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VARIATIONS IN NOISE DOSIMETER READINGS OF FLUCTUATING NOISE.(U)
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VARIATIONS IN NOISE DOSIMETER READINGS OF FLUCTUATING NOISE

by

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PREFACE

The widespread use of personal noise dosimeters has generated controversy over the instrument's ability to accurately measure personal noise exposure, especially when the exposure includes impulse or impact type noise. This controversy is evident in recent articles in Sound and Vibration[1,2] which attempt to explain the reported discrepancies between readings by different instruments. This report will supplement these previous findings and discussions and offer evidence which identifies those factors contributing most to the discrepancies noted between readings of the same noise exposure by different personal noise dosimeters.

INTRODUCTION

Significant differences in the mean Leq(24) values were observed with dosimeters used in a study monitoring the daily noise exposures of children[3]. That study, conducted by the Fels Research Institute, was jointly sponsored by the Air Force Aerospace Medical Research Laboratory and the United States Environmental Protection Agency. In the Fels study a difference was observed in the mean Leq(24) values of about 7 dB using General Radio (Gen Rad) and Metrosonics noise dosimeters. The only statistically significant difference observed was between instrument types with the Gen Rad units reading higher. Possible explanations such as age and sex differences among the subjects and procedural differences were examined and ruled out. It was reasoned that group differences in mean Leq(24) recorded by the two dosimeter types were due to idiosyncrasies in the instruments themselves which resulted in systematic measurement errors. An investigation was conducted by the Bioacoustics Laboratory at Wright-Patterson AFB to determine the cause and to quantify the observed differences. This report describes the method, the results, the discussion and the conclusions of the investigation.

METHOD

Theory

Initially, the Gen Rad and Metrosonics instruments were both believed to be at fault with each having its own idiosyncrasies contributing to the problem. Most of the literature describing shortcomings of noise dosimeters deals with measurement inaccuracies of impact or impulse noise and rapidly varying noise levels. This investigation examined the possibility that these types of noise could be the problem.

Equipment

The Gen Rad 1954-9730, and the Metrosonics dB-301 Metrologger were setup to operate on the equal energy rule (3 dB per doubling) with a 90 dB criterion level. The Gen Rad Instruments were field adjusted to switch them from the 4 dB rule to the 3 dB rule by changing the internal jumper wires and recalibrating according to the Gen Rad instructions manual. The Metrologger was the dB 301/16 with program version 4.1 to read out one minute Leq's.

Procedure

The first tests performed were acoustic measurements in an anechoic chamber. The dosimeter microphones were fixed in close proximity to each other on a microphone stand to insure that they received the same exposure. A Gen Rad 1382 random noise generator input pink noise to a loudspeaker located approximately six feet away from the dosimeters. Continuous noise was presented at several sound levels up to 120 dBA to demonstrate that each instrument would accurately measure the noise levels used during subsequent tests. The noise level inside the room was monitored by a B&K digital frequency analyzer type 2131, with the pick-up microphone in the same proximity as the dosimeter microphones. Tests were then conducted using various conditions of interrupted pink noise. Later in this investigation the acoustic signal was changed to an electrical input signal so that possible microphone differences would be avoided.

RESULTS

Several preliminary tests were performed to establish baseline performance of the dosimeters. A frequency response test was performed using an acoustic signal at two different levels (90 dBA and 100 dBA). The test signal was monitored by a B&K 2204 precision sound level meter. The results are presented in Figure 1. Each steady, pure tone signal was presented for a 5 minute period during which an Leq reading was taken.

Continuous pink noise was then presented to the Gen Rad and Metrosonics dosimeters at levels of 90 dBA, 95 dBA, 115 dBA, and 120 dBA. Exposure durations were ten minutes and readings were taken every minute during this time. The results are presented in Table 1.

NOISE LEVEL	DOSIMETER READING	
	GEN RAD	METROSONICS
90 dBA	89.5 dBA	89 dBA
95 dBA	95.2 dBA	95 dBA
115 dBA	115.2 dBA	114 dBA
120 dBA	119.8 dBA	118 dBA

TABLE 1 - Steady Noise Test. Results are 10 min Leq's.

Except for a small offset at the higher levels by the Metrosonics unit, there was very close agreement between expected and observed readings. All observed readings were the same as the 10 minute Leq, that is, the readings remained constant for each minute. The consistency of these readings indicated that the dosimeters accurately detected the high levels of noise that would be used in subsequent tests.

Interrupted pink noise was the exposure in the next series of tests. The test signal was low level, baseline noise of 80 dBA with intermittent pulses of 120 dBA. The total cycle time of low level-high level exposure was 15 seconds and the time duration for the high level noise was varied in length. Tests were performed with high level noise durations of 0.5, 1, 2, 4, and 8 seconds. Results are shown in Figure 2. A typical pattern of noise exposure is depicted in Figure 3.

