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# EVALUATION OF AN ACOUSTIC TECHNIQUE AS A NONDESTRUCTIVE METHOD OF MEASURING UV DEGRADATION OF NYLON RIP-STOP FABRIC

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To determine whether the frequency of the resulting vibration could be used as a nondestructive method of evaluating degradation, samples of nylon rip-stop fabric with varying degrees of UV degradation were suspended under tension and impacted. It was found that the generated frequency is dependent on several variables including the vibrating length of sample and the applied tension. The suitability of the technique as a nondestructive method could not be established in this study because of lack of a definable relationship between frequency and degree of degradation.

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## Preface

There is a need for a reliable nondestructive method of assessing fabric degradation. When flexible textile structures such as fabrics are used as stress-bearing components in military items, it is necessary to monitor whether degradation has reached a point that will result in failure and cause loss of life or damage equipment. Lack of such methods has resulted in the use of a service life for these items, after which they are discarded. Such a procedure invariably results in discarding both good and bad items, after a certain length of time.

As part of the task to develop new test methods, this study of a potential acoustic technique was undertaken to determine whether it could be developed into a nondestructive method of evaluating fabric degradation.

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Evaluation of an Acoustic Technique as a Nondestructive Method of Measuring UV Degradation of Nylon Rip-Stop Fabric

## Background and Purpose:

The nondestructive acoustic technique reported by Hoffman and Davidson* to determine the degree of degradation of nylon rip-stop fabric deals with the possibility of a relationship between UV degradation and the resonant frequency generated in a fabric sample under tension. Because of the limited nature of their experimental work, the authors recommended that a statistically valid experiment be conducted to determine the sensitivity and resolution of the used technique in determining the degree of degradation.

The material used by Hoffman and Davidson* was an experimental 1.1-oz ($37\text{-g/m}^2$) nylon rip-stop fabric dyed with a shade of yellow that was found to accelerate the rate of UV degradation. Samples exposed in a weatherometer for 34 and 68 hours and a control were individually suspended under the same tension and impacted with the eraser head of a pencil. The vibration thus generated was picked up by a microphone

*Bernard Hoffman and Jeffrey Davidson; Feasibility Study FCI-10-74; Determining Degree of Degradation of Nylon Rip-Stop Using Nondestructive Acoustic Techniques; US Army Armament R&D Command, Frankford Arsenal, Philadelphia, March 1974.

and fed into an oscilloscope. The oscilloscope trace was used to calculate the induced frequency. This frequency showed a drop of 20 Hz from control to the 34-hour exposed state. However, the trend did not continue to the 68-hour exposed state. Instead, the generated frequency after 68-hour exposure increased by 5 Hz from that of the 34-hour exposure. Based on this limited data, it was concluded that there is a possibility of a relationship between the induced frequency and degradation.

The degradation itself is generally measured as a loss in breaking strength and, although statements were made as to the expected losses in strength at 34- and 68-hour exposures of this material, no breaking strength data were reported.

The purpose of the study reported here is to expand the acoustic technique with any possible refinements and to verify if there is a relationship between the induced frequency and degradation.

Materials:

Two 1.1-oz (37-g/m$^2$) nylon rip-stop fabrics were used in the current study. One of the samples is the standard OG shade while the other was the experimental yellow #3 used in the original study. Samples from both these fabrics were exposed in a Carbon Arc Weatherometer.

Apparatus:

a. Clamps used for tensioning in the referenced study.

b. Instron tensile tester equipped with 3-inch (75-mm) wide air-activated clamps.

c. Audio microphone

d. Oscilloscope with Polaroid camera attachment

Procedure:

Both fabric samples were exposed to various levels of UV radiation in the Carbon Arc Weatherometer. Standard ravel strip method was used to determine breaking strengths of the control and the exposed samples.

Using the Instron to maintain a tension of 5.0 ± 0.1 lbf (22.0 ± 0.5 N), frequency traces were made on the Oscilloscope after impacting the sample with the eraser head of a pencil in the same manner described in the referenced study. In addition, the original clamps were used to recreate the experimental setup and to obtain frequency traces.

All of the testing was done only in the warp direction of the fabric.

Results and Discussion:

Breaking strength data are shown in Tables 1 and 2; and are plotted in Figures 1 and 2. The standard OG fabric showed a lower rate of degradation than the yellow #3 as evidenced from these data.

