IN-DEPTH SURVEY REPORT: EVALUATION OF LOCAL EXHAUST VENTILATION SYSTEMS FOR THE 010 CULLING SYSTEM

at

United States Postal Service
Merrifield Processing and Distribution Center
Merrifield, Virginia

REPORT WRITTEN BY
Bryan R. Beamer
Keith G. Crouch
Stephen Martin
Ernest S. Moyer
Jennifer L. Topmiller

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Division of Applied Research and Technology
Engineering and Physical Hazards Branch
4676 Columbia Parkway, Mail Stop R-5
Cincinnati, Ohio 45226-1998

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SURVEY CONDUCTED BY	Bryan Beamer, NIOSH Keith Crouch, NIOSH Stephen Martin, NIOSH Ernest Moyer, NIOSH
EMPLOYER REPRESENTATIVES CONTACTED	Tom Potter Senior Mechanical Engineer United States Postal Service
EMPLOYEE REPRESENTATIVE CONTACTED	W Corey Thompson, Jr Safety & Health Specialist American Postal Workers Union, AFL-CIO

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ABSTRACT

Researchers from the National Institute for Occupational Safety and Health (NIOSH) conducted an evaluation of the Ventilation/Filtration System (VFS) developed for the United States Postal Service (USPS) mail processing equipment–the 010 Culling System. The VFS was developed and installed by a private contractor hired by the USPS to reduce the potential for employee exposure to harmful substances that could be contained in mail pieces processed by the equipment This effort is in response to the 2001 terrorist attacks that used the mail as a delivery system for anthrax NIOSH was asked to assist the USPS in evaluating controls for this and other mail processing equipment

Evaluations were based on a variety of tests including tracer gas (TG) experiments, air velocity measurements and smoke release observations to evaluate contaminant capture efficiency; and simultaneous particle count experiments upstream and downstream of the VFS filtration to evaluate system filtration efficiency The experiments showed that, with few exceptions, the system meets or exceeds minimum contaminant capture requirements and that contaminant filtration capabilities meet or exceed 99 97% However, testing did reveal poor contaminant capture efficiency at Flats Ejector # 1 (about 28%)

Based on these results as discussed in this report, the following recommendations are made to further improve the control of potential contaminants by this mail sorting system.

- Both Flats Ejectors should be permanently modified to maximize smoke capture and TG capture efficiency
- Although smoke release observations suggest adequate contaminant capture at the Left-Hand Loose Mail Distribution System (LMDS) Hamper Dump, it is recommended that the gap to the side of the slotted intake be sealed This action may also increase contaminant capture velocities at the face of the curtain
- USPS Engineering should consider elimination of the exhaust at the LL-10 and LL-6 areas Since these areas are enclosed, workers should be adequately protected as long as the chute underneath is controlled by the Advanced Facer Canceller System (AFCS) VFS
- Although TG experiments suggest adequate capture efficiencies at the Dual Pass Rough Cull (DPRC) waterfall area, there are several open knock-outs in walls in this area that should be sealed to maximize VFS effectiveness
- The USPS and its vendors should consider redirection of the exhaust plumes from the air handling units as they may interfere with proper contaminant capture of the 010 Culling System VFS, DPRC VFS and AFCS VFS which are in the plumes
- Proper balance of the Left-Hand side of the LMDS System with the Right-Hand side could alleviate disparities in Hamper Dump contaminant capture velocities and Hand Culling Station TG capture efficiencies
- The skirt added by the vendor during testing to the SC-2 bypass chute should be made permanent, and similar modifications should be made to the SC-1 bypass chute
- To ensure optimal filtration system performance, the USPS and its vendors should take steps to guarantee that filters are changed often enough to be

operating within prescribed parameters and that filters are protected from physical damage Moreover, such steps should be taken prior to further testing of filtration system efficiency

- Proper and regular maintenance of the filtration component of the VFS unit is essential for effective filtration Work procedures for maintenance should be designed with this in mind and should be closely followed
- Further testing to investigate why computations for some areas indicate capture efficiency greater than 100% is warranted Therefore, future NIOSH testing should include making individual TG experiments longer in length

