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NAVAL RESEARCH LABORATORY
Washington, D.C.

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Ship-Shore Radio Division - Transmitter Section

21 September 1945

EFFECT OF TEMPERATURE ON THE RESONANT FREQUENCY OF MODIFIED MODEL 1541 (TFX-10GA) CAVITIES

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FR-2640

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ABSTRACT

An investigation was made to determine the frequency-temperature-characteristics of the Model 1541(TFX-10GA) reference cavity after the polyiron suppressor disc was removed. The resonant frequency of the cavities was found to vary not more than ± 1 Mc with a change in ambient temperature from 0°C to 60°C. However, the mechanical construction of the cavity was found to be unsatisfactory.

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INTRODUCTION

1. The reference cavities originally used in the Model AN/CPN-6 Transpondor Beacon Equipments exceeded the limits of frequency drift with variations in temperature as specified in paragraph 7-7(f) of reference 2. Two modified pre-production cavities and six modified production cavities were submitted by the contractor to determine the effectiveness of the modification. The temperature range specified in paragraph 7-7(f) of reference 2 was considered to be excessively severe because the reference cavities are enclosed in the Model AN/CPN-6 Equipment Cabinets and the ambient temperature range to which the equipment is subjected does not exceed the limits of minus 40°C to plus 50°C. The actual temperature variation of the cavities, when installed in the equipment, was determined. The variation in resonant frequency of the cavities in this temperature range was determined with an accuracy of plus or minus 0.05 Mc. The methods used to obtain these measurements and the results of the investigation are discussed in this report. These investigations were made at the Naval Research Laboratory during the period from 6 June 1945 to 24 July 1945.

RESULTS OF TESTS

2. Determination of Temperature Limits. An unmodified Model 1541(TFX-10GA), Serial 897, reference cavity was installed in the Model AN/CPN-6 Transpondor Beacon Equipment to determine the variation in temperature of the cavity with variations of ambient temperature from -40°C to +50°C. The cavity temperature was determined by means of two calibrated thermocouples attached to the top and the bottom surfaces of the cavity. The ambient temperature was maintained constant at the upper and lower limits until the thermocouple readings became stabilized. With the equipment operating at a line potential of 115 volts and with the cabinet door closed, the highest temperature attained by the cavity was 59.5°C in an ambient temperature of 50°C. With identical conditions of operation but in an ambient temperature of -40°C, the lowest temperature attained by the cavity was 12.9°C.

3. Method of Measuring Cavity Frequency. A block diagram of the system employed to measure the absolute frequency of the reference cavities is shown in Figure 1 of Plate 2. The repeller of the Klystron in the TS-13/AP, X-Band signal generator was modulated with a saw-tooth wave, causing the signal generator to produce a frequency modulated square wave signal having a band width of approximately three megacycles. The distribution of energy in this signal, as it appeared on a spectrum analyzer, is shown in Figure 2 of Plate 2. The output of the X-Band generator was conducted to the cavity undergoing tests, where it was modified by the high "Q" characteristics

of the cavity. This modified signal was then attenuated at the output of the cavity and applied to a spectrum analyzer. The attenuated signal, as it appeared on the spectrum analyzer, is shown in Figure 3 of Plate 2. The 10th harmonic of the c-w output from a Hewlitt Packard Type A, L-Band signal generator was also applied to the spectrum analyzer and the resultant pip was adjusted by varying the frequency of the generator until it coincided with the peak of the output signal from the cavity. This is illustrated by Figure 3 of Plate 2. The absolute frequency of the calibrating pip from the L-Band signal generator was determined by obtaining zero beat with a 5 Mc crystal oscillator at a frequency higher than and a frequency lower than the frequency at which coincidence was obtained between the peak of the cavity spectrum and the calibrating pip. The frequencies between these two readings were then interpolated. The 5 Mc oscillator was standardized by zero beating it with the 10 Mc signal from Radio Station WWV.

