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The Contribution of Personal Radios to the Noise Exposure of Employees at One Industrial Facility

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An investigation of the contribution made to an employee's noise dose from the output of personal radios was performed at a North Carolina textile manufacturing facility where the daily time-weighted average sound level (TWA) was approximately 87 dB, A-weighted sound pressure level [dB(A)]. The measured mean equivalent diffuse field output level of the personal radios was determined to be 83 dB(A) with a range from 70 to 98 dB(A). The daily TWA of a typical employee who did not use a personal radio was determined to be 86.6 dB(A), whereas the exposure of personal radio users was 88.5 dB(A) — an increase of 1.9 dB(A). This increase in exposure was estimated to result in 4 dB of additional permanent noise-induced hearing loss at 4 kHz for the 5th percentile (most sensitive portion) of the population after 20 years of exposure beginning at age 20. The study concluded that the additional contribution of the personal radios to the employee's daily TWA did not pose a significant additional threat to their hearing. Specific hearing conservation criteria, however, were recommended for continuation of personal radio use at the facility.

Introduction

In 1979 the Sony Corporation introduced the personal portable radio unit, commonly referred to as "the Walkman®" to the commercial market. Since that time these units have been worn by runners, joggers and cyclists during their workouts, by motorists while driving, by spectators at athletic events, and more recently, by employees while performing their jobs.[1,2] Along with the increased availability of the Walkman, other styles of reasonably priced personal radios have become available resulting in a dramatic increase in their use in public areas and while on the job.

The increased utilization of personal radios — both of the earphone and "boom box" variety — and their use in the public sector have given rise to annoyance complaints from citizens and concern by public safety officials. Several governing bodies have responded by passing ordinances and legislation to control the use of these units. The Town of Woodbridge, New Jersey passed an ordinance in 1982 prohibiting the playing of personal radios by any individual while on the streets of their city.[3,4] Kidder reported that the states of Massachusetts, Illinois and Pennsylvania have passed legislation prohibiting the use of these units while operating a motor vehicle.[4]

Use of personal radios in the workplace also has become controversial. Although in low-level noise environments [≤80 dB(A)] music can be beneficial in the areas of error reduction, output, and quality and staff turnover,[5] it can interfere with work and/or create hazards — especially in high-noise environments. In 1982 the United States Postal Service, with few exceptions, banned the use of portable radio headset devices by their employees while on the job.[6]

In many other organizations, however, radio use has been allowed.

It has only been in the past few years that researchers in the United States have begun to investigate the potentially harmful effects from the use of personal radios. One research effort reported "At a volume setting of 8 and above, the intensity level was predominantly in excess of 115 dB(A) for all units tested."[7] These researchers used a standard audiometric coupler to measure personal radio output levels. In reporting their findings it appears that they neglected to account for the transformation of the coupler-recorded sound pressure levels (SPLs) that are required in order to estimate the equivalent diffuse field exposure levels [a correction of from -5 to -15 dB(A)]. The transformation to equivalent diffuse field levels is needed since damage risk criteria are not based upon eardrum SPLs, but rather upon diffuse field measurements taken near the worker's ear or with the worker absent.

A policy decision which permits personal radio use while at work may be a popular one with employees, but the additional contribution of the personal radio to an employee's daily noise dose may increase the noise hazard significantly. Over time, this additional exposure could contribute to a compensable noise-induced permanent threshold shift (NIPTS) for which the employer may be responsible. Alternately, prohibiting personal radio use while at work may reduce management's risk of contributing to a compensable NIPTS, but can negatively impact management-labor relations. Whether or not the consequences of such a decision are tolerable is a difficult question to address.

