Workshop on Indoor Shooting Ranges: Responsible Care of Range Environment

Proceedings of the Workshop on Indoor Shooting Ranges September 16-17, 2005 – Rome, Italy

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The WFSA aims to act as a conduit for information and where there are questions pursuant to matters raised here in the accompanying materials, the WFSA encourages interested parties to make contact with the authors.
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FOREWORD

Responsible Care in Management of Indoor shooting ranges

Shooting in indoor ranges serves many important purposes. These vary from pure leisure time pursuits to preparing for Olympic competition and to law enforcement personnel improving their skills to protect the public. Shooting ranges have also provided an important venue to learn and practise firearms safety.

From its beginning, the WFSA has been concerned with the relationship between shooting and the environment. An integral part of this concern is the actual environment in the indoor ranges where so much shooting activity takes place.

There are a number of issues which are crucial to indoor shooting ranges. Lead contamination, gas emissions, unburnt propellant and noise are important issues this workshop addressed.

The information collected during the workshop and contained in this report will allow us to formulate better strategies for managing safe and healthy indoor ranges. These are examples and lessons from which we can learn to improve range operating conditions.

This workshop is not intended to establish universal standards. Specific procedures will always vary from one jurisdiction to another. Regardless, these are important lessons that can benefit us all.

A substantial amount of time and effort has been expended in preparation for this workshop. I want to thank both the Organizing Committee and the presenters. Their efforts in making this workshop possible are to be commended.

Carlo Peroni
President
INTRODUCTION

The WFSA

The World Forum on the Future of Sport Shooting Activities (WFSA) is an international association of over forty major hunting, sport shooting and firearms industry groups. It is chartered under Belgian law as an educational and scientific organization.

The WFSA is an official United Nations Non-Governmental Organization (roster status) and is the international voice for a hundreds million hunters and sport shooters. The issues addressed by WFSA are of concern not only to its members, but to the larger world community.
EXECUTIVE SUMMARY

A first ever “Workshop on Indoor Shooting Ranges – Responsible Care of the Range Environment,” was held in Rome, Italy, on 16 – 17 September, 2005. The Workshop was both an exchange of the latest available information and an examination of available solutions. Prominent experts made presentations and more than 40 representatives from ten countries attended.

Presentations were made under the following subject headings:

• Technical and Legislative Overview
• Indoor Shooting Risks and Experiences
• Risk Management Approaches
• Technologies – Solutions
• The Way Forward – Closing Session

The presentations highlighted the following main environmental and health issues:

• Lead
• Unburnt propellant
• Carbon monoxide and other gaseous emissions
• Noise

It was noted that every shooting range is unique in terms of structure and use. Despite the differences there are effective solutions to mitigate these above-mentioned issues.

Discussions illustrated the need to manage a range as a complete system. Management techniques to address these issues must be evaluated to ensure that their implementation does not have an adverse impact on the safe and successful operation of the facility. Effective range ventilation systems, a relatively well known solution to the problem of lead and gaseous emissions, were discussed in detail. Alternative ammunition and primers which avoid emissions of concern were discussed and critiqued.

Pertinent facts and specific techniques were brought to the attention of the Workshop. Emphasis was given to the fact that:

1. Dry sweeping in the range increases lead exposure;
2. Simple washing of face and hands after shooting considerably reduces the risk of lead exposure;
3. Risks of fire from accumulated unburnt propellant can be substantially reduced by proper range cleaning.

Primary Workshop conclusions included the following:

• When shooting ranges are properly managed, science tells us that risks associated with lead and other emissions can be eliminated or least minimized to an acceptable level;
• There is a pressing need to educate both shooters and range operators about indoor shooting range environment issues and management practices;
• Sport shooting organizations should make indoor shooting range environment issues a priority.
Workshop
Indoor Shooting Ranges
Responsible Care of Range Environment

Jolly Vittorio Veneto Hotel, Rome, Italy
September 16-17, 2005

AGENDA

Friday, September 16, 2005

8:30 – 9:00  Registration

Session 1.  Welcome, opening remarks

9:00 – 9:10  Welcome
Carlo Peroni, WFSA President

9:10 – 10:30  Plenary Session
Scope of the Workshop
Joachim Streitberger, Germany

Session 2.  Technical and Legislative Overview

Status of Lead Risk Assessment in the European Union
Andy Bush, LDA, UK

Keeping Indoor Ranges Open to Serve Society
Rick Patterson, USA

Overview of the ranges in Germany
Helmuth Kinsky, Germany

OPEN DISCUSSION

10:30 – 10:45  Coffee Break

Session 3.  Indoor Ranges: Risks and Experiences

Shooting Range Accidents: Lessons Learned in Safety and Health
Jean Paul Denis, Belgium

Fires in Indoor Shooting Ranges: Causes and Consequences
Joachim Streitberger, Germany

Gas Residues and Unburnt Propellant in Indoor Shooting Ranges
Jurgen Knappworst, Germany

OPEN DISCUSSION

12:45 – 1:45  Lunch
1:45 – 3:30  Plenary Session

Session 4.  Risk Management Approaches

German Standards versus Shooters’ Experiences
Hans Dieter Petersmeier, Germany

Control of Lead Exposure in Indoor Firing Ranges - a NIOSH Case Study
Bradley S. King, USA

OPEN DISCUSSION

Session 5.  Technologies - Solutions

Ventilation for Indoor Shooting Ranges
Gunter Mirbach, Germany

3:30 – 3:45  Coffee Break

3:45 – 5:15  Plenary Session

Ventilation System for the Largest Underground Shooting Range in Switzerland
Peter Berchtold, Switzerland

Latest Experiences on UITS Shooting Tunnels in Italy
Lorenzino Unio, Italy

Lead Exposure from Indoor Firing among Student on Shooting Teams
Scott Arnold, USA

Control of Lead and Unburned Propellant
Frank Compton, UK

OPEN DISCUSSION

Saturday, September 17, 2005

9:00 – 10:00  Plenary Session

Session 6.  The Way Forward – Closing Session

WORKSHOP OPEN DISCUSSION

10:00 – 10:30  Coffee Break

10:30 – 11:15  Plenary Session

Workshop Summary and Recommendation
Joachim Streitberger, Germany

10:30 – 11:15  Wrap-up

11:15  Meeting Adjourns
PROCEEDINGS

Session 1. Welcome and Opening Remarks

Welcoming remarks

Dr. Carlo Peroni, President of the WFSA, opened the Workshop at 9:00 a.m. on 16 September 2005 in the Hotel Jolly Vittorio Veneto, Rome Italy.

Remarks

Mr. Joachim Streitberger presented the reason for this workshop. In recent years, shooting organizations and regulators have been devoting quite some attention to hazards that can threaten health and safety in indoor shooting ranges. The World Forum on the Future of Sport Shooting Activities is proud of being proactive in addressing areas of concern in sport shooting, through its specific sub-committees. The European Commission has identified some occupational and user risks with airborne lead in indoor shooting ranges. The aim of the Workshop was to discuss the best way to handle them. It is a continuous learning process. Good management practices, together with improved technologies on ventilation, alternative materials and responsible care, will provide indoor ranges with an environment where all expectations in terms of health protection will be fully satisfied.

Session 2. Technical and legislative overview

Legislative Overview

Mr. Andy Bush, LDA Scientific Director, UK, presented the latest developments on the recently completed voluntary European Union Human Health and Environmental Risk Assessment on lead, including the use of lead ammunition. The assessment was carried out with the support of the European Commission and EU Member States and will now be subject to formal review. The presentation briefly explained the background to the project, the conclusions reached for lead ammunition on indoor firing ranges and the implications for the sport shooting industry.

Mr. Rick Patterson, Executive Director, National Association of Shooting Ranges, USA, presented remarks regarding the situation in USA. Shooting ranges are a valuable community asset. However, like any asset they must be managed properly to operate safely. Management of ranges is site-specific. The enclosed nature of indoor ranges requires addressing the potential for airborne lead exposure. There are case studies showing that airborne lead can adversely affect human health, but - just as important - there are adequate steps that can be taken to protect human health. Different management techniques were outlined.

Mr. Helmut Kinsky, DEVA, Germany, presented the fundamentals for construction and operation of shooting ranges in Germany, the so-called “Schießstand-Richtlinien” published by the German Shooting Sports Federation (DSB). These guidelines were developed in order to assure safety in, on and around shooting ranges. In addition detailed guidelines for aeration and de-aeration of indoor shooting ranges are given in order to protect the health of shooting range users from harm caused by the inhaled air. The German Firearms Act of October 11th, 2002 sanctions these requirements. On shooting ranges operated throughout Germany shortcomings of construction and mode of operation were demonstrated (in particular the use of inadequate ventilation systems).

Session 3. Indoor shooting risks and experiences

Mr. Jean Paul Denis, Belgium, presented a paper entitled “Shooting Range Accidents: Lessons Learned in Safety and Health.” He reported on fire in an indoor range. The fire was initiated when unburnt powder residues on the ground were ignited, resulting in a very high temperature that affected the
range structure, thereby generating toxic fumes. After this accident, shooting range layout, ventilation systems, emergency exits, safety features and regulations were all carefully investigated and modified to avoid this type of risk. In the future, other types of technical innovations will help to further reduce the risks in shooting.

**Mr. Dieter Stieffel**'s paper was presented by Joachim Streitberger, BVS, Germany. It gave a detailed analysis of several fires in indoor shooting ranges which killed several people. A change of the rules was made for the construction of indoor ranges, published in the Schießstandrichtlinien des Deutschen Schützenbundes, the official and mandatory guidelines for the construction and maintenance of private shooting ranges. Since then there have been no similar fatalities. This presentation showed some of the fires as examples, from which the new rules were developed. Particular emphasis was put on the problem of unburnt propellant and on the insulating materials used in indoor shooting ranges.

**Mr. Juergen Knappworst**, RUAG Technical Director, Germany, reported on studies that have been conducted to evaluate and analyse the presence of gas residues and unburnt propellant in indoor shooting ranges. The first study showed that carbon monoxide gas and fine dust lead particles are the leading components which must be de-aerated during shooting in indoor ranges. The second study resulted in published maximum threshold limits for concentration of CO gas and fine dust of heavy metals in indoor shooting ranges for law enforcement agencies on account of the higher volume of shooting activity. Non-toxic substitutes were presented as another potential management option. The final study identified amounts of unburned powder related to various cartridge and firearm combinations.

### Session 4. Risk management approaches

**Mr. Hans-Dieter Petersmeier**, Germany, presented a paper on existing restrictions on noise levels and other safety aspects in Germany. The presentation offered a short overview of the operating requirements. Displacement ventilation systems were presented as the current state-of-the-art technology. Operational costs and industrial solutions were identified, with reference to basic demands and calculations as required in ventilation technology.

**Mr. Bradley King**, of NIOSH, USA, presented a paper prepared in cooperation with Mr. Amir Khan on “Control of Lead Exposure in Indoor Firing Ranges”. An investigation of potential lead exposures was conducted at an indoor firing range to evaluate the ventilation system. Recommendations were made for engineering control improvements to minimize employee exposures to contaminants. These recommendations centred on ventilation and range design improvements to provide favourable conditions with regard to four criteria: filtration efficiency, airflow patterns within the range, range pressurization, and volumetric airflow rate at the firing line. The work is continuing, but implementation of several of these recommendations has already resulted in a reduction in exposures.

### Session 5. Technologies - Solutions

**Mr. Günter Mirbach**, Germany, presented a paper entitled: “Ventilation for Indoor Shooting Ranges”. Shooting activities may release harmful substances in the form of gases and unburnt propellant. Displacement ventilation and laminar flow away from the shooter was identified as the best way to evacuate these gases and particulates to prevent shooter exposure. He reported that mixing air ventilation systems will create turbulence which can bring gas- and particulate-laden air back into the user’s breathing zone.

**Mr. Peter Berchtold**, Switzerland, gave a presentation entitled “Ventilation System for the Largest Underground Shooting Range in Switzerland.” The facility described is the “Bruenig-Indoor Underground Sport Shooting Centre” in Lungern, Switzerland. It has three ranges including a 300-metre shooting tunnel. The ventilation system was designed to provide comfortable indoor climatic conditions (temperature and humidity) during all seasons. Other considerations included air quality (maximum concentration of harmful substances), frequency of use (number of shots fired), energy consumption, space requirements and construction costs.
**Mr. Lorenzino Unio**, of UITS, Italy, presented a paper entitled “Latest Experiences with UITS Shooting Tunnels in Italy”. Since shooting is an indispensable component in the training and preparation of the police forces whose task is to protect our society, it is an activity that certainly cannot be curtailed. The existence of specific facilities, suitably equipped, will increase the safety of both range personnel and marksmen, and will also permit better management, as regards environmental protection in general. Videos illustrated the ineffectiveness of mixing air systems and the effectiveness of laminar flow ventilation in protecting range users. He also presented a new solution for backstop material.

**Mr. Scott Arnold**, USA, presented a paper prepared in conjunction with Tracey Lynn, Charles Wood and John Middaugh entitled, “Elevated Blood Lead Levels Among Student Shooters at Indoor Firing Ranges with Inadequate Lead-Safety Operating Procedures and Range Design”. During 2002-2004, the Alaska Division of Public Health (DPH) conducted an investigation to determine whether school rifle teams using indoor rifle ranges were being exposed to excessive amounts of lead. Five indoor ranges used by 66 members of shooting teams, aged 7-19 years, were investigated. Improper range design, operation, and maintenance resulted in elevated BLLs among student shooters (> 10 µg/dL) and adult coaches in four of the five ranges. Blood lead levels were normal in students who practised at one range with a modern ventilation system and established safe operating procedures. Dry sweeping was a significant risk factor for elevated BLLs in student shooters.

**Mr Frank Compton**, UK, presented a paper on “Control of Lead Dust and Unburned Propellant in Indoor Ranges”. Range designers and managers need to consider the effects of lead, unburned propellant, carbon monoxide, and also the cleaning of the range. Effective ventilation within the range will resolve lead and carbon monoxide environmental health issues. Cleaning is critically important. Examples of well thought-out designs and effective cleaning regimes were illustrated. Each range is unique and therefore every range requires different management approaches.

**Session 6. The Way Forward - Closing Session**

**Mr. Joachim Streitberger**, Director of the German Federal Association of Shooting Ranges (BVS), presented a summary of the workshop. The assembly reviewed the summary and approved the recommendations without reservation.
Session 1
Welcome
Opening Remarks
Ladies and Gentlemen, Delegates:

My name is Carlo Peroni and I am the President of WFSA, the World Forum on the Future of Sport Shooting Activities.

It is a great privilege for me to welcome you to this Workshop organized by the WFSA in the attempt to present and debate some important developments connected with health protection on indoor shooting ranges.

Thank you all for coming. The excellent participation is a fine reward for the sacrifices necessary to make this event happen, and no doubt the presenters and chairs will be proud to play out their important roles in these coming two days.

I warmly thank you for attending, and by your presence making this event a very much more directed and successful one.

Now, to go on, let me ask a question: why are we here? My answer would be: because we have a problem and because we want to find a solution to it. I am sure that through the debates and presentations in the workshop we will either find an answer to our problem, or else we will go a very long way towards it.

As you are aware, The European Commission, in conjunction with the industry, is conducting a Lead Risk Assessment and some problems have been identified regarding health for users of indoor shooting ranges. We knew there was a richness of experience and knowledge spread all over the world which just needed to be gathered and be coordinated.

And here we are! We appreciate the effort you have made, travelling for thousand of miles, to spend a couple of days sitting in this room, discussing science and health protection, while you would probably have better enjoyed walking outside in the shadow of some Roman history.

Why this initiative? I would like to mention some of the guiding principles of the World Forum:

- The Forum is a constructive, active organization. In a spirit of goodwill and cooperation, it offers the world’s decisionmakers information and solutions to problems. It provides options when it is asked questions.
- The Forum is open, and it encourages the exchange of information and views among all interested parties.

This workshop is the second conference on themes of great importance for the exchange of information on all matters relating to environment and health protection in shooting activities. In the European Union, as well as in other regions of the world, there are many programmes attempting to give guidance on air, water and soil quality. These may have important
implications for environmental management programmes, plans and permits, community concerns, and market access for metal-containing ammunition.

This workshop will focus on principal aspects of health protection and safety in indoor shooting ranges. We will be talking about hazard, risk assessment and technical developments.

You have noted from the programme what a distinguished set of speakers we have from all over the world. They will give us the best of the best science and management. They will address problems and provide guidance. This is an opportunity for establishing key contacts, allowing good discussions, and exchanging ideas on both policy and strategic concepts.

I would like now to publicly thank the WFSA’s Organizing Committee of this Workshop: Mr. Vito Genco, Mr. Thomas Mason, Mr. Rick Patterson, Mr. Ted Rowe, Mr. Joachim Streitberger. The Committee has been an admirable driving force for this current event, the second in the subject area, having worked hard for almost six months to bring it about.

Thank you for your attention.
Why a Workshop on Indoor Shooting Range Ventilation?

By Joachim Streitberger, Germany

Director of the German Federal Association of Shooting Ranges (BVS)

In recent years, shooting organizations and regulators have been devoting quite some attention to risks that can threaten health and safety on indoor shooting ranges.

The World Forum on the Future of Sport Shooting Activities is proud of always being proactive in identifying areas of concern in sport shooting operations, through its specific sub-committees.

Our aim is to identify problems, to study their characteristics, to look for examples of effective legislation, to gather experience, and to search out solutions.

I am honoured to be the Chairman of the World Forum Environment Sub-Committee which is responsible for an area where environment, health and safety are the focus. At our General Assembly, in Nuremberg in 2005, the Forum decided to host this workshop and, since then, we have been working with the best experts worldwide, and asking for their contributions to the success of this meeting.

Our aim is for range designers and managers to consider the effects of lead, unburnt propellant, carbon monoxide and the cleaning of the indoor ranges in which cartridge-propelled lead-based ammunition is used.

We know indoor shooting creates air pollution problems with various consequences, such as potential lead and carbon monoxide exposure. Around the world, sport shooting associations, law enforcement agencies and regulators have been learning by doing, and have started giving guidance that is certainly improving the health-and-safety operating conditions of indoor ranges. But as in the case of every new process, we feel that there is a need for strong action aimed at speeding up the scientific knowledge on what to do and how to do it in the progress towards a safe and healthy environment housing indoor shooting.

As we know, industry, in cooperation with the European Commission, is conducting a Voluntary Risk Assessment on lead, in particular with the participation of the Lead Development Association (LDA) and the supervision of the Dutch Government. Mr. Andy Bush, Scientific Director of LDA, in one of the next presentations will provide us with an update of this important program which has reached the cost of roughly three million Euro. The European Commission has identified some occupational and user risks with airborne lead in indoor shooting ranges, and we are here to discuss the best way to handle them.

Ventilation is a concept more than a simple action. It is our belief that proper ventilation should respond to the many concerns related to the air in shooting tunnels: lead, carbon monoxide, and protection of workers during cleaning procedure. We, in particular in Germany, have had a series of accidents with fatalities due to fire caused by unburnt propellant. It is also our belief that proper cleaning procedures should address the accumulation of unburnt propellant.
The whole spectrum of hygiene and cleaning operations is important, central to good management practices. We believe that this is quite an unexplored area, one that to date has been erroneously considered the Cinderella of indoor shooting operations. We now know that all tasks related to cleaning carried out by range staff, including wearing of protective clothing such as face masks, hand washing and the cleanliness of the shooting tunnel, are extremely important in providing worker protection for health, and for safety against unburnt propellant.

In conclusion, and again: why this workshop?

WFSA has a unique mission to further carry on research and outreach as a priority to heighten awareness of controls of the hazards present in shooting facilities. We strongly believe that WFSA should guide the process of innovation and serve as a clearinghouse for such information, helping to make sport shooting safe as well as enjoyable.

What I would like to highlight is that we are in the middle of crossing a bridge. On our backs we have traditions which sometimes turn out to be no longer in accordance with new understandings of best practices for health and safety protection of workers and shooters.

We are in a continuous learning process. We are certain that good management practices, together with improved technologies on ventilation, alternative materials and responsible care, will provide indoor ranges with an environment where all expectations in terms of health protection will be fully satisfied.

That is why we are here today, to learn from the experts, to discuss solutions, and to make plans that will drive indoor shooting towards a safe and prosperous future.
Session 2

Technical and Legislative Overview
EU LEAD RISK ASSESSMENT
HEALTH RISK ON INDOOR SHOOTING RANGES

Andy Bush, UK
Manager for Science
Lead Development Association International

September 2005
EU Lead Risk Assessment  
Health risk on indoor shooting ranges  

Andy Bush, UK  
Manager for Science  
Lead Development Association International  

Abstract  
The lead industry recently completed a comprehensive voluntary European Union human health and environmental risk assessment on lead, including the use of lead ammunition. The assessment was carried out with the support of the European Commission and EU Member States and will now be subject to formal review. The presentation will briefly explain the background to the project, the conclusions reached for lead ammunition on indoor firing ranges and the implications for the sport shooting industry.

Introduction  
The lead industry recently completed a comprehensive European Union human health and environmental risk assessment on lead. The final reports are now under review by the European Commission and the EU Member States. The assessment covers all major applications of lead, including ammunition, and this paper explains the background to the project, the conclusions in relation to lead ammunition and the next steps which must be taken by industry in order to address the conclusions.

Why a Voluntary Lead Risk Assessment?  
Many chemicals possess harmful properties which can, under certain circumstances, give rise to risks either to human health or to the environment. If such risks are suspected, the conventional approach is to conduct a risk assessment and, if an unacceptable degree of risk is detected, take appropriate measures to manage that risk.

In recent years, however, there has been an increasing tendency for decisions to be taken on the use of chemicals without first establishing that they present any risks in specific applications. Some metals – notably lead, cadmium and mercury – have been particularly targeted in this way and various legislative proposals have been put forward to prohibit applications. Within the European Union, for example, legislation on end-of-life vehicles and electronic and electrical equipment has imposed wide-ranging bans on the use of lead whilst proposed legislation on waste electrical and electronic products and on construction and demolition waste will probably impose similar restrictions. At a national level Denmark has prohibited a large number of lead uses.
A Voluntary Risk Assessment

An official system exists in the EU for assessment risks from substances. However, this first requires a Member State to commit to conduct such a mandatory assessment on behalf of all other EU Member States. Lead has never been proposed for a mandatory risk assessment under the EU process. However, restrictions continue to be proposed and it was widely felt by industry that a formal risk assessment should be conducted to establish whether or not such restrictions are really justified. If the risk assessment reveals no serious risks it will provide a valuable tool in industry’s defence of the products in question. The European lead producing industry therefore decided to undertake a voluntary risk assessment.

In order to avoid possible criticisms of bias, the industry felt that it was necessary to involve the European Commission and/or relevant authorities in Member States to the maximum extent possible. This includes such issues as helping to ensure the validity and representativity of data and sites surveyed, as well as the chemical compounds and applications included in the assessment. In addition, their views have been sought on the consultants selected to conduct the risk assessment, and on the risk assessment reports themselves.

Roles and Responsibilities

After negotiations between industry and the European Commission and EU Member States, the main risk assessment commenced in 2002 and final reports were submitted to the European Chemicals Bureau in May 2005. The overarching principles under which the risk assessment has been conducted are briefly set out below:

Industry

The lead industry has been responsible for the management and funding of the risk assessment, with day-to-day coordination conducted by its trade association, Lead Development Association International (LDAI). The industry retained independent consultants to conduct the risk assessment and established a Scientific Review Panel (again comprising independent experts) to keep under review methodologies, data, compliance with the official EU Technical Guidance Document on risk assessment and the draft reports that were produced.

Reviewing Country

The Netherlands Government participated in the process as a “reviewing country” and monitored the progress of the risk assessment and advised the industry on key aspects of the project. This included the scientific methodologies used, the selection of consultants and review panel members and the review of the risk assessment reports themselves. The Dutch also reported to other Member States on industry’s progress with the project, in particular highlighting where differences of opinion remain.

Consultants

The following leading consultants in EU metals risk assessments conducted the main risk assessments:

Environment: Dr Patrick Van Sprang EURAS, Belgium
Prof Erik Smolders University of Leuven, Belgium

Health: Dr Craig Boreiko International Lead Zinc Research Organisation
Dr Rodger Battersby EBRC, Germany
These consultants were responsible for reviewing existing international literature on lead, proposing the scientific methodologies to be used and ultimately drafting the risk assessment reports themselves.

**Scope**

Lead metal, the main commercial lead oxides (PbO, Pb3O4) and lead stabilisers account for over 95% of lead uses and are therefore be covered in the risk assessment. As with any metal, there is a wide range of other chemical compounds in use, but applications are very low volume and, in many cases, represent in declining markets.

**Principles of Risk Assessment**

In simple terms risk assessment involves the identification of a hazard and the level of exposure at which it occurs, coupled with measurement of actual exposure levels of people and ecosystems. The combination of hazard and exposure data enables risks to be identified and appropriate risk management measures adopted. For humans risks may be associated with occupational, environmental or consumer exposures. The environment may be affected by industrial emissions or by diffuse sources – sometimes from products containing the chemical under investigation.

As already stated, the risk assessment reports have been conducted in compliance with guidelines set out in the EU Technical Guidance Document (TGD) for risk assessments on new and existing substances. The TGD requires that for each exposure endpoint, one of three conclusions are reached:

- **Conclusion (i)** There is need for further information and/or testing
- **Conclusion (ii)** There is at present no need for further information and/or testing or for risk reduction measures beyond those which are being applied
- **Conclusion (iii)** There is a need for limiting the risks: risk reduction measures which are already being applied shall be taken into account

Where “conclusion (i)” is reached in a voluntary risk assessment such as lead, there is a formal requirement for industry to agree with the Reviewing Country (i.e. the Netherlands government in the case of lead) on how additional data will be provided to characterise the risk.

Where “conclusion (iii) is reached, i.e. risks exist which need to be managed, industry must come submit a formal proposal for risk management measures to the European Commission for approval. Once approved, industry must implement the agreed measures.

**Conclusions on Lead Ammunition**

A targeted risk assessment was conducted on lead in ammunition in which environmental risks were assessed for the following scenarios using official European Commission risk assessment methods:

- Rifle/pistol ranges
- Clay target/sporting clay ranges
- Hunting

The report concluded that no environmental risks result from shooting ranges. The conclusions refer to the environment outside the boundary of the ranges and assumes that all lead falls within the range boundary and that the range is remediated upon closure.
For hunting, the report concludes that no risks exist with the exception of freshwater sediments, where using a worst case scenario of accumulating lead in the environment over the next 100 years from hunting, a potential risk is identified. However, further work is already underway to refine this assessment with a view to removing the risk at a later stage.

As yet the targeted assessment has not considered the issue of direct ingestion of lead shot or secondary poisoning of predators from consumption of lead shot contaminated prey. This assessment will need to be conducted in the near future, probably in 2006.

Regarding the human health risk assessment, the report concludes that there are currently insufficient data to assess possible risks from the reloading of cartridges with lead ammunition. The report therefore concludes that further information should be collected on this scenario.

For indoor firing ranges the report concludes that a hypothetical risk exists to both consumers and employees working on such ranges. This conclusion is reached on the basis of very limited data on air lead levels at indoor ranges and data on the levels of lead in the blood of workers and consumers. However, due to the very limited data available, it is concluded that further data are required in order to fully characterise the risk on ranges in the EU.

### Addressing the Conclusions for Lead Ammunition on Indoor Ranges

Assuming the conclusions in the May 2005 risk assessment reports are confirmed by the European Commission, industry will be required to address the recommendation that further information is needed to characterise the risk from the use of lead ammunition on indoor firing ranges. This could be done by industry committing to collect additional data on typical exposures to lead in air on indoor firing ranges in the EU, on a representative basis. Alternatively, the industry could opt to accept that a risk may be present and propose a risk management strategy. This could perhaps initially involve an assessment of appropriate ventilation systems and the generation of lead in air data which demonstrates that such systems deliver adequate protection. Industry might then consider developing a strategy for promoting the voluntary adoption of such systems across firing ranges in the EU.

### Next Steps

The risk assessment officially started in 2002 and final reports were submitted to the European Chemicals Bureau in May 2005 for technical review by the EU Member States through the EU Technical Committee on New and Existing Substances (TCNES). Member States must provide a first round of written comments on the reports by 30 September 2005. Industry, in consultation with the Netherlands government, must then respond in writing to the comments and update the reports accordingly. This will be followed by a full technical discussion of the reports by TCNES, possibly in the first half of 2006. It is anticipated that final agreed conclusions will be reached towards the end of 2006, after which industry will be required to come forward with proposals to manage risks and provide additional data where necessary.
KEEPING INDOOR RANGES OPEN TO SERVE SOCIETY

Richard Patterson, USA

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September 2005
Keeping Indoor Ranges Open to Serve Society

Richard Patterson, USA

Executive Director, National Association of Shooting Ranges USA

Abstract

Shooting ranges are a valuable community asset. However, like any asset they must be managed properly to operate safely. Management of ranges is site-specific. The enclosed nature of indoor ranges requires addressing the potential for airborne lead exposure. There are case studies showing that airborne lead can adversely affect human health, but – just as important – there are adequate steps that can be taken to protect human health.

