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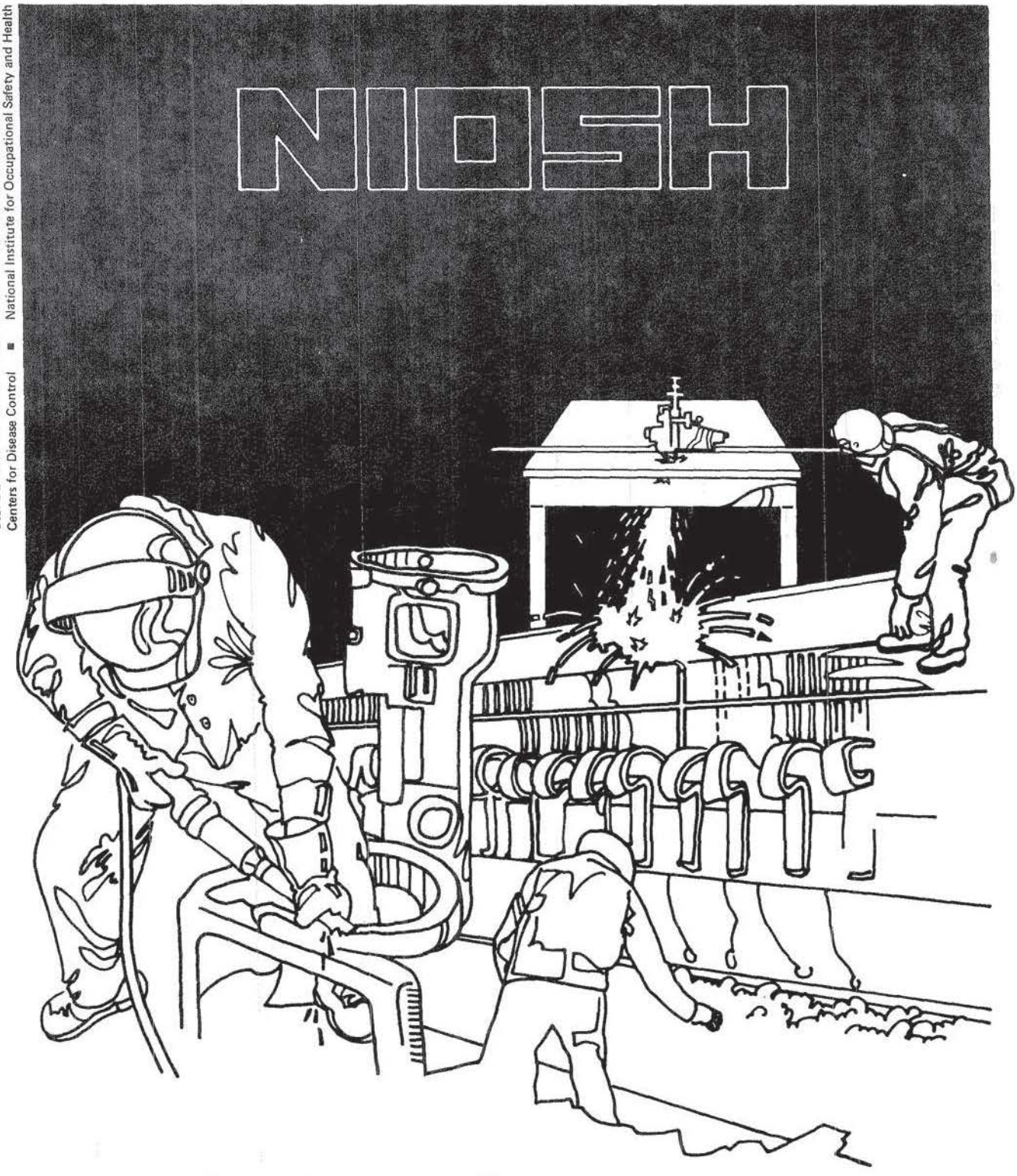

Health Hazard Evaluation Report

HETA 81-019-846
FEDERAL RESERVE BANK
CINCINNATI, OHIO

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

HETA 81-019-846
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Federal Reserve Bank
Cincinnati, Ohio

NIOSH INVESTIGATOR:
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I. SUMMARY

In October 1980, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Cincinnati Branch of the Federal Reserve Bank to evaluate lead exposure at their indoor firing range in Cincinnati, Ohio. NIOSH conducted an environmental survey on December 10, 1980. Personal breathing-zone and area samples were taken while firing standard lead wadcutter .38 special and experimental zinc wadcutter ammunitions. Ventilation measurements were conducted to evaluate the design of the range.