A procedure for accurately evaluating the contribution of a personal radio to an employee's time-weighted average (TWA) noise exposure would be beneficial to management

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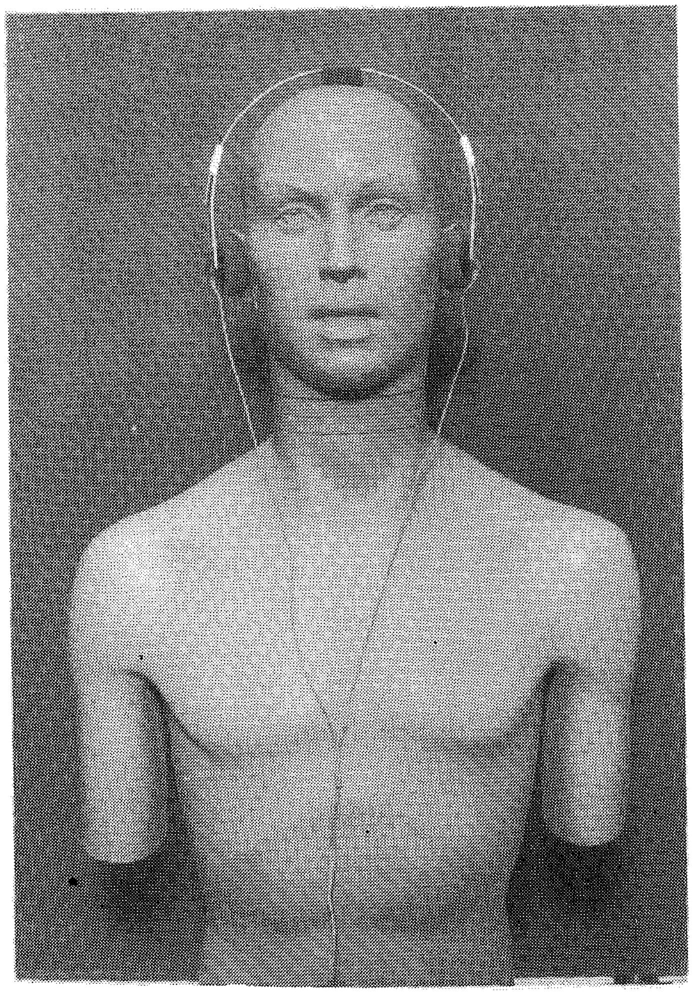


Figure 1 — The KEMAR manikin.

policy makers. The resulting data would not only aid in making a more informed decision regarding radio usage, but these data also could provide justification for retaining or altering existing policies. The objective of this study was to establish a procedure for collecting in-the-field data on the potential hazard to employees' hearing that results from personal radio usage and to implement that procedure in order to study the effects of such usage at one production facility.

In addition to the data presented herein, the insertion loss characteristics of personal radio headsets have also been investigated by the authors. That study concluded that personal radio headsets do not significantly modify external sound fields as perceived at the eardrum.[8,9]

Use of an Acoustic Manikin

An accurate and well-defined device for measuring the output levels of personal radios was needed to evaluate their contribution to an individual's noise exposure. The Knowles Electronics Corporation introduced the Knowles Electronic Manikin for Acoustic Research (KEMAR) in 1972 as a device to assist research audiologists and hearing aid manufacturers in the design of hearing assistive devices (Figure 1). Extensive research was conducted to create a device that could simulate the acoustical characteristics of the human ear adequately and the average anatomical dimensions of the head and upper body.[10-12]

A sound level measuring system using KEMAR was devised to record the acoustic measurements for this research.[8] Laboratory testing was performed on KEMAR to verify the eardrum-to-diffuse-field transformation ratio and performance of the associated electronics,[8] and to compare the findings with those previously published.[13]

Field Study

Data Collection Procedure

A field investigation was undertaken to determine the output sound levels at which personal radios typically were played by employees at a North Carolina textile manufacturing plant. The daily TWA of a typical employee at this facility originally was reported by management to be between 85 and 90 dB(A).

Two different production areas at two separate plant locations were surveyed. The plants will be referred to as "Plant A" and "Plant B"; the related production areas will be referred to as Areas A1, A2, B1 and B2, respectively.

