IN-DEPTH SURVEY REPORT
EVALUATION OF THE VENTILATION AND FILTRATION SYSTEM AND BIOHAZARD DETECTION SYSTEM FOR THE AUTOMATED FACER CANCELLER SYSTEM

at

United States Postal Service
Cleveland Processing and Distribution Center
Cleveland, OH

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SITE SURVEYED	USPS Processing and Distribution Center, Cleveland, OH
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SURVEY DATES	June 24, 2003 (Survey 1) November 13, 2003 (Survey 2)
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ABSTRACT

Researchers from the National Institute for Occupational Safety and Health (NIOSH) conducted an evaluation of capture efficiencies for the Biohazard Detection System (BDS) for the United States Postal Service (USPS). The BDS was developed for use on the ventilation system of the USPS mail processing equipment - the Automated Facer Canceller System (AFCS). The BDS samples and analyzes air from the AFCS to determine if a biohazard is present. This effort is in response to terrorist attacks in the fall of 2001 that used the mail to deliver *B. anthracis* spores. 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 that involved tracer gas experiments, air velocity measurements, and smoke release observations. The experiments showed that the capture efficiency of the BDS under the hood was highly effective under the most probable real-life scenario – when orifice "A", an airflow-restricting device installed near sensors of the AFCS singulator, was used with the Ventilation and Filtration System (VFS) on. Under these conditions, a capture efficiency of 96% (plus or minus 2.8% at the 90% confidence level) was documented near the singulator area of the BDS.

Based on the results in this report, the USPS expects to deploy airflow restrictors, like orifice "A", on all AFCS equipment within the USPS. Furthermore, given the need to implement a system to regularly evaluate the contaminant capture capabilities of the BDS system, the USPS has implemented a combination of sensors and inspections to maintain designed performance parameters for the BDS. As such, the USPS has specific plans to 1) ensure that BDS equipment provides a pressure sensor that detects if the BDS airflow is different from required values, and 2) under a contract with Northrop Grumman, institute a preventative maintenance plan to regularly test BDS airflow and inspect the mechanical seals of the BDS system. Further test requirements are under review by the USPS which will meet all federal guidelines for employee safety and health.

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 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 is one of several NIOSH reports evaluating controls used by the United States Postal Service (USPS) to control the release of contaminants into the work area of postal employees This report describes the evaluation of the capture efficiencies of the Biohazard Detection System (BDS)

BACKGROUND

Researchers from NIOSH were asked to assist the USPS in the evaluation of particulate controls for various types of mail processing equipment These new controls are being installed to significantly reduce operator exposure to any potentially hazardous contaminants emitted from mail during normal mail processing This effort is driven by the terrorist attacks in the fall of 2001 which used the mail to deliver *B anthracis* spores NIOSH researchers have subsequently made several trips to USPS postal facilities to observe various types of mail-processing equipment in operation and to study the effectiveness of the newly designed controls

The contaminant capture efficiency of the BDS for the Advanced Facer Canceller System (AFCS) is evaluated in this report The BDS was developed by USPS contractors for use on the AFCS It samples and analyzes air from the AFCS to determine if a biohazard is present This system was evaluated at the Cleveland, Ohio Processing and Distribution Center (P&DC) during two field surveys on June 24, 2003 and November 13, 2003

HAZARDS TO POSTAL EMPLOYEES

The bacterium *bacillus anthracis* is a spore forming bacterium, with spores typically in the size range of 1-5 μm Disease caused by *B anthracis* spores is manifested in one of three ways inhalational disease, cutaneous disease, and gastrointestinal disease [1] Recent cases resulting from terrorist attacks in which *B anthracis* 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 *B anthracis* spores by postal employees working in a mail processing facility that serves the U S Capitol resulted in the contraction of inhalational disease and subsequent deaths of several workers [2] One potential area of exposure is the automated mail processing equipment used to sort collection mail As the mail passes through the machinery, it is agitated and compressed in a number of places that could cause the release of substances from the mail

