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R-1714

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Date: 14 JUN 2016

Declassification authority: H. Do, P. HANNA

Declassification authority:

DECLASSIFIED: By authority of 5000A Dated: 8 Jan 1958

Entered By: E. Bliss Code 2027

DISTRIBUTION STATEMENT A

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22 April 1941

NRL Report No. R-1714  
Problem No. W1-2

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NAVY DEPARTMENT

Report on

Keying Characteristics of Station NSS

NAVAL RESEARCH LABORATORY  
ANACOSTIA STATION  
WASHINGTON, D. C.

Number of Pages: Text - 15 Tables 5 Plates - 33

Date of Test: December 4, 6, and 8, 1940.

Authorization: BuEng. Ltr. C-NOs-35693(9-2-R6), C-NOs-36484(9-2-R6)  
of 20 June 1939.  
BuShips Dispatch 272143 of 27 November 1940.

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Distribution:

BuShips (10)  
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ABSTRACT

This report is a study of oscillograms made in the Radio Receiver Section of the Naval Research Laboratory of keyed signals transmitted by Station NSS at Annapolis. Distortion of the signals by the receiver was avoided by broadening its circuits. Considerable distortion and attenuation of the dot signals were observed, especially at the lowest frequency used, 15.44 kcs. Oscillograms were enlarged and analyzed to determine the loss in amplitude and power, and curves were drawn to determine the effective Q of the antenna.

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## AUTHORIZATION

1. The general problem of acceptance tests on station NSS was authorized in reference (a). Dates for the tests were assigned in reference (b).

(a) BuEng. Ltr. C-NOs-35693(9-2-R6), C-NOs-36484(9-2-R6)  
of 20 June 1939.

(b) BuShips Dispatch 272143 of 27 November 1940.

## INTRODUCTORY

2. This report is a study of oscillograms made in the Radio Receiver Section of the Naval Research Laboratory of signals transmitted by Station NSS at Annapolis. A receiver with very broad circuits was used, to avoid distortion of the received signals.

## CONCLUSIONS

3. Considerable distortion and attenuation of dot signals are encountered. For instance, at 15.44 KC, at a transmission speed of 100 wpm, the dot cycle builds up so slowly that only 25% of the power is radiated that would appear if the dot cycle rose instantly to its full value. The maximum instantaneous value of carrier amplitude is only 50% of that which would eventually obtain after full build-up. Moreover, the wave shape is so distorted as to decrease considerably the intelligibility of the signal. In actual practice, the selectivity of the receiver employed will cause still further attenuation and distortion.

4. The effect appears to be caused chiefly by the transmitter antenna selectivity, since it is greatly reduced at higher carrier frequencies. The antenna is the only circuit in the transmitter with any appreciable selectivity.

5. Most of the oscillograms show a much slower build-up than decay. The most probable reason for this is a detuning of the final circuit due to mechanical strain on the variometer. The motion is actually visible when the transmitter is in operation.

THEORETICAL CONSIDERATIONS

6. In radio telegraphy transmission and reception there is usually some distortion and attenuation of dots and dashes, due to tuned antennas and circuits employed, in addition to that caused by relay and filter time constants, etc. If none of these effects were present, the keyed carrier envelope would be rectangular.

7. A rectangular envelope repeated at regular intervals, however, is actually a carrier modulated 100% by a rectangular wave. Since a rectangular wave is rich in harmonics, the carrier will have many sidebands. A wide band is therefore necessary to pass a radio CW telegraphy signal without distorting and attenuating its rectangular dots and dashes.

8. Radio transmitters operating at a low frequency are especially liable to distortion of rectangular modulation, since the band width of a circuit of given Q is proportional to its resonant frequency. In addition, the antenna Q of a low-frequency transmitter antenna is usually high because of its low radiation resistance.

9. Consequently, when the transmitter key is closed, the voltage does not build up instantly, but rises gradually to its maximum value. Similarly, when the key is opened, the voltage decays gradually. These time-lags are obviously more serious as the keying speed increases.

10. Let us consider Figure 1 of Plate 12 as a simplified one-tube transmitter. When the key is closed, the voltage across the tank builds up exponentially, and is

$$(I) \quad V = V_0 \left(1 - e^{-\frac{\omega t}{2Q}}\right), \text{ assuming the circuit is underdamped,}$$

( $Q > 1/2$ ), and was originally deenergized at the moment the key was closed.  $V_0$  is the rms voltage across the tank in the steady state condition, after the exponential term in the equation has become negligible.  $e$  is the Naperian logarithm base.  $\omega$  is  $2\pi$  times the frequency of the tank circuit and impressed voltage.  $Q$  is the ratio of the tank circuit reactance to its resistance (including the transferred resistance of the tube plate).

11. The above equation may be rewritten

$$(Ia) \quad \frac{V_0 - V}{V_0} = e^{-\frac{\omega t}{2Q}} = f(t)$$

If  $f(t)$  is plotted against  $t$  on semi-log cross section paper, a straight line will result. If an oscillogram of the voltage build-up is made, and  $f(t)$  is plotted against  $t$ , the coordinates of any point on the resulting straight line may be substituted in the following equation to determine the circuit Q.

$$(II) \quad Q = \frac{-\omega t}{2 \log_e f(t)} = \frac{-\omega t}{4.60 \log_{10} f(t)}$$

(II) was obtained from (Ia) by taking logarithms of both sides of the equation and clearing.

12. A transmission of  $n$  wpm (words per minute), contains on the average an equivalent of  $0.4n$  dot cycles per second. The period of a dot cycle is the length of time between the beginning of one dot and the beginning of the next one, and is equal to  $\frac{1}{0.4n}$ . Since a perfect dot lasts exactly one-half the period of a dot cycle, the time,  $T$ , during which the voltage is building up is  $\frac{1}{0.8n}$ . Thus the maximum voltage that will be attained is

$$(III) \quad V_T = V_0 \left( 1 - e^{-\frac{\omega}{2Q(0.8n)}} \right).$$

The ratio of this voltage to the voltage that would eventually be developed,  $V_0$ , is

$$(IV) \quad p = \frac{V_T}{V_0} = 1 - e^{-\frac{\omega}{1.6Qn}} = 1 - e^{-\frac{a}{0.8n}} \quad \text{where } a = \frac{\omega}{2Q}.$$

13. The voltage during the decaying half of the cycle is

$$(V) \quad V = V_T e^{-\frac{\omega t}{2Q}} = pV_0 e^{-\frac{\omega t}{2Q}}. \quad \text{Hence}$$

$$(VI) \quad Q = \frac{-\omega t}{4.6 \log_{10} \left( \frac{V}{pV_0} \right)}$$

It should be noted that in a practical transmitter the  $Q$  of a circuit during the decaying cycle (key up), may be considerably higher than that of the build-up cycle, due to variations in tube plate resistance with grid excitation.

14. The energy contained in a build-up cycle is

$$(VII) \quad W_1 = \frac{1}{r} \int_0^{\frac{1}{0.8n}} \frac{1}{V^2} dt, \quad \text{where } r \text{ is the circuit impedance.}$$

15. The energy contained in a decay cycle is

$$(VIII) \quad W_2 = \frac{1}{r} \int_0^{\frac{1}{0.8n}} \frac{1}{V^2} dt$$

The energy contained in a perfect rectangular wave is

$$W_0 = \frac{V_0^2 T}{r} = \frac{V_0^2}{0.8nr}, \text{ since } V = V_0, \text{ and is not a function}$$

of time.

16. Let us define  $E_k$ , the keying efficiency of the transmitter as the ratio of the energy contained in the actual build-up and decay of a dot cycle, to the energy that would be contained in the equivalent rectangular wave (see Fig. 2, plate 12). Then

$$E_k = \frac{W_1 + W_2}{W}$$

$$\frac{W_1}{W} = E_{k1} = \text{Build-up keying efficiency, and}$$

$$\frac{W_2}{W} = E_{k2} = \text{Decay keying efficiency}$$

Substituting (I) in (IV) gives

$$W_1 = \frac{V_0^2}{r} \int_0^1 \frac{1}{0.8n} (1 - e^{-\frac{\omega t}{2Q}})^2 dt$$

$$E_{k1} = \frac{W_1}{W_0} = 0.8n \int_0^1 \frac{1}{0.8n} (1 - e^{-\frac{\omega t}{2Q}})^2 dt$$

Integrating,

$$(IX) \quad E_{k1} = 1 - 0.8n \left\{ \frac{3}{2a} + \frac{1}{2a} \left( e^{-\frac{a}{0.8n}} \right)^2 - \frac{2}{a} e^{-\frac{a}{0.8n}} \right\}$$

$$\text{Where } a = \frac{\omega}{2Q}$$

Substituting (V) in (VIII),

$$W_2 = \frac{P^2 V_0^2}{r} \int_0^1 \frac{1}{0.8n} \left\{ e^{-\frac{\omega t}{2Q}} \right\}^2 dt$$

$$E_{k2} = \frac{W_2}{W_0} = 0.8np^2 \int_0^1 \frac{1}{0.8n} e^{-\frac{\omega t}{Q}} dt. \text{ Integrating,}$$

$$(X) \quad E_{k_2} = \frac{0.4np^2}{a} \left(1 - e^{-\frac{a}{0.4n}}\right)$$

Knowing  $\omega$ ,  $n$  and  $Q$ , equations (IX) and (X) permit the calculation of the theoretical keying efficiency, since  $E_{k_1} + E_{k_2} = E_k$ .

17. If the buildup causes a mechanical movement of the vario-meter, a progressive detuning will take place which will make the build-up non-exponential. It will also make the build-up slower, since the transmitter is tuned up under full power, and will be off tune when the key is first closed. The decay will not be slowed, but the frequency will change slightly during the decay cycle.

## SECTION II

### EXPERIMENTAL CONSIDERATIONS

18. In order to study the keying characteristics of Station NSS, a receiver was set up in the Receiver Section of the Naval Research Laboratory, equipped with an oscillograph and camera. The receiver was of special construction and employed 3 tuned r.f. stages of amplification, each tuned circuit having been broadened by shunt resistance, so as to cause negligible distortion of a rectangular envelope. Run 1, on Plate 2, shows an oscillogram obtained by keying the receiver antenna, with a 15.44 KC signal present. The film speed is 10 inches per second in all these oscillograms. The time constant of the receiver is shown to be between  $10^{-3}$  and  $1.6 \times 10^{-3}$  seconds, and will have little effect on the transmitter keying oscillograms. Run 2 on Plate 3 gives a time constant of  $3 \times 10^{-4}$  seconds at 26.1 KC. Run 1, on Plate 7, shows a very small time constant at 32.8 KC.

19. The rest of the oscillograms show signals radiated by keying the transmitter at various speeds and frequencies.

## SECTION III

### CALCULATIONS

20. The figures on Plate 17 were made with a projector. The negative of the run number indicated was inserted in the projector, which was focused on a screen. The cross-section paper was mounted on the screen, and the projected image outlined by pencil. It will be noticed that the sprocket holes were also outlined, thus giving a time reference for these figures. The sprocket holes are 19/64-inch apart on the negative, which progresses at a rate of 10 inches per second. Hence the distance between holes represents  $19/64 \text{ inch} \div 10 \text{ inches per sec.} = 2.97 \times 10^{-2} \text{ sec.}$  Other distances on the figures can thus be converted to seconds by proportionality.

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## CALCULATION OF WORDS PER MINUTE

21. The number of words per minute (WPM), indicated under the oscillograms on Plates 1 to 9, inclusive, and under the run numbers of the curves of Plate 13, and of the figures of Plates 17 to 26, inclusive, were obtained by measuring the whole length of a dot cycle on the oscillogram negative. This distance was divided by the film speed, 10 inches per second, to obtain the period of a dot cycle. The reciprocal of the period gives the number of dot cycles per second. Dividing the number of dot cycles per second by 0.4 gives the number of words per minute. Thus, for example, the dot cycle is 0.57 inches in length in Run 7, Plate 1. 0.57 inches divided by 10 inches per second gives a period of 0.065 second. The reciprocal of this quantity is 17.6 dot cycles per second. Dividing this last quantity by 0.4 gives a keying speed of 44. WPM.

22. Calculation of Factor p. The quantity p was determined by transmitting from time to time with the key down long enough to obtain a full build-up, thus affording a numerical comparison between full build-up and the build-up attained at various keying speeds.

23. This is the measured value of p. On Plate 1, Run 1 shows an amplitude of 0.272 inch with the key down. Run 7 shows an amplitude of 0.228 inch. Therefore,  $p = 0.228$  divided by  $0.272 = 0.838$ . In some cases the measurement was made directly on the oscillograph screen. Thus Run 19, on Plate 3, had an amplitude of  $1-13/16$  inches on the oscillograph, compared with a key-down amplitude of  $2-7/16$  inches. (See Appendix for tables of these values.)

24. Calculation of Keying Efficiency,  $E_k$ . In order to measure keying efficiency it is necessary to measure the energy contained in a dot cycle compared with the energy that would be contained in an equivalent rectangular envelope. The figures of Plates 17 to 19, inclusive, were used for this purpose. The figure for Run No. 7, Plate 17, will serve as an example for this calculation.

25. The dot cycle has been divided into 14 columns representing equal time intervals. The mean ordinate of each column is recorded next to it, the unit being chosen as 0.1 inch. These quantities are proportional to the average voltage during their time increments. The numbers in the next column are the square of the numbers in the first, and are therefore proportional to the energy contained in the time increments. The sum of the latter column, 409 energy units, is proportional to the energy contained in the whole cycle, or  $\int v^2 dt$ .

26. The rectangle is the envelope that would have resulted if the voltage had risen instantly to its maximum value when the key was closed, and decayed instantly to zero when the key was opened. Its amplitude is  $1/p$  times the maximum amplitude of the dot cycle. In this case, p was measured to be 0.838, and the maximum amplitude of the dot cycle was 7.8 units, so the amplitude of the rectangle is 9.32 units.

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Squaring 9.32 gives 86.7 energy units, for one time increment. Since there are ten time-increment columns in the rectangle, the product of 10 times 86.7 gives 867 energy units. The ratio of 409 to 867 energy units gives a keying efficiency of 47.2%. This is the measured value of  $E_k$ .

27. Calculation of Corrected Keying Speed. It will be noticed in most of these oscillograms that the key-down period is not equal to the key-up period, as it should be, being sometimes longer and other times shorter. The fraction of the total period during which the key is down will obviously cause great variations in keying efficiency for a given keying speed. Consequently, some correction must be made. It was decided to convert the actual WPM to a "corrected" WPM, the corrected WPM being that keying speed which would have the same time interval between the closing and opening of the key as did the oscillogram under analysis, assuming the key to be down half the total period of the dot cycle of the "corrected" envelope. In other words, we have merely altered the duration of the "key up" portion of the cycle to make it equal to the "key down" portion, and altered the dot cycle frequency accordingly. (See Plate 12, Fig. 2). In this figure, the period is  $T + T'$ ; and  $WPM =$

$$n = \frac{1}{0.4 (T+T')} \quad \text{The corrected WPM}$$

$$= n' = \frac{1}{0.4 (T+T)} = \frac{1}{0.8T}$$

28. For instance, Figure 1 of Plate 26, Run #7, was keyed at 44 WPM. The key-down portion of this projection is 3.3 inches long. Since one inch on this sheet equals  $0.884 \times 10^{-2}$  sec,  $T = 3.3 \times 0.884 \times 10^{-2}$  sec. =  $2.92 \times 10^{-2}$  second. Hence  $n' = \frac{1}{0.8(2.92) 10^{-2}} = 42.8$  WPM.

29. In a few cases the sprocket holes were not traced on the sheet. In these cases,  $n'$  was calculated by dividing  $n$  by the ratio of the key-down period to the half-period of the dot cycle. For example, in Run No. 8 of Plate 19, the dot cycle has a length of 2.04 inches, or a half-length of 1.02 inches. The key-down period is 1.3 inches. Dividing 96 WPM by the ratio 1.3 to 1.02 gives a corrected  $n'$  of 75.3 WPM. The only error in this correction occurs when the envelope does not have time to decay to a negligible value before the beginning of the next dot cycle. The latter part of the decay cycle contributes very little to the energy of the dot cycle, however, because of the square law relationship between energy and voltage. The curves of keying efficiency vs. WPM on Plates 8 and 9 are plotted using the corrected WPM.