Initially 28 personal radios were collected from a predominantly white, all-female employee population engaged in sewing operations. Nine of the personal radios evaluated included a tape cassette as part of the equipment. Each of the personal radios had some form of aural coupling mechanism, such as an ear canal insert or supra-aural headset. The sample population had a mean age of 36 years and a mean time of service of 9 years.

Care was taken to minimize the contamination of this data set due to employees changing the volume levels of their personal radios prior to the collection of the units for the initial data collection effort. This was achieved by having three separate investigators simultaneously remove the personal radios from different segments of the employee population approximately 3 hr after the beginning of the first work shift and before the workforce could become aware that the study was in progress.

The collected headsets were placed on KEMAR in a conference room remote from the manufacturing environment. The ear canal sound levels in dB(A) were recorded and then adjusted to estimate equivalent diffuse field levels using a previously established transformation ratio for KEMAR. The background sound level in the conference room was measured and found to be at least 10 dB(A) below the output sound levels for all radios investigated. This assured that the recorded sound levels were uncontaminated by ambient room noise.

A second set of ten additional personal radio units were collected on the following workday. The output sound levels were determined by moving KEMAR (on a dolly) to an aisle location adjacent to the employee work station. KEMAR was utilized to record the A- and C-weighted SPLs of the workplace and the A-weighted SPLs of the workplace + personal radio system. The A-weighted personal radio output

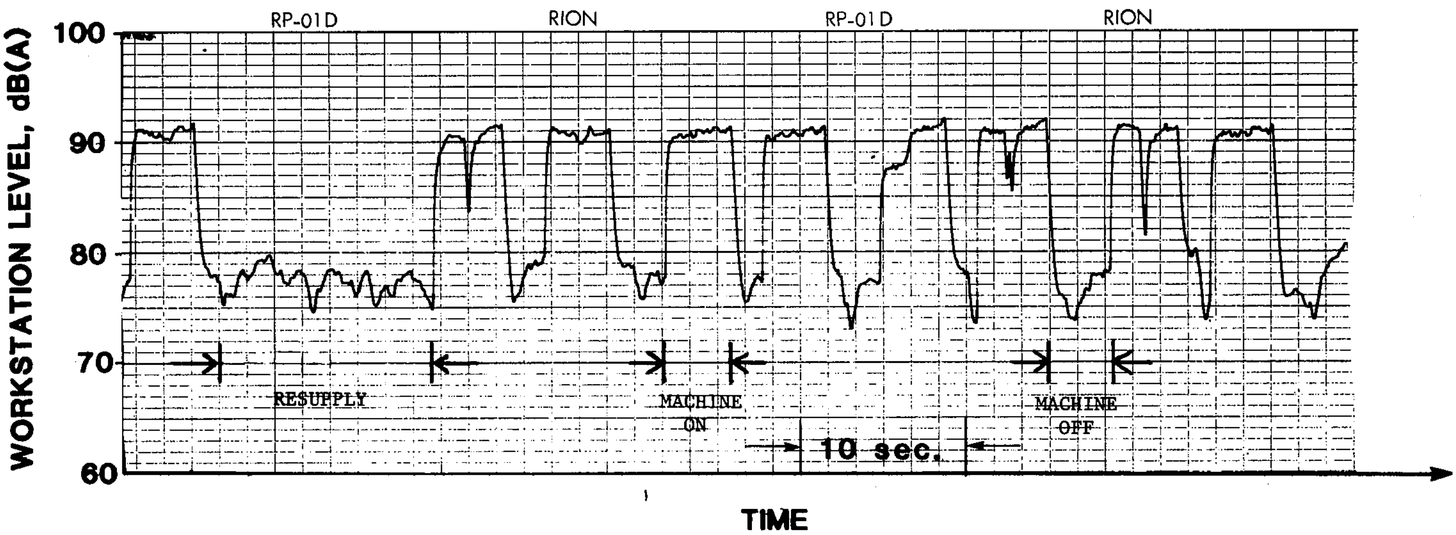


Figure 2 — Typical noise-level-time history at a sewing workstation.

level was estimated by subtracting (on an energy basis) the A-weighted workplace SPL from the A-weighted workplace + personal radio system SPL for each sample. The data then were transformed to equivalent diffuse field values.

