In-Depth Survey Report

# Biohazard Detection System Capture Efficiency Comparison of an Existing Advanced Facer Canceller System (AFCS) and an AFCS 200 Configuration at the North Texas Processing and Distribution Center

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## Abstract

Researchers from the National Institute for Occupational Safety and Health (NIOSH) conducted an evaluation of the Biohazard Detection System (BDS) and the Ventilation/Filtration System (VFS) developed for the United States Postal Service (USPS) mail processing equipment - the Advanced Facer Canceller System (AFCS). The BDS and VFS were developed and installed by private contractors hired by the USPS to reduce the potential for employee exposure to biological agents that could be contained in mail processed by the equipment. The VFS for the AFCS was designed to be used with a BDS that samples and analyzes air from the AFCS to determine if a biohazard is present. This effort was in response to terrorist attacks in the fall of 2001 that used the mail as a delivery system for anthrax. Since 2001, NIOSH researchers have tested the effectiveness of controls for the AFCS and other mail processing machinery at USPS Processing and Distribution Centers (P&DC) in Ohio, California, and in the Washington DC area.

The AFCS 200 was representative of a production configuration in the evaluated locations under the BDS hood and in the BDS area. The testing described in this report was to evaluate whether changes such as belt speeds, pulley sizes, and enclosures, might negatively impact BDS and VFS functionality of the AFCS 200. To evaluate this, an existing AFCS and AFCS 200 were tested side by side at the USPS Processing and Distribution Center (P&DC) in Coppell, Texas. The testing of the AFCS 200 in Coppell, Texas was performed as a follow-up to the testing of a prototype version of the AFCS 200 conducted in 2009 at the Santa Ana, California USPS P&DC. The additional testing was needed after temporary modifications during the testing in Santa Ana were made permanent for the AFCS 200.

Evaluations of the AFCS 200 and existing AFCS machines were based on a variety of tests including tracer gas experiments, air velocity measurements, and smoke release observations. The experiments showed that capture efficiencies measured from both the BDS and VFS were statistically significantly higher for the AFCS 200 than for the existing AFCS. The mean BDS capture efficiencies when testing at 200 LPM were 62% and 53% for the AFCS 200 and existing AFCS, respectively. The mean BDS capture efficiencies when testing at 400 LPM were 79% and 63% for the AFCS 200 and existing AFCS, respectively. The mean VFS capture efficiencies when testing at both 200 LPM and 400 LPM were 98% and 94% for the AFCS 200 and existing AFCS, respectively. The higher capture efficiencies of the AFCS 200 compared to the existing AFCS were likely due to the pre-hood, the more enclosed design, baffles, and modifications to air flow outside of the BDS hood. Based on the test results from this study, it is expected that postal workers would be at least as well protected against a biological hazard while working at an AFCS 200 design compared to an existing AFCS design. Smoke release experiments and velocity measurements were consistent with the results of tracer gas testing.

# Introduction

The National Institute for Occupational Safety and Health (NIOSH) is located in the Centers for Disease Control and Prevention, within the Department of Health and Human Services. NIOSH was established in 1970 by the Occupational Safety and Health Act at the same time that the Occupational Safety and Health Administration (OSHA) was established in the Department of Labor. The OSHAct legislation mandated NIOSH to conduct research and education programs separate from the standard-setting and enforcement functions conducted by OSHA. An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical, biological, and physical hazards.

The Engineering and Physical Hazards Branch (EPHB) of the Division of Applied Research and Technology (DART) has been given the lead within NIOSH to study and develop engineering controls and assess their impact on reducing occupational illness. Since 1976, EPHB (and its forerunner, the Engineering Control and Technology Branch) has conducted a large number of studies to evaluate engineering control technology based upon industry, process, or control technique. The objective of each of these studies has been to develop, evaluate, and document the performance of control techniques in reducing potential health hazards in an industry or for a specific process.

This report is for a project to evaluate controls that were put in place by the United States Postal Service (USPS) to control the release of contaminants into the work area of postal employees and to detect these contaminants during initial mail processing operations thereby preventing their delivery to a target destination address. This report describes the evaluation of the capture efficiencies of the Biohazard Detection System (BDS) and the Ventilation/Filtration System (VFS) for an existing Advanced Facer Canceller System (AFCS) machine and an AFCS 200 configuration. The AFCS 200 was representative of a production configuration in the evaluated locations under the BDS hood and in the BDS area.

The USPS AFCS 200 program has been developed to update the approximately twenty year old AFCS fleet. The AFCS 200 program deals with machine obsolescence, reduces maintenance and integrates additional functionality of the AFCS fleet. The USPS has added several external systems to the AFCS in recent years including the BDS and VFS. The testing described here is to validate that changes to the AFCS 200 do not negatively impact BDS and VFS functionality. This testing was conducted at the Coppell, Texas Processing and Distribution Center (P&DC) during a field survey that took place from January 18$^{th}$ – January 29, 2010. The testing of the AFCS 200 in Coppell, Texas was performed as a follow-up to the testing of a prototype version of the AFCS 200 conducted in 2009 at the Santa Ana, California USPS P&DC [Hammond, et al. 2009]. The additional testing was needed after temporary changes during the testing in Santa Ana were made permanent for the AFCS 200.

## Background

In 2001, researchers from NIOSH were requested to assist the USPS in the evaluation of particulate controls for various types of mail processing equipment. These controls have been installed to significantly reduce operator exposure to any potentially hazardous biological agents emitted from mail during normal mail processing. This effort is driven by the terrorist attacks in the fall of 2001 which used the mail as a delivery system for anthrax. Since 2001, NIOSH researchers have tested the effectiveness of the designed controls for the AFCS and other mail processing machinery at USPS P&DCs in Ohio [Beamer et al. 2004], California [Hammond et al. 2009], and the Washington DC area [Topmiller et al. 2003; Beamer et al. 2005].

