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Control of Exposure to Diesel Exhaust Emissions in Fire Stations

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ABSTRACT

Firefighters are potentially exposed to diesel exhaust emissions inside fire stations when vehicles start up or return to the station. A survey of 23 Ontario fire stations was conducted to assess the effectiveness of station design and ventilation measures in controlling the concentration of exhaust constituents in living areas. Methods consisted of walk-through surveys, smoke tube tests, and monitoring of changes in concentrations of carbon dioxide and carbon monoxide, used as indicators of contamination by exhaust constituents. Control measures evaluated included structural barriers, natural and mechanical ventilation, and pole hole location. Of the controls examined, the most effective was mechanical tailpipe exhaust. Other effective measures included enclosure of pole holes, general mechanical exhaust on the apparatus floor, natural ventilation, and maintenance of positive pressure in living areas.

INTRODUCTION

The use of diesel-powered vehicles has increased in recent years, prompting concerns regarding occupational exposure to diesel exhaust in workplaces such as fire stations. Because eating, working, sleeping, and recreational quarters for firefighters are usually located in the same building as the firefighting vehicles, there is potential for contamination of these areas by vehicle exhaust. Potential exposure of firefighters is exacerbated by the fact that they usually work extended shifts and sleep in the stations.

Reported health effects associated with diesel exhaust include reversible changes in pulmonary function, eye and respiratory irritation, and pulmonary emphysema. The major cause for concern, however, has resulted from epidemiological and animal studies suggesting the carcinogenicity of diesel exhaust (NIOSH 1988; Steenland 1986).

Products of the complete combustion of diesel fuel consist primarily of carbon dioxide, water, and sulfur dioxide. In addition to these products, incomplete combustion of diesel fuel produces carbon monoxide, soot particles, and oxides of nitrogen. Compared to gasoline engines, diesel engines produce 20 to 100 times more particulate matter, nearly all of which is in the respirable size range (Pepelko 1982). It has been estimated that 15% to 65% of the total particulate mass consists of organic compounds, such as polycyclic aromatic hydrocarbons (PAHs), adsorbed to the particle surface. It is these adsorbed compounds that are thought to be responsible for the carcinogenicity and mutagenicity of diesel exhaust (NIOSH 1988; Weisenberger 1984).

The exposure of firefighters to diesel exhaust has been examined in two recent studies. Grossi et al. (1986) monitored carbon monoxide, oxides of nitrogen, volatile organic hydrocarbons, PAHs, and the benzene soluble fraction of total particulate in five fire stations in New York City. Results indicated that the concentrations of all contaminants were above outdoor levels, with concentrations of oxides of nitrogen and benzene solubles in some locations approaching their respective ACGIH or NIOSH guidelines. Froines et al. (1987) monitored personal exposure to total particulate and the methylene-chloride soluble fraction of diesel particulate in New York, Los Angeles, and Boston fire departments. The highest exposure to total particulate found was an eight-hour time-weighted average of 0.48 mg/m^3. The methylene chloride extractable fraction averaged 24% of total diesel particulate.

The objective of the present study was to assess the effectiveness of control measures in fire stations to minimize indoor concentrations of diesel exhaust. Parameters examined included station layout, structural barriers, and natural and mechanical ventilation.

METHODS

Twenty-three fire stations in the Toronto and Ottawa areas were selected for study on the basis of variation in structural design and ventilation. Study methods consisted of walk-through surveys, smoke tube tests, and air sampling for markers of diesel exhaust. The constituents of diesel exhaust initially selected as markers were carbon monoxide, carbon dioxide, and oxides of nitrogen.

The selection of these gases was based on feasibility of obtaining instantaneous measurements and on previous research that supports their usefulness as markers for other constituents of diesel exhaust (Johnson 1980; Grossi 1986).

