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Noise Dosimeters: Past, Present, and Future

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NOISE DOSIMETERS: PAST, PRESENT, AND FUTURE

by

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ABSTRACT

An important, advance in instrumentation for the occupational health and safety field has been the introduction of the personnel audio noise dosimeter. The audio dosimeter is used to measure the noise exposure of personnel subject to high noise,levels during the course of a working day. This paper deals with the design, evaluation, usage, and future of personal noise dosimeters.

INTRODUCTION

Noise, when prevalent in an environment, can be physiologically harmful to man. It is known that long-term exposure to moderately loud noise (90 dBA or greater) can deteriorate man's hearing.

Excessive occupational noise, besides being injurious to a worker's health, can constitute a safety hazard when it interferes with communications or reception of important warning signals. From the employer's viewpoint, it means,a loss in efficiency and productivity as well as the added expense of hearing loss compensation.

The advent of Federal legislation dealing with the regulation of noise is evidence that the Government is concerned with this problem. 'Both the Occupational Safety and Health, Act of 1970 and the Federal Coal Mine Healthand Safety Act of 1969 adopted the Walsh Healy noise criteria as the heart of its standards.

This criteria, shown in table 1, is an attempt to quantify the maximum allowable noise levels versus exposure time that; will not be harmful to man. For example, exposure to a noise level of 90 dBA is allowed for a full 8-hour work shift. Exposure to a noise level of 115 dBA is allowed for 15 minutes of the total work shift. This criteria also stipulates that an employee is not to be exposed to noise levels in excess of 115 dBA. For the purpose of enforcement, the noise standard is considered violated if a man's multiple noise exposure exceeds 1 (or 100%) as computed from equation 1.

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$$\text{Multiple Noise Exposure} = \frac{C_1}{T_1} + \frac{C_2}{T_2} + \frac{C_3}{T_3} + \ldots \quad (1)$$

Where C_1 = Actual exposure time at noise level L_1

C_2 = Actual exposure time at noise level L_2

T_1 = Permissible exposure time at noise level L_1

T_2 = Permissible exposure time at noise level L_2

TABLE 1. - Permissible noise exposure

Duration per day (hours)	Noise level (dBA)
8	90
6	92
4	95
3	97
2	100
l-1/2	102
1	105
3/4	107
l/2	110
l/4 or less	115

Determination of compliance to, the noise regulation entails then conducting of a noise survey for each worker. The conventional method of conducting a noise survey consists of performing a time-noise level study of a worker during his normal shift. This involves monitoring each noise' level to which he is exposed and recording each exposure time. This necessitates the use of a sound level meter to measure noise levels and a stopwatch to measure time. A simplified block diagram of a typical sound level meter is shown in figure 1. The instrument basically consists of an omnidirectional microphone, calibrated attenuator, amplifier, weighting networks,and a meter for indicating the root-mean-square (rms) sound pressure level.

The weighting networks provide three standard sound level meter frequency responses A,- B, and C. These responses and tolerances are defined in the American National Standards Institute (ANSI) Specification S1.4-1971. The tolerances are classified as Types I, II, or III with Type I being the most

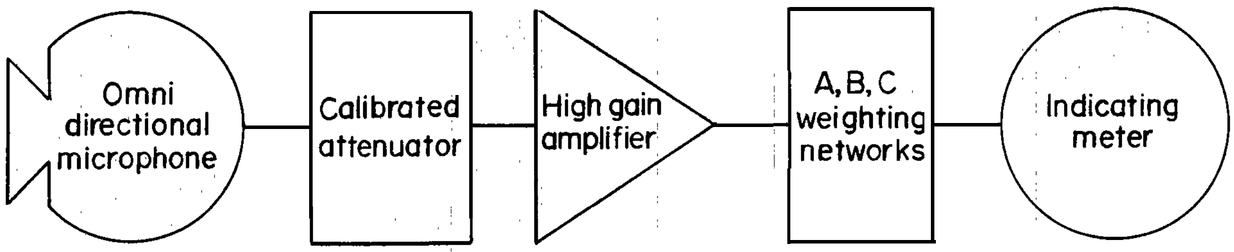

FIGURE. 1. - Simplified block diagram of a sound level meter.

precise. In order to be used in Occupational Safety and Health Administration (OSHA) type surveys, the tolerance must meet those of a Type II instrument or better and the A-weighting network must be used. Sound level meters cost from approximately $200 to $1,000 depending on the accuracy and sophistication.

