AD-766 291

ACOUSTICAL EVALUATION OF THE M60A1 TANK DURING TYPICAL OPERATIONS

Georges R. Garinther, et al

Human Engineering Laboratory
Aberdeen Proving Ground, Maryland

March 1973

U. S. ARMY

Technical Memorandum 6-73

ACOUSTICAL EVALUATION OF THE M60A1 TANK DURING TYPICAL OPERATIONS

Georges R. Garinther
Deane B. Blazie

March 1973
AMCMS Code 728012.12000

HUMAN ENGINEERING LABORATORY

ABERDEEN PROVING GROUND, MARYLAND

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* U. S. Army Human Engineering Laboratory Aberdeen Proving Ground, Maryland 21005	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

ACOUSTICAL EVALUATION OF THE M60A1 TANK DURING TYPICAL OPERATIONS

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

5. AUTHOR(S) *(First name, middle initial, last name)*

Georges R. Garinther
Deane B. Blazie

6. REPORT DATE March 1973	7a. TOTAL NO. OF PAGES 28	7b. NO. OF REFS 3
8a. CONTRACT OR GRANT NO. b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) Technical Memorandum 6-73 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES Details of illustrations in this document may be better studied on microfiche.	12. SPONSORING MILITARY ACTIVITY

13. ABSTRACT

Noise measurements were made in an M60A1 tank during four typical operational days of platoon-size maneuvers. The purpose of this study was to determine the average noise to which personnel are exposed, to assess the hearing hazard during typical tank operations based upon TB MED 251 and the CHABA damage risk criterion, and to evaluate the effectiveness of the attenuation provided by tankers' helmets.

The average sound level of the tank during the operation was 98.5 dBA in the turret and the sound level of the communication system at the ear was about 104 dBA. This study suggests that the primary cause of hearing damage among tank crews is the high speech and noise level produced at the ear by the communication system.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Damage-Risk Criterion						
Hearing						
Noise Measurements						
Speech						
M60A1 Tank						
Hazardous Noise						
Sound Pressure Level						
Hearing Protection						
Human Factors Engineering						

AMCMS Code 728012.12000

Technical Memorandum 6-73

ACOUSTICAL EVALUATION OF THE M60A1 TANK DURING TYPICAL OPERATIONS

Georges R. Garinther
Deane B. Blazie

March 1973

APPROVED: JOHN D. WEISZ
Director
U. S. Army Human Engineering Laboratory

U. S. ARMY HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland

ABSTRACT

Noise measurements were made in an M60A1 tank during four typical operational days of platoon-size maneuvers. The purpose of this study was to determine the average noise to which personnel are exposed, to assess the hearing hazard during typical tank operations based upon TB MED 251 and the CHABA damage risk criterion, and to evaluate the effectiveness of the attenuation provided by tankers' helmets.

The average sound level of the tank during the operation was 98.5 dBA in the turret and the sound level of the communication system at the ear was about 104 dBA. This study suggests that the primary cause of hearing damage among tank crews is the high speech and noise level produced at the ear by the communication system.

CONTENTS

ABSTRACT iii

INTRODUCTION 1

PURPOSE 2

METHOD

Selection of the Tank Exercise 3
Instrumentation 4
Analysis of Data 9

RESULTS 13

DISCUSSION 14

CONCLUSIONS 19

RECOMMENDATIONS 19

REFERENCES 20

FIGURES

1. CHABA Damage Risk Criterion for One Exposure per Day to Octave Bands of Noise 1

2. Interconnection Diagram for the Communication System of the M60A1 Tank Showing the Locations of the DC Generators, Tape Recorder and Sandwich Boxes. 5

3. Schematic Diagram for the Communication System of the M60A1 Tank Showing the Locations of the Sandwich Boxes 6

4. Commander's (Upper) and Driver's (Lower) Sandwich Boxes 7

5. Wiring Diagram for the Commander's (Upper) and Driver's (Lower) Sandwich Boxes 8

6. Sound Level (dBA) Versus Time History of the Noise of an M60A1 Tank During A Typical Operational Day (23 Sep 1971) 10

7. Tactical Route Taken by the M60A1 Tanks During the Typical Operational Day . 11

8. Octave Band Pressure Levels in the Turret of the M60A1 Tank at 5 and 10 MPH Compared to the Average Level for a Typical Operational Day 15

9. Calculated SPL of Typical Speech at the Ear of an M60A1 Crew Member when Wearing the T-56 Helmet 17

10. Calculated SPL of Typical Speech at the Ear of an M60A1 Crew Member when Wearing the DH-132 Helmet 18

TABLES

1. Operational Schedule for 23 September 1971 3

2. Average Octave Band Pressure Levels of an M60A1 Tank During Various Operations of a Typical Operational Day 12

3. Octave Band Pressure Levels (dB re 20 $\mu N/m^2$) in the Turret of the M60A1 Tank at Various Road Speeds 15

4. Attenuation, in dB, of the V51-R, T-56 Helmet and DH-132 Helmet 17

ACOUSTICAL EVALUATION OF THE M60A1 TANK DURING TYPICAL OPERATIONS

INTRODUCTION

In the design of the Army's combat equipment, it has become paramount to optimize its effectiveness; part of this optimization is the consideration of the noise produced by the system and its effect upon operating personnel. Unfortunately, in many instances, noise-reduction measures result in lowered equipment effectiveness. As examples, noise-reduction techniques often involve the use of more weight, larger silencers or mufflers, and additional wasted space, all to the detriment of weapon effectiveness. It is important, therefore, that Army systems be designed in a manner that provides optimum man-machine effectiveness. It is necessary neither to overdesign the equipment, thereby providing the user with unnecessary protection, nor to underdesign it, with the result of placing the operator in a hazardous environment.

In 1965, the National Academy of Sciences – National Research Council (NAS-NRC) Committee on Hearing, Bioacoustics and Biomechanics (CHABA), Working Group 46, developed the first comprehensive hearing damage risk criterion (DRC) for steady-state noise (1). In order to evaluate noise according to this criterion, the sound pressure level within each octave band and the duration of the exposure must be known. Included in the DRC are limits for continuous exposures extending from 1 1/2 minutes to 8 hours per day, plus intermittent-exposure data where regular on-off exposure schedules are maintained. Figure 1 shows these limits for continuous exposure to octave band noise.