DESCRIPTION OF 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) mailpieces Mail is delivered to the AFCS from the 010 loose mail distribution system The AFCS culls the mail to remove flats and overthick (greater than 0 25 in) mailpieces The mail is then properly oriented so it may be cancelled Optical character recognition technology is used to read the addresses on the mailpiece which is then sorted and distributed to numbered bins for further automated processing An overview of the AFCS is shown in Figure 1

The so-called Ventilation and Filtration System (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 mailpieces This is the major cause of contaminant release from tainted mailpieces

The BDS was designed to draw air from an area of the AFCS that would most likely contain a contaminant emitted from an envelope due to agitation or compression – the singulator area of the AFCS The hood of the BDS is shaped like a tunnel and fits over the singulator area In this area, the mailpieces are tightly compressed and abruptly accelerated in a process that caused them to move as individual pieces 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

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1 Pile, James C MD, et al Anthrax as a Potential Biological Warfare Agent Arch Intern Med 158 429-434 1998

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

then analyzes the air for potential biological agents   If a hazard is detected, an alarm sounds and appropriate steps may be taken

METHODS

TRACER GAS

Apparatus

To quantitatively evaluate the capture efficiency of the BDS, a tracer gas method was used When sampling was conducted at the AFCS, the following conditions applied The gas, chemically pure sulfur hexafluoride (SF_6), was released at a constant rate at various points to determine capture efficiency at these release points Release points included areas interior to the BDS and in the immediate vicinity 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 for particulates 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® SapphIRe 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) at approximately 30 lpm, and using Tygon® tubing throughout the sampling system After exiting the pump, the sampled air was released into the workroom The analog output signal from the MIRAN® was routed to a Personal Computer Memory Card International Association (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

In some instances, it was desirable to directly test the contaminant capture capabilities of the BDS Therefore, some modifications were made to this test setup when BDS capture efficiency was tested directly The tracer gas was 1% SF_6, and the sampling probe of the BDS was inserted into the exhaust of the BDS Because the BDS exhausts near the floor, this exhaust was directed to a fan to limit re-entrainment of the tracer gas in the experiment

Procedures

The output signal from the MIRAN® was recorded at 1 second intervals Each capture efficiency measurement was recorded for a 2 to 5 minute interval The MIRAN® concentration corresponding to 100% capture was measured by releasing the SF_6 directly into the ductwork of the VFS – at such a location all tracer gas would theoretically be entrained into the VFS to be delivered to the measuring instrument 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 Tracer gas measurements were made with the ventilation system blower both on and off Some measurements were made while the AFCS processed mail

Locations Evaluated – Survey 1

During Survey 1, conducted on June 24, 2003, various locations were tested for contaminant capture capabilities (see Figure 2 for a diagram of locations tested) Locations evaluated specifically included

- Pinch Point 1 pinch point 14 inches downstream of the BDS hood
- Pinch Point 2 pinch point 7 inches downstream of the BDS hood
- Downstream Face center of opening of the downstream face of the BDS hood
- Hood 1 location interior to the BDS hood, 28 inches downstream of the upstream BDS hood face
- Hood 2 location interior to the BDS hood, 18 inches downstream of the upstream BDS hood face
- Hood 3 location interior to the BDS hood, 6 inches downstream of the upstream BDS hood face
- Hood 4 location interior to the BDS hood, 2 inches downstream of the upstream BDS hood face
- Upstream Face center of opening of the upstream face of the BDS hood
- Pinch Point 3 pinch point 16 inches upstream of the BDS hood

Locations Evaluated – Survey 2

During Survey 2, conducted on November 13, 2003, various locations were tested for contaminant capture capabilities (see Figure 3 for a diagram of locations tested) Locations evaluated specifically included

- Downstream Face center of opening of the downstream face of the BDS hood
- Hood 1 location interior to the BDS hood, 28 inches downstream of the upstream BDS hood face
- Hood 2 location interior to the BDS hood, 18 inches downstream of the upstream BDS hood face
- Hood 3 location interior to the BDS hood, 6 inches downstream of the upstream BDS hood face
- Upstream Face center of opening of the upstream face of the BDS hood

