

LEAD EXPOSURE AND DESIGN CONSIDERATIONS FOR INDOOR FIRING RANGES

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ABSTRACT

Law enforcing agencies are demanding greater proficiency and accuracy in the use of handguns by their personnel. This has lead to an increase in the construction and use of indoor firing ranges.

Advantages of indoor ranges are: protection from the weather, control of the environment, and use of the facility around the clock. However, these indoor ranges can and do present health hazards in the form of lead poisoning due to improper ventilation control and high noise levels from poor acoustical treatment of the range. In addition to the lead and noise hazards problems from exposure to carbon monoxide and oxides of nitrogen, as well as psychological stress may exist.

This report attempts to point out the insufficiencies found in many indoor ranges from a health standpoint. Recommendations for design considerations and work practices are presented to reduce or eliminate health hazards associated with indoor firing ranges.

SUMMARY

During 1973 and 1974 the Industrial Hygiene Services Branch of the National Institute for Occupational Safety and Health conducted environmental surveys of nine indoor firing ranges. Environmental sampling was conducted to determine the airborne lead concentrations, noise levels, and ventilation rates.

The composite data indicated that a potential health hazard due to inorganic lead exposure existed at each range. In all ranges the concentration of lead increased as the number of shooters increased and it kept increasing after the number of shooters had been reduced, indicating that the ventilation system was incapable of preventing lead buildup in each range.

A total of 331 samples for airborne inorganic lead were taken during the surveys, of which 187 were personal samples and 144 were general area samples. The concentration of airborne lead contamination ranged from a low of 0.10 milligrams of lead per cubic meter of air (mg/M^3) to a high of 13.17 mg/M^3 for the area samples, and from a low of 0.01 mg/M^3 to a high of 34.50 mg/M^3 for personal samples. (Table 1)

In all the firing ranges surveyed, the ventilation was inadequate to keep airborne lead levels below the standard of 0.20 mg/M^3 . In some ranges the supply air was greater than the exhaust causing a positive pressure within the range. In other ranges the situation was reversed. (Table 2) A properly designed ventilation system should maintain the lead concentration below the standard at all times. However, the amount of supplied air means very little if it is not properly utilized.

A possible health hazard also exists in these indoor ranges from impulse types of noise. Sound pressure level readings were taken of various weapons used in the ranges. Sound pressure levels ranged from a 143 dB peak for a 12 gauge shotgun to a 166 dB peak for a .45 caliber revolver. The sound pressure level for the .38 special was a 150 dB peak. (Table 3)

All the ranges surveyed seemed to have one outstanding feature in common; insufficient planning in regard to the location and design of each range. Consideration must be given to the proper placement and design of each range if safe and healthful working conditions for persons involved with the firing ranges are to be assured.

INTRODUCTION

During the past few years the handgun has achieved great popularity in the United States. Besides being used by law enforcement agencies, handgun shooting is being popularized as a recreational activity by the general public. Many police and other law enforcement agencies require their personnel to qualify for accuracy using the handgun, and it is advantageous for these agencies to construct indoor firing ranges. Indoor ranges offer several advantages over outdoor ranges such as protection from inclement weather and around-the-clock use of the facility under controlled environmental conditions. There are, however, disadvantages in using an indoor firing range. Indoor ranges can and

do present health hazards in the form of lead poisoning and high noise levels. In addition, there may be problems with exposure to carbon monoxide and oxides nitrogen.

Most indoor firing ranges are designed primarily with safety, efficiency, and versatility in mind. Usually the walls, floor, and ceiling are constructed of bullet-resistant materials and the shooter booths are bullet resistant and equipped with automatic target spotters. In most ranges, bullet resistant glass separates the shooter from the range officer station and spectators. All of these safety features have little to do with protecting the health of the shooters, range officers, or maintenance personnel.