Instantaneous measurements of the marker gases were made during actual or simulated vehicle runs, under a variety of ventilation conditions. Carbon dioxide (CO_2) was measured with a carbon dioxide direct-reading monitor or a carbon dioxide analyzer and carbon monoxide (CO) with a CO direct-reading monitor or a another instrument. Manufacturer's data reported an accuracy of 2 ppm for the CO monitors. Oxides of nitrogen were measured with colorimetric detector tubes. Reported detection limits for these tubes are 0.5 ppm nitrogen dioxide and 1 ppm nitric oxide.

In each station, concentrations of carbon monoxide and carbon dioxide were measured in at least four locations at inter-

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vals of approximately 5 to 10 minutes for a duration of 20 to 30 minutes following a vehicle's starting up or returning to the station. Gasoline as well as diesel-powered vehicles were used in some of the simulations.

The exhaust emitted at the tailpipes of 16 fire department vehicles was tested for carbon monoxide and carbon dioxide using colorimetric detector tubes.

DESCRIPTION OF STATIONS AND FIREFIGHTERS' ACTIVITIES

Firefighters' shifts usually average 42 hours per week and rotate between a 10-hour day shift and a 14-hour night shift. When not responding to alarms, firefighters' duties include training and maintenance of equipment and station facilities. Parts of each shift are spent in cooking, eating, exercising, recreation, and (on the night shift) sleeping.

Facilities in most stations generally include an apparatus floor, which houses the vehicles, a dispatch office or "floor watch," a kitchen, sitting rooms, dormitories, an exercise room, and offices. Firepoles are provided in all two-story stations to allow rapid access to the apparatus floor from the second story. Most of the stations surveyed have hose towers providing mechanical exhaust for drying hoses.

Vehicles exit and return to the apparatus floor through bay doors. "Drive-through" stations have a set of both "front" and "back" bay doors, so that vehicles can drive forward into the station. Where there is only a single set of doors, returning vehicles must back in. Many stations have timers on the doors, so that they shut automatically within one to three minutes after vehicles leave the station.

Fifteen of the stations surveyed have general exhaust fans on the apparatus floor. One has a tail pipe exhaust to the outdoors that automatically disconnects from the vehicle as it exits the station. Living areas in some stations were served by HVAC systems. A summary of station facilities is provided in Table 1.

The number of vehicles assigned to each fire station usually varies between one and five. Recent models of vehicles (except for vans and cars) are primarily diesel-fueled; older vehicles may be gasoline-fueled.

RESULTS

Results of smoke tube tests are summarized in Table 2. Results of colorimetric detector tube sampling for oxides of nitrogen found no detectable levels of nitrogen dioxide and non-detectable or barely detectable concentrations of nitric oxide.

Background concentrations of carbon dioxide were generally between 350 and 500 ppm. Concentrations following vehicle runs were between 390 and 850 ppm and averaged approximately 500 ppm. Due to the relatively low elevation above background and the possibility of contamination by human respiration, carbon dioxide proved to be of little value as a marker for vehicle exhaust. Therefore, in analyzing the results, the concentration of carbon monoxide provided more useful data.

Selected results of carbon monoxide monitoring are provided in Table 3 and Figures 1 through 6. It must be noted that measured concentrations of CO are useful only as markers for vehicle exhaust and cannot be taken as an indication of personal exposure to CO. Results of sampling tailpipe exhaust are reported in Table 4.

DISCUSSION

As would be expected, results of sampling for carbon monoxide indicate that mechanical tailpipe exhaust was the most effective control measure examined with respect to preventing contamination of the station by vehicle exhaust (see Figure 1). Changes in carbon monoxide concentrations in the other stations indicate the effectiveness of apparatus floor exhaust fans in diluting vehicle emissions and preventing migration of contaminants to living areas. Examples are illustrated in Figures 2 and 3.

