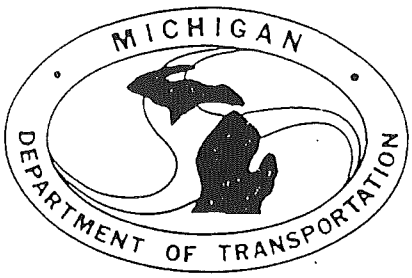
EVALUATION OF EXHAUST GAS EMISSIONS AND WORKER EXPOSURE FROM ASPHALT-RUBBER BINDERS IN HOT MIX ASPHALT MIXTURES



MATERIALS and TECHNOLOGY DIVISION

Michigan Department of Transportation
Construction and Technology Support Area
Research Report No. R - 1477

EVALUATION OF EXHAUST GAS EMISSIONS AND WORKER EXPOSURE FROM ASPHALT-RUBBER BINDERS IN HOT MIX ASPHALT MIXTURES

Final Report

Prepared for
Michigan Department of Transportation
and
Federal Highway Administration

by
Wildwood Environmental Engineering Consultants, Inc.

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EXECUTIVE SUMMARY

The Michigan Department of Transportation developed this project to evaluate the Air Quality concerns of the Michigan Department of Natural Resources (MDNR). The worker exposure testing was added to the project because of contractor concerns.

The project was set up to evaluate stack emissions at the hot mix facility and to limit the number of variables that might affect those emissions. Because of this the mixtures used were not designed for best performance, but they were acceptable. The project measured seven mixtures; a control mixture, a RAP mixture, a wet rubber mixture, a dry rubber mixture, a rubber RAP mixture, a mixture with wet rubber and rubber RAP, and a control mixture with a hard Asphalt Cement. 3600 tons of each mixture was produced and tested both at the hot mix facility and at the paving site. The results of this testing are enclosed with this report.

This report will be presented to the Michigan Department of Natural Resources for review. After this review they will issue a statement of findings and decisions as to Air Quality permits for hot mix facilities using crumb rubber. Until this review is complete, no crumb rubber projects can be completed in Michigan.

The conclusions discussed in this report are those of the testing consultant. The Michigan Department of Transportation will prepare its conclusions and issue a final summary after MDNR has reviewed the testing data and issued its opinion as to Air Quality.

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1.0 INTRODUCTION.

The Michigan Department of Transportation (MiDOT) developed and sponsored a project designed to look at the possible environmental and worker exposure effects that might result from the addition of crumb rubber to asphalt paving materials as a modifier or additive. Crumb rubber can be added to asphalt paving materials using two methods. One method is to mix the crumb rubber into the asphalt cement binder prior to mixing with aggregate materials. The other method is to add the crumb rubber to the manufacturing process as a separate process material. The first method is generally referred to as a "WET" process, and the latter method is generally referred to as a "DRY" process. MiDOT chose to use the Rouse method for the WET process, and developed their own mix design for the DRY process.

1.1 The WET Asphalt-Rubber Binder Method.

The Rouse method uses a very fine crumb rubber material, 100% passing an 80 mesh screen. The crumb rubber is blended into a very high penetration (i.e. very soft) asphalt cement which has been heated to 375°F in a primary mixing tank and mixed for a specified period of time to initiate digestion of the rubber. It is then transferred to a secondary mixing tank for further mixing and digestion. When this second step is completed, the asphalt-rubber binder is transferred to either directly the manufacturing process or to intermediate storage. At this point it is at about a temperature of 375°F. The mix design for the MiDOT project specified an amount of crumb rubber to be added to the asphalt cement binder in sufficient quantities to provide a ratio of 20 pounds of crumb rubber per ton of Hot Mix Asphalt (HMA).

1.2 The DRY Asphalt-Rubber Binder Method.

The DRY process uses a larger size crumb rubber. MiDOT specified a size passing a 1/4 inch sieve. The MiDOT mix design for the DRY process specified an amount of crumb rubber to be added to the asphalt manufacturing process in sufficient quantities to provide a ratio of 40 pounds of crumb rubber per ton of HMA. The point of introduction of the crumb rubber into the manufacturing process was not specified, but would depend on the type of equipment the successful bidding contractor would use--a batch mix facility, a parallel-flow drum mix facility, or a counter-flow drum mix facility.

1.3 Mixes to be Tested.

The MiDOT determined that seven mixes would be tested. Three of those mixes are considered Control Mixes, the other four are considered Rubber Mixes. Six of the mixes were to be manufactured with the same asphalt cement as required for the asphalt-rubber binder -- an asphalt cement of 200-250 penetration (roughly equivalent to an AC-2.5 asphalt cement). The low viscosity asphalt cement is

required in an asphalt-rubber binder because it is believed that the digestion process causes the rubber to absorb substantial amounts of light ends from the asphalt cement. MiDOT chose to use the same asphalt cement throughout the stack testing program to eliminate one variable -- asphalt cement related emissions. The seventh mix, Control Mix 1, was added to the program at a later date as a comparison for a "typical" mix compared to the "rubber" mixes because of the low viscosity asphalt cement used in the rubber mixes. There was concern that there might be emissions reported, particularly with the volatile organic compounds, that might be high because of the asphalt cement. The mixes are as follows:

Control Mix 1: This mix was to be a typical HMA using an asphalt cement with a penetration of 85-100, which is roughly equivalent to an AC-10 asphalt cement. This mix was included at a later date and was added because of concerns that the asphalt cement specified in the Rubber Mixes was a very soft asphalt and might result in emissions not normally found while producing HMA paving materials with a more viscous asphalt cement. The "typical" mix being produced during the stack testing which could be manufactured with an 85-100 PEN asphalt cement also contained 30% reclaimed asphalt pavement (RAP). This mix was designated as BM13A, Bituminous Mixture 13A -- **no Rubber, 30% RAP.**

Control Mix 2: This mix was to contain 100% virgin aggregates and asphalt cement with a penetration of 200-250 (roughly equivalent to an AC-2.5 asphalt cement). This mix was designated as MBM01, Modified Bituminous Mixture 01 -- **no rubber, no RAP.**

Control Mix 3: This mix was to contain 20% "regular" RAP materials. "Regular" as opposed to RAP with an asphalt-rubber binder. There has long been concern on the part of the paving industry as to the recyclability of asphalt pavements produced with an asphalt-rubber binder. Michigan had a roadway paved in the late 1970s with a mix containing an asphalt-rubber binder. The roadway was milled up in order to be used in this testing program. This mix was designated as MBM02, Modified Bituminous Mixture 02 -- **no Rubber, 20% RAP.**

Rubber Mix 1: The mix was to contain 100% virgin aggregates and an asphalt-rubber binder, manufactured by the WET process. This mix was designated as MBM03, Modified Bituminous Mixture 03 -- **Rubber-WET, no RAP.**

Rubber Mix 2: The mix was to contain 20% "rubber-RAP." "Rubber-RAP" because the pavement was originally manufactured with an

asphalt-rubber binder. The asphalt cement binder would not be modified with rubber crumb. This mix was designated as MBM05, Modified Bituminous Mixture 05 -- **no Rubber, 20% rubber-RAP.**

Rubber Mix 3: This mix was to contain 20% "rubber-RAP" and an asphalt-rubber binder, manufactured by the WET process. This mix was designated as MBM06, Modified Bituminous Mixture 06 -- **Rubber-WET, 20% rubber-RAP.**

Rubber Mix 4: The mix was to contain rubber, manufactured by the DRY process, with 100% virgin aggregates. This mix was designated as MBM04 -- **Rubber-DRY, no RAP.**

1.4 Development of the Stack Testing and Worker Exposure Assessment Program.

MiDOT consulted with the National Asphalt Pavement Association (NAPA) as to what environmental and worker exposure measurement approaches should be taken. They then consulted with the Michigan Department of Natural Resources Air Quality Division (MiDNR) about NAPA's recommendations. NAPA provided MiDOT with a copy of their stack testing protocol they had developed for their own stack testing program and the worker exposure sampling protocol NAPA had also developed, in conjunction with the Asphalt Institute. MiDNR endorsed the protocol, but made some additions. Furthermore, the protocol was distributed around the country for review, primarily to USEPA branches and some state air quality agencies. The additions were based on their feed back, and on MiDNR's practices and requirements. The stack testing methods specified by MiDOT are provided in Table 1.

The NAPA Stack Testing Protocol was developed by NAPA for a Stack Testing Program they were organizing. The purpose of the Stack Testing Program was gather emissions data for various pollutants for which the HMA Industry anticipated future regulation. EPA had conducted stack testing for these pollutants on ONE HMA facility in the mid to late 1970's and reported the results for that ONE test in their "Compilation of Air Pollution Emission Factors (AP-42)." This HMA facility was a batch mix facility equipped with a wet washer for particulate control. The NAPA members organizing the Stack Testing Program were concerned that the emissions did not reflect what might actually be occurring in more "modern" HMA facilities.

1.5 Description of the Hot Mix Asphalt Facility at which the Stack Sampling was Conducted.

The HMA facility that was involved in the stack testing program was a parallel-flow drum mix HMA facility rated at a production capacity of 600 tons of HMA per hour. Parallel-flow meaning that the exhaust gases and process materials move in the

same direction in the drum as the process materials are dried and heated to the desired mixing temperature. It is equipped with a 100% air burner capable of burning fuel oil or natural gas. The fuel used during the stack testing was a reprocessed used oil. The fuel was heated generally to 125°F to meet the SSU viscosity requirements of the burner manufacturer.

The original flights in the mixing section of the drum were replaced in 1991 with flights that *DO NOT* veil the asphalt-coated aggregate through the cross-section of the drum, thereby substantially minimizing the asphalt surface area to exhaust gas contact ratio between the exhaust gas and the asphalt cement--the primary cause of visible emissions in a drum mix HMA facility. The RAP is introduced to the process through a center entry inlet. The 1/4 inch crumb rubber was introduced into the process through the RAP center entry inlet for the DRY process. The air pollution control equipment for this facility is a baghouse for particulate control with a 120,000 CFM exhaust fan. The baghouse fines are conveyed to a silo prior to introduction to the process.

The design of the HMA facility used in this project is the best choice because it is likely to have almost the worst case emissions where asphalt-related emissions are concerned. The only design that is likely to generate higher levels of asphalt-related pollutant emissions is the parallel-flow drum mixer where the mixing flights veil the asphalt-coated aggregate particles through the cross-section of the drum. This veiling provides the maximum asphalt surface area to exhaust gas contact. It is also the design most likely to have asphalt vapor visible emissions--i.e., a condensing hydrocarbon plume. Careful design considerations can minimize the hydrocarbon plume problem even with veiling asphalt-coated aggregate. Another significant factor is the quality of the asphalt cement and the viscosity.

2.0 STACK SAMPLING PROCEDURES AND COMPOUNDS TO BE ANALYZED AND QUANTITATED.

The following text provides explanations as to why these particular procedures were conducted for the MiDOT Stack Testing Program and, if necessary, a list of the compounds for which analysis was to be conducted and any other specifics not provided in Table 1. It will also provide how the feedback from reviewers was incorporated, where applicable. Descriptions of the methods are provided in the appropriate appendices. EPA Methods 1, 2, 3, and 4 are required with all sampling trains for the determination of stack gas volumetric flow rates and stack gas moisture content.

2.1 Continuous Measurement of Carbon Monoxide, Oxides of Nitrogen, Sulfur Dioxide, Total Hydrocarbons, Oxygen, and Carbon Dioxide Emissions.

The compounds listed under the Continuous Emissions Measurement section in Table 1 are Products of Combustion (CO_2 and O_2) and Products of Incomplete Combustion (CO, NO_x , SO_2 , and THC). Measurement of the Products of Combustion is required for all stack sampling procedures in order to determine the physical characteristics of the exhaust gas. Measurement of the Products of Incomplete Combustion was included to monitor the combustion process of the HMA manufacturing system in order to demonstrate that normal operations were maintained throughout the stack testing program. It should be noted that the THC method, Method 25A, is efficient at collecting hydrocarbons containing up to 9 to 10 carbons. Therefore, it is theorized that asphalt fume is not reflected in this emission rate.

2.2 Particulate Emissions Measurement.

Particulate emissions measurements were conducted to determine if the asphalt-rubber binder mixes caused an increase in particulate emissions, and if so, did the particulate emission with asphalt-rubber binder mixes comply with the EPA New Source Performance Standard (NSPS) for Hot Mix Asphalt facilities -- a maximum allowable particulate emission concentration of 0.04 grains per standard cubic foot of dry exhaust gas (90 mg/DSCM), and less than 20% opacity for visible emission (excluding water vapor). The condensible particulate emissions measurement were conducted to determine if the asphalt-rubber binder mixes result in a higher level of asphalt vapor or fume. The condensible catch is believed to be condensed asphalt vapor. When heavy fuel oils are burned, the condensible catch could also include unburned fuel vapor.

2.3 Polynuclear Aromatic Hydrocarbon Emissions and Semi-Volatile Emissions Measurement.

2.3.1 Polynuclear Aromatic Hydrocarbon Emissions Collection and Analysis.

The polynuclear aromatic hydrocarbons (PAHs) for which sampling and analysis were to be conducted included the 17 PAHs listed in the National Institute for Occupational Safety and Health's Test Method 5506, plus 15 additional PAHs and semi-volatile compounds. The 17 NIOSH PAHs are:

Acenaphthene	Benzo(g,h,i)perylene	Fluorene
Acenaphthylene	Benzo(j)fluoranthene	Indeno(1,2,3-cd)pyrene
Anthracene	Benzo(k)fluoranthene	Naphthalene
Benz(a)anthracene	Chrysene	Phenanthrene
Benzo(a)pyrene	Dibenzo(a,h)anthracene	Pyrene
Benzo(e)pyrene	Fluoranthene	

The NAPA Stack Testing Protocol also included 2-Methylnaphthalene, 2-Chloronaphthalene, o-Cresol (2-methylphenol), m-Cresol (3-methylphenol), p-Cresol (4-methylphenol), and Cumene. The latter four compounds are included because they appear in the list of Hazardous Air Pollutants in Title III of the Clean Air Act.

MiDNR added the following PAHs for which analysis and quantitation was to be conducted, in accordance with their definition of "asphalt PAH fume":

Anthanthrene	Benzo(c)fluorene	Picene
Benzo(a)fluorene	Chrysene	Perylene
Benzo(b)fluorene	Coronene	Triphenylene

The laboratories that were contacted about performing the required analyses on the SW-846/0010 samples reported that analysis could not be conducted for all of the listed PAHs and that, in some cases, one compound co-eluted with another. Their discussion of these issues is summarized as follows:

> *PAH Compounds for which standards are available and can be done by Method SW-846/8270 using a single point calibration: Benzo(a)fluorene and Benzo(b)fluorene.*
>
> *PAH Compounds which co-elute--a total concentration for co-eluting compounds will be reported: Triphenylene co-elutes with Chrysene; Benzo(j)fluoranthene co-elutes with Benzo(b)fluoranthene and Benzo(k)fluoranthene.*
>
> *PAH Compounds which will not be attempted because the retention time under the GC/MS conditions of SW-846/8270: Coronene.*

PAH Compounds for which standards cannot be found commercially: Anthanthrene, Benzo(a)fluorene, and Picene.

2.3.2 Analysis for Pre-cursers of Dioxin Formation.

The USEPA Combustion Research Branch, which had reviewed the draft protocol, had recommended stack testing for dioxin. After some discussion with their representative, it was decided that, instead of adding a whole stack sampling train to the project when very little evidence existed to suggest that dioxin emissions would occur in the exhaust gas of a HMA manufacturing facility, analysis of the SW-846/0010 sample would include analysis for the various chlorobenzenes and chlorophenols found in the SW-846/8270 semi-volatiles list. SW-846/8270 is the analytical part of determining PAHs and semi-volatiles emissions in exhaust gases of waste incinerators and other combustion processes. Hence, analysis of the SW-846/0010 sample also included the following compounds:

2-Chlorophenol	2,4-Dichlorophenol	1,3-Dichlorobenzene
4-Chloro-3-Methylphenol	2,4,5-Trichlorophenol	1,4-Dichlorobenzene
Pentachlorophenol	2,4,6-Trichlorophenol	1,2,4-Trichlorobenzene
	1,2-Dichlorobenzene	Hexachlorobenzene

2.3.3 Analysis for "Rubber" Semi-volatile Organic Compounds.

NAPA recommended analyzing the SW-846/0010 samples for Nitrosamines, compounds inherent in rubber. The Nitrosamines for which analysis was specified were: n-Nitrosodimethylamine, n-Nitrosodipropylamine, n-Nitrosodibutylamine, and n-Nitrosodiphenylamine. The laboratories reported that they would only be able to analyze for n-Nitrosodipropylamine and n-Nitrosodiphenylamine.

2.3.4 Scan and Quanitfication of all Other SW-846/8270 Semi-Volatile Compounds.

NAPA also suggested having a complete 8270 scan conducted on the SW-846/0010 samples to see if there were compounds in the exhaust gas of a HMA facility that had not been looked for in previous studies of semi-volatile organic emissions from HMA facilities stacks. Following is a list of the compounds on the 8270 list that have not already been listed. The compounds highlighted with bold indicate they were found in detected levels in at least one run. The compounds that are italicized were found in both the samples and the laboratory blank, which indicates possible contamination by the laboratory procedures.

Phenol	Hexachloroethane	2,4-Dimethylphenol
bis(2-Chloroethyl)ether	Nitrobenzene	bis(2-Chloroethoxy)methane
2,2'-oxybis(1-Chloropropane)	Isophorone	*Benzoic acid*
Benzyl alcohol	2-Nitrophenol	4-Chloroaniline

Hexachlorobutadiene	2,4-Dinitrophenol	4-Bromophenyl-phenylether
Hexachlorocyclopentadiene	4-Nitrophenol	*Di-n-butylphthalate*
2-Nitroaniline	**Dibenzofuran**	Butylbenzylphthalate
Dimethylphthalate	Diethylphthalate	3,3'-Dichlorobenzidine
2,6-Dinitrotoluene	4-Chlorophenyl-phenylether	*bis(2-Ethylhexyl)phthalate*
2,4-Dinitrotoluene	4-Nitroaniline	Di-n-octylphthalate
3-Nitroaniline	4,6-Dinitro-2-methylphenol	

2.4 Heavy Metals Emissions Measurement.

Heavy metals were included primarily because of the metals used in manufacturing the steel-belted tires from which the rubber crumb was to come. MiDNR added zinc to the eight heavy metals listed in the Toxicity Characteristic Leachate Procedure and lead. Zinc is a substantial metal constituent of rubber tires.

2.5 Formaldehyde Emissions Measurement.

Formaldehyde stack testing is part of the NAPA Stack Testing Protocol. It is a product of incomplete combustion. Acetone was included because two EPA stack test reports for HMA facilities reported very high quantities of acetone. Review of the timing of when the formaldehyde stack testing was conducted compared to when the particulate stack testing was conducted suggested that perhaps the acetone was a contaminant from the particulate stack testing procedure. Acetone is used to rinse all the equipment during recovery of the sample. Since there was no additional cost involved, acetone analysis was included to determine if in fact acetone did occur in such high quantities. The project specifications required that the formaldehyde sampling be conducted on the day that particulate sampling *was not* conducted.

2.6 Volatile Organic Emissions Measurement.

The NAPA Stack Testing Protocol required measurement of Benzene, Toluene, Ethylbenzene, and all isomers of Xylene (BTEX). Styrene was specified because it is part of the rubber polymer. Chlorobenzene was included as discussed in Section 2.3.2. MiDNR added methyl-isobutylKetone. In addition, NAPA suggested also conducting a scan for all the SW-846/8240 compounds.

2.7 Method 18 Emissions Measurement.

1,3-Butadiene is part of the rubber polymer. Methane was included because most states regulate volatile organic compound emissions as non-Methane Total Hydrocarbons (NMTHC). Since Method 25A cannot distinguish methane from all the other hydrocarbons during analysis, methane must be measured separately and subtracted from the Method 25A results to obtain a non-Methane Total Hydrocarbon quantity.

3.0 FIELD WORK.

The stack sampling was carried out during the latter half of September 1993 and the first few days of October 1993 (9/15 through 10/5). Entropy Environmentalists, Inc. performed the stack testing, under the direction of Herbert Dixon, Project Manager. The stack testing and worker exposure sampling were overseen by Kathryn O'C. Gunkel, P.E. of WILDWOOD Environmental Engineering Consultants, Inc. Ms. Gunkel also oversaw collection of process materials samples, recordation of operating data, and recordation of process materials moisture content. There were some delays--mostly weather related. One major delay was caused by delivery problems with the 1/4 inch rubber crumb and the project had to be carried over another weekend.

3.1 Stack Testing Problems.

There were virtually no stack testing problems. It was discovered after the first day of stack sampling was completed, Control Mix 1, that the SW-846/0030 sampling had not been conducted. NAPA had been definitive on the issue that the SW-846/0010 and SW-846/0030 be conducted simultaneously. Entropy agreed to collect three more SW-846/ sample at their cost while conducting method SW-846/0030. These three runs were collected during the testing program when making one of the other mixes was not possible.

On the first Saturday of the stack testing program the total hydrocarbon analyzer went out--it was not maintaining temperature. Another analyzer was obtained and ready for testing by the following Monday. Stack testing was not delayed because of the problem with the hydrocarbon analyzer. It was felt that there were sufficient runs collected that the project should not be held up for this problem. Several other THC runs were lost throughout the stack testing program due to problems with the analyzer, but no more than two runs (out of six) were lost for any one mix, except the mix stack tested on that first Saturday (Control Mix 3). On the last day of stack testing, the stack testing team was advised that the laboratory had lost two SW-846/0010 samples, one for Control Mix 1 and one for Control Mix 2.

3.2 Visible Emission Observations.

The MiDOT stack testing program specified that visible emissions observations would be made for at least 20 minutes during each stack test run. Unfortunately, such readings were not possible during this program. Typically, when emissions occur at a parallel-flow drum mix HMA facility, they are a white to gray color, sometimes blue if the asphalt cement is burned. However, given the length and diameter of the drum at the HMA facility where the stack testing was conducted,

burning of the asphalt cement was not at all likely. Bright blue, clear skies occurred on only two days during the entire stack testing program, and one of those days was a Sunday, when no stack testing was conducted. Otherwise, the weather consisted mostly of overcast skies. Unfortunately, the skies were the same color as the visible emission that might be expected from this drum mix HMA facility. The terrain around the HMA facility did not provide elevated locations sufficiently high enough above the stack and "read" the visible emission against a more suitable background. Consequently, sufficient visible emission observations were not conducted to make any conclusions about the impact of rubber on visible emissions.

3.3 Odors from the Stack.

Odors were very noticeable during the manufacture of the mixes with the asphalt-rubber WET binders. It was described by observers as having "an old radiator hose smell." The odor was worse when RBR 3 was being manufactured.

4.0 DISCUSSION OF RESULTS.

The results of the various stack testing procedures are grouped together, where applicable. In some cases, there are separate tables for each unit of measurement provided. In all cases, all the operating data and stack conditions data are provided at the top of each table for quick reference. The data table are grouped together at the end of the report beginning at page 19.

4.1 Continuous Emissions Measurement (CEM) Results.

The results of the CEMs are presented in Tables 2, 3, and 4. The emissions are provided in units of lbs/hour, mg/m^3, and PPM. Since these emissions are strictly due to fuel combustion, emission factors, if desired, should be calculated on the basis of fuel use as opposed to production. Fuel use will change according to the moisture content in the aggregate and the amount of HMA being produced. The same amount of fuel is required for casing heat losses regardless of the amount of HMA being produced for a given mix temperature. The changes in fuel consumption per ton of HMA were reflected in the operations recordings according to weather conditions. For example, Monday, September 27, 1993, was lost completely due to a drenching rain. The next several days, the per ton fuel consumption was markedly higher than it had been the previous week.

The results are very consistent for the three Control Mixes and the first three Rubber Mixes. They are markedly higher for Rubber Mix 4, the DRY process. The CEM readings were checked regularly during the stack testing and the change in the readings was noted during the stack testing.

In checking the operations, it was found that the fuel temperature was lower than normal. It had been at around 125°F during all of the previous stack testing, however, it was down around 110°F. The heater was adjusted to increase the fuel oil temperature and it was brought up to temperature by the second run. The exhaust fan damper is automatically controlled via the pressure in the bulkhead of the drum and it was operating at what appeared to be normal. It was noted that the mix design for this mix was considerably different than the other six mixes in that it did not include as much fine aggregates as did the others. However, a clear, definitive cause for the markedly higher readings could not be determined. Clearly, however, the high CEM values are related to the mix because all the concentrations dropped to what was common during manufacture of the other six mixes when the SW-846/0010 run was conducted to replace the sample broken by the lab.

The stack conditions provided in the tables for the CEM and Method 18 results reflect averages of the stack conditions for sampling trains operated simultaneously. For example, the first three CEM runs and the Method 18 runs were conducted while the Particulate/Condensible and Metals sampling conducted with two different trains. The stack conditions reported for each run for each train were averaged and then the average for the Particulate/Condensible train was averaged with the average for the Metals train. Likewise for the second three CEM runs which were conducted while the PAHs and VOST sampling was conducted. The operating data provided is an average of the operating for the two days (or three days) over which all the stack sampling was conducted for a given mix. It is for this reason that these values will not match exactly with those provided in other tables.

4.1.1 Carbon Dioxide (CO_2) and Oxygen (O_2) Results.

The CEM results for these two compounds are fairly consistent for all the mixes except RBR 3. They correlate well with the Orsat measurements, which are essentially grab samples collected during the runs, for three of the seven mixes. The CEM results are likely more reliable than the Orsat results because of the continuous measurement nature of the sampling. The CO_2 and O_2 concentration are an indication of the excess air levels in the system. A certain amount of excess air is required for combustion, but there is the potential in HMA facilities for more excess air than is necessary. This affects fuel combustion efficiency and production efficiency. More excess air than is necessary generally occurs as a result of inadequate fan damper adjustments or leakage of ambient air into the system.

EPA and many states require many combustion sources to report their CEM results adjusted to a specified concentration of CO_2, O_2, or excess air. Typically these specified concentrations are 3% CO_2, 7% O_2, or 50% or 100% excess air, by volume. This prevents purposeful dilution of the stack gases which would result in low emission concentration results. HMA facilities, for one reason or another, are not generally required to make this adjustment. When reviewing CEM pollutant data, particularly from different facilities, it is best to compare emission rates based on a weight per time unit of measurement. It eliminates all issues surrounding the emission concentration results and excess air impacts. Hence, the reason for the results being provided in several sets of units.

The higher CO_2 concentration for RBR 3 reflects the higher fuel consumption rate that occurred. In fact, a comparison of the CO_2 to fuel consumption rate finds a range of 0.0093 $\%CO_2$ per gal/hr to 0.0108 $\%CO_2$ per gal/hr with an average ratio of 0.0099 $\%CO_2$ per gal/hr. The closeness of the results is not surprising since the O_2 concentrations were so consistent--there is a difference of 1.54% between the highest and lowest values.

4.1.2 Carbon Monoxide and non-Methane Total Hydrocarbon Carbon Results.

These two pollutants are primarily a reflection of incomplete combustion. Incomplete combustion occurs if material contacts the flame. The combustion reaction is short-circuited. Instead of going all the way to CO_2, the carbon-oxygen reaction stops at CO. The THC reflects the amount of fuel vapor that never gets involved in the combustion process. This is mostly due to inefficient atomization of the fuel, however, it could be caused by high exhaust gas velocities, too much excess air in the combustion zone (cools the flame), or not enough excess air (starves the flame of oxygen).

These pollutants are generally regulated on a parts per million basis where concentrations of CO under 500 PPM for a HMA facility is generally considered to represent good combustion conditions. Concentrations of THC up to 250 PPM are considered to represent good combustion conditions (good atomization efficiency)--for natural gas and distillate fuel combustion. It is not surprising to see higher THC concentrations and rates for heavier fuels--particularly those that require heating. This is where atomization efficiency of heavy fuels can differ radically from combustion of natural gas and distillate fuels.

4.1.3 Oxides of Nitrogen (NO_x) Results.

The NO_x emissions are a result of combustion of the N_2 in the fuel and also in the combustion air. As a rule, burner adjustments made to decrease CO emissions will result in higher NO_x emissions and vice versa. This is demonstrated in the CEM results for RBR 4. It should be noted that the burner opening (an operating parameter recorded during stack testing) during stack testing of RBR 4 was significantly smaller than for the other mixes--about 60% to 75% of the burner openings recorded for the other six mixes.

4.1.4 Sulfur Dioxide (SO_2) Results.

Sulfur dioxide is a result of oxidation of the sulfur found in the fuel being burned. Its concentration (by weight) increases with heavier fuel oils. The fuel oil/reprocessor reported that the sulfur content was fairly consistent at about 0.5 %. Using this sulfur number, rough estimates show that the SO_2 emissions actually measured were substantially lower than the calculated SO_2 emissions calculated from the amount of fuel consumed and the sulfur content. Furthermore, the data showed that the SO_2 emissions were much lower for mixes which had no RAP and a high percentage of fines.

4.2 Particulate and Condensible Matter Results.

The results of the Particulate and Condensible Matter stack sampling are presented in Table 5. Emission rates, concentrations, and factors are provided as follows: grains/SCFD, mg/m^3, lbs/hour, and lb/ton HMA.

4.2.1 Filterable Particulate Matter Results.

The NSPS for HMA facilities uses only the results of the filterable particulate (Method 5) for compliance demonstrations. The results of the Method 5 sampling demonstrated compliance with the NSPS for all seven mixes, by a wide margin.

4.2.2 Condensible Particulate Results.

As for the condensible emissions, no clear pattern emerges. The condensible particulate is most likely a vapor emission--asphalt vapor. Setting aside the RBR 4 results, it is clear that RAP plays a role in the quantity of condensible emissions reported. RBR 1 had 2/3 of the condensible emission rate that CTRL 2 had. This could be indicative of the rubber sucking up the light ends. However, the combined emission rate of both particulate do not reflect the same ratio. It should be noted that while the condensible emission most likely reflects a vapor emission (in the case of a HMA facility), the filterable particulate could reflect a combination of solid particulate emissions and vapor emissions. The vapor emissions on the filter would be asphalt vapor that condenses at the filter temperature (usually 250°F) or is prone to adsorb onto solid particulate when in contact with it. If the filters had been treated in the same manner as the worker exposure filter--where they are extracted with benzene to remove the hydrocarbons--could it be estimated as to how much of the filter catch was solid particulate and how much was condensed vapor. This procedure is not routinely performed on stack sample filters.

4.3 Results of Metals Stack Sampling and Metals Analysis of the Process Materials, Fuel Oil, and Baghouse Fines.

The results of the metals stack testing are provided in Table 6. The results of the materials analyses are provided in Tables 7, 8, and 9. The metals emission rates were extremely low--less than 4/1000 of a pound per hour (1.8 grams/hour) for any one metal. The used fuel oil contained detected quantities of Barium and Zinc only and their contribution to the total Barium and Zinc into the process was minor compared to the quantity of each introduced with the aggregate and RAP--1.38% of the total Barium and 5% of the total Zinc into the process. The rest of the Barium and Zinc and all the other metals (except for two) were introduced into the process with the aggregate and RAP materials. The rubber-RAP had higher concentrations of Zinc than the regular RAP--most likely due to the asphalt-rubber binder in the rubber-RAP.

4.4 Formaldehyde and Methyl-Isobutyl-Ketone Emissions Sampling Results.

The results of the formaldehyde and MIBK stack sampling are provided in Table 10. Formaldehyde is also a product of incomplete combustion for much the same reasons as the CO and THC. The formaldehyde results track almost exactly with the THC and CO results--where RBR 4 had the highest emission concentrations and rates of THC and CO, it also had the highest emission concentrations and rates of formaldehyde, and where RBR 3 had the lowest THC and CO results, it also had the lowest Formaldehyde results.

4.5 Volatile Organic Sampling Results.

The volatile organic samples are usually collected for 20 minute periods of time, according to the method specifications. However, at the suggestion of USEPA-RTP, three VOST samples were collected during each PAH run--one for 10 minutes, one for 20 minutes, and one for 40 minutes. The purpose for this was primarily because there was not time (nor funding) to send out a "scouting" team to collect some VOST stack samples for analysis to see what would be an optimum sampling time. If the 20 minute sample contains excessive amounts of more volatile volatiles, then they will mask the results of other volatiles that may also be present, and there is no way to dilute the sample which would not affect analysis of the other volatiles. If there are not sufficient amounts in the sample for detection, there is no way to concentrate the sample to improve the detection of the compounds. As it turns out, it was good advice on the part of USEPA-RTP. The 20 minute samples could not be used. The 10 minute samples were used in all cases. Even so, many of the samples for the rubber mixes reported saturated peaks for several of the compounds, which means that the amount of the compound reported is underestimated.

The results of the VOST sampling and analysis are provided in Tables 11, 12, and 13. The stack conditions provided in these three tables are the averages of the stack conditions reported for the formaldehyde and the PAHs sampling trains.

4.5.1 Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) Emissions Results.

The BTEX emission rates were all significantly higher for all the mixes using the 200-250 PEN asphalt cement, with or without rubber than were the BTEX emission for the mix with 85-100 PEN asphalt cement--CTRL 1. Comparing these BTEX results to those reported for an identical HMA facility located in Grand Rapids, Michigan, shows that the VOST method and analysis is much more sensitive than an onsite gas chromatograph which was used at the Grand Rapids facility. The BTEX results for the Grand Rapids facility were "not detected" with a detection limit of 1 PPM for each compound.

4.5.2 Styrene Emissions Results.

Styrene was detected in all mixes, but at considerably higher levels for the rubber mixes. There was one exception--RBR 1 had only slightly more styrene than CTRL 1. That CTRL 1 had some styrene detected is not surprising because of the RAP which had years of contact with vehicle tires.

4.5.3 Methyl-Isobutyl-Ketone (MIBK) Emissions Results.

Methyl-isobutyl-Ketone was reported for the two mixes containing the asphalt-rubber binders--RBR 1, RBR 3, and RBR 4. A small amount was reported for CTRL 1, at 24% of the RBR 1 MIBK result, at 6.46% of the RBR 3 result, and at 8.02% of the RBR 4 result.

4.5.4 Chlorobenzene Emissions Results.

Chlorobenzene was detected in one run each of CTRL 1, RBR 2, and RBR 3. It was reported detected in all three runs of RBR 4. The quantity of chlorobenzene reported for the asphalt-rubber binder mixes was 1,300% to a little over 8,000% higher than the quantity reported for CTRL 1.