The novelty of KEMAR being moved about the production areas increased the difficulty of selecting personal radios before the user became aware of the study in progress. The observation that one employee attempted to lower the volume setting of a personal radio prior to evaluation resulted in the termination of this part of the experiment after only 10 samples had been collected. It is possible that a portion of this data set was contaminated. Subsequent analyses, however, indicated no significant differences between the mean dB(A) readings for this data set and the other two data sets involved in the study.

Work Environment Sound Survey

A sound survey of the noise environment at each of the four production areas was conducted using a RION precision sound level meter (Model NA-61) with an attached octave-band filter (Model NX-01A). A- and C-weighted and octave band SPLs were measured at selected aisle locations and at certain employee workstations during the course of sewing operations. In addition, sample A-weighted SPL recordings of the sewing production machine noise were obtained using a RION graphic level recorder (Model LR-04). A typical time history appears in Figure 2. For the noise environment investigated, the C-weighted SPLs were typically 3-4 dB higher than the measured dB(A) levels.

Field Study Results

Personal Radio Output Levels

The three sets of predicted equivalent diffuse field personal radio output sound level data are shown in Table I and Figure 3. The two initial data sets were from Plants A and B where the personal radio units were removed from the employees and carried to a remote location; their output was evaluated using KEMAR (data sets A and B in quiet). The third data set was the result of moving KEMAR about both production Areas A and B and evaluating the personal radio outputs at the employee's workstation (data set A&B in noise). The mean equivalent diffuse field level for all samples was 83 dB(A) with a range of 28 dB(A). The wide range indicates that strong differences existed in the preferred listening level of the employees since a significant correlation was not found between the existing background sound levels and observed personal radio volume level for the environment studied.

The data shown in Table I and Figure 3 indicate that the typical employee at Plant A listened to their personal radio at 82.7 dB(A), which is roughly equivalent to the mean equivalent diffuse field across all 38 samples. The average employees at Plant B listened to their personal radios at 85.3 dB(A), approximately 2 dB(A) higher than the mean equivalent diffuse field level for all 38 samples. The workstation-recorded data (A&B in noise) show the mean listening level to be 81.7 dB(A), 1 dB(A) below the mean equivalent diffuse field level for all 38 samples. Based on an Analysis of Var-

TABLE I
Equivalent Diffuse Field Personal Radio Output Level, dB(A)

Location	Number of Subjects	Mean	Median	Range	SD[A]
All samples	38	83.0	82.0	70 to 98	7.5
Plant A (in quiet)[B]	17	82.7	80.0	72 to 98	8.0
Plant B (in quiet)[B]	11	85.3	84.0	70 to 97	9.0
Plants A and B (in noise)[C]	10	81.7	81.5	74 to 88	4.4

[A]Standard deviation.
[B]Radios removed from employees and measured on KEMAR in remote quiet location.
[C]Radios removed from employees and measured on KEMAR in noise adjacent to employee's workstation (see text).

iance, the mean radio output levels for the three data sets did not differ significantly (95% level of confidence) from each other.

