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Project 2510 (Miniature Audio Oscillator)

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This project required an oscillator with the following major specifications:

1. Maximum size, 3"x2"x1"
2. Frequency range, 30 to 3000 cps
3. Frequency stability 2% with a temperature variation of 0 to 55 degrees centigrade.
4. Pulse waveform is acceptable

A thorough investigation of the presently available circuit elements revealed that the only device that would approach these specifications in an audio oscillator was the General Electric ZJ-14 experimental unijunction transistor. A search of the literature revealed that no work had been done to determine which ZJ-14 parameters are important to the frequency stability of an audio oscillator. One way to determine the characteristics of any device is to obtain a quantity of them and run a statistical evaluation. With this in mind 24 ZJ-14 transistors were ordered and a series of tests were made on these units ~~in order~~ to determine what parameters should be specified ~~when ordering these transistors from the manufacture~~ in order to be able to build an oscillator with the required specifications. This report outlines the results of some of these tests.

Figure 1 shows the basic oscillator circuit. This is a relaxation oscillator. Resistor R determined the time required for the condenser C to charge. When the voltage across C reaches a certain value the forward resistance of the transistor junction reduces to a very low value discharging C. The condenser then charges through R again and

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the cycle is repeated. The frequency may be varied by changing the value of R or C. The value of the junction "breakdown" voltage (VOLTAGE BETWEEN the junction and base NUMBER 1) depends on two things; the voltage on base number 2 and the "stand-off ratio" of the transistor. The "stand-off ratio" (ρ) - (ds) is the ratio of the "breakdown" VOLTAGE to the base number 2 voltage ~~and the "breakdown" voltage~~ and is a function of the particular transistor and may have a value of from 0.5 to nearly 1.0. The base number 2 voltage is equal to $E - I_b R_1$.

In order ~~for~~ to design a stable ~~the~~ oscillator ~~to be frequency stable with variation temperature and supply voltage variations~~ the following parameters had to be investigated:

1. Leakage current. (This is the reverse current that flows across the junction when voltage is applied to the bases and the junction voltage is below the "breakdown" value.
2. Stand-off ratio (ρ).
3. Base to base resistance (R_b) (This resistance is important because it sets the value of base number 2 voltage).

*when it is assumed that the "on" time is small compared with the "off" time the frequency of oscillation is related to the transistor parameters by the following expression:

$$f = -\frac{1}{RC \ln(1 - K\rho)} \text{ cps}$$

Where: ρ is the stand-off ratio and K is $\frac{R_b}{R_b + R_1}$

R_b is the base-to-base resistance.

Figure 2 shows that this equation is accurate. This fugure also shows that leakage current has no effect on the frequency provided it is of the order of 1 microampere. It will be noted that all of the points lie to the left of the line. The effect of leakage current is to increase the measured frequency, therefore

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if leakage current had any effect on the frequency of oscillation the points would fall to the right of the line or at a higher measured frequency. Errors in measurement probably account for the fact that the points do not lie exactly on the 45 degree line.

In order to determine how these parameters are related to the frequency stability the first derivative of frequency with respect to K and ρ was found:

$$\frac{df}{d(K\rho)} = -\frac{1}{RC\ln^2\left(1-K\rho\right)\left(1-K\rho\right)}$$

This equation was checked and it was found that as the value of K and ρ is increased $\frac{df}{d(K\rho)}$ becomes smaller. In other words the oscillator will be more stable when the absolute value of K and ρ is large. Figure 3 shows that this is true.

Figure 3 can be used to determine what value R_b and ρ must have to obtain a given frequency stability over the temperature range of 0 to 55 deg. C.

Figure 4 gives an indication as to why these transistors are temperature stable. At a temperature of 80 degrees centigrade this particular unit has a base-to-base resistance of 9000 ohms. This same transitor had a base-to-base resistance of 9600 ohms when operated at room temperature in an oscillator circuit with an applied voltage of 45 volts. In other words the operating temperature of the transistor is greater than 80 degrees centigrade in this instance. ~~This sets an upper limit of temperature for a given power input and also sets a lower~~ As long as the operating temperature is much greater than the ambient temperature the oscillator should be relatively stable. ~~However, a short period of instability may occur during the initial application of power.~~

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this variation versus time is shown in figure 5. Assuming that the silicon in this transistor is .04" x .016" x .011" and a typical value of power input is 0.1 watt then the rise in temperature is approximately 510°C/second. Of course this assumes there is no dissipation of heat through the supports but it does indicate that the temperature should stabilize relatively fast.

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There is, however, a short period of instability during the initial application of power to the oscillator. Several curves showing this variation versus time are shown in figure 5. Assuming that the silicon in these transistors has the dimensions of .04" x .016" x .011" and a typical value of power input is 0.1 watt then the rise in temperature is approximately 510 degrees centigrade per second. This assumes there is no dissipation of heat through the mounting supports but the significant thing is that figure 5 shows that the temperature should stabilize relatively fast.

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Figure ~~5~~ 6 is another relation showing that the units with higher stand-off ratios tend to have higher base resitance. This is a favorable situation since both of these parameters should be large for the most stable operation.

Figures ~~6, 7~~ 7 8 and ~~8~~ 9 are plots of frequency variation vs. time. These curves show that there is considerable difference between units and all units show some frequency variation when run continuously for long periods of time. However the units with the higher stand-off ratio seem to have better stability in this respect. Further tests are needed to determine the secular stability of a large number of units.

Most of the units that were tested exibited only a small change in stand-off ratio with changes in supply voltage, provided the supply voltage was of the order of 45 volts. If the stand-off ratio remains constant with changing supply voltage then the only remaining variable affecting the frequency is the base resistance. This resistance will change because of changes in the power input to the silicon and resulting change in temperature. Units that were checked showed only a negligible change in frequency with supply voltage variations of from 45 to 35 volts.

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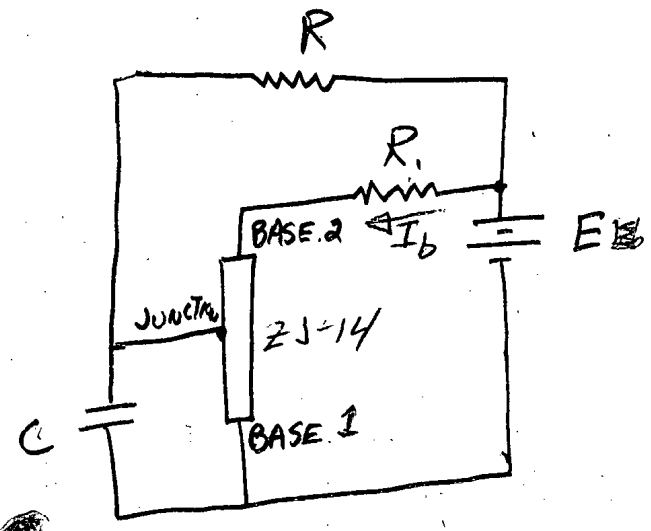

FIG. 1

~~220 = 240~~
~~390 = 422~~
~~457 = 490~~
~~472 = 509~~

245 = 260
385 = 419
515 = 558
545 = 592
595 =
625 = 679
660 = 718
675 = 732
690 = 750
805 = 874
935 =

