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Final Report

A PRELIMINARY INVESTIGATION OF SOME BLANKET DAMPING TREATMENT VARIABLES

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The laboratory is indebted to Owens-Corning Fiberglas for supplying certain test samples.

*Geiger and Hamme, Consultants in Acoustics, Ann Arbor, Michigan.

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ABSTRACT

An investigation of the dependence of vibration-damping capacity on frequency, septum weight, blanket density, and blanket thickness was carried out by means of the thick-plate decay rate apparatus for several fibrous-glass-blanket septum configurations, and correlations between these parameters were demonstrated.

INTRODUCTION

Although a large amount of data has been accumulated describing the effectiveness of various blanket-type damping treatments in suppressing mechanical vibrations in certain systems, the investigations carried out have been strongly influenced by environmental criteria (e.g., automobile dash pad investigations). Thus it is known that blanket-type treatments can provide useful amounts of damping, when applied to extended surfaces. However, little has been done in elucidating the causal relationships within a blanket damping treatment which lead to the damping or decay rate values. The purpose of this report is to present the results of certain experimental investigations on blanket type vibration-damping treatments which were directed toward delineating correlations between vibration decay rates and various treatment parameters, namely, frequency, septum mass, blanket density, and blanket thickness.

INSTRUMENTATION

Damping effectiveness was measured by means of the thick-plate decay rate method.[1] The apparatus used for these measurements is illustrated in Figure 1 and consists of an anechoic enclosure in which are located an electromagnetic exciter, a resilient support for the steel test plate being excited, and a microphone to receive the airborne energy emanating from the steel plate. Outside the enclosure are located a variable frequency oscillator and a power amplifier to drive the electromagnetic exciter, a microphone amplifier connected to an oscilloscope display unit and a moving film camera to record the resulting decay rate displays. The entire unit was carefully adjusted and calibrated prior to initiating the experimental effort.

TEST PLATES

A series of eight square steel test plates supported at the midpoint of each side were selected for the damping investigation both to provide a resonant frequency range of 67 to 281 cps and to complete coverage of the test plates by the available blanket material. A description of these plates is given in Table I.

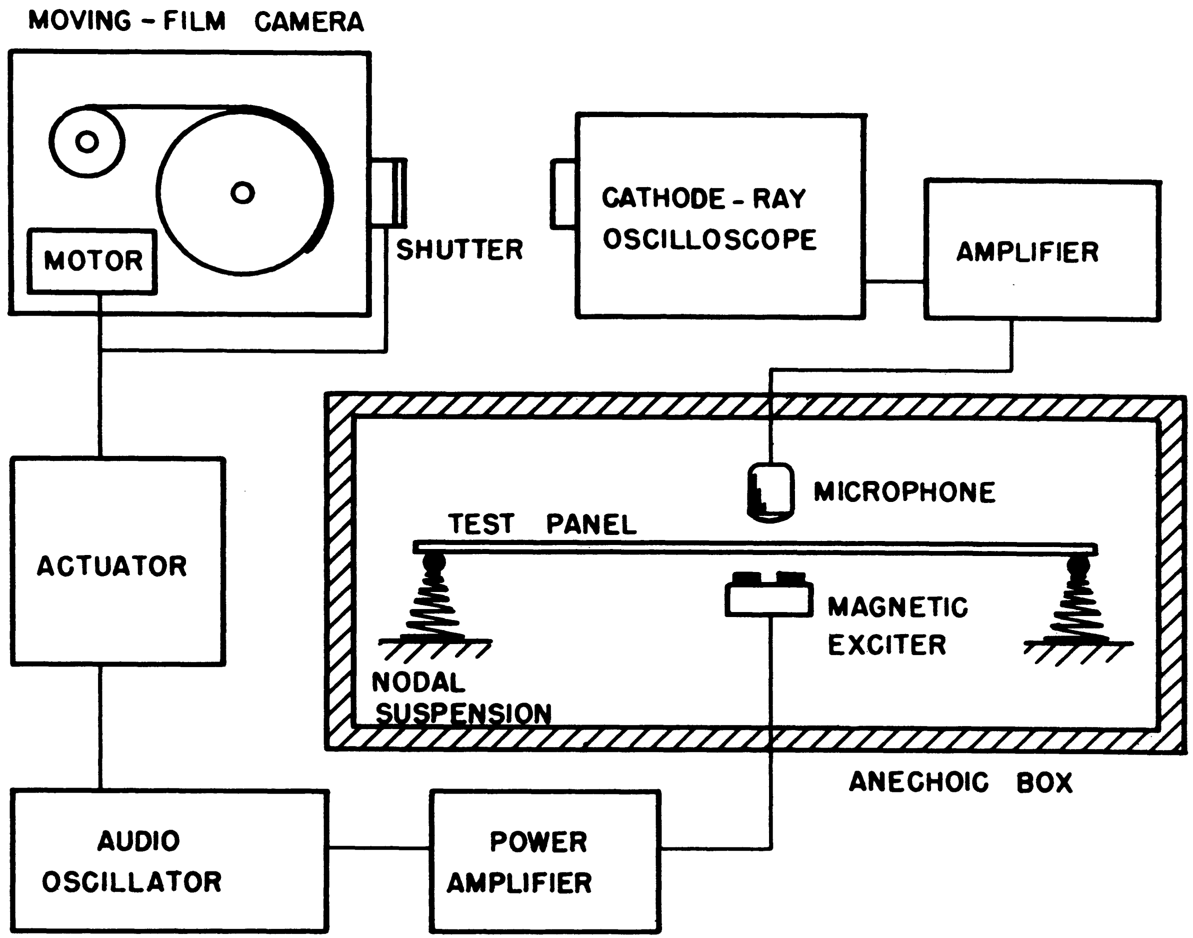


FIGURE 1. THICK PLATE DECAY - RATE MEASUREMENT APPARATUS.

TABLE I. DESCRIPTION OF TEST PLATES

Plate No.	Resonant Frequency (cps)	Plate Size (in.)	Thickness (in.)	Mass (lb)
1	180	20 x 20	.3013	33.4
2	146	20 x 20	.2580	28.9
3	84	18 x 18	.1090	9.94
4	113	23 x 23	.2525	37.3
5	129	24-1/8 x 24-1/8	.3419	55.9
6	67	25-1/2 x 25-1/2	.1890	34.8
8	224	17-3/4 x 17-3/4	.2699	23.5
10	281	15-3/8 x 15-3/8	.2678	17.9

BLANKET SAMPLES

In order to limit the scope of the investigation, all blanket materials tested were of a fibrous-glass constitution and were cut to conform to the lateral dimensions of the plate under test. A description of the blanket samples is given in Table II.

TABLE II. DESCRIPTION OF BLANKET SAMPLES

Owens-Corning PF No.	Fiber Diameter (10^{-5} in.)	Density (lb/ft^3)	Thickness (in.)
451	34	1.5	1
452	34	1.75	1
511	45	2.00	1
453	34	2.25	0.5,1,2,4,4.5
512	45	2.50	1
455	34	3.25	1
512h	45	3.25	1
513	45	3.75	1
614	60	4.25	1
615	60	6.00	1

