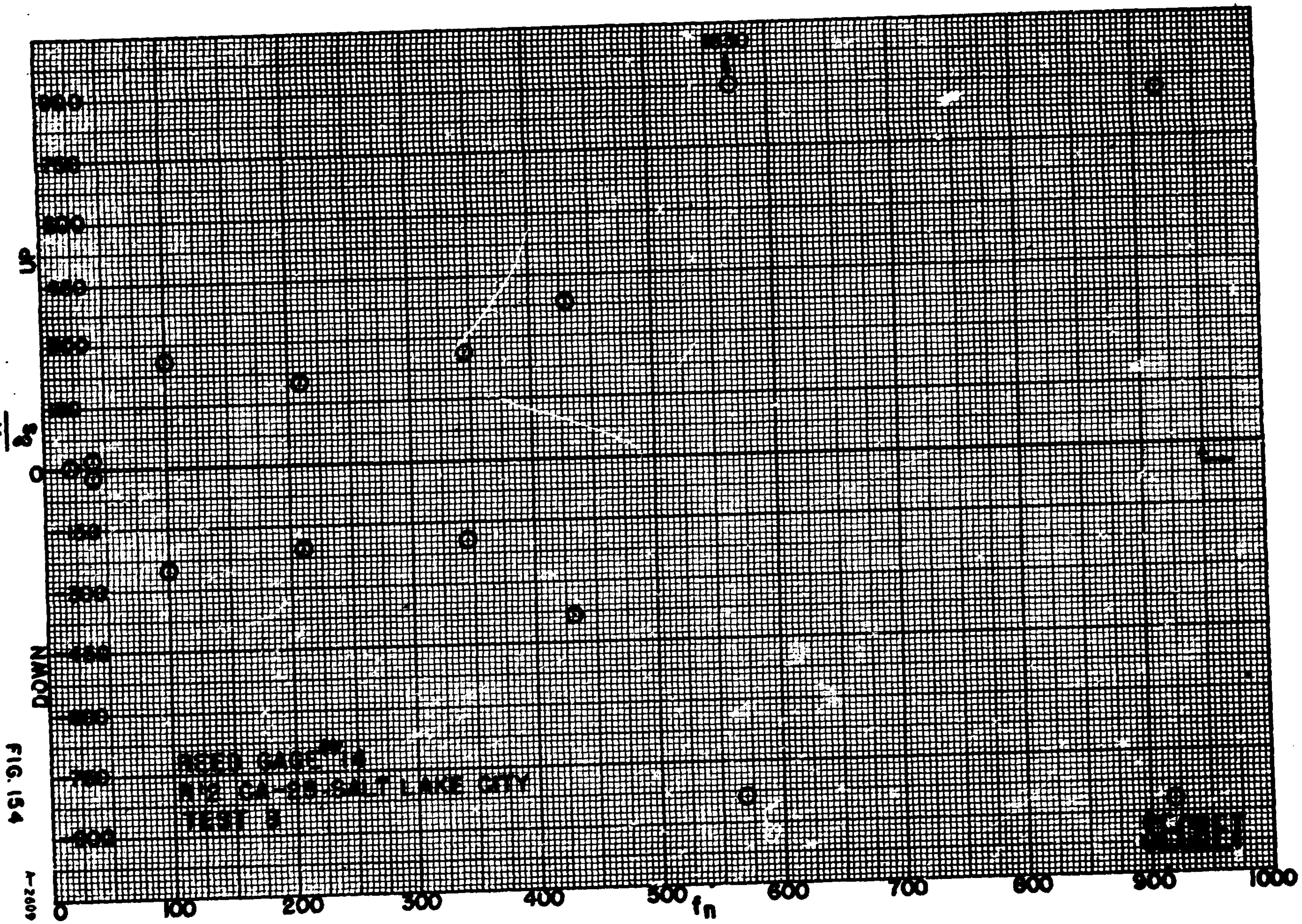


FIG. 154

A-2609

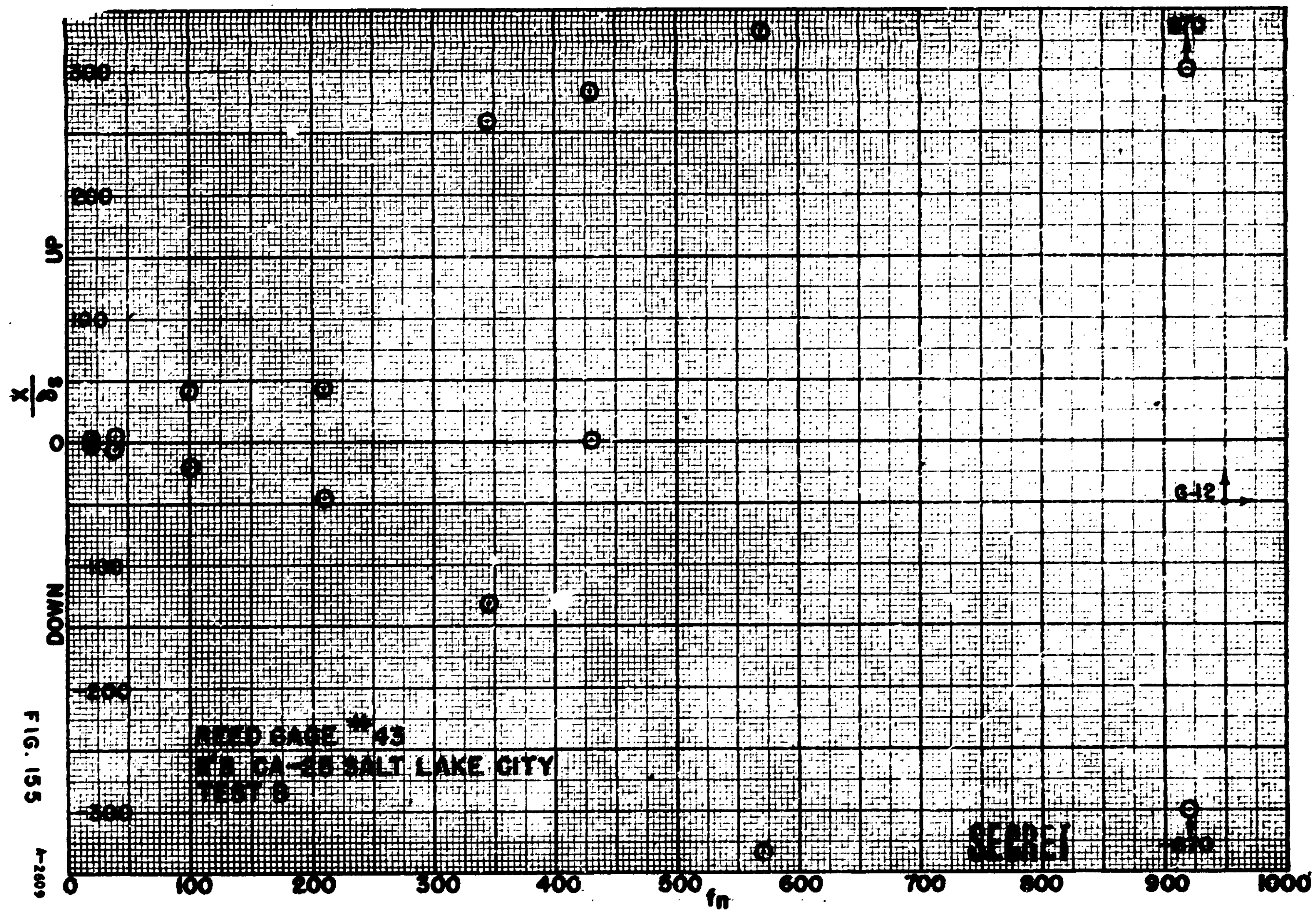


FIG. 155

A-2609

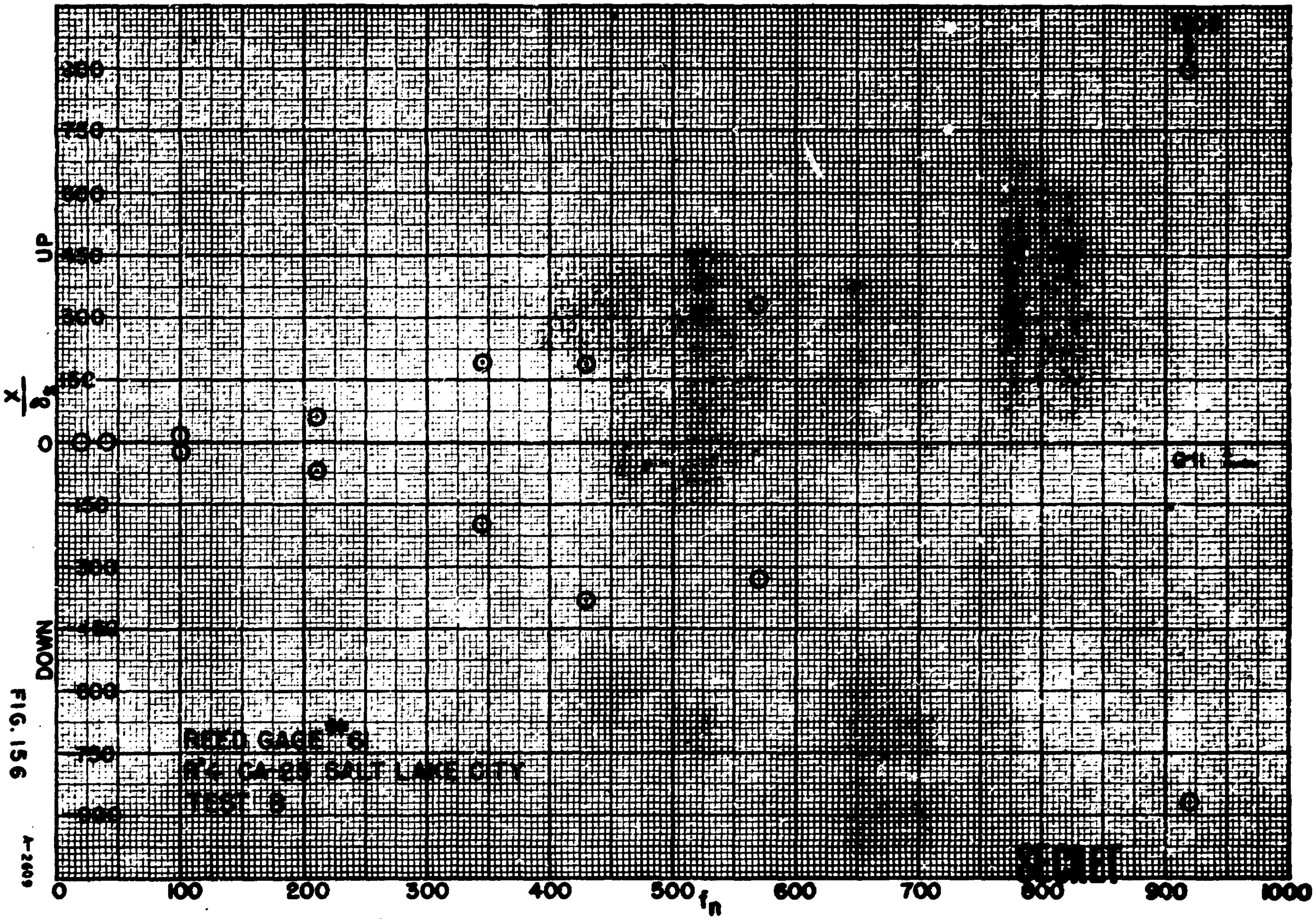


FIG. 156

A-2609

COMMENTS ON CAPITAL SHIPS

Able

Practically all gages registering shock were on or near bulkheads or decks exposed directly to the pressure. Readings up to 250g. on putty gages were obtained at these locations. The readings form a pattern which is quite consistent with those from other types of ships.

Baker

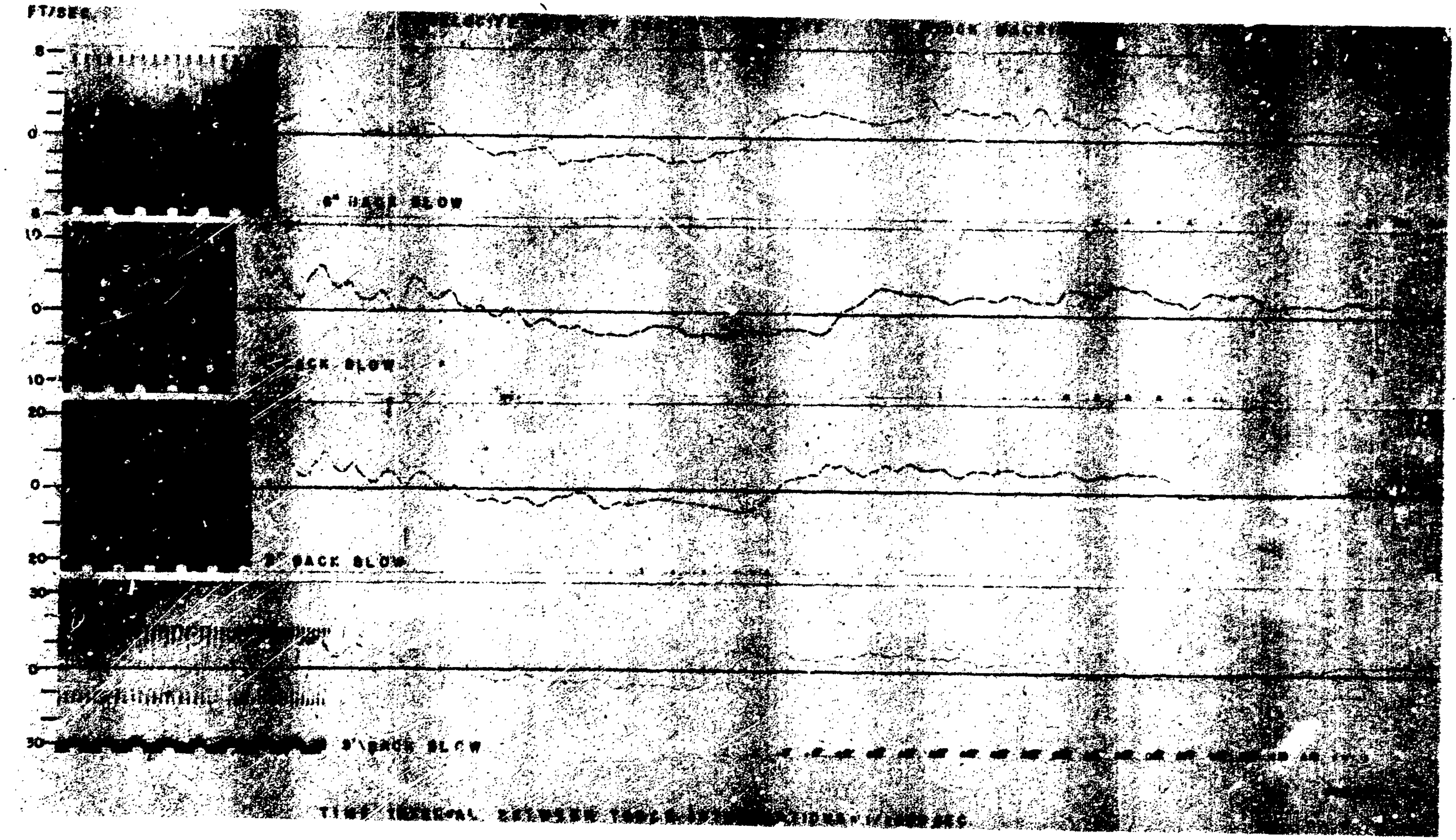
The capital ships instrumented were as a group closer to the explosion than the other types. Extensive shock damage was reported by DSM though this may be partially due to the age of the ships. The NEW YORK and the PENSACOLA were stern-on and bow-on to the explosion respectively. The region of shock damage on the NEW YORK in the vicinity of the stern suggests a dimunition of the pressure as the wave progressed along the keel. This effect was noted in the destroyer data. The NEVADA was broadside to the explosion and showed the decrease of peak acceleration with distance from the hull.