DOSIMETER DEVELOPMENT

The concept of dosimetry is not a new one, nor is it unique to the monitoring of noise exposure. In general terms, a dosimeter is a device capable of measuring the total dosage or quantity of radiation received by an individual over an extended period of time. The 'radiation monitored could be X-rays, alpha-rays, toxic gases, or perhaps noise:. For years, dosimeters have been used to measure the accumulated exposure individuals have obtained due to atomic radiation.

Only recently has the dosimeter concept been applied with some vigor to the field of noise exposure. Although patents were issued for the noise dosimeter as early as the 1950's, it was only with the introduction of micro-electronic technology that a practical small size, instrument could be produced.

The conventional noise survey, while accurate and somewhat representative, presents several difficulties., These factors fall into three categories: problems due to variations in the sound field, problems encountered in making measurements, and the introduction of human error into the survey. The presence of a man conductinga survey may cause pertubations in the sound field: The noise sources may have sound level and frequency fluctuations and the worker's orientation to these noise sources may vary. These fluctuations and changes in noise level may not be accounted for in the overall measurement.. When conducting a noise survey, the man who is being surveyed may not be in an accessible location and, as in the case of heavy machinery, it may be a safety hazard for a person to conduct a survey on moving, machinery.

Conducting a thorough survey is a tedious and time-consuming procedure. As time progresses, the person conducting the survey may become tired and distracted, thus introducing a significant error 'into the measurements* Variations in the survey procedure from person to person may also introduce error into the final results. There are quite a number of factors which can complicate a noise survey being performed with a sound level meter. For these reasons, the personal audio dosimeter was developed.

The audio dosimeter found on the market today is about as large as a package of cigarettes and weight approximately 10 ounces. A unit of this size lends itself quite readily to be worn for a full work shift. Figure 2 shows a simplified block diagram of a typical dosimeter. On all dosimeters, an omnidirectional microphone is used. The microphone responds to dynamic pressure variations, the output: being an electrical signal proportional to the sound pressure. The output signal of the microphone is fed into an attenuator and A-weighted network. The A-weighted filter meets the requirements for a Type II sound level meter as specified in ANSI Specification 51.4-1971. This A-weighted filter simulates the frequency response of the human ear so that the measured sound approximates that as would be heard by the worker. At this point, the dosimeter senses for a 115 dBA level. If a 115 dBA level is encountered, an indicating device or storage devices is activated. The next section is a filtering network that selectively eliminates any level less than 90 dBA. Since levels less than 90 dBA are not included in the calculation of noise exposure, they must be eliminated so that then dosimeter does not accumulate them. In the next section, the dosimeter ccmputes the dosage comparable to that obtained by ,a time-noise level study using a sound level meter. The final section of the dosimeter is the recording and integrator section. Here the dosage is stored, updated, and made available for display.

In addition to the electrical requirements for an audio dosimeter as listed above, there are also practical requirements,. They are:

1. Ear level measurement--The dosimeter must be capable of measuring the typical noise to which the person is exposed.

2. Continuous recording--The dosimeter must measure, calculate, and store the noise exposure for a worker's full shift.

3. Cutoff below 90 dBA--Since noise levels less than 90 dBA do not enter into the calculation of the multiple noise exposure figure, the dosimeter must not include it in its calculations.

4. Calculate exposure ratios--It must calculate C/T ratios equivalent to those obtained by using a sound level meter.

5. Add 8-hour total--The dosimeter must integrate over the total 8-hour shift.

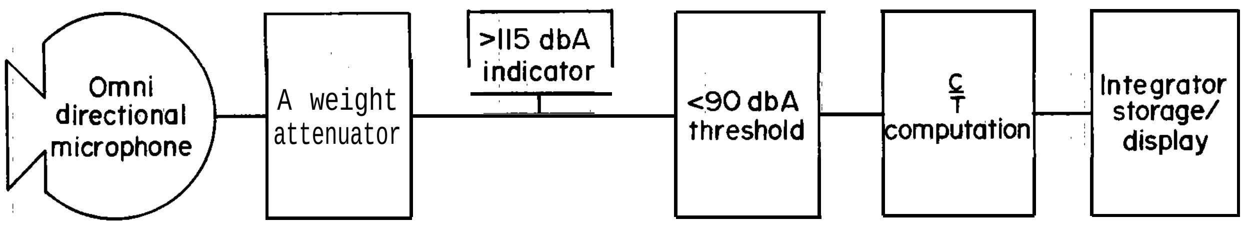

FIGURE 2. - Simplified block diagram of a dosimeter.