#### CALCULATION OF RECEIVER TIME CONSTANT

30. The oscillogram for Run No. 1, at 15.44 kc, was projected onto Plate 20. The time constant is defined as the time in which the voltage decays to  $\frac{1}{e}$  of its maximum voltage, or the time in which it

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rises to  $1 - \frac{1}{e}$  of its maximum voltage, where  $e$  is the base of Napierian

logarithms. One inch along the time axis =  $\frac{19/64 \text{ inch}}{10 \text{ in./sec.} \times 3.24 \text{ inches}} = 0.916 \times 10^{-2} \text{ sec.}$  The distance required for the voltage to rise to  $1 - \frac{1}{e}$ , or 0.632, of its final value, is 0.17 in., or  $1.53 \times 10^{-3} \text{ sec.}$  The distance for decay to  $\frac{1}{e}$ , or 0.368, of the maximum voltage, is 0.12 inch, or  $1.1 \times 10^{-3} \text{ sec.}$  Similar calculations were performed on Plate 28 to obtain the receiver time constant at 26.1 kc.

#### CALCULATION OF TRANSMITTER Q

31. It was decided to determine the effective Q of the transmitter, assuming that its time constant was due entirely to a single tuned circuit, say the antenna. For this purpose very large projections were made of some of the oscillograms of various keying speeds, (Plates 21 to 26, inclusive, and 29 to 32, inclusive). Tables were made of voltage units (tenths of an inch), against time units (inches.) The time units were converted to seconds in the usual way. For example, Run #7, on Plate 26, shows a

distance between sprocket holes of 3.34 inches. Hence 1 inch =

$\frac{19/64 \text{ in.}}{3.34 \text{ in.} \times 10 \text{ in./sec.}} = 0.884 \times 10^{-2} \text{ second.}$  The maximum amplitude of

the dot cycle is 26.4 divisions (1 division = 0.1 inch.)  $p$  was measured to be 0.838, so the maximum amplitude with the key down,  $V_0$ , would have been 26.4 divided by 0.838, or 31.5 divisions, or voltage units. Hence, to determine  $\frac{V_0 - V}{V_0}$ , or  $1 - \frac{V}{V_0}$ , substitute 31.5 for  $V_0$ , and

substitute for  $V$  the number of divisions amplitude at time  $t$ . On page 9 are the tabulated calculations for the voltage build-up of Run #7.

TABLE 1

Voltage Rise Curve. 44 WPM

15.44 KC. Run 7, Plate 26

Time Axis Inches	Voltage Axis = V Unit = 0.1 inch	Time (Column 1 x 0.83 x 10 <sup>-2</sup> ) Seconds x 10 <sup>-2</sup>	$1 - \frac{V}{V_0}$ (1 - $\frac{\text{Column 2}}{31.5}$ )
0	0	0	1.000
0.2	4	0.177	0.873
0.3	5.2	0.265	0.835
0.5	8.5	0.442	0.730
0.7	11.4	0.619	0.638
0.9	13.7	0.796	0.565
1.1	15.9	0.972	0.496
1.5	19.5	1.326	0.381
1.7	20.7	1.50	0.343
1.9	22.0	1.680	0.302
2.1	23.0	1.86	0.270
2.4	24.6	2.12	0.219
2.6	25.2	2.30	0.200
2.9	26.1	2.565	0.1714
3.1	26.4	2.74	0.162
3.3	26.4	2.92	0.162
$\infty$	31.5 = V <sub>0</sub>	$\infty$	0.000
1.3	17.7	1.10	0.438

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32. Similar tables were calculated for the other curves on Plates 13 and 15. Since these curves are not perfect straight lines, their Q's appear to be varying. The effective Q at any point on one of these curves can be obtained by drawing a tangent. For example, a tangent was drawn on Plate 13 to the curve for Run #10, intercepting the ordinate at a value A.

The equation of the tangent is

$$f(t) = Ae^{\frac{-4\pi t}{2Q}} \quad (\text{See equation (1a) in Theory})$$

$$\text{Hence } Q = \frac{-\omega t}{4.6 \log_{10} \frac{f(t)}{A}}$$

When  $t = 5 \times 10^{-2}$  second,  $f(t) = 0.107$ , and the intercept A is 0.61.  $\frac{f(t)}{A} = \frac{0.107}{0.61} = 0.1754$

$$Q = \frac{-2\pi (15.44) 10^3 (5) 10^{-2}}{4.6 (-0.756)} = \frac{-211}{-0.756} \times 5.$$

$$\text{Since } \frac{2\pi (15.44) 10}{4.6} = 211.$$

$$\text{And } Q = 1400.$$

The straight lines on Plates 13 and 15 labeled "Average Curve" were drawn to obtain the "average" Q of the transmitter during the build-up cycle.

33. The transmitter Q during a decay cycle is obtained in the same manner. The table below gives the coordinates for the decay curve of Run 7, Plate 26.

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TABLE 2

Voltage Decay Curve. 44 WPM

15.44 KC. Run 7, Plate 26.

Time Axis Inches	Voltage Axis=V Unit= 0.1 inch	Time (Column 1x0.838x10 <sup>-2</sup> ) Seconds x 10 <sup>-2</sup>	$\frac{V}{pV_0}$ (Column 2 divided by 26.2)
0	26.4=pV <sub>0</sub>	0	1.000
0.1	26.2	0.0884	0.992
0.2	25.1	0.1768	0.957
0.3	23.2	0.265	0.885
0.4	20.6	0.353	0.786
0.5	17.1	0.442	0.652
0.6	13.7	0.530	0.522
0.7	11.0	0.620	0.420
0.8	8.9	0.707	0.340
0.9	7.5	0.800	0.286
1.0	6.4	0.884	0.244
1.1	5.2	0.972	0.198
1.2	4.1	1.060	0.1565
1.3	2.6	1.148	0.0992

34. Similar tables were calculated for the other curves on Plates 14 and 16. Since they are not perfectly straight lines, their Q's appear to be varying. As in Paragraph 32, the effective Q at a given point can be determined by drawing a tangent, such as the one drawn to the curve for Run #7, on Plate 14. Again the equation of the tangent is

$$f(t) = Ae^{-\frac{\omega t}{2Q}} \quad \text{but for these curves, as was also the case for some curves}$$

on Plates 13 and 15, A is greater than one, and the intercept on the f(t) axis falls off the sheet. Q can now be most readily calculated by taking the coordinates of two points on the tangent.

$$\text{Then } \frac{f(t_1)}{f(t_2)} = \frac{Ae^{-\frac{\omega t_1}{2Q}}}{Ae^{-\frac{\omega t_2}{2Q}}} = e^{-\frac{\omega}{2Q}(t_1 - t_2)}$$

$$\text{Hence } Q = \frac{-\omega(t_1 - t_2)}{4.6 \log_{10} \left( \frac{f(t_1)}{f(t_2)} \right)}$$

For example, two sets of points on the curve for Run #7, Plate 14 are  $t_1 = 10^{-2}$  sec.,  $f(t_1) = 0.180$ , and  $t_2 = 2 \times 10^{-2}$  sec.  $f(t_2) = 0.0180$ .

$$Q = \frac{-2\pi (15.44)(10^3)(-1)10^{-2}}{4.6 \log_{10} \left( \frac{0.180}{0.0180} \right)} = 211$$

Calculation of Keying Efficiency: (Using equation (IX) of "Theoretical Considerations.")

35. The "Average Curve" of Plate 13 has a Q of 700. Thus at 15.44 kc.,

$$a = \frac{\omega}{2Q} = \frac{2(15.44)10^3}{2(700)} = 69.2$$

$$\text{and } E_{k1} = 1 + 0.8n \left[ 0.0289e^{-\frac{86.5}{n}} - 0.00723 \left( e^{-\frac{86.5}{n}} \right)^2 - 0.02165 \right]$$

36. Thus, for the curve of Run #7, Plate 13, where  $n = 44$  WPM,  $n$  corrected = 42.8 WPM.

$$E_{k_1} = 1 + 34.2 [0.0289e^{-2.02} - 0.00723 (e^{-2.02})^2 - 0.02165]$$

$$= 1 + 34.2(0.00384 - 0.000127 - 0.02165) = 1 - 0.613 = 0.387$$

37. In calculating  $E_{k_2}$ , equation (X) is not used, because the decay characteristics of Plates 14 and 16 are too curved to be represented by a single Q. On Plate 14, the curve of Run #5-2 was chosen as typical, and plotted on Plate 27. The square of this curve was then plotted, its area representing the energy of the decay cycle. By counting squares, the area under the curve is 21.5 sq. in. The square envelope drawn on this plate has an area of 40 sq. in. in  $10^{-2}$  seconds. Hence the decay envelope has  $\frac{21.5}{40} = 0.537$  of the energy contained in a rectangular envelope lasting  $10^{-2}$  seconds, or 0.00537 of the energy in one second. Multiplying by  $p^2 = 0.8p^2n$ , we get

$$E_{k_2} = 0.00430p^2n.$$

From equation (IV), in "Theoretical Considerations,"

$$p = 1 - e^{-\frac{a}{0.8n}}. \text{ From calculations in paragraph (36), (Run #7),}$$

$$e^{-\frac{a}{0.8n}} = e^{-2.02} = 0.1327$$

$$\text{Hence } p = 1 - 0.1327 = 0.867$$

$$E_{k_2} = 0.00430(0.867)^2(42.8) = 0.1382$$

$$E_{k_1} + E_{k_2} = 0.387 + 0.138 = 0.525. \text{ This is the calculated value}$$

of  $E_k$ .

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TABLE 3

Tabular Calculations

15.44 KC

Run No.	WPM	Corrected WPM	Calculated $E_k$	Measured $E_k$	Calculated p	Measured p
5	12.2	12.2	0.831	0.862	1.000	1.000
10	17	14.66	0.809		0.997	0.895
7	44	42.8	0.525	0.472	0.867	0.838
19	52.5	71	0.367	0.381	0.704	0.742
	1	1	0.983		1.000	
21	91	108	0.241	0.225	0.512	0.565
8	96	75.3		0.312		

26.1 kc.

3	17.2	19.4	0.935		1.000	1.00
6	38.3	45.5	0.848		0.997	1.00
14	91	101	0.681		0.930	0.882
11	145	137.	0.598		0.860	0.780

## SECTION IV

### SUMMARY

38. Plates 1 to 9, inclusive, show oscillograms made at various frequencies and sending speeds. The dot amplitude (amp.) in inches is recorded, as is the amplitude (max. amp.), in inches of the final build-up value with the key down indefinitely. The time of day is also recorded.

39. Although machine sending was employed, successive dots are not always identical, and some have rather irregular shapes, indicating that the functioning of the keying mechanism may be somewhat irregular, and that there may be key chatter at times.

40. However, these effects are unimportant compared with the slow build-up of the carrier after the key is closed, especially at 15.44 kc. This is apparently due to the high antenna  $Q$  and to some detuning of the antenna circuit during the build-up and decay periods. If the antenna variometer could be made more rigid, considerable improvement might be obtained. Also, some improvement might be obtained by tuning up the transmitter at 20 or 30% of full power, so that the antenna would pass through resonance part way up the build-up cycle.

41. Plates 10 and 11 show curves of keying efficiency against sending speed. The calculated curve was obtained by assuming the shape of the dot cycle to be determined entirely by the antenna  $Q$ . The effective antenna  $Q$  was calculated from the oscillograms. The purpose of this calculation was to obtain a smoother curve of keying efficiency vs. sending speed, relatively free of irregularities due to keying variations in individual cycles analyzed.

42. Plates 13 to 16, inclusive, show build-up and decay curves plotted on semilog paper. The  $Q$ 's of some of the slopes are recorded, including that of the average slope. Some inaccuracy in the determination of these  $Q$ 's is caused by the difficulty of locating the exact instants at which the build-up and decay of the dot cycles begin.

43. Plates 17 to 26, inclusive, show enlargements of individual oscillogram cycles at 15.44 kc. Plates 28 to 32, inclusive, show similar enlargements at 26.1 kc.

44. No enlargements were made at 32.8 kc., because of the rapid build-up and decay of these oscillograms and because of transients, perhaps due to keying irregularities, that distort the wave form. These effects would make a calculation of the effective  $Q$  of the antenna at 32.8 kc. very inaccurate.

45. Transients appear in the decay cycle of most of the oscillograms. These may be due to insufficient keying bias. Transient peaks in the keying bias may then decrease the bias sufficiently to permit plate current to flow.

DECLASSIFIED

APPENDIX

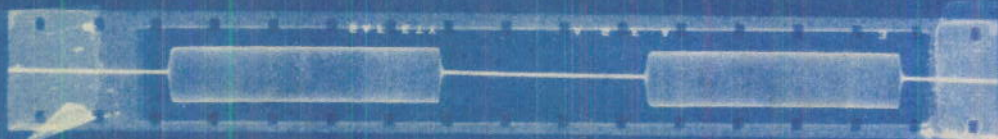
15.44 KC

<u>Run No.</u>	<u>WPM</u>	<u>Dot Amp.</u>	<u>Key Locked Amp.</u>	<u>Factor p</u>
1 & 2	38			0.853
6	18.6			0.890
7	44			0.838
8	96			0.650
10	17			0.895
13	48			0.738
15	38.6	1.75	2.125	0.824
16	17.4	1.75	1.8125	0.965
17	52.5	1.25	1.9375	0.645
18	52.5	1.75	2.4375	0.718
19	52.5	1.8125	2.4375	0.743
20	52.5	1.75	2.4375	0.718
21	91	1.375	2.4375	0.564

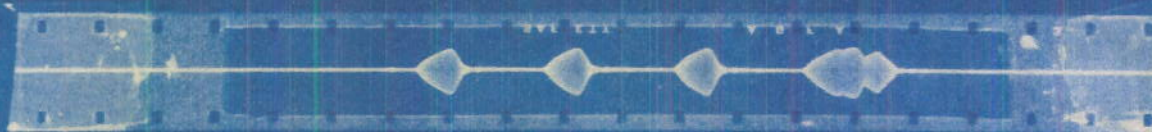
26.1 KC

<u>Run No.</u>	<u>WPM</u>	<u>Dot Amp.</u>	<u>Key Locked Amp.</u>	<u>Factor p</u>
9	93	1.625	1.875	0.867
10	142	1.312	1.75	0.750
11	145	1.562	2.00	0.781
12	188	1.5	2.062	0.728
13	189	1.5	2.062	0.728
14	91	1.875	2.125	0.882

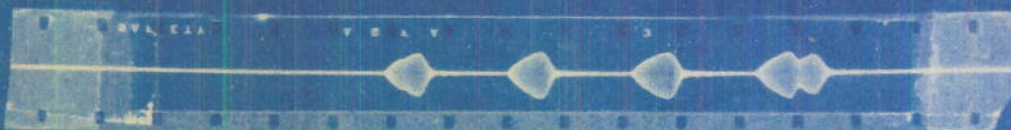
DECLASSIFIED



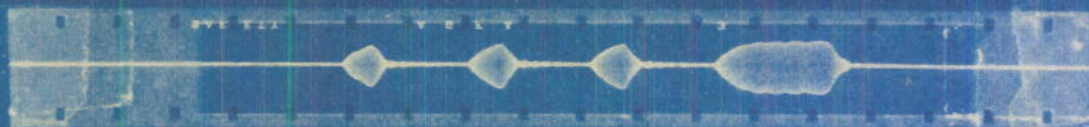
RUN #1 RECEIVER TIME CONSTANT AMP-272 1602



