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IN-DEPTH SURVEY REPORT:

A LABORATORY EVALUATION OF PROTOTYPE ENGINEERING CONTROLS DESIGNED TO REDUCE OCCUPATIONAL EXPOSURES DURING ASPHALT PAVING OPERATIONS

at

Blaw-Knox Construction Equipment Corporation
Mattoon, Illinois

REPORT WRITTEN BY:
Ronald L. Mickelsen
Kenneth R. Mead

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
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4676 Columbia Parkway, R5
Cincinnati, Ohio 45226

PLANT SURVEYED:	Blaw-Knox Construction Equipment Corporation 750 Broadway Avenue, East Mattoon, Illinois 61938
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SURVEY DATE:	July 5-7, 1995
SURVEY CONDUCTED BY:	Ronald L. Mickelsen Kenneth R. Mead Chandra Baker John W. Sheehy
EMPLOYER REPRESENTATIVES:	J.H. Jack Farley Manager of Product Support Leland J. Warren Design Engineer David L. James Engineering Design Draftsman
EMPLOYEE REPRESENTATIVES:	No Employee Representatives
MANUSCRIPT PREPARED BY:	Debra A. Lipps Bernice L. Clark Robin F. Smith

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EXECUTIVE SUMMARY

On July 5-7, 1995, researchers from the National Institute for Occupational Safety and Health (NIOSH) evaluated prototype engineering controls designed for the control of fugitive asphalt emissions during asphalt paving. The Blaw-Knox engineering control evaluation was completed as part of a Department of Transportation (DOT) project to evaluate the effectiveness of engineering controls on asphalt paving equipment. NIOSH researchers are conducting the research through an interagency agreement with DOT's Federal Highway Administration. Additionally, the National Asphalt Pavement Association is playing a critical role in coordinating the paving manufacturers' and paving contractors' voluntary participation in the study.

The study consists of two major phases. During the primary phase, NIOSH researchers visit each participating manufacturer and evaluate their engineering control designs under managed environmental conditions. The indoor evaluation uses tracer gas analysis techniques to both quantify the control's exhaust volume and determine the capture efficiency. Results from the indoor evaluations provided equipment manufacturers with the necessary information to maximize engineering control performance prior to the second phase of the study, performance evaluation of the prototype engineering controls under "real-life" paving conditions. The scope of this report is limited to the Blaw-Knox phase one evaluation.

The Blaw-Knox phase one evaluation studied the performance of a single engineering control design. The prototype control was installed and evaluated on a Blaw-Knox Model PF-5510 asphalt paving machine. The control design consisted of a long hood mounted above the auger and against the rear of the tractor. The control design included a clear plastic cover extending from the rear of the exhaust hood back to the screed, thus covering the top of the auger area. A duct connected the hood to the engine air intake. In this manner, the tractor engine's air intake demand dictated the volume of air mechanically exhausted through the engineering control. The control system exhaust volume was approximately 280 cubic feet per minute at a corresponding engine speed near 2100 revolutions per minute (RPM). The average indoor capture efficiency was approximately 25 percent. The average outdoor capture efficiency varied according to paver orientation. Evaluations revealed an average capture efficiency of less than 1 percent when the paver front faced into the wind or when the paver was oriented perpendicular to the wind flow. When the paver front faced away from the wind, evaluations revealed an average capture efficiency of 6 percent. In addition to the capture efficiency reductions, the outdoor efficiency results showed increased variation in capture efficiency as wind gusts hampered the control's ability to consistently capture the surrogate contaminant.

Recommendations to Blaw-Knox design engineers include: (1) Modify the hood to a slot inlet; (2) Increase the level of hood enclosure to minimize the wind effect near the ends of the auger area; (3) Seal the openings between the tractor engine compartment and the auger area to avoid the unwanted discharge of engine cooling air into the auger area; and (4) Redesign and increase the volumetric handling capacity of the exhaust system in order to capture and remove asphalt fume and other auger-area contaminants before they escape into the workers' breathing zones.

Since the intent of the phase one evaluations was to provide equipment manufacturers with engineering performance and design feedback, various original and imaginative approaches were developed with the knowledge that these prototypes would undergo preliminary performance testing to identify which designs showed the most merit. Each manufacturer received design modification recommendations specific to their prototypes' performance during the phase one testing. Prior to finalization of this report, each manufacturer received the opportunity to identify what modifications and/or new design features were incorporated into the "final" prototype design prior to the phase two evaluations. This design information for the Blaw-Knox engineering control is included, as it was received, in Appendix C of this report.

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH), a Federal agency located in the Centers for Disease Control and Prevention under the Department of Health and Human Services, was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct research and educational programs separate from the standard setting and enforcement functions conducted by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards.

The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering (DPSE), has the lead within NIOSH to study and develop engineering controls and assess their impact on reducing occupational illness. Since 1976, ECTB 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 document and evaluate control techniques and to determine their effectiveness in reducing potential health hazards in an industry or at specific processes. Information on effective control strategies is subsequently published and distributed throughout the affected industry and to the occupational safety and health community.

BACKGROUND

On July 5-7, 1995, researchers from the National Institute for Occupational Safety and Health (NIOSH) conducted an evaluation of a prototype engineering control designed for the control of fugitive asphalt emissions during asphalt paving. The NIOSH researchers included Leroy Mickelsen, Chemical Engineer; Ken Mead, Mechanical Engineer; and Chandra Baker, Engineering Intern; all from the NIOSH Engineering Control Technology Branch (ECTB), Division of Physical Sciences and Engineering (DPSE). The DPSE researchers were assisted by Blaw-Knox staff: Jack Farley, Manager of Product Support; Leland J. Warren, Design Engineer; and David L. James, Engineering Design Draftsman.

The Blaw-Knox engineering control evaluation was completed as part of a Department of Transportation (DOT) project to evaluate the effectiveness of engineering controls on asphalt paving equipment. NIOSH/DPSE researchers are conducting the research through an interagency agreement with DOT's Federal Highway Administration (FHWA). Additionally, the National Asphalt Pavement Association (NAPA) has played a critical role in coordinating the paving manufacturers' voluntary participation in the study. The study consisted of two major phases. During the primary phase, NIOSH researchers visited each participating manufacturer and evaluated their engineering control designs under managed environmental conditions. [General protocols for the indoor evaluations are located in Appendix A. Minor deviations from these protocols may sometimes occur depending upon available time, prototype design, equipment performance, and available facilities.] Results from the phase one evaluations were provided to the equipment manufacturers along with design change recommendations to maximize engineering control performance prior to the phase two evaluations. The second phase evaluations, which began in mid-1996, include a performance evaluation of the prototype engineering controls under "real-life" conditions at an actual paving site. The results from the Blaw-Knox phase two evaluation will be published in a separate report.

DESIGN REQUIREMENTS

When designing a ventilation control, the designer must apportion the initial design criteria among three underlying considerations; the level of enclosure, the hood design, and the available control ventilation. When possible, an ideal approach is to maximize the level of enclosure in order to contain the contaminant emissions. With a total or near-total enclosure approach, hood design is less critical, and the required volume of control ventilation is reduced. Many times, worker access or other process requirements limit the amount of enclosure allowed. Under these constraints, the designer must compromise on the level of enclosure and expend increased attention to the hood design and control ventilation parameters.

In the absence of a totally enclosed system, the hood design plays a critical role in determining a ventilation control's capture efficiency. Given a specified exhaust flow rate, the hood shape and configuration affect the ventilation control's ability to capture the contaminant, pull it into the hood, and direct it toward the exhaust duct. A well-engineered hood design strives to achieve a uniform velocity profile across the open hood face. When good hood design is combined with proper enclosure techniques, cross-drafts and other airflow disturbances have less of an impact on the ventilation control's capture efficiency.

In addition to process enclosure and hood design, a third area of consideration when designing a ventilation control, is the amount of ventilation air (volumetric flow and/or velocity) required to capture the contaminant and remove it from the working area. For most work processes, the contaminant must be "captured" and directed into the contaminant removal system. For ventilation controls, this is achieved with a moving air stream. The velocity of the moving air stream is often referred to as the capture velocity. In order to maintain a protected environment, the designed capture velocity must be sufficient to overcome process-inherent contaminant velocities, convective currents, cross-drafts, or other potential sources of airflow interference.

The minimum required exhaust flow rate (Q) is easily calculated by inputting the desired capture velocity and process geometry information into the design equations specific to the selected hood design. Combining Q with the calculated pressure losses within the exhaust system allows the designer to appropriately select the system's exhaust fan.

For most ventilation controls, including the asphalt paving controls project, these three fundamentals; process enclosure, hood design, and capture velocity are interdependent. A design which lacks process enclosure can overcome this shortcoming with good hood design and increased air flow. Alternatively, lower capture velocities may be adequate if increased enclosure and proper hood design techniques are followed. Additional information on designing ventilation controls can be found in the American Conference of Governmental Industrial Hygienists' (ACGIH) ***"INDUSTRIAL VENTILATION: A Manual of Recommended Practice"*** [ACGIH, 6500 Glenway Avenue, Building D-7, Cincinnati, Ohio 45211.]

EVALUATION PROCEDURE

The Blaw-Knox engineering control design was evaluated in a large bay area within a separate research building at the manufacturing plant. The paver was parked with the screed and rear half of the tractor positioned in the bay area (referred to as the testing area) and the front half of the tractor with the engine exhaust pipe positioned outside the building. An overhead door separated the two areas. The overhead door was lowered to rest on top of the tractor and the remaining doorway openings around the tractor were sealed to isolate the front and rear halves of the paver. During each test run, the engine exhaust (which also contained the engineering control's exhaust) was discharged to the outside of the building. This setup proved very effective at preventing the engine exhaust and the captured surrogate contaminants from reentering the testing area.

A theatrical smoke generator produced smoke as a surrogate contaminant that was subsequently discharged through a perforated distribution tube. The tube placement traversed the width of the auger area between the tractor and the screed and rested on the ground under the augers. Initially, the smoke was used to observe airflow patterns around the paver and to observe capture by the control systems. (The general smoke test protocol is in Appendix A.) This test also helped to identify failures in the integrity of the barrier separating the front and rear portions of the paver. After sealing leaks within this barrier, smoke was again released to identify airflow patterns within the test area and to visually observe the control system's performances.

The second method of evaluation was the tracer gas evaluation. This evaluation was designed to: (1) Calculate the total volumetric exhaust flow of each hood design; (2) Evaluate each hood's effectiveness in controlling and capturing a surrogate contaminant under the "controlled" indoor scenario. Sulfur hexafluoride (SF_6) was the selected tracer gas. At the concentrations generated for these evaluations, SF_6 behaves as a non-toxic, surrogate contaminant which follows the air currents of the ambient air in which it is released. Since SF_6 is not naturally found within ambient environments, it is an excellent tracer gas for studying ventilation system characteristics. The general protocol for the tracer gas evaluation is in Appendix A.

