PB99-166605

IN-DEPTH SURVEY REPORT:

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

at

Champion Road Machinery
Shippensburg, Pennsylvania

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SIC CODE:	1611
SURVEY DATE:	November 6-9, 1995
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DISCLAIMER

Mention of company names or products does not constitute endorsement by the Centers for Disease Control and Prevention (CDC).

EXECUTIVE SUMMARY

On November 6-9, 1995, researchers from the National Institute for Occupational Safety and Health (NIOSH) evaluated a prototype engineering control designed for the control of fugitive asphalt emissions during asphalt paving. The Champion 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 inter-agency agreement with DOT's Federal Highway Administration. Additionally, the National Asphalt Paving 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 visited each participating manufacturer and evaluated their engineering control designs under managed environmental conditions. The indoor evaluation used tracer gas analysis techniques to both quantify the control's exhaust flow rate 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 Champion phase one evaluation.

The Champion phase one evaluation studied the performance of a single engineering control design. The prototype control was installed and evaluated on a Champion Model 1010W asphalt paving machine. The control design consisted of two perforated hoods, one mounted over each auger. A duct from each hood lead into the engine compartment where they converged into a single exhaust duct. The single duct passed up through the paver deck and attached to a hydraulic exhaust fan horizontally mounted on the paver deck. Test measurements indicated that the control system's exhaust volume was approximately 1000 cubic feet per minute (cfm) throughout the evaluation. During the indoor testing, the average capture efficiency measured near 90 percent. During the outdoor testing, which was hampered by strong wind gusts, the average capture efficiency consistently measured below 20 percent as the prototype design was evaluated at prescribed stationary orientations relevant to the prevailing wind. In addition to the capture efficiency reductions, the outdoor test results showed increased variation in capture efficiency as the wind gusts hampered the control's ability to consistently capture the surrogate contaminant.

With an outdoor capture efficiency under 20 percent, the prototype engineering control, in the evaluated configuration, is not anticipated to substantially reduce worker exposure during asphalt paving operations. Recommendations provided to Champion design engineers included: (1) Increasing the hood enclosure to minimize wind effects within the auger area; and (2) Modifying the hood inlet to provide contaminant control capability across the entire width of the auger. Since total enclosure of the auger area may not be compatible with the paving process, design engineers should enclose the process as much as feasible and increase the prototype's exhaust volume, as required, to improve the system's performance in outdoor environments.

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. No further design information was provided for 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 identify or design engineering control techniques and to evaluate 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 November 6-9, 1995, researchers from the National Institute for Occupational Safety and Health (NIOSH) conducted an evaluation of prototype engineering controls designed for the reduction of fugitive asphalt emissions during asphalt paving. The NIOSH researchers included Ken Mead, Mechanical Engineer; Leroy Mickelsen, Chemical Engineer; and Dan Watkins, Engineering Technician, all from the NIOSH Engineering Control Technology Branch (ECTB), Division of Physical Sciences and Engineering (DPSE). The DPSE researchers were assisted by Champion Project Engineer, Scott Lyons.

The Champion 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 inter-agency 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 are provided to the equipment manufacturers along with design change recommendations to maximize engineering control performance prior to the phase two evaluations. The phase two evaluations, which began in mid-1996, included a performance evaluation of each prototype engineering control under "real-life" conditions at an actual paving site. The results from the Champion 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 hood design and control ventilation.

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 Champion Road Machinery phase one evaluation occurred in a large bay area within the prototype shop 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 both the engine exhaust and the engineering control exhaust located outside the building. An overhead door separated the two areas. The 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 prototype control's exhaust was discharged to the outside of the building. This setup proved very effective at preventing the engine exhaust, engine cooling air, 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 performance.

The second method of evaluation was the tracer gas method. This method was designed to: (1) Calculate the total volumetric exhaust flow of each hood design; and (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 method is in Appendix A.

A photo-acoustic infra-red multi-gas monitor (Bruel & Kjaer Model 1302) was used to measure concentrations of the tracer gas in the exhaust air stream. The multi-gas monitor 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 the instrument response to SF_6 concentrations. Calibration data are in Appendix B.

To quantify the 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) at a constant flow rate. The engineering control's exhaust fan utilized a horizontal, non-ducted discharge. A horizontal extension of matching diameter was connected to the discharge side of the fan. A monitoring location was selected within the extension and the multi-gas monitor measured the concentration of SF_6 in the control system's exhaust. The exhaust flow rate was calculated using the following equation:

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

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, the SF_6 was released through distribution plenums into the auger area. 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, the discharge plenums were placed 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. Once again, the multi-gas monitor measured the concentration of the tracer gas in the exhaust on the discharge side of the exhaust fan. The capture efficiency was calculated using the following equation:

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

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:

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

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

Multiple flow rate and capture efficiency tests were conducted and the paver was shut down between each trial. The paver's idle speed, which may partially affect the exhaust rate of the control system, was maintained near 2000 revolutions per minute (rpm) during the performance evaluations. Minor fluctuations in exhaust volume were possible due to small fluctuations in idle speed (estimated at 1-2 percent). However, such minor deviations would not greatly affect the prototype's overall performance.

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 exhaust system consisted of two hoods, positioned adjacent to each side of the auger gear box. Each hood design incorporated an exhaust plenum mounted on the end of a 6" duct. Each plenum had five circular inlets evenly spaced along the bottom surface. The hole diameters increased from 2.5" up to 4.5" as their distance from the gear box increased. The duct from each hood lead to the paver's engine compartment, where a converging wye combined the exhaust airstreams into a single duct leading up through the paver deck and into a hydraulic exhaust fan.

Each hood measured approximately 30" long and 6" wide. The exhaust plenum (referred to by Champion engineers as the suction box) was designed to fit around an extension arm which telescoped in and out with the paver's side extensions. Thus, the exhaust plenum design had additional openings other than the evenly spaced circular holes. Since each hood measured approximately 30" long, the outer third of each auger was not directly served by an exhaust hood. When the side extensions were extended, the percentage of unhooded area increased.

DATA RESULTS

Smoke Evaluation

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.

Tracer Gas Evaluation

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

Indoor Evaluations

The prototype engineering control 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 for each test run. Multiple tests were performed.

TABLE I. INDOOR TRIALS, EXHAUST FLOW RATES

	$Q_{(SF6)}$	$Q_{(exh)}$ (Range)	$Q_{(exh)}$ (Average)
Exhaust, Run 1a*	0.99 lpm	1013 - 1028 cfm	1017 cfm
Exhaust, Run 1b	2.05 lpm	992 - 1000 cfm	999 cfm
Exhaust, Run 2a	0.96 lpm	1013 - 1025 cfm	1021 cfm
Exhaust, Run 2b	2.00 lpm	995 - 1007 cfm	1001 cfm
Exhaust, Run 3a	0.96 lpm	1010 - 1021 cfm	1018 cfm
Exhaust, Run 3b	2.00 lpm	993 - 999 cfm	996 cfm
Exhaust, Run 3c	2.00 lpm	990 - 993 cfm	992 cfm
Elevated idle	2.00 lpm	977 - 988 cfm	986 cfm
Lowered idle	2.00 lpm	920 - 928 cfm	925 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	1001 cfm	74 - 100 %	88 %
Capture Eff Run 2	996 cfm	86 - 95 %	90 %

Outdoor Evaluations

The outdoor evaluation occurred on an open road behind the manufacturing plant. The outdoor evaluation was hampered by a rapidly moving storm front. Both wind speed and direction were recorded by a portable weather station mounted on the paver. The average wind speed was 6.5 miles per hour (mph) with wind gusts up to 32 mph. The paver was oriented with 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 two tests. Each test included both volumetric flow and capture efficiency evaluations.

TABLE III. OUTDOOR TRIALS
(Wind Into Front of Paver = Zero Degrees)

Orient./Run	$Q_{(SF6)}$	$Q_{(exh)}$ (Range)	$Q_{(exh)}$ (Average)	η(Range)	η(Average)
180°, Run 1a	0.96 lpm	956 - 998 cfm	985 cfm	7.5 - 36.1%	17.6 %
180°, Run 1b	2.00 lpm	976 - 985	984	1.7 - 36.6	14.1
90°, Run 2a	0.96	984 - 1006	1001	4.8 - 27.5	12.6
90°, Run 2b	2.00	976 - 988	984		
0°, Run 3a	0.96	984 - 995	993	8.3 - 19.5	12.6
0°, Run 3b	2.00	971 - 976	974		
270°, Run 4a	0.96	998 - 1017	1008	3.5 - 16.7	6.7
270°, Run 4b	2.00	981 - 997	989		
0°, Run 5a	0.96	980 - 998	987	5.4 - 51.2	18.8
0°, Run 5b	2.00	971 - 983	977		
90°, Run 6a	0.96	973 - 1006	996	3.9 - 37.4	9.5
90°, Run 6b	2.00	990 - 1004	995		

Q = Exhaust rate
η = Capture efficiency

DATA ANALYSIS AND DISCUSSION

Test results from the Champion Road Machinery outdoor evaluations revealed that the Champion prototype's design performance was significantly hampered by the minimal amount of enclosure around the auger area and the limited percentage of the auger area directly served by an exhaust hood. The limitations of these design features were exacerbated by weather conditions that included wind gusts up to 32 mph. The result was a dramatic reduction in capture efficiency. During the seven outdoor evaluations under varying orientations, the mean capture efficiency averaged only 13 percent and it never exceeded 19 percent.