TABLE 1
Summary of Station Facilities

Station No.	No. stories above ground	No. pole holes	General Mechanical Ventilation	Openable windows	AF[τ] exhaust	make-up air louvres	hose tower exhaust
1	2	1		√			
2	1	-		√	√		√
3	2	-	√				√
4	1	-	√	√			√
5	1	-		√	√	√	
6	1	-		2	√		
7	1	-	√		√		
8	2	1		1	√		√
9	1	-	√	√	√		
10	2	2	√	√	√		√[μ]
11	2	2	√	√	√		√[μ]
12	2	2	√		√		√[μ]
13	1	-		√			
14	2	2	√	1	√		√[μ]
15	2	2	√	√	√		√[μ]
16	2	3	√				√
17	2	3	√	√			√
18	2	2	√	√	√	√	√
19	1	-		√	√	√	√
20	2	3		√			√
21	2	2		√	√		√
22	1	-		√	√[σ]		
23	1	-	√	√	√	√	√

[σ] tail pipe exhaust
[μ] equipped with mechanically provided make-up air
[τ] AF: apparatus floor

TABLE 2
Smoke Tube Test Results
(with mechanical ventilation on in living areas, where applicable)

Station No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	23
AF exhaust off: A)	+	+	-	+	=	-	=	=	-	+	+/-	+	=	=	-/=			+			+	=
B)	+		=					-		-	-	-		-	+/-			-			+	
AF exhaust on: A)		+			-	-		-	-	-	-			-	-			-			-	-
B)								-		-	-			-	-			-			+	
Hose tower exhaust on A)								+		+/-	+/-	+		+		+	+		+	-		+
B)								-		-	-	-		-		-	+			+		
AF and hose tower exhaust A)										-	-			-					-			
on: B)								-			-			-								
Bay doors open & AF exhaust A)	-	++	+/	++	+	+	+/-	=	-	++	+/-	+	+/-	+	=							
off: B)	-		=					-		-	-	-		+	+/-							
Bay doors open & AF exhaust A)		++			=	=	+/-	=	-	++	+/-			+	=							
on: B)								-		-	-			+	+/-							

A)= Pressure of AF relative to adjacent areas
B)= Pressure of ground floor living areas or apparatus floor relative to second floor (via fire pole holes and stairwells)
+: positive -: negative ++: strong positive --: strong negative =: no relative pressure
/: the two different results were obtained at different doors or pole holes/stairwells

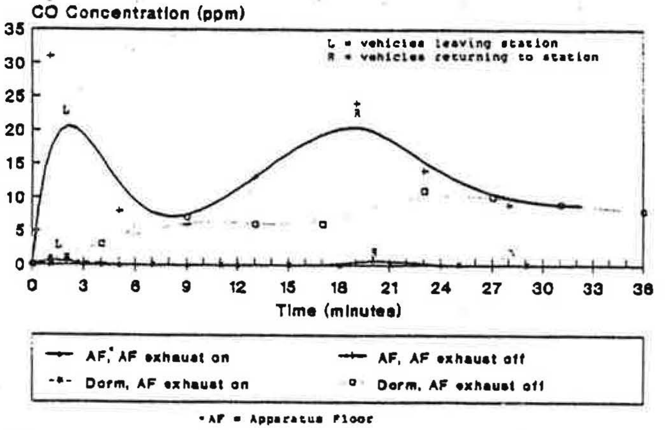

Figure 1 Effect of mechanical tailpipe exhaust on carbon monoxide concentration, stn. 22

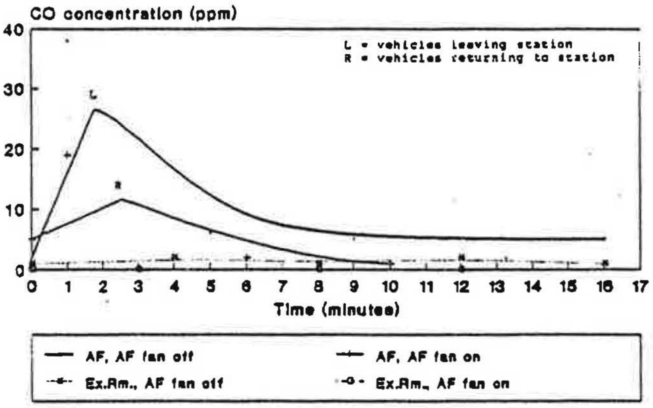

Figure 2 Effect of apparatus floor exhaust on carbon monoxide concentration, stn. 18