595 = 648
665 = 722
675

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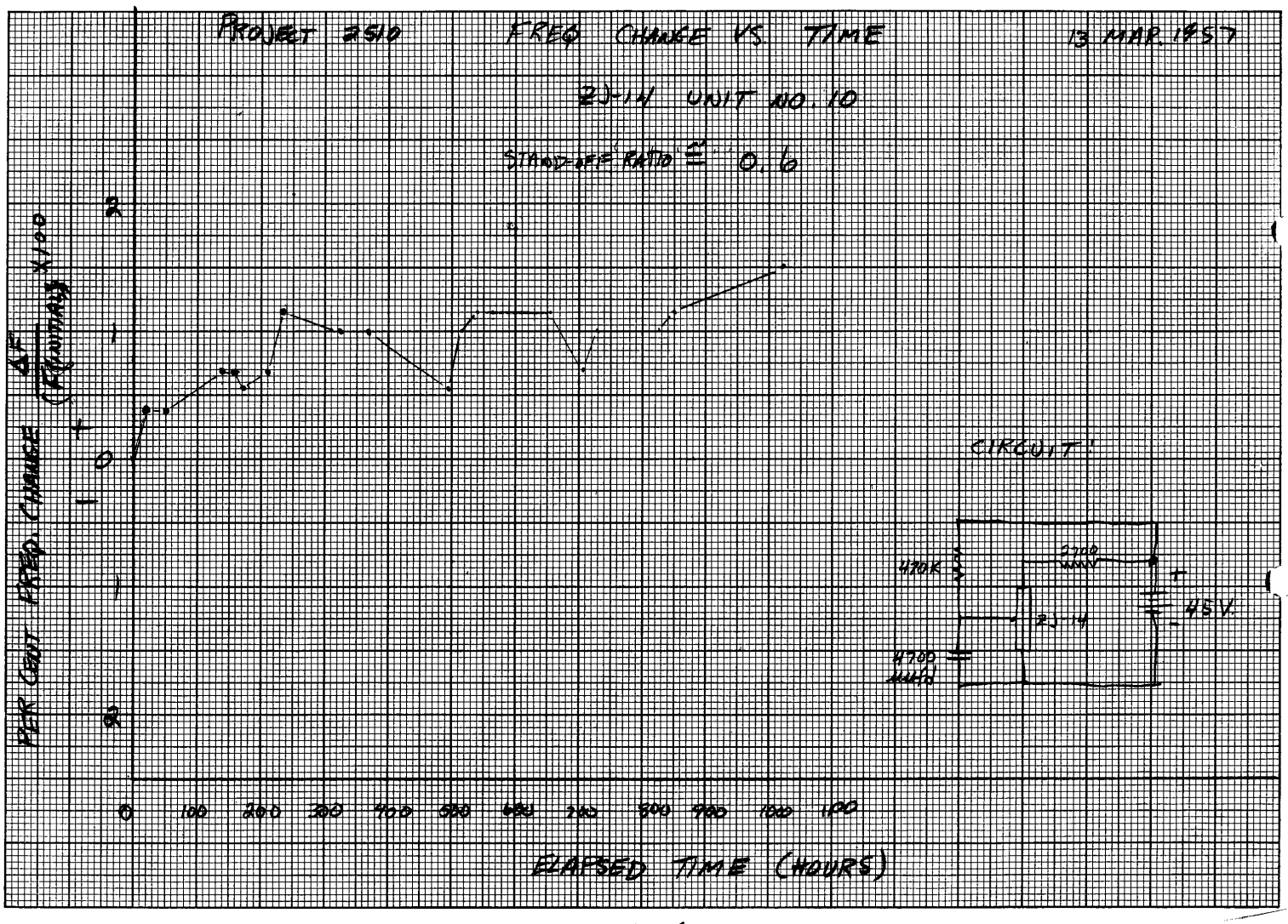

FIG 7

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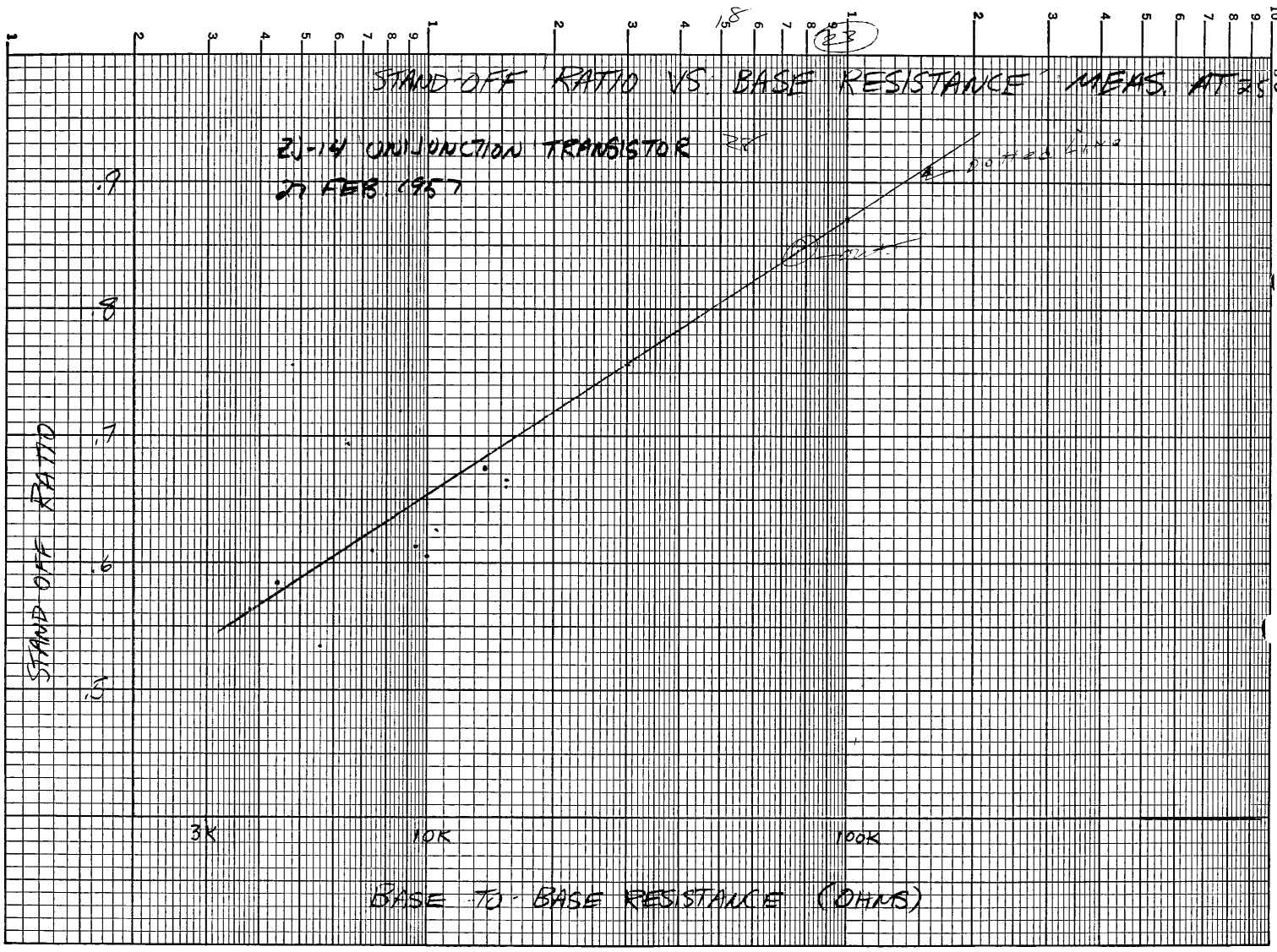