Navy Standard Lightweight H. I. Shock Testing Machine

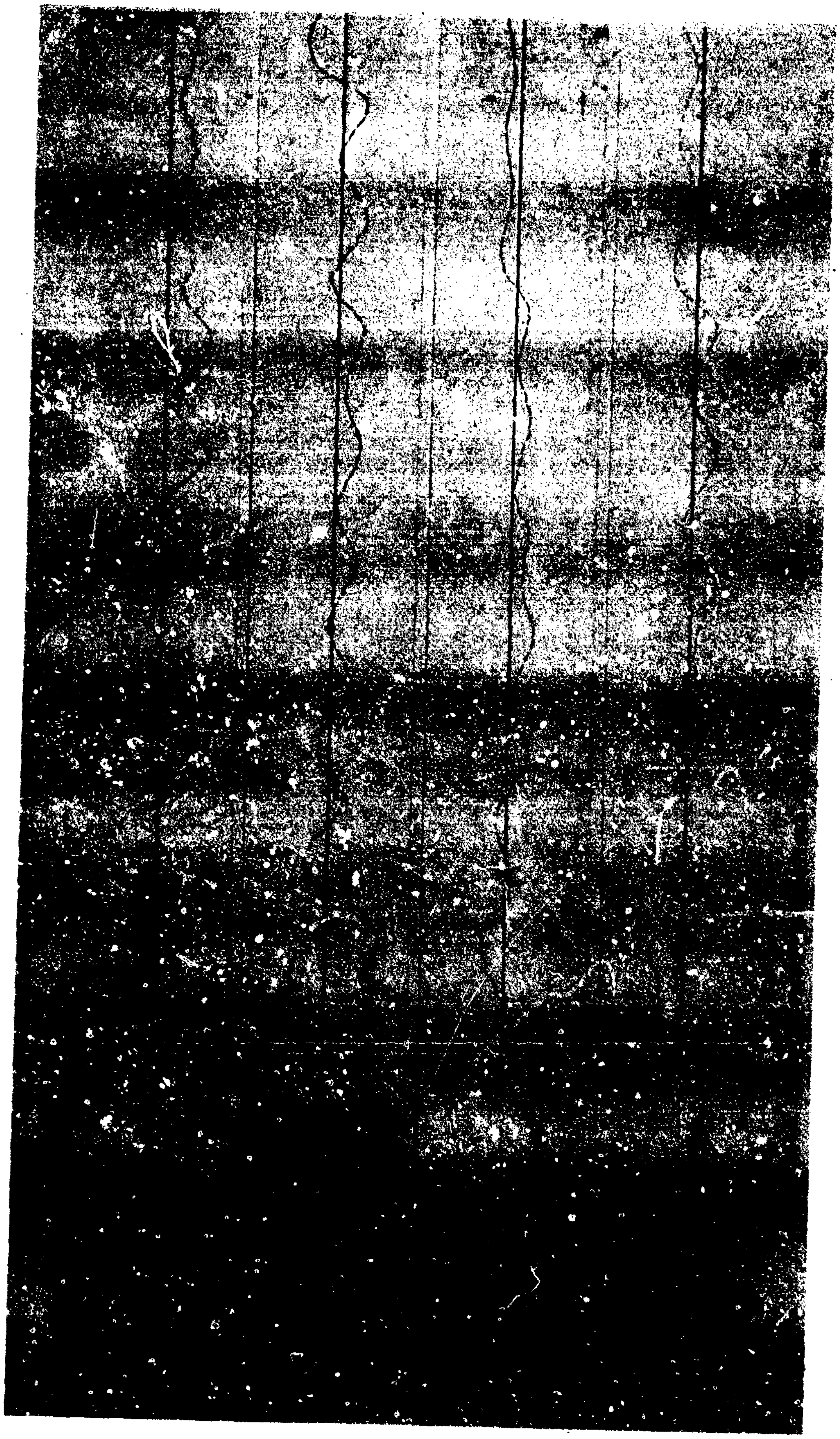
For comparison with the shock data from the target ships, velocity meter, reed gage, and putty gage data have been obtained using the back blow on the anvil plate of a standard H. I. Shock Machine at the Naval Research Laboratory. These tests were conducted prior to the modifications made in May and June 1947, to these machines. Two gage locations were used: one was at the center of the 4A plate where equipment is usually placed for test, the other was at the edge of the 4A plate over the supporting channel members and therefore was not cushioned by the flexibility of the 1/2″ thick 4A plate. The data is presented in the following figures:

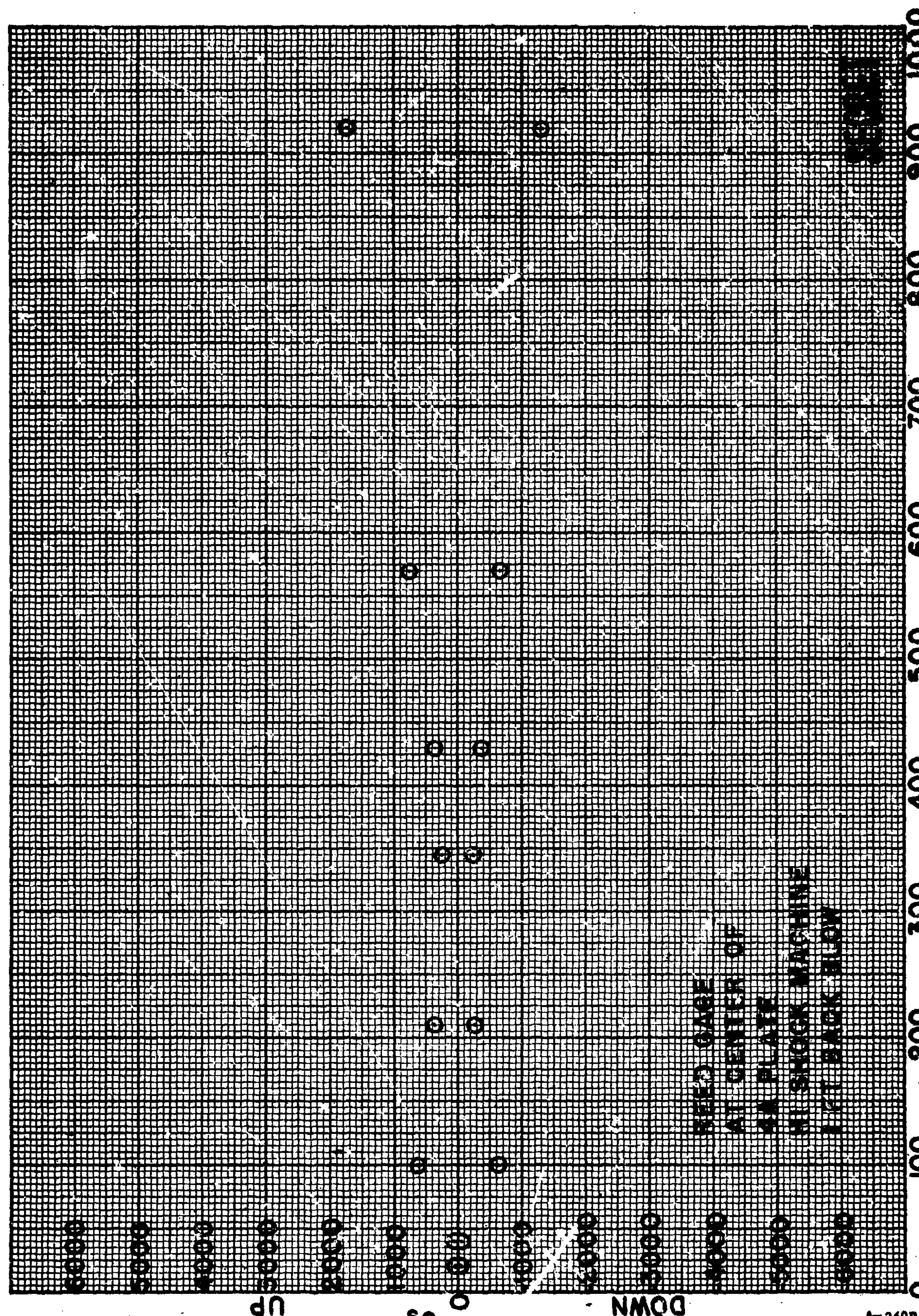
Hammer Drop	Center Position Vel. Meter	Center Position Reed	Center Position Putty	Edge position Vel. Meter	Edge position Reed	Edge position Putty
6″	Fig. 157	-		Fig 158		
1′	Fig. 157	Fig.159	Fig.169	Fig 158	Fig.164	Fig.170
2′	-	Fig.160	Fig.169	-	Fig.165	Fig.170
3′	Fig. 157	Fig.161	Fig.169	Fig 158	Fig.166	Fig.170
4′	-	Fig.162	Fig.169	-	Fig.167	Fig.170
5′	Fig. 157	Fig.163	Fig.169	Fig 158	Fig.168	Fig.170

The velocity meters were used without internal springs and the initial position of the magnet was about 1/8 inch from the upper stop.