4.6 Results of PAHs and Semi-Volatiles Sampling and Analysis.

In 1992, MiDNR established an emission concentration for "Total PAHs" in a permit to install condition for a HMA facility seeking such a permit for installation of a HMA facility in Grand Rapids, Michigan (the same one discussed in Section 4.5.1). They defined "Total PAHs" as the summation of the reported quantities of 25 PAHs, listed in Section 2.3.1, excluding the Naphthalene compounds. Stack testing was required to demonstrate compliance with the specified emission concentration. In 1993, MiDNR proposed to list asphalt fume PAHs on their List of Screening Levels with a maximum allowable annual ground level concentration of 0.0016 ug/m^3. MiDNR specified that for any compound reported as "Not Detected," the detection limit had to be used, i.e., zero could not be used for any compound not detected. EPA has not established a policy on handling "Not Detected," however, there is a work group reviewing the issue. In the case of waste incinerators, they require that detection limits be used for compounds reported as not detected if sampling time was not sufficient or analysis was not sufficiently sophisticated. Otherwise, they generally allow the use of zero for compounds reported as not detected. The state of California does not allow the use of zero for not detected compounds, however, 50% of the detection limit is used for not detected compounds.

There are two analytical procedures available for the analysis of the SW-846/0010 samples, commonly called "Low-resolution GC/MS analysis" and "High-

resolution GC/MS analysis." The latter procedure is more sensitive and can detect lower quantities of compounds than can the "low-res" procedure, on the order of three magnitudes lower. The "high-res" procedure was used by the Grand Rapids facility, and was specified in the Asphalt-Rubber project. However, it could not be used for analysis of the Asphalt-Rubber project samples because of extremely high concentrations of the more volatile semi-volatile compounds--naphthalene, 2-methyl-naphthalene, cumene, and phenanthrene. Consequently, the low-res analytical procedure was used for the Asphalt-Rubber project. The detection limits reported for not detected compounds were reported in units of micrograms (10^{-6} grams). The high-res analytical procedure was used successfully on the Grand Rapids facility samples and there was a reported quantity for virtually every PAH compound for which analysis could be performed. However, the reported results were in units of nanograms (10^{-9} grams).

Since this report is expected to be circulated out of Michigan, since NAPA's stack test program results have been reported, and since NAPA used zero for not detected compounds, the PAH data has been provided in two sets. One set is identified as "MiDNR PAHs" and reflects MiDNR's requirement to use the detection limit as a result for a not-detected compound. The other set is identified as "NAPA PAHs" and reflects the was NAPA reported the PAH results of its stack testing program--with zero for not-detected compounds. Also, the NAPA PAH results included Naphthalene and 2-methylNaphthalene, whereas, MiDNR's did not.

The results of the PAH, Cumene, and Cresol emissions measurements using the MiDNR criteria that not-detected compounds be set equal to their reported detection limit are provided in Tables 14, 15, 16, 20, 21, 22, 23, and 24. The results of the PAH, Cumene, and Cresol emissions measurements following the NAPA (and EPA) method of setting not-detected compounds equal to zero are provided in Tables 17, 18, 19, 20, 21, 22, 23, and 24.

The results of the Chlorobenzene, Chlorophenol, Nitrosamines, and 8270 Scan using the MiDNR criteria for not-detected compounds are provided in Tables 25, 26, and 27. The results for these compounds following the NAPA (and EPA) method of setting not-detected compounds equal to zero are provided in Tables 28, 19, and 30.

4.6.1 Target Polynuclear Aromatic Hydrocarbon (PAH) Emissions Results.

Reclaimed asphalt pavement clearly contributes to the PAH emission rate. Asphalt type (penetration) and rubber (wet) do not appear to make much difference. However, since a virgin mix with 85-100 PEN was not stack tested for PAH emissions at the same time, it is difficult to know if a difference exists with asphalt type. The PAH stack testing performed in Grand Rapids was on a 100% virgin aggregate mix with 85-100 PEN asphalt cement and natural gas. The MiDNR average PAH

concentration for three runs for the Grand Rapids facility was 0.0649 mg/m^3 and the NAPA concentration was 0.535 mg/m^3. The MiDNR average PAH concentration for CTRL 2 and RBR 1 was 0.1835 mg/m^3 and the NAPA average PAH concentration was 0.8815 mg/m^3. For the mixes containing RAP, the average MiDNR PAH concentration was 1.4351 mg/m^3 and the average NAPA PAH concentration was 3.099 mg/m^3. For the Grand Rapids facility, the production rate was similar to the one used in the Asphalt-Rubber project (avg. 368 TPH), the volumetric exhaust gas flow rate was slightly lower (avg. 40,188 DSCFM), and the CO_2 and O_2 concentrations were slightly higher (avgs. 4.5% and 13.6%, respectively). These results could be interpreted to indicate that asphalt cement type also plays a role in the PAH emissions results. There is also the possibility for PAHs to be in the fuel oil since the fuel used in the Asphalt-Rubber project was a reprocessed oil.

The higher PAH results for could be caused by the detection limit issue for not-detected compounds. The Asphalt-Rubber average PAH result for virgin mixes (excluding RBR 4) is 2.83 times higher than the Grand Rapids MiDNR average PAH result, while in the case of the NAPA PAHs, the Asphalt-Rubber average PAH result is 1.65 times higher. In comparing the RAP PAH results to the Grand Rapids results the MiDNR Asphalt-Rubber average PAH result is 22 times higher than the Grand Rapids MiDNR PAH result, and the NAPA result is only 5.8 times higher than the Grand Rapids NAPA result.

The quantities of 2-methylNaphthalene were considerably higher for the rubber mixes, especially for the ones with rubber-RAP. To a lesser degree, this was also true for phenanthrene. These compounds make up a substantial percentage of the total PAHs. In terms of percent of Total PAHs, the naphthalene compounds occurred at considerably higher percentages in the virgin mixes, as compared to the RAP mixes, while just the opposite is true for phenanthrene.

The laboratory had difficulty analyzing for Benzo(a)fluorene, and reported results for several hydrocarbons that elute at about the same point as Benzo(a)fluorene should. With no direction as to how to use these results--which hydrocarbon is the most likely to represent benzo(a)fluorene, all the reported results for the various hydrocarbons were averaged and the average used to calculate emission concentrations and rates. In some cases, nothing was reported for the "target" hydrocarbons, not even detection limits.

4.6.2 Cumene Emissions Results.

Cumene quantities were reported for all samples for all mixes. The concentrations did not range much, ranging from 0.0272 mg/m^3 to 0.0573 mg/m^3 (0.0046 to 0.0095 lb/hr) for the seven mixes. The Grand Rapids facility reported 0.0956 mg/m^3 (0.0115 lb/hr) for cumene.

4.6.3 Cresol Emissions Results.

Cresols were reported for all the mixes, although some individual samples had not-detected levels for o-Cresol. The combined concentrations for all three Cresols ranged from 0.0493 to 0.1489 mg/m^3 (0.0069 to 0.0168 lb/hr) for the three control mixes and RBR 1, 2, and 3 (where not-detected samples used zero). RBR 4 reported a combined concentration of 0.3198 mg/m^3 (0.0343 lb/hr). Cresols were reported as not detected for the Grand Rapids facility.

4.6.4 Dioxin Precursor Emissions Measurements Results.

Of the chlorophenols and chlorobenzenes, dioxin precursors, 2-chlorophenol was detected for all but CTRL 3 RBR 2 (two RAP mixes), at less than 0.0123 mg/m^3 (0.0016 lb/hr), while RBR 4 reported 0.0244 mg/m^3 (0.0041 lb/hr). The only other "precursor" detected was 1,2,4-Trichlorobenzene for three mixes, CTRL 1 (0.0052 mg/m^3, 0.0008 lb/hr), CTRL 2 (0.0119 mg/m^3, 0.0020 lb/hr), and RBR 4 (0.0354 mg/m^3, 0.0058 lb/hr).

4.6.5 Nitrosamines Emissions Measurements Results.

N-Nitrosodiphenylamine was found in detected quantities for at least one run of RBR 1 (0.0043 mg/m^3, 0.0007 lb/hr).

4.6.6 Results of Scan for other SW-846/8270 Semi-Volatile Compounds.

Six of the remaining compounds on the 8270 semi-volatile list had reported quantities for at least a couple of the mixes. Three of them were also found in the laboratory blank. Of particular interest is that Dibenzofuran and Phenol were reported at detected levels for all seven mixes. Again the emission concentrations and rates for both of these compounds were higher for mixes containing RAP, except for RBR 3, which was just between the results for the virgin mixes and the other RAP mixes for dibenzofuran and less than the virgin mixes for phenol. However, the phenol results were not as varied as were the dibenzofuran results. The phenol results ranged from 0.1891 to 0.4049 mg/m^3 (0.0321 to 0.0646 lb/hr) for the RAP mixes and 0.2030 to 0.2155 mg/m^3 (0.0347 to 0.0398 lb/hr) for the virgin mixes, not including RBR 4 which reported 1.0290 mg/m^3 (0.1706 lb/hr). The dibenzofuran results ranged from 0.0498 to 0.1713 mg/m^3 (0.0085 to 0.0277 lb/hr) for the RAP mixes and from 0.0229 to 0.0236 mg/m^3 (0.0039 to 0.0044 lb/hr) for the virgin mixes, with RBR 4 reporting 0.0671 mg/m^3 (0.0111 lb/hr). These compounds are products of incomplete combustion, and referring back to the CO/THC and formaldehyde results, the results for these two compounds appear to track with those results, particularly the phenol results. Whether they are a function of using reprocessed used oil or not cannot be addressed since they have not been looked for in other sampling with other types of fuels. These two chemicals are of particular interest in that they are both listed in the Clean Air Act Title III list of Hazardous Air Pollutants.

5.0 CONCLUSIONS.

Overall, in this limited stack testing, it cannot be said that adding rubber to HMA paving materials, either by the WET or DRY process, increases significantly the emissions of any undesirable compounds. However, it appears that the RAP used in this study, regardless of whether or not the original binder had rubber in it, increased the emissions of PAHs and SO_2. The amount of SO_2 emitted was around 25% to 30% of the theoretical emissions, calculated from the fuel consumption and fuel sulfur content, when the feed materials were all virgin aggregates. It was as high as 48% of the theoretical emissions when the feed materials included RAP. The soft asphalt cement appears to result in increased emissions of BTEX.

Odors from the stack caused by the use of rubber in HMA the manufacturing process could, however, present a problem for Hot Mix Asphalt facilities, especially those in heavily populated areas. Any future testing programs conducted for crumb rubber asphalt pavements should include an odor testing procedure (with odor panel) similar to the Wayne County, Michigan, procedure.

Do any of these emissions pose a health risk to communities near HMA facilities? It is difficult to say from just at the emission rates and emission concentrations. An analysis in conformance with Michigan's Toxic Air Contaminant rule would be in order for Michigan facilities. For facilities in other states, a similar analysis should be performed in conformance with that state's toxic air pollutant regulations. However, given the limited number of hours a HMA facility is generally operated annually, it is highly ***unlikely*** that an allowable fenceline concentration limit based on an annual averaging period would be exceeded.

TABLE 1. STACK SAMPLING AND ANALYTICAL PROCEDURES FOR MICHIGAN DEPARTMENT OF TRANSPORTATION'S ASPHALT-RUBBER BINDER STACK TESTING PROJECT

Compound	Method/Procedure Name	Designation
CONTINUOUS EMISSIONS MEASUREMENT		
Carbon Dioxide (CO_2) and Oxygen (O_2)	Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure)	EPA RM 3A
Sulfur Dioxide (SO_2)	Determination of Sulfur Dioxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)	EPA RM 6C
Oxides of Nitrogen (NO_x)	Determination of Nitrogen Oxides Emissions from Stationary Sources (Instrumental Analyzer Procedure)	EPA RM 7E
Carbon Monoxide (CO)	Determination of Carbon Monoxide Emissions from Stationary Sources	EPA RM 10
Total Hydrocarbons (THC)	Determination of Total Gaseous Organic Concentrations using a Flame Ionization Analyzer	EPA RM 25A
PARTICULATE EMISSIONS MEASUREMENT		
Particulate Matter (PM)	Determination of Particulate Emissions from Stationary Sources	EPA RM 5
Condensible Particulate Matter	Determination of Condensible Particulate Emissions from Stationary Sources	EPA RM 202
POLYNUCLEAR AROMATIC HYDROCARBON EMISSIONS & SEMI-VOLATILE EMISSIONS MEASUREMENT		
PAHs (Semi-volatiles), Chlorobenzenes, and Chlorophenols	Collection of Semivolatile Principal Organic Hazardous Compounds (POHCs) from Incineration Systems	EPA Method SW-846/0010, SW-846/8270, CARB 429
HEAVY METAL EMISSIONS MEASUREMENT		
Heavy Metals	Determination of Metals Emissions in Exhaust Gases from Hazardous Waste Incineration and Similar Combustion Processes	Draft EPA RM 29

CTRL1 = 85/100 PEN AC, 30% RAP ✠ **CTRL2** = No RBR, No RAP ✠ **CTRL3** = No RBR, 20% RAP
RBR1 = RBR-WET, No RAP ✠ **RBR2** = No RBR, 20% Rbr RAP ✠ **RBR3** = RBR-WET, 20% Rbr RAP ✠ **RBR4** = RBR-DRY, No RAP

Table 1. (continued)

Compound	Method/Procedure Name	Designation
FORMALDEHYDE AND ACETONE EMISSIONS MEASUREMENT		
Formaldehyde (CHCO), Acetone	Determination of Aldehyde and Ketone Emissions from Stationary Sources	EPA Draft Method 0011
VOLATILE ORGANIC EMISSIONS MEASUREMENT		
Benzene, Toluene, Ethyl-benzene, Xylene, Styrene, Chlorobenzene	Collection of Volatile Principal Organic Hazardous Constituents (POHCs)	EPA Method SW-846/0030, SW-846/8240
METHANE AND 1,3-BUTADIENE EMISSIONS MEASUREMENT		
Methane and 1,3-Butadiene	Measurement of Gaseous Organic Compound Emissions by Gas Chromatography	EPA RM 18

TABLE 2. CONTINUOUS EMISSIONS MEASUREMENTS RESULTS and METHOD 18 RESULTS (Units: PPM)

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	351	352	357	350	361	345
Dry Aggregate Rate (TPH)	234	330	245	333	267	277	320
Asphalt Cement Added (%)	4.26%	5.75%	4.78%	6.84%	4.67%	5.12%	7.50%
RAP Content (%)	28.50%		25.67%		19.00%	18.17%	
Mat'ls Moisture Content (%, dry)	5.35%	4.17%	5.25%	5.21%	4.79%	5.61%	3.94%
Fuel Consumption (gal/hr)	677	655	657	690	666	757	619
Exhaust Gas Temperature (F)	311	311	312	324	314	333	331
Mix Temperature (F)	284	296	289	316	296	308	310
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SCF)	45.289	46.501	42.799	42.823	41.668	43.937	39.912
Sample Volume (cu. m)	1.282	1.317	1.212	1.213	1.180	1.244	1.130
Exhaust Gas Moisture (%)	30.40%	27.0%	30.8%	29.3%	29.5%	31.8%	24.2%
Stack Temperature (F)	262	260	256	271	247	276	265
Actual Exhaust Gas Flow (ACFM)	88,946	89,540	85,706	95,450	88,001	95,427	82,772
Dry Exhaust Gas Flow (DSCFM)	44,447	47,076	42,874	47,836	45,267	45,638	44,385
Dry Exhaust Gas Flow (DSCMM)	1,259	1,333	1,214	1,355	1,282	1,292	1,257
CO2, %, Orsat Result	6.45%	5.79%	6.07%	6.02%	6.05%	6.62%	6.27%
O2, %, Orsat Result	11.97%	12.75%	12.42%	12.10%	12.40%	11.97%	12.27%
N2, %, Orsat Result	81.58%	81.46%	81.52%	81.88%	81.55%	81.42%	81.47%
CARBON DIOXIDE AND OXYGEN RESULTS (average of all runs for each mix).							
Carbon Dioxide (CO2)	6.84%	6.00%	6.77%	6.48%	6.65%	7.17%	6.23%
Oxygen (O2)	11.68%	12.87%	11.84%	12.18%	11.96%	11.34%	12.66%
CO, NOx, SO2, and NMTHC RESULTS, corrected PPM (average of all runs for each mix).							
Carbon Monoxide (CO)	339.1	369.7	434.7	222.8	291.5	140.0	529.6
Nitrogen Oxides (NOx)	81.4	72.8	81.8	65.0	69.2	74.7	58.5
Sulfur Dioxide (SO2)	58.5	27.9	63.5	28.8	45.9	65.9	71.2
NMTHC as Carbon	324.0	338.0	535.3	274.4	309.2	106.4	666.9
METHANE RESULTS --- Method 18 (average of all runs for each mix).							
Methane (CH4) as measured	24.0	41.5	50.0	15.9	34.7	14.7	41.5
Methane as Carbon	17.9	31.0	37.4	11.9	26.0	11.0	31.1
NON-METHANE HYDROCARBON CALCULATIONS (average of all runs for each mix).							
Total Hydrocarbons (THC) as Carbon	338.5	367.5	562.3	286.8	335.1	111.7	704.9
Methane as % of THC	4.30%	8.01%	4.79%	4.53%	7.71%	5.12%	5.29%
1,3-BUTADIENE RESULTS --- Method 18 (average of all runs for each mix).							
1,3-Butadiene		5.0	0.9				

NOTES:

1 >> NMTHC = Non-methane Total Hydrocarbons.

2 >> The Sample Volume, Exhaust Gas Moisture, Stack Temperature, and Actual Exhaust Gas Flow have been averaged between the two sample trains that were operated during the CEM operations. Except for Condition A--Mix Runs 1, 2, and 3 are from the Particulate/Condensible train, and Mix Runs 4, 5, and 6 are from the PAHs train. Based on how the sample trains were operated, the Metals and Particulate/-Condesibles trains are averaged together and the PAHs and Formaldehyde trains are averaged together.

3 >> Shaded columns identify those mixes that DO NOT contain RAP.

4 >> No results for a compound, indicated by a blank space, are because analytical procedures were not available for the compound.

TABLE 3. CONTINUOUS EMISSIONS MEASUREMENTS RESULTS and METHOD 18 RESULTS (Units: lbs per hour)

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	351	352	357	350	361	345
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RAP Content (%)	28.50%		25.67%		19.00%	18.17%	
Mat'ls Moisture Content (%, dry)	5.35%	4.17%	5.25%	5.21%	4.79%	5.61%	3.94%
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Exhaust Gas Temperature (F)	311	311	312	324	314	333	331
Mix Temperature (F)	284	296	289	316	296	308	310
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SCF)	45,289	46,501	42,799	42,823	41,668	43,937	39,912
Sample Volume (cu. m)	1.282	1.317	1.212	1.213	1.180	1.244	1.130
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Dry Exhaust Gas Flow (DSCFM)	44,447	47,076	42,874	47,836	45,267	45,638	44,385
Dry Exhaust Gas Flow (DSCMM)	1,259	1,333	1,214	1,355	1,282	1,292	1,257
CO2, %, Orsat Result	6.45%	5.79%	6.07%	6.02%	6.05%	6.62%	6.27%
O2, %, Orsat Result	11.97%	12.75%	12.42%	12.10%	12.40%	11.97%	12.27%
N2, %, Orsat Result	81.58%	81.46%	81.52%	81.88%	81.55%	81.42%	81.47%
CARBON DIOXIDE AND OXYGEN RESULTS (average of all runs for each mix).							
Carbon Dioxide (CO2)	6.84%	6.00%	6.77%	6.48%	6.65%	7.17%	6.23%
Oxygen (O2)	11.68%	12.87%	11.84%	12.18%	11.96%	11.34%	12.66%
CO, NOx, SO2, and NMTHC RESULTS, corrected PPM (average of all runs for each mix).							
Carbon Monoxide (CO)	66.1	75.9	81.5	46.1	57.5	27.9	102.5
Nitrogen Oxides (NOx)	25.9	24.6	25.1	22.3	22.4	24.4	18.6
Sulfur Dioxide (SO2)	25.9	13.1	27.2	13.8	20.7	30.1	31.5
NMTHC as Carbon	36.3	41.7	57.4	33.3	35.2	12.1	74.0
METHANE RESULTS --- Method 18 (average of all runs for each mix).							
Methane (CH4) as measured	2.7	4.9	5.4	1.9	3.8	1.7	4.6
Methane as Carbon	2.0	3.7	4.0	1.4	2.9	1.2	3.4
NON-METHANE HYDROCARBON CALCULATIONS (average of all runs for each mix).							
Total Hydrocarbons (THC) as CH4	37.9	43.4	60.3	34.8	38.1	25.4	78.2
NMTHC as Carbon	36.3	39.9	57.4	33.3	35.2	24.2	74.0
1,3-BUTADIENE RESULTS -- Method 18 (average of all runs for each mix).							
1,3-Butadiene		1.980	0.324				

NOTES:

1 >> NMTHC = Non-methane Total Hydrocarbons.

2 >> The Sample Volume, Exhaust Gas Moisture, Stack Temperature, and Actual Exhaust Gas Flow have been averaged between the two sample trains that were operated during the CEM operations. Except for Condition A--Mix Runs 1, 2, and 3 are from the Particulate/Condensible train, and Mix Runs 4, 5, and 6 are from the PAHs train. Based on how the sample trains were operated, the Metals and Particulate/-Condesibles trains are averaged together and the PAHs and Formaldehyde trains are averaged together.

3 >> Shaded columns identify those mixes that DO NOT contain RAP.

4 >> No results for a compound, indicated by a blank space, are because analytical procedures were not available for the compound.

TABLE 4. CONTINUOUS EMISSIONS MEASUREMENTS and METHOD 18 RESULTS (Units: mg/m^3)

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	351	352	357	350	361	345
Dry Aggregate Rate (TPH)	234	330	245	333	267	277	320
Asphalt Cement Added (%)	4.26%	5.75%	4.78%	6.84%	4.67%	5.12%	7.50%
RAP Content (%)	28.50%		25.67%		19.00%	18.17%	
Mat'ls Moisture Content (%, dry)	5.35%	4.17%	5.25%	5.21%	4.79%	5.61%	3.94%
Fuel Consumption (gal/hr)	677	655	657	690	666	757	619
Exhaust Gas Temperature (F)	311	311	312	324	314	333	331
Mix Temperature (F)	284	296	289	316	296	308	310
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SCF)	45	46.501	42.799	42.823	41.668	43.937	39.912
Sample Volume (cu. m)	1	1.317	1.212	1.213	1.180	1.244	1.130
Exhaust Gas Moisture (%)	30.40%	27.0%	30.8%	29.3%	29.5%	31.8%	24.2%
Stack Temperature (F)	262	260	256	271	247	276	265
Actual Exhaust Gas Flow (ACFM)	88,946	89,540	85,706	95,450	88,001	95,427	82,772
Dry Exhaust Gas Flow (DSCFM)	44,447	47,076	42,874	47,836	45,267	45,638	44,385
Dry Exhaust Gas Flow (DSCMM)	1,259	1,333	1,214	1,355	1,282	1,292	1,257
CO2, %, Orsat Result	6.45%	5.79%	6.07%	6.02%	6.05%	6.62%	6.27%
O2, %, Orsat Result	11.97%	12.75%	12.42%	12.10%	12.40%	11.97%	12.27%
N2, %, Orsat Result	81.58%	81.46%	81.52%	81.88%	81.55%	81.42%	81.47%
CARBON DIOXIDE AND OXYGEN RESULTS (average of all runs for each mix).							
Carbon Dioxide (CO2)	6.84%	6.00%	6.77%	6.48%	6.65%	7.17%	6.23%
Oxygen (O2)	11.68%	12.87%	11.84%	12.18%	11.96%	11.34%	12.66%
CO, NOx, SO2, and NMTHC RESULTS, corrected PPM (average of all runs for each mix).							
Carbon Monoxide (CO)	394.8	430.5	506.1	259.5	339.4	163.0	616.7
Nitrogen Oxides (NOx)	155.7	139.3	156.4	124.4	132.3	142.8	111.8
Sulfur Dioxide (SO2)	155.7	74.4	169.1	76.7	122.3	175.6	189.6
NMTHC as Carbon	216.1	225.5	357.0	183.0	206.2	71.0	444.8
METHANE RESULTS --- Method 18 (average of all runs for each mix).							
Methane (CH4) as measured	16.0	27.7	33.3	10.6	23.2	9.8	27.7
Methane as Carbon	12.0	20.7	24.9	7.9	17.3	7.4	20.7
NON-METHANE HYDROCARBON CALCULATIONS (average of all runs for each mix).							
Total Hydrocarbons (THC) as Carbon	225.7	245.1	375.0	191.3	223.5	149.0	470.1
NMTHC as Carbon	216.1	225.5	357.0	183.0	206.2	141.9	444.8
1,3-BUTADIENE RESULTS --- Method 18 (average of all runs for each mix).							
1,3-Butadiene		11.24	2.03				

NOTES:

1 >> NMTHC = Non-methane Total Hydrocarbons.

2 >> The Sample Volume, Exhaust Gas Moisture, Stack Temperature, and Actual Exhaust Gas Flow have been averaged between the two sample trains that were operated during the CEM operations. Except for Condition A--Mix Runs 1, 2, and 3 are from the Particulate/Condensible train, and Mix Runs 4, 5, and 6 are from the PAHs train. Based on how the sample trains were operated, the Metals and Particulate/-Condesibles trains are averaged together and the PAHs and Formaldehyde trains are averaged together.

3 >> Shaded columns identify those mixes that DO NOT contain RAP.

4 >> No results for a compound, indicated by a blank space, are because analytical procedures were not available for the compound.

TABLE 5. PARTICULATE and CONDENSIBLES MEASUREMENTS RESULTS (Units: all units)

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix).							
HMA Production Rate (TPH)	339	345	349	358	348	361	343
Dry Aggregate Rate (TPH)	225	324	221	333	266	275	317
Asphalt Cement Added (%)	4.54%	5.97%	4.62%	7.00%	4.41%	5.47%	7.51%
RAP Content (%)	29.00%		32.00%		19.00%	18.33%	
Mat'ls Moisture Content (%, dry)	4.86%	4.39%	4.72%	5.30%	4.77%	5.71%	3.81%
Fuel Consumption (gal/hr)	644	634	629	685	658	768	641
Exhaust Gas Temperature (F)	311	310	312	329	311	332	332
Mix Temperature (F)	285	294	287	321	293	307	308
STACK CONDITIONS (average of all runs for each mix).							
Sample Volume (SCF)	49.497	48.562	46.717	44.817	44.176	45.851	42.307
Sample Volume (cu. m)	1.402	1.375	1.323	1.269	1.251	1.298	1.198
Exhaust Gas Moisture (%)	28.1%	25.3%	29.3%	27.7%	28.7%	31.7%	23.8%
Stack Temperature (F)	258	259	248	274	257	269	262
Actual Exhaust Gas Flow (ACFM)	87,151	90,233	84,176	95,799	87,444	95,570	82,678
Dry Exhaust Gas Flow (DSCFM)	45,335	48,731	43,569	49,051	44,892	45,913	44,747
Dry Exhaust Gas Flow (DSCMM)	1,284	1,380	1,234	1,389	1,271	1,300	1,267
CO2, %	6.20%	5.90%	5.89%	6.00%	5.96%	6.60%	6.03%
O2, %	11.97%	12.63%	12.84%	12.07%	12.34%	12.03%	12.17%
N2, %	81.83%	81.47%	81.27%	81.93%	81.70%	81.37%	81.80%
Average PARTICULATE/CONDENSIBLES RESULTS			**<<< grains/SCFD >>>**				
Particulate (front-half catch)	0.0029	0.0029	0.0018	0.0058	0.0030	0.00832	0.0055
Condensibles (back-half catch)	0.0412	0.0297	0.0480	0.0199	0.0422	0.04779	0.0634
Average PARTICULATE/CONDENSIBLES RESULTS			**<<< mg/m3 >>>**				
Particulate (front-half catch)	2.00	6.69	3.77	13.28	6.76	19.03	12.65
Condensibles (back-half catch)	94.2	68.0	104.1	45.6	96.7	109.4	145.0
Average PARTICULATE/CONDENSIBLES RESULTS			**<<< lbs/hour >>>**				
Particulate (front-half catch)	1.11	1.22	0.66	2.44	1.14	3.27	2.12
Condensibles (back-half catch)	16.0	12.4	17.9	8.4	16.3	18.8	24.3
Average PARTICULATE/CONDENSIBLES RESULTS			**<<< lb/ton HMA >>>**				
Particulate (front-half catch)	0.0033	0.0035	0.0019	0.0068	0.0033	0.00907	0.0062
Condensibles (back-half catch)	0.0470	0.0359	0.0514	0.0234	0.0468	0.05213	0.0709

NOTE:

>> Shaded columns identify those mixes that DO NOT contain RAP.

TABLE 6. HEAVY METALS MEASUREMENTS RESULTS (Units: lb/hr & mg/m^3)

Mix Type >>	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix).						
HMA Production Rate (TPH)	345	349	358	348	361	343
Dry Aggregate Rate (TPH)	324	221	333	266	275	317
Asphalt Cement Added (%)	5.97%	4.62%	7.00%	4.41%	5.47%	7.51%
RAP Content (%)	0.00%	32.00%	0.00%	19.00%	18.33%	0.00%
Mat'ls Moisture Content (%, dry)	4.39%	4.72%	5.30%	4.77%	5.71%	3.81%
Fuel Consumption (gal/hr)	634	629	685	658	768	641
Exhaust Gas Temperature (F)	310	312	329	311	332	332
Mix Temperature (F)	294	287	321	293	307	308
STACK CONDITIONS (average of all runs for each mix).						
Sample Volume (SCF)	46.207	44.589	41.452	41.601	43.442	39.509
Sample Volume (cu. m)	1.308	1.263	1.174	1.178	1.230	1.119
Exhaust Gas Moisture (%)	26.6%	30.4%	29.5%	30.3%	33.4%	25.7%
Stack Temperature (F)	260	251	275	246	271	264
Actual Exhaust Gas Flow (ACFM)	87,103	82,910	93,276	84,435	94,550	83,004
Dry Exhaust Gas Flow (DSCFM)	46,082	42,089	46,402	43,057	44,200	43,702
Dry Exhaust Gas Flow (DSCMM)	1,305	1,192	1,314	1,219	1,252	1,238
CO2, %	5.90%	5.90%	6.00%	5.97%	6.60%	6.03%
O2, %	12.64%	12.83%	12.07%	12.33%	12.03%	12.17%
N2, %	81.46%	81.27%	81.93%	81.70%	81.37%	81.80%

METALS RESULTS (average of all runs for each mix).			lbs/hr			
Arsenic	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Barium	0.00481	0.00336	0.00105	0.00202	0.00154	0.00147
Cadmium	0.00017	0.00009	0.00009	0.00014	0.00016	0.00014
Chromium	0.00080	0.00029	0.00042	0.00052	0.00037	0.00035
Lead	0.00026	0.00014	0.00020	0.00014	0.00018	0.00020
Mercury	0.00119	0.00045	0.00053	0.00040	0.00051	0.00043
Nickel	0.00056	0.00033	0.00041	0.00033	0.00030	0.00033
Selenium	0.00013	0.00012	0.00015	0.00014	0.00014	0.00015
Silver	0.00008	0.00005	0.00006	0.00010	0.00014	0.00006
Zinc	0.00308	0.00201	0.00208	0.00337	0.00246	0.00288

METALS RESULTS (average of all runs for each mix).			mg/cu. meter			
Arsenic	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Barium	0.00481	0.00336	0.00105	0.00202	0.00154	0.00147
Cadmium	0.00017	0.00009	0.00009	0.00014	0.00016	0.00014
Chromium	0.00080	0.00029	0.00042	0.00052	0.00037	0.00035
Lead	0.00026	0.00014	0.00020	0.00014	0.00018	0.00020
Mercury	0.00119	0.00045	0.00053	0.00040	0.00051	0.00043
Nickel	0.00056	0.00033	0.00041	0.00033	0.00030	0.00033
Selenium	0.00013	0.00012	0.00015	0.00014	0.00014	0.00015
Silver	0.00008	0.00005	0.00006	0.00010	0.00014	0.00006
Zinc	0.00308	0.00201	0.00208	0.00337	0.00246	0.00288

NOTES:

1 >> Shaded columns identify those mixes that DO NOT contain RAP.

2 >> The horizontal lines in the list of compounds have no other significance than to help read numbers across the page.

TABLE 7. RESULTS OF METALS ANALYSIS OF FUEL OIL AND PROCESS MATERIALS (Units: lb/hr)

METALS INTO THE PROCESS

FUEL METALS INTO THE PROCESS	lbs/hr					
	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
Arsenic						
Barium	0.060	0.023	0.105	0.068	0.214	0.160
Cadmium						
Chromium						
Lead						
Mercury						
Nickel						
Selenium						
Silver						
Zinc	1.25	0.60	1.10	1.21	1.58	0.99

AGGREGATE METALS INTO THE PROCESS	lbs/hr					
	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
Arsenic	2.53	1.86	2.26	1.97	1.93	1.59
Barium	7.13	4.43	6.66	4.79	5.51	6.34
Cadmium						
Chromium	5.19	3.10	4.66	3.72	3.85	3.81
Lead						
Mercury						
Nickel	5.19	3.54	4.66	3.19	3.30	3.81
Selenium						
Silver						
Zinc	16.85	9.29	12.65	13.83	25.88	10.15

RAP METALS INTO THE PROCESS	lbs/hr					
	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
Arsenic		1.24		0.98	0.43	
Barium		5.07		2.51	2.47	
Cadmium						
Chromium		2.09		1.24	1.14	
Lead		4.55		1.37	2.46	
Mercury						
Nickel		2.61		1.50	1.63	
Selenium						
Silver						
Zinc		9.17		12.70	13.17	

NOTES:

1 >> Shaded columns identify those mixes that DO NOT contain RAP.

TABLE 8. ALL METALS INTO PROCESS and METALS OUT OF PROCESS (Units: lb/hr)

TOTAL METALS INTO THE PROCESS					lbs/hr	
	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
Arsenic	2.53	3.10	2.26	2.95	2.36	1.59
Barium	7.19	9.52	6.76	7.37	8.19	6.50
Cadmium						
Chromium	5.19	5.18	4.66	4.96	5.00	3.81
Lead		4.55		1.37	2.46	
Mercury						
Nickel	5.19	6.15	4.66	4.69	4.93	3.81
Selenium						
Silver						
Zinc	16.11	19.06	13.76	27.74	40.62	11.14

METALS OUT WITH BAGHOUSE HOPPER DUST					lbs/hr	
	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
Arsenic	0.0574	0.0056	0.0149	0.0237	0.0192	0.0032
Barium	0.0721	0.0389	0.1428	0.0783	0.1946	0.1101
Cadmium						
Chromium	0.0220	0.0130	0.0458	0.0226	0.0609	0.0360
Lead	0.0440	0.0303	0.0901	0.0487	0.1340	0.0445
Mercury	0.0001	0.0001		0.0001		
Nickel	0.0391	0.0192	0.0726	0.0356	0.0866	0.0402
Selenium				0.0006		
Silver	0.0024	0.0013	0.0049	0.0023	0.0065	0.0042
Zinc	0.2078	0.1411	0.3602	0.2066	0.6111	0.2965

METALS OUT OF THE STACK					lbs/hr	
	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
Arsenic						
Barium	0.0048	0.0034	0.0011	0.0020	0.0015	0.0015
Cadmium	0.0002	0.0001	0.0001	0.0001	0.0002	0.0001
Chromium	0.0008	0.0003	0.0004	0.0005	0.0004	0.0003
Lead	0.0003	0.0001	0.0002	0.0001	0.0002	0.0002
Mercury	0.0012	0.0004	0.0005	0.0004	0.0005	0.0004
Nickel	0.0006	0.0003	0.0004	0.0003	0.0003	0.0003
Selenium	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Silver	0.0001	0.0000	0.0001	0.0001	0.0001	0.0001
Zinc	0.0031	0.0020	0.0021	0.0034	0.0025	0.0029

NOTES:

1 >> Shaded columns identify those mixes that DO NOT contain RAP.