Shooters were exposed to inorganic lead at concentrations ranging from 3.4 to 12 milligrams per cubic meter of air (mg/M^3) while firing standard 148-grain lead wadcutter ammunition. Exposures ranged in duration from 7 to 10 minutes. Corresponding 8-hour time-weighted average (TWA) concentrations of lead in the shooters' breathing-zones ranged from 0.05 to 0.25 mg/M^3, with a mean of 0.16 mg/M^3. The OSHA 8-hour TWA exposure standard for inorganic lead is 0.05 mg/M^3.

A significant reduction in lead contamination was observed by NIOSH when firing 100-grain zinc wadcutter ammunition during one round of qualification practice. Both a personal breathing-zone and an area sample were found to contain 0.58 mg/M^3 of lead during firing. The corresponding 8-hour TWA concentration was 0.01 mg/M^3. Other recent NIOSH studies have found similar reductions in lead emissions when firing zinc, copper-jacketed, and nylon-jacketed bullets in indoor firing ranges.

Ventilation was found to be inadequate. Air flow at the firing line was erratic and turbulent with velocities ranging from non-detectable to 200 feet per minute (fpm). NIOSH recommends a smooth and constantly uniform air flow of 50 to 75 fpm at the firing line.

On the basis of the data obtained in this investigation, NIOSH has determined that a hazard from overexposure to inorganic lead did exist at the Federal Reserve Bank's Indoor Firing Range at the time of this investigation. However, lead levels were below the OSHA TWA exposure standard when firing zinc bullets.

Therefore, NIOSH recommended that ammunition containing non-lead or jacketed bullets be used at this indoor range. Recommendations for improved ventilation are also included in Section IX of this report.

KEYWORDS: SIC 6011 (Federal Reserve Banks), inorganic lead, indoor firing range, pistol range, indoor target ammunition.

II. INTRODUCTION

In October 1980, NIOSH received a request from the Cincinnati Branch of the Federal Reserve Bank for technical assistance with their indoor firing range in Cincinnati, Ohio.

The request was prompted by the management's concerns about possible health hazards from airborne lead being generated during use of the firing range by bank guards. Air samples and ventilation measurements were taken by NIOSH while guards fired the standard qualification course using .38 special service revolvers and lead wadcutter ammunition. Jacketed and non-lead bullets were investigated by NIOSH as a possible means of reducing airborne lead contamination.

III. BACKGROUND

The firing range is located in the Cincinnati Branch of the Federal Reserve Bank of Cleveland Building. The range is housed in a room about 93 feet long, 19 feet wide, and 9 feet high at the highest ceiling height. The actual firing range is 75 feet long, 19 feet wide, and 8 feet high.

There are five shooting booths, with each booth being about 3 1/2 feet wide, 6 feet long, and 6 1/2 feet high. Air is supplied into the range through 3 elongated openings at the top of the back wall, about 18 feet behind the shooting positions. Each of the openings are 7 inches wide with the two larger openings on the ends being about 34 inches long and the smaller one in the middle being about 8 inches long. There are no grills or louvres covering these air supply openings. Two exhaust grills are located on the ceiling about 4 feet downrange of the shooting positions. Exhaust openings are also located behind the bullet trap, which essentially caused the bullet trap to act as a series of 1 1/2 inch wide exhaust slots spanning the entire back wall.

The range is used by about 25 security guards who are required to qualify quarterly in small arms proficiency. As an administrative action for reducing lead exposure, range officers are rotated such that chronic exposures would not be expected to differ much from that of the shooters. During qualifications, each guard fires 60 rounds of .38 special 148-grain wadcutter ammunition. Each qualifying round requires 7 to 10 minutes to complete.

NIOSH had conducted a similar evaluation of this range in December 1975. Shooters firing 60 rounds each in 20-25 minutes were exposed to airborne lead concentrations ranging from 1.50 mg/M^3 to 6.96 mg/M^3. Corresponding 8-hour TWA concentrations ranged from 0.06 to 0.35 mg/M^3, with a mean of 0.17 mg/M^3. Conditions of using the range were essentially unchanged within the last 5 years. However, certain changes were made in the range itself. Adjustable louvres no longer exist over the air supply ducts, and the overall ventilation was decreased considerably. In 1975, total air supply was

6330 cubic feet per minute (cfm), and total exhaust was 3850 cfm, compared to 2050 and 2250 cfm, respectively, in 1980. Also, the lower half of the shooting booths had been blocked off by plywood panels.

