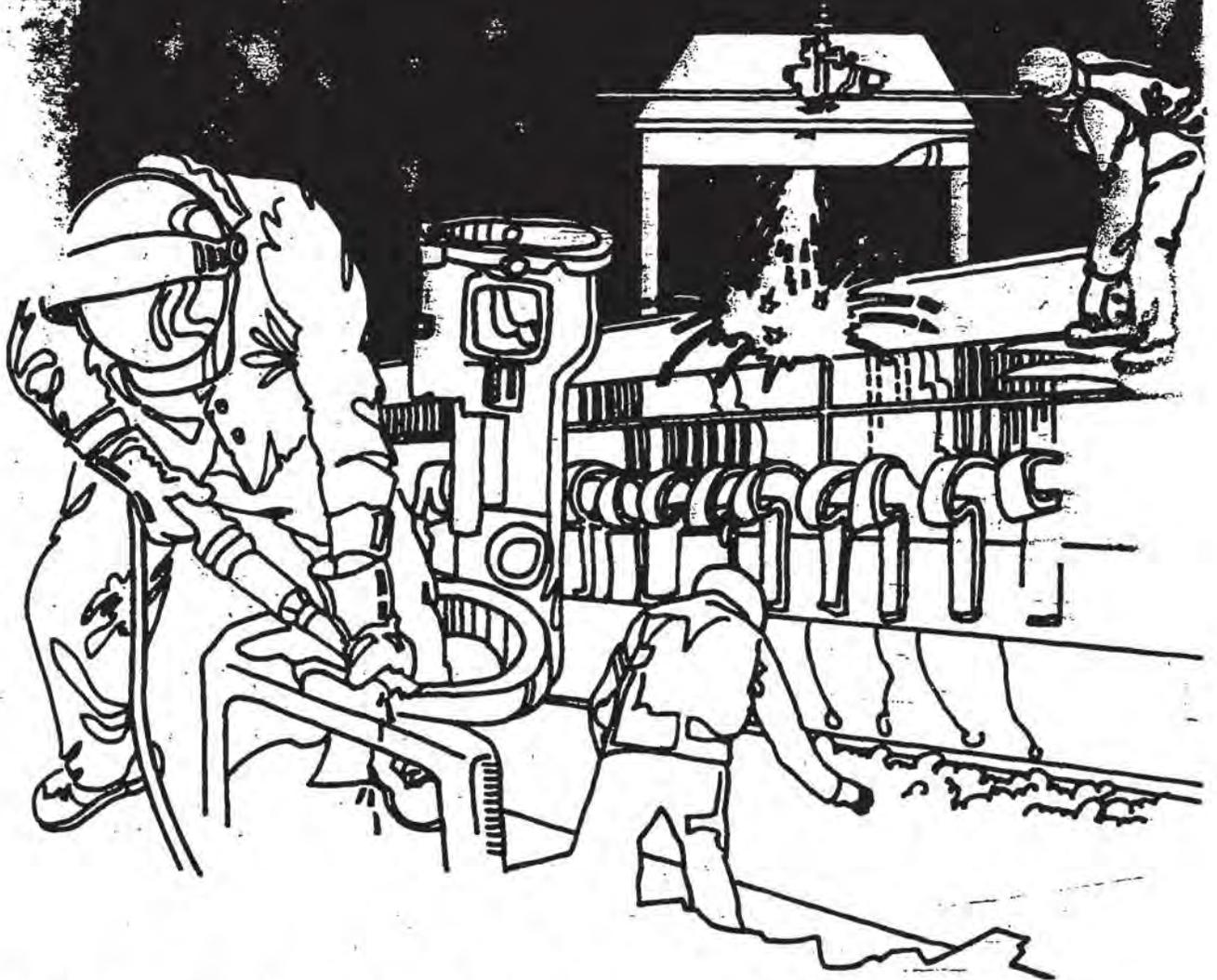


NIOSH



Health Hazard Evaluation Report

HETA 82-137-1264
REGIONAL TRANSPORTATION DISTRICT
DENVER, COLORADO

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

I. SUMMARY

In February 1982, the National Institute for Occupational Safety and Health (NIOSH) received a request to evaluate possible health hazards associated with exposure to diesel engine exhaust emissions in three bus repair shops operated by the Regional Transportation District (RTD) in Denver, Colorado.

On March 22-25, 1982, A NIOSH industrial hygienist collected air samples at the three facilities to determine workers' exposure to substances present in the diesel exhaust. Aldehyde concentrations (acetaldehyde, butyraldehyde, formaldehyde and propionaldehyde) were all less than 0.03 ppm and sulfur dioxide concentrations were less than 0.05 ppm. Carbon monoxide concentrations in the diesel bus storage and maintenance areas ranged from 3-21 ppm. At the Alameda facility the carbon monoxide concentration in the gas bus storage area during the peak morning dispatch period, was 170 ppm; however, only the drivers were in the area during this period and they were there for less than 15 minutes. Total particulate time weighted average concentrations ranged from 0.12 to 0.55 mg/cu m. During the peak morning period total particulate levels ranged from 0.15 to 0.81 mg/cu m. The cyclohexane soluble portion of these particulates ranged from 0.03 to 0.16 mg/cu m. Nitric oxide concentrations ranged from 0.33 to 5.62 ppm during the peak morning period and from 0.08 to 2.28 during the period when approximately half of the morning buses returned to the shop.

The nitrogen dioxide concentrations ranged from 0.16 to 1.81 ppm during the dispatch period and from 0.05 to 0.80 during the time the morning run buses were returned. Six of the 15 three-hour samples collected in the three facilities during the morning dispatch period exceeded the NIOSH recommended criteria of 1 ppm for any 15 minute period. They ranged from 1.01 to 1.81 with a mean of 1.21 ppm. Drivers and other workers may spend 15 minutes or more in these areas.

On the basis of the data collected in this evaluation, NIOSH has determined that the bus drivers in the East Metro and Platte facilities and diesel repair mechanics at the Alameda facility of RTD, Denver, Colorado, are exposed to nitrogen dioxide in excess of NIOSH recommended criteria. Recommendations to improve the ventilation systems and work practices to reduce such exposure are listed in Section IX of this report.

KEYWORDS: SIC 4172 (Terminal & Service Facilities for Motor Vehicle passenger transportation) Diesel Exhaust, Nitrogen Dioxide, Carbon Dioxide, Sulfur Dioxide, Particulates, Cyclohexane Solubles

II. INTRODUCTION

In February 1982, NIOSH received a Health Hazard Evaluation request from the Amalgamated Transit Union, Local 1001. This request was to determine the diesel engine exhaust concentrations present in three of the Regional Transportation District's (RTD) bus facilities located in Denver, Colorado. The initial and environmental surveys were conducted on March 22-25, 1982.

III. BACKGROUND

This request involved the three RTD bus maintenance and storage facilities. The same basic functions of bus storage, running repair, repair maintenance, servicing, and inspections are conducted at all three facilities. Each facility is different in design and construction and, therefore, will be discussed separately.

A. East Metro Facility

The East Metro facility was completed in the fall of 1980. It has 340,000 sq ft under one roof. Figure 1 is a floor plan of the facility. Entrance of the buses into the facility is through one door and the single exit is on the opposite side of the building. All movement of the buses to the various maintenance stations is done in the building.