TABLE 9. PERCENTAGES OF METALS LEAVING PROCESS, IN THE MIX and IN THE EXHAUST GAS (Units: lb/hr)

PERCENT (%) OF METALS LEAVING IN THE MIX

	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
Arsenic	97.8%	99.8%	99.3%	99.2%	99.2%	99.8%
Banum	98.9%	99.6%	97.9%	98.9%	97.7%	98.3%
Cadmium						
Chromium	99.6%	99.7%	99.0%	99.5%	98.8%	99.1%
Lead		99.3%		96.6%	94.8%	
Mercury						
Nickel	99.2%	99.7%	98.5%	99.2%	98.3%	98.9%
Selenium						
Silver						
Zinc	98.8%	99.3%	97.4%	99.2%	98.5%	97.4%

PERCENT (%) OF METALS LEAVING IN THE EXHAUST GAS

	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
Arsenic						
Banum	0.066%	0.035%	0.015%	0.027%	0.018%	0.022%
Cadmium						
Chromium	0.015%	0.006%	0.009%	0.010%	0.007%	0.009%
Lead		0.003%		0.010%	0.007%	
Mercury						
Nickel	0.011%	0.005%	0.009%	0.007%	0.006%	0.009%
Selenium						
Silver						
Zinc	0.017%	0.010%	0.015%	0.012%	0.006%	0.025%

NOTES:

1 >> Shaded columns identify those mixes that DO NOT contain RAP.

TABLE 10. FORMALDEHYDE AND ACETONE MEASUREMENTS RESULTS (Units: all units)

Mix Type >>	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix).						
HMA Production Rate (TPH)	357	355	357	353	361	348
Dry Aggregate Rate (TPH)	337	269	333	269	278	322
Asphalt Cement Added (%)	5.58%	4.93%	6.67%	4.93%	4.77%	7.48%
RAP Content (%)		19.33%		19.00%	18.00%	
Mat'ls Moisture Content (%, dry)	4.80%	5.78%	5.11%	4.80%	5.51%	4.07%
Fuel Consumption (gal/hr)	674	685	696	674	745	597
Exhaust Gas Temperature (F)	311	311	319	317	334	329
Mix Temperature (F)	296	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix).						
Sample Volume (SCF)	46.396	37.064	38.017	39.219	42.595	36.588
Sample Volume (cu. m)	1.314	1.050	1.077	1.111	1.206	1.036
Exhaust Gas Moisture (%)	27.4%	31.1%	29.8%	28.8%	30.5%	24.0%
Stack Temperature (F)	261	263	267	257	281	266
Actual Exhaust Gas Flow (ACFM)	91,280	88,311	93,214	94,109	96,795	83,387
Dry Exhaust Gas Flow (DSCFM)	47,684	43,490	46,515	48,121	47,062	44,784
Dry Exhaust Gas Flow (DSCMM)	1,350	1,231	1,317	1,363	1,333	1,268
CO2, %	5.67%	6.23%	6.03%	6.14%	6.63%	6.50%
O2, %	12.97%	12.00%	12.13%	12.48%	11.90%	12.37%
N2, %	81.36%	81.77%	81.83%	81.38%	81.47%	81.13%

Average FORMALDEHYDE RESULTS (for each mix)			lbs/hr			
Formaldehyde	2.5	2.3	1.2	2.0	0.79	4.1
Acetone	ND	ND	ND	ND	ND	ND

Average FORMALDEHYDE RESULTS (for each mix)			PPM			
Formaldehyde	11.4	11.3	5.5	8.9	3.6	19.4
Acetone	ND	ND	ND	ND	ND	ND

Average FORMALDEHYDE RESULTS (for each mix)			mg/m3			
Formaldehyde	14.2	14.1	6.9	11.1	4.5	24.3
Acetone	ND	ND	ND	ND	ND	ND

Formaldehyde Emission Factor – HOT MIX ASPHALT			lbs/ton HMA			
Formaldehyde	0.0071	0.0065	0.0034	0.0057	0.0022	0.0117
Acetone	ND	ND	ND	ND	ND	ND

Formaldehyde Emission Factor – FUEL OIL			lb/gal Fuel Oil			
Formaldehyde	0.0038	0.0034	0.0017	0.0030	0.0011	0.0068
Acetone	ND	ND	ND	ND	ND	ND

NOTES:
1 >> Shaded columns identify those mixes that DO NOT contain RAP.

TABLE 11. VOLATILE ORGANIC MEASUREMENTS RESULTS FOR BTEX, STYRENE, MIBK, AND CHLOROBENZENE (Units: lb/hr)

Mix Type>>>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	348	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	236	337	269	333	269	278	322
Asphalt Cement Added (%)	3.97%	5.49%	4.93%	6.67%	4.92%	4.77%	7.48%
RAP Content (%)	28.33%		19.33%		19.00%	18.00%	
Mat'ls Moisture Content (%, dry)	5.42%	3.09%	5.78%	5.11%	4.81%	5.51%	4.08%
Fuel Consumption (gal/hr)	672	680	685	696	674	745	597
Exhaust Gas Temperature (F)	312	312	311	319	317	334	329
Mix Temperature (F)	284	298	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SL)	4.726	5.119	5.820	4.643	4.286	5.144	4.487
Sample Volume (cu. m)	0.005	0.005	0.006	0.005	0.004	0.005	0.004
Exhaust Gas Moisture (%)	32.73%	28.13%	30.65%	30.03%	29.43%	31.05%	23.70%
Stack Temperature (F)	266	260	262	267	243	282	267
Actual Exhaust Gas Flow (ACFM)	90,740	90,412	87,870	96,362	90,063	95,794	82,703
Dry Exhaust Gas Flow (DSCFM)	43,559	46,745	42,920	47,946	46,560	46,221	44,545
Dry Exhaust Gas Flow (DSCMM)	1,233	1,324	1,215	1,358	1,318	1,309	1,261
CO2, %	6.70%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2, %	11.97%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81.33%	81.53%	81.77%	81.83%	81.40%	81.47%	81.13%

VOC RESULTS (for each mix)	*("Not-Detected" Compounds have been set equal to their reported Detection Limit.)*						
Benzene	0.182	0.316	0.253	0.222	0.384	0.299	0.499
Toluene	0.119	0.286	0.203	0.142	0.270	0.153	0.310
Ethylbenzene	0.012	0.034	0.026	0.023	0.038	0.050	0.062
m-/p-Xylene	0.047	0.122	0.091	0.155	0.143	0.264	0.168
o-Xylene	0.038	0.044	0.089	0.025	0.062	0.046	0.079
Styrene	0.030	0.067	0.056	0.033	0.199	0.151	0.207
4-Methyl-2-pentanone (MIBK)	0.044	0.001	0.001	0.173	0.002	0.664	0.534
Chlorobenzene	0.001	0.0005	0.0004	0.001	0.014	0.003	0.018

VOC RESULTS (for each mix)	*("Not-Detected" Compounds have been set equal to Zero.)*						
Benzene	0.181	0.316	0.254	0.223	0.383	0.298	0.499
Toluene	0.118	0.286	0.204	0.142	0.270	0.153	0.310
Ethylbenzene	0.012	0.034	0.026	0.023	0.038	0.050	0.062
m-/p-Xylene	0.046	0.123	0.091	0.155	0.143	0.264	0.168
o-Xylene	0.038	0.044	0.090	0.025	0.062	0.046	0.079
Styrene	0.030	0.067	0.056	0.032	0.199	0.151	0.207
4-Methyl-2-pentanone (MIBK)	0.043			0.179		0.664	0.534
Chlorobenzene	0.0002				0.015	0.003	0.018

NOTES:

1 >> Shaded columns identify those mixes that DO NOT contain RAP.

TABLE 12. VOLATILE ORGANIC MEASUREMENTS RESULTS FOR BTEX, STYRENE, MIBK, AND CHLOROBENZENE (Units: mg/m^3)

Mix Type>>>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	348	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	236	337	269	333	269	278	322
Asphalt Cement Added (%)	3.97%	5.49%	4.93%	6.67%	4.92%	4.77%	7.48%
RAP Content (%)	28.33%		19.33%		19.00%	18.00%	
Mat'ls Moisture Content (%, dry)	5.42%	3.09%	5.78%	5.11%	4.81%	5.51%	4.08%
Fuel Consumption (gal/hr)	672	680	685	696	674	745	597
Exhaust Gas Temperature (F)	312	312	311	319	317	334	329
Mix Temperature (F)	284	298	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SL)	4.726	5.119	5.820	4.643	4.286	5.144	4.487
Sample Volume (cu. m)	0.005	0.005	0.006	0.005	0.004	0.005	0.004
Exhaust Gas Moisture (%)	32.73%	28.13%	30.65%	30.03%	29.43%	31.05%	23.70%
Stack Temperature (F)	266	260	262	267	243	282	267
Actual Exhaust Gas Flow (ACFM)	90,740	90,412	87,870	96,362	90,063	95,794	82,703
Dry Exhaust Gas Flow (DSCFM)	43,559	46,745	42,920	47,946	46,560	46,221	44,545
Dry Exhaust Gas Flow (DSCMM)	1,233	1,324	1,215	1,358	1,318	1,309	1,261
CO2, %	6.70%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2, %	11.97%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81.33%	81.53%	81.77%	81.83%	81.40%	81.47%	81.13%

VOC RESULTS (for each mix)	*("Not-Detected" Compounds have been set equal to their reported Detection Limit.)*						
Benzene	1.116	1.803	1.575	1.237	0.384	1.726	2.992
Toluene	0.727	1.635	1.266	0.789	0.270	0.884	1.857
Ethylbenzene	0.073	0.192	0.159	0.130	0.038	0.291	0.369
m-/p-Xylene	0.286	0.699	0.568	0.862	0.143	1.527	1.006
o-Xylene	0.234	0.249	0.556	0.141	0.062	0.265	0.471
Styrene	0.183	0.384	0.350	0.181	0.199	0.874	1.243
4-Methyl-2-pentanone (MIBK)	0.269	0.006	0.006	0.963	0.002	3.837	3.201
Chlorobenzene	0.003	0.0027	0.0025	0.003	0.014	0.019	0.109

VOC RESULTS (for each mix)	*("Not-Detected" Compounds have been set equal to Zero.)*						
Benzene	1.116	1.803	1.575	1.237	2.202	1.726	2.992
Toluene	0.727	1.635	1.266	0.789	1.549	0.884	1.857
Ethylbenzene	0.073	0.192	0.159	0.130	0.218	0.291	0.369
m-/p-Xylene	0.286	0.699	0.568	0.862	0.818	1.527	1.006
o-Xylene	0.234	0.249	0.556	0.141	0.353	0.265	0.471
Styrene	0.183	0.384	0.350	0.181	1.140	0.874	1.243
4-Methyl-2-pentanone (MIBK)	0.264			0.963		3.837	3.201
Chlorobenzene	0.0014				0.078	0.017	0.109

NOTES:

1 >> Shaded columns identify those mixes that DO NOT contain RAP.

TABLE 13. VOLATILE ORGANIC MEASUREMENTS RESULTS FOR BTEX, STYRENE, MIBK, AND CHLOROBENZENE (Units: PPM)

Mix Type>>>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	348	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	236	337	269	333	269	278	322
Asphalt Cement Added (%)	3.97%	5.49%	4.93%	6.67%	4.92%	4.77%	7.48%
RAP Content (%)	28.33%		19.33%		19.00%	18.00%	
Mat'ls Moisture Content (%, dry)	5.42%	3.09%	5.78%	5.11%	4.81%	5.51%	4.08%
Fuel Consumption (gal/hr)	672	680	685	696	674	745	597
Exhaust Gas Temperature (F)	312	312	311	319	317	334	329
Mix Temperature (F)	284	298	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SL)	4.726	5.119	5.820	4.643	4.286	5.144	4.487
Sample Volume (cu. m)	0.005	0.005	0.006	0.005	0.004	0.005	0.004
Exhaust Gas Moisture (%)	32.73%	28.13%	30.65%	30.03%	29.43%	31.05%	23.70%
Stack Temperature (F)	266	260	262	267	243	282	267
Actual Exhaust Gas Flow (ACFM)	90,740	90,412	87,870	96,362	90,063	95,794	82,703
Dry Exhaust Gas Flow (DSCFM)	43,559	46,745	42,920	47,946	46,560	46,221	44,545
Dry Exhaust Gas Flow (DSCMM)	1,233	1,324	1,215	1,358	1,318	1,309	1,261
CO2, %	6.70%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2, %	11.97%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81.33%	81.53%	81.77%	81.83%	81.40%	81.47%	81.13%

VOC RESULTS (for each mix)	*("Not-Detected" Compounds have been set equal to their reported Detection Limit.)*						
Benzene	0.344	0.555	0.485	0.381	0.678	0.531	0.921
Toluene	0.190	0.427	0.330	0.206	0.404	0.231	0.485
Ethylbenzene	0.016	0.043	0.036	0.029	0.049	0.066	0.084
m-/p-Xylene	0.065	0.159	0.129	0.195	0.185	0.346	0.228
o-Xylene	0.053	0.056	0.126	0.032	0.080	0.060	0.107
Styrene	0.042	0.089	0.081	0.042	0.263	0.202	0.287
4-Methyl-2-pentanone (MIBK)	0.065	0.001	0.002	0.231	0.002	0.922	0.769
Chlorobenzene	0.001	0.0006	0.0005	0.001	0.017	0.004	0.023

VOC RESULTS (for each mix)	*("Not-Detected" Compounds have been set equal to Zero.)*						
Benzene	0.344	0.555	0.485	0.381	0.678	0.531	0.921
Toluene	0.190	0.427	0.330	0.206	0.404	0.231	0.485
Ethylbenzene	0.016	0.043	0.036	0.029	0.049	0.066	0.084
m-/p-Xylene	0.065	0.159	0.129	0.195	0.185	0.346	0.228
o-Xylene	0.053	0.056	0.126	0.032	0.080	0.060	0.107
Styrene	0.042	0.089	0.081	0.042	0.263	0.202	0.287
4-Methyl-2-pentanone (MIBK)	0.063			0.231		0.922	0.769
Chlorobenzene	0.0003				0.017	0.004	0.023

NOTES:

1 >> Shaded columns identify those mixes that DO NOT contain RAP.

CTRL1 = 85/100 PEN AC, 30% RAP ✠ **CTRL2** = No RBR, No RAP ✠ **CTRL3** = No RBR, 20% RAP

RBR1 = RBR-WET, No RAP ✠ **RBR2** = No RBR, 20% Rbr RAP ✠ **RBR3** = RBR-WET, 20% Rbr RAP ✠ **RBR4** = RBR-DRY, No RAP

TABLE 14. PAH EMISSIONS MEASUREMENTS RESULTS, MDNR PAH COMPOUNDS (Units: mg/m^3)

Not-Detected Compounds have been set equal to their reported Detection Limit.

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	235	336	269	333	269	278	322
Asphalt Cement Added (%)	4.20%	5.49%	4.93%	6.67%	4.93%	4.77%	7.48%
RAP Content (%)	28.40%		19.33%		19.00%	18.00%	
Mat'ls Moisture Content (%, dry)	5.47%	4.64%	5.78%	5.11%	4.80%	5.51%	4.07%
Fuel Consumption (gal/hr)	675	669	685	696	674	745	597
Exhaust Gas Temperature (F)	311	312	311	319	317	334	329
Mix Temperature (F)	284	298	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SCF)	42.862	44.841	42.827	47.004	41.676	43.859	41.244
Sample Volume (cu. m)	1.214	1.270	1.213	1.331	1.180	1.242	1.168
Exhaust Gas Moisture (%)	31.5%	28.9%	32.4%	30.3%	30.1%	31.6%	23.4%
Stack Temperature (F)	265	260	261	267	228	282	267
Actual Exhaust Gas Flow (ACFM)	88,513	89,544	87,429	99,509	86,017	94,793	82,020
Dry Exhaust Gas Flow (DSCFM)	43,396	45,805	42,350	49,377	44,998	45,380	44,305
Dry Exhaust Gas Flow (DSCMM)	1,229	1,297	1,199	1,398	1,274	1,285	1,255
CO2, %	6.54%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2, %	11.96%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81.50%	81.53%	81.77%	81.84%	81.40%	81.47%	81.13%
Average PAH RESULTS (for each mix)		*("Not-Detected" Compounds have been set equal to their reported Detection Limit.)*					
Acenaphthene	0.150	0.011	0.138	0.012	0.180	0.190	0.034
Acenaphthylene	0.036	0.013	0.043	0.014	0.060	0.056	0.112
Anthanthrene							
Anthracene	0.077	0.003	0.083	0.002	0.049	0.071	0.014
Benzo(a)anthracene	0.004	0.002	0.004	0.002	0.009	0.007	0.006
Benzo(a)fluorene	0.005	0.001	0.010	0.001	0.005	0.012	0.012
Benzo(a)pyrene	0.003	0.001	0.003	0.002	0.010	0.008	0.005
Benzo(b)fluoranthene	0.003	0.001	0.003	0.002	0.009	0.007	0.004
Benzo(b)fluorene							
Benzo(c)fluorene							
Benzo(e)pyrene	0.004	0.001	0.004	0.003	0.013	0.010	0.006
Benzo(g,h,i)perylene	0.003	0.001	0.003	0.003	0.011	0.008	0.004
Benzo(j)fluoranthene							
Benzo(k)fluoranthene	0.003	0.001	0.003	0.002	0.010	0.007	0.004
Chrysene	0.004	0.003	0.004	0.002	0.010	0.008	0.006
Coronene							
Dibenzo(a,h)anthracene	0.004	0.001	0.004	0.003	0.012	0.009	0.005
Fluoranthene	0.161	0.018	0.177	0.015	0.044	0.053	0.037
Fluorene	0.230	0.030	0.243	0.030	0.120	0.131	0.085
Indeno(1,2,3-cd)pyrene	0.003	0.001	0.003	0.003	0.010	0.007	0.004
Phenanthrene	0.603	0.070	0.655	0.079	0.669	0.808	0.236
Picene							
Pyrene	0.138	0.018	0.153	0.013	0.053	0.088	0.112
Perylene	0.003	0.001	0.003	0.002	0.010	0.008	0.005
Triphenylene							

NOTES:

1 >> Shaded columns identify those mixes that DO NOT contain RAP.

2 >> The horizontal lines in the list of compounds have no other significance than to help read numbers across the page.

3 >> No results for a compound, indicated by a blank space, are because analytical procedures were not available for the compound.

TABLE 15. PAH EMISSIONS MEASUREMENTS RESULTS, MDNR PAH COMPOUNDS (Units: lb/hr)

Not-Detected Compounds have been set equal to their reported Detection Limit.

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	235	336	269	333	269	278	322
Asphalt Cement Added (%)	4.20%	5.49%	4.93%	6.67%	4.93%	4.77%	7.48%
RAP Content, %	28.40%		19.33%		19.00%	18.00%	
Matls Moisture Content (%, dry)	5.47%	4.64%	5.78%	5.11%	4.80%	5.51%	4.07%
Fuel Consumption (gal/hr)	675	669	685	696	674	745	597
Exhaust Gas Temperature (F)	311	312	311	319	317	334	329
Mix Temperature (F)	284	298	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SCF)	42.862	44.841	42.827	47.004	41.676	43.859	41.244
Sample Volume (cu. m)	1.214	1.270	1.213	1.331	1.180	1.242	1.168
Exhaust Gas Moisture (%)	31.5%	28.9%	32.4%	30.3%	30.1%	31.6%	23.4%
Stack Temperature (F)	265	260	261	267	228	282	267
Actual Exhaust Gas Flow (ACFM)	88,513	89,544	87,429	99,509	86,017	94,793	82,020
Dry Exhaust Gas Flow (DSCFM)	43,396	45,805	42,350	49,377	44,998	45,380	44,305
Dry Exhaust Gas Flow (DSCMM)	1,229	1,297	1,199	1,398	1,274	1,285	1,255
CO2, %	6.54%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2, %	11.96%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81.50%	81.53%	81.77%	81.84%	81.40%	81.47%	81.13%
Average PAH RESULTS (for each mix)		*("Not-Detected" Compounds have been set equal to their reported Detection Limit.)*					
Acenaphthene	0.0242	0.0018	0.0219	0.0021	0.0303	0.0324	0.0057
Acenaphthylene	0.0058	0.0022	0.0068	0.0026	0.0101	0.0095	0.0185
Anthanthrene							
Anthracene	0.0125	0.0005	0.0132	0.0003	0.0082	0.0121	0.0023
Benzo(a)anthracene	0.0006	0.0003	0.0007	0.0004	0.0015	0.0013	0.0011
Benzo(a)fluorene	0.0008	0.0002	0.0016	0.0001	0.0009	0.0021	0.0020
Benzo(a)pyrene	0.0005	0.0002	0.0005	0.0005	0.0018	0.0013	0.0008
Benzo(b)fluoranthene	0.0004	0.0002	0.0005	0.0004	0.0016	0.0012	0.0007
Benzo(b)fluorene							
Benzo(c)fluorene							
Benzo(e)pyrene	0.0006	0.0002	0.0007	0.0006	0.0021	0.0016	0.0009
Benzo(g,h,i)perylene	0.0005	0.0002	0.0005	0.0006	0.0018	0.0014	0.0007
Benzo(j)fluoranthene							
Benzo(k)fluoranthene	0.0004	0.0002	0.0005	0.0004	0.0016	0.0013	0.0007
Chrysene	0.0006	0.0005	0.0007	0.0004	0.0017	0.0014	0.0011
Coronene							
Dibenzo(a,h)anthracene	0.0006	0.0002	0.0006	0.0006	0.0021	0.0015	0.0008
Fluoranthene*	0.0259	0.0030	0.0281	0.0025	0.0075	0.0090	0.0061
Fluorene	0.0372	0.0051	0.0386	0.0055	0.0203	0.0223	0.0140
Indeno(1,2,3-cd)pyrene	0.0005	0.0002	0.0005	0.0005	0.0016	0.0012	0.0006
Phenanthrene	0.0975	0.0120	0.1039	0.0141	0.1127	0.1373	0.0390
Picene							
Pyrene	0.0222	0.0030	0.0244	0.0022	0.0089	0.0149	0.0185
Perylene	0.0005	0.0002	0.0005	0.0005	0.0017	0.0013	0.0008
Triphenylene							

NOTES:

1 >> Shaded columns identify those mixes that DO NOT contain RAP.

2 >> The horizontal lines in the list of compounds have no other significance than to help read numbers across the page.

3 >> No results for a compound, indicated by a blank space, are because analytical procedures were not available for the compound.

TABLE 16. PAH EMISSIONS MEASUREMENTS RESULTS, MDNR PAH COMPOUNDS (Units: PPM)

Not-Detected Compounds have been set equal to their reported Detection Limit.

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	235	336	269	333	269	278	322
Asphalt Cement Added (%)	4.20%	5.49%	4.93%	6.67%	4.93%	4.77%	7.48%
RAP Content (%)	28.40%		19.33%		19.00%	18.00%	
Mat'ls Moisture Content (%, dry)	5.47%	4.64%	5.78%	5.11%	4.80%	5.51%	4.07%
Fuel Consumption (gal/hr)	675	669	685	696	674	745	597
Exhaust Gas Temperature (F)	311	312	311	319	317	334	329
Mix Temperature (F)	284	298	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SCF)	42.862	44.841	42.827	47.004	41.676	43.859	41.244
Sample Volume (cu. m)	1.214	1.270	1.213	1.331	1.180	1.242	1.168
Exhaust Gas Moisture (%)	31.5%	28.9%	32.4%	30.3%	30.1%	31.6%	23.4%
Stack Temperature (F)	265	260	261	267	228	282	267
Actual Exhaust Gas Flow (ACFM)	88,513	89,544	87,429	99,509	86,017	94,793	82,020
Dry Exhaust Gas Flow (DSCFM)	43,396	45,805	42,350	49,377	44,998	45,380	44,305
Dry Exhaust Gas Flow (DSCMM)	1,229	1,297	1,199	1,398	1,274	1,285	1,255
CO2, %	6.54%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2, %	11.96%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81.50%	81.53%	81.77%	81.84%	81.40%	81.47%	81.13%
Average PAH RESULTS (for each mix)		*("Not-Detected" Compounds have been set equal to their reported Detection Limit.)*					
Acenaphthene	0.0234	0.0016	0.0215	0.0018	0.0280	0.0297	0.0053
Acenaphthylene	0.0057	0.0020	0.0067	0.0023	0.0095	0.0089	0.0176
Anthanthrene							
Anthracene	0.0104	0.0004	0.0112	0.0002	0.0066	0.0096	0.0019
Benzo(a)anthracene	0.0004	0.0002	0.0004	0.0002	0.0010	0.0008	0.0007
Benzo(a)fluorene	0.0006	0.0001	0.0011	0.0001	0.0006	0.0014	0.0013
Benzo(a)pyrene	0.0003	0.0001	0.0003	0.0002	0.0010	0.0007	0.0004
Benzo(b)fluoranthene	0.0003	0.0001	0.0003	0.0002	0.0009	0.0007	0.0004
Benzo(b)fluorene							
Benzo(c)fluorene							
Benzo(e)pyrene	0.0003	0.0001	0.0004	0.0003	0.0012	0.0009	0.0005
Benzo(g,h,i)perylene	0.0003	0.0001	0.0003	0.0003	0.0009	0.0007	0.0004
Benzo(j)fluoranthene							
Benzo(k)fluoranthene	0.0003	0.0001	0.0003	0.0002	0.0009	0.0007	0.0004
Chrysene	0.0004	0.0003	0.0005	0.0002	0.0011	0.0009	0.0007
Coronene							
Dibenzo(a,h)anthracene	0.0003	0.0001	0.0003	0.0003	0.0011	0.0008	0.0004
Fluoranthene	0.0191	0.0021	0.0210	0.0018	0.0053	0.0063	0.0044
Fluorene	0.0333	0.0043	0.0352	0.0043	0.0174	0.0189	0.0122
Indeno(1,2,3-cd)pyrene	0.0002	0.0001	0.0003	0.0002	0.0008	0.0006	0.0003
Phenanthrene	0.0813	0.0095	0.0883	0.0107	0.0902	0.1090	0.0318
Picene							
Pyrene	0.0164	0.0021	0.0182	0.0015	0.0062	0.0105	0.0133
Perylene	0.0003	0.0001	0.0003	0.0002	0.0010	0.0007	0.0004
Triphenylene							

NOTES:

1 >> Shaded columns identify those mixes that DO NOT contain RAP.

2 >> The horizontal lines in the list of compounds have no other significance than to help read numbers across the page.

3 >> No results for a compound, indicated by a blank space, are because analytical procedures were not available for the compound.

TABLE 17. PAH EMISSIONS MEASUREMENTS RESULTS, INCLUDING CUMENE AND CRESOLS (Units: mg/m^3)

Not-Detected Compounds have been set equal to zero.

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	235	336	269	333	269	278	322
Asphalt Cement Added (%)	4.20%	5.49%	4.93%	6.67%	4.93%	4.77%	7.48%
RAP Content (%)	28.40%		19.33%		19.00%	18.00%	
Mat'ls Moisture Content (%, dry)	5.47%	4.64%	5.78%	5.11%	4.80%	5.51%	4.07%
Fuel Consumption (gal/hr)	675	669	685	696	674	745	597
Exhaust Gas Temperature (F)	311	312	311	319	317	334	329
Mix Temperature (F)	284	298	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SCF)	42.862	44.641	42.827	47.004	41.676	43.859	41.244
Sample Volume (cu. m)	1.214	1.270	1.213	1.331	1.180	1.242	1.168
Exhaust Gas Moisture (%)	31.5%	28.9%	32.4%	30.3%	30.1%	31.6%	23.4%
Stack Temperature (F)	265	260	261	267	228	282	267
Actual Exhaust Gas Flow (ACFM)	88,513	89,544	87,429	99,509	86,017	94,793	82,020
Dry Exhaust Gas Flow (DSCFM)	43,396	45,805	42,350	49,377	44,998	45,380	44,305
Dry Exhaust Gas Flow (DSCMM)	1,229	1,297	1,199	1,398	1,274	1,285	1,255
CO2, %	6.54%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2, %	11.96%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81.50%	81.53%	81.77%	81.84%	81.40%	81.47%	81.13%
Average PAH RESULTS (for each mix)			*("Not-Detected" Compounds have been set equal to Zero.)*				
Acenaphthene	0.150	0.011	0.088	0.012	0.180	0.190	0.034
Acenaphthylene	0.036	0.013	0.032	0.014	0.060	0.056	0.112
Anthracene	0.077	0.002	0.051		0.049	0.071	0.014
Benzo(a)anthracene	0.001	0.001	0.003				0.002
Benzo(a)pyrene							
Benzo(b)fluoranthene							
Benzo(e)pyrene							
Benzo(g,h,i)perylene							
Benzo(k)fluoranthene							
Chrysene	0.001	0.002	0.002				0.002
Dibenzo(a,h)anthracene							
Fluoranthene	0.161	0.018	0.118	0.015	0.044	0.053	0.037
Fluorene	0.230	0.030	0.160	0.030	0.120	0.131	0.085
Indeno(1,2,3-cd)pyrene							
Naphthalene	0.620	0.294	0.519	0.337	0.497	0.419	0.842
Naphthalene, 2-Chloro-							
Naphthalene, 2-Methyl-	0.506	0.339	0.501	0.425	1.769	1.621	0.805
Phenanthrene	0.603	0.070	0.428	0.079	0.669	0.808	0.236
Pyrene	0.138	0.018	0.104	0.013	0.053	0.088	0.112
Average OTHER PAH RESULTS (for each mix)			*("Not-Detected" Compounds have been set equal to Zero.)*				
Cumene	0.028	0.032	0.039	0.037	0.027	0.041	0.057
o-Cresol (2-Methylphenol)	0.036	0.017	0.049	0.007			0.113
m-/p-Cresol (3-/4-Methylphenol)	0.066	0.031	0.100	0.031	0.050	0.049	0.207

NOTES:

1 >> Shaded columns identify those mixes that DO NOT contain RAP.

2 >> The horizontal lines in the list of compounds have no other significance than to help read numbers across the page.

TABLE 18. PAH EMISSIONS MEASUREMENTS RESULTS, INCLUDING CUMENE AND CRESOLS (Units: lb/hr)

Not-Detected Compounds have been set equal to zero.

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	235	336	269	333	269	278	322
Asphalt Cement Added (%)	4.20%	5.49%	4.93%	6.67%	4.93%	4.77%	7.48%
RAP Content (%)	28.40%		19.33%		19.00%	18.00%	
Mat'ls Moisture Content (%, dry)	5.47%	4.64%	5.78%	5.11%	4.80%	5.51%	4.07%
Fuel Consumption (gal/hr)	675	669	685	696	674	745	597
Exhaust Gas Temperature (F)	311	312	311	319	317	334	329
Mix Temperature (F)	284	298	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SCF)	42.862	44.841	42.827	47.004	41.676	43.859	41.244
Sample Volume (cu. m)	1.214	1.270	1.213	1.331	1.180	1.242	1.168
Exhaust Gas Moisture (%)	31.5%	28.9%	32.4%	30.3%	30.1%	31.6%	23.4%
Stack Temperature (F)	265	260	261	267	228	282	267
Actual Exhaust Gas Flow (ACFM)	88,513	89,544	87,429	99,509	86,017	94,793	82,020
Dry Exhaust Gas Flow (DSCFM)	43,396	45,805	42,350	49,377	44,998	45,380	44,305
Dry Exhaust Gas Flow (DSCMM)	1,229	1,297	1,199	1,398	1,274	1,285	1,255
CO2, %	6.54%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2, %	11.96%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81.50%	81.53%	81.77%	81.84%	81.40%	81.47%	81.13%
Average PAH RESULTS (for each mix)			*("Not-Detected" Compounds have been set equal to Zero.)*				
Acenaphthene	0.0242	0.0018	0.0140	0.0021	0.0303	0.0324	0.0057
Acenaphthylene	0.0058	0.0022	0.0051	0.0026	0.0101	0.0095	0.0185
Anthracene	0.0125	0.0003	0.0082		0.0082	0.0121	0.0023
Benzo(a)anthracene	0.0002	0.0002	0.0005				0.0004
Benzo(a)pyrene							
Benzo(b)fluoranthene							
Benzo(e)pyrene							
Benzo(g,h,i)perylene							
Benzo(k)fluoranthene							
Chrysene	0.0002	0.0003	0.0004				0.0003
Dibenzo(a,h)anthracene							
Fluoranthene	0.0259	0.0030	0.0189	0.0024	0.0075	0.0090	0.0061
Fluorene	0.0372	0.0051	0.0256	0.0055	0.0203	0.0223	0.0140
Indeno(1,2,3-cd)pyrene							
Naphthalene	0.1005	0.0502	0.0839	0.0622	0.0837	0.0712	0.1396
Naphthalene, 2-Chloro-							
Naphthalene, 2-Methyl-	0.0822	0.0578	0.0813	0.0788	0.2982	0.2755	0.1335
Phenanthrene	0.0975	0.0120	0.0684	0.0141	0.1127	0.1373	0.0390
Pyrene	0.0222	0.0030	0.0167	0.0022	0.0089	0.0149	0.0185
Average OTHER PAH RESULTS (for each mix)			*("Not-Detected" Compounds have been set equal to Zero.)*				
Cumene	0.0045	0.0056	0.0062	0.0069	0.0046	0.0069	0.0095
o-Cresol (2-Methylphenol)	0.0059	0.0029	0.0078	0.0011			0.0187
m-/p-Cresol (3-/4-Methylphenol)	0.0109	0.0052	0.0159	0.0058	0.0084	0.0084	0.0343

NOTES:

1 >> Shaded columns identify those mixes that DO NOT contain RAP.

2 >> The horizontal lines in the list of compounds have no other significance than to help read numbers across the page.

TABLE 19. PAH EMISSIONS MEASUREMENTS RESULTS, INCLUDING CUMENE AND CRESOLS (Units: PPM)

Not-Detected Compounds have been set equal to zero.