4. Measurement Errors. The 5 Mc crystal oscillator frequency could be adjusted to less than one cycle per second of the frequency of Radio Station WWV, which at the X-Band frequency, resulted in a maximum error of 1 kc. The L-Band signal generator could be adjusted to within 50 cycles of the pertinent harmonics from the 5 Mc crystal oscillator. This caused an inaccuracy of 0.5 kc at the X-Band frequency. The dial reading of the L-Band signal generator could be determined with an accuracy of 5 parts of 1,000,000, representing a maximum error at the X-Band frequency of 50 kc. The frequency drift of the signal generator during the time required to make a measurement was less than 0.5 kc at the X-Band frequency. The error in resetting the calibrating pip to the peak of the cavity spectrum was less than 10 kc. The maximum error for each measurement, with all the errors summarized, was 62 kc or 0.062 Mc. This error was appreciably reduced by making a series of 15 measurements for each temperature condition of the cavity and then averaging the measurements. It can be shown (Reddick and Miller, Advanced Mathematics for Engineers, Arts. 88 and 89) that if the arithmetic mean of the values obtained for an infinite number of measurements is considered to be the true value, the maximum probable error for a number of measurements less than infinity will be,

$$e_m = 0.6745(\Sigma e^2)^{\frac{1}{2}}/n \qquad (1)$$

where

e = the maximum error for each measurement,
e_m = the maximum probable error of the mean, and
n = the number of measurements.

Since the maximum error for each measurement is the same, equation (1) may be rewritten,

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$$e_m = 0.6745(ne^2)^{\frac{1}{2}}/n = 0.6745(e)/(n)^{\frac{1}{2}} \qquad (2)$$

Substituting the value for the maximum error of each measurement into equation (2), it will be seen that the mean value for the frequency of the cavity was in error by not more than

$$(0.6745)(0.062)/(15)^{\frac{1}{2}} = 0.00875 \text{ Mc.}$$

However, for the purpose of this investigation, a probable error of 0.1 Mc is conceded.

5. Cavity Modifications. The original Model 1541(TFX-10GA) cavities supplied with the Model AN/CPN-6 Transpondor Beacon Equipment were not sealed and pressurized. Each cavity contained a poly-iron disc which was secured to the under-side of the top cap of the cavity. The purpose of this disc was to reduce the amplitude of spurious modes of oscillation. The poly-iron disc was believed to be responsible for the large variations in resonant frequency of the cavities when the ambient temperature was varied. It was also considered that these discs were unnecessary since the cavity was preset for a fixed frequency and any possible spurious modes would be sufficiently removed from the operating frequency to be unobjectionable. In the modified cavities the poly-iron discs were removed, glass windows were installed over the input and output coupling holes, and the cavities pressurized.

6. Variations of Cavity Resonant Frequency. An unsealed and unmodified cavity, serial 897, was installed in a temperature test chamber as indicated in Figure 1 of Plate 2. This type of cavity was originally supplied with the Model AN/CPN-6 equipment. The temperature of the test chamber was varied from 0°C to 60°C in increments of 20 degrees. The cavity was permitted to stabilize for 1/2 hour after each temperature change. A series of 15 measurements was made at the rate of three measurements every 15 minutes for each change in ambient temperature. Each set of 15 values was then averaged to permit graphical presentation. A similar procedure was followed with two modified pre-production cavities and six modified production cavities.

7. Figure 4, Plate 2, shows the temperature-frequency curve for the unmodified cavity, serial 897. The maximum frequency deviation of the cavity from the standard beacon frequency (9310 Mc), in the temperature range from 0°C to 60°C, was +0.75 Mc and -4.00 Mc. Paragraph 7-7(f) of reference 2 requires that the cavity shall maintain its resonant frequency within plus and minus 1.0 Mc of the standard beacon frequency.

8. The temperature-frequency characteristics for two modified pre-production cavities, serial 663AAC and serial 1205AAC, are shown in Figures 1 and 2 of Plate 3. The temperature-

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frequency characteristics of six modified production cavities are shown in Figures 3 and 4 of Plate 3 and Figures 1, 2, 3, and 4 of Plate 4. A summary of the maximum frequency deviations encountered is given below.