6. Indicate any exposure over 115 dBA--This is necessary so that the wearer knows that he is or has been exposed to a sound pressure level of 115 dBA or greater in magnitude:

7. Compactness--The unit should be as small and lightweight as possible. Since a person will be wearing it for a full work shift, it should be of no discomfort to him.

8. Accuracy standards compliance--Since there are no specific standards written for personal audio dosimeters, the practice has been for the dosimeter to meet the A-weighted tolerance for a Type II sound level meter per ANSI Standard S1.4-1971 and other applicable specifications.

9. Government acceptance--As stated in the Coal Mine Health and Safety Act of 1969, any noise measuring device must meet) two criteria: (a) approval under Schedule 2G for intrinsic safety and (b) the A-weighted tolerances for a Type II sound level meter as per ANSI Specification S1.4-1971.

In addition to the aforementioned requirements, there are other desirable features which should be incorporated into the practical dosimeter design. They are:

1. Controlled access to data--It may be desirable that only authorized people have access to the final noise exposure figures.

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2. Durability--The dosimeter should be housed in a durable case so that it can survive the jostling and impacting found in industrial environments.

3. Resistance to temperature, humidity, magnetic fields, and other environmental conditions--The dosimeter should be insensitive to those environmental conditions which are often found in industrial environments.

4. Microphone requirements--The microphone must be linear over a high dynamic range.

5. Low power requirements--Since the dosimeters are portable, they are battery operated. For maximum battery life, a low current drain is necessary*

6. Battery check circuitry--The inspector should be provided with a means to determine if the batteries are capable 'of powering the unit for a full shift.

7. Minimum calibration-The dosimeters should be capable of being field calibrated so that the inspector can tell if then unit is functioning correctly.

8. Simplicity of operation--The unit should be simple to operate to prevent incorrect usage.

Many of these requirements and desirable features have been incorporated in commercially available instruments. Basically, there are two distinct types of dosimeters being marketed. The first type consists of a small, compact (5"X3"X2") unit weighing approximately 10 ounces. It has as its main feature an integral noise exposure readout. The second type of dosimeter consists of two parts, a small monitor and a much larger and separate readout. Each type has its own inherent advantages and disadvantages. The advantage of the first type is that a person can easily carry all of the necessary instrumentation necessary to give an on-the-spot noise exposure reading. The advantage of the second type is that a number of monitors may be operated from a single readout unit. This may result in a monetary savings. The dosimeter buyer should be well aware of his needs before deciding which type to purchase.

Frequent calibration of dosimeters is essential if accurate results are to be obtained. A user should be able to tell if the dosimeter is operating correctly prior to use. Most manufacturers calibrate the dosimeter by exposing it to a predetermined pure tone acoustic signal of a known sound pressure for a specific length of time resulting in a predetermined noise exposure reading. This method is accurate but it falls short in that it is only valid for one particular frequency. It does not indicate correct operation of the dosimeter throughout the remainder of the audio spectrum. It is our suggestion that a standard be adopted specifying field calibration techniques for dosimeters.

COMMERCIALLY AVAILABLE DOSIMETERS

Figure 3 illustrates a dosimeter of the first type, one with a built-in readout. It is a Columbia Research Laboratory Model SPL-105.[3] Its dimensions are 2-5/8"xl-3/16"X4-l/2" and the weight is 3/4 pound. It is a typical example of the self-contained dosimeter. This unit can be carried in one's shirt pocket and may be purchased with an integral microphone or with one connected by an extension cable. The noise exposure readout may be obtained by opening the front case and reading the display (as seen in figure 4). Other dosimeters of this type currently being marketed are:

B&K Model 4425 Personal Noise Dosimeter

Edmont-Wilson Co. Model 60-520 Sound Dosimeter

Quest Electronics Model M6 Sound Hazard Integrator

Triplett Corporation Model 376 Personal Noise Dosimeter

Welsh Manufacturing Co. Model 9702 Pocket Size Noise Dosimeter

The range in price of these instruments is $325 to $800 with the average cost at $400.