Table 1. Breaking Strength Data on Standard Nylon Rip-Stop Fabric

| Condition | Breaking Strength in Warp, lb (N) | Loss of Strength, % |
|---|---|---|
| Control | 54.7 (243) | - |
| 24-hr exposure | 52.7 (235) | 3.7 |
| 48-hr exposure | 50.0 (222) | 9.4 |
| 100-hr exposure | 48.0 (214) | 12.2 |
| 300-hr exposure | 41.3 (184) | 24.5 |

Table 2. Breaking Strength Data on Nylon Rip-Stop Fabric, Shade Yellow #3

| Condition | Breaking Strength in Warp, lb (N) | Loss of Strength, % |
|---|---|---|
| Control | 47.0 (209) | - |
| 24-hr exposure | 42.7 (190) | 9.4 |
| 48-hr exposure | 39.0 (174) | 17.0 |
| 115-hr exposure | 19.5 (87) | 58.5 |

Table 3 and Figure 3 show the frequencies of the standard OG fabric at various levels of exposure using Instron to maintain a constant tension. The 3-inch (75-mm) gage length is the standard used in the breaking strength test and was, therefore, selected for the frequency measurement also. Although the actual breaking strength loss at 300-hour exposure is 25%, there was a drop in frequency of only 3 Hz. It was decided not to continue further evaluation of the standard OG fabric, but limit additional studies to yellow #3 since it showed a higher rate of degradation as evidenced by the breaking strength.

Table 3. Frequencies in the Standard Nylon Rip-Stop Fabric on the Instron at the 3-inch (75-mm) Gage Length

| Condition | Frequency, Hz |
|---|---|
| Control | 248 |
| 24-hr exposure | 247 |
| 48-hr exposure | 247 |
| 100-hr exposure | 245 |
| 300-hr exposure | 245 |

Table 4 shows the frequencies using the clamps from the original study placed at a distance of 10 inches (250 mm). This distance was approximated from the photograph of the experimental setup in order to keep the frequencies at the same level as those reported. During this testing phase, the sensitivity of the frequency to the gage length was observed. Table 5 shows the frequencies on the control yellow #3 at various gage lengths and Figure 4 shows this relationship. The four values in Table 4 are also plotted in Figure 5 at the 10-inch (250-mm) gage length.

It is evident from these data that there is a direct relationship between the generated frequency and the gage length. Minor changes in gage length can cause large variations in the frequencies obtained. There was no reference to this gage length effect in the earlier study.

Table 4. Frequencies in the Nylon Rip-Stop Fabric, Shade Yellow #3 with the Original Clamps at the 10-inch (250-mm) Gage

| Condition | Frequency, Hz |
|---|---|
| Control | 160 |
| 24-hr exposure | 166 |
| 48-hr exposure | 125 |
| 115-hr exposure | 146 |

Table 5. Effect of Gage Length Using the Original Clamps on Yellow #3, Nylon Rip-Stop Control Fabric

| Gage Length, in. (mm) | Frequency, Hz |
|---|---|
| 5 (125) | 222 |
| 8 (200) | 173 |
| 10 (250) | 160 |
| 12 (300) | 125 |
| 15 (375) | 54 |

Additional testing was conducted using the Instron as a tensioning device on the control and exposed samples at various gage lengths. Data are shown in Table 6, and plotted in Figures 5 and 6.

Table 6. Effect of Gage Length Using Instron Clamps on Yellow #3, Rip-Stop Control and Exposed Fabrics

| | | Frequency, Hz | | |
|---|---|---|---|---|
| Gage Length, in. (mm) | Control | 24-Hour Exposure | 48-Hour Exposure | 115-Hour Exposure |
| 3 (75) | 500 | 428 | 500 | 412 |
| 5 (125) | 286 | 260 | 285 | 264 |
| 8 (200) | 166 | 148 | 200 | 210 |
| 10 (250) | 117 | 121 | 153 | 140 |
| 12 (300) | 113 | 91 | 118 | 97 |

Once again, the gage length effect is evident from Figure 5. However, there was no pattern to the frequency vs. UV exposure relationship shown in Figure 6.

There was an apparent lowering in the frequency load at the first 24-hour exposure, but the trend did not continue similar to the data in the previous study. In some instances, the frequency in the sample with almost 60% loss in strength is higher than the control sample. The frequency of vibration as a function of loss in breaking strength is plotted in Figure 7 and shows no pattern. It is likely that other variables that are not considered in this study might be causing the apparent shifts in frequencies. The three values reported in the earlier study could be similar variations not necessarily related to degradation.

Conclusions:

1. The frequency of vibration of a sample of fabric held under tension is dependent upon many variables which include vibrating length and amount of tension.

2. The data show no definable relationship between the degree of degradation and the frequency of vibration of the nylon rip-stop fabric investigated.