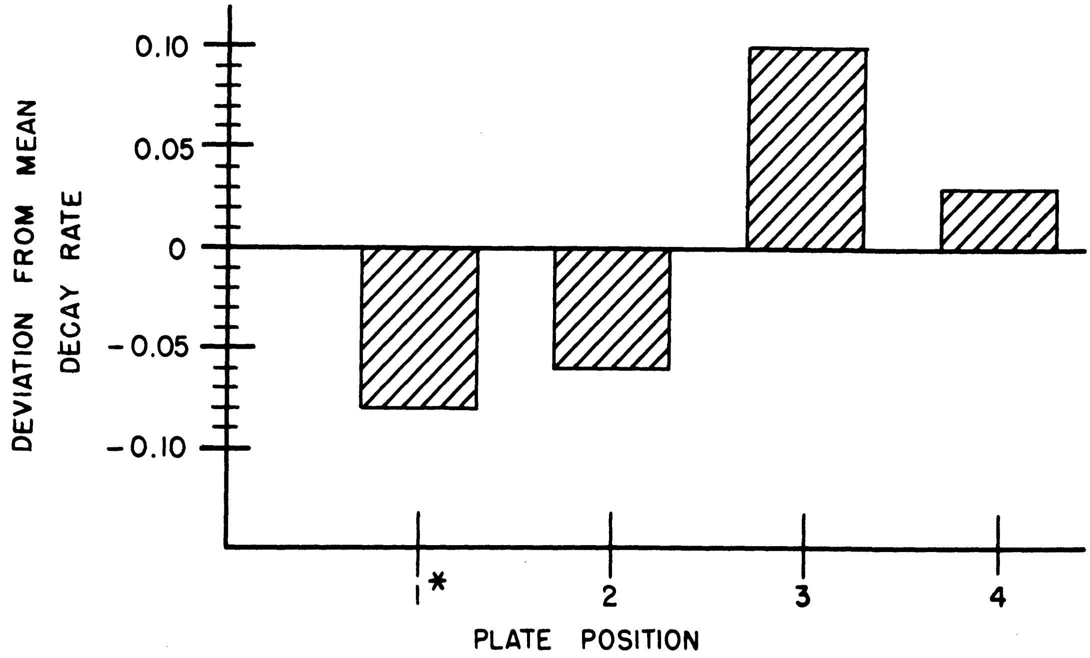
REPRODUCIBILITY OF DECAY RATE DATA

To establish the validity of the experimental data which were to be obtained, two facts had first to be ascertained. First, the reliability of the apparatus, the measuring technique, and the data processing had to be determined. Second, an insight into possible variations in nominally identical blanket samples had to be obtained. This was accomplished by means of three experiments, each utilizing the 129 cps test plate no. 5.

The first experiment consisted of obtaining the decay rates for an undamped plate in four positions, each position being displaced by successive 90-degree increments. Since the decay rate for a "live" plate is very small, lifting the plate, rotating it 90 degrees and replacing it on a "new" set of supports should change the decay rate of the system by a comparatively large amount if significant interactions between the plate and its supports are encountered. Figure 2 shows the comparison of the deviation of decay rate values at each of the four positions from the mean decay rate and indicates clearly the excellent reproducibility which was obtained.

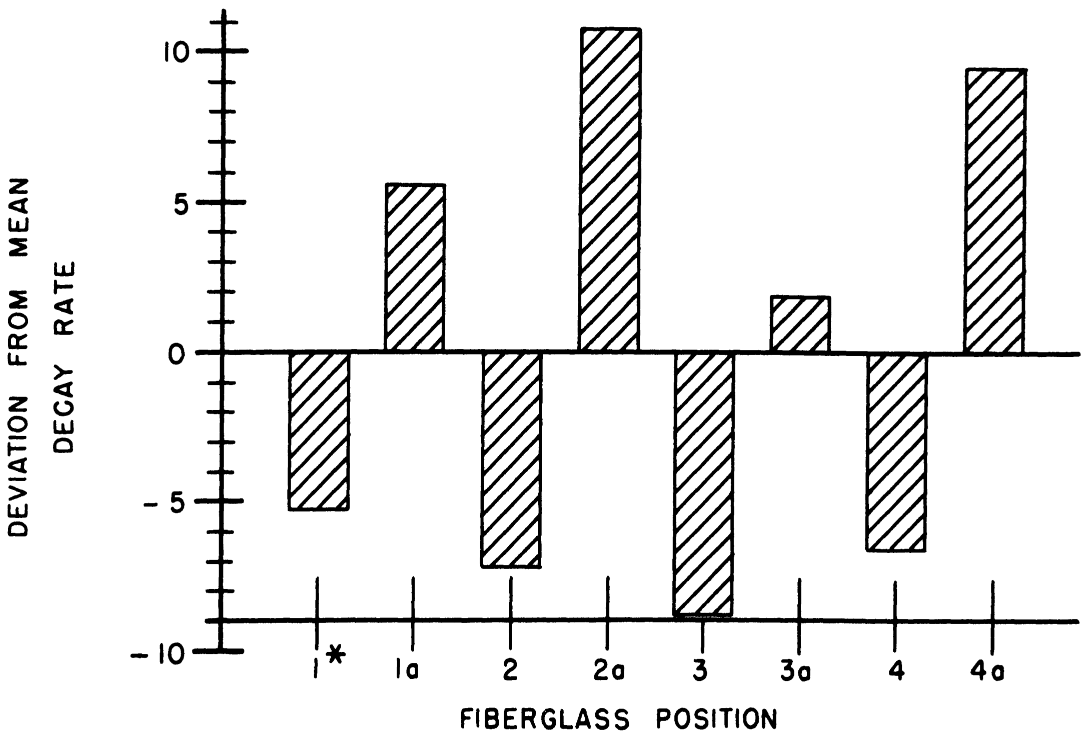
A second experiment dealt with the magnitude of the decay rate variations which might result from the handling of a fiberglass sample during the course of a series of decay rate determinations. In order to maximize the variations, no loading septum was utilized thus introducing the possibility of the blanket surface not conforming to the test plate surface. The blanket, 1" PF455, was rotated in four 90-degree successive increments with decay rate measurements obtained at each position. The blanket was then turned over and the procedure was repeated giving a total of eight decay rate measurement positions, with four replications at each orientation. Figure 3 illustrates the deviation at each position from the mean decay rate for the sample. Two facts may be observed: one, the deviations obtained in all positions in which the sample faced upwards are in a negative direction, while those obtained when the sample faced downwards are in a positive direction; two, the variation among deviations obtained with the sample facing in a single direction are small. Thus it may be concluded that the careful handling without inverting the sample will minimize experimental variations in decay rate. Also it is indicated that experiments without septa or perhaps, with very light, nonconforming septa are subject to serious scatter.

The decay rate data obtained from the bare plate and unweighted fiberglass experiments justified a reasonable reproducibility expectancy for the remainder of the proposed experiments. A third experiment was then carried out to ascertain a measure of the probable error incurred by variation in blanket consistency, or blanket sampling. Decay rate data were obtained on an 1" PF455 sample using 11 different septa ranging from 0.75 to 3.21 lb/ft^2 in weight. Measurements were taken four times in each of two orientations of the septa. In addition, measurements were taken with the fiberglass face reversed to average out any variations due to nonconforming of the blanket surface. Therefore, for each septum weight, a total of 16 decay rate measurements were obtained. Then the



* EACH NUMBER INDICATES A NEW PLATE ORIENTATION (AFTER A 90° ROTATION)

FIGURE 2. BARE TEST PLATE (NO. 5) REPRODUCIBILITY.



* EACH SINGLE NUMBER INDICATES THE BLANKET ORIENTATION (AFTER A 90° ROTATION). THE ADDITIONAL LETTER INDICATES INVERSION OF THE FIBERGLASS SAMPLE.

FIGURE 3. REPRODUCIBILITY OF TEST PLATE (NO.5) PLUS FIBERGLASS.

standard deviation of the decay rate was computed for each set of measurements and Figure 4 presents the mean decay rates vs septum weight. The standard deviation data were plotted as an envelope within which the decay rates obtained from any other 1" PF455 using the same septa should fall. Consistent wide excursions from the envelope would probably indicate a significant variation in blanket consistency.

The above experiment was repeated with a second piece of 1" PF455 "c" nominally identical to the first piece of 1" PF455 but having undergone considerable physical punishment. Figure 5 shows that at almost every septum weight the decay rate values obtained for the PF455 "c" sample are consistant with the standard deviations found in the prior experiment. It can then be concluded that no serious variation due to the performance of the apparatus, the measuring technique, the handling of samples, or among nominally identical blankets should be expected during the ensuing investigations.

SURFACE DENSITY CORRECTIONS

Since the mass and surface area of the plates listed in Table I differ from one another it is necessary to bring the experimental decay rates obtained using these plates into conformity before legitimate comparisons can be made. Since the available vibrational energy in a simple system is directly proportional to the mass of the system, the vibrational decay rate in db/sec must be inversely proportional to the mass of the system. On the other hand, the decay rate of these systems involving a uniform damping treatment covering the entire surface of the plate may be postulated as proportional to the surface area of the plate.[2] Therefore, the experimental decay rates must be adjusted by multiplying the decay rate by the mass of the particular plate which was used and dividing by the surface area of the plate. If these operations are carried out simultaneously, the correction factor takes the form of surface density (mass per unit area). This is a legitimate correction where the combined mass of the blanket and the septum are a fraction of the test plate mass. The surface density corrections are tabulated in Table III.