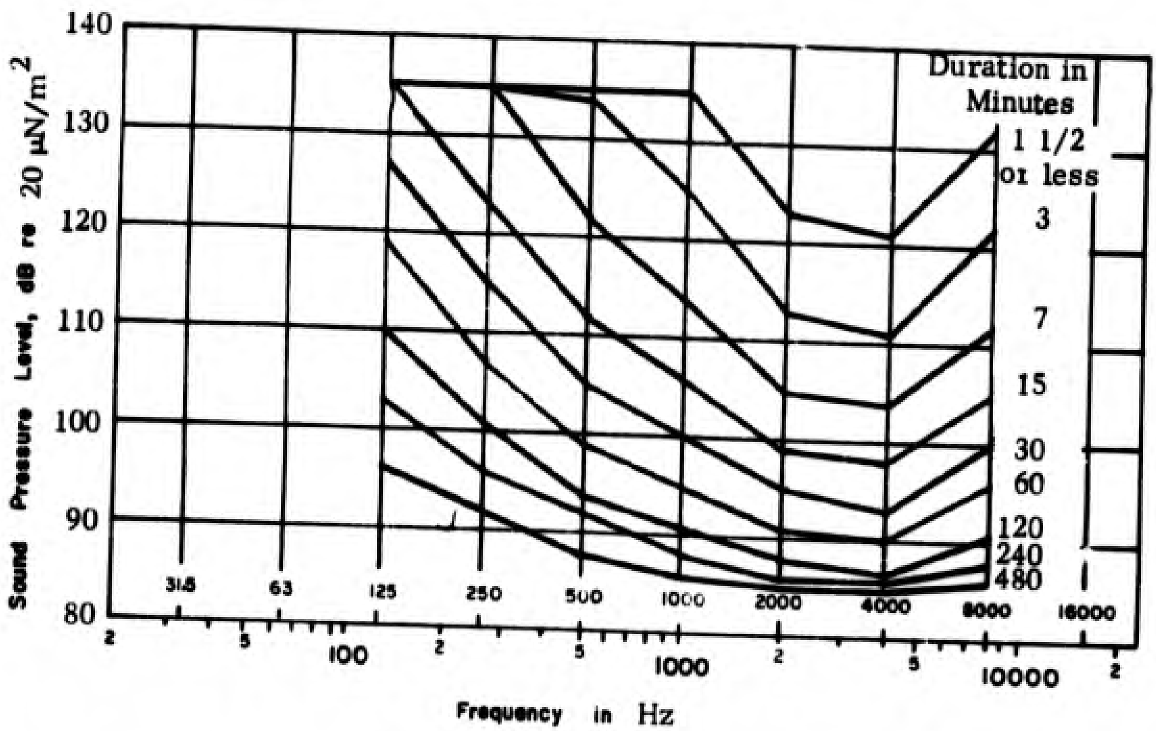


Fig. 1. CHABA DAMAGE-RISK CRITERION FOR ONE EXPOSURE PER DAY TO OCTAVE BANDS OF NOISE

Subsequent to the issuance of the CHABA document, TB MED 251 (1965), was revised, and based upon the CHABA eight-hour curve. This level was established as the Army's hearing conservation limit for unprotected exposure for eight-hour periods. In 1972, TB MED 251 was updated and the eight-hour limit was reduced somewhat to 85 dBA. Although the 1972 document lists higher sound levels for exposures under eight hours, it has become appropriate to require that the noise of all items, to which personnel will be exposed, remain no higher than 85 dBA. The rationale for adopting this single 85 dBA value is that additional exposures may occur during the day, such as riding to the motor pool in a truck, or working near a generator, etc. Therefore, the exposures to the typical operational days discussed in this report will be evaluated by both the CHABA limits and the 85 dBA limit provided in TB MED 251.

PURPOSE

This report deals with the problem of considering how quiet a tank must be and how much hearing protection must be provided for the crew in order to properly protect personnel while optimizing man-machine effectiveness. To determine the auditory hazard of a tank crew, based on the aforementioned documents, the following parameters must be known:

1. The average sound pressure level (SPL) of the vehicle, within each octave band, and the A-weighted SPL.

2. The duration of the exposure.

3. The amount of hearing protection provided.

It is apparent thet neither the average sound level, nor the duration of the exposure, can be determined by driving a tank along a test course as is normally done in obtaining the noise characteristics of a vehicle. Noise data needs to be obtained from a situation approaching that of a typical operational day. Only in this manner can we determine the variations in sound level produced by a tank in a tactical situation and also the average length of time that the tank is moving slowly, idling, stopped, moving at high speed, etc. From this study, the average sound level during a tactical road march or during an advance to contact can be obtained; also, the time during which it is below a damaging level during a given maneuver, as well as between maneuvers, can be determined.

Knowing the average noise produced during a typical operational day, it is then a simple matter to determine the effective sound level at the crew's ear. For purposes of evaluation with the CHABA DRC this would be accomplished by subtracting from the noise produced during a typical operational day the attenuation of the tanker's helmet for each octave band. For evaluation with the TB MED the effective octave band pressure levels at the ear are appropriately summed to obtain the effective A-weighted SPL at the ear. In this study, therefore, we can readily determine, based on both TB MED 251 and the CHABA DRC, the degree of hazard posed to the crew when wearing a helmet with known attenuation. Also, the CHABA DRC can be used to determine the amount of protection required by the helmet and/or the amount of noise reduction required for the tank.

METHOD

Selection of the Tank Exercise

This study was conducted by instrumenting one M60A1 tank per platoon exercise at the Advanced Officers Basic (AOB) Course, Fort Knox, Ky. Two different tanks were instrumented for two days each; the first exercise, AOB-2, was held on 20-21 September 1971; the second exercise, AOB-3, was held on 23-24 September 1971.

The AOB exercises were selected since they represented the closest approximation we could find in the continental United States to a typical operational day. A more precise situation could be found, we are sure, during tactical maneuvers in Germany; however, it was felt that this would have provided very little additional information. Each two-day AOB exercise consisted of operations extending from approximately 0600 to 2200 hours. As an example, the operations for the third day, from which were derived the main data presented in this report, are shown in Table 1.

TABLE 1

Operational Schedule for 23 September 1971

Operation	Time	Cumulative Miles
Road march from motor pool to CP 5	0600 - 0700	7
Cross country march from CP 5 to CP 53	0920 - 1035	9
Simulated attacks from CP 53 to hilltop and return (3 times)	1100 - 1225	12
Cross country march from CP 53 to CP 77	1315 - 1430	19
Movement to contact to CP 31 with simulated enemy attack at CP 71	1545 - 1640	21
Road march from CP 71 to CP 31	0715 - 1800	23
Simulated attack from CP 31 to CP 82 followed by road march and simulated attack to CP 12	1800 - 1850	26
Simulated night attack from CP 12 to CP 5	2100 - 2205	28

Instrumentation

Four parameters were continuously monitored during the exercises:

1. SPL inside the turret.

2. All electronic communications within the tank, including radio.

3. Engine speed.

4. Vehicle speed.

These data were recorded on a Honeywell Model 5600, 14-channel magnetic tape recorder which was shock mounted inside the turret on the rear deck. The shock mounting consisted of placing the recorder in a 1/8-inch thick aluminum box which was firmly bolted to the rear deck. The inside of the box was lined with polyurethane foam which acted as a vibration isolator for the recorder. This material was four inches thick on the bottom and two inches thick on all sides. The recorder was held in the box by a strap rather than by a cover, since we wanted easy access to the top of the recorder for tape changes. The entire system was 13.5 inches high, 17 inches wide, and 25.5 inches deep.

The recorder was operated at 1-7/8 inches per second using 3600-foot reels of one-inch tape, which provided six hours and 24 minutes of running time. Since only five channels of data were recorded, we were able to record in both directions on the tape, so that we obtained almost 13 hours of data per reel of tape. SPL and communications were recorded using direct electronics (50-9300 Hz frequency response); RPM and speed were recorded on FM electronics (0-1250 Hz frequency response).

Two General Radio (GR) Type 1565-A sound level meters (SLM) were connected to two channels of the recorder and set at different attenuator settings. The laboratory analysis was made of that channel which provided the best signal-to-noise ratio without overloading the electronics. The SLM which was used for the analysis, as discussed in this report, was located to the rear of the loader's hatch. It was positioned in the far left ammunition chute in the second row down, with the microphone three inches in front of the chute and with the SLM surrounded by foam rubber. At this location, the microphone was 12 inches below the top of the turret and facing the gun tube.

Calibration was accomplised at the beginning and end of each reel of tape and before and after the reel was turned over. A GR Type 1562A sound level calibrator, set at 1000 Hz, was used. New batteries were placed in the SLM prior to each calibration.

Communications were recorded by connecting to the commander's intercom amplifier at pin "L" at J505 (Figs. 2, 3). This connection was easily and quickly made by inserting a "sandwich box" (Fig. 4) at J505 (Fig. 2).

Vehicle speed was recorded by inserting a tach-generator in the speedometer cable at the front left track-support wheel. This generator was connected to another "sandwich box" (Fig. 4) which was connected to the driver's intercom box at J904 (Fig. 2). Engine speed was recorded by inserting a second tach-generator at the RPM cable connection located next to the battery box behind the driver. This generator was also connected to the driver's "sandwich box" as shown in Figure 2. Figures 2 and 5 show the manner in which the signal from the two tach generators went through the slip rings to the commander's "sandwich box" and then to the tape recorder, and the wiring diagram of the two sandwich boxes.