A photo-acoustic infra-red detector (Bruel & Kjaer Model 1302) was calibrated in the NIOSH laboratories prior to the evaluation. Known amounts of reagent grade SF_6 were injected into 12-liter Milar sampling bags and diluted with nitrogen to predetermined concentrations. Five concentrations ranging from 2 to 100 parts per million (ppm) SF_6/nitrogen were generated. A curve was fit to the data and used to convert detector response to SF_6 concentrations. Calibration data are in Appendix B.

To quantify exhaust flow rate, the tracer gas discharge tubes were placed directly into the exhaust ducts of the engineering control. A known volumetric flow rate of SF_6 was released into the duct(s) and the analytical instrument measured the concentration of SF_6 in the control system's exhaust. Measurements were taken downstream of the exhaust fan to allow for thorough mixing of the exhaust air stream. The exhaust flow rate was calculated using the following equation:

$$Q_{(exh)} = \frac{Q_{(SF_6)}}{C^{*}_{(SF_6)}} \times 10^6$$ **Equation 1**

where: **$Q_{(exh)}$** = flow rate of air exhausted through the ventilation system (lpm or cfm)

$Q_{(SF6)}$ = flow rate of SF_6 (lpm or cfm) introduced into the system

$C^*_{(SF6)}$ = concentration of SF_6 (parts per million) detected in exhaust. And the * indicates 100% capture of the released SF_6

[To convert from liters per minute (lpm) to cubic feet per minute (cfm), divide lpm by 28.3.]

To quantify capture efficiency, we released the SF_6 through distribution plenums. Each discharge hose fed from the SF_6 regulator, through a mass flow controller and into a T-shaped distribution plenum. Each plenum was approximately 4' wide and designed to release the SF_6 evenly throughout its width. During the capture efficiency test, we placed the discharge plenums within the auger area between the paving tractor and the screed. A known quantity of SF_6 slowly discharged through the plenums into the auger area. A direct-reading analytical instrument measured the concentration of the tracer gas in the exhaust on the discharge side of the control. The capture efficiency was calculated using the following equation:

$$\eta = 100 \times \frac{\frac{C_{(SF_6)} \times Q_{(exh)}}{10^6}}{Q_{(SF_6)}}$$ **Equation 2A**

where: η = capture efficiency

$C_{(SF6)}$ = concentration of SF_6 (parts per million) detected in exhaust

$Q_{(exh)}$ = flow rate of air exhausted through the ventilation system (lpm or cfm)

$Q_{(SF6)}$ = flow rate of SF_6 (lpm or cfm) introduced into the system
[To convert from liters per minute (lpm) to cubic feet per minute (cfm), divide lpm by 28.3.]
NOTE: When the flow rate of SF_6 [$Q_{(SF6)}$] used to determine the engineering control's capture efficiency is the same as that used to quantify the exhaust flow rate, equation 2A may be simplified to:
where the definitions for $C^*_{(SF6)}$, η, and $C_{(SF6)}$ remain the same as in equations 1 and 2A.

$$\eta = \frac{C_{(SF_6)}}{C^*_{(SF_6)}} \times 100 \qquad \text{Equation 2B}$$

Exhaust flow rate experiments were conducted by monitoring the exhaust airstream before it reached the engine air filter. Once the exhaust flow rates ($Q_{(exh)}$) were known, the SF_6 was distributed into the auger region for the capture efficiency (η) evaluations. Both flow rate and capture efficiency tests were repeated. The paver was shut down between trials. The airflow rate of the control system was partially governed by the paver idle speed which may have changed slightly between trials.

In addition to the indoor evaluation, an outdoor evaluation was completed with the paver positioned in prescribed stationary orientations. The outdoor stationary evaluation provided feedback on the sufficiency of the engineering control's hood enclosure for performance in an outdoor environment.

EQUIPMENT

(See Appendix A)

ENGINEERING CONTROL DESIGN DESCRIPTION

The Blaw-Knox engineering control prototype consisted of a large hood mounted on the back of the tractor and extending over the augers. A 6-inch duct connected the hood to the engine air intake filter. The engine air intake acted as the control system fan, providing the only source of mechanical air movement for the control system.

The hood measured approximately 108" long and 7" wide at the inlet. The plenum tapered to 36" long and 3" wide at the top of the 14-inch tall plenum body. From that point, the hood tapered to a 6-inch diameter transition for connection to the exhaust duct. Clear plastic connected the edge of the hood to the front of the screed, totally enclosing the top of the auger area. A small amount of clear plastic was also extended to each side of the auger area but only covered a small portion of the sides.

DATA RESULTS

Smoke Evaluations

The smoke test evaluation provided only qualitative information. The initial smoke tests revealed openings in the barrier between the testing and exhaust areas. After resealing the separating barrier, smoke was re-released to identify airflow patterns within the test area and to visually observe the control system's performance. This information assisted the researchers in preparing the test area for the quantitative tracer gas evaluation.

During the indoor evaluation, an additional use for the smoke generator was created when cooling air for the tractor's engine was suspected of entering the auger area at high velocities and disrupting contaminant capture. To test this suspicion, smoke from the smoke generator was discharged into the engine's cooling air intake. Subsequently, some of this smoke was observed turbulently entering the auger area via openings in the rear-wall of the engine compartment.

Tracer Gas Evaluation

(A copy of the tracer gas evaluation data files and associated calculations are included in Appendix B).

Indoor Evaluations

The prototype hood configuration was evaluated under the semi-controlled conditions described above. Exhaust flow experiments were repeated using different SF_6 flow rates ($Q_{(SF6)}$) to increase accuracy. Since building pressure fluctuations and air currents from moving people or equipment could momentarily disrupt the control's airflow characteristics, the results are reported in terms of an average and a range.

TABLE I. INDOOR TRIALS, EXHAUST FLOW RATES

	$Q_{(SF6)}$	$Q_{(exh)}$ (Range)	$Q_{(exh)}$ (Average)
Exhaust, Run 1a*	0.34 lpm	229 - 240 cfm	232 cfm
Exhaust, Run 1b	0.64 lpm	235 - 256 cfm	242 cfm
Exhaust, Run 2a	0.34 lpm	211 - 217 cfm	214 cfm
Exhaust, Run 2b	0.64 lpm	252 - 264 cfm	256 cfm

* The annotations "a" and "b" are for different SF_6 flow rates during the same test run.

TABLE II. INDOOR TRIALS, CAPTURE EFFICIENCY

	$Q_{(exh)}$	η (Range)	η (Average)
Capture Eff. Run 1	237 cfm	17 - 34 %	27 %
Capture Eff. Run 2	235 cfm	17 - 37 %	24 %

Outdoor Evaluations

The outdoor evaluation occurred in an open parking area. Four paver orientations were evaluated. A portable weather station mounted on top of the paver recorded a northwest wind gusting from 5 to 15 miles per hour (mph) throughout the outdoor evaluation. Paver orientations during testing included the paver front pointing toward the wind for two tests, paver sides toward the wind for three tests, and paver rear toward the wind for one test.

TABLE III. OUTDOOR TRIALS
(FRONT OF PAVER FACING THE WIND = ZERO DEGREES)

Orientation/ Run	$Q_{(SF6)}$	$Q_{(exh)}$ (Range)*	$Q_{(exh)}$ (Average)*	η(Range)	η(Average)
0°, Run 1a	0.34 lpm	275 - 283 cfm	278 cfm	0.6 - 1.3 %	0.8 %
0°, Run 1b	0.64	258 - 266	262	0.4 - 4.3†	1.5†
0°, Run 2a	0.34	285 - 297	292	0.2 - 3.3	0.7
0°, Run 2b	0.64	283 - 295	288		
90°, Run 1a◊	0.34	282 -289	285	0.2 - 0.7	0.5
90°, Run 1b	0.64	271 - 277	272		
0°, Run 2	0.34	285 -292	288	0.3 - 0.7	0.4
180°, Run 1a	0.34	271 - 288	280	4.6 - 7.3	5.7
180°, Run 1b	0.64	261 - 276	271		
70°, Run 1a	0.34	269 - 280	273	0.3 - 1.3	0.6
270°, Run 1b	0.64	271 - 277	275		

Q = Airflow rate
η = Capture efficiency

* Airflow rate of the control system is governed by the paver engine speed. This value may fluctuate slightly based upon changes in the paver engine's idle speed and temperature.
◊ The annotations "a" and "b" are for different SF_6 flow rates during the same test run.
† After run 1a, cardboard was placed in the slat-conveyor blast gate to block the wind.

DATA ANALYSIS

Test results from the Blaw-Knox engineering control evaluation show that the minimal amount of airflow induced by the engine air intake results in capture efficiency of about 25 percent when tested in the semi-controlled indoor environment. During the outdoor stationary tests, with wind gusts ranging from 5 to 15 mph, the prototype control was unable to remove a significant amount of the tracer gas (surrogate asphalt fume). Test results show that the system captured less than 1 percent of the tracer gas when either the front of the paver faced into the wind or when either side of the paver faced the wind. The prototype control captured 5.7 percent of the tracer gas when the rear of the paver faced into the wind.

Achieving a high average capture efficiency is only part of the ventilation control design approach. Another consideration is the control's ability to maintain high capture efficiencies without performance levels fluctuating over a wide range. Each excursion into the poor capture efficiency range represents an opportunity for contaminant to escape into a worker's breathing zone. Empirically, the performance can be evaluated by comparing the sampling data coefficients of variation (CV).

$$CV = \frac{Standard\ deviation}{Mean} X\ 100$$

Controls with smaller CV's were less subject to outside interferences and maintained more consistent capture efficiencies. The calculated CV's for both exhaust flow rate and capture efficiency evaluations are shown in Appendix B.

CONCLUSIONS AND RECOMMENDATIONS

Based on the evaluation results, the Blaw-Knox control prototype tested during the laboratory evaluation will not significantly reduce worker exposure. General recommendations for further improvements to the prototype design include:

Ventilation Exhaust Volume

The ACGIH Industrial Ventilation Manual provides guidance to facilitate the selection of minimum capture velocities. Additionally, NIOSH can assist in selecting a capture velocity based upon your intended control design. At a minimum, given the physical properties of the asphalt fume, the vapor contaminants, and the process by which they are generated, we recommend a minimum design capture velocity of 100 feet per minute (fpm) throughout the entire auger area. This recommendation assumes very good enclosure to minimize wind interference during paving operations. Based upon the selected hood design and the dimensions of the auger area, this velocity will be incorporated into the design calculations to determine a minimum exhaust flow rate requirement. There is some concern regarding convective currents and the generated volume of rising air induced above the hot paving process. However, adequate process enclosure plus an appropriately selected capture velocity will produce a sufficient exhaust flow rate to control and remove this convective exhaust volume. Additional information on controlling contaminants from hot processes may also be found in the ACGIH Ventilation Manual.

