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CHARACTERISTICS OF THE PERSONAL NOISE DOSE METER TYPE 4425 AS EXEMPLIFIED BY SERIAL NO. 453311

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Characteristics of the Personal Noise Dose Meter Type 4425
as Exemplified by Serial No. 453311

by

M. Savich*

ABSTRACT

In a study underway in the Elliot Lake Laboratory, we are attempting to establish procedures for testing the performance of noise dose meters and monitors, and to answer questions of accuracy, microphone placement, and how data obtained in the laboratory will relate to measurements in an underground environment.

A Personal Noise Dose Meter, Bruel and Kjaer, Type 4425, Serial No. 453311, was procured for evaluation. It was found that at the low-level end, the integration was inhibited at 92 dBA. According to our tests, the Personal Noise Dose Meter counts when the noise level is over 115 dBA. There was, however, no essential difference between the Dose Meter readings and exposure based upon sound level meter data.

Noise: Exposure: Dose Meter: Bruel and Kjaer: Accuracy

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1. INTRODUCTION

The Elliot Lake Laboratory is interested in the possibility of utilizing the Bruel and Kjaer (B and K) Type 4425 Personal Noise Dose Meter for testing ear muffs in underground environmental conditions. In a study in our laboratory, an attempt is being made to establish procedures for testing the performance of the noise dose meter using a precision sound level meter, B and K, Type 2203, ANSI* S1.4-61, to standardize the noise levels and to answer the following questions:

1. What accuracy can be expected from the B and K Noise Dose Meter?
2. What are the effects of microphone placement?
3. How will data obtained in the laboratory relate to measurements in an underground noise environment?

The Noise Dose Meter may be of great advantage when making measurements to determine if the noise exposure is excessive. Criteria for occupational noise exposure can be found in the "Occupational Safety and Health Act", (OSHA)(Table 1).

TABLE 1

Noise Exposure Limits for a Normal 8-Hour Working Day

Noise Level (dBA)	Maximum Exposure (hr)
90	8
90-92	6
92-95	4
95-97	3
97-100	2
100-102	1.5
102-105	1
105-110	0.5
110-115	0.25
Above 115 dBA	None

* American National Standards Institute.

The criteria are based on measurements of the equivalent continuous noise level, Leq , provided the noise is not of an "impulsive" nature. Limits are based on tests showing that, for every halving of the duration of exposure, the intensity of exposure can be increased 5 dBA without an increase in the risk of noise-induced hearing losses. The A-weighted reading is used to estimate the probability of hearing damage in industry.

2. DESCRIPTION OF THE INSTRUMENT

The manufacturer claims that the Dose Meter complies with ANSI S1.4.1971 for Type 2 Sound Level Meter, which relates to automatic computation of noise exposure in accordance with OSHA requirements (Table 2).

TABLE 2

Total Tolerance Limits for Sound at Random Incidence for Type 2 Sound Level Meter

Frequency (Hz)	A-Weighting (dB)
31.5	+3.5, -4.0
63	+3.0, -3.0
125	+2.5, -2.5
250	+2.5, -2.5
500	+2.0, -2.0
1000	+2.0, -2.0
2000	+3.0, -3.0
4000	+5.5, -4.5
8000	+6.5, -6.5

The range of tolerance limits for Type 2 Sound Level Meter is from plus 3.5 dB, or minus 4.0 dB in the low frequencies, to plus or minus 6.5 dB at 8000 Hz. The sound level tolerance limits are widest at 4000 to 8000 Hz, and the dose meter noise exposure percentage reading is greatly influenced by these limits, especially at the higher frequencies (Table 2).

A simplified block diagram of the Personal Noise Dose Meter, Type 4425, Serial No. 453311, is shown in Figure 1 (1).