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	235	336	269	333	269	278	322
Asphalt Cement Added (%)	4.20%	5.49%	4.93%	6.67%	4.93%	4.77%	7.48%
RAP Content (%)	28.40%		19.33%		19.00%	18.00%	
Mat'ls Moisture Content (%, dry)	5.47%	4.64%	5.78%	5.11%	4.80%	5.51%	4.07%
Fuel Consumption (gal/hr)	675	669	685	696	674	745	597
Exhaust Gas Temperature (F)	311	312	311	319	317	334	329
Mix Temperature (F)	284	298	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SCF)	42.862	44.841	42.827	47.004	41.676	43.859	41.244
Sample Volume (cu. m)	1.214	1.270	1.213	1.331	1.180	1.242	1.168
Exhaust Gas Moisture (%)	31.5%	28.9%	32.4%	30.3%	30.1%	31.6%	23.4%
Stack Temperature (F)	265	260	261	267	228	282	267
Actual Exhaust Gas Flow (ACFM)	88,513	89,544	87,429	99,509	86,017	94,793	82,020
Dry Exhaust Gas Flow (DSCFM)	43,396	45,805	42,350	49,377	44,998	45,380	44,305
Dry Exhaust Gas Flow (DSCMM)	1,229	1,297	1,199	1,398	1,274	1,285	1,255
CO2, %	6.54%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2, %	11.96%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81.50%	81.53%	81.77%	81.84%	81.40%	81.47%	81.13%
Average PAH RESULTS (for each mix)			*("Not-Detected" Compounds have been set equal to Zero.)*				
Acenaphthene	0.0234	0.0016	0.0137	0.0018	0.0280	0.0297	0.0053
Acenaphthylene	0.0057	0.0020	0.0050	0.0023	0.0095	0.0089	0.0176
Anthracene	0.0104	0.0003	0.0069		0.0066	0.0096	0.0019
Benzo(a)anthracene	0.0002	0.0001	0.0003				0.0002
Benzo(a)pyrene							
Benzo(b)fluoranthene							
Benzo(e)pyrene							
Benzo(g,h,i)perylene							
Benzo(k)fluoranthene							
Chrysene	0.0002	0.0002	0.0003				0.0002
Dibenzo(a,h)anthracene							
Fluoranthene	0.0191	0.0021	0.0140	0.0017	0.0053	0.0063	0.0044
Fluorene	0.0333	0.0043	0.0232	0.0043	0.0174	0.0189	0.0122
Indeno(1,2,3-cd)pyrene							
Naphthalene	0.1163	0.0551	0.0974	0.0632	0.0932	0.0786	0.1580
Naphthalene, 2-Chloro-							
Naphthalene, 2-Methyl-	0.0857	0.0573	0.0847	0.0718	0.2992	0.2741	0.1362
Phenanthrene	0.0813	0.0095	0.0578	0.0107	0.0902	0.1090	0.0318
Pyrene	0.0164	0.0021	0.0124	0.0015	0.0062	0.0105	0.0133
Average OTHER PAH RESULTS (for each mix)			*("Not-Detected" Compounds have been set equal to Zero.)*				
Cumene	0.0056	0.0065	0.0078	0.0075	0.0055	0.0081	0.0115
o-Cresol (2-Methylphenol)	0.0080	0.0037	0.0110	0.0015			0.0251
m-/p-Cresol (3-/4-Methylphenol)	0.0148	0.0068	0.0222	0.0069	0.0111	0.0110	0.0460

NOTES:

1 >> Shaded columns identify those mixes that DO NOT contain RAP.

2 >> The horizontal lines in the list of compounds have no other significance than to help read numbers across the page.

TABLE 20. TOTAL PAH EMISSIONS DETERMINATION (Units: mg/m^3)

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	235	336	269	333	269	278	322
Asphalt Cement Added (%)	4.20%	5.49%	4.93%	6.67%	4.93%	4.77%	7.48%
RAP Content (%)	28.40%		19.33%		19.00%	18.00%	
Mat's Moisture Content (%, dry)	5.47%	4.64%	5.78%	5.11%	4.80%	5.51%	4.07%
Fuel Consumption (gal/hr)	675	669	685	696	674	745	597
Exhaust Gas Temperature (F)	311	312	311	319	317	334	329
Mix Temperature, F	284	298	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SCF)	42 862	44,841	42.827	47.004	41.676	43.859	41.244
Sample Volume (cu. m)	1 214	1.270	1.213	1.331	1.180	1.242	1.168
Exhaust Gas Moisture (%)	31 5%	28.9%	32.4%	30.3%	30.1%	31.6%	23.4%
Stack Temperature (F)	265	260	261	267	228	282	267
Actual Exhaust Gas Flow (ACFM)	88 513	89,544	87,429	99,509	86,017	94,793	82,020
Dry Exhaust Gas Flow (DSCFM)	43 396	45,805	42,350	49,377	44,998	45,380	44,305
Dry Exhaust Gas Flow (DSCMM)	1,229	1,297	1,199	1,398	1,274	1,285	1,255
CO2 %	6.54%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2 %	11 96%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81 50%	81.53%	81.77%	81.84%	81.40%	81.47%	81.13%

MICHIGAN DNR PAHs --- mg/cu. meter.							
With "Not Detected" compounds set equal to their reported Detection Limit.	1 43	0.18	1.54	0.19	1.28	1.49	0.69
With "Not Detected" compounds set equal to Zero (0).	1 40	0.16	1.51	0.16	1.18	1.41	0.64
% Phenanthrene of Total MDNR with "ND" = DL quantity	42 1%	39.7%	42.6%	41.5%	52.1%	54.3%	34.2%
% Higher with "ND" = DL vs. "ND" = 0.	2.11%	7.01%	2.06%	16.76%	8.80%	5.63%	7.05%

NAPA PAHs --- mg/cu. meter.							
With "Not Detected" compounds set equal to Zero (0).	2 56	0.81	2.75	0.95	3.56	3.53	2.33
% Naphthalene Compounds of Total NAPA PAH quantity.	45.2%	79.6%	45.3%	82.9%	66.9%	60.0%	72.4%
% Phenanthrene of Total NAPA PAH quantity.	23.6%	8.7%	23.8%	8.3%	18.8%	22.9%	10.1%

Remember, NAPA PAHs include the Naphthalene compounds, which generally make up a high percentage of the Total PAH quantity.

TABLE 21. TOTAL PAH EMISSIONS DETERMINATION (Units: lb/hr)

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	235	336	269	333	269	278	322
Asphalt Cement Added (%)	4.20%	5.49%	4.93%	6.67%	4.93%	4.77%	7.48%
RAP Content (%)	28.40%		19.33%		19.00%	18.00%	
Mat'ls Moisture Content (%, dry)	5.47%	4.64%	5.78%	5.11%	4.80%	5.51%	4.07%
Fuel Consumption (gal/hr)	675	669	685	696	674	745	597
Exhaust Gas Temperature (F)	311	312	311	319	317	334	329
Mix Temperature (F)	284	298	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SCF)	42.862	44.841	42.827	47.004	41.676	43.859	41.244
Sample Volume (cu. m)	1.214	1.270	1.213	1.331	1.180	1.242	1.168
Exhaust Gas Moisture (%)	31.5%	28.9%	32.4%	30.3%	30.1%	31.6%	23.4%
Stack Temperature (F)	265	260	261	267	228	282	267
Actual Exhaust Gas Flow (ACFM)	88,513	89,544	87,429	99,509	86,017	94,793	82,020
Dry Exhaust Gas Flow (DSCFM)	43,396	45,805	42,350	49,377	44,998	45,380	44,305
Dry Exhaust Gas Flow (DSCMM)	1,229	1,297	1,199	1,398	1,274	1,285	1,255
CO2, %	6.54%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2, %	11.96%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81.50%	81.53%	81.77%	81.84%	81.40%	81.47%	81.13%

MICHIGAN DNR PAHs --- lbs per hour.							
With "Not Detected" compounds set equal to their reported Detection Limit.	0.231	0.030	0.244	0.034	0.216	0.253	0.114
With "Not Detected" compounds set equal to Zero (0).	0.227	0.028	0.239	0.029	0.199	0.240	0.107
% Phenanthrene of Total MDNR with "ND" = DL quantity.	42.1%	39.8%	42.6%	41.1%	52.1%	54.2%	34.2%
% Higher, with "ND" = DL vs. "ND" = 0.	2.12%	7.03%	2.05%	18.21%	8.81%	5.63%	7.07%

NAPA PAHs --- lbs per hour.							
With "Not Detected" compounds set equal to Zero (0).	0.414	0.138	0.437	0.176	0.600	0.600	0.387
% Naphthalene Compounds of Total NAPA PAH quantity.	45.3%	79.6%	45.3%	83.5%	66.8%	60.0%	72.4%
% Phenanthrene of Total NAPA PAH quantity.	23.5%	8.7%	23.8%	8.0%	18.8%	22.9%	10.1%

Remember, NAPA PAHs include the Naphthalene compounds, which generally make up a high percentage of the Total PAH quantity

CTRL1 = 85/100 PEN AC, 30% RAP ✠ **CTRL2** = No RBR, No RAP ✠ **CTRL3** = No RBR, 20% RAP
RBR1 = RBR-WET, No RAP ✠ **RBR2** = No RBR, 20% Rbr RAP ✠ **RBR3** = RBR-WET, 20% Rbr RAP ✠ **RBR4** = RBR-DRY, No RAP

TABLE 22. TOTAL PAH EMISSIONS DETERMINATION (Units: PPM)

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	235	336	269	333	269	278	322
Asphalt Cement Added (%)	4.20%	5.49%	4.93%	6.67%	4.93%	4.77%	7.48%
RAP Content (%)	28.40%		19.33%		19.00%	18.00%	
Mat'ls Moisture Content (%, dry)	5.47%	4.64%	5.78%	5.11%	4.80%	5.51%	4.07%
Fuel Consumption (gal/hr)	675	669	685	696	674	745	597
Exhaust Gas Temperature (F)	311	312	311	319	317	334	329
Mix Temperature (F)	284	298	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SCF)	42.862	44.841	42.827	47.004	41.676	43.859	41.244
Sample Volume (cu. m)	1.214	1.270	1.213	1.331	1.180	1.242	1.168
Exhaust Gas Moisture (%)	31.5%	28.9%	32.4%	30.3%	30.1%	31.6%	23.4%
Stack Temperature (F)	265	260	261	267	228	282	267
Actual Exhaust Gas Flow (ACFM)	88,513	89,544	87,429	99,509	86,017	94,793	82,020
Dry Exhaust Gas Flow (DSCFM)	43,396	45,805	42,350	49,377	44,998	45,380	44,305
Dry Exhaust Gas Flow (DSCMM)	1,229	1,297	1,199	1,398	1,274	1,285	1,255
CO2, %	6.54%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2, %	11.96%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81.50%	81.53%	81.77%	81.84%	81.40%	81.47%	81.13%

MICHIGAN DNR PAHs --- PPM.							
With "Not Detected" compounds set equal to their reported Detection Limit.	0.193	0.023	0.207	0.025	0.174	0.202	0.093
With "Not Detected" compounds set equal to Zero (0).	0.190	0.022	0.204	0.022	0.164	0.194	0.088
% Phenanthrene of Total MDNR with "ND" = DL quantity.	42.1%	40.3%	42.7%	42.5%	52.0%	54.0%	34.4%
% Higher, with "ND" = DL vs. "ND" = 0.	1.46%	4.97%	1.42%	11.78%	5.97%	3.86%	4.86%

NAPA PAHs --- PPM.							
With "Not Detected" compounds set equal to Zero (0).	0.395	0.136	0.425	0.160	0.568	0.555	0.387
% Naphthalene Compounds of Total NAPA PAH quantity.	51.8%	83.5%	52.0%	86.0%	71.1%	65.0%	77.2%
% Phenanthrene of Total NAPA PAH quantity.	20.6%	7.0%	20.8%	6.6%	15.9%	19.7%	8.2%

Remember, NAPA PAHs include the Naphthalene compounds, which generally make up a high percentage of the Total PAH quantity.

TABLE 23. TOTAL PAH EMISSION FACTORS (Units: lb/ton HMA and lb/ton AC)

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	235	336	269	333	269	278	322
Asphalt Cement Added (%)	4.20%	5.49%	4.93%	6.67%	4.93%	4.77%	7.48%
RAP Content (%)	28.40%		19.33%		19.00%	18.00%	
Mat'ls Moisture Content (%, dry)	5.47%	4.64%	5.78%	5.11%	4.80%	5.51%	4.07%
Fuel Consumption (gal/hr)	675	669	685	696	674	745	597
Exhaust Gas Temperature (F)	311	312	311	319	317	334	329
Mix Temperature (F)	284	298	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SCF)	42.862	44.841	42.827	47.004	41.676	43.859	41.244
Sample Volume (cu. m)	1.214	1.270	1.213	1.331	1.180	1.242	1.168
Exhaust Gas Moisture (%)	31.5%	28.9%	32.4%	30.3%	30.1%	31.6%	23.4%
Stack Temperature (F)	265	260	261	267	228	282	267
Actual Exhaust Gas Flow (ACFM)	88,513	89,544	87,429	99,509	86,017	94,793	82,020
Dry Exhaust Gas Flow (DSCFM)	43,396	45,805	42,350	49,377	44,998	45,380	44,305
Dry Exhaust Gas Flow (DSCMM)	1,229	1,297	1,199	1,398	1,274	1,285	1,255
CO2, %	6.54%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2, %	11.96%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81.50%	81.53%	81.77%	81.84%	81.40%	81.47%	81.13%

MICHIGAN DNR PAHs --- lbs per ton of HMA.							
With "Not Detected" compounds set equal to their reported Detection Limit.	0.00066	0.00009	0.00069	0.00010	0.00061	0.00070	0.00033
With "Not Detected" compounds set equal to Zero (0).	0.00065	0.00008	0.00067	0.00008	0.00056	0.00066	0.00031

NAPA PAHs --- lbs per ton of HMA.							
With "Not Detected" compounds set equal to Zero (0).	0.00117	0.00039	0.00122	0.00048	0.00164	0.00162	0.00111

MICHIGAN DNR PAHs --- lbs per ton of asphalt binder.							
With "Not Detected" compounds set equal to their reported Detection Limit.	0.0162	0.0016	0.0140	0.0014	0.0124	0.0147	0.0044
With "Not Detected" compounds set equal to Zero (0).	0.0159	0.0015	0.0137	0.0012	0.0114	0.0139	0.0041

NAPA PAHs --- lbs per ton of asphalt binder.							
With "Not Detected" compounds set equal to Zero (0).	0.0288	0.0071	0.0247	0.0071	0.0335	0.0339	0.0145

Remember, NAPA PAHs include the Naphthalene compounds, which generally make up a high percentage of the Total PAH quantity

CTRL1 = 85/100 PEN AC, 30% RAP ✠ **CTRL2** = No RBR, No RAP ✠ **CTRL3** = No RBR, 20% RAP
RBR1 = RBR-WET, No RAP ✠ **RBR2** = No RBR, 20% Rbr RAP ✠ **RBR3** = RBR-WET, 20% Rbr RAP ✠ **RBR4** = RBR-DRY, No RAP

TABLE 24. TOTAL PAH EMISSION FACTORS (Units: mg/ton HMA and mg/ton AC)

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	235	336	269	333	269	278	322
Asphalt Cement Added (%)	4.20%	5.49%	4.93%	6.67%	4.93%	4.77%	7.48%
RAP Content (%)	28.40%		19.33%		19.00%	18.00%	
Mat'ls Moisture Content (%, dry)	5.47%	4.64%	5.78%	5.11%	4.80%	5.51%	4.07%
Fuel Consumption (gal/hr)	675	669	685	696	674	745	597
Exhaust Gas Temperature (F)	311	312	311	319	317	334	329
Mix Temperature (F)	284	298	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SCF)	42.862	44.841	42.827	47.004	41.676	43.859	41.244
Sample Volume (cu. m)	1.214	1.270	1.213	1.331	1.180	1.242	1.168
Exhaust Gas Moisture (%)	31.5%	28.9%	32.4%	30.3%	30.1%	31.6%	23.4%
Stack Temperature (F)	265	260	261	267	228	282	267
Actual Exhaust Gas Flow (ACFM)	88,513	89,544	87,429	99,509	86,017	94,793	82,020
Dry Exhaust Gas Flow (DSCFM)	43,396	45,805	42,350	49,377	44,998	45,380	44,305
Dry Exhaust Gas Flow (DSCMM)	1,229	1,297	1,199	1,398	1,274	1,285	1,255
CO2, %	6.54%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2, %	11.96%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81.50%	81.53%	81.77%	81.84%	81.40%	81.47%	81.13%

MICHIGAN DNR PAHs --- mg per ton of HMA.							
With "Not Detected" compounds set equal to their reported Detection Limit.	301	38	312	44	278	318	149
With "Not Detected" compounds set equal to Zero (0).	294	36	305	37	256	301	139

NAPA PAHs --- mg per ton of HMA.							
With "Not Detected" compounds set equal to Zero (0).	532	175	552	216	745	734	493

MICHIGAN DNR PAHs --- mg per ton of asphalt binder.							
With "Not Detected" compounds set equal to their reported Detection Limit.	7,358	712	6,328	654	5,646	6,670	1,996
With "Not Detected" compounds set equal to Zero (0).	7,197	666	6,201	552	5,189	6,314	1,865

NAPA PAHs --- mg per ton of asphalt binder.							
With "Not Detected" compounds set equal to Zero (0).	13,073	3,202	11,194	3,239	15,188	15,396	6,595

Remember, NAPA PAHs include the Naphthalene compounds which generally make up a high percentage of the Total PAH quantity.

CTRL1 = 85/100 PEN AC, 30% RAP ✠ **CTRL2** = No RBR, No RAP ✠ **CTRL3** = No RBR, 20% RAP

RBR1 = RBR-WET, No RAP ✠ **RBR2** = No RBR, 20% Rbr RAP ✠ **RBR3** = RBR-WET, 20% Rbr RAP ✠ **RBR4** = RBR-DRY, No RAP

TABLE 25. 8270 SCAN INCLUDING CHLOROPHENOLS, CHLOROBENZENES, AND NITROSAMINES (Units: mg/m^3)

Not-Detected Compounds have been set equal to their reported Detection Limit.

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	235	336	269	333	269	278	322
Asphalt Cement Added (%)	4.20%	5.49%	4.93%	6.67%	4.93%	4.77%	7.48%
RAP Content (%)	28.40%		19.33%		19.00%	18.00%	
Mat'ls Moisture Content (%, dry)	5.47%	4.64%	5.78%	5.11%	4.80%	5.51%	4.07%
Fuel Consumption (gal/hr)	675	669	685	696	674	745	597
Exhaust Gas Temperature (F)	311	312	311	319	317	334	329
Mix Temperature (F)	284	298	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SCF)	42.862	44.841	42.827	47.004	41.676	43.859	41.244
Sample Volume (cu. m)	1.214	1.270	1.213	1.331	1.180	1.242	1.168
Exhaust Gas Moisture (%)	31.5%	28.9%	32.4%	30.3%	30.1%	31.6%	23.4%
Stack Temperature (F)	265	260	261	267	228	282	267
Actual Exhaust Gas Flow (ACFM)	88,513	89,544	87,429	99,509	86,017	94,793	82,020
Dry Exhaust Gas Flow (DSCFM)	43,396	45,805	42,350	49,377	44,998	45,380	44,305
Dry Exhaust Gas Flow (DSCMM)	1,229	1,297	1,199	1,398	1,274	1,285	1,255
CO2, %	6.54%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2, %	11.96%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81.50%	81.53%	81.77%	81.84%	81.40%	81.47%	81.13%
Average PAH RESULTS (for each mix)--"Not Detected" Compounds have been set equal to Detection Limit.							
2,4-Dichlorophenol	0.011	0.005	0.012	0.007	0.035	0.026	0.019
2,4,5-Trichlorophenol	0.013	0.006	0.015	0.008	0.043	0.032	0.024
2,4,6-Trichlorophenol	0.014	0.007	0.016	0.008	0.044	0.037	0.026
Pentachlorophenol	0.020	0.009	0.024	0.012	0.054	0.048	0.034
1,2-Dichlorobenzene	0.009	0.004	0.010	0.005	0.028	0.021	0.015
1,3-Dichlorobenzene	0.008	0.004	0.010	0.005	0.027	0.020	0.015
1,4-Dichlorobenzene	0.008	0.004	0.009	0.005	0.026	0.019	0.014
1,2,4-Trichlorobenzene	0.014	0.015	0.011	0.006	0.032	0.024	0.049
Hexachlorobenzene	0.013	0.006	0.015	0.007	0.035	0.029	0.023
N-Nitrosodiphenylamine	0.006	0.003	0.007	0.007	0.019	0.015	0.011
N-Nitroso-di-n-propylamine	0.019	0.008	0.021	0.012	0.063	0.046	0.032
Benzoic Acid [4]	0.644	0.383	0.718	0.318	0.199	0.242	0.357
Benzyl Alcohol	0.053	0.023	0.063	0.017	0.125	0.072	0.048
bis(2-Ethylhexyl)phthalate [4]	0.003	0.001	0.003	0.003	0.008	0.007	0.005
Di-n-Butylphthalate [4]	0.158	0.014	0.011	0.006	0.132	0.008	0.022
Dibenzofuran	0.171	0.023	0.170	0.024	0.084	0.053	0.067
Phenol	0.321	0.203	0.405	0.215	0.323	0.189	1.029

NOTES:

1 >> Shaded columns identify those mixes that DO NOT contain RAP.

2 >> Shaded rows identify those compounds that had detected/estimated quantities, but were not listed in the MDOT Special Conditions Document.

3 >> The horizontal lines in the list of compounds have no other significance than to help read numbers across the page.

4 >> These compounds were also found in the laboratory blanks.

TABLE 26. 8270 SCAN INCLUDING CHLOROPHENOLS, CHLOROBENZENES, AND NITROSAMINES (Units: lb/hr)

Not-Detected Compounds have been set equal to their reported Detection Limit.

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	235	336	269	333	269	278	322
Asphalt Cement Added (%)	4.20%	5.49%	4.93%	6.67%	4.93%	4.77%	7.48%
RAP Content (%)	28.40%		19.33%		19.00%	18.00%	
Mat'ls Moisture Content (%, dry)	5.47%	4.64%	5.78%	5.11%	4.80%	5.51%	4.07%
Fuel Consumption (gal/hr)	675	669	685	696	674	745	597
Exhaust Gas Temperature (F)	311	312	311	319	317	334	329
Mix Temperature (F)	284	298	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SCF)	42.862	44.841	42.827	47.004	41.676	43.859	41.244
Sample Volume (cu. m)	1.214	1.270	1.213	1.331	1.180	1.242	1.168
Exhaust Gas Moisture (%)	31.5%	28.9%	32.4%	30.3%	30.1%	31.6%	23.4%
Stack Temperature (F)	265	260	261	267	228	282	267
Actual Exhaust Gas Flow (ACFM)	88,513	89,544	87,429	99,509	86,017	94,793	82,020
Dry Exhaust Gas Flow (DSCFM)	43,396	45,805	42,350	49,377	44,998	45,380	44,305
Dry Exhaust Gas Flow (DSCMM)	1,229	1,297	1,199	1,398	1,274	1,285	1,255
CO2, %	6.54%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2, %	11.96%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81.50%	81.53%	81.77%	81.84%	81.40%	81.47%	81.13%
Average PAH RESULTS (for each mix)--"Not Detected" Compounds have been set equal to Detection Limit.							
2,4-Dichlorophenol	0.0018	0.0009	0.0020	0.0013	0.0059	0.0044	0.0032
2,4,5-Trichlorophenol	0.0022	0.0010	0.0024	0.0015	0.0072	0.0055	0.0039
2,4,6-Trichlorophenol	0.0023	0.0011	0.0026	0.0015	0.0074	0.0064	0.0042
Pentachlorophenol	0.0032	0.0015	0.0038	0.0023	0.0091	0.0081	0.0056
1,2-Dichlorobenzene	0.0014	0.0007	0.0016	0.0011	0.0048	0.0035	0.0025
1,3-Dichlorobenzene	0.0013	0.0006	0.0015	0.0010	0.0046	0.0034	0.0024
1,4-Dichlorobenzene	0.0013	0.0006	0.0014	0.0010	0.0043	0.0033	0.0023
1,2,4-Trichlorobenzene	0.0023	0.0025	0.0018	0.0012	0.0055	0.0041	0.0081
Hexachlorobenzene	0.0021	0.0010	0.0024	0.0014	0.0059	0.0049	0.0038
N-Nitrosodiphenylamine	0.0010	0.0005	0.0011	0.0012	0.0032	0.0025	0.0017
N-Nitroso-di-n-propylamine	0.0030	0.0014	0.0033	0.0024	0.0106	0.0078	0.0053
Benzoic Acid [4]	0.1049	0.0654	0.1138	0.0571	0.0335	0.0411	0.0595
Benzyl Alcohol	0.0086	0.0039	0.0100	0.0033	0.0211	0.0123	0.0080
bis(2-Ethylhexyl)phthalate [4]	0.0005	0.0002	0.0004	0.0006	0.0014	0.0012	0.0008
Di-n-Butylphthalate [4]	0.0247	0.0023	0.0017	0.0010	0.0222	0.0013	0.0037
Dibenzofuran	0.0277	0.0039	0.0270	0.0044	0.0141	0.0090	0.0111
Phenol	0.0524	0.0347	0.0646	0.0398	0.0543	0.0321	0.1706

NOTES:

1 >> Shaded columns identify those mixes that DO NOT contain RAP.

2 >> Shaded rows identify those compounds that had detected/estimated quantities, but were not listed in the MDOT Special Conditions Document.

3 >> The horizontal lines in the list of compounds have no other significance than to help read numbers across the page.

4 >> These compounds were also found in the laboratory blanks.

TABLE 27. 8270 SCAN INCLUDING CHLOROPHENOLS, CHLOROBENZENES, AND NITROSAMINES (Units: PPM)

Not-Detected Compounds have been set equal to their reported Detection Limit.

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	235	336	269	333	269	278	322
Asphalt Cement Added (%)	4.20%	5.49%	4.93%	6.67%	4.93%	4.77%	7.48%
RAP Content (%)	28.40%		19.33%		19.00%	18.00%	
Mat'ls Moisture Content (%, dry)	5.47%	4.64%	5.78%	5.11%	4.80%	5.51%	4.07%
Fuel Consumption (gal/hr)	675	669	685	696	674	745	597
Exhaust Gas Temperature (F)	311	312	311	319	317	334	329
Mix Temperature (F)	284	298	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SCF)	42.862	44.841	42.827	47.004	41.676	43.859	41.244
Sample Volume (cu. m)	1.214	1.270	1.213	1.331	1.180	1.242	1.168
Exhaust Gas Moisture (%)	31.5%	28.9%	32.4%	30.3%	30.1%	31.6%	23.4%
Stack Temperature (F)	265	260	261	267	228	282	267
Actual Exhaust Gas Flow (ACFM)	88,513	89,544	87,429	99,509	86,017	94,793	82,020
Dry Exhaust Gas Flow (DSCFM)	43,396	45,805	42,350	49,377	44,998	45,380	44,305
Dry Exhaust Gas Flow (DSCMM)	1,229	1,297	1,199	1,398	1,274	1,285	1,255
CO2, %	6.54%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2, %	11.96%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81.50%	81.53%	81.77%	81.84%	81.40%	81.47%	81.13%
Average PAH RESULTS (for each mix)--"Not Detected" Compounds have been set equal to Detection Limit.							
2,4-Dichlorophenol	0.0016	0.0007	0.0018	0.0010	0.0052	0.0038	0.0028
2,4,5-Trichlorophenol	0.0016	0.0007	0.0019	0.0009	0.0052	0.0040	0.0029
2,4,6-Trichlorophenol	0.0017	0.0008	0.0020	0.0010	0.0053	0.0046	0.0031
Pentachlorophenol	0.0018	0.0008	0.0022	0.0011	0.0048	0.0043	0.0031
1,2-Dichlorobenzene	0.0014	0.0006	0.0016	0.0009	0.0046	0.0034	0.0025
1,3-Dichlorobenzene	0.0014	0.0006	0.0016	0.0009	0.0044	0.0033	0.0024
1,4-Dichlorobenzene	0.0013	0.0006	0.0015	0.0008	0.0042	0.0031	0.0023
1,2,4-Trichlorobenzene	0.0019	0.0019	0.0015	0.0008	0.0043	0.0032	0.0065
Hexachlorobenzene	0.0011	0.0005	0.0013	0.0006	0.0030	0.0024	0.0019
N-Nitrosodiphenylamine	0.0007	0.0003	0.0008	0.0009	0.0023	0.0018	0.0013
N-Nitroso-di-n-propylamine	0.0034	0.0015	0.0039	0.0023	0.0116	0.0085	0.0060
Benzoic Acid [4]	0.1270	0.0754	0.1414	0.0626	0.0391	0.0476	0.0704
Benzyl Alcohol	0.0117	0.0050	0.0140	0.0038	0.0279	0.0161	0.0107
bis(2-Ethylhexyl)phthalate [4]	0.0002	0.0001	0.0002	0.0002	0.0005	0.0004	0.0003
Di-n-Butylphthalate [4]	0.0136	0.0012	0.0009	0.0005	0.0114	0.0007	0.0019
Dibenzofuran	0.0245	0.0033	0.0243	0.0034	0.0120	0.0075	0.0096
Phenol	0.0821	0.0519	0.1035	0.0551	0.0825	0.0483	0.2630

NOTES:

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4 >> These compounds were also found in the laboratory blanks.

TABLE 28. 8270 SCAN INCLUDING CHLOROPHENOLS, CHLOROBENZENES, AND NITROSAMINES (Units: mg/m^3)

Not-Detected Compounds have been set equal to zero.

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	235	336	269	333	269	278	322
Asphalt Cement Added (%)	4.20%	5.49%	4.93%	6.67%	4.93%	4.77%	7.48%
RAP Content (%)	28.40%		19.33%		19.00%	18.00%	
Mat'ls Moisture Content (%, dry)	5.47%	4.64%	5.78%	5.11%	4.80%	5.51%	4.07%
Fuel Consumption (gal/hr)	675	669	685	696	674	745	597
Exhaust Gas Temperature (F)	311	312	311	319	317	334	329
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Stack Temperature (F)	265	260	261	267	228	282	267
Actual Exhaust Gas Flow (ACFM)	88,513	89,544	87,429	99,509	86,017	94,793	82,020
Dry Exhaust Gas Flow (DSCFM)	43,396	45,805	42,350	49,377	44,998	45,380	44,305
Dry Exhaust Gas Flow (DSCMM)	1,229	1,297	1,199	1,398	1,274	1,285	1,255
CO2, %	6.54%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2, %	11.96%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81.50%	81.53%	81.77%	81.84%	81.40%	81.47%	81.13%
Average PAH RESULTS (for each mix)--"Not Detected" Compounds have been set equal Zero (0).							
2,4-Dichlorophenol							
2,4,5-Trichlorophenol							
2,4,6-Trichlorophenol							
Pentachlorophenol							
1,2-Dichlorobenzene							
1,3-Dichlorobenzene							
1,4-Dichlorobenzene							
1,2,4-Trichlorobenzene	0.005	0.012					0.035
Hexachlorobenzene							
N-Nitrosodiphenylamine				0.004			
N-Nitroso-di-n-propylamine							
Benzoic Acid [4]	0.644	0.383	0.718	0.318	0.199	0.242	0.357
Benzyl Alcohol	0.043	0.018	0.063				
bis(2-Ethylhexyl)phthalate [4]			0.003	0.003			
Di-n-Butylphthalate [4]	0.158	0.014	0.011	0.006	0.131	0.005	0.022
Dibenzofuran	0.171	0.023	0.170	0.024	0.084	0.050	0.067
Phenol	0.321	0.203	0.405	0.215	0.323	0.189	1.029

NOTES:

1 >> Shaded columns identify those mixes that DO NOT contain RAP.

2 >> Shaded rows identify those compounds that had detected/estimated quantities, but were not listed in the MDOT Special Conditions Document.

3 >> The horizontal lines in the list of compounds have no other significance than to help read numbers across the page.

4 >> These compounds were also found in the laboratory blanks.

TABLE 29. 8270 SCAN INCLUDING CHLOROPHENOLS, CHLOROBENZENES, AND NITROSAMINES (Units: lb/hr)

Not-Detected Compounds have been set equal to zero.

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	235	336	269	333	269	278	322
Asphalt Cement Added (%)	4.20%	5.49%	4.93%	6.67%	4.93%	4.77%	7.48%
RAP Content (%)	28.40%		19.33%		19.00%	18.00%	
Mat'ls Moisture Content (%, dry)	5.47%	4.64%	5.78%	5.11%	4.80%	5.51%	4.07%
Fuel Consumption (gal/hr)	675	669	685	696	674	745	597
Exhaust Gas Temperature (F)	311	312	311	319	317	334	329
Mix Temperature (F)	284	298	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SCF)	42.862	44.841	42.827	47.004	41.676	43.859	41.244
Sample Volume (cu. m)	1.214	1.270	1.213	1.331	1.180	1.242	1.168
Exhaust Gas Moisture (%)	31.5%	28.9%	32.4%	30.3%	30.1%	31.6%	23.4%
Stack Temperature (F)	265	260	261	267	228	282	267
Actual Exhaust Gas Flow (ACFM)	88,513	89,544	87,429	99,509	86,017	94,793	82,020
Dry Exhaust Gas Flow (DSCFM)	43,396	45,805	42,350	49,377	44,998	45,380	44,305
Dry Exhaust Gas Flow (DSCMM)	1,229	1,297	1,199	1,398	1,274	1,285	1,255
CO2, %	6.54%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2, %	11.96%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81.50%	81.53%	81.77%	81.84%	81.40%	81.47%	81.13%
Average PAH RESULTS (for each mix)--"Not Detected" Compounds have been set equal Zero (0).							
2,4-Dichlorophenol							
2,4,5-Trichlorophenol							
2,4,6-Trichlorophenol							
Pentachlorophenol							
1,2-Dichlorobenzene							
1,3-Dichlorobenzene							
1,4-Dichlorobenzene							
1,2,4-Trichlorobenzene	0.0008	0.0020					0.0058
Hexachlorobenzene							
N-Nitrosodiphenylamine				0.0007			
N-Nitroso-di-n-propylamine							
Benzoic Acid [4]	0.1049	0.0654	0.1138	0.0571	0.0335	0.0411	0.0595
Benzyl Alcohol	0.0070	0.0030	0.0100				
bis(2-Ethylhexyl)phthalate [4]			0.0004	0.0006			
Di-n-Butylphthalate [4]	0.0247	0.0023	0.0017	0.0010	0.0220	0.0009	0.0037
Dibenzofuran	0.0277	0.0039	0.0270	0.0044	0.0141	0.0085	0.0111
Phenol	0.0524	0.0347	0.0646	0.0398	0.0543	0.0321	0.1706

NOTES:

1 >> Shaded columns identify those mixes that DO NOT contain RAP.

2 >> Shaded rows identify those compounds that had detected/estimated quantities, but were not listed in the MDOT Special Conditions Document.

3 >> The horizontal lines in the list of compounds have no other significance than to help read numbers across the page.

4 >> These compounds were also found in the laboratory blanks.

TABLE 30. 8270 SCAN INCLUDING CHLOROPHENOLS, CHLOROBENZENES, AND NITROSAMINES (Units: PPM)

Not-Detected Compounds have been set equal to zero.

