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The Hunter Education Indoor Shooting Range in Fairbanks, Alaska, has an outdoor design temperature of -55°F (-48°C).

Indoor Shooting Range

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Protecting users from the inhalation of combustion-related contaminants is the key concern when designing an indoor shooting range. From a ventilation perspective, an indoor range is similar to a “walk-in” industrial fume hood with the firing line being the “sash” area. While either standing or sitting at the firing line, smoke must be rapidly drawn downrange and cleared to safeguard the shooter’s breathing zone and maintain target visibility.

The American Conference of Government Industrial Hygienists (ACGIH) recommends a minimum airflow velocity of 50 fpm (0.25 m/s) across the firing line and away from the shooter’s breathing zone. Traditional indoor ranges use a “once-through” 100% outside air ventilation system to provide this flow rate.

For the Hunter Education Indoor Shooting Range in Fairbanks, Alaska, where the outdoor design temperature is -55°F (-48°C), this traditional approach would consume 20,000 gallons

(75 000 L) of heating fuel oil annually and is not economically feasible. Fortunately, ANSI/ASHRAE Standard 62-2001, *Ventilation for Acceptable Indoor Air Quality*, allows a dilution ventilation strategy to maintain clean, breathable air for users in an energy-efficient manner.

Non-Traditional HVAC Design

The best energy-savings method is the partial recirculation of range air. However, this method imposes significant IAQ chal-

lenges. Most bullets contain lead, and when discharged the lead partially vaporizes. Lead causes serious long-term health risks, particularly in its respirable form. The gaseous pollutants of the propellant (“gun powder”) are also a concern.

Determination of the proper dilution ventilation rate requires an accurate assessment of contaminate buildup. Each ammunition manufacturer’s propellant has a different mix of chemicals, so quantifying all of the potential by-products is impractical. Fortunately, carbon monoxide (CO) is the most prevalent gaseous component of combustion in all cases, and is an ideal surrogate for firing-range activity. Since CO is a toxic gas and cannot

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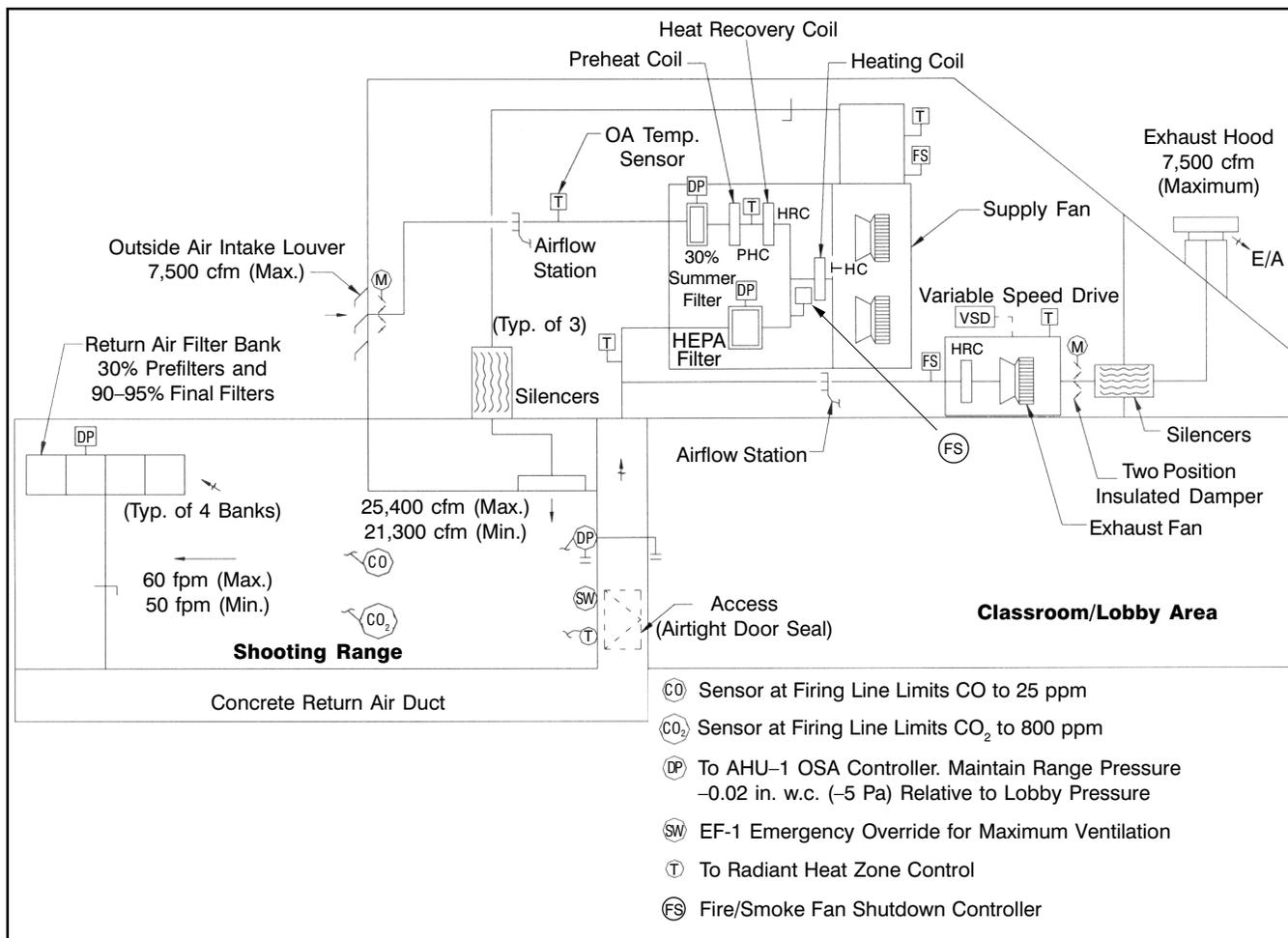