The general ventilation system in the bus storage area is designed to supply 168,000 cubic feet per minute (cfm) on the east side of the area and to exhaust it from the west side. In addition, there are five exhaust ducts located seven feet above the floor in the bus storage area. These are timer activated and are set to be turned on during peak bus traffic periods. A flow of 117,000 cfm of air is supplied to the repair area and 105,000 cfm to the service area. There are beehive-style supply air drops located throughout the repair and service area. Tailpipe local exhaust systems are available in the repair and service areas. During the sampling period, several bus engines were being operated but were not connected to the tailpipe exhaust system.

On the day of sampling, 170 buses were dispatched in the morning. About half of them returned after the morning run. A few buses left before 5:00 AM. By 6:00 AM activity was heavy, and the air in the building was hazy. By 7:30 most of the buses had left. At 8:00 AM the air in the building was clear. By 9:45 most of the buses that were to return were back in the storage area. During the sampling period (4:55 AM to 12:00 noon) there was constant bus activity in the repair and inspection area. On this day the outdoor temperature at 5:00 AM was 28°F.

The mechanics and other service type workers will spend most of their shift in their respective areas. The bus drivers will spend up to 15 minutes in the bus storage area in the morning when they start the bus, perform the required checks and wait for the bus to warm up. When returning the bus, the time spent in the bus storage area will usually be less than 15 minutes.

There are approximately 100 workers in the repair and maintenance portion of the facility. They include mechanics, bus washers, storeroom clerks, laborers, and supervisors. These workers are divided over three shifts.

B. Platte Facility

The Platte Facility covers 269,000 sq ft and is composed of several adjoining buildings. The bus storage area is separated from the repair and inspection areas. Figure 2 is a floor plan of the facility. Entrance of the buses into the bus storage area is through a single door. Each bus storage lane has its own overhead door exit. Buses moved to repair, inspection, wash, etc., are moved out of the storage building and to the appropriate area.

The ventilation system in the bus storage area consists of 12 sets of supply air and exhaust units distributed throughout the area. Each set is controlled by a separate sensor so that when the exhaust builds up in an area that system is activated. The exhaust unit consists of a ceiling fan which is a short distance from the supply air inlets. Short circuiting of the air near the ceiling can occur. In the inspection and running repair areas, there are tailpipe exhaust systems at each service bay. The supply air is brought into the area at several points 8-10 feet above the floor.

There are approximately 210 buses dispatched each morning and about half of them return after the morning run. On the day of sampling, a few buses had left by 4:30 AM. From 5:00 AM to 6:30 AM was the peak traffic period, and by 7:00 AM most of the buses had left. During this time period it was smoky in the building. By 8:00 AM the air was almost clear. Some of the buses began to return about 8:00 AM and by 10:00 AM most of those that were to return had returned. When the buses return, they stop at the vault where the collection box is removed and put in the vault. The returning buses are then assigned to a specific lane where the bus is then parked. At 5:00 AM on the day of sampling, the outside temperature was 30°F.

The mechanics and other service type workers will spend most of their shift in their respective area. The bus driver will spend up to 15 minutes in the bus storage area in the morning when they start the bus, perform the required checks and wait for the bus to warm up. When returning, the time spent in the bus storage area will be less than 15 minutes. Several employees work in the vault area and in the office by the vault.

The repair and inspection shops operate three shifts a day. There are about 75 mechanics, inspection persons and bus washers who work in these areas.

C. Alameda Facility

The Alameda Facility is smaller than the other two. Figure 3 is a floor plan of the facility. It is a series of adjoining long narrow buildings or bays. Bays A & B and D & E are the diesel bus storage areas. Each bay has five lanes that hold six buses each. Each lane has an overhead door for entrance and also one for exit on the opposite side. When one or more doors are open on both sides, there is a general air movement through the bay. Each bay has a ceiling exhaust fan that is manually operated.

Bay F is the gas engine repair and the gas bus storage area. There is a tailpipe exhaust system for the repair area and ceiling fan that is operated by a sensor.

Bay G contains the diesel and gas running repair. There are three manually controlled local exhaust hoods above three of the four bus lanes and a ceiling fan that is controlled by a sensor.

Bay H(a) is a storage area for cars and trucks. There is a ceiling fan that is sensor operated. Bay H(b) is the diesel engine repair and maintenance. There is no exhaust ventilation, either local tailpipe exhaust or ceiling fan, in the bay.

On the day of sampling the buses started to leave about 5:00 AM. By 6:15 AM, all the gas buses had left and about half of the diesel buses. By 7:00 AM all the buses had left. When the buses were leaving, one or more exit doors were open and one or more entrance doors were open. By 9:00 AM most of the morning run buses had returned. Approximately 100 buses are dispatched in the morning with about half returning after the morning run. The bus storage area was not very hazy or smoky this day. The outside temperature at 5:00 AM was 24°F.

Only 3 of the 8 mechanics were working in the diesel repair area (Bay H(b)); hence the number of engines run that day was reduced. When an engine was started, the smoke and haze built up immediately in the building.

There are approximately 50 workers (mechanics, inspector persons, and service and cleaning persons) who work the three shifts in the repair and service areas. The bus drivers will spend up to 15 minutes in the bus storage areas in the morning when they start the buses, perform the routine check and wait for the bus to warm up. When returning the bus, the time spent in the bus storage area will usually be less than 15 minutes.

IV. EVALUATION DESIGN

The environmental survey was conducted on March 23-25, 1982. One day of sampling was conducted at each of the three facilities involved. The measurements for diesel exhaust components were made in the general areas where the employees worked. Diesel exhaust is composed of a large mixture of compounds. Some are present in measurable quantities while others are not. As of the present time there is no single measurement that can be made that is indicative of the diesel exhaust concentration present. The diesel exhaust components that were sampled are listed below under Evaluation Methods. Area samples were selected due to the variety of jobs performed; the length of time spent in an area varied from employee to employee; and on many of the buses the exhaust pipe terminates at the top of the bus not at the breathing zone level. Locations were selected at each facility that covered the following basic areas: bus storage; inspection; running repair; and maintenance.

V. EVALUATION METHODS

Listed below are the sampling and analytical methods used in this evaluation:

<u>Substance</u>	<u>Collection Method</u>	<u>Flow Rate</u>	<u>NIOSH Analytical Method (1)</u>
Aldehydes	XAD-2 Resin coated with N-Benzylethanolamine	50 cc/min	P&CAM 354
Carbon Monoxide	Long Term Detector Tubes	20 cc/min	---
Cyclohexane Solubles	Silver membrane plus Glass Fiber Filters	1.5 lpm	P&CAM 217
Nitrogen Dioxide	TEA coated molecular Sieve Tubes	50 cc/min	P&CAM S-320
Nitric Oxide	TEA coated molecular Sieve Tubes	50 cc/min	P&CAM S-321
Sulfur Dioxide	Long Term Detector Tubes	20 cc/min	---
Total Particulates	PVC Filters	1.5 lpm	---

VI. EVALUATION CRITERIA

The environmental criteria for exposure to toxic substances used in this evaluation are based on the following: 1. NIOSH Criteria Documents, Recommended Standards for Occupational Exposures; 2. Threshold Limit Values (TLV) of the American Conference of Governmental Industrial Hygienists (ACGIH); 3. U.S. Department of Labor, OSHA, Standards.