Achieving a high average capture efficiency is only one aspect of the ventilation control evaluation. 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's coefficients of variation (CV).

$$CV = \frac{\text{Standard deviation}}{\text{Mean}} \times 100$$

Data sets with smaller CVs indicate the control was less influenced by outside interferences and maintained a more consistent capture efficiency. For example, the CVs obtained during the inside capture efficiency evaluation were both less than 8 percent as compared to the CVs up to 80 percent obtained during the outdoor capture efficiency evaluations. Similar to its adverse impact upon capture efficiency determinations, the wind gusts are theorized to have increased variability and adversely affected the CV calculations. The CVs for each test run are shown with the data in Appendix B.

CONCLUSIONS AND RECOMMENDATIONS

With an average outdoor capture efficiency consistently under 20 percent, the prototype engineering control, in its evaluated configuration, was not expected to substantially reduce worker exposures during asphalt paving. General recommendations for further improvements to the Champion prototype design included:

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 can 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 Industrial Ventilation Manual.

Hood Design

Depending upon the level of enclosure around the auger area in the final design, Champion engineers should consider extending the capture hood to cover the entire length of each auger. Additionally, sealing all unnecessary openings within each hood's plenum (suction box) will allow increased air distribution and improved capture performance along the full length of the hood. Proportional decreases in hood perforation diameters may also be required to achieve this effect. If the hood's length is extended, the inlet hole diameters should be further reduced or the inlet(s) should be reconfigured to a slot design to allow for airflow distribution across the length of the hood.

Enclosure

Other than the coincidental enclosure provided by the tractor and screed, the Champion prototype engineering control provided no additional enclosure for the auger area. The NIOSH engineers are aware of the operational preference for screed and paver operators to have a line-of-sight into the auger area during paving operations. Selective placement of a visual access point(s) could still allow this requirement to exist while enclosing the remainder of the open auger area. Increased enclosure will reduce the exhaust volume and capture velocity requirements for an effective engineering control. In addition, enclosure of the open area directly over the augers has been found to dramatically reduce the radiant and convective heat felt by paver and screed operators during paving operations. While not the original focus of this project, a reduction in heat exposures during summer paving is a significant occupational health benefit which could evolve into a major selling point for the engineering control package.

ACKNOWLEDGMENTS

We would like to thank the Champion Road Machinery management and staff for their gracious hospitality and assistance during our visit to the Ingersoll Rand/Champion manufacturing 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. Deactivate the engineering controls for comparison purposes.
9. Deactivate 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:

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

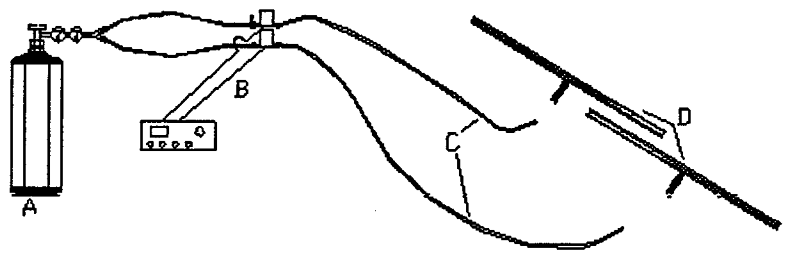
$\mathbf{C^*_{(SF6)}}$ = concentration of SF_6 (parts per million) detected in exhaust

[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



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 - 18 as time permits.

APPENDIX B

ENGINEERING CONTROLS FOR ASPHALT PAVING EQUIPMENT

TRACER GAS EVALUATION RESULTS

B&K DATA FILES AND CALCULATION RESULTS

CHAMPION ROAD MACHINERY
INDOOR EVALUATIONS

INDOOR TEST # 1: SUMMARY INFO				**RANGE**			**CV**
FLOW CALC. #1: Q =	1017	CFM	1013	TO	1028	CFM	0.52%
FLOW CALC. #2: Q =	999	CFM	992	TO	1000	CFM	0.30%
INDOOR TEST #2: SUMMARY INFO:				**RANGE**			**CV**
FLOW CALC. #1: Q =	993	CFM	986	TO	997	CFM	0.52%
FLOW CALC. #2: Q =	978	CFM	973	TO	985	CFM	0.36%
INDOOR CAPTURE EFF. =	88	%	74	TO	100	%	7.94%
INDOOR TEST #3: SUMMARY INFO:				**RANGE**			**CV**
FLOW CALC. #1: Q =	990	CFM	983	TO	1021	CFM	0.48%
FLOW CALC. #2: Q =	973	CFM	971	TO	976	CFM	0.16%
INDOOR CAPTURE EFF. =	90	%	86	TO	95	%	3.02%
FLOW CALC. #3: Q =	970	CFM	968	TO	971	CFM	0.19%
Elevated Idle: Q =	964	CFM	955	TO	966	CFM	0.33%
Lowered Idle: Q =	904	CFM	900	TO	907	CFM	0.31%

CHAMPION ROAD MACHINERY
OUTDOOR EVALUATIONS

OUTDOOR TEST # 1: SUMMARY INFO					RANGE			CV
(WIND INTO REAR OF PAVER)								
FLOW CALC. #1: Q =		985	CFM	956	TO	998	CFM	1.50%
FLOW CALC. #2: Q =		984	CFM	976	TO	985	CFM	0.36%
OUTDOOR CAPTURE EFF #1		18	%	7	TO	36	%	67.41%
OUTDOOR CAPTURE EFF #2		14	%	2	TO	37	%	80.12%
OUTDOOR TEST # 2: SUMMARY INFO					RANGE			CV
(WIND INTO RHS OF PAVER)								
FLOW CALC. #1: Q =		1001	CFM	984	TO	1006	CFM	0.34%
FLOW CALC. #2: Q =		984	CFM	976	TO	988	CFM	0.44%
OUTDOOR CAPTURE EFF =		13	%	5	TO	28	%	53.02%
OUTDOOR TEST # 3: SUMMARY INFO					RANGE			CV
(WIND INTO FRONT OF PAVER)								
FLOW CALC. #1: Q =		993	CFM	984	TO	995	CFM	0.36%
FLOW CALC. #2: Q =		974	CFM	971	TO	976	CFM	0.15%
OUTDOOR CAPTURE EFF =		13	%	8	TO	20	%	26.20%
OUTDOOR TEST # 4: SUMMARY INFO					RANGE			CV
(WIND INTO LHS OF PAVER)								
FLOW CALC. #1: Q =		1008	CFM	998	TO	1017	CFM	0.64%
FLOW CALC. #2: Q =		989	CFM	981	TO	997	CFM	0.62%
OUTDOOR CAPTURE EFF =		7	%	4	TO	17	%	57.36%
OUTDOOR TEST # 5: SUMMARY INFO					RANGE			CV
(WIND INTO FRONT OF PAVER)								
FLOW CALC. #1: Q =		987	CFM	980	TO	998	CFM	0.54%
FLOW CALC. #2: Q =		977	CFM	971	TO	983	CFM	0.40%
OUTDOOR CAPTURE EFF =		19	%	5	TO	51	%	68.46%
OUTDOOR TEST # 6: SUMMARY INFO					RANGE			CV
(WIND INTO RHS OF PAVER)								
FLOW CALC. #1: Q =		996	CFM	973	TO	1006	CFM	1.05%
FLOW CALC. #2: Q =		995	CFM	990	TO	1004	CFM	0.42%
OUTDOOR CAPTURE EFF =		10	%	4	TO	37	%	73.16%

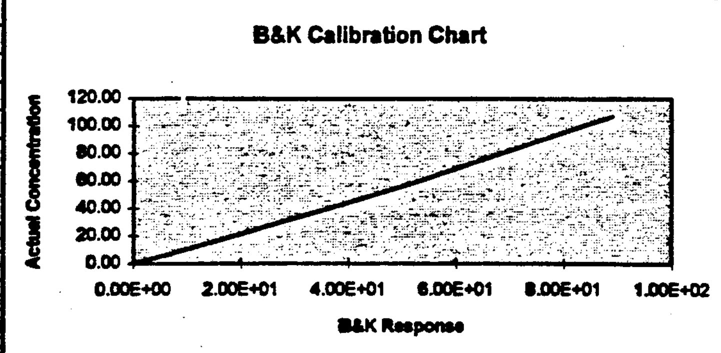
B&K CALIBRATION DATA: CHAMPION ROAD MACHINERY LAB EVALUATION

Samples Measured From 1995-10-31 10:54

Note: B&K was set for Normalization Temperature equaL to 43 deg F during file download so all data points were altered accordingly.