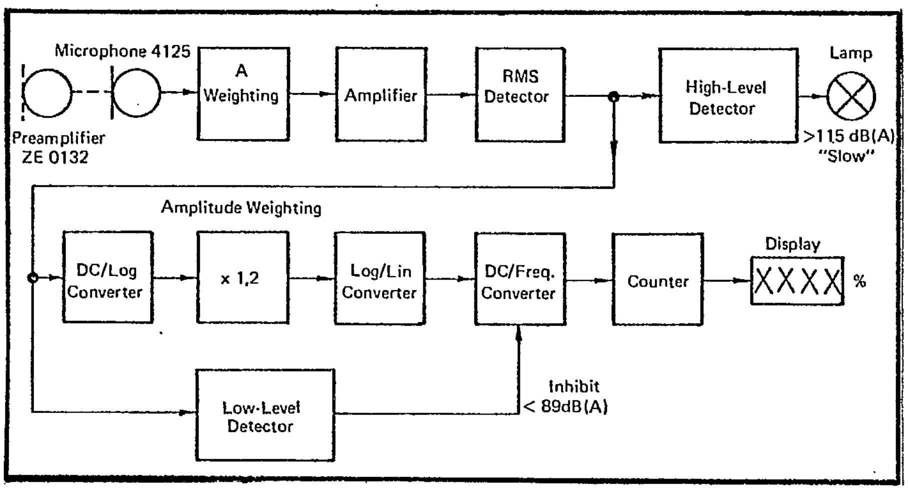

Figure 1: Simplified Block Diagram of the Personal Noise Dose Meter (1).

2.1 Microphone

The half-inch condenser microphone, Type 4125, No. 442805, can be mounted directly on the Noise Dose Meter or separately using the Preamplifier ZE 0132 with a 1 m cable.

2.2 Input Circuits

The input circuits in the Noise Dose Meter are identical to those in the Sound Level Meter. The electrical signal from the microphone is passed first to an A-weighting filter. After A-weighting the signal is passed to an amplifier with a nominal gain of 30 dB. The gain of the amplifier is variable to allow adjustment for calibration purposes. The amplified signal is averaged in the RMS detector to give the "slow" sound level meter characteristic. The RMS detector is followed by two level-detectors and the amplitude weighting circuit.

2.3 Detectors

The DC signal is passed to a high-level detector (which operates only when the OFF/RESET switch is in the "ON" position) for detection of levels in excess of 115 dBA slow. A light shows when 115 dB A-weighted sound level has been exceeded.

The low-level detector inhibits measurement below 89 dBA in accordance with the OSHA criterion. The use of low-level inhibition greatly reduces the integrator drift (which is usually a problem with integrator circuits) so that only straight forward drift compensation is required in the instrument (2).

2.4 Amplitude-Weighting Circuitry

Research has shown that, in practice, doubling the pressure more than doubles the damage potential. The Personal Noise Dose Meter must take this influence into account, the process being known as "amplitude weighting", by raising the sound pressure to some power. The following formula represents the evaluation of a particular noise dose (ND) (2):

$$ND = 100 \int_0^{\frac{T}{8}} \left[\frac{P(t)}{0.632} \right]^n dt\% \qquad \text{(Eq 1)}$$

where: P(t) is the A-weighted time varying sound pressure in pascals (Pa),
T is the measurement duration in hours,
0.632 Pa is the pressure corresponding to 90 dBA, and
t is the time in hours.

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Under the OSHA criterion an increase in the sound level of 5 dBA reduces the permissible exposure period by one half (q = 5 in Figure 2). It follows that the noise dose for 95 dBA for 4 hours is equivalent to that for 90dBA for 8 hours:

$$\int_0^4 \left[\frac{1.124}{0.632}\right]^n dt = \int_0^8 \left[\frac{0.632}{0.632}\right]^n dt \qquad \text{(Eq 2)}$$

where: 1.124 Pa is the pressure corresponding to 95 dBA.

