IN-DEPTH SURVEY REPORT:

EVALUATION OF VENTILATION AND FILTRATION SYSTEM FOR DELIVERY BAR CODE SORTER

at

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

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ABSTRACT

Researchers from the National Institute for Occupational Safety and Health (NIOSH) conducted evaluations of a Ventilation and Filtration System (VFS) for the United States Postal Service's Delivery Bar Code Sorter (DBCS) The VFS was designed by the manufacturer of the DBCS to reduce operator exposure to any potentially hazardous contaminants emitted from letter mail during normal mail processing Evaluations were conducted at the Dulles, Virginia Processing and Distribution Center (P&DC) during two separate field surveys Survey 1 took place on January 23, 2002 and Survey 2 took place on March 20, 2002

Evaluations were based on a variety of tests including particle count measurements, air velocity measurements, smoke release observations and tracer gas experiments Testing indicated the following regarding DBCS locations targeted by the VFS

- At the Vibrator Module, capture efficiency ranges from about 89% to 99% under normal working conditions
- At the Feeder Table, efficiency is about 76% under normal conditions
- The Feeder Module has capture effectiveness of about 99%
- At the Stacker Modules, efficiency ranges from about 97% to 99%
- With overhead ceiling fans on, there is some evidence that the VFS efficiency marginally decreases at the Stacker Modules, Vibrator Module and Feeder Table

Based on these results and others discussed in this report, the following recommendations are suggested regarding the VFS

- The contaminant capture velocity at the Vibrator Module should be increased to a level that makes its efficacy comparable to that of the Feeder Module and Stacker Module
- The contaminant capture velocity at the Feeder Table should be increased to at least 100 feet per minute
- The VFS exhaust slots at the Vibrator Module and Feeder Table should be moved to a height above the tallest envelope to ensure unobstructed contaminant capture
- Revision of the inlet area for the top row of Stacker Modules should be made to ameliorate the effects of ceiling fans on ambient air currents
- More testing should be done regarding the decay rate of smoke from areas under cabinet hoods since access to these hoods to clear jams is a frequent occurrence

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

This is the first report of a project to evaluate controls that are being put in place by the United States Postal Service (USPS) to prevent the release of contaminants into the work area of postal employees A number of mail processing machines are being considered for ventilation controls, and EPHB researchers have been invited to evaluate the performance of the Ventilation and Filtration System (VFS) on the Delivery Bar Code Sorter (DBCS)

BACKGROUND

Researchers from the National Institute for Occupational Safety and Health (NIOSH) were requested to assist the USPS in the evaluation of particulate controls for various mail processing equipment These new controls are being installed to reduce operator exposure to any potentially hazardous contaminants emitted from letter mail during normal mail processing This effort is driven by the recent 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 various mail-processing machinery in operation and to study the effectiveness of the newly designed controls

The particular control evaluated in this report is a Ventilation and Filtration System (VFS), designed and installed by the Delivery Bar Code Sorter (DBCS) manufacturer to reduce operator exposure to potential biological or chemical contaminants contained in the mail The VFS was evaluated at the Dulles, Virginia Processing and Distribution Center (P&DC) during two separate field surveys Survey 1 took place on January 23, 2002 and Survey 2 took place on March 20, 2002

HAZARDS TO POSTAL EMPLOYEES

The bacterium *bacillus anthracis* is a spore forming bacterium, with spores typically in the size range 1-5 µm Disease caused by anthrax manifests in one of three ways inhalational, cutaneous, and gastrointestinal [1] Recent cases resulting from terrorist attacks in which anthrax spores have been sent by mail to a U S Senator and to media offices have been both inhalational and cutaneous The cutaneous form of the disease generally develops 2-5 days following exposure and is usually successfully treated with antibiotics The onset for the inhalational form is typically 1-6 days after exposure and has a high fatality rate even with appropriate treatment Exposure to anthrax spores by postal employees working in a mail processing facility that serves the U S Capitol resulted in inhalational disease in several of the workers [2] One potential area of exposure is the automated mail processing equipment used to sort incoming mail As the mail passes through the machinery, it is compressed and impacted in a number of places that could cause the release of substances from the mail

DESCRIPTION OF EQUIPMENT

The Delivery Bar Code Sorter (DBCS) is a multilevel, high speed bar code sorter capable of processing bar coded mailpieces at an average rate of 35,000 mailpieces per hour This equipment can process mail between the dimensions of 3 5 inches by 5 inches and 6 125 inches by 11 5 inches [3] The DBCS unit that was retrofitted with a VFS consisted of a Vibrator Module, Feeder Table, Computer System, Feeder Module, Transport Module, Reader Module and multiple Stacker Modules Observed treatment of the mail through the system is described below A schematic of the DBCS is shown in Illustration 1

- Containers full of mail are taken from a large material handling cart behind the operator and placed or dumped onto either the Vibrator Module or the Feeder Table The purpose of the Vibrator Module is to settle the mail into the best position for acceptance by the Feeder Module An on-off switch, controlled by the worker, operates the Vibrator Module The Vibrator Module is sometimes bypassed when the mail is already well oriented for intake into the Feeder Module

- Following the Vibrator Module is a Feeder Table, which serves as a buffer for mail moving into the Feeder Module

- The Feeder Module is the first place at which mailpieces are conveyed through pinch rollers It is here that the greatest potential exists for discharge of dust into the ambient air, as mechanical forces of the pinch rollers can be as much as 22 pounds

- From here mail is automatically conveyed to the Reader Module by means of the Transfer Module The Reader Module collects address data for routing of mail to the Stacker Modules Both of these modules incorporate moving belts, rollers and route-switching gates to control mail movement

- Once mail has been conveyed to the Stacker Modules, it is fed into individual bins The mail piece experiences high deceleration as it is stopped in the bin An auger provides a constant, low mechanical force to the last letter in the bin

- Another worker is responsible for manually moving sorted mail from the Stacker Module bins into appropriate containers for further processing