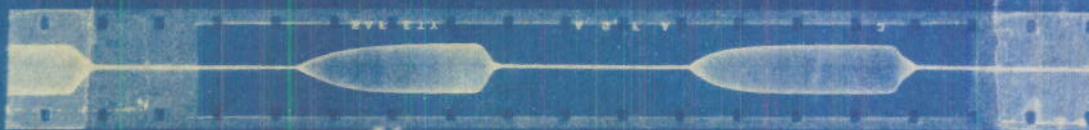
RUN #2 38 WPM AMP-232 1602



RUN #3 38 WPM AMP-232 MAX AMP-287 1608



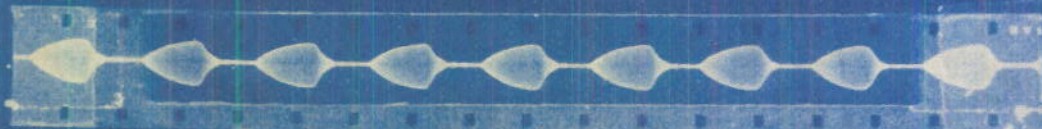
RUN #4 38 WPM 1614



RUN #5 122 WPM AMP-252 1619.5



RUN #6 186 WPM AMP-252 1620.5

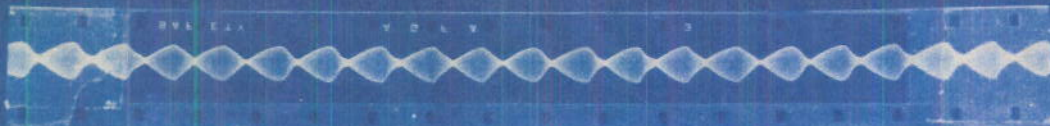


RUN #7 44 WPM AMP-228 1622.5

DECLASSIFIED

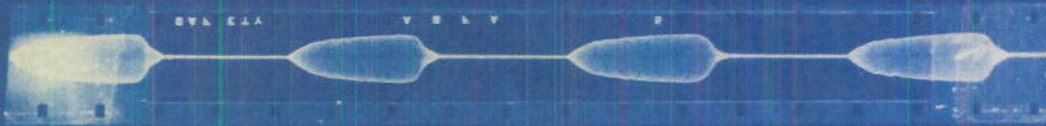
PLATE #1

DECLASSIFIED



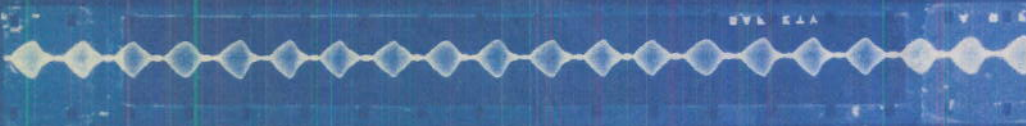
RUN #8 36 WPM

1624



RUN #10 17 WPM AMP - 252

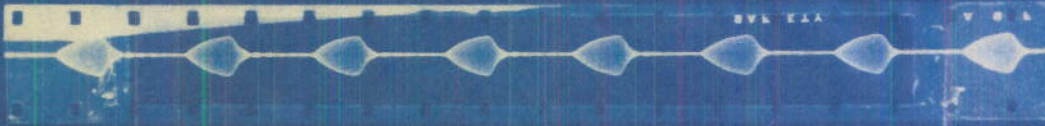
1636



RUN #2 31 WPM

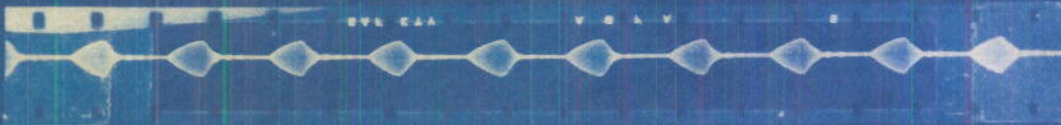
AMP - 20

1701



RUN #11 36.5 WPM AMP - 22

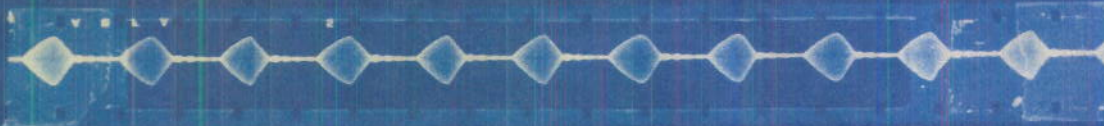
1640



RUN #12 48 WPM AMP - 84

1642.5

INCREASED GAIN 35%



RUN #13 48 WPM AMP - 248

1646



RUN #14 KEY DOWN AMP - 336

1646

PLATE #2

DECLASSIFIED

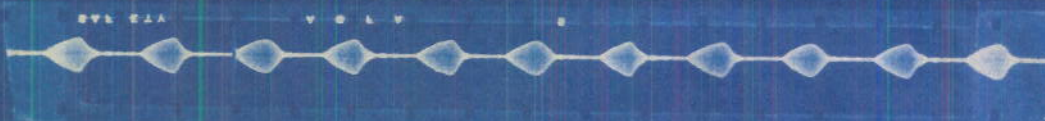
DECLASSIFIED



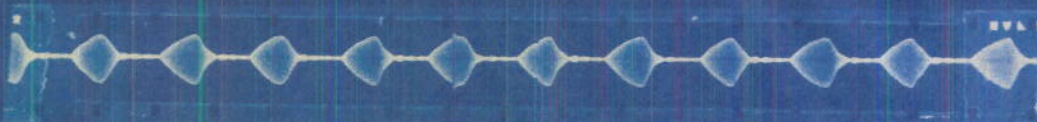
RUN #15 386 WPM AMP-25 1648  
REDUCED GAIN



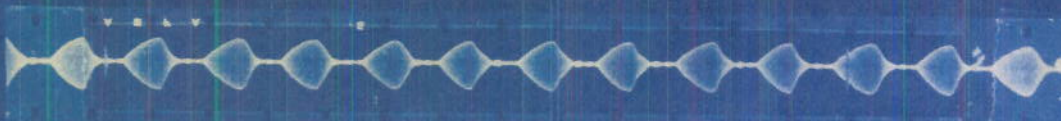
RUN #16 174 WPM 1652



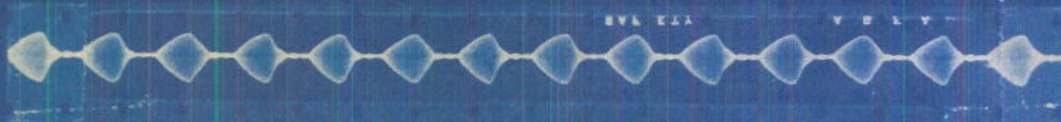
RUN #17 525 WPM 1654  
INCREASED GAIN



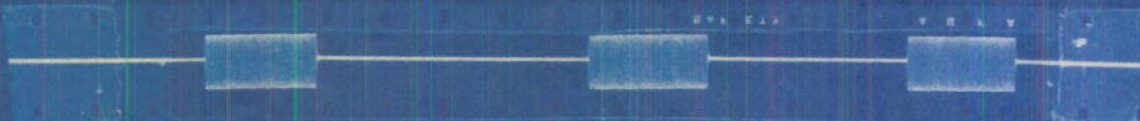
RUN #18 525 WPM 1658



RUN #19 525 WPM 1658



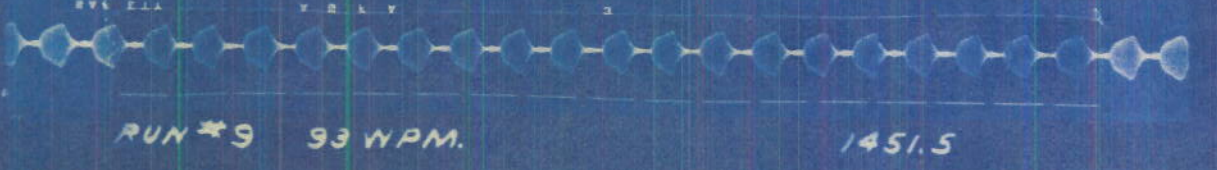
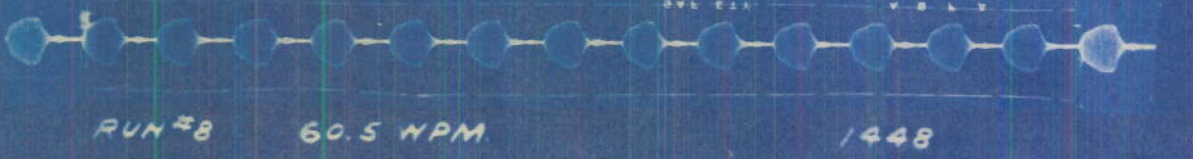
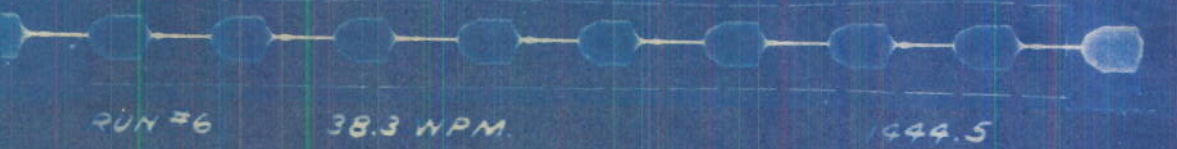
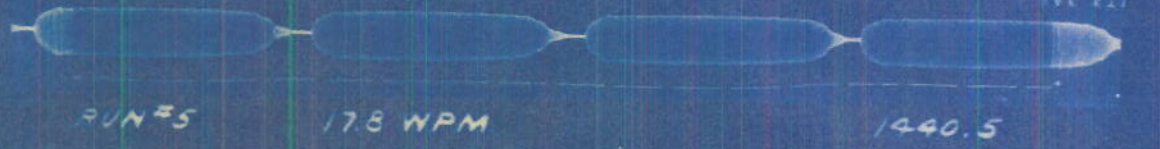
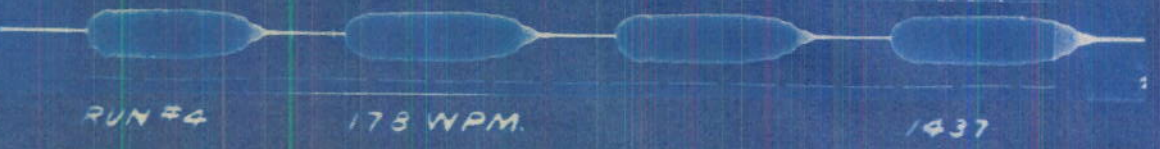
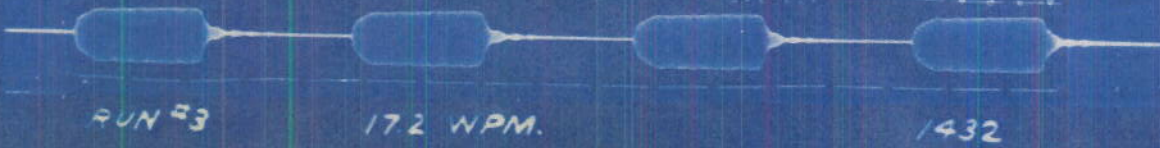
RUN #20 525 WPM 1658  
HSS TESTS 26.1 KC 6 DECEMBER 1940



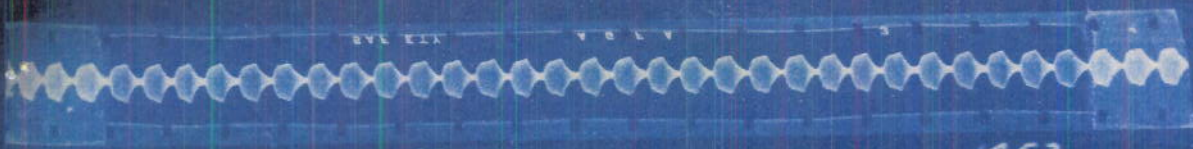
RUN #21 RECEIVER TIME CONSTANT 1431.5

PLATE #3

DECLASSIFIED



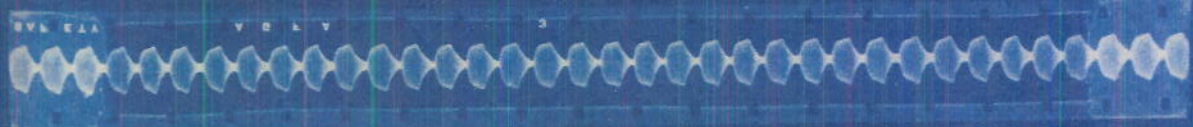
DECLASSIFIED



RUN #10

142 WPM.

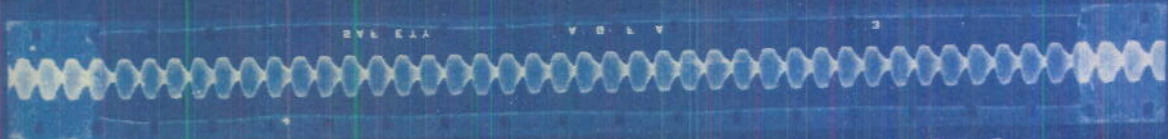
1453



RUN #11

145 WPM.

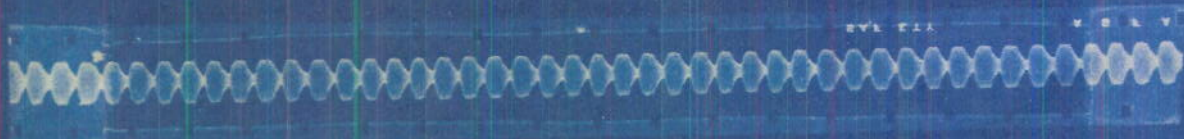
1454.5



RUN #12

188 WPM.

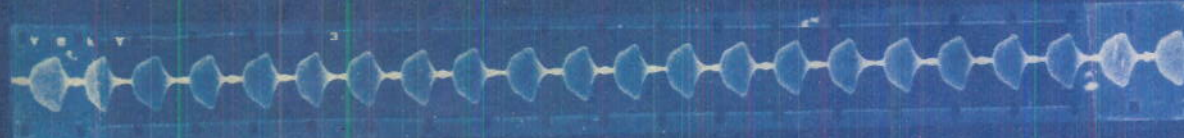
1455.5



RUN #13

189 WPM.

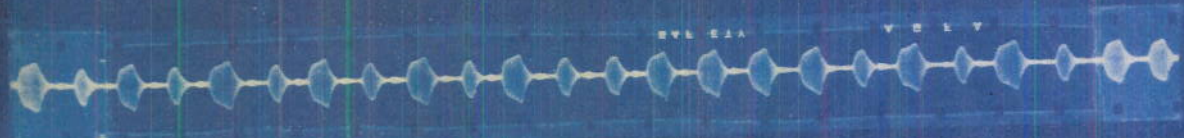
1457



RUN #14

91 WPM.

1459



RUN #15

98.5 WPM

1501



RUN #16

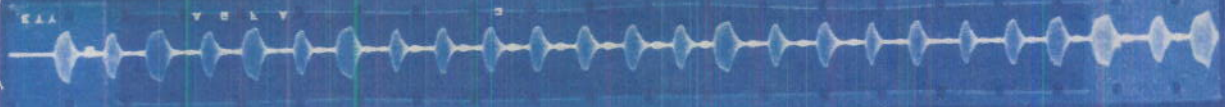
99 WPM.

1503.5

DECLASSIFIED

PLATE #5

DECLASSIFIED



RUN #17

101 WPM

1506



RUN #18

104 WPM

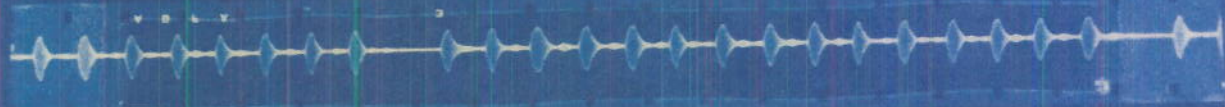
1511



RUN #19

106 WPM

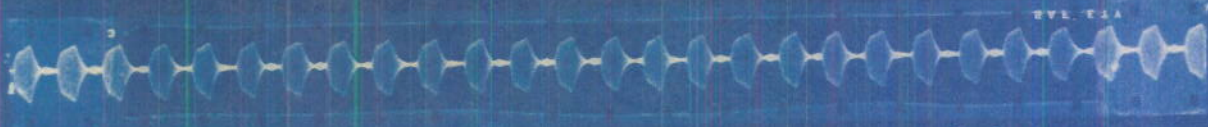
1513



RUN #20

108 WPM

1515



RUN #21

108 WPM

1518



RUN #22

25 WPM

1520.5



RUN #23

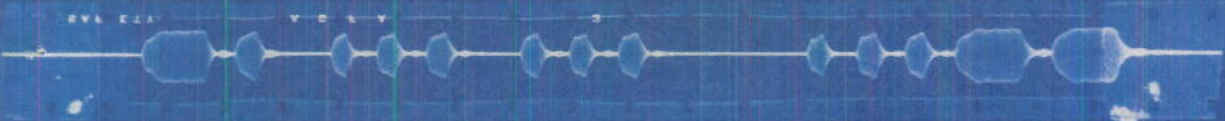
99 WPM

1522.5

PLATE #6

DECLASSIFIED

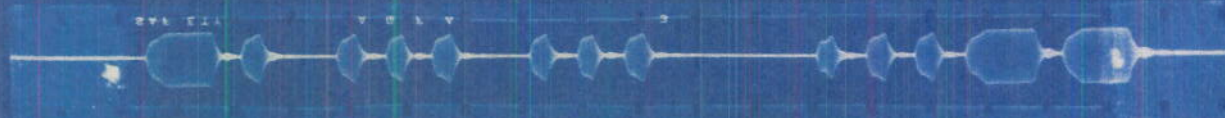
DECLASSIFIED



RUN #24

99 WPM

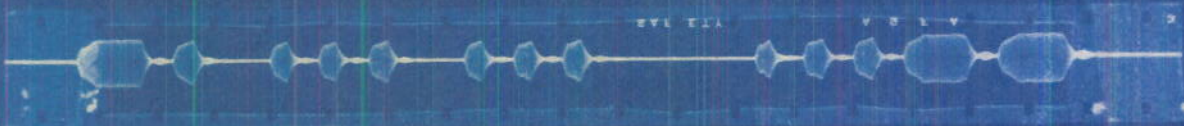
1524



RUN #25

99 WPM

1527



RUN #26

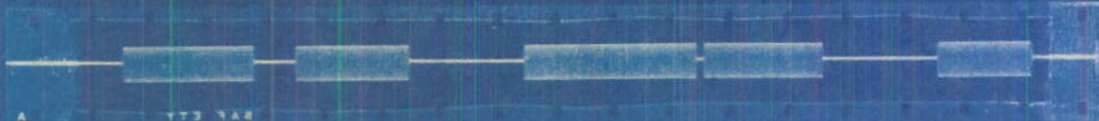
99 WPM

1529

NSS TESTS

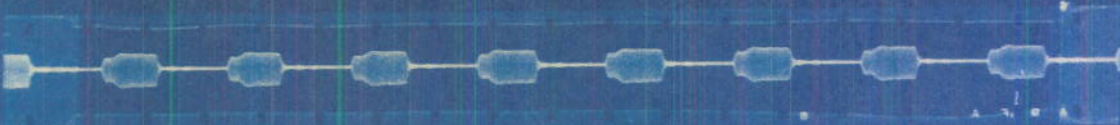
32.8 KC.