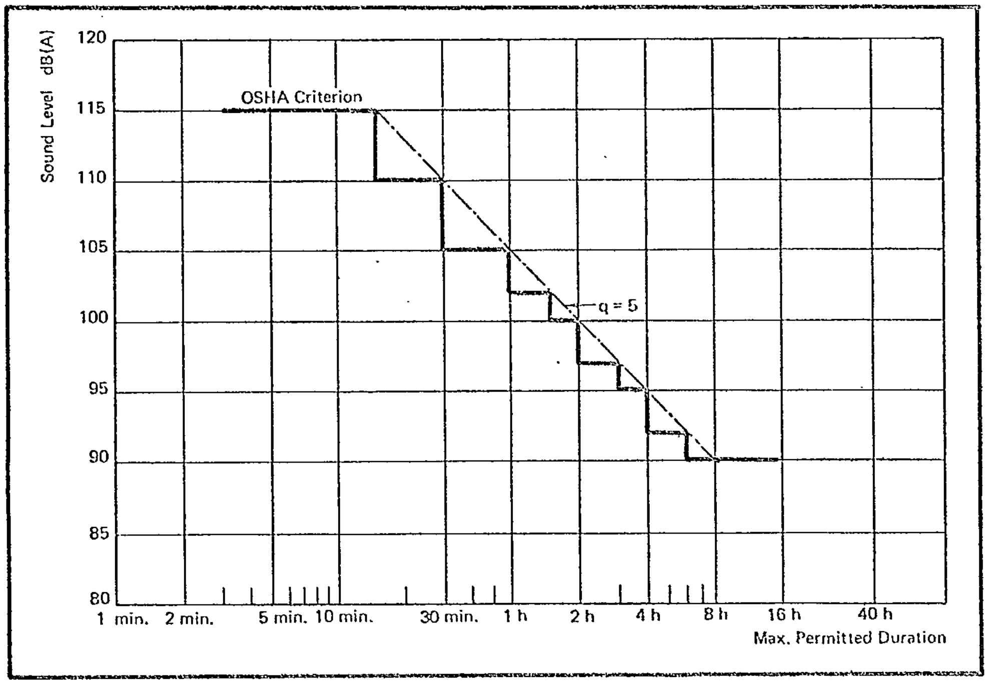

Figure 2: Relationship between Sound Level and Maximum Permitted Duration (OSHA).

Integration gives:

$$[1.780^n.t]_0^4 = [1^n.t]_0^8 \qquad \text{(Eq 3)}$$

or, $1.780^n . 4 = 8$

$1.780^n = 2$

$1.780^{1.2} = 2$

therefore, $n = 1.2$

Thus, under OSHA with a q = 5 from Eq 1,

$$ND_{OSHA} = 100 \int_0^T \left[\frac{P(t)}{0.632}\right]^{1.2} dt\% \qquad \text{(Eq 4)}$$

2.5 Integration

From the amplitude-weighting circuitry the DC signal is passed to a DC/frequency converter. This integration technique is a common feature of analog computers. The low-level detector inhibits measurement below 89 dBA following the OSHA criterion.

The counting circuitry stores the accumulated noise dose count with the maximum indication of the display 9999%. The display is reset to 0% by switching the OFF/RESET switch to "Off" for at least 5 seconds and then switching to "On" or "Cal" (for calibration) as required.

In the "Cal" mode the noise dose meter counting rate is increased relative to the "On" counting rate. This increase is given as follows:

$$C_{On} = \frac{1}{166} C_{Cal} \ (\%) \qquad \text{(Eq 5)}$$

where: C_{On} is a count in the "On" mode,
C_{Cal} is the equivalent count in the "Cal" mode.

The sound level range for "On" is 89 to 115 dBA Slow, and for "Cal" is 87 to 113 dBA Slow.

The calibration is made so that the Noise Dose Meter will count at a rate of 1% per second when a 94 dBA sound source (sound level calibrator, B and K, Type 4230) is applied. The Noise Dose Meter is supplied with two 9 V cells (IEC 6F22); the cell life is 50 hours under continuous use with the switch in the "On" position, and 30 hours for continuous use in the "Cal" position.

3. PERFORMANCE DATA FOR THE NOISE DOSE METER

Tests were carried out in a constant-temperature semi-reverberant room 4.25 m long, 4 m wide and 2.5 m high. The walls, ceiling and the floor were of wood construction and there was one window and one door in the room. The room was empty.

Under the same conditions, acoustical tests were performed using a Bruel and Kjaer, Random Noise Generator, Type 1402 and a Hewlett-Packard Test Oscillator, Model 650A. The high-powered loudspeaker was oriented to eliminate directional effects and to achieve a diffuse noise field condition. The noise dose microphone was suspended 1.3 m above the floor from ring stand clamps located in the middle of the room.

3.1 The Effect of dBA Variation on Percentage Readings

Tolerance limits for Type 2 Sound Level Meters are specified by a standard for measurement of OSHA compliance (Table 2). The effect of dBA

The sound level range for "On" is 89 to 115 dBA Slow, and for "Cal" is 87 to 113 dBA Slow.