Exhaust System Design

The evaluated exhaust system (engine air intake) was incompatible with the exhaust requirements of a properly operating ventilation control. It may be best to redesign the engineering control exhaust independent of the engine air intake. If it is desirable to use the engine's air intake to process some of the ventilation control's exhaust air, additional exhaust capacity will be necessary to create a engineering control design capable of creating a significant reduction in asphalt fume exposures. Regardless of the selected exhaust route(s), it should be compatible with the volume and static pressure limitations of the exhaust fans, and the exhaust should exit the system away from the workers' breathing zones.

Enclosure

In general, the prototype control design maintained good enclosure over the width of the auger. Blaw-Knox's use of a clear plastic to connect the hood to the screed should aid in user acceptance of the control so long as the visibility remains unimpaired. Additional enclosure efforts, especially above the ends of the auger and the screed extension areas, could increase capture efficiency, increase resistance to cross-draft disturbances and further reduce worker exposures.

Engine Cooling Air

During the laboratory evaluation, some of the airflow generated by the tractor engine's cooling fan was observed discharging into the auger area through openings in the rear wall of the engine compartment. This high velocity disruption dramatically reduced the control effect provided by the control system's capture velocity. To avoid the unwanted discharge of engine cooling air into the auger area, minimize and seal the openings between the tractor engine compartment and the auger area.

Hood Design

The evaluated hood design should perform well if adequately matched with a sufficient exhaust flow capacity and a compatible auger-area enclosure. An alternative design which evenly distributed exhaust air flow across the hood's face area would improve inlet flow distribution and increase protection across the full length of the augers. The evaluated design would be less-effective at locations away from the center of the hood. An evenly distributed intake can be achieved through the use of a slot hood or similar plenum-type exhaust hood configuration.

ACKNOWLEDGMENTS

We would like to thank the Blaw-Knox management and staff for their gracious hospitality and assistance during our visit to the Blaw-Knox facility. Their commitment to the design and implementation of engineering controls to reduce occupational exposures is an admirable pledge.

APPENDIX A

ENGINEERING CONTROLS FOR ASPHALT PAVING EQUIPMENT

PHASE ONE (LABORATORY) EVALUATION PROTOCOL

PURPOSE: To evaluate the efficiency of ventilation engineering controls used on highway-class hot mix asphalt (HMA) pavers in an indoor stationary environment.

SCOPE OF USE: This test procedure was developed to aid the HMA industry in the development and evaluation of prototype ventilation engineering controls with an ultimate goal of reducing worker exposures to asphalt fumes. This test procedure is a first step in evaluating the capture efficiency of paver ventilation systems and is conducted in a controlled environment. The test is not meant to simulate actual paving conditions. The data generated using this test procedure have not been correlated to exposure reductions during actual paving operations.

For the laboratory evaluation, we will conduct a two-part experiment where the surrogate "contaminant" is injected into the auger region behind the tractor and in front of the screed. For part A of the evaluation, smoke from a smoke generator is the surrogate contaminant. For part B, the surrogate contaminant is sulfur hexafluoride, an inert and relatively safe (when properly used) gas, commonly used in tracer gas studies.

SAFETY: In addition to following the safety procedures established by the host facility, the following concerns should be addressed at each testing site:

1. The discharge of the smoke generating equipment can be hot and should not be handled with unprotected hands.
2. The host may want to contact building and local fire officials in order that the smoke generators do not set off fire sprinklers or create a false alarm.
3. In higher concentrations, smoke generated from the smoke generators may act as an irritant. Direct inhalation of smoke from the smoke generators should be avoided.
4. All compressed gas cylinders should be transported, handled, and stored in accordance with the safety recommendations of the Compressed Gas Association.
5. The Threshold Limit Value for sulfur hexafluoride is 1000 ppm. While the generated concentrations will be below this level, the concentration in the cylinder is near 100 percent. For this reason, the compressed cylinder will be maintained outdoors whenever possible. Should a regulator malfunction or some other major accidental release occur, observers should stand back and let the tank pressure come to equilibrium with the ambient environment.

Laboratory Setup: The following laboratory setup description is based on our understanding of the facilities available at the asphalt paving manufacturing facilities participating in the study. The laboratory evaluation protocol may vary slightly from location to location depending upon the available facilities.

Paver Position: The paving tractor, with screed attached, will be parked underneath an overhead garage door such that both the tractor exhaust and the exhaust from the engineering controls exits into the ambient air. The garage door will be lowered to rest on top of the tractor and plastic or an alternative barrier will be applied around the perimeter of the tractor to seal the remainder of the garage door opening.

Laboratory Ventilation Exhaust: For this evaluation, smoke generated from Rosco Smoke Generators (Rosco, Port Chester, NY) is released into a perforated plenum and dispersed in a quasi-uniform distribution along the length of the augers. Due to interferences created by the auger's gear box, this evaluation may require a separate smoke generator and distribution plenum on each side of the auger region. Releasing theatrical smoke as a surrogate contaminant within the auger region provides excellent qualitative information concerning the engineering control's performance. Areas of diminished control performance are easily determined and minor modifications can be incorporated into the design prior to quantifying the control performance. Additionally, the theatrical smoke helps to verify the barrier integrity separating the front and rear halves of the asphalt paver. A video camera will be used to record the evaluation. The sequence from a typical test run is outlined below:

1. Position paving equipment within door opening and lower overhead door.
2. Seal the remaining door opening around the tractor.
3. Place the smoke distribution tube(s) directly underneath the auger.
4. Connect the smoke generator(s) to the distribution tube(s).
5. Activate video camera, the engineering controls and the smoke generator(s).
6. Inspect the separating barrier for integrity failures and correct as required.
7. Inspect the engineering control and exhaust system for unintended leaks.
8. De-activate the engineering controls for comparison purposes.
9. De-activate smoke generators and wait for smoke levels to subside.
10. End the smoke test evaluation.

Evaluation Part B (Tracer Gas): The tracer gas test is designed to: (1) calculate the total exhaust flow rate of the paver ventilation control system; and (2) evaluate the effectiveness in capturing and controlling a surrogate contaminant under a "controlled" indoor conditions. SF_6 will be used as the surrogate contaminant.

Quantify Exhaust Volume: To determine the total exhaust flow rate of the engineering control, a known quantity of sulfur hexafluoride (SF_6) is released directly into the engineering control's exhaust hood, thus creating a 100 percent capture condition. The SF_6 release is controlled by two Tylan Mass Flow controllers (Tylan, Inc., San Diego, CA). Initially, the test will be performed using a single flow controller calibrated at 0.35 lpm. A hole drilled into the engineering control's exhaust duct allows access for a multi-point monitoring wand into the exhaust stream. The monitoring wand is oriented such that the perforations are perpendicular to the moving air stream. A sample tube connects the wand to a Bruel & Kjaer (B&K) Model 1302 Photo acoustic Infra-red Multi-gas Monitor (California Analytical Instruments, Inc., Orange, CA) positioned on the exterior side of the overhead door. The gas monitor analyzes the air sample and records the concentration of SF_6 within the exhaust stream. The B&K 1302 will be programmed to repeat this analysis approximately once every 30 seconds. Monitoring will continue until approximate steady-state conditions are achieved. The mean concentration of SF_6

measured in the exhaust stream will be used to calculate the total exhaust flow rate of the engineering control. The equation for determining the exhaust flow rate is:

$$Q_{(exh)} = \frac{Q_{(SF_6)}}{C^*_{(SF_6)}} \times 10^6 \qquad \textbf{Equation 1}$$

where: $\mathbf{Q_{(exh)}}$ = flow rate of air exhausted through the ventilation system (lpm or cfm)

$\mathbf{Q_{(SF6)}}$ = flow rate of SF_6 (lpm or cfm) introduced into the system

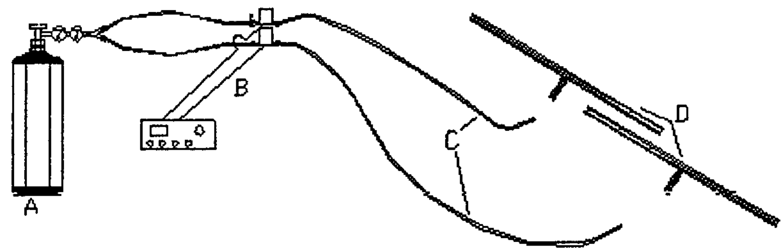
$\mathbf{C^*_{(SF6)}}$ = concentration of SF_6 (parts per million) detected in exhaust

[To convert from liters per minute (lpm) to cubic feet per minute (cfm), divide lpm by 28.3.]

In order to increase accuracy, the exhaust flow rate will be calculated a second time using two mass flow controllers, each calibrated at approximately 0.35 lpm of SF_6. Sufficient time will be allowed between all test runs to allow area concentrations to decay below 0.1 ppm before starting subsequent test runs.

Quantitative Capture Efficiency: The test procedure to determine capture efficiency is slightly different than the exhaust volume procedure. The mass flow controllers will each be calibrated for a flow rate approximating 0.35 liters per minute (lpm) of 99.8 percent SF_6. The discharge tubes from the mass flow controllers will each feed a separate distribution plenum, one per side, within the paver's auger area. The distribution plenums are designed to distribute the SF_6 in a uniform pattern along the length of the auger area. (See Figure 1.) The B&K multi-gas monitor analyzes the air sample and records the concentration of SF_6 within the exhaust stream until approximate steady-state conditions develop. Once this occurs, the SF_6 source will be discontinued and the decay concentration of SF_6 within the exhaust stream will be monitored to indicate the extent in which general area concentrations of non-captured SF_6 contributed to the concentration measured in the exhaust stream.

FIGURE 1



LEGEND
A–Trocer Gos Cylinder with regulotor
B–Tylon Moss Flow Controllers with Control Box
C–PTFE Distribution Tubes
D–Trocer Gos Distribution Plenums

A capture efficiency can be calculated for the control using the following equation:

$$\eta = 100 \times \frac{\dfrac{C_{(SF_6)} \times Q_{(exh)}}{10^6}}{Q_{(SF_6)}} \qquad \text{Equation 2A}$$

where: **η** = capture efficiency

$C_{(SF6)}$ = concentration of SF_6 (parts per million) detected in exhaust

$Q_{(exh)}$ = flow rate of air exhausted through the ventilation system (lpm or cfm)

$Q_{(SF6)}$ = flow rate of SF_6 (lpm or cfm) introduced into the system

[To convert from liters per minute (lpm) to cubic feet per minute (cfm), divide lpm by 28.3.]