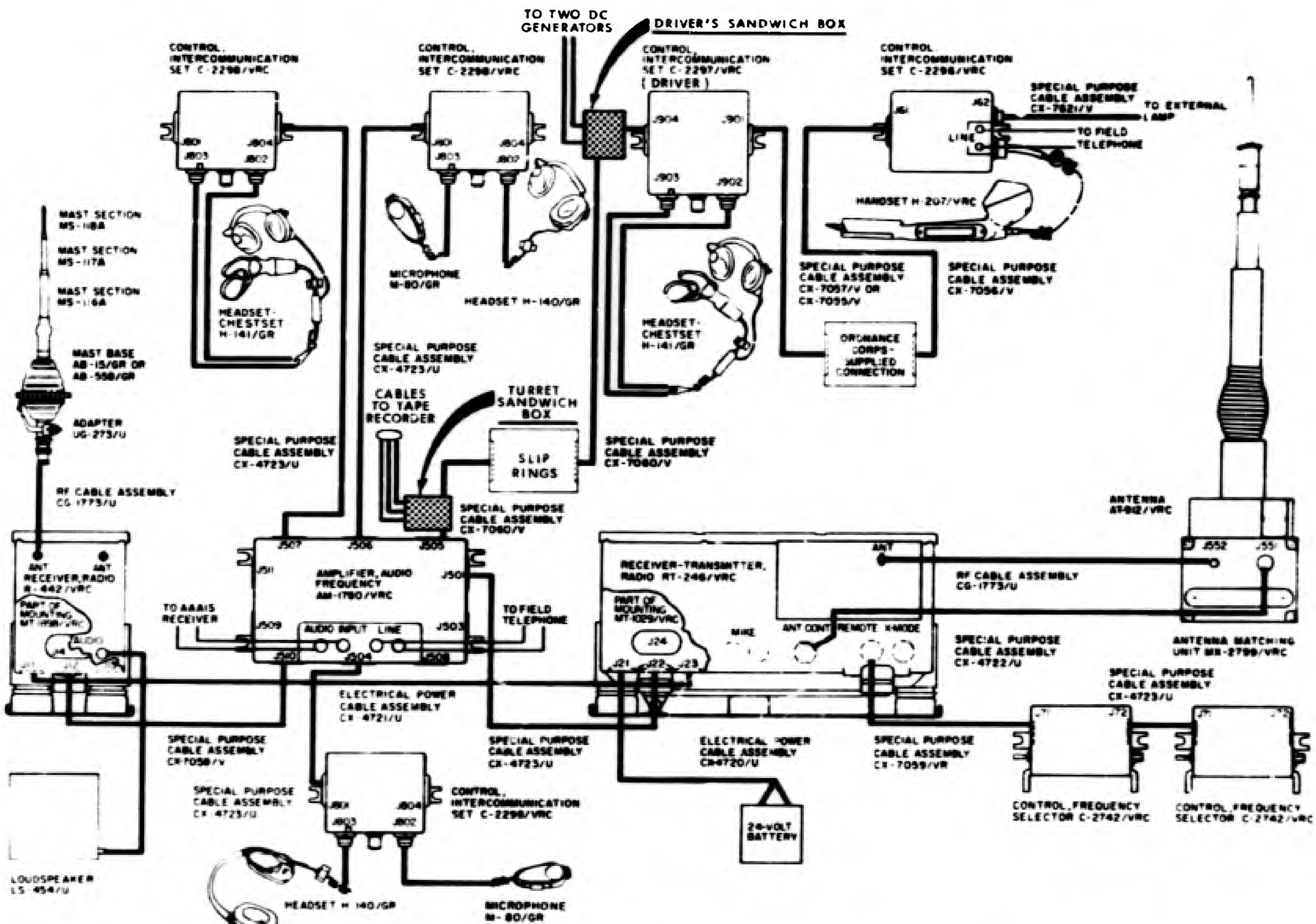
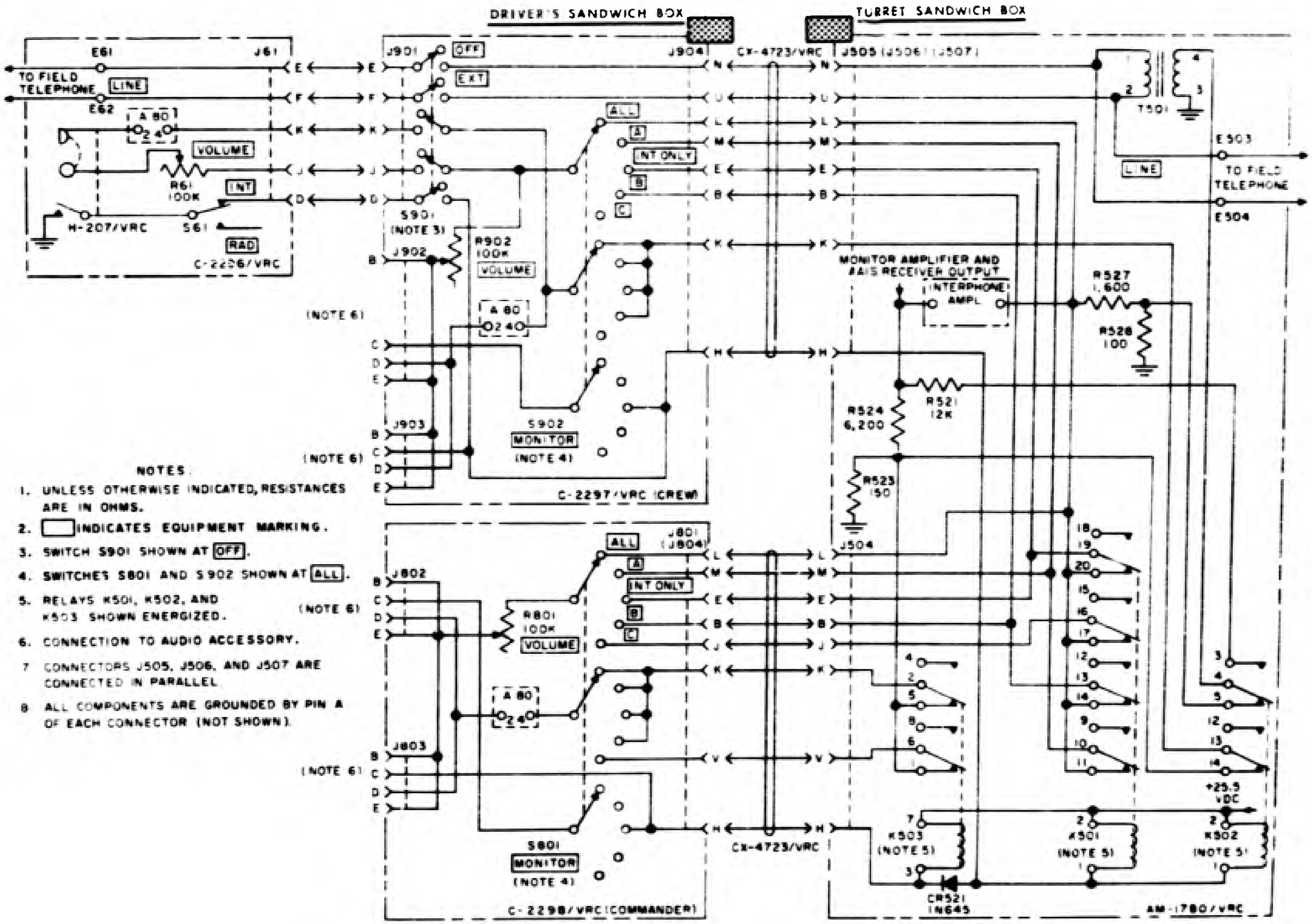


Fig. 2. INTERCONNECTION DIAGRAM FOR THE COMMUNICATION SYSTEM OF THE M60A1 TANK SHOWING THE LOCATIONS OF THE DC GENERATORS, TAPE RECORDER AND SANDWICH BOXES



NOTES:

1. UNLESS OTHERWISE INDICATED, RESISTANCES ARE IN OHMS.
2. ☐ INDICATES EQUIPMENT MARKING.
3. SWITCH S901 SHOWN AT OFF.
4. SWITCHES S801 AND S902 SHOWN AT ALL.
5. RELAYS K501, K502, AND K503 SHOWN ENERGIZED.
6. CONNECTION TO AUDIO ACCESSORY.
7. CONNECTORS J505, J506, AND J507 ARE CONNECTED IN PARALLEL.
8. ALL COMPONENTS ARE GROUNDED BY PIN A OF EACH CONNECTOR (NOT SHOWN).