8 DECEMBER 1940



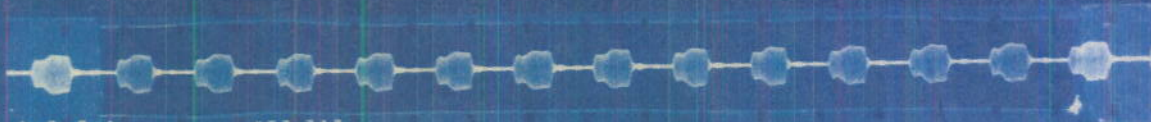
RUN #1

RECEIVER TIME CONSTANT



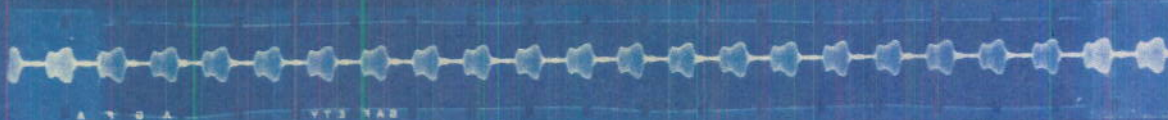
RUN #2

38 WPM



RUN #3

61 WPM



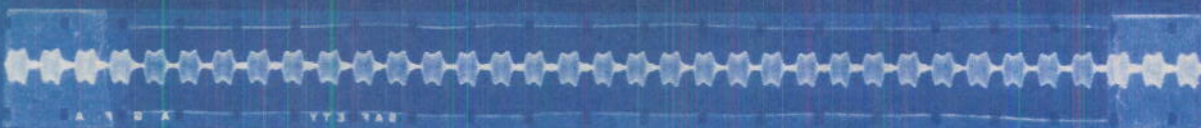
RUN #4

93 WPM

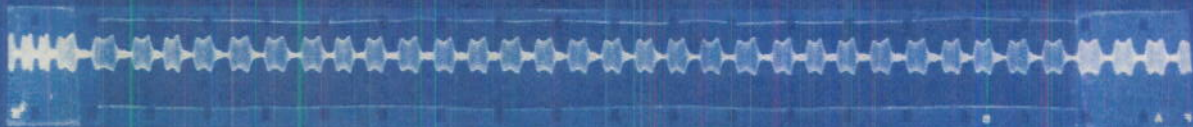
DECLASSIFIED

PLATE #7

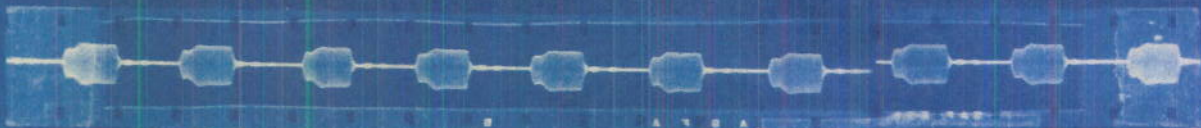
DECLASSIFIED



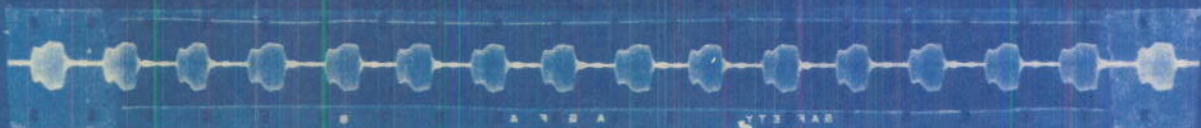
RUN #5 139 WPM



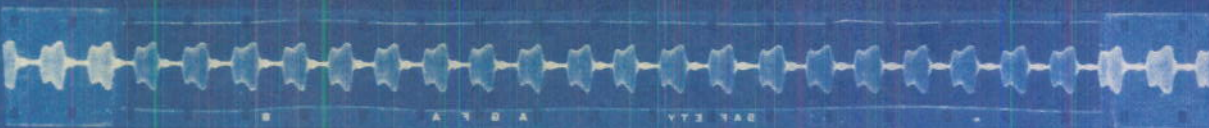
RUN #6 145 WPM.



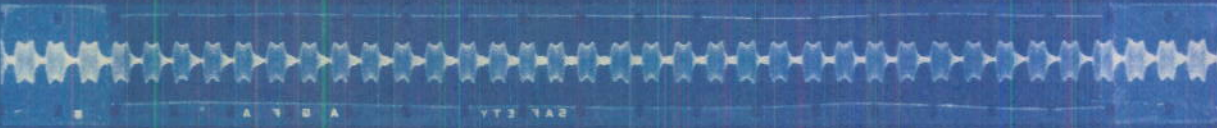
RUN #7 40 WPM



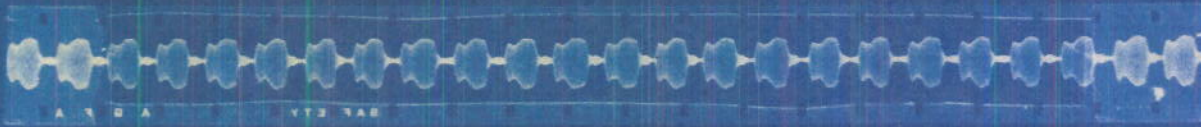
RUN #8 66 WPM



RUN #9 108 WPM.



RUN #10 152 WPM.

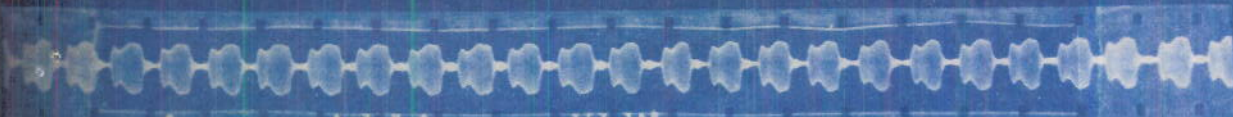


RUN #11 97 WPM.

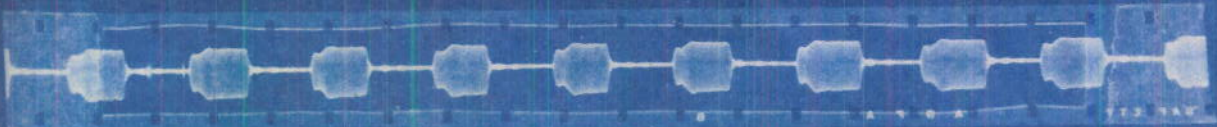
DECLASSIFIED

PLATE #8

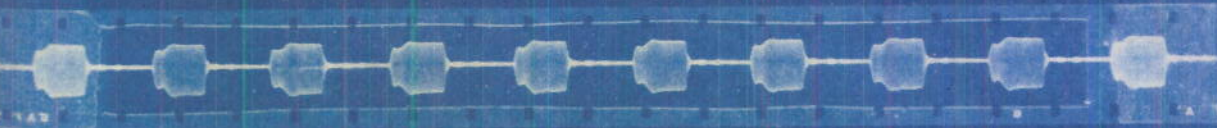
DECLASSIFIED



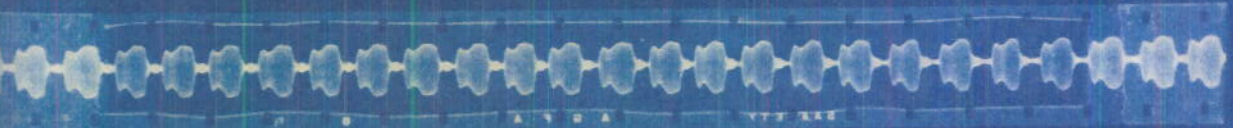
RUN #12 97 WPM.



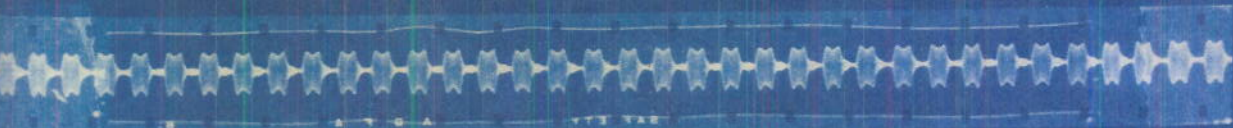
RUN #13 40 WPM.



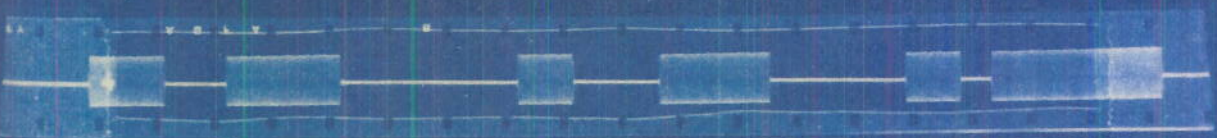
RUN #14 40.5 WPM.