## Description of Controls and Equipment

The controls evaluated in this report are the BDS and VFS for two AFCS machines. During this evaluation, the BDS and VFS of an existing AFCS machine and an AFCS 200 machine were tested side-by-side and compared. The controls were designed and installed by USPS contractors to significantly reduce the potential for operator exposure to biological contaminants that could be contained in mail processed by this equipment.

The AFCS is an automated mail-processing system that culls, orients, cancels, scans, and sorts standard size (5 to 11.5 inches long by 3.5 to 6.125 inches high) mail pieces. Mail is delivered to the AFCS from another mail processing machine referred to as the 010 loose mail distribution system. The AFCS culls the mail to remove flats such as large envelopes, newsletters, and magazines, and over-thick (greater than 0.25 in.) mail pieces. The mail is then properly oriented so it may be cancelled. Optical character recognition technology is used to read the addresses on the mail piece which is then sorted and distributed to numbered bins for further automated processing.

The VFS for the AFCS consisted of an air handling/filtration unit that provided exhaust for locations of possible contaminant release. The air handling unit was fitted with three stages of filtration composed of a pre-filter, a Minimum Efficiency Reporting Value (MERV) 14 filter, and a High Efficiency Particulate Air (HEPA) filter. The effectiveness of the VFS was enhanced by enclosures put in place on the AFCS by the contractor. Hoods/enclosures were fitted around areas that have higher potential for agitating or compressing mail pieces. The agitation and compression of mail was the major cause of contaminant release from tainted mail pieces.

The BDS was designed to draw air from an area of the AFCS that would most likely contain a biological contaminant emitted from an envelope due to agitation or compression. On the AFCS, this area is located just after the shingler at the singulator. As mail pieces move through the shingler, they are forced into an overlapping position, similar to roof shingles on a house. The mail stream continues to move toward the singulator. In this assembly, the mail stream is separated into individual pieces with a constant gap between the pieces. The mail pieces are tightly compressed and abruptly accelerated in a process that causes them to move as individual pieces.

The hood of the BDS is shaped like a tunnel and fits over the singulator area. The hood is approximately 4 inches wide by 5.5 inches high by 32 inches long. Air is drawn from the hood through a flexible duct into the detector which then analyzes the air for potential biological agents. If a hazard is detected, an alarm sounds and appropriate steps may be taken.

The configuration of the BDS hood over the existing AFCS was the same configuration as tested in previous NIOSH reports [Topmiller et al. 2003; Beamer et al. 2004; Beamer et al. 2005, Hammond et al. 2009]. Before testing occurred on either machine, the production BDS hood was removed and the BDS test hood was installed. The BDS test hood was identical in design to the production hoods on both machines except that the BDS test hood had three predrilled holes for injecting tracer gas.

Although the same BDS hood was tested on each machine, the AFCS 200 machine had several changes near the hood that were designed to improve containment at specified locations. The area downstream of the BDS hood on the AFCS 200 machine was entirely enclosed with removable lids. An upstream hood referred to as a pre-hood was mounted over the shingler to reduce the influence of room air currents on capture efficiencies near pinch points at locations upstream of the BDS hood. Baffles were installed downstream of the singulator area at the first and second covers as shown in Figures 1 and 2 respectively. A low flow backwash orifice shown in Figure 3 provided a 50 ALPM air flow into the downstream face of the BDS hood against the flow of mail. These changes were in place during all test measurements presented in this report.