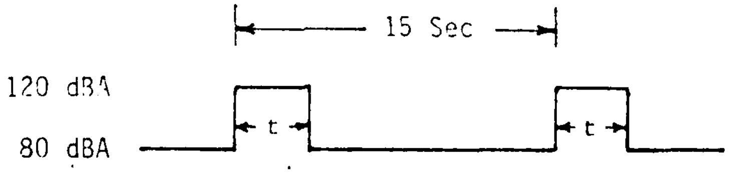

Figure 3 - Typical Test Cycle. For each test, t was either 0.5, 1, 2, 4, or 8 seconds.

Each point plotted in Figure 2 represents a 10 minute Leq as shown by the y-axis. The dynamic range setting was 80-130 dBA on the Gen Rad dosimeter and 60-123 dBA on the Metrosonics unit. The graph shows that the Gen Rad dosimeter performs quite well following the curve of the expected values except for a 1 dB offset. The response of the Metrosonics dosimeter, however, begins breaking down for high level noise durations less than 4 seconds in duration. A 12 dBA error was observed when the pulses were 0.5 second, and this error was observed as an underestimation of the actual exposure.

To determine if there was a dynamic range problem with the Metrosonics unit processing the high level noise pulse, this test was repeated using two Metrosonics dosimeters with different dynamic ranges of 60-123 dBA and 40-103 dBA. A baseline noise level of 60 dBA with high level noise pulses of 100 dBA was selected to remain within the dynamic range of the instruments. It was recognized that the small crest factor of the Metrosonics units might be a problem, and observed discrepancies could be a result of that problem. The results of this test are shown in Figure 4. This graph shows essentially no difference in the response of each dosimeter even with different dynamic ranges and lower noise exposure levels. This supports the crest factor position.

These first tests confirmed that a problem existed when the duration of the high noise pulse was varied. A logical follow up question was whether or not there would be variations in dosimeter readings if the level of the high noise pulse was varied while the time duration remained constant. An acoustic signal was presented to each type of dosimeter. The cycle of the noise exposure used is shown in Figure 5. Figure 6 shows the results of these tests.

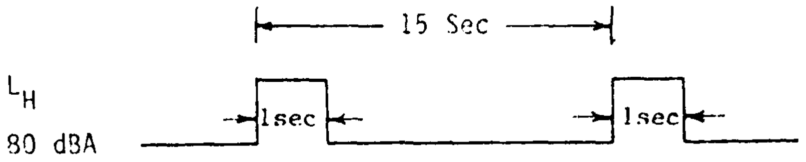

Figure 5 - Test pattern used in level variation tests. The high level pulses (L_H) were varied from 5 dBA to 40 dBA above the baseline level of 80 dBA in 5 dBA steps.

All points plotted in Figure 6 represent 10 minute Leq's. The calculated values were determined from equation 1:

$$\text{Equation 1:}\quad Leq = 10 \log \left[\frac{1}{T} \sum_{i=1}^{n} t_i 10^{(L_i/10)} \right]$$

Where = L_i = i th noise level (dBA)
t_i = time duration of i th noise level (seconds)
T = total time period in seconds or sum of all t_i
n = number of different L_i

Equation 1: Time Weighted Average Equation for determining cumulative Leq values.

The graph shows reasonable agreement between the expected values and the Gen Rad dosimeter readings. The Metrosonics dosimeter, however, had problems handling the higher level noise pulses. When the high level noise was 40 dBA above the baseline there was a 6 dBA underestimation of the actual noise exposure by the Metrosonics dosimeter.

Since the noise environments used in the Fels study[3] may have crossed below the 80 dBA threshold of the Gen Rad dosimeters, several tests were performed using noise environments that fluctuated above and below this threshold. First a linearity test was performed to determine the response of each dosimeter to the levels that would be used in the threshold tests. The results of the linearity tests are plotted in Figure 7. All instruments were calibrated according to manufacturer's specifications. The Gen Rad unit on each of the two dynamic ranges tested returned readings approximately 2 dBA above the level of the test signal. No reading below 78 dBA could be obtained using the 80-130 dBA range. The Metrosonics dosimeter was reading about 1 dBA too high above 90 dBA. There was little concern with these "small" problems, as each was most likely due to a calibration offset.

The first set of threshold tests were performed using an acoustic test signal composed of pink noise presented at a low level of 75 dBA and a high level of 85 dBA. Each signal was presented in a periodic pattern of high and low signals with each signal present for equal time durations. Tests were performed using t equal to 2, 5, and 10 seconds as the time durations for the high and low signal levels. A typical pattern of exposure is shown in Figure 8.

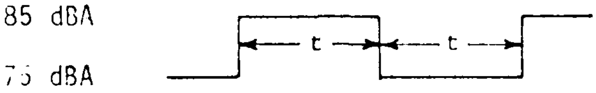

Figure 8 = Typical Noise Pattern for Threshold Tests.
The time (t) was either 2, 5, or 10 seconds.

This pattern of noise exposure was presented for a total of 3 minutes and the cumulative Leq is reported in Table 2. Since the high and low level noises were presented for equal amounts of time the theoretical value of the Leq in all cases was 82.4 dBA. The high dynamic range setting (80-130 dB) was used with the Gen Rad dosimeter and the Metrosonics' dynamic range was 60-124 dB.