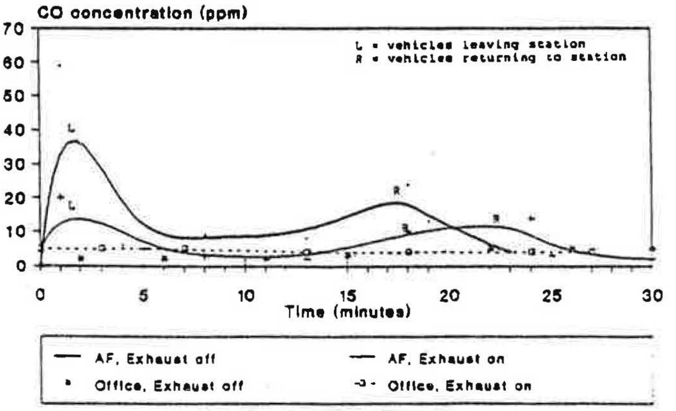

Figure 3 Effect of apparatus floor exhaust on carbon monoxide concentration, stn. 21

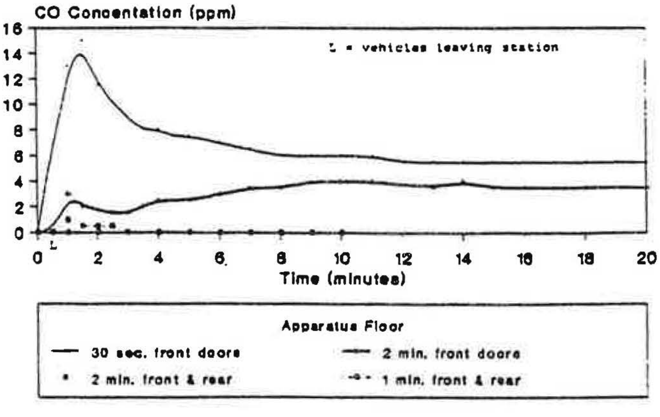

Figure 4 Effect of delayed closing of bay doors on carbon monoxide concentration, stn. 3

TABLE 3
Vehicle Response Simulations—Examples of Test Conditions and Results

Stn. No.	Run # and Test Conditions	Test Area	Background CO Concentration (ppm)	Maximum CO Concentration (ppm)
1	#1: 2 diesel & 1 gas vehicle drove out through front doors of station at 30 to 60 seconds; doors closed at 75 seconds; pole hole cover lifted open at 23 min.	living-G	0	3
	#2: 2 diesel trucks drove out of the station as above; pole hole cover remained closed.	living-G	0	0
2	#4: 1 gas truck drove out through rear door at 30 sec., door closed at 40 sec., ceiling fans on; AF exhaust on.	AF	0.5	13
	#7: as above, no exhaust;	AF	0.5	9
3	#6: 3 diesel & 1 gas vehicle drove out of station through front doors at 30 seconds with rear doors closed; doors closed at 2 minutes; ceiling fans on.	AF	0	5
	#7: as in #6 with a 2 minute delay on both the front and back bay doors.	AF	0	1
5	#5: 1 diesel truck was run inside the station for 20 minutes with bay doors open.	AF living-G	0 0.5	4 1
6	#5: gas truck left station at 30 sec., door closed at 40 sec., AF exhaust off; all doors opened at 30 minutes.	AF living-G	1 2	14 3.5
	#8: as above with AF exhaust on.	AF living-G	1 2	8 2
7	#3: 1 diesel & 2 gas vehicles drove out through front doors; doors closed at 45 seconds; exhaust turned on at 22 min. front 3 doors opened at 40 minutes.	AF	1	11
	#4: above 3 vehicles backing in; doors closed at 45 seconds; front 3 & 1 rear door opened at 30 minutes.	AF	1.5	17
8	#2: gas truck drove out at 40 seconds; door closed at 1 minute; exhaust turned on via the 15 minute timer at 20 and 55 minutes.	AF living-G living-U	1 1 1	37 33 1.5
10	#3: 3 diesel & 1 gas vehicles backed into station, then drove out at 10 seconds; doors closed after 90 second delay; no fans or exhaust.	AF	2.5	21
	#4: as above with exhaust on automatic; AF exhaust activated for < 5 minutes by NO_2 monitor.	AF	5	10