TABLE III. SURFACE DENSITY CORRECTIONS

Plate No.	Mass (lb)	Area (sq in.)	Mass/Area
1	33.4	400.0	.0835
2	28.9	400.0	.0723
3	9.94	324.0	.0307
4	37.3	529.0	.0705
5	55.9	582.0	.0960
6	34.8	650.3	.0535
8	23.5	315.1	.0746
10	17.9	236.4	.0757

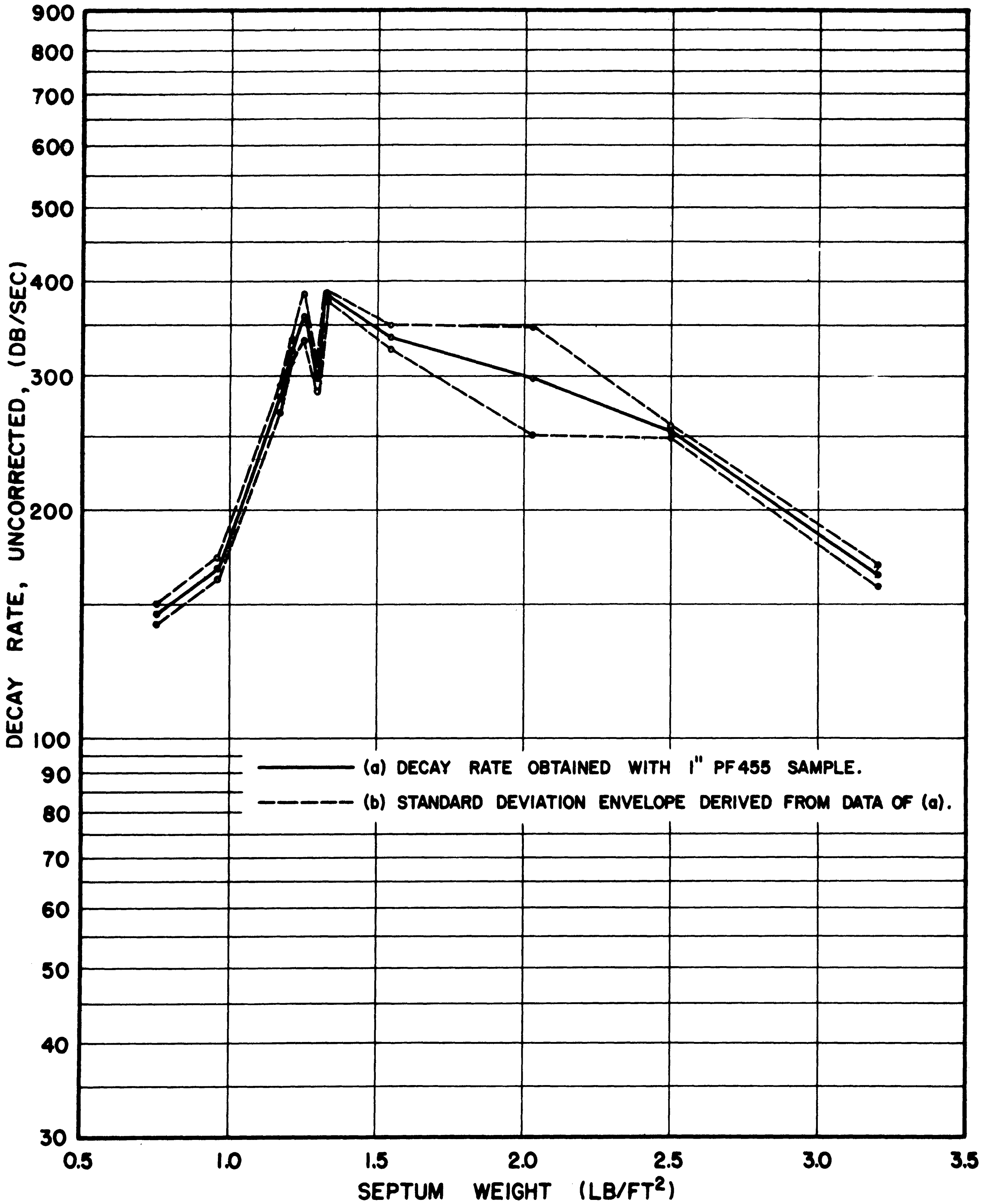


FIGURE 4. SINGLE SAMPLE REPRODUCIBILITY (STANDARD DEVIATION ENVELOPE).

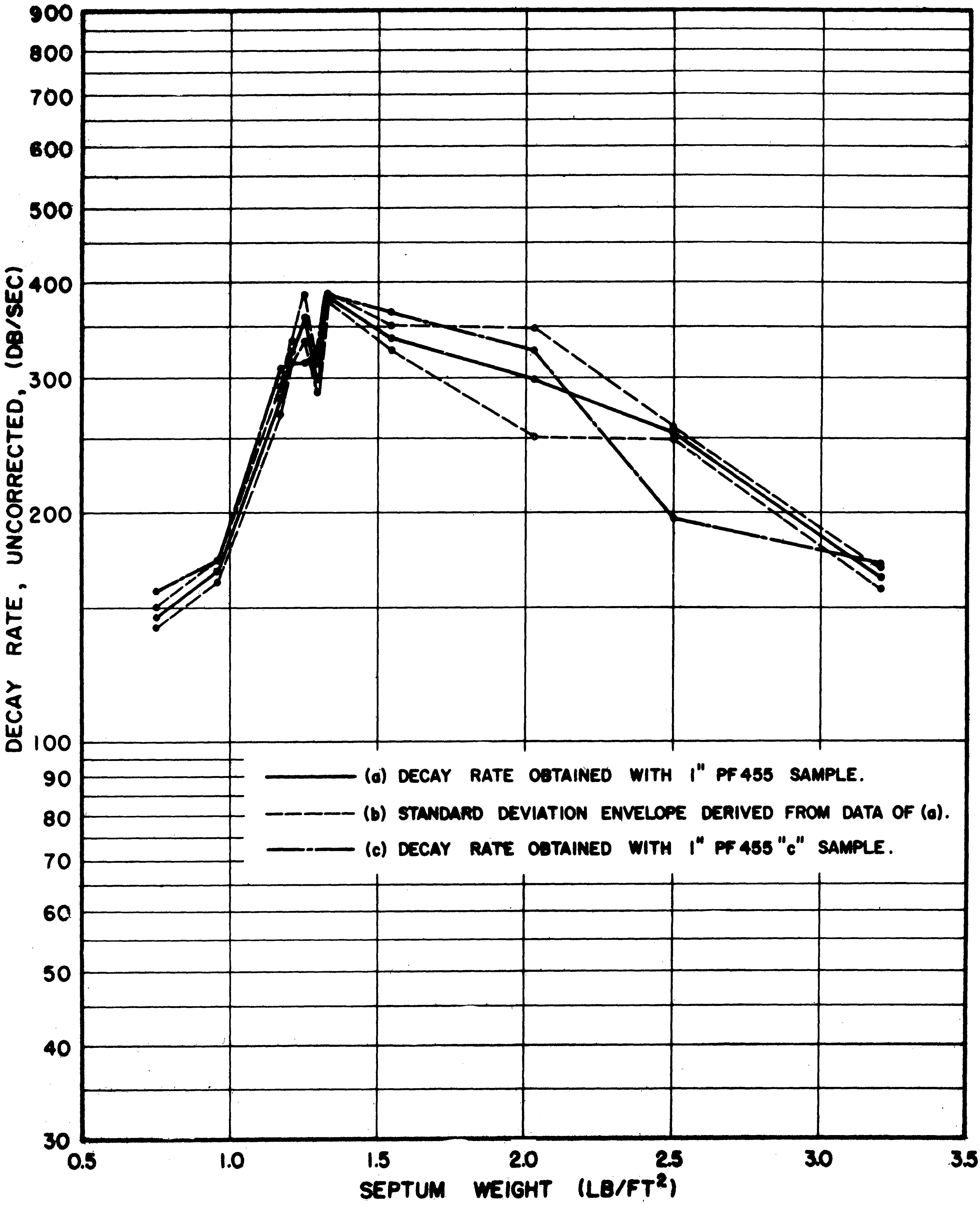


FIGURE 5. REPRODUCIBILITY OF NOMINALLY IDENTICAL SAMPLES.