FT/SEC
8
0
8
10
0
10
20
0
20
30
0
30
BACK BLOW





A-2609

FIG. 159

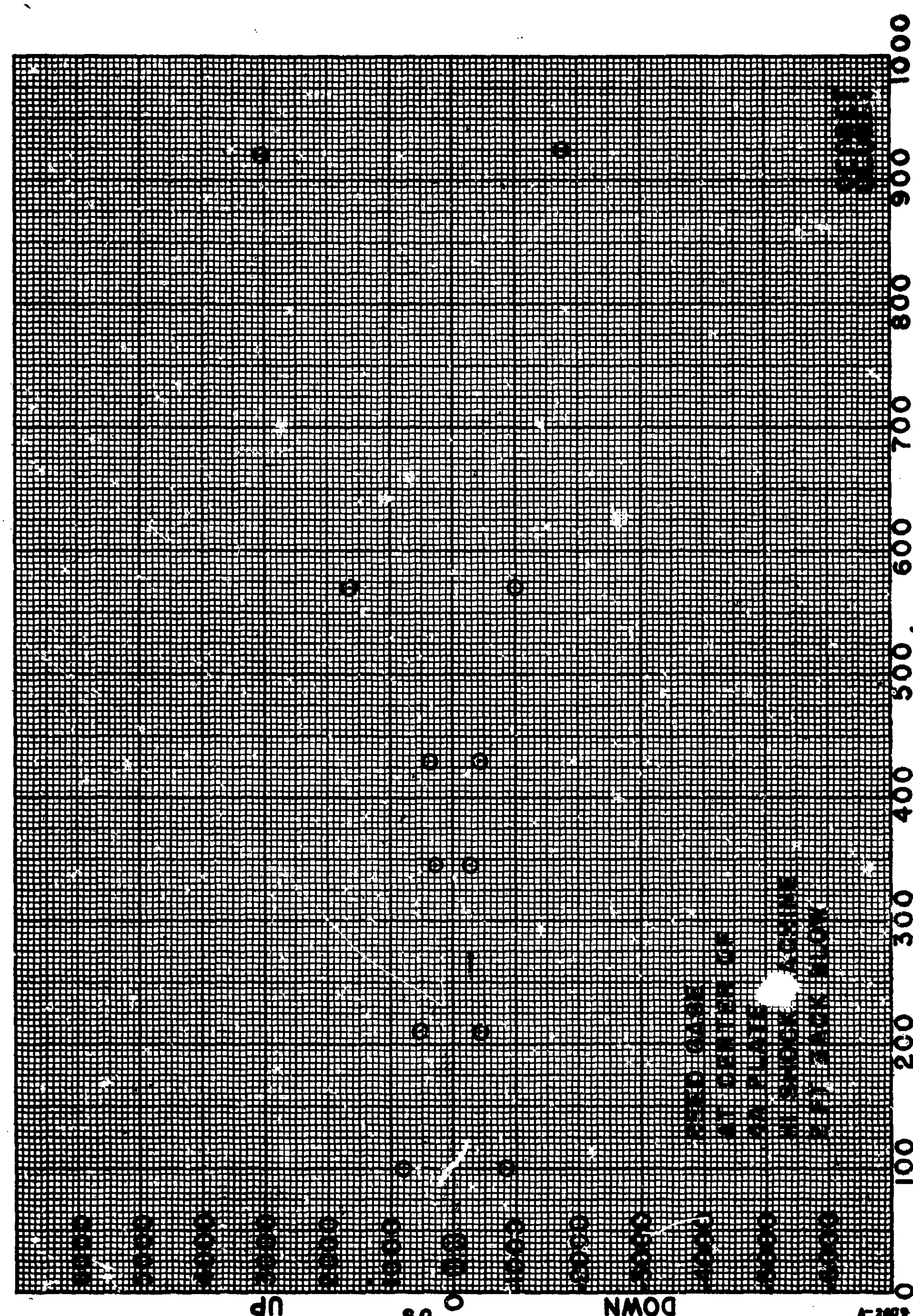


FIG. 16 C

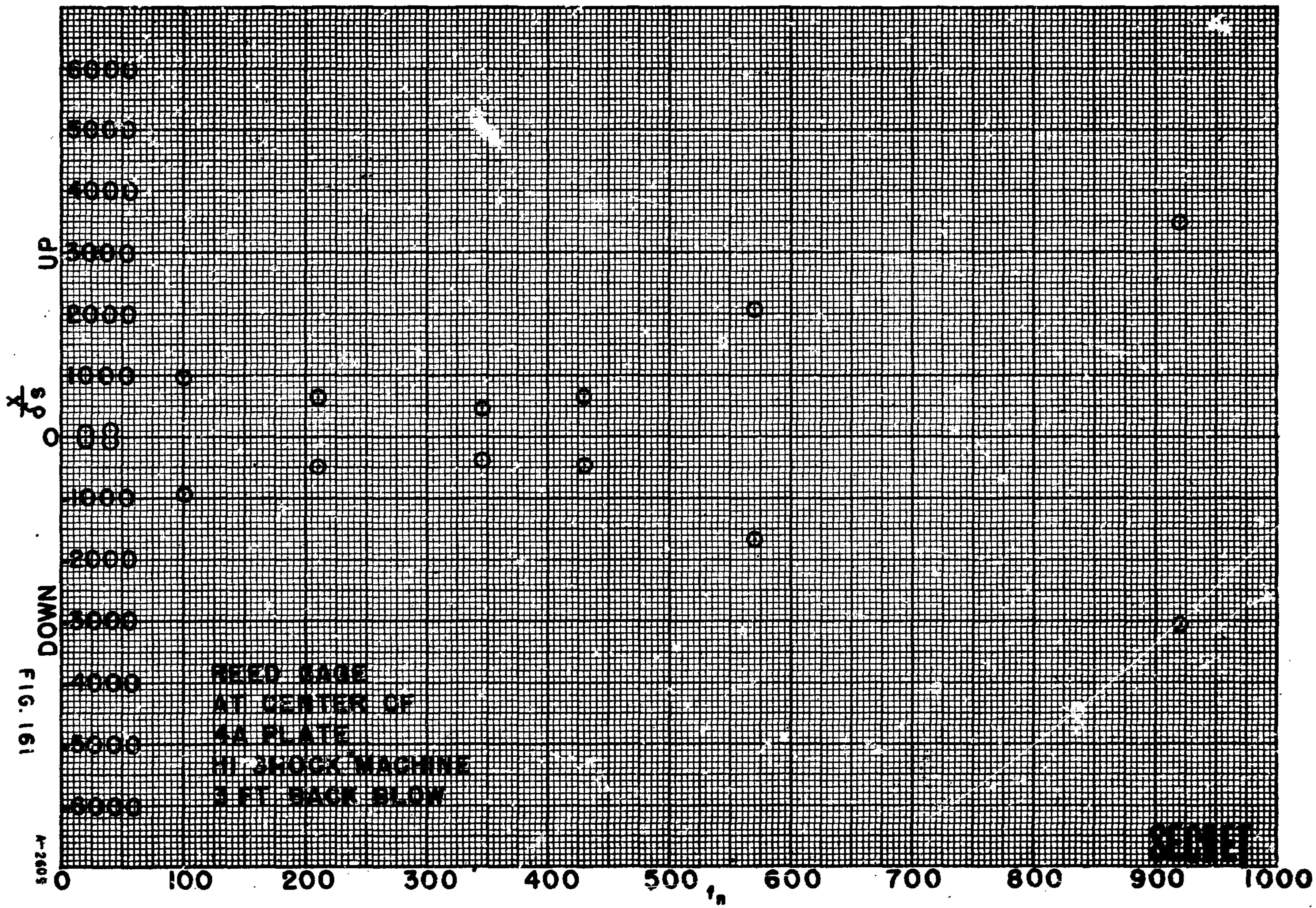

6000
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
-6000
UP
DOWN
0
100
200
300
400
500
600
700
800
900
1000
f_n
REED GAGE
AT CENTER OF
4A PLATE
HI SHOCK MACHINE
3 FT. BACK BLOW
SECRET
A-2605

FIG. 161

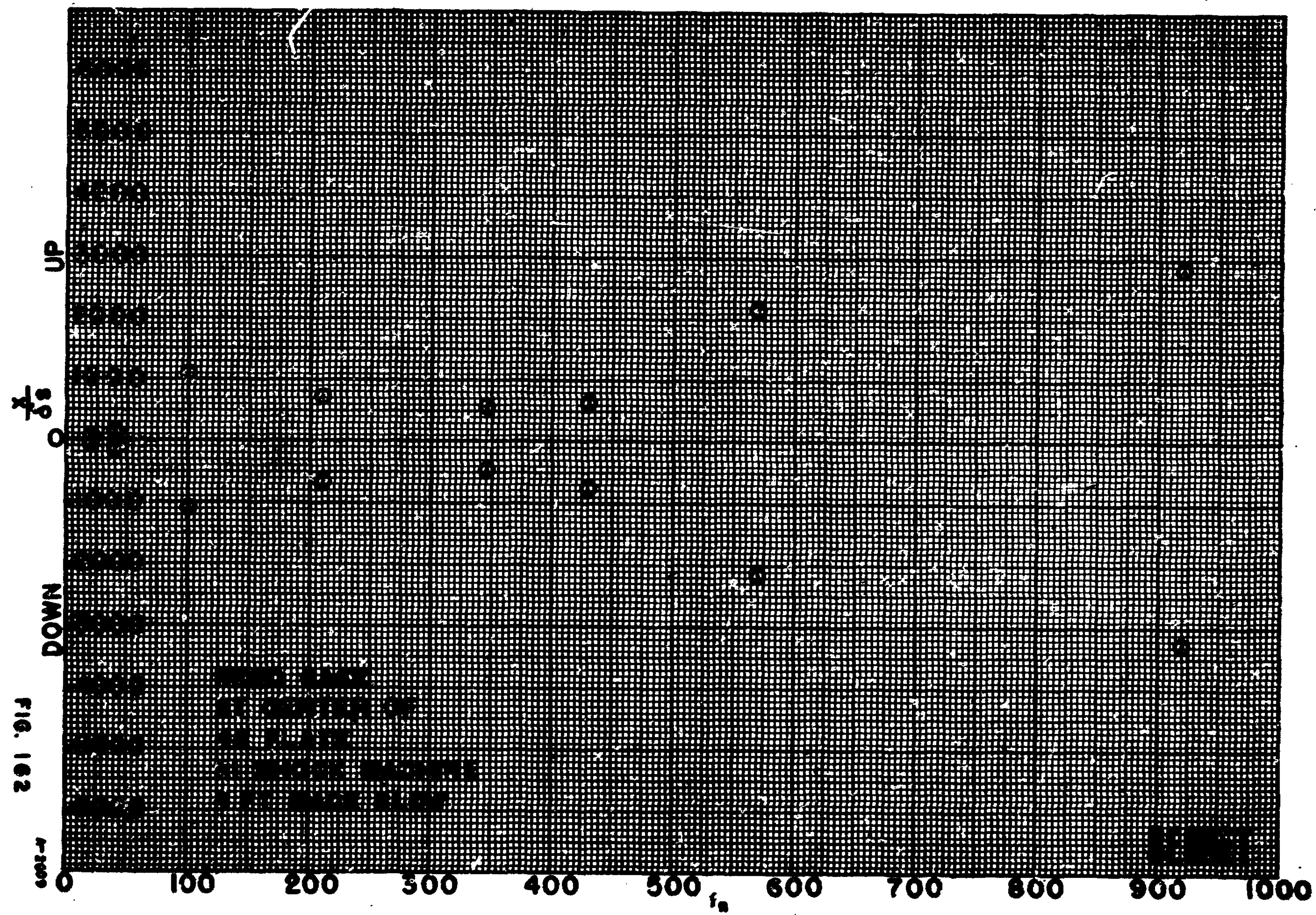


FIG. 162

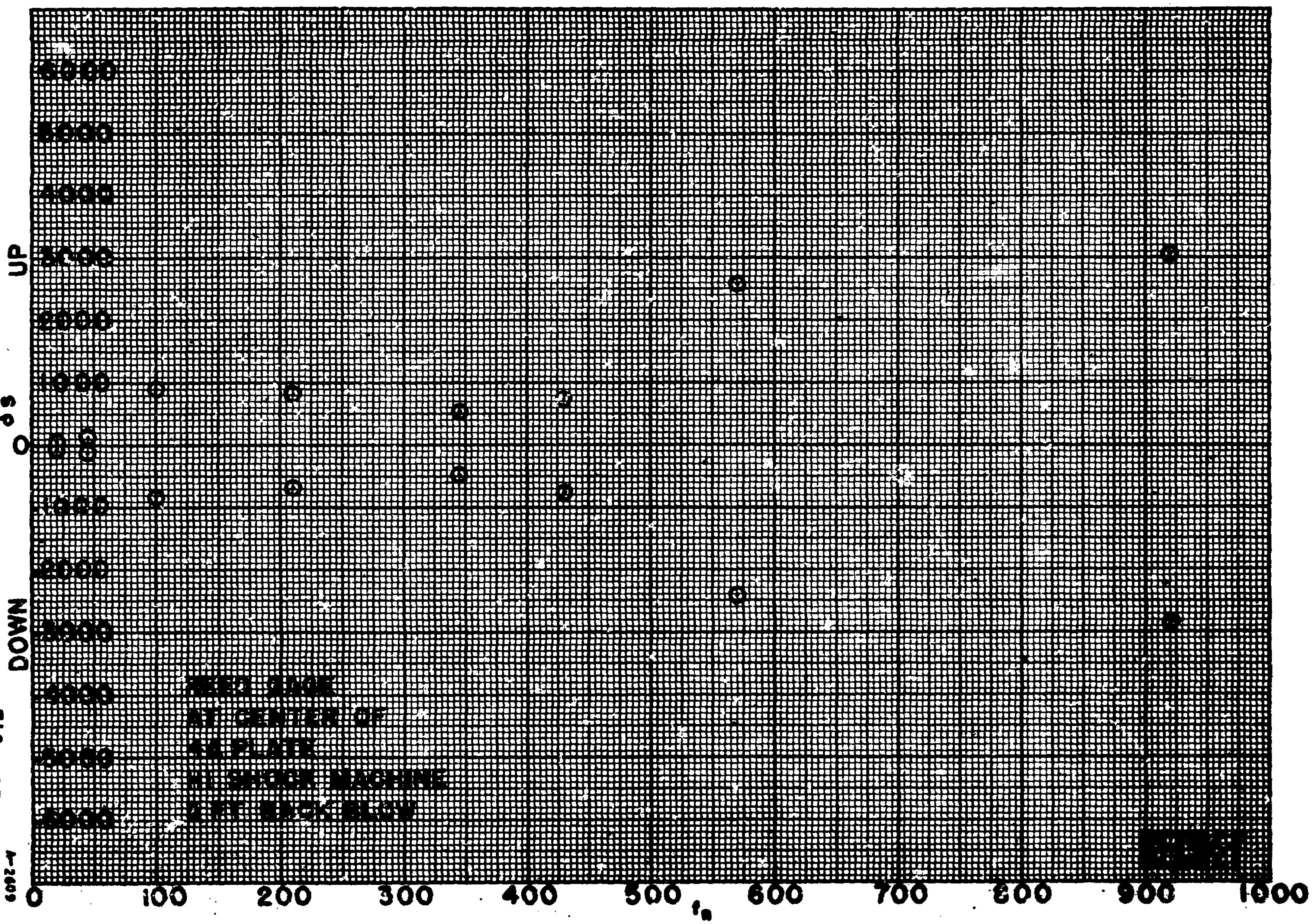


FIG. 163

A-2609

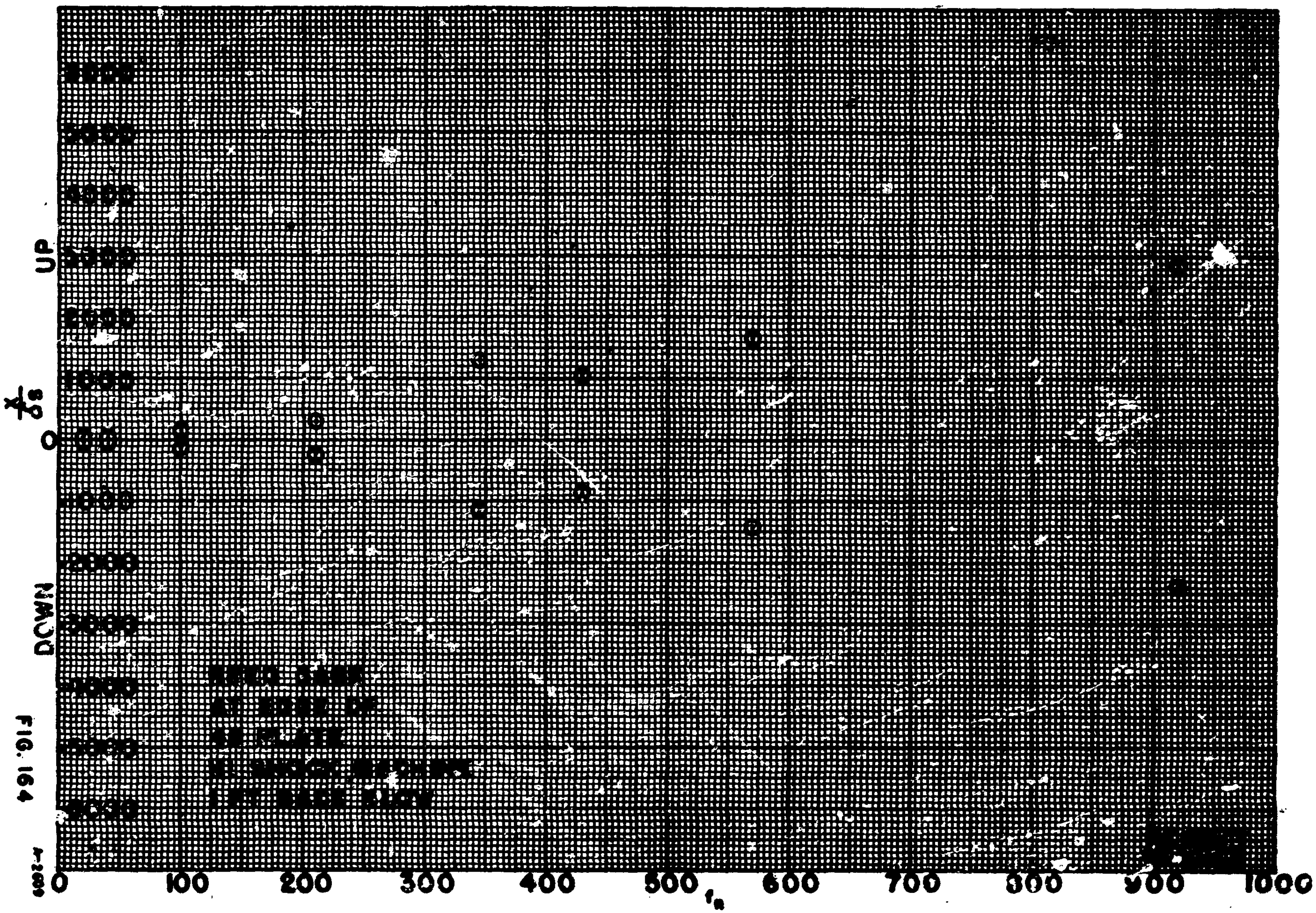

UP
DOWN
5000
4000
3000
2000
1000
0
1000
2000
3000
4000
5000
6000
0
100
200
300
400
500
600
700
800
900
1000
f_n