Mix Type >>	CTRL 1	CTRL 2	CTRL 3	RBR 1	RBR 2	RBR 3	RBR 4
OPERATING DATA (average of all runs for each mix)							
HMA Production Rate (TPH)	349	356	355	357	353	361	348
Dry Aggregate Rate (TPH)	235	336	269	333	269	278	322
Asphalt Cement Added (%)	4.20%	5.49%	4.93%	6.67%	4.93%	4.77%	7.48%
RAP Content (%)	28.40%		19.33%		19.00%	18.00%	
Mat'ls Moisture Content (%, dry)	5.47%	4.64%	5.78%	5.11%	4.80%	5.51%	4.07%
Fuel Consumption (gal/hr)	675	669	685	696	674	745	597
Exhaust Gas Temperature (F)	311	312	311	319	317	334	329
Mix Temperature (F)	284	298	292	311	299	308	311
STACK CONDITIONS (average of all runs for each mix)							
Sample Volume (SCF)	42.862	44.841	42.827	47.004	41.676	43.859	41.244
Sample Volume (cu. m)	1.214	1.270	1.213	1.331	1.180	1.242	1.168
Exhaust Gas Moisture (%)	31.5%	28.9%	32.4%	30.3%	30.1%	31.6%	23.4%
Stack Temperature (F)	265	260	261	267	228	282	267
Actual Exhaust Gas Flow (ACFM)	88,513	89,544	87,429	99,509	86,017	94,793	82,020
Dry Exhaust Gas Flow (DSCFM)	43,396	45,805	42,350	49,377	44,998	45,380	44,305
Dry Exhaust Gas Flow (DSCMM)	1,229	1,297	1,199	1,398	1,274	1,285	1,255
CO2, %	6.54%	5.70%	6.23%	6.03%	6.13%	6.63%	6.50%
O2, %	11.96%	12.77%	12.00%	12.13%	12.47%	11.90%	12.37%
N2, %	81.50%	81.53%	81.77%	81.84%	81.40%	81.47%	81.13%
Average PAH RESULTS (for each mix)--"Not Detected" Compounds have been set equal Zero (0).							
2,4-Dichlorophenol							
2,4,5-Trichlorophenol							
2,4,6-Trichlorophenol							
Pentachlorophenol							
1,2-Dichlorobenzene							
1,3-Dichlorobenzene							
1,4-Dichlorobenzene							
1,2,4-Trichlorobenzene	0.0007	0.0016					0.0047
Hexachlorobenzene							
N-Nitrosodiphenylamine				0.0005			
N-Nitroso-di-n-propylamine							
Benzoic Acid [4]	0.1270						
Benzyl Alcohol	0.0095	0.0039	0.0140				
bis(2-Ethylhexyl)phthalate [4]			0.0002	0.0002			
Di-n-Butylphthalate [4]	0.0136	0.0012	0.0009	0.0005	0.0113	0.0005	0.0019
Dibenzofuran	0.0245	0.0033	0.0243	0.0034	0.0120	0.0071	0.0096
Phenol	0.0821	0.0519	0.1035	0.0551	0.0825	0.0483	0.2630

NOTES:

1 >> Shaded columns identify those mixes that DO NOT contain RAP.

2 >> Shaded rows identify those compounds that had detected/estimated quantities, but were not listed in the MDOT Special Conditions Document.

3 >> The horizontal lines in the list of compounds have no other significance than to help read numbers across the page.

4 >> These compounds were also found in the laboratory blanks.

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LIST OF TABLES

Note: Table Sets contain 7 tables, one table for each worker position and the background blank in the following order: Background Sample, Paver Operator Sample, Roller Operator Sample, Screedman Sample, Luteman Sample, Laborer Sample, and Qualtiy Control Manager Sample.

1.0 INTRODUCTION.

The Michigan Department of Transportation (MiDOT) developed and sponsored a project designed to look at the possible environmental and worker exposure effects that might result from the addition of crumb rubber to asphalt paving materials as a modifier or additive. Crumb rubber can be added to asphalt paving materials using two methods. One method is to mix the crumb rubber into the asphalt cement binder prior to mixing with aggregate materials. The other method is to add the crumb rubber to the manufacturing process as a separate process material. The first method is generally referred to as a "WET" process, and the latter method is generally referred to as a "DRY" process. MiDOT chose to use the Rouse method for the WET process, and developed their own mix design for the DRY process.

1.1 The WET Asphalt-Rubber Binder Method.

The Rouse method uses a very fine crumb rubber material, 100% passing an 80 mesh screen. The crumb rubber is blended into a very high penetration (i.e. very soft) asphalt cement which has been heated to 450°F in a primary mixing tank and mixed for a specified period of time to initiate digestion of the rubber. It is then transferred to a secondary mixing tank for further mixing and digestion. When this second step is completed, the asphalt-rubber binder is transferred to either directly to the manufacturing process or to intermediate storage. At this point it is at about a temperature of 375°F. The mix design for the MiDOT project specified an amount of crumb rubber to be added to the asphalt cement binder in sufficient quantities to provide a ratio of 20 pounds of crumb rubber per ton of Hot Mix Asphalt (HMA).

1.2 The DRY Asphalt-Rubber Binder Method.

The DRY process uses a larger size crumb rubber. MiDOT specified a size passing a 1/4 inch sieve. The MiDOT mix design for the DRY process specified an amount of crumb rubber to be added to the asphalt manufacturing process in sufficient quantities to provide a ratio of 40 pounds of crumb rubber per ton of HMA. The point of introduction of the crumb rubber into the manufacturing process was not specified, but would depend on the type of equipment the successful bidding contractor would use--a batch mix facility, a parallel-flow drum mix facility, or a counter-flow drum mix facility.

1.3 Mixes to be Tested.

The MiDOT determined that seven mixes would be tested. Three of those mixes are considered Control Mixes, the other four are considered Rubber Mixes. Six of the mixes were to be manufactured with the same asphalt cement as required for

the asphalt-rubber binder -- an asphalt cement of 200-250 penetration (roughly equivalent to an AC-2.5 asphalt cement). The low viscosity asphalt cement is required in an asphalt-rubber binder because it is believed that the digestion process causes the rubber to absorb substantial amounts of light ends from the asphalt cement. MiDOT chose to use the same asphalt cement throughout the stack testing program to eliminate one variable -- asphalt cement related emissions. The seventh mix, Control Mix 1, was added to the program at a later date as a comparison for a "typical" mix compared to the "rubber" mixes because of the low viscosity asphalt cement used in the rubber mixes. There was concern that there might be emissions reported, particularly with the volatile organic compounds that might be high because of the low viscosity asphalt cement. The mixes are as follows:

Control Mix 1: This mix was to be a typical HMA using an asphalt cement with a penetration of 85-100, which is roughly equivalent to an AC-10 asphalt cement. This mix was included at a later date and was added because of concerns that the asphalt cement specified in the Rubber Mixes was a very soft asphalt and might result in emissions not normally found while producing HMA paving materials with a more viscous asphalt cement. The "typical" mix being produced during the stack testing which could be manufactured with an 85-100 PEN asphalt cement also contained 30% reclaimed asphalt pavement (RAP). This mix was designated as BM13A, Bituminous Mixture 13A -- **no Rubber, 30% RAP.**

Control Mix 2: This mix was to contain 100% virgin aggregates and asphalt cement with a penetration of 200-250 (roughly equivalent to an AC-2.5 asphalt cement). This mix was designated as MBM01, Modified Bituminous Mixture 01 -- **no rubber, no RAP.**

Control Mix 3: This mix was to contain 20% "regular" RAP materials. "Regular" as opposed to RAP with an asphalt-rubber binder. There has long been concern on the part of the paving industry as to the recyclability of asphalt pavements produced with an asphalt-rubber binder. Michigan had a roadway paved in the late 1970s with a mix containing an asphalt-rubber binder. The roadway was milled up in order to be used in this testing program. This mix was designated as MBM02, Modified Bituminous Mixture 02 -- **no Rubber, 20% RAP.**

Rubber Mix 1: The mix was to contain 100% virgin aggregates and an asphalt-rubber binder, manufactured by the WET process. This mix was designated as MBM03, Modified Bituminous Mixture 03 -- **Rubber-WET, no RAP.**

Rubber Mix 2: The mix was to contain 20% "rubber-RAP." "Rubber-RAP" because the pavement was originally manufactured with an asphalt-rubber binder. The asphalt cement binder would not be modified with rubber crumb. This mix was designated as MBM05, Modified Bituminous Mixture 05 -- **no Rubber, 20% rubber-RAP.**

Rubber Mix 3: This mix was to contain 20% "rubber-RAP" and an asphalt-rubber binder, manufactured by the WET process. This mix was designated as MBM06, Modified Bituminous Mixture 06 -- **Rubber-WET, 20% rubber-RAP.**

Rubber Mix 4: The mix was to contain rubber, manufactured by the DRY process, with 100% virgin aggregates. This mix was designated as MBM04, Modified Bituminous Mixture 04 -- **Rubber-DRY, no RAP.**

1.4 Development of the Stack Testing and Worker Exposure Assessment Program.

MiDOT consulted with the National Asphalt Pavement Association (NAPA) as to what environmental and worker exposure measurement approaches should be taken. They then consulted with the Michigan Department of Natural Resources Air Quality Division (MiDNR) about NAPA's recommendations. NAPA provided MiDOT with a copy of the stack testing protocol they had developed for their own stack testing program and the worker exposure sampling protocol for asphalt-rubber binder mixes that NAPA had also developed, in conjunction with the Asphalt Institute. Also, the protocol was distributed around the country for review, primarily to USEPA branches and some state air quality agencies. The additions were based on their feed back, and on MiDNR's practices and requirements. The worker exposure sampling and analytical procedures recommended by NAPA are provided in Table 1.

1.5 Description of the Paving Site at which the Worker Exposure Sampling was Conducted.

The paving site was a two-lane roadway designated as Michigan Route 50 (M-50). It was approximately nine miles long, running east/west, and is the main thoroughfare between Eaton Rapids, Michigan and Charlotte, Michigan. The paving work involved installing wedging along the curves of the roadway and several overlays of a base course pavement mixture and a surface course pavement mixture.

1.6 Description of the Personnel Positions for which Worker Exposure Sampling was Conducted and how Sampling was Conducted.

Five personnel positions were sampled at the paving site: Paver Operator, Roller Operator, Screedman, Luteman, and Laborer. At the Hot Mix Asphalt facility, the Quality Control Worker (in this case the QC Manager) position was sampled.

Most of the workers that were sampled were smokers. When a smoking break was desired, the industrial hygienist conducting the worker exposure sampling would turn off the pumps and cap the tubes until the smoking break was completed. This was done to eliminate the possible contamination of the samples from cigarette smoke. Cigarette smoke is known to contain some of the same PAHs for which the worker exposure assessment was being conducted.

Each worker was equipped with two sampling pumps. One pump was attached to the sampling equipment for collecting the Particulate Matter (PM), Benzene Soluble Organics (BSO), and Polynuclear Aromatic Hydrocarbons (PAHs) samples, and the other pump was attached to a tri-flow adapter to which the tubes for the 1,3-butadiene, BTEX/Styrene, and the Nitrosamine samples were connected. Each pump was operated for a minimum of 6 hours to a maximum of 8 hours each day. The inlets of the tubes were pinned to the front chest clothing as close to the breathing zone as possible without interfering with the workers' performance at their positions. The pumps were calibrated for specified flow rates, depending on the sampling being conducted--the PM/BSO/PAH pump was calibrated to draw 2 liters per minute, and the other pump was calibrated to draw 0.2 liters per minute.

1.6.1 Paver Operator Position Exposure.

The paver operator essentially steers the paving machine during paving operations. The operator sits on the top of the platform that is centered between the unloading hopper and the screed hopper. The operator's seat was located on the platform closest to the screed hopper. Because of the configuration of the seat, the pumps were affixed to the paver steering column so as not to interfere with the operator's operation of the paving machine.

1.6.2 Roller Operator Position Exposure.

The roller operator was centrally located between the front and back rollers. The exhaust pipe vented below the operator's platform. The roller was operated several hundred feet behind the paving machine. Based on the proximity to the asphalt paving materials and the temperature of the paving materials at time of exposure, the roller operator experiences the least exposure to asphalt fumes of all the paving crew positions.

1.6.3 Screedman Exposure.

The screedman stands over the screed hopper to ensure smooth feeding of the hot mix asphalt paving materials. The screedman also operates the screed extensions that set the width of the pavement mat placed by the paving machine. Based on proximity to the asphalt paving materials and the temperature of the paving materials at time of exposure, the screedman experiences the "worst-case" exposure to asphalt fumes of all the paving crew positions.

1.6.4 Luteman Exposure.

The luteman uses a rake-like device that has a flat board where the rake prongs would be to smooth out rough spots, clear away asphalt paving materials from manhole covers, and generally move asphalt paving materials according to need. The luteman works several feed behind the paving machine and works on the mat after it has been placed by the paving machine.

1.6.5 Laborer Exposure.

The laborer uses a shovel to move asphalt paving materials around on an as needed basis. The laborer can work several feet behind the paving machine, alongside the luteman, or alongside the screed--using the shovel to break up large chunks of asphalt paving materials in front of the screed extension, before it passes over the materials and forms them into the mat.

1.6.6 Quality Control Worker Exposure.

The quality control worker gets into the bed of the truck hauling the asphalt paving materials, on top of the paving materials to check the temperature of the materials in the truck and to collect a sample of the paving materials for QC procedures. The sample that is collected is generally a composite of asphalt paving materials from various spots in the truck bed, thus requiring the QC worker to walk along the length of the truck bed on top of the asphalt paving materials at least once. The QC worker works with the collected sample, first at a heated table to apportion it into several smaller samples. The worker then carries out several QC procedures on the various smaller samples. These procedures would include: pavement density determination, asphalt content determination (the asphalt cement is removed from the aggregate using a solvent), aggregate voids determination, etc.

1.7 Other Samples Collected.

Background samples were collected each day that worker exposure sampling was conducted. The background samples was situated upwind of the paving site so as not to be affected by emissions from the paving site. Field blanks were also collected. Since there were two days of sampling conducted for each mix type, one blank was set up at the paving site, generally on the first day of sampling, and one blank was set up at the Hot Mix Asphalt facility, generally on the second day of sampling. Table 2 provides a list of the field blanks indicating the sample number, the field blank location for each date of worker exposure sampling, and whether anything was detected on the blank.

2.0 WORKER EXPOSURE ASSESSMENT SAMPLING PROCEDURES AND COMPOUNDS TO BE ANALYZED AND QUANTITATED.

2.1 Measurements of Worker Exposure to 1,3-Butadiene in HMA Paving Material Fumes.

Samples for 1,3-Butadiene measurements were collected because 1,3-Butadiene is a part of the rubber polymer. OSHA Method 56 was used to collect and analyze this sample for 1,3-Butadiene. Two tubes of tert-butyl catechol coated charcoal were used, with the second tube acting as a backup for break-through determinations. The two tubes were to be analyzed separately.

2.2 Measurements of Worker Exposure to Particulate Matter and Benzene Soluble Organics in HMA Paving Material Fumes.

Particulate matter and Benzene Soluble Organics measurements were conducted according to NIOSH Methods 0500 and 5023, respectively. However, they were modified by using a pre-extracted 37 mm silver-membrane filter instead of a polyvinylchloride filter. The silver-membrane filter was used because of problems with artifacts from the polyvinylchloride filter dissolving in the benzene solvent extraction procedure and resulting in BSO results higher than the Particulate Matter results. The silver-membrane filter is recommended by Henry (Henk) Brandt of Shell Oil-Netherlands from research he has conducted, and has been used by NAPA and the Asphalt Institute in recently conducted worker exposure assessment studies.

2.3 Measurements of Worker Exposure to Polynuclear Aromatic Hydrocarbons in HMA Paving Material Fumes.

NIOSH Method 5506 was to be conducted for the collection and analysis of the 17 PAH compounds listed in the method. The silver-membrane filter was backed by a pre-extracted 100/50 mg XAD-2 sorbent tube. The two sections of XAD-2 sorbent being separated by glass wool. The 17 PAHs for which analysis was conducted are:

Acenaphthene
Acenaphthylene
Anthracene
Benz(a)anthracene
Benzo(a)pyrene
Benzo(e)pyrene
Benzo(g,h,i)perylene
Benzo(j)fluoranthene
Benzo(k)fluoranthene
Chrysene
Dibenzo(a,h)anthracene
Fluoranthene
Fluorene
Indeno(1,2,3-cd)pyrene
Naphthalene
Phenanthrene
Pyrene

2.4 Measurements of Worker Exposure to Several Volatile Organic Compounds in HMA Paving Material Fumes.

NAPA's Worker Exposure Assessment Protocol recommended measurement of Benzene, Toluene, Ethylbenzene, all isomers of Xylene (BTEX), and styrene. Styrene was specified because it is part of the rubber polymer.

2.5 Measurements of Worker Exposure to Several Nitrosamine Compounds in HMA Paving Material Fumes.

Measurement of nitrosamines was also recommended by NAPA in their Worker Exposure Assessment Protocol.

3.0 FIELD WORK.

The worker exposure sampling was carried out during the latter half of September 1993 and the first few days of October 1993 (9/15 through 10/5). Swanson Environmental, Inc. of Farmington Hills, Michigan, performed the worker exposure sample collection, under the direction of Henry Phillips, CIH. The analytical work for the worker exposure assessment samples was carried out by Data Chem Laboratories of Salt Lake City, Utah, except for the nitrosamines analyses. These analyses were performed by Thermedics Detection Inc. of Woburn, Massachusetts. The stack testing and worker exposure sampling were overseen by Kathryn O'C. Gunkel, P.E. of WILDWOOD Environmental Engineering Consultants, Inc. Ms. Gunkel also oversaw collection of process materials samples, recordation of operating data, and recordation of process materials moisture content. There were some delays--mostly weather related. One major delay was caused by delivery problems with the 1/4 inch rubber crumb and the project had to be carried over another weekend.

3.1 Worker Exposure Sampling Problems.

Thermedics Detection Inc. was unable to provide the required number of tubes with back-up sorbent traps prepared for the nitrosamines sample collection and analysis. Therefore, the original sampling protocol had to be modified somewhat. Originally, two field blanks were to be collected--one at the paving site and one at the HMA facility site. This was modified so that a field blank was collected for each mix sampled (which involved two days of sample collection)--one day at the paving site and the next day at the HMA facility site. Another modification was that only the first day of sampling for each mix had back-up Nitrosamines sorbent traps.

Because of the weather delays that occurred several times in the early morning, some worker exposure samples barely met the minimum six hours of sampling criteria. For the most part, the sample collection time averaged around seven hours. Also, because of the number of smokers on the paving crew, the smokers were accommodated by turning off their pumps and capping the tubes/cassettes during a smoking break to prevent contamination from cigarette smoke, as previously discussed.

3.2 Visible Emission Observations.

It was reported by various individuals that visible vapors from the asphalt paving materials seemed worse with the rubber mixes. However, as there is no method for evaluating fugitive visible emissions from a paving operation, some subjectivity would have to be factored in with these reports.

3.3 Paving Worker Complaints.

On Monday morning, October 4, 1993, Ms. Gunkel received reports that workers had complained of adverse health affects over the weekend following several consecutive days of paving with asphalt-rubber binders. One worker was reported to have complained to the paving superintendent about chest pains and constrictions in breathing over the weekend. Ms. Gunkel went out to the paving site to interview the workers. The paver operator, roller operator, and the laborer were interviewed prior to commencement of paving operations. The paver operator and roller operator reported no problems, while the laborer reported breathing difficulties. In following up with the paving superintendent, Ms. Gunkel learned that it was the paver operator that had originally complained about chest pains, the discrepancy in his report to the paving superintendent and his interview with Ms. Gunkel was not resolved. Ms. Gunkel also learned that the laborer was new to paving, the 1993 paving season being ***her*** first job on a paving crew. It was felt that her complaints were primarily due to this newness on the job and not having fully developed the physical conditioning that occurs when working in an intensely manual job, such as this.

4.0 DISCUSSION OF RESULTS.

The results of the worker exposure samples are grouped together by job category and by method conducted, where applicable. The data table are grouped together at the end of the report beginning at page 15. The reported detection limit for each compound is provided in the line just above the results for the samples for each worker position. The detection limit concentrations were calculated using the average of all the sample volumes collected for each worker position.

4.1 Sampling and Analytical Results for Particulate Matter and Benzene Soluble Organics (BSO).

The catch weight results of the Particulate Matter and Benzene Soluble Organics (BSO) samples are presented in Table Set I. The concentrations in units of mg/m^3 are also presented in Table Set I.

4.1.1 Particulate Matter Results.

The ACGIH Threshold Limit Value (TLV) for asphalt fumes is as total particulate matter--5 mg/m^3. The results of the sampling showed that exposure to total particulate matter, for all positions and mixes, is well below the TLV value.

4.1.2 Benzene Soluble Organics Results.

A substantial number of the BSO results were higher than the total particulate matter results of which the BSO is a fraction. Data Chem reported that after following the extraction procedures of NIOSH Method 5023, a gelatinous residue remained. It is believed that a chemical reaction occurred between the benzene and the filter or between the benzene and the materials captured on the filters that caused this residue to form. Furthermore, it is also believed that this residue is the reason many of the BSO sample results were higher than the total particulate matter results. As stated previously, using a pre-extracted silver-membrane in the cassette was to mitigate the problem of the BSO sample results being higher than the total particulate matter results.

4.2 Sampling and Analytical Results for 17 PAH Compounds.

The catch weight results of the PAH sampling and analysis are presented in Table Set II. The concentrations in mg/m^3 are presented in Table Set III. The concentrations in PPB are presented in Table Set IV.

The compound Acenaphthene was detected in all of the samples, including the background sample. Naphthalene was found in three of the background samples and in virtually all the worker samples (three roller operator samples did not report Naphthalene, one luteman sample did not report Naphthalene, and one quality control manager sample did not report Naphthalene). Acenaphthylene and Fluorene were found in virtually all the worker samples, while not in any of the background samples. Phenanthrene was found in most of the samples collected for each worker position except the roller operator, and not in any of the background samples. Anthracene was reported in 13 samples among the paver operator, screedman, and luteman samples. Of the 13 samples in which Anthracene was detected, 10 of the samples were collected while paving with rubber mixes--RBR 1, RBR 2, or RBR 3. Fluoranthene was reported in one paver operator sample (RBR 3--2nd day) and in one screedman sample (RBR 4--1st day). The rest were reported as "Not Detected." Of the detected compounds, only Naphthalene has an exposure level, as follows:

NAPHTHALENE:	NIOSH--10 PPM	OSHA--10 PPM
	NIOSH--50 mg/m^3	OSHA--50 mg/m^3

The Naphthalene results were in the ug/m^3 range and in the PPB range. Therefore, all of the workers were exposed to levels of Naphthalene significantly below the allowable eight-hour time weighted average concentration.

4.2.1 Problems with the Analytical Procedures Conducted for the PAH Analysis.

NIOSH Method 5506, which was specified by the MDOT Project Specifications, requires that the benzene extract from the filter (from NIOSH Method 5023) be analyzed for PAHs, as well as the extract from the XAD-2 resin in the glass sorbent tube, and uses high pressure liquid chromatography (HPLC) for the analysis. The method clearly stipulates that the filter extract is to be analyzed for PAH separately from the XAD-2 resin extract. The filter extract was not analyzed for PAHs by Data Chem. Their explanation for this omission was that they had originally only quoted for one PAH analysis, that most of their customers have the filter extract combined with the XAD-2 extract for a single analysis. Furthermore, they claim that they went by the Chain-of-Custody sheets which only listed particulate and benzene soluble organics (despite the work-orders which indicated that the PAH analysis was to be performed on the filter extract, and despite the fact that the method calls for analysis of the filter extract). Another problem that occurred was that Data Chem used NIOSH Method 5515 for the analysis, which uses gas chromatography, instead of NIOSH Method 5506. They claim it was because the samples were "dirty" and they routinely use gas chromatography for analysis of "dirty" samples.

4.3 Sampling and Analytical Results for Several Volatile Organic Compounds.

The catch weight results for the volatile organics sampling and analysis are presented in Table Set V. The concentrations as mg/m^3 are presented in Table Set VI. The concentrations as PPB are presented in Table Set VII.

Very few of the samples had reported results above the detection limits. In the case of Benzene, there were five samples with reported results above the detection limit of 1 ug/sample--one Paver Operator sample (RBR 3--2nd day), three Screedman samples (RBR 2--1st day, RBR 4--both days), and one Luteman sample (RBR 4--2nd day). In the case of Xylene, there were five samples with reported results above the detection limit of 10 ug/sample--one Paver Operator sample (RBR 3--2nd day), two Screedman samples (RBR 2--1st day, RBR 4--1st day), and two Luteman samples (RBR 1--1st day, RBR 2--1st day). The concentrations for the detected samples ranged from 3.06 PPB to 22.22 PPB for Benzene and from 24.40 PPB to 69.51 PPB for Xylene. The allowable exposure levels for these two compounds are as follows:

BENZENE: NIOSH--100 PPB; OSHA--1,000 PPB
XYLENE: NIOSH--100 PP*M*; OSHA--100 PP*M* . . . . . 435 mg/m^3

Styrene was not detected in any of the samples above the detection limit of 10 ug/sample.

4.4 Sampling and Analytical Results for 1,3-Butadiene.

The catch weight results and concentrations in mg/m^3 and PPB are provided in Table Set VIII. 1,3-Butadiene was found in one Background sample (RBR 4--1st day) and not in any of the Roller Operator samples. This compound was found in all the RBR 4 samples for all the other worker positions and in a significant number of the various RAP mix samples (in 22 of 35 RAP mix samples collected for all the worker positions combined except the Roller Operator position). 1,3-Butadiene was found in the virgin control mix of the Screedman position and in the virgin rubber mix of the Quality Control Manager.

OSHA has a PEL for 1,3-Butadiene of 1,000 PPM (2,200 mg/m^3), while ACGIH has a TLV of 10 PPM (22 mg/m^3). NIOSH does not provide an REL for 1,3-Butadiene because it classifies this compound as a carcinogen and, thus, its recommendation is to reduce worker exposure to the "lowest feasible concentration." ACGIH also classifies this compound as a carcinogen. ALL of the sample results for 1,3-Butadiene were significantly less than both the OSHA PEL and the ACGIH TLV--being at the PP*B* level. In fact, 23 of the 36 samples that reported detected levels of 1,3-Butadiene were at or below 0.1% of the ACGIH TLV and at or below 0.001% of the OSHA PEL.

4.5 Sampling and Analytical Results for Various Nitrosamines Compounds.

The catch weight results for various Nitrosamines compounds are presented in Table Set IX. The concentrations in ug/m^3 are presented in Table Set X, and the concentrations in PPB are provided in Table Set XI.

N-nitrosodimethylamine was detected in one background sample (CTRL 3--1st day) and N-nitrosodibutylamine was detected in one paver operator sample (CTRL 3--2nd day). Other than these two samples, nitrosamine compounds were not detected any of the samples collected and analyzed during the worker exposure sampling. N-nitrosodimethylamine is the only nitrosamine compound which is listed by OSHA, NIOSH, and ACGIH. All three organizations list this compound as a carcinogen and do not provide any exposure levels. However, since this compound was not detected in any of the worker samples, only the background sample, it should not be an issue with respect to worker exposure.

5.0 CONCLUSIONS.

The results of this worker exposure assessment project do not indicate a clear pattern that would suggest that asphalt-rubber binders or crumb rubber mixes increase a paving worker's exposure to hazardous compounds in asphalt fumes. The results also demonstrate that, for all samples and all mixes involved in the project, paving workers' exposures to the compounds looked at are significantly below exposure levels established by two governmental agencies and one nationally recognized voluntary organization.

TABLE 1. WORKER EXPOSURE SAMPLING AND ANALYTICAL PROCEDURES FOR MICHIGAN DEPARTMENT OF TRANSPORTATION'S ASPHALT-RUBBER BINDER STACK TESTING PROJECT

Compound	Analytical Procedure	Method Designation
Total Particulate	Gravimetry	Modified NIOSH Method 0500
Benzene-soluble organics	Benzene extraction followed by gravimetry	NIOSH Method 5023
PAHs (Semi-volatiles)	Benzene extraction, HPLC-fluorescence detector	NIOSH Method 5506
Benzene, Toluene, Ethyl-benzene, Xylene, Styrene	GC/FID	NIOSH Method 1501
1,3-Butadiene	GC/FID	OSHA 56
Nitrosamines (7 species)	GC/TEA	OSHA Method 27

NOTES:

Total Particulate Matter: The sample train shall include a pre-extracted and tared 37 mm silver membrane filter.

Benzene-Soluble Organics: The silver membrane filter used for the Particulate Matter determination shall be used for this procedure.

PAHs (semi-volatiles): The sample train shall include a pre-extracted and tared 37 mm silver membrane filter, followed by a glass tube containing 400 mg of XAD-2 resin separated from 200 mg of XAD-2 resin with glass wool. The glass tube shall be situated in the sample train such that the gas stream will pass through the 400 mg of XAD-2 resin first, then through the 200 mg of XAD-2 resin AFTER passing through the particulate filter cartridge.

TABLE 2. LIST OF FIELD BLANKS--SAMPLE NUMBERS AND LOCATION FOR EACH DAY OF WORKER EXPOSURE SAMPLING

LOCATION	DATE OF SAMPLING	COMPOUND	BLANK SAMPLE NO.
Paving Site	16-Sep-93	1,3-Butadiene	091693-B1
		BTEX	091693-A1
		Particulate/BSO Filter	091693-C1
		PAHs--XAD-2 resin	091693-C2
		Nitrosamines	E55808
Paving Site	17-Sep-93	1,3-Butadiene	091793-C+D
		BTEX	091793-A+B
		Particulate/BSO Filter	091793-E+F
		PAHs--XAD-2 resin	--
		Nitrosamines	E55923+E55884
Paving Site	20-Sep-93	1,3-Butadiene	092093-C+D
		BTEX	092093-A+B
		Particulate/BSO Filter	092093-E+F
		PAHs--XAD-2 resin	--
		Nitrosamines	E55795
HMA Facility	22-Sep-93	1,3-Butadiene	092293-C+D
		BTEX	092293-A+B
		Particulate/BSO Filter	092293-E+F
		PAHs--XAD-2 resin	--
		Nitrosamines	--
Paving Site	24-Sep-93	1,3-Butadiene	092493-C+D
		BTEX	092493-A+B
		Particulate/BSO Filter	092493-E+F
		PAHs--XAD-2 resin	--
		Nitrosamines	E56400+E56401
Paving Site	28-Sep-93	1,3-Butadiene	092893-C+D
		BTEX	092893-A+B
		Particulate/BSO Filter	092893-E+F
		PAHs--XAD-2 resin	--
		Nitrosamines	E56420
Paving Site	01-Oct-93	1,3-Butadiene	093093-C+D
		BTEX	093093-A+B
		Particulate/BSO Filter	093093-E+F
		PAHs--XAD-2 resin	--
		Nitrosamines	E56801

LOCATION	DATE OF SAMPLING	COMPOUND	BLANK SAMPLE NO.
HMA Facility	16-Sep-93	1,3-Butadiene	091693-B2
		BTEX	091693-A2
		Particulate/BSO Filter	--
		PAHs--XAD-2 resin	091693-C3
		Nitrosamines	--
HMA Facility	18-Sep-93	1,3-Butadiene	091893-C+D
		BTEX	091893-A+B
		Particulate/BSO Filter	091893-E+F
		PAHs--XAD-2 resin	--
		Nitrosamines	E55931+E55932
HMA Facility	21-Sep-93	1,3-Butadiene	092193-C+D
		BTEX	092193-A+B
		Particulate/BSO Filter	092193-E+F
		PAHs--XAD-2 resin	--
		Nitrosamines	E55797
Paving Site	23-Sep-93	1,3-Butadiene	092393-C+D
		BTEX	092393-A+B
		Particulate/BSO Filter	092393-E+F
		PAHs--XAD-2 resin	--
		Nitrosamines	E56402
HMA Facility	25-Sep-93	1,3-Butadiene	092593-C+D
		BTEX	092593-A+B
		Particulate/BSO Filter	092593-E+F
		PAHs--XAD-2 resin	--
		Nitrosamines	E56431+E56432
HMA Facility	29-Sep-93	1,3-Butadiene	092993-C+D
		BTEX	092993-A+B
		Particulate/BSO Filter	092993-E+F
		PAHs--XAD-2 resin	--
		Nitrosamines	E56416
HMA Facility	04-Oct-93	1,3-Butadiene	100493-C+D
		BTEX	100493-A+B
		Particulate/BSO Filter	100493-E+F
		PAHs--XAD-2 resin	--
		Nitrosamines	E56382

Table Set I
Particulate Matter and Benzene Soluble Organics
Worker Exposure Results

Catch Weight Results as ug/sample
Results as mg/m^3

TABLE SET I. PARTICULATE MATTER AND BENZENE SOLUBLE ORGANIC FRACTION SAMPLING AND ANALYTICAL RESULTS
(Units: ug/sample and mg/m^3)

Background Sample

Mix Type	Sampling Date	Sample Number	Sample Volume	Particulate ug	Benz. Sol Org ug	Particulate mg/m3	Benz Sol Org mg/m3
Detection Limits >>			Liters		0 05		0 00006
CTRL 1	16-Sep-93	23 B	804.1	600	ND	0 746	
CTRL 2	**17-Sep-93**	**24 B**	**666.0**	**40**	**ND**	**0.060**	
CTRL 2	**18-Sep-93**	**24 B**	**836.9**	**60**	**ND**	**0.060**	
CTRL 3	20-Sep-93	24 B	698.4	30	ND	0.043	
CTRL 3	21-Sep-93	24 B	595.6	50	150	0.084	0.252
RBR 1	**22-Sep-93**	**24 B**	**814.8**	**20**	**50**	**0.025**	**0.061**
RBR 1	**23-Sep-93**	**24 B**	**779.9**	**10**	**180**	**0.013**	**0.231**
RBR 2	24-Sep-93	24 B	883.1	30	ND	0.034	
RBR 2	25-Sep-93	24 B	887.0	70	650	0.079	0.733
RBR 3	28-Sep-93	24 B	766.4	30	ND	0.039	
RBR 3	29-Sep-93	24 B	828.8	20	50	0.024	0.060
RBR 4	**01-Oct-93**	**24 B**	**949.7**	**20**	**10**	**0.021**	**0.011**
RBR 4	**04-Oct-93**	**24 B**	**760.5**	**30**	**100**	**0.039**	**0.131**

NOTE: Shaded rows indicate mixes with 100% virgin aggregates. *Blanks indicate compound not detected in sample.*