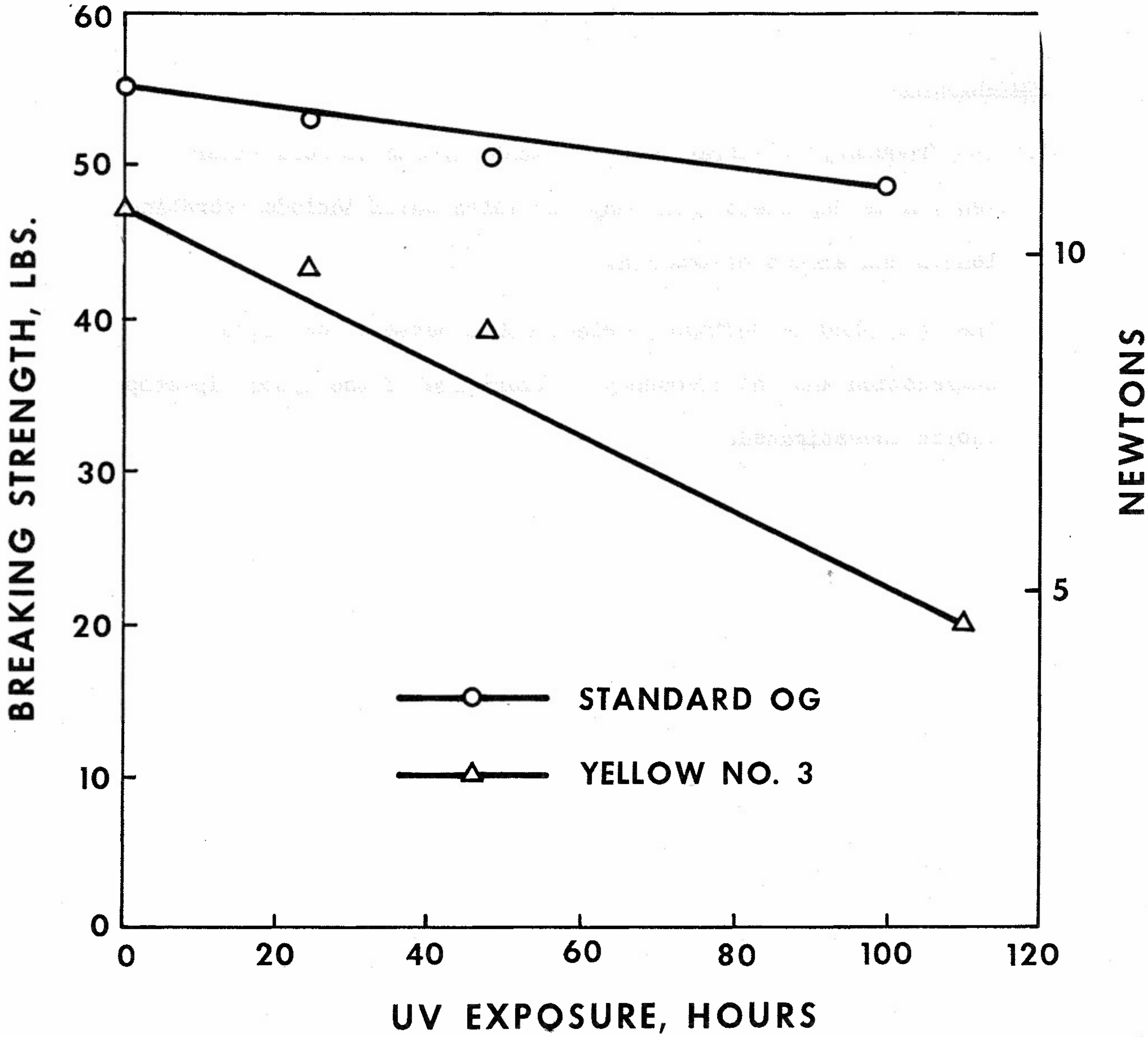


FIGURE 1. BREAKING STRENGTH VS. HOURS OF UV EXPOSURE.