FIG. 164

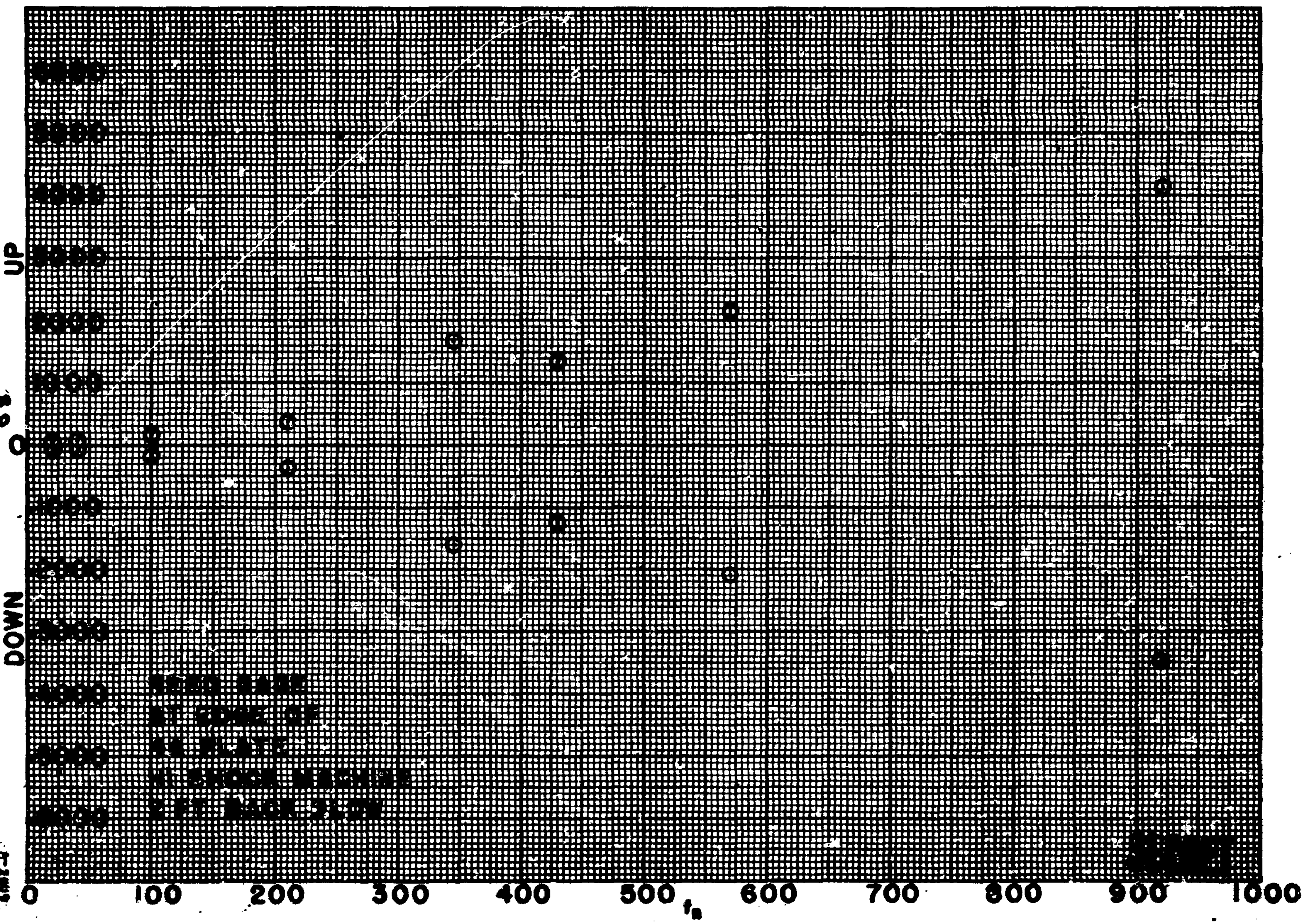


FIG. 165

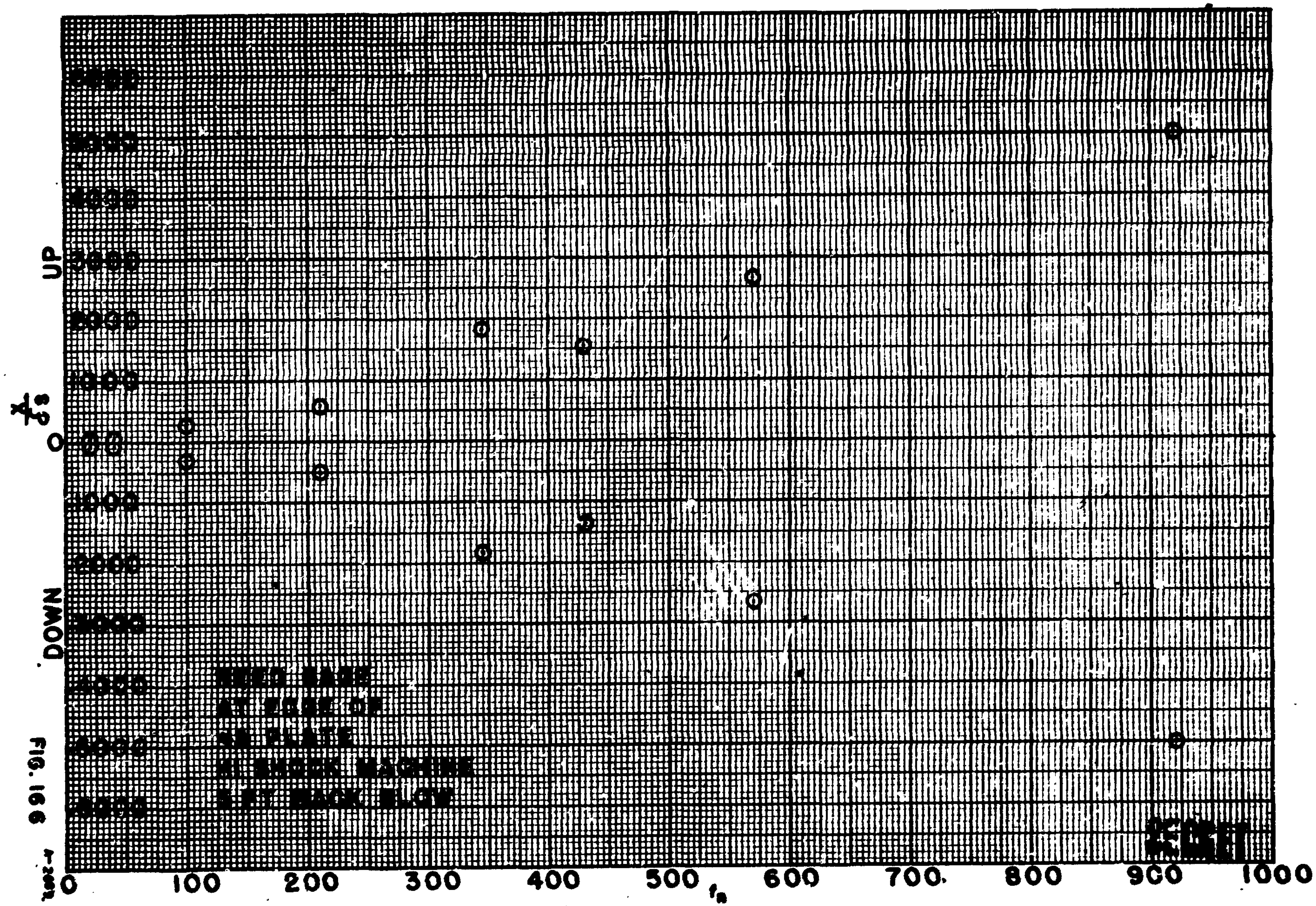


FIG. 166

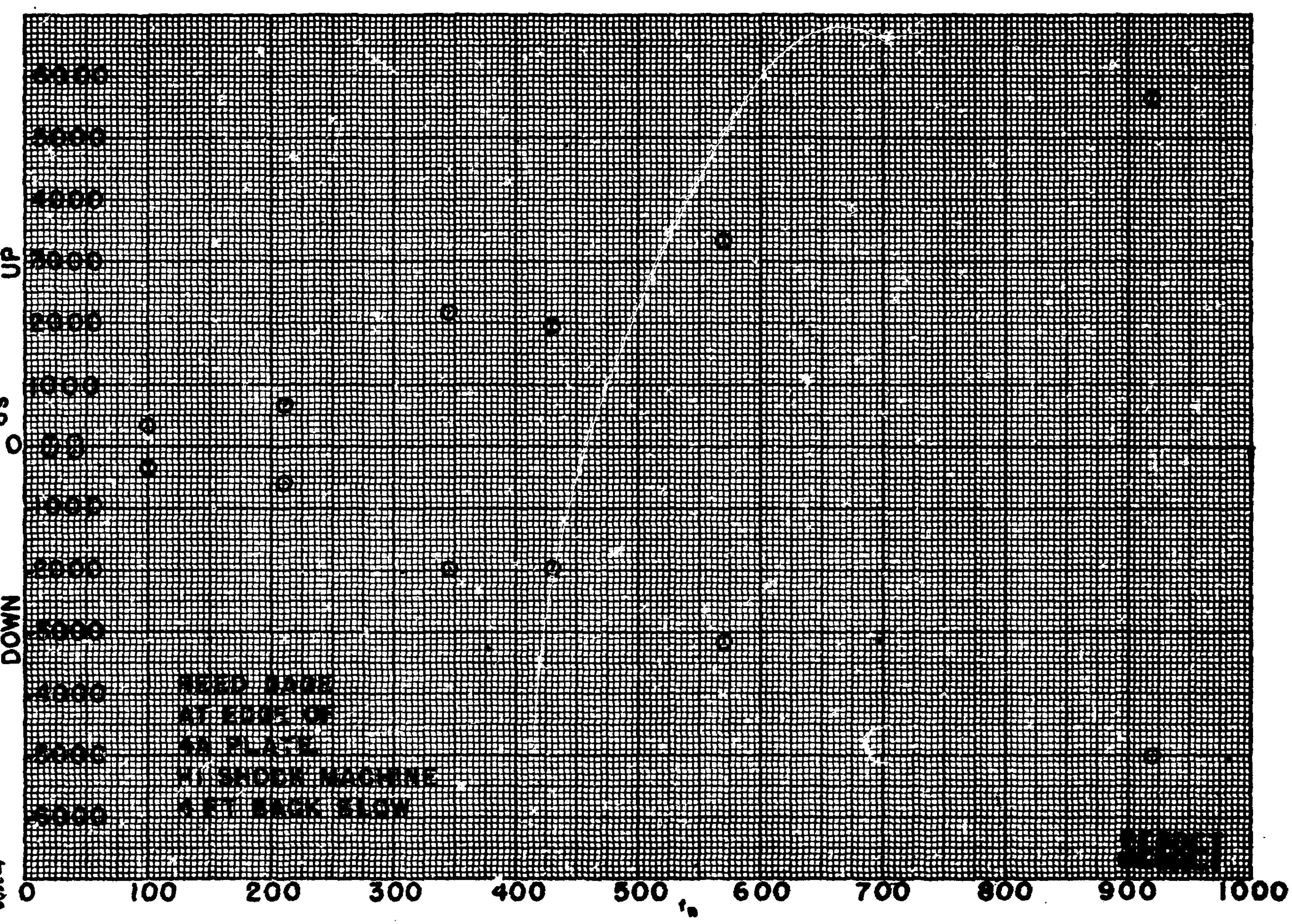
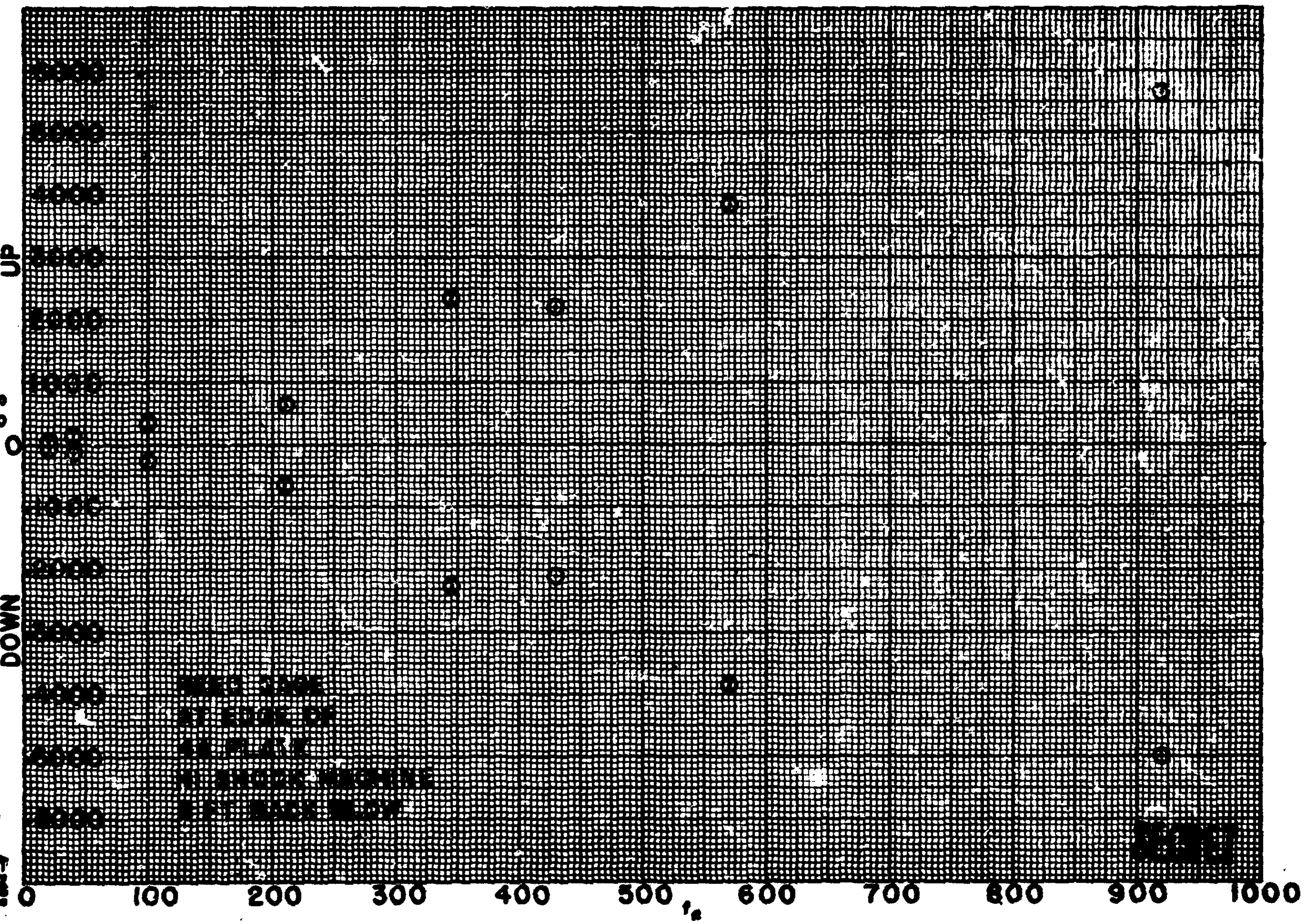