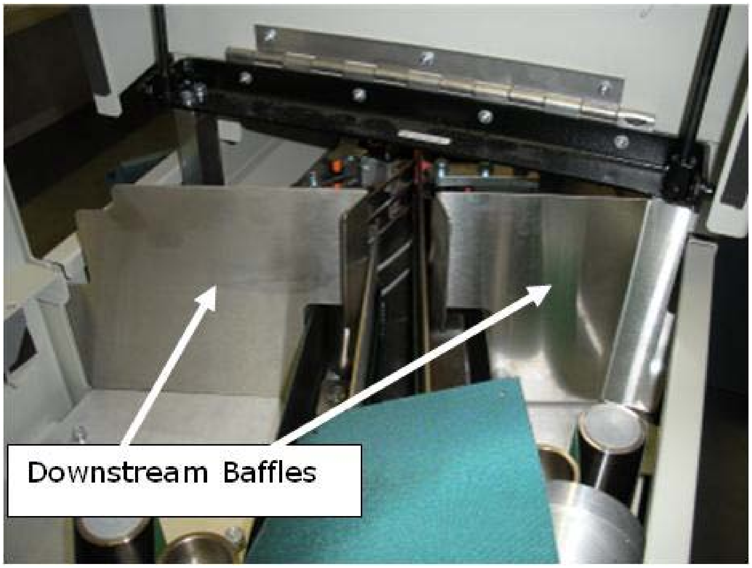


**Figure 1: Downstream baffle near the first cover**

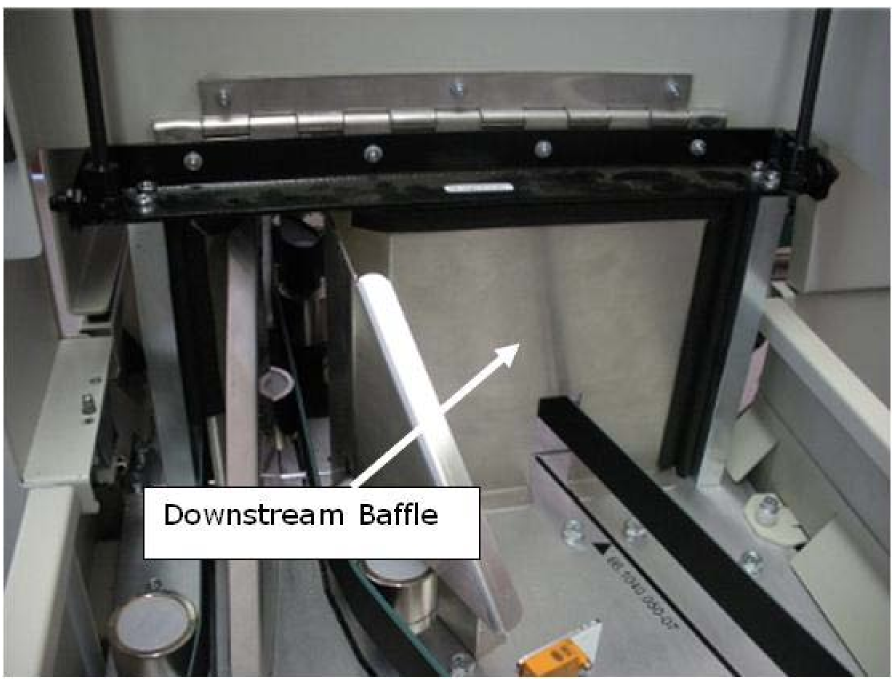


**Figure 2: Downstream baffle near the second cover**

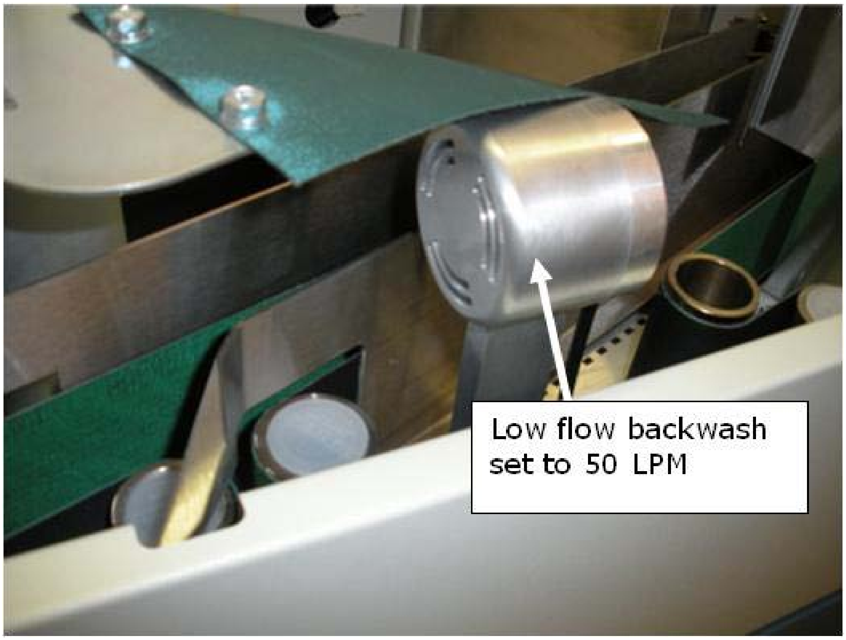


**Figure 3: Low-flow backwash orifice set to 50 ALPM**

The general building ventilation system was running for all tests on both machines. The general building ventilation system had multiple supply air diffusers near both evaluated machines and cross drafts were measured at approximately 75 ft/min in the direction directly opposite the flow of mail from the downstream face of the BDS hood on the existing AFCS machine. For this test, the VFS was located directly above the AFCS and was only connected to a single AFCS.

The BDS was manufactured by a different USPS contractor than the AFCS and use of the actual BDS pump (Model 117417-05 Type H Windjammer, Ametek Inc.) and a rotary flow meter (Model 11C175 ROOTS® Rotary Meter, Dresser Inc.) were provided during this testing. The inlet side of the BDS pump was connected to the BDS hood using a flexible hose referred to as the BDS hose. The outlet side of the BDS pump exhausted air through another flexible hose to the enclosure adjacent to the flats extractor. The flow of the BDS pump was adjusted using a set screw and measured using the ROOTS® rotary flow meter. Adjustments to the BDS pump using the ROOTS® meter were done in between each set of nine tracer gas measurements by removing the flexible hose on the outlet side of the BDS pump and connecting the ROOTS® meter. After the flow was adjusted to either 200 LPM or 400 LPM the ROOTS® meter was disconnected and the flexible hose was connected again. Tests were conducted with the BDS pump adjusted so that the flow rate through the BDS hose was either 200 or 400 LPM. Both machines were tested while the AFCS processed test mail. The VFS of the AFCS was running during all tests on both machines.

# Methodology

## *Tracer Gas*

Tracer gas is commonly used to evaluate capture efficiencies of local exhaust ventilation systems even when those systems are designed to control a particulate hazard. It has been used to evaluate local exhaust on asphalt paving machines where the hazard contains diesel particulate [Mickelson et. al. 1999]. Tracer gas has also been used to evaluate hoods designed to capture particles generated from grinding wheels [Fletcher, 1995]. One of the most common applications of tracer gas testing occurs in fume hood testing for local exhaust ventilation hoods that are designed to capture both gases and particles [ANSI/ASHRAE 1985].

Past NIOSH testing has resulted in the development of a test method that uses tracer gas to evaluate local exhaust ventilation of mail-processing equipment [Beamer B, 2003]. The test method for using tracer gas followed a thorough literature review which found multiple sources that indicated tracer gas was an appropriate evaluation method to test the capture efficiency of a hazard in particulate form. ANSI/ASHRAE Standard 110-1985 states that "fine dust, small enough to be of health significance will be carried along with the hood air currents in a fashion similar to the transport of a gas." In Hemeon's "Plant and Process Ventilation" [Hemeon, 1999], the author states that "to control small particle motion, one must control the motion of the air in which the small particles are suspended." The authors in "Risk Assessment of Chemicals" [Leeuwen et al. 2007] describe how "small particles tend to behave like gases." Probably the most compelling study compared capture efficiencies measured by tracer gas and aerosol tracer techniques and concluded that the transfer of aerosol to a local exhaust system was "nearly identical to that of a gas" for particles with diameters less than 30 µm [Beamer D, 1997]. This indicates that tracer gas testing will adequately represent the efficiency of a local exhaust system designed to capture anthrax spores.