Introduction

Thank you to the World Forum on the Future of Sport Shooting Activities for bringing together the top experts in the world to address the important issue of lead management at indoor shooting ranges. Shooting ranges provide safe venues of participation for more than 100,000,000 enthusiasts, are where military and law enforcement personnel learn firearm safety and proficiency, and contribute to local economies. Outdoor ranges protect valuable open space, and all ranges provide a place for people to learn and practise the safe handling of firearms.

In spite of these important benefits, we as a responsible industry and community can’t ignore proper management to prevent unintended consequences resulting from range activities. While most ranges are managing lead responsibly, there have been cases where the range was not managed properly and human health has been adversely affected. The National Association of Shooting Ranges is dedicated to providing range operators and developers with guidance and information. We are also keenly aware of the need to reach out and establish partnerships with others, such as government agencies and regulators.

That is exactly what we did in addressing the issue of spent ammunition at outdoor ranges. We are following that same successful model with management of airborne lead at indoor ranges. Our experience has been that industry and regulators working together can be more effective. None of us is as smart as all of us! The first step after establishing the partnership to address airborne lead was to create a guidance document based on real world experience and applications. Our publication is the result of collaboration between range operators, the Occupational Safety and Health Administration, the National Institute for Occupational Safety and Health and state health departments. It’s designed to educate range operators on regulatory requirements as well as provide an introduction to some of the management techniques that have been proven effective at preventing human lead exposure.
The problems

Before we can manage lead we have to know where it comes from. There are several different sources of lead at an indoor range. First is the primer. The primer is the part that is struck by the firing pin, ignites, and in turn ignites the powder. The burning powder generates gases of higher volume that propel the projectile down the barrel. Primers contain lead styphnate or lead azide. If the projectile has an exposed lead base, the hot gases can create a boil-off of airborne lead. An exposed bearing surface can create airborne lead particles from frictional heat and mechanical abrasion between the barrel rifling and the exposed lead. Most of the airborne lead at the firing line comes from an exposed lead projectile. By use of a jacketed projectile, airborne lead can be reduced by as much as 80%. Downrange lead dust can be generated by the projectile’s impact with the bullet trap. Different traps have different risks for generating lead dust. Using a trap that prevents bullet breakup and or traps lead dust in a liquid can notably reduce airborne lead from this source.

Perhaps the most difficult part of working with ranges is their site-specific nature. There is no one-size-fits-all answer to range management. Every range is different and requires its own solutions and, as we’ll see in the next two days, there are also many ways people have developed to implement any one solution.

Managements and solutions

Lead alternatives

One lead management solution is to stop using ammunition that contains lead. Technology is evolving in this area, but it’s not as simple as it sounds. Primers that do not contain lead exist, but their storage life is short and reliability seems not yet as good as traditional priming mixtures that contain lead compounds. Technology for non-lead projectiles is also developing. There are only so many materials on the periodic chart, and when we look at the ballistic requirements for ammunition, the list is even shorter. Even if a material can be engineered to function like lead, there is still the question of the fate and transport of the non-lead alternative. The US Army tried to develop what they called the “green bullet” only to discover that it was more vertically mobile than lead in the environment and had a 100% cancer rate in laboratory rats. As may be clear by now, I am not a fan of “wondermetal”. Beyond the potential unknown risks and unintended consequences of wondermetal, it could lead the range operator into a false sense of security about the need for range management. Lead has risks, but it has been studied for decades. We know what it can do, but just as important we also know how to manage it. While research continues on a suitable alternative, let’s manage lead.

Ventilation

Ventilation is perhaps the best-known management solution. It is the focus of this workshop (and I look forward to hearing how others are managing ventilation at indoor ranges). One of the biggest questions is closed loop versus direct vent systems— filtering and recirculating the air or moving the air out of the building. Both have advantages and both have disadvantages.

The closed loop system is more expensive to install and operate and requires periodic monitoring, but results in less expensive heating and cooling. There is no outside vent, so there is no need for additional management in this area.

Direct vent is less expensive to install and operate, but results in higher heating and cooling costs. It also may require additional management of the area around the outside vent.

Implementation is a simple concept with many alternatives. In general, we need to have air moving downrange from behind the shooter at no less than 50 feet per minute to no more than
75 feet per minute. If it moves too slowly, not enough air moves to supply fresh air in the shooter’s breathing zone. If it moves too quickly, it can create a vortex in front of the shooter that actually pulls the discharge gases back into the face of the shooter.

Other innovations, such as perforated walls and vent positioning, have also been used to prevent this vortex.

Ventilation is not just an install-and-forget system. Filter replacement - for systems using filters - is a required maintenance activity. Regular monitoring of system effectiveness is a good practice. In the United States, monitoring system effectiveness is mandatory for commercial ranges. US regulations require measurement of system effectiveness when the system is first installed, every three months and any time there is a significant change in use, controls or equipment.

I look forward to hearing from our other experts in ventilation practices over the course of this workshop.

Cleaning up

While ventilation is why we’re here, there are other important aspects to proper management of lead at an indoor range. Sanitization of the range (what we in the States refer to as “housekeeping”) is a critical part of effective lead management. A clean range is a healthy range. Lead dust can accumulate on surfaces and be stirred up by muzzle blast or shooter movement. An accumulation of unburnt powder is another risk in a poorly cleaned range. A 20-year-old range in Pennsylvania had a fire that lifted the floor when unburnt powder that accumulated in an expansion joint in the concrete in front of the firing line ignited. Fortunately no one was hurt, but it is a lesson on the importance of range sanitization.

How the range is cleaned is critically important. First and foremost, never dry sweep. This is one of the worst things that can be done at an indoor range. The sweeping action stirs up dust that has settled and can lead to very high airborne lead levels. A HEPA vacuum is perhaps the best, but wet mopping is effective also (just be aware that disposal of the water may be regulated). HEPA vacuuming also has the advantage of easier cleaning of vertical surfaces. Materials used in range construction and sound attenuation should be chosen for their ease of cleaning. Rough and porous surfaces may be more effective at absorbing sound energy, but are more difficult and time-consuming to clean.

Personal hygiene is another very important aspect of lead management at an indoor range. Eating, drinking or smoking on a range can expose a shooter or range worker to ingestion or inhalation of lead dust that has accumulated on the food, beverage or cigarettes. Smoking is particularly harmful because it creates a risk of both ingestion and inhalation. Not allowing eating, drinking or smoking on a range eliminates one potential exposure pathway. Washing hands when shooting is finished is another important step to reduce lead exposure. New York State Health Department did a before-and-after study on shooters with elevated lead levels and found that washing hands and face significantly reduced those blood lead levels.

Controls

Administrative controls are a recognized way to reduce lead exposure in employees. Essentially it means reducing the amount of time any one employee spends in the range area, and rotating range sanitization work. The advantage is this is a simple and low-cost way to reduce lead exposures of any one employee. The downside is additional work for the supervisor to ensure that schedules are being adhered to and an increased training load because more people need to be trained. In the US this can result in higher insurance costs.
Protection means

Use of respirators can also be part of a lead management plan. Like protective clothing, it is generally used for range cleaning and maintenance—activities that have the highest risk of lead exposure. That said, I do know of a club range in New Jersey that had an inferior ventilation system. At least one club member had an elevated lead level. Rather than spend the money on a new ventilation system, the club members voluntarily decided to wear respirators when using the indoor range. Using respirators as part of a lead management plan is not a simple case of buying a respirator and putting it on. Respirators put stress on the respiratory system. As a result, US regulations require an employee to get approval from a physician before using one. What type of filter is also important. Effectively filtering out airborne lead requires a P-100, R-100 or N-100 filter cartridge.

The respirator must fit properly in order to be effective. There are two tests for proper fit. One is the qualitative test and the other a quantitative test. The qualitative test introduces an irritant around the respirator while it is being worn. If the wearer can detect the irritant, the respirator does not fit properly. The quantitative fit test is more difficult to implement, since it generally must be performed in a laboratory. This test establishes a quantitative analysis of the seal around the face of the user. As with any equipment, maintenance is necessary to keep the respirator in working order. This means proper cleaning and storage, and replacement of filter cartridges.

Protective work clothing—the tyvec suits—is another way to reduce lead exposure in workers. This is usually used in industries and workplaces where lead levels are extremely high—higher than would be found in a range. However, it is still worth mentioning and can be a worthwhile practice during range cleaning and maintenance activities when lead levels at the range are likely to be highest.

Training

That is a brief overview of airborne lead management techniques for indoor ranges. All the management plans and equipment in the world won’t help one bit if the range operators are unaware of the issues and the potential solutions. The partnership between industry, OSHA and NIOSH is now entering the next phase—we are developing and scheduling a seminar series to help range operators develop effective airborne lead management plans (based on the information in our manual).

Range employees must also be educated in how to use and implement the plan. Educating the employees on what to do and why to do it is essential to success (and required by US regulations).

All stakeholders must be educated for us to be as effective as possible. In addition to our efforts to educate range operators and employees, we are also reaching out to educate the shooters themselves through articles in magazines and posters.

Conclusion

We know there are potential risks to lead at shooting ranges. Just as important, we also know lead can be managed. As an industry we are working to make sure ranges have the best information available to manage their ranges and keep them open and serving the public.

Thank you to the WFSA for bringing together the experts, and of course to each of the speakers for taking the time to share expertise. Working together in this cooperative forum will provide a synopsis of the latest information available and further promote effective range management techniques.
A GENERAL OVERVIEW OF INDOOR SHOOTING RANGES IN GERMANY

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September 2005
A General Overview of Indoor Shooting Ranges in Germany

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Abstract

The fundamentals for construction and operation of shooting ranges for handguns in Germany are the so-called “Schießstand-Richtlinien”, published by the German Shooting Sports Federation (DSB). These guidelines’ purpose is to assure safety in, on and around shooting ranges. Besides this, detailed guidelines for aeration and de-aeration of indoor shooting ranges are given in order to protect the health of shooting range users from harm caused by the inhaled air, polluted with gases and dust. The German Firearms Act of October 11th, 2002 confirms these requirements. Article 9 of the law determines the possibility of restricting operating permission on a shooting range in order to protect the health of human beings from any risks and serious disadvantages which can come about from the handling of firearms and ammunition. Impositions on aeration and de-aeration of shooting ranges are among possible restrictions to permissions. On shooting ranges operated throughout Germany shortcomings of construction and mode of operation are frequently seen (use of the wrong ventilation system).

Introduction

In Germany indoor shooting ranges are often operated by sports shooters and authorities (federal police, police and customs). The installations are mostly for the use of handguns of all calibres, and at distances up to 25m.

More and more indoor shooting ranges are being built for hunters. These are facilities with distances from 30 metres up to 100 metres, which have a canvas in front of the bullet traps. By dint of a video projector, sequences of fleeing game animals are shown. On these ranges, hunters are shooting with all kinds of rifle calibres allowed for hunting.

In the use of big bore rifles, large quantities of gases are discharged, and these place a heavy demand on aeration systems.

1 Richtlinien für die Errichtung, die Abnahme und das Betreiben von Schießständen, herausgegeben vom Deutschen Schützenbund e.V., Ausgabe August 1995, Stand Januar 2000;
In general, a high proportion of the existing aeration systems do not meet the demands at all, or else they fulfil them only insufficiently. This also applies to the older indoor shooting ranges used by the authorities.

The need for aeration systems is not only limited to indoor shooting ranges.

As the population in Germany becomes denser, more and more outdoor shooting ranges are experiencing problems as a result of exceeding the maximum permissible noise levels. In order to minimize the noise of discharge, sonic sluices of 5 metres to 10 metres are built. In these sluices the contaminated air cannot withdraw freely and in the case of unfavourable wind direction will be blown directly back to the shooter.

These structural alterations necessitate efficient aeration systems which are often lacking.

Pollution of the air around the shooter during shooting

If there is no low-pollution ammunition used, the amount of gas freed during the firing of a firearm is between 0.05 litres (small bore, calibre .22 LR) and 5.00 litres (in big bore rifles).

Referring to the composition of the propelling charge, the combustion frees the components CO – CO$_2$ – N$_2$ and NO$_2$. Beyond this, there is further pollution caused by lead and lead dust resulting from the composition of the primer and the projectile. In order to keep harmful and polluted air away from shooters and supervisors, the ventilation systems have to be built in a manner that provides de-aeration to the bullet trap’s direction. There must be no backflow in the direction of the shooter.

Different aeration concepts

In Germany there are two different concepts of aeration systems mainly used: there is mixed ventilation and displacement ventilation.

Sometimes through lack of detailed knowledge and also for reasons of economy, combinations and modifications of these two aeration systems are used. Usually they do not provide a satisfactory solution.

Mixed ventilation

Often the mixed ventilation system is used either at construction or during re-fitting of shooting ranges. This aeration system is characterized by incoming air which is blown into the room with high velocity through the correspondingly constructed air-discharge elements. The incoming air mixes with the air in the room. At the same time the air is extracted from different places on the shooting range.

The bigger the distance between the point of incoming air and the point of exhaust, the lower the velocity of flow, and because of the generation of negative pressure, the air starts to flow back in the shooter’s direction. In doing so, air rolls are created which provide for the backflow of gases and dust from the shooting lane to the shooter’s direction and for the air-pollution in the area around the firing points. So the creation of the air rolls provokes an equal spreading of pollutants.

With this kind of aeration system the required rate of air-exchange is determined by the calibre used. Common practice is:

- rifles (.22 LR) = 2.5 times per hour
- big bore handguns = 10 to 15 times per hour
- dynamic shooting at varying distances > 30 times per hour
The great disadvantage of the mixed ventilation system is the raising and the dispersal of dust and pollutants located on the floor of the shooting range, and their insufficient removal.

**Hence, this aeration system is not suitable for handgun shooting ranges.**

**Displacement ventilation**

This aeration system is characterized by an airflow which causes only very small turbulences. The precondition is that the outgoing air is exhaled all along the cross section of the shooting range back wall. The openings for the extraction of the air are situated in the bullet trap area.

In contrast to mixed ventilation, displacement ventilation provokes only a light airflow (about 0.25 m/s). The aeration must be trimmed to cause a slightly low pressure.

The supply air should be heated, especially when this is demanded in laws or by-laws (such as the regulations found in the employer’s liability insurance).

In the mechanism for supply, air and exhaust air filters have to be installed. These have to be cleaned regularly, especially in the exhaust section, because of the lead dust.

**Summary**

In regard to indoor shooting ranges, displacement ventilation is now state-of-the-art. Mixed ventilation is unsuitable for using on them.

The literature describes a combination of both, mixed and displacement ventilation (ILF= Inclined Laminar Flow), but sound experience of practical application of this combined system is still unavailable.

The Dutch police and the German Federal police department in Hangelar have a system with outlets for displacement ventilation – using piston-type air movement – as a result of a development produced by a German company.

It has to be realized that there are substantial shortcomings in aeration and de-aeration systems of indoor shooting ranges in Germany. Primarily the shooting ranges for sport shooters, hunters and commercialized facilities are involved. Also, the aeration system of partly covered shooting ranges is in some cases insufficient.

The reason for the insufficient functionality of some ventilation systems is a lack of knowledge concerning the special requirements of shooting range aeration systems, even among experts on ventilation engineering.

Often the ventilation systems are installed on a do-it-yourself basis for reasons of economy, in many cases with only poor and insufficient results.

For this reason it is strongly recommended either to control the planning and installation of the ventilation system’s construction with the help of an expert third party, or to put only experts in charge of planning and construction of the aeration system, employing people who have already proved their experience in meeting the special requirements of indoor shooting range ventilation systems.
Literature

Richtlinien für die Errichtung, die Abnahme und das Betreiben von Schießständen, herausgegeben vom Deutschen Schützenbund e.V., Ausgabe August 1995, Stand Januar 2000;

*Guidelines for the Construction, Approval and Operation of Shooting Ranges published by the German Shooting Sports Federation (DSB) in August 1995, version of January 2000*

Entwurf des überarbeiteten Kapitels 2 (”Be- und Entlüftung sowie Schallschutz”) der Schießstand-Richtlinien; Autor: Dieter Stiefel, Deutscher Schützenbund

*Draft version of the revised Chapter 2 of the Guidelines for the Construction, Approval and Operation of Shooting Ranges by Dieter Stiefel, German Shooting Sports Federation*

”Raumlufttechnische Anlagen für geschlossene Schießstände”
Günter Mirbach, fischer energie – haustechnik consult GmbH, Köln

*”Ventilation systems for indoor shooting ranges”*
Günter Mirbach, fischer energie – haustechnik consult GmbH, Cologne
Report on the occasion of the congress “shooting ranges and environment“, Ulm, 2002, April 29th, organized by the German Shooting Sports Federation
Session 3

Indoor Shooting Risk and Experience
SHOOTING RANGE ACCIDENTS:
LESSONS LEARNED IN SAFETY AND HEALTH

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September 2005
Shooting Range Accidents:
Lessons Learned in Safety and Health

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Consulting in Ballistics, R&D and Quality Assurance

Abstract

Some sixteen years ago, a bad accident occurred on a shooting range in Belgium.

A general fire started, and twelve shooters died from fire and inhalation of fumes. The fire was initiated when unburnt powder residues on the ground were ignited, resulting in a very high temperature that affected the range structure, thereby generating toxic fumes.

After this accident, shooting range layout, ventilation systems, emergency exits, safety features and regulations were all carefully investigated and modified to avoid this type of risk.

In the future, other types of technical innovations could help to further reduce the chemical risks in shooting. These would involve cleaner primers, lead-free bullets, and improvement of cleaning and ventilation systems.

Introduction

The risk level in a shooting range is extremely low, the main potential sources, beginning with the most consequentially direct, being as follows:

- Accidental direct shot;
- Ricochet or returning fragments;
- Fire;
- Toxic effects of lead and other chemical substances, from bullet and primer composition;
- Effects resulting from noise.

In fact, the risk level resulting from firearms use on a range is so low that in Belgium, shooter insurance represents less than two Euros per year to add to the insurance figure related to a shooting range.
This is a very difficult proposition: we have to deal with event frequency, gravity, consequences, and permanent damage

Fig.1 Evaluation of the risk from firearms use, in shooting ranges

Of the incidents and accidents on shooting ranges, 99% are domestic in their orientation: injuries from falls and from the use of tools are far more frequent than any injuries resulting from firearm use. Car accidents in parking are at about the same level compared to those in supermarket shopping. There is an incidence of light wounds caused by returning bullet fragments. These are relatively frequent but rarely serious enough to be declared as accidents.

Sometimes, however, an unexpected and severe event may occur, by a combination of specific circumstances.

Scenario of the accident; environment description

On January 23rd, 1989, at about 12 o’clock, a shooting match had taken place in a well-known 25m shooting range, in the city of Jette, near Bruxelles, in Belgium.

After an intensive practical shooting session, it appears that a great quantity of partially burned powder lay on the ground, and was also in partial suspension in the air.

In a well-designed cartridge propulsive powder load, only a few percent of the powder charge remains unburned. Unburnt, or, more exactly, partially burnt powder grains are caused by the following factors:

- In some handloads, and specially in short-barrelled firearms, unburnt powder grains can represent an important percentage of the initial quantity of propellant;
- Incorrect powder choice considerably increases this percentage;
- The propellant burning sequence is interrupted when the powder grains exit the muzzle and are suddenly exposed to a very important depression between the barrel pressure and the outside pressure (going from 2 000 to 3 000 atmospheres down to one atmosphere pressure).
As powder grains are very light, their individual energy is very low and their trajectory extremely curved, so they fall near the gun muzzle, and accumulate at a short distance from a few centimetres to a few metres.

Partially burnt powder grains are very easy to ignite; in the initial burning sequence, the protective envelope is actually destroyed, and the single- or double-base composition is fully exposed to the atmosphere.

The ventilation of this shooting range was of the type, which had input and output both located in the roof of the shooting tunnel. Aspiration was strong, as was the rule in those times, and it was situated near the bottom of the 25m tunnels.
It is important to note the shooting tunnel was under low pressure, relative to the surroundings, this being the result of the ventilation system. Note that this also offered a possibility of the powder particles coming from both the ground and from gun muzzles remaining suspended in the air.

Suddenly, unburnt powder started a fire on the ground.

There was an extinguisher in the shooting locale, but it did not succeed in stopping the fire.

Somebody opened the door to gain access to a more powerful extinguisher.

The combination of sudden air intake, situation of the ventilation system (on the roof), negative pressure of the area, and fire, caused the unburnt powder grains on the ground to be aspirated. A flour-silo condition had been created, resulting in a violent, rapid combustion, comparable to explosion, followed by intense fire.

The walls were covered with a classic noise-absorbing material consisting of polyurethane foam in pyramidal shape, offering a very great surface with a high degree of porosity, excellent for noise absorption. However, this is also ideal for dust (and propulsive powder dust) retention.

After the second fire, created by air intake, the walls instantly ignited very violently, much like an explosion.

The acoustic insulation was glued on the walls with a product based on cyanide. The resulting gases, mainly HCN, were extremely toxic and highly lethal; within a few seconds, twelve people occupying the area, probably already suffering from serious burns, were killed by chemical toxic action.

The installation had previously been approved by the authorities and had successfully passed the official fire safety inspection. The shooting range installation was considered safe and modern, corresponding to the specifications applying locally (Règlement Général de la Protection du Travail), and the ventilation system was considered adequate.

Investigations were difficult, because of the very short time lapse during the event, the lack of remaining evidence, and the conformity of the structure to the rules concerning this type of building.
Today, the identified causes of this accident are:

- Bad judgement about the risk levels, especially of the acoustic insulation, and ignorance of the fire danger;
- Use of potentially highly toxic materials, especially in the glue;
- Ineffective disposal or cleaning of unburnt powder, resulting from a lack of understanding of the problem at that time;
- Incorrect ventilation, relating to the equipment of the shooting range, with a tunnel under low pressure.

Once again, the installation was considered safe and had passed official inspection, being compatible with applicable specifications and safety conditions.

The fire and subsequent toxic effect were so rapid that even much better evacuation equipment would probably have been of little effect.

**Ventilation system analysis**

The powerful ventilation system was excessive. The positioning of air inlet and ventilating exhaust created an important low pressure along the tunnel, and made for a situation where it was easy for particles to be in air suspension.

About twenty years ago, the acoustic nuisance was becoming more widely considered. At the time, many shooters had been using primitive hearing protection, even empty cartridge cases pressed into the ears.

As this came to be considered the most important nuisance for shooters and the environment, efforts were made to protect both the shooters and the neighbours from noise.

**A modern Belgian shooting range**

As a model, consider a shooting range in Grâce-Hollogne, near Liège.
All the installations are on the same level, without stairs. The whole installation is rectangular in shape, without hidden parts. The shooting lines are clearly visible from outside the shooting stations, that is, the cafeteria, offices, and waiting rooms, so that any incident can be seen and help will be instantaneous. Individual, protected shooters’ positions are constructed in concrete, so that an accidental direct shot is impossible.

In this type of shooting range, the fire risk resulting from re-ignition of powder is managed by the construction of a low wall about 5m from the shooting line, with a bare concrete floor that greatly facilitates the cleaning procedure. Unburnt powder is gathered and burned in a safe location.

In a shooting range planned in WAVRE, near Bruxelles, a water spray will be provided to keep the unburnt powder on the ground.

The ventilation of this type of shooting range has been calculated on the following basis:

- Emission of gases resulting from handgun discharge is calculated at 2.5 litres every 30 seconds, for each shooter.
- Emission of gases resulting from rifle discharge is calculated at 10 litres every 60 seconds.
- Ventilation is obtained by a row of three exhausts:
  - 1000 m$^3$ per hour for a 25m handgun line.
  - 4000 m$^3$ per hour at 10m and 8000 m$^3$ per hour at 100m for both handgun and rifle lines.

<table>
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<th>Shots/min</th>
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<th>Gas emission</th>
<th>Ventilation</th>
<th>Gas %</th>
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<td>m$^3$/hour</td>
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<td>120</td>
<td>7.2</td>
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</table>

Fig.6  Gas volumes from combustion of propulsive powder versus ventilation potential

There are layers of sound-absorbent and fire-resistant material giving acoustic protection. Its clean, unpatterned surface leaves it accumulating no dust.

Of course, there is insulation against fire throughout, and no toxic materials are used in any part of the structure.

Initially, sand was considered for the ground, after 10m of concrete on the firing line, but sand is much more difficult to manage, and a fully concreted floor was selected.

Once again, common sense and respect for safety procedures are of primary importance, and each case will need to be examined on its own merits.
Shooting range management in the near future

As to chemical risk, it is well known that lead and other toxic substances have accumulated for a very long time on the grounds and in the structures of ranges. More and more firing ranges, indoor and outdoor, are being closed as a result of excessive contamination. Airborne toxic substances are breathed and particles are deposited on the skin. The hands are particularly sensitive, and failure to wash after a shooting session will cause ingestion of toxic substances when eating.

This is a long lasting problem, and it also involves accumulation: the half-life of lead in soft tissue is three months, and ten years in the bony structure.

Proper ventilation is of primary importance, and it must be calculated in terms of the frequency of shots, and volume of gases produced.

About the very specific risk of wounds created by returning fragments or ricochets, and health hazard by manipulation of potentially toxic products, such as lead and other heavy metals, oxides & salts generated by the priming compound and the bullet, a new approach must be presented in the future, to the sportsman:

To avoid these specific effects of returning fragments and toxic hazard, in the future, we (the ammunition R&D people, and all the other concerned) have to make an effort in development, cost evaluation, positive contacts with the politics for financial help, to ensure health & safe sport conditions.

There are already reasonable technological solutions, that can be developed in the near future, but novelties are difficult to introduce, because of cost, existing stocks, production facilities versus new manufacturing processes, and other factors, including misunderstanding from the final user (the sportsman) of some of the specific risks involved in his favorite sporting activity, as in any other human activity; education of the sportsman is also of primary importance.
We have to deal with today problems first, and have a constant search for preserving health of shooters in today indoor shooting environment.

New, clean ammunition types are being developed and will be released to shooters in the future.

This improved ammunition will have a clean primer, containing no heavy metals or other toxic components, and a truly lead-free bullet. Another great improvement will be the use of frangible and other lead-free bullets, with a 0% risk of splash back and ricochets, even in unfavorable shooting angles.

Thus, the physical and chemical risks would be kept to a very low level.

We already know the difficulty, cost and time involved in introducing a new concept, as it was demonstrated for the shot shell lead pellets.
The range protection structure could be lighter, and the ventilation will only deal with the gases from the propellant.

The higher cost of production of new ammunition is the key problem. Most shooters prefer a cheap cartridge, because it is extremely difficult for an individual to understand the whole problem of health and shooting installation management costs which combine to require increased expenditure.

This is a long and difficult path, from the manufacturers to the final user.

If clean, safe ammunition were to be presented today at 1.5 times the cost of an ordinary round, the toxic one will be preferred, because people generally still believe that health problems can only affect others, and not themselves.

Of course, a shooting range of the future, with less expense required for lead and toxic recovery, and with better safety features, would be less expensive to manage, and the money saving could be passed on to the shooter.

Of much more importance are the environmental politics: the world of both manufacturers and people who shoot is changing, and there are already spectacular and increasing efforts being made to protect the environment. That fact is much more important than most of the other industrial matters.

Conclusions

Safety on shooting ranges with regard to ventilation must be viewed as a complex entity, integrating all the elements of the specific profile of the range unit.

Ventilation is of course of primary importance, but it must be integrated with all the other elements that make up the entirety of shooting range design and environment protection measures.

We have seen that even a well-designed ventilation system, complying with many standards and specifications, and having passed the official controls, can nevertheless be a big source of problems if all the other conditions are not understood.

The safety problem in shooting ranges cannot be looked at as a series of propositions, counted off one at a time to fit the regulations. It must be seen in terms of a total proposal, considering all aspects of a concept.

Accidents should not occur, but by a combination of mistakes, lack of understanding and knowledge, no doubt they will always happen in areas from the simplest aspects of daily life all the way to space exploration. The most important thing in prevention is to understand as much as possible about the subject, to understand lessons, and, much more important: to apply those lessons to the future.