Time hh:mm:ss	Measured SF(6) ppm	Average	Normalize to T = 70 deg F	Actual Concentation
User	Event 1			
14:44:14	5.67E-03	4.23E-03	4.45E-03	0.00
14:44:50	4.89E-03			
14:45:25	2.12E-03			
User	Event 5			
14:52:14	9.78E+00	9.82E+00	10.34	10.73
14:52:52	9.83E+00			
14:53:27	9.83E+00			
14:54:03	9.82E+00			
User	Event 7			
14:57:38	1.96E+00	1.97E+00	2.07	2.15
14:58:16	1.97E+00			
14:58:51	1.97E+00			
14:59:27	1.96E+00			
User	Event 9			
15:01:27	2.39E+01	2.37E+01	24.92	26.80
15:02:07	2.36E+01			
15:02:42	2.35E+01			
15:03:18	2.36E+01			
User	Event 11			
15:05:09	4.55E+01	4.57E+01	48.10	53.70
15:05:50	4.57E+01			
15:06:25	4.57E+01			
15:07:00	4.57E+01			
User	Event 13			
15:09:27	8.43E+01	8.47E+01	89.25	107.30
15:10:38	8.50E+01			
15:11:14	8.48E+01			
15:11:49	8.47E+01			
15:12:25	8.47E+01			
User	Event 14			
15:13:00	3.49E-01	1.47E-01	0.16	
15:13:40	1.01E-01			
15:14:16	7.54E-02			
15:14:51	6.36E-02			

B&K	Actual
4.45E-03	0.00
2.07	2.15
10.34	10.73
24.92	26.80
48.10	53.70
89.25	107.30



Champion Road Machinery: Indoor Test #1

- 1302 Measurement Data —— 1804892/2803 - 1995-11-07 18:13 - 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: Formaldehyde	: NO
Gas B: Carbon dioxide	: NO
Gas C: Carbon monoxide	: NO
Gas D: TOC as Propane	: NO
Gas E: Sulfur hexafluoride	: YES
Water Vapour	: NO

Sampling Tube Length	: 15.0 ft
Air Pressure	: 760.0 mmHg
Normalization Temperature	: 63.5 F

General Information:

Start Time	: 1995-11-07 13:34
Stop Time	: 1995-11-07 14:55
Results Not Averaged	
Number of Event Marks	: 8
Number of Recorded Samples	: 133

	Alarm Limit	Max	Mean	Min	Std.Dev
Gas E:	898E+03	62.3E+00	6.93E+00	19.9E-03	17.6E+00

Samples	Measured	From	11/7/95	13:34	
Event No.	**Time hh:mm:ss**	**SF(6) measured**	**SF(6) Corrected**	**Comment**	
Event 1	13:59:36			Begin indoor bg	
	14:00:12	2.24E-01	0.118024		
	14:00:47	1.98E-01	0.090048		
	14:01:22	2.06E-01	0.098656		
	14:01:58	2.01E-01	0.093276		
	14:02:53	1.61E-01	0.050236	0.006221451	(Average)
	14:03:28	1.50E-01	0.0384	0.060820085	(Std Dev)
	14:04:03	1.85E-01	0.07606		
	14:04:39	1.89E-01	0.080364		
	14:05:14	1.90E-01	0.08144		
	14:05:50	1.81E-01	0.071756		
	14:06:25	1.82E-01	0.072832		

Champion Road Machinery: Indoor Test #1

	14:07:01	1.75E-01	0.0653			
	14:07:36	1.66E-01	0.055616			
	14:08:11	1.42E-01	0.029792			
	14:08:47	1.31E-01	0.017956			
	14:09:22	1.12E-01	-0.002488			
	14:09:58	8.55E-02	-0.031002			
	14:10:33	7.61E-02	-0.0411164			
	14:11:08	9.62E-02	-0.0194888			
	14:11:44	7.54E-02	-0.0418696			
	14:12:19	7.27E-02	-0.0447748			
	14:13:06	6.32E-02	-0.0549968			
	14:13:41	6.64E-02	-0.0515536			
	14:14:16	4.86E-02	-0.0707064			
	14:14:52	5.56E-02	-0.0631744			
	14:15:27	8.04E-02	-0.0364896			
	14:16:03	8.93E-02	-0.0269132			
	14:16:38	9.88E-02	-0.0166912			
	14:17:13	9.81E-02	-0.0174444			
	14:17:49	9.05E-02	-0.025622			
	14:18:24	8.96E-02	-0.0265904			
	14:19:00	6.42E-02	-0.0539208			
	14:19:35	9.75E-02	-0.01809			
	14:20:11	3.39E-02	-0.0865236			
	14:20:46	2.83E-02	-0.0925492			
Event 2	14:20:46			Wand moved outdoors		
	14:21:22	2.35E-02	-0.097714			
	14:21:58	1.99E-02	-0.1015876			
	14:23:04	2.64E-02	-0.0945936			
Event 3	14:23:04			Start paver & fan (put wand in duct)		
	14:23:40	2.22E-02	-0.0991128			
	14:24:15	1.07E-01	-0.007868			
	14:24:51	9.30E-02	-0.022932			
	14:25:26	1.05E-01	-0.01002			
	14:26:02	1.25E-01	0.0115			
	14:26:37	1.03E-01	-0.012172			
	14:27:12	9.16E-02	-0.0244384			
	14:27:48	9.62E-02	-0.0194888			
	14:28:23	1.01E-01	-0.014324			
	14:28:59	9.59E-02	-0.0198116			
Event 4	14:28:59			Start SF(6) on RHS @ 100% capture		
	14:29:35	1.03E-01	-0.012172	SF(6) flow = 0.9877 lpm		
	14:30:10	3.14E+01	34.0618			
	14:30:50	3.13E+01	33.9361			
	14:31:26	3.16E+01	34.3132	34.2713	(Average)	
	14:32:01	3.15E+01	34.1875	0.177766645	(Std Dev)	
	14:32:56	3.16E+01	34.3132	0.52%	CV	
	14:33:32	3.17E+01	34.4389			
	14:34:07	3.17E+01	34.4389			
	14:34:42	3.17E+01	34.4389			

Champion Road Machinery: Indoor Test #1

	14:35:18	3.16E+01	34.3132			
Event 5	14:35:18			Start SF6 on both sides @ 100% capture		
	14:35:53	6.18E+01	72.2746	SF(6) flow = 2.046 lpm		
	14:36:29	6.21E+01	72.6517			
	14:37:04	6.19E+01	72.4003	72.50086	(Average)	
	14:37:40	6.18E+01	72.2746	0.220124592	(Std Dev)	
	14:38:15	6.20E+01	72.526	0.30%	CV	
	14:38:51	6.18E+01	72.2746			
	14:39:26	6.19E+01	72.4003			
	14:40:02	6.20E+01	72.526			
	14:40:37	6.23E+01	72.9031			
	14:41:13	6.22E+01	72.7774			
	14:41:48	5.62E-01	0.481712			
Event 6	14:41:48			Wand passed to inside		
	14:42:29	2.15E-01	0.10834			
Event 7	14:42:29			Begin indoor bg		
	14:43:15	1.75E-01	0.0653			
	14:43:51	1.79E-01	0.069604			
	14:44:26	1.15E-01	0.00074	0.00060012	(Average)	
	14:45:02	1.25E-01	0.0115	0.039642421	(Std Dev)	
	14:45:37	1.10E-01	-0.00464			
	14:46:13	8.54E-02	-0.0311096			
	14:46:48	7.85E-02	-0.038534			
	14:47:23	7.69E-02	-0.0402556			
	14:47:59	8.79E-02	-0.0284196			
	14:48:34	1.16E-01	0.001816			
Event 8	14:48:34			SF6 disabled, fans still on		
	14:49:10	6.67E-02	-0.0512308			
	14:49:45	8.96E-02	-0.0265904			
	14:50:20	6.89E-02	-0.0488636	-0.055515236	(Average)	
	14:50:56	7.05E-02	-0.047142	0.012186461	(Std Dev)	
	14:51:31	5.95E-02	-0.058978			
	14:52:07	5.15E-02	-0.067586			
	14:53:13	6.62E-02	-0.0517688			
	14:53:49	5.58E-02	-0.0629592			
	14:54:24	5.28E-02	-0.0661872			
	14:54:59	5.59E-02	-0.0628516			
	14:55:35	5.25E-02	-0.06651			
INDOOR TEST # 1: SUMMARY INFO					RANGE (CFM)	
FLOW CALC. #1: Q =		1017.13	CFM	1013.42	1028.43	
FLOW CALC. #2: Q =		998.57	CFM	991.68	1000.31	

