Winterization Design for Outdoor Particulate Collection Technology

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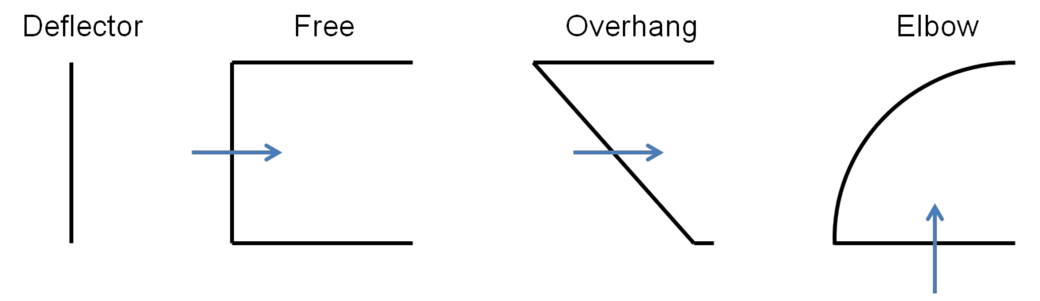
Abstract

Particulate matter 2.5 is a serious form of pollution that affects public health and is produced from burning wood and coal. The purpose of this project is to develop an electrostatic precipitator capable of removing these harmful particulates from the air that can operate in weather extremes common to Alaska.

Introduction

$PM_{2.5}$ refers to particulate matter suspended in the air that is 2.5 micrometers in diameter or smaller. The particles can be made of various materials including dust, dirt, soot, smoke, liquid droplets, or other substances. Due to their small size, $PM_{2.5}$ can penetrate deep into the respiratory system, and cause serious health problems including asthma, bronchitis, heart attacks and strokes. $PM_{2.5}$ is a significant problem in Fairbanks due to a number of factors, including fossil fuel and wood burning, cold temperatures and inversions and geographical factors. In Fairbanks fossil fuels and wood are burned for energy generation, heat, and to power vehicles, contributing to high $PM_{2.5}$ concentrations. Fairbanks is located in a valley surrounded by mountains, which limits the wind and therefore air mixing. The extreme cold winter temperatures combined with Fairbanks' geography can create inversions where a layer of warmer air traps cooler air below it. High levels of $PM_{2.5}$ can build up in these cold pockets of air.

AirVitalize Innovations is developing outdoor particulate collection technology to remove $PM_{2.5}$ from the air. This technology needs to be adapted to operate in the extreme winter conditions found in the Fairbanks region. The goal of this project is to provide winterization, allowing the particulate collector to function during Fairbanks' winter inversions.



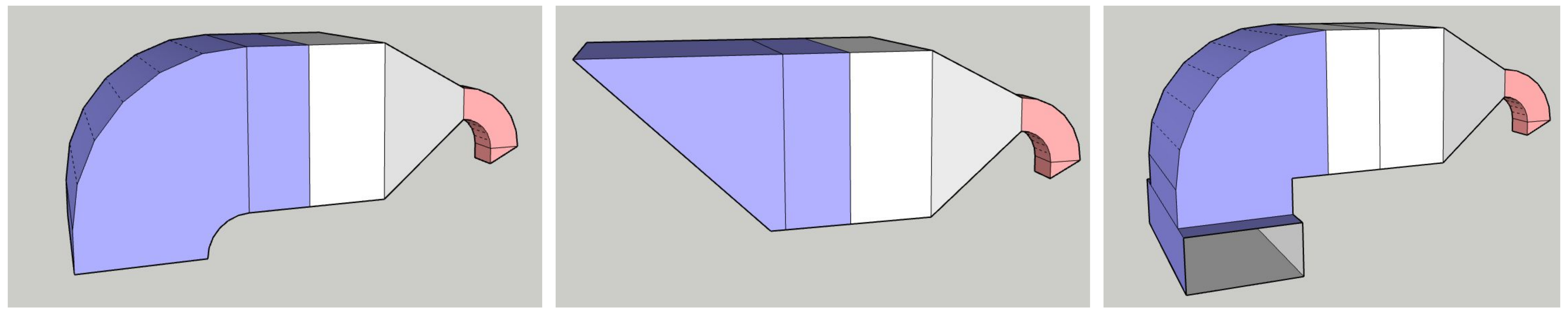
Best practices for limiting snow intrusion into HVAC systems depend on inlet geometry.The main categories are deflector, free, overhang, and elbow [1].