Cavity Serial No.	Max. Deviation above Beacon Frequency Mc	Max. Deviation below Beacon Frequency Mc	Max. Frequency Variation Total Mc
663AAC	1.35 to 1.73	--	0.38
1205AAC	--	0.20 to 0.55	0.35
1238C	0.52	0.34	0.86
567C	0.47	0.33	0.90
458C	0.02	0.19	0.21
674C	0.35	0.43	0.78
1193C	0.31	0.52	0.83
1166C	0.33	0.58	0.91
Beacon Freq.	9310 Mc.		

9. The limits of frequency variation in the temperature range given was satisfactory for all of the cavities except for the two pre-production cavities, serial 663AAC and serial 1205AAC, which would not resonate at the beacon frequency. Cavity serial 663AAC had been preset by the contractor to a frequency so far beyond the normal frequency band that it failed to fulfill the requirements of paragraph 7-7(f) of reference 2.

10. Paragraph 4b of reference 1 states that the modified cavities will be preset to the beacon frequency at a temperature of 50°C. The following table indicates the temperatures at which the resonant frequencies of the various cavities coincided with the beacon frequency.

Cavity Serial No.	Test Cycles	Temp. at Beacon Frequency °C
663AAC	1	*
1205AAC	1	*
1238C	1	30
567C	1	17
458C	2	37-45
674C	2	24-39
1193C	3	*
1166C	4	20-43

* Resonant frequency of cavity did not reach 9310 Mc.

It will be noted that none of the cavities resonated to the beacon frequency at a temperature of 50°C.

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11. Plates 3 and 4 illustrate that the characteristics of the modified cavities were not reproducable. A summary of the number of tests conducted on each cavity and the maximum frequency dispersion encountered is given below.

Serial No.	Cycles	Max. Freq. Dispersion Mc	Temp. at Point of Maximum Dispersion °C
663AAC	3	0.09	20
1205AAC	3	0.17	60
1238C	1	----	--
567C	1	----	--
458C	2	0.10	40
674C	2	0.22	20
1193C	3	0.64	55
1166C	4	0.36	20

12. An integration of the frequency-temperature characteristics of the six modified production cavities yielded the frequency dispersion band illustrated on Plate 5. It is probable that the frequency characteristics of other modified cavities will fall in this frequency band. The maximum band widths appear at 0°C and at 60°C. At a temperature of 0°C the band width is 0.62 Mc and at a temperature of 60°C the band width is 1.08 Mc. At temperatures from 0°C to 30°C the frequency band is asymmetrically spaced with respect to the standard beacon frequency. At a temperature of 0°C the frequency deviation from the standard beacon frequency is plus 0.04 Mc and minus 0.58 Mc. At temperatures from 30°C to 60°C the frequency band becomes symmetrical with respect to the standard beacon frequency.

13. Consideration of the graphs on Plates 3 and 4 reveals that cavity serial number 458C had the least frequency deviation and the least frequency dispersion of any of the six modified production cavities. Its characteristic curve is almost flat and parallels the beacon frequency line. The characteristic curves for the other cavities have a considerable slope. The reason for this could not be immediately ascertained. Cavity serial 9311C was placed in an oven and subjected to a temperature of 110°C for a period of 24 hours in an effort to stabilize the cavity characteristics but the cavity failed during the heating period and no conclusive data could be obtained. A further study to ascertain the causes for the superiority of random cavities is contemplated.

14. Mechanical Construction. When cavity 9311C was removed from the oven it was found that the solder forming the seals had melted and that the cavity was no longer air-tight. Disassembly and examination of the cavity revealed that only two screws, spaced diametrically opposite to each other, as shown in

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Figure 2, Plate 1, were employed to secure the cap of the cavity to the cylinder. However, the cap was provided with six screw holes for the purpose. The inside of the cylinder had been silverplated but it is doubtful if such treatment had been given to the under side of the brass tuning plate. The plate appeared to be lacquered. The solder employed at all the seams of the cavity and relied upon to form a seal was determined to be Rose's metal. It had a melting point of 89°C and a flow point of 92°C. The reason for the use of Rose's metal as the bonding agent is not understood. It is probable that the use of this material and the use of only two screws to secure the cap of the cavity to the cylinder causes mechanical instability of the cavity with variations in temperature and thereby results in frequency dispersion. It was found that the seal around the glass windows in the cavity could be made with solder having a melting point above 200°C without damaging any of the cavity components.