<u>Substance</u>	<u>NIOSH (or ACGIH) Recommended Criteria 10 Hr TWA*</u>	<u>OSHA Standards 8 Hr TWA</u>	<u>Health Effects(2,3,4)</u>
<u>Aldehydes</u>			
Acetaldehyde	100 ppm (ACGIH)	200 ppm	Eye, nose & throat irritation.
Butyraldehyde	---	---	Eye and skin irritation.
Formaldehyde	Lowest feasible level (NIOSH)	3 ppm 5 ppp ceiling	Conjunctivitis, eye irritation, upper respiratory irritation, skin sensitization and dermatitis; Suspected carcinogen
Propionaldehyde	---	---	Eye and skin irritation
Carbon Monoxide	35 ppm (NIOSH) 200 ppm ceiling	50 ppm	Headache, nausea, weakness, dizziness, confusion
Cyclohexane Solubles (Particulate polycyclic aromatic hydrocarbons)	0.2 mg/cu m (ACGIH)	0.2 mg/cu m	Diesel exhaust* may contain some polynuclear aromatic hydrocarbons which have a cancer causing potential
Nitrogen Dioxide	1 ppm ceiling	5 ppm	Respiratory irritation, delayed pulmonary edema, eye irritation
Nitric Oxide	25 ppm (NIOSH) (ACGIH)	25 ppm	Irritation of the eyes, nose & throat
Sulfur Dioxide	0.5 ppm (NIOSH)	5 ppm	Irritation of eyes, nose, throat, cough
Total Particulates	10 mg/cu m (ACGIH)	15 mg/cu m	Reduced visibility, unpleasant deposits in eyes & nasal passages

*NIOSH report "Industrial Hygiene Study of Diesel Bus Maintenance Facilities" which will be published in the near future (as of this date does not have a publication number) showed the polynuclear aromatic hydrocarbons portion of the cyclohexane concentrations were just at or less than detectable concentrations.

VII. RESULTS AND DISCUSSION

1. East Metro Facility

The results of the collected air samples are shown in Table 1 and the sample locations in Figure 1. There were five sample locations, three in bus storage area, one near the inspection lanes and bus exit and one in the maintenance area. The aldehydes, which were analyzed for acetaldehyde, butyraldehyde, formaldehyde and propionaldehyde, were all less than the detectable concentration of 0.03 ppm. Aldehydes can produce eye and upper respiratory irritation. Although the sample results were all low on the day of sampling, a single diesel bus, not operating properly, can produce a sufficient amount of aldehydes over a short period to cause a worker in the area to experience irritation of the eyes and respiratory tract. The sulfur dioxide samples were all less than or equal to the detectable concentration of 0.05 ppm which is well below the NIOSH recommended criterion of 0.5 ppm. The carbon monoxide samples ranged from 3 to 10 ppm. The 10 ppm sample was collected over a time period that a gas powered truck was in the bus storage area. These carbon monoxide concentrations are well below the NIOSH recommended criterion of 35 ppm.

Total particulates in the air contain particles emitted by the diesel engine and dust from dirt stirred up off the floor by the moving vehicles. Separate samples were collected during the first part of the morning when all the buses were leaving and during the second part of the morning when a portion of the buses were returning. In all cases the concentration during the first part of the shift was higher than the second part. This is reflective of the higher activity in the first part of the day when all the buses are leaving. The time weighted average total particulate concentration ranged from 0.15 to 0.55 mg/cu m which were all less than 6% of the nuisance dust criterion of 10 mg/cu m. The cyclohexane solubles are that portion of the diesel exhaust that can be dissolved in cyclohexane. They range from 0.07 to 0.16 mg/cu m. There is no standard for the cyclohexane soluble fractions of diesel exhaust. However, ACGIH recommends an 8-hour allowable level of 0.2 mg/cu m for particulate polycyclic aromatic hydrocarbons which would be a portion of the cyclohexane solubles. All the samples collected were below this level.

Nitrogen dioxide and nitric oxide are components of diesel exhaust. The NIOSH recommended allowable exposure to nitrogen dioxide is 1 ppm for any 15 minute period and for nitric oxide it is a 25 ppm average for a 10 hours workday. There was an approximate 4-fold difference in the nitrogen dioxide concentration between the first and second part of the shift. In the bus storage area, the average of the three sample locations was 1.06 ppm for the first portion of the shift when the buses went out and 0.23 ppm over the second part of the shift when a portion of the buses returned to the facility. Since one 3-hour average was 1.06 ppm, the NIOSH criterion of 1 ppm for any 15 minute period was exceeded. The nitrogen dioxide concentration was probably higher when the bus activity was at its peak. Some drivers could

experience a slight eye and/or respiratory irritation when warming up and checking the bus before the day's run. They should not experience a problem when returning the bus at the end of the run. The nitrogen dioxide concentrations during the first portion of the shift were 0.43 ppm near the inspection line and 0.74 ppm in the maintenance area. In the latter part of the morning, they dropped to 0.27 and 0.21 ppm, respectively.

The nitric oxide concentrations varied directly with the nitrogen dioxide. They ranged from 1.14 ppm to 2.62 ppm during the first portion of the shift and from 0.50 to 1.30 ppm during the latter portion. These concentrations are all less than the criterion of 25 ppm.

2. Platte Facility

The results of the air samples collected are shown in Table 2 and the sample locations in Figure 2. There were five sample locations, three in bus storage area, one in the inspection area and one in the running repair area. The aldehydes, which were analyzed for acetaldehyde, butyraldehyde, formaldehyde and propionaldehyde, were all less than the detectable concentration of 0.03 ppm. Aldehydes can produce eye and upper respiratory irritation. Although the sample results were all low on the day of sampling, a single diesel bus not operating properly can produce a sufficient amount of aldehydes over a short period to cause a worker in the area to experience irritation of the eyes and respiratory tract. The sulfur dioxide samples were all less than or equal to the detectable concentration of 0.05 ppm which is less than the NIOSH recommended criterion of 0.5 ppm. The carbon monoxide samples ranged from 2 to 16 ppm. The 16 ppm sample was collected in the bus storage near the vault. These carbon monoxide concentrations are below the NIOSH recommended criterion of 35 ppm.

Total particulates in the air contain particles emitted by the diesel engines and dust from dirt stirred up off the floor by the moving vehicles. Separate samples were collected the first part of the morning when all the buses were leaving and the second part of the morning during which time a portion of the buses returned. In all cases the concentration during the first part of the shift was higher than the second part. This is reflective of the higher activity in the first part of the day when all the buses are leaving. The time weighted average total particulate concentration ranged from 0.13 to 0.55 mg/cu m which were all less than 6% of the nuisance dust criteria of 10 mg/cu m. The cyclohexane solubles are that portion of the diesel exhaust that can be dissolved in cyclohexane. They range from 0.06 to 0.13 mg/cu m. There is no standard for cyclohexane solubles fractions of diesel exhaust. However, ACGIH recommends an 8-hour allowable level of 0.2 mg/cu m for particulate polycyclic aromatic hydrocarbons which would be a portion of the cyclohexane solubles. All the samples collected were below this level.