RUN #15



RUN #16

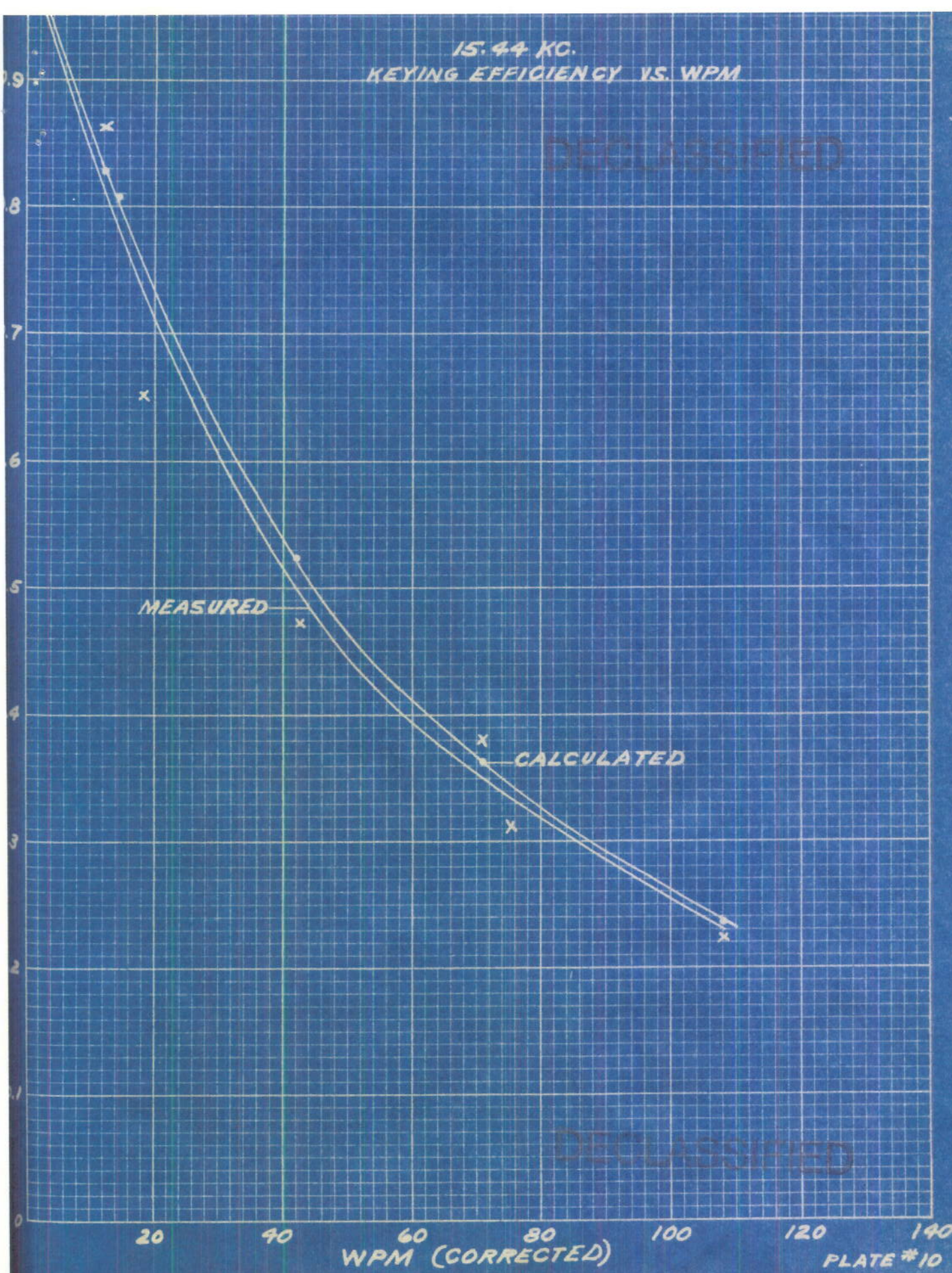


RUN #17 RECEIVER TIME CONSTANT 1700

DECLASSIFIED

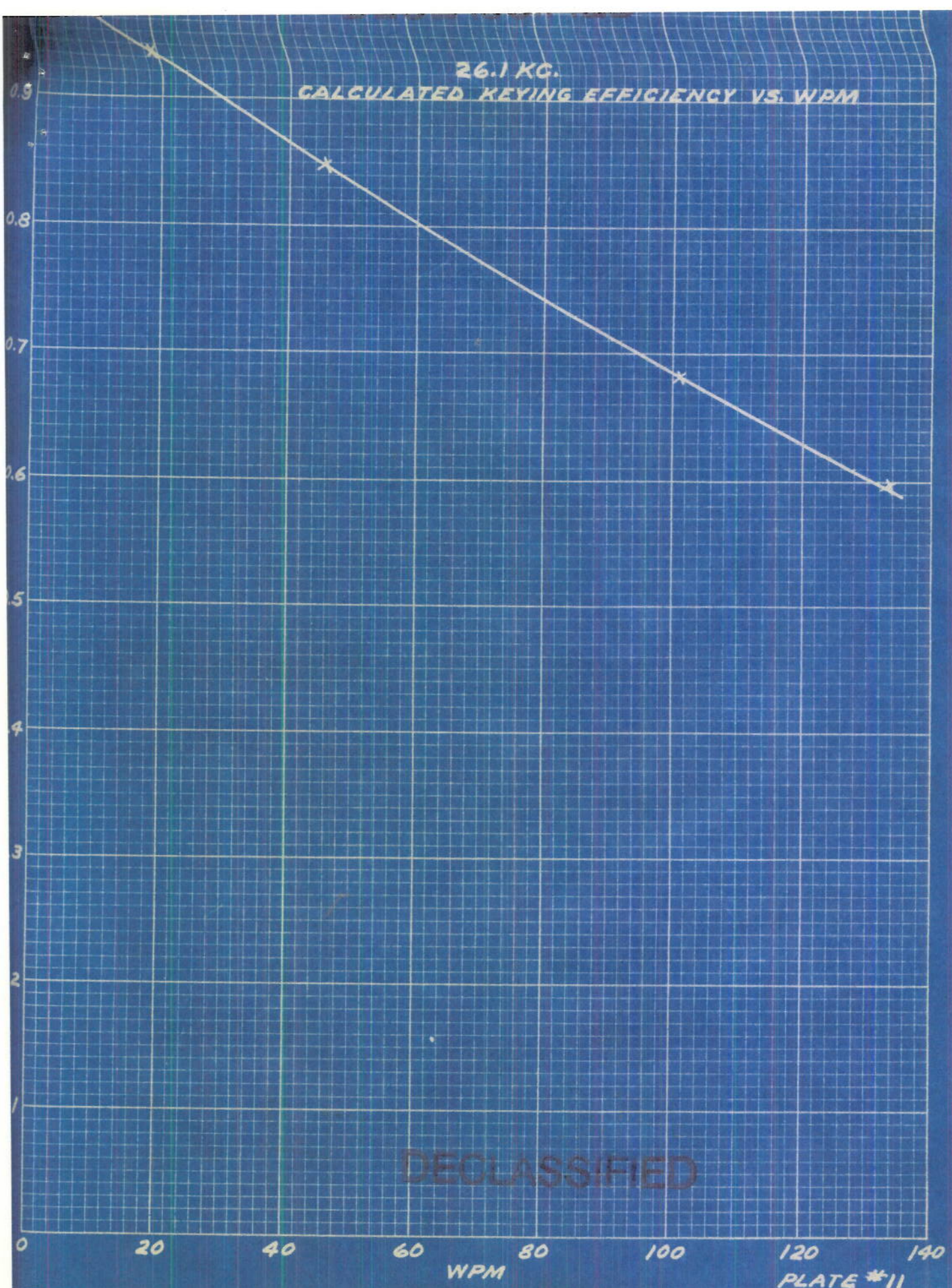
15.44 KC.  
KEYING EFFICIENCY VS. WPM

DECLASSIFIED



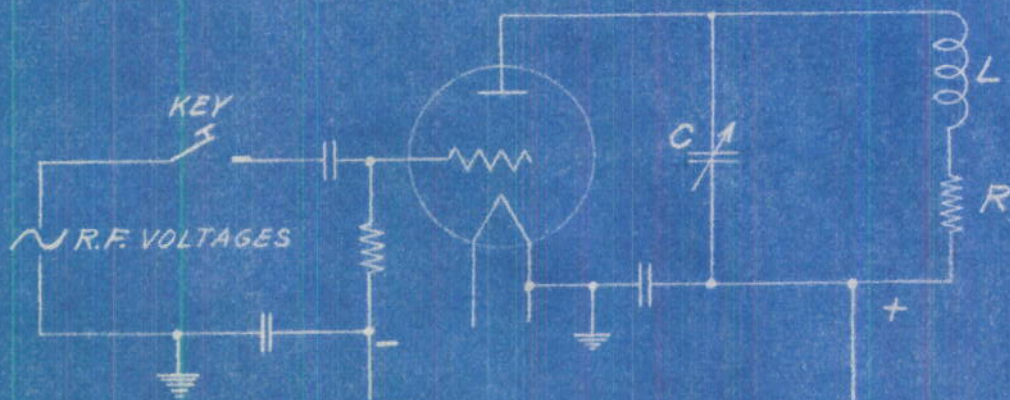
DECLASSIFIED

26.1 KC.  
CALCULATED KEYING EFFICIENCY VS. WPM



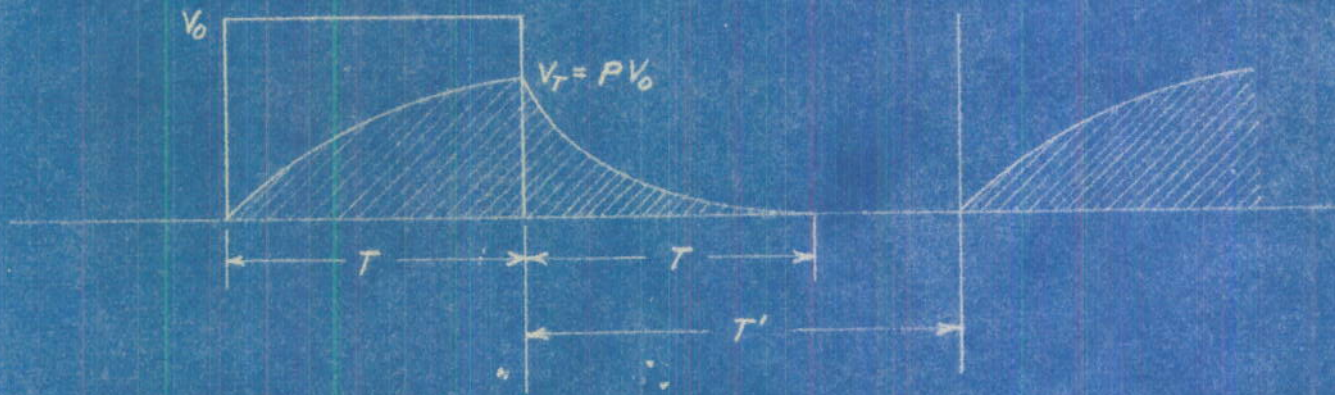
DECLASSIFIED

DECLASSIFIED



SIMPLIFIED TRANSMITTER CIRCUIT

FIG. 1



TYPICAL KEYING CHARACTERISTIC

FIG. 2

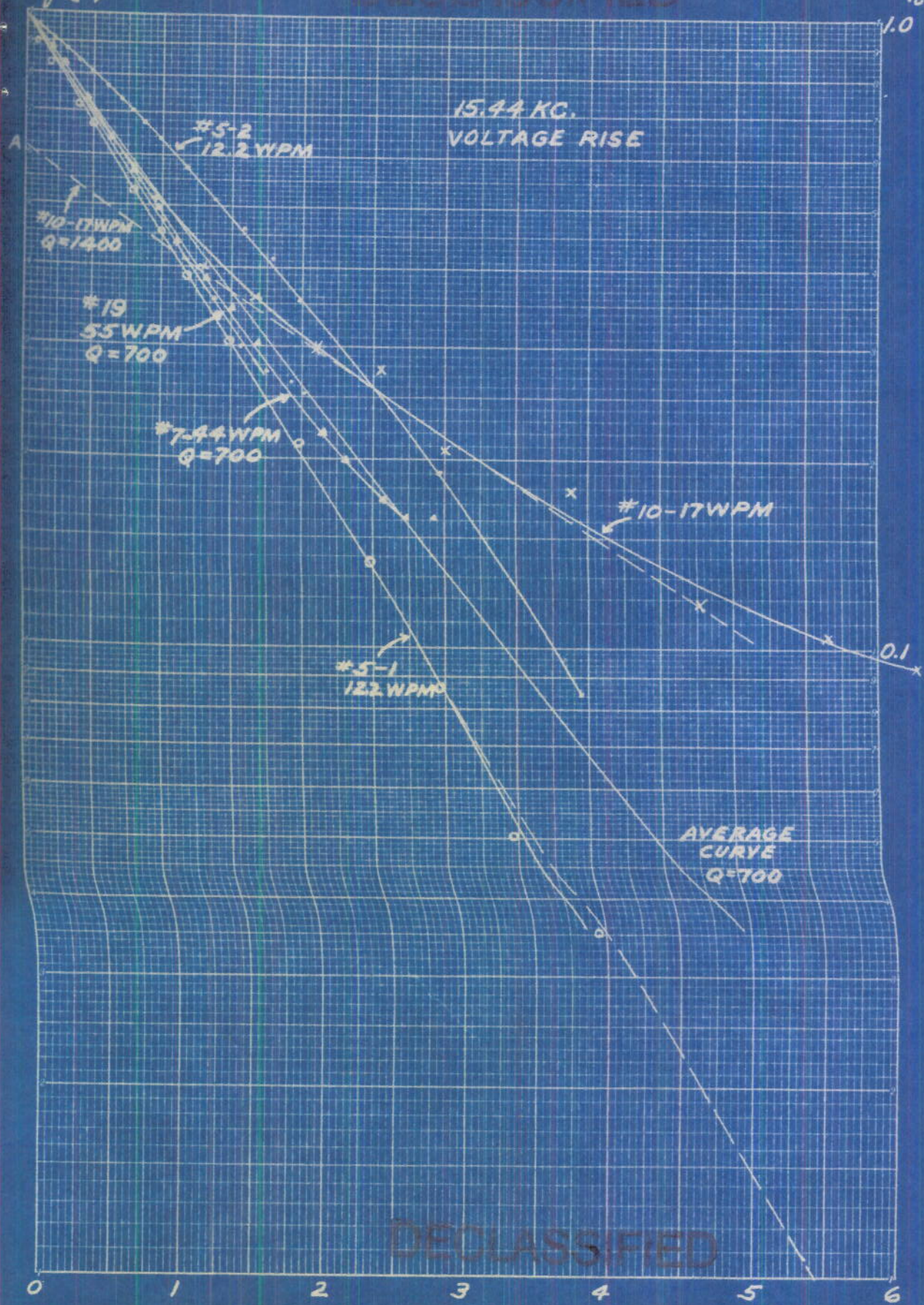
DECLASSIFIED

DECLASSIFIED

$\frac{V_0 - V}{V_0}$   
1.0

$\frac{V_0 - V}{V_0} = f(x)$

15.44 KC.  
VOLTAGE RISE

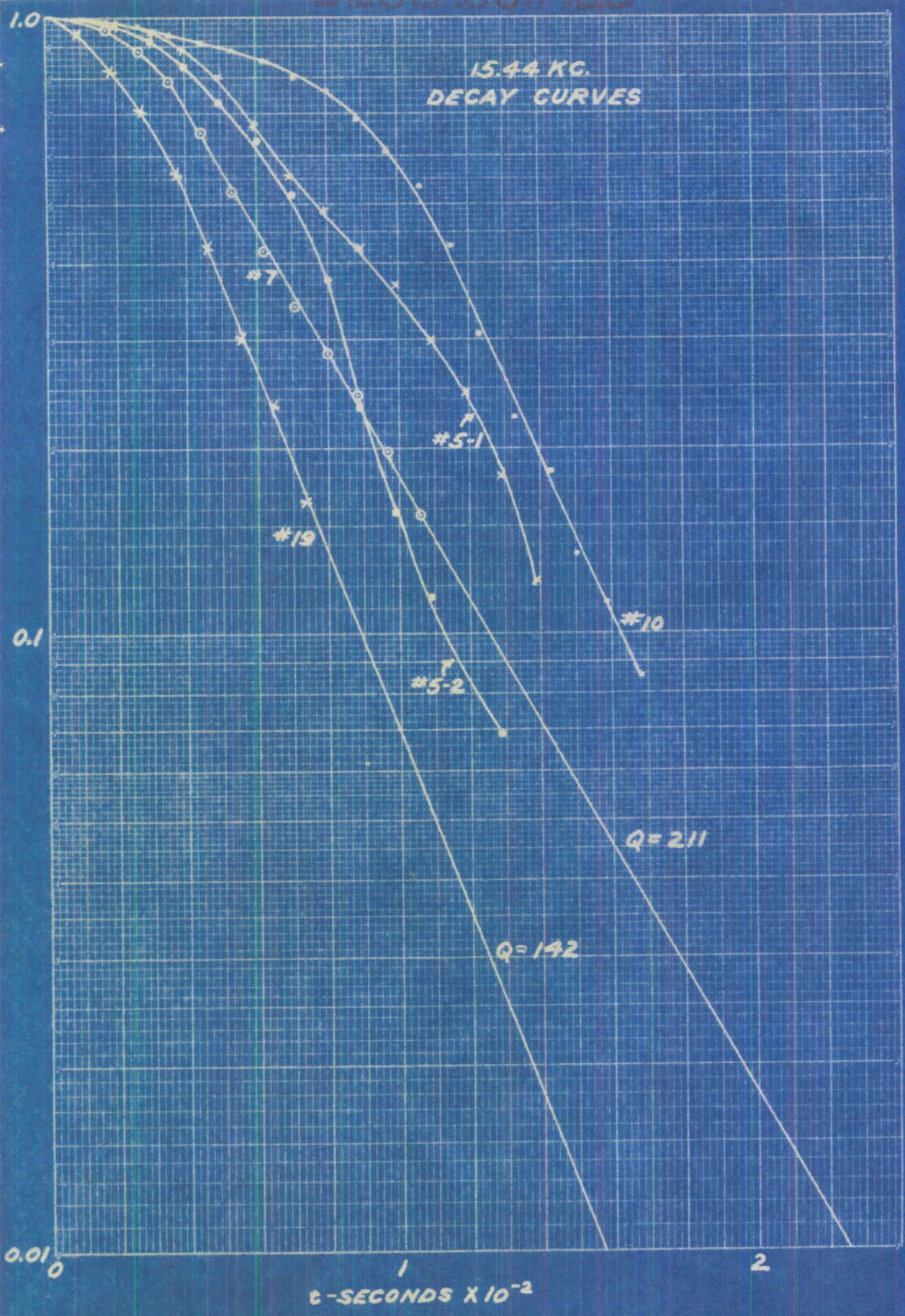


DECLASSIFIED

$t - \times 10^{-2}$  SECONDS

PLATE #13

15.44 KG.  
DECAY CURVES

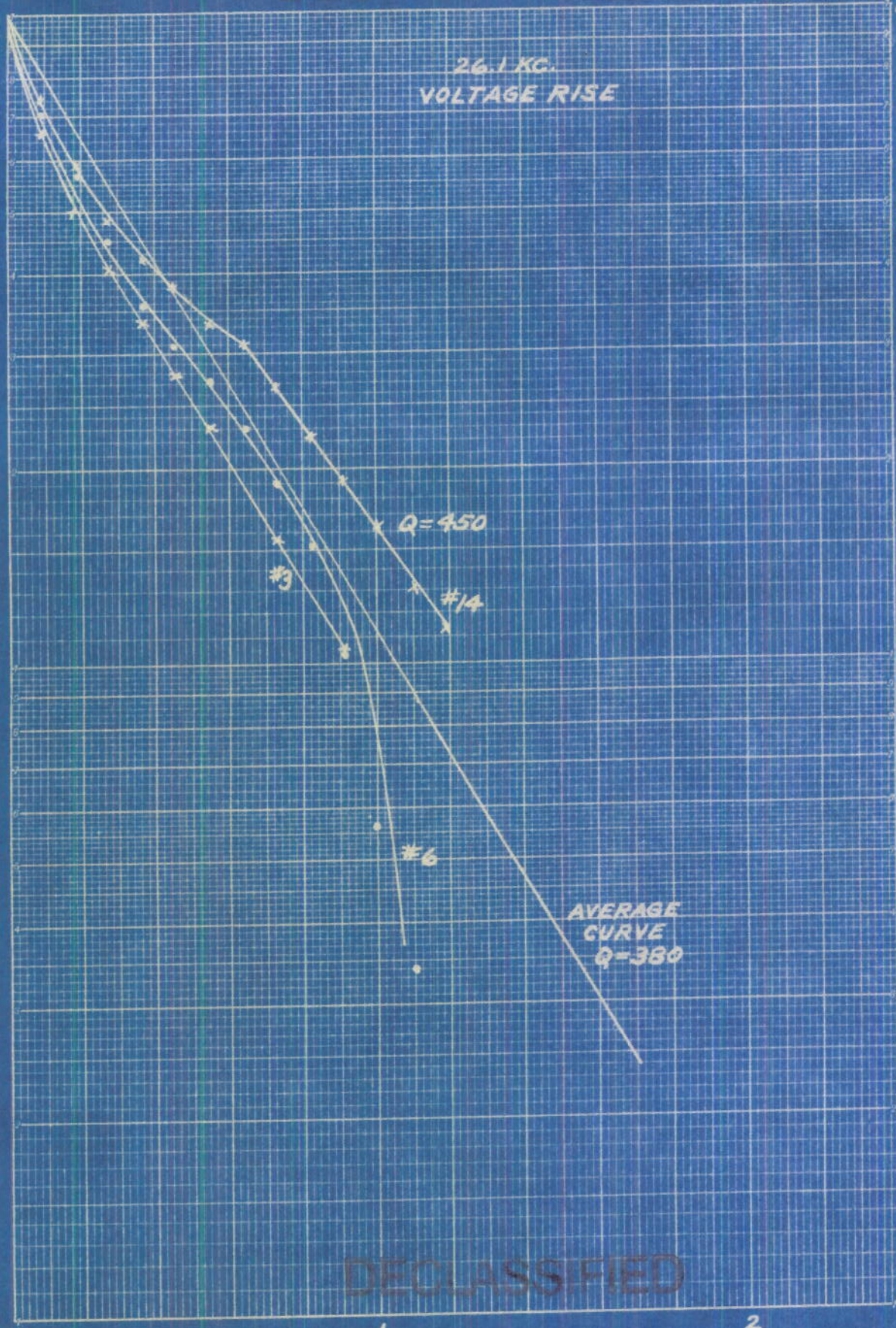


DECLASSIFIED

PLATE #74

DECLASSIFIED

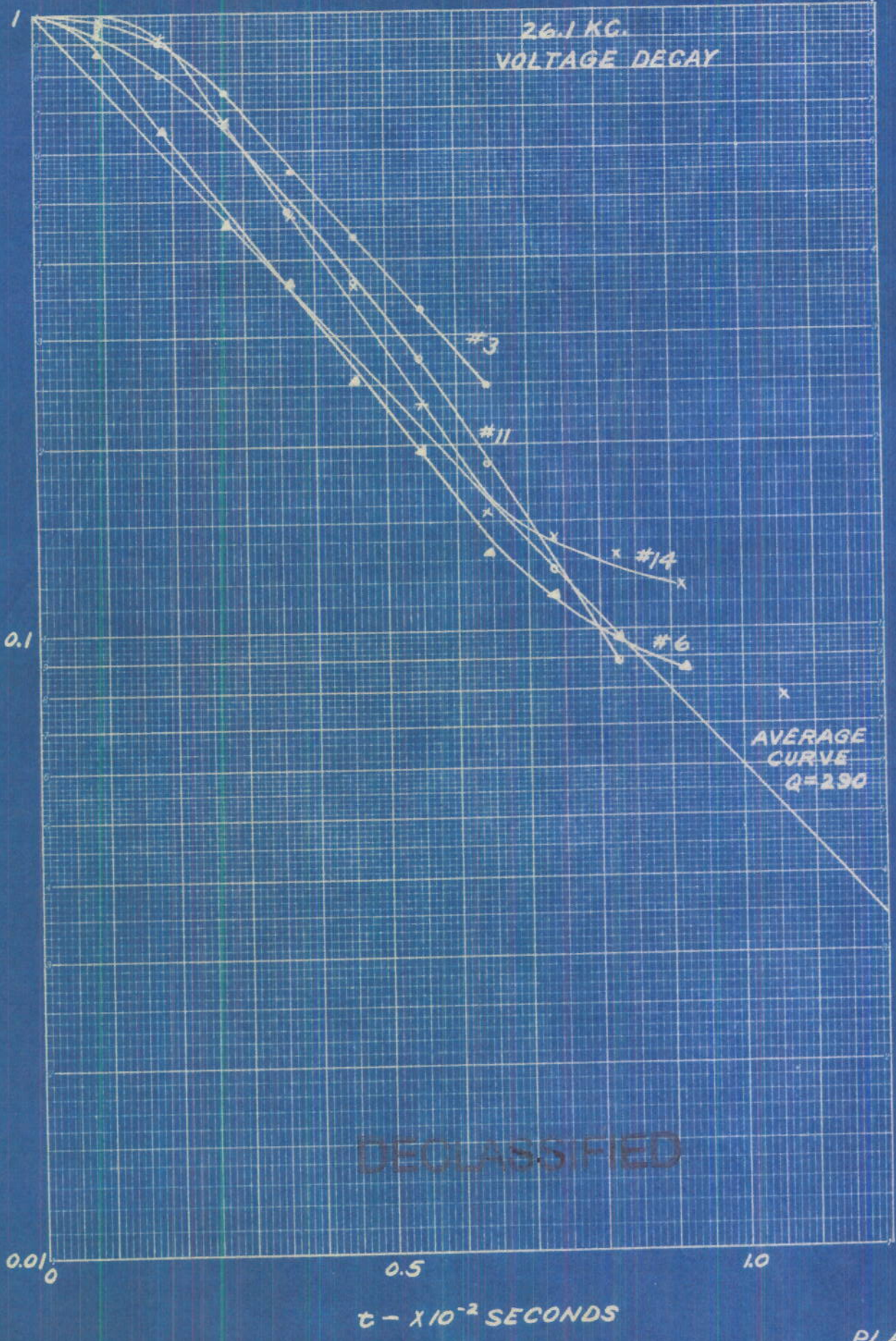
$$\frac{V_0 - V}{V_0}$$



DECLASSIFIED

0 1 2 0.01  
 $t - \times 10^{-2}$  SECONDS

DECLASSIFIED

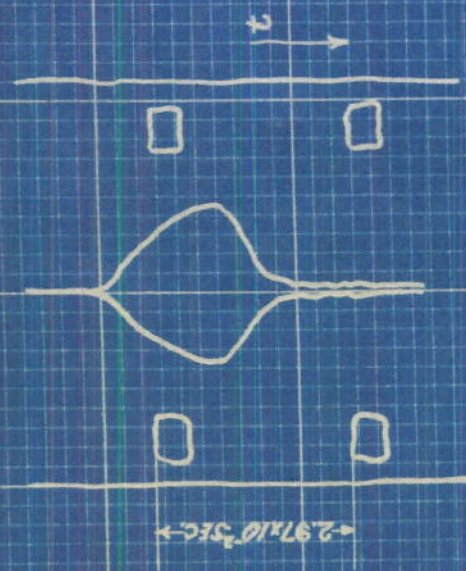


DECLASSIFIED

DECLASSIFIED