CHAMPION ROAD MACHINERY: Indoor Test #2

1302 Settings:

Compensate for Water Vap. Interference : NO
Compensate for Cross Interference : NO
Sample Continuously : YES
Pre-set Monitoring Period : NO

Measure
Gas A: Formaldehyde : NO
Gas B: Carbon dioxide : NO
Gas C: Carbon monoxide : NO
Gas D: TOC as Propane : NO
Gas E: Sulfur hexafluoride : YES
Water Vapour : NO

Sampling Tube Length : 15.0 ft
Air Pressure : 760.0 mmHg
Normalization Temperature : 63.5 F

General Information:

Start Time : 1995-11-07 16:12
Stop Time : 1995-11-07 16:51
Results Not Averaged
Number of Event Marks : 5
Number of Recorded Samples : 64

	Alarm Limit	Max	Mean	Min	Std.Dev
Gas E:	898E+03	62.1E+00	27.0E+00	28.4E-03	27.1E+00

Event No.	Time hh:mm:ss	SF(6) measured	SF(6) Corrected	Comment	
Event 0				Begin Indoor BG Readings	
	16:12:48	5.54E-02	-0.0633896		
	16:13:31	4.87E-02	-0.0705988		
	16:14:06	4.63E-02	-0.0731812	-0.07542735	(Average)
	16:14:42	5.01E-02	-0.0690924	0.009445266	(Std Dev)
	16:15:17	4.14E-02	-0.0784536		
	16:15:53	3.52E-02	-0.0851248		
	16:16:28	4.82E-02	-0.0711368		
	16:17:03	2.84E-02	-0.0924416		
Event 1	16:17:03			Wand into Duct Fan & paver are on	
	16:17:39	5.88E-02	-0.0597312		
	16:18:14	6.07E-02	-0.0576868	-0.0598926	(Average)
	16:18:50	5.53E-02	-0.0634972	0.002544006	(Std Dev)

	16:19:25	5.98E-02	-0.0586552			
Event 2	16:19:25			Start 100% Capture on RHS		
	16:20:00	5.27E-02	-0.0662948	SF(6) Flow = 0.9611 lpm		
	16:20:36	3.17E+01	34.4389			
	16:21:16	3.14E+01	34.0618	34.1875	(Average)	
	16:21:51	3.14E+01	34.0618	0.177766645	(Std Dev)	
	16:22:58	3.15E+01	34.1875	0.52%	CV	
Event 3	16:22:58			Start 100% Capture Both sides		
	16:23:33	3.14E+01	34.0618	SF(6) Flow = 2.000 lpm		
	16:24:09	6.14E+01	71.7718			
	16:24:44	6.18E+01	72.2746	72.243175	(Average)	
	16:25:20	6.16E+01	72.0232	0.25804608	(Std Dev)	
	16:25:55	6.19E+01	72.4003	0.36%	CV	
	16:26:30	6.21E+01	72.6517			
	16:27:06	6.18E+01	72.2746			
	16:27:41	6.18E+01	72.2746			
	16:28:17	6.18E+01	72.2746			
Event 4	16:28:17			Switch to dist. plenums		
	16:28:53	3.45E+01	37.9585			
	16:29:28	4.68E+01	53.4196			
	16:30:03	5.37E+01	62.0929	63.23081579	(Average)	
	16:30:39	5.20E+01	59.956	5.019520965	(Std Dev)	
	16:31:14	5.67E+01	65.8639	7.94%	CV	
	16:31:50	5.15E+01	59.3275			
	16:32:44	5.14E+01	59.2018			
	16:33:20	6.11E+01	71.3947			
	16:33:55	5.52E+01	63.9784			
	16:34:31	5.64E+01	65.4868			
	16:35:06	5.40E+01	62.47			
	16:35:42	5.02E+01	57.6934			
	16:36:17	5.80E+01	67.498			
	16:36:52	5.39E+01	62.3443			
	16:37:28	5.91E+01	68.8807			
	16:38:03	6.15E+01	71.8975			
	16:38:39	5.74E+01	66.7438			
	16:39:14	4.88E+01	55.9336			
	16:39:50	5.68E+01	65.9896			
	16:40:25	5.30E+01	61.213			
Event 5	16:40:25			Kill SF(6), bring wand indoors		
	16:41:00	1.28E+00	1.25428			
	16:41:41	7.85E-02	-0.038534			
	16:42:16	5.06E-01	0.421456			
	16:43:03	1.73E-01	0.063148			
	16:43:38	1.81E-01	0.071756			
	16:44:13	1.96E-01	0.087896			
	16:44:49	1.79E-01	0.069604	0.040552	(Average)	
	16:45:24	1.64E-01	0.053464	0.039268546	(Std Dev)	
	16:46:00	2.07E-01	0.099732			
	16:46:35	1.50E-01	0.0384			
	16:47:10	1.41E-01	0.028716			

CHAMPION ROAD MACHINERY: Indoor Test #2

	16:47:46	1.39E-01	0.026564				
	16:48:21	1.49E-01	0.037324				
	16:48:57	1.35E-01	0.02226				
	16:49:32	1.05E-01	-0.01002				
	16:50:07	1.82E-01	0.072832				
	16:50:43	9.24E-02	-0.0235776				
	16:51:18	8.66E-02	-0.0298184				
INDOOR TEST #2: SUMMARY INFO:					**RANGE**		
FLOW CALC. #1: Q =		993.38	CFM	986.13	TO	997.04	CFM
FLOW CALC. #2: Q =		978.24	CFM	972.74	TO	984.67	CFM
INDOOR CAPTURE EFF. =		87.52	%	73.94	TO	99.52	%

CHAMPION ROAD MACHINERY: Indoor Test #3

1302 Settings:

Compensate for Water Vap. Interference : NO
Compensate for Cross Interference : NO
Sample Continuously : YES
Pre-set Monitoring Period : NO

Measure
Gas A: Formaldehyde : NO
Gas B: Carbon dioxide : NO
Gas C: Carbon monoxide : NO
Gas D: TOC as Propane : NO
Gas E: Sulfur hexafluoride : YES
Water Vapour : NO

Sampling Tube Length : 15.0 ft
Air Pressure : 760.0 mmHg
Normalization Temperature : 63.5 F

General Information:

Start Time : 1995-11-07 16:52
Stop Time : 1995-11-07 17:59
Results Not Averaged
Number of Event Marks : 9
Number of Recorded Samples : 109

	Alarm Limit	Max	Mean	Min	Std.Dev
Gas E:	898E+03	97.3E+00	30.9E+00	215E-03	29.9E+00

Samples Measured From 1995-11-07 16:53

Event No.	Time hh:mm:s	SF(6) measured	SF(6) Corrected	Comment	
Event 0	16:53:00	2.15E-01	0.10834	Indoor BG	
	16:53:44	2.99E-01	0.198724		
Event 1	16:54:19	2.95E-01	0.19442	BG in duct	
	16:54:54	2.55E-01	0.15138		
	16:55:30	2.65E-01	0.16214		
	16:56:05	2.78E-01	0.176128		
	16:56:41	2.56E-01	0.152456		
	16:57:16	2.65E-01	0.16214	0.162636615	(Average)
	16:57:51	2.50E-01	0.146	0.02315949	(Standard Dev.)
	16:58:27	3.16E-01	0.217016		
	16:59:02	2.73E-01	0.170748		
	16:59:37	2.40E-01	0.13524		
	17:00:13	2.39E-01	0.134164		
	17:00:48	2.65E-01	0.16214		
	17:01:24	2.54E-01	0.150304		
Event 2	17:01:59	3.18E+01	34.5645	Start 100% SF(6) on RHS	
	17:02:59	3.15E+01	34.1875	SF(6) Flow = 0.9611 lpm	
	17:03:34	3.15E+01	34.1875	34.28806	(Average)
	17:04:09	3.16E+01	34.3132	0.163892748	(Standard Dev.)
	17:04:45	3.15E+01	34.1875	0.48%	CV