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is located in the Centers for Disease Control and Prevention (CDC), 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 (DOL) 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 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 evaluate and document control techniques and to determine the effectiveness of the control techniques in reducing potential health hazards in an industry or for a specific process

Researchers from NIOSH were requested to assist the USPS in the evaluation of contaminant controls for various mail processing equipment These new controls are being installed to significantly reduce operator exposure to any potentially hazardous contaminants emitted from mail pieces during normal mail processing This effort is driven by the 2001 terrorist attacks which used the mail as a delivery system for anthrax NIOSH researchers have subsequently made several trips to Washington, DC area postal facilities to observe mail-processing equipment in operation and to study the effectiveness of the newly designed controls

The control evaluated in this report is a pre-production model ventilation/filtration system (VFS) for the 010 Culling System. This control was designed and installed by a USPS contractor to significantly reduce the potential for operator exposure to bacterial contaminants that could be contained in mail pieces processed by this equipment This system was evaluated at the Merrifield, Virginia Processing and Distribution Center (P&DC) during a field survey that took place October 9-10, 15 and 17, 2002

DESCRIPTION OF EQUIPMENT

The USPS 010 Culling System is comprised of 2 conveyor systems that size the collection mail brought to the P&DC into letters, flats (magazine size), and parcels The first system is called the Dual Pass Rough Cull (DPRC) and the second is the Loose Mail Distribution System (LMDS) The hampers of raw mail are loaded into the DPRC. Flats and parcels are separated from the letter mail and sent to the appropriate areas of the facility for processing The output of the LMDS sends letter mail to the next stage in its processing which is the cancellation equipment

At the time of evaluation, the VFS for the 010 Culling System consisted of 2 separate air-handling/filtration units that provided exhaust for various locations of possible contaminant release Air-handling Unit # 1 processed about 19,000 cubic feet per minute (cfm) and could be switched to service various areas depending upon USPS processing needs, including the LMDS area and conveyors that send mail to equipment downstream of the 010 Culling System. Air-Handling Unit # 2 processed about 18,000 cfm and serviced the primary areas of the DPRC. Each of these air-handling units was fitted with three stages of filtration composed of a pre-filter, a MERV 14 filter and a High Efficiency Particulate Air (HEPA) filter Furthermore, several areas of potential contaminant release were enclosed or partially enclosed by the manufacturer so that the VFS could more effectively protect the worker from exposure

METHODS

TRACER GAS

Apparatus

To quantitatively evaluate the capture efficiency of the ventilation system, a tracer gas method was used The gas, CP sulfur hexafluoride (SF_6), was released at a constant rate at points in and near the sorter to determine the capture efficiency of the VFS at these release points The gas was supplied through a mass flow controller (Model 1359C-10000SV, MKS Baratron® & Control Products, Six Shattuck Road, Andover, Massachusetts, 01810) set to produce about 4 parts per million (ppm) in the exhaust outlet of the system. The exhaust from the ventilation system was filtered and then returned to the workroom near the ceiling The concentration of the SF_6 was measured in the exhaust duct, just upstream of the filters In order to sample this air stream uniformly, the exhaust air was drawn through a 1/4 in diameter copper tube having six 3/32 in diameter holes spread uniformly across the duct diameter, inserted into and perpendicular to the exhaust duct After exiting the copper tube, 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® 203 Specific Vapor Analyzer (Thermo Environmental Instruments, 8 West Forge Parkway, Franklin, MA 02038), using an AirCon® high volume air sampler (Gilian Instrument Corporation, W Caldwell, New Jersey) set for approximately 30 liters per minute, and using Tygon® tubing throughout the sampling system. After exiting the pump, the sampled air was released into the workroom. The analogue output signal from the MIRAN® was routed to a PCMCIA 12-bit analog card (Quatech Model # DAQP-12, Akron, OH) which allowed data storage and display at one-second intervals in real-time on a portable computer