Fig. 3. SCHEMATIC DIAGRAM FOR THE COMMUNICATION SYSTEM OF THE M60A1 TANK SHOWING THE LOCATIONS OF THE SANDWICH BOXES

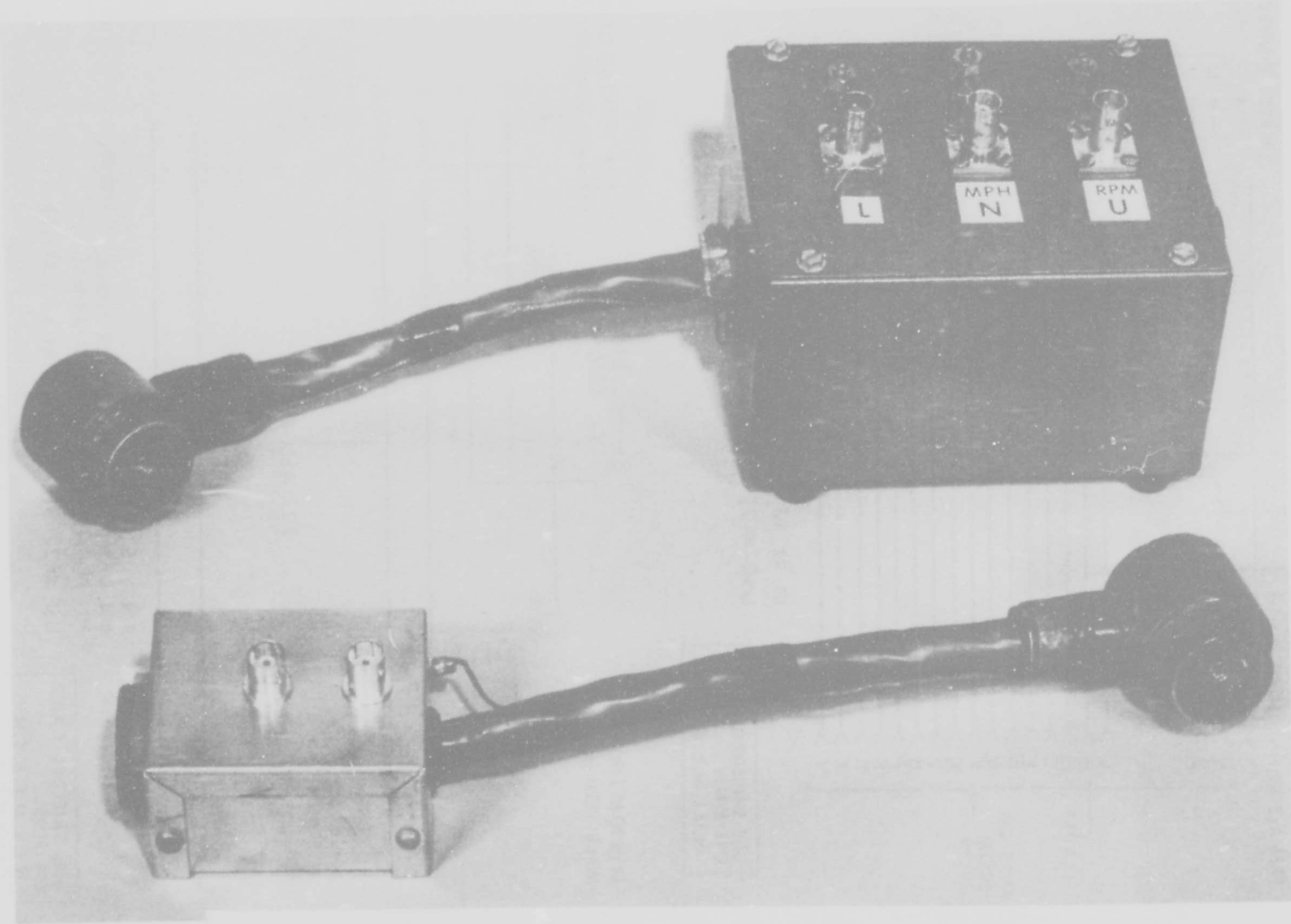


Fig. 4. COMMANDER'S (UPPER) AND DRIVER'S (LOWER) SANDWICH BOXES

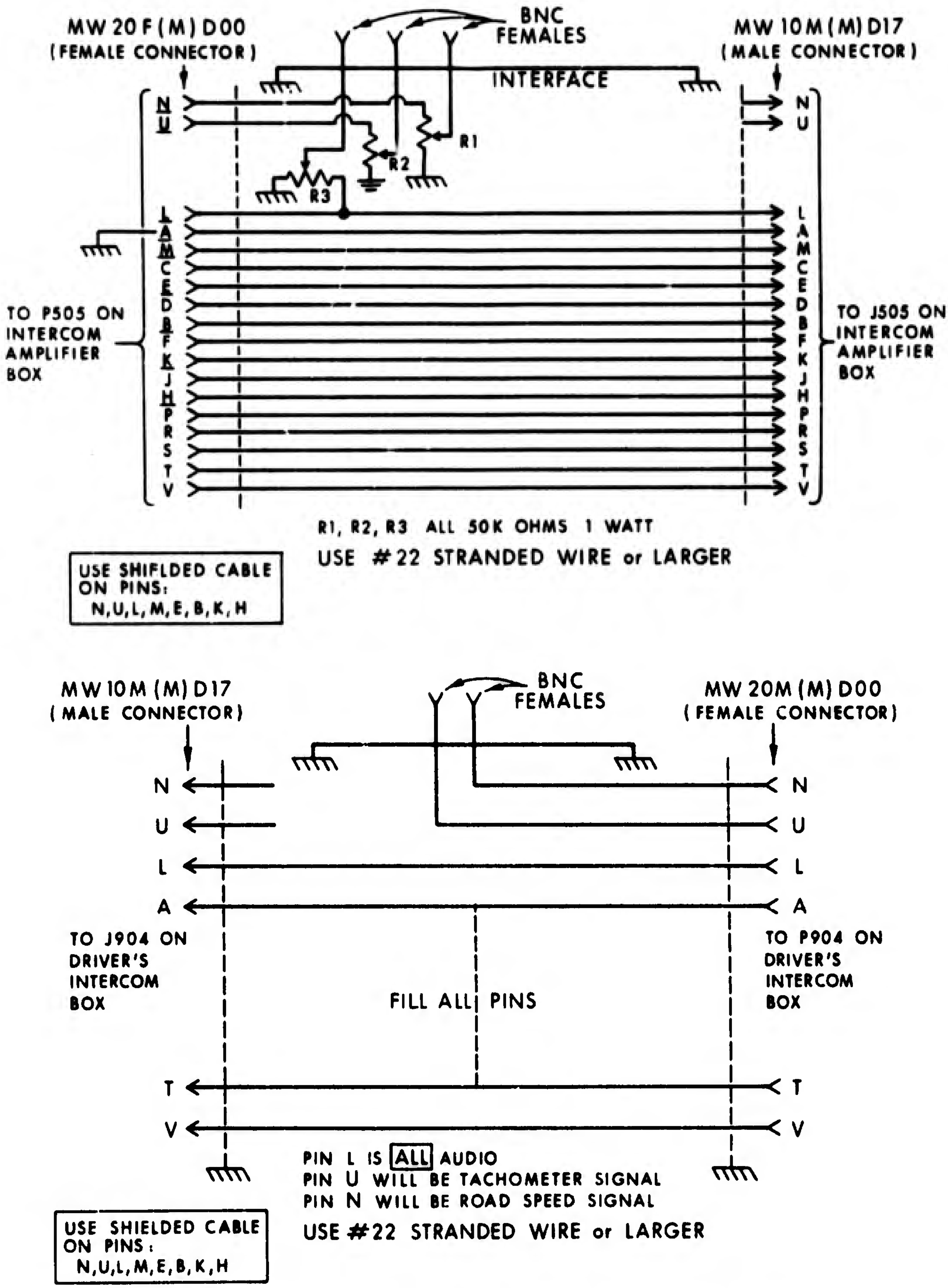


Fig. 5. WIRING DIAGRAM FOR THE COMMANDER'S (UPPER) AND DRIVER'S (LOWER) SANDWICH BOXES

Power for the tape recorder was obtained from the 24 VDC auxiliary power outlet located in the ceiling at the rear center of the turret. The tape recorder was wired so that it would begin recording whenever the vehicle master switch was turned on and would stop when the master switch was off. Therefore, tape was not wasted during those portions of the day when the crew was out of the tank and not being exposed to noise. The experimenters followed the tank throughout the exercises to note the type of operation being conducted, mileage of the tank after each operation, time of engine start and shutdown, and location of the tank at various times.

Four days of data were recorded. After the first two days, it was found that the SLM padding and tape recorder gain were not optimally set to obtain sufficient dynamic range for all the noise conditions encountered during the various operations. After the proper adjustments were made, data were obtained for the third and fourth days.

Analysis of Data

The acoustical data was first analyzed by plotting the A-weighted SPL versus time for the third and fourth days. The on-off time of the tank engine for the typical operational day may also be readily obtained from this plot of dBA versus time. The instrumentation used for this portion of the analysis was a Bruel and Kjaer (B&K) Type 2604 microphone amplifier and a B&K Type 2305 graphic level recorder.