NOTE: When the flow rate of SF_6 [$Q_{(SF6)}$] used to determine the engineering control's capture efficiency is the same as that used to quantify the exhaust flow rate, equation 2A may be simplified to:

$$\eta = \frac{C_{(SF_6)}}{C^*_{(SF_6)}} \times 100 \qquad \text{Equation 2B}$$

where the definitions for $C^*_{(SF6)}$, η, and $C_{(SF6)}$ remain the same as in equations 1 and 2A.

The sequence from a typical test run is outlined below:

1. Position paving equipment and seal openings as outlined above.
2. Calibrate (outdoors) both mass flow meters at approximately 0.35 lpm of SF_6.
3. Drill an access hole in the engineering control's exhaust duct on the outdoor side of the overhead door and position the sampling wand into the hole.
4. While maintaining the SF_6 tanks outdoors, run the discharge hoses from the mass flow meters to well-within the exhaust hood(s) to create 100 percent capture conditions.
5. With the engineering controls activated, begin monitoring with the B&K 1302 to determine background interference levels.
6. Initiate flow of SF_6 through a single mass flow meter.
7. Continue monitoring with the B&K for five minutes or until three repetitive readings are recorded.
8. Deactivate flow of the SF_6 and calculate exhaust flow rate using the calculation identified above.
9. Repeat steps #2 through #8 using both mass flow controllers.
10. Allow engineering control exhaust system to continue running until SF_6 has ceased leaking from the discharge hoses then remove the hoses from the hoods.
11. End the exhaust flow rate test.
12. Locate an SF_6 distribution plenum on each side of the auger area and connect each plenum to the discharge hose of a mass flow meter.
13. Initiate B&K monitoring to establish background interference levels until levels reach 0.1 ppm or below.
14. Initiate SF_6 flow through the mass flow meters and monitor with the B&K until approximate steady state conditions appear.
15. Once steady state is achieved, discontinue SF_6 flow and quickly remove the distribution plenums and discharge hoses from the auger area.
16. Continue monitoring with the B&K to determine the general area concentration of SF_6 which escaped auger area into the laboratory area.
17. Discontinue B&K monitoring when concentration decay is complete.
18. Calculate the capture efficiency.
19. Repeat steps 11 - 17 as time permits.

APPENDIX B

ENGINEERING CONTROLS FOR ASPHALT PAVING EQUIPMENT

TRACER GAS EVALUATION RESULTS

B&K DATA FILES AND CALCULATION RESULTS

APPENDIX C

ENGINEERING CONTROLS FOR ASPHALT PAVING EQUIPMENT

BLAW-KNOX PROTOTYPE DESIGN MODIFICATIONS PRIOR TO PHASE TWO FIELD EVALUATIONS

Blaw Knox		Summary from data sheets				
Inside garage, "no wind"						
	Ventilation flow tylan #2 (cfm)	Ventilation flow two tylans (cfm)	Capture efficiency %	Ventilation flow tylan #2 (cfm)	Ventilation flow two tylans (cfm)	Capture efficiency %
Mean	232	242	27	214	256	24
Min	229	235	17	211	252	17
Max	240	256	34	217	264	37
CV	2	3	25	1	1.5	26
Outside with paver front to the wind, 0 degrees with north = zero degrees.						
	Ventilation flow tylan #2 (cfm)	Ventilation flow two tylans (cfm)	Capture efficiency %*	Ventilation flow tylan #2 (cfm)	Ventilation flow two tylans (cfm)	Capture efficiency %
Mean	278	262	0.81 (1.52)	292	288	0.73
Min	275	258	0.58 (0.42)	285	283	0.16
Max	283	266	1.29 (4.33)	297	295	3.27
CV	1.2	1.1	39 (81)	1.7	1.3	116
Outside with paver side to the wind, 90 degrees with north = zero degrees.						
	Ventilation flow tylan #2 (cfm)	Ventilation flow two tylans (cfm)	Capture efficiency %	Ventilation flow tylan #2 (cfm)	Ventilation flow two tylans (cfm)	Capture efficiency %
Mean	285	272	0.47	288	-	0.42
Min	282	271	0.22	285	-	0.25
Max	289	277	0.74	292	-	0.73
CV	0.7	1	40	0.8	-	39
Outside with paver rear to the wind, 180 degrees with north = zero degrees.						
	Ventilation flow tylan #2 (cfm)	Ventilation flow two tylans (cfm)	Capture efficiency %	Ventilation flow tylan #2 (cfm)		
Mean	280	271	5.67	272		
Min	271	261	4.55	256		
Max	288	276	7.3	284		
CV	2.1	2	15	4.9		
Outside with paver side to the wind, 270 degrees with north = zero degrees.						
	Ventilation flow tylan #2 (cfm)	Ventilation flow two tylans (cfm)	Capture efficiency %			
Mean	273	275	0.61			
Min	269	271	0.29			
Max	280	277	1.26			
CV	1.2	1	43			
* Cardboard placed in slat-convayer blast gate to block off wind.						

Blaw Knox	Inside Garage Measurements, Engine outside							
1302 Measurement Data 17886 11/2803 - 7/5/95 19:11 Page 1								
1302 Settings:								
Compensate for Water Vapor Interference: NO								
Compensate for Cross Interference: NO								
Sample Continuously: YES								
Preset Monitoring Period: NO								
Measure								
Gas A: Sulfur hexafluoride: YES								
Water Vapour: NO								
Sampling Tube Length: 15.0 ft								
Air Pressure ressure: 760.0 mmHg								
Normalization Temperature: 80.0 F								
Start Time: 1995-07-05 17:01								
Stop Time: 1995-07-05 19:06								
Results Not Averaged								
Number of Events Marked: 13								
Number of Recorded Samples: 199								
Alarm Limit	Max	Mean	Min	Std.Dev				
Gas A:_______	237	15.2 E+00	5.49E-02	2.87E+01				
Samp.	Time	Gas A	Calibration					
No.	hh:mm:ss	ppm	Correction					
1	17:01:47	6.64E-02	0.077934	**Area background**				
2	17:02:30	6.20E-02	0.072769					
3	17:03:05	6.65E-02	0.078051			**SF6 flow**		
4	17:03:40	5.65E-02	0.066314			tylan #2		
5	17:04:16	5.98E-02	0.070187			0.3388	lpm	
6	17:05:02	6.05E-02	0.071009			Both tylans		
7	17:05:37	6.61E-02	0.077582			0.6374	lpm	
8	17:06:13	6.11E-02	0.071713					
9	17:06:48	5.91E-02	0.069366					
10	17:07:23	6.17E-02	0.072417					
11	17:07:59	6.10E-02	0.071596					
12	17:08:34	5.92E-02	0.069483					
13	17:09:09	6.13E-02	0.071948					
14	17:09:45	5.96E-02	0.069953					
15	17:10:20	5.89E-02	0.069131					
16	17:10:56	5.49E-02	0.064436					
17	17:11:31	6.09E-02	0.071478	Avg.	0.071231			
18	17:12:06	5.68E-02	0.066666	Std. Dev.	0.003662			
19	17:12:42	6.08E-02	0.071361	CV	5.14%			
	17:13:17	User Event		Number	1			
20	17:13:17	3.58E+00	4.201846	In duct				
21	17:13:55	4.43E+01	51.99491	**Tylan #2 only**				
22	17:15:04	4.45E+01	52.22965	**100% capture**				
23	17:15:39	4.24E+01	49.76488	Avg.	51.5489	232.0057	Mean flow	
24	17:16:15	4.41E+01	51.76017	Std. Dev.	1.011018	228.9818	Min	
25	17:16:50	4.43E+01	51.99491	CV	1.96%	240.3229	Max	
	17:17:26	User Event		Number	2			
26	17:17:26	4.61E+01	54.10757	**In duct w/ 90 degree**				
27	17:18:01	4.62E+01	54.22494	**change in sample probe.**				

28	17:18:37	4.57E+01	53.63809	**Tylan #2 only**				
29	17:19:12	4.42E+01	51.87754	**100% capture**				
30	17:19:47	4.62E+01	54.22494	Avg.	53.49138	223.5807	Mean flow	
31	17:20:23	4.44E+01	52.11228	Std. Dev.	1.018871	219.1331	Min	
32	17:20:58	4.53E+01	53.16861	CV	1.90%	230.536	Max	
33	17:21:34	4.65E+01	54.57705					
	17:21:34	User Event		Number	3			
34	17:22:09	8.14E+01	95.53918	**Both tylans on**				
35	17:22:45	8.17E+01	95.89129	**100% capture**				
36	17:23:20	7.75E+01	90.96175					
37	17:23:56	7.97E+01	93.54389	Avg.	93.07441	241.7444	Mean flow	
38	17:24:50	8.00E+01	93.896	Std. Dev.	2.744217	234.643	Min	
39	17:25:26	7.98E+01	93.66126	CV	2.95%	255.6044	Max	
40	17:26:01	7.50E+01	88.0275					
	17:26:01	User Event		Number	4			
41	17:26:37	8.07E+00	9.471759	**SF6 off**				
42	17:27:15	6.92E+00	8.122004	**SF6 tubing placed in**				
43	17:27:50	6.91E+00	8.110267	**distribution tubes**				
44	17:28:25	6.02E+00	7.065674					
45	17:29:01	4.48E+00	5.258176					
46	17:29:36	4.77E+00	5.598549					
47	17:30:12	4.03E+00	4.730011					
48	17:30:47	2.52E+00	2.957724					
49	17:31:23	3.15E+00	3.697155					
50	17:31:58	4.44E+00	5.211228					
51	17:32:33	2.41E+00	2.828617					
52	17:33:09	2.28E+00	2.676036					
53	17:33:46	5.84E-01	0.685441					
54	17:34:22	2.17E-01	0.254693					
55	17:35:08	1.73E-01	0.20305					
56	17:35:43	1.77E-01	0.207745					
57	17:36:19	1.43E-01	0.167839					
58	17:36:54	1.11E-01	0.130281	Avg.	0.137792			
59	17:37:29	1.24E-01	0.145539	Std. Dev.	0.019225			
60	17:38:05	1.05E-01	0.123239	CV	13.95%			
61	17:38:40	1.04E-01	0.122065					
	17:38:40	User Event		Number	5			
62	17:39:15	3.83E-01	0.449527	**Background in building**				
63	17:39:50	4.07E-01	0.477696	**Probe above screed.**				
64	17:40:26	3.16E-01	0.370889					
65	17:41:01	3.27E-01	0.3838					
66	17:41:37	2.85E-01	0.334505					
67	17:42:12	4.19E-01	0.49178					
68	17:42:48	3.58E-01	0.420185					
69	17:43:24	3.54E-01	0.41549					
70	17:43:59	3.65E-01	0.428401					
71	17:45:06	2.96E-01	0.347415					
72	17:45:41	3.01E-01	0.353284					
73	17:46:16	2.56E-01	0.300467					
74	17:46:52	2.55E-01	0.299294					
75	17:47:27	2.54E-01	0.29812					
76	17:48:03	2.51E-01	0.294599					