Switching Time	Dosimeter Reading (Leq 3 min)	
	Gen Rad	Metrosonics
2 Sec	84.7 dBA	82.0 dBA
5 Sec	87.7 dBA	82.0 dBA
10 Sec	86.2 dBA	82.8 dBA

Table 2 = Acoustic Signal Threshold Crossing Tests.
Expected Leq value was 82.4 dBA.

Table 2 indicates a significant problem with the Gen Rad dosimeter readings of noises that cross back and forth over the threshold of this instrument. The errors appear as overestimations, and under these circumstances a 5 dBA error was measured for the 5 seconds switching time. The Metrosonics dosimeter readings were accurate, however, the noise fluctuations did not cross over the low threshold of 60 dBA of this instrument. Therefore, in subsequent threshold crossing tests the Metrosonics dosimeter was excluded.

To further verify this problem comparison tests were done with two Gen Rad dosimeters, #178 used in the above tests and #134. Each unit was set to operate on the 3 dB per doubling rule (equal energy) with a criterion level of 90 dBA. An electrical signal of 1000 Hz was chosen as the test signal rather than pink noise. The electrical signal was used instead of an acoustic signal to avoid possible errors due to microphone dynamics. The same pattern of exposure as shown in Figure 7 was used for the first series of tests. It is important to note that the signal input levels of 75 dBA and 85 dBA, and all electrical signal levels used in subsequent tests, were set and referenced to the dosimeter unit being tested. That is, after the initial calibration checks were made, the electrical signal was applied for a specific amount of time that would produce a known noise dose reading. The electrical signal was adjusted until this reading was obtained on the dosimeter. For example, a reading of 01.00 should be obtained on the 60-110 dB range setting when a signal of 75 dBA is presented for 1.5 minutes. This procedure reduced the chances that observed differences between dosimeter readings during testing would be the result of a calibration offset present in one or the other dosimeter. The results of these tests are presented in Table 3. The Leq's cover a 3 minute time period.

Switching Time	Range Setting	Dosimeter Number	Leq (3 min)
2 sec	80-130	134	89.4 dBA
		178	89.4 dBA
	60-110	134	81.9 dBA
		178	81.9 dBA
5 sec	80-130	134	86.4 dBA
		178	86.4 dBA
	60-110	134	81.9 dBA
		178	82.4 dBA
10 sec	80-130	134	84.3 dBA
		178	84.8 dBA
	60-110	134	82.0 dBA
		178	82.3 dBA

TABLE 3 - Electrical Signal Threshold Crossing Tests. Expected Leq value was 82.4 dBA.

The Gen Rad dosimeter overestimates the actual noise exposure, but only when the 80-130 dB range setting is used. A 7 dBA overestimation of the actual signal was observed for the 2 seconds switching time between high and low level test signals. The readings are fairly accurate on the lower dynamic range setting of 60-110 dB when the test signals do not cross over the dosimeter's threshold. These results further substantiated the theory that a systematic error is being introduced when the Gen Rad dosimeters attempt to integrate fluctuating noise levels that cross back and forth over the threshold level of the instrument. More tests were conducted to further quantify and define the extent of this problem.

DOSIMETER NUMBER	RANGE SETTING (dB)	HIGH LEVEL SIGNAL (dBA)	SWITCHING TIME (SEC)	NOISE DOSE READING (3 MIN)	ACTUAL LEQ (3 MIN) (dBA)	EXPECTED RESPONSE (dBA)	ERROR (dBA)
178	80-130	80	0.5 2.0 5.0 10.0	NONE 00.46 00.21 00.11	0 88.7 85.3 82.5	77.4	 11.3 7.9 5.1
178	80-130	85	0.5 2.0 5.0 10.0	00.10 00.55 00.26 00.18	82.0 89.4 86.2 84.6	82.1	-0.1 7.3 4.1 2.5
178	80-130	90	0.5 2.0 5.0 10.0	00.31 00.31 00.48 00.39	87.0 87.0 88.9 88.0	87.0	0 0 1.9 1.0
178	80-130	95	0.5 2.0 5.0 10.0	01.01 00.96 01.14 01.03	92.1 91.9 92.6 92.2	92.0	0.1 -0.1 0.6 0.2
134	80-130	80	0.5 2.0 5.0 10.0	NONE 00.47 00.20 00.12	0 88.8 85.1 82.8	77.4	 11.4 7.7 5.4
134	80-130	85	0.5 2.0 5.0 10.0	00.09 00.53 00.27 00.19	81.6 89.3 86.4 84.8	82.1	-0.5 7.2 4.3 2.7
134	80-130	90	0.5 2.0 5.0 10.0	00.32 00.32 00.49 00.41	87.1 87.1 88.9 88.2	87.0	0.1 0.1 1.9 1.2
134	80-130	95	0.5 2.0 5.0 10.0	00.98 00.93 01.15 01.06	92.0 92.0 92.7 92.3	92.0	0 0 0.7 0.3

TABLE 4: ELECTRICAL SIGNAL THRESHOLD CROSSING TESTS COMPARING TWO GEN RAD DOSIMETERS.