Figure 1: Firing range dilution ventilation schematic for Hunter Education Indoor Shooting Range.

be removed by filtration, it must be diluted with outside air to obtain acceptable concentration levels.

The EPA National Primary outdoor air standard for CO is 9 ppm (8-hour exposure). OSHA/ACGIH Guidelines for CO are 25 ppm for an 8-hour exposure in the workplace.

The proper mix of outside and recirculated air under various scenarios is best understood by mathematically modeling the calculated propellant/primer weight for the variety of anticipated cartridge loads. Peak dilution ventilation is required when all shooting lanes are active and simultaneously firing at the design rate.

Mechanical filtration effectively removes airborne lead. All return and exhaust air is first filtered through 30% pre-filters and 90% to 95% secondary filters at the return air filter bank. Filtering exhaust air to the 90% to 95% level alleviates the concerns of neighborhood residents from potential lead particulate contamination. All recirculated air is additionally cleaned by 99.99% HEPA filters for maximum lead removal.

Range Dilution and Pressure Control

Figure 1 illustrates the range ventilation system. The supply fan operates at constant speed to maintain a steady capture

velocity at the firing line. The range exhaust and outside air intake rates are modulated by the building automation system (BAS) to maintain the CO concentration below the setpoint limit and to control range pressure. The carbon dioxide (CO₂) level is also limited in accordance with ASHRAE recommendations.

As range activity increases, the variable speed exhaust fan also increases flow to eliminate the additional gaseous concentrations. The outside air intake damper modulates open as necessary to maintain a slightly negative range pressure (0.02 in. w.c. [5 Pa]) with respect to other areas of the building and to provide range makeup air.

Other areas of the building are ventilated using a conventional constant volume ventilation system. The two ventilation systems are isolated from one another to prevent cross contamination.

The oil-fired boiler system is designed to carry the entire building heating load at -55°F (-48°C), with the range operating at maximum capacity. A constant temperature radiant slab provides heating throughout the facility to maximize comfort. Mechanical cooling (direct expansion) is provided for all areas, except the range, during the summer months.