Objectives

The objectives of the winterization design modifications are as follows:

- System must be safe for operators, the public, and wildlife.
- System must operate between 80°F to -60°F.
- System must remove particulate matter (PM_{10} & $PM_{2.5}$).
- System must fit in a standard size parking space.
- System must provide reasonable protection against theft and vandalism.

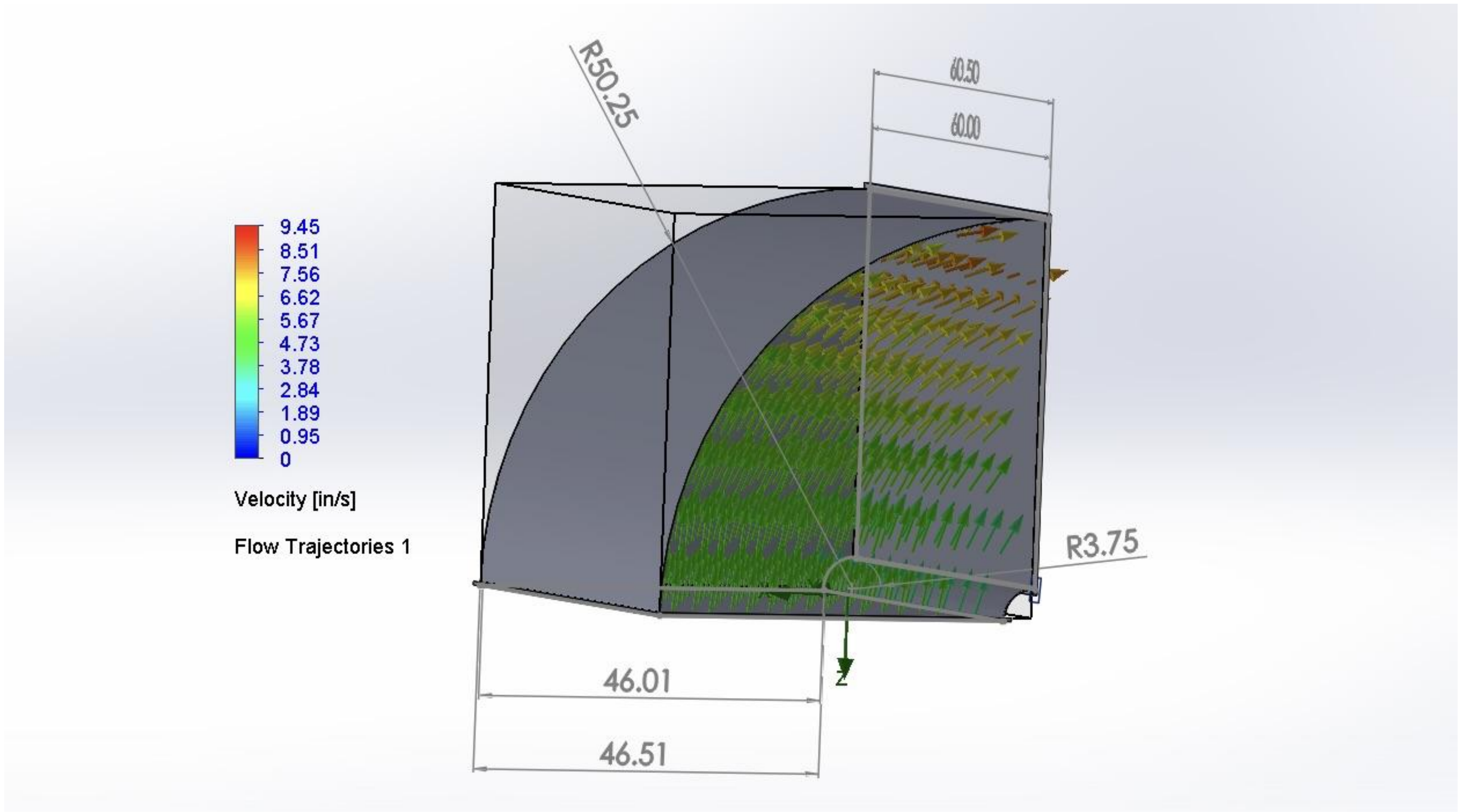
Designs



The proposed inlet and outlet hood designs for the outdoor particulate collection machine. The systems incorporate elbow, overhang, and tee design geometries for low-velocity inlets. Each system uses a high-velocity, elbow outlet hood.

The inlet and outlet hoods are designed to passively protect the system from precipitation intrusion while trying to mitigate the impacts to the airflow rate required to clean the air. Utilizing large inlet hoods maximizes net-free, cross-sectional areas for low intake velocity of less than 200 ft/min (fpm). This is done to minimize large particles, such as snow flakes or suspended ice crystals, from being pulled into the system during operation and increase the snow removal efficiency [2]. The three designs are referred to as the Overhang, Antarctic Elbow, and Arctic Tee, where the initial intake velocity is 32 fpm, 45 fpm, and 98 fpm, respectively. The geometry of the hoods, which are inspired by air-handling system components found in circumpolar environments, are also designed to prevent liquid precipitation from getting into the system when it is not operating. The outlet hood is designed with a small cross-sectional area to maintain a high airflow velocity for discharging the cleaned air. The elbow aspect is intended to prevent air from flowing horizontally where people may encounter extremely frigid air at high speeds.The addition of a cut-back edge as a deflector prevents cleaned air from being directed back towards the inlet of the air cleaner [3]. The heating system is designed to actively manage any ice build up that may occur in the system throughout a season of winter operation. A combination of electric resistive heaters and foil-backed, fiberglass insulation were parametrically designed to melt away ice formation in a 15-minute defrost period.