FIG. 6

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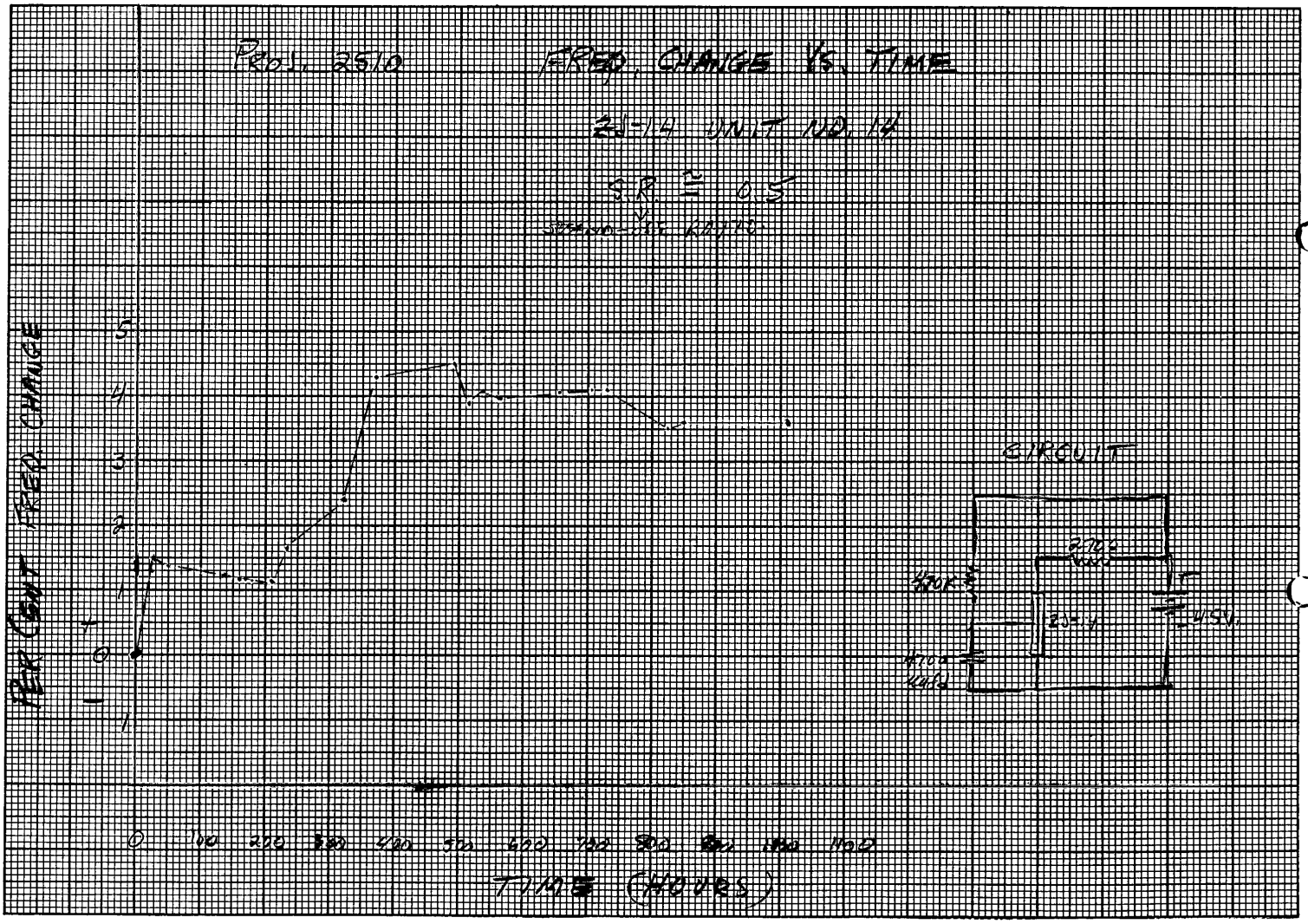

FIG. 8

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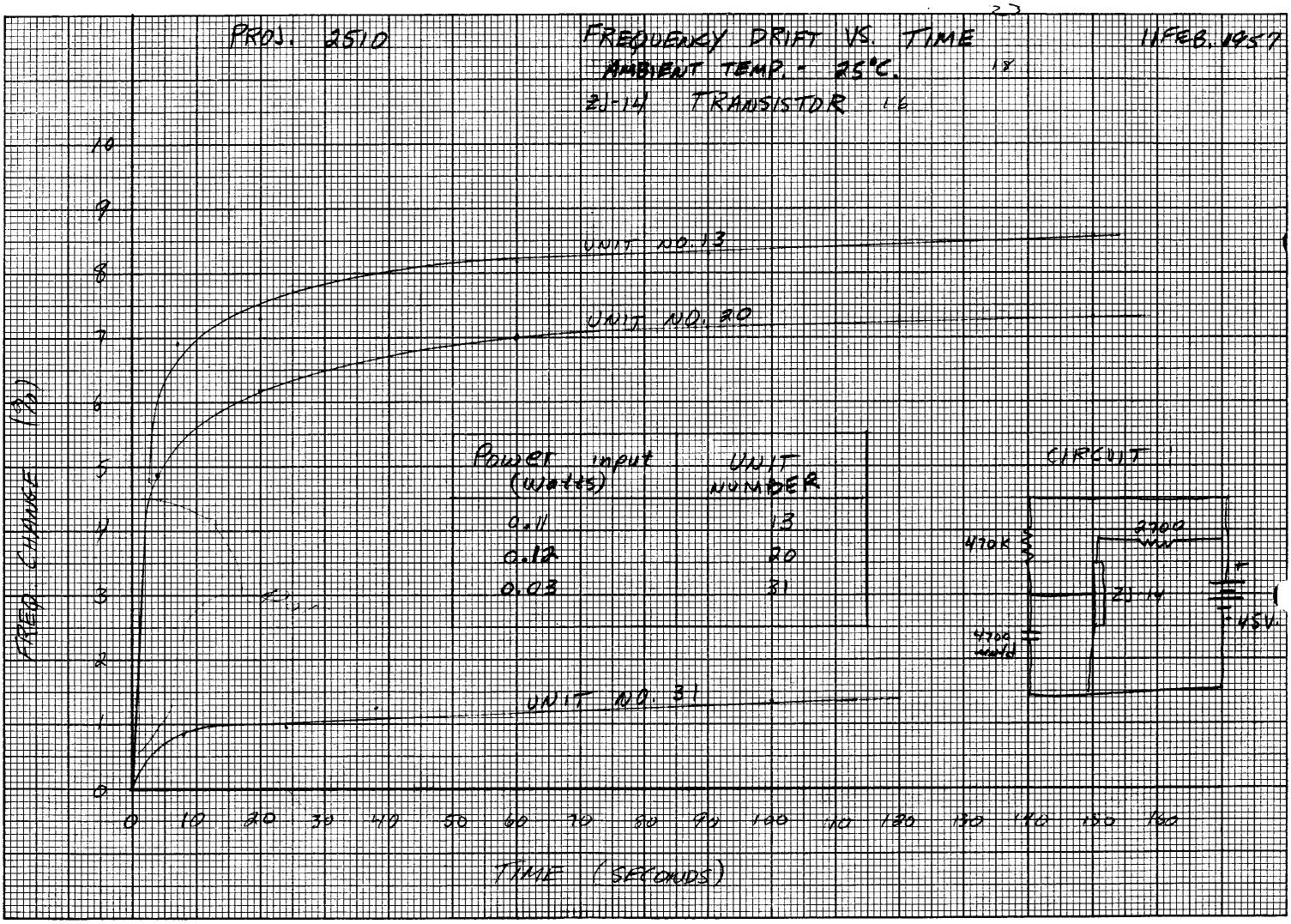

