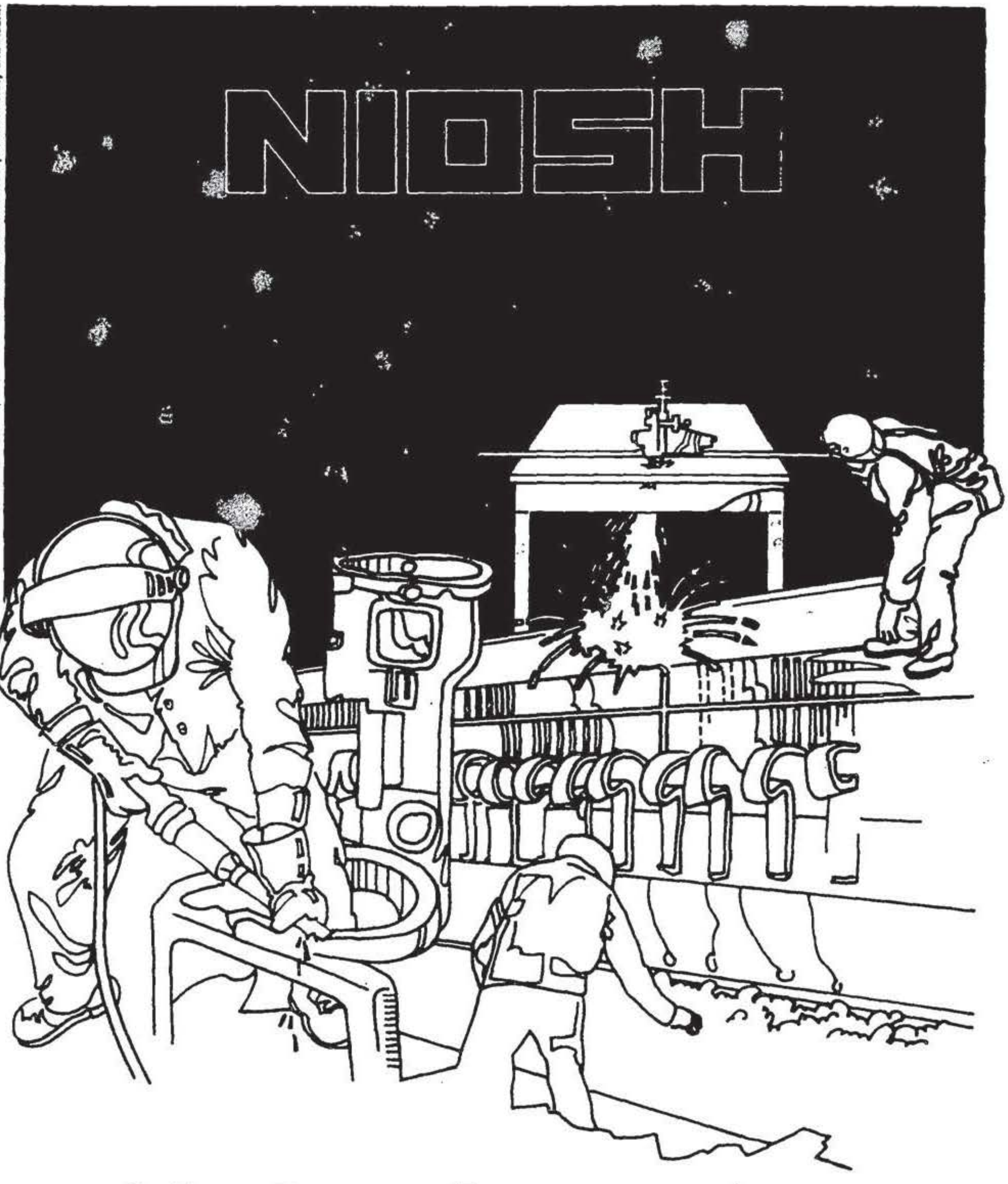

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health

Health Hazard Evaluation Report

HETA 84-299-1524
ASPEN ICE RINK
ASPEN, 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.