Nitrogen dioxide and nitric oxide are components of diesel exhaust. The NIOSH recommended allowable exposure to nitrogen dioxide is 1 ppm for any 15 minute period and for nitric oxide it is a 25 ppm average for a 10 hours workday. There was a large difference in the nitrogen dioxide concentration between the first and second part of the shift. In the bus storage area, the average of 3 sample locations was 1.29 ppm for the first portion of the shift when the buses went out and 0.48 ppm over the second part of the shift when a portion of the buses returned to the facility. Since one 3-hour average was 1.29 ppm, the NIOSH criterion of 1 ppm for any 15 minute period was exceeded. The nitrogen dioxide concentration was probably higher when the bus activity was at its peak. Some drivers could experience a slight eye and/or respiratory irritation when warming up and checking the bus before the day's run. They should not experience a problem when returning the bus at the end of the run. The nitrogen dioxide concentrations during the first portion of the shift were 0.53 ppm near the inspection area and 0.58 ppm in the running repair area. In the latter part of the morning, they dropped to 0.32 and 0.16 ppm, respectively.

The nitric oxide concentrations varied directly with the nitrogen dioxide. They ranged from 1.79 ppm to 4.81 ppm during the first portion of the shift and from 0.49 to 2.28 ppm during the latter portion. These concentrations are all less than the criterion of 25 ppm.

3. Alameda Facility

The results of the air samples collected are shown in Tables 3 & 4 and the sample locations in Figure 3. There were five sample locations, two in the bus storage areas, one in the running repair area and two in the maintenance area. The aldehydes, which were analyzed for acetaldehyde, butyraldehyde, formaldehyde and propionaldehyde, were all less than the detectable concentration of 0.03 ppm. Aldehydes can produce eye and upper respiratory irritation. Although the sample results were all low on the day of sampling, a single diesel bus, not operating properly, can produce a sufficient amount of aldehydes over a short period to cause a worker in the area to experience irritation of the eyes and respiratory tract. The sulfur dioxide samples were all less than or equal to the detectable concentration of 0.05 ppm which is well below the NIOSH recommended criterion of 0.5 ppm

The carbon monoxide samples ranged from 1 to 170 ppm. The bus storage area ranged from 1 - 6 ppm and in the repair area from 4 - 21 ppm. The carbon monoxide concentrations in these two areas are well below the NIOSH recommended criterion of 35 ppm. In the running repair area the concentration ranged from 5 - 170 ppm. Between Bay F and G, in the area where the tires are repaired, the concentration from 5:00 AM to 6:25 AM was 170 ppm. During this time the gas buses stored nearby were started and moved out of the garage. There was no one working in the immediate area except the drivers who were there for 10 to 15 minutes. It is possible that

the drivers' exposure could, on occasion, exceed the ceiling criterion of 200 ppm. From 6:25 AM to 12:45 AM, the concentration dropped to 19 ppm. The tire changer worked nearby during this time. His exposure was less than the NIOSH criteria of 35 ppm. In the running repair area, bay G, the carbon monoxide concentration from 4:50 AM to 7:30 AM was 30 ppm. This concentration is probably a result of the gas buses being started in bay F. From 7:30 to 11:40 AM the concentration dropped to 5 ppm. There is a tailpipe exhaust system in the running repair area for three of the four lanes. This reduces the amount of engine exhaust entering the work atmosphere. The time weighted average carbon monoxide concentration in the running repair area from 4:50 to 11:50 AM was 18 ppm which also is less than the criterion of 35 ppm.

Total particulates in the air contain particles emitted by the diesel engine and dust from dirt stirred up off the floor by the moving vehicles. Separate samples were collected the first part of the morning when all the buses were leaving and the second part of the morning during which time a portion of the buses returned. In all but the diesel repair area, the concentration during the first part of the shift was higher than the second part. This is reflective of the higher activity in the first part of the day when all the buses are leaving. The time weighted average total particulate concentration ranged from 0.08 to 0.36 mg/cu m which were all less than 4% of the nuisance dust criteria of 10 mg/cu m. The cyclohexane solubles are that portion of the diesel exhaust that can be dissolved in cyclohexane. They ranged from 0.03 to 0.16 mg/cu m. There is no standard for cyclohexane solubles fractions of diesel exhaust. However, ACGIH recommends an 8-hour allowable level of 0.2 mg/cu m for particulate polycyclic aromatic hydrocarbons which would be a portion of the cyclohexane solubles. All the samples collected were below this level.

Nitrogen dioxide and nitric oxide are components of diesel exhaust. The NIOSH recommended allowable exposure to nitrogen dioxide is 1 ppm for any 15 minute period and for nitric oxide it is a 25 ppm average for a 10 hours workday. There was a difference in the nitrogen dioxide concentration between the first and second part of the shift. In the bus storage area, the average of 2 sample locations was 0.16 ppm for the first portion of the shift when the buses went out and 0.07 ppm over the second part of the shift when a portion of the buses returned to the facility. These concentrations are well below the 1 ppm criterion for any 15 minute period. The nitrogen dioxide concentrations in the diesel repair area during the first portion of the shift were 0.85 and 1.01 ppm and in the latter part of the morning, they dropped to 0.43 and 0.58 ppm, respectively. The NIOSH criteria of 1 ppm for any 15 minute period was exceeded in this area. On the day of sampling only 3 of the 8 mechanics assigned to the repair area were working. Having more workers present would have increased the amount of time engines would have been run; thus, the diesel exhaust concentrations would have been higher than measured.

The nitric oxide concentrations varied along with the nitrogen dioxide. They ranged from 0.33 ppm to 3.99 ppm during the first portion of the shift and from 0.08 to 2.28 ppm during the latter portion. These concentrations are all less than the criterion of 25 ppm.

VIII. SUMMARY AND CONCLUSIONS

The sample results from all three facilities are summarized in the following paragraph:

Aldehyde concentrations (acetaldehyde, butyraldehyde, formaldehyde and propionaldehyde) were all less than 0.03 ppm and sulfur dioxide concentrations were less than 0.05 ppm. Carbon monoxide concentrations in the diesel bus storage and maintenance areas ranged from 3-21 ppm. At the Alameda facility the carbon monoxide concentration in the gas bus storage area during the peak morning dispatch period, was 170 ppm; however, only the drivers were in the area during this period and they were there for less than 15 minutes. Total particulate time weighted average concentrations ranged from 0.12 to 0.55 mg/cu m. During the peak morning period total particulate levels ranged from 0.15 to 0.81 mg/cu m. The cyclohexane soluble portion of these particulates ranged from 0.03 to 0.16 mg/cu m. Nitric oxide concentrations ranged from 0.33 to 5.62 ppm during the peak morning period and from 0.08 to 2.28 during the period when approximately half of the morning buses returned to the shop.

The nitrogen dioxide concentrations ranged from 0.16 to 1.81 ppm during the dispatch period and from 0.05 to 0.80 during the time the morning run buses were returned. Six of the 15 three-hour samples collected in the three facilities during the morning dispatch period exceeded the NIOSH recommended criteria of 1 ppm for any 15 minute period. They ranged from 1.01 to 1.81 with a mean of 1.21 ppm. Drivers and other workers may spend 15 minutes or more in these areas.