Procedures

For these measurements, the output signal from the MIRAN® was recorded at 1 second intervals Each measurement of capture efficiency was recorded for a 2 to 4 minute interval The MIRAN® concentration corresponding to 100% capture was measured by releasing the SF_6 directly into a duct supplying the exhaust intake in that part of the system. This measurement was made immediately before and after the rest of the capture efficiency measurements as well as between a number of the efficiency measurements, to detect and correct for drift in the 100% level All of the tracer gas measurements were made with the ventilation system blower turned on A list of the sampling sites is given in Table 1

SMOKE RELEASE

Apparatus

A smoke machine (Mini Fogger, Model F-800, Chauvet USA, 3000 North 29th Court, Hollywood, Florida, 33020) was used to visualize air movement in and around these systems

Procedures

By releasing smoke at points in and around the sorter with the VFS operating, the path of the smoke, and thus any airborne material released at that point, could be determined If the smoke was captured quickly and directly by the VFS, it was a good indication of acceptable control design and performance If the smoke was slow to be captured when released at a certain point, or took a circuitous route to the air intake for the exhaust, the VFS design was considered marginal at that point A list of the sampling sites is given in Table 2

CAPTURE VELOCITY

Apparatus

An anemometer was used to measure air speeds at exhaust openings on the LMDS and DPRC (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 flow direction at those points Velocities were recorded at the hamper dumper and at exhaust openings around the system. To check capture velocities at the furthest point from the air intake, the anemometer was held at the edge of the equipment where a worker would be positioned A list of the sampling sites is given in Table 3

FILTRATION EFFICIENCY

Apparatus

The apparatus used to make measurements to calculate filtration efficiency was a Grimm Portable Dust Monitor which uses optical scattering technology to measure particle concentration and estimate particle size (Model 1 108, Grimm Technologies, Incorporated, Douglasville, GA) The Grimm 1 108 provides continuous monitoring of aerosol particles and measures number (count) concentration per unit volume (typically liters) For experiments conducted, data concerning concentrations of the following particle sizes were collected 0 3 μm, 0 4 μm, 0 5 μm, 0 65 μm, 0 8 μm, 1 0 μm, 1 6 μm, 2 0 μm, 3 0 μm, 4 0 μm, 5 0 μm, 7 5 μm, 10 0 μm, 15 0 μm, and 20 0 μm.

Procedures

The challenge aerosol used for measurements was the ambient aerosol that enters the HVAC system from air intakes One Grimm Portable Dust Monitor was placed upstream of the filters to count particles with an isokinetic sampling probe facing the air stream. Simultaneously, another GRIMM Portable Dust Monitor was placed downstream of the filters with an isokinetic sampling probe facing the HEPA filters The particular Grimm's used were a matched pair to minimize instrument-to instrument variability Filter penetration [P] was calculated by taking the ratio of the downstream particle counts [C_{down}] to the upstream particle counts [C_{up}] (× 100 gives percent penetration) Filter efficiency is then determined as 100 minus the calculated value for P Filter efficiencies were made both before and during periods of mail processing on the 010 System.

RESULTS

Tracer gas

The mass flow controller was set to produce a 4 ppm concentration of SF_6 in the ventilation system exhaust when 100% of the gas was being captured The relative concentration in the exhaust as a result of tracer dosing at any point, which is equivalent to the capture efficiency at that point, is given in Table 1 This data is shown graphically in Figure 1 The measured capture efficiencies ranged from 0 28 to 1 06

Smoke

Smoke release experiments were conducted to visually determine how effective the exhaust ventilation control is at various points around the mail distribution system. Smoke was well controlled in most areas and was found to be effectively captured by the exhaust system (see Table 2) Special note should be made that at Right-Hand LMDS Hand Culling Stations A, B and C, smoke was captured quickly and efficiently into the VFS exhaust, an observation made several times

Smoke release observations did, however, indicate marginal or poor contaminant capture capabilities at the Flats Ejectors, where much smoke escaped the influence of the VFS exhaust When the vendor made simple, temporary modifications at Flats Ejector 2, this situation changed and most of the smoke was then entrained into the VFS At the time of the survey the vendor agreed to make future modifications to both Flats Ejectors to rectify this situation