A series of tests was performed where both the switching time and the high level signal were varied. A low level signal of 70 dBA was selected as a baseline for all of these tests. No noise dose count should be picked up by the dosimeter when this 70 dBA signal is present with the instrument operating on the high dynamic range of 80-130 dB. The high level signals used were 80 dBA, 85 dBA, 90 dBA, and 95 dBA. The switching times used were 0.5, 2, 5, and 10 seconds. A signal of 1000 Hz was used as the electrical input. The results of these tests are presented in Table 4. The expected response values shown were determined from equation 1. The error between the expected values and the actual Leq's measured is as high as 11 dBA. A plot of one of these "worse case" conditions would look like Figure 9.

A theory on the source of the problem was developed. It is obvious that the problem is time dependent with the shorter switching time producing greater error (exclusive of 0.5 second). This seemed to indicate the importance of the number of times the test signal crossed the dosimeter's threshold. Another important factor seemed to be the level of the high test signal. The magnitude of the errors observed decreased sharply as the high level test signal approached and went above 90 dBA. Whatever systematic errors were being introduced at the lower test signal levels of 80 dBA and 85 dBA were now being suppressed by the intensity of the high level noise signal. It was theorized that an erroneous noise dose count was being introduced into the reading each time a noise below threshold rose to a higher level crossing the threshold of the dosimeter. In addition, the amount of error being introduced appeared to be equivalent to introducing a signal at a level of approximately 90 dBA.

This theory could be tested mathematically. In theory, a periodic test signal pattern would result in the same Leq for one cycle of exposure as resulted for the three minute time period used in the tests. The dosimeter's threshold is crossed twice each period, however, the important phase is the one time in each cycle of exposure that the noise crosses the threshold from the low level going to the high level. According to this theory, an erroneous noise dose count is introduced on the upward crossing of the threshold. The "worst case" situation from Table 4, which was dosimeter number 134 with exposure conditions of 80 dBA high level test signal and two seconds switching time, produced an Leq of 88.8 dBA. Knowing the Leq and the time duration of the period, the noise dose count actually obtained in one period can be determined. The noise dose count that should have been obtained with the actual exposure conditions can also be determined. The difference in these noise dose counts should be the amount of erroneous noise dose that is being introduced during the threshold crossing. The equation used by Gen Rad for calculating Leq's was employed:

Equation 2: $$Leq = 10 \log \left(\frac{D}{100} \times \frac{8}{T}\right) + 90$$

where T = measurement time in hours

D = index number (noise dose)

Solving this equation for noise dose (D) and setting it up so time (T) is measured in seconds we get:

Equation 3: $$D = \frac{T}{288} \text{ X } 10^{\left[\frac{(Leq-90)}{10}\right]}$$

By this equation an Leq of 88.8 dBA for a 4 second period would give a noise dose count of 00.0105358. However, under the actual exposure conditions of 70 dBA for 2 seconds then 80 dBA for 2 seconds a noise dose count of only 00.00076389 would be obtained. With this small noise dose count per period of exposure, it would take approximately 13.1 periods or 52.36 seconds before a noise dose count of 00.01 would be obtained (00.01 being the lowest noise dose count that can be obtained on the Gen Rad dosimeters). The difference between these noise dose counts is 00.0097719 or approximately 00.01. Therefore, each time the noise exposure crosses the dosimeter's threshold going from a low level exposure below threshold to a high one, an erroneous noise dose count equal to the lowest reading capable on the Gen Rad dosimeters (00.01) is introduced into the noise exposure reading.

This hypothesis can be further tested by applying a correction factor to each of the noise dose readings in Table 4 and recomputing the Leq's. The correction factor will be equal to the number of times in each period that the threshold is crossed, multiplied by 00.01, and this number will be subtracted from the noise dose reading. For example, when the switching time is 2 seconds the threshold of the dosimeter will be crossed, from low to high, 15 times each minute (once every 4 seconds). In a 3 minute time period the threshold is crossed 45 times, thus an erroneous noise dose count of 00.45 is introduced. Likewise for the 5 and 10 seconds switching times, erroneous counts of 00.18 and 00.09 should have been introduced respectively. No correction will be made for any of the 0.5 second switching times since there was little or no error present. The corrections will also not be applied to any of the situations where the high level signal was 90 dBA or more, since the dosimeters appear to behave normally at these levels. The corrections are made in Table 5. As the table indicates, when this type of a correction is applied the amount of error seen is significantly reduced.

Dosimeter Number	Range Setting (dB)	High Level Signal (dBA)	Switching Time (sec)	Noise Dose Reading (3 min)	Actual Leq(3 min) (dBA)	Expected Response (dBA)	Error (dBA)
178	80-130	80	2 5 10	00.01 00.03 00.02	72.0 76.8 75.1	77.4	-5.4 -0.6 -2.3
178	80-130	85	2 5 10	00.10 00.08 00.09	82.0 81.1 81.6	82.1	-0.1 -1.0 -0.5
134	80-130	80	2 5 10	00.02 00.02 00.03	75.1 75.1 76.8	77.4	-2.3 -2.3 -0.6
134	80-130	85	2 5 10	00.08 00.09 00.09	81.1 81.6 81.6	82.1	-1.0 -0.5 -0.5