Natural ventilation also provided effective dilution of contaminants (e.g., Figures 4 and 5). Sampling results indicate that, in "drive-through" stations, leaving both doors open for at least 90 seconds is even more effective than an apparatus floor fan in diluting exhaust emissions. However, keeping doors open in the winter may not be practical or comfortable, and inflow from the doors may disperse contaminants into other parts of the station.

TABLE 3 (*continued*)
Vehicle Response Simulations—Examples of Test Conditions and Results

Stn. No.	Run # and Test Conditions	Test Area	Background CO Concentration (ppm)	Maximum CO Concentration (ppm)
11	#4: gas truck ran inside station for 20 seconds, bay doors closed; ceiling fans off; AF exhaust off.	AF	3	14
	#5: as above, exhaust on; 3 bay doors opened at 20 minutes.	AF	1	17
	#6: as above, exhaust off; 1 bay door opened at 21 minutes.	AF	1	20
12	#3: 2 diesel trucks left station at 25 seconds; ceiling fans on; doors closed at 35 and 40 seconds.	AF	0	22
	#5: driving out as in #3 above; doors closed at 90 seconds.	AF	4	9
	#6: driving out as in #1; doors closed at 2 minutes; returned at 12 minutes (actual alarm).	AF	3	9
14	#9: 3 diesel & 1 gas vehicle drove out at 20 seconds; doors closed at 30 sec.; ceiling fans on; AF exhaust off.	living-G	2	3
	#10: above vehicles backed into station; doors closed by 75 seconds; firemen walked through door from AF to living areas as normally would upon returning from an alarm.	living-G	2	12
15	#2: 2 diesel trucks backed into station with doors closed at 30 seconds; AF exhaust was set to NO_2 monitor and was not activated.	AF	1	1
	#3: as above, driving out.	AF	1	1
16	#1: drive through station; 3 trucks started and left through south doors; south doors closed after 2 minutes; 2 north doors left open; central air conditioning on upstairs.	AF	2	120
		living-G	2	6
		living-U		2
	#2: 3 trucks started, exit through south doors; all doors closed after 3 minutes.	AF	2	7
		living-G	2	4
		living-U		2
17	doors close 1 minute after 2 diesel trucks exit; windows closed & air conditioning off.	AF	0	62
		living-G	0	10
		living-U	0	10
18	#1: doors closed 4 minutes after 3 diesel trucks exit; AF exhaust fan off.	AF	2	38
		living-G	2	7
		living-U	1	2
	#2: doors closed 4 minutes after truck returned; exhaust fan on.	AF	2	19
		living-G	2	10
		living-U	1	0

Smoke tube tests and CO measurements were used to assess potential for migration of contaminants from the apparatus floor to other areas of the stations. Under the best ventilation conditions, CO concentrations in areas outside the apparatus floor rose no more than 1 ppm above background, even in stations with high peak concentrations on the apparatus floor. In less favorable situations, levels rose to as high as 10 ppm above background (e.g., Figure 6).