Although both the third and fourth days were analyzed, they were found to produce almost identical noise exposures, since the students went through the same exercises on both days. Therefore, only sound level versus time history is shown for the third day in Figure 6, with Figure 7 showing the route which was taken.

Further analysis was made of the third day operation by analyzing the octave-band distribution of the noise produced during each operation shown in Table 2. The instrumentation used was a B&K 3347 real-time 1/3-octave-band analyzer, connected to a Hewlett-Packard 9100B computer/calculator with Type 9120A printer, Type 9101A extended memory and Type 2570A coupler/controller. A program was written whereby the output of the real-time analyzer (set at fast-random time constant) was scanned every eight seconds. The program combined the 1/3-octave-band data into octave bands and placed these calculated data into one of 21 registers extending from 76 dB to 118 dB for each octave band. Each register, therefore, represented a two-dB increment for a given octave band and accepted cumulative data for the entire analysis period. Those data which fell below 76 dB were placed in one underrange register for each octave band. The 76-118 dB range had been selected because no data occurred above this range. This technique provided us with a statistical distribution of the noise within each octave band for each different operation indicated in Table 1 and for the total day.

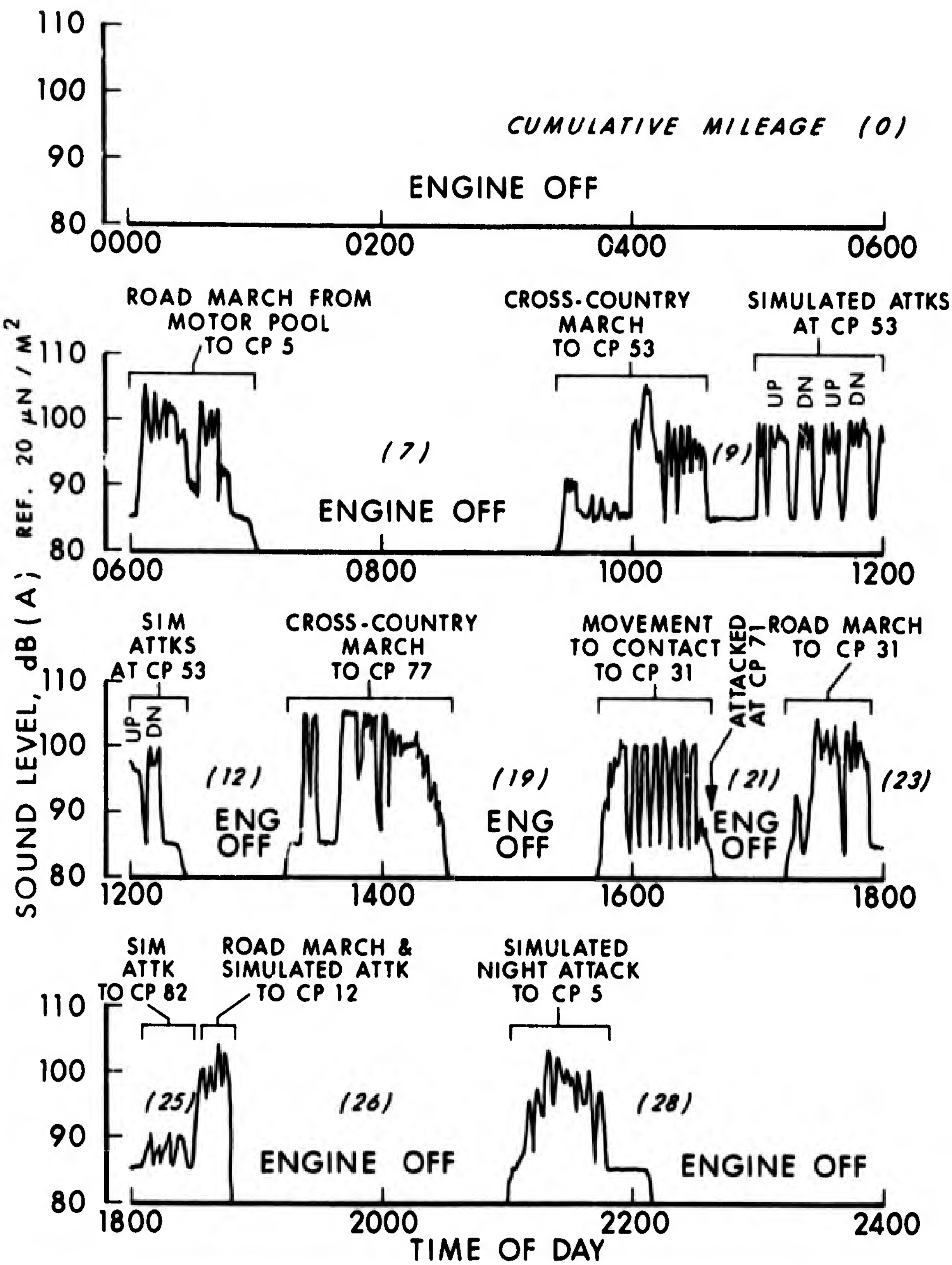


Fig. 6. SOUND LEVEL (dBA) VERSUS TIME HISTORY OF THE NOISE OF AN M60A1 TANK DURING A TYPICAL OPERATIONAL DAY (23 SEP 1971)

Fig. 7. TACTICAL ROUTE TAKEN BY THE M60A1 TANKS DURING THE TYPICAL OPERATIONAL DAY
(Total distance travelled was 28 miles. Time of travel from point to point is shown in Table 1.)