Analysis to Date



Analyses of air flow trajectories are necessary for determining the performance of particulate matter collection.

Analysis to Date

Initial analysis focused on optimizing airflow through preliminary hood designs, developing ice melting systems based on heat and mass flow calculations, and designing a stand to support the winterized system. The airflow design has consisted of aerodynamic efficiency calculations for minimized inlet velocity and geometric designs to limit effective length and turbulence that would inhibit the air handler's ability to clean the air at a rate of 550 cubic feet per minute. The heat and mass flow analysis was parametrically conducted using the calculated R-value of the system for a required temperature difference, Btu/h generated by the heater, and surface area of the insulated portion of the system. This was done to allow for flexibility in heat or insulation choice, depending on which factor influenced the design more: material or utility cost. The stand design analysis consisted of calculations based on weight, wind load, and snow height. Software tools utilized in the analysis to date have been Microsoft® Excel®, MATLAB®, SketchUp®, and Solidworks® Flow Simulation.

Future Work

Future work on the winterization designs will consist of evaluating the defrost system's performance in an environmental cold chamber. This will ensure that the combination of heat capacity and insulation designed is adequate or excessive. Additionally, the airflow through the different inlet hood systems will be evaluated experimentally using physical components and analytically using simulations for the selection of a single inlet hood as part of the final design. The final design will be selected based on the ideal combination of optimized airflow, fabrication and material costs, ease of integration with the baseline air handler, and aesthetics.

Acknowledgments

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