77	17:48:38	1.93E-01	0.226524					
78	17:49:13	1.40E-01	0.164318					
79	17:49:49	1.54E-01	0.18075					
80	17:50:24	1.29E-01	0.151407					
81	17:51:00	9.32E-02	0.109389					
82	17:51:35	9.12E-02	0.107041					
83	17:52:10	9.83E-02	0.115375	Avg.	0.289733			
84	17:52:46	9.48E-02	0.111267	Std. Dev.	0.129523			
	17:55:56	User Event		Number	6			
85	17:55:20	6.04E-02	0.070891	**Probe into duct**				
86	17:55:56	6.83E-02	0.080164	Avg.	0.075547			
87	17:56:50	6.44E-02	0.075586	Std. Dev.	0.004636			
	17:57:26	User Event		Number	7			
88	17:57:26	1.78E+00	2.089186	**Both tylans on**				
89	17:58:01	1.12E+01	13.14544	**SF6 distribution**				
90	17:58:39	2.64E+01	30.98568					
91	17:59:14	1.82E+01	21.36134					
92	17:59:50	1.89E+01	22.18293					
93	18:00:25	1.34E+01	15.72758					
94	18:01:01	2.69E+01	31.57253					
95	18:01:36	1.52E+01	17.84024					
96	18:02:12	1.94E+01	22.76978	Avg.	24.97373	26.83%	Ave Eff	
97	18:02:47	2.60E+01	30.5162	Std. Dev.	6.316419	16.90%	Min Eff	
98	18:03:22	2.71E+01	31.80727	CV	25.29%	34.17%	Max Eff	
	18:04:00	User Event		Number	8			
99	18:04:00	5.84E+00	6.854408	**SF6 off**				
100	18:04:49	1.31E+00	1.537547					
101	18:05:27	3.54E-01	0.41549					
102	18:06:03	1.47E-01	0.172534					
103	18:06:38	1.12E-01	0.131454					
104	18:07:13	9.50E-02	0.111502					
105	18:07:49	9.77E-02	0.11467					
106	18:08:24	1.04E-01	0.122065					
107	18:09:00	9.24E-02	0.10845					
108	18:09:35	9.03E-02	0.105985					
109	18:10:11	9.38E-02	0.110093					
110	18:10:46	8.04E-02	0.094365					
111	18:11:21	7.62E-02	0.089436					
112	18:11:57	8.47E-02	0.099412					
113	18:12:32	7.51E-02	0.088145					
114	18:13:08	7.42E-02	0.087089					
115	18:13:43	6.96E-02	0.08169					
116	18:14:18	6.96E-02	0.08169					
117	18:15:25	6.71E-02	0.078755					
118	18:16:00	6.84E-02	0.080281	Avg.	0.082941			
119	18:16:36	2.23E-01	0.261735	Std. Dev.	0.003795			
120	18:17:11	1.63E-01	0.191313	CV	4.58%			
	18:17:47	User Event		Number	9			
121	18:17:47	2.34E-01	0.274646	**Both tylans on**				
122	18:18:22	1.87E+01	21.94819	**SF6 distribution**				
123	18:19:01	1.60E+01	18.7792					
124	18:19:37	2.73E+01	32.04201					

125	18:20:14	2.19E+01	25.70403					
126	18:20:52	1.38E+01	16.19706					
127	18:21:28	2.92E+01	34.27204					
128	18:22:06	2.03E+01	23.82611					
129	18:22:43	1.67E+01	19.60079	Avg.	22.75911	24.45%	Ave Eff	
130	18:23:19	1.27E+01	14.90599	Std. Dev.	6.025428	17.40%	Min Eff	
131	18:23:54	1.87E+01	21.94819	CV	26.47%	36.82%	Max Eff	
132	18:24:49	1.80E+01	21.1266					
	18:24:49	User Event		Number	10			
133	18:25:25	2.05E+00	2.406085	**SF6 off**				
134	18:26:02	1.99E+00	2.335663					
135	18:26:38	7.31E-01	0.857975					
136	18:27:13	8.62E-01	1.011729					
137	18:27:49	3.30E+00	3.87321					
138	18:28:26	1.31E+00	1.537547					
139	18:29:04	2.97E+00	3.485889					
140	18:29:42	1.53E+00	1.795761					
141	18:30:20	3.61E+00	4.237057					
142	18:30:58	3.00E+00	3.5211					
143	18:31:33	1.61E+00	1.889657					
144	18:32:11	1.61E+00	1.889657					
145	18:32:47	5.17E-01	0.606803					
146	18:33:22	1.20E+00	1.40844					
147	18:33:57	3.05E+00	3.579785					
148	18:34:46	1.45E+00	1.701865					
149	18:35:25	1.93E+00	2.265241					
150	18:36:00	2.36E+00	2.769932					
151	18:36:36	3.83E+00	4.495271					
152	18:37:14	6.52E+00	7.652524					
153	18:37:49	4.51E+00	5.293387					
154	18:38:24	3.62E+00	4.248794					
155	18:39:00	3.08E+00	3.614996					
156	18:39:35	7.66E-01	0.899054					
157	18:40:13	2.70E-01	0.316899					
158	18:40:49	1.87E-01	0.219482					
159	18:41:24	1.76E-01	0.206571					
160	18:42:00	1.70E-01	0.199529					
161	18:42:35	1.48E-01	0.173708					
162	18:43:11	1.17E-01	0.137323					
163	18:43:46	1.12E-01	0.131454					
164	18:44:22	9.12E-02	0.107041					
165	18:45:28	7.82E-02	0.091783					
166	18:46:04	7.05E-02	0.082746	Avg.	0.102065			
167	18:46:39	9.81E-02	0.11514	Std. Dev.	0.014213			
168	18:47:15	9.68E-02	0.113614	CV	13.93%			
	18:47:51	User Event		Number	11			
169	18:47:51	2.63E-01	0.308683	**Tylan #2 only**				
170	18:48:26	4.83E+01	56.68971	**100% capture**				
171	18:49:07	4.77E+01	55.98549					
172	18:49:42	4.70E+01	55.1639					
173	18:50:17	4.77E+01	55.98549	Avg.	55.93854	213.7996	Mean flow	
174	18:50:53	4.76E+01	55.86812	Std. Dev.	0.541685	210.9667	Min	

175	18:51:28	4.35E+01	51.05595	CV	0.97%	216.8019	Max	
	18:52:04	User Event		Number	12			
176	18:52:04	2.37E+02	278.1669	**Both tylans on**				
177	18:52:39	7.21E+01	84.62377	**100% capture**				
178	18:53:14	7.56E+01	88.73172					
179	18:53:50	7.52E+01	88.26224					
180	18:54:25	7.56E+01	88.73172					
181	18:55:20	7.54E+01	88.49698					
182	18:55:55	7.61E+01	89.31857					
183	18:56:31	7.44E+01	87.32328					
184	18:57:06	7.38E+01	86.61906	Avg.	87.8045	256.2536	Mean flow	
185	18:57:41	7.57E+01	88.84909	Std. Dev.	1.315673	251.9098	Min	
186	18:58:17	7.27E+01	85.32799	CV	1.50%	263.691	Max	
187	18:58:52	7.36E+01	86.38432					
	18:58:52	User Event		Number	13			
188	18:59:28	3.88E-01	0.455396	**Background in room.**				
189	19:00:08	1.36E-01	0.159623					
190	19:00:43	1.27E-01	0.14906					
191	19:01:19	1.12E-01	0.131454					
192	19:01:54	1.20E-01	0.140844					
193	19:02:30	1.02E-01	0.119717					
194	19:03:05	9.87E-02	0.115844					
195	19:03:40	9.42E-02	0.110563					
196	19:04:16	8.42E-02	0.098826					
197	19:05:02	8.43E-02	0.098943	Avg.	0.099483			
198	19:05:38	8.22E-02	0.096478	Std. Dev.	0.006705			
199	19:06:13	7.89E-02	0.092605	CV	6.74%			

Blaw Knox — Inside Garage Measurements, Engine exhausted through duct

- 1302 Measurement Data ------- 1788611/2803 - 1995-07-06 17:15 - Page 1 -

1302 Settings:
Compensate for Water Vap. Interference : NO
Compensate for Cross Interference : NO
Sample Continuously : YES
Pre-set Monitoring Period : NO
Measure
Gas A: Sulfur hexafluoride : YES
Water Vapour : NO
Sampling Tube Length : 15.0 ft
Air Pressure : 760.0 mmHg
Normalization Temperature : 80.0 F
Start Time : 1995-07-06 15:31
Stop Time : 1995-07-06 16:21
Results Not Averaged
Number of Event Marks : 6
Number of Recorded Samples : 82

	Alarm Limit	Max	Mean	Min	Std.Dev
Gas A:	________	71.7E+00	11.8E+00	49.9E-03	20.8E+00

Samp. No.	Time hh:mm:ss	Gas A ppm	Calibration Correction				
1	15:31:19	6.09E-02	0.071478	**Area background**			
2	15:32:02	4.99E-02	0.058568	**then in duct background.**			
3	15:32:37	5.15E-02	0.060446	Avg.	0.063497	**SF6 flow**	
4	15:33:13	2.93E-01	0.343894	Std. Dev.	0.006975	tylan #2	
5	15:33:48	2.72E-01	0.319246	CV	10.99%	0.3397	lpm
6	15:34:23	2.26E-01	0.265256			Both tylans	
	15:34:23	User Event		Number	1	0.6435	lpm
7	15:34:59	3.67E+01	43.07479	**Tylan #2 only**			
8	15:35:39	3.52E+01	41.31424	**100% capture**			
9	15:36:15	3.48E+01	40.84476				
10	15:36:50	3.53E+01	41.43161				
11	15:37:25	3.48E+01	40.84476	Avg.	41.66635	287.796	Mean flow
12	15:38:01	3.60E+01	42.2532	Std. Dev.	0.807497	278.3858	Min
13	15:38:36	3.57E+01	41.90109	CV	1.94%	293.585	Max
	15:39:23	User Event		Number	2		
14	15:39:23	4.43E+01	51.99491	**Both tylans on**			
15	15:39:58	7.12E+01	83.56744	**100% capture**			
16	15:40:33	7.15E+01	83.91955				
17	15:41:09	7.11E+01	83.45007				
18	15:41:44	7.07E+01	82.98059	Avg.	83.587	271.7594	Mean flow
19	15:42:19	7.17E+01	84.15429	Std. Dev.	0.409395	269.9274	Min
20	15:42:55	7.11E+01	83.45007	CV	0.49%	273.7453	Max
	15:43:30	User Event		Number	3		
21	15:43:30	7.12E+01	83.56744	Avg.	1.784024		
22	15:44:06	1.52E+00	1.784024	**Moving equipment**			
	15:44:46	User Event		Number	4		
23	15:44:46	9.35E-01	1.09741	**Both tylans on**			
24	15:45:21	3.51E+00	4.119687	**SF6 distribution**			
25	15:45:59	3.41E+00	4.002317				
26	15:46:35	4.39E+00	5.152543				
27	15:47:10	4.71E+00	5.528127				
28	15:47:46	6.01E+00	7.053937				
29	15:48:21	6.68E+00	7.840316	Avg.	6.208873	7.43%	Ave Eff
30	15:49:27	6.50E+00	7.62905	Std. Dev.	1.722479	4.79%	Min Eff
31	15:50:03	7.11E+00	8.345007	CV	27.74%	9.98%	Max Eff
	15:50:38	User Event		Number	5		