TABLE 2

Average+ Octave Band Pressure Levels of an M60A1 Tank during Various Operations of a Typical Operational Day

Type Operation Time of Day		Frequency (Hz) 63	125	250	500	1000	2000	4000	8000	dBA	Percent Hazardous** Exposure Time
Road March (0600-0700)	SPL	104.9	101.4	99.0	96.2	93.1	91.2	89.6	89.0	99.5	
	Duration*	28.3	37.9	39.2	38.5	36.3	34.8	27.9	6.1		65
Cross Country March (0920-1035)	SPL	03.8	101.9	95.9	94.7	92.2	89.2	88.4	87.9	98.1	
	Duration	7.6	17.2	13.2	17.7	23.1	19.5	15.9	1.6		31
Simulated Attacks (1100-1225)	SPL	103.6	101.5	95.2	93.2	90.6	88.0	87.0	87.0	96.9	
	Duration	8.9	13.0	13.3	20.6	22.2	15.2	4.3	0.1		26
Cross Country March (1315-1430)	SPL	105.1	101.5	98.2	95.9	93.3	91.4	83.7	88.5	99.3	
	Duration	22.7	32.1	31.3	33.6	33.5	30.6	21.0	1.7		45
Movement to Contact (1545-1640)	SPL	104.3	102.0	96.2	94.0	92.5	89.8	89.5	87.8	98.3	
	Duration	5.2	14.0	19.4	19.7	24.4	21.6	16.8	1.2		44
Cross Country March & Simulated Attack (1715-1850)	SPL	105.2	101.0	96.8	94.3	92.2	88.7	89.0	88.6	98.1	
	Duration	28.0	39.9	43.1	40.1	47.0	37.5	28.1	4.2		49
Simulated Night Attack (2100-2205)	SPL	105.3	100.4	95.1	93.1	90.0	88.0	89.0	88.4	97.1	
	Duration	8.8	13.3	15.9	14.0	8.0	10.0	3.0	1.5		24
Total Operating Day	SPL	104.8	101.4	97.2	94.8	92.4	89.8	89.0	88.6	98.5	
	Duration	113.9	173.4	181.7	190.2	200.6	174.9	121.3	17.3		21
Highest Instantaneous SPL Obtained During any Operation		117.0	[illegible]	107.0	105.0	103.0	101.0	99.0	95.0	108.7	---
8-hour CHABA DRC		102.0	96.0	92.0	89.0	86.0	85.0	85.0	87.0		---
Attenuation in dB Required to Reduce Average SPL to the 8-hour DRC		3	6	6	6	7	5	4	2		

+This is the average only of those values above the 8-hour DRC

*Time in minutes during which each octave band is above the 8-hour DRC

**% of time for each operation during which any octave band of the tank noise exceeds the 8-hour DRC

RESULTS

In assessing the hearing hazard of a noise which does not have a regular intermittency cycle and cannot be assessed in the normal manner stipulated in the DRC, two facts basic to a DRC must be kept in mind:

1. Effective quiet exists when the noise is below the eight-hour DRC.

2. When the noise has a fluctuating level which never drops below the eight-hour DRC, its effective level is equal to the average over the exposure period.

In addition to these points, two assumptions were made in order to properly assess our data in a conservative manner:

1. No recovery from hearing loss took place when the noise of the tank was below the eight-hour DRC.

2. Exposure time is defined here as that time during which the noise level was above the eight-hour CHABA DRC. (Exposure time, therefore, was different for each octave band.).

With this in mind, when computing the average band pressure level (BPL) and the A-weighted sound pressure level, we used only those levels which were above the eight-hour CHABA DRC in our computation. Inclusion of levels below the eight-hour CHABA DRC would have lowered the average level obtained during the day, providing an erroneously low level, which would not be indicative of the hearing hazard which might result from the exercise. As an example, in computing the average BPL at 250 Hz for the road march which lasted from 0600-0700 hours, the computer first determined the duration of the BPL within each two dB register. The BPL times the duration for all two-dB incremental levels above the eight-hour CHABA DRC were added together, and divided by the total duration above the eight-hour CHABA DRC, to produce an average BPL of 99.0 dB for a duration of 39.2 minutes at 250 Hz.

Table 2 shows the average BPL, duration and A-weighted SPL for each different operation conducted between 0600 and 2205 hours on 23 September 1971. Also shown are the same three parameters for the entire day. It can be seen from this table that, although the road march (0600-0700) lasted 60 minutes, that band which exceeded the eight-hour CHABA DRC for the longest duration was the 250 Hz octave band and was hazardous for 39.2 out of 60 minutes, or 65 percent of the time. Sixty-five percent was, for this operational condition, the percent hazardous exposure time, which is determined by dividing the greatest duration obtained for any octave band by the total duration of the operation.

The average A-weighted SPL for the entire day was 98.5 dBA and the average octave band pressure level met the 75 minute curve of the CHABA DRC (Fig. 1). It is interesting, at this point, to note that if the time weighting table of TB MED 251 were utilized, 98.5 dBA also indicates a tolerable exposure time of 75 minutes.

DISCUSSION

The discussion which follows will deal mainly with the noise data obtained on 23 September 1971, since the operations for the four days were essentially the same. Figure 6 shows the sound level (dBA) distribution with time for the entire day. As can be seen, the tank crew was moving for a significant portion of the day. Those periods when the engine was off were for critiques and dissemination of the operations orders for the successive phases. During this exercise the tanks were actually operating for 8 1/2 hours. A cursory glance at this figure indicates that the highest sound level appears to vary between 95 and 105 dBA.

Examination of the data of Table 2 indicates that the average sound level is approximately the same regardless of the type of operation. The highest level obtained was, as expected, during the road march, where the convoy speed was 12 mph with a catch-up speed of 15 mph. Also, as expected, the lowest average sound level was obtained during simulated attacks which produced values of 96.9 and 97.1 dBA. The average sound level for the entire day was 98.5 dBA. As would be expected, the percent hazardous exposure time was greatest for the road march (65%), since this operation kept the tanks moving for the most sustained period of time. During simulated attacks, the percent hazardous exposure time was the least since the tanks spent much of their time in protected positions with the engine at idle.

Examination of the total operating day indicates that the noise level is above the eight-hour CHABA DRC for 21 percent of the time between 0600 and 2205 hours, or for a total of three hours and 20 minutes, and that the average octave-band sound pressure level is as shown in Table 2.

It has been found useful, for predicting exposure levels in other armored vehicles and in establishing the operating conditions for evaluating the noise of vehicles, to determine what road speed produces noise that corresponds most closely to that of a typical operational day. Table 3 shows the SPL of the M60A1 for road speeds of 5 to 25 mph. Comparing the average SPL of the typical operational day with the noise produced at constant speeds, we see from Figure 8 that it falls between 5 and 10 mph. These speeds seem low, but we must remember that even in a road march, where the tanks are moving at a nearly constant rate, the march speed is only 12 mph with a maximum of 15 mph for catch-up. In other maneuvers, the tanks rarely exceeded 10 mph.

It should be noted that, although engine and vehicle speed were recorded during the AOB exercises, they were used in this test mainly to ascertain precisely when the tank engine was started and the time at which the vehicle began to move. Further analysis of the tapes to obtain additional data is possible and is planned for a later date.

Comparison of the average octave-band levels for the total operating day with the CHABA DRC, shown in Figure 1, indicates that unprotected exposure to the noise produced by operations such as those discussed in this report, should not exceed 1-1/4 hours per day. This comparison also indicates that 4000 Hz is the frequency which is most hazardous to hearing when protection is not worn. Although this exercise, which was quite intense, produced hazardous noise levels for 3 hours and 20 minutes, it is anticipated that some situations may arise in training or combat which would require a longer exposure. Therefore, in order to be assured that personnel would not be exposed to a hazardous noise situation when wearing hearing protection, we have compared the average octave-band pressure level of the typical operational day to the eight-hour CHABA DRC. Table 2 shows the attenuation required to reduce the average SPL of the M60A1 to the eight-hour CHABA DRC. These attenuation values have been rounded off to the next higher dB.