TABLE 5: CORRECTED NOISE DOSE READINGS

To further define this threshold problem the "trigger point" was determined. A count of 00.01 is automatically introduced each time the noise exposure crosses the 80 dBA threshold point moving from a noise level below threshold to a higher level noise. It was necessary to determine how low the noise exposure would have to go before the trigger mechanism was reset, allowing another 00.01 count to be introduced upon the next upward threshold crossing. A level of 70 dBA is low enough to cause this resetting. However, it was the 80 dBA point where a noise dose count is first observed. With 2 seconds switching time and a low level signal of 70 dBA, the high level signal was set at 79 dBA and no noise dose count was observed on either Gen Rad dosimeter when set on the high dynamic range of 80-130 dBA. No difference in this result was observed when the low level noise was switched off, that is, when no low level signal was present. Tests were then conducted using 2 seconds switching time and an electrical input signal at 1000 Hz. The high level noise was kept constant at 80 dBA and the low level signal was varied starting with a setting of 80 dBA and moving down each time in 1 dB steps until the "trigger point" was discovered. When the low level signal was set at 80 dBA the signal was essentially constant over the entire 3 minute period of the test. The signal was, however, sent through the same timing and switching circuitry as during the previous tests. When observed on an oscilloscope, the input signal contained no stray "clicks" or "spikes." Therefore, the switching circuitry was not adversely affecting the input signal. The results of these test are shown in Table 6.

Dosimeter Number	Range Setting (dB)	Low Level Signal (dBA)	Switching Time (Sec)	Noise Dose Reading (3 Min)	Leq (3 Min) (dBA)
178	80-130	80	2	00.06	79.8
178	80-130	79	2	00.06	79.8
178	80-130	78	2	00.48	88.5
134	80-130	80	2	00.06	79.8
134	80-130	79	2	00.06	79.8
134	80-130	78	2	00.49	88.9

TABLE 6 - "Trigger Point" Tests

The table clearly shows that the noise dose readings "blow up" when the low level signal reaches 78 dBA. Therefore, the noise exposure level must drop to 78 dBA prior to going back above the threshold level of 80 dBA before the problem with threshold crossing occurs. The significance of knowing this will be explained in the discussion section of this report.

DISCUSSION

The results of this investigation reveal a never before reported reason for the observed discrepancies among dosimeter readings. Certain laboratory conditions of noise exposure were created whereby the cumulative Leq reading given by a noise dosimeter was almost 9 dBA above the highest level of the actual test signal because of threshold crossover problems. There may be many Air Force, industrial, or even everyday situations where similar conditions of noise exposure might be present. The human voice can fluctuate in level across 78 dBA to 80 dBA which is the range of noise levels where the threshold crossing problem occurs. A dosimeter microphone worn on the shoulder or chest can pick up direct voice signals from the wearer. The fact that an Leq reading from a noise dosimeter could actually be higher than the noise environment that is being measured is significant. There is no way of knowing how much of a correction factor to apply to the data.

The mathematical problems[4] and integration problems[1] that have been associated with personal noise dosimeters are not being disputed by the arguments presented in this report. Rather, these results should provide some new insight to an old problem. The difficulty encountered when using dosimeters to monitor noise environments which fluctuate across the threshold of the instrument may be at least a partial explanation for some of the observed discrepancies reported by many users of such equipment. This explanation is simple and its plausibility has been demonstrated both mathematically and experimentally.

It is important to make the results of studies such as this known to the public. Unfortunately, the burden of choosing a particular make of noise dosimeter to do a job is placed on the user. There is no national laboratory for standardization testing of noise measuring instruments which could offer useful consumer product information. Anyone purchasing noise monitoring equipment must rely on the manufacturer's specifications, which typically comply with all applicable ANSI and OSHA standards. However, when these various instruments can give completely different readings when measuring the same noise exposure, there is a problem with the standards and the methods used to determine compliance. This report should be viewed as further evidence for better standardization of noise dosimeters. It is unlikely that such standardization will come about in the very near future. It is, however, important to recognize that a lack of such standardization is contributing to the variability in noise dose measurements as well as confusion among users. The concept of noise dosimetry is certainly good, and its desirability and usefulness would be greatly enhanced by improved instrumentation and noise standards.

CONCLUSION

The Air Force has been using noise dosimeters in its hearing conservation programs for several years. The most widely used unit is the Gen Rad model 1954 dosimeter. The Air Force uses noise dosimeters that operate on a 4 dB per doubling rule with a criterion level of 84 dBA. Although this investigation used dosimeters operating on the 3 dB rule, similar threshold crossing problems would occur using dosimeters that operate on the 4 dB or 5 dB rule, although the extent of the problem is not now known.

One of the reasons for discrepancies in noise dose readings taken with noise dosimeters, particularly overestimations of noise exposure when Gen Rad dosimeters were used, is due to the introduction of a noise dose count into the reading when noise fluctuates across the threshold level of the dosimeter. The threshold problem does not present itself when the threshold level of the dosimeter is lowered. Unfortunately when the threshold is lowered several decibels of noise measuring capability on the high end of the dosimeter's dynamic range are sacrificed. One solution is to expand the noise dosimeter's dynamic range to include a wider range of noise levels that a worker could be expected to experience. When Gen Rad noise dosimeters are to be used it is essential that the proper dynamic range be selected before use. The 60-110 dBA range setting should be selected whenever the majority of the noise exposure is expected to be within this middle range. This will help avoid the threshold crossing problems.