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3.1 The Effect of dBA Variation on Percentage Readings

Tolerance limits for Type 2 Sound Level Meters are specified by a standard for measurement of OSHA compliance (Table 2). The effect of dBA variation on percentage reading was derived from Table 1 and Table 2 (Table 3).

TABLE 3

The Effect of dBA Variation
on % OSHA Exposure Measurement

dBA Error	% Reading (When Expecting 100%)
+6.5	246.2
+6.0	229.7
+5.5	214.4
+5.0	200.0
+4.5	186.6
+4.0	174.1
+3.5	162.4
+3.0	151.6
+2.5	141.4
+2.0	132.0
+1.5	123.1
+1.0	114.9
+0.5	107.2
0	100.0
-0.5	93.3
-1.0	87.1
-1.5	81.2
-2.0	75.8
-2.5	70.7
-3.0	66.0
-3.5	61.6
-4.0	57.4
-4.5	53.6
-5.0	50.0
-5.5	46.7
-6.0	43.5
-6.5	40.6

The relationship of the dBA error scale and the percentage reading scale is that 5 dBA doubles the percentage reading (OSHA). Ideally the input signal spectrum should be representative of "mine" noise. A calculation was done using "pink noise" from 20 Hz to 10,000 Hz for the input signal spectrum.

Spectra were computed for the A response and again for the upper and lower limits for Type 2 tolerances. The results show that the dBA value deviates from +3.4 dBA to -2.1 dBA from the correct pink noise level (3). Therefore, for every result, if we are expecting 100% noise exposure, between 75% and 160% will be acceptable (Table 3).

3.2 Test Data for Dynamic Range

The test for dynamic range was conducted in the "Cal" mode, with the microphone Type 4125 mounted on the clip-on preamplifier ZE 0132 (Figure 3). At 89 and 90 dBA the readings were zero; at 91 dBA the noise dose meter counted extremely low. Readings at 95, 100, 105 and 110 dBA were within tolerance. The test at a maximum level of 115 dBA resulted in maximum error of 22%, but the range for "Cal" was 87 to 113 dBA Slow. Lower levels did not correspond to the factory's claims. During the high level noise testing, the preamplifier ZE 0132 broke down. After this test, the microphone Type 4125 was mounted directly on the noise dose meter.

The same test was repeated with a condenser microphone Type 4125 mounted directly on the noise dose meter (Figure 4). The reading at the 90 dBA level was once again zero. Other readings were within tolerance.

3.3 Accumulative Test for 100% Total

This test was carried out to evaluate the ability of the Noise Dose Meter to accumulate noise signals of various fixed levels and durations (Figure 5). The sound level was controlled in each interval to correspond to a 16.6 percent exposure. In the "Cal" mode all readings were within tolerance. In the "On" mode the reading at 92 dBA was zero. Other readings were within tolerance.