FIG. 167

A-1609



UP
DOWN
0
1000
2000
3000
4000
100
200
300
400
500
600
700
800
900
1000
f_s

FIG. 16B

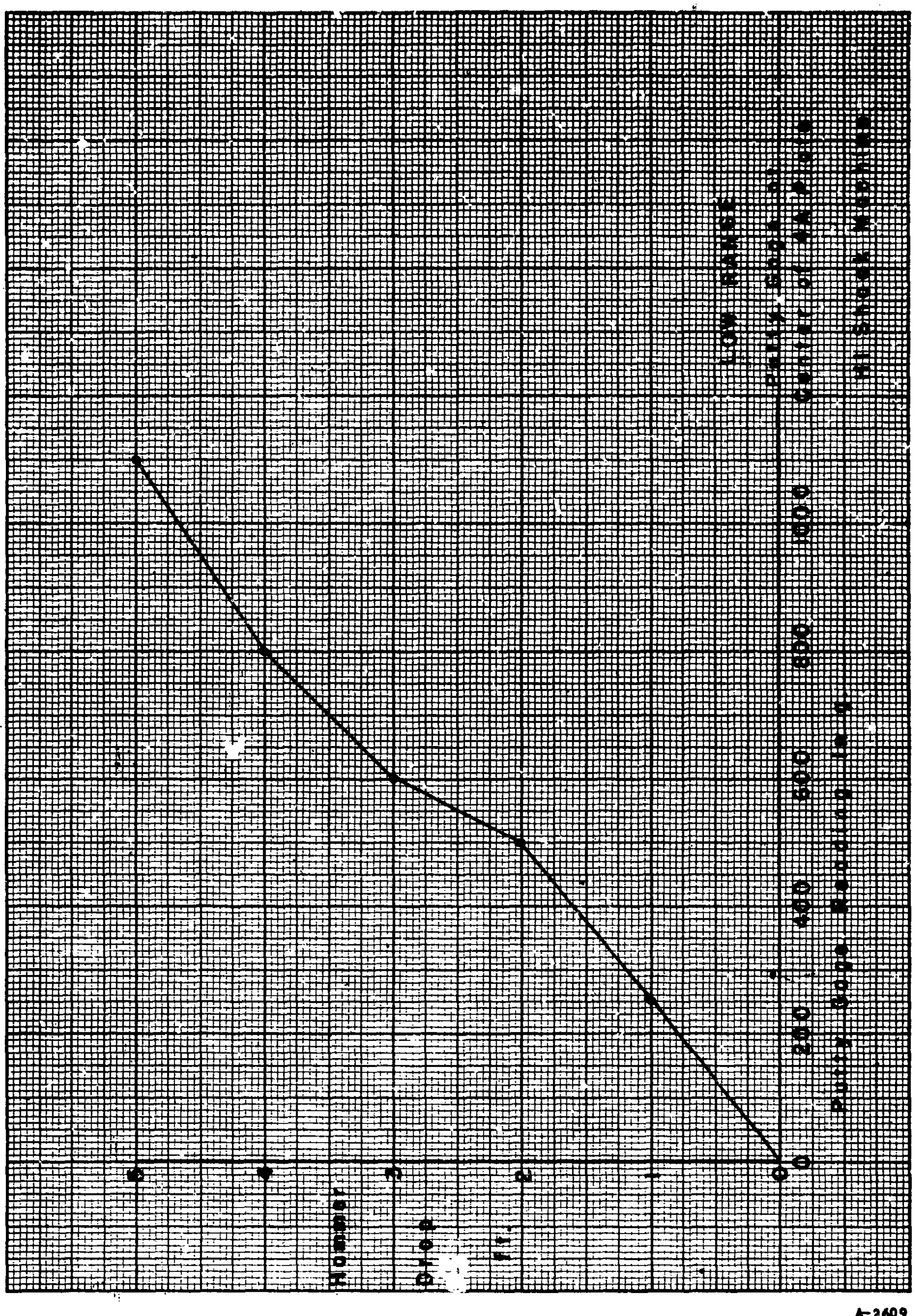


FIG. 169

A-2609

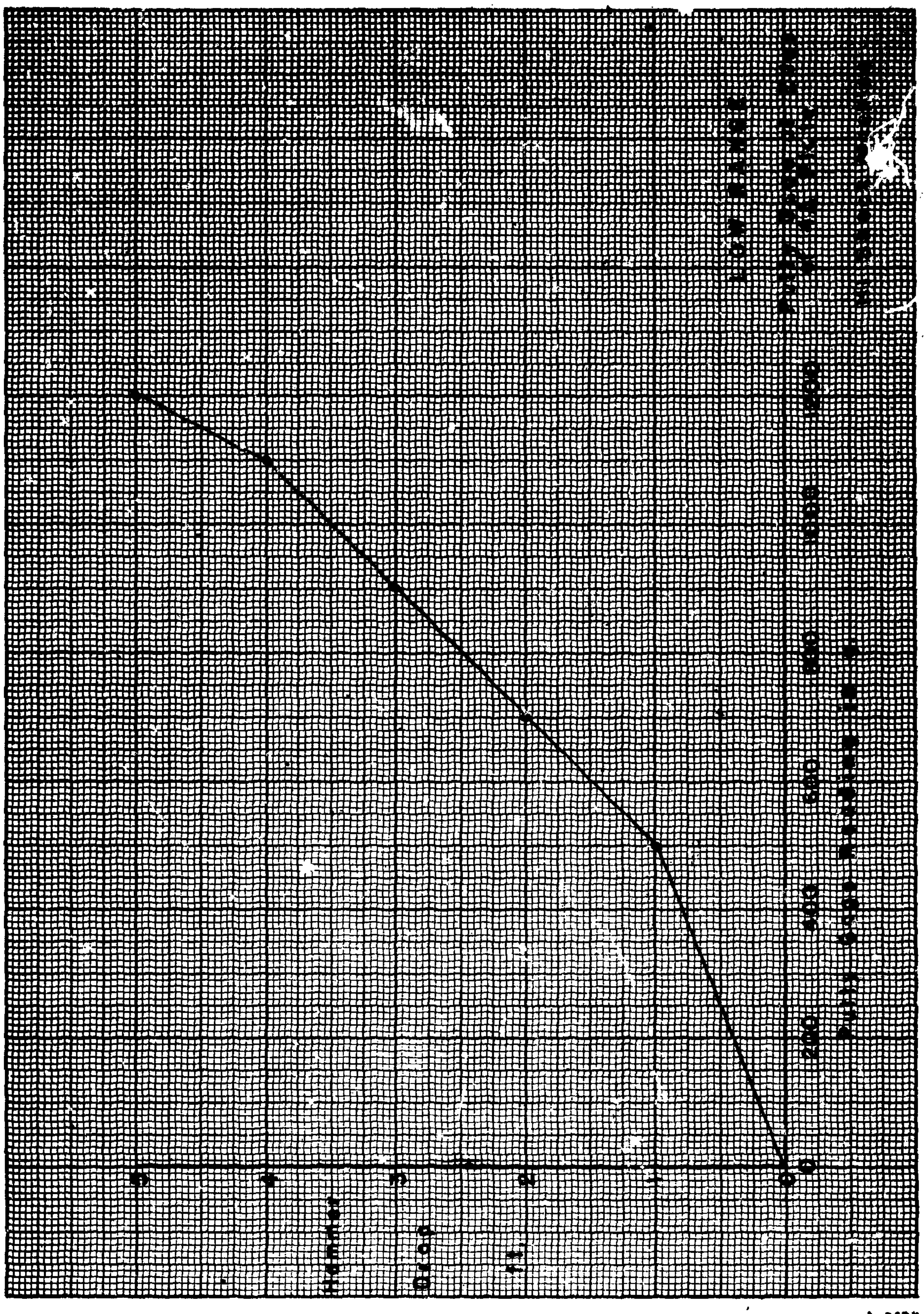


FIG. 170

A-2609

V. DISCUSSION OF DATA

Instruments

The gages used were predominantly mechanical as a precaution against loss of records through the action of radiation from the bombs. A large number of gages had to be made in a relatively short time and there was little opportunity for thorough evaluation of existing gages or development of new types. In several respects the instruments used were not wholly satisfactory. The following brief criticisms of the gages summarize what was learned through experience in their use and the interpretation of their records. Detailed discussions of gage theory and accuracy were given in Section III.

The reliability of putty gages is fairly good in that the readings were usually consistent with one another, but a reading not apparently consistent with others could not be assumed to be correct - nor could it be wholly disregarded. Due to the difficulty of predicting the probable peak accelerations and the necessity for limiting the number of standard gage ranges used, the gages were capable of recording much higher accelerations than was necessary in most locations. This made the accuracy of definition of acceleration undesirably poor, particularly in the range 0 to 100g.

The putty gage records peak acceleration of a shock motion provided the duration of that acceleration exceeds about one millisecond. From the practical standpoint of equipment design, the tendency of the gage to read too low for short duration accelerations is not serious since few equipments are sensitive to the value of an acceleration when its duration is short. However, this error of the putty gage may be the reason for the poor correlation of many reed gage records with adjacent putty gages.

The putty gage reading alone is not an adequate measure of shock since it does not indicate important characteristics such as duration of the acceleration, transient vibration frequencies, etc. By supplementing the readings with other gage readings and certain assumptions, the putty gage readings yield some approximate design criteria. For example, the long duration of the pressure wave in Test Able suggests the assumption that initial accelerations will be as long as the natural frequencies of the ship's structure will permit. The periods of the initial acceleration, shown by the few reed gage and velocity meter records obtained, were on the order of 5 to 25 milliseconds. This means that the putty gage readings will not be too low and that the readings apply within the limits of their probable accuracy to the design of small equipments having natural frequencies of vibration over 40 or 200 cycles per second, depending upon the location.

The indenter gage is subject to the serious criticism that vibratory shock motions can produce readings which may be indefinitely too large. It is a simple gage but should not be used for measurement of shock involving several reversals of the acceleration. The readings of many indenter gages indicate that the shock motion was often of a vibratory nature. The readings are therefore useful only in showing that the actual acceleration was some value smaller than the reading.

The reed gage is a simulated piece of equipment in that it contains elements having various discrete natural frequencies. It demonstrates how much elastic distortion an element of an equipment must be designed to withstand, as a function only of the natural frequency of the equipment element. The data can be readily converted into terms of how much steady acceleration the equipment element should be able to withstand as a function of its natural frequency. Thus the reed gage yields fundamental data as to the capacity of a shock motion to produce damage in equipment. This damage is defined however as a permanent set in ductile materials or fracture of ductile materials, opening of relays, slipping of friction bonds, and other non-linear or inelastic elements may or may not be treated from reed gage data, depending upon the individual case. Reed gage data does not apply to the design of equipment so large that installation of the equipment would change the shock motion at the point of installation.

A plot of reed gage response can be used to estimate the nature of the shock motion, or at least to name a simple shock motion which would produce the same response pattern and therefore be likely to cause the same damage. This "equivalent simple shock" is sometimes more easily dealt with than the original complex shock. The worst feature of the reed gage is the inaccuracy of measurement of the high-frequency reed deflections.

The velocity meter records all significant aspects of a shock motion. Analysis of the record yields data on acceleration and its duration, displacement, frequencies of vibration present, and the effect of the shock upon elements of any natural frequency. The latter is more easily obtained directly from the reed gage. The permanent velocity meter record permits construction of shock machine for reproduction of the motion.

Velocity meters of course involve a great deal more apparatus than the purely mechanical gages. The meter could be improved by providing a positive means of identifying on the record the times at which the magnet bottoms. Hard-bottoming stops seem to be desirable and the springs could be softer. Any decrease in the size and weight of the instrument would improve its utility and allow its use in more restricted locations.

A shock displacement gage has the disadvantage that integration and/or differentiation of its record is necessary. Its advantage, peculiar to the atomic bomb tests, lay in its not using photographic recording or faint electrical signals which might be altered by ionization or shock. Such precautions were apparently not necessary and the velocity meter is to be preferred.

Due to the fact that no one type of instrument records all information of interest and since some checking of one instrument by another is desirable, use of clusters of instruments was the most satisfactory. A velocity meter, a reed gage and a peak-reading accelerometer are the recommended components of such a cluster.

TEST ABLE

The air pressure wave of Test Able was of very long duration and of very low peak pressure compared to the underwater pressure waves from underwater explosions. The pressure was capable of producing high accelerations only on members which had a high ratio of exposed area to mass being accelerated. The actual pressure acting upon a surface is a function of the free-field pressure, the angle of incidence of the pressure wave, the motion of the surface, the "leakage" of air pressure around the boundaries of the surface, and such complex effects as shielding and reflections due to other portions of the ship. Such factors are not within the scope of this report but are necessary elements of a detailed study of the shock produced. Since such a detailed study also requires knowledge of the masses and stiffness of the structures involved, only a qualitative examination of the data has been attempted. Some quantitative approximations are given.

It is necessary to distinguish between two types of shock caused by the pressure wave. These types are commonly called "direct blast shock" and "indirect blast shock". Direct blast shock occurs in members directly loaded by the pressure wave. Indirect blast shock occurs in members not directly loaded by the pressure wave. Equipment subjected to indirect blast shock is affected by the motion of its foundation. The equipment foundation has, however, been directly excited by the blast. In its damage reports, DSM terms the indirect blast shock simply "shock" and direct blast shock damage was called "blast damage". Only indirect blast shock is considered in this report since the instrumentation was planned for measurement of motion characteristics at potential equipment locations not directly affected by the air blast.

A useful picture of the variation of indirect blast shock intensity with location in a ship can be obtained by considering the effect of suddenly applying a constant pressure to an external deck or bulkhead of a ship. At the instant of application of the pressure, the only force acting on the surface plating is the pressure. An acceleration value for the plating could be computed from the pressure and the mass per unit area of the plating. As the plating starts to move inward, it transmits part of the pressure loading to members to which it is attached. These members are added to the mass being accelerated and the acceleration of the plating and these members is less than the initial acceleration of the plating. As the effect of the pressure progresses into a ship, more and more mass is being accelerated by the external pressure. The peak acceleration of a particular location is a function of how much mass had to be set into motion to start acceleration of that location. It is realized that this is an oversimplified picture of a very complex phenomenon and no claim is made for its technical accuracy. It is simply a working hypothesis which was found to agree with the data to a useful degree of accuracy. Indirect blast shock could be described as having "low penetration" since it was usually negligable beyond a few feet from external surfaces.