An indoor range can be designed to protect the health as well as the safety of anyone connected with the range. Ranges should not be placed in basements or converted garages simply because the space is available. Prime consideration must be given to proper ventilation and noise control. However, lighting, psychological factors and stresses, as well as safety must also be considered. If this is done, the indoor range can be a modern up-to-date working facility meeting health and safety standards rather than a dungeon-like, dust-filled, inadequately ventilated enclosure.

DESCRIPTION OF FIRING RANGES

The firing ranges surveyed by NIOSH varied in length from 70 to 120 feet, in width from 20 to 80 feet, and in height from eight to ten feet. The number of firing booths varied from four to forty. Six of the ranges were located in basements or sub-basements, one on the first floor, and two on the top two floors of a building that previously housed a bank. Only two of the facilities were originally designed to be firing ranges. The rest: were installed in "available space." None of the ranges were designed for noise exposure control.

Each range was equipped for the firing of handguns, shotguns, rifles, and machine guns. The .38 caliber police special comprised approximately 90% of all firing of weapons, using .38 special 148 grain lead wad cutter ammunition.

The ventilation in all firing ranges surveyed was inadequate to purge the ranges and keep the lead levels below the standard of 0.20 mg/M³. In some ranges the supply air was greater than the exhaust and in others the situation was reversed. (Table 2) For instance, the KCK facility had only 8% of its required supply air and was exhausting only 27% of the required amount. This condition created a high negative pressure in the range. The DEA #2 facility had 93% of its required supply air, but was exhausting only 27% of the required amount creating a positive pressure which caused areas adjacent to the range to become contaminated.

In some instances the supply openings were located above and slightly in front of the shooter with the exhaust grilles located approximately four feet away causing a "short-circuiting" effect of the ventilation system.

In one instance the air was supplied approximately at mid-range and was exhausted in the vicinity of the shooter. In two other ranges it was found that the exhaust system was part of the main ventilation system within the building where exhaust air from the range was recirculated to other parts of the building.

In all ranges tested the concentration of lead in the environment increased as the number of shooters increased and continued increasing after the number of shooters had been reduced. This indicated that the ventilation systems were incapable of preventing airborne lead "build-up" in the ranges. In most cases it took approximately one to two hours to purge the ranges and reduce the lead concentration to an acceptable level. A properly designed ventilation system should maintain the lead concentration below the existing standard at all times.

There have been many recommendations for the amount of air that should be supplied to the firing line, ranging from 25 to 100 feet per minute (fpm) ^(1,2,3). However, the amount of air supplied means very little if the ventilation system is not balanced and the air flow pattern is not evenly distributed across the shooter.

While practicing or qualifying, the law enforcement personnel stand in bulletproof booths approximately 4 feet wide, 6 feet long, and 9 feet high. Each booth is equipped with an automatic target spotter that can be operated by the shooter or by the range officer. The distance from the firing line to the bullet trap is approximately 75 feet. Each range was equipped with a steel bullet trap where the spent lead was accumulated in a trough at the bottom of the trap. The spent lead is removed from the trough when necessary. In some cases it was found that the spent lead was being remelted after collection within the confines of the range facility and cast into small ingots which can cause an additional lead exposure burden.

Most ranges surveyed employ one or more full-time range officers who are always present when any firing takes place. In many instances the range officers also serve as instructors requiring them to remain in the firing area and outside of the range office for extended periods of time. Therefore, a range officers overall exposure to lead and noise is greater than any other individual using the range.

HOUSEKEEPING

The overall housekeeping of the ranges was poor including general clean up at the end of each day and the periodic cleaning of the bullet trap. In most instances the ranges were swept using a hand broom with dry sweeping compounds used occasionally by a janitor after the range was closed and the ventilation shut off.

Another part of the housekeeping operation included reclaiming, cleaning, and remelting of spent lead collected at the bullet trap. This can be a very hazardous operation if proper precautions are not followed. For cleaning and maintaining the bullet trap, a NIOSH approved respirator should be worn. Remelting of spent lead within the confines of the range should be prohibited.