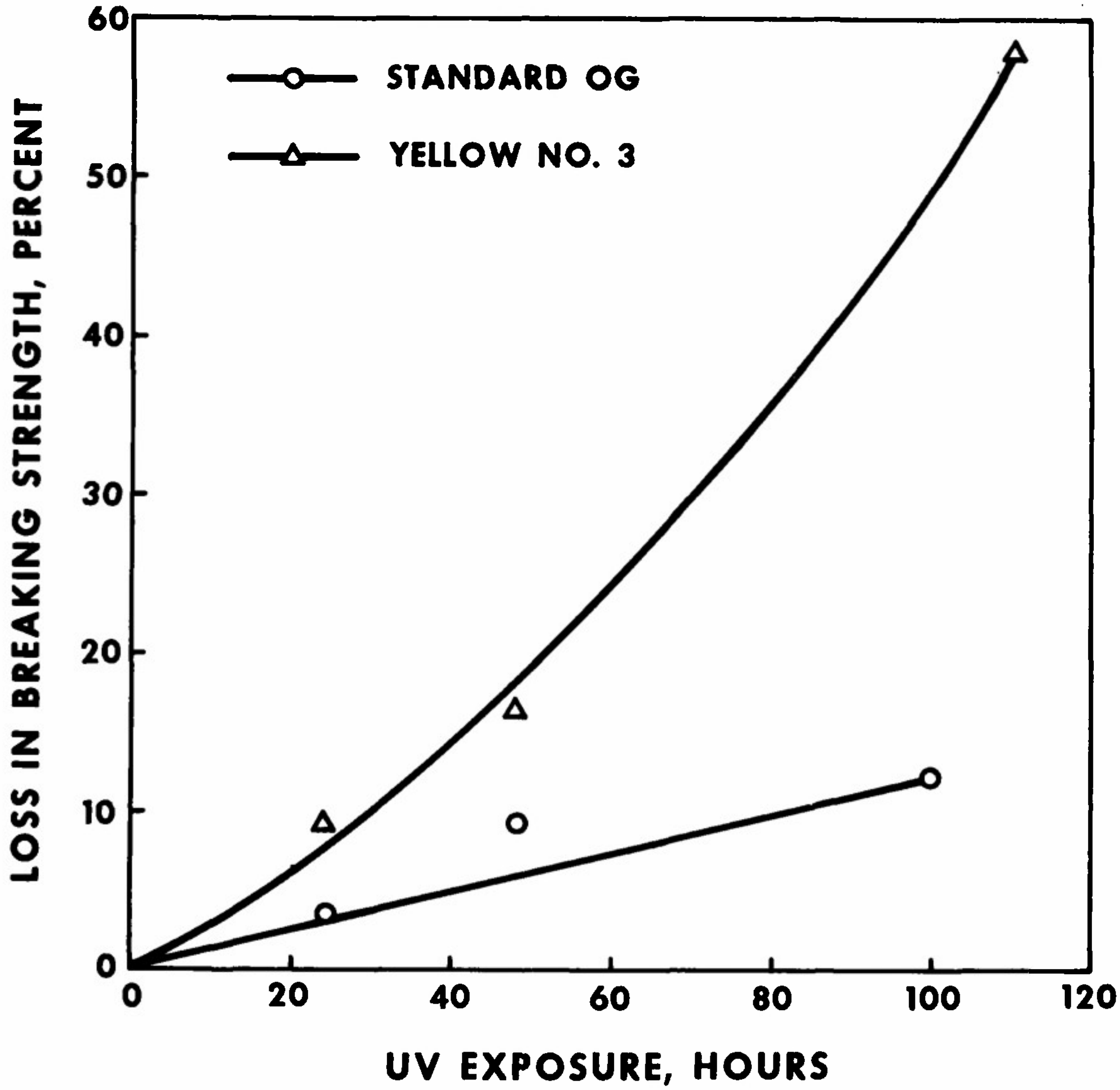


FIGURE 2. PERCENT LOSS IN BREAKING STRENGTH VS. HOURS OF UV EXPOSURE.