Locations on a ship can be classified in accordance with the relative intensity of shock to be expected from the airblast of Test Able. This has been done for the gage locations listed in Section IV. A number (1), (2), or (3) immediately following the "A" in the data for a gage indicates in which of the following classes the gage location is considered to be. The numbers were estimated from consideration of the gage location and the bearing of the explosion, not from the gage reading.

Class (1). Moderate to severe shock - stiffened diaphragms not carrying heavy masses. This class includes the average superstructure bulkhead or deck which is directly acted upon by the pressure. The area exposed is large and the restraining force of the surrounding structure is negligible for the first few milliseconds. Equipment mounted on such a surface or its stiffening ribs will receive moderate to severe shock. Examples of such locations at which gages were placed are: hulls of destroyers r APA's above the waterline; external bulkheads of destroyer supply office in the superstructure; overhead in a cruiser pilot house; bulkhead of 5" battery directory and of main battery fire control station on capital ships; etc.

Class (2). Moderate shock-locations adjacent to the above decks or bulkheads not requiring acceleration of large mass to set these locations into motion. Examples of such locations where gages were placed are: on the in mechanism case of a mark 33 gun director ; most internal locations in the superstructure of a destroyer such as the deck of the C.I.C. room; within the fire control tower of a capital ship; etc.

Class (3). Ligh negligible shock - any location not directly acted upon by the pre ure wave and which has fairly heavy structure or masses between it and exterior surfaces. Examples of such locations are: within the hull of a ship more than a few feet from exposed surfaces; near the main deck at the centerline of a destroyer superstructure; within a capital ship superstructure on the order of, say, 10 feet from external surfaces; etc.

A plot of putty gage readings versus range is shown in fig. 171. Gage readings from class (1) locations are represented by circled dots; class (2) locations, by horizontal bars through dots; and class (3) locations, by dots alone. A short arrow down from a point indicates that no reading was obtained on the gage and the point is placed at the minimum setting he gage. The dotted curve "A" is copied from a peak pressure vs. distance curve given in the "Coordinator's Report on Air Blast and Water Shock in Tests Able and Baker." The pressure scale is not given. Curve "B" connects points obtained from athwartships gages on deck brackets near the exterior bulkheads of destroyer C.I.C. rooms. Curve "C" connects points obtained from gages on the external bulkheads of the supply offices of the DD404 and DD408. No other sets of locations were deemed adequately similar to warrant connecting their points except the DD404 and DD408 gages on the hull frames 5 feet below the main deck. The DD404 reading of 450g. at this location is not in good agreement with that on the DD408 of less than 50g. nor does it agree with the adjacent reed gage. It should therefore be disregarded.

Curve 171A shows only the points from class (1) putty gage locations. A curve "D" has been added such that the data points are all contained under curve "D". Thus the equation expressing D in units of gravity, namely $D = \frac{43 \times 10^6}{d^{1.5}}$ where d is range in feet, represents a maximum acceleration that may reasonably be expected at class (1) locations. This is an entirely empirical result and applied approximately to ranges from 2500 to 7000 feet and all types of ships with the probable exception of submarines. The accelerations indicated by the gages extend to frequency components somewhat greater than 1000 cps. It is to be noted that the pressure wave "A" is not greatly dissimilar to "D". The maximum acceleration indicated may therefore be said to be proportional to the maximum air blast pressure for the range considered.

Similarly, the plot of figure 171B shows only the points for class (2) locations and indicates that accelerations in units of gravity no greater than $\frac{27 \times 10^6}{d^{1.5}}$ may normally be expected. Again it is noted that the maximum accelerations are approximately proportional to the peak pressure of the blast wave.

For class (3) locations, the shocks were usually so small that accelerations were bracketed principally between zero and the lowest gage setting of 20 or 50g. An upper limit of acceleration in units of gravity may be expected to be below $17 \times 10^6 / d^{1.5}$. Generally the values will be very much lower than the figures calculated.

Little can be done to summarize and generalize the data presented by the reed gage over that previously presented for the individual ships in Section IV. The effects of resonance of reeds with transient vibrations of supporting structures tend to make for little consistency between reed deflection and shock intensity. This statement does not detract from the usefulness of the reed gage which indicates in a simple manner the damaging potential of the shock motion for a linear elastic system.

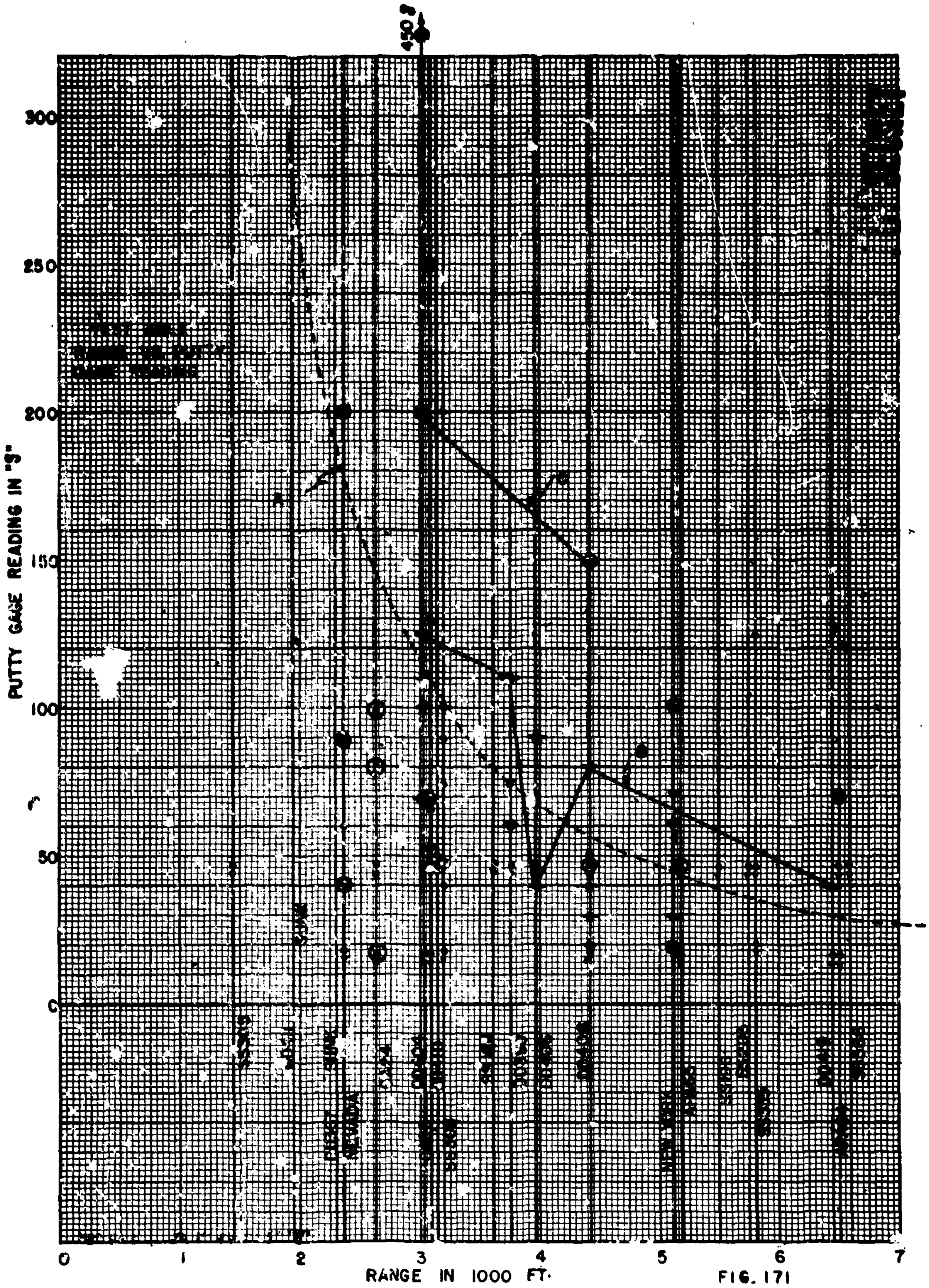


FIG. 171

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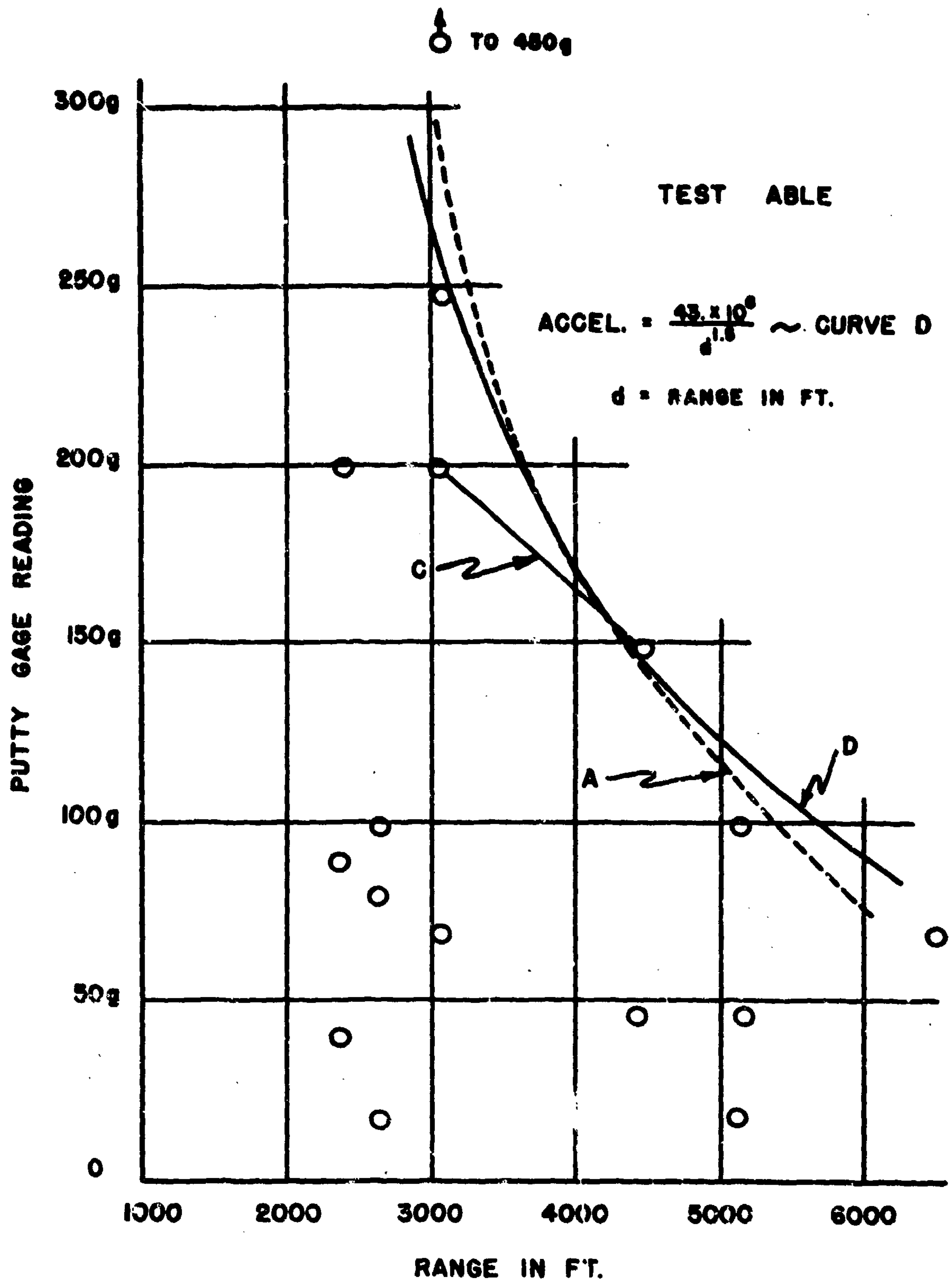

RANGE vs PUTTY GAGE READINGS FOR CLASS (I) LOCATIONS FOR ALL TYPES OF SURFACE SHIPS.

FIG. 171A

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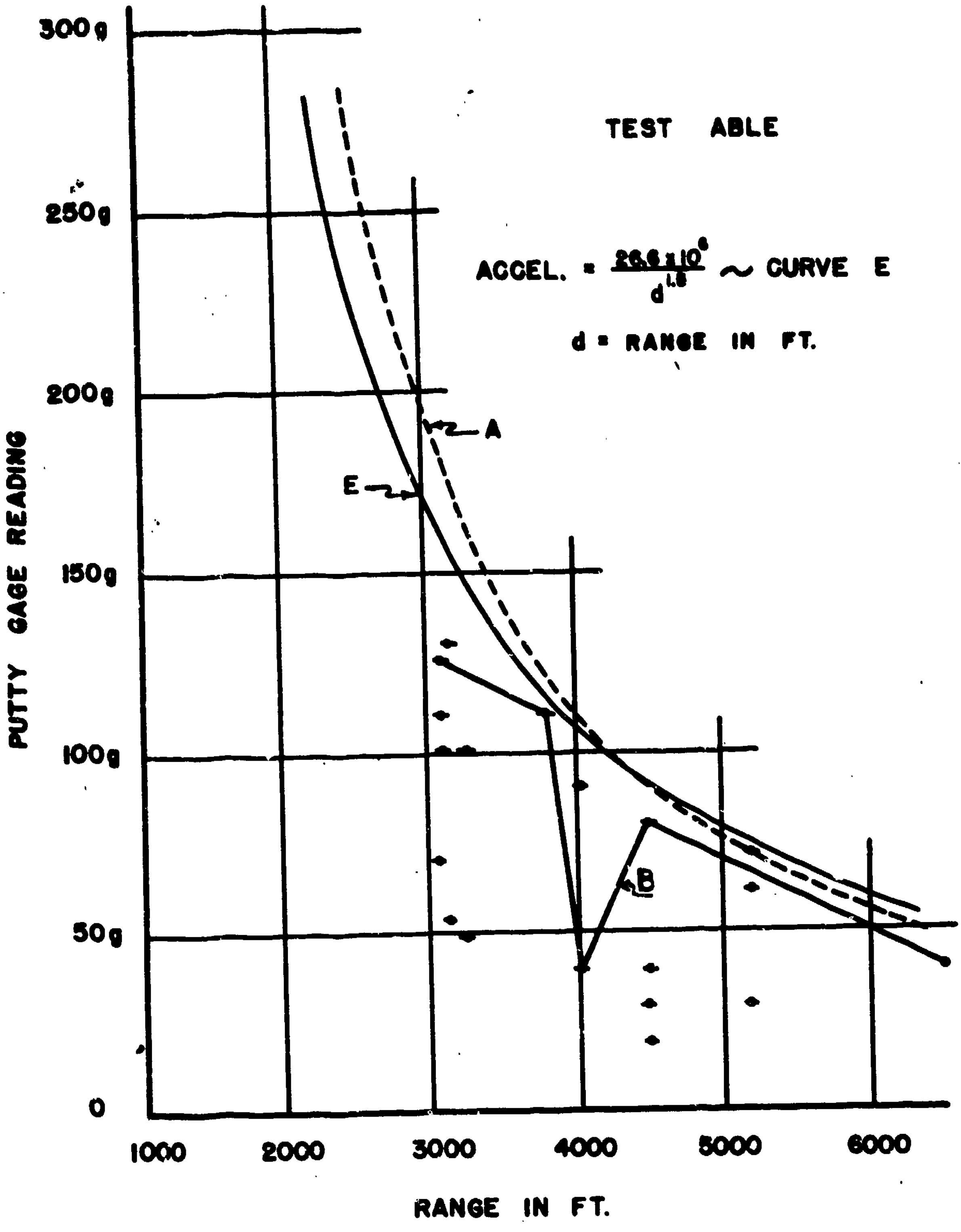