SOURCES OF CONTAMINATION

There are many sources for lead dust and fume generation in the ranges during the firing of weapons. One Source is from the bullet primer. The primer contains approximately 25-30 milligrams of material, of which approximately 35% is lead styphnate and lead peroxide. The lead styphnate is used as a detonator. Other sources of lead generation are from vaporization (due to the heat of explosion) and fragmentation of the projectile (due to cylinder and barrel misalignments and gaps from wear and manufacturing tolerances) as it passes through the weapon after being fired. The 20000F temperature generated at firing causes the gases to expand creating a pressure build-up of approximately 18,000 to 20,000 PSI in the cylinder that literally blows the dust and fumes from the weapon, much of it at right angles to the direction of fire. This is commonly known as "side blast." The side blast creates turbulence in the breathing zone of the shooter, thus increasing exposure to lead dust and fumes.

Another source of lead contamination is from fragmentation of the bullet as it strikes the bullet trap. The problem of personal exposure from this source is believed to be minimal since the distance between the shooter and the bullet trap is normally 75 feet or more away.

TOXICOLOGY AND HYGIENIC STANDARDS

Lead poisoning may occur through the inhalation and/or ingestion of lead fumes or dust. This results in the deposition of lead in the bones and tissues of the body and alterations in normal physiological functions. No single sign or symptom may be considered diagnostic of lead poisoning. Lead poisoning may present such symptoms as a metallic taste in the mouth, loss of appetite, indigestion, nausea, vomiting, constipation, abdominal cramps, nervousness and insomnia.

Many of the sources of lead poisoning are industrial, but man also absorbs lead in small amounts from his food and water, and from the air. These sources create the "normal" body burden of lead. The normal burden in workmen is 27-30 micrograms of lead per 100 milliliters of blood. Thus, the lead absorbed in the course of occupational exposure is super imposed on lead absorbed from other sources. Lead poisoning is preceded by a stage of lead absorption, but lead absorption is not always followed by lead poisoning.

The existing U.S. Department of Labor standard for inorganic lead exposures (29 CFR 1910.93 Table G2) is 0.20 mg/M³ based on an eight hour time-weighted average* (TWA). Any exposure above 0.6 mg/M³ for an eight hour time-weighted span is considered a serious violation by the U.S. Department of Labor. Although the current standard for inorganic lead is .0.20 mg/M³, the American Conference of Governmental Industrial Hygienists Threshold Limit Value (TLV) Committee and the NIOSH criteria for a proposed standard on exposure to organic lead recommends that the standard be lowered to 0.15 mg/M³. (10,11)

ENVIRONMENTAL STUDY PROCEDURES AND INSTRUMENTATION

Atmospheric samples for lead were collected on Millipore filters Type AA, ** with a 0.8u pore size. The filters were encased in a three-piece plastic field monitor cassette with the face cap removed and the filter completely exposed. The samples were taken at the operators breathing zone using battery powered Mine Safety Appliance (MSA) gravimetric pumps, Model G. The pumps and samplers were worn by the shooters and range officers. Area samples were also taken using a Research Appliance Corporation (RAC) sequential sampler with the same type of filters. The automatic sequential sampler was positioned behind the firing line. The sequential sampler collected samples for a 30-minute period. The procedure continues through the day, making it possible to determine how the lead levels fluctuate as a function of time and number of rounds fired. All samples were collected at a rate of 2.0 liters per minute (lpm). The samples were then analyzed in the NIOSH laboratory by atomic absorption spectrophotometry. The ventilation system was evaluated using an Alnor velometer and smoke tubes.

* The standard is based on a computed time-weighted average exposure during any 8-hour work shift of a 40-hour work week. The standard represents conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effects. Mention of commercial names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

INDOOR FIRING RANGE DESIGN CONSIDERATIONS

Ventilation

Effective control of lead dust and fumes and products of combustion in an indoor range can be achieved by utilizing a properly designed ventilation system. Caution must be exercised in design to insure even air flow across the shooting position. Excessive turbulence could cause the contaminant to be blown back into the shooters face.