DEPENDENCE OF DECAY RATE ON FREQUENCY AND SEPTUM WEIGHT

To gain some insight as to the effect of variation of frequency and septum weight on the decay rate values derived from a single blanket sample, experimental decay rate measurements were obtained from a 1" PF455 blanket on each of the test plates tabulated in Table I, each test being conducted with eight different septa of the following weights: 0.75, 0.96, 1.17, 1.33, 1.54, 2.03, 2.50, and 3.21 lb/ft^2. For each test plate, both the blanket and the septum were cut to cover the full surface area. Figure 6a and 6b illustrate the relationship of decay rate to frequency at constant septum weight. It may be noted that peak damping occurs between 129 and 180 cps depending on the septum weight, with no indication of the decay rate approaching a stabilized value within the frequency range investigated. Decay rate maxima which rise some 25 to 30 db/sec indicate that the blanket plus septum system under examination definitely assumes the attributes of a tuned system. The peak decay rate is observed to be at 146 cps when a septum of 1.17 lb/ft^2 weight is employed. The decay rate values fall off gradually on either side of 146 cps and with both smaller and larger values of septum weight. It may also be noted that only single decay rate maxima as a function of frequency occur for each septum weight up to a septum weight of 2.50 lb/ft^2. However, for septum weights of 2.50 and 3.21 lb/ft^2, two maxima are observed. This is interpreted as indicating a change in the effective damping mechanisms accompanying heavy surface loading.

From Figure 7, which illustrates the variation of decay rate with surface loading at constant frequency, it may be noted that the septum weight required for maximum damping varies inversely with frequency. Thus peak damping at 67 cps is attained with a septum weight of 2.50 lb/ft^2, while at 146 cps, peak damping is attained using a septum weight of 1.17 lb/ft^2. At the higher frequencies of 180, 224, and 281 cps, it had been observed that the lowest septum weight of 0.75 lb/ft^2 provided initially was inadequate to complete the desired range. Therefore, three additional septa of 0.60, 0.46, and 0.29 lb/ft^2 were employed at these frequencies with the results also included in Figure 7.

Figure 8 illustrates the relationship between the septum weight required for peak damping and the frequency at which this peak damping occurred in the form of a log-log plot. This relationship is well represented by a straight line, the only significant discrepancies occurring at 84 cps with a septum weight of 2.50 lb/ft^2 and at 281 cps with a septum weight of 0.29 lb/ft^2. The discrepancy at 84 cps may be attributed to a change in the behavior of the test system since the 84-cps plate is quite light in weight (as shown in Table I) and the mass of the blanket plus the septum form a significant fraction of the total mass of the system. The discrepancy at 281 cps may be attributed to the possible nonconforming of the light 0.29 lb/ft^2 septum on the fiberglass surface. The possibility of this error had been foreseen during the previous reliability measurements. From Figure 8, it can be observed that the straight line has a slope of approximately -1, implying that the septum weight corresponding to peak damping is inversely related to frequency. Mathematically

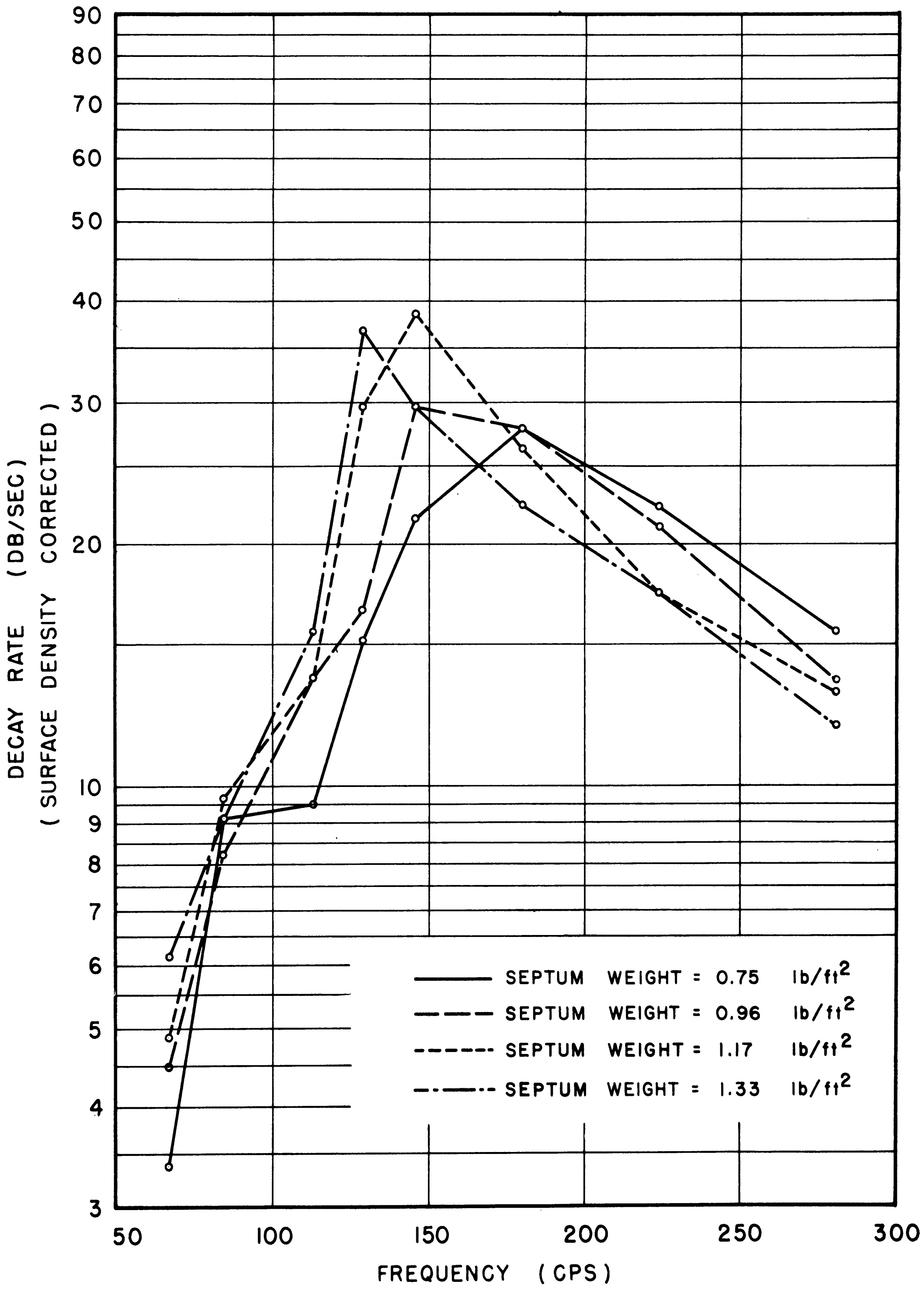


FIGURE 6a. DECAY RATE VARIATION OF 1" PF455 WITH FREQUENCY FOR CONSTANT SEPTUM WEIGHTS.