CHAMPION ROAD MACHINERY: Indoor Test #3

Event 3	17:05:20	6.22E+01	72.7774	Start 100% SF(6) thru both sides				
	17:05:56	6.19E+01	72.4003	SF(6) Flow = 2.000 lpm				
	17:06:31	6.20E+01	72.526					
	17:07:06	6.20E+01	72.526	72.6045625	(Average)			
	17:07:42	6.21E+01	72.6517	0.11515696	(Standard Dev.)			
	17:08:17	6.21E+01	72.6517	0.16%	CV			
	17:08:53	6.21E+01	72.6517					
	17:09:28	6.21E+01	72.6517					
	17:10:03	3.34E+01	36.5758	omit				
Event 4	17:10:39	5.74E+01	66.7438	Switch to dist. plenums				
	17:11:14	5.65E+01	65.6125					
	17:11:49	5.84E+01	68.0008					
	17:12:36	5.57E+01	64.6069					
	17:13:11	5.50E+01	63.727					
	17:13:46	5.59E+01	64.8583	65.43292857	(Average)			
	17:14:22	5.55E+01	64.3555	1.973200078	(Standard Dev.)			
	17:14:57	5.82E+01	67.7494	3.02%	CV			
	17:15:32	5.53E+01	64.1041					
	17:16:08	5.91E+01	68.8807					
	17:16:43	5.59E+01	64.8583					
	17:17:19	5.39E+01	62.3443					
	17:17:54	5.77E+01	67.1209					
	17:18:30	5.45E+01	63.0985					
Event 5	17:19:05	9.73E+01	116.8981	Back to 100% capture, both sides				
	17:19:41	6.24E+01	73.0288					
	17:20:16	6.24E+01	73.0288	72.87796	(Average)			
	17:20:52	6.22E+01	72.7774	0.137697451	(Standard Dev.)			
	17:21:27	6.22E+01	72.7774	0.19%	CV			
	17:22:02	6.22E+01	72.7774					
Event 6	17:23:09	6.32E+01	[illegible]	Raise idle, still 100% capture, both sides				
	17:23:45	6.26E+01	73.2802					
	17:24:20	6.26E+01	73.2802					
	17:24:55	6.28E+01	73.5316	73.33821538	(Average)			
	17:25:31	6.25E+01	73.1545	0.238583902	(Standard Dev.)			
	17:26:06	6.26E+01	73.2802	0.33%	CV			
	17:26:42	6.27E+01	73.4059					
	17:27:17	6.25E+01	73.1545					
	17:27:52	6.25E+01	73.1545					
	17:28:28	6.25E+01	73.1545					
	17:29:03	6.27E+01	73.4059					
	17:29:38	6.26E+01	73.2802					
	17:30:14	6.26E+01	73.2802					
Event 7	17:30:49	6.63E+01	77.9311	Idle lowered to 1000 rpm				
	17:31:25	6.68E+01	78.5596					
	17:32:00	6.66E+01	78.3082					
	17:32:55	6.66E+01	78.3082	78.19646667	(Average)			
	17:33:30	6.67E+01	78.4339	0.238866752	(Standard Dev.)			
	17:34:06	6.63E+01	77.9311	0.31%	CV			
	17:34:41	6.63E+01	77.9311					
	17:35:17	6.64E+01	78.0568					
	17:35:52	6.66E+01	78.3082					
Event 8	17:36:27	1.03E+00	0.98528	SF(6) disabled				
	17:37:08	9.07E-01	0.852932					
	17:37:43	4.63E+00	4.85888					
	17:38:21	2.59E-01	0.155684					
	17:38:59	2.46E-01	0.141696					
	17:39:34	1.14E+00	1.10364					

CHAMPION ROAD MACHINERY: Indoor Test #3

	17:40:10	9.38E-01	0.886288					
	17:40:45	4.93E-01	0.407468					
	17:41:21	5.11E-01	0.426836					
	17:41:56	7.27E-01	0.659252					
	17:42:42	8.06E-01	0.744256					
	17:43:18	8.67E-01	0.809892					
	17:43:53	1.25E+00	1.222					
	17:44:28	3.55E+00	3.6968					
	17:45:06	2.96E+00	3.06196					
	17:45:42	2.34E+00	2.39484					
	17:46:17	2.16E+00	2.20116					
	17:46:53	2.39E+00	2.44864					
	17:47:28	2.53E+00	2.59928					
Event 9	17:48:04	2.83E+00	2.92208	Begin BG w/in duct				
	17:48:39	2.16E+00	2.20116					
	17:49:14	4.12E+00	4.31012					
	17:49:50	3.15E+00	3.2664					
	17:50:25	1.88E+00	1.89988					
	17:51:00	1.55E+00	1.5448					
	17:51:38	2.42E+00	2.48092					
	17:52:16	1.58E+00	1.57708					
Event 10	17:53:25	1.68E+00	1.68468	Begin pulling dist tubes, continue				
	17:54:01	1.28E+00	1.25428	taking BG w/in duct				
	17:54:36	1.41E+00	1.39416					
	17:55:12	1.01E+00	0.96376					
	17:55:47	1.14E+00	1.10364					
	17:56:22	1.32E+00	1.29732					
	17:56:58	1.96E+00	1.98596					
	17:57:36	1.97E+00	1.99672					
	17:58:11	1.98E+00	2.00748					
	17:58:47	1.22E+00	1.18972					
	17:59:24	7.24E-01	0.656024					
	INDOOR TEST #3: SUMMARY INFO					**RANGE**		
	FLOW CALC. #1: Q =		990.47	CFM	982.54	TO	1020.87	CFM
	FLOW CALC. #2: Q =		973.37	CFM	971.06	TO	976.12	CFM
	INDOOR CAPTURE EFF.		90.12	%	85.87	TO	94.87	%
	FLOW CALC. #3: Q =		969.72	CFM	967.72	TO	971.06	CFM
	Elevated Idle: Q =		963.64	CFM	954.57	TO	966.06	CFM
	Lowered Idle: Q =		903.77	CFM	899.59	TO	906.84	CFM

CHAMPION ROAD MACHINERY: Outdoor Test #1

Ingersol Rand: Outdoor Test Number One. Wind blowing into rear of paver.

1302 Settings:

Compensate for Water Vap. Interference	: NO
Compensate for Cross Interference	: NO
Sample Continuously	: YES
Pre-set Monitoring Period	: NO

Measure

Gas A: Formaldehyde	: NO
Gas B: Carbon dioxide	: NO
Gas C: Carbon monoxide	: NO
Gas D: TOC as Propane	: NO
Gas E: Sulfur hexafluoride	: YES
Water Vapour	: NO

Sampling Tube Length	: 15.0 ft
Air Pressure	: 760.0 mmHg
Normalization Temperature	: 43.0 F

General Information:

Start Time	: 1995-11-08 10:53
Stop Time	: 1995-11-08 11:44
Results Not Averaged	
Number of Event Marks	: 7
Number of Recorded Samples	: 81

	Alarm Limit	Max	Mean	Min	Std.Dev
Gas E:	863E+03	62.0E+00	12.9E+00	18.2E-03	20.1E+00

Samples Measured From 1995-11-08 10:54

Event No.	Time hh:mm:ss	SF(6) measured	SF(6) Corrected	Comment
Event 0	10:54:13	2.92E-02	-0.0915808	OA BG in duct
	10:54:56	2.58E-02	-0.0952392	
	10:55:32	2.42E-02	-0.0969608	
	10:56:19	4.59E-02	-0.0736116	
	10:56:54	2.55E-02	-0.095562	
	10:57:29	2.40E-02	-0.097176	
	10:58:05	3.38E-02	-0.0866312	
	10:58:40	2.56E-02	-0.0954544	
	10:59:16	2.91E-02	-0.0916884	
	10:59:51	7.44E-02	-0.0429456	
	11:00:27	4.41E-02	-0.0755484	
	11:01:02	6.24E-02	-0.0558576	
	11:01:37	6.36E-02	-0.0545664	
	11:02:13	4.01E-02	-0.0798524	
	11:02:48	3.03E-02	-0.0903972	
	11:03:24	2.72E-02	-0.0937328	
	11:03:59	2.24E-02	-0.0988976	
	11:04:34	3.29E-02	-0.0875996	
	11:05:10	3.28E-02	-0.0877072	
	11:05:45	2.99E-02	-0.0908276	