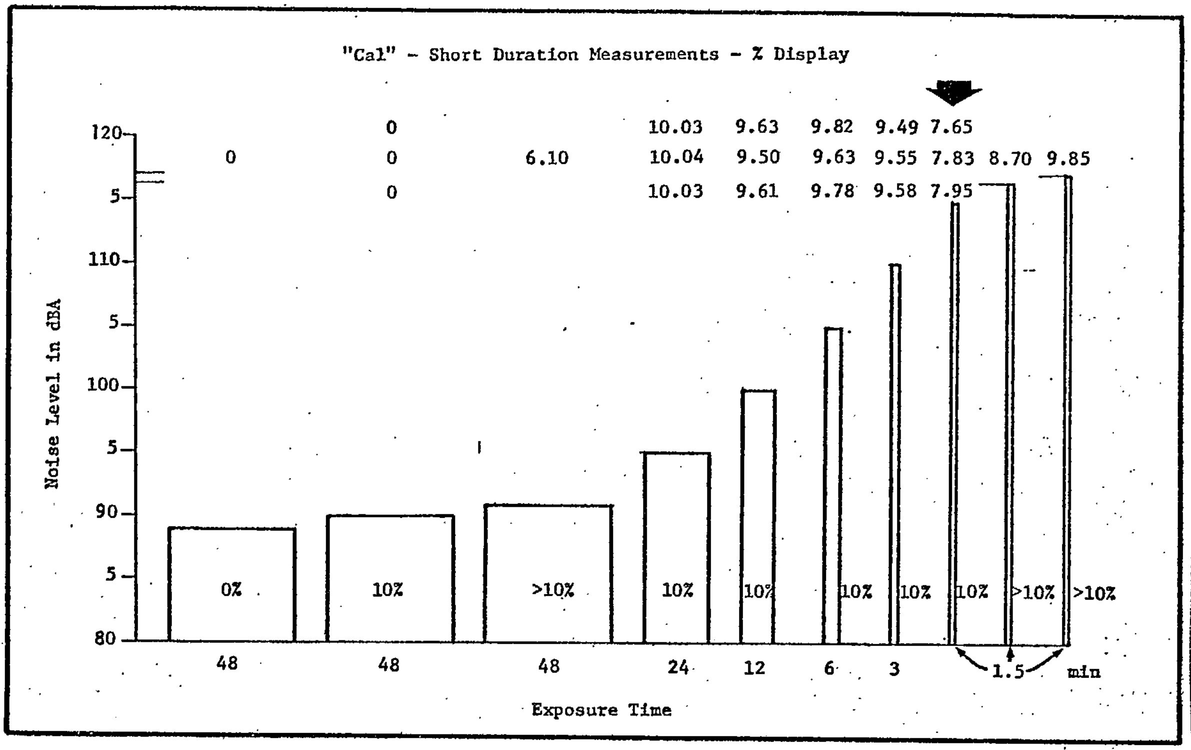

Figure 3: Test Level for Dynamic Range.
(Alternative mounting of microphone Type 4125 on clip-on preamplifier ZE 0132 which connects to Noise Dose Meter via 1 m cable.)

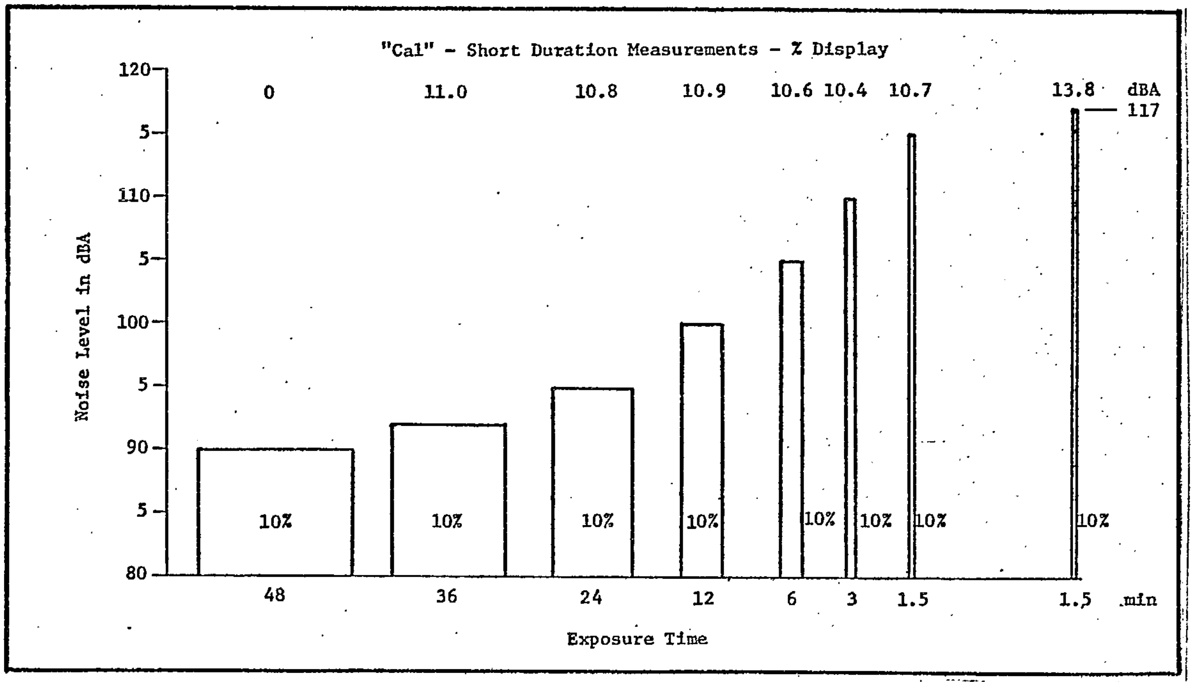

Figure 4: Test Level for Dynamic Range.
(Condenser Microphone Type 4125 mounted directly on Noise Dose Meter.)