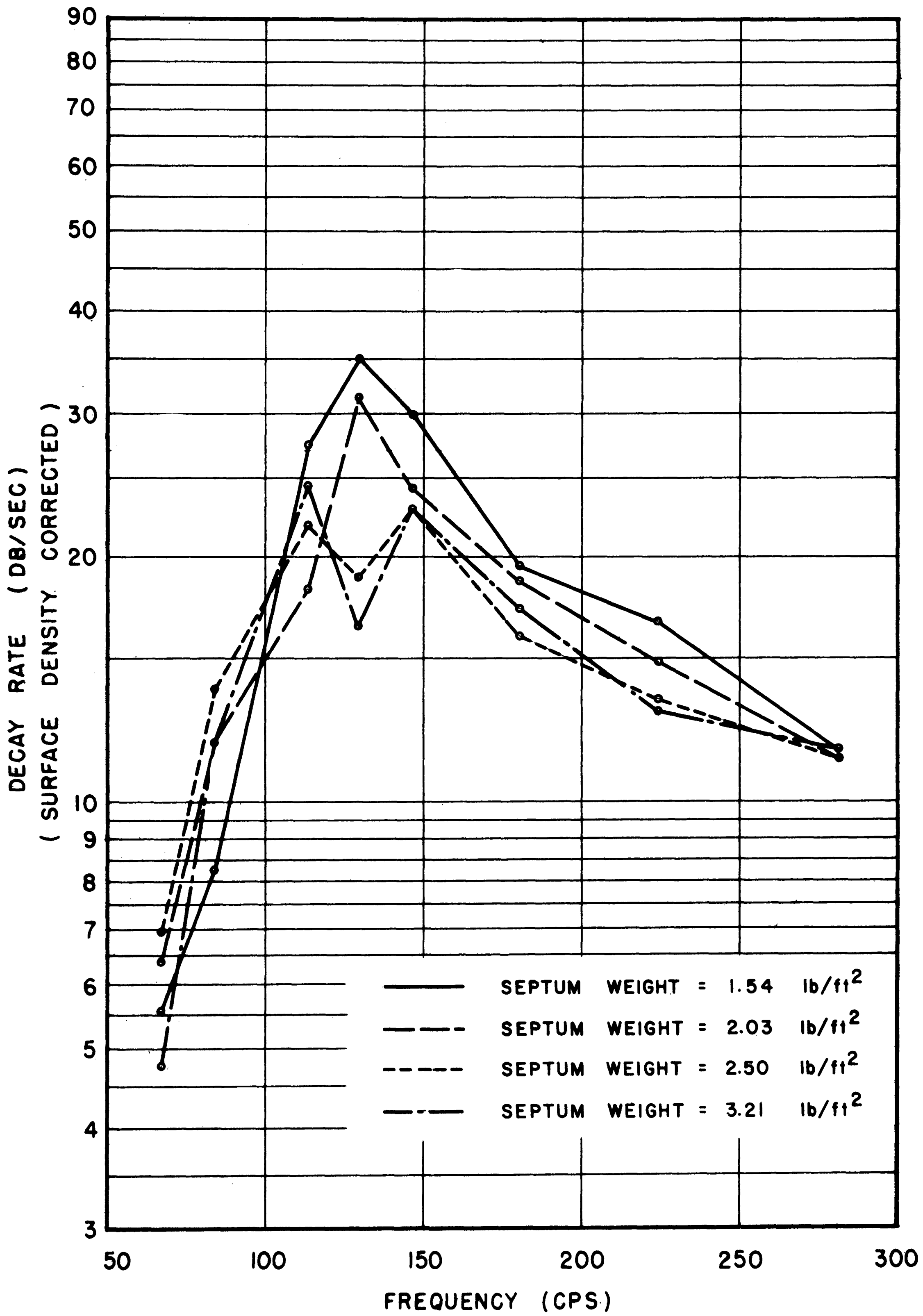


FIGURE 6b. DECAY RATE VARIATION OF 1" PF455 WITH FREQUENCY FOR CONSTANT SEPTUM WEIGHTS.

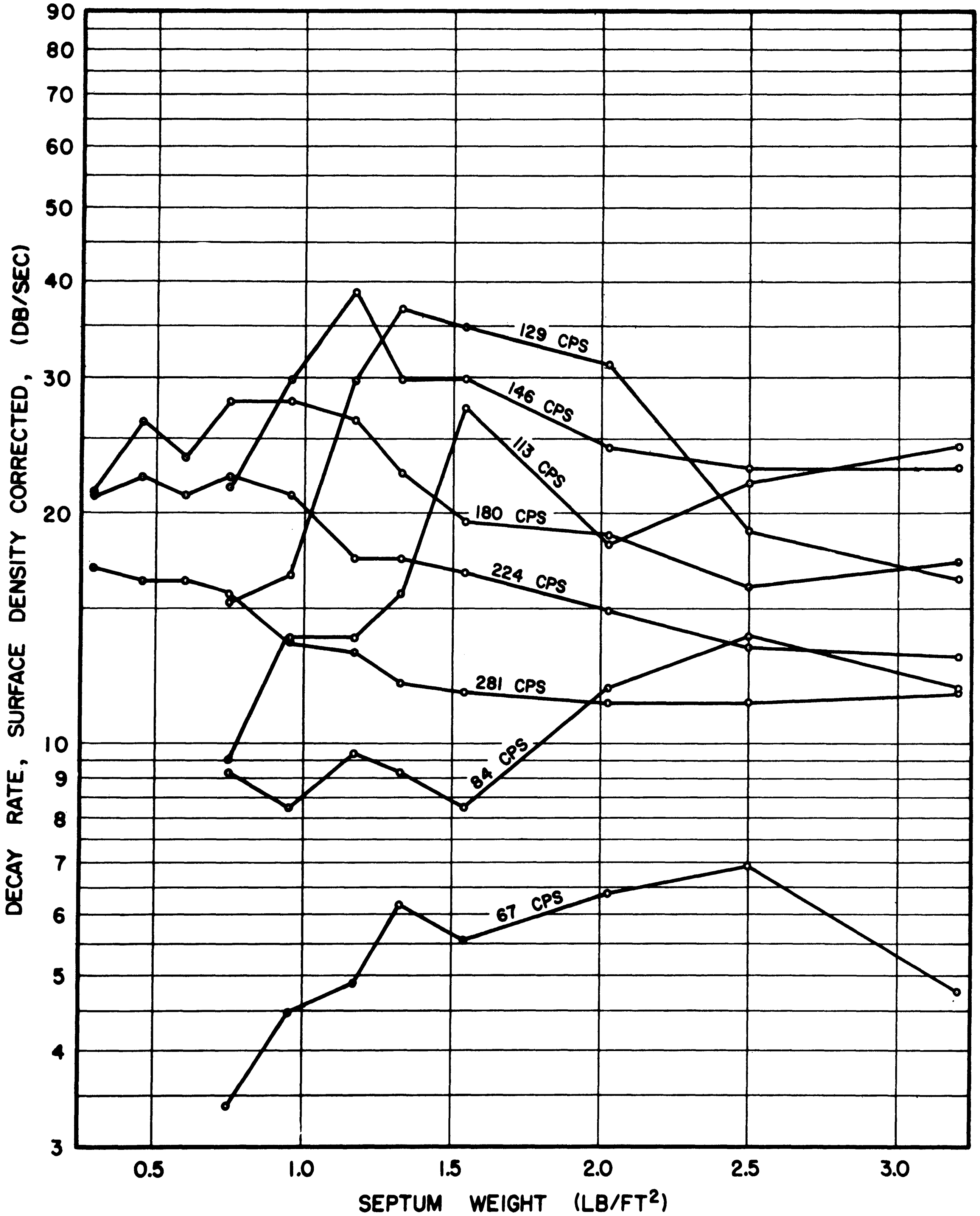


FIGURE 7. DECAY RATE VARIATION OF 1" PF 455 WITH SEPTUM WEIGHT AT CONSTANT FREQUENCIES.