HETA 84-299-1524
NOVEMBER, 1984
ASPEN ICE RINK
ASPEN, COLORADO

NIOSH INVESTIGATORS:
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I. SUMMARY

In April 1984, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Pitkin County Health Department to evaluate the carbon monoxide (CO) exposures in the Aspen Ice Garden produced by their gasoline-powered ice resurfacing machine. As Aspen is 7,907 feet above sea level, the effect of reduced oxygen due to elevation was of added concern.

On June 19 and 20, 1984, NIOSH investigators conducted an environmental/medical evaluation of the ice rink and of both the old and new ice resurfacing/polishing machines. Carbon monoxide measurements were taken using an Ecolyzer® CO analyzer and direct reading detector tubes.

Review of the results obtained by the Aspen-Pitkin County environmental health department on March 6th and 29th, 1984, found an 8-hour time weighted average (TWA) carbon monoxide concentration as high as 53.8 parts per million (ppm), and a one-hour reading as high as 80.5 ppm. The old ice resurfacing machine was in use at the time.

NIOSH's area CO monitoring was carried out in the office areas, in the rink area, in the bleachers and on the two resurfacing machines. For the rink area decay curves showed 1.02 and 1.40 air changes per hour, and for the bleachers, 1.36. These exchanges were calculated against CO free outside air which could infiltrate through the numerous cracks and, except to a slight extent in the bleachers, would not be influenced by the exhaust fan. Carbon monoxide measurements at the edge of the rink showed highest readings of 55 and 65 ppm when the new ice resurfacer was run and a high of 90 ppm when the old resurfacer was run. CO levels decayed between these times. For the ice resurfacing and polishing machines, peak CO levels were 250-400 ppm and averaged about 140-175 ppm for the new ice resurfacing/polishing machine, and 500 ppm peak and 200 ppm average for the older machine.

During the morning the outside door in the office area was closed, as was the door from the second floor office into the rink area. Levels in the downstairs office rapidly rose to 12 ppm after the first morning resurfacing and stayed at about that level until the outside door was opened for the afternoon. In the afternoon with the door open decay showed 1.32 air changes per hour measured against outside air. Evidently the air did not exchange overly freely with the rink as the level in the office did not rise much during the second resurfacing and only moderately following the afternoon resurfacing with the old

machine. The upstairs office ran a fairly constant level of 10-13 ppm CO all morning with a small rise to 18 ppm on one occasion unrelated to resurfacing activity. Considering both office levels, it appears that the west end of the rink and adjacent offices does not get sufficient fresh air to keep CO levels down unless the outside door is open.

On the basis of the environmental data and medical data, NIOSH concluded that a potential hazard to CO existed at the Aspen Ice Garden. Recommendations are included in this report to help alleviate this hazard.

KEYWORDS: SIC (7999), ice rink, carbon monoxide, high altitude, zamboni

II. INTRODUCTION

The Aspen-Pitkin County Environmental Health Department monitored carbon monoxide (CO) exposures at the Aspen Ice Rink during the spring of 1984 using personal exposure monitors. Having found an 8-hour time weighted average (TWA) reading as high as 53.8 parts per million (ppm), and a one-hour reading as high as 80.5 ppm, on April 17, 1984 they asked NIOSH assistance in evaluating health effects both for workers at the rink and for the skaters who spend considerable time in the building exercising vigorously. Of added concern is Aspen's elevation of 7,907 feet above sea level (2,410 meters).

On June 19th and 20th, 1984 NIOSH conducted an environmental-medical evaluation of the ice rink and both old and new ice surfacing/polishing machines. The findings were discussed with the rink manager and the environmental health officers in a closing conference on June 20, 1984.

III. EVALUATION DESIGN & METHODS

A. Environmental

Continuous air monitoring for carbon monoxide was performed by NIOSH personnel while riding on the ice making and polishing machine. These measurements were taken with an Ecolyzer® CO Analyzer and recorder. The sampling period lasted for the entire time the floor was being resurfaced & polished. This took from six to ten minutes.