CHAMPION ROAD MACHINERY: Outdoor Test #1

	11:06:52	3.56E-02	-0.0846944					
	11:07:27	3.43E-02	-0.0860932					
	11:08:03	2.96E-02	-0.0911504					
	11:08:38	3.46E-02	-0.0857704					
	11:09:14	3.44E-02	-0.0859856					
	11:09:49	3.83E-02	-0.0817892					
	11:10:24	2.23E-02	-0.0990052					
Event 1	11:11:00	2.45E-02	-0.096638	Start paver & fan				
	11:11:35	2.07E-02	-0.1007268					
	11:12:10	2.46E-02	-0.0965304					
Event 2	11:12:46	3.26E+01	35.5702	Start 100% Capture thru RHS				
	11:13:26	3.21E+01	34.9417					
	11:14:02	3.20E+01	34.816					
	11:14:37	3.18E+01	34.5646	34.50873333	(Average)			
	11:15:13	3.16E+01	34.3132	0.518697631	(Std Deviation)			
	11:16:07	3.15E+01	34.1875	1.50%	CV			
	11:16:43	3.14E+01	34.0618					
	11:17:18	3.14E+01	34.0618					
	11:17:54	3.14E+01	34.0618					
Event 3	11:18:29	6.20E+01	72.526	Start 100% Capture thru both sides				
	11:19:05	6.15E+01	71.8975					
	11:19:40	6.16E+01	72.0232					
	11:20:16	6.14E+01	71.7718	71.9446375	(Average)			
	11:20:51	6.15E+01	71.8975	0.259681024	(Std Deviation)			
	11:21:27	6.15E+01	71.8975	0.36%	CV			
	11:22:02	6.13E+01	71.6461					
	11:22:37	6.15E+01	71.8975					
	11:23:13	5.94E+01	69.2578					
Event 4	11:23:48	1.14E+01	12.1434	Switch to dist tubes				
	11:24:26	5.15E+00	5.4184					
	11:25:02	2.01E+00	2.03976					
	11:25:37	7.19E+00	7.61344					
	11:26:26	8.18E+00	8.67868	12.691138	(Average)			
	11:27:04	1.02E+01	10.8522	8.555169456	(Std Deviation)			
	11:27:39	6.75E+00	7.14	67.41%	CV			
	11:28:15	2.32E+01	24.8402					
	11:28:52	2.51E+01	26.1427					
	11:29:28	2.06E+01	22.0426					
	11:30:03	1.11E+00	1.07136					
Event 5	11:30:44	1.28E-01	0.014728	Stop SF(6) [out of gas]				
	11:31:19	8.32E-02	-0.0334768					
	11:31:55	4.44E-01	0.354744					
	11:32:30	1.33E-01	0.020108					
	11:33:05	5.00E-01	0.415					
	11:33:41	1.09E-01	-0.005716					
	11:34:16	7.99E-02	-0.0370276					
	11:34:52	1.60E+01	17.093					
Event 6	11:35:32	8.96E+00	9.51796	Restart SF(6) thru both dist. tubes				
	11:36:41	2.48E+01	26.5618					
	11:37:19	8.86E+00	9.41036	10.13435429	(Average)			
	11:37:57	1.19E+01	12.6814	8.119819759	(Std Deviation)			
	11:38:32	4.95E+00	5.2032	80.12%	CV			
	11:39:08	1.23E+00	1.20048					
	11:39:46	6.03E+00	6.36528					
Event 6	11:40:24	9.14E-01	0.860464	Kill SF9^), remove wand, move paver				
	11:41:02	2.72E-02	-0.0937328					
	11:41:37	2.34E-02	-0.0978216					
	11:42:13	1.91E-02	-0.1024484					

CHAMPION ROAD MACHINERY: Outdoor Test #1

	11:42:48	1.92E-02	-0.1023408					
	11:43:23	1.82E-02	-0.1034168					
	11:43:59	1.89E-02	-0.1026636					
	SUMMARY INFO:					**RANGE**		
	FLOW CALC. #1: Q =		985.46	CFM	956.05	TO	998.39	CFM
	FLOW CALC. #2: Q =		984.27	CFM	976.38	TO	984.91	CFM
	OUTDOOR CAPTURE EFF #		17.64	%	7.47	TO	36.05	%
	OUTDOOR CAPTURE EFF #		14.09	%	1.66	TO	36.62	%

CHAMPION ROAD MACHINERY: Outdoor Test #2

Ingersol Rand: Outdoor Test Number 2. Wind blowing into RHS of paver. RPM=2000

T(duct) = 62.5 deg

1302 Settings:

Compensate for Water Vap. Interference	:	NO
Compensate for Cross Interference	:	NO
Sample Continuously	:	YES
Pre-set Monitoring Period	:	NO

Measure

Gas A: Formaldehyde	:	NO
Gas B: Carbon dioxide	:	NO
Gas C: Carbon monoxide	:	NO
Gas D: TOC as Propane	:	NO
Gas E: Sulfur hexafluoride	:	YES
Water Vapour	:	NO

Sampling Tube Length	:	15.0 ft
Air Pressure	:	760.0 mmHg
Normalization Temperature	:	43.0 F

General Information:

Start Time	:	1995-11-08 11:47
Stop Time	:	1995-11-08 12:10
Results Not Averaged		
Number of Event Marks	:	4
Number of Recorded Samples	:	38

	Alarm Limit	Max	Mean	Min	Std.Dev
Gas E:	863E+03	66.2E+00	25.0E+00	35.2E-03	23.2E+00

Samples Measured From 1995-11-08 11:47

Event No.	Time hh:mm:ss	SF(6) ppm measured	SF(6) ppm Corrected	Comment	
Event 0	11:47:22	7.83E-02	-0.038749	BG in duct	
	11:48:05	4.15E-02	-0.078346		
	11:48:40	5.15E-02	-0.067586		
	11:49:16	4.30E-02	-0.076732		
	11:49:51	3.52E-02	-0.085125		
Event 1	11:50:27	3.18E+01	34.5646	Start SF(6) thru RHS @ 100% capture	
	11:51:07	3.13E+01	33.9361		
	11:51:42	3.13E+01	33.9361		
	11:52:18	3.14E+01	34.0618	33.9832375	(Average)
	11:52:53	3.13E+01	33.9361	0.11515696	(Standard Deviation)
	11:53:29	3.14E+01	34.0618	0.34%	CV
	11:54:04	3.15E+01	34.1875		
	11:54:39	3.13E+01	33.9361		
	11:55:15	3.12E+01	33.8104		
Event 2	11:56:01	6.62E+01	77.8054	Start SF(6) in both sides @ 100% capture	
	11:56:37	6.20E+01	72.526		
	11:57:12	6.14E+01	71.7718		
	11:57:47	6.13E+01	71.6461	71.93341429	(Average)
	11:58:23	6.17E+01	72.1489	0.313950572	(Standard Deviation)

CHAMPION ROAD MACHINERY: Outdoor Test #2

	11:58:58	6.15E+01	71.8975	0.44%	CV				
	11:59:33	6.13E+01	71.6461						
	12:00:09	6.15E+01	71.8975						
Event 3	12:00:44	5.56E+01	64.4812	Switch to dist plenums					
	12:01:20	7.46E+00	7.90396						
	12:01:57	6.75E+00	7.14						
	12:02:33	3.33E+00	3.46008						
	12:03:08	7.31E+00	7.74256						
	12:03:44	5.17E+00	5.43992	9.085904615	(Average)				
	12:04:19	6.82E+00	7.21532	4.817238193	Standard Deviation				
	12:04:54	8.88E+00	9.43188	53.02%	CV				
	12:05:30	5.31E+00	5.59056						
	12:06:36	6.52E+00	6.89252						
	12:07:12	6.21E+00	6.55896						
	12:07:47	1.57E+01	16.7702						
	12:08:23	1.33E+01	14.1878						
	12:08:58	1.85E+01	19.783						
Event 4	12:09:36	1.31E+00	1.28656	Kill SF(6), remove wand, move paver					
	12:10:16	1.97E-01	0.088972						
	SUMMARY INFO:					**RANGE**			
	FLOW CALC. #1: Q =		1000.70	CFM	983.87	TO	1005.82	CFM	
	FLOW CALC. #2: Q =		984.42	CFM	976.38	TO	988.37	CFM	
	OUTDOOR CAPTURE EFF		12.63	%	4.81	TO	27.50	%	

CAMPION ROAD MACHINERY: Outdoor Test #3

Ingersol Rand Outdoor Test Number 3 (Wind blowing into Front of paver)