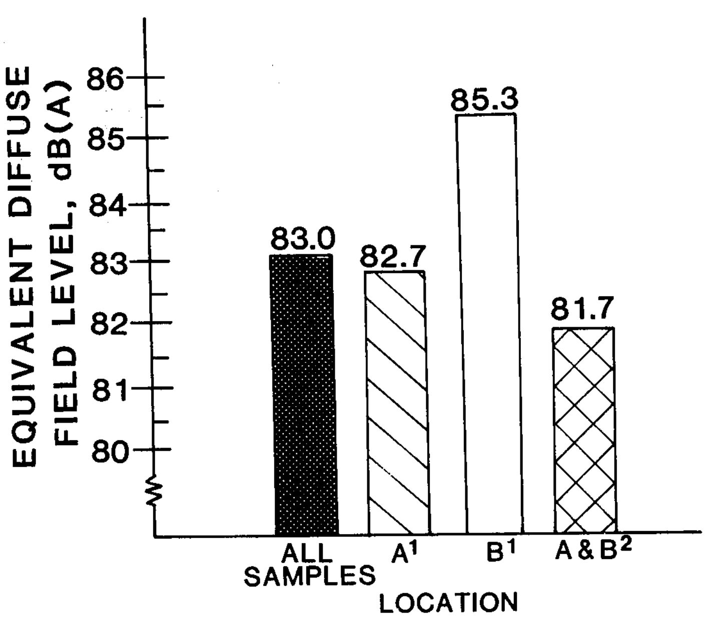
A probability plot of the data for the 38 samples is presented as Figure 4. The normality of the sample was tested by applying the Chi-square goodness-of-fit statistic. The data were found to fit a normal distribution at the 95% confidence level.

Workplace Noise Levels

The results of the workplace aisle noise level measurements are listed in Table II. The results indicate that the mean aisle noise level across all 24 samples was approximately 80 dB(A) with a standard deviation of 3 dB(A). The aisle noise levels for production area B1 were approximately 3 dB(A) higher than the value averaged across all samples. These higher levels may potentially explain the slightly (but not significantly) higher radio listening levels at Plant B than at Plant A (Table I and Figure 3).

Workstation Noise Levels

The results of the workstation noise level measurements during sewing operations are listed in Table III. Table III reveals the mean workstation noise level across all 14 samples to be 89.5 dB(A). The levels are similar in Areas A1, A2 and B1 but are 4-5 dB(A) lower for Area B2. The lower levels were due, in part, to the type of equipment being used, as well as the reduced rate of production in Area B2. At the time of the survey, Area B2 had the largest number of idle machines of all production areas investigated.



¹ – **Measured in quiet room**

² – **Measured at employee workstations**

Figure 3 — Equivalent diffuse field personal radio output sound level for the populations investigated.

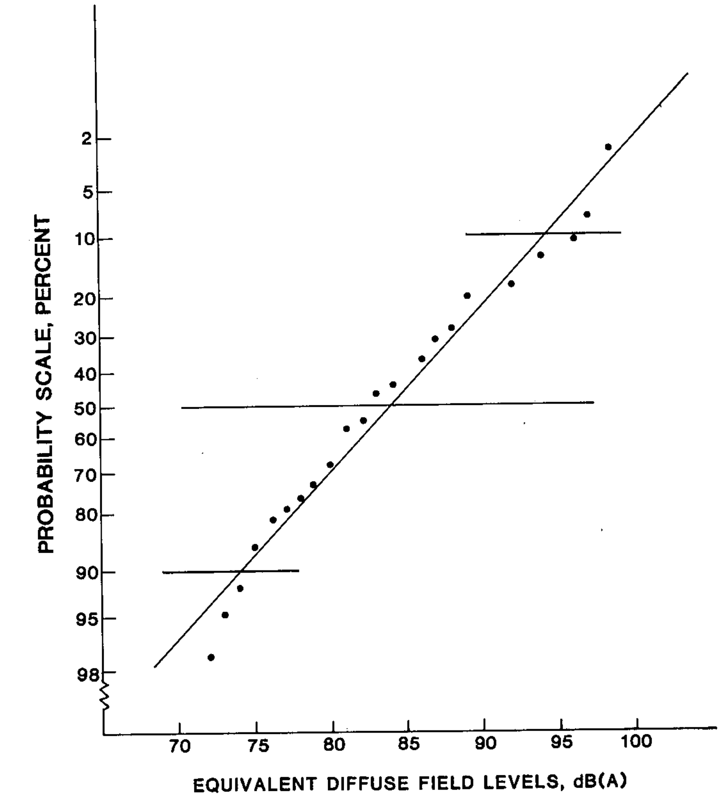


Figure 4 — Probability plot of the equivalent diffuse field personal radio output levels for the total population.