CONCLUSIONS

15. Except for cavity serial 663AAC, all of the modified cavities fulfilled the electrical requirements of the liberalized specification of reference (2). The mechanical construction of all the modified cavities is considered to be unsatisfactory.

RECOMMENDATIONS

16. It is recommended that all of the screw holes provided in the caps of the cavities be employed to secure the caps to the cylinders, and that solder having a melting point not lower than 200°C be employed to seal the cavities.

17. Further investigation of the characteristics of the cavities should be undertaken to determine the reasons for the superiority of cavity serial 458C and to devise methods for producing equally satisfactory cavities.

REFERENCES

1. BuShips ltr C-NXss-32854(918Cn), Ser. 6-918.330822-11945 dated 18 May 1945; Request for extension of Problem S458T-C.

2. BuShips Specification RE 9016; Specification for Microwave Transpondor Beacon.

3. Reddick, H. W. and F. H. Miller. Advanced Mathematics for Engineers. John Wiley & Sons, Inc., New York, 1938. Art. 88-89.

Original data recorded in NRL Log Books 1010, 1011, and 1019.

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FIG. 1 ASSEMBLED VIEW OF THE MODEL 1541(TFX-10GA) CAVITY

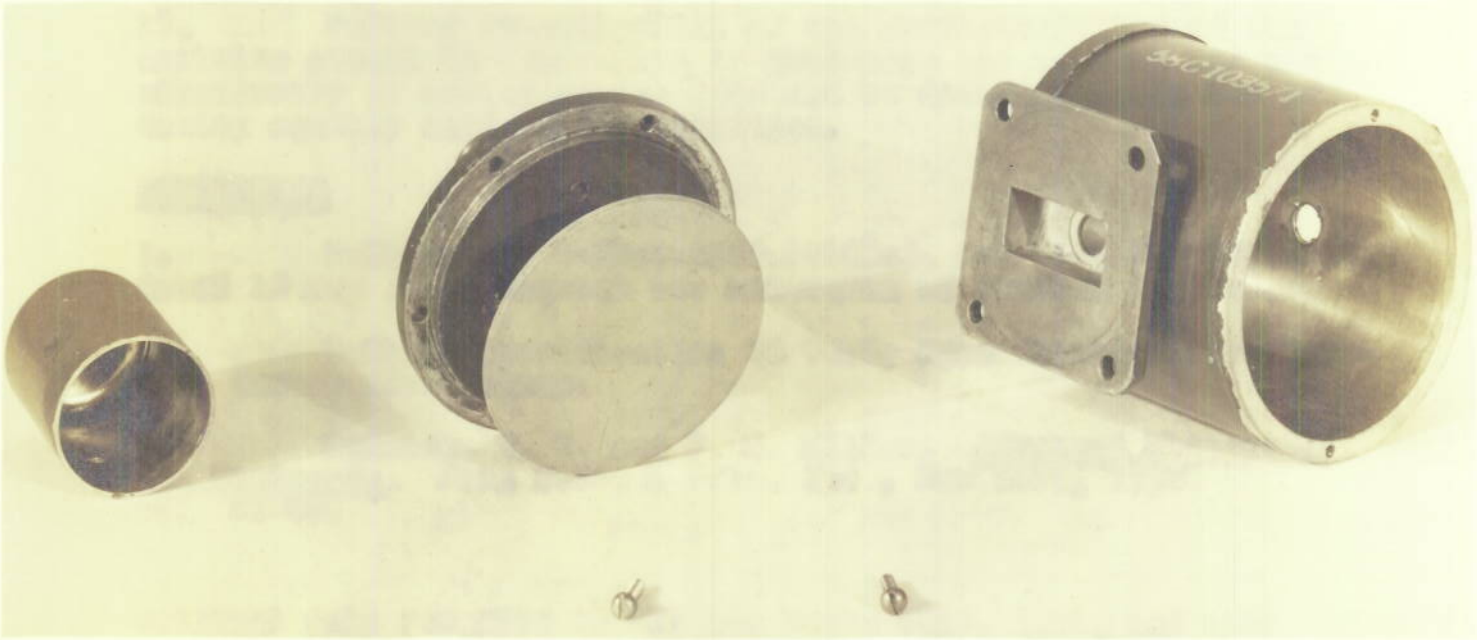

FIG. 2 EXPLODED VIEW OF THE MODEL 1541(TFX-10GA) CAVITY

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SYSTEM EMPLOYED TO MEASURE FREQUENCY OF THE MODEL 1541 TFX-10 GA CAVITIES

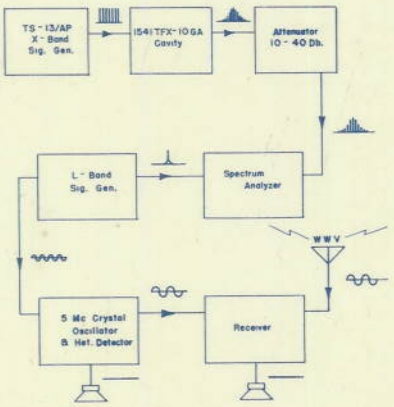

FIGURE 1

OUTPUT WAVEFORM OF TS-13/AP SIGNAL GENERATOR AS VIEWED ON SPECTRUM ANALYZER

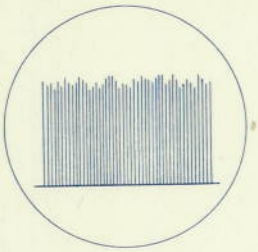

FIGURE 2

WAVEFORM AT OUTPUT OF 1541 TFX-10 GA CAVITY WITH CALIBRATING PIP FROM L-BAND GENERATOR SUPERIMPOSED AS VIEWED ON SPECTRUM ANALYZER