### Equipment

To quantitatively evaluate the capture efficiency of the ventilation system, a tracer gas method was used. The tracer gases used were 99.5% minimum purity Sulfur Hexafluoride ($SF_6$) when capture efficiencies of the VFS were tested and 1% gravimetric grade $SF_6$ in air when capture efficiencies of the BDS were tested. A dual stage series 200 brass regulator with a CGA 590 inlet was connected to the tracer gas cylinders. The gas was supplied through ¼ in. diameter Teflon tubing and controlled using a mass flow controller set to produce about 2.5 parts per million (ppm) in the exhaust outlet of the system. The mass flow controller for the 99.5% $SF_6$ was manufactured by Aalborg (model GFC17, Aalborg Instruments and Controls, Inc., Aalborg, Denmark) and had a flow range of 0-1000 ml/min when calibrated to $SF_6$. The mass flow controller for the 1% $SF_6$ was manufactured by Omega (model FMA 5400/5500, Omega Engineering, Inc., Stamford, Connecticut) and had a flow range of 0 – 500 ml/min when calibrated to nitrogen.

When evaluating capture efficiencies of the VFS, the concentration of the $SF_6$ was measured in the exhaust duct. In order to sample this air stream, the exhaust air was sampled through a 20 in. long ¼ in. diameter copper tube, the same length as the duct diameter. Six 3/32 in. diameter holes were drilled uniformly across the length of the tube, and it was inserted into and perpendicular to the exhaust duct. Figure 4 shows the copper tube inserted into the exhaust duct. When evaluating capture efficiencies of the BDS, the $SF_6$ concentration was measured in the BDS hose by pulling air from the hose through ¼ in. Teflon tubing using an MNPT fitting with a Swagelok connection in PVC pipe as shown in Figure 5. The fitting was installed upstream of the pump.

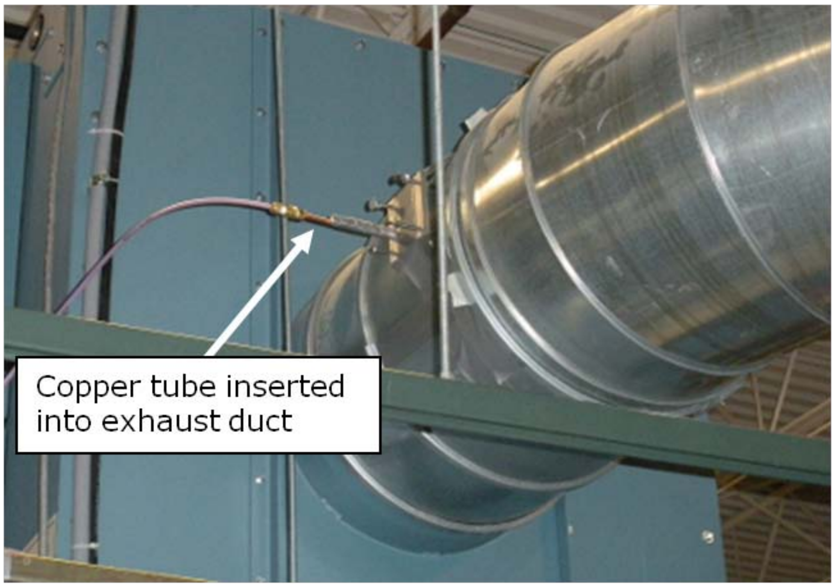


**Figure 4: Copper tube to sample tracer gas from exhaust duct**

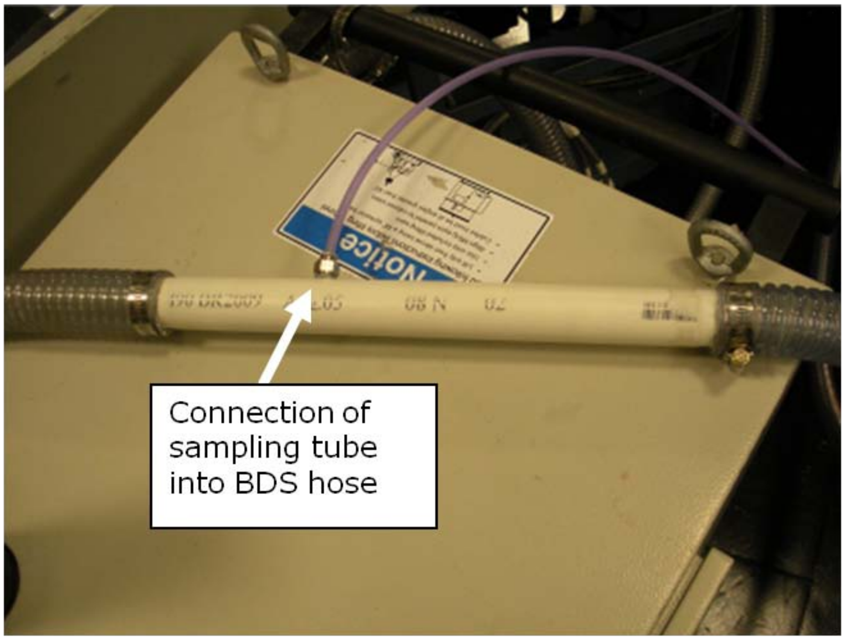


**Figure 5: Connection of sampling tube to the BDS hose**

After the sample was drawn from the duct or BDS hose, the air was first filtered (HEPA Capsule Filter, Model #12127, Gelman Sciences, Incorporated, Ann Arbor, Michigan, 48106) to remove dust and then pulled through a MIRAN® Sapphire Specific Vapor Analyzer (Thermo Environmental Instruments, 8 West Forge Parkway, Franklin, MA 02038), using an external pump (Zefon High Volume Rotary Vane Pump, Serial No. 02668, Zefon International, Inc. Ocala, Florida) at approximately 30 LPM. Teflon tubing was used throughout the sampling system. After exiting the pump, the sampled air was released through Tygon tubing to a VFS hood on the machine not being tested. The analog output signal from the MIRAN® was routed to a USB 12-bit analog and digital I/O module (Measurement Computing Corp, Norton, MA) and displayed at one-second intervals in real-time on a portable computer.