Employee Noise Exposure

A sample noise signature for a typical workstation was presented as Figure 2. With a review of Figure 2, it is apparent that the production cycle for a sewing operation was composed of three distinct components, which we referred to as "machine on," "machine off" and "resupply" periods. The "resupply" period includes the regular activities of one "machine off" period and the time needed for an employee to gather a new bundle of work materials.

An analysis of the machine noise signature recorded at individual workstations was performed to estimate the employee's typical exposure level. The maximum duration of the "machine on" and "machine off" periods were such estimated to be typically 50% of the total workday. With the use of these data, an idealistic graphic representation of the assumed employee noise exposure time history, with and without the effects of a personal radio, was developed. This is presented as Figure 5.

The broken line shown in Figure 5 indicates the assumed exposure level over time for an average employee without a personal radio as 80 dB(A) during the "machine off" period and 90 dB(A) during the "machine on" period. The 80 and 90 dB(A) values are the approximate mean values for the workplace and workstation data across all samples.

The solid line in Figure 5 represents the assumed noise exposure level for an average employee with a personal radio. As expected, there is an increase in the noise exposure level for these employees. Adding the mean equivalent diffuse field across all samples of 83 dB(A) to the 80 dB(A)

TABLE II
Sound Survey Analysis of the Workplace (Aisle) Noise Level, dB(A)

Location	Number of Measurements	Mean	Median	Range	SD[A]
Combined areas	24	79.9	80.0	75 to 85	3.0
Production area A1	4	80.8	-	79 to 82	-
Production area A2	9	78.1	-	75 to 85	-
Production area B1	8	82.9	-	78 to 85	-
Production area B2	3	76.8	-	75 to 77	-

[A]Standard deviation

mean workplace value results in an effective exposure level of 85 dB(A) during the "machine off" period. Similar addition during the "machine on" period results in an effective exposure level of 90.8 dB(A) [83 dB(A) + 90 dB(A)].

The daily noise dose of an employee now can be estimated for a typical work cycle and converted to an 8-hr equivalent TWA as specified in the OSHA noise standard.[14] For an employee using a personal radio the equivalent daily TWA was 88.5 dB(A). The corresponding TWA of an employee without a personal radio was calculated to be 86.6 dB(A).

Predicted Hearing Loss

In order to predict a population's NIPTS for a given noise exposure, the mathematical model defined by the ISO/DIS 1999 Draft International Standard was utilized.[15] The potential NIPTS was determined for the 4 kHz test frequency. The effects of personal radio usage for a 20-year exposure period (no prior noise exposure) were determined for the 5th percentile of the population (most sensitive). The predicted NIPTS for the population without personal radios was 11.4 dB [TWA of 86.6 dB(A)] compared to 15.0 dB [TWA of 88.5 dB(A)] for the same population when personal radio use was included. The increase in predicted NIPTS as a result of personal radio use was approximately 4 dB at 4 kHz.

Summary

The results of this study indicate that the typical employee who regularly uses a personal radio in the noise environment investigated [TWA of 86.6 dB(A)] experiences an increase in the daily mean TWA of 1.9 dB(A). The potential NIPTS from this increase in noise exposure — as determined for the 5th percentile (most sensitive portion) of the population at 4 kHz over 20 years of exposure — is 4 dB. The measured increase in noise exposure is sufficient to place the general population of personal radio users at a slightly greater risk of noise-induced permanent hearing loss. The magnitude of the increase in exposure, however, does not appear to be sufficient to require discontinuation of radio use at this particular manufacturing facility.