TABLE 3 (*concluded*)
Vehicle Response Simulations—Examples of Test Conditions and Results

Stn. No.	Run # and Test Conditions	Test Area	Background CO Concentration (ppm)	Maximum CO Concentration (ppm)
19	#1: door closed 3 minutes after 1 truck drove out of station; exhaust fan on until 45 seconds after door closed.	AF living-G	1 1	11 4
	#2: as in A); no exhaust fan.	AF living-G	1 1	14 6
20	#1: doors closed 3 minutes after 2 trucks exit; all doors and windows closed.	AF living-G living-U	0 1 2	40 7 4
	#2: as in A); upstairs windows open.	AF living-G living-U	0 1 2	5 6 2
21	#1: doors closed 2.5 minutes after 2 trucks exit; AF exhaust fan off.	AF living-G living-U	0 2 1	59 8 3
	#2: doors closed 3 minutes after 2 trucks exit; AF exhaust fan on.	AF living-G living-U	0 2 1	20 18* 5
22	#1: 1 truck exits; tailpipe exhaust on.	AF living-G	0 0	1 1
	#2: 1 truck exits; tailpipe exhaust off.	AF living-G	0 0	31 7
23	#1: door closed immediately after 1 truck exits; AF exhaust fan on until 4 minutes after truck exits.	AF living-G	1 0	4 2

* possible contamination from cigarette smoke

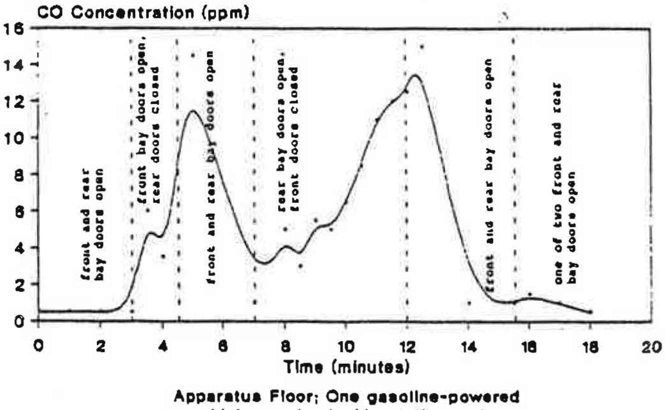

Figure 5 *Effect of natural ventilation on carbon monoxide concentration, stn. 2*

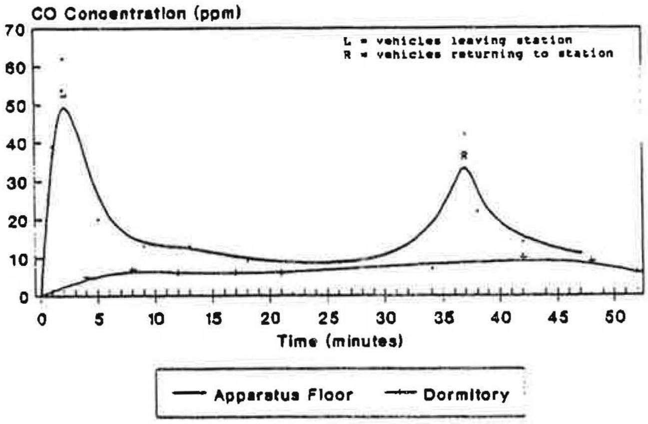

Figure 6 *Carbon monoxide concentration in the absence of apparatus floor exhaust*

As expected, CO concentrations tend to be elevated in living areas under negative pressure relative to the apparatus floor. Results of smoke tube tests indicate that, in the absence of an apparatus floor exhaust fan, the apparatus floor is seldom maintained under negative pressure. Negative pressure in living areas may be exacerbated if the hose tower exhaust draws air from living areas, especially in the absence of make-up air.

As apparatus floor fans are normally turned off shortly after vehicles leave the station, the presence of these fans does not ensure that the apparatus floor will remain negative. In some cases, fans were not kept on long enough to prevent elevated CO concentrations in living areas.