Nitrogen dioxide exposures were the only diesel exhaust component sampled for that exceeded individual substance exposure criteria used in this evaluation. There is no criterion for diesel exhaust as a whole. Table 5 is a summary of the nitrogen dioxide concentrations in the three bus storage areas and in the Alameda diesel repair area. The bus storage in the East Metro and Platte facilities both are large areas that depend on the general ventilation systems to control the diesel exhaust in the facilities. The Alameda facilities has several smaller areas with overhead doors that open on both sides of the storage bays that permits natural ventilation along with general exhaust ventilation to control the diesel exhaust. This difference is reflected in differences in the nitrogen dioxide concentrations of 1.06 and 1.29 ppm in the East Metro and Platte facilities versus the 0.16 ppm concentration in the Alameda facility during the time the buses left in the morning. The diesel repair area in the Alameda facility has no exhaust ventilation, which is the reason for the 0.85 and 1.01 ppm nitrogen dioxide concentrations in that area. Excessive carbon monoxide exposures could occur at the Alameda facility in the area where the gas powered buses are stored. During the time the buses are warming up before the morning run, the carbon monoxide concentration increases.

Only the drivers are in the area at that time. Personal carbon monoxide breathing zone samples on each driver are needed to identify any exposure above the 200 ppm ceiling criterion. The use of tail pipe exhaust ventilation can keep the carbon monoxide concentration down to a lower level.

The separate health effects of most contaminants in diesel exhaust are fairly well known. It is possible to establish a criterion for simultaneous exposures to substances that have similar health effects such as upper respiratory irritation, etc. However, there is currently no single permissible exposure level to diesel exhaust since all the substances present do not have the same health effects and the ratio of the substances present in the exhaust varies from one engine to another. The variation is a result of the variation in the diesel fuel, maintenance of the engine, temperature of the engine, etc.

There are many components of diesel exhaust that cause irritation of the eye, nose, throat and respiratory system. Some of these components, such as the aldehydes, are produced in larger quantities when a diesel engine is out of tune. This being the case, it is possible for a driver or a mechanic to experience discomfort over a short period of time in one portion of the bus storage area when such an engine is in operation. Changes in the existing ventilation systems or the addition of new systems in these areas could reduce the diesel exhaust concentrations.

IX. RECOMMENDATIONS

A. East Metro Facility

1. Several buses were run in the maintenance repair area while not connected to the tailpipe exhaust system. These systems must be used whenever an engine is run and the bus is not going to be immediately moved.
2. In addition to the regular general ventilation system, there are five exhaust systems that terminate in 12" open ducts 7 foot above the floor. These are timer-activated for peak traffic periods. There should be a system like these between every set of pillars in the bus storage area. A more efficient system would include an exhaust hood over the tailpipe of each bus.

B. Platte Facility

1. The automatic sensors that operate the supply and exhaust system should be set to be more sensitive. This can probably be accomplished by increasing the light path length in the sensor.
2. Some short circuiting of the supply air occurs. The supply air hits the roof of the buses and is deflected laterally toward the exhaust fans, therefore, sweeping the air at the ceiling level instead of at the breathing zone. Some of the supply air should be supplied at the floor level to purge the air at the breathing zone level.

3. More exhaust fans or collector plenums should be installed to cover a wider area for the exhaust air to return as opposed to a point return.
4. Increase the supply and exhaust air volumes during the peak period in the morning when the buses leave the facility.
5. Under certain outside atmospheric conditions (i.e., wind direction), reentry of the exhaust air into the supply air is possible. Extending the exhaust discharge point above the solar panels and exhausting the air vertically will reduce the potential for reentry.
6. Fresh air should be supplied to the small office by the vault and the area by the vault door as employees spend considerable time there when the buses are returning.
7. In the running repair area the supply air is distributed about 8 feet above the floor. This provides for poor air distribution and does not effect the breathing zone level some distance away. Supplying the air closer to the floor will aid in purging the air at the breathing zone level.
8. The local exhaust systems provided at each bay must be used whenever buses are run in place.

C. Alameda Facility

1. A local tailpipe exhaust system should be installed for each bus bay in the Bay H(b) diesel repair area. It should include adaptors for all makes and varieties of exhaust pipe discharge points (e.g., bottom exhaust and top exhaust). Supply air then has to be provided to make up for the air exhausted.
2. The air pressure in the Bay H(b) repair area should be positive relative to the air in Bay H(a) storage area to prevent the gas engine exhausts from entering the repair area. More supply air may have to be provided to the diesel repair area to accomplish this.
3. Bay G - The exhaust hoods only provide tailpipe exhaust ventilation only to the buses with bus top exhaust. Adaptors need to be provided for the buses with under the bus exhaust pipes.
4. Bay G - The wheel stops on the floor for the buses in running repair are about 18 inches too far forward. At this location the bus is too far forward and the tailpipe is at the front edge of the hood. The stops should be moved back 18 inches so the tailpipe will be directly under the center of the hood.
5. The exhaust fumes in Bay G for the tailpipe exhaust hoods are not on at all times the bus engines are running. One of the reasons is that the switches are not in a convenient location. Additional switches should be installed and at locations where the mechanics can easily reach them. Also the units need to be on whenever an engine is run in place.

6. There are only three exhaust hoods in Bay G running repair for 4 lanes of buses. Each lane should have a tailpipe exhaust system.
7. The ceiling exhaust fan in Bays A-B and D-E are turned on manually and are usually turned on only on Sundays when the buses are started prior to the Monday run. These fans should be put on timers and run during the peak morning startup-warming period.
8. The roof fans in Bays F, G and H are controlled by a single sensor in each bay which is mounted near the ceiling. The fan is not activated until the smoke reaches the sensor. There should be several sensors spaced near the roof and several more at a lower point so that when the exhaust builds up in any area of the bay the exhaust fan will be activated.
9. The automatic sensors that operate the ceiling fans should be set to be more sensitive. This can probably be accomplished by increasing the path length in the sensor.
10. The carbon monoxide concentration in Bay F from 5:00 AM to 6:25 AM was 170 ppm. A tailpipe exhaust system for use when the buses are warming up would reduce this carbon monoxide concentration in this area.
11. On Sunday's an employee starts all the buses that will be dispatched on Monday morning. He will spend a considerable amount of time in bus storage area. His exposure to nitrogen dioxide should be monitored.

X. REFERENCES

1. NIOSH Manual of Analytical Methods, Vol. 1-7.
2. NIOSH Criteria Documents, Recommended Standards for Occupational Exposure.
3. Occupational Diseases: A Guide to their Recognition. NIOSH Pub. (77-181).
4. Patty FA. Patty's industrial hygiene and toxicology. Vol II--toxicology, 3rd revised ed. New York: John Wiley & Sons, 1978.

XI. AUTHORSHIP AND ACKNOWLEDGEMENTS

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Originating Office: Hazard Evaluations and Technical
Assistance Branch
Division of Surveillance, Hazard
Evaluations and Field Studies

XII. DISTRIBUTION AND AVAILABILITY OF REPORT:

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. Regional Transportation District, Denver, Colorado
2. Amalgamated Transit Union, Local 1001, Denver Colorado
3. U. S. Department of Labor, Occupational Safety and Health Agency (OSHA), Region VIII, Denver, Colorado