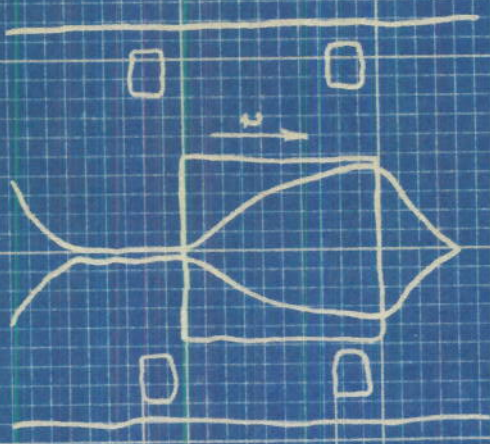
15.44 KC.

RUN 2 - 38 WPM



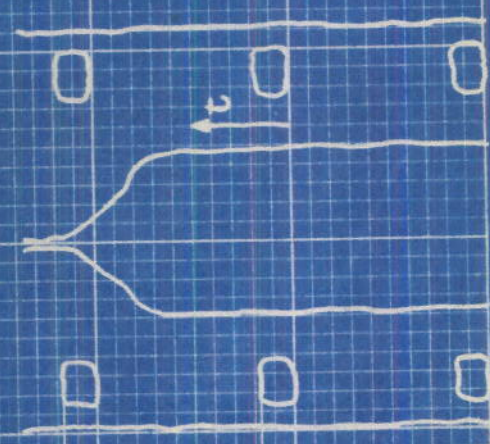
$\leftarrow 2.97 \times 10^{-8} \text{ SEC} \rightarrow$

RUN 7 - 44 WPM

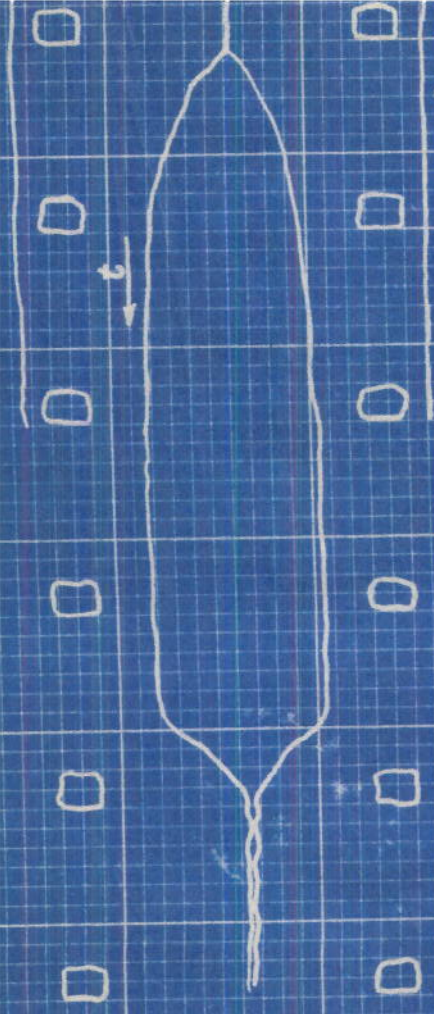


$\leftarrow 2.97 \times 10^{-8} \text{ SEC} \rightarrow$

RUN 5-1  
12.2 WPM



$\leftarrow 2.97 \times 10^{-8} \text{ SEC} \rightarrow$

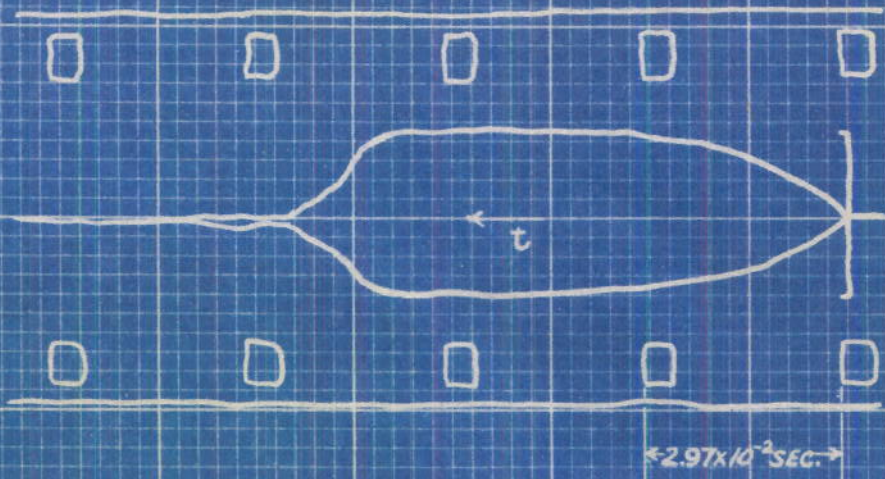


$\leftarrow 2.97 \times 10^{-8} \text{ SEC} \rightarrow$

DECLASSIFIED

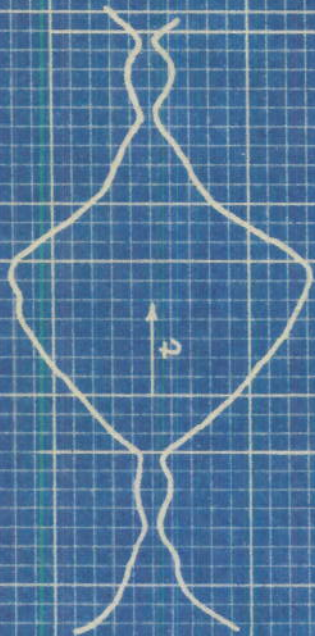
DECLASSIFIED

RUN 6-18.6 WPM



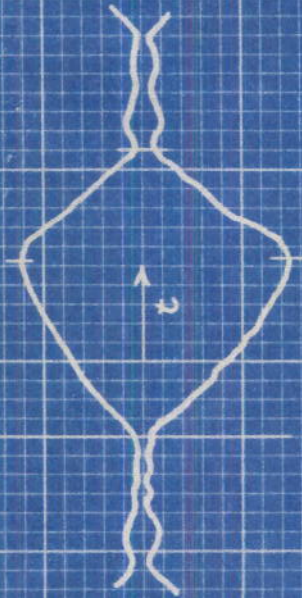
15.44 KC.

RUN 21-91 WPM



← 2.75x10^-2 SEC. →

← 2.97x10^-2 SEC. →



RUN 19-52.5 WPM



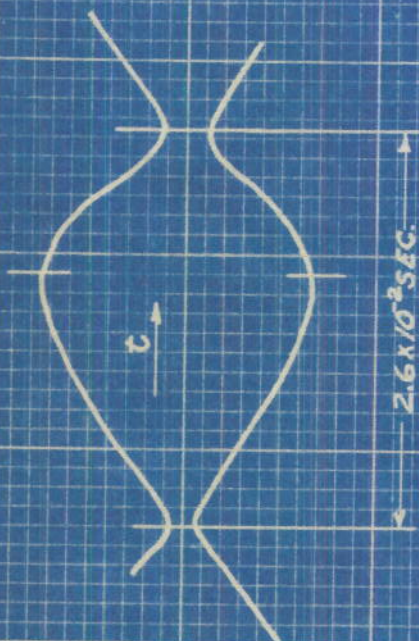
DECLASSIFIED

PLATE #18

DECLASSIFIED

15.44 KC.

RUN 8-96 WPM

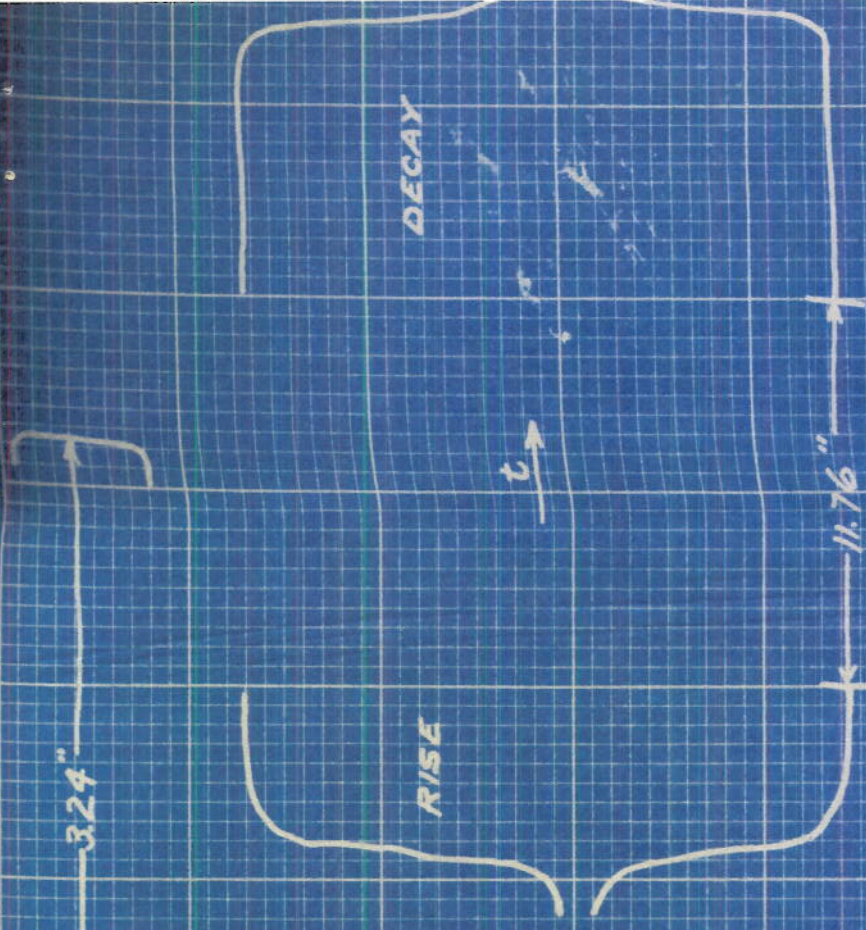


DECLASSIFIED

PLATE #19

DECLASSIFIED

1544 KC.  
RUN 1  
RECEIVER CHARACTERISTIC



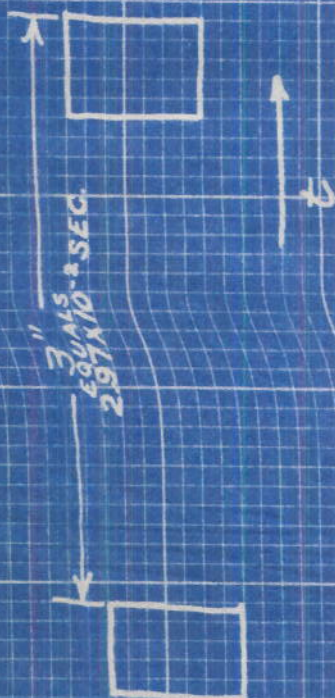
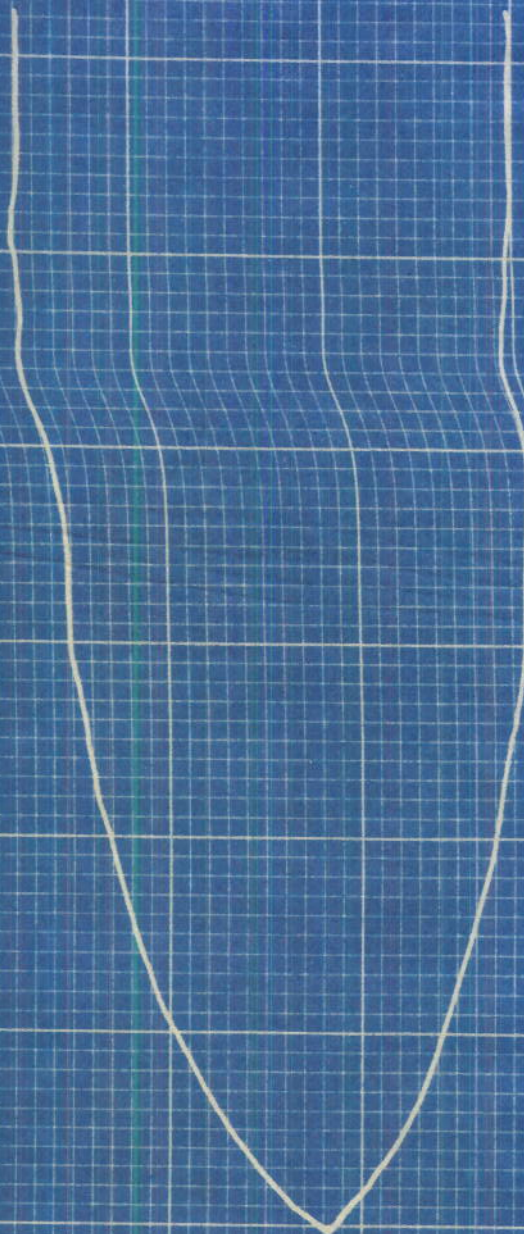
← 0.917 x 10<sup>-2</sup> SEC →