The Gen Rad dosimeters are good in most situations, but because the Metrosonics dosimeters with the time history capability give more information that is of practical value, it should be the preferred dosimeter for Air Force use. As explained in previous reports[3,5,6], it is important in hearing conservation work to know where and when a noise overexposure occurs. This is the only way that proper hearing conservation and noise control procedures can be implemented.

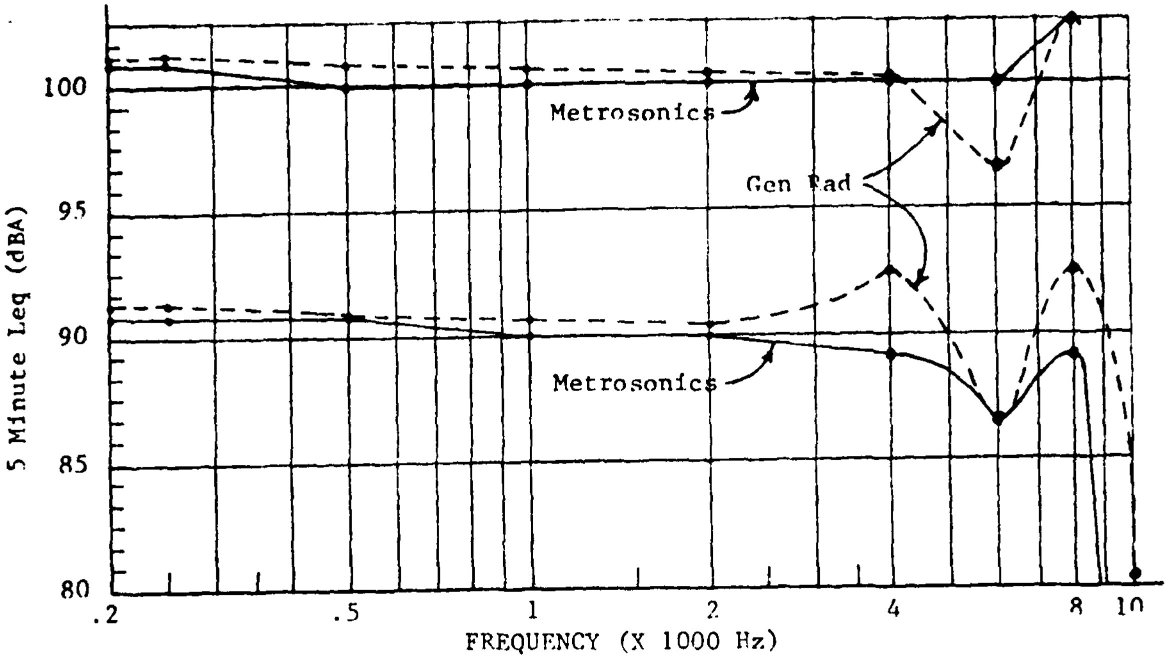

FIGURE 1: Noise dosimeter frequency response at 90 dBA and 100 dBA.

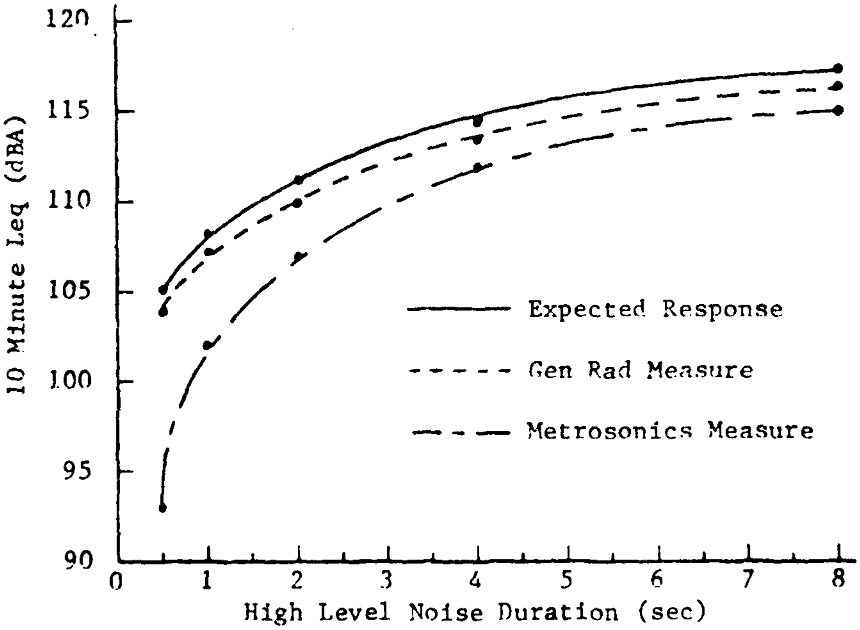

FIGURE 2: Dosimeter response under conditions of interrupted pink noise with an 80 dBA baseline noise level and intermittent pulses of 120 dBA.