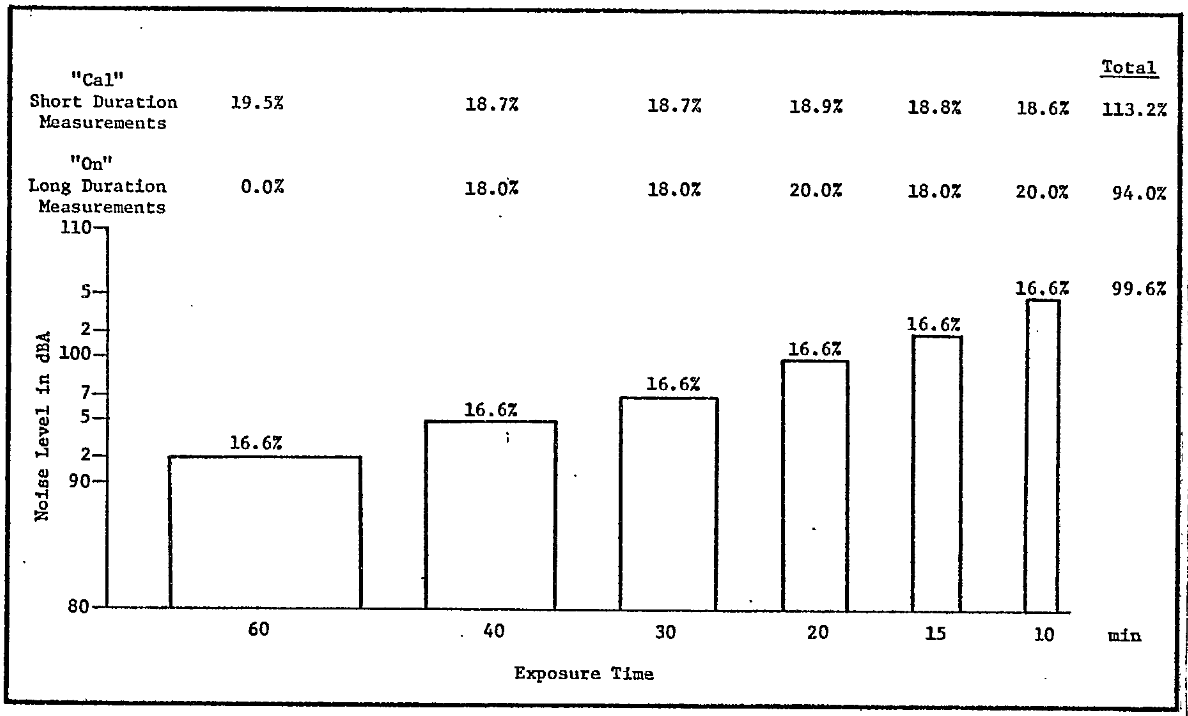

Figure 5: Accumulative Test for 100% Total.
(Condenser Microphone Type 4125 mounted directly on Noise Dose Meter.)

3.4 Exposure Test to Octave Bands of Noise

The Dose Meter was exposed to octave bands of noise at 100 dBA for one hour each except for 8 kHz (95 dBA). Each exposure except the last corresponds to a 50% exposure according to the OSHA criterion. The exposure at 95 dBA corresponds to 25% (Figure 6). Examination of the test data showed the 8 kHz band to have the greatest error.