Several stations used carbon monoxide or nitrogen dioxide sensors to activate apparatus floor exhaust fans. Such monitors

TABLE 4
Concentration of CO and CO_2 in the Undiluted Exhaust of Selected Vehicles

Station No.	Vehicle Description: Type	Engine (T= turbocharged)	Year	Fuel type[1]	Engine size[2]	idling RPM	CO ppm	CO_2 %
1	Pumper	3208T Caterpillar	1989	D	636 in^3	600	550	1.5
1	Pumper	3208T Caterpillar	1985	D	636 in^3	700	750	1.8
1	Rescue	GMC	1978	G	350 in^3	-	65000	>6.0
2	Rescue	3208T Caterpillar	1985	D	636 in^3	600	160	1.7
2	Pumper	Detroit 6V71	1984	D	426 in^3	700	90	1.0
2	Service	GM	1983	D	6.2 L	-	120	2.3
3	Aerial	Detroit 6V71T	1987	D	426 in^3	500	100	-
3	Pumper	Detroit 6V71T	1986	D	426 in^3	500	60	-
3	Squad	3306T Caterpillar	1989	D	638 in^3	700	350	-
5	Pumper	Detroit 6V71T	1985	D	426 in^3	600	130	1.3
7	Tanker	3208T Caterpillar	1985	D	636 in^3	-	350	-
10	Aerial	Detroit 6V71N	1986	D	426 in^3	800	150	1.9
10	Pumper	Cummings LTA10-IPC	1983	D	10 L	500	100	1.4
12	Aerial	Detroit 6V71N	1985	D	426 in^3	525	70	1.0
14	Snorkel	Detroit 8V92	1984	D	736 in^3	530	70	1.1
14	Pumper	Cummings LTA10-IPC	1987	D	10 L	700	80	2.5

1. D = Diesel; G = Gasoline — 1% CO_2 = 10,000 ppm
2. reported in units of Litres or in^3 according to nomenclature adopted by the industry (1L = 61 in^3)

used as the only trigger for the fans were not effective, as concentrations were rarely high enough to trigger the sensor.

As floorwatches are located in close proximity to the apparatus floor and in some stations were under negative pressure relative to the floor, CO concentrations tended to be higher in the floorwatch than in other living areas. This is a concern, as the firefighters tend to congregate in the floorwatch even when not on watch duty. Another area with potential for elevated contamination by exhaust were exercise rooms, which were also frequently located near the apparatus floor and under negative pressure.

Structural barriers (e.g., enclosed stairwells, doors, pole hole covers) were relatively effective in preventing contaminant migration from the apparatus floor into living areas, especially where these barriers were well sealed. Many of the pole hole covers were, however, poorly sealed, which limited their usefulness. Another deficiency of pole hole covers was the necessity of leaving them off when all firefighters responded to an alarm.

Migration of contaminants to the second story tended to be lower where the ground floor location of the fire poles was in an area separated from the apparatus floor. Where fire poles lead directly to the apparatus floor, enclosure of poles on the second story in vestibules separated from living areas reduced migration of contaminants to living areas. The use of self-closing doors and maintenance of appropriate pressure balance in the vestibules (positive to apparatus floor, negative to living areas) contributed to their effectiveness.

Monitoring of tailpipe exhaust indicates that the concentration of CO in the exhaust can vary significantly among vehicles with the same engine size. The CO emitted was not found to be dependent on preventive maintenance schedules. However, tuning to increase engine efficiency is not routinely carried out as part of the maintenance procedure. As such tuning increases the efficiency of combustion and can therefore be expected to reduce particulate emissions as well as CO, it should be included in routine preventive maintenance. Although its effectiveness was not examined as part of this study, a filter on the vehicle tailpipe may prove to be successful in preventing diesel particulates from entering the station.

CONCLUSIONS AND RECOMMENDATIONS

Of the control measures observed, mechanical tailpipe exhaust was the most effective in preventing contamination of the fire station by diesel exhaust emissions. Fire departments have indicated, however, that use of mechanical tailpipe exhaust systems may not always be feasible or practical.