32	15:50:38	6.87E+00	8.063319	**SF6 off**					
33	15:51:14	7.83E+00	9.190071						
34	15:51:49	6.33E+00	7.429521	Avg.	7.793368				
35	15:52:25	6.25E+00	7.335625	Std. Dev.	0.877454				
36	15:53:00	5.92E+00	6.948304	CV	11.26%				
	15:53:35	User Event		Number	6				
37	15:53:35	5.59E+00	6.560983	**In room decay rate**					
38	15:54:11	5.08E+00	5.962396						
39	15:54:46	4.92E+00	5.774604						
40	15:55:21	4.59E+00	5.387283						
41	15:55:57	4.37E+00	5.129069						
42	15:56:32	4.08E+00	4.788696						
43	15:57:08	3.78E+00	4.436586						
44	15:57:43	3.58E+00	4.201846						
45	15:58:18	3.36E+00	3.943632						
46	15:59:13	3.34E+00	3.920158						
47	15:59:49	3.11E+00	3.650207						
48	16:00:24	2.94E+00	3.450678						
49	16:00:59	2.88E+00	3.380256						
50	16:01:35	2.67E+00	3.133779						
51	16:02:10	2.62E+00	3.075094						
52	16:02:45	2.45E+00	2.875565						
53	16:03:21	2.38E+00	2.793406						
54	16:03:56	2.24E+00	2.629088						
55	16:04:32	2.20E+00	2.58214						
56	16:05:10	2.09E+00	2.453033						
57	16:05:45	2.00E+00	2.3474						
58	16:06:20	1.94E+00	2.276978						
59	16:06:56	1.85E+00	2.171345						
60	16:07:31	1.77E+00	2.077449						
61	16:08:06	1.67E+00	1.960079						
62	16:08:42	1.61E+00	1.889657						
63	16:09:28	1.52E+00	1.784024						
64	16:10:04	1.44E+00	1.690128						
65	16:10:39	1.34E+00	1.572758						
66	16:11:14	1.32E+00	1.549284						
67	16:11:50	1.24E+00	1.455388						
68	16:12:25	1.21E+00	1.420177						
69	16:13:01	1.15E+00	1.349755						
70	16:13:36	1.10E+00	1.29107						
71	16:14:11	1.06E+00	1.244122						
72	16:14:47	1.01E+00	1.185437						
73	16:15:22	9.62E-01	1.129099						
74	16:15:58	9.23E-01	1.083325						
75	16:16:33	8.94E-01	1.049288						
76	16:17:09	8.68E-01	1.018772						
77	16:17:44	8.30E-01	0.974171						
78	16:18:19	7.88E-01	0.924876						
79	16:19:26	7.37E-01	0.865017						
80	16:20:01	7.20E-01	0.845064						
81	16:20:37	6.92E-01	0.8122						
82	16:21:12	6.54E-01	0.7676						
**********	**** COM	NT *******	*******						
indoor test after some modificatins to wind (increased					90	between			
engine and the rear of tractor			intended ot minimize		amount				
of engine cooling air which intefers with engineering control in auger area.									
**********	* END OF	OMMENT	*******						

Blaw Knox — Outside, wind @ 0 degrees blowing @ front of paver, 8-10 mph

- 1302 Measurement Data ------- 1788611/2803 - 1995-07-06 12:54 - Page 1 -

1302 Settings:

Compensate for Water Vap. Interference	:	NO
Compensate for Cross Interference	:	NO
Sample Continuously	:	YES
Pre-set Monitoring Period	:	NO
Measure		
Gas A: Sulfur hexafluoride	:	YES
Water Vapour	:	NO
Sampling Tube Length	:	15.0 ft
Air Pressure	:	760.0 mmHg
Normalization Temperature	:	80.0 F
Start Time	:	1995-07-06 10:33
Stop Time	:	1995-07-06 10:54
Results Not Averaged		
Number of Event Marks	:	5
Number of Recorded Samples	:	33

	Alarm Limit	Max	Mean	Min	Std.Dev
Gas A:	________	75.1E+00	20.1E+00	56.6E-03	28.4E+00

Samp. No.	Time hh:mm:ss	Gas A ppm	Calibration Correction				
1	10:33:55	6.36E-02	0.074647	**Background**			
	10:34:38	User Event		Number	1		
2	10:34:38	5.66E-02	0.066431	In duct		**SF6 flow**	
3	10:35:13	6.09E-02	0.071478			tylan #2	
	10:35:13	User Event		Number	2	0.3397	lpm
4	10:35:49	1.89E-01	0.221829	In duct		Both tylans	
5	10:36:24	5.16E-01	0.605629	**Both tylans on**		0.6435	lpm
6	10:37:00	5.66E-01	0.664314	**SF6 distribution**			
7	10:37:35	9.54E-01	1.11971				
8	10:38:10	4.61E-01	0.541076				
9	10:38:46	7.67E-01	0.900228				
10	10:39:21	8.41E-01	0.987082	Avg	0.703046	0.81%	Ave Eff
11	10:39:56	4.29E-01	0.503517	Std. Dev	0.275263	0.58%	Min Eff
12	10:40:43	2.58E-01	0.302815	CV	39.15%	1.29%	Max Eff
	10:41:18	User Event		Number	3		
13	10:41:18	7.32E-01	0.859148	**Same as above**			
14	10:41:53	3.13E-01	0.367368	**Cardboard placed in**			
15	10:42:29	1.58E+00	1.854446	**blast gates.**			
16	10:43:04	4.69E-01	0.550465				
17	10:43:39	1.29E+00	1.514073				
18	10:44:15	3.19E+00	3.744103				
19	10:44:52	3.40E-01	0.399058	Avg	1.311936	1.52%	Ave Eff
20	10:45:30	1.39E+00	1.631443	Std. Dev	1.063215	0.42%	Min Eff
21	10:46:05	7.56E-01	0.887317	CV	81.04%	4.33%	Max Eff
	10:46:42	User Event		Number	4		
22	10:46:42	2.22E+01	26.05614	**In duct**			
23	10:47:20	7.40E+01	86.8538	**both tylans on**			
24	10:47:58	7.51E+01	88.14487	**100% capture**			
25	10:48:33	7.38E+01	86.61906				
26	10:49:08	7.30E+01	85.6801	Avg	86.54081	262.4837	Mean flow
27	10:49:44	7.28E+01	85.44536	Std. Dev	0.961193	257.707	Min
28	10:50:19	7.37E+01	86.50169	CV	1.11%	265.8488	Max
	10:51:26	User Event		Number	5		
29	10:51:26	3.72E+01	43.66164	**100% capture**			
30	10:52:01	3.71E+01	43.54427	**Tylan #2 only**			
31	10:52:37	3.61E+01	42.37057	Avg	43.14521	277.9314	Mean flow
32	10:53:12	3.65E+01	42.84005	Std. Dev	0.53529	274.6441	Min
33	10:53:48	3.69E+01	43.30953	CV	1.24%	283.0127	Max

Blaw Knox	Outside, wind @ 0 degrees blowing @ front of paver, 8-10 mph								
- 1302 Measurement Data ------- 1788611/2803 - 1995-07-06 13:00 - Page 1 -									
1302 Settings:									
Compensate for Water Vap. Interference : NO									
Compensate for Cross Interference : NO									
Sample Continuously : YES									
Pre-set Monitoring Period : NO									
Measure									
Gas A: Sulfur hexafluoride : YES									
Water Vapour : NO									
Sampling Tube Length : 15.0 ft									
Air Pressure : 760.0 mmHg									
Normalization Temperature : 80.0 F									
Start Time : 1995-07-06 12:06									
Stop Time : 1995-07-06 12:24									
Results Not Averaged									
Number of Event Marks : 3									
Number of Recorded Samples : 30									
	Alarm Limit	Max	Mean	Min	Std.Dev				
Gas A:	________	68.3E+00	23.5E+00	69.3E-03	28.3E+00				
Samp.	Time	Gas A	Calibration						
No.	hh:mm:ss	ppm	Correction						
1	12:06:31	2.27E-01	0.26643	Area background					
2	12:07:14	8.72E-02	0.102347	Avg.	0.090336				
3	12:07:49	7.44E-02	0.087323	Std. Dev.	0.010824	**SF6 flow**			
4	12:08:24	6.93E-02	0.081337	CV	11.98%	tylan #2			
	12:09:00	User Event		Number	1	0.3397	lpm		
5	12:09:00	7.22E-02	0.084741	In duct		Both tylans			
6	12:09:35	2.77E-01	0.325115	**Both tylans on**		0.6435	lpm		
7	12:10:10	1.33E-01	0.156102	**SF6 distribution**					
8	12:10:46	6.21E-01	0.728868						
9	12:11:21	1.00E+00	1.1737						
10	12:11:57	1.89E-01	0.221829						
11	12:12:32	1.05E-01	0.123239						
12	12:13:07	3.27E-01	0.3838						
13	12:13:43	3.90E-01	0.457743						
14	12:14:18	2.65E-01	0.311031						
15	12:14:53	2.20E+00	2.58214	Avg.	0.576846	0.73%	Ave Eff		
16	12:15:40	5.06E-01	0.593892	Std. Dev.	0.669933	0.16%	Min Eff		
17	12:16:15	3.04E-01	0.356805	CV	116.14%	3.27%	Max Eff		
	12:16:50	User Event		Number	2				
18	12:16:50	6.83E+01	80.16371	**100% capture**					
19	12:17:31	6.75E+01	79.22475	**Both tylans**					
20	12:18:06	6.57E+01	77.11209						
21	12:18:41	6.68E+01	78.40316						
22	12:19:17	6.76E+01	79.34212	Avg.	79.00678	287.5139	Mean flow		
23	12:19:52	6.78E+01	79.57686	Std. Dev.	0.985322	283.3645	Min		
24	12:20:28	6.75E+01	79.22475	CV	1.25%	294.5783	Max		
	12:21:03	User Event		Number	3				
25	12:21:03	5.13E+01	60.21081	**100% capture**					
26	12:21:38	3.59E+01	42.13583	**Tylan #2 only**					
27	12:22:14	3.50E+01	41.0795						
28	12:22:49	3.44E+01	40.37528	Avg.	41.0795	291.9074	Mean flow		
29	12:23:25	3.46E+01	40.61002	Std. Dev.	0.679328	284.5894	Min		
30	12:24:00	3.51E+01	41.19687	CV	1.65%	296.9988	Max		
**********	**** COM	NT *******	*******						
outdoor te	st, paver	oriented i	nto wind,	7/6/95					
**********	* END OF	OMMENT	*******						