### Procedures

Each measurement of capture efficiency was recorded for a three to four minute interval. The MIRAN® concentration corresponding to 100% capture was measured by releasing the $SF_6$ directly into the 14 in. duct for VFS capture and directly into the BDS hose for BDS capture. This measurement was made both immediately before and after the rest of the capture efficiency measurements as well as between every three efficiency measurements, to detect and correct for drift in the 100% concentration. All tracer gas measurements were made with the building ventilation system on and with both the BDS and the VFS on. All tracer gas measurements were also made while the AFCS processed test mail.

Tracer gas was released at a constant rate at the following locations in and around the BDS hood.

A  About 7.5 inches downstream of the downstream face of the BDS hood

B At the downstream face of the BDS hood

C Inside the BDS hood about 8 inches from the downstream face

D Inside the BDS hood about 15.25 inches from the downstream face

E Inside the BDS hood about 8.5 inches from the upstream face

F At the upstream face of the BDS hood

G About 2.5 inches upstream of the upstream face of the BDS hood

H About 6 inches upstream of the upstream face of the BDS hood

I About 17 inches upstream of the upstream face of the BDS hood

The ¼ in. diameter Teflon tubing was inserted approximately ¾ in. through pre-drilled holes at each of the nine locations. Each location was covered with electrical tape when not in use to prevent additional air from being pulled in through the holes. Locations B through I are shown in Figure 6 and location A in Figure 7.

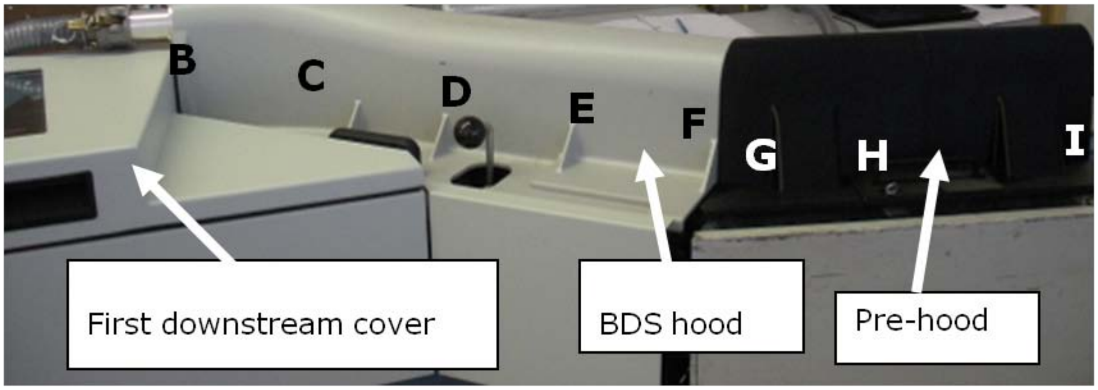


**Figure 6: Tracer gas release locations B through I for the BDS hood of the AFCS 200**

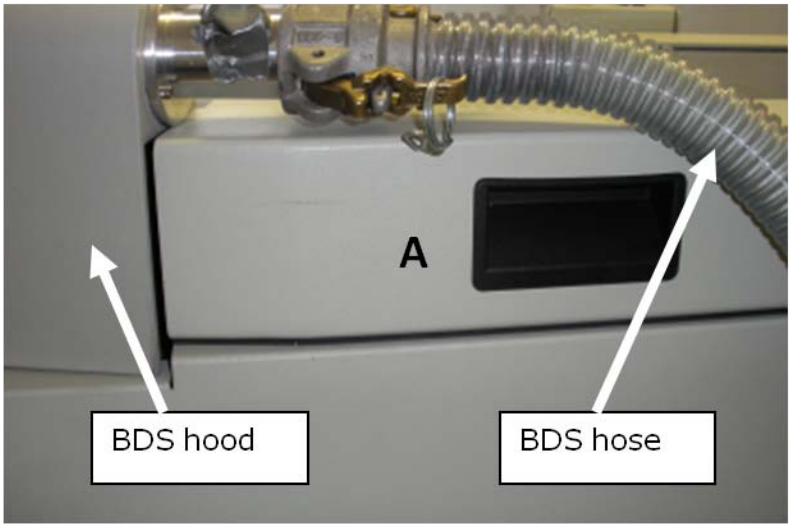


**Figure 7: Tracer gas location A for the BDS hood of the AFCS 200**

Tracer gas was released at each of the nine locations A through I individually with the sequence randomized for every scenario tested. Tracer gas release locations on the existing AFCS and the AFCS 200 were the same for locations inside the hood and at the face. The release locations outside the hood on the existing AFCS were at the same locations as corresponding locations on the AFCS 200 except that the tracer gas supply hose was taped to the machine instead of the enclosure since locations outside the BDS hood were not enclosed on the existing AFCS. For each machine, capture efficiencies at the nine locations were tested for the following scenarios.

Existing AFCS:

- Tracer gas detector positioned in BDS hose with the BDS flow set at 200 LPM
- Tracer gas detector positioned in BDS hose with the BDS flow set at 400 LPM
- Tracer gas detector positioned in the VFS duct with the BDS flow set at 200 LPM
- Tracer gas detector positioned in the VFS duct with the BDS flow set at 400 LPM

AFCS 200:

- Tracer gas detector positioned in BDS hose with the BDS flow set at 200 LPM
- Tracer gas detector positioned in BDS hose with the BDS flow set at 400 LPM
- Tracer gas detector positioned in the VFS duct with the BDS flow set at 200 LPM
- Tracer gas detector positioned in the VFS duct with the BDS flow set at 400 LPM

Each of the eight test scenarios were evaluated three times for a total of 24 sets of nine tracer gas capture efficiency measurements. When testing the capture efficiency of the VFS, tracer gas was released at a constant rate into the base of the 14 in. duct which led to a 20 in. duct where the tracer gas detector drew a sample of air to represent 100% capture concentration (C100). The outlet to the BDS hose was routed to the flats extractor which was partially enclosed by a hood that was under the influence of the VFS.