RANGE vs PUTTY GAGE READINGS FOR CLASS (2) LOCATIONS FOR ALL TYPES OF SHIPS

FIG. 171 B

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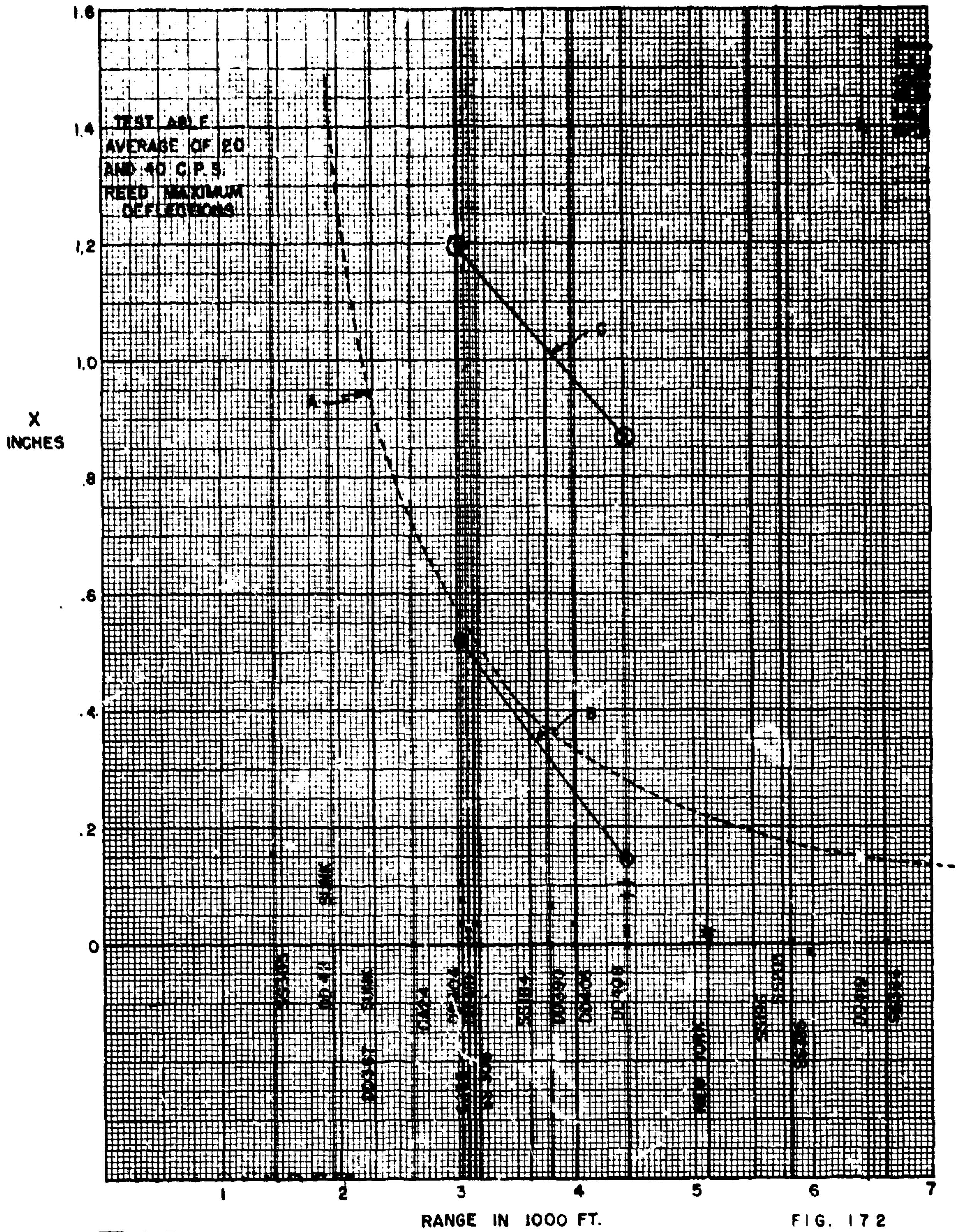

FIG. 172

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A plot of "Average of 20 and 40 Cycle Reed Maximum Deflections" versus range is shown in figure 172. These values were computed by simple averaging in order to decrease deviations due to resonance of either a 20 or 40 cps reed. The values indicate the amount of distortion to be expected in low frequency structures. They indicate the deflection of an average shock mounted equipments in the mounts are linear for all deflections. The dotted curve "A" is a copy of a peak pressure versus distance curve. The line "B" connects points from the DD404 and DD408 gages on a hull frame 5 feet below the main deck. The line "C" connects points from the DD404 and DD408 gages on the external supply office bulkhead. From line "C" the "response" or deflection of the 20 to 40 cps. reeds may be estimated to be between 0.8 and 1.5 inches for external bulkheads of destroyer superstructures which were dished in several inches for the lower values and ruptured for the higher values. The response on light hull frames above the waterline, as indicated by line "B", will be up to 0.5 inches for low frequency reeds. Low frequency reed deflections for interior parts of the ship, class (3) are generally less than 0.1 inch for distances greater than 3000 feet from the explosion.

In figures 171 and 172, no emphasis should be placed upon whether points are concentrated in a region of high or low readings. The gages were placed largely in anticipation of Test Baker and their distribution did not necessarily reflect the distribution of equipment susceptible to shock.

A list has been studied of the references to shock damage made in a D.S.M. report for Test Able. Such a tabulation of damage cannot be used to indicate the distribution of shock intensity in the fashion of gage readings because the failure strength of these equipments are not known to the writer. However, with the reservation that some shock failures must have escaped the notice of the damage inspection group, the damage reports indicate to what extent past design practice was inadequate for Test Able shock. In all instances, the shock damage reported accounted for a very small proportion of the damage to a ship. Only a relatively few items per ship were reported to be damaged by shock.

The SS305 had shock damage to more important items than the other surviving ships. This apparently was due to its extremely close range which made the shock intensity within the hull (class (3) locations) adequate to cause failure of a few of the weaker items. However the total number of shock failures was small and shock damage could not be termed "widespread".

On the other ships, shock damage was scattered and frequently occurred on items which were probably designed without any consideration of shock. The only consistently mentioned type of failure was in light bulbs. Beyond a range of 3500 feet, shock damage was very slight and confined largely to light bulbs.

TEST BAKER

Readings were obtained from shock gages distributed over a large number of ships. However, there were many variables involved, such as position of a gage in a ship, type of ship, range, draft, and heading of a ship, etc. Thus data was not obtained for many combinations of the above variables which were of great interest, and for other combinations the data was not very extensive. This was due to the uncertainty in predicting the closest range at which ships could be expected to survive, the limited number of ships at a given range and changes made in the target array.

The question arises as to whether or not the readings for a given ship can be appropriately altered to those to be expected for a different range and heading of the ship. There seems to be hope that this could be done to some extent through study of the underwater pressure-time records. This prospect is based upon the success of the British tests of the destroyer "HMS Cameron" in showing the effect of change in weight of explosive charge, distance of the explosive, and angular position of the explosive upon shock gage readings. The conclusions of Section II of the Cameron Report, reference 5, are quoted below.

"For explosions insufficiently severe to cause permanent dishing of the shell plating or distortion of the hull framework the constituents of the motion normal to the shell plating which provide a measure of the liability of damage to any object can, if certain assumptions are made, be calculated with a fair degree of accuracy in terms of the following:

(a) Weight of charge - W.
(b) Distance of the explosion - D.
(c) Pressure-time curve of main pressure pulse caused by the explosion.
(d) Angle of incidence of the path of the pressure pulse on the shell plating in the vicinity of the object - θ.
(e) The area of shell plating from which the object received its motion, or conversely the weight supported per unit area of plating - M'.
(f) The stiffness of the panels of shell plating - S_1.
(g) The stiffness of the hull framework - S_2.

"Observed results justify the assumptions used in the calculations that a vacuum gap occurs in the water near the plating resulting in a certain amount of water being entrained with the shell plating and setting a limit to the amount of impulse in the main pressure pulse which can act on the plating.

"This limit is usually caused by the movement of the structure, which depends on its elasticity and the mass loading, but in certain circumstances there is a curtailment of the effects due to the arrival of tensile reflections from the surface of the sea. The latter effect is largely dependent on the draught and while of considerable importance near the waterline particularly for shallow explosions and heavier weights of charge it is likely to be unimportant if the draught exceeds 10 feet, or if the depth of the explosion below the surface of the sea is more than say one third of its horizontal distance from the target.

"Approximate formulae can be derived for the motion when cutoff depends on movement of the structure, and comparison of these with the observed results leads to the following relationships being shown to be approximately correct within the elastic limit of the shell plating and when diffraction can be neglected.

Maximum Velocity of Object = $\frac{1000}{M'^{\frac{1}{2}}} Q_A$ ft/sec

Maximum Acceleration of Object = $135 \frac{S_1^{\frac{1}{2}}}{M'} Q_A$ g ft/sec²

Maximum deceleration of object = $150 \frac{S_2^{1/2}}{M'} Q_A$ g ft/sec²

First peak of absolute displacement of object = $\frac{3800}{S_2^{1/2}} Q_A$ in.

Where $Q_A = \frac{(W \sin\theta)^{1/2}}{D} - .015$

"The presence of the term(-.015) which represents a mean value only is probably due to the difference in pressure inside and outside the hull when a vacuum gap occurs outside, but may be connected with the fact that beyond a critical distance for any given weight of charge, a vacuum gap is unlikely to form, hence the motion that can be caused is very restricted.

"For angles of incidence below 30° say, objects near the first point of impingement of the pressure pulse in the vicinity may have their motion considerable modified by diffraction. Observed results show that the formulae given above can still be used under these conditions if Q_D is substituted for Q_A, where $Q_D = \frac{W}{D}\left(\frac{1+\sin\theta}{2}\right) - .015$. For values of θ above 30° there is little difference between Q_A and Q_D.

"Only the fringe of the plastic range of the shell plating could be explored during CAMERON Trials, and although it seems probable that the same approximate formulae should apply with suitable adjustment of the constant S_1 and possibly also of S_2, there is not at present sufficient experimental evidence to ascertain what these adjustments should be in any particular case."

The fundamental quantities in the impingement of a pressure pulse upon hull plating, upon which the reading of a particular gage was considered to depend, were the mass and initial velocity of the water entrained with the shell plating from which the gage location received its motion. These in turn depend upon the shape of the pressure-time curve, the hull plating, and the angle of incidence of the wave with the hull plating. The shock factor obtained by the British was applicable only when cavitation of the water was assumed to occur; it was not applicable when plastic dishing of the hull plating occurred, and its applicability was demonstrated only for a destroyer.

Because of the shift of about 90° in the heading of bow-anchored ships on Baker Day, a large proportion of the gages were affected by shell plating contacted by the diffracted wave front of the direct pressure pulse from the explosion. Diffraction of the tensile reflection from the ship's bottom is dealt with in the Cameron report but diffraction of the positive wave front was apparently of little interest in the tests. In many cases in Test Baker, the initial pressure pulse travelled at grazing incidence for long distances along a ship's bottom before reaching the plating closest to a gage location. It is suggested that the peak pressure in this case and in the case of "negative angles of incidence" would be decreased by diffraction of the wave. An estimate of the appropriate shock factor could probably be obtained by using the method of Dr. Penny given in his Crossroads report - "Reasons for Expecting the Peak Pressure in Baker to Fall Off with Radius Faster Than R^{-1}".

The ships on which all gages were affected by hull plating having a small or negative angle of incidence with the initial pressure wave were: capital ships NEW YORK, PENSACOLA, and SALT LAKE CITY; destroyers 390, 402, 403, 404, 406, 408, and 419; and the APA64. The remaining ships from which readings were obtained were: capital ships NEVADA and PENNSYLVANIA; APA's 65 and 87; surfaced submarines 305 and 384; and submerged submarines 196, 203, and 335. Of these, the PENNSYLVANIA and APA87 readings are of little value. The Cameron report and the preceding discussion indicate the <u>the gage readings on the first ships listed above were low compared to those to be expected if the ships' headings had been such that maximum angles</u>

of incidence occurred. Unless suitable correction factors for change in heading of a ship can be applied, the majority of the data will remain of limited usefulness. The problem of correction factors for change in range of a ship is of equal importance since closer ranges than obtained for most ships are of most interest.

Another important result might come from study of the pressure-time records. It may be possible to state whether or not the problem of designing equipment to withstand Test Baker type shock is significantly different from that for ordinary explosives. If the pressure pulses from the Baker explosion and an ordinary explosion are shown to be the same in essential characteristics, the data given in this report becomes a part of data previously obtained on shock in ships and attention need be given only to the portions of this data likely to extend the knowledge of this subject.

Test Baker was further complicated by the numerous pressure pulses which struck the ships. Air blast can be shown to have caused the readings of same gages, but for other gages it is not certain whether air blast or underwater pressure waves caused the readings. This reduces the value of attempts to show the changes in shock from underwater pressure waves with varying distance of a gage from the hull.

It is stated in some underwater pressure reports that the second underwater pressure pulse had more capacity to cause damage than the initial pulse. The relative damage capacity of the two pulses apparently varied with range and depth. Conflicting theories of the cause of the second pulse were advanced in the early reports on the subject. If the "water hammer" theory is correct, the direction of travel of the second pulse may have had a large upward component. This would produce a radically different angle of incidence on shell plating from that of the initial pulse. This of course would require evaluation of shock factors for both pulses. Further discussion of this subject and that of later underwater pulses is not considered to be necessary. The purpose of the preceding paragraphs is to indicate the factors outside of the ship's structure itself which have a profound influence upon the gage readings and their interpretation.