FIG. 5

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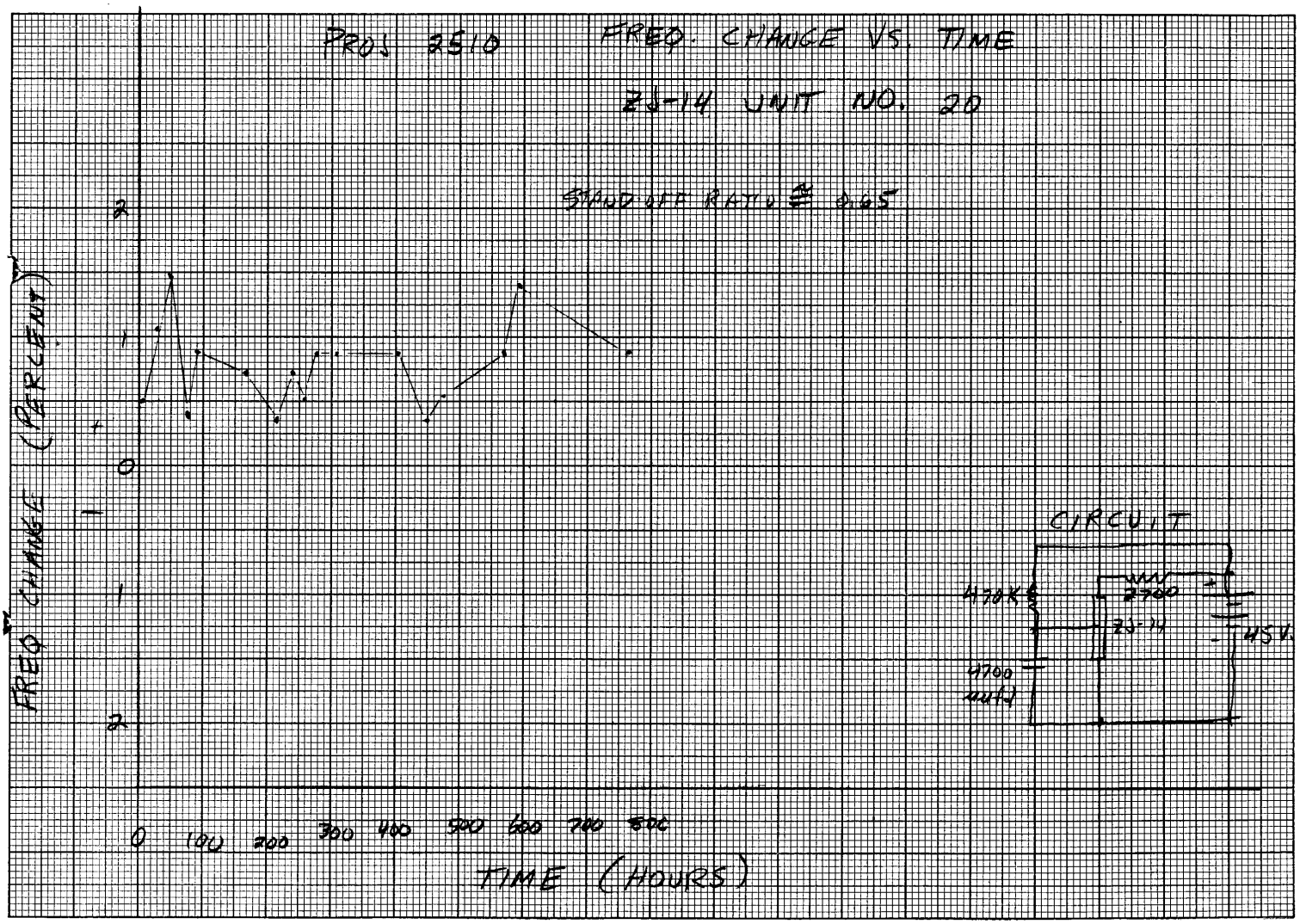

FIG 9

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K+E KEUFFEL & ESSER CO. MADE IN U.S.A.

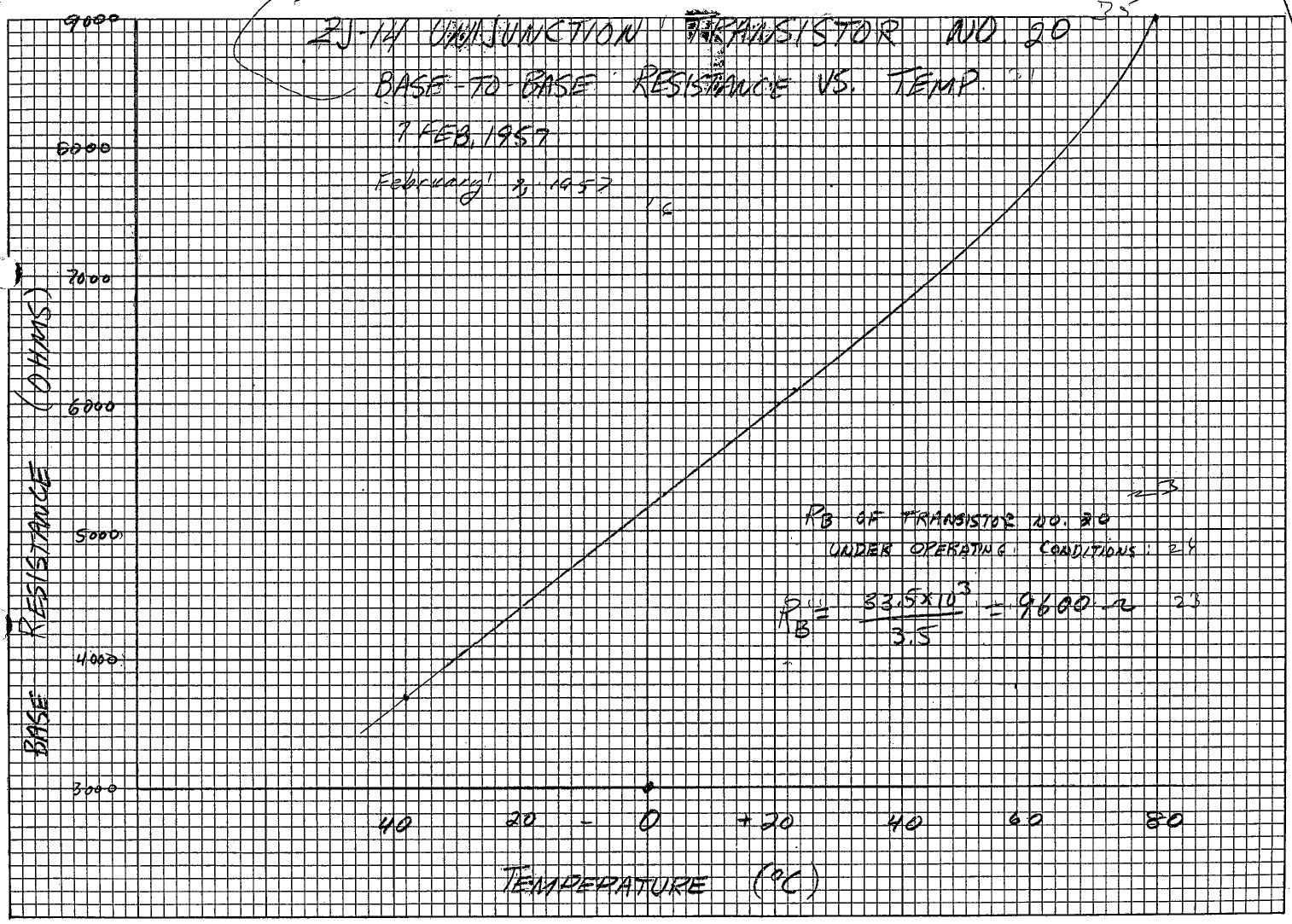

FIG. 4

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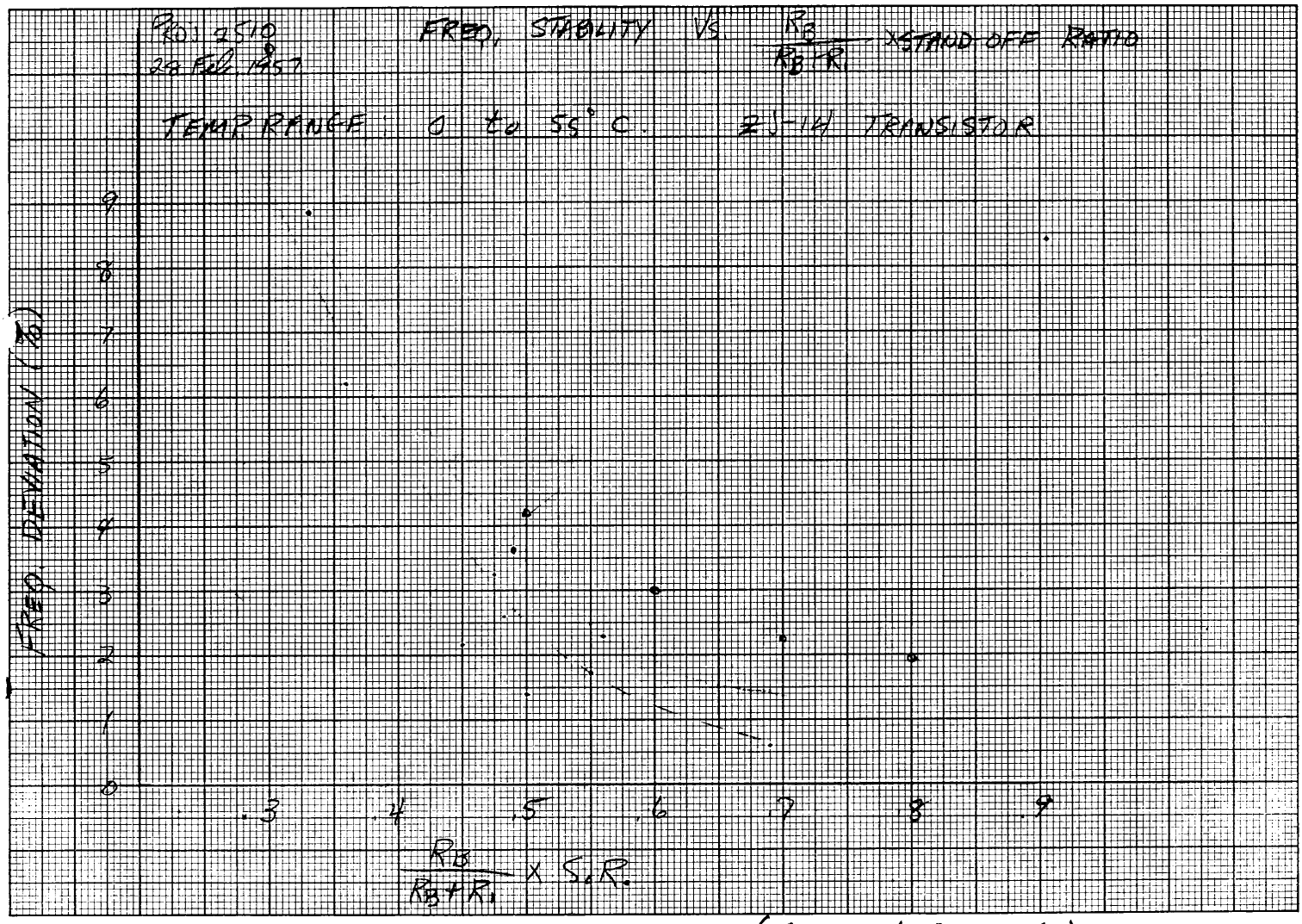