When testing the capture efficiency of only the BDS hood, tracer gas was released at a constant rate directly into the BDS hose. At the same time, the tracer gas detector measured a sample of air drawn from a downstream location in the same hose until a desirable baseline C100 concentration was achieved. For this experiment, a target concentration of 2.5 ppm of $SF_6$ as measured by the MIRAN® was used since it was slightly above half of the 0 to 4 ppm range of the instrument.

For both the BDS and VFS measures of capture efficiency, the stabilized value when gas was released directly in the hose or duct corresponded to the C100 concentration. Once the concentration corresponding to C100 stabilized, data logging began and the average of the stabilized C100 values was used as the denominator of the capture efficiency ratio. The $SF_6$ concentration when released at a location A through I provided a value for the numerator C in the ratio C/C100 which was the measure of capture efficiency at that location. Baseline C100 measurements were typically made before and after three measurement locations. An interpolation line was drawn as the average of these two stabilized values. The baseline C100 value was the point on the interpolated line corresponding to the midpoint of stabilized values for the experiment of interest.

Tracer gas efficiency for any location was computed as the ratio:

$$\frac{[\textit{average of stabilized values for a location}]}{[C100\,\textit{value}]} \times 100\%$$

## *Smoke Release*

### Equipment

A smoke machine (Mini Fogger, Model F-800, Chauvet USA, 3000 North 29th Court, Hollywood, Florida, 33020) was used to qualitatively observe air movement when a large quantity of smoke was needed. A second smoke machine (Wizard Stick, Zero Toys, Concord, MA) was used to qualitatively observe capture at the hood face when a smaller amount of smoke was needed.

### Procedures

By releasing smoke at points in and around the BDS hood with the BDS and VFS operating, the path of the smoke, and thus any airborne material potentially released at that point, could be qualitatively determined. If the smoke was captured quickly and directly by the VFS, it was a good qualitative indication of acceptable control design and performance. If the smoke was slow to be captured when released at a certain point, or took an indirect route to the hood or air intake to the exhaust, the BDS or VFS design was considered marginal at that point. Smoke release observations were made at the upstream and downstream face of the BDS hood and along the mail path of the AFCS upstream of the BDS hood. All smoke release observations were recorded while the AFCS processed test mail.

## *Capture Velocity*

### Equipment

An anemometer was used to measure air speeds at exhaust openings on the AFCS and BDS (Velocicalc Plus Anemometer, Model 8388, TSI Incorporated, P.O. Box 64394, St. Paul, Minnesota, 55164).

### Procedures

To measure the velocities achieved by the control at critical points, the anemometer was held perpendicular to the air flow direction at those points. Velocity measurement points included upstream and downstream face velocities and several locations to measure room air currents and cross drafts. The AFCS was not processing test mail when capture velocities were taken.

# Results

## Tracer gas

The mass flow controller was set to produce a 2.5 ppm concentration of $SF_6$ in the VFS exhaust duct or BDS hose when 100% of the gas was captured. The capture efficiency of each point under the BDS hood was calculated from the measured concentrations.

Appendix A and B contain detailed capture efficiency results for the existing AFCS and the AFCS 200 respectively. The Appendices include the three efficiency measurements and the mean of these measurements at each of the nine locations A through I for all evaluated test conditions for the existing AFCS and AFCS 200. Table I below presents the mean of the three individual BDS and VFS capture efficiency measurements at each of the nine locations A through I for all evaluated test conditions. Table II presents the overall mean of the 27 measurements (three measurements at nine locations) of capture efficiency for the BDS and VFS under each evaluated test condition along with standard deviation, minimum, and maximum values.

**Table I: Mean BDS and VFS capture efficiency data for the existing AFCS and AFCS 200 at location A through I.**

| BDS Flow (ALPM) Machine | VFS Mean Capture Efficiency | | | | BDS Mean Capture Efficiency | | | |
|---|---|---|---|---|---|---|---|---|
| | Existing AFCS | | AFCS 200 | | Existing AFCS | | AFCS 200 | |
| | 200 ALPM | 400 ALPM | 200 ALPM | 400 ALPM | 200 ALPM | 400 ALPM | 200 ALPM | 400 ALPM |
| A | 97% | 97% | 99% | 100% | 10% | 16% | 16% | 47% |
| B | 89% | 94% | 96% | 99% | 67% | 98% | 84% | 87% |
| C | 95% | 95% | 95% | 97% | 98% | 100% | 96% | 100% |
| D | 97% | 93% | 100% | 97% | 86% | 96% | 77% | 99% |
| E | 93% | 94% | 96% | 97% | 81% | 93% | 75% | 94% |
| F | 95% | 92% | 97% | 98% | 58% | 78% | 67% | 84% |
| G | 96% | 96% | 98% | 99% | 52% | 56% | 65% | 88% |
| H | 96% | 95% | 99% | 98% | 20% | 27% | 62% | 81% |
| I | 94% | 91% | 100% | 98% | 5% | 7% | 23% | 27% |
| **Mean Capture** | 94% | 94% | 98% | 98% | 53% | 63% | 62% | 79% |

**Table II: Mean, standard deviation, minimum, and maximum capture efficiency summary data for the BDS and VFS of the existing AFCS and AFCS 200.**

| Hood | Machine | BDS Flow Rate (ALPM) | Mean Capture | n | Standard Deviation | Min | Max |
|---|---|---|---|---|---|---|---|
| VFS | AFCS 200 | 200 | 0.98 | 27 | 0.02 | 0.92 | 1.00 |
| VFS | AFCS 200 | 400 | 0.98 | 27 | 0.01 | 0.95 | 1.00 |
| VFS | Existing AFCS | 200 | 0.94 | 27 | 0.03 | 0.85 | 0.99 |
| VFS | Existing AFCS | 400 | 0.94 | 27 | 0.03 | 0.86 | 0.99 |

| Hood | Machine | BDS Flow Rate (ALPM) | Mean Capture | n | Standard Deviation | Min | Max |
|---|---|---|---|---|---|---|---|
| BDS | AFCS 200 | 200 | 0.62 | 27 | 0.26 | 0.05 | 0.98 |
| BDS | AFCS 200 | 400 | 0.79 | 27 | 0.24 | 0.22 | 1.00 |
| BDS | Existing AFCS | 200 | 0.53 | 27 | 0.34 | 0.04 | 0.99 |
| BDS | Existing AFCS | 400 | 0.63 | 27 | 0.37 | 0.04 | 1.00 |

### *Statistical Analysis*

A two-way analysis of variance (ANOVA) procedure followed by a t-test was used to test for differences in percent capture efficiency between machines and between flow rates. Interactions between machines, and flow rate were also tested. The general normality assumption required for ANOVA was tested and met.