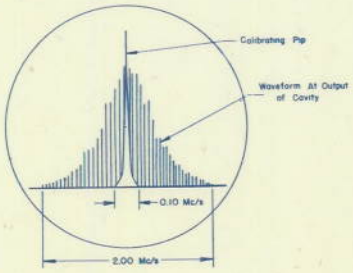

FIGURE 3

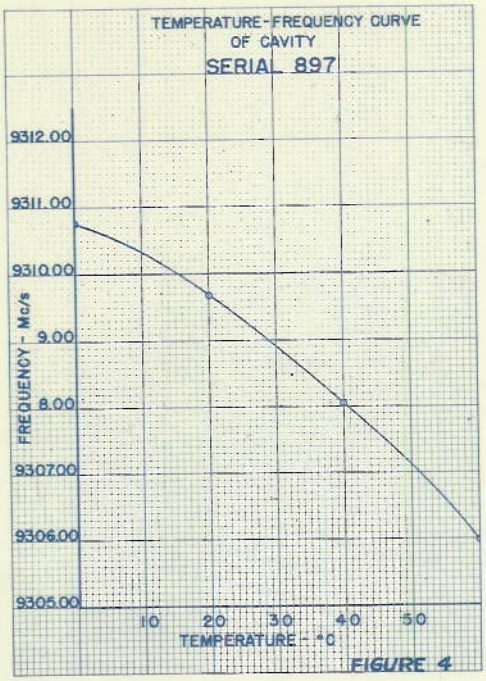

FIGURE 4

PLATE 2

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MODEL 1541 TFX - 10GA CAVITIES
TEMPERATURE VS FREQUENCY