IV. EVALUATION DESIGN AND METHODS

Five personal breathing-zone samples were taken from the guards for the duration of their qualifying rounds. Four of the samples were taken while firing 148-grain lead wadcutters and the other sample was collected when firing 100-grain zinc "Indoor Target" full wadcutter rounds manufactured by 3-D Police Ammunition Company. Area samples were taken near the shooter during and after shooting for the purpose of determining clearance rates of airborne lead from the firing line. The samples were collected on mixed cellulose ester filters using battery-powered sampling pumps operated at 1.5 liters per minute. Analysis was by atomic absorption spectroscopy according to NIOSH Analytical Method S-341.

Ventilation measurements were taken using an Alnor Velometer, Model 6000P. A series of linear air velocity measurements were taken of each supply and exhaust source. These readings were averaged and total air volumes in cubic feet per minute were computed. Measurements were also taken to check linear air velocities at the firing line and to check the downrange conveying velocity. Smoke tubes were used for delineating airflow patterns.

V. EVALUATION CRITERIA

Lead

Lead exhibits toxic effects on the kidneys, the peripheral and central nervous systems, and the hematopoietic system. These effects are felt as weakness, tiredness, irritability, digestive disturbances, high blood pressure, premature aging, nephritis, mental deficiencies, and other changes detected by medical testing. The OSHA permissible exposure level standard states that occupational exposure to inorganic lead shall be controlled so that workers shall not be exposed to lead at a concentration greater than 0.05 mg/M^3 determined as a time-weighted average exposure for an 8-hour workday.

Reports of lead poisoning among firing range workers are not uncommon. In 1977, for example, an investigation of adverse neurological and gastrointestinal symptoms among firearms instructors was conducted. A high prevalence of lead-induced biochemical abnormalities was found.[1]

VI. RESULTS

The results of personal and area sampling are illustrated in Table I. Shooters were exposed to lead at concentrations ranging from 3.4 to 12 mg/M^3 while firing lead wadcutter ammunition. The corresponding 8-hour TWA concentration ranges from 0.05 to 0.25 mg/M^3, with a mean of 0.16 mg/M^3.

A visible reduction in smoke was observed when firing the 100-grain zinc "Indoor Target" full wadcutter rounds. The airborne lead concentration during the qualifying round in Booth 3 was 0.58 mg/M^3 with a corresponding 8-hour TWA concentration of 0.01 mg/M^3. Unlike some other ranges surveyed by NIOSH, no "bounce back" of zinc bullets or fragments occurred from the steel plate venetian blind type bullet trap in this 25 yard range. Therefore, zinc bullets were not considered to pose a significant eye hazard.

Area samples taken during and after shooting showed that over 95% of airborne lead was cleared from the shooting positions within 5 minutes after firing lead wadcutter ammunition.

The air supply openings were found to provide a total air volume of approximately 2050 cfm. The firing line ceiling grills were exhausting about 600 cfm and the bullet trap slots were exhausting about 1650 cfm. Air flow at the shooters' positions on the firing line was very erratic with velocities ranging from non-detectable to 200 fpm. Smoke tube observation showed the air to be turbulent with swirls of smoke occasionally traveling backwards into the shooter's face.

VII. DISCUSSION

The airborne lead levels generated by standard lead target ammunition in the Federal Reserve Bank indoor firing range has changed very little in the previous 5 years. The average 8-hour TWA lead exposure was 0.17 mg/M^3 in 1975, and despite various ventilation and air flow changes, the average 8-hour TWA lead exposure was 0.16 mg/M^3 in 1980. These levels are over three times the current OSHA standard, and they should be reduced for safe operation of the range.

A. Methods for Controlling Lead Exposure

In 1975, NIOSH developed specific firing range design and ventilation criteria for controlling airborne lead contamination.[2] In ranges surveyed since that time, however, it has become evident that those ventilation criteria are very difficult to achieve and maintain. Also, a reduction in the OSHA lead standard from 0.20 to 0.05 mg/M^3 has occurred since those criteria were developed. Furthermore, the trend toward faster rates of fire during modern police "combat" target practice tends to generate very high airborne lead levels (up to 35 mg/M^3) in short periods of time. After considering all these factors, it appears that ventilation design alone may not be sufficient for maintaining acceptable lead levels.