Three smoke release observations that did not indicate poor VFS performance did, however, reveal opportunities for improvement of the system. For instance, at the Left-Hand LMDS Hamper Dump, it was noted that some smoke was escaping through a small opening in the hood to the left of the VFS exhaust Also the SC-2 bypass hood showed acceptable smoke capture only when a temporary skirt was added, a modification that the vendor promised to make permanent at both the SC-1 and SC-2 bypass hoods Lastly, at the bottom of the drop for the DPRC Waterfall area, some smoke could escape through knockouts in the equipment with a large blast of smoke

Air Velocity

Air velocity measurements were taken at various locations Most measurements met or exceeded the USPS minimum standard of 100 feet per minute (see Table 3) The exception to this was at the Left-Hand LMDS Hamper Dump, where measurements were consistently lower than 100 feet per minute

Filtration Efficiency

Both Merrifield Air Handling Units showed system efficiencies greater than 99 97%, which is the minimum HEPA filter efficiency level (See Table 4)

DISCUSSION

While air velocity measurements at the Left-Hand LMDS Hamper Dump were consistently lower than 100 feet per minute (USPS minimum requirement), the VFS met or exceeded overall expectations for TG experimentation (99% capture efficiency) and for smoke release observations (very good, except for the potential for some smoke to escape a corner of the hood) These good results can be explained by the large air mass that is being moved into the VFS in this area Thus, it is the NIOSH position that the VFS provides good protection for the worker at this location, even though air velocity measurements did not meet USPS minimum requirements at the time of testing During the survey, however, it was discussed with the vendor that small adjustments could be made to elevate capture velocities at this location For instance, closing a small gap at the side of the slotted VFS intake of the LMDS Left-Hand Hamper Dump can increase capture velocities at that point

At the SC-2 bypass some smoke did escape at the top of the cart However this condition was adequately modified when the vendor installed a temporary skirt around the cart At the time of the survey the vendor indicated that they would make this modification permanent at both the SC-1 and SC-2 locations

Even though the LL-10 and LL-6 areas were fitted with hooded exhausts, they were completely enclosed It should also be noted that at the bottom of the chutes under LL-10 and LL-6 the mail processing equipment was not enclosed by the 010 Culling System VFS, but these areas would be protected by AFCS VFS when both systems are installed in tandem.

Two areas existed that enjoyed good protection by the VFS but that could also be easily improved by slight modifications to the system. First, at the bottom of the DPRC waterfall areas, some smoke could escape through knock-outs in the side of the DPRC with the introduction of large amounts of smoke (a condition that did not affect the overall good performance of the LEV) Also, a small gap existed in the VFS hood at the side of the slotted intake at the LMDS Left-Hand Hamper Dump VFS performance could be improved here by closing this gap

The results of 2 tests showed poor performance of the LEV underneath the Flats Ejectors (1 and 2) First, smoke escaped from underneath the Flats Ejectors prior to any modifications made by the vendor Also, the area underneath Flats Ejector 1 showed poor TG capture (about 28%) However, immediate and temporary modifications by the vendor greatly improved the performance of the VFS at the Flats Ejectors, and the vendor agreed to rectify the situation for the next survey

TG capture efficiencies of 80% to 94% were measured at the Right-Hand 010 Hand Culling Stations, however smoke release observations at these stations showed very good capture effectiveness It is believed that these relatively low TG capture efficiencies can be improved by balance of the exhaust system by the vendor