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[3] Reference-to specific brands, equipment, or trade names in this report is made only to facilitate understanding and does not constitute an endorsement by the Mining Enforcement and Safety Administration.

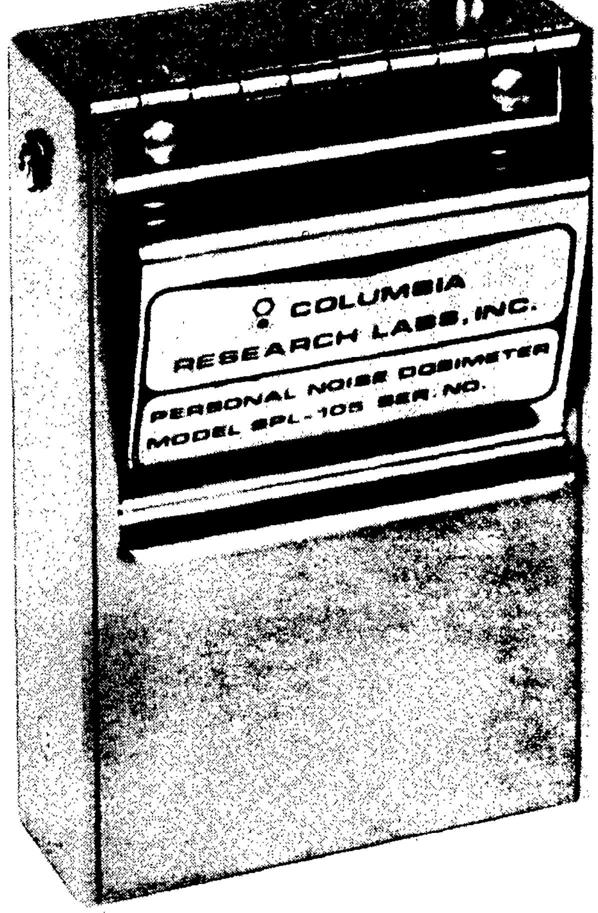

FIGURE 3. - Columbia Laboratory Model SPL-105 dosimeter.

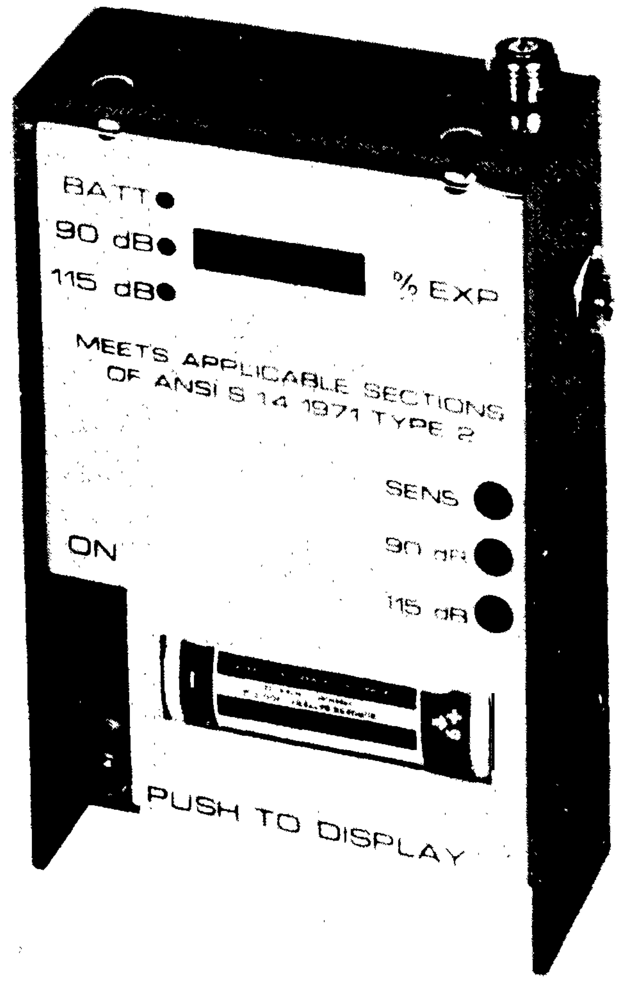

FIGURE 4. - View of Columbia Laboratory SPL-105 with case opened.