It should be noted that during Survey 2, four different sets of experimental conditions were tested First, two types of orifices were used to regulate airflow along the sensors of the singulator area inside the BDS hood Orifice "A" was .016 inches in diameter and orifice "B" was .023 inches in diameter These two air flow regulating orifices were used to determine which was optimal for BDS capture efficiency while still delivering enough air to keep sensors cleared at the singulator area Furthermore, both of these orifices were tested with the VFS both on and off for a total of four different sets of testing conditions during Survey 2 All tracer gas testing results are only point estimates except for orifice "A" with the VFS on Under these conditions, three trials were made to compute an average capture efficiency and confidence limits because USPS personnel stated that this set of conditions was the most likely to be used under normal working conditions

SMOKE RELEASE

Apparatus

Two devices were used to visualize air movement in and around the BDS a smoke machine (Mini Fogger, Model F-800, Chauvet USA, 3000 North 29th Court, Hollywood, Florida, 33020), and smoke tubes (Ventilation Smoke Tubes, P/N 5645, Mine Safety Appliances Company, 3000 P O Box 426, Pittsburgh, PA 15230)

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 potentially released at that point, could be qualitatively 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 Smoke release observations were made at pinch points along the mail path of the AFCS and around the area of the singulator both with and without the BDS in place

CAPTURE VELOCITY

Apparatus

An anemometer was used to measure air speeds at exhaust openings of the 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 locations at the face of the BDS hood

Survey 1 Specific Procedures

For Survey 1, air velocity measurements were made at points corresponding to Pinch Points 1, 2 and 3 as well as at the downstream and upstream BDS hood faces (see Figure 2 for details) Each sample is the average of three individual readings The grand average was computed as the average of three samples

Survey 2 Specific Procedures

For Survey 2, air velocity measurements were made at the downstream and upstream faces of the BDS hood Each trial reported is the average of three individual air velocity readings For each of four sets of criteria (VFS on/off, orifice "A" or "B") six to eight trials were made

RESULTS

Survey 1 (June 24, 2003)

Tracer gas

To estimate the total, combined contaminant capture efficiencies of the BDS and VFS, the probe of the Miran SapphIRe was inserted in the exhaust of the AFCS with the exhaust of the BDS entrained directly into the ductwork of the VFS Under these circumstances, tracer gas experimentation revealed that the combined capture of the BDS and VFS met expected standards of at least 98% capture efficiency at Pinch Point 1, and Pinch Point 3 However, somewhat marginal capture efficiency was experienced at other locations tested Please refer to the third column of Table 1 for details

To estimate the contaminant capture efficiency of the BDS alone, the probe of the Miran SapphIRe was inserted into the exhaust of the BDS The exhaust of the BDS was subsequently directed to the ambient air Inside of the BDS hood, point estimates of tracer gas capture ranged from 0% to 100% Specifically, the BDS captured contaminant well at the downstream BDS face and interior points close to the downstream face However, at the upstream hood and interior locations close to the upstream hood, BDS capture efficiency was minimal For point estimates of tracer gas capture for Survey 1, under these conditions, please refer to the second column of Table 1

Smoke Release Observations

Smoke released at locations at or near the upstream BDS hood indicated that smoke was not entrained into either the BDS or VFS at the upstream face of the BDS hood Also, smoke was not entrained into the BDS or VFS at the first singulator pinch point inside of the BDS hood However, smoke released at other locations in and around the BDS was captured by either the BDS or the VFS exhaust

Air Velocity Measurements

Air velocity measurements made at the BDS hood faces and points exterior to the BDS hood are relatively low, ranging from 11 to 65 fpm These air velocity measurements do not contradict results of smoke release observations and tracer gas experimentation Please refer to Table 2 for details

Survey 2 (November 13, 2003)