(Leave out Red marks)

FIG 3

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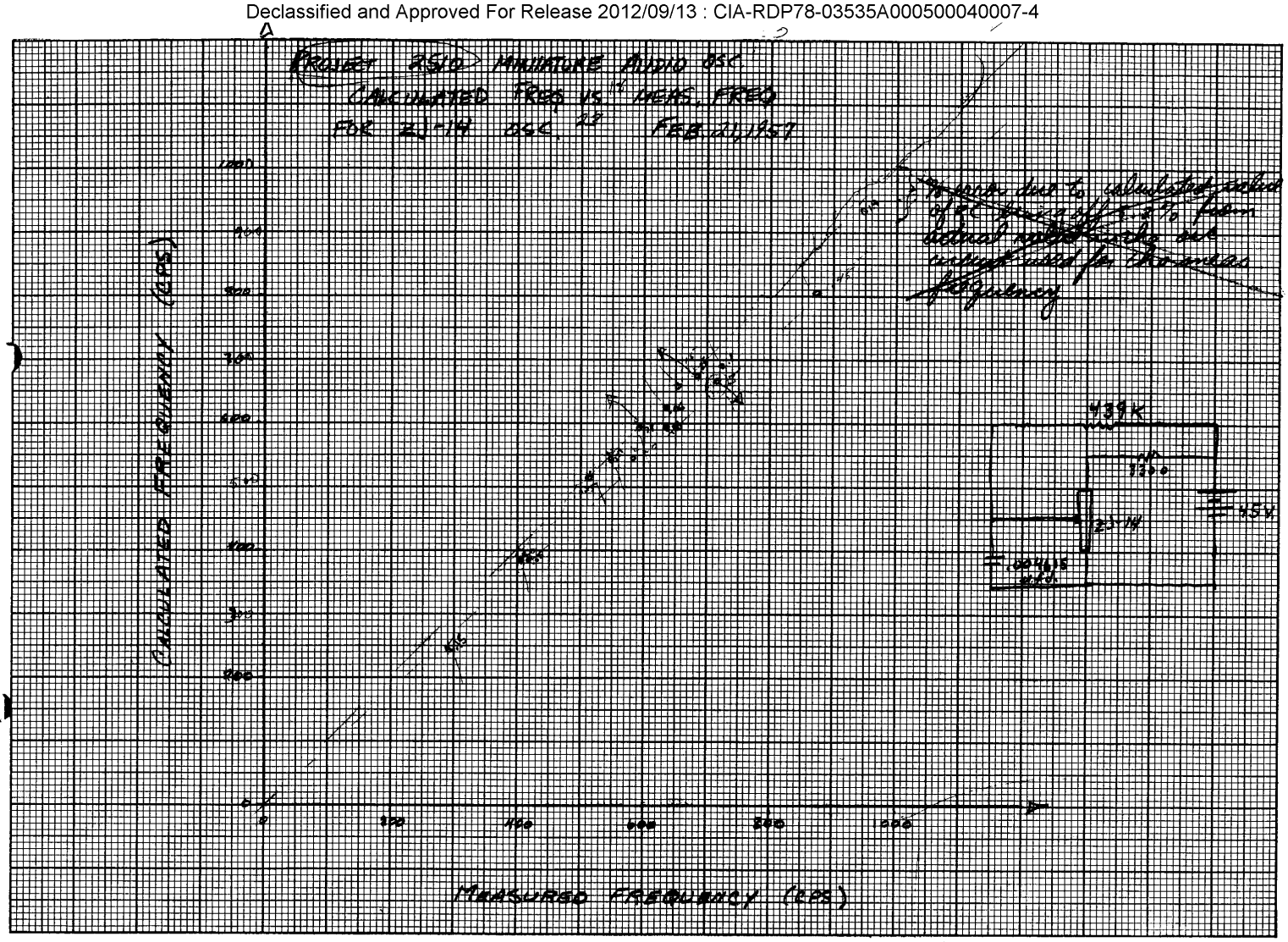

FIG. 2

(leave off no. on points & draw line on lower one -

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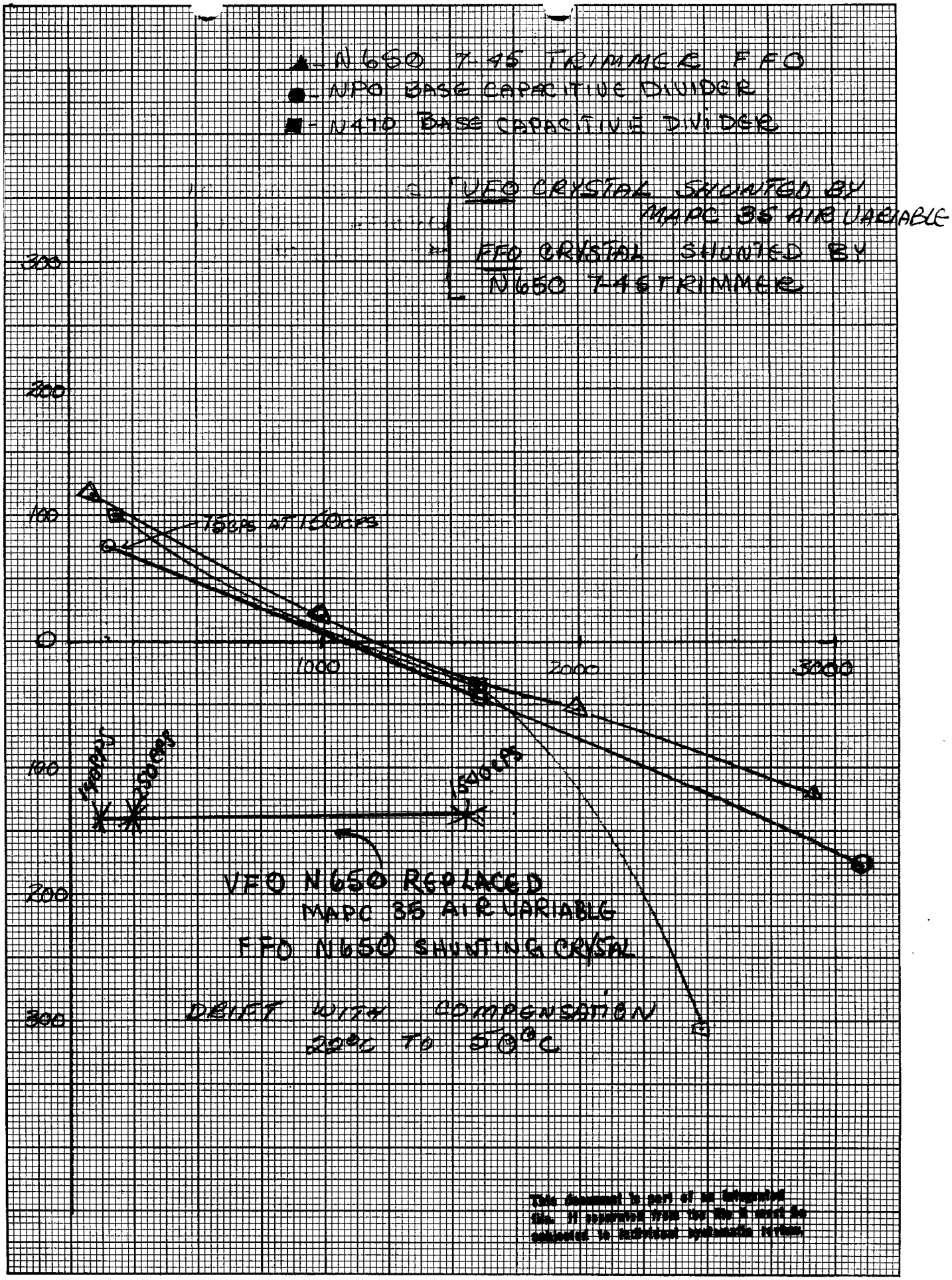