An important factor in ventilation design is that the supply air intakes to the range should be located at that part of the building upwind from the exhaust stacks. In addition, increased heights of exhaust stacks with high outlet velocities will minimize the possibility of contaminated air being re-introduced and circulated throughout the range.

All supply air entering the range should be filtered and conditioned (heat and cool) depending upon the part of the country where the range is located. The higher the filtration efficiency, the better the efficiency of the heating and cooling coils and the lower the interference with air flow balance. The supply air temperatures are set to maintain the desired room temperature. Since this air is being relied upon for ventilation and replacement purposes, the usual temperature range will be 65-80 degrees. (8)

To control lead fumes, dust, and gaseous combustion products in the range a minimum ventilation rate of 50 feet per minute (fpm) should be maintained at the firing line with all of the air being exhausted at the bullet trap. This recommendation results from a study conducted by NIOSH and the American Air Filter Company to determine ventilation rates for indoor firing ranges.

The study also indicated that an optimum ventilation rate would be 75 fpm at the firing line. When using the rate of 75 fpm, 25% of the air should be exhausted 15-20 feet down range of the shooting position, and the remaining 75% at the bullet trap. However, 100% of the air may be exhausted at the bullet trap. For maximum efficiency the exhaust ducts should be placed behind and at the apex of the bullet trap. An alternative is to place the exhaust ducts on the side of the wall and slightly in front of the apex. All air being exhausted from the range should be filtered using a High Efficiency Particulate Filter (HEPA) or equivalent to insure that state regulations for airborne lead are not violated.

For optimum air distribution there should be a minimum distance of 15 feet from the shooters position to the wall directly behind the shooter. (Fig. 1) The supply air inlets should be placed on the back wall if possible, or placed in the ceiling. Proper placement of supply air inlets and the 15 feet distance from the back wall to the shooters position will insure an even air flow pattern across the shooter and minimize turbulence at the firing line.

Each range should have its own ventilation system so as to prevent circulation of contaminated air from the range into other areas of the building. The firing range should be maintained at a slight negative pressure with respect to adjacent areas (e.g. range office, other offices, halls, restrooms, lunch rooms, etc.) The supply and exhaust systems must be electrically interlocked. This eliminates the possibility of turning one system on and not the other. The system should operate on one fan speed and not on multiple fan speeds.

Noise

In addition to the lead fumes, dust, and products of combustion, another severe health hazard exists in the firing range. The hazard is noise. When fired, the bullet strikes the surrounding air breaking the sound barrier, resulting in the familiar "crack." This particular type of noise is known as impulse noise. A secondary source of impulse noise is generated when the bullet strikes the bullet trap. However, the initial blast exceeds the noise generated at the bullet trap by so many orders of magnitude that the second impulse source contribution is minimal.

It should be kept in mind that the shooter is exposed not only to the noise from their own gun, but to the noise from all the other shooters' guns as well. This noise, although somewhat less intense, is generally more frequent.

Much of the secondary noise can be eliminated at the bullet trap by applying an epoxy resin or equivalent to the back side of the trap plates. Reducing the primary source of noise is much more difficult. (Table 3)

The latest regulation (29 CFR 1910.95, Vol.39 Part II June 27, 1974) from the Occupational Safety and Health Administration (OSHA) states that the peak impulse sound pressure levels (SPL) shall not exceed a 140 dB peak. However, peak impulse alone is not the sole factor in hearing damage. A report to the Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) indicates that the duration of the impulse also has an effect. (6) For example, CHABA calculated on the basis of tests that about 95% of the population could tolerate, without permanent hearing loss, 100 impulses per day of up to 164 dB, peak (without ear protection) as long as the impulse time was 2 microseconds or less. As duration increases, the peak permissible pressure decreases to a terminal level of 138 dB for 200-1000 millisecond impulses.