Tracer gas

Of the four sets of conditions tested during Survey 2, three point averages were only made for the set of conditions corresponding to the use of orifice "A" with the VFS on Under these conditions, the average upstream face capture efficiency was 89% +/- 12%, and the average downstream capture efficiency was computed at 65% +/- 10 5% At points interior to the BDS hood, average tracer gas capture efficiencies ranged from 96% to 98% Please refer to Table 3 for details

For other sets of conditions, point estimates of capture efficiencies were made For instance with orifice "A" in place and the VFS off, capture efficiencies ranged from about 41% at the downstream face to about 98% at points interior to the BDS hood When using orifice "B" with the VFS off, point estimates of capture efficiencies ranged from about 46% at the downstream face to capture efficiencies in the mid to upper 90% range inside the BDS hood Lastly, when using orifice "B" with the VFS on, the downstream face capture efficiency was about 82%, while point estimates of capture efficiencies interior to the BDS hood ranged from 89% to 98% For all point estimates at specific locations, please refer to Table 3

Smoke Release Observations

Smoke release observations were not made during this survey because of vendor concerns that particulate generated from either the smoke machine or smoke tubes would interfere with the proper function of the BDS Indeed, the BDS unit tested during Survey 2 was a working unit intended to be used on a daily basis to protect workers against a bioterrorist attack Therefore it was considered to be in the best interest of the workers to limit contaminant capture evaluations to tracer gas testing and air velocity measurements during Survey 2

Air Velocity Measurements

Air velocity measurements during survey 2 were made under the same four sets of conditions that tracer gas testing was made Specifically, they were made with orifices "A" and "B" with the VFS both on and off Please refer to Table 4 for specific averages at locations tested In general, the capture velocities at the upstream faces were low, ranging from negligible (Orifice "A", VFS off) to 45 fpm on average (Orifice "A", VFS on) The average capture velocities at the downstream BDS faces were somewhat higher ranging from 54 feet per minute to 92 feet per minute

DISCUSSION

The contaminant capture capabilities of the BDS as measured during Survey 1 were inadequate to provide enough of a sample to the BDS in the event of a release of *B anthracis* spores This is most clearly evidenced by the fact that, at the upstream face of the BDS and under the BDS hood near the singulator, the BDS capture efficiency was only about one percent According to representatives from the BDS vendor, in order for the BDS to operate properly, a large percentage of the sample must be entrained into the BDS for analysis

Subsequent to Survey 1, therefore, USPS personnel hired a private contractor to complete more testing These additional tests were made in conjunction with the BDS, VFS and AFCS vendors It was discovered during these supplementary tests that the jet of air used to clear sensors in the singulator area was interfering with the ability of the BDS to adequately capture contaminant in the singulator area which is near the upstream hood face of the BDS It was then resolved to regulate this airflow and for NIOSH to conduct supplemental tests during Survey 2

For Survey 2, the airflow was regulated by the use of 2 different flow-regulating orifices Orifice "A" had a diameter of 016 inches, while orifice "B" had a diameter of 023 inches The USPS wanted to test BDS capture efficiency with both orifices in order to determine which was most optimal for adequate BDS capture efficiency while effectively keeping the sensors in the singulator area clear

After testing several sets of conditions during Survey 2, it was decided by USPS personnel, that orifice "A" would most likely be used to regulate air flow in the singulator area Furthermore, the BDS would most likely be run with the VFS running concurrently Therefore, three replications of tests under this set of circumstances were performed The results indicated that the capture efficiency of the BDS under the hood was highly effective – a capture efficiency of 96% (plus or minus 2 8% at the 90% confidence level) was documented near the singulator area of the BDS

CONCLUSIONS AND RECOMMENDATIONS

It should be noted that in response to the need for regulation of air flow near singulator sensors on AFCS equipment where the BDS is installed, the USPS has designed an air flow restrictor on the prototype design in the Cleveland Processing and Distribution Center Furthermore, the USPS expects to deploy this technology to all AFCS equipment within the USPS

Given the need to implement a system to regularly evaluate the contaminant capture capabilities of the BDS system, the USPS has implemented a combination of sensors and inspections to maintain designed performance parameters for the BDS In order to implement this system