A statistically significant difference in VFS capture efficiency was found between machines at the 5% significance test level ($p<0.001$). The mean VFS capture efficiency of the AFCS 200 was higher than that of the existing AFCS. No statistically significant differences in VFS capture efficiencies were found between flow rates. For the VFS test, the differences between the two machines were consistent across flow rates since no statistically significant interactions between machine and flow rate were found.

A statistically significant difference in BDS capture efficiency was found between machines at the 5% significance test level ($p<0.04$). The mean BDS capture efficiency of the AFCS 200 was higher than that of existing AFCS. Statistically significant differences ($p=0.03$) in BDS capture efficiencies were found on each machine between flow rates. BDS capture efficiencies were statistically significantly higher ($p=0.03$) while testing at 400 LPM than capture efficiencies while testing at 200 LPM on each machine. For the BDS test, the interaction between machine and flow rate was not statistically significantly different. This indicated that the difference between the two machines was consistent across flow rates.

### *Smoke Release*

Qualitative smoke release experiments were conducted to visually determine how effective the BDS hood is at the upstream and downstream face, pinch points A, G, H, and I outside the hood for both the existing AFCS and the AFCS 200. Smoke release observations were not noticeably different between BDS flow rates of 200 LPM and 400 LPM.

Smoke release observations on the existing AFCS:

- At location A, most of the smoke entered the VFS and but some smoke was carried into the BDS hood by room air currents.
- At the downstream face of the BDS hood, nearly all of the smoke released entered the hood as a result of the strong room air currents that were directed into the downstream face of the hood.
- At the upstream face of the BDS hood most of the smoke appeared to enter the BDS hood.
- At location G, most of the smoke entered the VFS and a small amount escaped capture.
- At location H, some smoke appeared to escape the influence of any exhaust.
- At location I, the smoke results were nearly identical to those of location H.

Smoke release observations of the AFCS 200:

- Locations A through I including both the upstream and downstream face of the BDS hood were enclosed. Therefore, smoke release observations were made at the opening to the pre-hood extension. The upstream face to the pre-hood was located just upstream of location I.
- Smoke release observations from the upstream face of the pre-hood indicated that smoke entered the hood.

### *Capture Velocity*

Air velocities collected at the upstream and downstream face of the BDS hood are shown in Table IV. These results are consistent with other findings in this report. It should be noted that the BDS air handling system was designed to have low capture velocities at the hood faces so as not to interfere with the proper function of the VFS for the AFCS. The AFCS was not processing test mail when capture velocity measurements were taken.

**Table IV: Capture velocities of the BDS hood**

| Machine | BDS EXHAUST (actual liters/min) | TEST LOCATION | Measurement 1 (ft/min) | Measurement 2 (ft/min) | Measurement 3 (ft/min) |
|---|---|---|---|---|---|
| Existing AFCS | 200 | Upstream face | 10 | 7 | 2 |
| Existing AFCS | 200 | Downstream face | 97 | 92 | 101 |
| Existing AFCS | 400 | Upstream face | 2 | 1 | 1 |
| Existing AFCS | 400 | Downstream face | 108 | 106 | 104 |
| AFCS 200 | 200 | Upstream face | 40 | 34 | 37 |
| AFCS 200 | 200 | Downstream face | 45 | 49 | 44 |

| Machine | BDS EXHAUST (actual liters/min) | TEST LOCATION | Measurement 1 (ft/min) | Measurement 2 (ft/min) | Measurement 3 (ft/min) |
|---|---|---|---|---|---|
| AFCS 200 | 400 | Upstream face | 39 | 42 | 46 |
| AFCS 200 | 400 | Downstream face | 62 | 70 | 69 |

## Discussion

The findings in this report were based on side-by-side testing of the existing AFCS and AFCS 200 conducted at the Coppell, Texas P&DC and may not necessarily compare directly with similar testing conducted under different plant configurations or VFS designs. For example, past evaluations may have been conducted in plants where ceilings were higher or where supply diffusers from the general building ventilation system were closer or farther from the BDS hood. This would have the effect of lowering or increasing cross drafts which could influence capture efficiencies. For this study, a single AFCS was ducted to a single VFS which was located directly above the AFCS machine. Since the VFS is contained in a large enclosure, it would likely have the effect of blocking or redirecting room air currents compared to a design with the VFS located across the aisle. For these and other reasons, it may be inappropriate to compare the test results of the AFCS 200 from this evaluation with previous tests of the existing AFCS conducted at other facilities several years earlier. Instead, it is more appropriate to draw comparisons between the AFCS 200 and existing AFCS as tested side by side at the Coppell, TX P&DC.

## Conclusions and Recommendations

Under the evaluated test conditions, capture efficiencies measured from both the BDS and VFS were statistically significantly higher for the AFCS 200 than for the existing AFCS. Design features on the AFCS 200 such as the pre-hood and enclosures downstream of the BDS hood provide more protection against room air currents than the existing AFCS design. Based on this information and the test results from this study, it is expected that postal workers would be at least as well protected against a biological hazard while working at an AFCS 200 design compared to an existing AFCS design.