In further research, impulse noises were divided into two groups as shown in Fig. 2. Fig. 2A shows the pressure wave form that is observed when a gun is fired out-of-doors with no reflecting surfaces. Fig. 2B shows what occurs when a weapon is fired indoors. There is an initial series of dampened oscillations which maybe followed by a reflected wave at only a slightly lower level.

Many experiments have shown that gunfire can damage hearing.(6,7) The key parameters are peak sound pressure level, duration, and frequency of exposure. In an indoor range reverberation also becomes an important factor. This reverberation can be suppressed somewhat by using proper acoustical material on the walls and in the booths. However, the use of ear protectors must not be eliminated even after steps have been taken to reduce the noise.

To minimize the effect of peak sound pressure levels on individuals in indoor ranges, all reflecting walls should be covered with high efficiency sound absorbing material such as fiberglass insulation covered with perforated aluminum or steel sheets with openings equivalent to 10-15% of the area to permit sound absorption. The coverings should be designed to permit easy access to the acoustical material for periodic replacement due to accumulation of lead dust. The floors directly behind the shooter should be covered with acoustical flooring carpet.

The bullet trap should never be anchored or attached to any structural support for the building without appropriate energy-absorbing linkages. The energy of the bullet striking the trap can be transmitted as noise and vibration throughout the building.

A hearing conservation program should be instituted and periodic audio metric examinations given. Proper ear protection should be available for use at each indoor range which should be worn by all individuals in the range. The protectors should be selected to provide maximum protection.

Although either ear plugs or ear muffs can be used, muffs have the advantage of ease in monitoring usage, and are generally considered preferable by shooters. Each shooter should have their own personal ear protection and some variety should be provided to allow for individual variations and preferences. If ear plugs are used they must be properly fitted. In case of extremely loud handguns, it may be advisable to wear both plugs and muffs simultaneously.

Psychological

The psychological stresses associated with the position of range officer should be considered when designing a new range. By its very nature the job demands close confinement, constant watchfulness for safety violations, rote repetition, and exposure to high noise levels and to lead dust and fumes.

Although the stresses encountered in the range facility are difficult to eliminate, there is much that can be done to reduce them. The walls and surroundings could be painted in soft, contrasting pastel colors to reduce dungeon effect. The floor behind the shooters should be carpeted. The range should be equipped with sound attenuating material in the range officer's quarters, areas for cleaning of weapons, and storing materials. The range should also be equipped with complete toilet facilities. Other considerations that play an important role in reducing psychological stress are proper noise control, ventilation, lighting, and maintenance.

Floors

Floors are a vital part of the firing range from both a health and safety standpoint. The floor is the place where most of the lead dust and any other particulate contaminant finally come to rest. Therefore it is important that the floors be properly constructed.

Floors should be constructed of dense, continuous-poured concrete or steel of a thickness to withstand the impact of the most powerful weapon fired in the range. The concrete should be finished to a smooth surface to facilitate proper clean-up using either the wet method or the vacuum cleaner method.

Each floor should be constructed with a floor drain. The drain should be placed approximately 20 feet down range of the firing line. The slope of the floor from the firing line to the drain should be 2 to 3 inches so that water will collect at the drain. Although the contaminants that will be washed down the drain will be thoroughly diluted, they may still constitute a health hazard according to the Federal Environmental Protection Agency standards. Therefore, it is essential that a collection trap be included in the drain.

Maintenance

To keep the range operating properly and to keep possible hazards to a minimum, a routine range maintenance program is essential. Accessibility of duct work and fans should become part of the overall design. Intake and exhaust velocities should be monitored periodically by performing pitot traverses of the duct to insure proper carrying velocities. Each range should be periodically inspected to determine repair requirements.