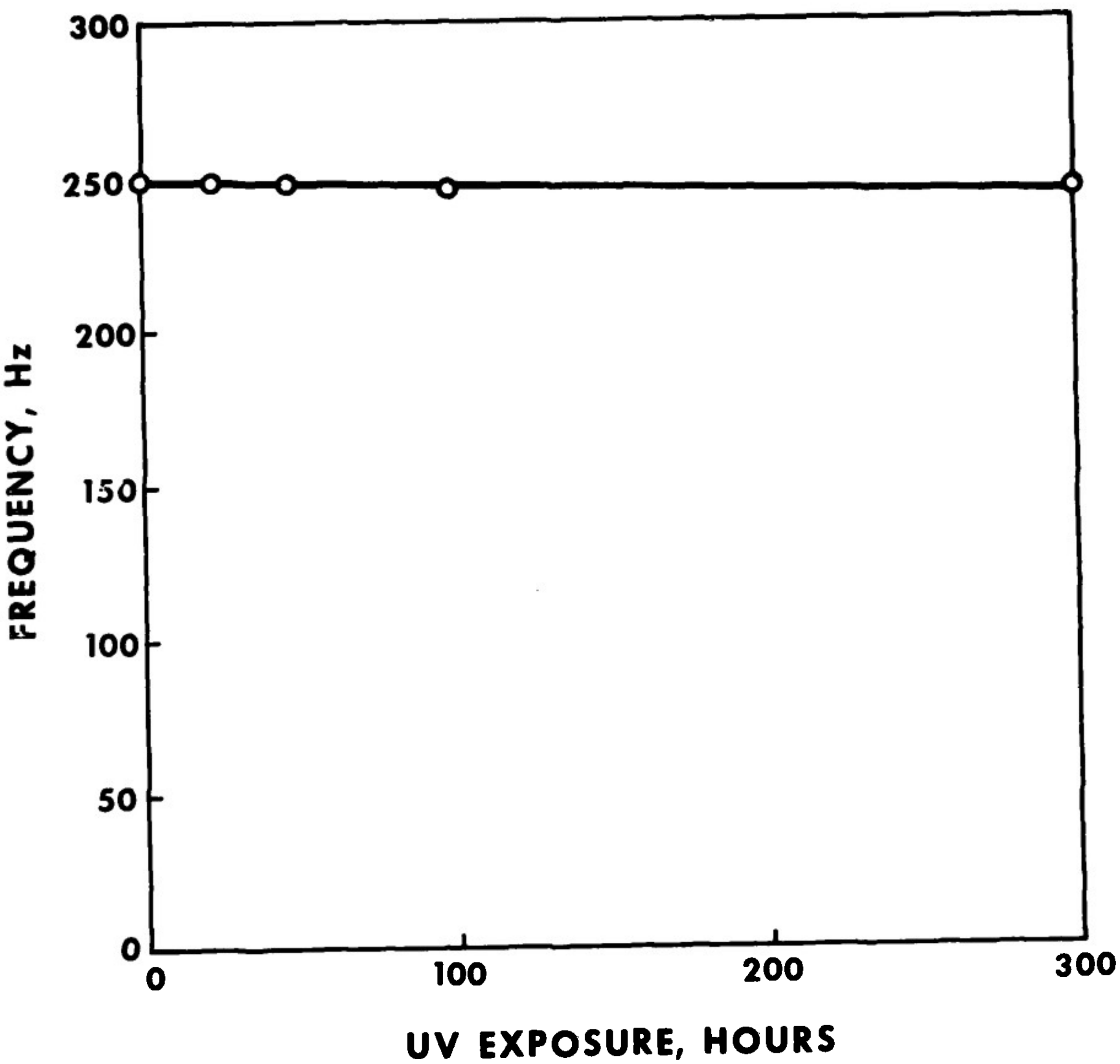


**FIGURE 3. HOURS OF UV EXPOSURE VS. FREQUENCY GENERATED IN THE STANDARD OG FABRIC.**

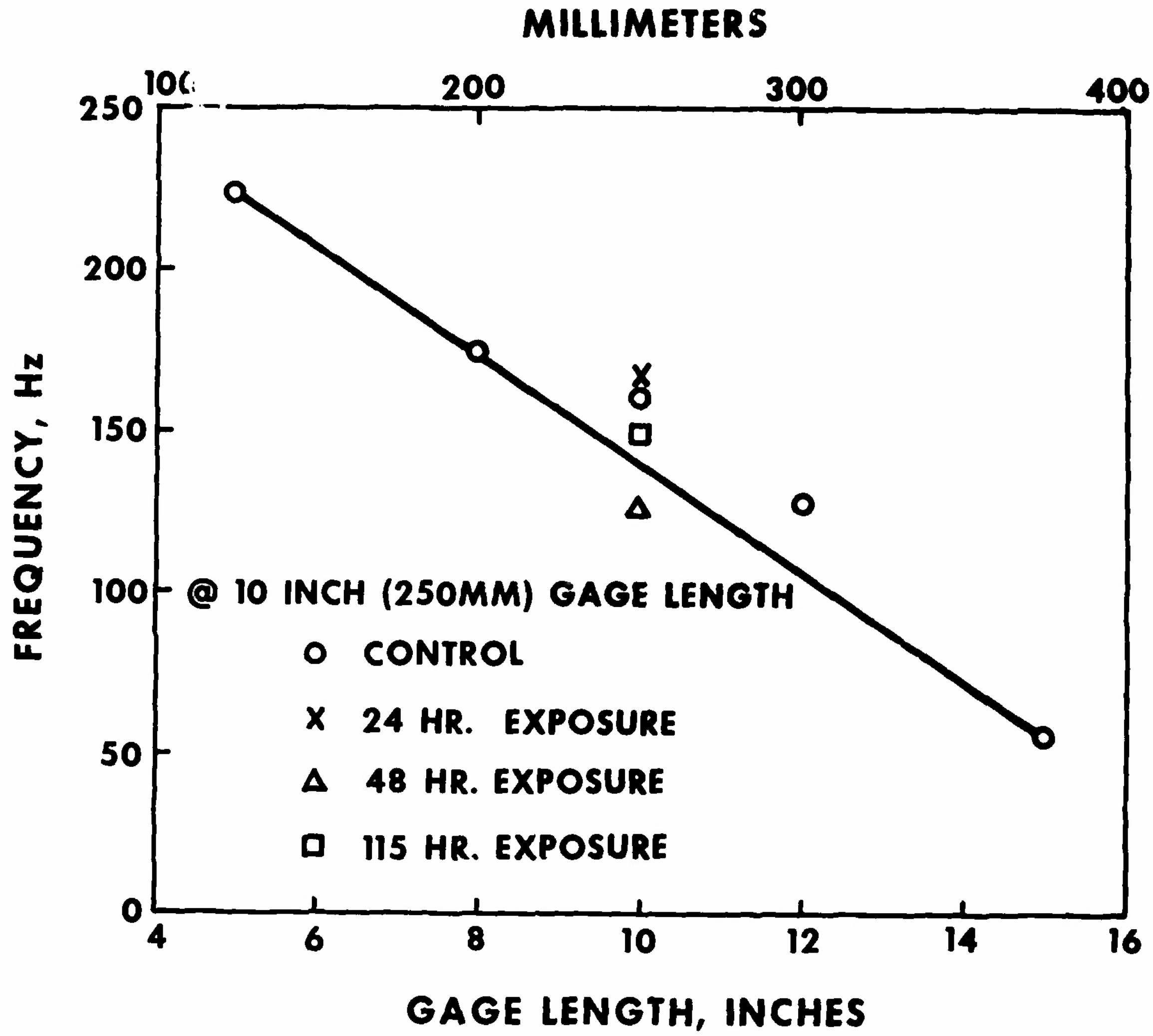


FIGURE 4. RELATIONSHIP BETWEEN GAGE LENGTH AND FREQUENCY GENERATED WITH THE ORIGINAL CLAMPS ON YELLOW #3 CONTROL FABRIC.