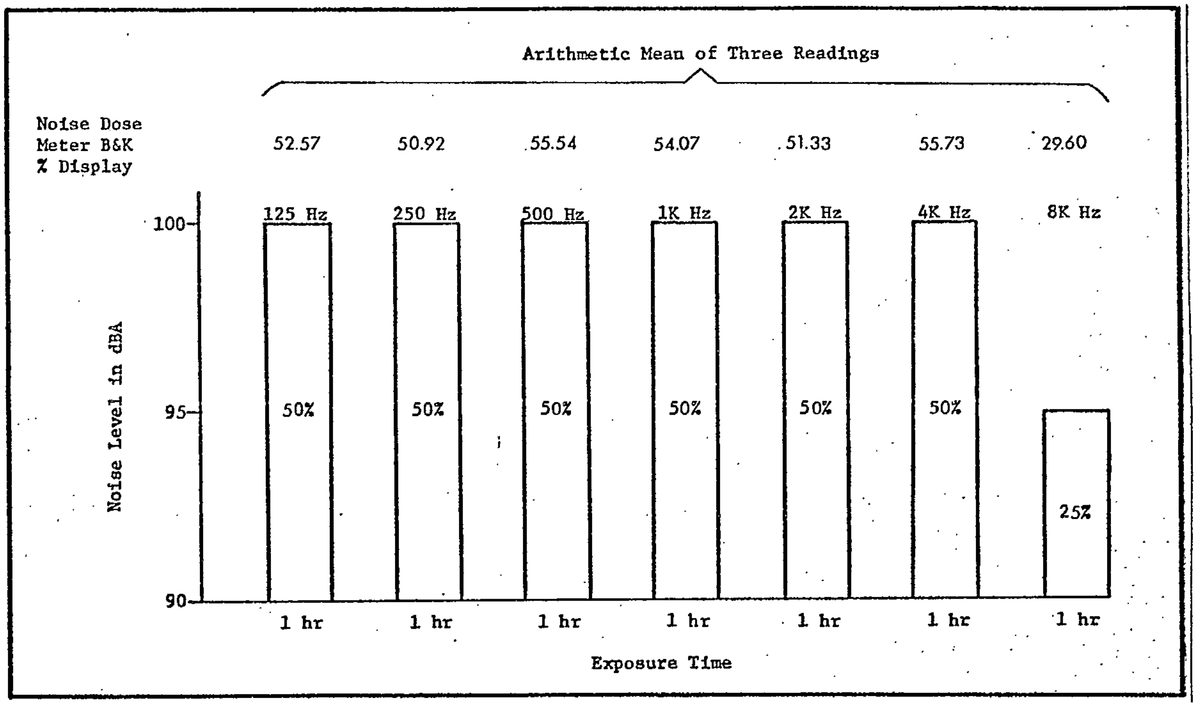

Figure 6: One-Hour Exposure to Octave Bands of Noise. (Condenser Microphone Type 4125 mounted directly on Noise Dose Meter.)

3.5 Noise Burst Test

The noise burst test was performed to investigate the effects of intermittent noise peaks (Figure 7). The background level on the storage circuits of the Noise Dose Meter was 97 dBA with 115 dBA pulses of 2-seconds duration after every ten seconds; 30 minutes produces 47.2% exposure. OSHA has established the A-scale at slow response characteristic of a sound level meter as the criterion for measuring noise levels. It was believed that results obtained with the Noise Dose Meter from short duration noise pulses may be lower than calculated values of time versus intensity. The results for both modes of measurements are within tolerance. The test was repeated many times and showed the high quality of the instrument.