Paver Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	Particulate ug	Benz. Sol. Org. ug	Particulate mg/m3	Benz. Sol. Org. mg/m3
Detection Limits >>			Liters		0.05		0.00006
CTRL 1	16-Sep-93	8 B	816.4	130	ND	0.159	
CTRL 2	**17-Sep-93**	**4 B**	**699.1**	**10**	**ND**	**0.014**	
CTRL 2	**18-Sep-93**	**4 B**	**844.2**	**90**	**50**	**0.107**	**0.059**
CTRL 3	20-Sep-93	4 B	606.4	70	700	0.115	1.154
CTRL 3	21-Sep-93	4 B	651.0	120	330	0.184	0.507
RBR 1	**22-Sep-93**	**4 B**	**844.4**	**60**	**80**	**0.071**	**0.095**
RBR 1	**23-Sep-93**	**4 B**	**756.6**	**70**	**80**	**0.093**	**0.106**
RBR 2	24-Sep-93	4 B	884.6	170	ND	0.192	
RBR 2	25-Sep-93	4 B	820.6	170	80	0.207	0.097
RBR 3	28-Sep-93	4 B	831.6	30	50	0.036	0.060
RBR 3	29-Sep-93	4 B	871.2	260	130	0.298	0.149
RBR 4	**01-Oct-93**	**4 B**	**831.6**	**90**	**50**	**0.108**	**0.060**
RBR 4	**04-Oct-93**	**4 B**	**712.8**	**120**	**150**	**0.168**	**0.210**

NOTE: Shaded rows indicate mixes with 100% virgin aggregates. *Blanks indicate compound not detected in sample.*

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP
RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Table Set I. .... (continued)

Roller Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	Particulate ug	Benz. Sol. Org. ug	Particulate mg/m3	Benz. Sol. Org. mg/m3
Detection Limits >>			Liters		0.05		0.00006
CTRL 1	16-Sep-93	4 B	789.1	140	ND	0.177	
CTRL 2	**17-Sep-93**	**20 B**	**807.5**	**70**	**ND**	**0.087**	
CTRL 2	**18-Sep-93**	**20 B**	**837.9**	**10**	**ND**	**0.012**	
CTRL 3	20-Sep-93	20 B	634.8	100	ND	0.158	
CTRL 3	21-Sep-93	20 B	661.5	80	100	0.121	0.151
RBR 1	**22-Sep-93**	**20 B**	**888.5**	**80**	**100**	**0.090**	**0.113**
RBR 1	**23-Sep-93**	**20 B**	**806.0**	**40**	**50**	**0.050**	**0.062**
RBR 2	24-Sep-93	20 B	872.9	130	ND	0.149	
RBR 2	25-Sep-93	20 B	913.5	60	ND	0.066	
RBR 3	28-Sep-93	20 B	894.4	70	50	0.078	0.056
RBR 3	29-Sep-93	20 B	825.8	270	100	0.327	0.121
RBR 4	**01-Oct-93**	**20 B**	**811.2**	**190**	**80**	**0.234**	**0.099**
RBR 4	**04-Oct-93**	**20 B**	**773.8**	**70**	**150**	**0.090**	**0.194**

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Screedman

Mix Type	Sampling Date	Sample Number	Sample Volume	Particulate ug	Benz. Sol. Org. ug	Particulate mg/m3	Benz. Sol. Org. mg/m3
Detection Limits >>			Liters		0.05		0.00006
CTRL 1	16-Sep-93	16 B	790.0	90	ND	0.114	
CTRL 2	**17-Sep-93**	**8 B**	**673.2**	**260**	**130**	**0.386**	**0.193**
CTRL 2	**18-Sep-93**	**8 B**	**813.5**	**170**	**ND**	**0.209**	
CTRL 3	20-Sep-93	12 B	647.5	110	200	0.170	0.309
CTRL 3	21-Sep-93	12 B	668.5	100	300	0.150	0.449
RBR 1	**22-Sep-93**	**12 B**	**880.5**	**80**	**400**	**0.091**	**0.454**
RBR 1	**23-Sep-93**	**12 B**	**762.6**	**50**	**1460**	**0.066**	**1.927**
RBR 2	24-Sep-93	12 B	853.6	190	ND	0.223	
RBR 2	25-Sep-93	12 B	842.0	90	ND	0.107	
RBR 3	28-Sep-93	12 B	756.6	400	400	0.529	0.529
RBR 3	29-Sep-93	12 B	938.8	480	330	0.511	0.351
RBR 4	**01-Oct-93**	**12 B**	**964.3**	**250**	**150**	**0.259**	**0.156**
RBR 4	**04-Oct-93**	**12 B**	**705.6**	**650**	**500**	**0.921**	**0.709**

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP
RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Table Set I. .... (continued)

Luteman

Mix Type	Sampling Date	Sample Number	Sample Volume	Particulate ug	Benz. Sol. Org. ug	Particulate mg/m3	Benz. Sol. Org. mg/m3
Detection Limits >>			Liters		0.05		0.00006
CTRL 1	16-Sep-93	12 B	794.8	110	ND	0.138	
CTRL 2	**17-Sep-93**	**12 B**	**705.6**	**160**	**ND**	**0.227**	
CTRL 2	**18-Sep-93**	**16 B**	**804.1**	**120**	**ND**	**0.149**	
CTRL 3	20-Sep-93	16 B	659.6	40	100	0.061	0.152
CTRL 3	21-Sep-93	16 B	638.5	140	80	0.219	0.125
RBR 1	**22-Sep-93**	**16 B**	**829.8**	**80**	**10**	**0.096**	**0.012**
RBR 1	**23-Sep-93**	**16 B**	**742.1**	**50**	**1000**	**0.067**	**1.347**
RBR 2	24-Sep-93	16 B	818.9	200	ND	0.244	
RBR 2	25-Sep-93	16 B	811.3	110	ND	0.136	
RBR 3	28-Sep-93	16 B	774.2	110	50	0.142	0.065
RBR 3	29-Sep-93	16 B	926.3	290	130	0.313	0.140
RBR 4	**01-Oct-93**	**16 B**	**941.9**	**260**	**200**	**0.276**	**0.212**
RBR 4	**04-Oct-93**	**16 B**	**709.8**	**170**	**150**	**0.240**	**0.211**

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Laborer

Mix Type	Sampling Date	Sample Number	Sample Volume	Particulate ug	Benz. Sol. Org. ug	Particulate mg/m3	Benz. Sol. Org. mg/m3
Detection Limits >>			Liters		0.05		0.00006
CTRL 1	16-Sep-93	20 B	838.9	190	50	0.226	0.060
CTRL 2	**17-Sep-93**	**16 B**	**482.2**	**110**	**ND**	**0.228**	
CTRL 2	**18-Sep-93**	**12 B**	**784.4**	**180**	**ND**	**0.229**	
CTRL 3	20-Sep-93	8 B	644.1	100	130	0.155	0.202
CTRL 3	21-Sep-93	8 B	669.3	40	ND	0.060	
RBR 1	**22-Sep-93**	**8 B**	**867.2**	**200**	**100**	**0.231**	**0.115**
RBR 1	**23-Sep-93**	**8 B**	**766.3**	**50**	**80**	**0.065**	**0.104**
RBR 2	24-Sep-93	8 B	865.7	90	ND	0.104	
RBR 2	25-Sep-93	8 B	861.7	90	ND	0.104	
RBR 3	28-Sep-93	8 B	771.6	40	ND	0.052	
RBR 3	29-Sep-93	8 B	979.7	320	100	0.327	0.102
RBR 4	**01-Oct-93**	**8 B**	**993.8**	**100**	**150**	**0.101**	**0.151**
RBR 4	**04-Oct-93**	**8 B**	**730.8**	**130**	**150**	**0.178**	**0.205**

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Table Set I. . . . . **(continued)**

Quality Control Manager

Mix Type	Sampling Date	Sample Number	Sample Volume	Particulate ug	Benz. Sol. Org. ug	Particulate mg/m3	Benz. Sol. Org. mg/m3
Detection Limits >>			Liters		0.05		0.00006
CTRL 1	16-Sep-93	25 B	807.5	70	ND	0.087	
CTRL 2	**17-Sep-93**	**28 B**	**675.1**	**90**	**ND**	**0.133**	
CTRL 2	**18-Sep-93**	**28 B**	**737.3**	**120**	**ND**	**0.163**	
CTRL 3	20-Sep-93	28 B	716.4	140	ND	0.195	
CTRL 3	21-Sep-93	28 B	722.4	220	100	0.305	0.138
RBR 1	**22-Sep-93**	**28 B**	**806.0**	**100**	**80**	**0.124**	**0.099**
RBR 1	**23-Sep-93**	**28 B**	**777.4**	**170**	**400**	**0.219**	**0.515**
RBR 2	24-Sep-93	28 B	846.1	210	12250	0.248	14.478
RBR 2	25-Sep-93	28 B	825.1	420	80	0.509	0.097
RBR 3	28-Sep-93	28 B	754.7	230	ND	0.305	
RBR 3	29-Sep-93	28 B	935.1	170	50	0.182	0.053
RBR 4	**01-Oct-93**	**28 B**	**954.5**	**180**	**150**	**0.189**	**0.157**
RBR 4	**04-Oct-93**	**28 B**	**931.2**	**190**	**150**	**0.204**	**0.161**

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Table Set II
Polynuclear Aromatic Hydrocarbon Worker Exposure Results

Results as ug/sample

TABLE SET II. POLYNUCLEAR AROMATIC HYDROCARBON SAMPLING AND ANALYTICAL RESULTS

(Units: ug/sample)

Background Sample

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene ug	Acenaphthylene ug	Acenaphthene ug	Fluorene ug	Phenanthrene ug	Anthracene ug	Fluoranthene ug
Detection Limits >>			Liters	0 5	0 5	0 5	0 5	0 5	0 5	0 5
CTRL 1	16-Sep-93	23 B	804.1			4 8				
CTRL 2	17-Sep-93	24 B	666.0			3.3				
CTRL 2	18-Sep-93	24 B	838.9	0.5		8.9				
CTRL 3	20-Sep-93	24 B	698.4	0.8		2.3				
CTRL 3	21-Sep-93	24 B	595.6			3.6				
RBR 1	22-Sep-93	24 B	814.8			5.9				
RBR 1	23-Sep-93	24 B	779.9			1.7				
RBR 2	24-Sep-93	24 B	883.1			4.7				
RBR 2	25-Sep-93	24 B	887.0			1.9				
RBR 3	28-Sep-93	24 B	766.4			1.6				
RBR 3	29-Sep-93	24 B	828.8			1.9				
RBR 4	01-Oct-93	24 B	949.7			2.3				
RBR 4	04-Oct-93	24 B	760.5	0.5		2.1				

NOTE: Shaded rows indicate mixes with 100% virgin aggregates. *Blanks indicate compound not detected in sample.*

Paver Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene ug	Acenaphthylene ug	Acenaphthene ug	Fluorene ug	Phenanthrene ug	Anthracene ug	Fluoranthene ug
Detection Limits >>			Liters	0.5	0.5	0.5	0.5	0.5	0.5	0.5
CTRL 1	16-Sep-93	8 B	816.4	4.2	2.0	7.7	4.3	0.9		
CTRL 2	17-Sep-93	4 B	699.1	3.4	3.3	16.0	7.4	0.8	1.1	
CTRL 2	18-Sep-93	4 B	844.2	2.4	1.5	5.0	3.2			
CTRL 3	20-Sep-93	4 B	606.4	4.6	2.7	12.0	4.7	0.8		
CTRL 3	21-Sep-93	4 B	651.0	3.2	1.9	6.0	3.9	0.7		
RBR 1	22-Sep-93	4 B	844.4	1.9	1.3	4.1	2.7			
RBR 1	23-Sep-93	4 B	756.6	3.2	3.1	12.0	6.5	0.8	0.6	
RBR 2	24-Sep-93	4 B	884.6	12.0	6.7	12.0	8.6	2.6	1.0	
RBR 2	25-Sep-93	4 B	820.6	9.2	7.2	27.0	17.0		2.3	
RBR 3	28-Sep-93	4 B	831.6	1.5	1.3	4.0	2.2			
RBR 3	29-Sep-93	4 B	871.2	9.3	7.7	24.0	15.0	1.1		0.5
RBR 4	01-Oct-93	4 B	831.6	2.3	2.2	6.3	4.2			
RBR 4	04-Oct-93	4 B	712.8	1.5	1.4	7.4	2.3			

NOTE: Shaded rows indicate mixes with 100% virgin aggregates. *Blanks indicate compound not detected in sample.*

Table Set II. . . . . (continued)

Roller Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene ug	Acenaphthylene ug	Acenaphthene ug	Fluorene ug	Phenanthrene ug	Anthracene ug	Fluoranthene ug
Detection Limits >>			Liters	0.5	0.5	0.5	0.5	0.5	0.5	0.5
CTRL 1	16-Sep-93	4 B	789.1	0.7		3.0	0.7			
CTRL 2	**17-Sep-93**	**20 B**	**807.5**			**3.0**	**1.0**			
CTRL 2	**18-Sep-93**	**20 B**	**837.9**	**1.4**	**0.8**	**6.1**	**1.9**			
CTRL 3	20-Sep-93	20 B	634.8			4.3	0.6			
CTRL 3	21-Sep-93	20 B	661.5	1.9	0.7	4.2	1.5			
RBR 1	**22-Sep-93**	**20 B**	**888.5**			**4.6**	**1.1**			
RBR 1	**23-Sep-93**	**20 B**	**806.0**	**1.0**	**0.9**	**7.4**	**2.2**			
RBR 2	24-Sep-93	20 B	872.9	4.5	2.2	12.0	4.5			
RBR 2	25-Sep-93	20 B	913.5	1.7	1.3	5.6	3.3			
RBR 3	28-Sep-93	20 B	894.4	1.5	0.9	4.4	1.6			
RBR 3	29-Sep-93	20 B	825.8	3.6	1.3	3.5	2.0			
RBR 4	**01-Oct-93**	**20 B**	**811.2**	**1.1**	**0.7**	**5.9**	**1.7**			
RBR 4	**04-Oct-93**	**20 B**	**773.8**	**3.5**	**0.5**	**3.1**	**0.9**			

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Screedman

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene ug	Acenaphthylene ug	Acenaphthene ug	Fluorene ug	Phenanthrene ug	Anthracene ug	Fluoranthene ug
Detection Limits >>			Liters	0.5	0.5	0.5	0.5	0.5	0.5	0.5
CTRL 1	16-Sep-93	16 B	790.0	3.3	1.6	6.8	3.2	0.8		
CTRL 2	**17-Sep-93**	**8 B**	**673.2**	**5.8**	**6.1**	**23.0**	**14.0**		**1.8**	
CTRL 2	**18-Sep-93**	**8 B**	**813.5**	**4.8**	**3.8**	**13.0**	**8.6**	**0.8**		
CTRL 3	20-Sep-93	12 B	647.5	3.8	2.4	7.3	4.2	0.7		
CTRL 3	21-Sep-93	12 B	668.5	3.7	2.4	10.0	5.1	0.9		
RBR 1	**22-Sep-93**	**12 B**	**880.5**	**2.1**	**1.7**	**8.0**	**3.9**	**0.6**		
RBR 1	**23-Sep-93**	**12 B**	**752.6**	**3.4**	**3.0**	**14.0**	**6.6**	**0.9**	**0.7**	
RBR 2	24-Sep-93	12 B	853.6	20.0	11.0	26.0	15.0	3.2	1.5	
RBR 2	25-Sep-93	12 B	842.0	3.1	2.8	9.1	6.7		1.0	
RBR 3	28-Sep-93	12 B	756.6	7.8	6.2	22.0	14.0	1.7	0.8	
RBR 3	29-Sep-93	12 B	938.8	8.5	7.0	23.0	14.0	2.0		
RBR 4	**01-Oct-93**	**12 B**	**964.3**	**6.5**	**7.6**	**27.0**	**18.0**	**2.6**		**0.5**
RBR 4	**04-Oct-93**	**12 B**	**705.6**	**6.8**	**7.1**	**20.0**	**15.0**	**1.4**		

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP

RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Table Set II. .... (continued)

Luteman

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene ug	Acenaphthylene ug	Acenaphthene ug	Fluorene ug	Phenanthrene ug	Anthracene ug	Fluoranthene ug
Detection Limits >>			Liters	0.5	0.5	0.5	0.5	0.5	0.5	0.5
CTRL 1	16-Sep-93	12 B	794.8	2.6	1.2	5.1	2.6	0.6		
CTRL 2	17-Sep-93	12 B	705.6	6.6	4.8	22.0	9.1	0.7		
CTRL 2	18-Sep-93	16 B	804.1	4.3	3.2	11.0	7.0	0.6		
CTRL 3	20-Sep-93	16 B	659.6	2.9	1.6	8.2	3.0			
CTRL 3	21-Sep-93	16 B	638.5	4.9	3.6	14.0	7.3	1.1	0.6	
RBR 1	22-Sep-93	16 B	829.8	5.7	4.0	18.0	8.0	1.0	0.5	
RBR 1	23-Sep-93	16 B	742.1	5.8	4.4	19.0	9.7	1.2	1.0	
RBR 2	24-Sep-93	16 B	818.9		6.6	28.0	15.0		0.8	
RBR 2	25-Sep-93	16 B	811.3	2.6	2.2	9.7	5.1			
RBR 3	28-Sep-93	16 B	774.2	3.1	2.2	7.0	3.7			
RBR 3	29-Sep-93	16 B	926.3	6.9	3.9	14.0	6.7	0.9		
RBR 4	01-Oct-93	16 B	941.9	3.8	3.5	13.0	7.7	0.6		
RBR 4	04-Oct-93	16 B	709.8	2.0	2.0	7.1	3.5			

NOTE: Shaded rows indicate mixes with 100% virgin aggregates. *Blanks indicate compound not detected in sample.*

Laborer

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene ug	Acenaphthylene ug	Acenaphthene ug	Fluorene ug	Phenanthrene ug	Anthracene ug	Fluoranthene ug
Detection Limits >>			Liters	0.5	0.5	0.5	0.5	0.5	0.5	0.5
CTRL 1	16-Sep-93	20 B	838.9	3.0	1.4	6.3	3.4	0.8		
CTRL 2	17-Sep-93	16 B	482.2	1.3	1.1	7.5	2.1			
CTRL 2	18-Sep-93	12 B	784.4	2.4	2.0	8.0	5.0	0.5		
CTRL 3	20-Sep-93	8 B	644.1	3.1	2.2	10.0	3.7	0.7		
CTRL 3	21-Sep-93	8 B	669.3	1.2	0.8	4.6	1.7			
RBR 1	22-Sep-93	8 B	867.2	1.4	1.2	8.6	2.1			
RBR 1	23-Sep-93	8 B	766.3	1.9	2.1	12.0	4.5	0.6		
RBR 2	24-Sep-93	8 B	865.7	2.8	2.1	11.0	4.0	0.6		
RBR 2	25-Sep-93	8 B	861.7	1.7	1.7	9.0	3.8			
RBR 3	28-Sep-93	8 B	771.6	1.0	0.8	4.1	1.3			
RBR 3	29-Sep-93	8 B	979.7	4.5	3.0	11.0	5.6	0.9		
RBR 4	01-Oct-93	8 B	993.8	3.0	2.5	11.0	5.5	0.6		
RBR 4	04-Oct-93	8 B	730.8	1.3	1.1	5.0	1.8			

NOTE: Shaded rows indicate mixes with 100% virgin aggregates. *Blanks indicate compound not detected in sample.*

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP
RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Table Set II. . . . . (continued)

Quality Control Manage

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene ug	Acenaphthylene ug	Acenaphthene ug	Fluorene ug	Phenanthrene ug	Anthracene ug	Fluoranthene ug
Detection Limits >>			Liters	0.5	0.5	0.5	0.5	0.5	0.5	0.5
CTRL 1	16-Sep-93	25 B	807.5	8.3		2.3	1.3			
CTRL 2	17-Sep-93	28 B	675.1			7.2	1.0			
CTRL 2	18-Sep-93	28 B	737.3	4.1		6.4				
CTRL 3	20-Sep-93	28 B	716.4	4.7	0.8	6.6	1.8			
CTRL 3	21-Sep-93	28 B	722.4	5.3	0.7	7.8	1.5			
RBR 1	22-Sep-93	28 B	806.0	3.9	0.6	4.5	1.4			
RBR 1	23-Sep-93	28 B	777.4	3.3	0.7	2.3	2.3			
RBR 2	24-Sep-93	28 B	846.1	3.4	0.8	11.0	1.9			
RBR 2	25-Sep-93	28 B	825.1	16.0	0.9	3.5	2.2			
RBR 3	28-Sep-93	28 B	754.7	3.7	0.9	7.7	1.9			
RBR 3	29-Sep-93	28 B	935.1	5.7	0.7	14.0	1.7	0.7		
RBR 4	01-Oct-93	28 B	954.5	8.4	0.5	10.0	1.1			
RBR 4	04-Oct-93	28 B	931.2	3.2	0.7	9.3	1.8			

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Table Set III
Polynuclear Aromatic Hydrocarbon Worker Exposure Results

Concentrations as mg/m^3

TABLE SET III. POLYNUCLEAR AROMATIC HYDROCARBON SAMPLING AND ANALYTICAL RESULTS

(Units: mg/m^3)

Background Sample

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene mg/m3	Acenaphthylene mg/m3	Acenaphthene mg/m3	Fluorene mg/m3	Phenanthrene mg/m3	Anthracene mg/m3	Fluoranthene mg/m3
Detection Limits >>			Liters	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
CTRL 1	16-Sep-93	23 B	804.1			0.0060				
CTRL 2	17-Sep-93	24 B	846.0			0.0050				
CTRL 2	18-Sep-93	24 B	836.9	0.0006		0.0108				
CTRL 3	20-Sep-93	24 B	698.4	0.0011		0.0033				
CTRL 3	21-Sep-93	24 B	595.6			0.0060				
RBR 1	22-Sep-93	24 B	614.1			0.0072				
RBR 1	23-Sep-93	24 B	779.9			0.0022				
RBR 2	24-Sep-93	24 B	883.1			0.0053				
RBR 2	25-Sep-93	24 B	887.0			0.0021				
RBR 3	28-Sep-93	24 B	766.4			0.0021				
RBR 3	29-Sep-93	24 B	828.8			0.0023				
RBR 4	01-Oct-93	24 B	948.7			0.0024				
RBR 4	04-Oct-93	24 B	760.6	0.0007		0.0028				

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Paver Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene mg/m3	Acenaphthylene mg/m3	Acenaphthene mg/m3	Fluorene mg/m3	Phenanthrene mg/m3	Anthracene mg/m3	Fluoranthene mg/m3
Detection Limits >>			Liters	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
CTRL 1	16-Sep-93	8 B	816.4	0.0051	0.0024	0.0094	0.0053	0.0011		
CTRL 2	17-Sep-93	4 B	699.1	0.0049	0.0047	0.0229	0.0126	0.0011	0.0016	
CTRL 2	18-Sep-93	4 B	844.2	0.0028	0.0018	0.0056	0.0033			
CTRL 3	20-Sep-93	4 B	606.4	0.0076	0.0045	0.0198	0.0078	0.0013		
CTRL 3	21-Sep-93	4 B	651.0	0.0049	0.0029	0.0092	0.0060	0.0011		
RBR 1	22-Sep-93	4 B	744.4	0.0023	0.0015	0.0049	0.0032	0.0011	0.0008	
RBR 1	23-Sep-93	4 B	786.8	0.0042	0.0041	0.0159	0.0085			
RBR 2	24-Sep-93	4 B	884.6	0.0136	0.0076	0.0136	0.0097	0.0029	0.0011	
RBR 2	25-Sep-93	4 B	820.6	0.0112	0.0088	0.0329	0.0207		0.0028	
RBR 3	28-Sep-93	4 B	831.6	0.0018	0.0016	0.0048	0.0026			
RBR 3	29-Sep-93	4 B	871.2	0.0107	0.0088	0.0275	0.0172	0.0013		0.0006
RBR 4	01-Oct-93	4 B	831.6	0.0028	0.0026	0.0076	0.0051			
RBR 4	04-Oct-93	4 B	712.6	0.0021	0.0020	0.0104	0.0032			

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP

RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Table Set III. .... (continued)

Roller Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene mg/m3	Acenaphthylene mg/m3	Acenaphthene mg/m3	Fluorene mg/m3	Phenanthrene mg/m3	Anthracene mg/m3	Fluoranthene mg/m3
Detection Limits >>			Liters	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
CTRL 1	16-Sep-93	4 B	789.1	0.0009		0.0038	0.0009			
CTRL 2	17-Sep-93	20 B	807.8			0.0037	0.0012			
CTRL 2	18-Sep-93	20 B	837.9	0.0017	0.0010	0.0073	0.0023			
CTRL 3	20-Sep-93	20 B	634.8			0.0068	0.0009			
CTRL 3	21-Sep-93	20 B	661.5	0.0029	0.0011	0.0063	0.0023			
RBR 1	22-Sep-93	20 B	685.5			0.0052	0.0012			
RBR 1	23-Sep-93	20 B	696.0	0.0012	0.0011	0.0092	0.0027			
RBR 2	24-Sep-93	20 B	872.9	0.0052	0.0025	0.0137	0.0052			
RBR 2	25-Sep-93	20 B	913.5	0.0019	0.0014	0.0061	0.0036			
RBR 3	28-Sep-93	20 B	894.4	0.0017	0.0010	0.0049	0.0018			
RBR 3	29-Sep-93	20 B	825.8	0.0044	0.0016	0.0042	0.0024			
RBR 4	01-Oct-93	20 B	611.2	0.0014	0.0009	0.0073	0.0021			
RBR 4	04-Oct-93	20 B	773.8	0.0045	0.0008	0.0040	0.0012			

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Screedman

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene mg/m3	Acenaphthylene mg/m3	Acenaphthene mg/m3	Fluorene mg/m3	Phenanthrene mg/m3	Anthracene mg/m3	Fluoranthene mg/m3
Detection Limits >>			Liters	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
CTRL 1	16-Sep-93	16 B	790.0	0.0042	0.0020	0.0086	0.0041	0.0010		
CTRL 2	17-Sep-93	8 B	673.2	0.0086	0.0091	0.0342	0.0208		0.0027	
CTRL 2	18-Sep-93	8 B	813.5	0.0059	0.0047	0.0160	0.0108	0.0010		
CTRL 3	20-Sep-93	12 B	647.5	0.0059	0.0037	0.0113	0.0065	0.0011		
CTRL 3	21-Sep-93	12 B	668.5	0.0055	0.0036	0.0150	0.0076	0.0013		
RBR 1	22-Sep-93	12 B	850.5	0.0024	0.0019	0.0091	0.0044	0.0007		
RBR 1	23-Sep-93	12 B	782.6	0.0045	0.0040	0.0186	0.0088	0.0012	0.0009	
RBR 2	24-Sep-93	12 B	853.6	0.0234	0.0129	0.0305	0.0176	0.0037	0.0018	
RBR 2	25-Sep-93	12 B	842.0	0.0037	0.0033	0.0108	0.0080		0.0012	
RBR 3	28-Sep-93	12 B	756.6	0.0103	0.0082	0.0291	0.0185	0.0022	0.0011	
RBR 3	29-Sep-93	12 B	938.8	0.0091	0.0075	0.0245	0.0149	0.0021		
RBR 4	01-Oct-93	12 B	954.3	0.0087	0.0079	0.0280	0.0187	0.0027		0.0005
RBR 4	04-Oct-93	12 B	795.6	0.0096	0.0101	0.0283	0.0213	0.0020		

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Table Set III. . . . . (continued)

Luteman

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene mg/m3	Acenaphthylene mg/m3	Acenaphthene mg/m3	Fluorene mg/m3	Phenanthrene mg/m3	Anthracene mg/m3	Fluoranthene mg/m3
Detection Limits >>			Liters	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
CTRL 1	16-Sep-93	12 B	794.8	0.0033	0.0015	0.0064	0.0033	0.0008		
CTRL 2	17-Sep-93	12 B	705.6	0.0094	0.0068	0.0312	0.0129	0.0010		
CTRL 2	18-Sep-93	16 B	804.1	0.0053	0.0040	0.0137	0.0087	0.0007		
CTRL 3	20-Sep-93	16 B	659.6	0.0044	0.0024	0.0124	0.0045			
CTRL 3	21-Sep-93	16 B	638.5	0.0077	0.0056	0.0219	0.0114	0.0017	0.0009	
RBR 1	22-Sep-93	16 B	629.8	0.0069	0.0048	0.0217	0.0096	0.0012	0.0006	
RBR 1	23-Sep-93	16 B	742.1	0.0078	0.0059	0.0258	0.0131	0.0016	0.0013	
RBR 2	24-Sep-93	16 B	818.9		0.0081	0.0342	0.0183		0.0010	
RBR 2	25-Sep-93	16 B	811.3	0.0032	0.0027	0.0120	0.0063			
RBR 3	28-Sep-93	16 B	774.2	0.0040	0.0028	0.0090	0.0048			
RBR 3	29-Sep-93	16 B	926.3	0.0074	0.0042	0.0151	0.0072	0.0010		
RBR 4	01-Oct-93	16 B	941.8	0.0040	0.0037	0.0135	0.0082	0.0006		
RBR 4	04-Oct-93	16 B	709.8	0.0028	0.0028	0.0100	0.0049			

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Laborer

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene mg/m3	Acenaphthylene mg/m3	Acenaphthene mg/m3	Fluorene mg/m3	Phenanthrene mg/m3	Anthracene mg/m3	Fluoranthene mg/m3
Detection Limits >>			Liters	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
CTRL 1	16-Sep-93	20 B	838.9	0.0036	0.0017	0.0075	0.0041	0.0010		
CTRL 2	17-Sep-93	16 B	482.2	0.0027	0.0023	0.0156	0.0044			
CTRL 2	18-Sep-93	12 B	784.4	0.0031	0.0025	0.0102	0.0064	0.0008		
CTRL 3	20-Sep-93	8 B	644.1	0.0048	0.0034	0.0155	0.0057	0.0011		
CTRL 3	21-Sep-93	8 B	669.3	0.0018	0.0012	0.0069	0.0025			
RBR 1	22-Sep-93	8 B	567.2	0.0016	0.0014	0.0098	0.0024			
RBR 1	23-Sep-93	8 B	756.3	0.0025	0.0027	0.0157	0.0059	0.0008		
RBR 2	24-Sep-93	8 B	865.7	0.0032	0.0024	0.0127	0.0046	0.0007		
RBR 2	25-Sep-93	8 B	861.7	0.0020	0.0020	0.0104	0.0044			
RBR 3	28-Sep-93	8 B	771.6	0.0013	0.0010	0.0053	0.0017			
RBR 3	29-Sep-93	8 B	979.7	0.0046	0.0031	0.0112	0.0057	0.0009		
RBR 4	01-Oct-93	8 B	593.8	0.0030	0.0025	0.0111	0.0055	0.0006		
RBR 4	04-Oct-93	8 B	730.8	0.0018	0.0015	0.0068	0.0025			

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Table Set III. . . . . (continued)

Quality Control Manager

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene mg/m3	Acenaphthylene mg/m3	Acenaphthene mg/m3	Fluorene mg/m3	Phenanthrene mg/m3	Anthracene mg/m3	Fluoranthene mg/m3
Detection Limits >>			Liters	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
CTRL 1	16-Sep-93	25 B	807.5	0.0103		0.0028	0.0016			
CTRL 2	17-Sep-93	26 B	676.1			0.0107	0.0016			
CTRL 2	18-Sep-93	26 B	737.3	0.0058		0.0087				
CTRL 3	20-Sep-93	28 B	716.4	0.0066	0.0011	0.0092	0.0025			
CTRL 3	21-Sep-93	28 B	722.4	0.0073	0.0010	0.0108	0.0021			
RBR 1	22-Sep-93	28 B	806.0	0.0046	0.0007	0.0056	0.0017			
RBR 1	23-Sep-93	28 B	777.4	0.0042	0.0009	0.0039	0.0030			
RBR 2	24-Sep-93	28 B	846.1	0.0040	0.0009	0.0130	0.0022			
RBR 2	25-Sep-93	28 B	825.1	0.0194	0.0011	0.0042	0.0027			
RBR 3	28-Sep-93	28 B	754.7	0.0049	0.0012	0.0102	0.0025			
RBR 3	29-Sep-93	28 B	935.1	0.0061	0.0007	0.0150	0.0018	0.0007		
RBR 4	01-Oct-93	28 B	864.5	0.0058	0.0005	0.0105	0.0012			
RBR 4	04-Oct-93	28 B	831.2	0.0034	0.0004	0.0100	0.0018			

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP

RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Table Set IV
Polynuclear Aromatic Hydrocarbons
Worker Exposure Results

Concentrations as PPB

TABLE SET IV. POLYNUCLEAR AROMATIC HYDROCARBON SAMPLING AND ANALYTICAL RESULTS (Units: PPB)

Background Sample

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene PPB	Acenaphthylene PPB	Acenaphthene PPB	Fluorene PPB	Phenanthrene PPB	Anthracene PPB	Fluoranthene PPB
Detection Limits >>			Liters	0.119	0.100	0.099	0.092	0.085	0.085	0.075
CTRL 1	16-Sep-93	23 B	804.1			0.931				
CTRL 2	17-Sep-93	24 B	666.0			0.773				
CTRL 2	18-Sep-93	24 B	836.9	0.112		1.669				
CTRL 3	20-Sep-93	24 B	698.4	0.215		0.514				
CTRL 3	21-Sep-93	24 B	595.6			0.943				
RBR 1	22-Sep-93	24 B	814.8			1.130				
RBR 1	23-Sep-93	24 B	779.9			0.340				
RBR 2	24-Sep-93	24 B	883.1			0.830				
RBR 2	25-Sep-93	24 B	887.0			0.334				
RBR 3	28-Sep-93	24 B	766.4			0.326				
RBR 3	29-Sep-93	24 B	828.8			0.358				
RBR 4	01-Oct-93	24 B	949.7			0.378				
RBR 4	04-Oct-93	24 B	760.6	0.123		0.431				

NOTE: Shaded rows indicate mixes with 100% virgin aggregates. *Blanks indicate compound not detected in sample.*

Paver Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene PPB	Acenaphthylene PPB	Acenaphthene PPB	Fluorene PPB	Phenanthrene PPB	Anthracene PPB	Fluoranthene PPB
Detection Limits >>			Liters	0.120	0.101	0.100	0.092	0.086	0.086	0.076
CTRL 1	16-Sep-93	8 B	816.4	0.966	0.387	1.471	0.762	0.149		
CTRL 2	17-Sep-93	4 B	699.1	0.913	0.746	3.570	1.532	0.154	0.212	
CTRL 2	18-Sep-93	4 B	844.2	0.534	0.281	0.924	0.549			
CTRL 3	20-Sep-93	4 B	606.4	1.424	0.704	3.087	1.122	0.178		
CTRL 3	21-Sep-93	4 B	651.0	0.923	0.461	1.438	0.867	0.145		
RBR 1	22-Sep-93	4 B	844.4	0.422	0.243	0.757	0.463			
RBR 1	23-Sep-93	4 B	756.6	0.794	0.648	2.474	1.243	0.143	0.107	
RBR 2	24-Sep-93	4 B	884.6	2.546	1.197	2.116	1.407	0.397	0.153	
RBR 2	25-Sep-93	4 B	820.6	2.104	1.387	5.132	2.998		0.378	
RBR 3	28-Sep-93	4 B	831.6	0.339	0.247	0.750	0.383			
RBR 3	29-Sep-93	4 B	871.2	2.003	1.397	4.297	2.492	0.170		0.068
RBR 4	01-Oct-93	4 B	831.6	0.519	0.418	1.182	0.731			
RBR 4	04-Oct-93	4 B	712.8	0.395	0.310	1.619	0.467			