Blaw Knox	Outside, wind @ 90 degrees blowing @ rt. side of paver, 8-10 mph								
- 1302 Measurement Data ------ 1788611/2803 - 1995-07-06 12:57 - Page 1 -									
1302 Settings:									
Compensate for Water Vap. Interference :				NO					
Compensate for Cross Interference :				NO					
Sample Continuously :			YES						
Pre-set Monitoring Period :			NO						
Measure									
Gas A: Sulfur hexafluoride :			YES						
Water Vapour :			NO						
Sampling Tube Length :			15.0 ft						
Air Pressure :			760.0 mmHg						
Normalization Temperature :			80.0 F						
Start Time		: 1995-07-06 10:58							
Stop Time		: 1995-07-06 11:21							
Results Not Averaged									
Number of Event Marks :			3						
Number of Recorded Samples :			37						
	Alarm Limit	Max	Mean	Min	Std.Dev				
Gas A:	________	259E+00	26.6E+00	64.9E-03	46.9E+00				
No.	hh:mm:ss	ppm	Calibration						
------	----------	----------	Correction						
1	10:58:37	2.85E-01	0.334505	**Background air**					
2	10:59:20	9.28E-02	0.108919						
3	10:59:55	9.71E-02	0.113966			**SF6 flow**			
4	11:00:30	7.95E-02	0.093309			tylan #2			
5	11:01:06	2.07E-01	0.242956			0.3397	lpm		
6	11:01:41	9.44E-02	0.110797			Both tylans			
7	11:02:17	6.54E-02	0.07676	Avg	0.108802	0.6435	lpm		
8	11:02:52	6.78E-02	0.079577	Std. Dev	0.052726				
9	11:03:27	6.54E-02	0.07676	CV	48.46%				
10	11:04:03	6.49E-02	0.076173						
	11:04:03	User Event		Number	1				
11	11:04:38	3.61E+01	42.37057	In duct					
12	11:05:18	3.57E+01	41.90109	**Tylan #2 only**					
13	11:05:54	3.62E+01	42.48794	**100% capture**					
14	11:06:29	3.57E+01	41.90109						
15	11:07:04	3.58E+01	42.01846						
16	11:07:40	3.59E+01	42.13583	Avg	42.06876	285.0431	Mean flow		
17	11:08:15	3.55E+01	41.66635	Std. Dev	0.286353	282.2309	Min		
18	11:08:51	3.50E+01	41.0795	CV	0.68%	287.796	Max		
	11:09:37	User Event		Number	2				
19	11:09:37	2.59E+02	303.9883	**Both tylans on**					
20	11:10:13	6.98E+01	81.92426	**100% capture**					
21	11:10:48	7.07E+01	82.98059						
22	11:11:24	7.12E+01	83.56744						
23	11:11:59	7.15E+01	83.91955	Avg	83.37182	272.4608	Mean flow		
24	11:12:34	7.15E+01	83.91955	Std. Dev	0.798346	270.6825	Min		
25	11:13:10	7.15E+01	83.91955	CV	0.96%	277.275	Max		
	11:13:45	User Event		Number	3				
26	11:13:45	7.35E+00	8.626695	**SF6 distribution**					
27	11:14:23	4.91E-01	0.576287	**Both tylans on**					
28	11:15:01	3.89E-01	0.456569						
29	11:15:36	3.39E-01	0.397884						
30	11:16:12	2.01E-01	0.235914						
31	11:16:47	3.08E-01	0.3615						
32	11:17:23	5.23E-01	0.613845						
33	11:17:58	1.55E-01	0.181924						
34	11:18:33	4.43E-01	0.519949						
35	11:19:40	2.06E-01	0.241782	Avg	0.392336	0.47%	Ave Eff		
36	11:20:15	1.86E-01	0.218308	Std. Dev	0.154999	0.22%	Min Eff		
37	11:20:50	4.36E-01	0.511733	CV	39.51%	0.74%	Max Eff		
****	******	**** COM	NT *******	*******					
outdoor test, paver oriented 90 deg with wind, 7/06/95-									
****	******	* END OF	COMMEN	*******					

Blaw Knox **Outside, wind @ 90 degrees blowing @ rt. side of paver, 8-10 mph**

- 1302 Measurement Data ------- 1788611/2803 - 1995-07-06 13:01 - Page 1 -

1302 Settings:
Compensate for Water Vap. Interference : NO
Compensate for Cross Interference : NO
Sample Continuously : YES
Pre-set Monitoring Period : NO
Measure
Gas A: Sulfur hexafluoride : YES
Water Vapour : NO
Sampling Tube Length : 15.0 ft
Air Pressure : 760.0 mmHg
Normalization Temperature : 80.0 F
Start Time : 1995-07-06 12:29
Stop Time : 1995-07-06 12:42
Results of Event Marks : 2
Number of Recorded Sampl : 21
Number of Recorded Samples : 21

	Alarm Limit	Max	Mean	Min	Std.Dev
Gas A:	________	35.8E+00	9.92E+00	67.3E-03	15.4E+00

Samp. No.	Time hh:mm:ss	Gas A ppm	Calibration Correction				
1	12:30:01	2.11E-01	0.247651	**Area background**			
2	12:30:43	8.05E-02	0.094483	Avg	0.08615		
3	12:31:19	7.24E-02	0.084976	Std. Dev.	0.007813	**SF6 flow**	
4	12:31:54	6.73E-02	0.07899	CV	9.07%	tylan #2	
	12:32:30	User Even	#VALUE!	Number	1	0.3397	lpm
5	12:32:30	2.74E+01	32.15938	**100% capture**		Both tylans	
6	12:33:10	3.56E+01	41.78372	**Tylan #2 only**		0.6435	lpm
7	12:33:45	3.50E+01	41.0795				
8	12:34:21	3.55E+01	41.66635	Avg	41.6194	288.1207	Mean flow
9	12:34:56	3.54E+01	41.54898	Std. Dev.	0.348176	285.3843	Min
10	12:35:31	3.58E+01	42.01846	CV	0.84%	291.9074	Max
	12:36:07	User Even	#VALUE!	Number	2		
11	12:36:07	3.37E-01	0.395537	**Both tylans on**			
12	12:36:47	4.98E-01	0.584503	**SF6 distribution**			
13	12:37:22	5.16E-01	0.605629				
14	12:37:58	2.69E-01	0.315725				
15	12:38:33	3.05E-01	0.357979				
16	12:39:08	1.75E-01	0.205398				
17	12:39:44	2.60E-01	0.305162				
18	12:40:30	2.20E-01	0.258214				
19	12:41:06	2.25E-01	0.264083	Avg	0.344748	0.42%	Ave Eff
20	12:41:41	1.85E-01	0.217135	Std. Dev.	0.135733	0.25%	Min Eff
21	12:42:16	2.41E-01	0.282862	CV	39.37%	0.73%	Max Eff

********** **** COM NT ******* *******
outdoor tester, paver oriented 90 deg with wind, 7/6/95
********** * END OF OMMENT *******

Blaw Knox	Outside, wind @ 180 degrees blowing @ rear of paver, 8-10 mph								
- 1302 Measurement Data ------- 1788611/2803 - 1995-07-06 12:58 - Page 1 -									
1302 Settings:									
Compensate for Water Vap. Interference : NO									
Compensate for Cross Interference : NO									
Sample Continuously : YES									
Pre-set Monitoring Period : NO									
Measure									
Gas A: Sulfur hexafluoride : YES									
Water Vapour : NO									
Sampling Tube Length : 15.0 ft									
Air Pressure : 760.0 mmHg									
Normalization Temperature : 80.0 F									
Start Time : 1995-07-06 11:26									
Stop Time : 1995-07-06 11:53									
Results Not Averaged									
Number of Event Marks : 5									
Number of Recorded Samples : 44									
	Alarm Limit	Max	Mean	Min	Std.Dev				
Gas A:	_________	73.9E+00	22.7E+00	58.3E-03	27.0E+00				
Samp.	Time	Gas A	Calibration						
No.	hh:mm:ss	ppm	Correction						
1	11:26:51	8.24E-02	0.096713	**Area background**					
2	11:27:34	6.93E-02	0.081337						
3	11:28:10	6.04E-02	0.070891			**SF6 flow**			
4	11:28:45	6.45E-02	0.075704			tylan #2			
5	11:29:20	6.50E-02	0.076291			0.3397	lpm		
6	11:29:56	6.74E-02	0.079107			Both tylans			
7	11:30:31	6.02E-02	0.070657			0.6435	lpm		
8	11:31:06	6.51E-02	0.076408						
9	11:31:42	5.83E-02	0.068427	Avg	0.076771				
10	11:32:17	6.08E-02	0.071361	Std. Dev.	0.006524				
11	11:32:53	7.63E-02	0.089553	CV	8.50%				
12	11:33:28	7.22E-02	0.084741						
	11:33:28	User Event		Number	1				
13	11:34:03	8.14E+00	9.553918						
14	11:34:41	2.72E+00	3.192464						
15	11:35:16	3.83E+00	4.495271	**Start SF6, both tylans**					
16	11:35:52	3.84E+00	4.507008	**SF6 distribution**					
17	11:36:27	3.87E+00	4.542219						
18	11:37:02	3.74E+00	4.389638						
19	11:37:49	3.52E+00	4.131424						
20	11:38:24	4.86E+00	5.704182						
21	11:39:00	4.24E+00	4.976488						
22	11:39:35	4.44E+00	5.211228						
23	11:40:10	3.25E+00	3.814525	Avg	4.749217	5.67%	Ave Eff		
24	11:40:46	5.21E+00	6.114977	Std. Dev.	0.689118	4.55%	Min Eff		
25	11:41:21	3.71E+00	4.354427	CV	14.51%	7.30%	Max Eff		
	11:41:56	User Event		Number	2				
26	11:41:56	7.39E+01	86.73643	**100% capture**					
27	11:42:35	7.01E+01	82.27637	**Both tylans on**					