DESCRIPTION OF CONTROL

The VFS has been designed and installed for the DBCS by the DBCS manufacturer The VFS was designed to reduce emission of biological contaminants such as spores of *B anthracis* into the ambient atmosphere through use of local exhaust ventilation (LEV) and air filtration units Additionally, the VFS was designed to reduce machine down time and maintenance caused by paper dust accumulation

Filtration System

The VFS manufacturer claims that the filtration system of the VFS will remove particles as small as 0 5 micron with an efficiency of 99 999% and particles as small as 0 3 microns with an efficiency of 99 97% with a combination of standard filtration and high-efficiency particulate air (HEPA) filters According to the manufacturer, the primary filter cleans itself automatically and needs to be changed every 1 to 1 5 years, while the HEPA (secondary) filters must be changed about every 3 to 4 5 years Moreover, the manufacturer states that the filtration unit generates noise to a level of about 80 dBA at five feet from the floor at a distance of one foot from the platform edge of the filtration unit The floor space required for the Collection, Vacuum and Filtration Unit is about 6 ft by 10 ft

Dust Collection Unit

The manufacturer's strategy for dust collection was, in part, to modify access covers of the machines in order to totally or partially enclose the source of contaminant and control the direction of airflow into the machine Prior to Survey 1, areas that were targeted for dust collection were the Stacker Module, Transport Module, Reader Module, Vibrator Module, Feeder Table and Feeder Module The Vibrator Module and Feeder Table were not yet modified for dust collection by the manufacturer before Survey 1, so additional evaluations of control effectiveness at the Vibrator Module and Feeder Table were conducted during Survey 2

Letter transport locations such as the Transport Module and Feeder Module were fitted with vented covers, where needed, to surround dust-emitting areas In applicable Transport Module locations, turbulent induction methods were used to prevent dust particles from settling

In the Stacker Modules, clear, polyvinyl slitted curtains were installed to reduce airflow area and increase capture velocities, as well as to reduce sound emissions while permitting worker access to remove mail The rear doors of the Stacker Modules, not accessed during normal operation, were fitted with slotted plenum structures to more evenly distribute the flow of air at the front, working side of the module

METHODS

AIR VELOCITY MEASUREMENTS

Velocity measurements were taken using a Velocicalc Air Velocity Meter (TSI, Incorporated, Shoreview, MN) Measurements were taken at exhaust inlets to the DBCS, including at the Feeder Module and Stacker Modules

PARTICLE COUNT EXPERIMENTS (*Survey 1*)

Since NIOSH had previously used particle count methods to evaluate LEV at the Internal Revenue Service, it was decided to try to use these methods to evaluate the LEV at the USPS Two particle count methods were used as follows

1 POWDER-SPIKED ENVELOPE EXPERIMENTS

Experiments were made to simulate the release of anthrax into the DBCS and work zone by using regular business envelopes containing powder provided by USPS Engineering A bright orange, fluorescent powder (Day-Glo Color Corp , PN FT-15-N) was placed inside a standard business envelope along with an 8 5 in by 11 in sheet of copy paper that was folded in thirds The folded paper was used to create a pocket of air, as is present in most mailpieces, that would aid in the dispersal of the powder when a mechanical force was applied to the envelope It should be noted that no precise effort was made to measure the amount of powder put in the envelopes, although similar amounts of the powder were placed in each Likewise, no attempt was made to regulate the amount of powder emitting from the envelopes upon application of force as there is currently no known available method for doing so

For each experimental run, one to three powder-filled envelopes were placed into test mail at the Feeder Table before the Feeder Module Twenty-one powder-filled envelope experiments were conducted Data were collected simultaneously from particle counters located in four different places for these experiments at the Feeder Module (Met One Hand-Held Particle Counter, Model # 227, Met One, Incorporated, Grants Pass, OR), the computer system directly behind the Feeder Table (Met One), and approximately in the breathing zone of the worker at the Stacker Module Bins 1 and 8 (Grimm Technologies Particle Size Analyzers, 1100 Series, Grimm Technologies, Incorporated, Douglasville, GA)

2 REGULAR MAIL EXPERIMENTS

Particle count experiments were also made with regular mail (i e , not with envelopes spiked with powder) The procedure for these experiments was simply to compare particle count values with the control on to particle count values with the control off In all, 10 experiments were made (5 control-off and 5 control-on) The locations of monitoring and particle size distributions analyzed were identical to those of the spiked-letter experiments These were of much longer duration than the powder-spiked envelope experiments, lasting between three and eight minutes

For both the powder-filled envelope experiments and for regular mail experiments, data for Stacker Module Bins 1 and 8 were based on particle counts of the 1 to 5 micron size This range of particle diameters was selected for analysis because it matches the diameter range of the target contaminant, anthrax Data for the Feeder Module and Computer System locations were based on particle counts in the > 1 micron range, this range of particle diameters was selected because it was the available choice most closely approximating anthrax

For the calculation of control effectiveness, the median particle count value in each trial was used For trials carried out during runs of regular mail, the 95th percentile particle count value was also used in efficiency calculations to characterize effectiveness at extremes For either response variable, ratios were used to estimate reduction due to the control-on compared to control-off For the powder-filled envelope experiments, these experiments were intended to see if the peaks associated with powder-filled envelopes in the control-off environment were distinguishable from peaks in the control-on environment Also, the data were to provide a basis for comparing the average value of the control-off trials with that of the control-on trials

SMOKE RELEASE OBSERVATIONS (Survey 2)

Smoke was released at all gaps in the machine chassis, where internally released aerosol might escape into the workroom environment Qualitative observations centered on determination of how quickly and effectively the control captured smoke generated For example, if the smoke was captured quickly and directly by the exhaust system, it was a good indication of acceptable control design and performance However, if the smoke was slow to be captured when released at a certain point, or took a circuitous route to the exhaust inlet, the ventilation system design was considered marginal at that location These observations were aided by the use of a focused, high-intensity light source