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# Appendix A

Tracer gas capture efficiency results

Existing AFCS machine

BDS 200 LPM

| 200 ALPM, TRACER GAS DETECTOR LOCATED AT BDS EXHAUST | | | | |
|---|---|---|---|---|
| LOCATION | Measurement 1 | Measurement 2 | Measurement 3 | AVERAGE |
| A | 6% | 10% | 15% | 10% |
| B | 45% | 90% | 67% | 67% |
| C | 98% | 99% | 98% | 98% |
| D | 79% | 88% | 92% | 86% |
| E | 81% | 83% | 79% | 81% |
| F | 69% | 55% | 50% | 58% |
| G | 49% | 49% | 59% | 52% |
| H | 19% | 17% | 25% | 20% |
| I | 4% | 6% | 5% | 5% |

VFS 200 LPM

| 200 ALPM, BDS EXHAUST ROUTED TO VFS, TRACER GAS DETECTOR LOCATED AT VFS EXHAUST | | | | |
|---|---|---|---|---|
| LOCATION | Measurement 1 | Measurement 2 | Measurement 3 | AVERAGE |
| A | 98% | 95% | 99% | 97% |
| B | 93% | 85% | 90% | 89% |
| C | 95% | 90% | 99% | 95% |
| D | 96% | 98% | 96% | 97% |
| E | 94% | 87% | 96% | 93% |
| F | 95% | 94% | 95% | 95% |
| G | 98% | 96% | 94% | 96% |
| H | 94% | 97% | 96% | 96% |
| I | 93% | 94% | 94% | 94% |

BDS 400 LPM

| 400 ALPM, TRACER GAS DETECTOR LOCATED AT BDS EXHAUST | | | | |
|---|---|---|---|---|
| **LOCATION** | **Measurement 1** | **Measurement 2** | **Measurement 3** | **AVERAGE** |
| A | 11% | 24% | 15% | 16% |
| B | 97% | 99% | 100% | 98% |
| C | 100% | 99% | 100% | 100% |
| D | 90% | 98% | 99% | 96% |
| E | 90% | 98% | 90% | 93% |
| F | 81% | 84% | 68% | 78% |
| G | 64% | 59% | 44% | 56% |
| H | 26% | 29% | 27% | 27% |
| I | 4% | 14% | 4% | 7% |

VFS 400 LPM

| 400 ALPM, BDS EXHAUST ROUTED TO VFS, TRACER GAS DETECTOR LOCATED AT VFS EXHAUST | | | | |
|---|---|---|---|---|
| LOCATION | **Measurement 1** | **Measurement 2** | **Measurement 3** | **AVERAGE** |
| A | 98% | 98% | 95% | 97% |
| B | 93% | 95% | 93% | 94% |
| C | 90% | 98% | 97% | 95% |
| D | 90% | 96% | 92% | 93% |
| E | 90% | 94% | 97% | 94% |
| F | 88% | 95% | 95% | 92% |
| G | 95% | 95% | 99% | 96% |
| H | 94% | 97% | 95% | 95% |
| I | 86% | 93% | 95% | 91% |

# Appendix B

Tracer Gas Efficiency Measurements

AFCS 200 Machine

BDS 200 LPM

| 200 ALPM, TRACER GAS DETECTOR LOCATED AT BDS EXHAUST | | | | |
|---|---|---|---|---|
| **LOCATION** | **Measurement 1** | **Measurement 2** | **Measurement 3** | **AVERAGE** |
| A | 5% | 22% | 19% | 16% |
| B | 86% | 83% | 82% | 84% |
| C | 98% | 95% | 94% | 96% |
| D | 80% | 74% | 76% | 77% |
| E | 74% | 77% | 73% | 75% |
| F | 62% | 69% | 69% | 67% |
| G | 71% | 65% | 58% | 65% |
| H | 61% | 61% | 63% | 62% |
| I | 18% | 25% | 25% | 23% |

VFS 200 LPM

| 200 ALPM, BDS EXHAUST ROUTED TO VFS, TRACER GAS DETECTOR LOCATED AT VFS EXHAUST | | | | |
|---|---|---|---|---|
| **LOCATION** | **Measurement 1** | **Measurement 2** | **Measurement 3** | **AVERAGE** |
| A | 100% | 98% | 99% | 99% |
| B | 98% | 98% | 93% | 96% |
| C | 94% | 95% | 96% | 95% |
| D | 99% | 100% | 100% | 100% |
| E | 92% | 100% | 97% | 96% |
| F | 94% | 99% | 97% | 97% |
| G | 97% | 97% | 100% | 98% |
| H | 97% | 100% | 100% | 99% |
| I | 100% | 100% | 100% | 100% |

BDS 400 LPM

| 400 ALPM, TRACER GAS DETECTOR LOCATED AT BDS EXHAUST | | | | |
|---|---|---|---|---|
| **LOCATION** | **Measurement 1** | **Measurement 2** | **Measurement 3** | **AVERAGE** |
| A | 42% | 37% | 62% | 47% |
| B | 83% | 80% | 99% | 87% |
| C | 100% | 100% | 100% | 100% |
| D | 99% | 97% | 99% | 99% |
| E | 93% | 92% | 96% | 94% |
| F | 72% | 89% | 89% | 84% |
| G | 89% | 88% | 87% | 88% |
| H | 79% | 81% | 83% | 81% |
| I | 27% | 22% | 33% | 27% |

VFS 400 LPM

| 400 ALPM, BDS EXHAUST ROUTED TO VFS, TRACER GAS DETECTOR LOCATED AT VFS EXHAUST | | | | |
|---|---|---|---|---|
| **LOCATION** | **Measurement 1** | **Measurement 2** | **Measurement 3** | **AVERAGE** |
| A | 100% | 100% | 99% | 100% |
| B | 98% | 98% | 100% | 99% |
| C | 95% | 99% | 98% | 97% |
| D | 96% | 97% | 98% | 97% |
| E | 98% | 96% | 98% | 97% |
| F | 98% | 98% | 98% | 98% |
| G | 98% | 100% | 99% | 99% |
| H | 98% | 99% | 99% | 98% |
| I | 97% | 100% | 98% | 98% |

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