NOTE: Shaded rows indicate mixes with 100% virgin aggregates. *Blanks indicate compound not detected in sample.*

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP

RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Table Set IV. . . . . (continued)

Roller Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene PPB	Acenaphthylene PPB	Acenaphthene PPB	Fluorene PPB	Phenanthrene PPB	Anthracene PPB	Fluoranthene PPB
Detection Limits >>			Liters	0.116	0.098	0.096	0.089	0.083	0.083	0.074
CTRL 1	16-Sep-93	4 B	789.1	0.166		0.593	0.128			
CTRL 2	17-Sep-93	20 B	807.5			0.580	0.179			
CTRL 2	18-Sep-93	20 B	837.9	0.314	0.151	1.136	0.328			
CTRL 3	20-Sep-93	20 B	634.8			1.057	0.137			
CTRL 3	21-Sep-93	20 B	661.5	0.539	0.167	0.990	0.328			
RBR 1	22-Sep-93	20 B	888.5			0.808	0.179			
RBR 1	23-Sep-93	20 B	806.0	0.233	0.176	1.432	0.395			
RBR 2	24-Sep-93	20 B	872.9	0.968	0.398	2.144	0.746			
RBR 2	25-Sep-93	20 B	913.5	0.349	0.225	0.956	0.523			
RBR 3	28-Sep-93	20 B	894.4	0.315	0.159	0.767	0.259			
RBR 3	29-Sep-93	20 B	825.8	0.818	0.249	0.661	0.351			
RBR 4	01-Oct-93	20 B	811.2	0.254	0.136	1.135	0.303			
RBR 4	04-Oct-93	20 B	773.8	0.849	0.102	0.625	0.168			

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Screedman

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene PPB	Acenaphthylene PPB	Acenaphthene PPB	Fluorene PPB	Phenanthrene PPB	Anthracene PPB	Fluoranthene PPB
Detection Limits >>			Liters	0.119	0.100	0.099	0.091	0.085	0.085	0.075
CTRL 1	16-Sep-93	16 B	790.0	0.784	0.320	1.343	0.586	0.137		
CTRL 2	17-Sep-93	8 B	673.2	1.617	1.432	5.329	3.010		0.361	
CTRL 2	18-Sep-93	8 B	813.5	1.107	0.738	2.493	1.530	0.133		
CTRL 3	20-Sep-93	12 B	647.5	1.101	0.586	1.759	0.939	0.146		
CTRL 3	21-Sep-93	12 B	668.5	1.039	0.567	2.333	1.104	0.182		
RBR 1	22-Sep-93	12 B	880.5	0.448	0.305	1.417	0.641	0.092		
RBR 1	23-Sep-93	12 B	752.6	0.848	0.630	2.902	1.269	0.161	0.126	
RBR 2	24-Sep-93	12 B	853.6	4.397	2.037	4.751	2.543	0.506	0.237	
RBR 2	25-Sep-93	12 B	842.0	0.691	0.526	1.686	1.152		0.160	
RBR 3	28-Sep-93	12 B	756.6	1.935	1.295	4.536	2.678	0.303	0.143	
RBR 3	29-Sep-93	12 B	938.8	1.699	1.178	3.821	2.158	0.288		
RBR 4	01-Oct-93	12 B	964.3	1.265	1.246	4.368	2.701	0.364		0.062
RBR 4	04-Oct-93	12 B	705.6	1.809	1.590	4.421	3.076	0.268		

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Table Set IV. .... **(continued)**

Luteman

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene PPB	Acenaphthylene PPB	Acenaphthene PPB	Fluorene PPB	Phenanthrene PPB	Anthracene PPB	Fluoranthene PPB
Detection Limits >>			Liters	0.120	0.101	0.100	0.093	0.086	0.086	0.076
CTRL 1	16-Sep-93	12 B	794.8	0.614	0.239	1.001	0.473	0.102		
CTRL 2	**17-Sep-93**	**12 B**	**705.6**	**1.756**	**1.075**	**4.864**	**1.866**	**0.134**		
CTRL 2	**18-Sep-93**	**16 B**	**804.1**	**1.004**	**0.629**	**2.134**	**1.260**	**0.101**		
CTRL 3	20-Sep-93	16 B	659.6	0.825	0.383	1.939	0.658			
CTRL 3	21-Sep-93	16 B	638.5	1.440	0.891	3.420	1.655	0.233	0.127	
RBR 1	**22-Sep-93**	**16 B**	**829.8**	**1.289**	**0.762**	**3.384**	**1.395**	**0.163**	**0.081**	
RBR 1	**23-Sep-93**	**16 B**	**742.1**	**1.467**	**0.937**	**3.994**	**1.892**	**0.218**	**0.182**	
RBR 2	24-Sep-93	16 B	818.9		1.274	5.334	2.651		0.132	
RBR 2	25-Sep-93	16 B	811.3	0.601	0.429	1.865	0.910			
RBR 3	28-Sep-93	16 B	774.2	0.752	0.449	1.410	0.692			
RBR 3	29-Sep-93	16 B	926.3	1.398	0.665	2.358	1.047	0.131		
RBR 4	**01-Oct-93**	**16 B**	**941.9**	**0.757**	**0.587**	**2.153**	**1.183**	**0.086**		
RBR 4	**04-Oct-93**	**16 B**	**709.8**	**0.529**	**0.445**	**1.560**	**0.714**			

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.   *Blanks indicate compound not detected in sample.*

Laborer

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene PPB	Acenaphthylene PPB	Acenaphthene PPB	Fluorene PPB	Phenanthrene PPB	Anthracene PPB	Fluoranthene PPB
Detection Limits >>			Liters	0.119	0.100	0.099	0.092	0.086	0.086	0.075
CTRL 1	16-Sep-93	20 B	838.9	0.671	0.264	1.171	0.587	0.129		
CTRL 2	**17-Sep-93**	**16 B**	**482.2**	**0.506**	**0.361**	**2.426**	**0.630**			
CTRL 2	**18-Sep-93**	**12 B**	**784.4**	**0.574**	**0.403**	**1.591**	**0.922**	**0.086**		
CTRL 3	20-Sep-93	8 B	644.1	0.903	0.540	2.422	0.831	0.147		
CTRL 3	21-Sep-93	8 B	669.3	0.336	0.189	1.072	0.368			
RBR 1	**22-Sep-93**	**8 B**	**867.2**	**0.303**	**0.219**	**1.547**	**0.350**			
RBR 1	**23-Sep-93**	**8 B**	**766.3**	**0.465**	**0.433**	**2.443**	**0.850**	**0.106**		
RBR 2	24-Sep-93	8 B	865.7	0.607	0.383	1.982	0.669	0.094		
RBR 2	25-Sep-93	8 B	861.7	0.370	0.312	1.629	0.638			
RBR 3	28-Sep-93	8 B	771.6	0.243	0.164	0.829	0.244			
RBR 3	29-Sep-93	8 B	979.7	0.862	0.484	1.751	0.827	0.124		
RBR 4	**01-Oct-93**	**8 B**	**993.8**	**0.567**	**0.398**	**1.727**	**0.801**	**0.081**		
RBR 4	**04-Oct-93**	**8 B**	**730.8**	**0.334**	**0.238**	**1.067**	**0.356**			

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.   *Blanks indicate compound not detected in sample.*

Quality Control Manage

Mix Type	Sampling Date	Sample Number	Sample Volume	Naphthalene PPB	Acenaphthylene PPB	Acenaphthene PPB	Fluorene PPB	Phenanthrene PPB	Anthracene PPB	Fluoranthene PPB
Detection Limits >>			Liters	0.116	0.098	0.097	0.090	0.084	0.084	0.074
CTRL 1	16-Sep-93	25 B	807.5	1.929		0.444	0.233			
CTRL 2	**17-Sep-93**	**28 B**	**675.1**			**1.664**	**0.214**			
CTRL 2	**18-Sep-93**	**28 B**	**737.3**	**1.044**		**1.354**				
CTRL 3	20-Sep-93	28 B	716.4	1.231	0.176	1.437	0.364			
CTRL 3	21-Sep-93	28 B	722.4	1.377	0.153	1.684	0.301			
RBR 1	**22-Sep-93**	**28 B**	**806.0**	**0.908**	**0.118**	**0.871**	**0.251**			
RBR 1	**23-Sep-93**	**28 B**	**777.4**	**0.797**	**0.142**	**0.462**	**0.428**			
RBR 2	24-Sep-93	28 B	846.1	0.754	0.149	2.028	0.325			
RBR 2	25-Sep-93	28 B	825.1	3.639	0.172	0.662	0.386			
RBR 3	28-Sep-93	28 B	754.7	0.920	0.188	1.592	0.364			
RBR 3	29-Sep-93	28 B	935.1	1.144	0.118	2.335	0.263	0.101		
RBR 4	**01-Oct-93**	**28 B**	**964.5**	**1.662**	**0.083**	**1.634**	**0.167**			
RBR 4	**04-Oct-93**	**28 B**	**931.2**	**0.645**	**0.119**	**1.558**	**0.280**			

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blenks indicate compound not detected in sample.

Table Set V
Benzene, Toluene, Ethylbenzene, Xylene, and Styrene
Worker Exposure Results

Results as ug/sample

TABLE SET V. VOLATILE ORGANIC COMPOUNDS SAMPLING AND ANALYTICAL RESULTS
(Units: ug/sample)

Background Sample

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene ug	EthylBenzene ug	Toluene ug	Xylene ug	Styrene ug
Detection Limits >>			Liters	1	10	10	10	10
CTRL 1	16-Sep-93	21 A & B	88.0					
CTRL 2	**17-Sep-93**	**21 A & B**	**69.9**					
CTRL 2	**18-Sep-93**	**21 A & B**	**92.4**					
CTRL 3	20-Sep-93	21 A & B	77.8					
CTRL 3	21-Sep-93	21 A & B	66.3					
RBR 1	**22-Sep-93**	**21 A & B**	**90.7**					
RBR 1	**23-Sep-93**	**21 A & B**	**84.2**					
RBR 2	24-Sep-93	21 A & B	99.9					
RBR 2	25-Sep-93	21 A & B	92.6					
RBR 3	28-Sep-93	21 A & B	90.3					
RBR 3	29-Sep-93	21 A & B	94.6					
RBR 4	**01-Oct-93**	**21 A & B**	**90.3**					
RBR 4	**04-Oct-93**	**21 A & B**	**83.9**					

NOTE: Shaded rows indicate mixes with 100% virgin aggregates. *Blanks indicate compound not detected in sample.*

Paver Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene ug	EthylBenzene ug	Toluene ug	Xylene ug	Styrene ug
Detection Limits >>			Liters	1	10	10	10	10
CTRL 1	16-Sep-93	5 A & B	85.0					
CTRL 2	**17-Sep-93**	**1 A & B**	**49.9**					
CTRL 2	**18-Sep-93**	**1 A & B**	**82.1**					
CTRL 3	20-Sep-93	1 A & B	58.0					
CTRL 3	21-Sep-93	1 A & B	72.1					
RBR 1	**22-Sep-93**	**1 A & B**	**91.3**					
RBR 1	**23-Sep-93**	**1 A & B**	**80.2**					
RBR 2	24-Sep-93	1 A & B	85.3					
RBR 2	25-Sep-93	1 A & B	92.7					
RBR 3	28-Sep-93	1 A & B	67.1					
RBR 3	29-Sep-93	1 A & B	100.7	1			10	
RBR 4	**01-Oct-93**	**1 A & B**	**102.4**					
RBR 4	**04-Oct-93**	**1 A & B**	**76.3**					

NOTE: Shaded rows indicate mixes with 100% virgin aggregates. *Blanks indicate compound not detected in sample.*

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP
RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Table Set V. .... (continued)

Roller Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene ug	EthylBenzene ug	Toluene ug	Xylene ug	Styrene ug
Detection Limits >>			Liters	1	10	10	10	10
CTRL 1	16-Sep-93	1 A & B	85.7					
CTRL 2	**17-Sep-93**	**17 A & B**	**47.9**					
CTRL 2	**18-Sep-93**	**17 A & B**	**81.6**					
CTRL 3	20-Sep-93	17 A & B	69.7					
CTRL 3	21-Sep-93	17 A & B	68.5					
RBR 1	**22-Sep-93**	**17 A & B**	**92.5**					
RBR 1	**23-Sep-93**	**17 A & B**	**81.2**					
RBR 2	24-Sep-93	17 A & B	67.3					
RBR 2	25-Sep-93	17 A & B	67.6					
RBR 3	28-Sep-93	17 A & B	78.2					
RBR 3	29-Sep-93	17 A & B	71.8					
RBR 4	**01-Oct-93**	**17 A & B**	**97.4**					
RBR 4	**04-Oct-93**	**17 A & B**	**74.4**					

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Screedman

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene ug	EthylBenzene ug	Toluene ug	Xylene ug	Styrene ug
Detection Limits >>			Liters	1	10	10	10	10
CTRL 1	16-Sep-93	13 A & B	81.6					
CTRL 2	**17-Sep-93**	**5 A & B**	**71.5**					
CTRL 2	**18-Sep-93**	**5 A & B**	**50.8**					
CTRL 3	20-Sep-93	9 A & B	68.1					
CTRL 3	21-Sep-93	9 A & B	66.5					
RBR 1	**22-Sep-93**	**9 A & B**	**87.6**					
RBR 1	**23-Sep-93**	**9 A & B**	**84.7**					
RBR 2	24-Sep-93	9 A & B	88.6	2			20	
RBR 2	25-Sep-93	9 A & B	85.5					
RBR 3	28-Sep-93	9 A & B	82.5					
RBR 3	29-Sep-93	9 A & B	95.9					
RBR 4	**01-Oct-93**	**9 A & B**	**83.1**	**6**			**10**	
RBR 4	**04-Oct-93**	**9 A & B**	**71.6**	**3**				

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP
RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Table Set V. .... (continued)

Luteman

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene ug	EthylBenzene ug	Toluene ug	Xylene ug	Styrene ug
Detection Limits >>			Liters	1	10	10	10	10
CTRL 1	16-Sep-93	9 A & B	81.2					
CTRL 2	**17-Sep-93**	**8 A & B**	**72.4**					
CTRL 2	**18-Sep-93**	**13 A & B**	**86.1**					
CTRL 3	20-Sep-93	13 A & B	70.0					
CTRL 3	21-Sep-93	13 A & B	72.2					
RBR 1	**22-Sep-93**	**13 A & B**	**92.9**				**10**	
RBR 1	**23-Sep-93**	**13 A & B**	**84.3**					
RBR 2	24-Sep-93	13 A & B	86.7				10	
RBR 2	25-Sep-93	13 A & B	86.8					
RBR 3	28-Sep-93	13 A & B	77.2					
RBR 3	29-Sep-93	13 A & B	95.8					
RBR 4	**01-Oct-93**	**13 A & B**	**97.9**					
RBR 4	**04-Oct-93**	**13 A & B**	**61.5**	1				

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Laborer

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene ug	EthylBenzene ug	Toluene ug	Xylene ug	Styrene ug
Detection Limits >>			Liters	1	10	10	10	10
CTRL 1	16-Sep-93	17 A & B	56.9					
CTRL 2	**17-Sep-93**	**13 A & B**	**68.8**					
CTRL 2	**18-Sep-93**	**9 A & B**	**86.1**					
CTRL 3	20-Sep-93	5 A & B	63.1					
CTRL 3	21-Sep-93	5 A & B	69.7					
RBR 1	**22-Sep-93**	**5 A & B**	**93.0**					
RBR 1	**23-Sep-93**	**5 A & B**	**75.1**					
RBR 2	24-Sep-93	5 A & B	94.4					
RBR 2	25-Sep-93	5 A & B	85.3					
RBR 3	28-Sep-93	5 A & B	76.4					
RBR 3	29-Sep-93	5 A & B	97.0					
RBR 4	**01-Oct-93**	**5 A & B**	**98.4**					
RBR 4	**04-Oct-93**	**5 A & B**	**72.0**					

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Quality Control Manager

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene ug	EthylBenzene ug	Toluene ug	Xylene ug	Styrene ug
Detection Limits >>			Liters	1	10	10	10	10
CTRL 1	16-Sep-93	22 A & B	84.2					
CTRL 2	**17-Sep-93**	**25 A & B**	**81.2**					
CTRL 2	**18-Sep-93**	**25 A & B**	**88.6**					
CTRL 3	20-Sep-93	25 A & B	72.7					
CTRL 3	21-Sep-93	25 A & B	64.6					
RBR 1	**22-Sep-93**	**25 A & B**	**72.1**					
RBR 1	**23-Sep-93**	**25 A & B**	**72.1**					
RBR 2	24-Sep-93	25 A & B	85.1					
RBR 2	25-Sep-93	25 A & B	89.1					
RBR 3	28-Sep-93	25 A & B	87.7					
RBR 3	29-Sep-93	25 A & B	81.0					
RBR 4	**01-Oct-93**	**25 A & B**	**79.6**					
RBR 4	**04-Oct-93**	**25 A & B**	**97.9**					

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Table Set VI
Benzene, Toluene, Ethylbenzene, Xylene, and Styrene
Worker Exposure Results

Concentrations as mg/m^3

TABLE SET VI. **VOLATILE ORGANIC COMPOUNDS SAMPLING AND ANALYTICAL RESULTS**
(Units: mg/m^3)

Background Sample

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene mg/m3	EthylBenzene mg/m3	Toluene mg/m3	Xylene mg/m3	Styrene mg/m3
Detection Limits >>			Liters	0.0116	0.1160	0.1160	0.1160	0.1160
CTRL 1	16-Sep-93	21 A & B	88.0					
CTRL 2	17-Sep-93	21 A & B	69.9					
CTRL 2	18-Sep-93	21 A & B	92.4					
CTRL 3	20-Sep-93	21 A & B	77.8					
CTRL 3	21-Sep-93	21 A & B	66.3					
RBR 1	22-Sep-93	21 A & B	90.7					
RBR 1	23-Sep-93	21 A & B	84.2					
RBR 2	24-Sep-93	21 A & B	99.9					
RBR 2	25-Sep-93	21 A & B	92.6					
RBR 3	28-Sep-93	21 A & B	90.3					
RBR 3	29-Sep-93	21 A & B	94.6					
RBR 4	01-Oct-93	21 A & B	90.3					
RBR 4	04-Oct-93	21 A & B	83.9					

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Paver Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene mg/m3	EthylBenzene mg/m3	Toluene mg/m3	Xylene mg/m3	Styrene mg/m3
Detection Limits >>			Liters	0.0125	0.1246	0.1246	0.1246	0.1246
CTRL 1	16-Sep-93	5 A & B	85.0					
CTRL 2	17-Sep-93	1 A & B	49.9					
CTRL 2	18-Sep-93	1 A & B	82.1					
CTRL 3	20-Sep-93	1 A & B	58.0					
CTRL 3	21-Sep-93	1 A & B	72.1					
RBR 1	22-Sep-93	1 A & B	91.3					
RBR 1	23-Sep-93	1 A & B	80.2					
RBR 2	24-Sep-93	1 A & B	85.3					
RBR 2	25-Sep-93	1 A & B	92.7					
RBR 3	28-Sep-93	1 A & B	67.1					
RBR 3	29-Sep-93	1 A & B	100.7	0.0099			0.0993	
RBR 4	01-Oct-93	1 A & B	102.4					
RBR 4	04-Oct-93	1 A & B	76.3					

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP
RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Table Set VI. . . . . (continued)

Roller Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene mg/m3	EthylBenzene mg/m3	Toluene mg/m3	Xylene mg/m3	Styrene mg/m3
Detection Limits >>			Liters	0.0132	0.1321	0.1321	0.1321	0.1321
CTRL 1	16-Sep-93	1 A & B	85.7					
CTRL 2	**17-Sep-93**	**17 A & B**	**47.9**					
CTRL 2	**18-Sep-93**	**17 A & B**	**81.6**					
CTRL 3	20-Sep-93	17 A & B	69.7					
CTRL 3	21-Sep-93	17 A & B	68.5					
RBR 1	**22-Sep-93**	**17 A & B**	**92.5**					
RBR 1	**23-Sep-93**	**17 A & B**	**81.2**					
RBR 2	24-Sep-93	17 A & B	67.3					
RBR 2	25-Sep-93	17 A & B	67.6					
RBR 3	28-Sep-93	17 A & B	78.2					
RBR 3	29-Sep-93	17 A & B	71.8					
RBR 4	**01-Oct-93**	**17 A & B**	**97.4**					
RBR 4	**04-Oct-93**	**17 A & B**	**74.4**					

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Screedman

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene mg/m3	EthylBenzene mg/m3	Toluene mg/m3	Xylene mg/m3	Styrene mg/m3
Detection Limits >>			Liters	0.0128	0.1277	0.1277	0.1277	0.1277
CTRL 1	16-Sep-93	13 A & B	81.6					
CTRL 2	**17-Sep-93**	**5 A & B**	**71.5**					
CTRL 2	**18-Sep-93**	**5 A & B**	**50.8**					
CTRL 3	20-Sep-93	9 A & B	68.1					
CTRL 3	21-Sep-93	9 A & B	66.5					
RBR 1	**22-Sep-93**	**9 A & B**	**87.6**					
RBR 1	**23-Sep-93**	**9 A & B**	**84.7**					
RBR 2	24-Sep-93	9 A & B	88.6	0.0226			0.2257	
RBR 2	25-Sep-93	9 A & B	85.5					
RBR 3	28-Sep-93	9 A & B	82.5					
RBR 3	29-Sep-93	9 A & B	95.9					
RBR 4	**01-Oct-93**	**9 A & B**	**83.1**	**0.0722**			**0.1203**	
RBR 4	**04-Oct-93**	**9 A & B**	**71.6**	**0.0419**				

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Table Set VI. .... (continued)

Luteman

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene mg/m3	EthylBenzene mg/m3	Toluene mg/m3	Xylene mg/m3	Styrene mg/m3
Detection Limits >>			Liters	0.0122	0.1221	0.1221	0.1221	0.1221
CTRL 1	16-Sep-93	9 A & B	81.2					
CTRL 2	**17-Sep-93**	**8 A & B**	**72.4**					
CTRL 2	**18-Sep-93**	**13 A & B**	**86.1**					
CTRL 3	20-Sep-93	13 A & B	70.0					
CTRL 3	21-Sep-93	13 A & B	72.2					
RBR 1	**22-Sep-93**	**13 A & B**	**92.9**				**0.1076**	
RBR 1	**23-Sep-93**	**13 A & B**	**84.3**					
RBR 2	24-Sep-93	13 A & B	86.7				0.1154	
RBR 2	25-Sep-93	13 A & B	86.8					
RBR 3	28-Sep-93	13 A & B	77.2					
RBR 3	29-Sep-93	13 A & B	95.8					
RBR 4	**01-Oct-93**	**13 A & B**	**97.9**					
RBR 4	**04-Oct-93**	**13 A & B**	**61.5**	**0.0163**				

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Labcrer

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene mg/m3	EthylBenzene mg/m3	Toluene mg/m3	Xylene mg/m3	Styrene mg/m3
Detection Limits >>			Liters	0.0125	0.1255	0.1255	0.1255	0.1255
CTRL 1	16-Sep-93	17 A & B	56.9					
CTRL 2	**17-Sep-93**	**13 A & B**	**68.8**					
CTRL 2	**18-Sep-93**	**9 A & B**	**86.1**					
CTRL 3	20-Sep-93	5 A & B	63.1					
CTRL 3	21-Sep-93	5 A & B	69.7					
RBR 1	**22-Sep-93**	**5 A & B**	**93.0**					
RBR 1	**23-Sep-93**	**5 A & B**	**75.1**					
RBR 2	24-Sep-93	5 A & B	94.4					
RBR 2	25-Sep-93	5 A & B	85.3					
RBR 3	28-Sep-93	5 A & B	76.4					
RBR 3	29-Sep-93	5 A & B	97.0					
RBR 4	**01-Oct-93**	**5 A & B**	**98.4**					
RBR 4	**04-Oct-93**	**5 A & B**	**72.0**					

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Table Set VI. . . . . . **(continued)**

Quality Control Manager

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene mg/m3	EthylBenzene mg/m3	Toluene mg/m3	Xylene mg/m3	Styrene mg/m3
Detection Limits >>			Liters	0.0123	0.1231	0.1231	0.1231	0.1231
CTRL 1	16-Sep-93	22 A & B	84.2					
CTRL 2	17-Sep-93	25 A & B	81.2					
CTRL 2	18-Sep-93	25 A & B	80.6					
CTRL 3	20-Sep-93	25 A & B	72.7					
CTRL 3	21-Sep-93	25 A & B	64.6					
RBR 1	22-Sep-93	25 A & B	72.1					
RBR 1	23-Sep-93	25 A & B	72.1					
RBR 2	24-Sep-93	25 A & B	85.1					
RBR 2	25-Sep-93	25 A & B	89.1					
RBR 3	28-Sep-93	25 A & B	87.7					
RBR 3	29-Sep-93	25 A & B	81.0					
RBR 4	01-Oct-93	25 A & B	70.6					
RBR 4	04-Oct-93	25 A & B	97.9					

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP

RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Table Set VII
Benzene, Toluene, Ethylbenzene, Xylene, and Styrene
Worker Exposure Results

Concentrations as PPB

TABLE SET VII. VOLATILE ORGANIC COMPOUNDS SAMPLING AND ANALYTICAL RESULTS
(Units: PPB)

Background Sample

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene PPB	EthylBenzene PPB	Toluene PPB	Xylene PPB	Styrene PPB
Detection Limits >>			Liters	3.57	26.28	30.28	26.29	26.79
CTRL 1	16-Sep-93	21 A & B	88.0					
CTRL 2	17-Sep-93	21 A & B	89.9					
CTRL 2	18-Sep-93	21 A & B	92.4					
CTRL 3	20-Sep-93	21 A & B	77.8					
CTRL 3	21-Sep-93	21 A & B	66.3					
RBR 1	22-Sep-93	21 A & B	90.7					
RBR 1	23-Sep-93	21 A & B	84.2					
RBR 2	24-Sep-93	21 A & B	99.9					
RBR 2	25-Sep-93	21 A & B	92.6					
RBR 3	28-Sep-93	21 A & B	90.3					
RBR 3	29-Sep-93	21 A & B	94.6					
RBR 4	01-Oct-93	21 A & B	90.3					
RBR 4	04-Oct-93	21 A & B	83.9					

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Paver Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene PPB	EthylBenzene PPB	Toluene PPB	Xylene PPB	Styrene PPB
Detection Limits >>			Liters	3.84	28.24	32.54	28.25	28.79
CTRL 1	16-Sep-93	5 A & B	85.0					
CTRL 2	17-Sep-93	1A & B	49.9					
CTRL 2	18-Sep-93	1A & B	82.1					
CTRL 3	20-Sep-93	1 A & B	58.0					
CTRL 3	21-Sep-93	1 A & B	72.1					
RBR 1	22-Sep-93	1 A & B	81.1					
RBR 1	23-Sep-93	1 A & B	80.2					
RBR 2	24-Sep-93	1 A & B	85.3					
RBR 2	25-Sep-93	1 A & B	92.7					
RBR 3	28-Sep-93	1 A & B	67.1				22.51	
RBR 3	29-Sep-93	1 A & B	100.7	3.06				
RBR 4	01-Oct-93	1 A & B	102.4					
RBR 4	04-Oct-93	1 A & B	76.3					

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP

RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Roller Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene PPB	EthylBenzene PPB	Toluene PPB	Xylene PPB	Styrene PPB
Detection Limits >>			Liters	4.07	29.94	34.50	29.95	30.52
CTRL 1	16-Sep-93	1 A & B	85.7					
CTRL 2	17-Sep-93	17 A & B	47.9					
CTRL 2	18-Sep-93	17 A & B	81.8					
CTRL 3	20-Sep-93	17 A & B	69.7					
CTRL 3	21-Sep-93	17 A & B	68.5					
RBR 1	22-Sep-93	17 A & B	92.5					
RBR 1	23-Sep-93	17 A & B	81.2					
RBR 2	24-Sep-93	17 A & B	67.3					
RBR 2	25-Sep-93	17 A & B	67.6					
RBR 3	28-Sep-93	17 A & B	78.2					
RBR 3	29-Sep-93	17 A & B	71.8					
RBR 4	01-Oct-93	17 A & B	97.4					
RBR 4	04-Oct-93	17 A & B	74.4					

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Screedman

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene PPB	EthylBenzene PPB	Toluene PPB	Xylene PPB	Styrene PPB
Detection Limits >>			Liters	3.93	28.94	33.34	28.95	29.50
CTRL 1	16-Sep-93	13 A & B	81.6					
CTRL 2	17-Sep-93	5 A & B	71.5					
CTRL 2	18-Sep-93	5 A & B	50.8					
CTRL 3	20-Sep-93	9 A & B	68.1					
CTRL 3	21-Sep-93	9 A & B	66.5					
RBR 1	22-Sep-93	9 A & B	87.5					
RBR 1	23-Sep-93	5 A & B	84.7					
RBR 2	24-Sep-93	9 A & B	88.6	6.95			69.51	
RBR 2	25-Sep-93	9 A & B	85.5					
RBR 3	28-Sep-93	9 A & B	82.5					
RBR 3	29-Sep-93	9 A & B	95.9					
RBR 4	01-Oct-93	9 A & B	83.1	22.22			37.03	
RBR 4	04-Oct-93	5 A & B	71.8	12.59				

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Table Set VII. . . . . (continued)

Lutteman

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene PPB	EthylBenzene PPB	Toluene PPB	Xylene PPB	Styrene PPB
Detection Limits >>			Liters	3.76	27.66	31.87	27.67	28.20
CTRL 1	16-Sep-93	9 A & B	81.2					
CTRL 2	17-Sep-93	8 A & B	72.4					
CTRL 2	18-Sep-93	13 A & B	86.1					
CTRL 3	20-Sep-93	13 A & B	70.0					
CTRL 3	21-Sep-93	13 A & B	72.2					
RBR 1	22-Sep-93	13 A & B	92.9				24.40	
RBR 1	23-Sep-93	13 A & B	84.3					
RBR 2	24-Sep-93	13 A & B	86.7				26.15	
RBR 2	25-Sep-93	13 A & B	86.8					
RBR 3	28-Sep-93	13 A & B	77.2					
RBR 3	29-Sep-93	13 A & B	95.8					
RBR 4	01-Oct-93	13 A & B	97.9					
RBR 4	04-Oct-93	13 A & B	61.5	3.68				

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Laborer

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene PPB	EthylBenzene PPB	Toluene PPB	Xylene PPB	Styrene PPB
Detection Limits >>			Liters	3.86	28.43	32.76	28.44	28.98
CTRL 1	16-Sep-93	17 A & B	56.9					
CTRL 2	17-Sep-93	13 A & B	68.8					
CTRL 2	18-Sep-93	9 A & B	86.1					
CTRL 3	20-Sep-93	5 A & B	63.1					
CTRL 3	21-Sep-93	5 A & B	69.7					
RBR 1	22-Sep-93	5 A & B	93.0					
RBR 1	23-Sep-93	5 A & B	76.1					
RBR 2	24-Sep-93	5 A & B	94.4					
RBR 2	25-Sep-93	5 A & B	85.3					
RBR 3	28-Sep-93	5 A & B	76.4					
RBR 3	29-Sep-93	5 A & B	97.0					
RBR 4	01-Oct-93	5 A & B	98.4					
RBR 4	04-Oct-93	5 A & B	72.0					

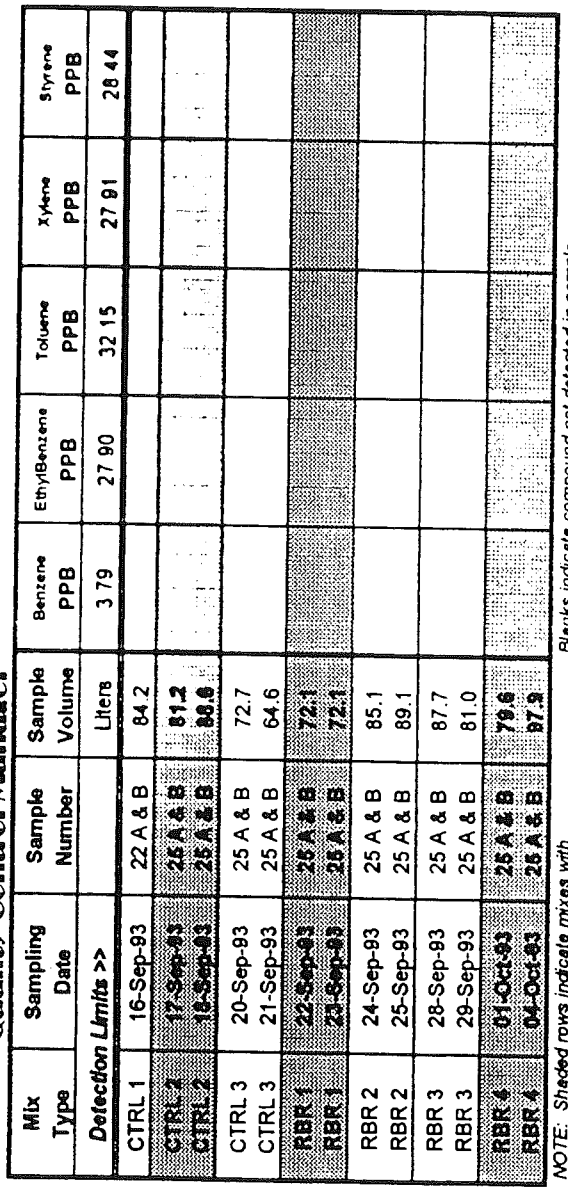
NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP

RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Table Set VII. . . . . (continued)



Quality Control Manager

Mix Type	Sampling Date	Sample Number	Sample Volume	Benzene PPB	EthylBenzene PPB	Toluene PPB	Xylene PPB	Styrene PPB
Detection Limits >>			Liters	3 79	27 90	32 15	27 91	28 44
CTRL 1	16-Sep-93	22 A & B	84.2					
CTRL 1	17-Sep-93	25 A & B	81.2					
CTRL 2	18-Sep-93	25 A & B	80.6					
CTRL 3	20-Sep-93	25 A & B	72.7					
CTRL 3	21-Sep-93	25 A & B	64.6					
RBR 1	22-Sep-93	25 A & B	72.1					
RBR 1	23-Sep-93	25 A & B	72.1					
RBR 2	24-Sep-93	25 A & B	85.1					
RBR 2	25-Sep-93	25 A & B	89.1					
RBR 3	28-Sep-93	25 A & B	87.7					
RBR 3	29-Sep-93	25 A & B	81.0					
RBR 4	01-Oct-93	25 A & B	79.6					
RBR 4	04-Oct-93	25 A & B	87.9					