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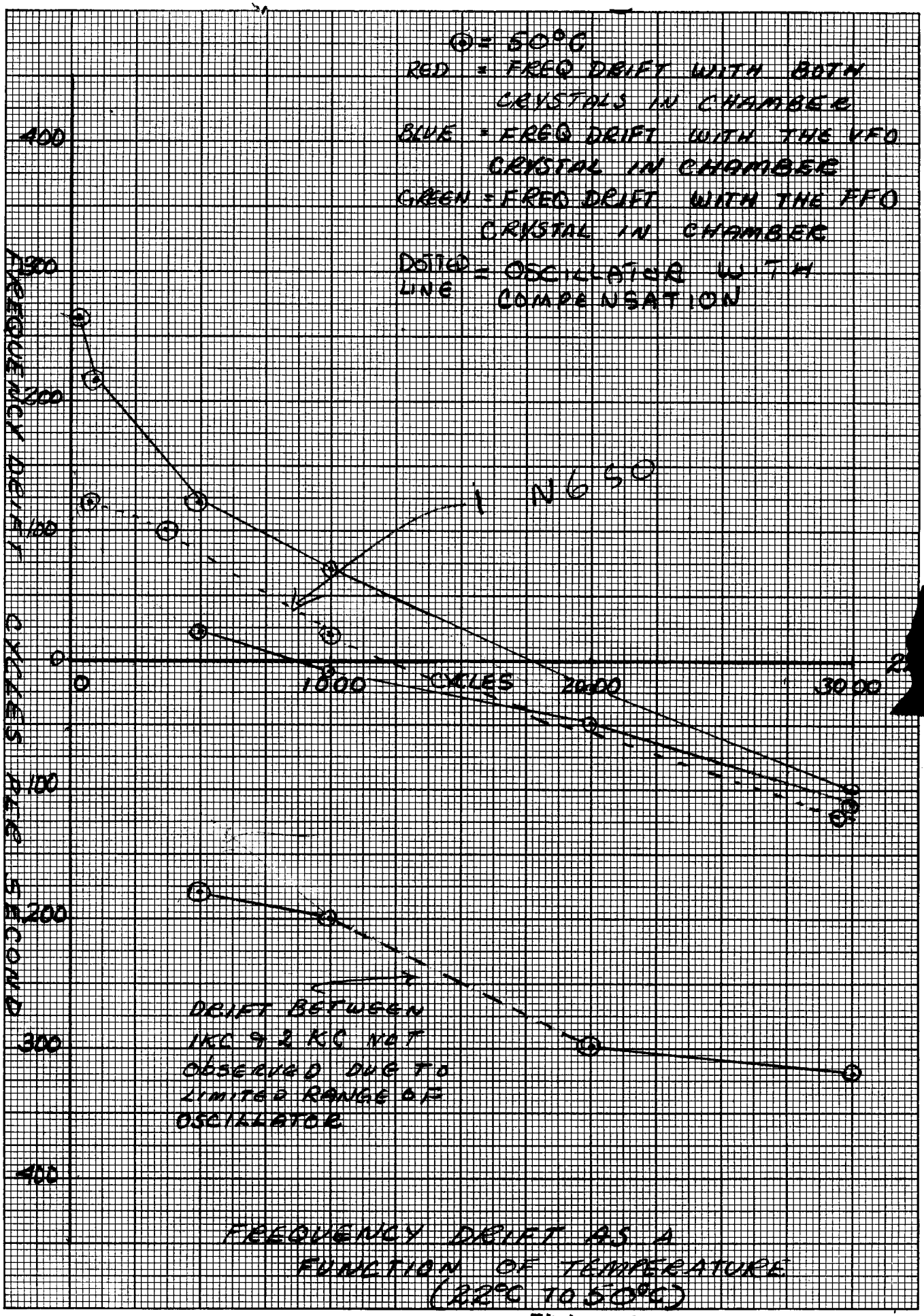

FREQUENCY DRIFT AS A FUNCTION OF TEMPERATURE (22°C TO 50°C)

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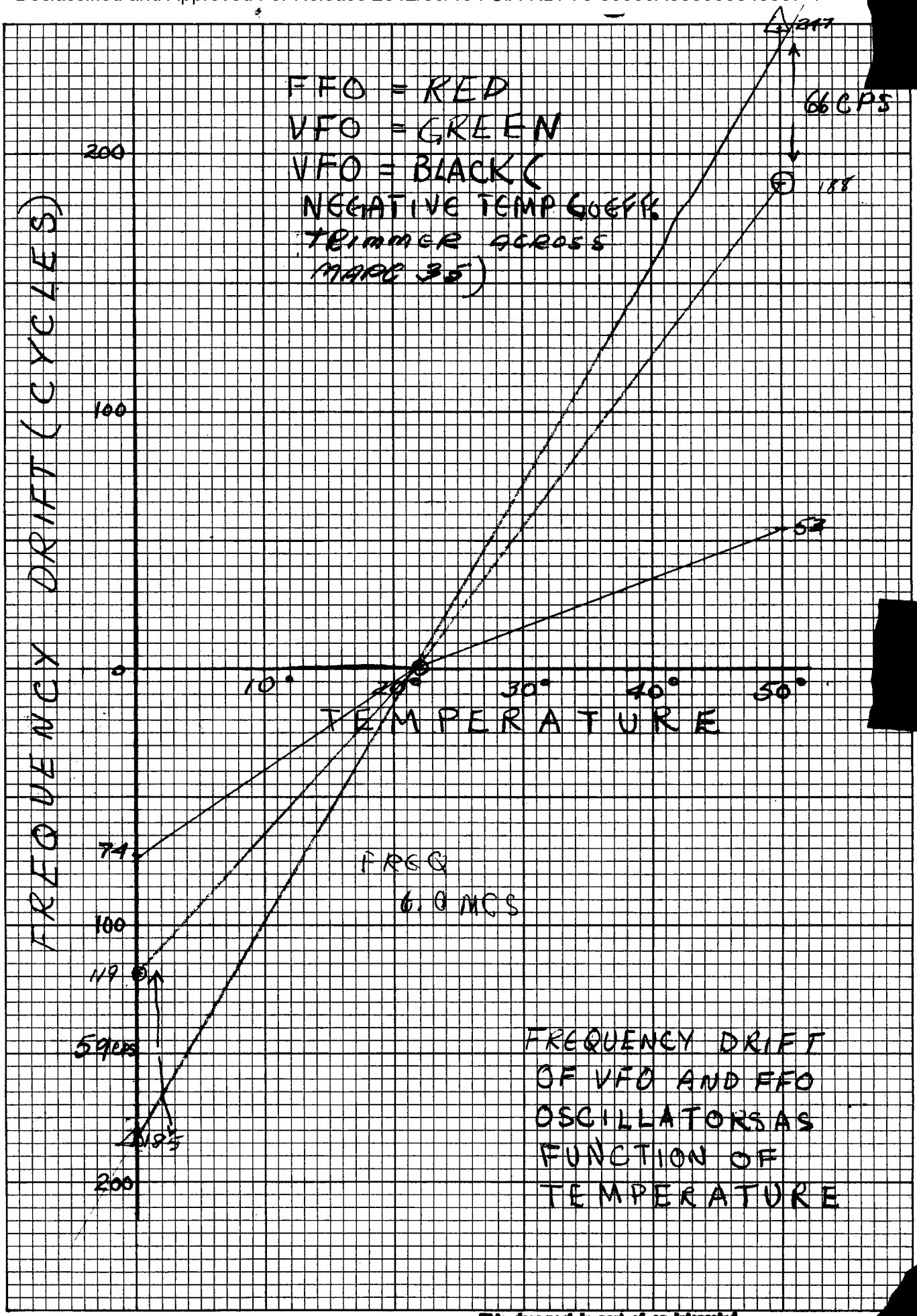