Where mechanical tailpipe exhaust is not feasible, the following measures would help to reduce exposure of fire station personnel to diesel exhaust emissions:

1. Good ventilation should be provided on the apparatus floor to achieve rapid clearance of diesel exhaust. In the absence of an exhaust fan, bay doors should be kept open for at least 90 seconds after vehicles leave or return. If this is done, doors and other openings to living areas should be well sealed to prevent wind dispersal of contaminants to living areas. In drive-through stations, cross-ventilation afforded by opening both sets of doors can be as effective as mechanical ventilation in clearing contaminants.
2. Where an exhaust fan is provided, it should be situated so that air is drawn away from living quarters. Apparatus floor exhaust fans should be mechanically triggered by the opening of bay doors and should be left on long enough to clear exhaust contaminants. Fans should also have a manual switch. Use of carbon monoxide or nitrogen dioxide sensors to trigger exhaust fans has not been found to be effective at the trigger concentrations commonly used.
3. Living areas should be maintained under positive pressure relative to the apparatus floor. Creation of negative pressure in living areas due to the hose tower exhaust should be avoided.
4. Particular attention should be paid to good ventilation in the floorwatches and exercise rooms, due to the amount of time that they are occupied and their proximity to the apparatus floor.
5. Passive tailpipe exhaust should be used on vehicles when idling within the stations for extended periods of time is necessary.
6. Structural barriers (e.g., pole hole covers, closed stairwell doors) should be used wherever possible to reduce migra-

tion of contaminants. The ground-floor location of the fire poles should be in an area separated from the apparatus floor. In stations where poles lead directly to the apparatus floor, second-story pole hole enclosures with appropriate pressure balances are effective in reducing migration of contaminants to living areas.

7. Vehicles should be well maintained in order to keep exposure to diesel particulate to a minimum. Consideration should be given to the use of filters on the vehicles to reduce particulate emissions.

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REFERENCES

Froines, J.R., W.C. Hinds, R.M. Duffy, E.J. Lafuente, and W.V. Liu. 1987. "Exposure of firefighters to diesel emissions in fire stations." *American Industrial Hygiene Association Journal*, Vol. 48, No. 3, pp. 202-207.

Grossi, M.T., J.B. Cropper, A. Stern, and L. Todd. 1986. *Evaluation of diesel exhaust exposure in five New York City firehouses*. New York, NY: New York City Department of Health.

Holliday, M.G., J.W. Sifton, F.R. Engelhardt, S.W. Langdon, and R.A. Meng. 1981. *Occupational health aspects of diesel exhaust emissions in Ontario*. Prepared under contract to the Ontario Ministry of Labour.

Johnson, J.H. 1980. "An overview of monitoring and control methods for diesel pollutants in underground mines using diesel equipment." *CIM Bulletin*, July, pp. 73-86.

NIOSH (National Institute for Occupational Safety and Health). 1988. *Current intelligence bulletin No. 50, Carcinogenic effects of exposure to diesel exhaust*. Publication No. 88-116, U.S. Department of Health and Human Services.

Pepelko, W.E. 1982. EPA Studies on the Toxicological Effects of Inhaled Diesel Engine Emissions. *Toxicological effects of emissions from diesel engines*, J. Lewtas, ed., pp. 121-142 New York: Elsevier Science Publishing Co., Inc.

Steenland, K. 1986. "Lung cancer and diesel exhaust: A review." *American Journal of Industrial Medicine*, Vol. 10, pp. 177-189.

Stewart, D.B., P. Morgan, and E.D. Dainty. 1978. "Diesel emissions and mine ventilation." *CIM Bulletin*, March, pp. 144-151.

Weisenberger, B.L. 1984. "Health effects of diesel emissions—An update." *Journal of the Society of Occupational Medicine*, Vol. 34, pp. 90-92.