The second grouping of dosimeters, those with separate monitors and readouts, can further be divided into two groups: one with electronic exposure accumulation and one with electrochemical exposure accumulation.

A typical example of electronic accumulation and storage type dosimeters is illustrated in figures 5 and 6. It is the General Radio Model 1944 noise dosimeter (fig. 5) and readout (fig. 6). The readout unit contains a built-in acoustic calibrator and battery check circuitry. One readout may operate a number of monitors and the noise exposure data may be read at any time without erasing the stored data. Other dosimeters of this type currently being marketed are:

Bendix Model 1150 Noise Exposure Monitor and Readout

Tracoustics Model ND-100 Personal Integrating Noise Dosimeter

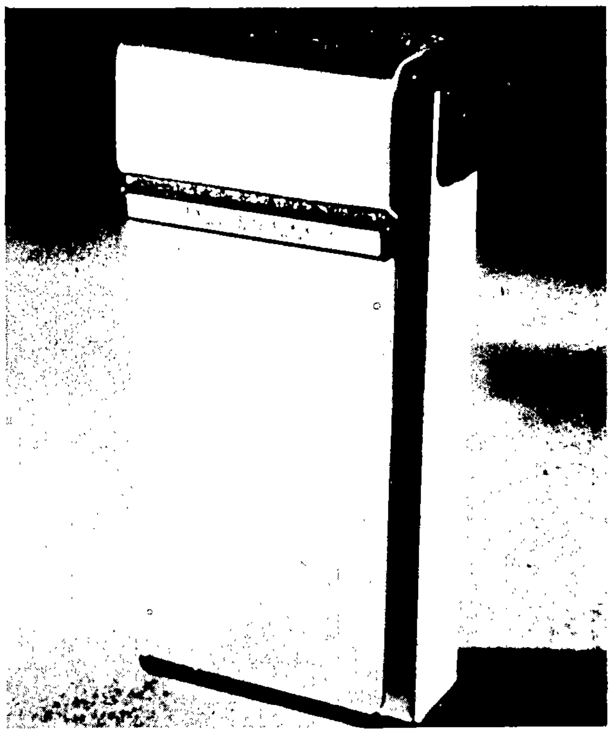

FIGURE 5. - General Radio Model 1944 dosimeter model.