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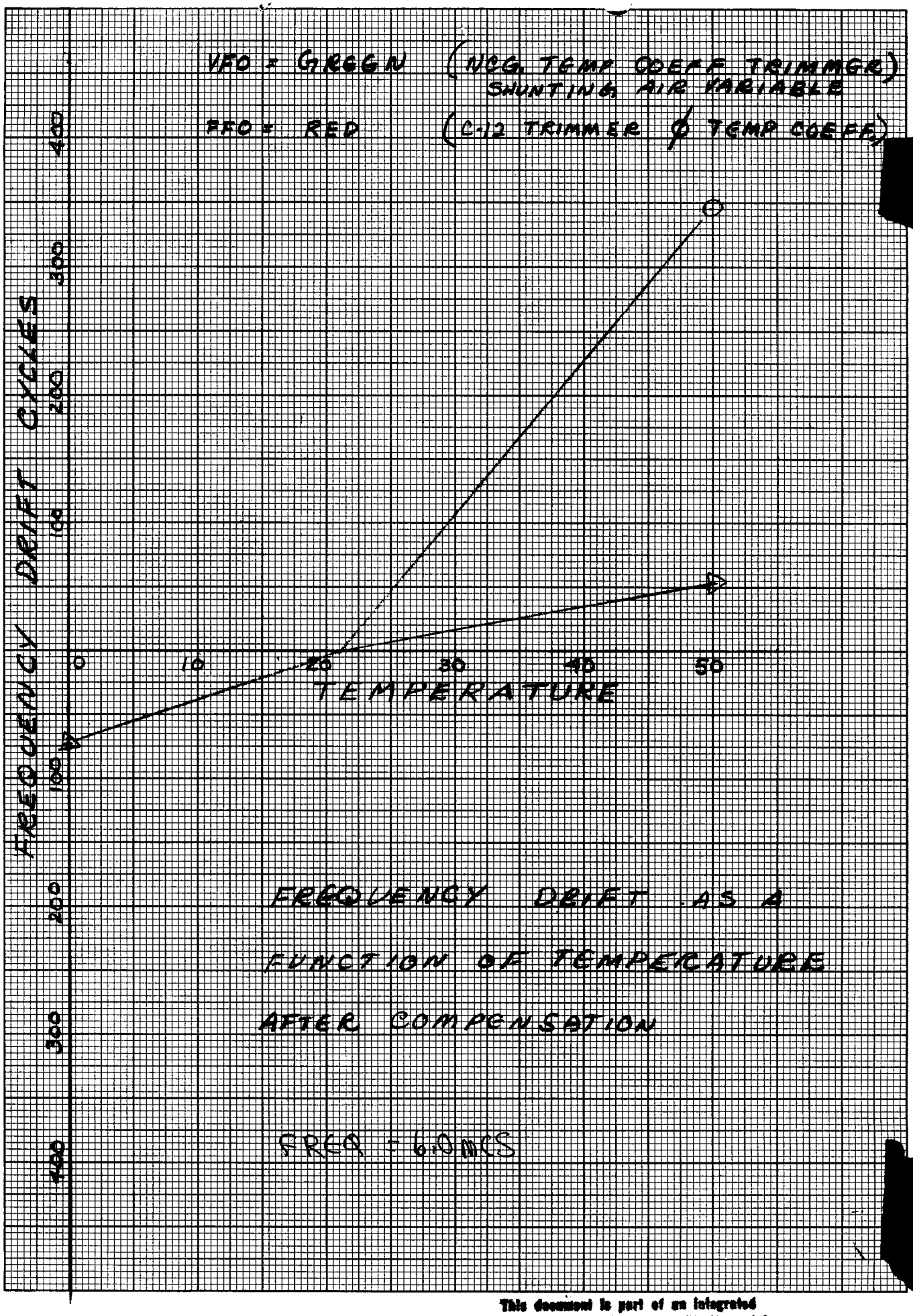

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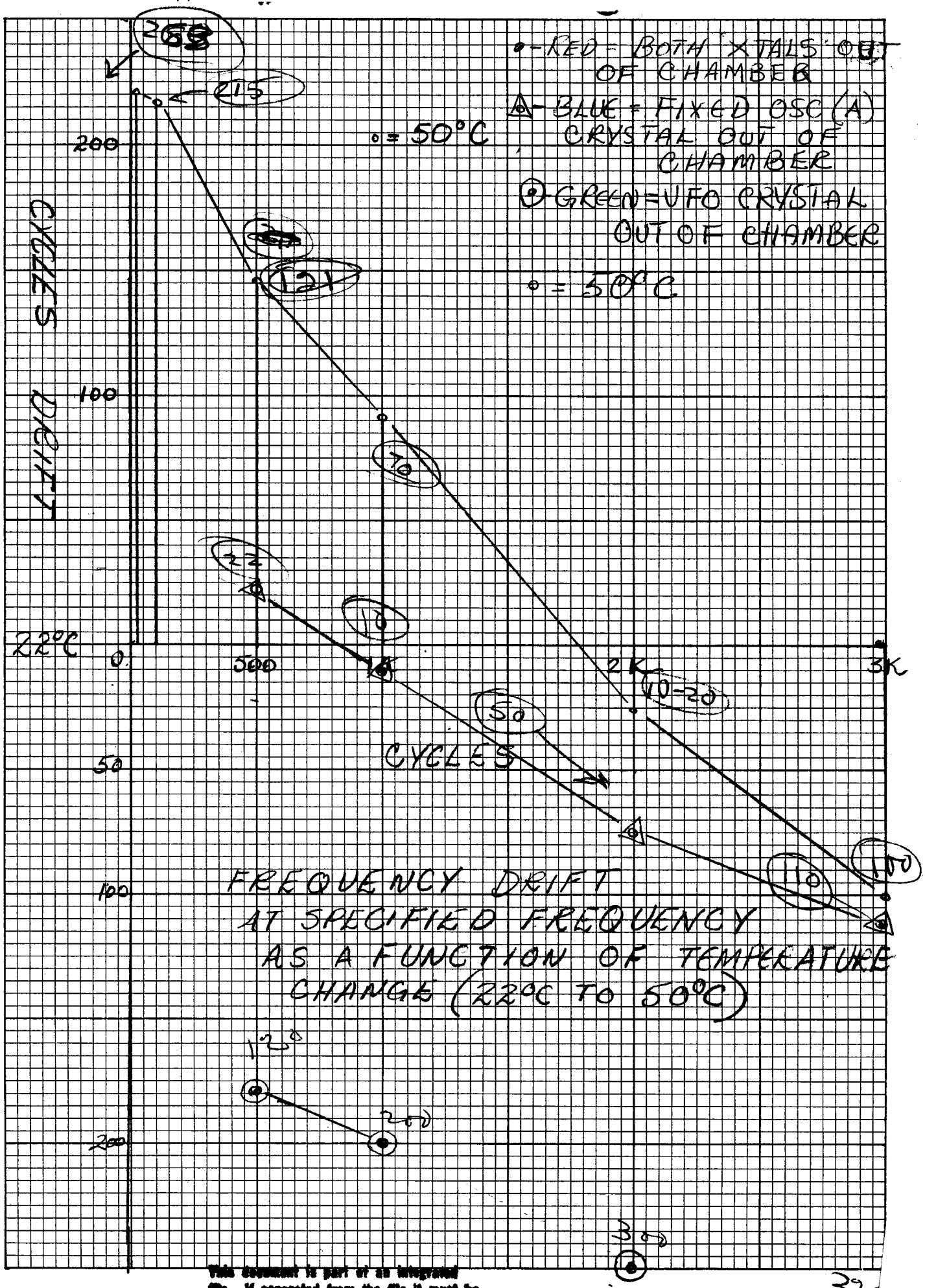