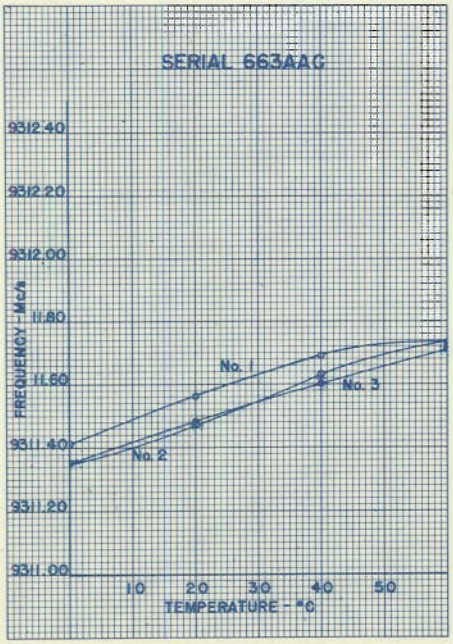

FIGURE 1

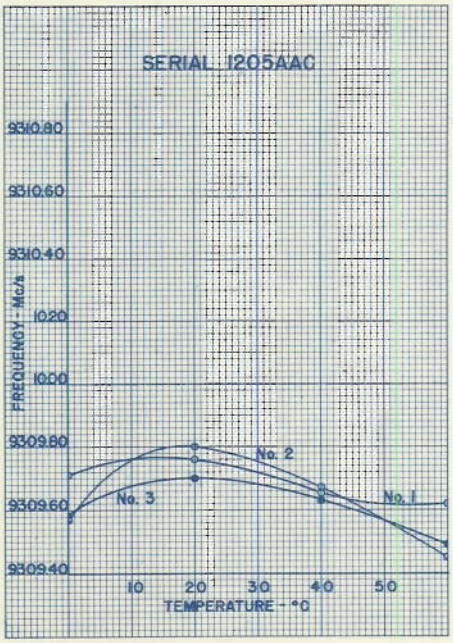

FIGURE 2

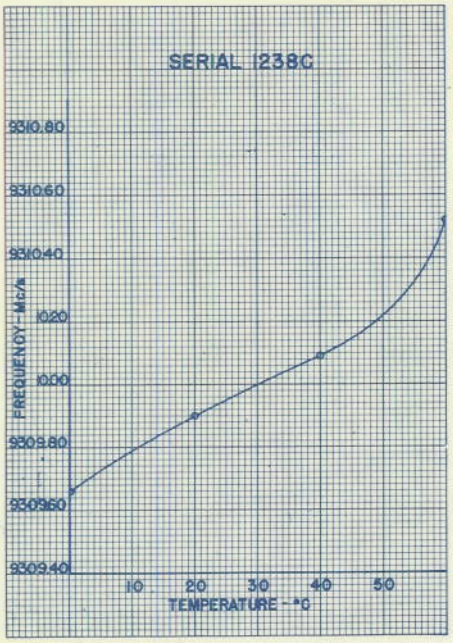

FIGURE 3

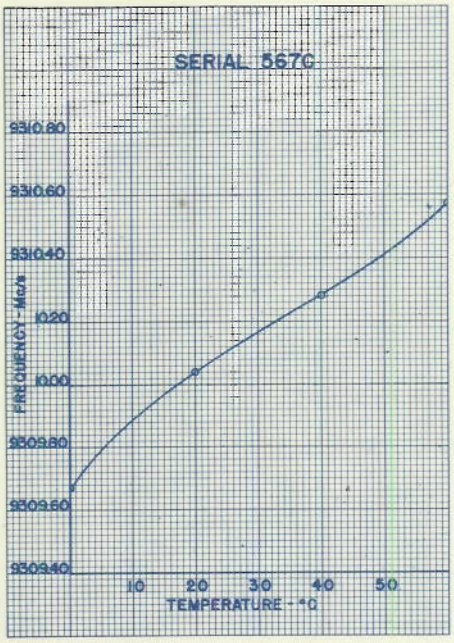

FIGURE 4