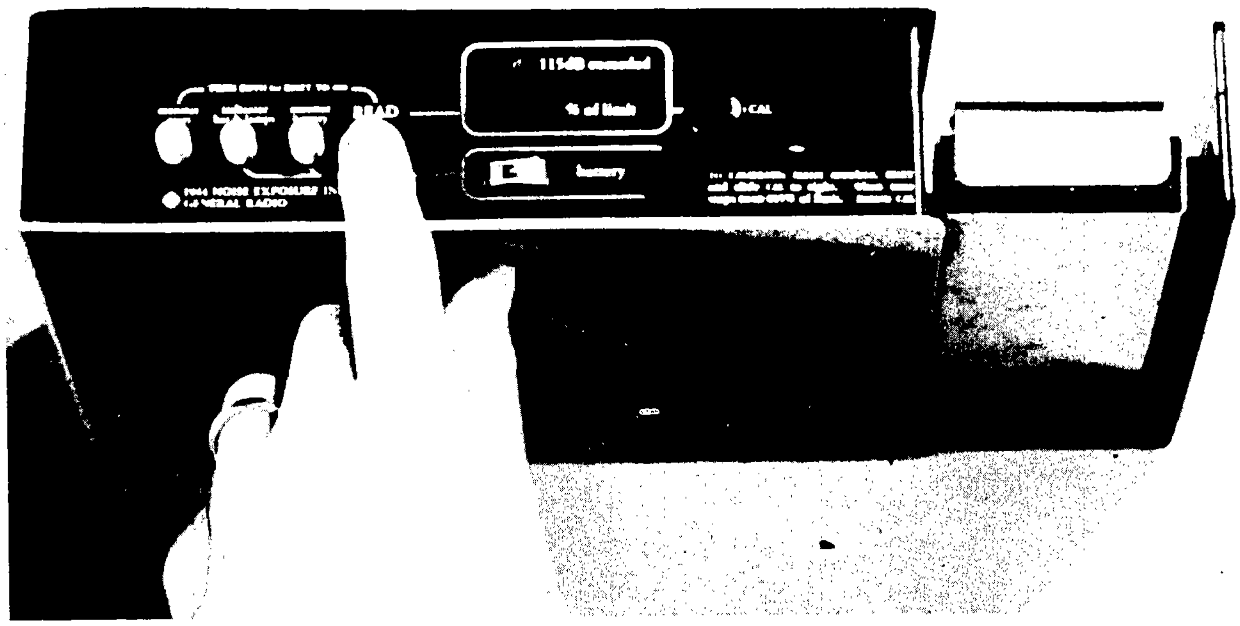

FIGURE 6. - General Radio dosimeter readout.

The total cost for the monitor and readout is approximately $900; $600 for the monitor and $300 for the readout.

An example of the electrochemical accumulation and storage type is shown in figures 7 and 8. It is the E. I. Du Pont Model D-100 noise dosimeter

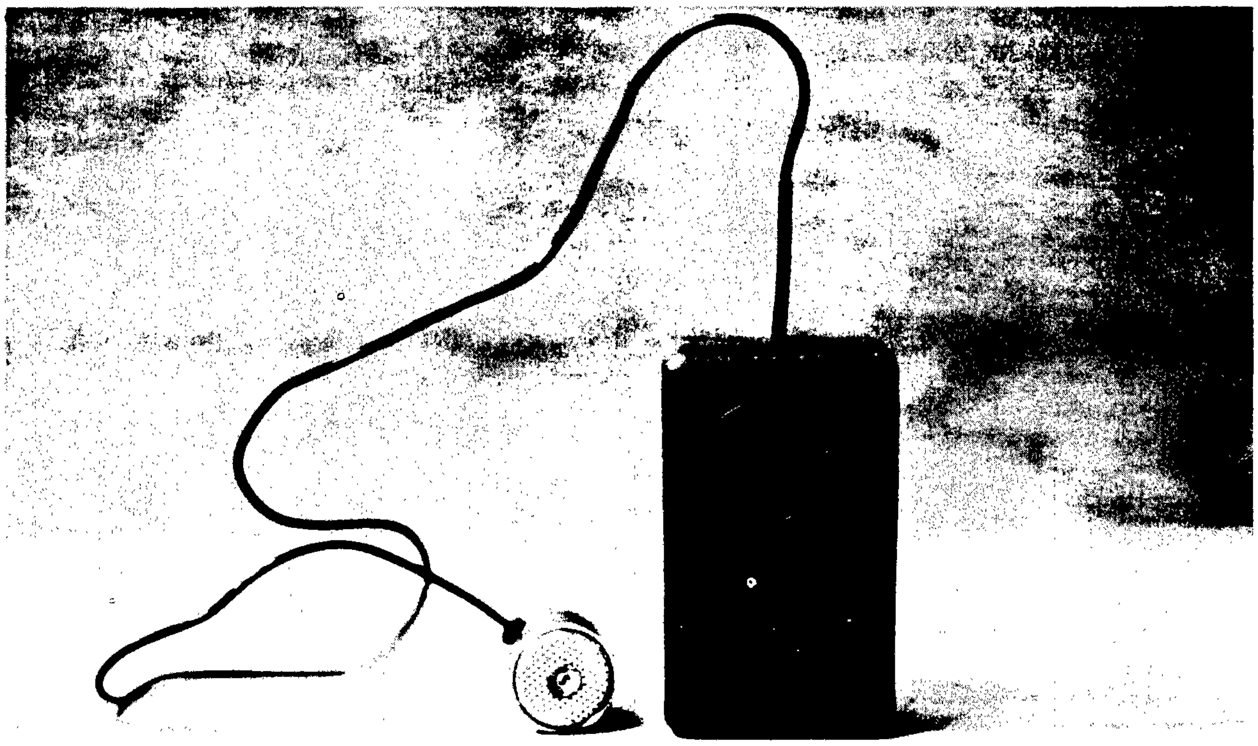

FIGURE 7. - Du Pont Model D-100 dosimeter monitor.