DECLASSIFIED

PLATE #20

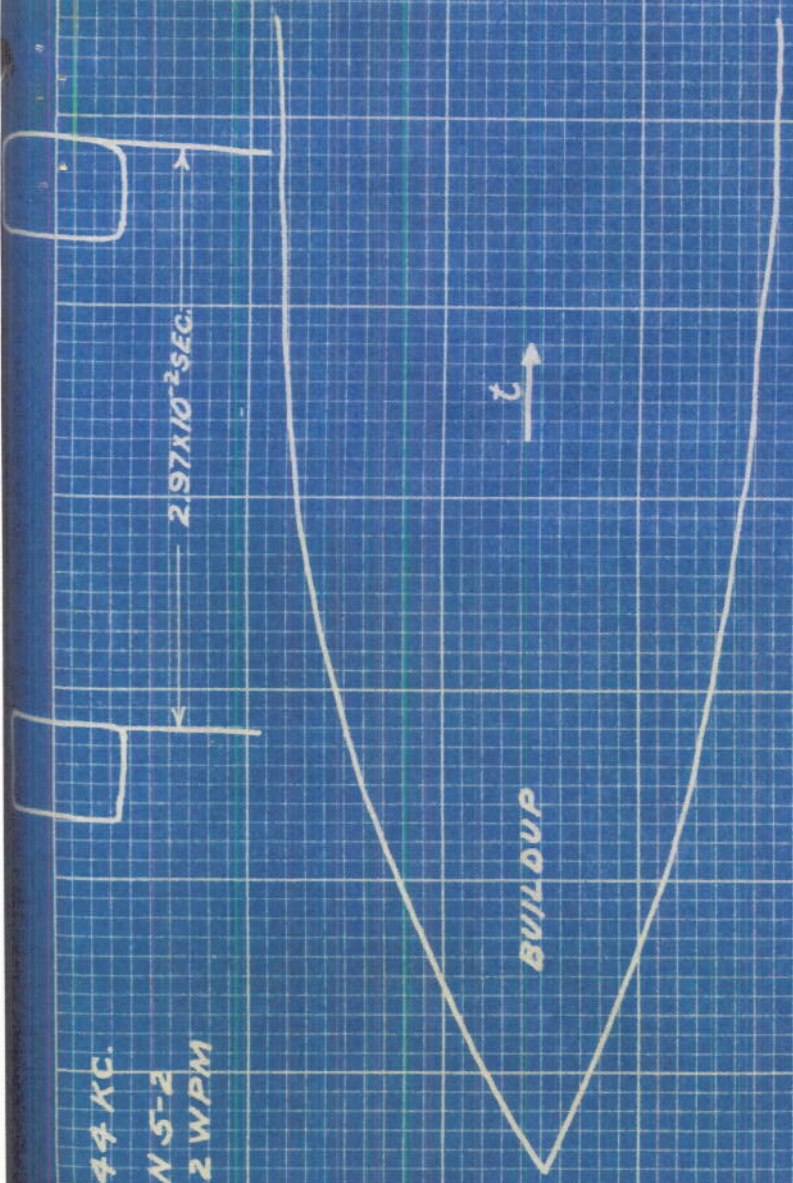
DECLASSIFIED

15.44 KC.  
RUN 5-1  
12.2 WPM



DECLASSIFIED

DECLASSIFIED



15.44 KC.  
RUN 5-2  
12.2 WPM

t

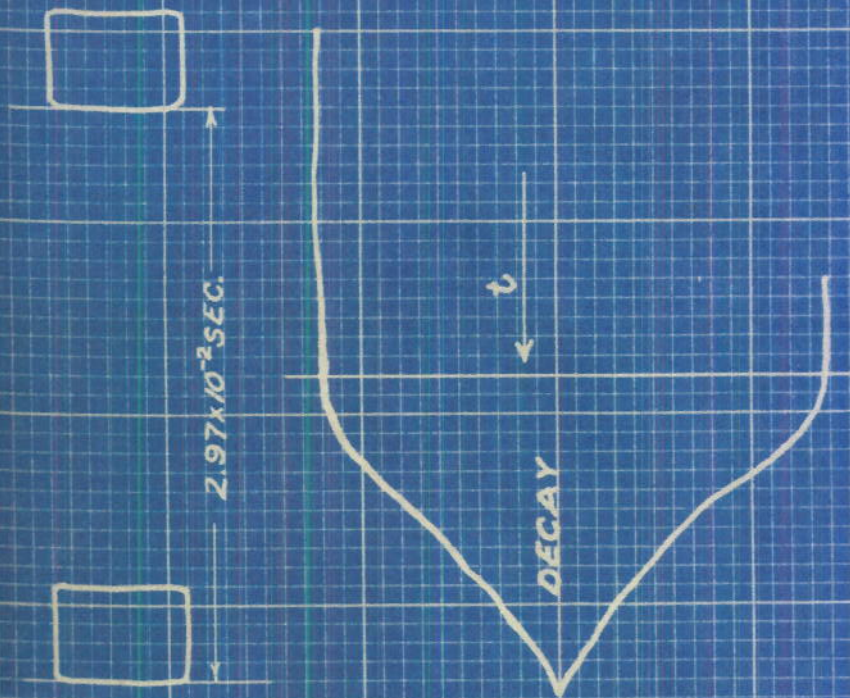
BUILDUP

2.97 x 10<sup>-2</sup> SEC.

DECLASSIFIED

DECLASSIFIED

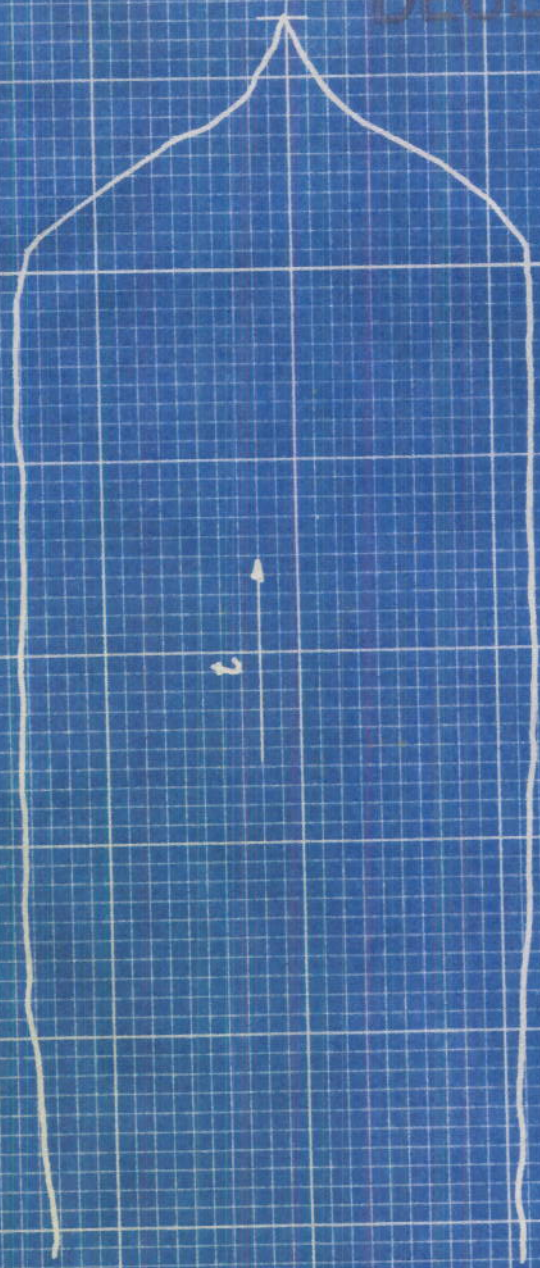
15.44 KC.  
RUN 5-1  
12.2 WPM



DECLASSIFIED

DECLASSIFIED

15.44 KG.  
RUN 5-2  
12.2 WPM



DECLASSIFIED

MAR 29 1944

PLATE #24

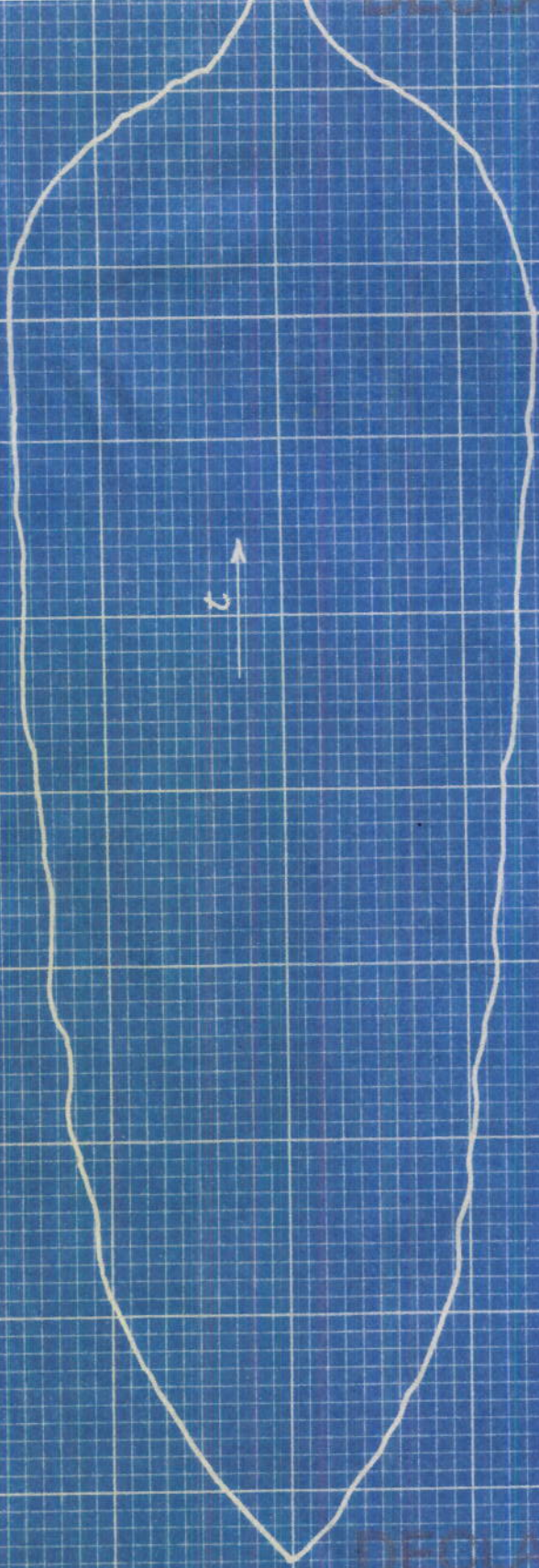
DECLASSIFIED



3.36"  
EQUALE  
2.97X10<sup>10</sup> SEC.



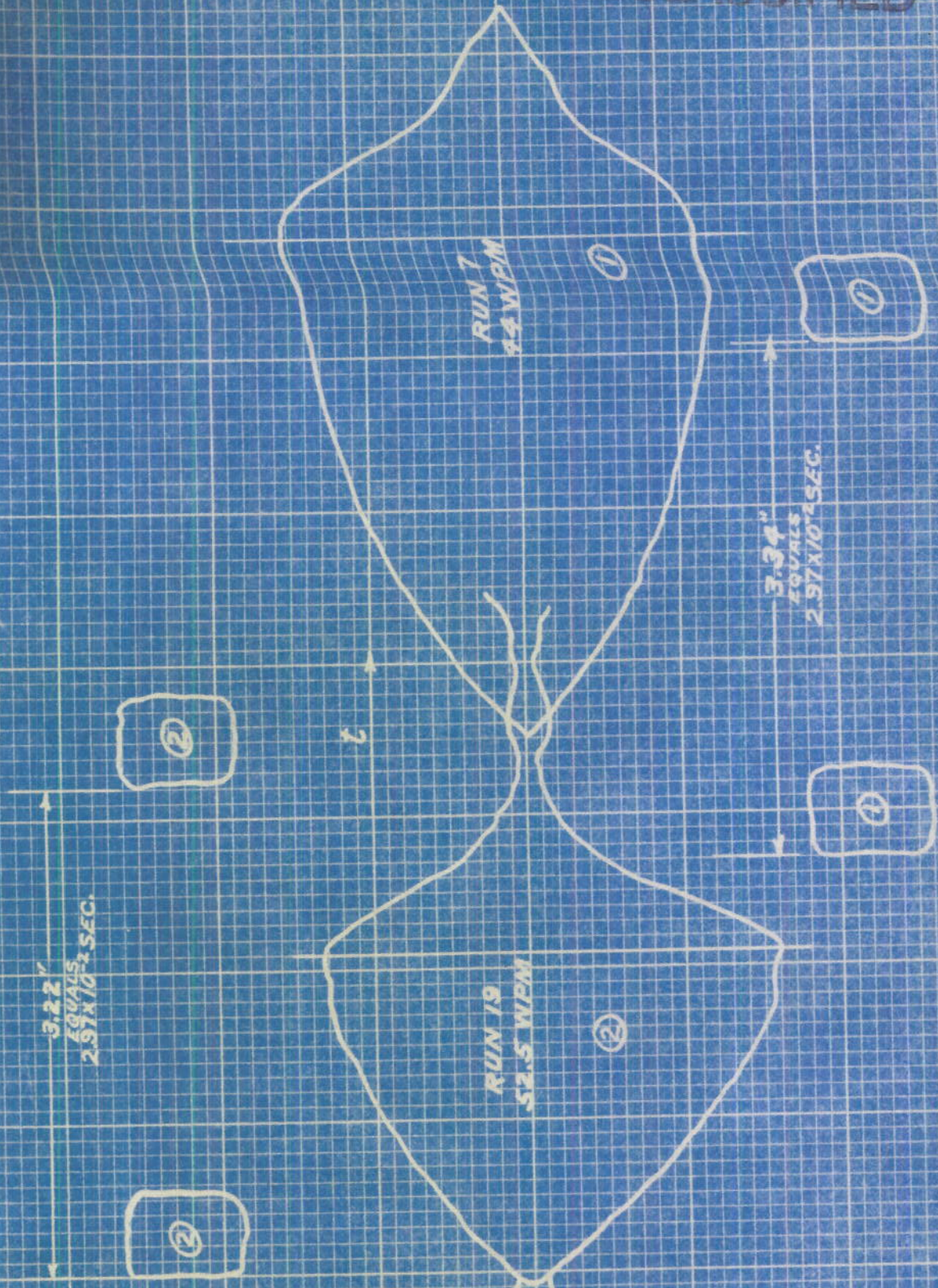
15.44 KC.  
RUN 10  
17 WPM



DECLASSIFIED

DECLASSIFIED

15.44 KG.



DECLASSIFIED

15.44 KG.

(a) DECAY CURVE

(b) DECAY CURVE SQUARED

DECLASSIFIED

$$f(t) = \frac{V}{V_0}$$

(a)

(b)