Removing spent lead from the bullet trap or making repairs on the trap can be extremely hazardous. While performing maintenance or removing lead from the trap, a NIOSH approved respirator must be worn by the employee. Personal hygiene should be practiced by all individuals using or maintaining the range to minimize the potential for lead ingestion. This can be accomplished by installing toilet and washing facilities within the range.

RECIRCULATION OF RANGE AIR

When large amounts of air are exhausted from a room in order to remove toxic dusts, gases, and fumes, an equivalent amount of fresh, tempered air should be supplied to the room. The supplied air must be heated in cold weather and heating costs may be large if sizeable amounts of air are handled. Attempts have been made to eliminate such heating costs by appropriate cleaning of the exhausted air prior to recirculation of the air into the room.

Most official health agencies do not recommend the recirculation of exhaust air if contaminant is a material which may have an effect on the health of the worker. However, recirculation in some cases may be the only feasible method of providing ventilation control.

Theory and preliminary test data developed by NIOSH and the American Air Filter company indicate that recirculation of the range air is feasible. However, test results are incomplete at this time. Further supporting data will be developed from actual installation testing and the results will be issued as an addendum to this report.

RECOMMENDATIONS AND DESIGN CONSIDERATIONS

To reduce and/or eliminate the health hazards associated with indoor firing ranges the following design considerations and work practices are recommended.

Design Considerations

1. An optimum air supply would be 75 fpm at the firing line.
The minimum air supply must be 50 fpm at the firing line.
2. Filtered and conditioned air must be introduced behind the firing line to guarantee an evenly distributed flow of air through the shooting positions.
3. Supplied air inlets should be placed approximately 15 feet behind the shooters position.
4. The entire range facility should be maintained at a slightly negative pressure with respect to adjacent areas to prevent the escape of contaminants. This criteria suggests that exhaust air should exceed supplied air by 10%.
5. For maximum efficiency, exhaust ducts should be located behind and at the apex of the bullet trap.
An alternative location is to place the exhaust ducts on the side walls slightly in front of the apex of the trap.
6. A minimum down range conveying velocity of 35 fpm must be maintained.
7. When the 75 fpm rate is used, a minimum of 25% of the air should be exhausted 15-20 feet down range of shooting position and the remaining 75% at the bullet trap.
8. When the 50 fpm rate is used, 100% of the air should be exhausted down range at the bullet trap.
9. Each range should have its own ventilation- system to prevent the circulation of contaminated air to other areas of the building.
10. The supply and exhaust systems must be electrically interlocked, thereby eliminating the error of turning one system on and not the other. The system should operate on one fan speed only and not on variable speeds.
11. Each range should be equipped with a floor drain and trap to facilitate cleaning by wet methods.
The drain location should be approximately 20 feet down range of the firing line. The floor should slope 2-3 inches toward the drain.
12. To minimize the effect of peak sound pressure levels on individuals on the range, all reflecting walls should be covered with high efficiency sound absorbing material such as fiberglass insulation covered with perforated aluminum or steel sheets with openings equivalent to 10-15% of the area to permit sound absorption. The coverings should be designed to permit easy access to the acoustical material for periodic replacement.
The floors directly behind the shooting booths should be covered with acoustical flooring (carpet that has good acoustical absorption characteristics].
13. Range officer quarters should be acoustically treated to reduce noise levels.
14. The bullet trap should never be anchored or attached to any structural support for the building.
The energy of the bullet striking the trap can be transmitted as noise and vibration throughout the building.
15. The walls and surroundings could be painted in soft, contrasting pastel colors to reduce the dungeon effect.
16. The range should be equipped with range officer's quarters, areas for cleaning of weapons and storing materials, and with toilet and washing facilities.
17. All air being exhausted from the range should be filtered using a High Efficiency Particulate Filter (HEPA) or equivalent.