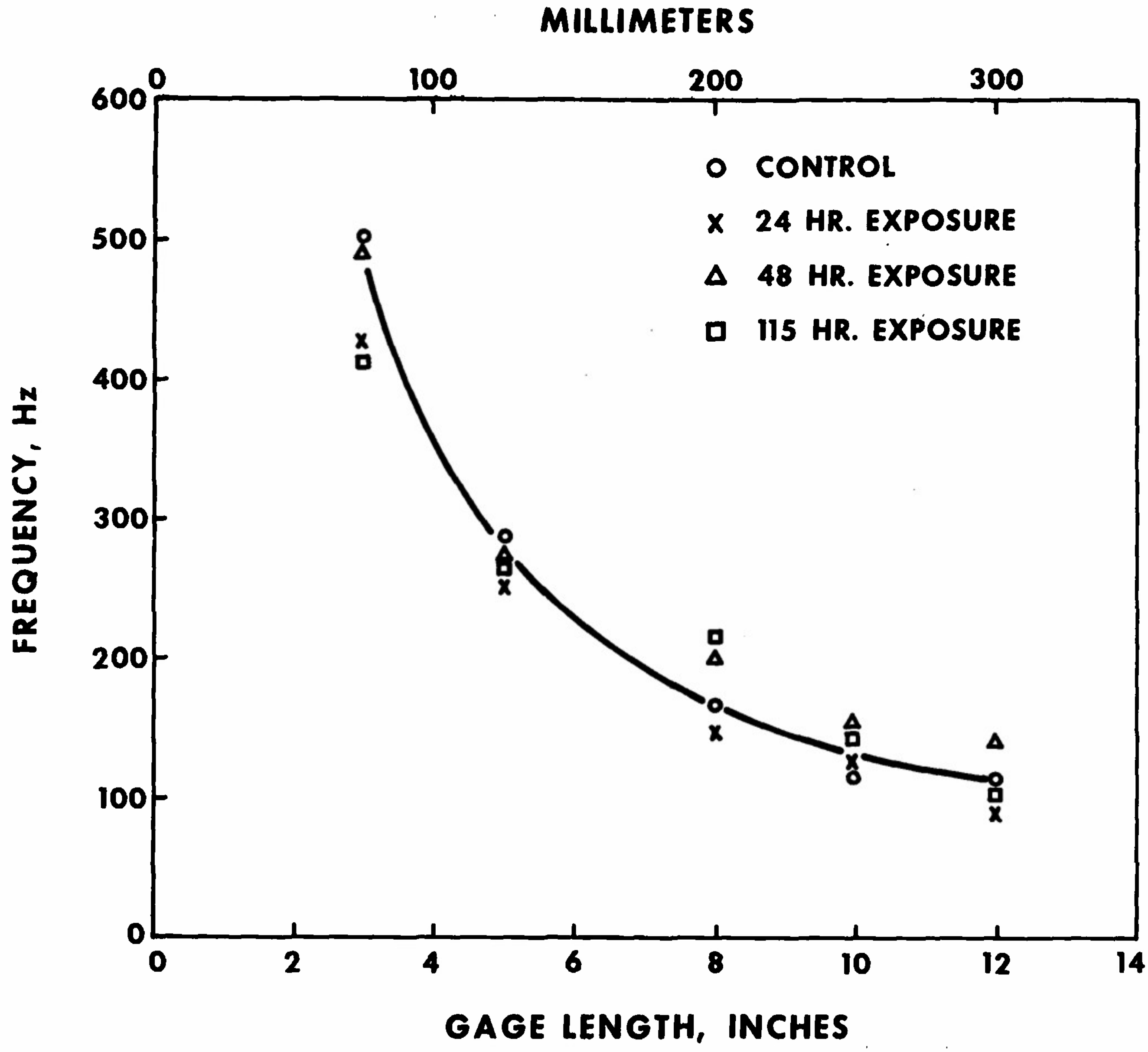


FIGURE 5. RELATIONSHIP BETWEEN GAGE LENGTH AND FREQUENCY GENERATED WITH INSTRON CLAMPS ON YELLOW #3 CONTROL AND EXPOSED FABRICS.