The variability between individuals in preferred personal radio listening levels at this facility does require some attention. For 33% of the employee population using personal radios it is predicted that if their radio use continued for eight hours per day on a regular basis, their daily TWA would increase to or exceed 90 dB(A). Therefore, it was recommended that the following steps be taken by managment at this specific facility:

1) Conduct an education program aimed directly at the proper use of personal radios by employees.
2) Audiometric testing that identifies an age corrected NIPTS[16] of 20 dB or greater at any test frequency in either ear would require the discontinuation of personal radio use by the affected individual(s).
3) Conduct an annual audiometric data base analysis[17] with specific attention to the differences between the hearing threshold level changes for the wearers and non-wearers of personal radios. The findings of a significant increase in hearing loss for the personal radio user population as compared to the non-radio users would result in the termination of the use of personal radios at this facility.

Conclusion

This report has focused on the potential for additional hearing damage as a function of personal radio use. Other significant health and safety issues such as distraction and speech interference also may be of concern. The need for further objective testing and evaluation is imperative if questions regarding these issues are to be resolved. Only with the benefit of such research can we be confident that proper decisions are made for the health, safety and job satisfaction of all concerned. Since the use of personal radios for job functions that are categorized as repetitive and do not present a safety threat is desirable from the employees' point of view, such use may be warranted as long as an evaluation of the specific noise conditions is performed and suitable precautions are instituted.

TABLE III
Sound Survey Analysis of the Workstation Noise Levels Recorded During Machine Operation, dB(A)

Location	Number of Measurements	Mean	Median	Range	SD[A]
Combined areas	14	89.5	90.0	79 to 93	3.3
Production area A1	3	89.8	-	88 to 93	-
Production area A2	4	90.0	-	89 to 91	-
Production area B1	5	90.4	-	89 to 91	-
Production area B2	2	85.5	-	79 to 92	-

[A]Standard deviation

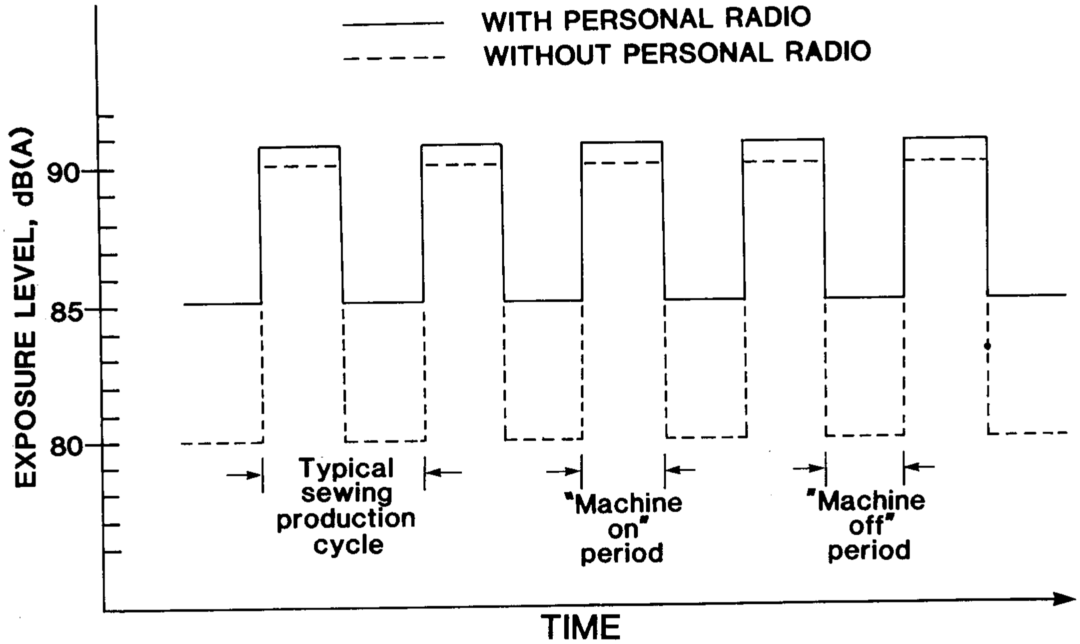


Figure 5 — Assumed ideal machine noise-level-time history cycle with and without the use of a personal radio.

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