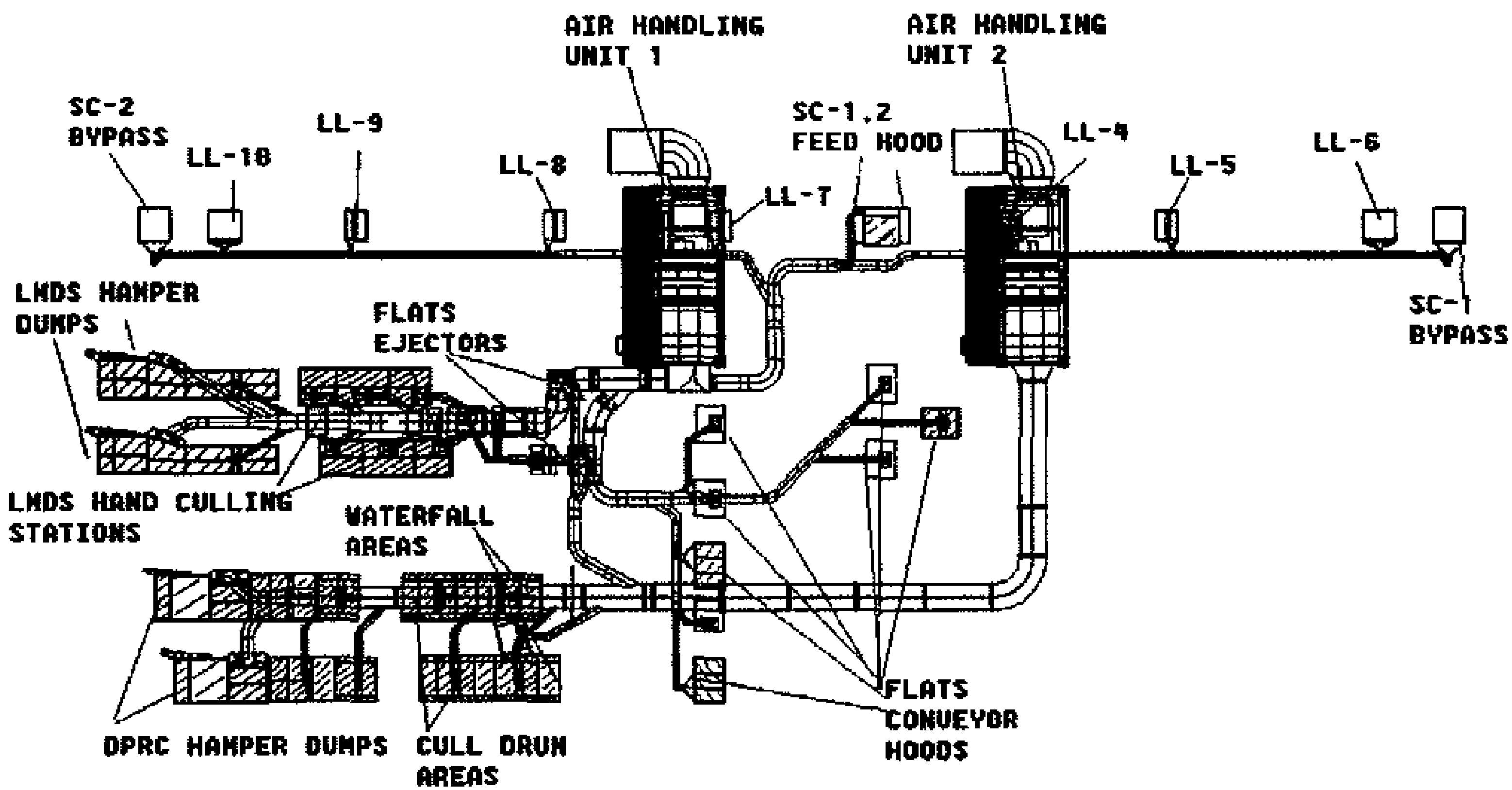
It is believed that TG capture efficiencies in excess of 100% represent complete TG capture and that these values would level off to 100% if test runs were extended or if further testing to investigate this phenomenon were made

RECOMMENDATIONS

Based on the results of the measurements and observations from the survey, the following recommendations are made to further improve the control of potential contaminants by this VFS