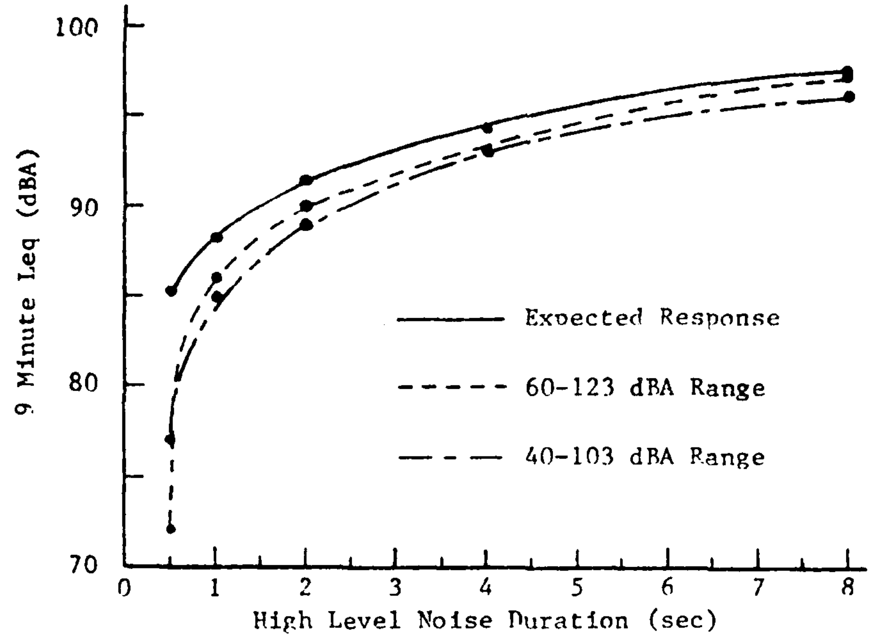

FIGURE 4: Dosimeter response comparing two Metrosonics dosimeters with different dynamic ranges under conditions of interrupted pink noise.

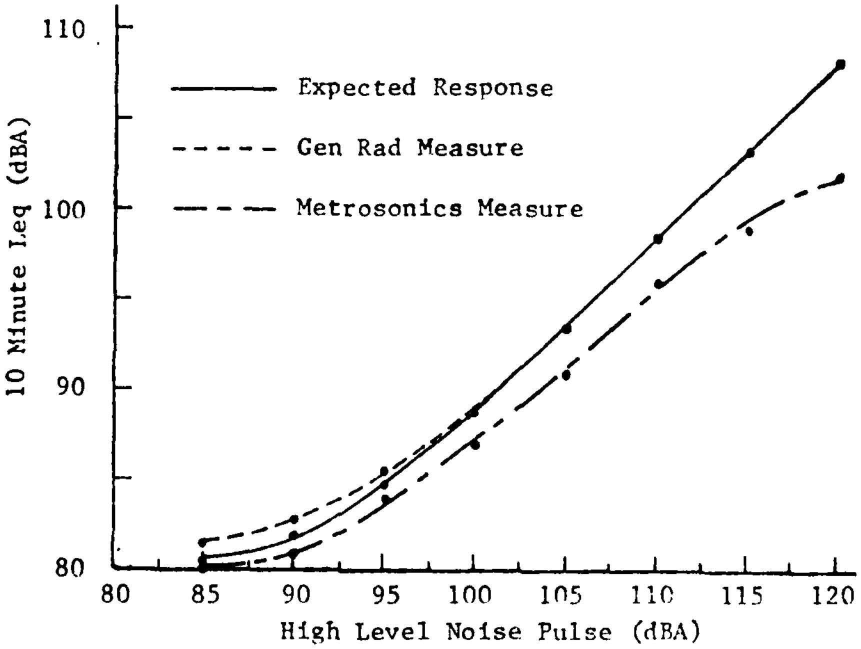

FIGURE 6: Dosimeter response to variations in level **of the high level noise pulse.**