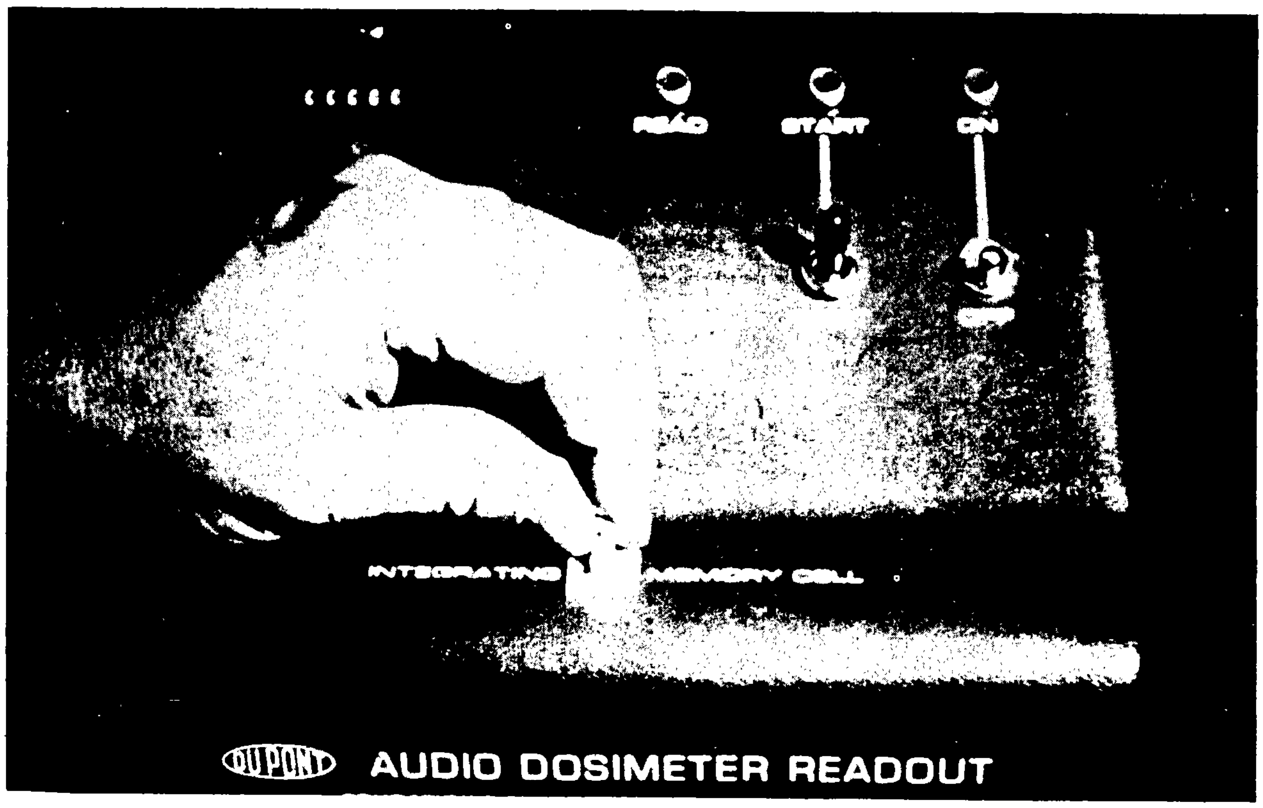

FIGURE 8. - Du Pont dosimeter readout.

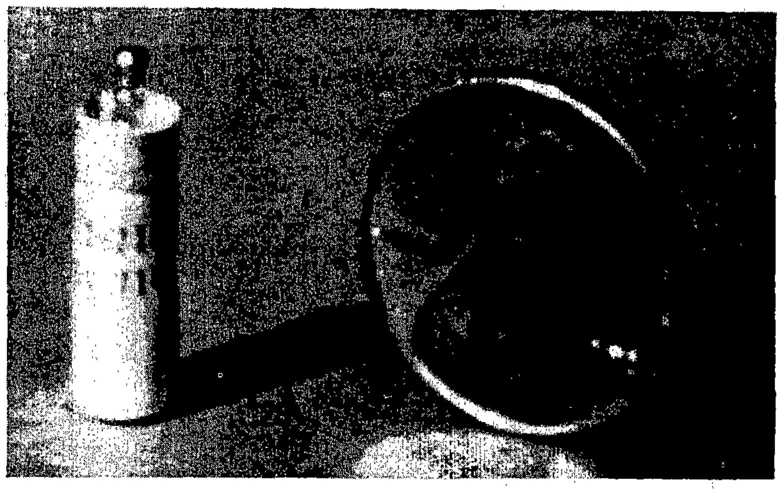

FIGURE 9; - Du Pont integratini chemical cell.