- Both Flats Ejectors should be permanently modified to maximize smoke capture and TG capture efficiency
- Although smoke release observations suggest adequate contaminant capture at the Left-Hand 010 Culling System Hamper Dump, it is recommended that the gap to the side of the slotted intake be sealed This action may also increase contaminant capture velocities at the face of the curtain
- USPS Engineering should consider elimination of the exhaust at the LL-10 and LL-6 areas Since these areas are enclosed, workers should be adequately protected as long as the chute underneath is controlled by the AFCS VFS
- Although TG experiments suggest adequate capture efficiencies at the DPRC waterfall area, there are several open knock-outs in walls in this area that should be sealed to maximize VFS effectiveness
- The USPS and its vendors should consider redirection of the exhaust plumes from the air handling units as they may interfere with proper contaminant capture of the 010 Culling System VFS, DPRC VFS and AFCS VFS which are in the plumes
- Proper balance of the Left-Hand side of the LMDS System with the Right-Hand side could alleviate disparities in Hamper Dump contaminant capture velocities and Hand Culling Station TG capture efficiencies
- The skirt added by the vendor during testing to the SC-2 bypass chute should be made permanent, and similar modifications should be made to the SC-1 bypass chute
- To ensure optimal filtration system performance, the USPS and its vendors should take steps to guarantee that filters are changed often enough to be operating within prescribed parameters and that filters are protected from physical damage Moreover, such steps should be taken prior to further testing of filtration system efficiency

- Proper and regular maintenance of the filtration component of the VFS unit is essential for effective filtration Work procedures for maintenance should be designed with this in mind and should be closely followed
- Further testing to investigate why computations for some areas indicate capture efficiency greater than 100% is warranted Therefore, future NIOSH testing should include making individual TG experiments longer in length



OVERVIEW OF 010 LOOSE MAIL CULLING SYSTEM

Table 1 Positions for Tracer Gas Release and Measured Efficiencies

Description of Measurement Location	Efficiency
LEFT HAND LMDS HAND CULLING STATION A (CLOSEST TO HAMPER DUMP)	104%
LEFT HAND LMDS HAND CULLING STATION B	106%
LEFT HAND LMDS HAND CULLING STATION C	106%
LEFT HAND LMDS HAMPER DUMP	99%
RIGHT HAND LMDS HAND CULLING STATION A (CLOSEST TO HAMPER DUMP)	94%, 92%
RIGHT HAND LMDS HAND CULLING STATION B	89%, 90%
RIGHT HAND LMDS HAND CULLING STATION C	80%, 80%
RIGHT HAND LMDS HAMPER DUMP	99%,100%
LEFT-HAND DPRC HAMPER DUMP	101%
RIGHT-HAND DPRC HAMPER DUMP	100%
LEFT-HAND DPRC WATERFALL AREA (BOTTOM OF LETTER DROP)	103%
RIGHT-HAND DPRC WATERFALL AREA (BOTTOM OF LETTER DROP)	101%
SC-2 BYPASS AT BOTTOM OF CART	100%
SC-2 FEED HOOD	97 2%
UNDERNEATH FLATS EJECTOR # 1 (UNIT WITH NO CAPTURE ENHANCEMENTS)	*28%*
UNDERNEATH FLATS EJECTOR # 2 (UNIT WITH SOME ROUGH CAPTURE ENHANCEMENTS MADE BY USPS PERSONNEL)	103%