28	11:43:11	7.25E+01	85.09325						
29	11:43:46	7.14E+01	83.80218						
30	11:44:21	7.09E+01	83.21533	Avg	83.75188	271.2244	Mean flow		
31	11:44:57	7.02E+01	82.39374	Std. Dev.	1.634574	261.8917	Min		
32	11:45:32	7.05E+01	82.74585	CV	1.95%	276.0884	Max		
	11:46:08	User Event		Number	3				
33	11:46:08	7.26E+01	85.21062						
34	11:46:43	3.64E+01	42.72268	**Tylan #2 only**					
35	11:47:49	3.77E+01	44.24849	**100% capture**					
36	11:48:25	3.69E+01	43.30953	Avg	42.82049	280.0391	Mean flow		
37	11:49:00	3.62E+01	42.48794	Std. Dev.	0.876485	271.0016	Min		
38	11:49:36	3.55E+01	41.66635	CV	2.05%	287.796	Max		
39	11:50:11	3.62E+01	42.48794						
	11:50:11	User Event		Number	4				
40	11:50:47	6.18E-01	0.725347	**Pull #2 tylan tubing**					
	11:51:27	User Event		Number	5				
41	11:51:27	3.99E+01	46.83063	**Put #2 back, pull #3**					
42	11:52:07	3.60E+01	42.2532	Avg	43.95507	272.8107	Mean flow		
43	11:52:43	3.78E+01	44.36586	Std. Dev.	2.148224	256.0591	Min		
44	11:53:18	3.61E+01	42.37057	CV	4.89%	283.7989	Max		
**********	****COM	NT *******	*******						
outdoor te	7/6/95								
**********	* END OF	OMMENT	*******						

Blaw Knox	Outside, wind @ 270 degrees blowing @ lt. side of paver, 8-10 mph								
- 1302 Measurement Data ------- 1788611/2803 - 1995-07-06 12:51 - Page 1 -									
1302 Settings:									
Compensate for Water Vap. Interference :			NO						
Compensate for Cross Interference :			NO						
Sample Continuously :			YES						
Pre-set Monitoring Period :			NO						
Measure									
Gas A: Sulfur hexafluoride :			YES						
Water Vapour :			NO						
Sampling Tube Length :			15.0 ft						
Air Pressure :			760.0 mmHg						
Normalization Temperature :			80.0 F						
Start Time		: 1995-07-06 09:47							
Stop Time		: 1995-07-06 10:23							
Results Not Averaged									
Number of Event Marks :			5						
Number of Recorded Samples :			59						
	Alarm Limit	Max	Mean	Min	Std.Dev				
Gas A:	________	71.5E+00	14.8E+00	50.4E-03	25.3E+00				
Samp.	Time	Gas A	Calibration						
No.	hh:mm:ss	ppm	Correction						
1	9:47:34	7.41E-02	0.086971	**Area background**					
2	9:48:17	7.64E-02	0.089671						
3	9:48:52	1.01E+00	1.185437			**SF6 flow**			
4	9:49:27	7.01E-02	0.082276			tylan #2			
5	9:50:03	2.32E-01	0.272298			0.3397	lpm		
6	9:50:38	3.49E-01	0.409621			Both tylans			
7	9:51:13	1.13E-01	0.132628			0.6435	lpm		
8	9:51:49	3.53E-01	0.414316						
9	9:52:24	3.40E-01	0.399058						
10	9:52:59	6.29E-02	0.073826						
11	9:53:35	6.17E-02	0.072417						
12	9:54:10	6.42E-02	0.075352						
13	9:55:17	5.71E-02	0.067018	Avg.	0.072143				
14	9:55:52	6.47E-02	0.075938	Std. Dev.	0.003703				
15	9:56:27	5.82E-02	0.068309	CV	5.13%				
	9:57:03	User Event		Number	1				
16	9:57:03	5.90E-02	0.069248	**In duct**					
17	9:57:38	6.19E-02	0.072652	**No SF6**					
18	9:58:14	5.04E-02	0.059154						
19	9:58:49	5.87E-02	0.068896						
20	9:59:25	5.91E-02	0.069366						
21	10:00:00	6.10E-02	0.071596						
22	10:00:36	7.15E-02	0.08392	Avg.	0.072222				
23	10:01:11	6.90E-02	0.080985	Std. Dev.	0.007218				
24	10:01:46	6.32E-02	0.074178	CV	9.99%				
	10:02:22	User Event		Number	2				
25	10:02:22	6.12E-02	0.07183	**In duct**					
26	10:02:57	3.80E+01	44.6006	**Tylan #2 on**					
27	10:03:38	3.65E+01	42.84005	**100% capture**					

28	10:04:13	3.75E+01	44.01375						
29	10:05:08	3.76E+01	44.13112						
30	10:05:43	3.72E+01	43.66164	Avg.	43.84608	273.4888	Mean flow		
31	10:06:18	3.75E+01	44.01375	Std. Dev.	0.545727	268.8621	Min		
32	10:06:54	3.72E+01	43.66164	CV	1.24%	279.9112	Max		
33	10:07:29	3.71E+01	43.54427						
	10:07:29	User Event		Number	3				
34	10:08:05	6.94E+01	81.45478	**In duct**					
35	10:08:40	7.02E+01	82.39374	**Tylan #2 & #3 on**					
36	10:09:15	6.99E+01	82.04163	**100% capture**					
37	10:09:51	7.09E+01	83.21533						
38	10:10:26	7.08E+01	83.09796	Avg.	82.67878	274.7446	Mean flow		
39	10:11:02	7.15E+01	83.91955	Std. Dev.	0.81558	270.6825	Min		
40	10:11:37	7.04E+01	82.62848	CV	0.99%	276.8783	Max		
41	10:12:12	7.00E+01	82.159						
	10:12:12	User Event		Number	4				
42	10:12:48	4.96E-01	0.582155	**In duct**					
43	10:13:28	2.28E-01	0.267604	**Both tylans on**					
44	10:14:04	3.86E-01	0.453048	**SF6 in distribution**					
45	10:14:50	4.54E-01	0.53286						
46	10:15:25	6.08E-01	0.71361						
47	10:16:01	5.39E-01	0.632624						
48	10:16:36	3.56E-01	0.417837						
49	10:17:11	8.90E-01	1.044593						
50	10:17:47	4.48E-01	0.525818						
51	10:18:22	2.19E-01	0.25704						
52	10:18:57	2.06E-01	0.241782						
53	10:19:33	5.44E-01	0.638493	Avg.	0.505362	0.61%	Ave Eff		
54	10:20:08	2.99E-01	0.350936	Std. Dev.	0.215711	0.29%	Min Eff		
55	10:20:43	3.55E-01	0.416664	CV	42.68%	1.26%	Max Eff		
	10:21:19	User Event		Number	5				
56	10:21:19	8.94E-02	0.104929	**Stop SF6**					
57	10:21:54	1.10E-01	0.129107	Avg.	0.103667				
58	10:22:29	6.19E-02	0.072652	Std. Dev.	0.023305				
59	10:23:05	9.20E-02	0.10798	CV	22.48%				
**********	**** COM	NT *******	*******						
outdoor te	sts on 7-6	-95. Pave	r oriented	into wind	90 deg	with wind			
**********	* END OF	OMMENT	*******						

APPENDIX C

ENGINEERING CONTROLS FOR ASPHALT PAVING EQUIPMENT

BLAW-KNOX PROTOTYPE DESIGN MODIFICATIONS PRIOR TO PHASE TWO FIELD EVALUATIONS

BLAW-KNOX
FAX TRANSMITTAL

Sheet 1 of 2

TO: R. Leroy Mickelsen
U.S. Dept. of Health and
Human Services
NIOSH

FAX#: (513) 841-4506

FROM: Leland J. Warren
Blaw-Knox Const. Equip. Corp.
750 Broadway Avenue East
Mattoon, IL 61938-4600
(217) 234-8811 Phone
(217) 234-8827 Fax

DATE: February 1, 1996

RE: Appendix to the report on the laboratory test at Blaw-Knox.

Attached please find the "Appendix X, Equipment Manufacturer's Improvements Based on Draft Report Recommendations" for attachment to the report on your laboratory test of the Blaw-Knox prototype asphalt fume engineering control performed at Blaw-Knox. This was drafted based on the outline you supplied to Jack Farley in your FAX of December 13, 1995. Thank you for the opportunity to add this information to the report.

Please keep us informed on the progress toward finalization and publication of the report and the progress and direction of the program in general. I assume we will receive a copy of the final report as soon as it available.

Thank you for your time and consideration.

Leland J. Warren

Attachment

cc: T. Roth
J. Farley

Appendix X
Equipment Manufacturer's Improvements Based on Draft Report Recommendations.

The exhaust system was changed by revising the collection hood configuration and adding a separate exhaust fan. The hood was revised to reduce the inlet area to increase the air velocity at the hood face to improve capture of asphalt emissions. The hood was also split into two hoods (left and right) to accommodate clearance problems. A separate exhaust fan was added to provide more air flow. The clear vinyl barrier between the hoods and screed was revised to improve coverage of the auger area.

The exhaust exits the system eight (8) feet above the paver deck where the operator stations are located. This will assure that it is exhausted away form the workers' breathing zone.

In previous tests, fugitive air from the engine's cooling system caused turbulence in the auger area and made the capture of asphalt emissions more difficult. This air is now diverted from the auger area by a sheet metal barrier installed in the center of the under-deck space through which the air was flowing.

The exhaust fan is rated at 2770 cubic feet per minute (cfm) free blowing and up to 6.5 inches of water static pressure. Measurements taken on 11/8/95 and 1/12/96 show that the system operates at 2200 cfm under normal use conditions. The flow rate was measured at the center of a straight portion of the ducting upstream of the fan using a TSI Inc. model 8630 VelociCalc Plus air velocity meter. The meter was set to the flow rate function and the probe inserted into the duct to a depth of half the duct diameter through a small hole just large enough to accept the probe. This flow rate represents an 815% increase over the 270 cfm exhaust flow rate measured during the initial evaluation.

Four (4) capture velocities were measured along the top of each auger (left and right) for a total of eight (8) velocity measurements. The measurements were taken 6 inches away from the face of the hood. The measured values in feet per minute (fpm) were:

LEFT AUGER				RIGHT AUGER			
LH Side	Center		RH Side	LH Side	Center		RH Side
91	124	110	116	106	133	158	239

The new hood dimensions are 1.75 in. deep x 48 in. wide x 19 in. high. Two hoods are used; one over each auger area. Eight (8) face velocity measurements (four (4) for each hood) were made across the width of the hoods. These measurements, from left to right, were :

LEFT HOOD				RIGHT HOOD			
1190	1680	1170	960	860	1070	1380	1980

All velocity measurements were conducted using a TSI Inc. Model 8630 VelociCalc Plus air velocity meter. The meter was set to the velocity function and the probe was manually positioned at the measurement locations. The data was recorded using a TSI Inc. Model 8925 portable printer connected to the meter.

Visual studies using a Rosco model 1500 fog machine showed improved capture and better resistance to cross wind affects.