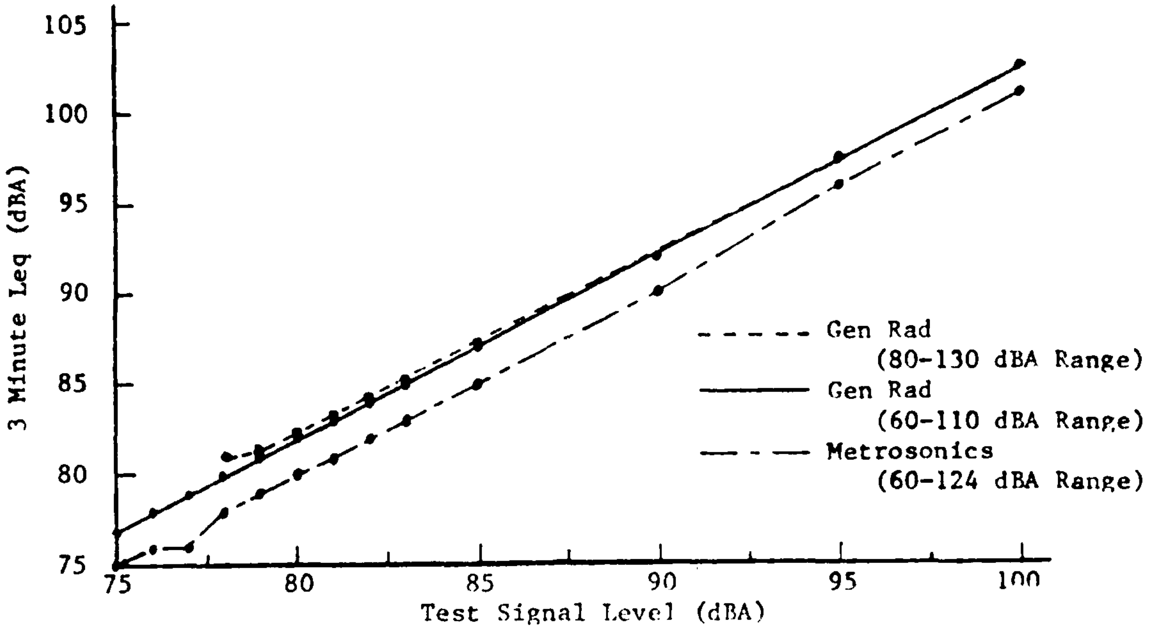

FIGURE 7: Linearity test of dosimeter response using a steady continuous pink noise acoustic test signal.

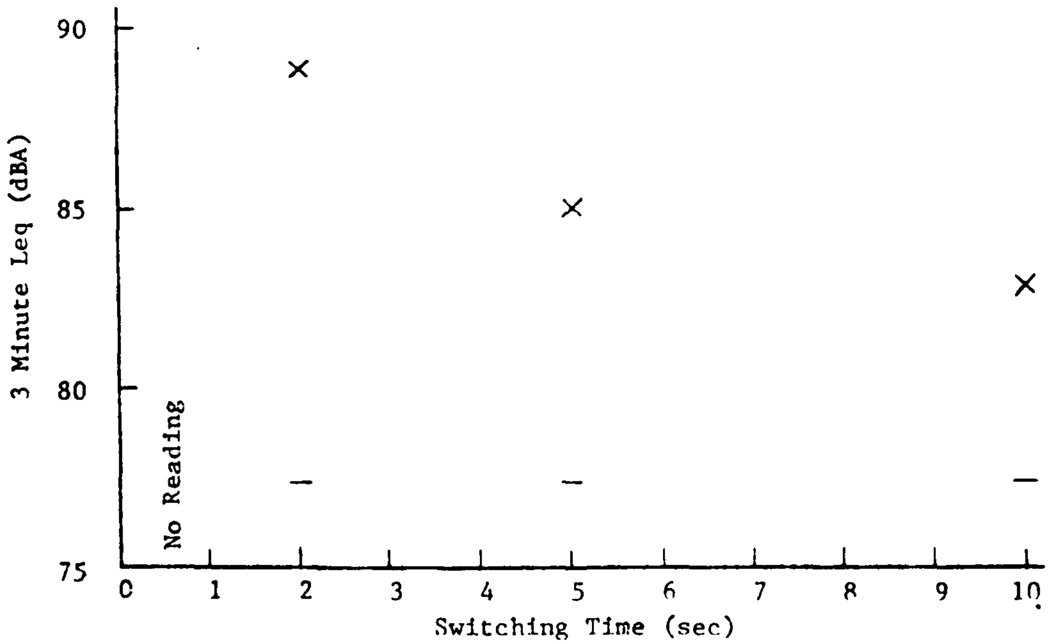

FIGURE 9: Worst Case Threshold Crossing Test. Dosimeter response in each case should be 77.4 dBA.

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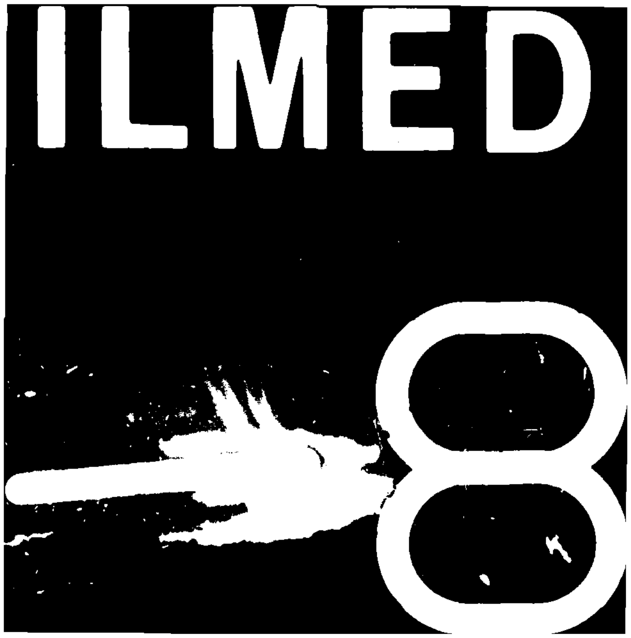
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