Work Practices

1. The ventilation system should be in operation at all times while the range is in use and during clean-up.
2. Sweeping the range should be accomplished by vacuum cleaning or wet methods. Use of a hand broom, even with dust suppression compounds, should be prohibited.
3. At all times while cleaning, repairing, or reclaiming lead in the bullet trap, a NIOSH approved respirator for the removal of lead dust and fumes must be worn.
4. Proper ear protection should be provided for and worn by all individuals inside the firing area. The ear protectors should be selected on the basis of offering maximum protection.
5. Ear plugs when worn must be properly fitted.
6. In case of extremely loud weapons, both plugs and muffs should be worn simultaneously.
7. A hearing conservation program should be instituted and yearly audiometric examinations given.
8. A rotation system should be instituted for the range officer position. It is suggested that one month of duty be followed by three months of alternate activity. This change is suggested not only to alleviate any possible lead absorption and prevent its accumulation, since this should be minimal following the engineering changes, but to prevent undue psychological stresses associated with the position.
9. Eating, drinking, and smoking in the range should be prohibited.
10. A specific schedule must be established to perform maintenance and repair work to keep the range facilities operational and free of hazardous conditions.

REFERENCES

1. Ross, C.R., et al: *Survey of Lead Hazard in Indoor Firing Ranges*. J.AIHA, 21:256
2. Michigan's Occupational Health. *Design Consideration for Indoor Firing Ranges*. 7:4
3. Detroit Bureau of Industrial Hygiene: *Long Illness of Police Officers Leads to Discovery of Lead Exposure on Firing Range*. Ind. Health Monthly 11:185
4. Nat. Inst. for Occ. Safety & Health: *Lead Exposure at an Indoor Firing Range*. HEW Pub. # (NIOSH) 74-100.
5. Weissler, P.G., & Kobal, M.T.: *Noise of Police Firearms*, Institute for Basic Standards, NBS.
6. Kryter, X.D., Ward, W.D. I Miller, J.D.: *Hazardous Exposure to Intermittent and Steady-State Noise*. J.Acoust.Soc.Am 39:451-463
7. Coles, R.R., Garinther, G.R. Hodge, D.C., and Rice, C.G.: *Hazardous Exposure to Impulse Noise*. J.Acoust.Spc.Am. 43:336-343
8. American Conf. of Governmental Industrial Hygienists: *Industrial Ventilation Manual*. 14th Ed.
9. NIOSH: *Certified Personal Protective Equipment Manual*
10. *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment* with intended changes; ACGIB
11. Criteria for a recommended standard: *Occupational Exposure to Inorganic Lead*; HEW Publication HSM: 73-11010, Second Printing.

TABLES

SUMMARY OF LEAD SAMPLING DATA

FACILITY	No. OF SAMPLES	PERSONAL SAMPLES	AREA SAMPLES	PERSONAL SAMPLES			AREA SAMPLES		
				RANGE OF LEAD CONTAM. (mg/M ³)			RANGE OF LEAD CONTAM. (mg/M ³)		
				LOW	HIGH	AVG.	LOW	HIGH	AVG.
ORL	56	27	29	1.90	12.12	4.52	0.45	7.76	2.69
ORL-F	24	18	6	0.01	0.42	0.10	0.02	0.13	0.07
IPA	66	36	30	0.23	5.10	1.48	0.20	1.22	0.51
KCK	44	27	17	1.42	24.43	7.44	0.03	3.25	0.99
KCM	42	30	12	0.30	34.50	7.77	0.10	13.17	3.36
OMA	30	16	14	0.38	2.53	0.93	0.02	0.59	0.40
PP	4	2	2	6.42	11.28	8.85	1.18	6.58	4.20
DEA*1	40	20	20	0.37	6.50	2.32	0.06	1.50	0.66
DEA*2	25	11	14	0.05	4.67	2.09	0.01	2.20	0.74

