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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

Champion Road Machinery
Shippensburg, Pennsylvania

REPORT WRITTEN BY
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PLANT SURVEYED	Champion Road Machinery 312 Ingersoll Drive Shippensburg, PA 17257
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SURVEY DATE	November 6-9, 1995
SURVEY CONDUCTED BY	Ronald L Mickelsen Kenneth R Mead Daniel S Watkins
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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

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

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)

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

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

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

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

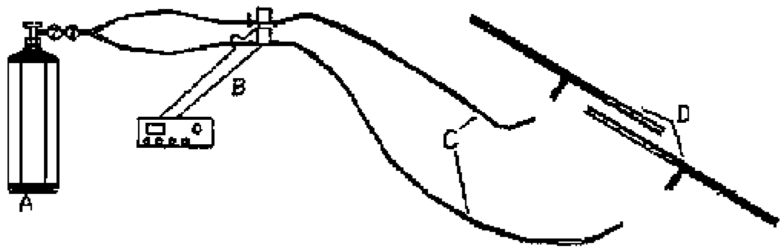
$\mathbf{C^*_{(SF6)}}$ = concentration of SF_6 (parts per million) detected in exhaust

[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—Tracer Gas Cylinder with regulator
B—Tylon Mass Flow Controllers with Control Box
C—PTFE Distribution Tubes
D—Tracer Gas Distribution Plenums

A capture efficiency can be calculated for the control 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

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

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	%	60 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%

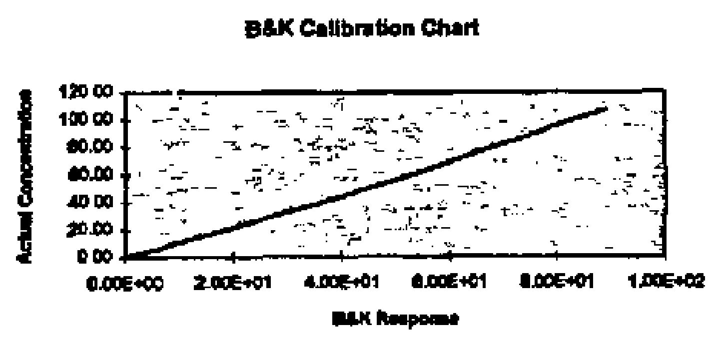
B&K CALIBRATION DATA, CHAMPION ROAD MACHINERY LAB EVALUATION

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 072632			

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 1876	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 0690824	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 0829	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 134184			
	17 00 48	2 65E-01	0 16214			
	17 01 24	2 54E-01	0 150304			
Event 2	17 01 59	3 18E+01	[illegible] 5646	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 8951	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 686268					
	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 26E+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 2684					
	17 50 25	1 86E+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 54	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 2528	Start 100% Capture thru both sides				
	11 19 05	6 15E+01	[illegible] 8975					
	11 19 40	6 16E+01	72 10232					
	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 18	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 6481					
	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 48006					
	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 28556	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

- 1302 Measurement Data ------ 1804892/2803 - 1995-11-08 14 49 - 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 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 78	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	72.528				
	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	18 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 —— 1604892/2803 - 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 ss	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	3.25584				
	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 8E+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 0567628	BG in duct				
	13 21 00	1 47E-01	0 035172					
	13 21 36	1 44E-01	0 031644					
	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 0616					
	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 85784		
	13 38 09	7 53E+00	7.87928		
	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 8417	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	[illegible]					
	14 04 56	8 36E+00	[illegible]					
	14 05 33	2 55E+01	[illegible]					
	14 06 11	3 26E+00	[illegible]					
	14 06 49	4 33E+00	[illegible]					
	14 07 25	1 00E+01	[illegible]	10 47543	(Average)			
	14 08 00	3 41E+00	[illegible]	7 663910134	tandard Dev)			
	14 08 35	9 17E+00	[illegible]	73 16%	CV			
	14 09 11	9 14E+00	[illegible]					
	14 09 46	4 61E+00	[illegible]					
	14 10 22	2 70E+00	[illegible]					
	14 10 57	6 14E+00	[illegible]					
	14 11 32	2 25E+01	[illegible]					
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 0976216					
	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)								