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PLATE 3

MODEL 1541 TFX - 10GA CAVITIES
TEMPERATURE VS FREQUENCY

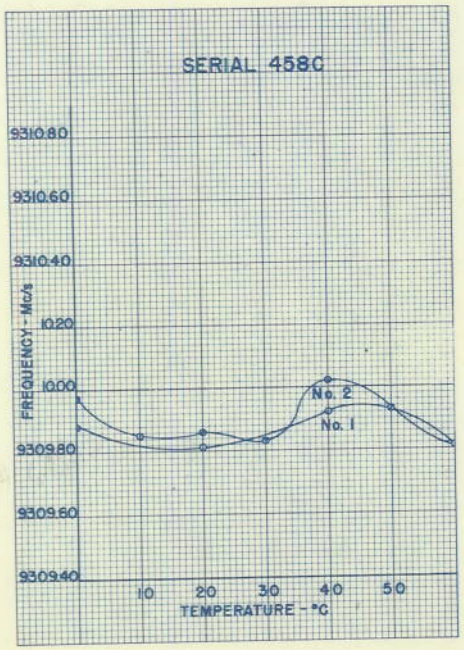

FIGURE 1

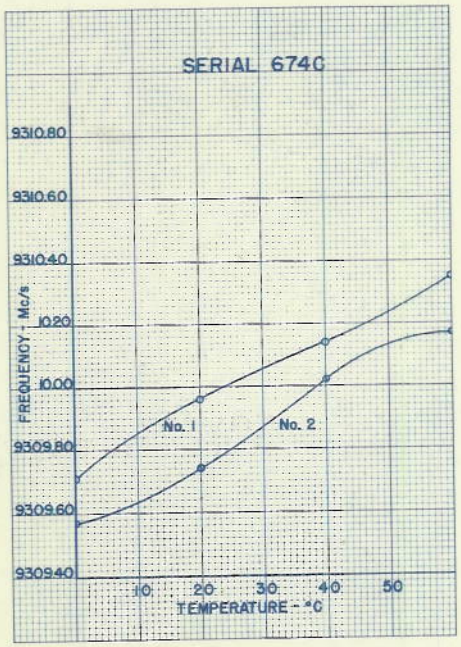

FIGURE 2

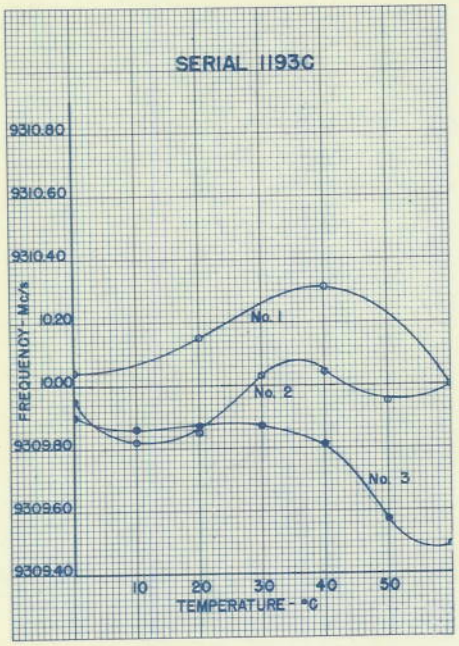