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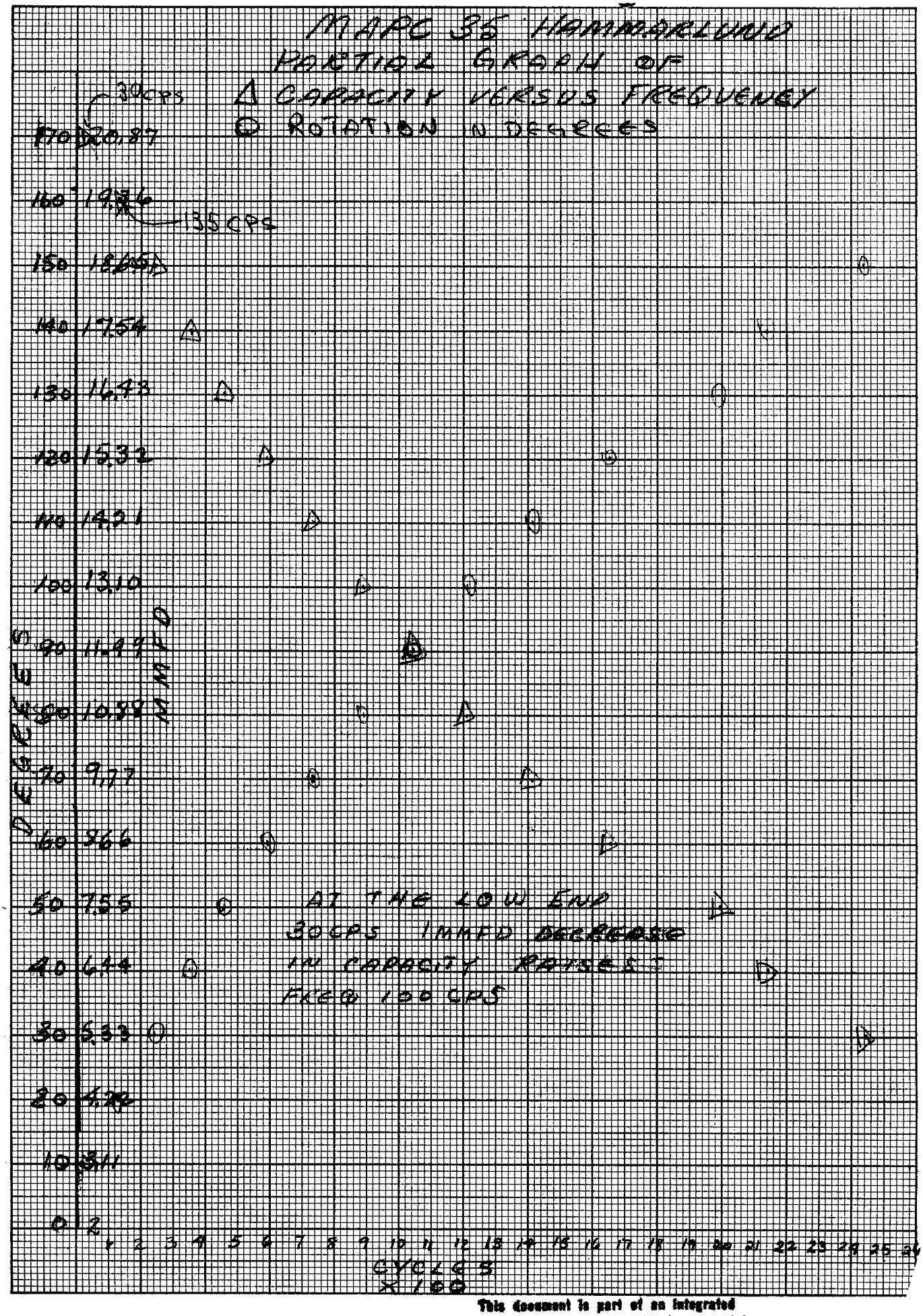

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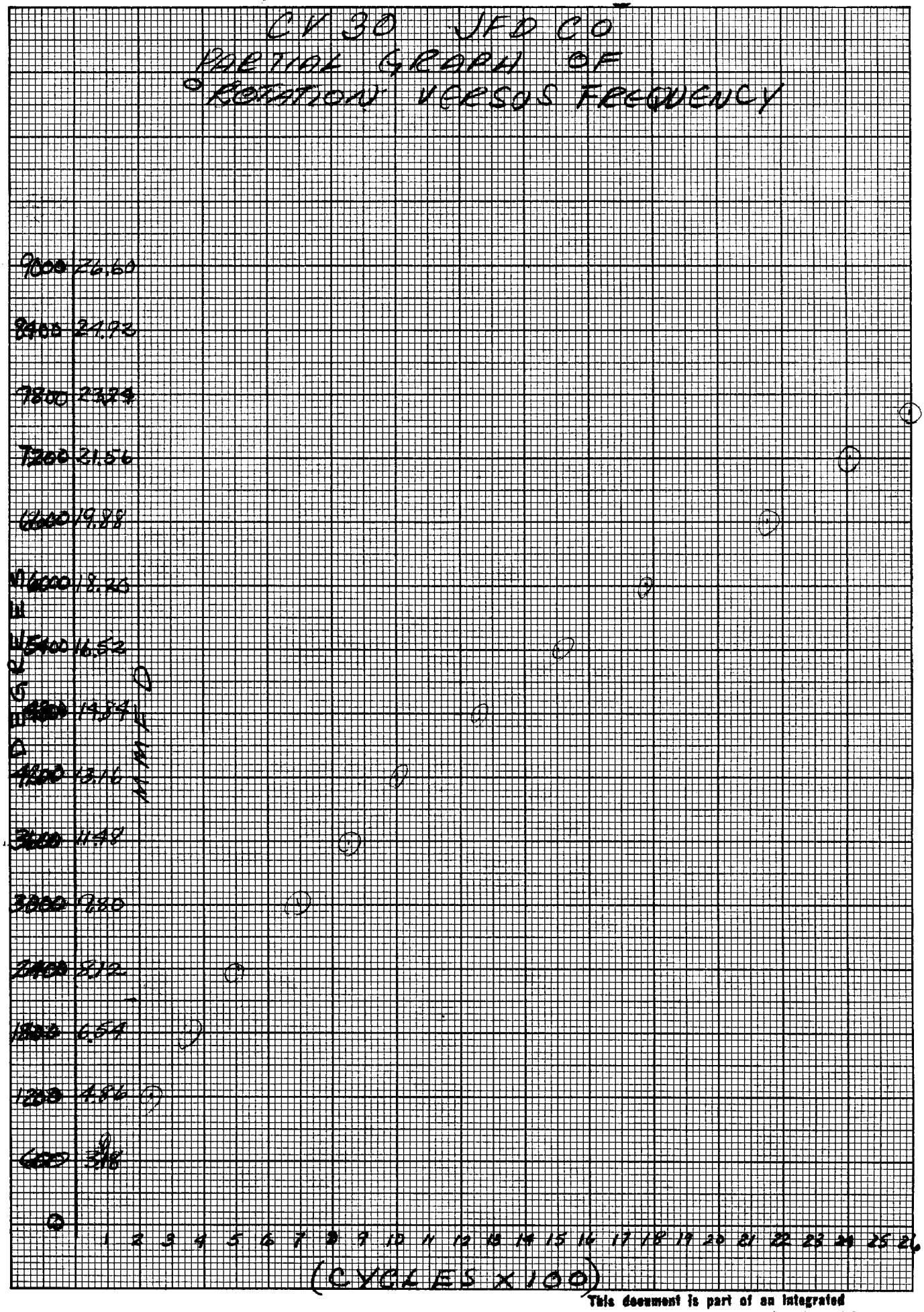

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