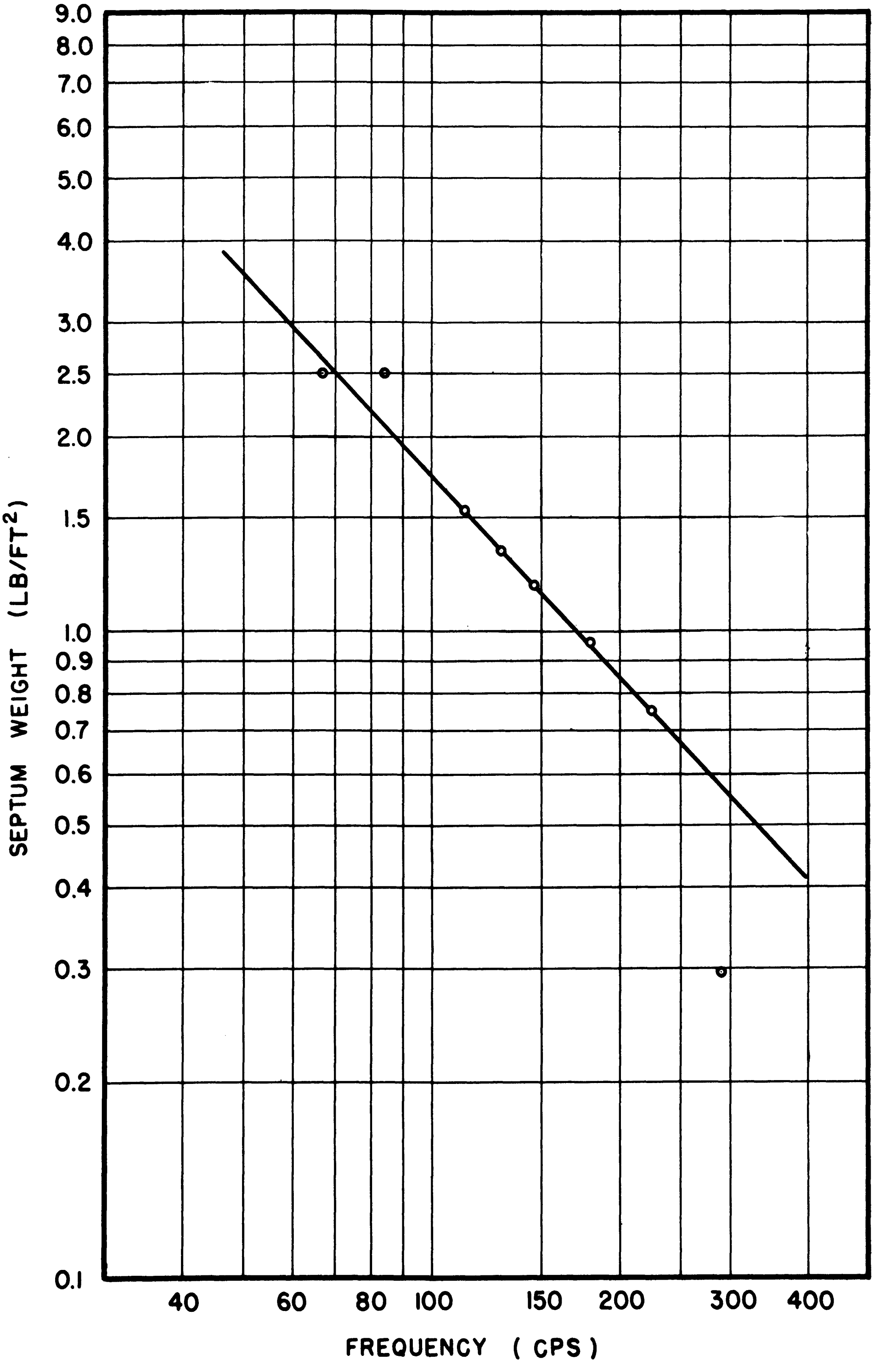


FIGURE 8. SEPTUM WEIGHT FOR MAXIMUM DECAY RATE VS FREQUENCY.

this relation is represented as follows:

$$\text{Log (septum weight)} = (-1)\ \text{Log (frequency)} + \text{Log (constant)} \qquad (1)$$

or

$$\text{Septum weight} = \frac{\text{Constant}}{\text{Frequency}} \ . \qquad (2)$$

For a composite damping treatment consisting of a fibrous blanket and a surface loading septum, the roll normally ascribed to the septum is that of providing inertia. When such a system receives vibrational excitation, the septum provides a relatively immobile surface, leaving the fibrous blanket to be "crushed" between the septum and the vibrating plate. In this crushing process the fibers of the blanket are caused to run against one another thus dissipating the vibrational energy into heat. Without the inertia provided by the septum, a fibrous blanket is quite ineffective. However, as the septum weight or inertia is increased, the "crushing" action also increases and the damping capacity is enhanced. It seems reasonable that the damping capacity of this system will continue to increase with increased inertia until the frictional dissipative mechanism has been fully developed. If this is the case, then for each such damping treatment, there would appear to be a particular amount of septum inertia, say I_m, necessary to develop fully the dissipative mechanism.

The inertia (I) of any system is proportional to the product of its mass (M) and its velocity (V), i.e.,

$$I \propto MV \qquad (3)$$

and for simple harmonic motion, this becomes

$$I \propto Mf \qquad (4)$$

where f is the frequency. Thus under the above assumptions

$$I_m \propto Mf \qquad (5)$$

which is equivalent to Equation (2). Therefore as a direct consequence of assigning the septum the role of providing inertia and of postulating a particular amount of inertia required to develop fully the damping capacity for each particular fibrous blanket, the straight line of slope minus one displayed in Figure 8 must be expected.

DEPENDENCE OF DECAY RATE ON BLANKET DENSITY

The 129-cps tuned test plate was selected for the density investigation. From Figure 7, it may be observed that for the 1" PF455 blanket, a maximum decay rate was obtained with the 1.33 lb/ft^2 septum and the decay rate has already dropped to a considerably lower value for a septum weight of 2.50 lb/ft^2. These two septa weight of 2.50 lb/ft^2. These two septa were selected as providing extreme conditions. Therefore, should variations in blanket density prove to have significant influence on the decay rate it would be expected that appreciable variation in decay rate would be observed with the two selected septa. Ten 1" samples listed in Table II provided a density range of from 1.5 to 6.0 lb/ft^3. Figure 9 illustrates that although large changes in decay rates with density variations were obtained, the decay rates appear to be independent of septum weight. Two samples, PF455 and PF512h, each having a density of 3.25 lb/ft^3 but having different fiber diameters permit checking for possible influence of fiber diameter on decay rate. The decay rates obtained with these two blankets differed widely, thus implying that fiber diameter is in itself another significant variable. Since fibrous blankets of several different glass fiber diameters were employed in the density evaluation experiments, it is not possible to define uniquely the dependence of decay rate upon density from these experimental data.

DEPENDENCE OF DECAY RATE ON BLANKET THICKNESS

Experimental decay rates were obtained with several thicknesses of PF453 blanket on the 129-cps test plate. Five blanket thicknesses of 1/2, 1, 2, 4, and 4-1/2 inches were tested, utilizing eight septa ranging in weight from 0.75 to 3.21 lb/ft^2.

The corrected data were plotted in Figure 10 as decay rate vs septum weight for constant blanket thicknesses. From this graph it seems evident that the best overall decay rate is obtained with the 1" sample, some 25 db/sec better than the 4" sample. It can also be noted that the heavier septa applied to the 1/2" blanket produces abnormally large decay rates. Figures 11a and 11b present the relationship between the decay rates and blanket thickness at each septum weight. Here, once again, it can be observed that the 1" thick blanket is most effective. Furthermore, peak decay rates, except where the heaviest septa are involved, occur in the range of 1.33 to 2.03 lb/ft^2. From Figure 11b it can be observed that a combination of the two heaviest septa and the thinnest blanket leads to anomalous behavior. Probably these heavy septa overcompress the thin blanket so that the normal frictional damping mechanism no longer predominates. Some other phenomena, such as impact damping, may now occur.