FIGURE 3

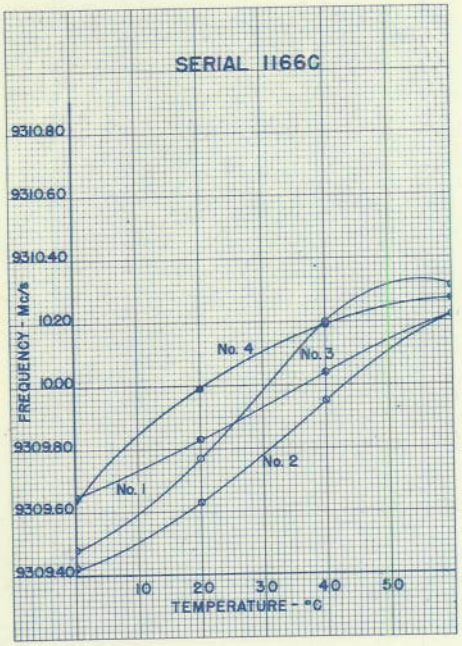

FIGURE 4

PLATE 4

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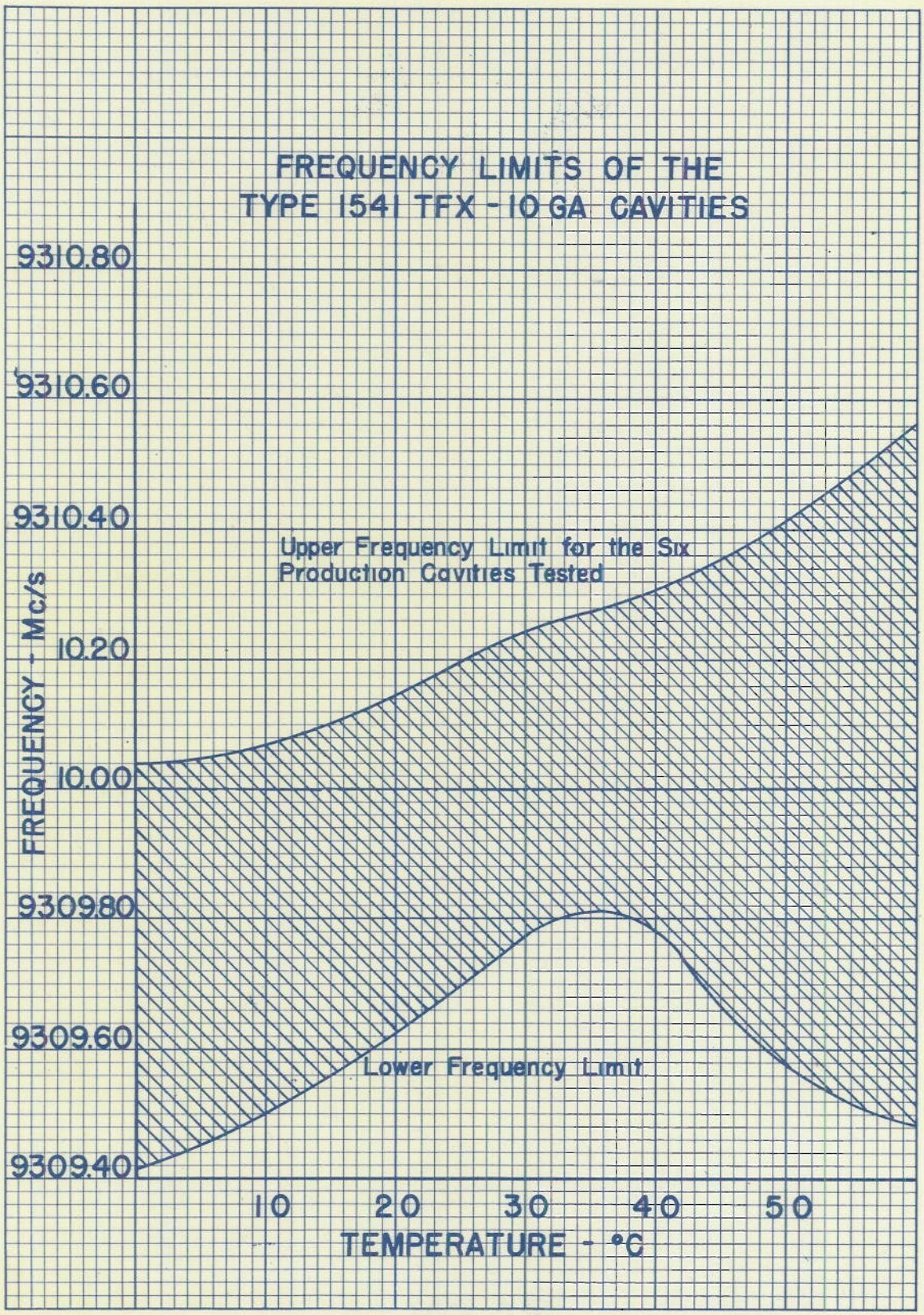

PLATE 5

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