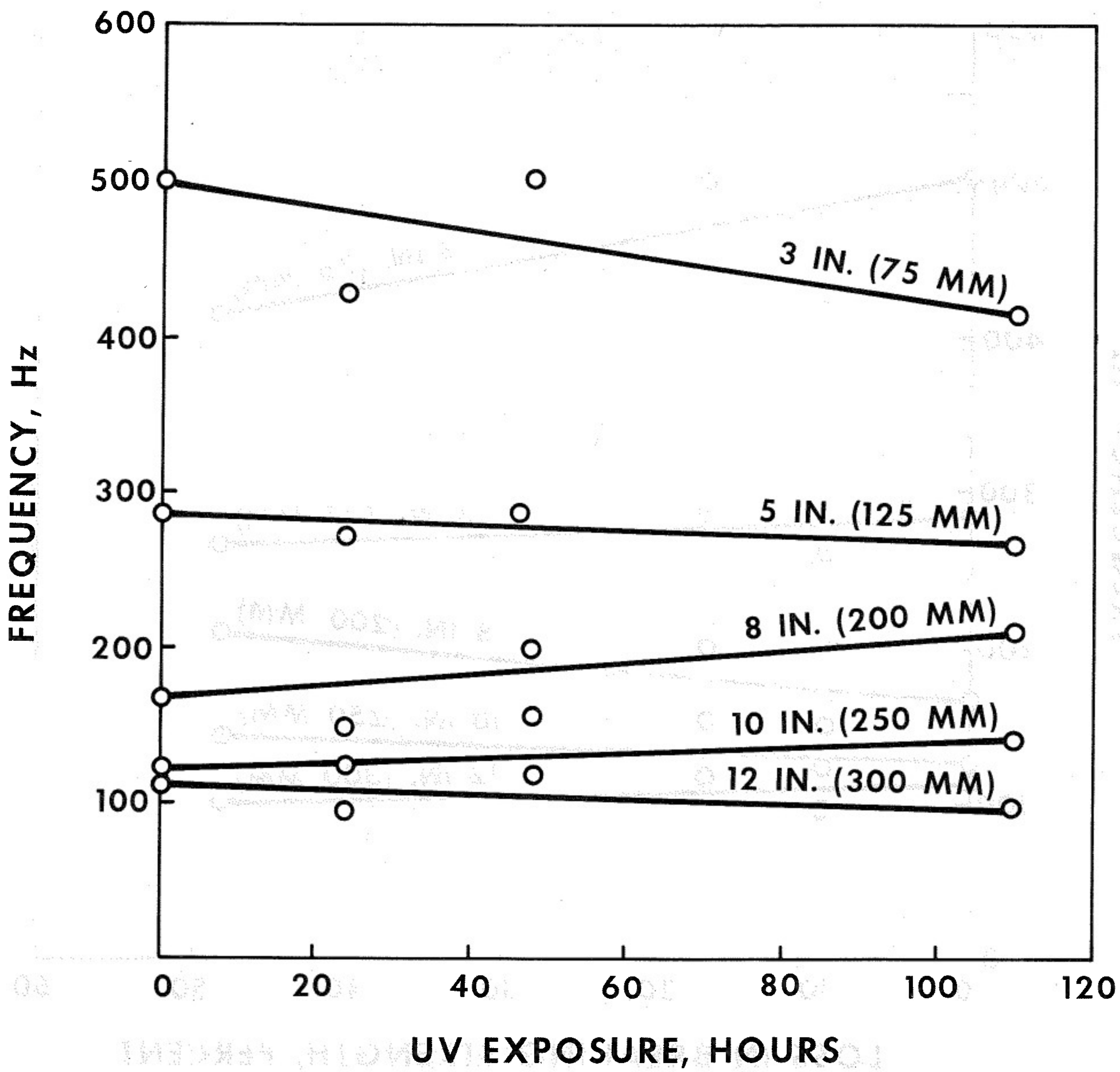


FIGURE 6. HOURS OF EXPOSURE VS. FREQUENCY AT VARIOUS GAGE LENGTHS, USING INSTRON CLAMPS ON YELLOW #3 FABRIC.