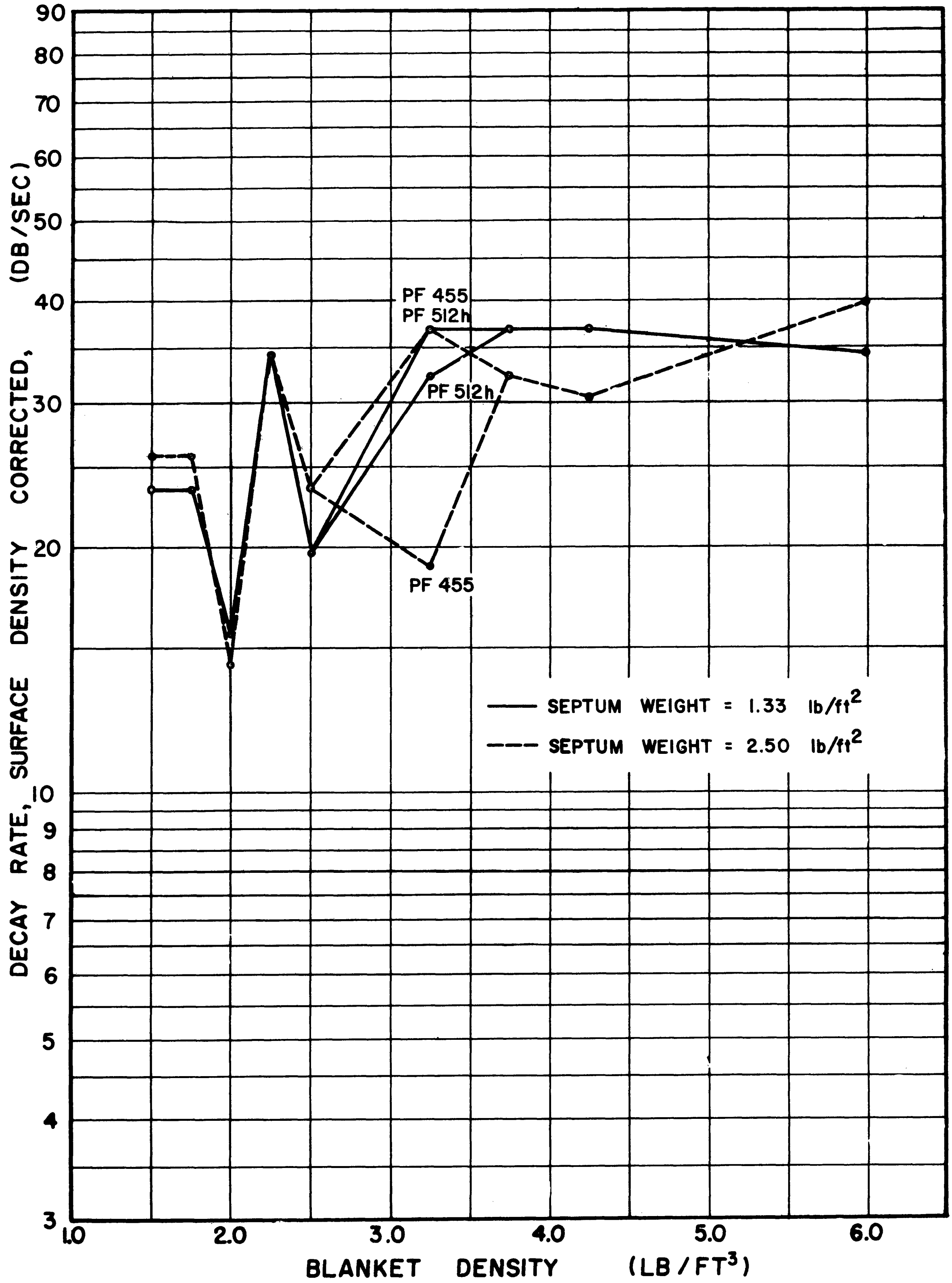


FIGURE 9. DECAY RATE VARIATION OF VARIOUS 1" BLANKETS AT 129 CPS WITH BLANKET DENSITY AT TWO SEPTUM WEIGHTS.

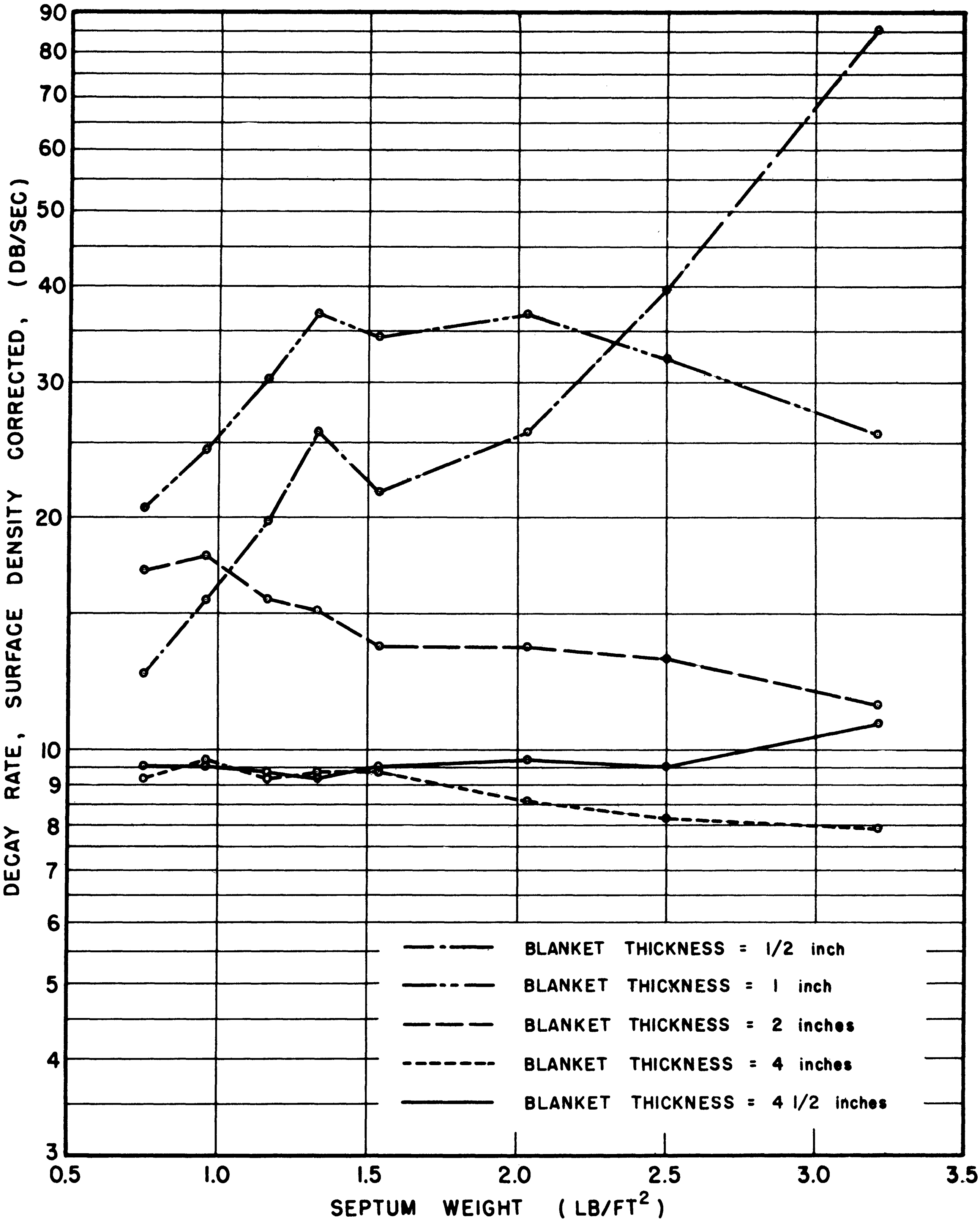


FIGURE 10. RELATION OF DECAY RATE TO SEPTUM WEIGHT FOR CONSTANT BLANKET (PF 453) THICKNESSES AT 129 CPS.