Table 2 Positions for Smoke Release Observations and Comments

AREA OF RELEASE	COMMENTS
LEFT-HAND LMDS HAMPER DUMP AT BOTTOM OF CONVEYOR	VERY GOOD EVACUATION OF SMOKE IN GENERAL SMOKE CAN ESCAPE THROUGH SMALL GAP IN THE HOOD TO THE LEFT OF THE SLOTTED VFS INTAKE
RIGHT-HAND LMDS HAMPER DUMP AT BOTTOM OF CONVEYOR	VERY GOOD EVACUATION OF SMOKE
LEFT HAND LMDS HAND CULLING STATIONS A, B, C	VERY GOOD EVACUATION OF SMOKE
RIGHT-HAND LMDS HAND CULLING STATIONS A, B, C	VERY GOOD EVACUATION OF SMOKE
LEFT HAND LMDS INCLINE/CC-3 TRANSITION	VERY GOOD EVACUATION OF SMOKE
LEFT-HAND LMDS INCLINE/CC-3 TRANSITION	VERY GOOD EVACUATION OF SMOKE
CC-2/LL-1 HOOD AREA	VERY GOOD EVACUATION OF SMOKE
MX-2 TO MX-3 HOOD AREA	VERY GOOD EVACUATION OF SMOKE
MX-3 TO SP 2 HOOD AREA	VERY GOOD EVACUATION OF SMOKE
LL-2 TO LL-3 HOOD AREA	VERY GOOD EVACUATION OF SMOKE
LL-1 TO LL-3 HOOD AREA	VERY GOOD EVACUATION OF SMOKE
FL-4 TO FL 5 HOOD AREA	VERY GOOD EVACUATION OF SMOKE
FL-2 TO FL-5 HOOD AREA	VERY GOOD EVACUATION OF SMOKE
FL-6 TO LEFT HAND DISCHARGE HOOD AREA	VERY GOOD EVACUATION OF SMOKE
FL-5 TO FL-6 HOOD AREA	VERY GOOD EVACUATION OF SMOKE
FL-6 TO RIGHT HAND DISCHARGE HOOD AREA	VERY GOOD EVACUATION OF SMOKE
SP-2 DISCHARGE HOOD AREA	VERY GOOD EVACUATION OF SMOKE
SC-2 BYPASS (INTO CART) BEFORE ADDITION OF SKIRT TO HOOD	SOME SMOKE ESCAPES AT THE TOP
SC-2 BYPASS (INTO CART) AFTER ADDITION OF SKIRT TO HOOD	VERY GOOD EVACUATION OF SMOKE
LL-10 HOOD AREA	ENCLOSED AT TOP/NO SMOKE TEST MADE
LL-6 HOOD AREA	ENCLOSED AT TOP/NO SMOKE TEST MADE
LL 9 HOOD AREA	VERY GOOD EVACUATION OF SMOKE
LL-8 HOOD AREA	VERY GOOD EVACUATION OF SMOKE
LL-7 HOOD AREA	VERY GOOD EVACUATION OF SMOKE
LL 5 HOOD AREA	VERY GOOD EVACUATION OF SMOKE
SC-2/SC-1 FEED HOOD	VERY GOOD EVACUATION OF SMOKE
RIGHT-HAND DPRC HAMPER DUMP AT BOTTOM OF CONVEYOR	VERY GOOD EVACUATION OF SMOKE
RIGHT-HAND DPRC METERING CONVEYOR	VERY GOOD EVACUATION OF SMOKE
RIGHT-HAND DPRC WATERFALL AREA (TOP OF CONVEYOR)	VERY GOOD EVACUATION OF SMOKE
RIGHT-HAND DPRC WATERFALL AREA (BOTTOM OF LETTER DROP)	SMALL AMOUNT OF SMOKE ESCAPES WITH LARGE BLAST OF SMOKE
LEFT-HAND DPRC HAMPER DUMP AT BOTTOM OF CONVEYOR	VERY GOOD EVACUATION OF SMOKE
LEFT-HAND DPRC METERING CONVEYOR	VERY GOOD EVACUATION OF SMOKE
LEFT-HAND DPRC WATERFALL AREA (TOP OF CONVEYOR)	VERY GOOD EVACUATION OF SMOKE
LEFT-HAND DPRC WATERFALL AREA (BOTTOM OF LETTER DROP)	SMALL AMOUNT OF SMOKE ESCAPES WITH LARGE BLAST OF SMOKE
UNDERNEATH FLATS EJECTOR # 1 (UNIT WITH NO CAPTURE ENHANCEMENTS)	LARGE AMOUNT OF SMOKE ESCAPES VFS EXHAUST
UNDERNEATH FLATS EJECTOR # 2 (UNIT WITH SOME ROUGH CAPTURE ENHANCEMENTS MADE BY USPS PERSONNEL)	SOME SMOKE ESCAPES VFS EXHAUST
UNDERNEATH FLATS EJECTOR # 1 (UNIT WITH CAPTURE ENHANCEMENTS MADE BY VENDOR)	SOME SMOKE ESCAPES VFS EXHAUST
DROP ONTO CONVEYOR BETWEEN DPRC CULL DRUMS	VERY GOOD EVACUATION OF SMOKE
UNDERNEATH DPRC RIGHT-HAND CULL DRUM	VERY GOOD EVACUATION OF SMOKE
UNDERNEATH DPRC LEFT-HAND CULL DRUM	VERY GOOD EVACUATION OF SMOKE