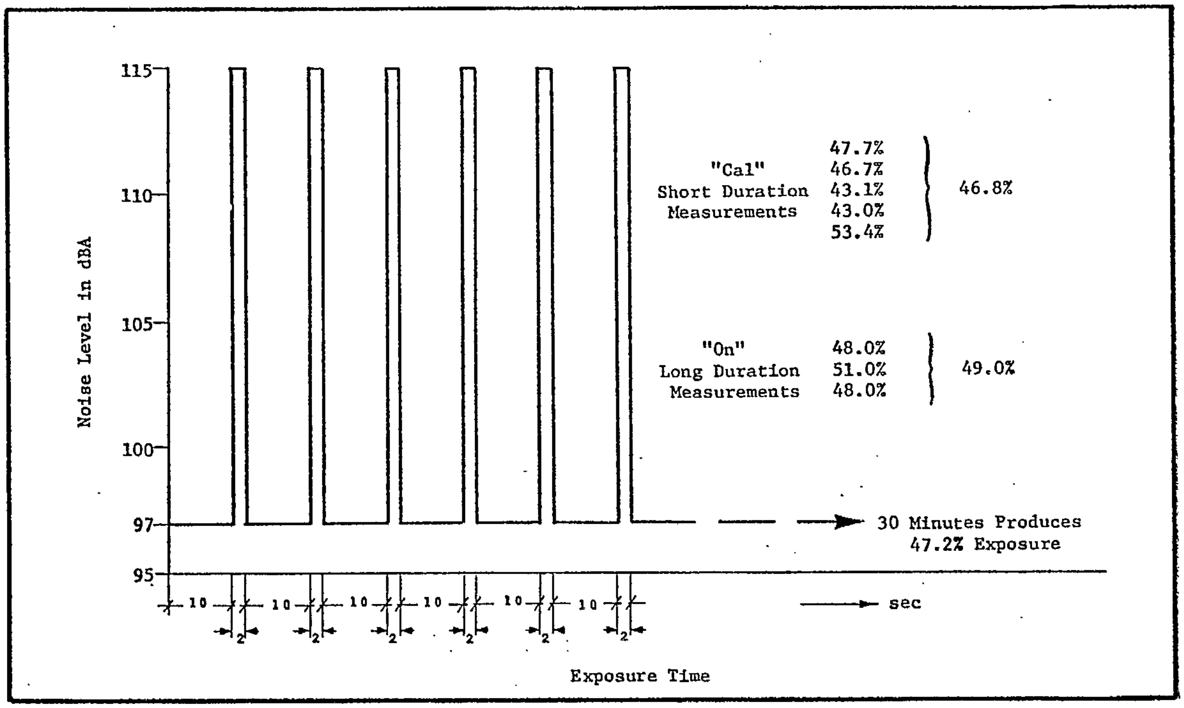

Figure 7: Noise Burst Test with 97 dBA Background. (Condenser Microphone Type 4125 mounted directly on Noise Dose Meter).

3.6 Errors of Microphone Position

Industrial testing showed possible errors due to body shielding and reflection effects (4). Industrial tests also showed that highly directional sound fields can produce differences depending upon the microphone position. The Personal Noise Dose Meter should be mounted near the operator's ear.

4. CONCLUSIONS

1. The low-level detector should be improved. B and K claim inhibition of <89 dBA (Figure 1), but this was not correct. The integration was inhibited at 92 dBA (see Figures 3, 4 and 5).

2. For sound level range the factory claims: "90 dBA to 115 dBA in accordance with OSHA requirements (to 125 dBA including 10 dB crest factor allowance at 1 dB error)". But according to our tests the Personal Noise Dose Meter counts over 115 dBA (Figures 3 and 4). At rock drilling machines, the Dose Meter measures the value >115 dBA contrary to the OSHA law. Since 115 dBA is the maximum allowable, the instrument should stop recording and not allow exposure readings to be taken above the safe limit. This would ensure that action would be taken to correct the problem since all one needs to know in such a situation is that 115 dBA is being exceeded. Any exposure reading is insignificant compared to the fact that a permissible limit has been exceeded. It is clear that only a qualified person can carry out the test procedures.
3. The tests showed that there were no essential differences between the Dose Meter readings and calculated exposure based upon sound level meter data.

5. ACKNOWLEDGEMENTS

B. Brownlee and B. Fulcher, Bruel and Kjaer Canada Limited, Bramalea, Ontario, are thanked for lending the Personal Noise Dose Meter to be tested. Dr. Gibbs, Director of Occupational Health and Safety Unit, Institute for Mineral Industry Research, McGill University, lent the Random Noise Generator, amplifier and loudspeaker for testing.

The author acknowledges the contribution of R. Tervo, Research Scientist, Elliot Lake Laboratory, and of H. Montone and R. Regan who provided technical assistance.

2. For sound level range the factory claims: "90 dBA to 115 dBA in accordance with OSHA requirements (to 125 dBA including 10 dB crest factor allowance at 1 dB error)". ~~Also in our tests~~ Our tests confirmed that the Personal Noise Meter counts over 115 dBA (Figures 3 and 4); ~~It~~ it would, however, be better if the upper limit was 115 dBA because of simpler interpretation of results. Any exposure reading over 115 dBA is insignificant compared to the fact that a permissible limit has been exceeded. It is clear that only a qualified person can carry out the test procedures and clarify results.

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