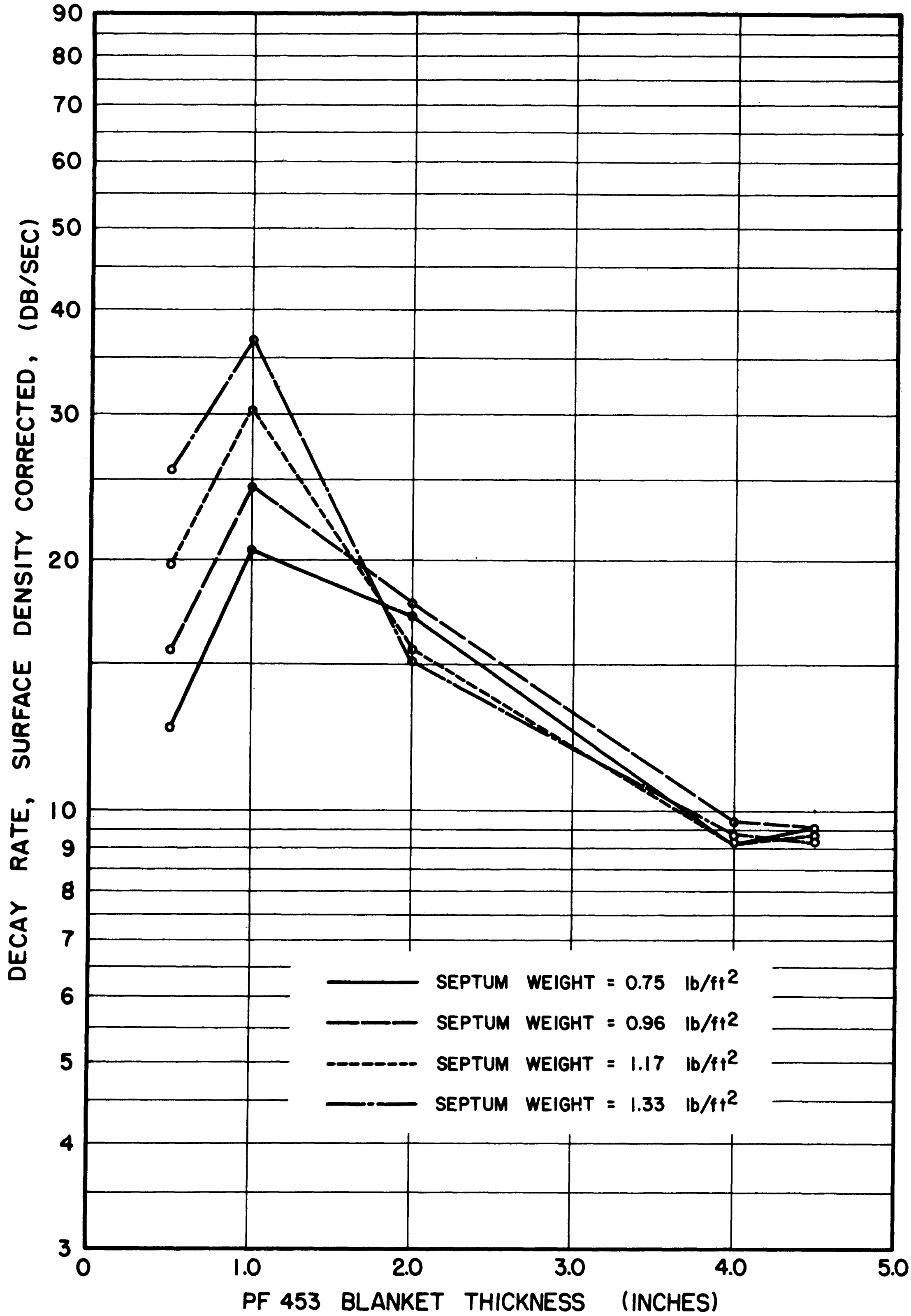


FIGURE 11a. RELATION OF DECAY RATE TO BLANKET (PF 453) THICKNESS FOR CONSTANT SEPTUM WEIGHTS AT 129 CPS.

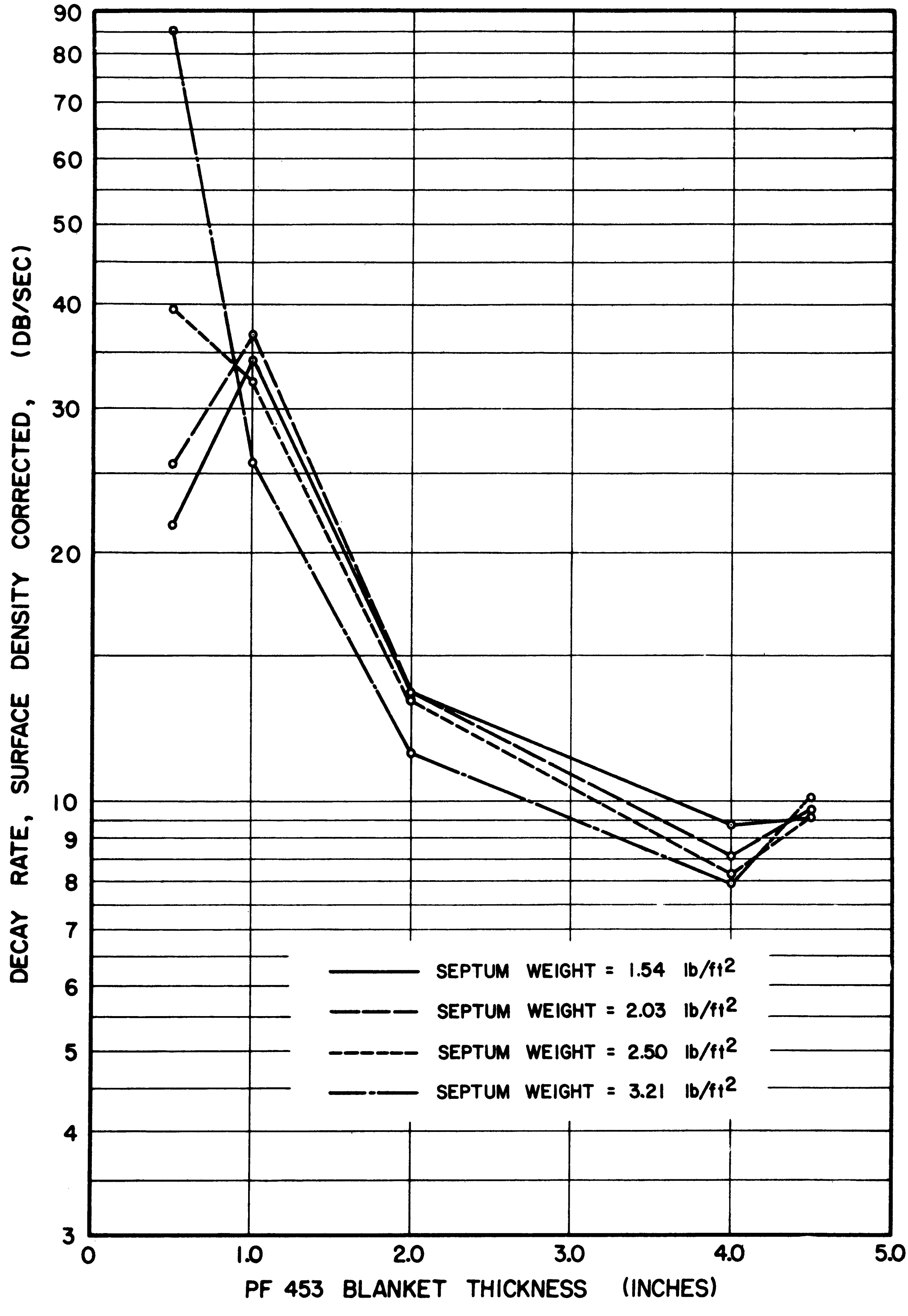


FIGURE 11 b. RELATION OF DECAY RATE TO BLANKET (PF 453) THICKNESS FOR CONSTANT SEPTUM WEIGHTS AT 129 CPS.

CONCLUSIONS AND RECOMMENDATIONS

For the damping treatments investigated, namely the complete coverage of a vibrating panel with a fibrous glass blanket loaded with a septum, a correlation has been displayed between decay rate and the variables of frequency, septum weight, blanket density, and blanket thickness. These experiments were exploratory in many respects and thus are neither complete nor exhaustive. However, they have indicated the need for an experimental program of a much broader scope. Such a program ought to be undertaken in order to fill in the gaps and present a more comprehensive description of the correlation between experimentally observed decay rates and blanket treatment variables.

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2. R. N. Hamme, "Summary of Panel-Damping Technology: A Motivation for Submarine Hull-Damping Treatments," The University of Michigan Report, August, 1957. Sponsored by Office of Naval Research, Undersea Warfare Branch (Code 466), Contract No. N6onr-23219. (CONFIDENTIAL)

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