DECLASSIFIED

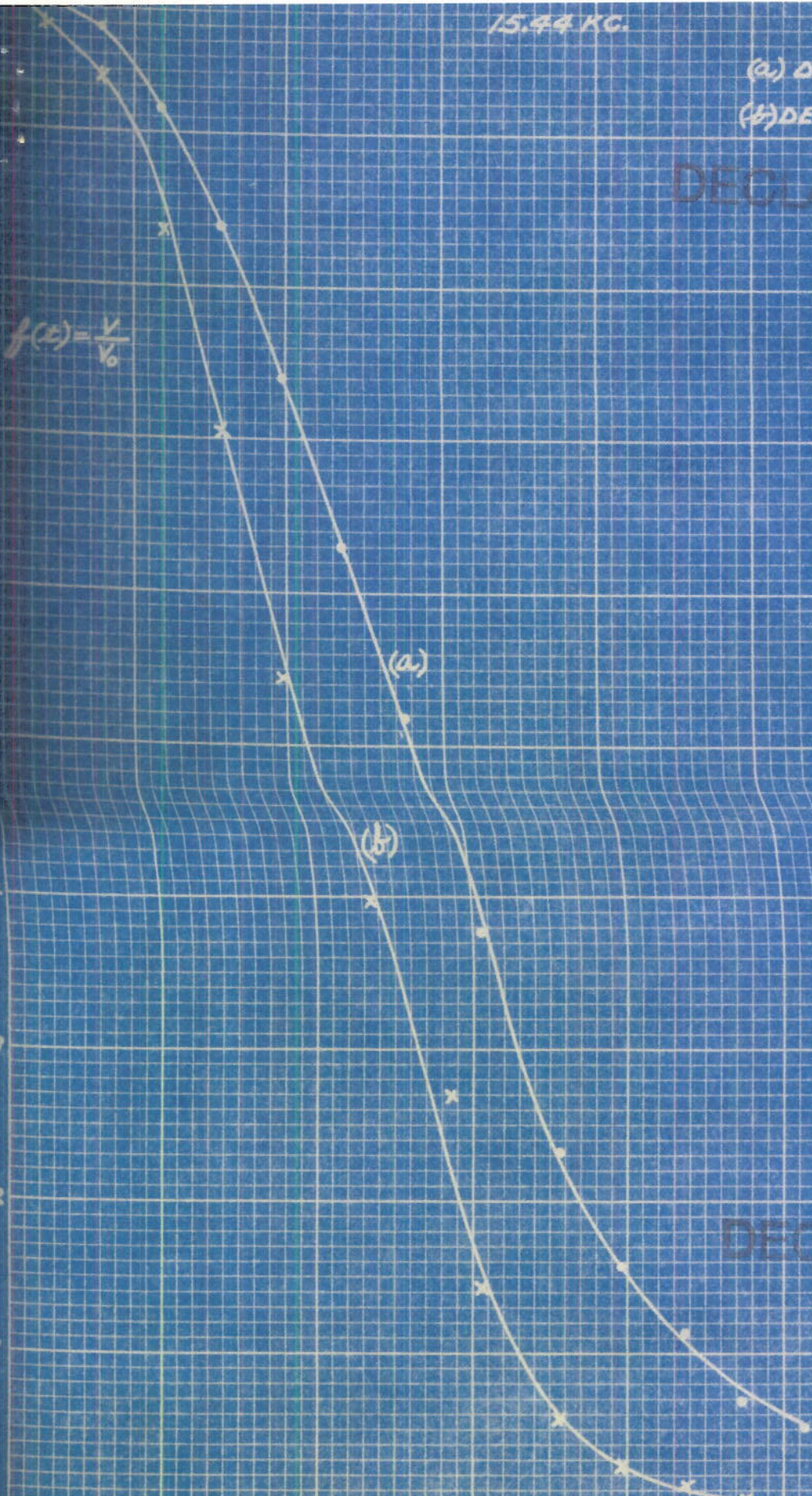
0

0.5

1.5

t - SECONDS  $\times 10^{-2}$

PLATE #27

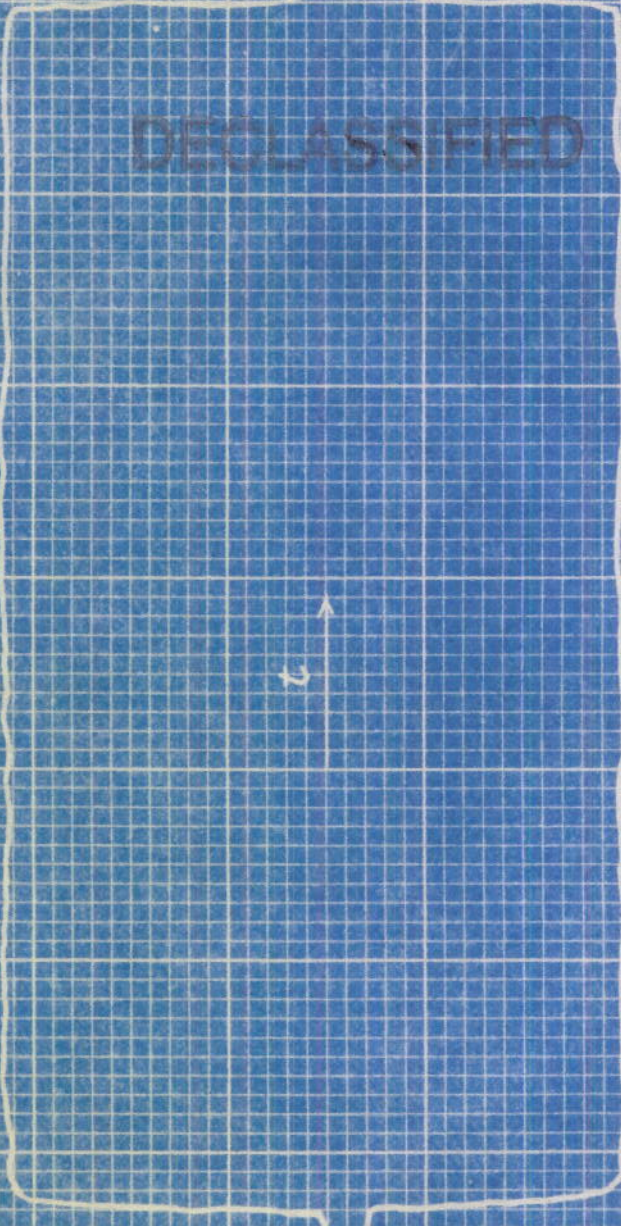


DECLASSIFIED

261 KC.  
RUN 2 - RECEIVER TIME CONSTANT



$2.97 \times 10^{-4}$  SEC.



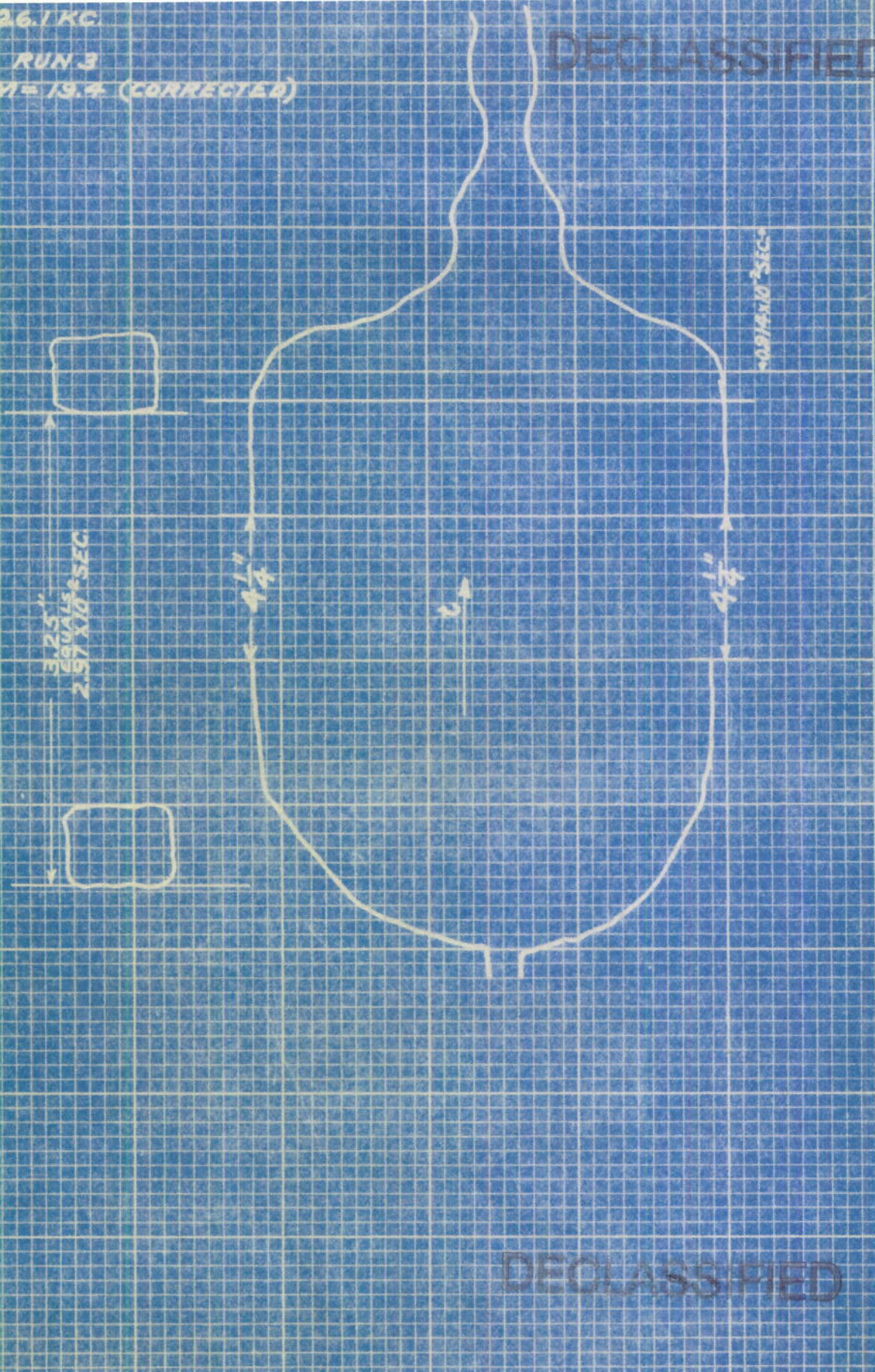
DECLASSIFIED

26.1 KC.

RUN 3

WPM = 19.4 (CORRECTED)

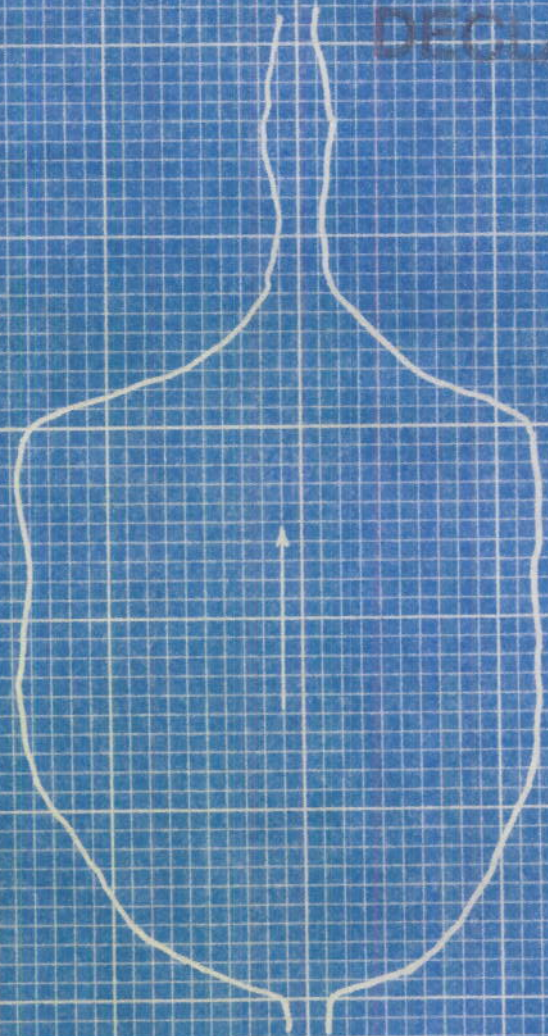
DECLASSIFIED



DECLASSIFIED

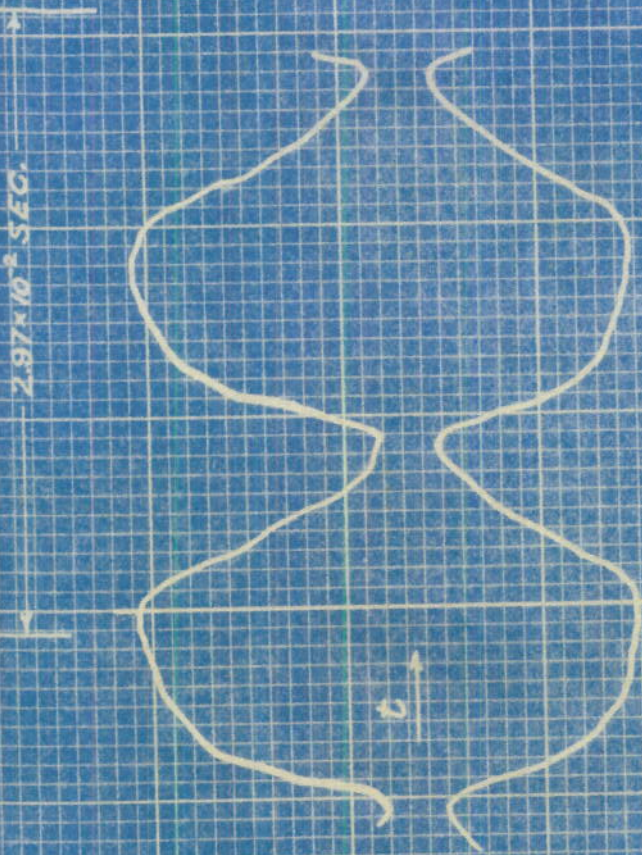
DECLASSIFIED

2.67 KG.  
RUN 6 - 45.5 WPM (CORRECTED)



DECLASSIFIED

DECLASSIFIED



26.1 KC.

RUN II

145 WPM

136.6 WPM CORRECTED

DECLASSIFIED

DECLASSIFIED

]

$2.97 \times 10^{-2}$  SEC.

]

b

26.1 KC.  
RUN 14  
101 WPM CORRECTED

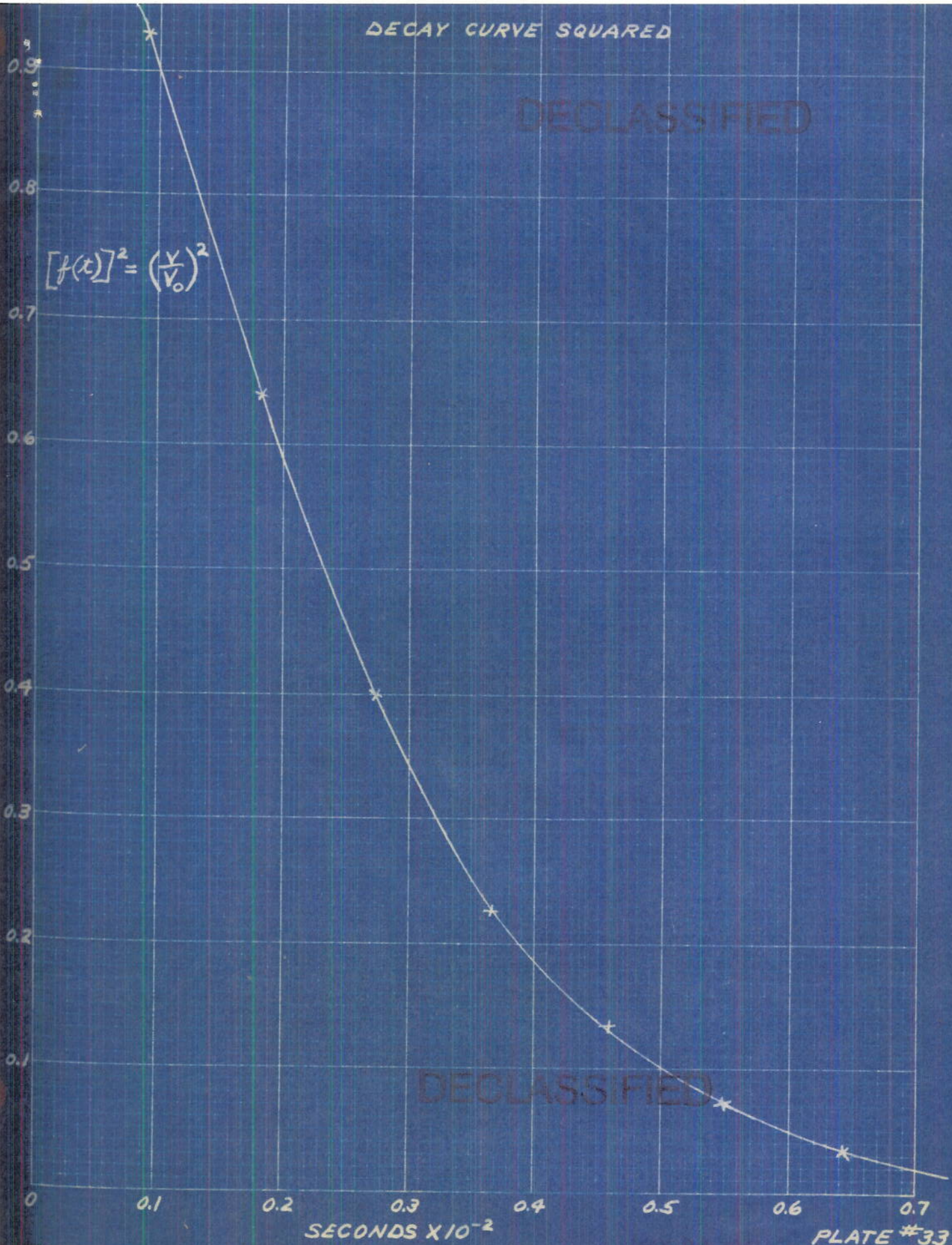
DECLASSIFIED

PLATE #32

DECAY CURVE SQUARED

DECLASSIFIED

$$[f(x)]^2 = \left(\frac{V}{V_0}\right)^2$$



DECLASSIFIED

SECONDS X 10<sup>-2</sup>

PLATE #33