Energy Conservation

Energy conserving strategies include dilution ventilation of the range, an exhaust air heat recovery loop, and a dedicated boiler energy management system. Additionally, when the building is unoccupied it is entirely heated by the radiant slab system, which allows complete shutdown of all fan systems. Precise system control and adjustment for the entire facility is maintained and monitored by the direct digital control BAS. The building fully complies with the prescriptive requirements of ANSI/ASHRAE/IESNA Standard 90.1-1989, *Energy Code for Commercial and High-Rise Residential Buildings*.

Determining the most energy-efficient operating schedule, while serving the public interest, required several operating hour schedule changes during the first year of occupancy. Consequently, the initial operating data was not representative of the design intent and the anticipated long-term facility usage. In lieu of actual data, the building was modeled using Power DOE, which is a Microsoft Windows® version of the nationally recognized DOE-2 computer modeling program.

Life-Cycle Cost of Dilution Ventilation

A traditional range ventilation system requires a large heating system to support the 100% outside air ventilation load. In con-

trast, a dilution system requires HEPA filtration, CO monitoring, variable speed exhaust fan control, and modulating outside air damper control. The smaller heating system for the dilution ventilation system nearly offsets these additional filtration and BAS control costs. Additional maintenance costs for the dilution ventilation system include the purchase, change out and disposal costs associated with the HEPA filter bank, periodic calibration of carbon monoxide and carbon dioxide sensors and periodic range monitoring to verify safe gaseous contaminate levels.

The dilution ventilation system first cost is about \$2,000 more than the traditional option, and the additional operation and maintenance costs are estimated at just under \$4,000 annually. However, the dilution ventilation method saves approximately \$14,000 per year in energy costs, so the pay-back is immediate.

Building Comfort

Temperatures and airflow are controlled with respect to user activity and dress. Shooters move in various positions and are lightly active with a metabolic rate at or below 2.0 met (116 W/m²). In winter, the “average” person wears clothing with insulating effects totaling 1.0 to 1.3 clo (0.15 to 0.20 K · m²/W). In this circumstance, ANSI/ASHRAE Standard 55-1992, *Thermal*

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Environmental Conditions for Human Occupancy, suggests an optimum indoor operating temperature of 68°F (20°C). A combination of thermally controlled ventilation and hydronic radiant slab heating is used to maintain zone temperatures between 68°F to 71°F (20°C to 22°C), with classroom/lobby areas somewhat warmer than the range. To maximize mixing and minimize drafts, the zone ventilation supply air temperature matches room temperature. This effectively removes the ventilation component from the zone heat load, allowing the radiant floor heating system to control zone temperature. Humidification is universally problematic in arctic regions, and the owner opted to omit humidity control from the project.

Laminar Flow

The best method for supplying laminar airflow to an indoor shooting range is from a full-length perforated plenum wall located behind and parallel to the firing line. Range viewing from the gallery was required for this project, so the majority of the back wall of the range is glass. Supply air is provided from the ceiling, as close to the back wall as possible, using two rows of single throw adjustable air outlets connected to a large supply air plenum and directed downrange. This arrangement required time-consuming adjustments during

commissioning to minimize eddy currents. Small eddy currents in the corners of the range, which could not be removed through adjustments, require strategic location of heavy smoke-generating firearms during peak operation. Eddy currents appear to be characteristic of the overhead location of the supply diffusers. Future designers should consider using a supply air wall behind the firing line to create more laminar flow.

Operations and Maintenance

The range filter banks are arranged to minimize contamination of the ventilation system ductwork and optimize filter-loading rates. Access within the mechanical spaces is very good and filters are located and sized to accommodate workers wearing restrictive anti-contamination clothing. The downrange 30% filters require replacement about every two weeks and the downrange 90% to 95% filters require replacement about every six weeks. These downrange filters would be required regardless of ventilation system design. The original HEPA filter bank was replaced after 20 months of intermittent service without complication. In Fairbanks, the disposal of lead-contaminated waste is limited by weight, on a monthly basis. The use of compressible, lightweight filters is recommended to minimize disposal costs. ●

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