Smoke was generated where mechanical forces from the machine are greatest and where potential contaminant release is furthest away from the control's exhaust, these are locations where the greatest potential for release of contaminant into the workroom environment At the Vibrator Module and Feeder Table, the smoke was released at a point where contaminant would be released from the corner of a business envelope furthest away from the control, 5 in from the slot and 3 5 in from the top of the module surface At the Feeder Module, the smoke was released at several pinch points where mechanical forces are the greatest, including the set of pinch rollers closest to the face of the control's exhaust At the Stacker Modules, each row was tested (rows 1-4) at every Stacker Module (modules 1-12) for a total of 48 observations Smoke for each one of these observations was directed at the area between the tail end of the mail piece and the deceleration pad at the adjacent stacker bin

Also, smoke was introduced inside the machine at the Feeder Module and Reader Module to observe the dynamic behavior of the ventilation control system For example, the DBCS was filled with smoke inside the cover at the Feeder Module and then the cover was opened to make observations regarding the rate at which smoke evacuated the machine

TRACER GAS EVALUATIONS (Survey 2)

By releasing a tracer gas (TG) at a constant rate where contaminant control is desired, and by measuring the corresponding TG concentration downstream inside the exhaust duct, a quantitative measure of control efficiency can be made The first step was to release the TG inside the duct to find the concentration C100 corresponding to 100% capture, this was done before and after other TG experiments were made Then, when the TG was released at a point near the Feeder Module, for example, resulting in a concentration C in the duct, the capture efficiency at the feeder point was calculated as C/C100 While the exhaust air carrying the TG should ideally be released outside to eliminate an increase of the background level of TG, experimentation in a large room such as the one containing the DBCS should not significantly increase the background concentration during testing For these experiments, 100% sulfur hexafluoride was used as the tracer The instrument used to detect the sulfur hexafluoride was a Miran 203 Specific Vapor Analyzer (The Foxboro, Company, Foxboro, MA)

In each TG trial, one minute was allowed for the concentration to equilibrate before average concentrations were determined Because the C100 values appeared to drift during the study, the maximum of each trial was usually used as the C100 value for that trial Exceptions were in trials 3 ,4 and 5 (Vibrator Module and Feeder Table), in which the average C100 value over other trials was used for efficiency calculations The numerator of the efficiency determinations was the mean of the trial values In addition, a measure of variability was computed for each trial – the interquartile range, the difference between the 75th and 25th percentiles [4]

At the far right side of the Vibrator Module, TG was released at points corresponding to the top-outer corner, top-inner corner and bottom-inner corner of a standard business envelope At the far left side, TG was released at the top-outer corner of a standard business envelope At the Feeder Table, TG was released near the center of the module at a point matching the top-outer corner of a standard business envelope Here, the Feeder Table was loaded with test mail to more accurately simulate working conditions At the Feeder Module, TG was released at the first pinch rollers, and at points corresponding to the top and bottom-outer corners of a standard business envelope For Feeder Module experiments, test mail was on the adjacent Feeder Table to simulate regular working conditions At all Stacker Module locations, the TG was released at a point halfway between the top and bottom corners of a standard business envelope on the left side Moreover, one envelope was placed in each Stacker Module bin to simulate standard working conditions Stacker Module locations tested were at bins 4-7 (Stacker 1), bins 84-87 (Stacker 6) and bins 179-182 (Stacker 12) These stacker locations represented all four rows of bins at the far left, center and far right of the bank of Stacker Modules

Also, TG was introduced inside the machine at the Feeder Module, Transport Module and Reader Module to quantify the dynamic behavior of the ventilation control system To this end, the DBCS was filled with TG for a period of 2 minutes inside the cover at each of these 3 locations Directly afterward, the cover was opened, the TG was removed from the module at a distance of about 20 yards and TG levels were recorded downstream by the Miran 203 Specific Vapor Analyzer for a period of 2 minutes These recorded TG levels were subsequently used to characterize the dynamic behavior of the control system It should be noted that when the cover was opened and the TG was removed from the modules for these dynamic behavior experiments, the TG was not simply turned off, but was taken a distance away from the control This method of removing the TG from the modules was employed due to concern that turning off the TG would affect the flow rate for subsequent TG experiments

RESULTS

PARTICLE COUNT MEASUREMENTS

1 POWDER-SPIKED ENVELOPE EXPERIMENTS

It turned out that the comparison of the of maximum values for each control-off experiment indicated no statistical difference between the maximum values when powder-filled envelopes were sent through versus when only regular mail was processed The data taken at the two Stacker Modules were studied extensively, since it was possible to study a restricted particle size range, from one to five microns At these locations, the difference were not statistically significant, and in practical terms, the differences were quite small For instance, for Stacker Module 1 the average difference between the maximum values when powder-filled envelopes were sent through versus when only regular mail was processed was less than 10%

2 REGULAR MAIL EXPERIMENTS

Based on these trials, the point estimates of particulate reduction with the LEV on compared to LEV off (Table 1) was computed to be about 99 5% at the Feeder Module, 56% at the computer, 45% at Stacker Module 1 and indeterminate for Stacker Module 8 The control system was capturing particles at a high efficiency at the Feeder Module, but the efficiency of the control was reduced at other locations This can be attributed to the high variability of data at certain locations and inconsistency of data in different trials Based on the variability of the data, the use of other test methods were recommended, which led to the use of Smoke Release Observations and Tracer Gas experiments for Survey 2

AIR VELOCITY MEASUREMENTS

Air velocity measurements were made at the entrance to the Feeder Module and at various locations at the Stacker Module Results are given below