Table 3 Positions for Air Velocity Measurements and Recorded Values

AREA	CONTAMINANT CAPTURE VELOCITY (VALUES OF TRIALS IN FEET PER MINUTE)
LEFT-HAND LMDS HAND CULLING STATION A (AT FACE OF PLASTIC CURTAIN AT VARIOUS LOCATIONS)	131, 145, 123
LEFT-HAND LMDS HAND CULLING STATION B (AT FACE OF PLASTIC CURTAIN AT VARIOUS LOCATIONS)	145, 160, 113
LEFT-HAND LMDS HAND CULLING STATION C (AT FACE OF PLASTIC CURTAIN AT VARIOUS LOCATIONS)	143, 127, 163
RIGHT-HAND LMDS HAND CULLING STATION A (AT FACE OF PLASTIC CURTAIN AT VARIOUS LOCATIONS)	122, 183, 139
RIGHT-HAND LMDS HAND CULLING STATION B (AT FACE OF PLASTIC CURTAIN AT VARIOUS LOCATIONS)	167, 167, 141
RIGHT-HAND LMDS HAND CULLING STATION C (AT FACE OF PLASTIC CURTAIN AT VARIOUS LOCATIONS)	160, 148, 144
LEFT-HAND LMDS HAND CULLING STATION A (AT FACE OF PLASTIC CURTAIN AT VARIOUS LOCATIONS)	131, 145, 123
LEFT-HAND DPRC HAMPER DUMP (AT FACE OF PLASTIC CURTAIN AT VARIOUS LOCATIONS)	TRIAL 1 121, 166, 138 TRIAL 2 84, 151, 124
RIGHT-HAND DPRC HAMPER DUMP (AT FACE OF PLASTIC CURTAIN AT VARIOUS LOCATIONS)	TRIAL1 153, 115 TRIAL 2 102, 152, 119
LEFT-HAND LMDS HAMPER DUMP (AT FACE OF PLASTIC CURTAIN AT VARIOUS LOCATIONS)	TRIAL 1 74, 87, 68 TRIAL 2 61, 88, 83
RIGHT-HAND LMDS HAMPER DUMP (AT FACE OF PLASTIC CURTAIN AT VARIOUS LOCATIONS)	TRIAL 1 102, 92, 100 TRIAL 2 74, 99, 97

Table 3 Filtration Efficiencies at Air Handling Units 1 & 2

Ventilation Unit	Particle Size Range							
	0.3-0.4 µm	0.4-0.5 µm	0.5-0.65 µm	0 65-0.8 µm	0.8-1.0 µm	1.0-1.6 µm	1.6-2.0 µm	2.0-3.0 µm
Merrifield # 1 Before Processing 10/15	99 998	99 994	>99 999	>99 999	>99 999	>99 999	>99 999	>99 999
Merrifield # 1 During Processing 10/15	99 997	99 995	99 994	>99 999	>99 999	>99 999	>99 999	>99 999
Merrifield # 2 Before Processing 10/15	99 996	99 992	99 998	>99 999	>99 999	>99 999	>99 999	>99 999
Merrifield # 2 During Processing 10/15	99 995	99 989	>99 999	>99 999	>99 999	>99 999	>99 999	>99 999
Merrifield # 1 Before Processing 10/17	99 999	99 999	99 996	>99 999	>99 999	>99 999	>99 999	>99 999
Merrifield # 1 During Processing 10/17	99 998	99 995	99 995	>99 999	>99 999	>99 999	>99 999	>99 999
Merrifield # 2 Before Processing 10/17	99 999	99 999	>99 999	>99 999	>99 999	>99 999	>99 999	>99 999
Merrifield # 2 During Processing 10/17	>99 999	>99 999	>99 999	>99 999	>99 999	>99 999	>99 999	>99 999