The easiest and most direct solution would be to eliminate or isolate the major source of emission--the lead bullet. The other remaining source of lead would then be the primer, which contains lead styphnate and lead peroxide. Even when firing the zinc bullets, a lead concentration of 0.58 mg/M^3 was generated. This lead came from the cartridge primer. Due to the short

exposure time, however, the 8-hour TWA concentration for shooters was only 0.01 mg/M^3. When taking into consideration that there were no full-time range masters or instructors employed at this range, lead levels generated only from the cartridge primers were within safe limits.

B. Additional Supporting Studies for Bullet Substitution

Fischbein, et al.[3] also found jacketed lead bullets (either copper or nylon jackets) to have good potential for reducing lead emissions. Under the laboratory sampling conditions of that study, cartridges with jacketed bullets emitted 2 to 5 micrograms (µg) of lead per shot, whereas conventional lead target ammunition emitted 12 to 40 µg of lead per shot.

In another study under actual field conditions,[4] NIOSH observed a reduction in lead emissions when using jacketed bullets during typical police "combat" target practice (60 rounds fired in 8-10 minutes). Airborne lead levels were reduced from an average of 8.2 mg/M^3 with lead bullets down to 0.17 mg/M^3 with copper jacketed ammunition (see Table II). A later study at that same range showed that nylon jacketed bullets and zinc bullets also yielded considerable reductions in lead emissions (see Table III). Lead concentrations of 7.5 and 10 mg/M^3 were emitted in the breathing-zone of two shooters for 10 minutes when using lead wadcutter ammunition. When using zinc bullets, lead was emitted at concentrations ranging from 0.25 to 0.50 mg/M^3 with a mean of 0.43 mg/M^3. When using nylon jacketed bullets (Smith and Wesson, "Nyclad"), lead levels ranged from 0.63 to 1.2 mg/M^3, with a mean of 0.92 mg/M^3.

C. Conflicting Studies

Another NIOSH study,[5] involving two indoor firing ranges, gave seemingly conflicting results. There was actually very little difference observed between the airborne lead contamination from copper jacketed and lead wadcutter ammunition. Lead emissions in the breathing-zones of shooters in one range were an average of 0.34 mg/M^3 with jacketed bullets, and 0.55 mg/M^3 with wadcutters. Shooters in the other range were exposed to lead at 1.50 mg/M^3 when using jacketed bullets, and 1.30 mg/M^3 with wadcutters. Since the ventilation at these two ranges was not judged superior to most, there remains 2 other possible explanations for the conflicting results:

1. Shooters at those ranges were firing at much slower rates or "bullseye" target practice (100 rounds per hour). The sampling results show that even the lead wadcutter bullets were emitting relatively low levels of lead when compared to other studies. Therefore, it could be assumed that the rate of fire plays an important role in airborne lead emissions.

2. Another possible explanation involves the quality variations among lead bullets. It is interesting to note the wide discrepancy of lead emitted by different lead bullet cartridges in the study by Fischbein, et al.[2] One cartridge type emitted about 12 µg of lead per shot whereas another averaged about 40 µg per shot. It is well known that cast lead alloy bullets should

contain relatively high amounts of tin and antimony for hardening purposes (typically 90% lead, 5% tin, and 5% antimony). Bullets that are too soft or improperly sized and lubricated may cause excessive barrel leading problems. Such bullets may also be viewed suspiciously as causing excessive airborne lead emissions. These quality variations could pose a problem for those agencies who must depend on the lowest local bidder for the casting and reloading of their target ammunition.

D. Possible Disadvantages of Bullet Substitutes

The expense of the jacketed ammunition was the major disadvantage that was voiced by firing range personnel when interviewed by NIOSH. The zinc bullets were considerably less expensive, but were found unacceptable in some ranges because of "bounce back" of the much harder zinc bullets from the bullet trap. The resulting eye hazard to shooters made the use of the bullet unsafe unless changes were made in the bullet trap. In one study designed to test the quality of the new cartridge for target use,[6] it was recommended that heavy canvas curtains be hung on the front of the backstops of ranges where bounce back is a problem. That study also found the accuracy of the ammunition to be comparable with standard 158-grain lead service loads, and the author concluded that the cartridge "appears a highly serviceable alternative to lead ammunition for use on indoor ranges when required."