Safety on the shooting range is our primary concern, and, considering the risks, which are already very few, we may nevertheless hope in the near future to encourage wide understanding of the following:

- A well-designed shooting range including individual, protected positions can avoid wounding by direct accidental shot;
- Ricochet and fragmentation hazards could be suppressed by the use of specific ammunition designed today;
- Fire risk can only be reduced by common sense and intelligent range structure design;
Chemical intoxication of the shooter and environmental pollution could be solved in the future by using specifically designed ammunition. It will offer the same practical characteristics as lead projectiles, but without danger to the environment & sportsman, and is less likely to cause political controversy directed towards the shooting sports. We have to think today for these improvements, for tomorrow, but we have to improve the existing structures, using the material that is already on hand today.

Fig.10 specific risk evaluation from use of ammunition,
Potential responses & solutions

I am quite sure that the inherent architectural problems of avoiding wounding by an accidental direct shot, providing good acoustic insulation, excellent ventilation and offering resistance to fire are all technically possible today.

I believe that the most important proposition in reducing the health and mechanical accident risk (due to projectile behaviour) is to consider as soon as possible, between other management techniques, the use of specific ammunition in indoor shooting ranges, involving true lead-free and non-toxic components, and also significantly reducing the risk of returning fragments.

Finally, proper ventilation, taking account of every aspect of the specific shooting range, will always be of premium importance.
FIRES ON INDOOR SHOOTING RANGES: CAUSES AND CONSEQUENCES

Joachim Streitberger on behalf of Dieter Stiefel, Germany

Chairman of the Committee of Experts on the Construction of Shooting Ranges of the Deutsche Schützenbund

September  2005
Fires on Indoor Shooting Ranges: Causes and Consequences

Joachim Streitberger on behalf of Dieter Stiefel

Chairman of the Committee of Experts on the Construction of Shooting Ranges of the Deutsche Schützenbund

Abstract

In the years 1967 to 1995 in Germany there were 25 fires on indoor shooting ranges, killing 20 people.

After a change of the rules for the construction of indoor ranges in the Schießstandrichtlinien des Deutschen Schützenbundes, the official and mandatory guidelines for the construction and maintenance of private shooting ranges, another 20 fires occurred, especially in bullet-traps, but these were totally without casualties.

This presentation shows some of the fires as examples, from which the new rules were developed. Particular emphasis is put on the problem of unburnt propellant and on the insulating materials used in indoor shooting ranges.

General Remarks

The following presentation is based on a report of Dieter Stiefel, Chairman of the Committee of Experts on the Construction of Shooting Ranges. It gives an overview of the experience in Germany about the causes of fires on indoor ranges from 1967 to 1995, when new rules were implemented.

The topic of fires on indoor ranges is not directly in the focus of this workshop, but – as we always try to make our shooting range operators aware – we should never focus on one potential problem of the shooting range, but instead bear them all in mind.

1. Introduction

From 1967 to 1995, there were 25 fires on indoor shooting ranges, killing 20 people.

The main causes for the fires were:

1. Easily inflammable sound absorption material
2. Unburnt propellant (lack of or ineffective cleaning of the range) in combination with
   a. deep-pile carpeting
   b. gravel beds (in front of the shooter)
3. Use of (prohibited) pyrotechnic ammunition
4. Sparks (where a bullet hits a steel component, such as in the bullet catcher)
Overview

1. Wall covering

The problem of unsuitable sound absorption material – used as wall covering – has been understood since 1967. After a fire on a shooting range in Schramberg, the German “Bundesamt für Materialprüfung” (Federal agency for the Testing of Materials) stated that the causes of the fire were:

- lack of cleaning (unburnt propellant)
- unsuitable wall covering

Nevertheless, unsuitable wall covering continued to be the main problem of indoor ranges for more than two decades.

PU – (Polyurethane) and Moltopren were two commonly used materials. They were frequently used in combination, especially with a structured surface (such as a pyramid form) for better sound absorption. Both are problematical.

The trouble with PU is the enormous velocity at which this material burns. It takes literally seconds, in which time any people on the range have to recognize the problem and then react, by leaving the range without any hesitation.

In most of the cases that have taken place, the actual cause for the fire was found in

- cigarette smoking of the shooters
- shooting that did not follow the regulations (use of prohibited calibres, shooting from varying distances)
- use of pyrotechnic ammunition

2. Unburnt propellant

Depending on the barrel length and the calibre of the gun in use, in an area of four to ten metres from the shooter unburned propellant can be expected.

That means: amount of unburned propellant in front of the shooter with different arms, barrel length and with muzzle loading revolver
In case the range is not constructed according to the (new) rules and does not have this unburnt propellant regularly cleaned up, it accumulates – in one presented case, an astonishing 50 kilograms of propellant – in the area in front of the shooter.

One test of carpeting showed that it was charged (in the first 3 metres only) with 500 grams of unburnt propellant.

3. Unsuitable bullet traps

Especially in recent days, fires have occurred as a result of use of steel components (especially steel plates) in bullet traps.

When bullets (especially semi- and fully-metal-jacketed bullets) strike steel – either installations on the range, or steel plates implemented in the bullet trap – sparks are created, and these have temperatures high enough to ignite, for instance, woollen fabric.

Consequently, the rules recommend placing no steel components in bullet catchers with woollen material. It is much better not to use any material that is easy to ignite.

In various examples the Stiefel presentation shows pictures of the fire damage on several ranges, and then gives indications as to the causes.
Consequences

Dieter Stiefel examined all the fires that were shown in the presentation, and was largely responsible for the creation of the new rules for indoor shooting ranges.

These new rules, in operation since 1995, are:

- Mandatory use of suitable sound absorbing material
- Of at least category B1, which is “hard to ignite”
- With no structured surfaces (such as pyramid-shaped)
- With sufficient mechanical strength (to withstand ejected cartridge cases, shoulder pressure from leaning, and so on)
- PU-foam B3 (easy inflammable) is not allowed under any circumstances
- There must be a reinforced, easily-cleaned shooting range floor between shooter and targets
- There must be no carpeting and no textile anywhere in the shooting range building
- An emergency exit is required in the area of the bullet trap
- Regular and general cleaning procedures are required (defined in the safety rules for shooting ranges)
- There is mandatory recording of the cleaning procedures (proof of the fact of cleaning)
- There must be supervision of a complete smoking ban
- There must be caution with welding and any other spark-creating procedures
- There must be introduction of responsible supervisory staff
- Electric installations must be protected against bullets and fragments
- There must be an emergency exit with acoustic and optical warning system (siren and flashing lights)
- There must be special, cleanable floor covering
- The walls and ceilings are to be covered with material that is rebound-safe
- When shooting is conducted at various distances on the same range, special rules must provide appropriate flooring and rebound-safe surfaces at all of them
- And there must be suitable aeration and de-aeration.

Summary

During a series of fires in German indoor shooting ranges, caused by various faults in the construction and maintenance of the indoor ranges, between 1967 and 1995 20 people were killed. In the year 1995 the rules for the construction and maintenance of indoor ranges were completely revised and clarified, and mandatory regulations were implemented.

Under these regulations fires still occur – mostly in the bullet trap – without causing any casualties on the indoor ranges.
GAS RESIDUES AND UNBURNED PROPELLANT IN INDOOR SHOOTING RANGES

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September 2005
Gas Residues and Unburnt Propellant in Indoor Shooting Ranges

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Abstract

Studies have been conducted to evaluate and analyse the contamination of indoor shooting ranges by gas residues and unburned propellant.

• The first study was carried out under laboratory conditions, in a closed test shooting device, using different ammunition and gun types. The results showed that carbon monoxide gas and fine dust lead particles are the leading toxic components, which must be de-aerated during shooting in indoor sport shooting ranges.

In the second step a German working group standardized a test method in a closed test-shooting unit and published maximum threshold limits for concentration of CO gas and fine dust of heavy metals in indoor shooting ranges for law enforcement agencies. Those indoor ranges are frequently in use that results in a high number of fired rounds.

• It is very important to avoid fine dust lead particles in indoor sport shooting ranges. If the ventilation system in use is not very effective or the frequency of shooting is very high, “green” ammunition is recommended, using heavy-metal-free components to avoid up-range contamination.

• Several studies have been carried out to evaluate the quantity and quality of unburnt propellant in relation to ammunition and firearm type. The results show that one can expect a figure up to and even beyond 25% to be unburnt when used in revolvers with short barrels and centrefire ammunition. The unburnt propellant consists of more than 70% of nitrocellulose or nitroglycerine (depending on the propellant types that have been used). The major deposit area of unburnt propellants is between 0,5m and 6,0m in front of the muzzle.

Background

The demand for indoor shooting ranges has steadily increased in the last decades. The reason is the noise contamination of outdoor ranges in sensitive areas. This requires enclosed indoor ranges. One environmental problem is solved by the reduction of shooting noise, but two other problems are created. These are:

1. Health problems for range personnel and shooters resulting from the increase of breathing gas residues, caused by combustion of propellants and in addition the breathing of heavy metal fine dust, coming from primers and bullets.

2. Safety problems for range personnel and shooters resulting from the accumulation of critical amounts of unburnt propellant. This propellant can be ignited by burning particles or other priming sources and may instantly create large flames from the deflagration of the propellant. Several serious accidents resulting in deaths have been recorded in Europe in the last years. Most of the victims were not killed directly by fire, but were suffocated by the toxic halogenated gases resulting from the burning sound-absorbent plastic material.
Content

This paper covers three parts:

Gas residues in indoor shooting ranges

Investigation of gas residues and heavy metals caused by:

- combustion of smokeless gun propellants (nitrocellulose and nitroglycerin)
- combustion of primers
- launching solid lead or jacketed lead-core projectiles

Tests under laboratory conditions in closed test shooting devices and thermo-chemistry calculations of CO concentrations have been conducted. The results are reported.

The WIWEB (Institute of the German Army) conducted tests with different types of sporting ammunition in a closed test shooting device. Test results will be discussed.

In Germany a new standardized test method for law enforcement ranges, under the guidance of the Police Academy, has been developed, using a closed test shooting cabin with a defined volume.

Fine dust of lead in indoor shooting ranges

The second part describes the effect on lead fine dust contamination of different projectile and primer types. The reduction of lead fine dust contamination can be solved by using alternative ammunition components:

- Non-toxic primers, free of heavy metal
- Projectiles that are either lead-encapsulated or lead-free

Safety problem at indoor shooting ranges - caused by unburnt propellant

This part shows the weight of unburnt propellant in relation to distance in front of the muzzle. Several different ammunition types have been used out of handguns and rifles with different barrel lengths.

This part will describe in principle the great danger for shooters and range personnel because of igniting unburnt propellants at indoor shooting ranges. Many people have been killed by catastrophic fires in indoor shooting ranges in the last decades.

Investigations of gas and fine dust residues

Test set up

The German WIWEB (Institute of the German Army) (see Literature 2) conducted a series of tests under laboratory conditions in a closed test-shooting device (Figure 1).

Handguns and rifles were mounted in fixed positions, and the guns manipulated from outside. Test samples of gas and fine dust particles were sucked out of the closed device by a pipeline, sealed at the exit of the closed test-shooting device. The measurements were conducted under standard atmospheric conditions (air temperature, pressure and humidity).
Analyses of gas residues at indoor shooting ranges

The analysed gas concentration measurement data showed that CO is the leading toxic contamination gas. The values for NOX, hydrocyanic (HCN) and aldehyde can be disregarded in respect to toxicology rating, because the CO contamination is the major issue.

If the CO is de-aerated according to the CO threshold limits the other gas elements are also being de-aerated.

The CO concentration increases with the charge weight of the propellant, depending on the ammunition type. The data are listed in Figure 2. The range is between 36 mg for .22 Long Rifle rimfire and 1347 mg for centrefire rifle ammunition. The results are given in mg per round.

That results in an absolute requirement for de-aeration of the CO by effective ventilation systems.

CO – thermo-chemistry calculations

Sporting ammunition is mostly loaded with nitrocellulose single base or nitroglycerine double base propellants (mostly ball powders).

The combustion process of the load of a sporting cartridge produces gas residues. It can be calculated that one gram of propellant produces approximately one litre of cold gas.
Figure 3 shows the calculated CO concentration curves of single and double base propellants depending on the propellant mass, based on the new standard test method with a test cabin volume of 7.5 m³.

![Graph showing CO concentration curves](image)

**Fig 3. Calculated carbon monoxide (CO) concentration per round as a function of propellant mass**

**Analysis of fine dust components on indoor shooting ranges**

The total fine dust concentration has been determined and the elements have been analysed by the XRF method.

The main elements are lead, barium, antimony, zinc and copper. Measurements showed that lead is the leading element requiring assessment of the toxicology limits.

The other fine dust elements can mostly be disregarded on sport shooting ranges, because the frequency of rounds per time unit is relatively small, in some contrast to the shooting on police ranges.

If the lead is de-aerated according to the threshold limit at sport shooting ranges, the heavy metals will mostly be de-aerated also.

In sport shooting cartridges there are two different lead sources, first, the projectile, and, second, the standard lead styphnate primer.

• **Projectile**

Projectiles which contain unprotected lead have the major lead contamination effect (Figure 7/1).

The worst case is represented by a solid lead projectile, not jacketed. First there is an evaporation of lead at the base from the hot combustion gases. Further on, lead abrasion will appear while the projectile is moving in the grooves of the barrel.

A fully metal-jacketed lead core projectile will produce only the evaporation effect at the projectile base.

The amount of lead contamination of the different projectile types is shown in Figure 8.

• **Primer**

The standard lead styphnate Sinoxid primer also creates a substantial lead contamination effect (Figure 4). The amount is shown in Figure 8.

**Standardization of a test method for law enforcement indoor ranges**

In 2001 a working group under the guidance of the German Police Academy developed new standards for police ammunition. One of the new requirements is low contamination of indoor shooting ranges.
A new ammunition type can qualify for use in German law enforcement agencies if the measured contamination and calculated data are below the permitted contamination limits.

Fig. 4 Standard lead styphnate Sinoxid primer

A Closed Test Shooting Cabin has been defined with a volume of 7,5 m³ (Figure 5).

Fig. 5 Closed Test Shooting Cabin

The maximum permitted contamination data will be calculated on the basis of the German MAK threshold limits. They are listed for gases and different heavy metals: i.e. the value for CO is 35 mg/m³, and for lead is 0,1 mg/m³. The ventilation must have a factor for change of air of 20 times. The frequency per firing position at a shooting range is 100 rounds per hour.

Recommendations for the use of alternative “green” ammunition

It is possible that in some indoor sport shooting ranges the airborne lead level will be above the threshold limits. This can be caused by a high shooting frequency on this range, or from the existing ventilation system not being very effective.

To solve this problem on an indoor range, one can use “green” ammunition without decreasing the number of fired rounds, or else change the ventilation system. Green ammunition is favoured in centrefire pistol ammunition. Other calibres are under development.
• Non-toxic primers
For instance, the non-toxic Sintox primer is available. This primer contains no heavy metals — no lead, no barium and no antimony. It has been on the market for 25 years, and especially in use by law enforcement agencies in Europe and by the German Army.
In Figure 6 there is a list of the components in the priming composition of both the standard lead styphnate Sinoxid primer and the non-toxic Sintox primer.

![Figure 6](image)

• “Green” projectile types
In Figure 7/2 there are different projectile design recommendations to solve lead contamination.

![Figure 7/1](image)  ![Figure 7/2](image)

**Air contamination effects, using different types of ammunition**
In Figure 8 lead emissions are described in accordance with projectile and primer type.
In Figure 9 there is a comparison of the air contamination of a standard 9mm Luger and a non-toxic Sintox 9mm Luger cartridge type.
Safety concerns at indoor shooting ranges caused by unburnt propellants

The quality of unburnt propellant varies greatly. It depends very much on the ammunition in use. All collected samples of unburnt propellant are mixed with primer mixtures, lead, antimony and barium. The explosive characteristic is similar to single base NC or double base NGL propellants.

A figure up to and even beyond 25% of propellant can be expected to remain unburnt, especially if fired in large calibre ammunition out of handguns with extremely short barrels.

Amount of unburnt propellant

In Figure 10 there is a matrix of the quantity of unburnt propellant in percentage of charge weight as a function of the cartridge and gun type. The level of confidence placed in these values is relatively high, because they are based on 1,000 rounds per cartridge and gun type.
Expulsion distances of unburnt propellant granules

In Figures 11/1 and 11/2 there are graphs of the distances unburnt propellants are expelled as a function of the cartridge and gun types.
Conclusion

• **Gas residues on indoor sport shooting ranges**

Range contamination caused chiefly by carbon monoxide and lead fine dust must be de-aerated during shooting by an effective ventilation system.

Recommendation: If effective ventilation systems are not available, it is necessary to use ammunition with lead-free primers and lead-free projectiles, or those with an encapsulated lead core.

• **Safety problems from unburnt propellant**

It is necessary to avoid unburnt propellant in indoor shooting ranges because of fire danger and the threat it brings to shooters and range personnel.

Using revolvers with short barrels and centrefire ammunition one can expect a figure up to and even beyond 25% of propellant to remain unburnt in an indoor sport shooting range. The deposit area of this is approximately 0.5 to 6.0m in front of the muzzle.

Ranges must be cleaned after every shooting event.

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Session 4
Risk Management Approaches
GERMAN STANDARDS VERSUS SHOOTERS' EXPERIENCES

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German Standards Versus Shooters’ Experiences

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Abstract

Particularly important on indoor ranges in Germany are restrictions on noise levels, safety aspects, and also special regional problems.

This paper offers a short overview of the classification and the operators of indoor ranges, and operating requirements.

Discussion covers a draft-free displacement ventilation system and state-of-the-art technology. It also touches on operational costs and industrial solutions, with reference to basic demands and calculations required in ventilation technology.

Finally, a specific ventilation-related example is covered in the form of the sequences in a dynamic pistol-shooting competition.

Need for indoor shooting ranges resulting from population density in Germany

Indoor shooting ranges have essential importance for all shooters in Germany. The growing population density and the regulations on air-pollution control often require the shooting facilities in a given area to be enclosed. Within the borders of my home town we would not be granted permission to plan or build a completely open range, for reasons of noise prevention. And here we are talking about an area of approximately 200 km². Relatively high construction costs for such indoor ranges would, however, give almost unlimited long life of the range and use of it into the future. And, unlike open-air ranges which may be subject to limitations by the hour or by the day of the week, such as not being used on Sundays, they would have no limitations on their use, which is exactly the outcome we want.

Who are the operators of indoor ranges in Germany?

This paper focuses only on such facilities that do not belong to authorities like the police or the army, because there are only very few possibilities to use those kinds of ranges as a place for sport shooting.
Facilities that are only used for shooting with air-powered arms are also not mentioned. Our German body of rules and regulations does not include any technical instructions regarding ventilation for these. So, I look only at indoor shooting ranges for firearms, starting with .22 rimfire.

In Germany there are mainly three types of indoor ranges. Some of them are single facilities, and some offer a combination of the different types.

1. 25m Target distance
2. 50m Target distance
3. 100m Target distance

Now for a closer look at the ranges and their use.

First, most of the 25m ranges are run by local clubs, and they have only this fixed distance to work with. The shooters always stand at the same place, in most cases in front of a bench or balcony, when they fire their guns.

Only a few of the 25m ranges do allow for shooting at different distances closer than that, and require a different layout. These ranges can also be used for the so-called dynamic shooting disciplines, where the shooter changes his stand and the distance towards the target several times during the competition. These ranges are well established. As far as official authorization is concerned, these facilities in which shooters move around are generally identical with those used mainly by security companies for training in combat shooting.

Second, the majority of the existing 50m ranges are currently used for shooting with .22 rimfire arms. Nowadays, ranges offering different distances – as are required by our association for the growingly popular dynamic shooting disciplines – are still exceptions.

Third, most of the closed 100m ranges are used for the purpose of sighting in hunting rifles, and there are only a few of these that can be used by sport shooters.

**Purposes of ventilation technology in indoor shooting ranges**

The main purpose of ventilation technology is to remove very quickly those hazardous gases and microdusts from the air the shooter breathes. Another purpose is to provide enough fresh air that can be breathed.

Although the ventilation is working all the time, heavy substances such as the remains of unburnt gunpowder can fall to the ground so that they can be removed during the regular cleaning of the whole range. The currents in the ventilation need to be not so powerful that they can whip up heavier particles after they have fallen to the ground.

Of course, it is an advantage from the technical point of view if the shooter does not move. The exchange of air can then be limited to a distance of approximately 5m. The situation can be compared to the well known off-take of gases in welding workplaces. In this case, the aim is to absorb them close to the source of contamination. For a number of reasons, this is not possible on the range.
Consequently, for the layout of the ventilation it is important to know how the shooters perform their shooting on the range. Is there only one firing line, or does the shooter move with his gun? Which firearms and what kinds of ammunition are in use? These different conditions lead to different technical solutions.

From the security point of view, an indoor range is basically regarded as a closed room from which it is not possible to simply take off a considerable quantity of air. It would lead to low pressure in the room, which would preclude any further take off. So there has to be a certain balance between the quantity of air taken off and the fresh air that comes in. As the entrance of fresh air and the exhaust outlet are more or less well away from each other, this leads to the necessary airflow that carries the polluted air outside.

In contrast to many applications of ventilation technology, there is a need to create a determined airflow. It is important that the shooter does not come into the area of circulation of already polluted air, and that substances from the ground should not be lifted up again by turbulence.

If the air is made to move too fast no one can concentrate on firing a gun. Personal well-being is also a main part of range safety. Consequently, the airflow must be rapid enough to carry the polluted air away from the shooter, but not fast enough to annoy him or her.

Experiences in German indoor ranges have shown that an average airflow of at least 0.25 m/sec, considering the commonly rectangular shape of the room, is most efficient. This amount rises to approx. 0.30m/sec on those ranges where the shooter moves around and in which distances to the target vary.
These amounts are still comfortable if the outgoing airflow is made as constant as possible.

The shooter does not want to be distracted by the running of the ventilation.

There are several spheres of ventilation which have similar requirements, such as restaurants, department stores, laboratories, etc.

Here we find a technical solution, which has been used successfully in enclosed ranges in the past years.

**Draft-free displacement ventilation.**

Fresh air is not let in by spot jets but by inputs distributed all over the back wall. The airflow thus created always moves away from the shooter, following the bullet. Like an air-pump this piston of fresh air shifts the polluted air only towards the exhaust outlets.

Good inlet elements are, for example, textile inlets or wall constructions made of perforated metal sheets. A simple solution can also be a perforated plastic bag placed at the end of the inlet pipe. After prior consultation with qualified builders of ventilation facilities, there are a lot of possibilities for building such devices.

The industrially-produced inlets in the illustration are offered in different sizes and can be combined.

![Industrial solutions – draft-free air inlets](image)

The offtake of the polluted air occurs at the end of the range. Outlets are positioned in the ceiling and in the floor close to the bullet catcher. An archway can also be built around the bullet catcher. This makes sense, if a steel-plate type bullet catcher is in place. This type of bullet catcher still emits micro-dusts, when the bullets smash into its surface.

It can be a real irritation for shooters if the noise produced by the ventilation fans becomes too loud. This should be prevented during the planning phase, so the shooters can keep their concentration at optimum levels. This is also central to range safety. It is very important that the commands of the range officers can be clearly heard, and not be drowned out by the tremendous howling of the ventilation.

**The dimensions of a ventilation system**

Regarding the preferred displacement ventilation with a 0.25 m/sec flow, we now look at the way to do a rough calculation of the required air mass.

The first approach sees the range as an oversized tube, in which an air-flow is to be generated.
Our approximate calculation is done for a standard indoor range with a target distance of 25m. This normally is given by a total length of the building of 30m including shooters’ stands and bullet catcher areas. We have 6 targets and the height of the room is 2,50m. In our sample we have positioned the whole ventilation technology on top of the building, which can sometimes be the best place. The required space for all the fans, filters and tube constructions can be very large, and should carefully considered at the earliest possible time if someone is planning a new range or setting out to upgrade an existing one.

In-principle sketch of displacement ventilation

1) Required fresh air volume:
Height of room in metres x width of room in metres x 0,25 x 3600 = air mass m³/h

2) Required exhaust volume:
Fresh air volume x factor 1,05 for minimal sub-pressure areas

3) Calculation:
Indoor range, target distance 25m, width 6m, height 2,50m, required air speed 0,25 m/sec

   6 x 2,5 x 0,25 x 3600 = 13.500 m³/h Fresh air

   13.500 x 1,05 = 14.175 m³/h Outlet air

In this case the calculated air mass corresponds with a total air-replacement rate of 30 times per hour.

The required electric energy to drive only the fans comes to 5-7 KW for fresh air fans and 3-4 KW for the exhaust fans.
Cross ventilation – a useful option?

Our German guidelines show also a special type of cross-working ventilation. Fresh air inlets and exhaust inlets are placed in the side walls. This style can look quite convincing on the first examination. The distance between the side walls is even shorter than the length of a range. But very often we find a straight line of marksmen in sport shooting events, all of whom are firing their guns at the same time. What happens then is shown here:

Cross-ventilation is unsuitable, if shooters are in line

Limited success of cross-ventilation, without shooters in line

The cross-type ventilation offers suitable conditions only for the first shooter in the line, irrespective of the air-flow direction. All other shooters are breathing more or less of the exhaust fumes of their neighbours. This type of ventilation cannot be recommended for multifunctional indoor ranges. Again it should be said that it is always important for those proposing the ventilation layout to know exactly how shooting is to be organized on the individual range.

To check and measure air flows

Operators of indoor shooting ranges need to know whether or not their ventilation runs in keeping with the above-mentioned criteria. To find out, the air flow must be made visible. This can be done best by using a small fog generator, as we know it from the range of disco-equipment. To measure the very low air-flow of a maximum 0,5m/sec, a special anemometer
is needed. This works by the principle of wind chill temperature. Normal propeller-driven anemometers are not sensitive enough in this range of air flow.

Anemometer, windchill type

For and against preheating of fresh air

Anyone entering an open shooting range during the cold seasons in central Europe will certainly have to choose the right clothing for the outside temperatures. But these days, contrary to what was done in the past, more and more shooters are looking for living-room comfort when they enter an indoor range. I mean here those indoor ranges which are operated by non-commercial clubs and associations, where people shoot for the pleasure of it. These ranges are non-commercial, and that is important in regard to the German regulations.

The various German authorities are placing emphasis on a required minimum inside air temperature of 17°C. This is no problem in warmer parts of the world. In Germany, however, we have many months when the outside temperatures are under this value, and the average yearly temperature amounts to 10°C. In times of rising energy costs today, frequently the question arises as to what extent this comfort is justifiable. A 25m range with 6 courses has a middle space volume of 560m³. In the case of an outside temperature of 0°C and a desired average ambient temperature of 17°C, the thermal system has to operate at about 100 KW/h. Produced by gas, at present this amount of heat costs €6.69 per hour of operation without taking into account the electricity for the fans. The use of heat-recovery technology is thus compellingly recommended here.

With commercially operated ranges here, under German rights in workplace regulations, all persons employed, and this includes supervising personnel on shooting ranges, are to be protected with a stated minimum temperature. Unfortunately, this regulation of the preheated supply air has already – even if only as a recommendation – found its way into the relevant German set of rules. Our German guidelines do not differentiate here between non-profit and commercial operations. Bureaucracy is pervasive and inclined to take circumstances at face value. It is not the first time that an authorizing agency has raised the status of a recommendation and turned it into the rule.

As has already been established, selfmade ventilation systems are frequently not efficient, and may even be counter-productive, if the project was not overseen by professional planning and consultation. On the other hand, only a few professional manufacturers have technical know-how in this sector, because of the scarcity of indoor shooting ranges. We regard it therefore as an important task to maintain close contacts and a constant exchange of ideas with the manufacturers of room ventilation technology machinery in order to clarify with them the special expectations and requirements of this clientele.
Keep costs in mind

By its continuous power requirement, the ventilation of indoor ranges brings a substantial part of the overall operating cost. If the facilities are not commercial, but are operated by associations and federations, these costs need to be passed on to the club members and notably raise the price of our sport.

We should always endeavour to find the balance between the really necessary and the technically feasible. We also need to be careful not to fall into the traps of well-known health risks. It is just as is the case with so much in life: some plans can backfire. Intelligent opponents of shooting sports activities know about our tender spots. And the special requirements of our sports facilities represent a possible point of attack.

The operation of ventilation equipment

Malfunctions in the ventilation equipment during the shooting process must be indicated to the supervisory personnel immediately by signalling systems. Essential elements include a stop-control of the fans, and also the monitoring of the filter by flow sensors. When a manual is prepared, it is necessary to plan specific time intervals for examination, for maintenance and for cleaning of the ventilation system.

An example: ventilation technology in the international match PPC 1500

As an example, the dynamic PPC 1500 match takes place in many countries in the world following the same rules. In the main match the shooter fires about 170 rounds, including allowed test shots.

With pistol or revolver, the prevailing calibres are .38 Special, 9mm Parabellum and .45 ACP. The shooter constantly moves on the range during the match at distances between 0m, reviewing targets, to 50m in actual shooting. Most of the competitors use handloaded ammunition for precision reasons.
The International PPC 1500 Event (main match): order of events

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If we add the walking distances of every competitor during the match, we find a total of 480 metres. Each shooter fires several times from four different distances and stays on the range for roughly 50 minutes. On the range described here, we have 70-100 starters during one match day. On such a day between 12 000 and 17 000 shots would be fired and these will produce approximately 45 000 litres of polluted air.

Only a well designed, efficient ventilation system can protect shooters, supervision personnel and range officers during this match against an unacceptable load on their health.

With help from:
Mies & Reichelt
Planungsbüro für Gebäudetechnik
33647 Bielefeld
Germany

Quellen:
Schießstandrichtlinien 02/2005 Kapitel 2
Sportordnung des BDMP e.V.
Firma Trox Lüftungstechnik
Firma Testo Meßgeräte
CONTROL OF LEAD EXPOSURE IN INDOOR FIRING RANGES: A NIOSH CASE STUDY

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September 2005
Control of Lead Exposure in Indoor Firing Ranges: a NIOSH Case Study

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Abstract

An investigation of potential lead exposures was conducted at an indoor firing range to evaluate the ventilation system and provide recommendations on engineering control improvements. Over the course of several site visits, recommendations were made to minimize employee exposures to contaminants resulting from weapons fire. These recommendations centered on ventilation and range design improvements to provide favorable conditions with regard to four criteria: filtration efficiency, airflow patterns within the range, range pressurization, and volumetric airflow rate at the firing line. Further research and outreach by NIOSH has been identified as a priority to heighten awareness of available controls of lead hazards present in firing range facilities.

Introduction

The National Institute for Occupational Safety and Health (NIOSH) of the U.S. Centers for Disease Control and Prevention (CDC) is the federal agency of the United States responsible for conducting research and making recommendations for the prevention of work-related injury and illness. In recent years, NIOSH researchers have been associated with investigational research and educational outreach in occupational lead exposures in indoor firing ranges. This paper summarizes a study recently conducted at an indoor firing range facility and provides a brief overview of ongoing NIOSH activities involving outreach and information dissemination.

Background

Investigational research has been conducted through the NIOSH Health Hazard Evaluation (HHE) Program, which responds to requests for workplace evaluations from employers, employees and their representatives, and other government agencies. Through the HHE program, NIOSH identifies hazards and proposes practical, scientifically valid solutions including engineering controls as recommendations to reduce exposures and prevent disease, injury, and disability. NIOSH investigators have conducted over 20 evaluations of indoor firing ranges through the HHE program. Information on these health hazard evaluations in indoor firing ranges can be found on the CDC/NIOSH website at the following link: http://www.cdc.gov/niosh/hhe/.
Recently, NIOSH investigated lead exposures at an indoor firing range of the U.S. Immigration and Naturalization Service (INS). Industrial hygienists from the HHE group performed the exposure assessments and engineers from NIOSH's Engineering and Physical Hazards Branch evaluated the ventilation system. NIOSH received the request in March 2000 which cited management concerns about officers’ potential exposure to airborne lead in their newly designed indoor firing range at the National Firearms Unit (NFU) in Altoona, Pennsylvania.

The focus of the evaluation was a 20-lane indoor firing range facility constructed in the fall of 1999. It was ventilated by two rooftop heating, ventilating, and air conditioning (HVAC) units, each ventilating half of the range. The range building also housed a classroom, offices, and storage facility separately ventilated by another HVAC unit. Filtered, conditioned air was provided to the range through 20 supply diffusers and removed from the range through 12 mid-range exhaust diffusers and 12 end-range exhaust diffusers. The supply diffusers were installed at ceiling height on the wall behind the shooters while the mid-range exhaust vents were installed at ceiling height fifteen feet downrange from the firing line and the end-range exhaust vents were installed above the bullet trap. The bullet trap was exhausted by a dust collection unit (DCU) located outside the building. The investigation included a series of worksite evaluations to assess lead exposures before and after ventilation and facility improvements were made at the facility.

**Methods, Results, and Recommendations:**

**VENTILATION**

To minimize employee exposures to contaminants resulting from weapons fire, ventilation systems of indoor firing ranges should provide favorable conditions with regard to at least four criteria: filtration efficiency, airflow patterns, range pressurization, and volumetric flow rate. Any air filtered and re-circulated through the range must be high-efficiency particulate air (HEPA) filtered. Air moving downrange should do so in as laminar (non-turbulent) a flow as possible, especially near the firing line. Firing ranges should be under slight negative pressure so that no contaminants escape the range under normal operating conditions. The volumetric flow rate of air supplied to and exhausted from the range should provide a minimum average downrange air velocity at the firing line of 50 feet per minute (fpm), with an optimum rate of 75 fpm. Even if the range is pressurized correctly and a minimum downrange air velocity of 50 fpm is achieved at the firing line, range users may still receive excessive exposures to lead if large-scale eddies exist that create “backflow” and bring contaminated air back into their breathing zones.

**HEPA Filtration**

Each of the range’s HVAC units was designed to accommodate a series of filter banks for the exhaust air. During the ventilation evaluation, it was confirmed that, in addition to a series of 30% efficient pleated pre-filters and 95% efficient 8-pocket bag filters, each unit also had HEPA filters. This allowed for highly efficient filtration ensuring only a negligible amount of lead dust was re-circulated back into the supply air. The life of the HEPA filters was also extended due to the presence of the filters in-line before them.

**Airflow Patterns and Range Pressurization**

Airflow patterns and pressurization of the empty range were evaluated using a fog machine (Roscoe Model 1500™). Smoke was released at different heights between the floor and the level of a shooter’s shoulder in several lanes near the firing line and in some lanes downrange. The flow of smoke in each lane was observed and recorded. In general, the smoke test revealed...
the supply air at the firing line pushed the smoke downrange toward the exhaust diffusers. However, the smoke generated in lanes near the walls traveled a short distance downrange before a portion of it began to migrate up-range along the walls. This backflow continued toward the firing line before it was again pushed downrange by the supply air.

In addition to the general airflow patterns, range leaks were identified through the use of the fog machine at all the entrances followed by leak testing of the overall structure of the range. These types of leaks overburden the range ventilation system, and negatively affect its overall performance. Large leaks in the building can (1) prevent the range from being maintained at a negative pressure, (2) create temperature and humidity variations throughout the facility, (3) influence the formation of eddy currents that disturb the range airflow, making it more turbulent, and (4) reduce the amount of air flowing past the firing line. If not eliminated, these eddy currents can cause lead-contaminated air to stop moving downrange away from shooters, swirl in a circular motion, and move back up range to the firing line. The effect of such leaks was most pronounced in and around lane 20 where an overhead corrugated metal roll-top garage door was located immediately behind the firing stations in this area of the range. Smoke tests around this door confirmed the negative pressure inside the firing range. However, they also demonstrated that the inflow of air around the door created air currents that drew the smoke from downrange of the firing line back to the uprange side. It was recommended that all major leaks in the range be closed to ensure successful ventilation in the indoor firing range. The overhead garage door located behind the firing line was recommended to be replaced with an airtight door. The facility management acted on this recommendation by removing the overhead garage door and instead replacing it with brick to complete the wall.

Airflow within the range should be uniformly laminar, ideally flowing smoothly without swirling or turbulence. Introduction of any turbulence, particularly behind or at the firing line, can compromise the safe operation of the range. During portions of the qualification exercises, the officers in this facility used removable lane partitions behind which they stood to simulate a real-world scenario. In this range, the widest section of the partitions was installed perpendicularly to the airflow, partially obstructing range airflow. This induced the formation of eddy currents and created more turbulence near the firing line. It was recommended that the widest section of lane partitions should always be installed parallel to the airflow to minimize its obstruction. However, management decided this was not a feasible option for this facility due to the certain requirements of the qualification exercises.

**Volumetric Flow Rate at the Firing Line**

It was recommended to the facility management that the ventilation system be optimized to improve the flow rate across the firing line at each lane. The first step was to verify whether equal airflow is being discharged from all of the supply diffusers. This was performed by collecting air volume measurements using a flow measuring hood at each supply diffuser. Since the range's supply airflow was found to be unevenly distributed, the supply airflow dampers were appropriately adjusted via trial and error until the overall range airflow was evenly distributed among all of the diffusers.

The second step was twofold. The first part required optimizing the overall range exhaust airflow to allow for 25% at the midrange exhaust and 75% at the downrange exhaust. This would allow for maximizing the ability of the system to capture emissions without greatly impacting the overall range flow to the bullet trap. The second part would ensure equal distribution of exhaust airflow across the midrange vents, as well as across the downrange vents. The balancing of the exhaust among vents at each location was implemented using the same procedure employed in balancing the supply airflow.
Measuring the supply and exhaust volumetric airflows further verified the range was under negative pressure as the exhaust airflow was slightly higher than the supply airflow, although it did not reach the 10% higher level of exhaust typically recommended by NIOSH for maintaining negative pressure in firing ranges.\(^1\)

The third step was to determine the recirculation fan speed at which the air velocity for all of the lanes at the firing line can be maintained ideally at 75 fpm. This could be accomplished by increasing the speed of the recirculation fans in fixed increments until the desired air velocity across each lane is attained. It was recommended that if the optimization of the ventilation system failed to produce 75 fpm airflow across each lane, then the ventilation system's fans capacities should be upgraded. It was determined that the airflow at the firing line was approximately 43 fpm. The facility management followed the recommendation by substituting the current 30HP electrical motors with larger 40HP electrical motors to increase the air velocity across the firing line. This improvement increased the airflow to 57 fpm.

The design of the supply airflow diffusers typically plays a critical role in ensuring uniform dispersion of the range airflow across the firing line. The performance of supply airflow diffusers can be evaluated by measuring the air velocity variations between each lane. Although there are no standards for maximum air velocity variations permitted between each lane, it was recommended that air velocity in each lane be measured and that modifications to the diffusers be made if the variations in air velocity exceed 50%. If the air velocity variations in the majority of the lanes varied by more than 50%, then the outdated supply airflow diffusers that were responsible for the introduction of excessive turbulence in the supply airflow were recommended to be replaced with state-of-the-art diffusers that were laminar airflow-friendly.

**EXPOSURE ASSESSMENT**

Several site visits were made throughout the improvement process to collect exposure assessment data from individuals using the firing range. The sampling results of each site visit are in table format in Appendix A. During the first site visit in April 2000, NIOSH investigators conducted task-based air sampling for lead during three separate time periods. On the morning of April 19, 2000, personal breathing zone (PBZ) air samples were collected on 10 of 20 shooters who completed a single pistol qualification exercise. A single pistol exercise typically lasts 15-20 minutes. In the afternoon, 10 PBZ air samples were collected on the same shooters while they completed two consecutive pistol qualification exercises, which lasted 45-50 minutes. A pistol qualification exercise consisted of each agent firing 73 rounds of 155 grain jacketed hollow point .40 Smith and Wesson (S&W) ammunition at targets of varying distances. On the next morning, 10 PBZ air samples were collected during a single shotgun qualification exercise from 10 of the 20 shooters previously not sampled, lasting approximately 15-20 minutes. The shotgun exercise consisted of each agent firing 30 rounds using 12 gauge shotguns, 25 rounds of 2¾” 00 Buck and five 2¾” slugs.

Time-weighted average (TWA) concentrations were calculated to determine the levels of airborne lead exposure during the short-term sampling periods. The TWA concentrations of lead in the PBZ air samples for the single pistol exercise ranged from 4 micrograms per cubic meter (µg/m\(^3\)) (lanes 3, 5, and 7) to 89 µg/m\(^3\) (lane 19). The TWA concentrations for the two consecutive pistol qualification exercises ranged from 4 µg/m\(^3\) (lane 5) to 159 µg/m\(^3\) (lane 19). During the shotgun qualification, the TWA lead concentrations ranged from trace (lane 6) to 718 µg/m\(^3\) (lane 20).

Under the Occupational Safety and Health Administration (OSHA) general industry lead standard, the permissible exposure limit (PEL) for airborne exposure to lead is an 8-hour TWA of 50 µg/m\(^3\), with an action level of 30 µg/m\(^3\).\(^2\) The NIOSH recommended exposure limit
REL, a criteria intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects, is also set at 50 µg/m³. Since the sampling times during these individual exercises only ranged from 15 to 60 minutes, a direct comparison to OSHA's enforceable 8-hr TWA criteria is inappropriate. However, if one were to make the assumption that the individuals sampled received only the lead exposures during that single exercise and no additional exposure during the rest of the shift, certain individuals would still have received a high enough exposure during the short 15-60 minute sampling times to surpass these criteria. For example, the individual in lane 20 during the shotgun exercise received an average exposure of 718 µg/m³ during the 60 minute sampling period. If he received no additional lead exposure, this 60-minute period (only 12.5% of the workday) still would have resulted in an 8-hour TWA of 84 µg/m³ (or 1.67 times the PEL). It is unlikely that an individual would perform solely a single qualification exercise during a typical 8-hour work shift. In fact, on a given day, individuals in the firing range may perform a variety and multitude of these different exercises. Therefore, exposures for many of the individuals could exceed the PEL, REL or AL during a typical 8-hour workday.

The exposures received by shooters in the lanes nearest the walls were consistently among the highest of the data set. There were two likely explanations for this. First, the inflow of air through the overhead corrugated metal roll-top garage door immediately behind firing lanes 15-20 resulted in stronger eddy currents near the firing line and more backflow along the adjacent range-right wall compared to the range-left wall (adjacent to lane 1). The second possible explanation is that these shooters had to move downrange several times during each qualifier to adjust their target to the proper distance from the firing line. This required them to walk through an area of the range having higher lead concentrations than the firing line, though this is not commonly done during normal range use.

NIOSH conducted a lead exposure assessment on March 26, 2002 after the facility managers implemented the recommendation of removing the overhead roll-top garage door to reduce leaks and airflow turbulence. Three shooting periods were again monitored: (1) a single shotgun qualification; (2) two immediately consecutive pistol qualifications (double pistol qualification); (3) one single pistol qualification. The number of rounds fired per qualification was the same as those during the April 2000 exposure assessment reported above. PBZ samples were collected on shooters in a similar manner as the previous evaluation, although not all the samples collected were from the same lanes as the previous evaluation.

The TWA concentrations of lead in the PBZ air samples for the single pistol exercise ranged from 21.8 µg/m³ (lane 11) to 149.5µg/m³ (lane 18). The TWA concentrations for the two consecutive pistol exercises ranged from 11.4µg/m³ (lane 6) to 122µg/m³ (lane 18). For the shotgun exercise, the TWA concentrations of lead in the PBZ air samples ranged from 22.9µg/m³ (lane 12) to 318.3µg/m³ (lane 19). Both increases and decreases in average exposure per lane in comparison to the previous site visit were recorded.

After recommendations for optimization of the ventilation system and upgrading the fan motors to increase airflow at the firing line were implemented, NIOSH investigators returned to the facility and collected PBZ and area air samples for lead during two sessions of qualification exercises. The first session consisted of fifteen shooters completing a single pistol qualification round in lanes 2 through 9 and 11 through 17. PBZ samples were collected on all fifteen shooters and the qualification instructor. Area air samples were collected in unoccupied lanes 10 and 18. A second round of sampling was performed while shotguns were used during the second qualification exercise using the same sampling protocol.
The TWA concentrations of lead in the PBZ air samples for the pistol exercise ranged from 1.3µg/m³ (lane 7) to 45.1µg/m³ (lane 17). For the shotgun exercise, the TWA concentrations of lead ranged from 19.1µg/m³ (lane 3) to 1513.3µg/m³ (lane 17). Overall the concentrations of the samples collected during the shotgun qualification were considerably higher than the samples collected during pistol qualification. As shown, increases and decreases in average exposure per lane in comparison to the previous site visit were recorded for this assessment as well. These results continued to demonstrate a pattern of increased exposures to individuals shooting in lanes 14–18 relative to the exposures received by individuals at other lanes during their respective qualification exercises. These lead sampling findings were re-confirmed by the smoke tests. When smoke was released at the firing line of lanes 15-18, a high level of turbulence and the presence of eddies and backflow of air was still observed, which circulated the smoke back into the breathing zone of the individual at each position on the firing line. This increase in turbulence in these lanes may be attributed to the higher air flowing through the existing diffusers, that are laminar unfriendly. A recommendation was made to install new supply air diffusers that are laminar friendly, but the implementation of the recommendation has not been completed.

Conclusions

The objective for this indoor firing range study was to implement a series of phased-in recommendations in order of their expected increasing cost so that the lead exposure issues could be resolved. According to the exposure monitoring data, the implemented changes thus far at the facility did not always result in expected decreases in exposure. This suggests that the implementation of the full round of recommendations, which has not been completed at this time, is an important next step for this facility. However, it is felt that the full course of outlined strategies for this range can be applied successfully in other facilities. These recommendations can be implemented in three phases. In Phase I the recommendations associated with fixing major air leaks and operational variables contributing to increased air turbulence were implemented. If recommendations in Phase I fail to lower airborne lead to the desired levels, then recommendations of Phase II, associated with optimizing the ventilation systems, should be implemented. If these fail to adequately lower the lead exposures in all of the firing lanes, then recommendations of Phase III associated with upgrading the ventilation systems should be implemented.

While the focus of this case study was on the use of ventilation for controlling exposures to lead, several other control measures were recommended to this facility to be used to limit worker exposures and also are applicable to other facilities including:

- investigating the feasibility of using a completely lead-free practice round
- using wipe sampling results as an indicator of ongoing housekeeping effectiveness
- using a HEPA vacuum on the range before it is wet mopped
- including range housekeeping personnel, and anyone else with regular occupational exposure to lead, in the blood lead and zinc protoporphyrin monitoring program
- requiring range users to wash their face and hands upon leaving the range and before eating, drinking, or smoking

Further research and outreach has been identified as a priority to heighten awareness of available controls of both lead and noise hazards present in these facilities. To that end, a NIOSH webpage devoted to these indoor firing range health and safety issues is being designed to serve as a clearinghouse for such information. A NIOSH Hazard Alert (currently in draft form), intended to describe the potential exposures associated with indoor firing ranges, will be included on this webpage when completed. This Hazard Alert will include several
NIOSH case studies of lead and noise exposure in indoor firing ranges and present practical recommendations for controlling lead and noise hazards in indoor firing ranges that can be implemented. Additionally, an update of NIOSH’s 1975 technical document “Lead Exposure and Design Considerations for Indoor Firing Ranges” is planned.

References


## Appendix A

### Results from Lead Exposure Assessments

#### Time-weighted Average Concentrations of Lead, $\mu$g/m$^3$

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Dashed line means a shooter was present in the lane, but a sample was not collected on the individual.

- Average duration for a single pistol qualification exercise (Pistol-1): 15-20 minutes
- Average duration for consecutive pistol qualification exercises (Pistol-2): 45-50 minutes
- Average duration for shotgun qualification exercise: 20 minutes
Session 5
Technologies
Solutions
VENTILATION IN INDOOR SHOOTING RANGES

Günter Mirbach, Germany
Consultant and Site Supervisor for Ventilation Air Conditioning

September 2005
Ventilation in Indoor Shooting Ranges

Günter Mirbach, Germany

Consultant and Site Supervisor for Ventilation Air Conditioning

Abstract

When firearms are fired, irrespective of their calibre, harmful substances are released in the form of gas and powder. In indoor shooting ranges these substances can only be shown to be removed safely by using mechanical ventilation, that is, using fans, in order to avoid harming the health of the shooters.

Health hazards stemming from changes in the blood content of those working at police shooting ranges were behind the fact that as early as 1977-78 steps were taken to ventilate police shooting ranges in the federal region of Nordrhein Westphalia in the Federal Republic of Germany.

All indoor shooting ranges which had already been built at that time in Germany had only ever been ventilated on the mixed ventilation principle.

Description of how mixed ventilation works

A mixed ventilation system can be recognized by the fact that with these systems individual air supply inlets are located on the ceiling and or walls, and are more or less evenly spaced.

Clean air is blown into the room at high speed through these air supply inlets. Because of the high speed at which this air moves, a certain degree of low pressure is formed along the edges of the air jet. The ambient air flows in these low pressure areas and moves with the clean air blown in. This phenomenon means that a greater quantity of air is moved, while the speed of the air jet diminishes continuously. At a certain distance from the air supply inlet, some of the air blown in (mixed with the ambient air) starts to flow back towards the inlet point as a result of the low pressure (see figure 1).
This current configuration is referred to as an “air cylinder”. This physical effect causes other air cylinders to form in a given environment.

The nature of the flow of an air current in an environment can be seen in figures 2 and 3.

Mixed ventilation 1 in general

Without a uniform air current, conveyance of harmful substances (in the form of gas) as waste is only possible under certain conditions. The dust falls to the floor as a result of an air current that is too weak and deviated. If the air extractor grille is located too close to the inlet for blow air, almost only fresh air is extracted (it functions as a short-circuit).

Mixed ventilation 2 in general

All the rest as for figure 2

Mixed ventilation is also referred to as turbulent ventilation, or dilution ventilation. In this system the ambient air is weighed down by harmful substances diluted by the clean air introduced, and the harmful substances are only removed in limited quantities, as the time lapse before they are finally removed is very long. The turbulent air current also results in uniform mixing of the fresh air with the ambient air in the entire environment.

In the case of areas in which comfort is called for, such as offices or shops, this effect is desirable and is used to create a uniform temperature in the rooms.

One important disadvantage to using mixed ventilation in shooting ranges in which firearms are used is this mixing of the fresh air and the ambient air, and the resulting slow and insufficient extraction (dilution) of the harmful substances in the ambient air via the air cylinders (air deviation) resulting from such a system.

For a shooting range, what has been stated above means that the gas and powder mixture is conveyed by the air cylinders in a direction opposite to that of the shooting, and is taken into
the area in which the shooters are breathing.

Because of the reversal of the direction of the current, the powder floating in the air is also separated.

This means that the powders emitted by gunpowder and lead are deposited on the floor and walls of the entire shooting range. When targets are changed manually, these powders are kicked up by the feet of people walking over them and end up in the respiratory system in a concentrated form. In addition, deposits of the powders released by shooting also create a greater fire hazard.

Curve “a” (broken line) in figure 4 shows the measurement values found in a shooting range with a mixed ventilation system. The measurements were taken during a police practice shooting session in 1978. At the start of the shooting exercise, within about five minutes the number of powder particles in the ambient air increased from 2,000 to 120,000, and finally reached 200,000, that is, 60 to 100 times higher than the initial level. During breaks in shooting the drop in the powder particle content was very slow, and went down to 60,000 to 80,000 particles. During subsequent shooting sessions, in less than a minute the number of particles rose to 200,000 again. Once shooting ended, it took at least 20 minutes to return to the initial value.

In addition to these observations, the concentration measurements taken showed that the concentration of harmful substances was 0,25 mg lead / m³ of air. The maximum MAK value permitted (Maximum Concentration in the Workplace) is only 0,1 mg/m³. This limit had therefore been exceeded by 2,5 times.
By way of clarification, it should be said that 23 air changes per hour were used at the shooting range studied – that is, all the air in the shooting range was changed every 2.5 minutes (the equivalent of a storm). A further increase in air changes was experimented with, providing a complete air change every 1.5 minutes, but this did not improve the results in any way. It was not possible to show any substantial reduction in the concentration of harmful substances.

The results of the measurements taken show that a mixed ventilation system is not suitable for indoor shooting ranges used for firearms.

The ventilation system for the shooting range was reconstructed after a lot of thought had been put into a system that involves a displacement ventilation (with piston type air movement).

**Description of how a piston type air movement ventilation system works**

Unlike a mixed ventilation system, a displacement ventilation system uses an ambient air current without significant turbulence (also referred to as a piston type air movement) that directly conveys the particles and gases, without any counter-currents from the air supply inlets to the impure air extraction outlets. This system, which had already been tried and tested in industry for at least 70 years, is used mainly for keeping clean environments free of powders and harmful substances in pharmaceutical and electronics production plants.

The main difference, compared to a mixed ventilation system as described above, simply involves how and where the fresh air is fed into the environment. In this system the fresh air is introduced exclusively behind the shooter, over a large surface covering the entire rear wall. The fresh air can only flow at low speed covering a large surface in the environment, and cannot be blown in through a few air supply inlets. The wall must have the smallest possible number of door and window openings, so as to avoid obstructing the air current.

A schematic representation of the air flow is shown in figure 5.
The quantity of air is determined in such a way as to make it possible to maintain an air flow speed of at least 0.25 m/s over the entire cross section of the room. For long shooting ranges, or where shooting is more frequent, the air current speed must have a value of up to 0.35 m/s.

The impure air is extracted in the area of the bullet trap. The air is taken at the top and bottom or at the sides, so as to remove the powder and gases from the environment altogether.

This means that the air is moved throughout the entire environment. No counter-currents can be formed, as no air cylinders are formed. The impure air, full of harmful substances, is then blown out into the open air.

The schematic layout of a shooting range with piston type air movement ventilation is shown in figure 6.

Figure 7 shows a detailed perspective of a shooting range with this type of ventilation.
The (gray) curve b measurement data in the figure give convincing evidence that the particle content of the air when this type of ventilation system is used is significantly lower, and also drops more quickly and efficiently. The maximum number of particles only reaches 30,000, that is, compared to the values for the mixed ventilation system, the content of harmful substances is reduced by 80-85%.

Along with the particle count, the concentration was also measured. These measurements showed that the maximum content of harmful substances was 0.1 mg of lead / m$^3$, which means that when this system is used the maximum MAK value set at an international level is complied with, unlike the case with a mixed ventilation (dilution) system.

Costly long-term measures taken in shooting ranges have confirmed that this system is able to produce stable current conditions, even for ranges that are longer than 100 metres.

One further advantage of piston type air movement ventilation is shown by the fact that the quantity of ventilation air depends solely on the height and width of the shooting range and not the entire volume of the space.

**Reconstructing existing systems**

When reconstructing existing shooting ranges, the prerequisites laid out above are often not available, because of space restrictions. Where, for example, limited space in small shooting ranges makes it impossible to introduce fresh air behind the shooters, an alternative is available. In Germany, it has been shown that fresh air as shown in figure 9 can be moved up to ceiling height and sideways, at right angles behind the shooters.

This is, however, a second-best solution and should only be used when there is no other option. The air current conditions are acceptable.
On open air shooting ranges, where for acoustic reasons the shooting positions and part of the shooting range are enclosed, there is often only an air extraction system for the shooting station. This system is wrong in terms of air current techniques. If an air extraction system is installed for the shooting station, the air flows into the encapsulated shooting station from the front, that is, in a direction that is opposite to that of the shot in the shooters’ area, thereby pushing the polluted air into the air that the shooters are breathing. It is for this reason that in general terms an air supply system must be installed. The fresh air must be blown in as described above, behind the shooter. The air must also be blown in over the entire rear wall. In this case the direction of the air current will be parallel to the shooting direction. The combustion gases are consequently pushed into the open air, away from the shooter.

**Structure of a ventilation system**

A ventilation system for shooting ranges in which firearms are used can only be run using fresh air from outside. Under no circumstances can impure (return) air that has been recovered be used.

Figure 10 shows a layout for the structure of this type of ventilation system. In this case the fresh air also had to be heated when running the system in winter. If the air has to be heated, the possibility of recovering heat as shown in the layout must be studied carefully, as such recovery can reduce heating costs by up to 60%.
Figure 11 shows a wall for introducing the amount of fresh air required. This wall is specially designed for piston type air movement ventilation, for target shooting ranges. This air blowing wall is made in Germany by Companies like Strulik, Phone: +49 6438 839 0.

Displacement ventilation with an air extraction wall by the Strulik Company at the shooting range for the federal police in Hangelar (Nordrhin Westphalia/Germany)

Summing up

In a system for feeding air into and extracting air from an indoor shooting range, particular requirements must be met, in accordance with the specific, somewhat unusual operating conditions. Provision must be made for the various types of firearms, and the design must allow for various shooting disciplines, such as airguns and muzzle-loaders.

The architect and ventilation engineer must start working together very early in the process of designing a shooting range, in order to arrive at a layout and sizing that is accurate and provides a high performance system, in terms of the technical aspects of ventilating the space.

When conventional ventilation methods are used, even where a high number of air changes are provided for, or air conveyance currents are planned, it is not possible to obtain suitably low concentrations of harmful substances in indoor shooting ranges.

A low turbulence displacement ventilation system (piston type air movement) provides the correct conditions for rapid conveyance of harmful substances to the extraction outlets in the area of the bullet trap.

The measurements and studies carried out so far clearly show that, without any doubt, it is possible to markedly improve the quality of the air only when this type of system is used. It has proved to be effective in police shooting ranges in Germany for more than 25 years, and for the past ten years it has been used for all new indoor shooting range systems. One can therefore consider this type of ventilation in Germany to be the current state of the art.
VENTILATION SYSTEM
FOR THE LARGEST UNDERGROUND
SHOOTING RANGE IN SWITZERLAND

Peter Berchtold, Switzerland
Ing.Büro Energie und Haustechnik

September 2005
Ventilation System for the Largest Underground Shooting Range in Switzerland

Peter Berchtold, Switzerland

Peter Berchtold Ing.HTL Ing. Büro

Abstract

A ventilation system has been designed for the Brünig-Indoor underground shooting range that should meet the most wide-ranging requirements.

The facility described is the “Brünig-Indoor Underground Sport Shooting Centre” in Lungern, Switzerland. It has three ranges including a 300-metre shooting tunnel. The ventilation system was designed to provide comfortable indoor climatic conditions (temperature and humidity) during all seasons. Other considerations included air quality (maximum concentration of harmful substances), frequency of use (number of shots fired), energy consumption, space requirements and construction costs.

Initial position

In October, 1983, the federal law on ecological conservation came into force. According to this law, shooting ranges not complying with the requirements of the environmental laws must be updated. Based on the legislation for acoustic protection of December, 1986, these updates were to be completed, at the very latest, within fifteen years of the date on which this law was passed.

In the Obwalden Canton, there are several shooting ranges that were not in compliance with the legal requirements, and therefore requiring substantial updates.

This being the case, in 1997 Mr. Thomas Gasser (Gasser Felsbau, Lungern) started the work necessary for designing an underground shooting range. In May, 2001, the first official building authorization was granted to build an underground shooting range. After about 15 months of work, the first 300-metre civilian shooting range in the world will be inaugurated.

As of the inauguration date, 100-metre, 150-metre and 300-metre shooting ranges are available. The completion of the underground systems does not end with these structures. As a matter of fact, in February 2003 a Polyhalle (multifunctional hall), and in November 2004 the Olympic shooting range, were opened for shooting on with rifles and handguns.

When shooting range facilities are moved from outside to indoors, additional requirements are created, including the need to take air into the various rooms and to expel it. When dealing with ventilation systems for indoor shooting ranges, it is necessary to satisfy special needs in response to the unusual and specific operating conditions.

To this end, the PB technical office was given the task of designing the structures concerning the technical aspects of the domestic systems. The structure of the Breunig indoor shooting range offers many possibilities for various types of shooting, and this, in turn, allows for usage by a very diverse public. Installations involving the technical aspects of the domestic systems must be capable of satisfying a wide range of requirements.
Basic elements

Inbound and outbound ventilation, sufficiently powerful, must guarantee that in the area in which the users are breathing there is no stale air, in order to be able to exclude the possibility of damaging the shooters’ health. The following are the most important basic elements to be considered in determining the quantity of air:

Number of shots:

Regarding the calculation of the number of shots, there are no requirements, regulations or laws to consult. The definition of the number of shots was therefore calculated on the basis of interviews with military men, amateur shooters, hunters and dynamic sport shooters. Based on the figures collected according to the experience of the various users, the number of shots and the shooting frequencies of the single-use units were established. Initially the expected number of shots was very high and so the calculated air volume was also very high. This required relatively large quantities of air, subsequently resulting in high investment costs.

Following an agreement with all the people involved, the definitive number of shots was finally established, to be taken as the basis for the dimensions of the ventilation system.

Ammunition used:

The priming system, the propulsion charge gases and the materials in the ammunition must be taken into account in order to arrive at the correct dimensions for the ventilation system.

As was done with the number of shots, the type of ammunition was also established on the basis of interviews with the most recent users of the shooting range. For a certain number
of types of ammunition used, the data concerning the emission of harmful substances were not available. It is also important to keep in mind that many of the shooters load their own ammunition. These measurements existed only for military ammunition.

Since mainly military ammunition is used in the 300-metre shooting range area, these available figures were used as the basis for the process of deciding dimensions.

**Shooting position:**

The distribution of the gases and dust in the environment also depends on the shooting position. In the 300-metre shooting range, and also in the Olympic hall, the shooting position is generally fixed. In the Polyhalle, a mobile shooting position needs to be taken into account.

**Quality of the air:**

As for the maximum permitted concentration of harmful substances in the breathable air, the SUVA (Swiss Institute for Accident Insurance) maximum values for the workplace were used (– MAK values: maximum concentration of harmful substances in breathable air in the workplace). The most significant values for the shooting station areas concerned CO (carbon monoxide, gas), lead and copper (powders).

**Limiting values:**

- CO: 30 ppm
- Lead: 0.1 mg/m³
- Copper: 0.1 mg/m³

**Climate conditions inside the rock:**

The location of the range was inside the rock, and the natural climatic conditions in it need to be considered for the heating and ventilation systems.

Winter / Summer: Room temperature 9°C – 11°C, humidity 60 – 80 % u.r.

**External conditions:**

As basic elements for allocating dimensions to the ventilation system, the external air conditions indicated by the SIA (the Swiss society of Engineers and Architects) are valid:

- External temperature in winter -15°C, External humidity 90% u.r.
- External temperature in summer +28°C, External humidity 50% u.r.

**Environmental conditions:**

The air conditioning requirements for the internal environments at Brünig were established as follows:

- Room temperature: 18°C, Humidity: max 65% u.r. (maximum humidity in the inbound air 8 g/kg).

**Conception of the systems**

Considering the basic elements indicated above, the following quantities of air were calculated for the various uses:

- 300m shooting range: 8‘400 m³/hour
- Polyhalle: 11‘000 m³/hour
- Olympic Hall: 11‘000 m³/hour
- Administration/offices: 6‘700 m³/hour
Building systems through rock involves relatively high costs. It becomes necessary to minimize the need for space in the ventilation systems. After examination of various possibilities, an air input technique based on a central ventilation appliance was chosen. Taking into account various simultaneous-use needs, an overall quantity of 21,900 m$^3$/hour of air was calculated.

The structure of the central air treatment system is shown in the diagram.

![Diagram of central air treatment system]

It is particularly important to point out that, in order to avoid structural damage, it is vitally important to dehumidify the external air. The dehumidification is carried out by means of an air-cooling unit. The production of the necessary cooling energy is obtained by means of a refrigerating machine, built into the ventilation system. The heat obtained from the output from the cooling process is first of all used for heating the input air. There is also a possibility of inserting this waste heat into the network of the heating system.

If the external air does not need to be dehumidified, the refrigerating machine’s process is reversed. This means that the machine, in this case, works as a heat pump and uses the residual heat from the impure air. The recovered heat is supplied to the input air and to the heating system.

**300m shooting range**

The system is made up of three shooting ranges, one on top of the other, and the three-hundred-metre tunnel. The shooting ranges are separated structurally by the tunnel. The shot is fired through windows that can be opened in the dividing wall (see figure 2). The layout of the windows depends on the position of the shooters, whether they are standing, lying down, or kneeling. Overall, 15 shooting stations have been installed.

![Image of 300m shooting range]

*Figure 2: The 300m shooting range - firing room*
Thanks to careful selection of the system and the suitable arrangement of the pure and impure air, it is possible to create very efficient ventilation.

In figure 3, there is a plotted diagram of the ventilation system compared to the three-hundred-metre shooting range system. The pure air is injected at the rear area of the room, and then moves longitudinally down the room. About 35 percent of the impure air is discharged in the shooting range directly around the position of the firearm. In this way, an increase in pressure is created within the shooting range. The residual air flows through the open windows into the tunnel.

In order to immediately gather the maximum possible quantity of harmful substances that appear at the muzzle of the firearm, about 55% of the impure air is collected immediately outside the dividing wall. In order to collect the impure air, turbulence hoods are used. These were initially built for collecting fumes. A smaller part of the impure air is collected in the target and bullet collecting area.

In order to avoid dirtying the channels, and also for purposes concerning the sucking of residual dust into the channel system through the air movement, special washable filters were installed immediately below the impure air collection elements.

Measurements

In the shooting range area, the significant values of the harmful substances were measured over a period in excess of two hours. During that time, five shooters were busy in the shooting range (100 percent of occupation of the available positions), and they fired 720 shots overall.

The dust particles in the breathable air (lead and copper), were collected by means of fixed measuring apparatus as well as apparatus carried by people. The gas (CO) measurements were carried out continuously by means of fixed apparatus.

The results of the measurements are indicated in the diagrams. One can see, from the results obtained, that these values are well below the maximum permitted values. Except for a few brief moments above the limiting values, the health of the people present was never put at any risk. The peak values were reached only during rapid firing that lasted only a moment and were rapidly reduced again thanks to the efficient ventilation system.
The results of the measurements are indicated in figures 6 and 7. From the results of the measurements, one can clearly see that the maximum permitted values are evidently much higher than the measured values. Except for a few brief moments above the limiting values, the health of the people present was

**Conclusions**

Based on the plan for ventilating the underground shooting range plant in Lungern, it is necessary to keep in mind that it was mainly the establishment of the basic elements that proved particularly expensive, since basically no prior data was available.

According to our evaluation, the situation will not change for future systems, either, since the establishment of the basic elements to decide the dimensions may only be carried out in correlation with future users.

The main requisite for the air ventilation system concerns the fact that there must be no polluted air in the users’ breathing area, thus making it possible to exclude the possibility of damage to their health. The management of the system proves how it is possible to reach that aim with a well-designed structure of the system and, subsequently, with a relatively low cost of installation. And this is also confirmed by the measurements.

As already mentioned in section 3, building systems through rock causes relatively high costs. This requires minimizing the need for space in the systems involved in the technical aspects of ventilation. Based on the evaluation of the various solutions, a technical air input system was chosen, through a central ventilation mechanism with various adjustment sections and well-designed simultaneity.

The experience gained over the first years of business shows it would have been useful, because of the large variety of activities carried out in the Polyhalle, to add a separate ventilation system for that area.

The Polyhalle was built in a relatively deep position among the rocks. A separate system, equipped with the corresponding air channels, both for the external air and the waste air, would require very high building costs. This aspect was a determining element in reaching a decision concerning the construction of the ventilation system.

The underground shooting range is visited a lot. In spite of the abundance of users, the limit values have still never been exceeded. And this result has also been achieved thanks to the systematic maintenance procedures carried out on the system.
### Brünig Indoor Shooting Range Sports Complex
6078 Lungern

#### Results of the dust Measurements
2.12.2002

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**MAK [maximum toxic concentration] value, with an exposure of 8 hours**

|            | 3¹) | 0,1 | 0,1²) |

**Comments**: Since, in the case of the measurement of shooting smoke, the driving component is usually lead, and lead has a MAK value that refers to dust-e, in these measurements a sample of dust-e is taken. In the case of shooting smoke, the diameter of a dust particle is considered to be less than one micron. The established concentration of dust-e may therefore be considered equal to the concentration of dust-a.

Dust-e = breathable dust  
Dust-a = Dust that can transit at an alveolar level.  
MAK = maximum toxic concentration levels in the work place  
• Due to analysis problems, it was impossible to reach the deepest levels of demonstration.  
1) = General dust limit value for dust-a  
2) = Valid for copper dust (dust-a)  

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*Figure 6. Results of the SUVA measurements*
Figure 7. Results of the SUVA measurements.
LATEST EXPERIENCES ON UITS
SHOOTING TUNNELS IN ITALY

Eng. Lorenzino Unio, Italy

UITC National Councillor
ESC Environment Sub-Commission Member

September 2005
Latest Experiences on Uits Shooting Tunnels in Italy

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Abstract

All human activities produce pollutant materials in varying amounts. Shooting, whether for sporting or other purposes, certainly cannot be considered as one of the major causes of environmental pollution that our society must address, but it too is no exception to the general rule.

Since shooting is an indispensable component in the training and preparation of the police forces whose task is to protect our society, it is an activity that certainly cannot be curtailed; rather, it will presumably become more and more necessary.

Thus the existence of specific facilities, suitably equipped, will enhance the passive safety of both range personnel and marksmen, and will also permit better management, as regards environmental protection in general, of the pollutant residues produced by shooting which cannot be totally eliminated with today’s technology.

The costs involved are clearly not irrelevant but necessary and unavoidable. Economies of scale and or rational use of resources must be achieved through astute management of programs, after careful analysis of requirements, so that ranges are encouraged to work for the optimum in management, and respect requirements to handle pollution. Facilities will have to operate at maximum productivity to eliminate negative effects.

A Introduction

1.1 Production of pollutants during shooting sessions

As is known, shooting using firearms and commercial products causes pollutants to be released into the environment. These are caused by the chemical-physical processes that the components in a cartridge are subject to, both inside and outside the firearm.

In order to identify these pollutants, one must therefore start from the nature of the primary components.

In the case of target shooting, these are basically:

- Lead (Pb)
- Antimony (Sb)
- Barium (Ba)

which are included in the priming mixture, and:

- Lead
- Antimony

that make up the projectiles.
The processes by which the pollutants are released are essentially:

a) On the firing line:
   - Primer combustion, which releases Pb, Sb, and Ba;
   - Melting of the bottom of the projectile resulting from the very high explosion temperature in the charge, which is of the order of 1,800–2,000°C, compared to a melting point of the same that is around 327°C (pure lead), and higher values depending on the percentage of antimony in the alloy. This process releases Pb and Sb;
   - Friction between the projectile and the barrel, with Pb and Sb being released;
   - Combustion of the charge, with CO being released.

b) On the target:
   - Friction between the projectile and the steel plating used to stop the projectile, with Pb and Sb being released.

Please note that the pollution generated on the firing line is released from the mouth of the gun, but also from the space between the chamber and the barrel in the case of revolvers, or from the ejection opening in the case of semi-automatic firearms, as is clearly shown in Photograph N° 1 below.

This is important in that, unlike the gas expelled from the mouth of the gun, the gas expelled by the cartridge chamber moves in a direction towards the face of the person firing the gun.

In terms of quantity, values vary in relation to the calibre and the type of charge used in the firearms.

In the case of the pollutants released on the firing line only, experiments have shown that 2–5 mg/m$^3$ are released immediately after shooting and in the area around the shot.

If these powders are not adequately removed and filtered, they are deposited on the person shooting the gun, on the walls of the shooting stalls and the gallery, the floor, and especially, unfortunately, they are also inhaled directly.

During analysis of forensic ballistic problems, the following values were measured for deposits, broken down in relation to the space between the thumb and index finger on the firing hand (for a single shot).

The values shown below obviously vary, given that the ammunition used for the tests was
all of a commercial type, without any great fluctuations in quality between the minimum and maximum values, based solely on the type and make of firearm in use, as these depend on the operating dynamics (opening and extraction times) and geometry.

Table 1: Values for pollutants deposited on the hand of the person firing the gun after a single shot

<table>
<thead>
<tr>
<th>Calibre</th>
<th>µg Pb</th>
<th></th>
<th>µg Ba</th>
<th></th>
<th>µg Sb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
<td>max</td>
<td>min</td>
<td>max</td>
<td>min</td>
</tr>
<tr>
<td>6.35</td>
<td>4</td>
<td>7</td>
<td>0.17</td>
<td>7.89</td>
<td>0.17</td>
</tr>
<tr>
<td>7.65</td>
<td>3.1</td>
<td>8</td>
<td>0.32</td>
<td>7.27</td>
<td>0.14</td>
</tr>
<tr>
<td>9 mm Short</td>
<td>5.7</td>
<td>6.8</td>
<td>0.66</td>
<td>3.71</td>
<td>0.51</td>
</tr>
<tr>
<td>9mm Para</td>
<td>3.4</td>
<td>6.5</td>
<td>0.39</td>
<td>4.2</td>
<td>0.04</td>
</tr>
<tr>
<td>.45 ACP</td>
<td>5</td>
<td>4.5</td>
<td>1.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The difference between the emission and the almost immediate deposit on the hand of the person firing the gun indicates the amount of pollutant in the air, which, if not adequately removed, could be inhaled directly, or could be deposited on the walls of the shooting stall, the floor, the soundproofing on the walls of the tunnel, etc.

Thus, over time, this would present the following risks:

- Inhalation by the person firing the gun;
- Introduction of the deposit through the skin of the hand and face into the person firing the gun;
- Subsequent re-emission of previous deposits on the lining material into the air, as a result of its being dislodged for any reason (shaking, impact, etc. involving the material);
- Combustion of the lining due to ignition of unburnt material deposited on it;
- Subsequent re-emission into the air of deposits on the floor, through people walking on it.

1.1 Characteristics of the pollutants

1.1.1 LEAD

Means by which this is taken in by the organism

Looking only at the most dangerous metal, one finds that lead can be introduced into the organism in three ways:

- By inhalation
- Orally
- Cutaneously

In the case of shooting, the most dangerous way is by inhalation, which means that the lead ends up in the organism in the form of powder and smoke.

Cutaneously, the intake is very limited and can be ignored.

It should be remembered that lead that is inhaled and gets into the lungs is highly bio-available, with absorption on the part of the organism approaching 100%.
Toxicity

Chronic lead intoxication is known as lead poisoning, and may lead to:

- Anaemia (drop in the red globule count);
- Abdominal pain (colic);
- Arterial hypertension;
- Increased reaction time;
- Renal damage;
- Damage to the nervous system in general.

It should be noted that serious lead poisoning is now extremely rare.

The tests used to evaluate lead poisoning include:

Plombemia (PbB), which indicates the quantity of lead in the blood
Plomburia (PbU), which indicates the quantity of lead in the urine

Limiting values

Italy has laid down environmental and biological limits for places occupied by people who are in contact with lead pollutants in Legislative decree No. 277 of 15th August, 1991.

These limiting values are:

**Environment:** 150 μg/m$^3$ of air (which must not be exceeded for more than 30 days continuously)

**Biological:** 70 μg / dl of blood (reduced to 40 μg / dl for women of childbearing age)

In addition to these, “warning sign” values have been established:

**Environment:** 40 μg / m$^3$ of air

**Biological:** 35 μg / dl of blood

If these are exceeded the condition of personnel must be monitored using different, greater, and more frequent means.

It should be noted that in the US, the OSHA (Occupational Safety and Health Administration) has set the limit for exposure to PEL and the warning Action Limit significantly lower, at 50 μg/m$^3$ and 30 μg/m$^3$ respectively, and the CDC (Centers for Disease Control) have set the biological limits at 25 μg/dl for everyone excepting for children under the age of 6, for whom the limit is 10 μg/dl).

It should be pointed out that the Law defines the “limiting values” as: “average concentration that occurs due to exposure for a period of eight hours per day, of a substance in a gas or vapour state or in the form of material suspended in the air “.

In the case of shooting, therefore, one must look at the effective time people using firearms spend on the firing line (1 - 2 hours continuously?), in order to determine the risk they are at in terms of the law.

The position is different for range personnel and shooting instructors, who because of their duties are forced to be in the shooting area continuously.

The Toxicological Institute of the University of Kiel has published research that examined 38
volunteers who worked as shooting controllers in eight police shooting ranges in Schleswig-Holstein, and compared the lead content in their blood with that of a group of adults from Kiel who were not in contact with lead.

Blood samples were taken and evaluated using the PbB method: the spectroscope of atomic absorption (a very exact analytical method) showed plombemia of between 6 and 32 μg/100 ml of blood, with most values being between 13 and 20 μg/100 ml, and average plombemia of 16 μg/100 ml.

The plombemia value for the control group was 10 μg/100 ml.

Similarly, the Alaska Environmental Public Health Program (EPHP) conducted research on instructors and young shooters at a shooting school, in order to evaluate their BLL (Blood Lead Level), and found a BLL of 21 to 31 μg/dl, with an average of 24.3 for shooters and 44 μg/dl for instructors, compared with an average value of 3.5 μg/dl for family members who did not shoot (from 1 to 7 μg/dl).

If compared to the physiological limits in terms of the law, these values are not a reason for concern, but it should be remembered that medical-scientific studies show that:

- Values exceeding 10 μg/100 ml are harmful to the blood system (they do not cause illness, but lead to general weakness);
- Values of 25 μg/100 ml can cause a reduction in performance and behaviour.

What is needed therefore are:

- The elimination of the physiological risks faced by shooters, ensuring pollutants in indoor shooting tunnels never reach upper limits;
- Improvement of the ambient conditions for shooting, increasing the usability of facilities.

1. 1. b CARBON MONOXIDE

1. 1. 1. i Means by which this is taken in by the organism

This pollutant is taken in solely by inhalation.

1. 1. 1. ii Toxicity

Chronic CO intoxication is known as oxycarbonism, and involves the haemoglobin being blocked, which prevents it from transporting oxygen.

In its initial stages oxycarbonism can cause:

- Constrictive cephalae
- Sensory changes (hot – cold)
- Muscular weakness

We will not deal with second and third stage symptoms.

CO intoxication can be evaluated symptomatically, and can be quantified in a laboratory, using tests that are based on measuring the dosage of carboxyhaemoglobin (haemoglobin combined with CO) or by direct measurement of the CO content in the blood.

1. 1. 1. iii Limiting values

The standards state that in environments in which the formation of CO is possible, detectors are to be installed, connected to a suitable alarm system for evacuating the area whenever the CO concentration in the indoor environment reaches 70 ppm (with a pre-alarm at 50 ppm).
B   Methods for reducing ambient pollution in shooting tunnels

The ambient conditions inside indoor shooting ranges can be improved by:

1. Reducing pollution at the source, by eliminating the polluting factors;
2. Removing the pollutants in loco, using mechanical means;
3. A combination of the previous two, using the best technology available;
4. Correct, routine maintenance of the structures.

1.1 Reducing pollution at the source, by eliminating the polluting factors.

A reduction in the sources of pollution can be achieved by:

a) Equipping the galleries with total-absorption bullet traps, which eliminate the lead vapours caused by striking steel plates (one thinks of bullet traps made of thermoplastic materials, or sand combined with a specific bonding gel, or a number of rubber curtains of suitable thickness);

b) Using projectiles that are not made of bare lead, but that are coated with various metal alloys (nickel, brass, and zinc-nickel alloy, are the materials most commonly used for coating). This reduces the emission of lead due to grinding between the barrel surface and the projectile;

c) The use of bullets with a coating on the bottom as well, which eliminates the emission of lead through melting at the time the propellant ignites;

d) The use of cartridges with lead-free primers.

These steps would undoubtedly reduce the risk faced by users, but an air-conditioning system, even if it only removes the smoke caused by combustion, makes the facilities more usable and shooting less strenuous.

It is important that the precautions referred to in point a) above are provided for at the design stage, and since not producing pollutants is of primary importance, or at least reducing them as far as possible, based on current technological resources, the use of total absorption bullet traps is highly recommended, with these eliminating the lead vapours caused by scraping against steel plates.

There are various solutions on the market that vary in price, ease of installation, setting up, and maintenance (one thinks of bullet traps made of thermoplastic materials, or sand combined with a specific bonding gel, or a number of rubber curtains of suitable thickness). The choice must be made based on investigation by the designers in the light of the specific size of the facility being designed, in addition to the parameters dealt with above.

Clearly, in terms of final solutions, ventilation of indoor shooting ranges, and especially those that are enclosed, takes pride of place.

In fact, there is nothing like correct ventilation, which creates an atmosphere of the same quality as that outside, and which is controlled and regulated on the basis of real-time needs, taking in temperature and humidity, involving systems that can be checked at any time, for guaranteeing good results and consistent service and performance over time.

1.1 Removing the pollutants in loco, using mechanical means: Ventilation systems

Ventilation systems are used to remove pollutants from the firing line, that is from those shooting and from personnel working on the shooting range.

In order to determine the specific characteristics beforehand, at least from a technical point of view, one need first refer to the Italian standard in this regard.
1.1.a Current Italian Standard

Reference must be made to the DT – P1: Technical Directive for Indoor Shooting Ranges, issued by the Engineering Corps Arms Inspectorate, which is the competent body in terms of Italian law.

In Chapter IV of this Directive: Technical Plants, point c), the text reads:

(2) [They] must be:

- Completely outside air systems, and air recycling is forbidden;
- Of a washing type;
- Dual speed.

with an intake in the indoor shooting range.

The system must guarantee a constant air flow at a speed of 0.3 – 0.6 m/s, over the area used for the firing line.

(4) For extracting the air, the following four sections are indicated:

- The first, positioned 5 metres from the firing line;
- The second, at a distance of 1/3 of the length of the indoor shooting range;
- The third, at a distance of 2/3 of the length of the indoor shooting range;
- The fourth, positioned 5 metres from the bullet trap.

The air must be extracted as follows:

- 35% in the area between the first and second section;
- 35% in the area between the second and third section;
- The remaining 30% in the area between the third and fourth section.

(5) The system must use only outside air. The air intake and air outlet points outside the range must not interfere with one another.

(6) At least two air changes per hour must be guaranteed in the firing control box.

(8) On indoor shooting ranges with a filtration system, all the outlet ducting from the shooting range must lead into this system.

The filtration system is to be fitted with a sensor to detect the degree of clogging of the filters.

UITS has always referred to this standard for the approval of facilities for target shooting, and has updated its rules from time to time on the basis of experience gained with previous systems and technological innovation. In this they are completely aligned with the Engineering Corps Arms Inspectorate, which has the power to approve structures being examined and issue licences.

In addition, what was issued was a directive. It lays down essential aims, but suggests methods that can be modified, added to, and modernized, always with a view to attaining the preset technical objectives.

However, the practice of accumulating experience through designing and building new plants is highly recommended, especially as far as infrastructures are concerned, such as indoor shooting ranges, in which accidental phenomena are difficult to study and evaluate at a technical level.

1.1.b Theoretical considerations on ventilation systems

The aim is to remove smoke and vapour from the firing line, where shooters and instructors are in action, and experience has clearly shown that, apart from any prior technical evaluation, the results are only obtained by creating a laminar flow towards the bullet trap.
The most recent studies on fluid movement have shown that a turbulent flow is very effective in dispersing particles, which, taken up by vortexes that have local pressures that are well below the ambient mean, can be (and in fact are) expelled in diffuse directions, with a degree of probability, in terms of direction and velocity, of up to 80 times the standard deviation.

From a practical point of view, this means that if the flow is not perfectly laminar there is always the possibility that the pollutant (and polluted) powder will return towards the firing line, and that this probability increases in direct proportion to the degree to which the flow strays from being laminar.

By introducing air behind the shooter’s back and extracting it in the area of the bullet trap, the air flow is naturally drawn in the required direction, but it is essential that this remains as laminar as possible.

Nothing that creates turbulence along the flow path can be tolerated (or worse, planned) as there are already natural sources of turbulence that come into play.

In this regard, see photographs n° 2 and 3 (taken from “Le Scienze”, July 2005).
Even simple, unavoidable movements by the shooters (body, shoulders, and head), and the very
dynamics (albeit limited) of the firearms themselves, create vortexes and air currents that carry
the smoke and vapour back to the firing line area, and must consequently be accounted for.

The same occurs in terms of local variations in indoor climatic parameters.

As to the causes of turbulence referred to previously, the result can be obtained by keeping
up a sufficient airflow speed at the firing line, since too low a velocity obviously helps the
phenomenon. However, one must not lose sight of the need for a laminar air flow, which is not
compatible with velocities that are too high. In this regard, the standard provides correct values
(that have been confirmed by experience and existing publications), setting the value at between
0.25 and 0.4 m/s (50–75 fpm), compared to the 0.30–0.60 m/s indicated in the DT-P1.

1.1.c Type of ventilation systems

A correct laminar flow is obviously created from the firing line, and this can be achieved by
carrying out a detailed study at the design stage of the flow dynamics in operation.

a) The way in which air is introduced (forced or not);
b) The type of air diffuser (ceiling-mounted directional, or wall-mounted air chamber);
c) The existence of introduction and or extraction in the shooting tunnel;
d) The existence of any other cause of discontinuity along the route.

1.1.1.i The way air is introduced

The air flow in the tunnel can be shown in the drawings below, where there is:

- A purely natural flow (drawing 1);
- A flow with mechanical extraction (drawing 2);
- A flow with mechanical introduction and extraction (drawing 3);
- A flow with mechanical introduction and extraction at a number of points (drawing 4).

A purely natural flow (drawing 1)

This clearly shows how the (theoretically) perfect laminar nature of the undisturbed airflow is
subject to directional (and pressure) variations in the flow from the simple effects of shooting.
The energy introduced by the explosion (heat and dynamics) on the air particles causes a
turbulent movement.

A flow with mechanical extraction (drawing 2)
Using only mechanical extraction, correct sizing of the system can undoubtedly limit the formation of vortexes, with insignificant returns to the firing line. This is confirmed by checks carried out on systems installed recently.

A flow with mechanical introduction and extraction (drawing 3)

Where both introduction and extraction are controlled mechanically, one sees how the airflows in the tunnel tend to jump up around the shooter on the pressure wave caused by the shot, resulting in returns towards the shooter.

In addition, with this type of system, both parts must be interlinked via the control console, in order to allow simultaneous operation of both systems, in compliance with preset curves, controlled by the system program.

There is no denying the difficulties with this type of plant, which, according to the author, requires sufficient space between the introduction stations and the firing booths, meaning that it is not possible to realistically create a suitable balance and regulate the flow over too short a route.

1.1.1.ii Types of diffusers

As to the type(s) of the air diffusers, it is believed that both ceiling-mounted diffusers and wall-mounted air chambers can be suitable and adequate, provided that at the design stage the kinematic differences the two systems make to the flow created are taken into account.

A ceiling-mounted diffuser with directional diffusers that are able to direct the flow downwards and towards the firing line gives the flow kinematic and dynamic values that differ from those induced by a wall-mounted air chamber behind the firing line. The design must also take these factors into account, and must always take into account the main objective, which is to have a laminar flow right from the shooting area.

Also for the purposes of correct ventilation, a slightly low pressure must be created and maintained in the tunnel. This can be done by simply expelling air at a rate that is 4 to 7 % higher than the rate at which air is taken in.

B.2.c.iii The existence of introduction and or extraction in the shooting tunnel

A flow with mechanical introduction and extraction at a number of points (drawing 4).

A solution that makes use of a number of points at which the internal air is extracted mechanically, notwithstanding positive theoretical evaluations, has been shown instead to
work poorly in practice, and it may also be very difficult to manage.

In fact, in this case the flow cannot be laminar over the whole length of the tunnel (see drawing 5: detail of the air intake area in case d), as any variation in the flow rate of necessity creates pressure turbulence, and therefore disturbs the laminar nature of the airflow.

Drawing n° 5 is attached. This gives a clear explanation of the macro phenomena that occur around intermediate extraction points.

If set up correctly and in suitable sections it can be managed, but everything depends on the type of system being considered. For facilities with a limited range length, clearly this solution is almost impossible to implement, as well as being absolutely useless and costly. For large size ranges, however, it could be necessary to look at this type of solution.

Most of all, in short ranges, extracting the air at intermediate points between the firing line and the bullet trap could be counterproductive. This is due to the fact that where this air is extracted a localized low-pressure area would create a vortex, which would return some of the vapour and smoke straight to the firing line.

**B.2.C.iv The existence of any other cause of discontinuity along the route.**

In addition to the factors associated with the type of system, there are other causes of turbulence in the laminar movement that can mainly be attributed to projections in ceiling-mounted equipment and deflectors in general.

If it is designed for the sole purpose of protection, one risks adding elements into the airflow that cause vortices that are able to keep polluted air in the range. In extreme cases they may even cause a return flow of polluted air towards the firing line.

Thus the sizing and positioning of these is essential, after having analysed how the flow behaves at these points, and a reverse flow must never be possible.

**1.2 A combination of the previous two, using the best technology available.**

If the two solutions dealt with in points 1) and 2) above can be combined correctly, all comments are superfluous, in the light of the explanations already given in the relevant points.

Here, we wish to present some ventilation schemes, found in publications, as a negative example: how a shooting range should not be set up.

Figure 4 shows a diagram of an underground tunnel, with air being introduced above the heads of the shooters, and the first extraction point immediately downstream of the firing line.
Since the intakes referred to in point 2) above have not been respected, or aligned with the design criteria that follow, what we can expect to happen is simply that it becomes impossible to create a laminar airflow at the shooting line, which means that the shooting gases and vapours are blown back onto the shooter.

In addition, the negative effects of this bad situation are aggravated by the existence of deflectors that are positioned incorrectly. The flow that can legitimately be expected will be as shown in red in the table.

To demonstrate this, photograph n° 5 is provided to show the air intake conditions with the plant operating normally, with extraction immediately downstream of the firing line, taken from the firing area.

*Photograph N° 5 (a + b): Airflow with extraction immediately downstream of the firing line.*
Figure 6 shows the layout for an artificial tunnel.

This layout includes the design errors dealt with previously, as well as the addition of a ventilation opening on the bullet trap, immediately downstream of the forced ventilation.

This would certainly further aggravate the situation in the bullet trap area, as an airflow would be created that moves from the outside to the inside, working against the system for the range.

In addition to stopping the gas escaping, causing it to remain in the indoor environment, this flow would also introduce powder coming from washing the bullet trap (in earth or sand), which has been made very fine by the shooting, as a result of the simple mechanical action of the projectiles on the sand particles.

In this case too, the airflow directions that can be predicted are shown in red.

1.3 Correct, routine maintenance of the structures.

One important point that is often overlooked is maintenance of the plant in general, as well as of the components most affected.

Every aspect of the fluid-dynamics inside the indoor shooting range is mainly governed by the way the ventilation system works, as this creates pressure differences between significant points on the range.

In the same way, the pollutants removed from the range must be passed through a system that does not simply conduct them into the atmosphere, but that also provides for reclaiming them.

The ducting and filters in the plant must therefore be maintained in a perfectly efficient state, since:

- For the filters, clogging causes a reduction in the efficiency of the ventilation system, as well as incorrect treatment of the polluted air.
- For the ducting, poor maintenance and lack of cleanliness may cause reverse cycles in the pollutants.

These components are so important that the installation of specific pressure sensors in the filter spaces is called for. They can indicate abnormal pressure differences related to excessive clogging. When this happens, the system cuts out and the components must be replaced immediately.

As far as cleaning the ventilation ducts is concerned, this is dealt with in terms of a national regulation.
The ENV 12097 standard ("Ducting networks. Requirements for components intended to facilitate maintenance of ducting networks" – January 1997) gives precise indications for the design, construction, and installation of air-conditioning and ventilation systems, in order to allow all internal surfaces and components to be cleaned.

In terms of this regulation, regular technical inspections and frequent health checks must be carried out, and specialist personnel must also be involved in these activities.

The acceptable limit for particles deposited in air ducts for them to be considered clean, and without an internal coating, is 0,1 g/m².

C Recent UITS plants

We wish to deal with two indoor facilities that were built recently, and that continue to show good general functioning, especially of the ambient ventilation.

1. A 50 m biathlon range at the Sport Secondary School, in Malles, in the Bolzano Province;
2. A 20 m range for operational training at the Novi Ligure – Piedmont Target Shooting Range.

1. A 50m biathlon range at the Sport Secondary School, in Malles, in the Bolzano Province.

The functional layout for the ventilation of this plant is as shown in attached drawing n° 6.

As can be seen in n° 4, intakes were created for extracting the inside air, in compliance with the DT – P1 Directive, while air is introduced by means of a full section plenum chamber positioned about 4 m behind the shooters.

The extraction ducts are connected, for essential reasons, to the ventilation system for the entire building, which was already in place. However, although not being optimum for the purposes of the shooting range, this plant was assessed as being acceptable.

The claim made in point B. 2. c. iii was confirmed when it was found that, at the time of start-up and over the initial time of operation, an optimum balance in the internal flow rate was obtained with the extraction dampers n° 1, 2 and 3 almost fully closed.
2. A 20m range for operational training at the Novi Ligure – Piedmont Target Shooting Range.

The functional layout for the ventilation of this plant is as shown in attached drawings n° 7 and 8.

Note the air inlet via a plenum chamber 2.5 m behind the firing line, and only one extraction point at the end of the range.
The dimensioning of the extraction flow rate and the sections is such that there is only a slight low pressure area inside, which creates a minimum air speed of 0.30 m/s at the 20m firing line, and 40 m/s at the 15m firing line.

These values were determined at the design stage and were effectively measured during the tests carried out for acceptance, as shown in the certificate issued by the Engineering Corps Arms Inspectorate.

In addition, we wish to point out the care taken not to interfere with the airflow, so as not to disturb its laminar nature (there are no incorrectly designed or built deflectors).
Photograph n° 9: view of the range
Notice the cleanliness of the section.

Extraction tests produced positive results, as shown in the following photographs:

Photographs n° 10, 11 and 12: System operating normally – section at the first deflector.

Note that there is clearly no return flow back to the firing line.
The photographs above show the phenomena created by the deflectors. Their shape causes vortex movements downstream as a result of local low pressure areas.

Correct sizing of the section and an efficient ventilation system make it possible, even in these critical sections, to:

- Prevent return airflows towards the firing line;
- Eliminate, albeit over longer periods of time, the vapours from the deflector area as well.

A correctly-sized system removes residual smoke, overcoming local turbulence, and reinstating the laminar airflow.

The extraction time for these areas is longer, but is always within 30 seconds when maximum flow rate has been achieved.

This is demonstrated in practice in the photographs below.
After 20 seconds there is still residual smoke behind the deflector, but it is clear the total washing has taken place in the section upstream, and that the residue behind the deflector is also being extracted.

This system obviously has CO sensors that cover all the shooting sections.

The bullet trap is made of sand bags with a bonding gel additive, which is able to stop a .308 calibre bullet fired from a distance of 20m, all of which takes place behind 8cm thick Regupol thermoplastic panels.
The sandbags are stacked in a high-strength HB 400 steel support structure, 6mm thick, and the bullet trap is created between panels that overlap by at least 10cm.

In addition to preventing the formation of lead vapours, this type of bullet trap is easy to maintain, as it is possible to shift the individual bags, including those in the middle of the overall structure, thereby making it possible to replace individual bags around the centre of the target, without having to dismantle the entire structure.

Restoring the bullet trap is also made easy in this way, and, once the lead has been retrieved by simple sifting, the material can be reused.

Details of the bullet trap are given in the attached drawing n° 9.

To round off this plant, thermoplastic material was placed on the floor to trap any shrapnel resulting from shots which actually struck the floor.

The acoustics for those using the facility are guaranteed, as shown in the test report, and were measured and certified to be at noise levels of below 85 dB(A), which is well below the limit set in the DT - P1 standard.

Finally, we look at the shooting control area, with the control console and related security installations.

All the sides are made of steel with a hardness of HB 400, and bullet-proof glass that is suitable for this class of shooting range, all duly certified.

Obviously, the Shooting Controller’s area has a ventilation system that is able to produce two air changes per hour, as per the standards.
Photograph n° 16: glazing at the entrance to the tunnel, with the shooting controller’s post.

Photograph n° 17: glazing at the entrance to the tunnel, with the shooting controller’s post – detail.
D Conclusions

The design and construction of indoor shooting ranges is a vast, complex problem that makes it necessary to draw on all sorts of knowledge, from physics to fluid-dynamics, especially when it comes to designing the technical services.

We also believe that proven experience in the sector is essential, as there are few examples like the case in point in which theory and practice can differ so greatly in terms of results. Saying and doing are worlds apart.

Nevertheless, at least the most recent of UITS experiences have shown that it is possible to build indoor shooting ranges that are both safe and able to be enjoyed by shooters, even though the running costs are increasing all the time.

In addition, UITS is pleased to be able to offer all the consultancy necessary to the various sections of the organization, including greater involvement in the field of the safety of indoor facilities and ranges approaching the National Target Shooting Section.

The current unfavourable economic juncture is certainly not helping, but the UITS is aware of the great effort being made to modernize and upgrade facilities by the National Target Shooting Sections, always with a view to promoting and developing target shooting in complete safety.
LEAD EXPOSURE FROM INDOOR FIRING RANGES AMONG STUDENTS ON SHOOTING TEAMS

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Environmental Public Health Program
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September 2005
Lead Exposure from Indoor Firing Ranges among Students on Shooting Teams

Scott Arnold, Tracey Lynn, Charles Wood, John Middaugh

Environmental Public Health Program Alaska Division of Public Health

Abstract

During 2002-2004, the Alaska Division of Public Health (DPH) conducted a stateside investigation to determine whether school rifle teams using indoor rifle ranges were being exposed to excessive amounts of lead. This effort began in response to the discovery, through the DPH’s mandatory blood lead surveillance system, of a school rifle team coach with an elevated blood lead level (BLL) of 44 µg/dL. The adult BLL of concern is 25 µg/dL.

Five indoor ranges used by 66 members of shooting teams, aged 7-19 years, were investigated. Improper range design, operation, and maintenance resulted in elevated BLLs among student shooters (> 10 µg/dL) and adult coaches in four of the five ranges. Blood lead levels were normal in students who practiced at one range with a modern ventilation system and established safe operating procedures. Dry sweeping was a significant risk factor for elevated BLLs in student shooters.

We recommend that range operators should evaluate their lead-safe operating procedures and ventilation systems. Furthermore, periodic BLL testing should be considered for children and adolescents who use indoor firing ranges, since they are at risk for adverse effects from lower levels of lead exposure.

Reprinted from MMWR (below).
http://www.cdc.gov/mmwr/PDF/wk/mm5423.pdf

Lead Exposure from Indoor Firing Ranges Among Students on Shooting Teams – Alaska, 2002-2004

CDC recognizes blood lead levels (BLLs) of ≥ 25 µg/dL in adults and ≥ 10 µg/dL in children aged ≤ 6 years as levels of concern; no similar level has been set for older children and adolescents (1,2). During 2002–2004, the Alaska Environmental Public Health Program (EPHP) conducted lead-exposure assessments of school-based indoor shooting teams in the state, after a BLL of 44 µg/dL was reported in a man aged 62 years who coached a high school shooting team in central Alaska. This report summarizes the results of the EPHP investigation of potential lead exposure in 66 members of shooting teams, aged 7–19 years, who used five indoor firing ranges. The findings suggest that improper design, operation, and maintenance of ranges were the likely cause of elevated BLLs among team members at four of the five firing ranges. Public health officials should identify indoor firing ranges that have not implemented lead-safety measures and offer consultation to reduce the risk for lead exposure among shooters, coaches, and employees.

The shooting-team coach was asymptomatic for lead exposure; in January 2002, he sought BLL testing from his healthcare provider after reading about potential lead exposure at firing ranges. The BLL test result of 44 µg/dL was reported to EPHP in accordance with the Alaska
lead surveillance system, which requires laboratories to report all BLLs ≥ 10 µg/dL. An epidemiologic investigation by EPHP revealed that the man was the chief range officer and shooting-team coach for firing range A, which was used primarily by adolescents. In February 2002, EPHP tested BLLs for all seven members of the shooting team, who were aged 15–17 years. The mean BLL was 24.3 µg/dL (range: 21.0–31.0 µg/dL). BLLs for 14 nonsmoking family members were significantly (p<0.05) lower (mean: 3.5 µg/dL; range: 1.0–7.0 µg/dL) (Table). EPHP advised parents of the team members that their children should discontinue use of the firing range.

Range A, an indoor firing range, was used by the shooting team on school property in a multipurpose building that also housed a hockey rink. A utility fan located near the bullet backstop ventilated the range; no formal range maintenance protocol was observed. An environmental evaluation performed in May 2002 by an independent environmental and engineering consulting firm concluded that the range and its ventilation system were contaminated with lead dust. Three months after their initial testing, the four shooting-team members available for retesting all had lower BLLs; their levels declined from 29 to 16 µg/dL, 23 to 11 µg/dL, 22 to 16 µg/dL, and 21 to 14 µg/dL (retest mean: 14.3 µg/dL; range: 11–16 µg/dL) (Table). Range A was closed for 1 year, during which time the building was renovated, and a new ventilation system was installed.

Because of the potential for similar lead exposures, during October 2002–January 2004, EPHP investigated four additional indoor firing ranges used by school-based shooting teams in central and southwest Alaska. Range B was a commercial range with paid employees. Ranges C and E were operated by volunteer-run sport associations. Range D was a school-operated range located in a multipurpose room that was also used for lunches, physical education, wrestling practice, and meetings.

Range B had a written maintenance protocol that specified daily, weekly, 6-month, and annual maintenance tasks; range surfaces were cleaned with wet mops and vacuums equipped with high-efficiency particulate air (HEPA) filters. Ranges C, D, and E had no written maintenance protocols; dry sweeping, which aerosolizes lead dust particles, was used to clean floors (Table). Independent assessments by certified industrial hygienists were performed at ranges B, C, and D. The ventilation system at range B was determined adequate in both design and function for the firing range. Ventilation systems for ranges C and D were determined inadequate. Range E ventilation was not assessed; however, EPHP advised the operators to seek an independent assessment.

BLLs of all eight shooting team members tested at range B were ≤ 5.0 µg/dL. Twenty-two (43%) of 51 shooters had BLLs ≥ 10 µg/dL at ranges C, D, and E; eight (33%) of 24 shooters had BLLs ≥ 25 µg/dL at range C (Table). Among nonsmoking family members tested, BLLs were lower than those for shooters at ranges C (p<0.05) and E (p=0.06); BLL testing was not performed for family members of shooters at ranges B and D. After 3 months away from ranges C and D, 19 (61%) of 31 shooters at those ranges were retested. Test results indicated that BLLs had declined in all but two of the 19 shooters; no further testing was conducted.

EPHP made no recommendations for range B because BLLs among shooters were not elevated and the range had an adequate ventilation system and maintenance practices. Ranges C and D voluntarily shut down. Range C later reopened after installing an improved ventilation system. Shooting practice for team members who used range D was moved to another location. EPHP recommended that range E discontinue dry sweeping, institute a regular maintenance schedule, and acquire the services of an industrial hygienist to evaluate the ventilation system.

Reported by: T Lynn, DVM, S Arnold, PhD, C Wood, MS, L Castrodale, DVM, J Middaugh, MD, Section of Epidemiology, Alaska Dept of Health and Social Svcs, M Chimonas, MD, EIS Officer, CDC
Editorial Note: Low levels of lead exposure can adversely affect the intellectual development of young children (1). Even BLLs ≤ 5 µg/dL can have deleterious effects on intelligence quotients for persons aged 6–16 years (3); however, no BLLs of concern have been set for children and adolescents in this age group. During 1999–2002, the geometric mean BLL in the United States was 1.6 µg/dL for persons aged ≥ 1 year and 1.1 µg/dL for persons aged 6–19 years (4). Findings in this report indicate that, at four of the five ranges investigated, BLLs among students on shooting teams were elevated, with mean BLLs ranging from 7.6 µg/dL at range E to 24.3 µg/dL at range A. None of the four ranges had written protocols for maintenance; three had inadequate ventilation systems, and ventilation at the fourth was not assessed. Range B, where all shooters had BLLs ≤ 5 µg/dL, had a modern, well-maintained ventilation system, followed a written maintenance protocol, and did not employ dry sweeping to clean the range.

Firing ranges have been recognized as potential sources of lead exposure since the 1970s (5). Lead-containing dust is produced by 1) the combustion of lead-containing primers, 2) the friction of bullets against the gun barrel, and 3) fragmentation as bullets strike the backstop (5). Lead dust inhaled into the lungs is highly bioavailable, with an absorption rate near 100% (6). The Occupational Safety and Health Administration (OSHA) has established acceptable standards for airborne lead exposure in the workplace, including indoor firing ranges, since 1979 (7). Guidelines for proper design and operation include use of a separate ventilation system for firing lanes, written protocol for range maintenance, use of wet mopping or HEPA vacuuming instead of dry sweeping to remove dust and debris, and use of copper-jacketed bullets (8,9).

The findings in this report are subject to at least three limitations. First, detailed shooting histories of the extent of indoor firing range use were not obtained for the students in the study. Second, persons using the firing ranges who were not members of the school shooting teams were not included in the analysis. Finally, limited information was obtained regarding other possible sources of lead exposure. However, other common causes of the elevated BLLs were unlikely because 1) BLL samples of nonshooting family members were not elevated, 2) BLLs decreased for 21 of 23 shooters retested after removal from the firing ranges, 3) lead paint is rare in Alaska (approximately 93% of houses were built since 1950) (1), 4) drinking water measurements were below the action level for lead for each community (10), and 5) the ammunition used by those in the study is not commonly homemade.

This investigation revealed that lead exposure can occur at indoor firing ranges despite federal regulations and specific guidelines pertaining to range design and operation. Because OSHA regulations were created to protect employees and not users of firing ranges, legal requirements for a lead-safety program and adequate range design and operation do not apply to volunteer-run ranges; moreover, schools with onsite shooting ranges likely are unaware of such requirements. Public health officials should identify volunteer-run or other firing ranges in their areas that do not fall under the jurisdiction of regulatory agencies. Lead-risk assessments should be conducted, and ranges with antiquated design and maintenance protocols should be encouraged to modernize and adopt published recommendations (8,9). Because children and adolescents are at risk for adverse effects from lower levels of lead exposure, they should not participate in range maintenance or clean-up. Periodic BLL testing should be considered for children and adolescents who use indoor firing ranges to ensure that they are not exposed to lead.
TABLE. Assessment of blood lead levels* (BLLs) of school-based shooting-team members and nonshooting family members, by indoor firing range
Alaska, 2002–2004

<table>
<thead>
<tr>
<th>Firing range</th>
<th>Indoor firing range</th>
<th>Shooting-team members</th>
<th>Nonshooting family members</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Written maintenance protocol</td>
<td>Dry sweeping performed</td>
<td>Assessment of ventilation system</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>School range</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>B</td>
<td>Commercial</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>C</td>
<td>Volunteer-run</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>D</td>
<td>School range</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>E</td>
<td>Volunteer-run</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

* Expressed as µg/dL.
† Testing repeated 3 months after discontinued use of firing range.
§ Two shooters had no change in BLL at 3 months, but all others had a decline.
References


CONTROL OF LEAD AND UNBURNT PROPELLANT IN INDOOR RANGES

Frank S. Compton, UK

Officer Commanding The Technical Advisory Section
Royal Engineers (TAS(RE)) (UK Range Design Authority.)

September 2005
Control of Lead Dust and Unburnt Propellant in Indoor Ranges

Frank S. Compton

Abstract

Indoor shooting ranges present several environmental challenges to the range designer and range safety manager. All ranges in which cartridge propelled lead based ammunition is used designers and managers will need to consider the effect of lead, unburnt propellant, carbon monoxide and the cleaning of the range. Effective air management within the range can resolve lead and carbon monoxide environmental health issues. Well thought out designs and effective cleaning regimes will resolve residual lead and unburnt propellant problems. Ranges and users exist in many forms and each must be considered in their own right to ensure the effective control of environmental health hazards that are generated within firing ranges.

References

B. Control of Lead at Work Regulations (UK)

1. Introduction.

The aim of this paper is to describe how UK MOD provides control for the environmental emissions from the use of firearms in indoor range facilities. To provide effective controls it is necessary to determine the source and predicted extent of the hazard. For this reason there is no standard solution for all ranges, it is necessary to assess each range, the personnel using the range and the weapons used. It is often the case within UK MOD that a range has many uses, and in this case, each use must be assessed. For example some test ranges are used by site security police to zero weapons, some cadet ranges are used as meeting or class rooms when the range is not in use.

2. Types of Indoor Ranges.

It is important to understand the different types of range that exist and how the control of emissions can be effectively dealt with in each. Most ranges have down range air flows that help move the hazardous emissions away from the firing point down range. Some, such as test facilities and special facilities do not have any controlled air flow in the range.
a. Traditional. The traditional indoor range is illustrated in Reference A. It is generally 25m from the furthest firing point to targets and may have intermediate firing points.

b. Tube. Many of the cadet ranges consist of a firing and target room with small concrete tubes between the two. Some newer tube ranges have larger diameter tubes up to 1.2m in diameter. There are also tube ranges with open firing points and target areas.

c. Tunnel. These type ranges are mostly used by civil shooting clubs taking advantage of old railway tunnels.

d. Special Forces (SF). There are many different configurations of indoor ranges used by SF from single direction to 3600 engagement of targets.

e. Test Ranges. Most of these have firing rooms with a controlled environment but within the range there is no controlled air flow. This becomes a problem with dual use facilities.
f. Other – Training, commercial, mobile, temporary. In the UK and in operational theatres there are many unusual ranges either provided to meet a specific training need or a commercial user making use of an existing structure. For example – using a disused concrete water storage reservoir with large concrete supports spaced at 2m in every direction.

3. Users/category.

Most safety legislation will take account of the status of range users. Young persons and women of reproductive capacity will have more stringent protection than other users (Reference B). Military and police undertaking operational training may be exposed to more hazards than an employee at a place of work. Those who use ranges for sport should expect to be protected from any significant hazardous environments.

a. Cadet (young persons) – sport.
b. Service personnel – operational training, sport
c. Police – operational training
d. Special Forces – operational training
e. Research staff – work place
f. Civilian – sport
g. Range wardens – work place
h. Cleaners / contractors – work place
i. Range conducting officer – work place
j. Safety supervisors – work place


UK range standards are currently based on Reference A that takes account of current UK MOD service weapons and ammunition only. Safety data sheets should be supplied by ammunition suppliers that provide the details necessary to assess the environmental impact when used on both open and indoor ranges. Trials and evidence from completed environmental assessments will provide safety managers with the environmental impact of the weapon systems used on a particular range. All of the environmental issues will be affected by the type of weapon and ammunition involved.

5. Emission hazards considered.

Although there are many chemicals and compounds involved in the process of discharging weapons in enclosed areas. Only lead, unburnt propellant and carbon monoxide are considered to be in sufficient quantity to cause concern. In many ranges it is the target and bullet catcher area that become the most contaminated areas within a range.

a. Lead fume and particle. Each cartridge propelled ammunition type expels lead fume and particles as it is fired from the weapon breach and from the muzzle. Where steel plate bullet catchers are used, more lead particles are generated and lead fume is released on impact. The amount of lead released when a weapon is fired is dependent upon the weapon type and ammunition. The degree of exposure will be influenced by the cleanliness of the range and air flow across the firing point. An indication of the amount of lead expelled from UK MOD weapons is provided at ANNEX A.

b. Unburnt Propellant. Potentially the most hazardous of all emissions is unburnt propellant. Unburnt propellant is difficult to measure and UK MOD have taken the view that it must be assumed that any dust in a range will have unburnt propellant in it and is therefore an explosive hazard. Where dust is collected such as in a vacuum cleaner bag or behind elements of the structure not easily accessible to clean, there is a serious risk of an explosion.
c. Carbon Monoxide (CO). All weapons when discharged expel carbon monoxide. This emission however is easily transported down range with any degree of air flow in that direction. In ranges where there is no air intake and extract it is necessary to install CO detectors to indicate when CO levels reach a critical level. ANNEX B provides Best Practice Guides for the control of CO.

d. Noise. Noise in ranges is unavoidable and hearing protection will in most cases be required. Although little can be done to mitigate muzzle blast there are many engineering solutions that limit reverberation within a range. For those who wish to understand more about noise on ranges a separate paper is provided at ANNEX C.

Assessments must look at predicted worst case situations and they must be reviewed at least annually or whenever circumstances change.

a. Lead in air Assessment. Reference B states under Regulation 5: An employer shall not carry out work which is liable to expose any employees to lead unless he has made a suitable and sufficient assessment of the risk created by that work. UK MOD has recently completed a survey of some 700 assessment results in a variety of small cadet ranges within UK. The results in the main indicated that the low use rate of two or three hours each week using .22” ammunition generated a lead in air rate of well below the significant first action level described in Reference B.

- Reg.2 - OEL - 0.15mg/m$^3$ (medical surveillance required at this point)
- Reg.2 - Significant - ½OEL (0.075mg/m$^3$) or where there is a risk of ingestion.
- Reg.5 – Assessment criteria to determine “significant”:
  - Range in daily use. ½OEL is assessed over an 8hr TWA.
  - Intermittent exposure (only a few hours per week)

Below OEL when averaged over 8 hrs and is below ½OEL when averaged over 40 hrs.

b. CO monitoring. Monitoring the carbon monoxide levels in a range is only necessary where there is no managed laminar air flow down range away from the firing point. This mostly involves test range firing rooms and enclosed firing points on open ranges where there is no controlled ventilation. ANNEX B provides best practice guidance on levels of CO that are safe.

c. Noise assessment. All new ranges should be designed to minimise reverberation within the range. On completion of a new range commissioning tests should be undertaken to measure noise levels at all firing points to determine the standard of hearing protection required. ANNEX C provides more detail.

7. Environmental controls.

a. Ventilation. All ranges require some form of ventilation from simple single input extract fan to sophisticated air handling plant. UK range works policy requires that all ventilation systems are inspected at least annually to ensure the design performance criteria is maintained. Systems should be switched on at least 15mins prior to range use to ensure the system is working at optimum level before firing commences. Systems should be left on at least 15mins after firing ceases to ensure residual dust is removed from the range, ductwork and filters. Smoke tests will help assess actual air flow within the range and identify any areas of turbulence.

b. Range Cleaning. Any dust inside a range that is in use will contain both lead and unburnt propellant. Experience has shown that even the most elementary forms of air input and extract systems will control emissions from .22” ammunition in intermittent use ranges. However if a range contains residual dust from previous range uses then this combined with emissions may
cause the lead in air levels to rise above the “significant” level. From the collection of lead in air assessment data it became very clear that those ranges recording lead in air levels in excess of 0.075mg/m³ had not carried out a deep clean for over 12 months. After a deep clean each of the ranges found on re-assessment that they were well below the ½OEL requirement. Cleaning is a very important part of managing a range.

c. Hearing protection. Ear protection is required on most ranges. Where high velocity weapons are used in indoor ranges, double hearing protection should be considered. The problem of noise is particularly a concern in tunnel and tube ranges as these generally do not have noise dampening lining to the walls. Active hearing protection is the most efficient form of ear protection as this system allows firers to hear the Range Conducting Officer (RCO) clearly. More detail is provided in ANNEX C.

8. Environmental design considerations.

In most circumstances the design solution for a range is a compromise. To minimise the opportunity for dust to accumulate, ease cleaning and assist laminar air flow, materials used on the internal surfaces of a range should be smooth and non-porous. To reduce reverberation the same surfaces should be open textured with rough surfaces.

a. Materials used in the range structure. Materials used in a range need to meet both ballistic and environmental requirements.

<table>
<thead>
<tr>
<th>Element</th>
<th>Performance requirement</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor</td>
<td>(1) Hard smooth sealed, minimum joints.</td>
<td>Helps control dust, flow of air and ricochet.</td>
</tr>
<tr>
<td></td>
<td>(2) No carpets or rugs of any sort that might harbour dust.</td>
<td>Fire / explosive hazard and places lead dust in the breathing zone of firers in the prone position.</td>
</tr>
<tr>
<td>Walls</td>
<td>There are many proprietary noise inhibiting systems available. Sheet material presents</td>
<td>Defence zone areas need to prevent bullets escaping.</td>
</tr>
<tr>
<td></td>
<td>less joints than tiles.</td>
<td></td>
</tr>
<tr>
<td>Ceilings</td>
<td>Avoid solutions where dust can penetrate and settle out of sight.</td>
<td>Defence zone areas need to prevent bullets escaping.</td>
</tr>
<tr>
<td>Bullet catcher</td>
<td>The ideal design is one which captures bullets intact (no lead dust or noise) and depth</td>
<td>Granulated rubber for all ammunition natures or curtain traps for low velocity ammunition provide an optimum solution that minimises environmental issues.</td>
</tr>
<tr>
<td></td>
<td>of penetration can be assessed.</td>
<td></td>
</tr>
</tbody>
</table>

b. Equipment in the range. The range floor should be kept free of equipment that will disrupt air flow and collect dust. Electrical equipment should be protected from bullet strike damage. Electrical equipment or fittings placed in areas where dust is able to collect are a source of ignition. Vacuum cleaners are potentially dangerous as they collect into a small space (bag) fine dust that contains unburnt propellant. Fatalities have already occurred in ranges where a spark from a vacuum motor has caused an explosion. Use only approved spark free motor vacuums.

c. Ventilation specification. The level of ventilation required in a range will depend on a number of factors including number of firers, types of weapons, amount of ammunition fired and frequency of use. Some cadet ranges have only a small extract fan located at the bottom of the range. For infrequent use ranges firing only .22” ammunition this may well be sufficient providing the range is kept clean. Test ranges with fixed bench firing mounts are able to utilise Local Exhaust Ventilation (LEV) mounted directly over the source of emission. Most ranges however have to allow for several firing positions (prone, kneeling and standing) and several firing points often at different distances from the targets. The shape of the structure
and finishes within the range will also have an effect on the flow of air within the range. The ideal performance specification to be achieved will provide a laminar air flow down range towards the targets with an air speed over the firers at each position of between 0.15 – 0.25m/s. By rating the extract systems at 10% more efficient than air intake laminar flow down range will be encouraged even where there are baffles in the range.

9. Cleaning requirements.

a. Frequency. Range managers must ensure that during use visible dust is not collecting on the firing point or range floor. This might require daily cleaning or weekly routine cleaning by range staff dependent upon the amount and type of ammunition fired. Deep cleaning should be considered annually on ranges that are regularly used. UK MOD will use the following guidelines for deep cleaning:
   - 0 to 5000 rounds fired each year – Every 2 years.
   - 5000-10,000 rounds fired each year – Annually
   - Over 10,000 rounds fired each year – Every six months.

b. Methods. Clearly, dry sweeping fine lead dust should not be considered without full disposable Personal Protective Equipment (PPE). Wet wiping surfaces around the firing point and range floor will avoid lifting lead dust into the breathing zone. Only authorised spark free vacuum’s should be used. All staff who are involved in cleaning should receive training on the hazards and any PPE provided to them. No young person or woman of reproductive capacity should be asked to clean a range. Deep cleaning which will include the bullet catcher and exposed roof structures should only be undertaken by competent specialist contractors.

c. Waste disposal. Cartridge cases should be recovered for recycling. All dust collected from a range that has been used will contain both lead dust and unburnt propellant. The waste from filters and range cleaning should be stored in sealed plastic containers in a damp condition in a secure area away from the range until it is removed by registered contractors. New regulations in UK require any site that produces hazardous waste to register with the UK Environment Agency. Disposal contractors cannot remove hazardous waste without a reference number issued by the Environment Agency.

10. Conclusions.

There is now sufficient evidence and experience to determine that indoor ranges can be and are constructed and used without adversely affecting the health of either the users of the range or those who have cause to enter the range. For new ranges where lead based ammunition is to be used the designer must take into account the factors described in this paper. In existing ranges, application of the principles described in this paper will help ensure ranges are operated in a safe environment. For all ranges, effective cleaning has the most dramatic effect in delivering a safe environment. Effective air management systems within the range will ensure exposure to lead and carbon monoxide is controlled within limits set by current legislation. Well thought out designs and effective cleaning regimes will ensure any residual lead and unburned propellant problems can also be effectively controlled.

Enclosures:

ANNEX A – An indication of lead emissions from UK MOD weapons. Report produced by UK MOD Army Medical Directorate and results from full lead in air assessments.

ANNEX B -  Best practice guide for the control of carbon monoxide. Produced by Carbon Monoxide Safety Awareness Advisory Council UK.

ANNEX A
To Control of the Indoor Range Environment
For WFSA Workshop in Rome
16-17 Sep 2005

Prediction of Lead Emissions from current UK MOD Service Weapons

Research by MOD Army Medical Directorate
(Scanned letter attached)

Full Lead in Air Assessment Results from Cadet 0.22” ranges (Chart)
LEAD-IN-AIR STUDY
ITDU INDOOR PIPE RANGE - WARMINSTER
INTERIM REPORT

1. The subject assessment was conducted, on behalf of TAS, by Capt B Pearce RAMC of MOD Army Medical Directorate, Environmental Monitoring Team during the period 5-6 Jan 99.

2. This interim report outlines the results of the study and some preliminary findings. The wider implications of the study are still being assessed and will be reported on in due course.

3. Outline of the Study
   a. The study aimed to assess the amount of lead fume generated by small arm ammunition and compare the effectiveness of increasing airspeeds over the firer.
   b. The ITDU pipe range was modified by enclosing the firing position at the 25m firing point. The purpose of this was to control the area into which the lead fume was being generated and provide an easily cleanable area.
   c. To produce controlled down range air velocities, a variable domestic fan was modified and positioned directly behind the firer.
   d. Ammunition and Weapons:
      (1) 7.62mm - SLR
      (2) 5.56mm-SA80
      (3) 9mm-MP5
      (4) 0.22» - SA80 (sub calibre conversion)
   e. Monitoring Equipment
      (1) SKC Sidekick Air Sampling Pumps
      (2) Cassella Direct Reading Dust Meter
      (3) Airflow Ltd Digital Anemometer

4. Methodology
   a. A polythene enclosure was constructed at the 25m firing point; this was to reduce external dust contamination and allow the firing point to be cleaned between serials. To control down range air velocity, a variable speed domestic fan was built into the pipe behind the firer.
   b. A trial firing detail indicated that 70 rounds fired over 10 mins would produce sufficient fume for collection and analysis.
   c. Air sampling pumps were placed on the firer (with the sampling head within the breathing zone), midway down the range and in the target room.
Prior to firing the down range air velocities were measured and recorded as 0.12 m/s, 2 m/s and 2.5 m/s. The volume airflow were calculated at 277,468 and 515 m respectively for the 10 min period.

A serial of each type of ammunition was fired at each air speed, with the firing point being wet wiped between each serial. The direct reading dust meter was used to ensure that any residual airborne fume/dust had dissipated before the firing the next serial.

5. Results. The results from all serials are tabulated below:

<table>
<thead>
<tr>
<th>Serial</th>
<th>Position</th>
<th>Ammo</th>
<th>Air Velocity</th>
<th>Concentration (Mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Firer</td>
<td>7.62mm</td>
<td>0.12m/s</td>
<td>0.046</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>5.56mm</td>
<td>0.2m/s</td>
<td>0.074</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>9mm</td>
<td>0.25m/s</td>
<td>0.334</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>0.22&quot;</td>
<td>0.046</td>
<td>0.036</td>
</tr>
<tr>
<td>5</td>
<td>Mid Range</td>
<td>7.62mm</td>
<td>0.12m/s</td>
<td>5.32</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>5.56mm</td>
<td>0.2m/s</td>
<td>6.61</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>9mm</td>
<td>0.25m/s</td>
<td>4.015</td>
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<tr>
<td>8</td>
<td></td>
<td>0.22&quot;</td>
<td>0.046</td>
<td>1.66</td>
</tr>
<tr>
<td>9</td>
<td>Target</td>
<td>7.62mm</td>
<td>0.12m/s</td>
<td>4.13</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>5.56mm</td>
<td>0.2m/s</td>
<td>4.09</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>9mm</td>
<td>0.25m/s</td>
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<td>12</td>
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<td>0.046</td>
<td>0.832</td>
</tr>
<tr>
<td>13</td>
<td>Average</td>
<td>7.62mm</td>
<td>0.12m/s</td>
<td>3.2</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>5.56mm</td>
<td>0.2m/s</td>
<td>3.6</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>9mm</td>
<td>0.25m/s</td>
<td>1.9</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>0.22&quot;</td>
<td>0.046</td>
<td>0.6</td>
</tr>
</tbody>
</table>

6. Preliminary Interpretation of Results

a. Calculation of the average concentration at all air velocities shows that, 7.62mm produces the most airborne lead followed by 5.56 mm, 9mm and 0.22”. The result at serial 3, (9mm at 0.12 m/s) stands out and may indicate a particular characteristic of that type of weapon, e.g., how the lead fume is emitted from the weapon. Alternatively, the very low air speed may have caused eddies around the firer which may have drawn the lead into the breathing zone. Further investigation may be deemed necessary; however, at 0.25 m/s the fume appears to be adequately controlled.

b. The effect of increasing the air velocity can clearly be seen at the firing point for 7.62 mm, 5.56 mm and 9 mm. The results from the 0.22 cannot be explained at this time.

c. In an indoor training theatre the general practice is for the firers to walk down the range to check and change the targets. By doing so they walk through the lead contaminated air, which is being moved down the range by the air velocity. Irrespective of down range velocity, the majority of the personal exposure would occur mid range and at the targets. Based on this study, approximately 98% of the exposure to airborne lead would occur down range for 7.62, 5.56 and 9 mm. For 0.22”, approximately 94% of the exposure would occur down range.
7 Further Interpretation.
The further interpretation of data will include the calculation of the amount of lead produced by a round of each type of ammunition. In addition, investigation will be undertaken into the prediction of the lead in air concentration from the number of rounds fired and the volume airflow.

B PEARCE Capt for DGAMS

Comments on the AMD Report.
Collection filters were placed on the firer’s shirt near his breathing zone and down range.

1. 9 mm ammunition as expected presented the highest concentration of lead to the firer.
2. Not always did a higher air speed reduce the amount of lead in the firer's breathing zone. Turbulence increase in front of the firer’s face as air speed from behind increased was considered to be the cause of these higher readings on the throat filter.
3. With the exception of 0.22” ammunition an air speed of 0.12 m/s was least effective at clearing the air in the firer’s breathing zone.
4. Optimum air speed over the firing point was considered to be minimum of 1.5 m/s maximum of 2.5 m/s.

Results from 0.22” indoor range full lead in air Assessments.
Most peaks proved to be from assessments undertaken in ranges that had not been deep cleaned annually. Three of the peaks were from ranges that have intensive competition shooting.
Best Practice Guide
Carbon Monoxide

Produced by
Carbon Monoxide Safety Awareness Advisory Council
US based data

1. Introduction.
The Standards and Best Practices listed in this document are non-fuel specific except where noted. They form the basis of the CO Analyst Protocol. This protocol has been designed by the Carbon Monoxide Safety Awareness Advisory Council and serves as a means of defining minimum standards for the response industry. It must be realized that any government agency or business entity may choose to uphold higher standards than the protocol defines. Consistent with the Building Performance Institute’s other certifications, the protocol has been arranged into a format of standards and best practices.

2. Carbon Monoxide Action Levels - Standard for Action Levels

The following action levels have been defined as minimums for BPI certified Carbon Monoxide Analysts. Analysts may work for a government agency or business entity that has adopted more stringent standards than the ones defined in this document. As such, CO Analysts may enforce those higher standards. Under no circumstances shall a BPI certified CO Analyst recognize less stringent standards or ignore conditions in excess of the defined action levels. The action levels are considered net indoor ambient readings - i.e. - indoor ambient minus outdoor ambient readings.

   a. **0 to 9 parts per million (ppm)**
      Normal - No Action: Typical from: outdoor sources, fumes from attached garages, heavy smoking, fireplace spillage and operation of un-vented combustion appliances.

   b. **10 to 35 parts per million (ppm)**
      Marginal: This level could become problematic in some situations. Actions: Occupants should be advised of a potential health hazard to small children, elderly people and persons suffering from respiratory or heart problems.

   c. **36 to 99 parts per million (ppm)**
      Excessive: Medical Alert. Conditions must be mitigated. Actions: Ask occupants to step outside and query about health symptoms. Advise occupants to seek medical attention. If occupants exhibit any symptoms of CO poisoning, have someone drive them to a medical facility. Enter the building, open doors and windows to ventilate the structure. If forced air equipment is available, continuous operation of the air handler is recommended at this time.

   d. **100 - 200 parts per million (ppm)**
      Dangerous: Medical Alert. Emergency conditions exist. Actions: Evacuate the building immediately and check occupants for health symptoms. Advise all occupants to seek medical attention. Occupants should have someone else drive them to a medical facility. If occupants exhibit symptoms of CO poisoning, emergency service personnel must be called. Evacuation is important, but Analysts must not subject themselves to excessive conditions. Maximum exposure time is 15 minutes. Open all doors and windows that can be done quickly. Continually monitor indoor ambient levels while moving through the building.

   e. **Greater than 200 parts per million (ppm)**
      Dangerous: Medical Alert. Emergency conditions exist. Actions: Evacuate the building immediately and check occupants for health symptoms. Advise all occupants to seek medical attention. Occupants should have someone else drive them to medical facility. If occupants exhibit symptoms of CO poisoning, emergency service personnel must be called. Evacuation is important, but analysts must not subject themselves to these conditions. Do not stay inside or re-enter the building until conditions have dropped below 100 ppm. Open all doors and windows that can be done quickly without entering the structure.
Technical Data Sheet

Noise and Small Arms Ranges.

Produced by
TAS(RE)
Session 5. Technologies - Solutions

TAS
TECHNICAL DATA SHEET
NO 10

Subject: NOISE AND SMALL ARMS RANGES
Drafted by: WO1 K M GALE BEM RE
Ref: G5/5/9
Date: 28 APR 97

NOISE AND SMALL ARMS RANGES -- NOISE LEVELS, ENGINEERING AND MANAGEMENT CONTROLS

INTRODUCTION
1. Where noise is characterised by a sharp rise to a transient peak pressure, which decays with or without subsidiary oscillations within a short period of time, it is known as impulse noise. This is in contrast to steady-state (continuous) noise, which can be defined in terms of pressure oscillation at given frequencies and intensities over relatively long periods of time. After exposure to intense noise of either impulse or steady-state type, there is often deterioration of hearing ability.

2. On ranges the primary noise source is the weapon system and for this reason it is important to clarify the relation between impulsive noise and blast. Impulsive noise as defined, includes blast, as well as shock waves and sonic booms. Although the weapons may produce shock waves from the projectiles fired, the primary noise source is the muzzle blast, and in some instances subsidiary pressure pulses or oscillations associated with reflections from surrounding surfaces or with the operation of the gun mechanism.

3. Measurements of peak pressure levels for typical Infantry Weapons System have been made. The principal findings are scheduled at Annex A.

4. The effects of these noise levels regarding range design and administration is now examined, in relation to indoor and outdoor ranges, as follows:
   a. Part A - Indoor Ranges.
   b. Part B - Outdoor Ranges.

PART A - INDOOR RANGES

SOUND IN ROOMS

5. General. When analysing the acoustic properties of a room, the sound arriving at the ears, can be considered under 3 headings:
   a. Direct Sound.
   b. Early Sound Reflections.
   c. Reverberation.

6. Direct Sound. This is the sound which travels directly from the source to the listener. It is the first sound to reach the listener, having travelled by the shortest route at a velocity of approximately 340 m/s.

7. Early Sound Reflections. Shortly after the direct sound arrives, the listener receives a series of sound wavefronts which have been reflected one or more times from the walls, ceiling and any other reflective surfaces in the room. These wavefronts have taken a longer path than the direct sound and therefore arrive later. The later they arrive, the greater their potential for interfering with speech intelligibility.

8. Reverberation. Sound wavefronts are repeatedly reflected from the room surfaces and, as a result of absorption, gradually grow weaker and weaker. The reverberation time (RT) is a measure of the rate at which the sound dies away. It is defined as the time taken for the reverberant sound energy to decay to one-millionth of its original intensity, or by 60 dB. The RT is proportional to the volume of the room,
and inversely proportional to the quality of absorption present. The RT may be calculated using the sabine formula:

\[
RT (\text{sec}) = 0.16 \times \frac{\text{Room Volume (m}^3\text{)}}{\text{effective area of absorption (m}^2\text{)}}
\]

*Note: the effective area of absorption is determined by multiplying the absorption co-efficient of each finish, by its surface area and the summing for all room finishes. Appropriate absorption co-efficients must also be included for room occupants, where relevant.*

**NOISE CHARACTERISTICS ON INDOOR SMALL ARMS RANGES**

9. Indoor small arms ranges, should be sited in spaces specifically designed to house them. When a weapon is fired outdoors, in a clear area, the sound energy is dissipated in all directions and only a small fraction is detected by a person standing nearby. This would have a typical waveform as shown in Fig 1 overleaf.

![Fig 1: Idealised Free-Air Blast Wave](image1.png)

10. Indoors, sound energy is usually reflected from the walls and other solid objects, as previously described, with a much greater proportion of the original energy falling on the range users ears. Reflected energy is delayed, depending on the distance the sound has to travel, from the weapon to the reflector (possibly the bullet catcher) and back to the ear (the path length). In most indoor ranges much of the sound energy undergoes multiple reflections before it reaches the observers ears. At each reflection, some of the energy is absorbed, but as previously stated, the amount of absorption depends on the sound absorbing characteristic of the various surfaces. The result is that the waveform experienced is a combination of direct sound, sound with a short path length and sound with a long path length as shown in Fig 2:

![Fig 2: Blast Wave with Reverberation and/or Close Reflections](image2.png)
11. In some situations a reflector (possibly the bullet catcher) which does not absorb much of the sound energy can be located at some distance from the weapon and this can result in a pulse of sound energy arriving at the ear after the original sound and reflections have died away. If the time separation is sufficient, this can be heard as a separate echo as shown in Fig 3 overleaf:

![Fig 3: Blast Wave with Reverberation and Late Reflections.](image)

12. If the path length is not too great, this pulse is merged within the original decay, as shown in Fig 4

![Fig 4: Blast Wave with Reverberation and Early Reflections.](image)

13. The direct sound and early reflections (short path length) from hard (non absorbent) reflectors, usually produce the highest peaks in the waveform. It is possible that the firers body or other solid objects can act as a shield and reduce the level of the direct sound to below that of the strong reflections.

14. Long path lengths caused by multi reflectors (all with non-absorbent surfaces) lengthen the decay of sound. When the reflections become indistinct, merge into each other and there are many of them, then the term reverberation is used. At each reflection of an absorbent surface, some of the energy will be taken out of the sound wave and the sound will decay quickly (short reverberation). If the reflections take place on a relatively hard or non reflecting surface, little energy will be removed and little sound will be removed.

**ENGINEERING CONTROLS**

15. These may vary depending on where the range is sited and the type of ammunition used, ie whether it is high or low velocity. The Engineering Controls will therefore fall into two categories reflecting the ammunition used.

16. High Velocity Rounds. The range is to incorporate measures that will reduce the transmission of sound to the outside environment or the surrounding structure and which will reduce reflected sound, such as:
a. Noise Nuisance Criteria. The Engineering Controls within this Technical Data Sheet are the minimum standards to be applied to all indoor ranges, where high velocity ammunition is used. Local Authorities may impose higher standards to abate Noise Nuisance. In these circumstances local requirements should prevail.

b. Airborne Sound. The range fabric, detailing of the doors, ducting and service installations are to incorporate measures that will reduce the direct and flanking transmissions of airborne sound to the outside environment or the surrounding structure. Different standards will be required subject to the siting of the range. Where the range is to be built adjacent to a public, residential or street area, a higher level of sound insulation will be required compared to remote or rural locations. The standards the structure will be expected to achieve are as follows:

(1) Remote/Rural Locations. The floors, roofs and walls are to provide a minimum weighted standardised level difference ($D_{N,T,W}$) of 47 dB (individual value) for airborne sound insulation, when tested in accordance with BS 5821: Part 1: 1984.

(2) Public, Residential or Street Locations. The floors, roofs and walls are to provide a minimum weighted standardised level difference ($D_{N,T,W}$) of 56 dB (individual value) for airborne sound insulation, when tested in accordance with BS 5821: Part 1: 1984.

c. Impact Sound. The range floors are to incorporate measures that will reduce impact sound transmissions. The floor covering selected will be expected to achieve the following:

(1) A reduction of impact sound pressure level equivalent to that given in Table 1. These figures relate to typical values achieved for a suitable floor covering laid on a suspended floor of 120mm thick concrete.

<table>
<thead>
<tr>
<th>Ser</th>
<th>Frequency (Hz)</th>
<th>Reduction of Impact Sound Pressure Level (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>(b)</td>
<td>(c)</td>
</tr>
<tr>
<td>1</td>
<td>125</td>
<td>3.0</td>
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<tr>
<td>2</td>
<td>250</td>
<td>4.0</td>
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<td>2,000</td>
<td>23.0</td>
</tr>
<tr>
<td>6</td>
<td>4,000</td>
<td>46.5</td>
</tr>
</tbody>
</table>

Table 1: Typical Floor Covering Impact Sound Level Reductions

(2) A resistance to oil and grease.

(3) High durability and able to last for 15 years with minimal maintenance. The floor covering should have a high resistance to indentation and abrasion.

(4) The surface must be easy to vacuum clean, washdown and wipe clean.

(5) The floor covering must be able to withstand contamination from lead particles given off by bullets and unburnt propellant.

(6) A smooth finish with the minimum of joints. All joints in sheet materials to be welded.

d. Reflected Sound. The nature and treatment of wall and ceiling surfaces should be such that sound reflections are reduced, so that the RT does not lead to the loss of speech intelligibility or cause echoes. It is accepted that the use of sound absorbent materials may not reduce the initial peak sound pressure level produced by the weapon. The selected coverings must achieve the following minimum requirements:

(1) A RT of not more than 0.5 seconds at 500 and 1000 Hz.

(2) A Class 1 rating when tested to BS476: Pts 6 & 7.

(3) A resistance to oil and grease.
(4) High durability and able to last for 15 years with minimal maintenance. The wall covering should be able to withstand knocks and abrasions.

(5) A smooth surface easy to vacuum clean, washdown and wipe clean.

(6) All surface finishes must be able to withstand contamination from lead particles given off by bullets.

e. Doors and Windows. The treatment of doors, windows and their associated openings must be such that the sound insulation standards of the wall in which they occur are not compromised. Different standards will be required, subject to the siting of the range. As for airborne sound a higher level of sound insulation will be required for public, residential or street locations compared to remote or rural locations. Specifically doors and windows will be expected to meet the following standards.

(1) Doors.

(a) To be an industrial standard metal door supplied complete with frame. The frame is to be fitted with a threshold and seals around the edges to produce an airtight seal.

(b) A 90° door stay is to be fitted, to each leaf in double doorsets.

(c) A single mortice sash lock, 5 pin tumbler mechanism pick resistant to BS 5872: 1990 and panic opening facility. All locks to be suited.

(d) Supplied with a weatherlip at the base of all external doors.

(e) To be supplied factory primed ready for painting.

(f) Able to withstand positive or negative pressures up to 600 Pa.

(2) Windows.

(a) Manufactured to satisfy the requirements of BS 6375: Parts 1 and 2.

(b) Glazed with clear safety glass which satisfies the requirements of BS 6206.

(c) Incorporate the recommendations of BS 8213: Part 1 for safety in use and during cleaning.

(d) To be supplied with a factory applied low maintenance finish which is compatible with the material selected to form the frame.

2. Low Velocity Rounds. Spare.

MANAGEMENT CONTROLS

3. Noise assessments have been undertaken by the Defence Medical Services, Environmental Monitoring Team, with the purpose of:

a. Establishing the sound pressure levels to which persons are exposed to within indoor ranges.

b. Recommend control measures to ensure that personnel can work within this environment.

4. The findings of these assessments are as follows:

a. High Velocity Rounds. The sound pressure levels measured and impulse exposure levels for different weapons firing single shot and rapid fire are given in Annex B. Based on these findings the following management controls are to be implemented:

(1) Carry out noise assessments and keep records of these until new ones are made after a periodic review. Only competent persons should carry out the assessment.

(2) Provide adequate information, instruction and training for all range users, about the risks to hearing, the steps to be taken to minimise the risks, and how range users can obtain hearing protectors and details of their obligations under the Noise at Work Regulations, 1989.

(3) Take steps to reduce noise exposure so far as is reasonably practicable by means other than provision of hearing protection. In effect these are the Engineering Controls previously described. The RT achieved by the use of acoustic lining is critical, to ensure that these management controls are effective.

(4) Establish hearing protection zones, marking them with notices.
(5) Supply suitable hearing protection, ensure it is worn, fits correctly and that training is given regarding its use. In addition, such hearing protection must be regularly maintained.
(6) Ensure employees report defects on any noise control measures and/or equipment.
(7) Hearing defence regimes have been compiled by the Environmental Monitoring Team based on the use of approved hearing protection and limiting the amount of rounds fired to which the firer or any person in attendance can be exposed to per day. One such regime must be adopted and should be stated in the Schedule on the MOD Form 904 as a limitation to the safe use of the range. The hearing regimes are:

(a) Use of Peltor H72A/01 Hearing Defenders plus Ear Plugs.

<table>
<thead>
<tr>
<th>Daily Personal Noise Exposure ($L_{EP,d}$)</th>
<th>Number of Rounds per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>89 dB(A)</td>
<td>1300</td>
</tr>
<tr>
<td>88 dB(A)</td>
<td>1000</td>
</tr>
<tr>
<td>85 dB(A)</td>
<td>500</td>
</tr>
<tr>
<td>84 dB(A)</td>
<td>400</td>
</tr>
</tbody>
</table>

(b) Use of Peltor H10A Hearing Defenders plus Ear Plugs.

<table>
<thead>
<tr>
<th>Daily Personal Noise Exposure ($L_{EP,d}$)</th>
<th>Number of Rounds per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>89 dB(A)</td>
<td>2000</td>
</tr>
<tr>
<td>85 dB(A)</td>
<td>800</td>
</tr>
<tr>
<td>84 dB(A)</td>
<td>600</td>
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</table>


PART B - OUTDOOR RANGES

SOUND IN THE OPEN AIR

21. **General.** As an observer moves away from a sound source, the sound pressure level diminishes. The rate which this occurs depends on the nature of the source itself and this principle is true as long as the observer is not too close. Most practical situations may be described in terms of two ‘ideal’ sources: point sources and line sources. Sources which approximate to point sources include aircraft, small machines and individual vehicles (artillery guns and tanks). Free-flowing traffic on a busy road approximates to a line source. A military convoy can behave like a line source or a point source, depending on the distance to the observer.

22. **Point Source.** The sound source is represented by a point and sound is radiated equally from it in all directions. This principle is illustrated in Fig 5 below. The intensity of sound is constant for all points on the surface of any sphere centred on the source. The larger the radius of the sphere, the larger will be its surface area and the more thinly spread the sound energy passing through it. If the radius of the sphere is doubled, the surface area increases by a factor of 4 and the intensity decreases by a factor of 4. If the radius of the sphere is increased by a factor of 3, the surface area increases by a factor of 9 and the intensity decreases by a factor of 9, simply by application of the inverse square law. In decibel terms, a change of intensity by a factor of 4 is 6dB (10log4). Everytime the distance from a point source is doubled, the level decreases by 6dB. A point source, such as a weapon, which produces a level of 130dB at 10 m will produce a level of 124dB at 20 m. At a distance of 30 m, the level will have fallen by 10 dB (10log9). In other words, when the distance is trebled, the loudness is halved.
23. **Line Source.** The sound source is represented by a large number of point sources arranged in close spacing along an infinitely long straight line. Intensity now relates to the area of a cylinder centred on the line. Whenever the radius of a cylinder is doubled, the surface area increases by a factor of 2 and the intensity decreases by a factor of 2. In decibel terms, a change of intensity by a factor of 2 is 3dB (10log2). Everytime the distance from a line source is doubled, the level decreases 3dB. A line source, such as a military convoy, which produces a level of 70dB at 10m, will produce 67dB at 20m. For a 10dB reduction, half as loud as the level at 10m, the observer must retreat to a distance of approximately 100m from the source or ten times the original distance. This principle is illustrated in Fig 6 below:

24. **Other Factors.** Surfaces and objects in the open air affect sound propagation. The main physical principles which determine the end result are reflection, absorption and diffraction. Reflection and absorption have been previously discussed, whilst diffracted sound is that which is deflected from the edge of a body or through a narrow aperture or slit.
ATTENUATION IN OPEN AIR

25. So far the discussion of sound in the open air, has applied to the radiation of sound in an idealised atmosphere. That is to say, one that is homogeneous, isotropic and completely free of reflecting surfaces. Even without the reflecting surfaces, air is anything but uniform throughout in its properties. The effect of these non-uniformities is generally to provide some degree of additional attenuation, over and above that due to the effect of distance alone. When calculating the sound pressure level outside, it is usual to first calculate the sound pressure level in ideal conditions, and then add the decibel corrections (positive or negative) due to the various atmospheric effects as follows:

(a) **Molecular Absorption.** The most important effect giving additional attenuation at large distances from the source is molecular absorption in the air. Because air has viscosity, some energy has to be used to overcome intermolecular friction. The result is that over long distances, a significant amount of energy can be removed from the sound waves. The orders of magnitude to be expected are shown in Fig 7 overleaf, in terms of decibels of extra attenuation for various frequencies as a function of distance from the source. These attenuations should be subtracted from the sound pressure level evaluated from ideal conditions.

Fig 7: Approximate additional attenuation due to air absorption

(b) **Wind and Temperature Gradients.** Wind and temperature gradients can have very peculiar effects. Sound travels faster in air as the temperature increases. The absolute speed also increases with wind speed (downwind propagation). This means that if the wind speed increases with height, or there is a temperature inversion, the top regions of the sound waves travel faster, and the path the wave takes tends to be bent over as shown in Fig 8 overleaf. The effect of a normal temperature gradient (decreasing with height) is much the same as upwind propagation. The effect of this phenomenon is to create a “shadow zone” just beyond the point where the lowest waves graze the ground, and then propagate upwards again. In the shadow zones the sound levels are usually less than they would be from normal propagation, because some of the energy that would normally have been received there has been diffracted upwards. With the temperature inversion and downwind propagation, the opposite happens. Energy which would normally have been radiated upwards is redirected downwards in a
sort of focusing effect on the ground. It is possible through this effect to get a negative attenuation, that is, rather higher sound pressure levels than would be expected due to the distance and direction alone. Unfortunately, these effects of atmospheric conditions upon propagation are among the least quantified. So it is not possible to give general rules for taking them into account. As far as excess attenuation is concerned, this should be regarded as a bonus, and not relied upon for design purposes. The worst case will be when there is negative attenuation. In practice this will probably be small, not greater than 10 dB at frequencies upwards of 500 Hz and occur under conditions of marked temperature inversion and light winds.

(c) **Attenuation from Screens and Barriers.** In addition to the effect of the properties of air over and above normal free field radiation, there are often buildings or similar objects which lie between the source and the observer and prevent line of sight between them. When a sound wave meets an obstacle like a fence or a building, a proportion of it is reflected, and the rest of
the wave carries on past the edge of the obstacle. However, the ‘bare’ edge of a sound wave cannot sustain itself in free space - the vibrating air molecules at the end start themselves to act like sources and radiate in all directions. The result is, that a sound wave which has passed the obstacle, bends or diffracts round it into the shadow zone behind the obstacle. Fig 9 shows the attenuation in dB to be expected in these circumstances. Again, the attenuation should be subtracted from the sound pressure levels calculated for ideal radiation less any attenuation for molecular absorption.

ENGINEERING CONTROLS

26. The only two controls that can be harnessed for all practicable purposes on outdoor ranges are distance and barriers, as follows:

a. **Normal Atmospheric Propagation (Distance).** Apart from reduction of the source sound power level (possibly by the use of silencers), the only parameter we can control is the distance between source and receiver. As a general rule therefore, the greater one can make the distance the better. There will always be a reduction in sound pressure level by increasing distance from the source, but the law of diminishing returns holds true. As shown in Fig 10, to get a worthwhile reduction, greater than say 5dB, the distance has to be doubled. This means that if you are a small distance from the source, you can get a very worthwhile reduction by moving to a large distance. On the other hand, if you are already at a large distance, doubling it will probably be prohibitive. Control of Noise by variation of distance from source is really a matter for consideration in the planning stage. It is a matter of maximising distance from the receiver, as this is normally a fixed location eg a residential area. The aim should be to locate the noisiest sources on the side of the site farthest from the most critical receiving point, taking care of course that this does not make some other sensitive area even more critical.

![Fig 10: Attenuation due to Distance from Source.](image)

b. **Excess Attenuation (Atmospheric Effects and Barriers).** Of the types of attenuation discussed in para 25, atmospheric effects and barriers, the former is of course virtually uncontrollable. The only way we can improve by design on the attenuation achieved from distance alone, is by placing a screen or a similar barrier between source and receiver. The attenuation that can be expected from a barrier has already been shown in Fig 9. One very important point to note is that with the order of magnitude of attenuation that can be expected from a barrier, it is pointless to construct a barrier of heavy material
to give a high transmission loss. The best that can be achieved at low frequencies - around 125 Hz - is about 10 to 15 dB. A barrier construction with a sound reduction index greater than about 20 dB at this frequency would be needlessly expensive. Adequate barriers could therefore be constructed from blocks of surface density of 50 kg/m² or by the use of plantations of densely populated trees. Obviously specialist advice should be sought to give the optimum site specific solution. Again, the importance of considering at the planning stage the disposition of the source relative to sensitive areas cannot be over emphasised.

**MANAGEMENT CONTROLS**

27. **Risk Assessment.** It is a management responsibility to assess and record in writing the significant risks to anyone, including MOD personnel, contractors, visitors, members of the public etc who might be affected by their working activities and revise the assessment if there is reason to suppose it has become invalid. This risk assessment process will identify the measures necessary to control the site specific noise hazard. However, certain measures should be common to all range areas. Primarily these are the use of Hearing Protection and effective Range Boundary Controls.

28. **Hearing Protection.** The noise of discharge of modern weapons can cause considerable damage to unprotected ears. The sound pressure levels measured and impulse exposure levels for different weapons firing single shot and rapid fire are given in Annex B. Infantry Training Volume IV Pamphlet 21, Range Conduct and Safety Rules states:

> “Whenever troops are engaged in firing small arms the wearing of issued ear muffs or defenders is compulsory. This also applies to Range Conducting Officers, coaches, safety staff and visitors on or close to the firing point.”

a. **Additional Steps.** The following additional steps to control the noise hazard must also be implemented:

(1) Carry out noise assessments and keep records of these until new ones are made after a periodic review. Only competent persons should carry out the assessments.

(2) Provide adequate information, instruction and training for all range users, about the risks to hearing, the steps to be taken to minimise the risks and how range users can obtain hearing protectors and details of their obligations under the Noise at Work Regulations, 1989.

(3) Take steps to reduce noise exposure so far as is reasonably practicable by means other than provision of hearing protection. In effect these are the Engineering Controls previously described. Whenever possible troop shelters should be sited at such a distance, so that the troops within or around it avoid being at risk from the noise hazard. This could enable the necessary information, instruction and training to take place before troops approach the firing points.

(4) Ensure all personnel are in possession of suitable hearing protection, that it is worn, fits correctly and training is given regarding its use. In addition, such hearing protection must be regularly maintained. Infantry Training Volume IV, Pamphlet 21, states:

> “All ear defenders are to be inspected before the start of firing session. This is to ensure that Firers have adequate hearing protection”.

(5) Ensure employees report defects on any noise control measures and/or equipment.

29. **Range Boundary Controls.** The Ministry of Defence (MOD) as a property owner or occupier is required by the Health and Safety at Work Act 1974 to ensure, so far as is reasonably practicable, that no person will be exposed to risks to their health and safety from activities on a range or in a danger area. This includes exposure to excessive noise levels. This duty of care extends beyond its own employees to any person who may be affected by MOD activities, including members of the public using a right of way, trespassers and especially children. Recommended steps to be taken are:

a. **Controlling Access.** Steps are to be taken, to ensure that the range danger area is clear of unauthorised personnel before firing or hazardous training commences and remain clear for the
duration that the hazard exists; methods may be sentries, vedettes, radar, CCTV or a combination. Means must also be available to ensure that firing can be stopped promptly when it is known that there has been unauthorised entry into the Range Danger Area. These measures are to be laid down in Range Standing Orders.

b. **Fencing.** Fencing is to be provided around the range curtilage of those parts of the range, when fencing is the most effective way of controlling access. Special consideration must be given to local byelaws, planning constraints and in conservation areas. A combination of various types of fencing and surveillance may be acceptable, but the advice of the Defence Land Agent should be sought in all cases.

c. **Flags and Lights.** Warning Flags, normally red in colour or by night red lights are to be displayed so that at least one flag or light can be easily seen from any point on the range boundary. They should be displayed at least half an hour before firing or hazardous training begins and for the duration that any hazard exists.

d. **Signs and Notices.** The range boundary and all access points are to be marked with permanent signs and warning notices fixed to fences, barriers, gates and posts. **These must include a warning of all the hazards that exist when firing is taking place, including the noise hazard.** Signs and warning notices must be positioned where they can easily be seen and read, away from potential obstructions such as growing foliage or gates which could obscure the signs. The interval between the signs should not normally exceed 100m. All signs are to be in accordance with the Health and Safety (Safety Signs and Signals) Regulations 1996.

e. **Maintenance.** All fences, barriers, flagpoles and signs are to be inspected frequently to ensure that they are in place and are being kept in an acceptable condition to satisfactorily control access and provide adequate warning to the general public.
MEASUREMENTS OF PEAK PRESSURE LEVELS (dB) AND PULSE DURATION (milliseconds) FOR TYPICAL INFANTRY WEAPON SYSTEMS

<table>
<thead>
<tr>
<th>SER</th>
<th>WEAPON/AMMUNITION</th>
<th>EAR POSITION</th>
<th>INSTRUCTOR OR ADJACENT PERSONNEL</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.3m to Side</td>
<td>1.2m Side</td>
</tr>
<tr>
<td></td>
<td></td>
<td>dB</td>
<td>ms</td>
</tr>
<tr>
<td>(a)</td>
<td>SLR/7.62mm Live</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.3M above Ground</td>
<td>160</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>1.5M above Ground</td>
<td>151</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>SLR/7.62 Blank</td>
<td>150</td>
<td>10.0</td>
</tr>
<tr>
<td>2</td>
<td>SA80/5.56mm Live</td>
<td>158</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Colt Armalite/5.56mm Live</td>
<td>151</td>
<td>1.0</td>
</tr>
<tr>
<td>4</td>
<td>SMG/9mm Live</td>
<td>157</td>
<td>1.0</td>
</tr>
<tr>
<td>5</td>
<td>GPMG/7.62mm Live</td>
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<td>-</td>
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<td>Shotgun/12 bore</td>
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<td>13</td>
<td>Carl Gustav/84mm Practice AT</td>
<td>183</td>
<td>8.0</td>
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Note:
1. The pulse duration is the total time taken for the pressure fluctuations to decay by 20 dB from the peak pressure level.
NOISE SURVEY RESULTS FOR A TYPICAL CENTREFIRE INDOOR TUBE RANGE

1. Frequencing Analysis - SA 80 5.56mm Ball.

<table>
<thead>
<tr>
<th>Hz</th>
<th>63</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
<th>8000</th>
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</thead>
<tbody>
<tr>
<td>dB</td>
<td>127</td>
<td>138</td>
<td>140</td>
<td>145</td>
<td>151</td>
<td>144</td>
<td>147</td>
<td>145</td>
</tr>
</tbody>
</table>

2. SA80 5 Rounds Single Shot.

| Max Peak | 158 | 157 | 157 | 156 | 157 |
| IEL      | -   | 143 | 143 | 143 | 144 |

3. SA80 Rapid Fire.

| Max Peak | 158 | 158 | 158 | 157 | 158 |
| IEL      | 145 | 144 | 144 | 144 | 145 |

4. Frequency Analysis - GPMG 7.62mm Ball.

<table>
<thead>
<tr>
<th>Hz</th>
<th>63</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
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<th>4000</th>
<th>8000</th>
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</thead>
<tbody>
<tr>
<td>dB</td>
<td>129</td>
<td>140</td>
<td>148</td>
<td>148</td>
<td>148</td>
<td>150</td>
<td>150</td>
<td>150</td>
</tr>
</tbody>
</table>

5. GPMG 5 rounds Single Shot.

| Max Peak | 159 | 160 | 161 | 160 | 161 |
| IEL      | 144 | 144 | 141 | 142 | 144 |

6. GPMG Rapid Fire.

| Max Peak | 162 | 160 | 160 | 160 | 158 |
| IEL      | 149 | 145 | 144 | 141 | 142 |


Note: IEL - Impulse Exposure Level.
Session 6
The Way Forward
Closing Session
THE WAY FORWARD
CLOSING SESSION

Mr. Joachim Streitberger, Germany
Director of the German Federal Association of Shooting Ranges (BVS)

September 2005
Workshop Summary and Recommendations
Mr. Joachim Streitberger, Germany

Director of the German Federal Association of Shooting Ranges (BVS)

As Chairman of the Environment Committee of the World Forum, I now have the task to provide a summary of these proceedings. We have been listening to the finest and most respected minds in the field of indoor shooting ranges: we have discussed health, pollution, safety, research, practical range management, and, principally, ventilation, in its different styles.

We have learnt about issues that until today have only ever been in the hands of few specialists.

The first point to make is we must differentiate between the perception of risk, actual risk, and our ability to manage risk. With that said, yes, it is clear that indoor shooting ranges present a risk under certain conditions.

Regardless of questions about responsible care of ranges, the worldwide trends show Olympic and competitive shooting remaining very substantial in the world with about a hundred million participants. Shooting is an important and continuing activity.

Not only that, but shooting ranges have important community, cultural, economic and historic value. The full spectrum of community practices and expectations need to be taken into account. Partnerships and co-operation are utterly central.

One of the greatest needs is for communication. One cannot help but be impressed by the scope of the work that is being done in this area and it must not be wasted. We have seen that sport shooting groups have already been proactive in identifying and managing risk, in designing and managing shooting ranges.

The presentations highlighted the following main environmental and health issues: lead, unburnt propellant, carbon monoxide and other gaseous emissions, and noise.

It was noted that every shooting range is unique in terms of structure and use. Despite the differences, there are effective solutions to mitigate these above-mentioned issues.

Discussions illustrated the need to manage a range as a complete system. Management techniques to address these issues must be evaluated to ensure that their implementation does not have an adverse impact on the safe and successful operation of the facility.

Effective range ventilation systems, which constitute a relatively well-known solution to the problem of lead and gaseous emissions, were discussed in detail. Alternative ammunition and primers which avoid emissions of concern were discussed and critiqued.

Pertinent facts and specific techniques were brought to the attention of the workshop. Emphasis was given to the fact that dry sweeping of the range increases lead exposure; in contrast, simple washing of face and hands after shooting considerably reduces the risk of lead exposure; in addition, risks of fire from accumulated unburnt propellant can be substantially reduced by proper range cleaning.
Primary Workshop conclusions incorporated the following:

- When shooting ranges are properly managed, science tells us that risks associated with lead and other emissions can be eliminated or least minimized to an acceptable level;
- There is a pressing need to educate both shooters and range operators about indoor shooting range environment issues and management practices;
- There are already successful models in both education and range management techniques;
- Sport shooting organizations should make indoor shooting-range environment issues a priority.
Appendix 1
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Appendix 1. Participants List

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Appendix 2

Contributors’ Biographies
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*Environmental Toxicologist, Environmental Public Health Program, Section of Epidemiology Alaska Department of Health and Social Services*

Scott M. Arnold, PhD, has been an environmental toxicologist in Anchorage, Alaska, USA since 1997. He is currently with the Environmental Public Health Program in the Alaska Department of Health and Social Services. He took a Bachelor’s degree from the Department of Environmental Health in Colorado State University in 1988, and then a PhD in 1995 from the Environmental Toxicology Center in the University of Wisconsin.

A reviewer for journals of the Soil Science Society of America, he has made many contributions to the professional literature, both alone and in collaboration with other authors. His subject material has touched on chemicals such as atrazine and DDT, and heavy metals including lead, mercury and cadmium. His work has been as diverse as including research into chemical and biological remediation, soil contamination from mines, human biomonitoring, and also waste reclamation.

Peter Berchtold - Switzerland

*Consulting Engineer for Ventilation and Air Conditioning, Heating and Cooling Systems Ing. Büro P. Berchtold, CH - Sarnen*

Peter Berchtold graduated in 1982 as an engineer from the technical university in Lucerne, Switzerland. After graduation, for four years he worked for a consultancy office in Geneva. In this period he spent two years as a site engineer in Saudi Arabia.

In 1986 he founded a consultancy office for ventilation, air conditioning, heating and cooling. This office specializes in total, optimized energy systems using renewable energy sources.

The office designed the ventilation and air conditioning plant for the largest underground shooting facility in Switzerland. The facility contains a 300m shooting lane as well as other, different shooting ranges. The office has also worked on various large scale projects, for example high rise buildings such as the GALLILEO and SKYPER skyscrapers in Frankfurt am Main, Germany.

Andy Bush, UK

*LDA's Manager for Science*

Dr Andy Bush graduated from the University of Southampton in 1997 with a doctorate in chemistry before joining the Lead Development Association International as a Technical Officer. Now the LDAI's Manager for Science, Dr Bush's main responsibility is the co-ordination of the voluntary lead risk assessments for health, and environment and waste. He is also involved in scientific activities related to regulatory initiatives relevant to lead in the United Kingdom, the EU and international fora.
Major (Retd) Frank S. Compton – UK

*Officer Commanding The Technical Advisory Section Royal Engineers (TAS(RE)) (UK Range Design Authority.)*

A military engineer involved in construction works and projects since 1973. During this time he has held the post of Senior Instructor at the Royal School of Military Engineering. Works and project experience includes offshore works in Hong Kong, support to USAF in UK, construction of ammunition storage facilities for the Canadian air force in Alberta Canada. Support to airfields in Oman, range development work for Kenyan Forces near Mombassa, infrastructure work on Falkland Islands, responsible for UK rail infrastructure in Europe based in Germany. Since 1995 he has held this current post providing UK standards for range design. Member of the UK Defence Land Ranges Safety Committee and Secretary and technical advisor to the UK Land Ranges Working Party.

Jean-Paul Denis - Belgium

*Manager of BALIST Engineering*

Nationality: Belgian, born August 20th 1947.

After formation in science and data processing, specialized in ballistics and Project Management in ENSTA (Paris); gained a thirty-five years experience in Quality Assurance, ballistics and ammunition design, mainly small caliber, caseless, heavy machine gun and sabot ammunition. He studied projects in ammunition disposal, propellant and explosives recovery; and worked for more than ten years as Forensic and Ballistic consultant.

He is Manager of BALIST Engineering, specialized in “green” ammunition design.

Vito Genco, Italy

*Executive Secretary, Europe, for the WFSA; Executive Secretary for the European Association of Sporting Ammunition Manufacturers (AFEMS)*

Dr. Vito Genco has served for more than 20 years as Vice President of the Italian Association of Sporting Guns and Ammunition Manufacturers (ANPAM). He has had a parallel position with AFEMS. With a degree in science and geochemistry from the University of Rome, Dr. Genco has conducted most of his career working for one of the major Italian chemical industries, where he was responsible for many business units, specifically in various types of civilian explosives. His responsibilities have included positions as chief of production, marketing director, chief of division and managing director. His latest business responsibilities have been addressed to carrying out international strategic plans of developments for his company, worldwide. This experience in particular has subsequently been the foundation for his appointment in relevant positions with AFEMS, ANPAM and WFSA.
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 Bradley S. King - USA

_Industrial Hygienist, Hazard Evaluation and Technical Assistance Branch, National Institute for Occupational Safety and Health (NIOSH), US Centers for Disease Control and Prevention (CDC)_

Bradley King has held the position of industrial hygienist with the Centers for Disease Control and Prevention’s (CDC’s) National Institute for Occupational Safety and Health (NIOSH) since 1999. In 1996, he took a Bachelor of Science degree in Biology from Loyola University in New Orleans and then a Master of Public Health degree in Environmental/Occupational Health from the Saint Louis University School of Public Health in 1998. As an industrial hygiene project officer in NIOSH’s Health Hazard Evaluation (HHE) program, he performs field site visits investigating biological, chemical, and/or physical health hazards in work sites throughout the United States. Past evaluations have included lead exposure assessments in firing ranges, as well as a variety of other worksites and occupational hazards.

Helmut Kinsky – Germany

_Executive Director DEVA (German Test and Proof Agency for Hunting and Sporting Firearms)_

Manager of the German Institute for Experimentation and Testing of Hunting and Sports Weapons [registered body, translator’s note] (DEVA)
Engineer, since 1969 Manager of the DEVA in Altenbeken-Buke, Ostwestfalen
Member of the “Decision-making Council” of the “Committe of experts on Dangerous Explosion Substances” and the “Consultative Committee for problems regarding Sports Huntsmen” at the head office.
Since 1972: expert in hunting problems all over Germany. (Member of the Committee)
“Target Shooting Experts” at the “German Shooting Federation” and the “DIN Standards Committee at Wasserwesen, Working Centre for Shooting Ranges” in Berlin.
Chairman of the “Committee for studying craftsmanship for the small arms manufacturing sector” for the Chamber of Craftsmen in Muenster.
Member of the “Committee of Experts of the German Association for the Protection of Hunting (DIV)”.
Author of several features and books of the shooting theorie and praxis.

Jürgen Knappworst, Germany

_Head of Research and Development in the area of ammunition_

Jürgen Knappworst graduated as a mechanical engineer from a technical academy in Braunschweig, Germany. For more than 30 years he worked for Dynamit Nobel in Fürth, Bavaria, as head of research and development of ammunition. His research focused on environmentally friendly ammunition and explosives. At RUAG Ammotec in Fürth, Germany, he is now responsible for special strategic ammunition projects. In addition, for eleven years he has been chairman of the Technical Committee of the Association of European Ammunition Manufacturers (AFEMS). This Technical Committee is heavily engaged in issues concerning ammunition, the environment, health and safety.
Thomas L. Mason, Esq. - USA

*American Executive Secretary of the WFSA*

J.D. Lewis and Clark Law School, M.S. Portland State University, Portland, Oregon, USA. Mr. Mason is the American Executive Secretary of the WFSA. He is an attorney by profession and has concentrated his practice on international government relations for nine years. Mr. Mason taught Administration of Justice for ten years and was a member of the Oregon Legislature for 16 years. He has also been a practicing criminal lawyer both prosecuting and defending cases.

Günter Mirbach – Germany

*Consultant and Site Supervisor for Ventilation and Air Conditioning*

Trained as a mechanical engineer, since 1972 he has worked in various international consultancy offices and has specialized in the design and supervision of construction work for ventilation and air conditioning plants. For 15 years he was manager of a design office for large-scale projects and collaborated, for example, in the rebuilding of the Reichstag (the German Parliament) at Berlin. He was involved in the directives for the construction of shooting ranges in Germany in 1995 and their modernization. His work involves the training of technical consultants for the ventilation of shooting ranges. As a marksman, he is active in the sector of muzzle-loading weapons; he has taken part in various world championships (winning 2 gold medals, 1 silver medal and 2 world records).

R. Richard Patterson, USA

*Managing Director, Sporting Arms and Ammunition Manufacturers’ Institute, Inc. (SAAMI); Executive Director, National Association of Shooting Ranges*

Rick Patterson is Managing Director of the Sporting Arms and Ammunition Manufacturers’ Institute, Inc. (SAAMI), and Executive Director of the National Association of Shooting Ranges (NASR), a division of the National Shooting Sports Foundation. SAAMI was founded in 1926 and sets the voluntary technical standards for the firearm and ammunition industries for US manufacturers, handling regulatory issues both domestic and international. Mr. Patterson joined the National Shooting Sports Foundation (NSSF) in 1997 and as the first Executive Director of the National Association of Shooting Ranges, he created NASR’s facility development program. He developed and launched the Facility Development Series of shooting range management publications and videos; the Rangeinfo website, a comprehensive resource for range operators, and NASR’s 5-Star Rating System. He has developed successful partnerships with state and federal environmental and occupational health agencies to provide guidance and resources for range issues such as lead management and employee safety. In 2003 Mr. Patterson was presented with the United States Department of Environmental Protection Agency’s Environmental Quality Award for Promoting and Enhancing Environmental Quality.
Carlo Peroni, Italy

**WFSA President**

President of The World Forum on the Future of Sport Shooting Activities, Carlo Peroni is a graduate doctor in law who has specialized in marketing. He worked for over 30 years for the Italian firearms company Pietro Beretta in Gardone Val Trompia (Brescia), Italy, as manager of sales and marketing departments. He is now the President of ANPAM (Associazione Nazionale Produttori Armi e Munizioni) in Rome (Italy) and President of IEACS (Institut Europeen des Armes de Chasse et de Sport) in Bruxelles (Belgium).

Hans-Dieter Petersmeier – Germany

**BDMP referent for shooting Ranges**

Age 51, Federal Consultant Shooting Ranges of the german BDMP, Member of the german working group “Shooting Range Experts”, Vice-Chairman of a local shooting-club operating an own range, active as a competition-shooter in the world-association 1500 matches.

Ted Rowe, USA

**Chairman of WFSA Manufacturers Advisory Group.**

Mr. Rowe is Chairman of the Manufacturers Advisory Group (MAG) of the World Forum and also a member of the Executive Committee. He is the Director of Government and Industry Relations for Sturm, Ruger & Co., Inc. (USA). He has been President & CEO of SIGARMS Inc. and of Harrington & Richardson, Inc.(USA). He has served several terms as Chairman of the Sporting Arms and Ammunition Institute and of the National Shooting Sports Foundation. Mr. Rowe is also an attorney and is admitted to practise before the U.S. Federal Courts and the U.S. Supreme Court. He has just been elected to the Board of Directors of the Theodore Roosevelt Conservation Partnership.

Joachim Streitberger, Germany

**Director of BVS (Federal Association of Shooting Ranges, Germany)**

Joachim Streitberger is the Director of BVS, an association of shooting ranges in Germany. He is a lawyer by profession, and he specializes in the field of firearms legislation (he is the spokesperson for the German Forum Waffenrecht) and the environmental problems of shooting ranges. His association, BVS, was founded in 1994, facing the coming legislation on soil protection in Germany, and he has worked since this time on finding sustainable solutions, especially for clay target shooting ranges. He is a member of the DIN Committee on Environmentally Friendly Operation of Shooting Ranges, Chairman of the Environment Sub-Committee of the WFSA and member of the Technical Committee of AFEMS.
Lorenzino Unio – ITALY

Aeronautical Engineer, Manager of Shooting Ranges

Ing. Lorenzino UNIO, born at Vercelli on 04/03/1950 and resident in Vercelli, Corso Adda n° 22, married.

He graduated in Aeronautical Engineering in 1976 at Turin Polytechnic, and was listed on the Roll of Engineers of Vercelli and Province in 1977 after passing the State examination for authorization to practise the profession.

From 1976 to 1993 Unio taught Mechanics and Machinery at State secondary schools.

He has acted in a professional capacity in the field of public construction work and infrastructures.

A member of U.I.T.S. since 1989 as marksman, he has experience relating to facilities and infrastructures of shooting ranges both as Section Manager and as a free-lance professional, designer and consultant.

Unio was Manager of the Shooting Ranges in the Piedmont Region as part of the U.I.T.S. Regional Committee from 2000 to 2004; member of the U.I.T.S. Shooting Ranges Commission from 2000 to 2004; he is a member of the U.I.T.S. Federal Council elected for the four-year term 2004 - 2008 and confirmed as member of the Shooting Ranges Commission, as well as being a member of the Shooting Ranges Office of the U.I.T.S. with competence for ranges in the North Italian area.