TABLE 3

Octave Band Pressure Levels (dB re 20 $\mu N/m^2$)
in the Turret of the M60A1 Tank at Various Road Speeds

Vehicle Speed (MPH)	Center Frequency (Hz)							
	63	125	250	500	1000	2000	4000	8000
5	101.8	100.9	92.1	93.2	93.3	87.7	81.0	77.0
10	106.1	105.2	100.1	99.6	99.2	93.2	88.8	85.4
15	109.2	109.5	105.1	104.2	105.0	103.6	102.7	98.7
20	115.9	114.0	107.3	106.9	105.1	101.8	99.0	96.4
25	111.2	112.5	106.0	105.8	103.9	99.0	94.6	90.8

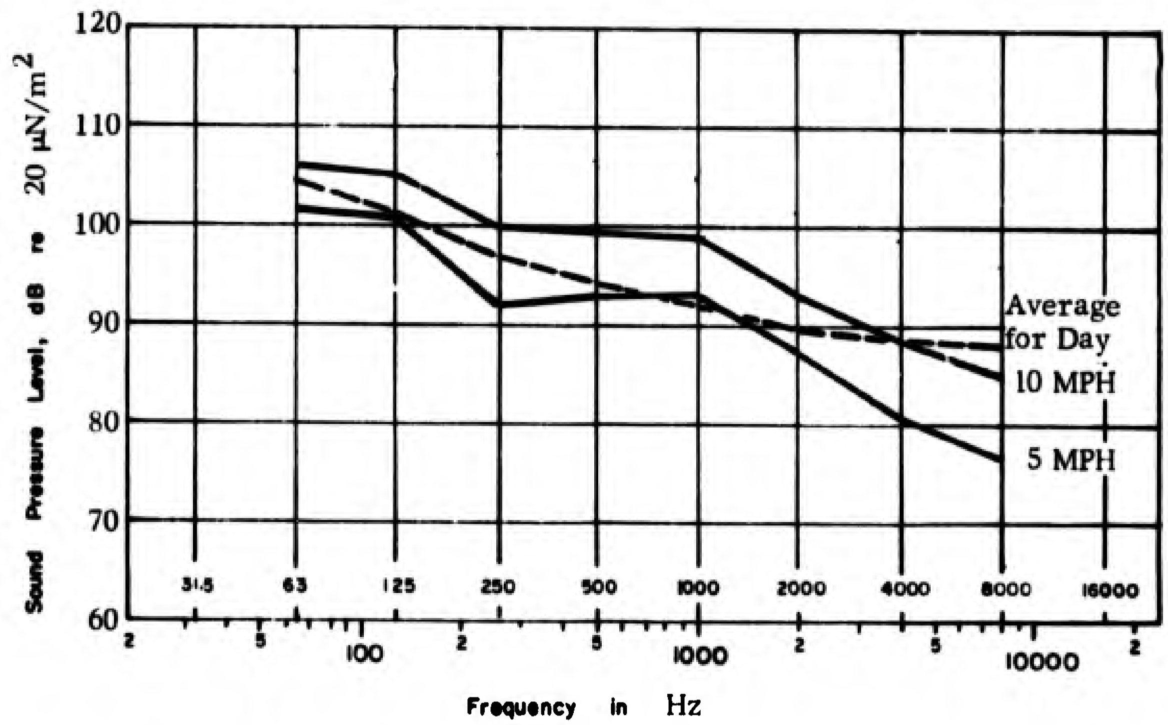


Fig. 8. OCTAVE BAND PRESSURE LEVELS IN THE TURRET OF THE M60A1 TANK AT 5 AND 10 MPH COMPARED TO THE AVERAGE LEVEL FOR A TYPICAL OPERATIONAL DAY

Table 4 shows the attenuation values of several hearing protectors. It can be seen by comparing the attenuation of the T-56 CVC helmet to the attenuation required to reduce the average SPL to the eight hour CHABA DRC (Table 2), that, although this is a very poor hearing protector, it is, based upon CHABA, within one dB of preventing the crew from being exposed to excess noise produced by normal tank operations. In assessing the protection afforded the crew by the T-56 helmet based upon TB MED 251, we first subtracted its attenuation from the average BPL of the typical operational day. Appropriate summation of these BPL's provided an effective A-weighted SPL of 88.8 dBA at the ear. This assessment also indicated that the crew's exposure is slightly above the prescribed level of 85 dBA. Similar computations indicate that both the new DH-132 CVC helmet and the V51-R earplug provide sufficient attenuation, based upon both CHABA and the TB MED, to protect personnel from the noise of the M60A1 tank.

Although the T-56 helmet does not provide adequate attenuation, it appears that the noise of the M60A1, in itself, is not sufficiently intense to produce the severe hearing loss reported to exist among tankers (3). What, therefore, is producing this hearing loss among tankers? The answer to this question appears to be associated with the communication system rather than vehicle or gun noise. Calculations which have not yet been verified by measurements indicate that the volume of the communications system must usually be raised to a level which is aurally hazardous to the crew. This high volume setting is normally established by tankers during the maximum noise-producing condition of the tank. During quieter periods of time they do not take the time to lower the gain setting. Our observations during this study also indicate that the volume controls are normally set near full gain.

In order to calculate the SPL at the ear due to the communication system using the T-56 helmet, we have assumed that a five dB signal-to-noise ratio at 1000 Hz would be required to obtain adequate intelligibility and that the gain would be established during the maximum noise-producing condition of the tank. Table 2 and Figure 9 show the highest SPL measured during any eight-second period in each octave band during the total operating day. We have assumed that the volume control was set during this loudest portion of the tank noise. Figure 9 then shows the effective SPL of the tank noise at the ear, after subtracting the attenuation of the T-56 helmet. A typical speech spectrum is then superimposed with a five dB signal-to-noise ratio at 1000 Hz to produce the SPL of the communication system at the ear.

Comparison of the communication system's SPL at the ear with the CHABA DRC indicates that only a 35-minute exposure would be safe when wearing the T-56 helmet. This comparison also indicates that 500 Hz is the frequency which is most hazardous when wearing this helmet. Appropriate summation of the BPL's provides a sound level of 103.8 dBA, which is significantly higher than the TB MED recommended level of 85 dBA. Again it is interesting to note that if the time weighting table of TB MED 251 were used, it would also indicate a tolerable exposure time of about 35 minutes.

Computations were also made of the SPL which would be present, at the ear, using the attenuation values of the DH-132 CVC helmet.The dashed line of Figure 10 shows the resultant levels at the ear for this helmet. Comparison of these levels with the CHABA DRC indicates that they just meet those levels specified for an eight-hour exposure, with 500 Hz again being the most critical frequency. When wearing this helmet the effective sound level of the communication system at the ear is 85.8 dBA.

TABLE 4

Attenuation, in dB, of the V51-R, T-56 Helmet and DH-132 Helmet

	Frequency (Hz)							
	63	125	250	500	1000	2000	4000	8000
V51-R Earplug	24	23	21	23	25	33	31	29
T-56 Helmet	-	5	7	7	10	17	25	30
DH-132 Helmet**	-	15	14	24	28	30	35	30

** Attenuation values based on the "Draft Proposed Materiel Need – Abbreviated MNA for Armored Vehicle Protective Headgear" dated 19 October 1971. (2)