- The USPS BDS equipment provides a pressure sensor that detects if the BDS airflow is different from required values
- The BDS airflow will be tested with ROOTS® flow meters
- The mechanical seals of the BDS will be inspected as part of preventative maintenance performed under a contract with Northrop Grumman

- Testing of VFS system capture capabilities will include inspection and flow meter checks
- Further test requirements are under review by USPS Safety which will meet all federal guidelines for employee safety and health

Table 1 Point Estimates of Capture Efficiencies for the Biohazard Detection System for Survey 1 Capture efficiencies in bold italics indicate locations where BDS capture efficiency is not high enough to ensure that a sufficient sample is captured for analysis

Testing Location	Capture Efficiency of BDS/ Miran at BDS	Total combined capture (BDS with VFS)
Pinch Point 1	6%	> 98%
Pinch Point 2	20%	88%
Downstream Face	> 98%	92%
Hood 1	> 98%	97%
Hood 2	> 98%	86%
Hood 3	88%	85%
Hood 4	***0%***	90%
Upstream Face	***1%***	91%
Pinch Point 3	0%	> 98%

Table 2 BDS Air Velocity Data for Survey 1 (feet per minute)

	Sample 1	Sample 2	Sample 3	***Grand Average***
Pinch Point 1	8	7	17	***11***
Pinch Point 2	46	34	24	***35***
Downstream Face	86	44	66	***65***
Upstream Face	23	57	43	***41***
Pinch Point 3	50	22	22	***31***

Table 3 Estimated Capture Efficiencies for the Biohazard Detection System Please note that all test results are point estimates, except for when testing occurred with orifice "A" and with the VFS on Three point averages and 90% confidence limits were supplied for results corresponding to these criteria as they were the most likely in a real world situation (Survey 2)

Testing Location	Orifice	VFS on/off	Capture Efficiency of BDS	Trial 2	Trial 3	Avg.	CL (90%)
Downstream Face	A	Off	41%				
Hood 1	A	Off	>98%				
Hood 2	A	Off	>98%				
Hood 3	A	Off	>98%				
Upstream Face	A	Off	92%				
Downstream Face	A	On	69%	58%	69%	65%	10 5%
Hood 1	A	On	>98%	98%	>98%	>98%	5 4%
Hood 2	A	On	96%	96%	98%	97%	2 0%
Hood 3	A	On	96%	94%	97%	96%	2 8%
Upstream Face	A	On	89%	97%	82%	89%	12 0%
Downstream Face	B	Off	46%				
Hood 1	B	Off	95%				
Hood 2	B	Off	98%				
Hood 3	B	Off	94%				
Upstream Face	B	Off	86%				
Downstream Face	B	On	82%				
Hood 1	B	On	>98%				
Hood 2	B	On	93%				
Hood 3	B	On	89%				
Upstream Face	B	On	90%				

Table 4 BDS Air Velocity Data for Survey 2 (feet per minute)

Testing Location	Orifice	VFS on/off	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Avg.
Downstream Face	A	Off	55	76	102	71	49	61	77	87	**72**
Upstream Face	A	Off	0 - 7	0 - 7	0 - 7	0 - 7	0 - 7	0 - 7	-	-	**N/A**
Downstream Face	A	On	65	45	75	43	55	57	37	56	**54**
Upstream Face	A	On	27	35	65	67	35	32	40	55	**45**
Downstream Face	B	Off	75	67	46	82	65	37	-	-	**62**
Upstream Face	B	Off	9	13	7	13	12	12	-	-	**11**
Downstream Face	B	On	110	90	76	106	89	80	-	-	**92**
Upstream Face	B	On	8	11	26	20	15	20	-	-	**17**