While answers to some of the more important questions of Test Baker shock are believed to depend upon finding of shock factors many observations can be made regarding the data. Since drawing of generalizations from the data was not possible in many cases, the data itself in section IV contains information not to be found in any attempt to reduce its bulk. Comments on data for each ship and type of ship were made in section IV which represents the first stage of reduction of the data. The observations in the following paragraphs represent a further reduction in size. The reader is cautioned that

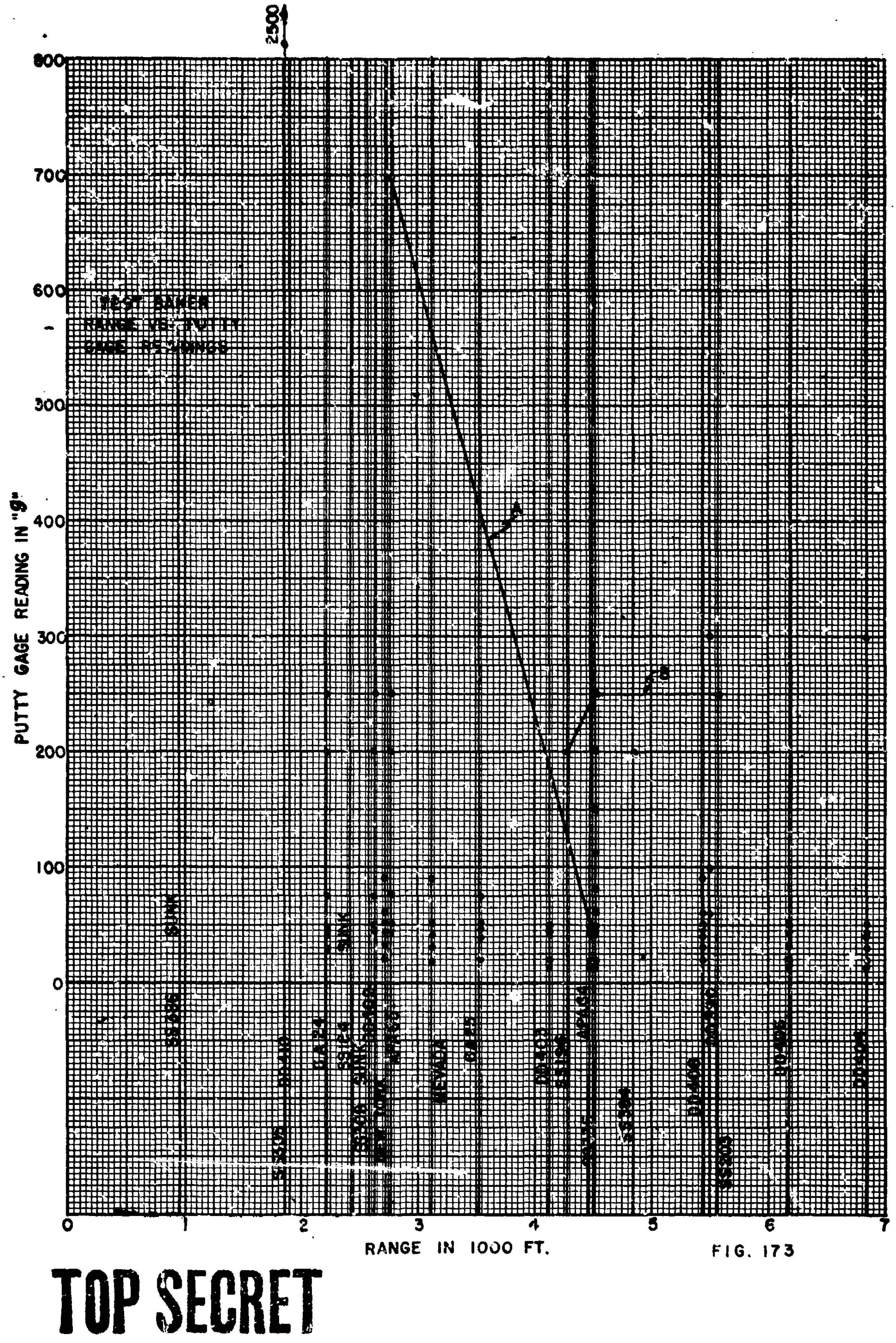

FIG. 173

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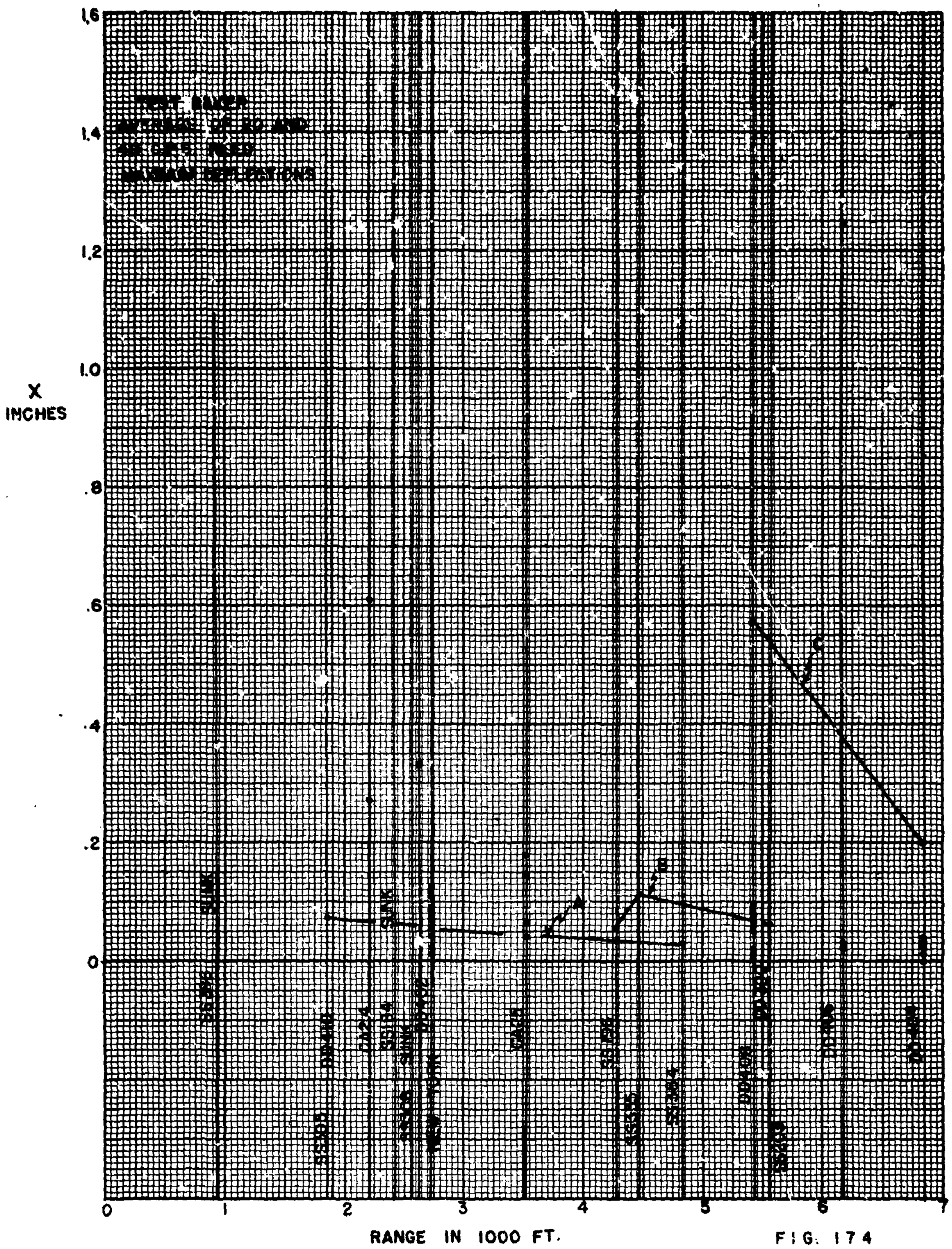

FIG. 174

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this was largely a process of omission of detail rather than integration into more concise form.

The putty gage and the low-frequency reed readings have been plotted as in Test Able. Referring to figure 173, it is seen that the putty gage readings on hull frame members nearest to the explosion stand out far above the other readings. The SS305 reading of 2500g., the APA65 reading of 700g., the SS384 reading of 200g. and the three submarine readings connected by line B represent the only putty gage locations on hull frame members with an angle of incidence of the initial pressure pulse of over, say, 15° and their angles of incidence were all over 60°. The line A connects readings of identical portside hull frame locations below the waterline on the APA's 65 and 64. The explosion was to port of the APA 65 and to starboard of the APA64. For a different orientation of the ships the upper limit of gage readings is indicated by the few high readings.

Figure 174 shows a plot of low-frequency reed deflections versus range, using the average of 20 and 40 cycle reed deflections to obtain one point per gage. Line A connects points from reed gages on torpedo room frame members on the side closest to the explosion for the surfaced submarines SS305 and SS384. Line B connects points for the same type of location on the submerged submarines SS196, SS335, and SS203. Line C connects points from reed gages on the DD408 and DD404 supply office bulkheads. The latter readings are due to airblast. The submarine reed gages were the only ones on hull frame members with angles of incidence of over, say 20°.

The Test Baker reed gage frequency-response curves indicate the major excitation to be due to an acceleration pulse on the order of 2 milliseconds or less. The implications of this statement require many qualifications. First, records in general were obtained at locations close to the hull so the low-pass filter effect of the ship's structure was not observed. Many gages had high-frequency-reed deflections little longer than the probable error in their measurement so a peak in the frequency-response curve at, say, 600 cps. could easily be missed. The initial pulse records on the APA65 velocity meters near the hull also show an initial acceleration period of 2 milliseconds or less.

Limited deflections were indicated on the submarine and APA65 hull frame gages. These gages were on side frame members closest to the explosion. The submarine data consists of reed gage records and the effect is most noticeable on the SS305 where a peak acceleration of over 2500g. resulted in a deflection of less than .10 inch. The

TMB velocity meters, V6 and V12, on the hull of the APA65 show an inward deflection of the hull frame of .15 and .12 inches respectively due to the initial acceleration and an equal deceleration which brought the frame to rest. Velocity meters on the APA65 keel top did not show this sudden stopping effect. The reason for this limited deflection is not clear although several hypotheses might be advanced to account for it. If cutoff severely reduced the mass of entrained water on the hull plating, the sudden stop simply represents the stopping time of the hull frame discussed in the Cameron Report. Application of a load to hull plating some feet away from the gage location can result in an outward motion at the gage location. The sequence of pressure application to the hull may have been such as to produce an outward acceleration due to this effect. Failure of the water to cavitate would cause only limited deflection of the hull plating.

Because of the evidence of the APA65, it cannot be concluded that motion of all parts of the submarines was less than .10 inch. It is possible that this limited deflection effect represents a difference between Test Baker and ordinary shock; the writer's knowledge of available shock records is too small to justify a positive statement.

There are many illustrations in the data of the decrease in readings due to diffraction of the pressure wave front. The Salt Lake City, the APA65 and APA64, the SS335 and the destroyers all show that lower readings are to be expected on the side of the hull away from the explosion. The evidence to show that shock decreases as the wave passes along the keel of a ship stern-or bow- to the explosion is not conclusive. It can only be stated that this was the impression which the writer obtained from the New York and the destroyer data.

The implication of the preceding paragraph is that the underwater pressure pulse which caused the non-time-recording-gage readings travelled at a low angle to the horizontal. While the Nevada putty gage readings support this view, the APA65 velocity meters do not wholly agree with this. In the discussion of the APA65 data, it appeared that the shock occurring .21 and .24 seconds after the initial shock caused larger velocity changes at some gage locations than the initial shock. The pattern of the gage locations and the velocity changes was shown to indicate that the two later shocks were due to pressure pulses from below. The initial pulse showed a direction of propagation nearly horizontal, as expected.

A question of possible tactical importance is whether or not the bearing relative to a ship of the explosion in a Test Baker type attack has a significant influence upon the damage to that ship. The data in this report is only a fragment of that necessary to answer this question, but the impression of the writer is that a ship bow- or stern-to the explosion is likely to suffer less total damage than one broadside to the explosion. The question probably is applicable to Test Able but the data of this report is considered to be of little value to such a study.

The time-recording instruments on the DD404, DD408 and APA65 showed the excitations due to the wave through the coral, the direct underwater pressure wave, the later underwater pressure waves and the air blast. A remarkably constant period between successive underwater shocks is observable in some of the velocity meter records. These records might be useful as a supplement to underwater pressure-time records.

VI. CONCLUSIONS.

TEST ABLE.

A designer who has familiarized himself with this report can estimate the intensity of shock at any particular lo ation on a ship subject to a Test Able type attack.

The indirect shock damage caused by Test Able is minor relative to the damage from direct blast. The indirect shock damage is usually limited to regions close to surfaces exposed directly to the air blast. Shock damage was usually confined to a relatively small proportion of equipments which apparently were below average in shock resistance.

The range beyond which shock damage appeared to be negligible was 3500 feet. On many ships at less than this range, the shock damage was of very minor importance.

The maximum acceleration occuring on external decks and bulkheads can be very approximately stated as being less than:

$$A(1) = \frac{45 \times 10^6}{\ell^{1.5}} \quad \text{units of gravity.}$$

The maximum accelerations occurring on decks and bulkheads adjacent to the above locations are less than:

$$A(2) = \frac{27 \times 10^6}{\ell^{1.5}} \quad \text{units of gravity.}$$

The maximum accelerations occurring at more protected interior parts of a ship are generally much less than:

$$A(g) = \frac{12 \times 10^{6}}{d^{1.5}} \quad \text{units of gravity.}$$

The accelerations are composed principally of frequency components up to several thousand cycles per second and d is the distance in feet of the ship from the explosion.

The deflections of single-degree-of-freedom systems (20 to 40 c.p.s.) are generally less than 0.2 inch for interior locations in a ship. For exposed locations, the deflections may extend to nearly 2.0 inches.

TEST BAKER.

The shock motions of most interest in Test Baker were caused by underwater pressure pulses of positive durations of a few milliseconds or less. Since underwater pressure pulses from ordinary explosives have durations of the same order of magnitude, it was expected that in general the shock motions would be similar for the two types of explosion. This was the case in that orders of magnitude of readings and time effects, and change in shock with position in a ship were approximately the same for Test Baker and previous shock tests. It does not seem possible to state from this data alone whether the shock design problem for Test Baker is essentially the same as for ordinary explosives.

It was stated in section IV that a method for scaling shock gage readings obtained to those which would have occurred with different orientation and range was necessary. Without such a scaling method, much of the data is of limited value. Many ships were not headed as planned in the target array, with the consequence that a considerable number of gages were on the shielded side of a ship. There were few ships instrumented at the range which turned out to be the closest range of interest. It is hoped that scaling methods can be devised by analysis of the underwater pressure-time records.

The time-recording instruments showed the arrival of the successive pressure waves and may be of interest to groups studying these waves.