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

TABLE 1
DIESEL EXHAUST COMPONENTS
GENERAL AREA AIR CONCENTRATIONS
March 23, 1982

EAST METRO FACILITY
REGIONAL TRANSPORTATION DISTRICT
DENVER, COLORADO
HETA 82-137

Substance	Sample Time	Unit of Measure	Location 1 Bay 29	Location 2 Bay 12	Location 3 Bay 16	Location 4 Near exit & Inspection Line	Location 5 Maintenance By Hoist 6
cyclohexane solubles	4:55a-11:55a	mg/cu m	0.16	0.13	0.07	0.07	0.07
total particulates (TWA)*	4:55a-11:55a	mg/cu m	0.55	0.43	0.15	0.31	0.34
total particulates	4:55a-8:00a	mg/cu m	0.81	0.45	0.18	0.47	0.43
total particulates	8:00a-11:55a	mg/cu m	0.34	0.41	0.12	0.18	0.27
aldehydes**	4:55a-8:00a	ppm	<0.03	<0.03	<0.02	<0.03	<0.02
aldehydes	8:00a-11:55a	ppm	<0.02	<0.02	<0.02	<0.02	<0.02
nitrogen dioxide	4:55a-8:00a	ppm	1.33	0.85	1.01	0.43	0.74
nitrogen dioxide	8:00a-11:55a	ppm	0.21	0.16	0.32	0.27	0.21
nitric oxide	4:55a-8:00a	ppm	5.62	3.34	2.52	1.14	2.45
nitric oxide	8:00a-11:55a	ppm	1.30	1.22	0.50	0.90	1.14
sulfur dioxide	4:55a-8:00a	ppm	0.05	ND	ND	ND	0.05
sulfur dioxide	8:00a-11:55a	ppm	ND†	ND	ND	ND	ND
carbon monoxide	4:55a-8:00a	ppm	6	3	5	5	4
carbon monoxide	8:00a-11:55a	ppm	10	6	7	4	3

* TWA - Time Weighted Average

** Aldehydes - include acetaldehyde, butyraldehyde, formaldehyde, and propionaldehyde

† Not Detectable - less than 0.05 ppm

TABLE 2
DIESEL EXHAUST COMPONENTS
GENERAL AREA AIR CONCENTRATIONS
March 24, 1982

PLATTE FACILITY
REGIONAL TRANSPORTATION DISTRICT
DENVER, COLORADO
HETA 82-137

Substance	Sample Time	Unit of Measure	Location 1 Bus Storage Lane 30-31	Location 2 Bus Storage Lane 12-13	Location 3 Bus Storage By Vault	Location 4 Bus Inspec- tion Area	Location 5 Running Repair
cyclohexane solubles	4:45a-12:00n	mg/cu m	0.13	0.09	0.10	0.03	0.06
total particulates (TWA)*	4:45a-12:00n	mg/cu m	0.32	0.40	0.55	0.22	0.13
total particulates	4:45a-7:45a	mg/cu m	0.47	0.44	0.65	0.31	0.15
total particulates	7:45a-12:00n	mg/cu m	0.23	0.38	0.48	0.16	0.11
aldehydes**	4:45a-7:45a	ppm	<0.02	<0.03	<0.02	<0.02	<0.03
aldehydes	7:45a-12:00n	ppm	<0.02	<0.02	<0.02	<0.02	<0.02
nitrogen dioxide	4:45a-7:45a	ppm	1.06	1.81	1.01	0.53	0.58
nitrogen dioxide	7:45a-12:00n	ppm	0.32	0.80	0.32	0.32	0.16
nitric oxide	4:45a-7:45a	ppm	4.81	3.75	3.67	2.20	1.79
nitric oxide	7:45a-12:00n	ppm	1.71	1.46	2.28	1.22	0.49
sulfur dioxide	4:45a-7:45a	ppm	0.05	ND†	ND	ND	ND
sulfur dioxide	7:45a-12:00n	ppm	ND	ND	ND	ND	ND
carbon monoxide	4:45a-7:45a	ppm	8	7	14	4	5
carbon monoxide	7:45a-12:00n	ppm	5	4	16	4	2

* TWA - Time Weighted Average

** Aldehydes - include acetaldehyde, butyraldehyde, formaldehyde, and propionaldehyde

† Not Detectable - less than 0.05 ppm

TABLE 3
DIESEL EXHAUST COMPONENTS
GENERAL AREA AIR CONCENTRATIONS
March 25, 1982

ALAMEDA FACILITY
REGIONAL TRANSPORTATION DISTRICT
DENVER, COLORADO
HETA 82-137

Substance	Sample Time	Unit of Measure	Location 1 Bus Storage Bay A & B	Location 2 Bus Storage Bay D & E	Location 3 Repair East Side of Bay H	Location 4 Repair West Side of Bay H	Location 5 Running Repair Bay G
cyclohexane solubles	4:50a-11:50a	mg/cu m	0.03	0.02	0.16	0.16	0.04
total particulates (TWA)*	4:50a-11:50a	mg/cu m	0.12	0.23	0.22	0.28	0.27
total particulates	4:50a-7:30a	mg/cu m	0.18	0.28	0.32	0.24	0.36
total particulates	7:30a-11:50a	mg/cu m	0.08	0.19	0.16	0.31	0.22
aldehydes**	4:50a-7:30a	ppm	<0.03	<0.03	<0.02	<0.03	<0.03
aldehydes	7:30a-11:50a	ppm	<0.03	<0.02	<0.02	<0.02	<0.02
nitrogen dioxide	4:50a-7:30a	ppm	0.16	0.16	0.85	1.01	0.48
nitrogen dioxide	7:30a-11:50a	ppm	<0.05	0.10	0.43	0.58	0.43
nitric oxide	4:50a-7:30a	ppm	0.33	0.57	2.93	3.99	1.55
nitric oxide	7:30a-11:50a	ppm	0.08	0.49	1.79	2.28	0.57
sulfur dioxide	4:50a-7:30a	ppm	ND†	ND	ND	ND	ND
sulfur dioxide	7:30a-11:50a	ppm	ND	ND	ND	ND	ND
carbon monoxide	4:50a-7:30a	ppm	1	6	21	21	38
carbon monoxide	7:30a-11:50a	ppm	2	3	4	5	5

* TWA - Time Weighted Average

** Aldehydes - include acetaldehyde, butyraldehyde, formaldehyde, and propionaldehyde

† Not Detectable - less than 0.05 ppm

TABLE 4
DIESEL EXHAUST COMPONENTS
GENERAL AREA AIR CONCENTRATIONS
March 25, 1982

ALAMEDA FACILITY
REGIONAL TRANSPORTATION DISTRICT
DENVER, COLORADO
HETA 82-137

<u>Substance</u>	<u>Sample Time</u>	<u>Location</u> F - G Bay <u>Next to Gas Buses</u>
carbon monoxide	5:00a - 6:25a	170 ppm
carbon monoxide	6:25a - 10:45a	19 ppm