Location	Meaurement 1 *(feet per minute)*	Meaurement 2 *(feet per minute)*	Meaurement 3 *(feet per minute)*
Entrance to Feeder Module	600	525	450
Stacker Bin 4	58		
Stacker Bin 5	56		
Stacker Bin 6	38		
Stacker Bin 7	36		
Stacker Bin 12	64		
Stacker Bin 13	46		
Stacker Bin 14	37		
Stacker Bin 15	24		
Stacker Bin 20	45		
Stacker Bin 21	57		
Stacker Bin 22	30		
Stacker Bin 23	25		
Stacker Bin 68	72		
Stacker Bin 69	80		
Stacker Bin 70	54		
Stacker Bin 71	50		
Stacker Bin 100	54		
Stacker Bin 101	78		
Stacker Bin 102	63		
Stacker Bin 103	46		
Stacker Bin 108	73		
Stacker Bin 109	81		
Stacker Bin 110	74		
Stacker Bin 111	49		
Stacker Bin 175	32		
Stacker Bin 176	38		
Stacker Bin 177	31		
Stacker Bin 178	19		
Stacker Bin 183	34		
Stacker Bin 184	34		
Stacker Bin 185	39		
Stacker Bin 186	22		

SMOKE RELEASE EXPERIMENTS

Smoke Release experiments showed the following results regarding the capture efficiency of the VFS

- Smoke release experiments clearly corroborated earlier findings that the control is highly effective at the Feeder Module When smoke was introduced into the opening, where a burst of particles would probably originate, all visible smoke was quickly carried away by the exhaust system
- At the Vibrator Module, smoke release experiments showed marginal results The large smoke cloud was only partially captured at this location and, moreover, smoke capture worsened as the generation point moved away from the control's intake slot
- At the Feeder Table, smoke capture was minimal, most of the generated smoke diffused into the ambient atmosphere rather than entering the exhaust slot
- At the Stacker Modules, smoke release experiments were uniform for all locations The rate of capture at all locations was not as high as at the Feeder Module but was uniformly adequate to keep smoke from entering the workroom environment Moreover, the smoke was eventually entirely captured by the control at all locations The only exception to these observations was during times when the ceiling fan was running when the cloud of smoke was not entirely entrained into the control for the top row of bins at stackers directly under the ceiling fans (Figure 2)
- Smoke release experiments were conducted under the door of the Feeder Module and Reader Module to determine the decay rate of visible smoke from covered areas that are frequently opened by the operator to clear jams inside the machine In the Feeder Module, visible smoke was evacuated in less than 5 seconds and in the Reader Module it took more than 15 seconds

TRACER GAS EXPERIMENTS

At the Vibrator Module, point estimates of the efficiency ranged from about 89% to 99% Specifically, the efficiency of the control at the far right of the Vibrator Module was 97% when the TG was placed at a location corresponding to the top-outer corner of a standard business envelope (Figure 2) Also, at the far right of the Vibrator Module, the efficiency was 99% when the TG was placed in a position corresponding to the top-inner corner of a standard business envelope and 92% when the TG was placed at a location corresponding to the bottom-outer corner of a standard business envelope When the TG was placed at the far left of the Vibrator Module and at a position corresponding to the top-outer corner of a standard business size envelope, the control's efficiency was 89%

Variability is another important aspect of the TG data measured at the Vibrator Module locations Clearly as the tracer gas is moved away from the slot, the efficiency not only decreased but was also much more inconsistent (Figures 3 and 4) The interquartile ranges for the trials further from the slot were statistically distinguishable (larger) from those closer to the slot (Table 2)

At the Feeder Table, the TG indicates that the efficiency was about 76% This value indicates that the control was most ineffective at this location, which is supported by qualitative observations made at this location during the smoke release experiments In addition, the interquartile range was larger than the majority of the trials

Efficiencies of 99% were observed for all tested locations at the Feeder Module The efficiency of the system at the Stacker Modules is quite consistent at each location tested and shows a range of 97 3% to 99 4% (Table 2) Experiments were also made at the Feeder Module, Transport Module and Reader Module to estimate the attenuation rate of TG from the system once doors were open These results are shown in Figures 5-7

DISCUSSION AND RECOMMENDATIONS

FEEDER MODULE

Data collected from spiked-envelope experiments and regular mail experiments during the January 2002 survey clearly indicate that the control is efficient at the Feeder Module intake (Table 1) This determination is supported also by observations made during the smoke release experiments and TG experiments (Table 2) With capture rates in the 99% range, the LEV is most effective at the Feeder Module location

It should be noted that no experiments were made to determine the efficacy of the control at the Feeder Module with the cover open During Survey 2, it was noted by USPS maintenance personnel that operators frequently find the cover an obstruction and leave the cover open while running mail This situation would theoretically cause a significant decrease in the control's effectiveness at this location Control at this location is critical since pinch rollers exert about 22 pounds of mechanical force on the envelopes in close proximity to the operator's work zone at the Feeder Module inlet It is recommended that a determination be made whether the cover does, indeed, obstruct proper operation of the DBCS Follow-up to such a determination could include training on the use and benefits of the DBCS with a control, alteration of the cover, or alteration of standard operating procedures at this location

VIBRATOR MODULE

Due to the imprecision of the data from particle count experiments and because the VFS was changed significantly at the Feeder Table and Vibrator Module following Survey 1, discussion of LEV effectiveness at these locations is solely based on data collected during Survey 2

Smoke release data suggest that the control at the Vibrator Module is not as effective as it is at other locations, such as the Stacker Modules or Transport Modules This conclusion is based on the observation that some smoke visibly escaped into the workroom environment during observations at the Vibrator Module (Figure 8) TG experiments substantiate this conclusion since the LEV efficiency at the Vibrator Module was estimated to be as low as 89 4% at the point where a corner of a standard business-size envelope is furthest away from the slot

Comparatively, at the Stacker Modules, the LEV efficiency estimated by the TG experiments was at least 97% and at least 98 8% at the Feeder Module