Temp OA=39 deg rpm=2100

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1302 Settings:

Compensate for Water Vap. Interference : NO
Compensate for Cross Interference : NO
Sample Continuously : YES
Pre-set Monitoring Period : NO

Measure
Gas A: Formaldehyde : NO
Gas B: Carbon dioxide : NO
Gas C: Carbon monoxide : NO
Gas D: TOC as Propane : NO
Gas E: Sulfur hexafluoride : YES
Water Vapour : NO

Sampling Tube Length : 15.0 ft
Air Pressure : 760.0 mmHg
Normalization Temperature : 43.0 F

General Information:

Start Time : 1995-11-08 12:16
Stop Time : 1995-11-08 12:44
Results Not Averaged
Number of Event Marks : 4
Number of Recorded Samples : 45

	Alarm Limit	Max	Mean	Min	Std.Dev
Gas E:	863E+03	83.4E+00	24.3E+00	64.2E-03	24.2E+00

- 1302 Measurement Data ------ 1804892/2803 - 1995-11-08 14:49 - Page 2 -

Samples Measured From 1995-11-08 12:16

Event No.	Time hh:mm:ss	SF(6) ppm measured	SF(6) ppm Corrected	Comment
Event 0	12:16:56	1.75E+00	1.76	BG in duct
	12:17:36	1.76E+00	1.77076	
	12:18:12	1.84E+00	1.85684	
	12:18:47	7.26E-02	-0.044882	
	12:19:25	1.98E-01	0.090048	
	12:20:01	1.17E-01	0.002892	
	12:20:36	8.40E-02	-0.032616	
	12:21:11	7.55E-02	-0.041762	
	12:21:47	6.42E-02	-0.053921	
	12:22:22	9.35E-02	-0.022394	
Event 1	12:22:57	3.15E+01	34.1875	Begin 100% Capture in RHS

CAMPION ROAD MACHINERY: Outdoor Test #3

	12:23:38	3.18E+01	34.5646				
	12:24:13	3.15E+01	34.1875				
	12:24:48	3.15E+01	34.1875				
	12:25:24	3.16E+01	34.3132	34.25035	(Average)		
	12:26:10	3.16E+01	34.3132	0.122158442	(Standard Dev.)		
	12:26:46	3.15E+01	34.1875	0.36%	CV		
	12:27:21	3.15E+01	34.1875				
	12:27:56	3.15E+01	34.1875				
	12:28:32	3.15E+01	34.1875				
Event 2	12:29:07	8.34E+01	99.4258	Start 100% CApture in both sides			
	12:29:43	6.22E+01	72.7774				
	12:30:18	6.22E+01	72.7774				
	12:30:54	6.20E+01	72.526				
	12:31:29	6.21E+01	72.6517	72.7355	(Average)		
	12:32:04	6.22E+01	72.7774	0.108859393	(Standard Dev.)		
	12:32:40	6.22E+01	72.7774	0.15%	CV		
	12:33:15	6.21E+01	72.6517				
	12:33:51	6.22E+01	72.7774				
	12:34:26	6.23E+01	72.9031				
Event 3	12:35:01	1.71E+01	18.2766	Switch to distribution tubes			
	12:35:37	9.62E+00	10.22812				
	12:36:46	1.24E+01	13.2194				
	12:37:21	5.72E+00	6.03172				
	12:37:57	8.77E+00	9.31352				
	12:38:32	6.83E+00	7.22608				
	12:39:08	5.71E+00	6.02096	9.155430769	(Average)		
	12:39:43	1.33E+01	14.1878	2.398359446	(Standard Dev.)		
	12:40:18	8.33E+00	8.84008	26.20%	CV		
	12:40:54	7.86E+00	8.33436				
	12:41:29	8.45E+00	8.9692				
	12:42:04	7.53E+00	7.97928				
	12:42:40	9.23E+00	9.80848				
	12:43:15	8.35E+00	8.8616				
Event 4	12:43:51	2.66E-01	0.163216	End of test			
SUMMARY INFO:				RANGE			
FLOW CALC. #1: Q =		992.90	CFM	983.87	TO	994.72	CFM
FLOW CALC. #2: Q =		973.56	CFM	971.33	TO	976.38	CFM
OUTDOOR CAPTURE EFF =		12.59	%	8.28	TO	19.51	%

CHAMPION ROAD MACHINERY: Outdoor Test #4

Ingersol Rand Outdoor Test #4. (Wind blowing into LHS of paver)				
rpm=2100				
Temp OA=38 deg		Temp duct= 65 deg		
- 1302 Measurement Data ------ 1804892/2803 - 1995-11-08 14:52 - 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: Formaldehyde : NO				
Gas B: Carbon dioxide : NO				
Gas C: Carbon monoxide : NO				
Gas D: TOC as Propane : NO				
Gas E: Sulfur hexafluoride : YES				
Water Vapour : NO				
Sampling Tube Length : 15.0 ft				
Air Pressure : 760.0 mmHg				
Normalization Temperature : 43.0 F				
General Information:				
--				
Start Time : 1995-11-08 12:52				
Stop Time : 1995-11-08 13:13				
Results Not Averaged				
Number of Event Marks : 4				
Number of Recorded Samples : 34				
Alarm Limit Max Mean Min Std.Dev				
--				
Gas E: 863E+03 61.7E+00 20.9E+00 35.3E-03 23.4E+00				
Samples Measured From 1995-11-08 12:52				
--				
Event No.	Time hh:mm:s	SF(6) ppm measured	SF(6) ppm Corrected	Comment
--				
Event 0	12:52:59	5.75E-02	-0.06113	BG
	12:53:42	4.33E-02	-0.0764092	
	12:54:17	3.56E-02	-0.0846944	
	12:54:53	5.23E-02	-0.0667252	
	12:55:28	3.53E-02	-0.0850172	
Event 1	12:56:03	3.10E+01	33.559	Start 100% capture @ RHS
	12:56:44	3.12E+01	33.8104	
	12:57:19	3.14E+01	34.0618	33.73857143 (Average)
	12:57:55	3.11E+01	33.6847	0.215983948 (Standard Dev.)

CHAMPION ROAD MACHINERY: Outdoor Test #4

	12:58:30	3.09E+01	33.4333	0.64%	CV		
	12:59:06	3.13E+01	33.9361				
	12:59:41	3.11E+01	33.6847				
Event 2	13:00:16	6.17E+01	72.1589	Start 100% Capture on both sides			
	13:00:52	6.14E+01	71.7718				
	13:01:27	6.12E+01	71.5204				
	13:02:02	6.08E+01	71.0176	71.59222857	(Average)		
	13:02:38	6.08E+01	71.0176	0.446527867	(Standard Dev.)		
	13:03:24	6.13E+01	71.6461	0.62%	CV		
	13:04:00	6.16E+01	72.0232				
Event 3	13:04:35	5.95E+00	6.2792	Switch to dist tubes			
	13:05:13	4.07E+00	4.25632				
	13:05:49	2.99E+00	3.09424				
	13:06:24	3.14E+00	3.25564				
	13:07:00	2.55E+00	2.6208				
	13:07:35	7.07E+00	7.48432	4.782791429	(Average)		
	13:08:10	1.12E+01	11.9282	2.743238294	(Standard Dev.)		
	13:08:46	3.21E+00	3.33096	57.36%	CV		
	13:09:24	2.55E+00	2.6208				
	13:10:01	3.71E+00	3.86896				
	13:10:37	7.69E+00	8.15144				
	13:11:12	2.45E+00	2.5132				
	13:11:48	2.98E+00	3.08348				
	13:12:23	4.27E+00	4.47152				
Event 4	13:12:58	1.63E-01	0.052388				
SUMMARY INFO:				**RANGE**			
FLOW CALC. #1: Q		1007.96	CFM	998.39	TO	1017.16	CFM
FLOW CALC. #2: Q		989.11	CFM	981.48	TO	997.12	CFM
OUTDOOR CAPTUR		6.68	%	3.51	TO	16.66	%

CHAMPION ROAD MACHINERY: Outdoor Test Medley

Ingersol Rand: Final Outdoor Test Medley		
Events 0-5: Wind into front of paver	T(OA)=47 deg	RPM=2100
Events 6-10: Wind into RHS of paver	T(duct) = 70 deg	rpm=2100
Events 11-14: Wind into rear of paver	T(duct)=64.7 deg	rpm=2100

(Test aborted after running out of SF(6)

- 1302 Measurement Data ——— 1804892/2803 - 1995-11-08 14:56 - 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: Formaldehyde : NO
Gas B: Carbon dioxide : NO
Gas C: Carbon monoxide : NO
Gas D: TOC as Propane : NO
Gas E: Sulfur hexafluoride : YES
Water Vapour : NO