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP

RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Table Set VIII
1,3-Butadiene Worker Exposure Results

Results as ug/sample
Concentrations as mg/m^3
Concentrations as PPB

TABLE SET VIII. 1,3-BUTADIENE SAMPLING AND ANALYTICAL RESULTS (Units: ug/sample, mg/m^3, and PPB)

Background Sample

Mix Type	Sampling Date	Sample Number	Sample Volume	1,3-Butadiene ug	1,3-Butadiene PPB	1,3-Butadiene mg/m3
Detection Limits >>			Liters	1	5.86	0.0132
CTRL 1	16-Sep-93	22 A & B	80.4	ND		
CTRL 2	17-Sep-93	23 A & B	76.5	ND		
CTRL 2	18-Sep-93	23 A & B	84.4	ND		
CTRL 3	20-Sep-93	23 A & B	70.9	ND		
CTRL 3	21-Sep-93	23 A & B	60.5	ND		
RBR 1	22-Sep-93	23 A & B	82.7	ND		
RBR 1	23-Sep-93	23 A & B	76.8	ND		
RBR 2	24-Sep-93	23 A & B	91.7	ND		
RBR 2	25-Sep-93	23 A & B	85.0	ND		
RBR 3	28-Sep-93	23 A & B	85.3	ND		
RBR 3	29-Sep-93	23 A & B	89.3	ND		
RBR 4	01-Oct-93	23 A & B	85.3	3	15.65	0.0352
RBR 4	04-Oct-93	23 A & B	79.2	ND		

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Paver Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	1,3-Butadiene ug	1,3-Butadiene PPB	1,3-Butadiene mg/m3
Detection Limits >>			Liters	1	6.32	0.0142
CTRL 1	16-Sep-93	7 A & B	81.2	ND		
CTRL 2	17-Sep-93	3 A & B	41.1	ND		
CTRL 2	18-Sep-93	3 A & B	80.8	ND		
CTRL 3	20-Sep-93	3 A & B	59.3	1	7.50	0.0169
CTRL 3	21-Sep-93	3 A & B	72.4	ND		
RBR 1	22-Sep-93	3 A & B	87.2	ND		
RBR 1	23-Sep-93	3 A & B	76.8	ND		
RBR 2	24-Sep-93	3 A & B	89.6	1	4.96	0.0112
RBR 2	25-Sep-93	3 A & B	85.0	2	10.47	0.0235
RBR 3	28-Sep-93	3 A & B	69.5	ND		
RBR 3	29-Sep-93	3 A & B	93.6	1	4.75	0.0107
RBR 4	01-Oct-93	3 A & B	95.2	1	4.67	0.0105
RBR 4	04-Oct-93	3 A & B	70.9	1	6.27	0.0141

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP

RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Roller Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	1,3-Butadiene ug	1,3-Butadiene PPB	1,3-Butadiene mg/m3
Detection Limits >>			Liters	1	5.80	0.0130
CTRL 1	16-Sep-93	3 A & B	70.5	ND		
CTRL 2	17-Sep-93	19 A & B	67.7	ND		
CTRL 2	18-Sep-93	19 A & B	89.2	ND		
CTRL 3	20-Sep-93	19 A & B	71.8	ND		
CTRL 3	21-Sep-93	19 A & B	65.5	ND		
RBR 1	22-Sep-93	19 A & B	95.3	ND		
RBR 1	23-Sep-93	19 A & B	83.6	ND		
RBR 2	24-Sep-93	19 A & B	66.0	ND		
RBR 2	25-Sep-93	19 A & B	66.3	ND		
RBR 3	28-Sep-93	19 A & B	82.9	ND		
RBR 3	29-Sep-93	19 A & B	74.4	ND		
RBR 4	01-Oct-93	19 A & B	100.3	ND		
RBR 4	04-Oct-93	19 A & B	76.6	ND		

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Screedman

Mix Type	Sampling Date	Sample Number	Sample Volume	1,3-Butadiene ug	1,3-Butadiene PPB	1,3-Butadiene mg/m3
Detection Limits >>			Liters	1	6.36	0.0143
CTRL 1	16-Sep-93	15 A & B	89.2	4	19.93	0.0448
CTRL 2	17-Sep-93	7 A & B	51.3	1	8.68	0.0195
CTRL 2	18-Sep-93	7 A & B	42.0	6	63.50	0.1428
CTRL 3	20-Sep-93	11 A & B	65.1	6	41.00	0.0922
CTRL 3	21-Sep-93	11 A & B	74.2	1	5.99	0.0135
RBR 1	22-Sep-93	11 A & B	97.7	ND		
RBR 1	23-Sep-93	11 A & B	79.8	ND		
RBR 2	24-Sep-93	11 A & B	89.5	1	4.97	0.0112
RBR 2	25-Sep-93	11 A & B	89.9	ND		
RBR 3	28-Sep-93	11 A & B	76.6	ND		
RBR 3	29-Sep-93	11 A & B	101.7	ND		
RBR 4	01-Oct-93	11 A & B	65.1	2	10.33	0.0232
RBR 4	04-Oct-93	11 A & B	76.0	3	17.56	0.0395

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP
RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Luteman

Mix Type	Sampling Date	Sample Number	Sample Volume	1,3-Butadiene ug	1,3-Butadiene PPB	1,3-Butadiene mg/m3
Detection Limits >>			Liters	1	5 79	0 0130
CTRL 1	16-Sep-93	11 A & B	88 8	2	10 01	0 0225
CTRL 2	17-Sep-93	11 A & B	69.1	ND		
CTRL 2	18-Sep-93	15 A & B	70.8	ND		
CTRL 3	20-Sep-93	15 A & B	70.4	ND		
CTRL 3	21-Sep-93	15 A & B	68.0	3	19.62	0.0441
RBR 1	22-Sep-93	15 A & B	93.4	ND		
RBR 1	23-Sep-93	15 A & B	84.7	ND		
RBR 2	24-Sep-93	15 A & B	88.0	1	5.05	0.0114
RBR 2	25-Sep-93	15 A & B	87.7	ND		
RBR 3	28-Sep-93	15 A & B	79.5	1	5.59	0.0126
RBR 3	29-Sep-93	15 A & B	98.7	2	9.01	0.0203
RBR 4	01-Oct-93	15 A & B	103.8	1	4.28	0.0096
RBR 4	04-Oct-93	15 A & B	63.7	1	6.98	0.0157

NOTE: Shaded rows indicate mixes with 100% virgin aggregates. *Blanks indicate compound not detected in sample.*

Laborer

Mix Type	Sampling Date	Sample Number	Sample Volume	1,3-Butadiene ug	1,3-Butadiene PPB	1,3-Butadiene mg/m3
Detection Limits >>			Liters	1	6.57	0.0148
CTRL 1	16-Sep-93	19 A & B	47.1	2	18.89	0.0425
CTRL 2	17-Sep-93	15 A & B	67.7	ND		
CTRL 2	18-Sep-93	11 A & B	61.8	ND		
CTRL 3	20-Sep-93	7 A & B	70.4	ND		
CTRL 3	21-Sep-93	7 A & B	71.8	ND		
RBR 1	22-Sep-93	7 A & B	87.6	ND		
RBR 1	23-Sep-93	7 A & B	83.7	ND		
RBR 2	24-Sep-93	7 A & B	86.6	ND		
RBR 2	25-Sep-93	7 A & B	86.6	7	35.95	0.0808
RBR 3	28-Sep-93	7 A & B	77.5	ND		
RBR 3	29-Sep-93	7 A & B	98.5	1	4.52	0.0102
RBR 4	01-Oct-93	7 A & B	89.9	2	8.91	0.0200
RBR 4	04-Oct-93	7 A & B	73.1	1	6.09	0.0137

NOTE: Shaded rows indicate mixes with 100% virgin aggregates. *Blanks indicate compound not detected in sample.*

Table Set VIII. . . . . . **(continued)**

Quality Control Manager

Mix Type	Sampling Date	Sample Number	Sample Volume	1,3-Butadiene ug	1,3-Butadiene PPB	1,3-Butadiene mg/m3
Detection Limits >>			Liters	1	5.83	0.0131
CTRL 1	16-Sep-93	24 A & B	60.4	ND		
CTRL 2	17-Sep-93	27 A & B	86.8	ND		
CTRL 2	18-Sep-93	27 A & B	84.7	ND		
CTRL 3	20-Sep-93	27 A & B	74.9	1	5.94	0.0134
CTRL 3	21-Sep-93	27 A & B	75.5	2	11.78	0.0265
RBR 1	22-Sep-93	27 A & B	73.7	6	36.20	0.0814
RBR 1	23-Sep-93	27 A & B	73.7	10	60.33	0.1357
RBR 2	24-Sep-93	27 A & B	83.0	3	16.08	0.0361
RBR 2	25-Sep-93	27 A & B	86.9	30	153.62	0.3454
RBR 3	28-Sep-93	27 A & B	85.1	1	5.22	0.0117
RBR 3	29-Sep-93	27 A & B	78.6	3	16.97	0.0382
RBR 4	01-Oct-93	27 A & B	77.2	4	23.04	0.0518
RBR 4	04-Oct-93	27 A & B	85.0	1	4.68	0.0105

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Table Set IX
Nitrosoamine Worker Exposure Results

Results as ug/sample

TABLE SET IX. NITROSAMINE SAMPLING AND ANALYTICAL RESULTS (Units: ug/sample)

Background Sample

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine ug	N-nitroso-diethylamine ug	N-nitroso-dipropylamine ug	N-nitroso-dibutylamine ug	N-nitroso-piperidine ug	N-nitroso-pyrrolidine ug	N-nitroso-morpholine ug
Detection Limits >>			Liters	0.005	0.008	0.008	0.010	0.008	0.008	0.008
CTRL 1	16-Sep-93	25 A	82.1							
CTRL 2	17-Sep-93	E55890	71.4							
CTRL 2	18-Sep-93	E55927	86.2							
CTRL 3	20-Sep-93	E55934	71.3	0.007						
CTRL 3	21-Sep-93	E55803	60.8							
RBR 1	22-Sep-93	E55942	83.2							
RBR 1	23-Sep-93	E55947	77.2							
RBR 2	24-Sep-93	E56411	90.7							
RBR 2	25-Sep-93	E56398	84.2							
RBR 3	28-Sep-93	E56425	82.7							
RBR 3	29-Sep-93	E56413	86.7							
RBR 4	01-Oct-93	E56391	82.7							
RBR 4	04-Oct-93	E56382	76.8							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Paver Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine ug	N-nitroso-diethylamine ug	N-nitroso-dipropylamine ug	N-nitroso-dibutylamine ug	N-nitroso-piperidine ug	N-nitroso-pyrrolidine ug	N-nitroso-morpholine ug
Detection Limits >>			Liters	0.005	0.008	0.008	0.010	0.008	0.008	0.008
CTRL 1	16-Sep-93	E55873 & E55885	88.0							
CTRL 2	17-Sep-93	2 A & B	50.4							
CTRL 2	18-Sep-93	E55924	89.9							
CTRL 3	20-Sep-93	E55936 & 355974	67.8							
CTRL 3	21-Sep-93	E55802	74.2				0.018			
RBR 1	22-Sep-93	E55438 & E55441	87.6							
RBR 1	23-Sep-93	E55948 & E55941	77.0							
RBR 2	24-Sep-93	E56405 & E56406	87.5							
RBR 2	25-Sep-93	E55393	84.5							
RBR 3	28-Sep-93	E56430	75.8							
RBR 3	29-Sep-93	E56417	92.6							
RBR 4	01-Oct-93	E56388	94.2							
RBR 4	04-Oct-93	E56381	79.4							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP
RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Roller Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine ug	N-nitroso-diethylamine ug	N-nitroso-dipropylamine ug	N-nitroso-dibutylamine ug	N-nitroso-piperidine ug	N-nitroso-pyrrolidine ug	N-nitroso-morpholine ug
Detection Limits >>			Liters	0.005	0.008	0.008	0.010	0.008	0.008	0.008
CTRL 1	16-Sep-93	E55881, E55882	86.5							
CTRL 2	17-Sep-93	E55918	39.6							
CTRL 2	18-Sep-93	E55925	62.4							
CTRL 3	20-Sep-93	E55935	71.4							
CTRL 3	21-Sep-93	E55800	65.8							
RBR 1	22-Sep-93	E55796	94.8							
RBR 1	23-Sep-93	E55949	83.2							
RBR 2	24-Sep-93	E56404	87.0							
RBR 2	25-Sep-93	E56395	87.4							
RBR 3	28-Sep-93	E56422	78.6							
RBR 3	29-Sep-93	E56414	81.2							
RBR 4	01-Oct-93	E56391	95.5							
RBR 4	04-Apr-93	E56378	81.7							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Screedman

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine ug	N-nitroso-diethylamine ug	N-nitroso-dipropylamine ug	N-nitroso-dibutylamine ug	N-nitroso-piperidine ug	N-nitroso-pyrrolidine ug	N-nitroso-morpholine ug
Detection Limits >>			Liters	0.005	0.008	0.008	0.010	0.008	0.008	0.008
CTRL 1	16-Sep-93	14 A & B	80.3							
CTRL 2	17-Sep-93	E55887 & E55880	70.0							
CTRL 2	18-Sep-93	E55929	71.8							
CTRL 3	20-Sep-93	E55790 & E55793	65.4							
CTRL 3	21-Sep-93	E55807 & E55806	76.6							
RBR 1	22-Sep-93	E55944 & E55939	101.0							
RBR 1	23-Sep-93	E55953 & E55952	85.5							
RBR 2	24-Sep-93	E56403 & E56412	95.2							
RBR 2	25-Sep-93	12 A	825.1							
RBR 3	28-Sep-93	E56424 & E56428	75.9							
RBR 3	29-Sep-93	E56426	96.4							
RBR 4	01-Oct-93	E56384	89.1							
RBR 4	04-Oct-93	E56379	81.6							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP
RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Table Set IX. . . . . (continued)

Luteman

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine ug	N-nitroso-diethylamine ug	N-nitroso-dipropylamine ug	N-nitroso-dibutylamine ug	N-nitroso-piperidine ug	N-nitroso-pyrrolidine ug	N-nitroso-morpholine ug
Detection Limits >>			Liters	0.005	0.008	0.008	0.010	0.008	0.008	0.008
CTRL 1	16-Sep-93	E55878, E55877	82.0							
CTRL 2	17-Sep-93	E55917	74.9							
CTRL 2	18-Sep-93	E55930	66.9							
CTRL 3	20-Sep-93	E55789	72.1							
CTRL 3	21-Sep-93	E55798	72.9							
RBR 1	22-Sep-93	E55837	95.6							
RBR 1	23-Sep-93	E55948	86.7							
RBR 2	24-Sep-93	E56407	89.3							
RBR 2	25-Sep-93	E56399	93.3							
RBR 3	28-Sep-93	E56423	75.7							
RBR 3	29-Sep-93	E56415	93.9							
RBR 4	01-Oct-93	E56388	95.4							
RBR 4	04-Oct-93	E56380	79.6							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Laborer

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine ug	N-nitroso-diethylamine ug	N-nitroso-dipropylamine ug	N-nitroso-dibutylamine ug	N-nitroso-piperidine ug	N-nitroso-pyrrolidine ug	N-nitroso-morpholine ug
Detection Limits >>			Liters	0.005	0.008	0.008	0.010	0.008	0.008	0.008
CTRL 1	16-Sep-93	18 A & B	80.5							
CTRL 2	17-Sep-93	E55992	75.2							
CTRL 2	18-Sep-93	E55928	84.4							
CTRL 3	20-Sep-93	E55792	72.7							
CTRL 3	21-Sep-93	E55799	71.4							
RBR 1	22-Sep-93	E55943	93.9							
RBR 1	23-Sep-93	E55950	86.5							
RBR 2	24-Sep-93	E56410	86.1							
RBR 2	25-Sep-93	E56394	87.9							
RBR 3	28-Sep-93	E56427	80.2							
RBR 3	29-Sep-93	E56419	101.9							
RBR 4	01-Oct-93	E56387	103.3							
RBR 4	04-Oct-93	E56377	86.1							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Table Set IX. .... (continued)

Quality Control Manager

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine ug	N-nitroso-diethylamine ug	N-nitroso-dipropylamine ug	N-nitroso-dibutylamine ug	N-nitroso-piperidine ug	N-nitroso-pyrrolidine ug	N-nitroso-morpholine ug
Detection Limits >>			Liters	0 005	0 008	0 008	0 010	0 008	0 008	0 008
CTRL 1	16-Sep-93	24	82 5							
CTRL 2	17-Sep-93	E55919 & E55920	82.0							
CTRL 2	18-Sep-93	E55928	91.7							
CTRL 3	20-Sep-93	E55791 & E55933	74.5							
CTRL 3	21-Sep-93	E55804 & E55805	66.1							
RBR 1	22-Sep-93	E55940 & E55945	84.2							
RBR 1	23-Sep-93	E55955 & E55954	84.2							
RBR 2	24-Sep-93	E54709	88.2							
RBR 2	25-Sep-93	E56396	92.3							
RBR 3	28-Sep-93	E56421 & E56429	86.9							
RBR 3	29-Sep-93	E56418	80.2							
RBR 4	01-Oct-93	E56383	78.8							
RBR 4	04-Oct-93	E56384	97.0							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Table Set X
Nitrosoamine Worker Exposure Results

Concentrations as ug/m^3

TABLE SET X. NITROSAMINE SAMPLING AND ANALYTICAL RESULTS (Units: µg/m³)

Background Sample

>>> *Units are in MICROgrams per meter^3* <<<

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine ug/m3	N-nitroso-diethylamine ug/m3	N-nitroso-dipropylamine ug/m3	N-nitroso-dibutylamine ug/m3	N-nitroso-piperidine ug/m3	N-nitroso-pyrrolidine ug/m3	N-nitroso-morpholine ug/m3
Detection Limits >>			Liters	0.063	0.100	0.100	0.125	0.100	0.100	0.100
CTRL 1	16-Sep-93	25 A	82.1							
CTRL 2	17-Sep-93	E55890	71.4							
CTRL 2	18-Sep-93	E55927	88.2							
CTRL 3	20-Sep-93	E55934	71.3	0.098						
CTRL 3	21-Sep-93	E55803	60.8							
RBR 1	22-Sep-93	E55942	83.2							
RBR 1	23-Sep-93	E55947	77.2							
RBR 2	24-Sep-93	E56411	90.7							
RBR 2	25-Sep-93	E56398	84.2							
RBR 3	28-Sep-93	E56425	82.7							
RBR 3	29-Sep-93	E56413	86.7							
RBR 4	01-Oct-93	E56391	82.7							
RBR 4	04-Oct-93	E56382	76.8							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Paver Operator

>>> *Units are in MICROgrams per meter^3* <<<

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine ug/m3	N-nitroso-diethylamine ug/m3	N-nitroso-dipropylamine ug/m3	N-nitroso-dibutylamine ug/m3	N-nitroso-piperidine ug/m3	N-nitroso-pyrrolidine ug/m3	N-nitroso-morpholine ug/m3
Detection Limits >>			Liters	0.062	0.099	0.099	0.124	0.099	0.099	0.099
CTRL 1	16-Sep-93	E55873 & E55885	88.0							
CTRL 2	17-Sep-93	2 A & B	50.4							
CTRL 2	18-Sep-93	E55924	89.9							
CTRL 3	20-Sep-93	E55936 & 355974	67.8							
CTRL 3	21-Sep-93	E55802	74.2				0.243			
RBR 1	22-Sep-93	E55438 & E55441	87.6							
RBR 1	23-Sep-93	E55948 & E55941	77.0							
RBR 2	24-Sep-93	E56405 & E56406	87.5							
RBR 2	25-Sep-93	E55393	84.5							
RBR 3	28-Sep-93	E56430	75.8							
RBR 3	29-Sep-93	E56417	92.6							
RBR 4	01-Oct-93	E56368	94.2							
RBR 4	04-Oct-93	E56381	79.4							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP

RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Table Set X. .... **(continued)**

Roller Operator

>>> Units are in MICROgrams per meter^3 <<<

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine ug/m3	N-nitroso-diethylamine ug/m3	N-nitroso-dipropylamine ug/m3	N-nitroso-dibutylamine ug/m3	N-nitroso-piperidine ug/m3	N-nitroso-pyrrolidine ug/m3	N-nitroso-morpholine ug/m3
Detection Limits >>			Liters	0.063	0.100	0.100	0.126	0.100	0.100	0.100
CTRL 1	16-Sep-93	E55881, E55882	86.5							
CTRL 2	17-Sep-93	E55918	39.6							
CTRL 2	18-Sep-93	E55925	82.4							
CTRL 3	20-Sep-93	E55935	71.4							
CTRL 3	21-Sep-93	E55800	65.8							
RBR 1	22-Sep-93	E55796	94.8							
RBR 1	23-Sep-93	E55949	83.2							
RBR 2	24-Sep-93	E56404	87.0							
RBR 2	25-Sep-93	E56395	87.4							
RBR 3	28-Sep-93	E56422	78.6							
RBR 3	29-Sep-93	E56414	81.2							
RBR 4	01-Oct-93	E56391	95.5							
RBR 4	04-Apr-93	E56378	81.7							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Screedman

>>> Units are in MICROgrams per meter^3 <<<

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine ug/m3	N-nitroso-diethylamine ug/m3	N-nitroso-dipropylamine ug/m3	N-nitroso-dibutylamine ug/m3	N-nitroso-piperidine ug/m3	N-nitroso-pyrrolidine ug/m3	N-nitroso-morpholine ug/m3
Detection Limits >>			Liters	0.036	0.057	0.057	0.072	0.057	0.057	0.057
CTRL 1	16-Sep-93	14 A & B	80.3							
CTRL 2	17-Sep-93	E55887 & E55880	70.0							
CTRL 2	18-Sep-93	E55929	71.8							
CTRL 3	20-Sep-93	E55790 & E55793	65.4							
CTRL 3	21-Sep-93	E55807 & E55806	76.6							
RBR 1	22-Sep-93	E55944 & E55939	101.0							
RBR 1	23-Sep-93	E55953 & E55952	85.5							
RBR 2	24-Sep-93	E56403 & E56412	95.2							
RBR 2	25-Sep-93	12 A	825.1							
RBR 3	28-Sep-93	E56424 & E56428	75.9							
RBR 3	29-Sep-93	E56426	96.4							
RBR 4	01-Oct-93	E56384	89.1							
RBR 4	04-Oct-93	E56379	81.6							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP
RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rlr RAP ✠ RBR 4 = RBR-DRY, No RAP

Table Set X. . . . . (continued)

Luteman

>>> *Units are in MICROgrams per meter^3* <<<

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine ug/m3	N-nitroso-diethylamine ug/m3	N-nitroso-dipropylamine ug/m3	N-nitroso-dibutylamine ug/m3	N-nitroso-piperidine ug/m3	N-nitroso-pyrrolidine ug/m3	N-nitroso-morpholine ug/m3
Detection Limits >>			Liters	0 059	0 094	0 094	0 118	0 094	0 094	0 094
CTRL 1	16-Sep-93	E55878, E55877	82 0							
CTRL 2	17-Sep-93	E55917	74.8							
CTRL 2	18-Sep-93	E55930	86.9							
CTRL 3	20-Sep-93	E55789	72.1							
CTRL 3	21-Sep-93	E55798	72.9							
RBR 1	22-Sep-93	E55837	95.6							
RBR 1	23-Sep-93	E55848	86.7							
RBR 2	24-Sep-93	E56407	89.3							
RBR 2	25-Sep-93	E56399	93.3							
RBR 3	28-Sep-93	E56423	75.7							
RBR 3	29-Sep-93	E56415	93.9							
RBR 4	01-Oct-93	E56386	98.4							
RBR 4	04-Oct-93	E56380	79.6							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Laborer

>>> *Units are in MICROgrams per meter^3* <<<

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine ug/m3	N-nitroso-diethylamine ug/m3	N-nitroso-dipropylamine ug/m3	N-nitroso-dibutylamine ug/m3	N-nitroso-piperidine ug/m3	N-nitroso-pyrrolidine ug/m3	N-nitroso-morpholine ug/m3
Detection Limits >>			Liters	0.059	0.094	0.094	0.117	0.094	0.094	0.094
CTRL 1	16-Sep-93	18 A & B	80.5							
CTRL 2	17-Sep-93	E55992	75.2							
CTRL 2	18-Sep-93	E55926	84.4							
CTRL 3	20-Sep-93	E55792	72.7							
CTRL 3	21-Sep-93	E55799	71.4							
RBR 1	22-Sep-93	E55943	93.9							
RBR 1	23-Sep-93	E55950	86.5							
RBR 2	24-Sep-93	E56410	86.1							
RBR 2	25-Sep-93	E56394	87.9							
RBR 3	28-Sep-93	E56427	80.2							
RBR 3	29-Sep-93	E56419	101.9							
RBR 4	01-Oct-93	E56387	103.3							
RBR 4	04-Oct-93	E56377	86.1							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP

RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Quality Control Manager

>>> Units are in MICROgrams per meter^3 <<<

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine ug/m3	N-nitroso-diethylamine ug/m3	N-nitroso-dipropylamine ug/m3	N-nitroso-dibutylamine ug/m3	N-nitroso-piperidine ug/m3	N-nitroso-pyrrolidine ug/m3	N-nitroso-morpholine ug/m3
Detection Limits >>			Liters	0.060	0.096	0.096	0.119	0.096	0.096	0.096
CTRL 1	16-Sep-93	24	82.5							
CTRL 2	17-Sep-93	E55919 & E55920	82.0							
CTRL 2	18-Sep-93	E55928	91.7							
CTRL 3	20-Sep-93	E55791 & E55933	74.5							
CTRL 3	21-Sep-93	E55804 & E55805	66.1							
RBR 1	22-Sep-93	E55940 & E55945	84.2							
RBR 1	23-Sep-93	E55956 & E55954	84.2							
RBR 2	24-Sep-93	E54709	88.2							
RBR 2	25-Sep-93	E56396	92.3							
RBR 3	28-Sep-93	E56421 & E56429	86.9							
RBR 3	29-Sep-93	E56418	80.2							
RBR 4	01-Oct-93	E56383	78.8							
RBR 4	04-Oct-93	E56384	97.0							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Table Set XI
Nitrosoamine Worker Exposure Results

Concentrations as PPB

TABLE SET XI. NITROSAMINE SAMPLING AND ANALYTICAL RESULTS (Units: PPB)

Background Sample

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine PPB	N-nitroso-diethylamine PPB	N-nitroso-dipropylamine PPB	N-nitroso-dibutylamine PPB	N-nitroso-piperidine PPB	N-nitroso-pyrrolidine PPB	N-nitroso-morpholine PPB
Detection Limits >>			Liters	0.020	0.024	0.019	0.019	0.021	0.024	0.021
CTRL 1	16-Sep-93	25 A	82.1							
CTRL 2	17-Sep-93	E55890	71.4							
CTRL 2	18-Sep-93	E55927	86.2							
CTRL 3	20-Sep-93	E55934	71.3	0.032						
CTRL 3	21-Sep-93	E55803	60.8							
RBR 1	22-Sep-93	E55942	83.2							
RBR 1	23-Sep-93	E55947	77.2							
RBR 2	24-Sep-93	E56411	90.7							
RBR 2	25-Sep-93	E56398	84.2							
RBR 3	28-Sep-93	E56425	82.7							
RBR 3	29-Sep-93	E56413	86.7							
RBR 4	01-Oct-93	E56391	82.7							
RBR 4	04-Oct-93	E56352	76.8							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Paver Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine PPB	N-nitroso-diethylamine PPB	N-nitroso-dipropylamine PPB	N-nitroso-dibutylamine PPB	N-nitroso-piperidine PPB	N-nitroso-pyrrolidine PPB	N-nitroso-morpholine PPB
Detection Limits >>			Liters	0.020	0.023	0.018	0.019	0.021	0.024	0.021
CTRL 1	16-Sep-93	E55873 & E55885	88.0							
CTRL 2	17-Sep-93	2 A & B	60.4							
CTRL 2	18-Sep-93	E55924	89.9							
CTRL 3	20-Sep-93	E55936 & 355974	67.8							
CTRL 3	21-Sep-93	E55802	74.2				0.037			
RBR 1	22-Sep-93	E55438 & E55441	87.6							
RBR 1	23-Sep-93	E55948 & E55941	77.0							
RBR 2	24-Sep-93	E56405 & E56406	87.5							
RBR 2	25-Sep-93	E55393	84.5							
RBR 3	28-Sep-93	E56430	75.8							
RBR 3	29-Sep-93	E56417	92.6							
RBR 4	01-Oct-93	E56388	94.2							
RBR 4	04-Oct-93	E56381	79.4							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP

RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Table Set XI. . . . . (continued)

Roller Operator

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine PPB	N-nitroso-diethylamine PPB	N-nitroso-dipropylamine PPB	N-nitroso-dibutylamine PPB	N-nitroso-piperidine PPB	N-nitroso-pyrrolidine PPB	N-nitroso-morpholine PPB
Detection Limits >>			Liters	0.020	0.024	0.019	0.019	0.021	0.024	0.021
CTRL 1	16-Sep-93	E55881, E55882	86.5							
CTRL 2	17-Sep-93	E55916	39.6							
CTRL 2	18-Sep-93	E55925	82.4							
CTRL 3	20-Sep-93	E55935	71.4							
CTRL 3	21-Sep-93	E55800	65.8							
RBR 1	22-Sep-93	E55796	94.8							
RBR 1	23-Sep-93	E55949	83.2							
RBR 2	24-Sep-93	E56404	87.0							
RBR 2	25-Sep-93	E56395	87.4							
RBR 3	28-Sep-93	E56422	78.6							
RBR 3	29-Sep-93	E56414	81.2							
RBR 4	01-Oct-93	E56391	95.5							
RBR 4	04-Apr-93	E56378	81.7							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Screedman

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine PPB	N-nitroso-diethylamine PPB	N-nitroso-dipropylamine PPB	N-nitroso-dibutylamine PPB	N-nitroso-piperidine PPB	N-nitroso-pyrrolidine PPB	N-nitroso-morpholine PPB
Detection Limits >>			Liters	0.012	0.014	0.011	0.011	0.012	0.014	0.012
CTRL 1	16-Sep-93	14 A & B	80.3							
CTRL 2	17-Sep-93	E55887 & E55880	70.0							
CTRL 2	18-Sep-93	E55929	71.8							
CTRL 3	20-Sep-93	E55790 & E55793	65.4							
CTRL 3	21-Sep-93	E55807 & E55806	76.6							
RBR 1	22-Sep-93	E55944 & E55939	101.0							
RBR 1	23-Sep-93	E55953 & E55952	85.5							
RBR 2	24-Sep-93	E56403 & E56412	95.2							
RBR 2	25-Sep-93	12 A	825.1							
RBR 3	28-Sep-93	E56424 & E56428	75.9							
RBR 3	29-Sep-93	E56426	96.4							
RBR 4	01-Oct-93	E56384	89.1							
RBR 4	04-Oct-93	E56379	81.6							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP

RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Table Set XI. . . . . **(continued)**

Luteman

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine PPB	N-nitroso-diethylamine PPB	N-nitroso-dipropylamine PPB	N-nitroso-dibutylamine PPB	N-nitroso-piperidine PPB	N-nitroso-pyrrolidine PPB	N-nitroso-morpholine PPB
Detection Limits >>			Liters	0 019	0 022	0 017	0 018	0 020	0 023	0 020
CTRL 1	16-Sep-93	E55878, E55877	82 0							
CTRL 2	17-Sep-93	E55917	74.9							
CTRL 2	18-Sep-93	E55930	88.9							
CTRL 3	20-Sep-93	E55789	72.1							
CTRL 3	21-Sep-93	E55798	72.9							
RBR 1	22-Sep-93	E55837	95.6							
RBR 1	23-Sep-93	E55848	88.7							
RBR 2	24-Sep-93	E56407	89.3							
RBR 2	25-Sep-93	E56399	93.3							
RBR 3	28-Sep-93	E56423	75.7							
RBR 3	29-Sep-93	E56415	93.9							
RBR 4	01-Oct-93	E56388	98.4							
RBR 4	04-Oct-93	E56360	79.6							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

Laborer

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine PPB	N-nitroso-diethylamine PPB	N-nitroso-dipropylamine PPB	N-nitroso-dibutylamine PPB	N-nitroso-piperidine PPB	N-nitroso-pyrrolidine PPB	N-nitroso-morpholine PPB
Detection Limits >>			Liters	0.019	0.022	0.017	0.018	0.020	0.023	0.019
CTRL 1	16-Sep-93	18 A & B	80.5							
CTRL 2	17-Sep-93	E55992	75.2							
CTRL 2	18-Sep-93	E55926	84.4							
CTRL 3	20-Sep-93	E55792	72.7							
CTRL 3	21-Sep-93	E55799	71.4							
RBR 1	22-Sep-93	E55943	93.9							
RBR 1	23-Sep-93	E55960	86.5							
RBR 2	24-Sep-93	E56410	86.1							
RBR 2	25-Sep-93	E56394	87.9							
RBR 3	28-Sep-93	E56427	80.2							
RBR 3	29-Sep-93	E56419	101.9							
RBR 4	01-Oct-93	E56387	103.3							
RBR 4	04-Oct-93	E56377	86.1							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP

RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP

Table Set XI. . . . . (continued)

Quality Control Manager

Mix Type	Sampling Date	Sample Number	Sample Volume	N-nitroso-dimethylamine PPB	N-nitroso-diethylamine PPB	N-nitroso-dipropylamine PPB	N-nitroso-dibutylamine PPB	N-nitroso-piperidine PPB	N-nitroso-pyrrolidine PPB	N-nitroso-morpholine PPB
Detection Limits >>			Liters	0.019	0.023	0.018	0.018	0.020	0.023	0.020
CTRL 1	16-Sep-93	24	82.5							
CTRL 2	17-Sep-93	E55919 & E55920	62.0							
CTRL 2	18-Sep-93	E55928	91.7							
CTRL 3	20-Sep-93	E55791 & E55933	74.5							
CTRL 3	21-Sep-93	E55804 & E55805	66.1							
RBR 1	22-Sep-93	E55940 & E55945	84.2							
RBR 1	23-Sep-93	E55956 & E55954	84.2							
RBR 2	24-Sep-93	E54709	88.2							
RBR 2	25-Sep-93	E56396	92.3							
RBR 3	28-Sep-93	E56421 & E56429	86.9							
RBR 3	29-Sep-93	E56418	80.2							
RBR 4	01-Oct-93	E56383	76.8							
RBR 4	04-Oct-93	E56384	97.0							

NOTE: Shaded rows indicate mixes with 100% virgin aggregates.

Blanks indicate compound not detected in sample.

CTRL 1 = 85/100 PEN AC, 30% RAP ✠ CTRL 2 = No RBR, No RAP ✠ CTRL 3 = No RBR, 20% RAP

RBR 1 = RBR-WET, No RAP ✠ RBR 2 = No RBR, 20% Rbr RAP ✠ RBR 3 = RBR-WET, 20% Rbr RAP ✠ RBR 4 = RBR-DRY, No RAP