Unfortunately, the amount of biological contaminant that could escape from an envelope is dependent on the amount contained in the envelope and other factors such as the porosity of the envelope material, how well it is sealed, etc Also, the threshold limit of a contaminant that could cause illness is unknown as it will vary for each worker Therefore, determination of how efficient the control should be at the Vibrator Module is uncertain, at best It is recommended, however, that the capture velocity at the Vibrator Module be increased to a level that makes its efficacy comparable to that of the control at the Feeder Module and Stacker Modules There are several reasons for this recommendation First, it seems reasonable to expect the vendor to create a consistent capture capability across the entire work zone of the operator, and as smoke release experiments and TG experiments indicate, this is not the case at the Vibrator Module Furthermore, special care should be taken to protect the operator from biological contaminants here because of the mechanical forces placed upon letters while being vibrated

Local exhaust ventilation design principles predict that a control becomes less effective at points further away from the intake slot of the control This is consistent with our field study, since the control was only 89 4% effective when TG was released at a point corresponding to the corner of a business envelope farthest away from the slot Since it is just as likely for biological contaminant to be released at this point as any other, it is recommended that the system be designed to create a capture velocity here (5 inches away from the slot and 3 5 inches above the table) that is comparable to capture velocities of modules with efficiencies in the high 90% range It is also recommended that the position of the slot be above the level of envelopes so that the slot is not blocked during normal operating procedures

FEEDER TABLE

As mentioned in the discussion of the Vibrator Module above, discussion of the control at the Feeder Table is limited to smoke release and TG experiments made during Survey 2 Observations made during the smoke release experiments indicate not only that little smoke was being captured by the control but also that this was the weakest link in the control system TG experiments substantiate these observations in that only 76% capture efficiency was observed at the Feeder Table

Recommendations for a capture velocity at the furthest theoretical source of contaminant are more difficult to specify for the Feeder Table First, mechanical agitation at this location is much less than at the Feeder Module, Vibrator Module or Stacker Module Moreover, varying operating procedures make a clear recommendation difficult, during NIOSH observations some operators flipped entire trays of mail onto the Feeder Table with much force, while some operators placed the mail onto the Vibrator Module and gently moved the mail to the Feeder Table with little agitation According to the Industrial Ventilation Manual, which makes recommendations for capture velocities based on a variety of conditions, for cases in which the contaminant is released with practically no velocity into quiet air, the recommended minimum capture velocity is 100 fpm However, where the contaminant is released at low velocity into moderately still air, the recommended capture velocity is 200 fpm [5] Based upon these recommendations and observed conditions at the Dulles PD&C, we recommend a capture velocity at the furthest point of contamination along the boundary of the largest piece of mail to be no less than 100 fpm at the Feeder Table Furthermore, it is strongly recommended that the exhaust slot at the feeder table be higher than the letters that rest up against it, which is currently not the case In the event that an entire tray full of letters is dumped onto the Feeder Table, a condition frequently observed, letters would cover a large portion of the slot, and the efficacy of the control would be adversely affected

STACKER MODULES

Estimates of the control's efficiency at the Stacker Modules based on the dust-spiked letter experiments and regular mail experiments range from negative to 60% It should be noted, however, that determination of reduction ratios in these experiments are a *minimum* estimate and that actual reduction of contaminant directly affected by the control could be significantly higher There are several reasons that the experiments conducted during Survey 1 were inadequate to determine the total capture efficiency of the control First and foremost, we were unable to consistently generate enough particle dust in the powder-filled envelope experiments to be discernable from background dust at Stacker Modules 1 and 8 Furthermore, rises in particle counts at Stacker Modules 1 and 8 that were not from the powder-filled envelopes confounded more precise data analysis Such rises can be explained by worker activity in the vicinity of the particle counting instruments, just working with mail seems to generate enough dust to match or exceed that generated by mechanical forces on the powder-laden envelopes

Because of this situation, among others, it was decided that LEV effectiveness should be re-evaluated at the Stacker Modules with TG and smoke release experiments Indeed, these methods did provide a much more solid basis for evaluation at the Stacker Modules Results of the smoke release experiments show that the control is effective at keeping a simulated contaminant out of the breathing zone of the worker during normal operating conditions Also, TG experiments support the observation that under normal conditions at least 98 3% of the TG is eventually being entrained into the exhaust

When the overhead fan was turned on, however, some of the smoke did escape into the area, especially when the smoke was released on the top row of bins TG experiments with the overhead fans on somewhat contradict smoke release experiment observations that contaminant may be escaping when released under the ceiling fan On the top rows of bins, the TG experiments still show a TG capture of 98 3% One explanation for this discrepancy is that, with the fan on, the relatively high release velocity of the smoke compared to the TG, makes it more likely for the smoke to exit the control's exhaust, thus making smoke release observations more susceptible to ambient air currents A contradictory explanation of why TG capture rates at the top rows of Stacker Modules remain high, while smoke experiment observations indicate incomplete capture, is that even though the TG may be blown away from the exhaust system temporarily, it may be recaptured later at a different location in the system Therefore, since the use of these fans may be unpredictable, it might be prudent to revise the inlet area for the top row of stackers so that the draft from the fan does not pull air out of the capture region

TG AND SMOKE ATTENUATION EXPERIMENTS

Smoke release experiments made in the Feeder Module indicate that if a biological contaminant were to be released under the hood and a worker were to immediately walk over to open the cover to clear a jammed piece of mail, it would take at least 5 seconds from the time of release for the area to be cleared of the majority of the contaminant Therefore, as long as it takes at least 5 seconds to get to the cover and open it, the majority of the contaminants would have been removed (new contaminants could not have been introduced since jammed mailpieces stop the machine) Similarly, if release took place at the Reader Module, it would take at least 15 seconds for the contaminant to be evacuated from the area Therefore, a delay on the part of the operator is suggested before opening the doors of the Reader Module TG attenuation experiments only support these smoke release observations to a certain degree Although the TG is evacuated from the Feeder Module at a faster rate than at the Reader Module, there is still a large percentage of TG that appears to remain in the system several minutes after the TG is removed Although no clear explanation exists as to why this should be true, accumulation of the TG in downstream portions of the ventilation system might be responsible for the TG data Conclusions drawn from these experiments are therefore somewhat uncertain It is recommended that additional testing be done to determine the time needed to evacuate covered areas that are frequently opened to clear jams