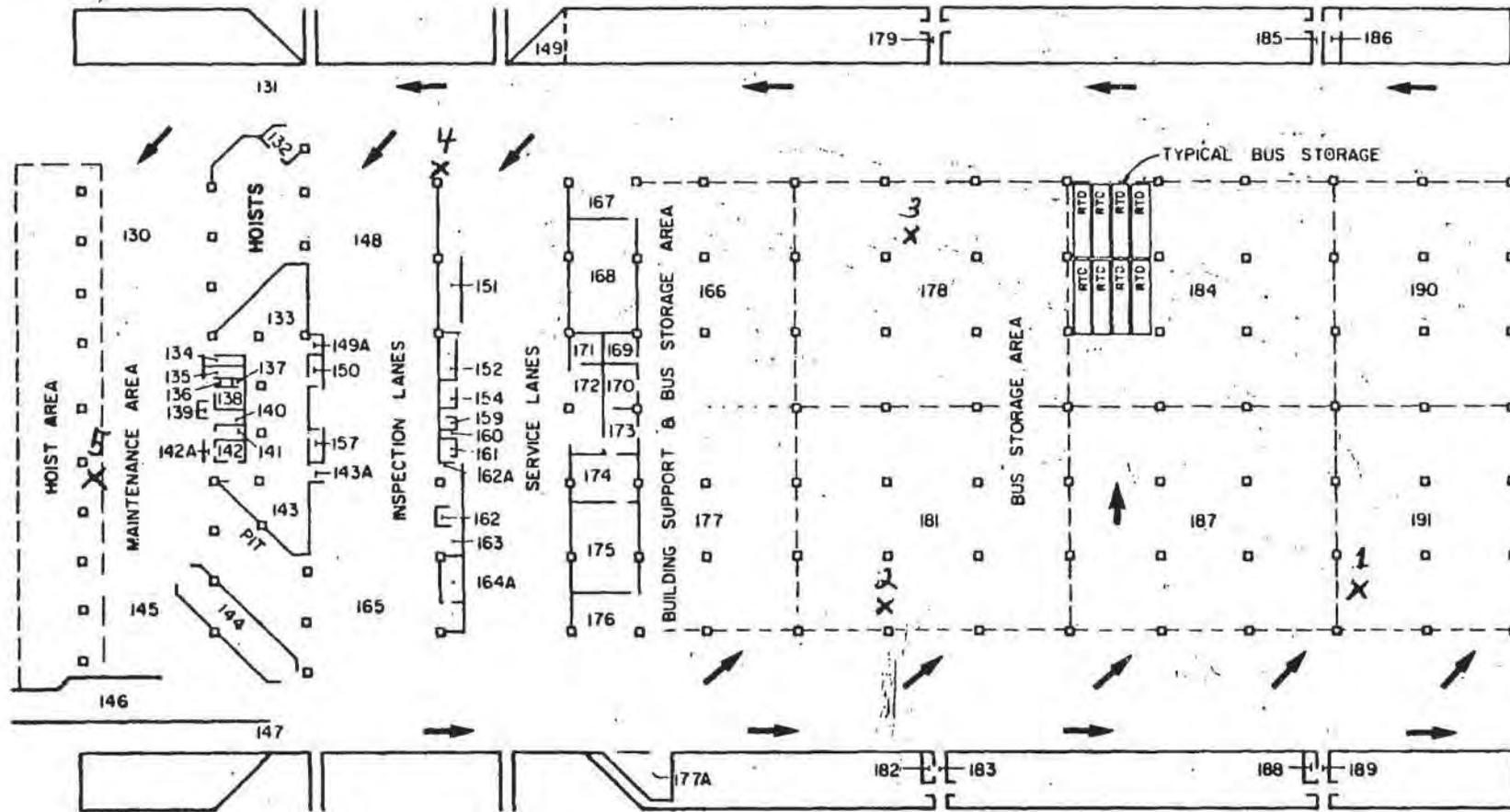
TABLE 5
COMPARISON OF NITROGEN DIOXIDE CONCENTRATIONS
MARCH 23 - 25, 1982

REGIONAL TRANSPORTATION DISTRICT
DENVER, COLORADO
HETA 82-137

<u>Area</u>	<u>First Portion of Shift</u>	<u>Second Portion of Shift</u>
East Metro Facility Bus Storage	1.06 ppm	0.23 ppm
Platte Facility Bus Storage	1.29 ppm	0.48 ppm
Alameda Facility Bus Storage	0.16 ppm	0.07 ppm
Alameda Facility Diesel Repair	1.01 ppm	0.58 ppm

END OF DOCUMENT

FIGURE 1



X - SAMPLE LOCATIONS

RTD EAST METRO FACILITY
 Building Floor Plan &
 Internal Circulation

ORIGINAL SCALE 1" = 50'-0"



- A Administration
- B Body Shop
- BS Bus Storage
- BW Bus Washer
- D Dynamometer
- I Inspection

- M Mezzanine
- P₁ Parts
- P₂ Paint
- RR Running Repair

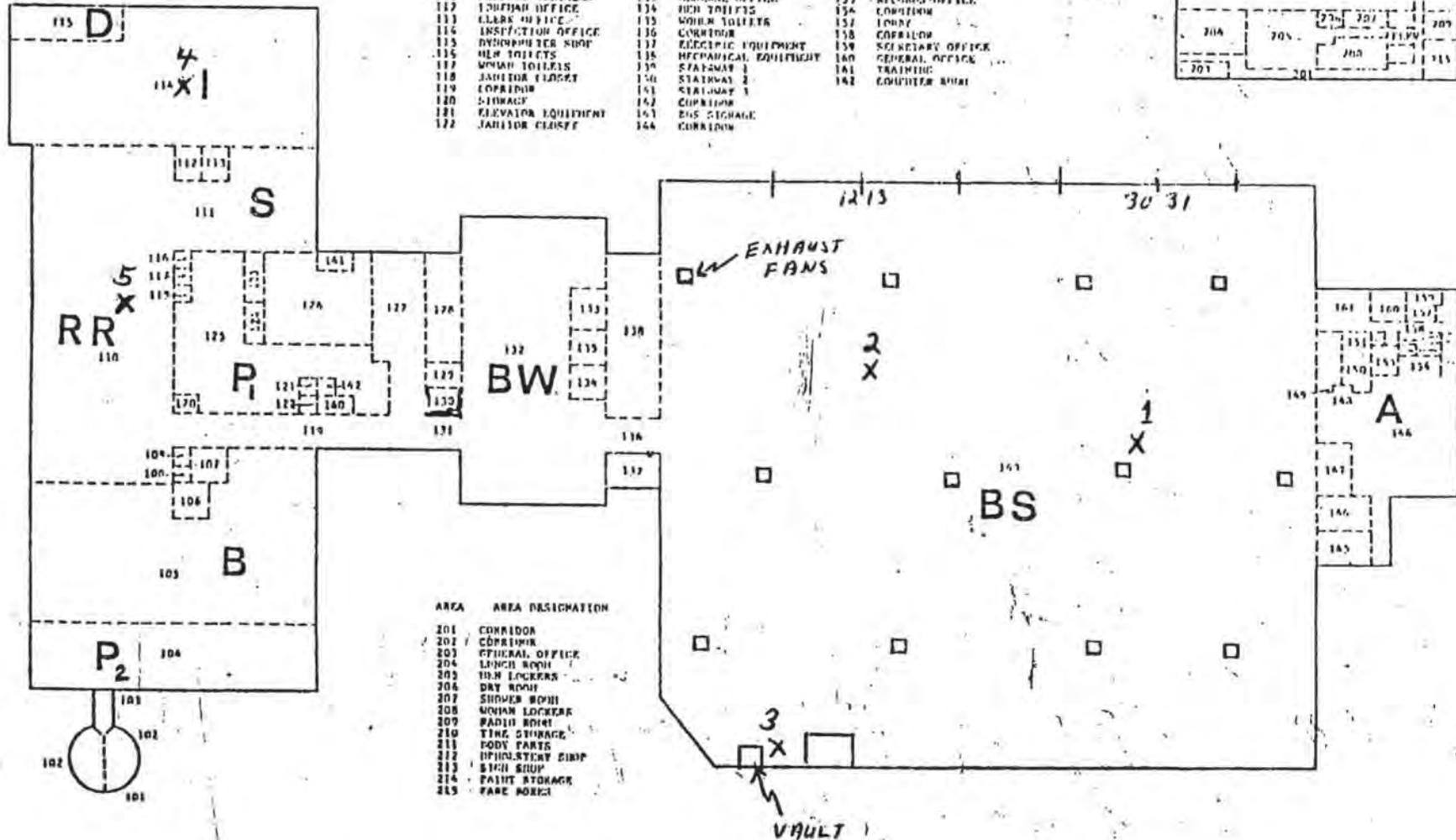
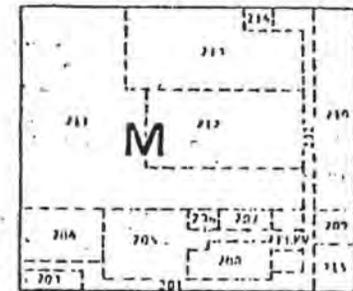
- S Support Vehicle
- OS All Roof & Yard Outside Work