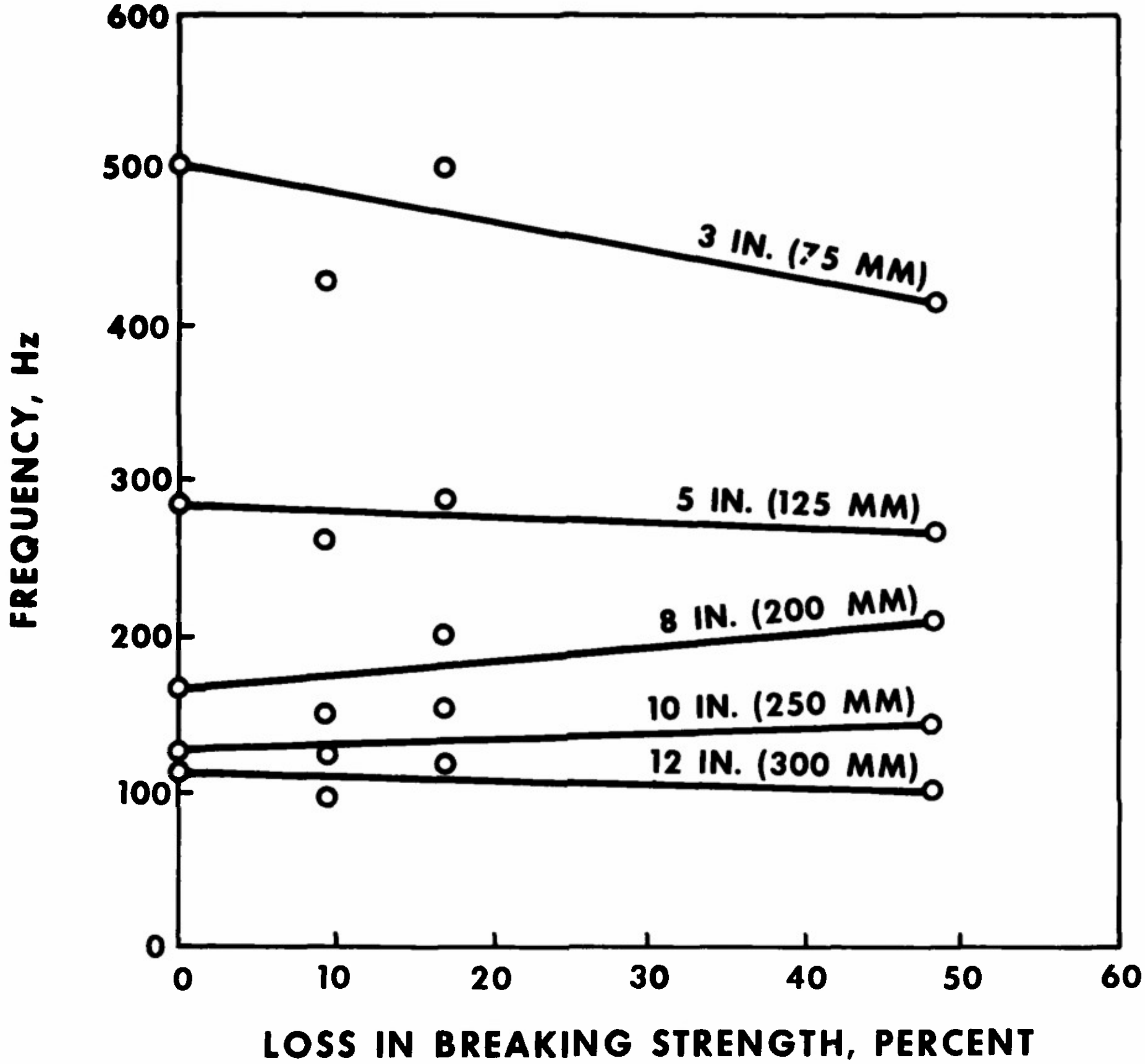


FIGURE 7. LOSS IN BREAKING STRENGTH VS. FREQUENCY AT VARIOUS GAGE LENGTHS, USING INSTRON CLAMPS ON YELLOW #3 FABRIC.