REFERENCES

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2 Mayer, Thom MD, et al Clinical Presentation of Inhalational Anthrax Following Bioterrorism Exposure JAMA 286(20) 2549-2553 2001

3 USPS Domestic Mail Manual

4 Mosteller, F and Tukey, J W , Data Analysis and Regression, a Second Course in Statistics, Addison-Wesley, Reading, MA, 1977, P 207

5 Industrial Ventilation Manual American Conference of Governmental Industrial Hygienists Cincinnati, Ohio 2000 Page 3-6

Table 1

Particle Count Experiments-Regular Mail

Estimated Reductions for Various Locations & 95% Individual Lower Confidence Limits
For > 1 micron at Feeder Module and Computer System
Between 1 and 5 microns for Stacker Modules 1 and 8
(Pairs (control-on, control-off) treated as fixed)

Location	Points Deleted	Capture Efficiencies Based on Median Value of Trials (LCL)	Capture Efficiencies Based on 95th Percentile Value of Trials (LCL)
Feeder Module	None	**99.5** (99 3)	99 0 (93 0)
	1st 10 values in trial	99 5 (99 4)	99 1 (93 8)
Computer	None	**56** (22)	52 (26)
	1st 10 values in trial	60 (26)	62 (41)
Stacker Module 1	None	45 (27)	59 (28)
	1st 10 values in trial	52 (26)	60 (33)
Stacker Module 8	None	**-6**	-31
	1st 10 values in trial	1 2	-29

Table 2
TG Experiment Efficiencies

Experiment	Efficiency Point Estimates*	Experiments with Same Letter Have Efficiencies That Are Not Different at the 95% Confidence Level	Inter-quartile Range (ppm)	Experiments with Same Letter Have Inter-Quartile Ranges That Are Not Different at the 95% Confidence Level	Location
1	0.97	B	0.103	B	Vibrator Mod -right/top-out
2	0.994	B	0.015	B	Vibrator Mod -right/top-in
3	0.916	D	0.177	C	Vibrator Mod -right/bottom-out
4	0.894	D	0.182	C	Vibrator Mod -left/top-out
5	0.76	C	0.15	C	Feeder Table
6	0.99	B	0.039	B	Feeder Module Inlet
7	0.99	B	0.018	B	Feeder Module
8	0.988	B	0.059	B	Feeder Module
9	0.993	B	0.022	B	Stacker 1-bin 4
10	0.984	B	0.076	B	Stacker 1-bin 5
11	0.985	B	0.095	B	Stacker 1-bin 6
12	0.973	B	0.052	B	Stacker 1-bin 7
13	0.993	B	0.036	B	Stacker 6-bin 84
14	0.994	B	0.022	B	Stacker 6-bin 85
15	0.991	B	0.049	B	Stacker 6-bin 86
16	0.994	B	0.013	B	Stacker 6-bin 87
17	0.993	B	0.02	B	Stacker 12-bin 179
18	0.985	B	0.059	B	Stacker 12-bin 180
19	0.994	B	0.024	B	Stacker 12-bin 181
20	0.984	B	0.062	B	Stacker 12-bin 182
21	0.983	B	0.045	B	Stacker 6-fan on
22	0.987	B	0.054	B	Stacker 1-fan on
23	0.985	B	0.069	B	Vibrator Mod -fan on
	*for runs 3-5 100% value based on average values for runs 1,2,6-15				
	* for other runs, 100% values are each experiment's maximum values				

Delivery Bar Code Sorter (DBCS)

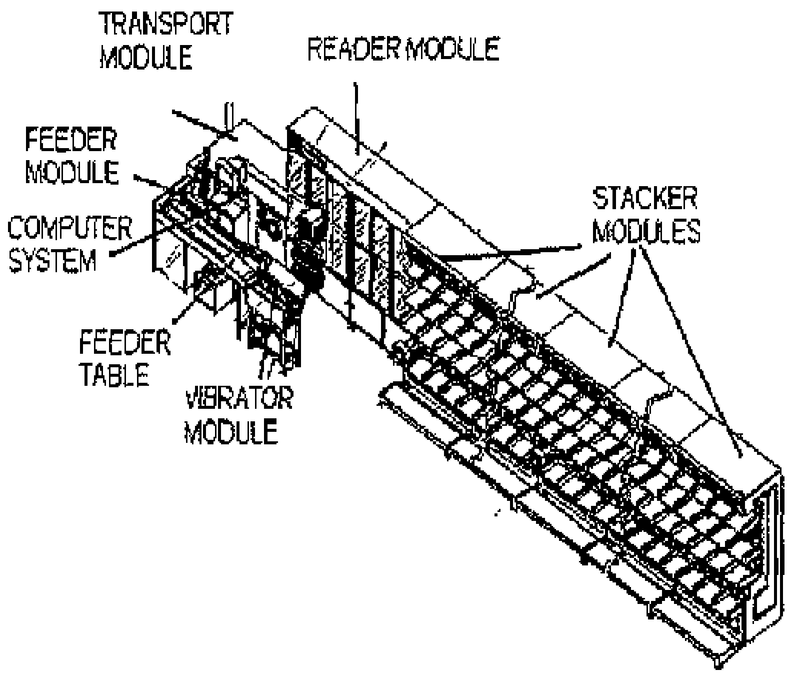

Figure 1. Picture of Smoke Release Experiment at Stacker Module. Note that at the top level of bins, the smoke is escaping past the plastic curtains when the overhead ceiling fan is on