TABLE 1

VENTILATION SUMMARY

FACILITY	INTAKE (CFM)			%	EXHAUST (CFM)		
	MEASURED	REQUIRED	MEASURED / REQUIRED		MEASURED	REQUIRED	MEASURED / REQUIRED
ORL	6900	9500	73		4200	10,000	42
ORL-F	9800	9500	—		10,100	10,000	—
IPA	3800	33,000	12		3700	35,000	11
KCK	900	12,000	8		3500	13,000	27
KCM	3600	9000	40		500	9500	5
OMA	2100	6500	32		2700	7000	39
PP	1700	6000	28		1600	6700	24
DEA*1	6800	8000	85		2400	9000	27
DEA*2	7400	8000	93		2400	9000	27

TABLE 2

PEAK SOUND PRESSURE LEVELS OF FIREARMS

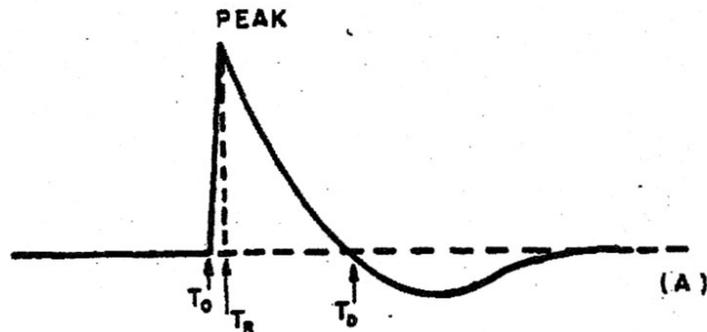
<u>WEAPON</u>	<u>dB PEAK * SOUND PRES. LEVEL</u>
12 — GAUGE SHOTGUN	141 - 143
.38 — SPECIAL SERVICE REVOLVER	147 - 150
.22 — CAL. REVOLVER	142 - 145
.357 — MAGNUM REVOLVER	161 - 166
.32 — SMITH & WESSON (S & W)	148 - 152
.45 — CAL. REVOLVER	160 - 164

*Measurements were taken using a Bruel & Kjaer 2209 SLM with impact analyzer. Measurements were taken inside the range.

TABLE 3

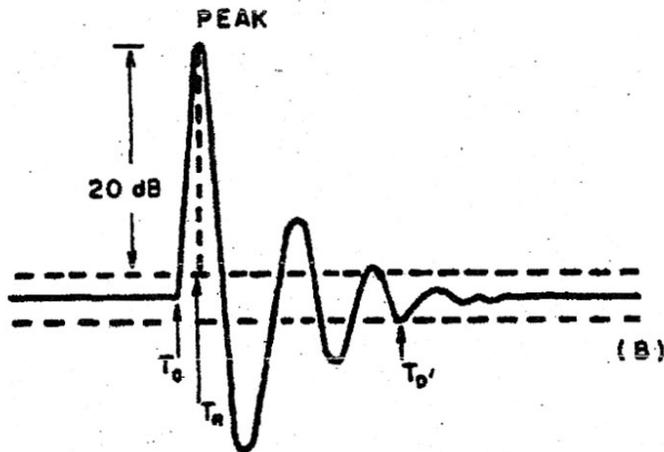
FIGURES

Fig. 2. Two principal types of impulse noise . (8)



1. T_0 IS START OF PRESSURE WAVE.
2. T_R IS TIME REQUIRED FOR PRESSURE WAVE FORM TO GO FROM AMBIENT TO PEAK PRESSURE
3. T_D IS TIME REQUIRED FOR PRESSURE WAVE FORM TO FIRST REACH AMBIENT PRESSURE

2 A . Pressure wave form when gun is fired out of doors with no reflecting surfaces .



1. $T_{D'}$ IS TIME REQUIRED FOR ENVELOPE OF PRESSURE WAVE FORM TO REACH LEVEL 20dB BELOW PEAK SPL
- TA-822522-208

2 B . Pressure wave form when gun is fired indoors with reflecting surfaces .