Figure 1   Overview of Automated Facer Canceller System

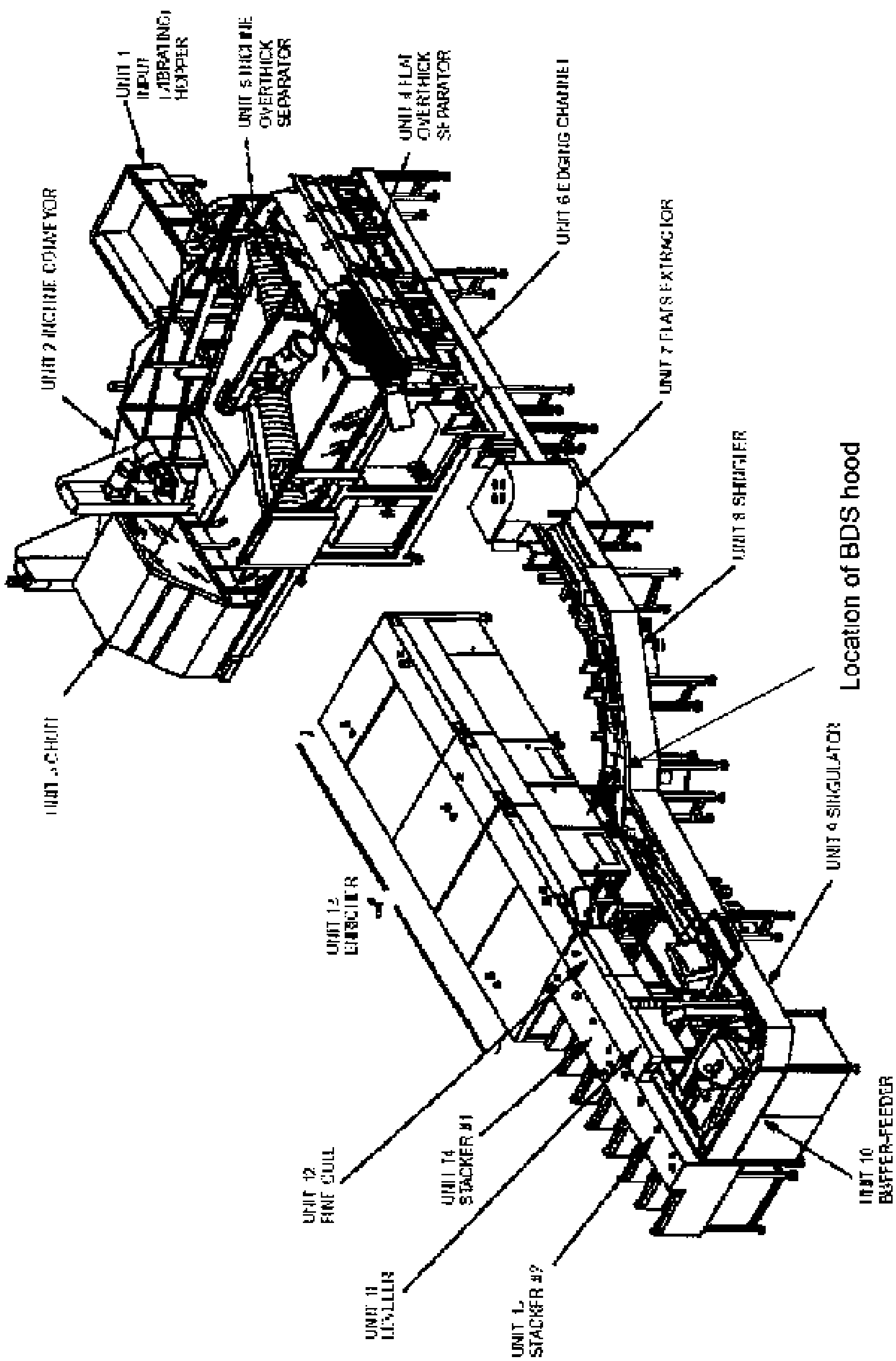
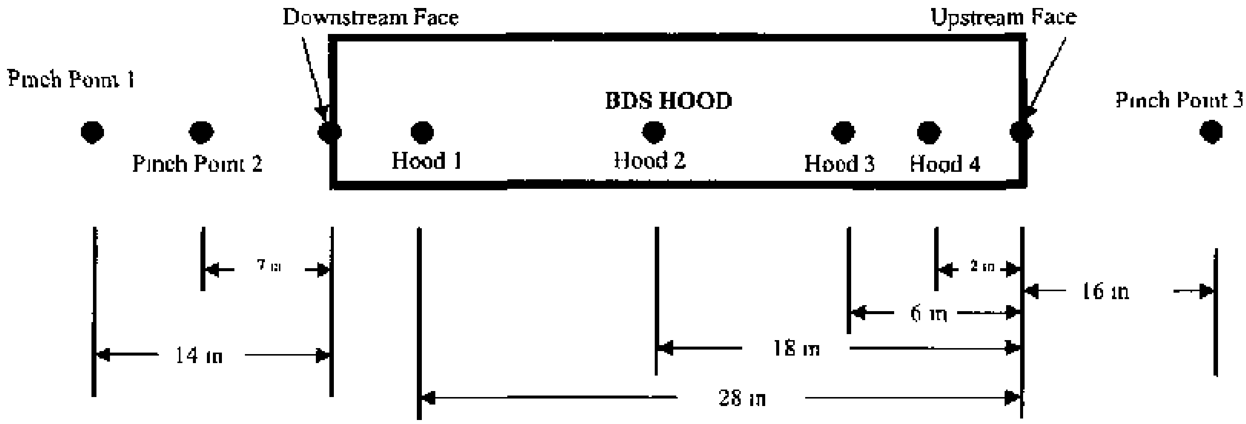
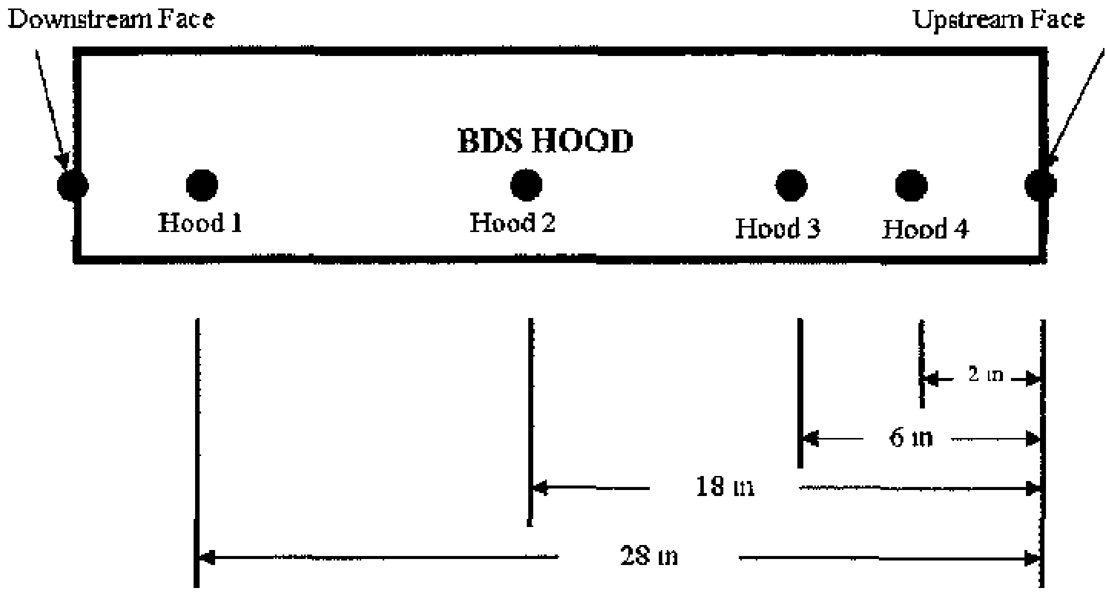


Figure 2 Survey 1 Locations Evaluated



Note Drawing not to scale

Figure 3 Survey 2 Locations Evaluated



Note Drawing not to scale

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