PLATTE
DIVISION

EXHIBIT VIII-2

REGIONAL TRANSPORTATION DISTRICT
PLATTE BUS TERMINAL

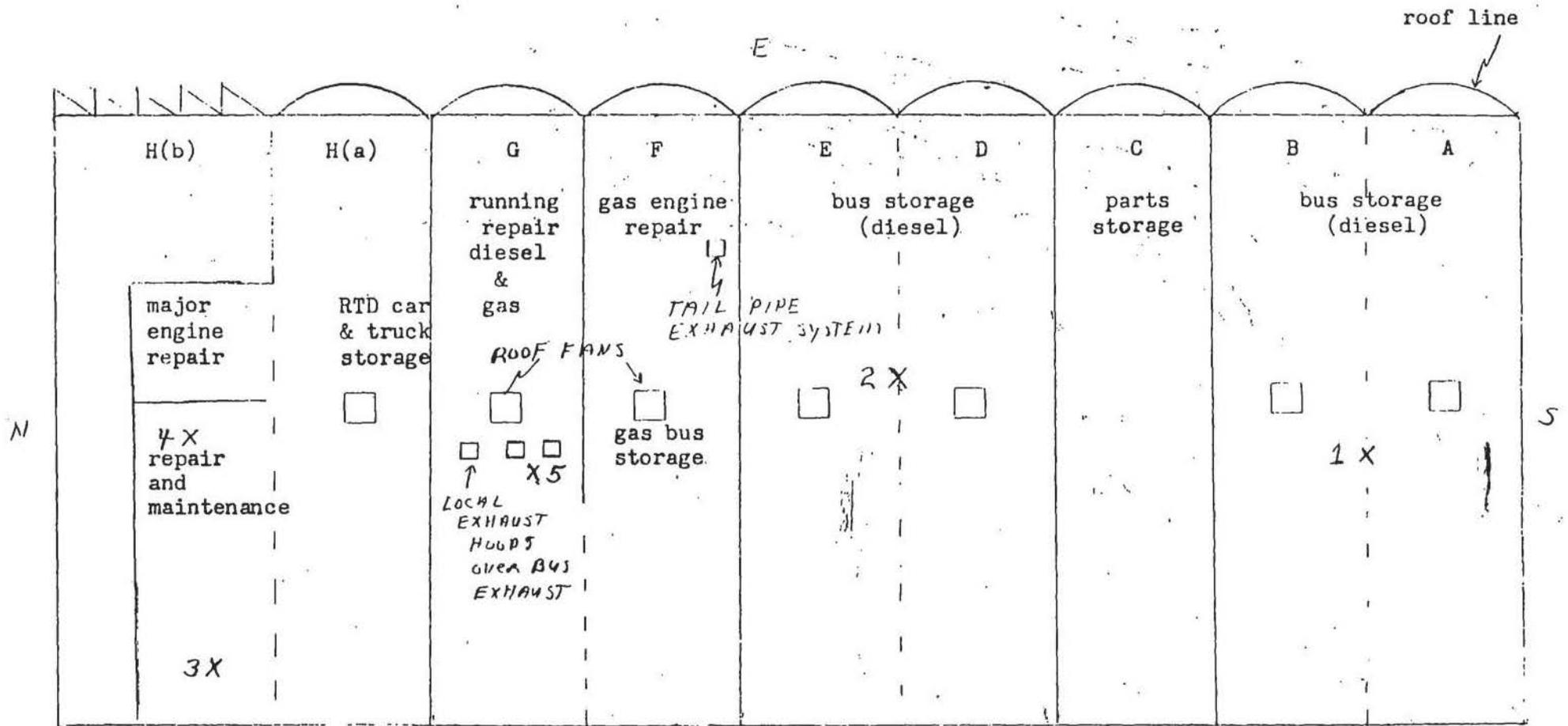
AREA	AREA DESIGNATION	AREA	AREA DESIGNATION	AREA	AREA DESIGNATION
101	PAINT STORAGE	123	BATTERY SHOP	145	ELECTRICAL EQUIPMENT
102	SMALL PARTS	124	LADG. SHOP	146	DAY ROOM
103	LEGS	125	PAPER SHOP	147	CHIT ROOM
104	PAINT SHOP	126	TIRE SHOP	148	WOMAN TOILET/LOCKERS
105	PAINT SHOP	127	TIRE CHANGE	149	WOM. TOILET/LOCKERS
106	FOREMAN OFFICE	128	CHASSIS WASH	150	WOMAN TOILET
107	WELDING	129	COURTRESS	151	MEN TOILET
108	WOMAN TOILETS	130	BUILDING MAINTENANCE	152	MECHANICAL EQUIPMENT
109	MEN TOILETS	131	PIPELINE	153	DRY ROOM
110	PAINT CHANGE SHOP	132	RETRIEVAL/WASH	154	CLERK OFFICE
111	SUPPORT VEHICLES	133	GENERAL OFFICE	155	RECORDS OFFICE
112	FOREMAN OFFICE	134	MEN TOILETS	156	CORRIDOR
113	CLERK OFFICE	135	WOMAN TOILETS	157	CORRIDOR
114	INSPECTION OFFICE	136	CORRIDOR	158	CORRIDOR
115	DYNAMOMETER SHOP	137	ELECTRICAL EQUIPMENT	159	GENERAL OFFICE
116	MEN TOILETS	138	MECHANICAL EQUIPMENT	160	GENERAL OFFICE
117	WOMAN TOILETS	139	STAIRWAY 1	161	TRAINING
118	SMOKER CLOSET	140	STAIRWAY 2	162	CORRIDOR
119	CORRIDOR	141	STAIRWAY 3		
120	STORAGE	142	CORRIDOR		
121	ELEVATOR EQUIPMENT	143	BUS STORAGE		
122	JANITOR CLOSET	144	CORRIDOR		



AREA	AREA DESIGNATION
201	CORRIDOR
202	CORRIDOR
203	GENERAL OFFICE
204	LUNCH ROOM
205	TOILET LOCKERS
206	DAY ROOM
207	SHOWER ROOM
208	WOMAN LOCKER
209	MEN LOCKER
210	TIRE STORAGE
211	BODY PARTS
212	INDUSTRY SHOP
213	TIRE SHOP
214	PAINT STORAGE
215	PAINT STORAGE

X - SAMPLE LOCATIONS

FIGURE 3
ALAMEDA FACILITY



X - SAMPLE LOCATIONS