Sampling Tube Length : 15.0 ft
Air Pressure : 760.0 mmHg
Normalization Temperature : 43.0 F

General Information:

Start Time : 1995-11-08 13:19
Stop Time : 1995-11-08 14:28
Results Not Averaged
Number of Event Marks : 14
Number of Recorded Samples : 111

	Alarm Limit	Max	Mean	Min	Std.Dev
Gas E:	863E+03	96.5E+00	25.8E+00	21.4E-03	24.6E+00

Samples Measured From 1995-11-08 13:20

Event No.	Time hh:mm:s	SF(6) ppm measured	SF(6) ppm Corrected	Comment		
				Start w/ wind blowing into front of paver		
Event 0	13:20:17	5.97E-02	-0.0587628	BG in duct		
	13:21:00	1.47E-01	0.035172			
	13:21:36	1.44E-01	0.031944			
	13:22:11	7.50E-02	-0.0423			
Event 1	13:22:46	3.19E+01	34.6903	Start 100% Capture in RHS		
	13:23:46	3.18E+01	34.5646			
	13:24:22	3.18E+01	34.5646			
	13:24:57	3.18E+01	34.5646		34.4389	(Average)
	13:25:32	3.16E+01	34.3132		0.187382497	tandard Dev.)
	13:26:08	3.16E+01	34.3132		0.54%	CV
	13:26:43	3.17E+01	34.4389			
	13:27:18	3.14E+01	34.0618			
	13:27:54	3.16E+01	34.3132			
	13:28:29	3.18E+01	34.5646			

CHAMPION ROAD MACHINERY: Outdoor Test Medley

Event 2	13:29:05	9.65E+01	115.8925	Start 100% Cature in both sides	
	13:29:40	5.78E+01	67.2466	Sticky Flow Controller	
	13:30:15	6.86E+01	80.8222	Sticky Flow Controller	
Event 3	13:30:51	6.17E+01	72.1489	Retry 100% in both sides	
	13:31:26	6.23E+01	72.9031		
	13:32:02	6.18E+01	72.2746		
	13:32:37	6.20E+01	72.526		
	13:33:24	6.22E+01	72.7774	72.45058	(Average)
	13:33:59	6.19E+01	72.4003	0.291498755	tandard Dev.)
	13:34:34	6.16E+01	72.0232	0.40%	CV
	13:35:09	6.18E+01	72.2746		
	13:35:45	6.22E+01	72.7774		
	13:36:20	6.19E+01	72.4003		
Event 4	13:36:56	3.39E+00	3.52464	Switch to dist. Tubes	
	13:37:34	9.09E+00	9.65784		
	13:38:09	7.53E+00	7.97928		
	13:38:45	6.64E+00	7.02164		
	13:39:20	9.90E+00	10.5294		
	13:39:55	3.38E+01	37.0786		
	13:40:33	1.33E+01	14.1878	13.63222333	(Average)
	13:41:11	1.35E+01	14.403	9.332936239	tandard Dev.)
	13:41:47	4.83E+00	5.07408	68.46%	CV
	13:42:22	1.07E+01	11.3902		
	13:42:58	3.74E+00	3.90124		
	13:44:04	1.69E+01	18.0614		
	13:44:42	2.27E+01	24.3022		
Event 5	13:45:17	2.24E-01	0.118024	Kill SF(6), move paver so	
	13:45:58	3.25E-02	-0.08803	that wind blows into	
	13:46:33	3.06E-02	-0.0900744	RHS of paver	
	13:47:09	2.83E-01	0.181508		
	13:47:44	9.40E-02	-0.021856		
	13:48:19	3.23E-02	-0.0882452		
	13:48:55	4.08E-02	-0.0790992		
	13:49:30	3.35E-02	-0.086954		
	13:50:06	6.99E-02	-0.0477876		
	13:50:41	6.69E-02	-0.0510156		
Event 6	13:51:17	5.33E-02	-0.0656492	Begin BG in duct	
	13:51:52	8.37E-02	-0.0329388		
Event 7	13:52:27	3.21E+01	34.9417	Start 100% Capture in RHS	
	13:53:08	3.16E+01	34.3132		
	13:54:02	3.15E+01	34.1875		
	13:54:38	3.15E+01	34.1875	34.156075	(Average)
	13:55:13	3.13E+01	33.9361	0.36026343	tandard Dev.)
	13:55:49	3.13E+01	33.9361	1.05%	CV
	13:56:24	3.12E+01	33.8104		
	13:57:00	3.13E+01	33.9361		
Event 8	13:57:35	6.97E+01	82.2049	Start 100% in both sides	
	13:58:10	6.08E+01	71.0176		
	13:58:46	6.10E+01	71.269		
	13:59:21	6.12E+01	71.5204		
	13:59:57	6.12E+01	71.5204	71.1852	(Average)
	14:00:32	6.09E+01	71.1433	0.301418011	tandard Dev.)
	14:01:07	6.10E+01	71.269	0.42%	CV
	14:01:43	6.10E+01	71.269		
	14:02:18	6.09E+01	71.1433		
	14:02:54	6.04E+01	70.5148		
Event 9	14:03:40	1.19E+01	[redacted]	Switch to dist tubes	

	14:04:18	1.75E+01	[redacted]					
	14:04:56	8.36E+00	[redacted]					
	14:05:33	2.55E+01	[redacted]					
	14:06:11	3.26E+00	[redacted]					
	14:06:49	4.33E+00	[redacted]					
	14:07:25	1.00E+01	[redacted]	10.47543	(Average)			
	14:08:00	3.41E+00	[redacted]	7.663910134	tandard Dev.)			
	14:08:35	9.17E+00	[redacted]	73.16%	CV			
	14:09:11	9.14E+00	[redacted]					
	14:09:46	4.61E+00	[redacted]					
	14:10:22	2.70E+00	[redacted]					
	14:10:57	6.14E+00	[redacted]					
	14:11:32	2.25E+01	[redacted]					
Event 10	14:12:10	1.11E-01	-0.003564	Kill SF(6), move paver				
	14:12:51	3.58E-02	-0.0844792	so that wind blows into				
	14:13:57	2.72E-02	-0.0937328	rear of paver				
	14:14:32	2.58E-02	-0.0952392					
	14:15:08	2.37E-02	-0.0974988					
	14:15:43	2.15E-02	-0.099866					
	14:16:19	2.75E-02	-0.09341					
	14:16:54	2.14E-02	-0.0999736					
	14:17:30	9.31E-02	-0.0228244					
	14:18:05	2.34E-02	-0.0978216					
	14:18:40	5.79E-02	-0.0606996					
Event 11	14:19:16	3.69E-02	-0.0832956	BG in duct (1 reading)				
	14:19:52	2.87E-01	0.185812					
Event 12	14:20:27	3.14E+01	34.0618	Begin 100% capture in RHS				
	14:21:07	3.06E+01	33.0562					
	14:21:43	3.09E+01	33.4333					
	14:22:18	3.10E+01	33.559	33.559	(Average)			
	14:22:53	3.09E+01	33.4333	0.316338063	tandard Dev.)			
	14:23:48	3.12E+01	33.8104	0.94%	CV			
	14:24:24	3.10E+01	33.559					
	14:24:59	4.20E+01	47.386					
Event 13	14:25:34	6.12E+01	71.5204	Begin 100% capture in both sides				
	14:26:10	6.05E+01	70.6405	71.3109	(Average)			
	14:26:45	6.14E+01	71.7718	0.594035024	tandard Dev.)			
	14:27:20	5.91E+01	68.8807	0.83%	CV	This data point was omitted		
Event 14	14:27:56	3.41E+01	37.4557	Running out of SF(6)				
SUMMARY INFO: (Wind blowing into front of paver)				**RANGE**				
FLOW CALC. #1: Q		987.46	CFM	980.30	TO	998.39	CFM	
FLOW CALC. #2: Q		977.39	CFM	971.33	TO	983.19	CFM	
OUTDOOR CAPTUR		18.82	%	5.38	TO	51.18	%	
SUMMARY INFO: (Wind blowing into RHS of paver)				**RANGE**				
FLOW CALC. #1: Q		995.64	CFM	973.25	TO	1005.82	CFM	
FLOW CALC. #2: Q		994.77	CFM	990.11	TO	1004.22	CFM	
OUTDOOR CAPTUR		9.52	%	3.91	TO	37.43	%	
SUMMARY INFO: (Wind blowing into rear of paver)								
NOTE: Test aborted due to lack of SF(6)								