Unfortunately, a few ranges, such as the one at the Federal Reserve Bank, would not be able to use a canvas curtain because the exhaust vents are located behind the bullet trap. Further study of copper-plated lead bullets may be fruitful for use in those ranges with zinc bullet bounce back problems. Copper flash-plated target bullets would be less expensive than copper jacketed service bullets. Furthermore, such a bullet could be just as effective in reducing lead emissions, provided the copper is thick enough to prevent the barrel rifling from cutting into the inner lead portion of the bullet. Of course, the total solution for eliminating indoor lead emissions could be achieved by the development of a lead-free primer, if possible.

Airborne zinc oxide levels were found to be well below the NIOSH recommended TWA concentration of 5 mg/M^3. They were also below the NIOSH recommended 15-minute exposure standard of 15 mg/M^3. Therefore, no zinc oxide health hazard would seem likely from firing zinc bullets. Similar observations were made when sampling for copper while firing copper jacketed bullets.[5]

VIII. CONCLUSIONS

All three ammunition types that were studied gave significant reductions in lead emissions during rapid-fire target practice when compared to traditional lead target ammunition. Unfortunately, due to a lack of sufficient quantities of copper and nylon-jacketed bullets during the study, there were not enough air samples obtained to give meaningful comparisons between the three non-lead and jacketed bullet types. The slightly higher lead levels generated by the nylon jacketed ammunition may possibly indicate that part of the jacket has decomposed before the lead bullet has cleared the end of the barrel. Before such a conclusion can be made, however, more samples would be needed and other variables, such as primer type and muzzle velocity, would have to be investigated.

IX. RECOMMENDATIONS

A. Bullet Substitution

On this basis of our sampling results, NIOSH recommends that either non-lead or jacketed bullets be used to help reduce lead contamination.

B. Ventilation

To provide an additional margin of safety, ventilation should be improved by consulting NIOSH publication No. 76-130, Lead Exposure and Design Considerations for Indoor Firing Ranges. Specifically, the following 2 areas need improvement:

1. The quantity of supplied air should be increased from the present 2050 cfm to about 7600 cfm. Also, total exhaust ventilation should be increased from 2250 cfm to 8400 cfm. If evenly distributed, this air quantity would provide a minimum linear air velocity of 50 feet per minute through the shooting booths and help sweep contaminants away from the shooters breathing-zone.

2. Air flow should be more evenly distributed. During the NIOSH survey, we observed uneven and turbulent air flow across the firing line. At times, smoke could actually be seen traveling backwards into the shooter's face. The plywood panels covering the bottom half of some shooting booths should be removed to allow air flow throughout the entire booth. Also, grills or louvres should be placed over the air supply openings to help direct air towards the firing line, and the obstacles (cabinets, boxes, etc.) along the back wall should be removed.

X. REFERENCES

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XI. AUTHORSHIP AND ACKNOWLEDGEMENTS

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XII. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are currently available, upon request, from NIOSH, Division of Technical Services, Publications Dissemination, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

Copies of this report have been sent to:

1. Federal Reserve Bank of Cleveland, Cincinnati Branch
2. U.S. Department of Labor (OSHA), Region V
3. NIOSH, Region V

TABLE III

TABLE I

Sampling Results for Inorganic Lead

Federal Reserve Bank Indoor Firing Range
Cincinnati, Ohio
HETA 81-019

December 10, 1980

Location	Sample Type	Bullet Type	Sampling Time	Lead Concentration (mg/M^3)	8-hour TWA (mg/M^3)
Booth 3	BZ*	Zinc	2:18-2:26	0.58	0.01
Booth 3	Area	Zinc	2:18-2:26	0.58	
Booth 3	BZ	Lead Wadcutter	2:36-2:43	3.4	0.05
Booth 3	Area	Lead Wadcutter	2:36-2:43	4.5	
Booth 3	BZ	Lead Wadcutter	2:53-3:03	9.3	0.19
Booth 3	Area	Lead Wadcutter	2:53-3:03	7.3	
Booth 4	BZ	Lead Wadcutter	2:53-3:03	12	0.25
›oth 4	Area	Lead Wadcutter	2:53-3:03	12	
Booth 4 (after shooting)	Area	Lead Wadcutter	3:09-3:19	N.D.**	
Booth 5	BZ	Lead Wadcutter	2:53-3:03	6.3	0.13
Booth 5	Area	Lead Wadcutter	2:53-3:03	4.7	
Booth 5 (after shooting)	Area	Lead Wadcutter	3:09-3:19	0.27	

* BZ = Personal Breathing-Zone Sample

OSHA Standard = 0.05 mg/M^3
(8-hour TWA)

** N.D. = Non-detectable

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