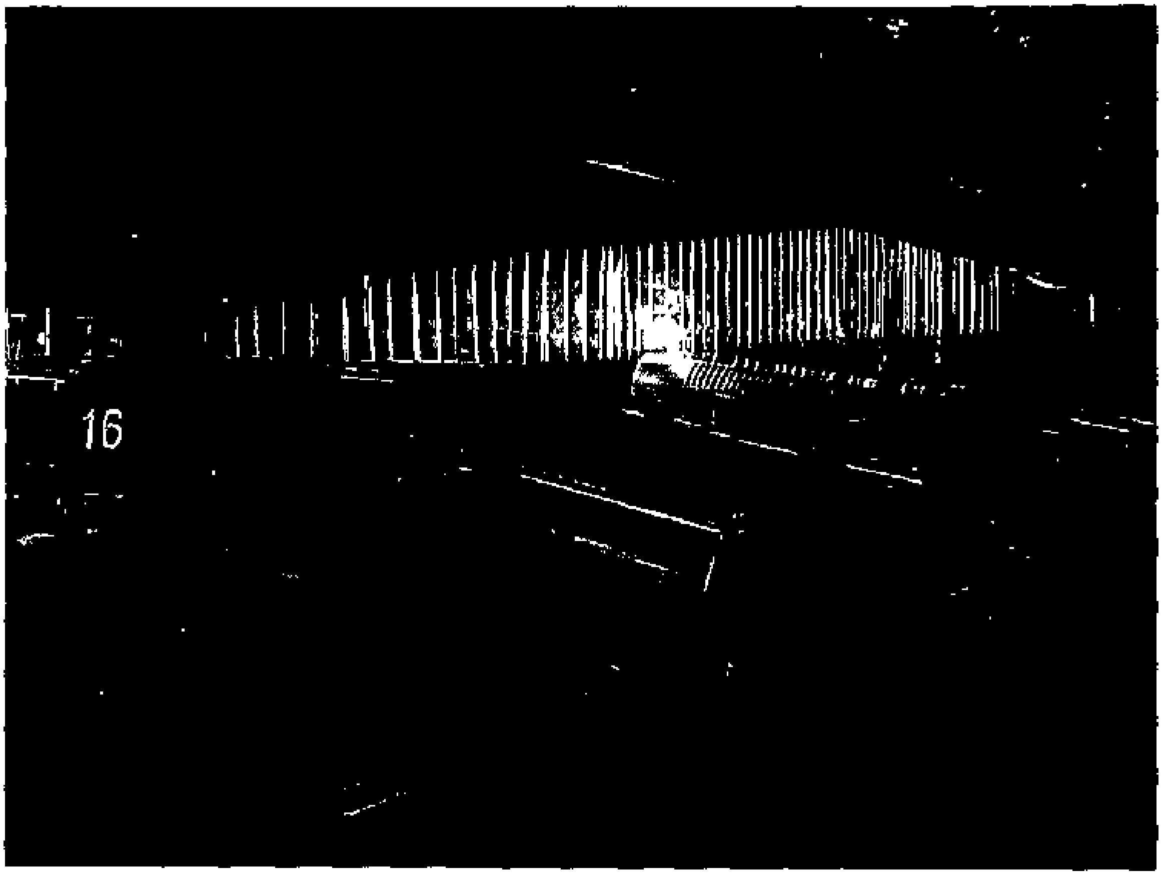

Figure 2. *Location of TG Experiment at far right of Vibrator Module at a location corresponding to the top-outer corner of business sized envelope*

Figure 3. TG data at far left of Vibrator Module at point representing top-outer corner of business sized envelope.

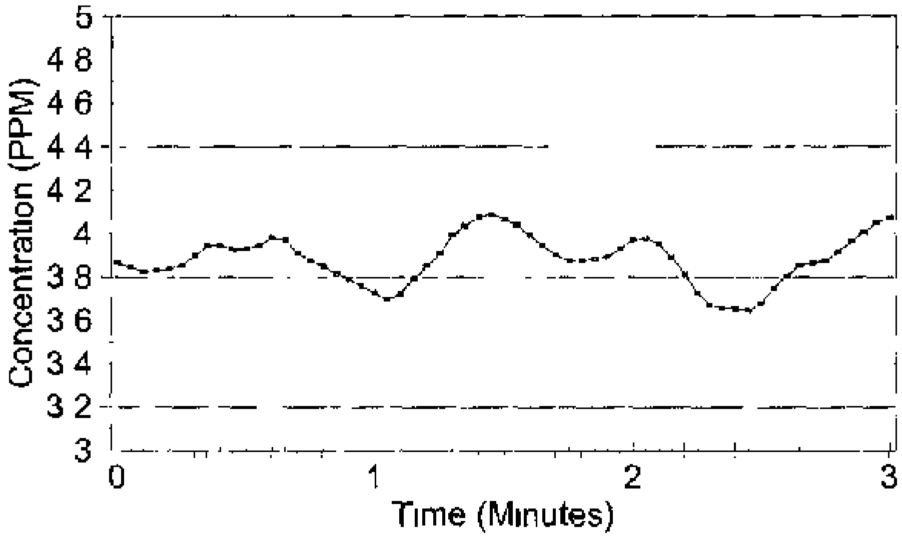

Figure 4. TG data at far right of Vibrator Module at point representing top-outer corner of business sized envelope.

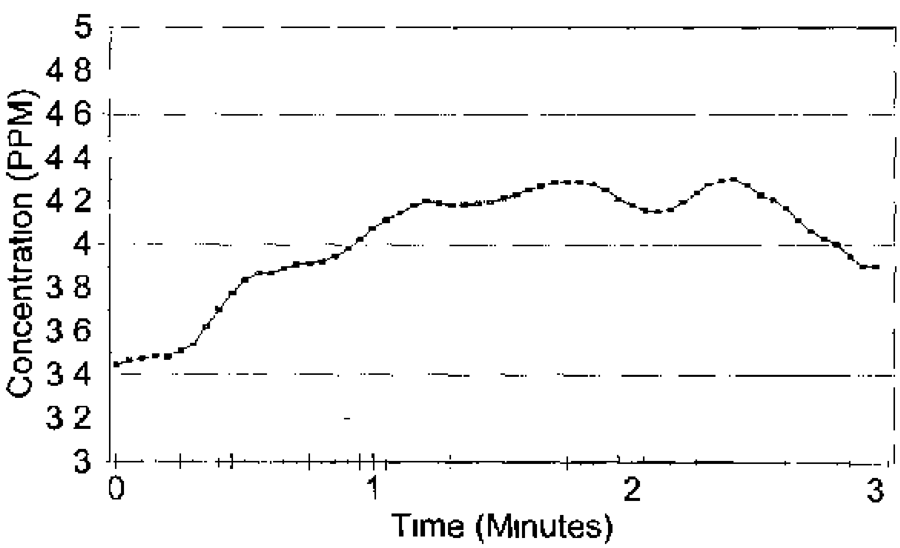

Figure 5. TG attenuation experiment data at Transport Module
Data is taken over 3 minute experiment