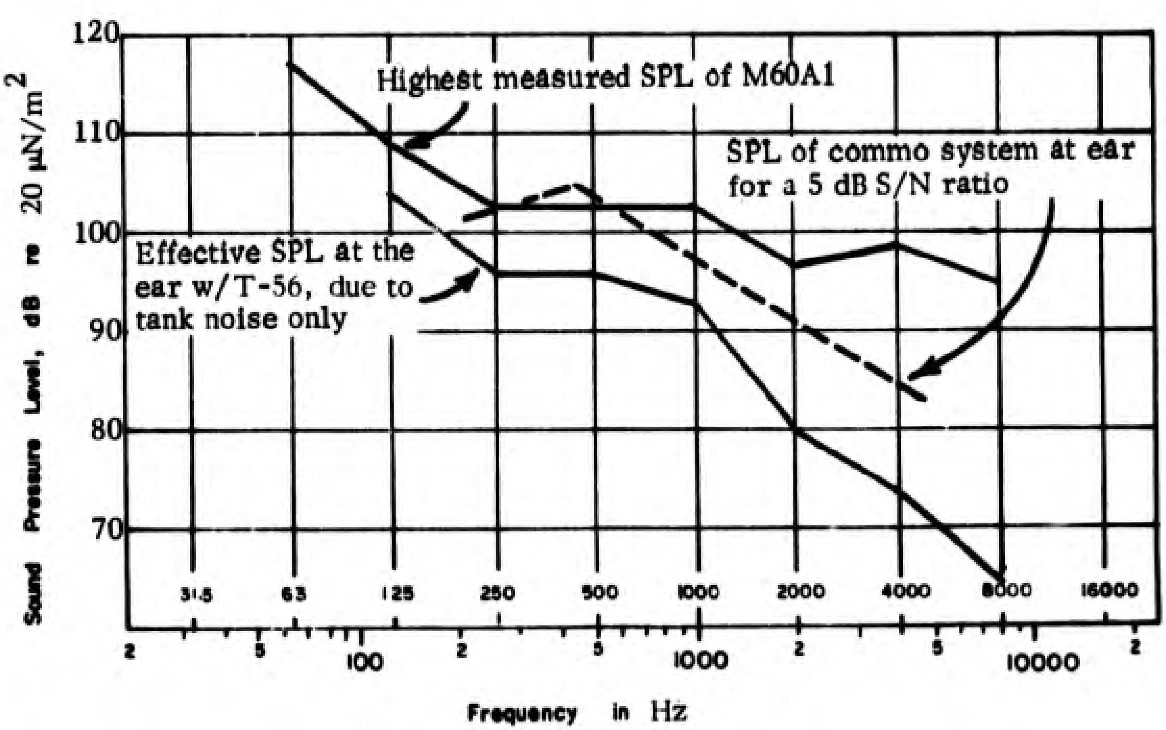


Fig. 9. CALCULATED SPL OF TYPICAL SPEECH AT THE EAR OF AN M60A1 CREW MEMBER WHEN WEARING THE T-56 HELMET

It appears from these calculations that the specifications of the DH-132 helmet almost provide adequate attenuation against the speech and noise of the communication system of the M60A1 during most typical operations. Three precautions, however, must be kept in mind. First, the estimated hearing hazard of the communication system is based on calculations which must be verified by actual measurements. Second, the design of the helmet must fully meet the specifications as given in Table 4; meeting this specification is particularly important at 500 Hz, which is that frequency at which the SPL is closest to the eight-hour CHABA DRC. Third, the helmet must be properly worn in order to provide the wearer with the specified attenuation.

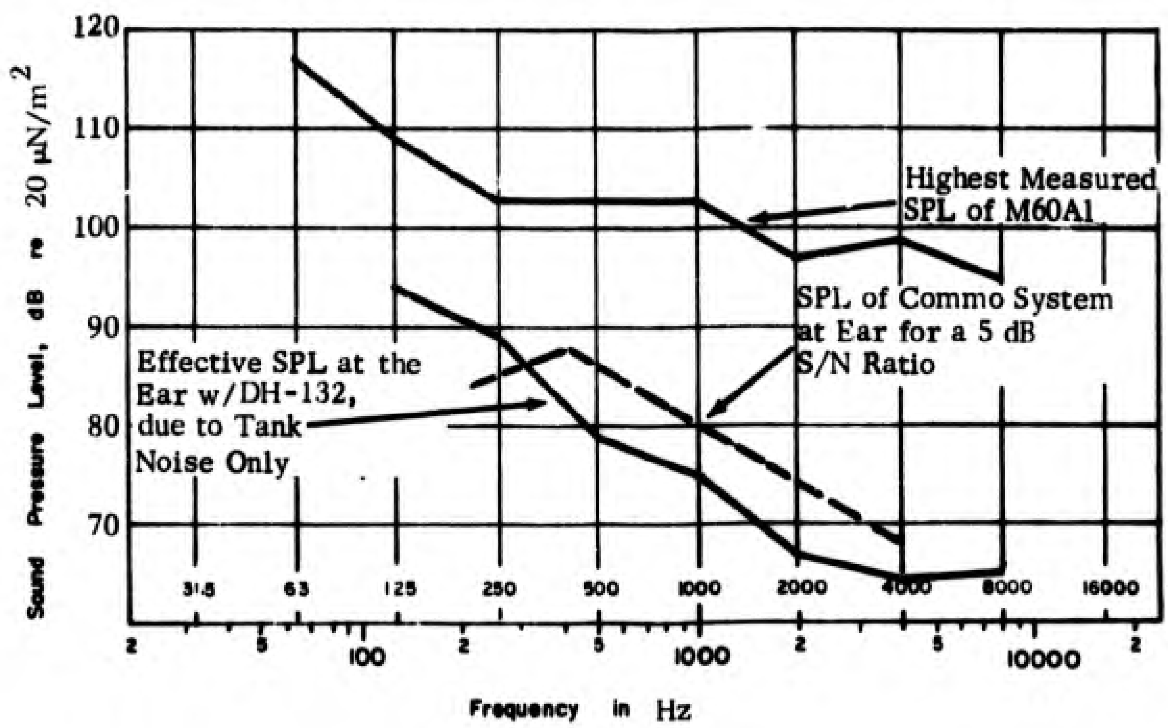


Fig. 10. CALCULATED SPL OF TYPICAL SPEECH AT THE EAR OF AN M60A1 CREW MEMBER WHEN WEARING THE DH-132 HELMET

CONCLUSIONS

1. The average A-weighted SPL in an M60A1 tank during a typical operational day was 98.5 dBA.

2. The SPL of the communication system at the ear is greater than that of the M60A1 tank noise. Computation indicates that it is about 104 dBA.

3. The primary cause of hearing damage among tank crews appears to be the communication system.

4. The T-56 CVC helmet does not provide adequate attenuation against either tank noise or communication noise.

5. The DH-132 CVC helmet almost provides adequate attenuation against both tank noise and communication noise.

6. During the typical operational day evaluated in this report, personnel were in or around the tanks for 16 hours, the engines were operated for 8 1/2 hours, and the personnel were exposed to a SPL above the eight-hour CHABA DRC for three hours and 20 minutes.

7. The average SPL of the M60A1 tank during a typical operational day corresponds most closely to the noise produced at a constant speed of 10 mph.

RECOMMENDATIONS

1. Typical operational noise exposures must be determined for all types of materiel to determine the extent of noise reduction required in various systems and also to help refine Army noise standards.

2. The results of this study indicate that to prevent excessive hearing loss among tank personnel the following must be accomplished to varying degrees:

   a. Noise reduction of tanks, particularly at 500 Hz.

   b. Improved attenuation of helmets, particularly at 500 Hz.

   c. Improved communication systems.

3. Research must be conducted to predict more precisely the amount of hearing loss produced in tank personnel by the communication system. This work should be directed toward providing a system which has an adequate signal-to-noise ratio under all operational conditions while maintaining the lowest possible SPL at the ear.

4. The attenuation values of the DH-132 CVC helmet must be achieved under all conditions of wear.

REFERENCES

1. Committee on Hearing, Bioacoustics and Biomechanics. Hazardous exposure to intermittent and steady-state noise. Report of Working Group 46, National Academy of Sciences – National Research Council, Washington, D. C., January 1965.

2. U. S. Army Combat Development Command Armor Agency. Draft proposed materiel need (abbreviated) (MN(A)) for armored vehicle crewman's (AVC) protective headgear. Fort Knox, Ky., 10 August 1971.

3. Walden, B. E., Worthington, D. W., & McCurdy, H. W. The extent of hearing loss in the U. S. Army: A survey report. U. S. Army Medical R&D Command, Washington, D. C., 21 December 1971.