(fig. 7) and readout (fig. 8). The monitor contains the battery check circuitry, over 115 dBA light and an electrochemical storage cell (fig. 9). In order to read the noise exposure, the cell is removed from the monitor, placed in the readout, and then read out on the digital display.

The drawback to this system is that once the electrochemical cell has been read, the memory is erased. The memory cells can be reused. Du Pont is the only manufacturer currently marketing this type of unit. The cost for a monitor and readout is approximately $750.

LIMITATIONS OF DOSIMETER

Unfortunately, the dosimeter, like everything else, has its limitations. Its most desirable feature, simplicity of use, can sometimes be its biggest pitfall. The ease with which a noise survey can be, conducted often lulls the user into a false sense of security. Since 'noise exposure measurements are done automatically, one readily accepts the reliability of the readings. However, many factors can introduce errors into the' dosimeter reading. Some of these factors are:

1. Wind noise--A 12 mile per hour wind blowing across the microphone can give false readings in excess of 90 dBA. This factor is especially important for employees operating open cab vehicles or those working in outside environments. It may necessitate the use of windscreens on the microphone.

2. Body shielding--The shielding of the dosimeter microphone from the noise source by the worker's body can many times lower the readings that the dosimeter accumulates. This is particularly true for free field conditions (environments with little or no' reflecting surfaces) and for highly directional noise sources.

3. Extraneous noises--False localized noises such as loud talking, singing, or whistling very near to the microphone can cause erroneous readings in excess of 90 dBA. Prolonged (1 second or more) scraping of the microphone against surrounding objects can trip the "over 115 dBA" light indicating wrongly that the worker has been exposed to noise levels in excess of 115 dBA during his work shift.

4. Calibration drift--Because the measurements are continually taken for an extended period of time, small errors introduced because of instrument

drift can drastically affect the accuracy of the accumulated reading. For example, an error of only 2 dBA in measuring noise level can cause an error of 33% in the noise exposure reading.

Thus, by accepting this tool which makes possible more efficient noise surveys, one must also accept its limitations. Only by being aware of the dosimeter's shortcomings can one utilize it in an intelligent manner. As with any tool, its effectiveness is dictated mainly by the skill of the user.

FUTURE OF THE NOISE DOSIMETER

Presently the noise dosimeter has been officially accepted for use in the enforcement of noise regulations by several Federal 'Government agencies. Some of these include the Department of Labor, Occupational Safety and Health Administration, and the Department of Interior, Mining Enforcement and Safety Administration. In addition, more and more State Governments, concerned with occupational health, are accepting the noise dosimeters as a legitimate noise survey tool. In line with this, proliferation of the instrument is also seen in many sections of private industry.

In the ensuing years, as micro-microelectronics' begin to shrink the size and reduce the price of the noise dosimeter, it can be expected to supersede the sound level meter as a routine noise survey device. This does not imply that the sound level meter, or its more sophisticated variations, will disappear from the field of noise measurement. It will, however, be progressively relegated to the more exacting task of precise noise measurements for engineering noise control.

Along with the inevitable reduction in size, the second generation noise dosimeter will increase in complexity allowing the collection of more pertinent noise data. For example, the Bureau of Mines has recently developed the Time Resolved Noise Dosimeter. This device not only; reads out the noise exposure of a worker, but also gives a complete histogram of noise level versus time for the entire work shift. In physical Appearance, it is about the same weight and size as the presently used dosimeter. When worn by the worker, it samples the environmental noise level every 30 seconds and stores this level serially with respects to time. When read out through an appropriate interface and x-y plotter, a dBA ,level versus time plot is given, at 30-second intervals, for an 8-hour work shift. In addition, the noise exposure of the employee is also given.' This prototype, Time Resolved Noise Dosimeter, is perhaps a forerunner of things to come in the field of poise, dosimetry.

No matter which perspective; one uses, it is apparent that the concept of the noise dosimeter is here to stay. The instrument's ability to record continuously and calculate noise exposure with relative accuracy and a minimum of experimental supervision assures its place in the realm of noise measuring instruments: