

# Camfil Farr

Technical Services Bulletin

## On Target with Camfil Farr

Shooting Ranges, Design, Ventilation & Filtration



Exposure to lead dust and fumes at the firing range can present a potential health risk to shooters, instructors and other range employees. Protecting the health of range employees and shooters, while minimizing environmental contamination from lead exposures, is an important element in the safety plan for firing ranges.

### How does lead affect the body?

Adults can be exposed to lead by breathing in lead dust or fumes from shooting or work activities, also by eating, drinking or smoking in work areas, or by handling contaminated objects - and accidentally swallowing lead dust.

Workers and shooters can accumulate lead in their bodies, with the result that they are being slowly poisoned. The symptoms may hardly be noticeable at first. But over time, lead can damage the brain, blood, nerves, kidneys and reproductive organs. This damage can cause serious disability: memory loss, extreme tiredness, emotional problems, even kidney failure, coma or death.

Lead poisoning can occur when people are exposed to large or small amounts of lead over time. Lead builds up in the body and may cause temporary or permanent damage. A blood lead test can show whether your body has absorbed a dangerous amount of lead. A high blood lead level is an indication that lead is building up in the body faster than it can be eliminated.

### Symptoms of Lead Blood Poisoning

There are many symptoms or signs that suggest a problem with lead, but they can also be symptoms of other illnesses. It is also possible to have lead poisoning without noticing any symptoms. If you work around lead you should regularly see your doctor, whether or not you are experiencing the following symptoms.

#### Early Signs and Symptoms of Lead Poisoning

Fatigue                      Headache                      Uneasy stomach  
 Sleeplessness              Irritability or nervousness      Metallic taste  
 Poor appetite              Reproductive problems

#### Later Signs and Symptoms

Aches/pains in stomach      Memory problems      Constipation  
 Muscle and joint pains      Nausea                      Weak wrists or ankles  
 Weight loss                      Kidney problems

Extreme cases of lead poisoning can result in convulsions, coma or death.

Health Effect	Blood Lead Level (mcg/dl) (micrograms per deciliter)
Severe brain damage (encephalopathy)	100
Headaches, memory and concentration problems, sleep disturbances, mood changes	60 - 70
Anemia	60
Stomach pain, constipation, diarrhea, loss of appetite	50 - 70
Nerve disorders; decreased red blood cells	50
Male reproductive problems; kidney damage	40
Slower reflexes	30
Harmful effects on the fetus; increase in blood pressure	10 - 15

Each individual responds differently to lead exposure. This chart indicates the blood lead levels at which you may experience the various ill effects of lead. In general, the effects of lead on children are even more serious.

### Sources of Lead Dust in Firing Ranges

- Exploding primers containing lead styphnate and the friction from lead slug against the gun barrel create airborne lead.
- High lead dust levels can accumulate inside indoor ranges with inadequate ventilation.
- Slugs hitting the bullet trap, walls, floors, or ceiling of the range also create lead dust.
- Airborne lead dust can concentrate in outdoor ranges, depending on weather conditions.
- Spent bullets and settled

dust can contaminate both indoor and outdoor ranges

- Improperly cleaning the range also can cause settled dust to become airborne.

High levels of lead dust in firing ranges can settle on the bodies and clothes of employees and shooters. The dust can then be carried to their cars and homes, where it can be a hazard to others in their family.

Bullet loading creates a fine dust that is very difficult to clean. Melting lead to cast bullets produces fumes, which can remain airborne for several hours. Resultant dusts can contaminate surfaces or be carried to other inhabited areas.

Never load bullets or melt lead in an unventilated area, inside the home, or anywhere children may frequent.

Copper or nylon-clad bullets and non-lead primers (such as mannitol hexanitratetetracene) can significantly reduce the amount of airborne lead discharged in firing. In cases where it is necessary to use conventional primers, use this ammunition loaded with jacketed bullets.

### **Exposure Regulation**

The Occupational Safety and Health Administration (OSHA) has established a standard for lead (29 CFR 1910.1025) which covers firing range employees. This regulation sets a "Permissible Exposure Limit" (PEL) for airborne lead of 50 micrograms per cubic meter (mcg/m<sup>3</sup>), averaged over an 8-hour period.

However, the range owner should reduce the lead exposure to both employees and shooters to as low a level as possible. Instructors are especially at risk because they spend more time on the firing range. The range instructor has the greatest potential long-term exposure to lead. A separate booth, with its own tempered and filtered air supply should be installed in the range. The construction will not reduce lead exposures to other range users, but it will reduce the range instructor's lead exposure.

### **Ventilation System for Indoor Ranges**

The planned use of a firing range should determine the design of the ventilation system. Improper use or maintenance of a firing range, or the ventilation system, can defeat the purpose of the safety efforts and increase the chance of lead contamination. An effective ventilation system produces a smooth airflow pattern.

Poorly designed ventilation systems produce eddies and recirculation that can carry fumes and dusts emitted from weapons to the area behind the firing line. Recirculation and channeling air flow can be caused by various structures in the firing range, such as:

- overhead barriers
- sound barriers
- booth walls
- light fixtures
- poorly located air inlets, or even the shooters.

Employees should be informed as to the importance of maintaining design airflow patterns through the range. Air supplies and exhaust should never be blocked, and care should be taken when placing objects in the range area that may obstruct airflow.

**It is very important that a ventilation system that serves the range area be completely separated from any ventilation for the rest of the building.**

The exhaust air from the range should not feed into air supplies for offices, meeting rooms or other businesses.

Avoid the use of angled backstops with sand traps. Although they are somewhat inexpensive, sand traps can generate a large amount of airborne lead dust and require frequent cleaning. Escalator backstops and their variations, which trap bullets and their fragments, generate less dust and are easier to clean. Also, the waste lead can be sold to a recycler without having to be separated from sand.

Indoor firing ranges also require frequent cleaning. Walls, floors, ceilings, and bullet traps must be cleaned regularly. Frequent cleaning prevents settled dust from becoming an airborne inhalation hazard from people using the range or from air circulation.

It is essential to use appropriate methods in cleaning a firing range.

1. **DO NOT DRY SWEEP!**
2. Use a vacuum cleaner equipped with a high efficiency particulate air (HEPA) filter to remove lead-contaminated dust.
3. If a vacuum cleaner with a HEPA filter is not available, then a wet cleaning method should be used.
4. Anyone cleaning a range should wear appropriate protective equipment. This includes an approved respirator, protective clothing, and shoes.
5. To reduce the possibility of bringing lead dust into their homes, the employees cleaning the range should shower and change clothes before leaving the site.
6. Work clothing should be disposable or laundered separately to prevent contaminating the home.

### Firing Range Design

Firing ranges present unique problems for the design engineer. Aside from the consideration of removing smoke buildup that restricts the vision of shooters, toxic byproducts of shooting materials must be removed to protect users, and the range officer. The National Institute for Occupational Safety and Health (NIOSH) has determined that users may be subjected to unsafe exposure levels of generated contaminants unless proper design precautions are enacted. Some of the additional contaminants of concern include:

**Gaseous:** Carbon monoxide, barium oxide, nitrogen dioxide, nitrogen tetroxide and oxides of sulfur. (Due to difference in primer material, some traces of chlorine and mercury compounds may be found.)

**Particulates (respirable and non respirable):** Stannous oxide, stannic oxide, unburned gunpowder and other compounds of sulphur (in

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addition to aforementioned lead, and lead styphnate).

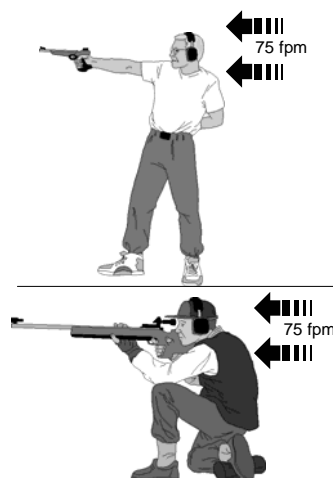
**Vapors:** Oil (gun lubricants) and water vapor.

The following list includes contaminants from a firing range in their order of importance to human health:

1. Mercury Compounds
2. Lead
3. Lead Oxide
4. Lead Styphanate
5. Chlorine Compounds
6. Barium Oxide
7. Stannic Oxide
8. Nitrogen Dioxide
9. Stannous Oxide
10. Sulphur Dioxide
11. Carbon Monoxide

The simplest system to reduce these contaminants is a high volume, single pass, ventilation system using 100% outside air. High energy costs, the space required for ductwork, and the requirement to filter the air before discharge, make this an ineffectual and rarely selected choice. (See note Page 8).

Most engineers opt for a system that will provide proper airflow across the breathing zone of range occupants, introduce sufficient levels of fresh outside air, maintain a negative range pressure differential with respect to other areas of the building, and remove offending contaminants through the use of air filtration. Air should be introduced in a horizontal laminar pattern if possible.



### Breathing Zone

The breathing zone is different for these two shooters.

Most firing ranges are for pistol use and the shooter shoots primarily from a standing position. The breathing zone is typically 4 to 7 feet from the floor.

If the firing range accommodates kneeling or prone positions, then the breathing zone for these positions are much closer to the floor (1 to 4 feet).

Supply air should always be introduced behind the shooting positions.

The system should be capable of accommodating all planned shooting positions.

Range design varies, but most ranges are about 100 feet long, 8 to 10 feet high, and will have a varying width based upon the number of shooting stations.

Use the following to calculate airflow through the range (where 75 (fpm) equals the recommended velocity through the range to carry contaminants):

$$Q = H \times W \times 75$$

Where:

Q = the total amount of supply air required

H = Height of the range, from floor to highest ceiling point

W = Width of the range, wall to wall at shooters stations

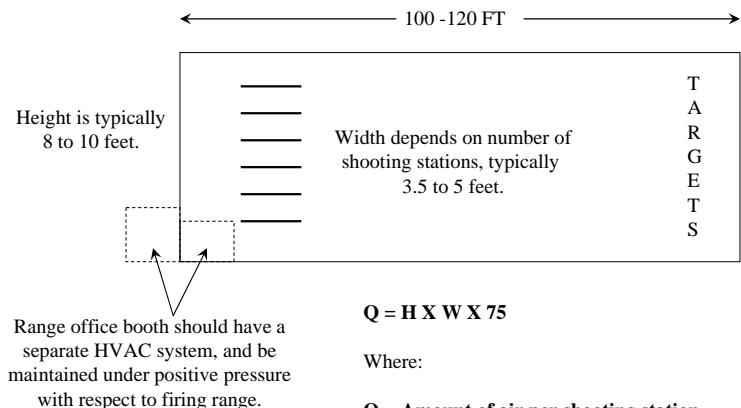
Many ranges include a range office, wherein the range officer is able to operate the targets and communicate with the shooters. Since this individual is subject to longer exposure terms, a separate filtration/ventilation system should be considered. It is important that this area be maintained under positive pressure, with respect to the shooting area (be sure to include the negative pressure already designed into the shooting area when considering calculations for this area).

## System Design

### Outside Ventilation Air Minimum

All of the pollutive components of a range may be addressed by the use of air filtration, except nitrogen oxide and carbon monoxide. Systems do exist to remove this contaminant (catalytic conversion) but they are unlikely to be applied because of factors of economy. Control of these contaminants is better accomplished through ventilation dilution, and a recirculation system. A make-up air ration of 30% is recommended to prevent the buildup of oxides of nitrogen and carbon monoxide.

Additionally, supply air should be less than exhaust air, to create a slightly negative pressure, with respect to other areas of the facility. A 'rule of thumb' is the difference between the supply and exhaust should be 10% of the total CFM being handled.



$$Q = H \times W \times 75$$

Where:

Q = Amount of air per shooting station

H = Total range height

W = Total range Width

75 = Minimum airflow (fpm) per station

## Recirculation and Contaminant Removal

The air system must be capable of removing gaseous contaminants (through ventilation dilution), smoke, unburned powder, lead particles, paper debris and various other contaminants. Normal contaminants generated by the occupants are not a consideration, as proper system application exceeds the clean air criteria published in other air quality standards or recommendations (non-industrial). Ventilation is required for two specific reasons. One is to prevent the buildup of smoke, which could interfere with the vision of shooters. The second is to prevent hazardous exposure to the range officer and the people using the firing range. Prime consideration must be given to removing contaminants from the participants and operating personnel breathing zones.

## Ventilation System Design

Ventilation system design of a firing range is similar in concept to the design of a horizontal laminar flow cleanroom. In addition, maintenance of proper air patterns is equally important, as system selection as one can not succeed without the other. The following basic rules must be applied:

Supply air uniformly across the width of the room, and as far up-range as possible. Ideally, the supply air would be introduced through the entire back wall.

Since this is usually not possible, air is usually introduced at the ceiling or at an angle between the wall and the ceiling. A ventilation rate which will result in a horizontal airflow of 75 fpm across the room is recommended. Velocities in excess of 100 FPM will create undesirable turbulence and velocities less than 50 FPM will not provide adequate velocity to remove contaminants.

A separate exhaust system should be installed, to remove approximately 25% of total supply air, downstream of the firing range. This exhaust air must be filtered in accordance with the United States Environmental Protection Agency (EPA) requirements.

This step applies dilution ventilation for removal of oxides of nitrogen and carbon monoxide from the range. Supply less make-up air than is exhausted to create A negative pressure, thereby preventing cross contamination to other areas of the facility. The usual rule of thumb is that the difference between supply and exhaust should be 10% of

the total air being handled.

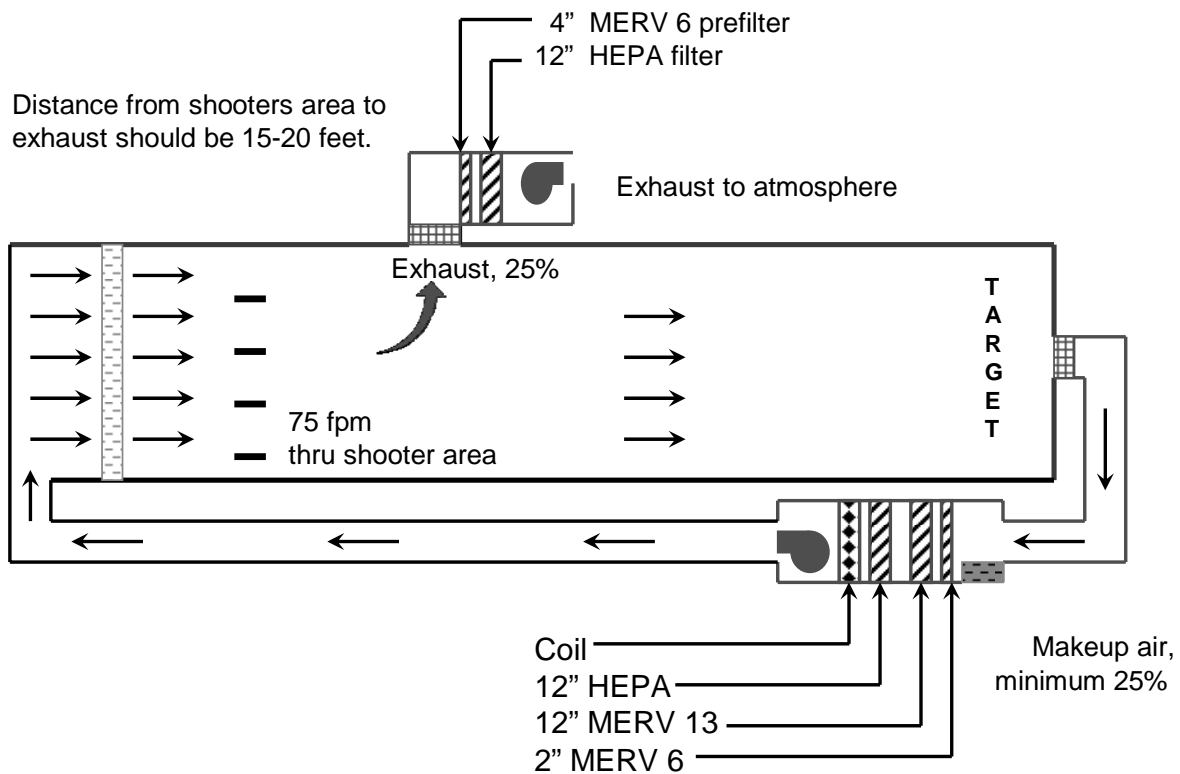
Negative pressure should be checked on a daily basis, using a pressure differential sensing device that confirms a negative pressure of 0.02" w.g. (5 Pa).

Camfil Farr recommends that this be a permanently wall mounted device to allow range officers to review negative pressure at a glance.

### Filter Selection

#### An exhaust system should include:

A HEPA grade filter housing designed to provide a filter face velocity of 250 fpm. The housing or framing system should be manufactured of 14-gauge steel and should be specifically designed for the application of HEPA filters. The housing or framing system shall be designed to accept full size (24" by 24") or half size (12" by 24") nominal size filter products. The housing



## Typical Firing Range Diagram

should be labeled as to the hazardous nature of the contaminants captured by the filter components.

A prefilter designed to remove paper debris, larger contaminants and extend the life of the final filter (s).

The prefilter should have a MERV of 6 or higher when evaluated under ASHRAE Standard 52.2. Prefilter should be installed in frames or housings of 16-gauge steel with appropriate gasketing so filter bypass is minimized. Prefilters may also be installed as an integral component to the HEPA housing, if so designed.

A 12" deep HEPA filter having an efficiency of not less than 99.97% when tested in accordance with IEST Recommended Practice for HEPA filter evaluation. The filter supplier should provide a letter of certification, with the filter, detailing the testing, and noting that each individual filter has met the requirements with regard to CFM and efficiency. Each filter should be serialized on the label, with corresponding reference in the letter of certification.

Each filter bank should include connections for a device to measure the pressure drop across filtration components. Provisions should be included to provide separate readings for both pre-filter (s) and final filter (s).

**A re-circulating system should include:**

A HEPA filter housing or frame system, selected to provide a filter face velocity of 250 fpm. The housing or framing system should be manufactured of 14-gauge steel and should be specifically designed for the application of HEPA filters. The housing should be labeled as to the hazardous nature of the contaminants captured by the filter components. The housing or framing system shall be designed to accept full size (24" by 24") or half size (12" by 24") nominal size filter products.

An air filter housing or framing system designed to provide a filter face velocity of 350-400 fpm. The housing or framing system should be constructed of 16 gauge galvanized

steel and designed to provide a minimum air bypass and minimized housing to ambient leakage. Systems may be selected to incorporate prefilters and secondary filters in housings or a framing system, or in a combination housing that allows installation of both prefilters and secondary filters. The system shall be labeled as to the hazardous nature of the contaminants captured by the filter components. The system shall be designed to accept full size (24" by 24") or half size (12" by 24") nominal size filter products.

The HEPA housing should hold 12" deep HEPA filters having an efficiency of not less than 99.97% when tested in accordance with IEST Recommended Practice for HEPA filter evaluation. The number of filters should be dependent upon manufacturers rating, but should not exceed 250 fpm face velocity. The filter supplier should provide a letter of certification, with each filter, detailing the testing, and noting that each individual filter has met the requirements with regard to cfm and efficiency. Each filter should be serialized on the label, with corresponding reference in the letter of certification.

The secondary filters should be high efficiency box style or multi-pocket extended surface filters. The number of filters will be dependent upon manufacturer's rating but should not exceed 400 fpm face velocity. The filter should be classified as MERV 14 when tested under ASHRAE Standard 52.2.

The prefilter should be designed to remove paper debris, larger contaminants, and extend the life of the secondary and HEPA filters. The prefilter should have a MERV of 6 when evaluated under ASHRAE Standard 52.2. Prefilters should be installed in frames or housings, of 16-gauge steel, with appropriate gasketing so filter bypass is minimized. Prefilters may also be installed as an integral component to the secondary filter housing, if so designed.

Filters should be 24" by 24" nominal size or 12" by 24" nominal size, with a filter face velocity not to exceed 400 fpm. The filter should have a MERV of 6 or higher when

evaluated under ASHRAE Standard 52.2.

Each filter housing should include connections for a device to measure the pressure drop across filtration components. Provisions should be included to provide separate readings for pre-filters, secondary filters, and HEPA filters.

### **System Maintenance**

#### **Employee Protection**

Employees should be protected during air filter change. Standard garb for filter service should include proper clothing including work gloves. Additionally, employees should consider respiratory protection during filter service. Respirators should meet the requirements as published under OSHA CFR 1910.134.

### **Filter Service Recommendations**

Manufacturers' recommendations for filter changing procedure should be followed when servicing air filters.

### **Filter Evaluation (gages)**

To ensure that filters are operating properly and that the maximum life of each stage is utilized, magnehelic gages should be used to evaluate filter pressure drop. Although an optimum installation includes a filter gage for each filter stage, a single gage, with applicable gage cocks, designed to isolate individual filter stage readings is acceptable. Multiple gages allow immediate evaluation of an individual bank, so corrective measures may be taken as soon as possible. (IE: A sudden drop in gage reading may indicate a filter failure).

HVAC system velocities can vary widely based upon the designer (typically from 350 fpm to 500 fpm). Filter manufacturers publish recommended final pressure drop values that are considered maximum to prevent degradation of the filter. In a firing range system, an additional level of security is recommended. A good 'rule of thumb' is to change the air filter when the initial pressure drop doubles. If a prefilter has an initial pressure drop of 0.30" w.g. that filter should be designated for change at 0.60" w.g. or as soon as possible thereafter. The same rule holds true for additional filter stages.

### **Filter Disposal**

Used filters should be wrapped in two layers of six mil poly and sealed with duct tape. If your county burns trash, the materials should be taken to a mixed municipal solid waste landfill for disposal.

For more information on ventilation for firing ranges, call or write to National Rifle Association, 1600 Rhode Island Avenue, NW, Washington, DC 20036

Note referenced on page 3: Single pass 100% OSA systems If this type of system is used the design parameters beyond recirculation components still apply. Exhaust air filtration may be required by law and local codes (especially in populated areas). Camfil Farr recommends a minimum of MERV 6 prefiltration and MERV 13 final filtration. Preferred filtration design includes the addition of HEPA filtration.

## Glossary

The following terms and abbreviations may be used within this document.

AC – Air Conditioning  
ACH – Air Changes per Hour  
AHU – Air Handling Unit  
ANSI - American National Standards Institute  
ASHRAE - American Society of Heating, Refrigerating and Air Conditioning Engineers  
ASME – American Society of Mechanical Engineers  
ASTM - American Society for Testing and Materials  
CAV – Constant Air Volume  
CO – Carbon Monoxide  
CO<sup>2</sup> – Carbon Dioxide  
CFR – Code of Regulations (Federal, OSHA)  
cfm. - Cubic feet per minute; a volumetric measurement used to size fans and duct work.  
DP – Differential Pressure  
EPA - Environmental Protection Agency  
fpm. - Feet per minute; a measurement of air velocity used in calculating cfm requirements.  
HEPA - A high efficiency particulate air filter that has been tested to ensure an efficiency of at least 99.97% on particles 0.3-micron in size.  
HVAC - Heating, Ventilation, and Air Conditioning  
IAQ – Indoor Air Quality  
NO<sub>x</sub> – Nitrogen Oxide  
O<sup>2</sup> - Oxygen  
OA – Outdoor Air  
OSHA – U.S. Occupational Safety and Health Administration  
PEL - Permissible Exposure Level; a standard level of exposure levels set by government regulations.  
PM – Particulate Matter  
RESPIRABLE PARTICLES - ASHRAE defines lung damaging particles as those that may be retained in the lungs and are 0.2 to 5 micrometers in size.”  
SA – Supply air

SMACNA – Sheet Metal and Air Conditioning Contractors National Association

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