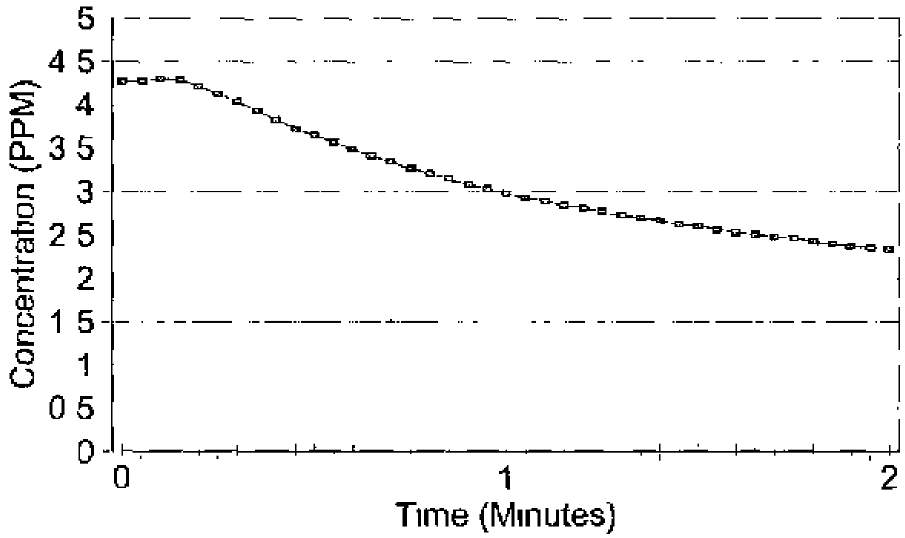

Figure 6 TG attenuation experiment data at Feeder Module.
Data is taken over 3 minute experiment

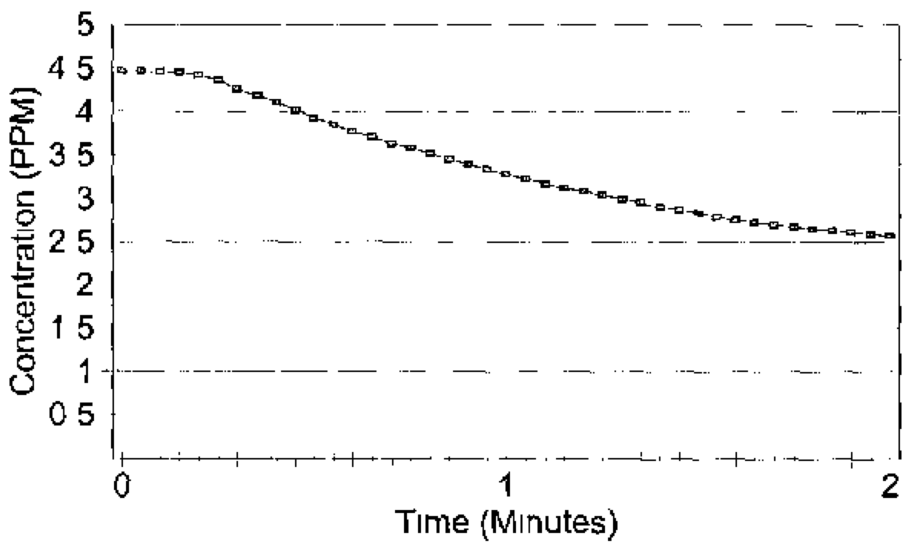

Figure 7. TG attenuation experiment data at Reader Module
Data is taken over 3 minute experiment

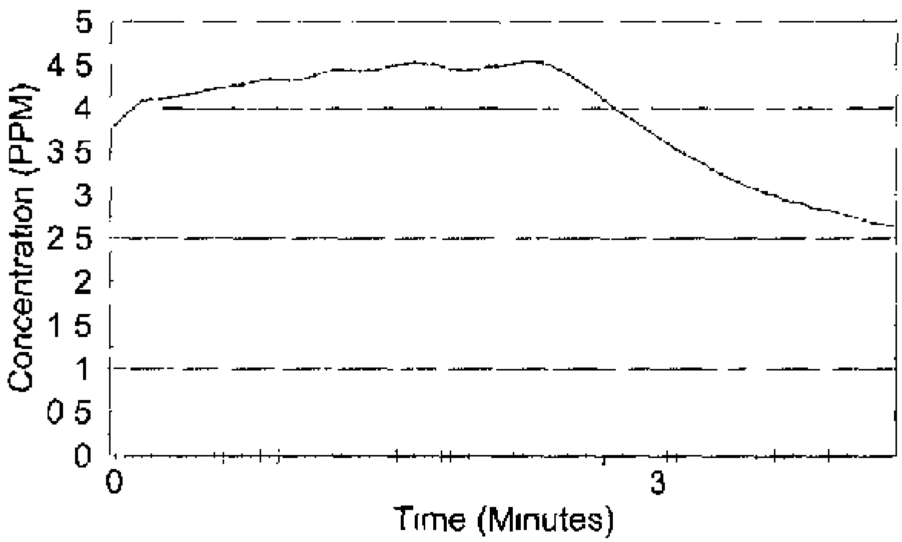

Figure 8. Smoke Release Experiment made at Vibrator Module.
Note that some smoke is escaping into ambient air