Area carbon monoxide monitoring was performed June 19, 1984 in the downstairs office intermittently during the day, in the upstairs during the morning, and in the afternoon on the south edge of the rink using Ecolyzer® CO Analyzers. Other area monitoring on the south edge of the rink and in the bleachers was done using detector tubes (Drager Carbon Monoxide 5/c - range 5-150 ppm with 10 strokes). Additional sampling was done in the offices and around the four sides of the rink on the morning of June 20, 1984.

Air changes per hour (ach) were calculated from the decay of CO levels by calculating the least squares line for log(CO) vs. time and then using the formula[1]:

$$\text{ach} = \frac{1}{(t_2 - t_1)} [\ln(C_1 - C_o) - \ln(C_t - C_o)]$$

where:

t_1	= starting time (hours)	C_1	= concentration at t_1
t_2	= ending time	C_t	= concentration at t_2
C_o	= outside concentration	ln	= natural logarithms

Air flow measurements for the exhaust fan were made using a hot wire anemometer (Kurz Air Velocity Meter Model 441).

B. Medical

Individual exposures to carbon monoxide (CO) were monitored on June 19, 1984 by following carboxyhemoglobin (COHb) concentration as determined by concentration of CO in the expired air after 20-second breath holding. The six workers and both county sanitarians were monitored. An initial test was performed before the first ice resurfacing (8:00 AM) except for 3 workers who were not available until about 8:30. Except for one person who left at approximately noon, afternoon tests were performed between 1:00 and 2:00 PM. The worker running the ice resurfacing machines had several intermediate tests. In addition to COHb determinations, workers were asked about smoking and current symptoms.

Alveolar CO concentrations were determined by having the worker take a deep breath, holding it for at least 20 seconds (timed), exhaling about half the air and breathing the rest into a milar bag. The CO in the exhaled air was then analyzed using an Ecolyzer® CO Analyzer. Parts per million (ppm) CO in the expired air was converted to % COHb of total hemoglobin utilizing the formula:

$$\% \text{ COHb} = 2.7566 \times \sqrt{\text{CO} + 14.3105} - 11.8727$$

IV. EVALUATION CRITERIA

A. Environmental

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations,

2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLV's), and 3) the U.S. Department of Labor (OSHA) occupational health standards. Often, the NIOSH recommendations and ACGIH TLV's are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLV's usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended standards, by contrast, are based solely on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet only those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

	Environmental Exposure Limits 8-Hour Time-Weighted Average (TWA)		
	mg/m^3	ppm	Source
Carbon Monoxide (CO)..................	(40)	35*	NIOSH
		C 200	
	55	50	ACGIH
	55	50	OSHA

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mg/M^3 = milligrams of substance per cubic meter of air.
ppm = parts of contaminant per million parts of air.
C = ceiling concentration-should never be exceeded

* NIOSH recommends that at "very high altitudes (e.g., 5,000 - 8,000 feet above sea level), the permissible exposure stated in the recommended standard should be appropriately lowered to compensate for loss in the oxygen-carrying capacity of the blood." Utilizing Coburn's formula from the NIOSH criteria document[2], the altitude pressure correction from Lange's Handbook of Chemistry[3], and hemoglobin dissociation curves from a physiology text[4], it is estimated that at Aspen's altitude a sedentary worker could tolerate 22 ppm CO for the work day, but an active worker should be limited to 16 ppm exposure as a time weighted average.

Toxicological

Carbon Monoxide[1] -- The signs and symptoms of carbon monoxide (CO) poisoning may include headache, nausea, vomiting, dizziness, drowsiness, and collapse. Carbon monoxide rapidly binds to the oxygen-carrying molecule of the red blood cells, hemoglobin, forming "carboxyhemoglobin" (COHb). When CO binds with hemoglobin to form COHb, it reduces the oxygen-carrying capacity of the blood. The more COHb is formed, the more significant the symptoms are. Heart disease may be made worse in workers who have coronary heart disease and are exposed to CO, particularly concentrations high enough to produce a COHb level greater than 5% of total hemoglobin (referred to as % saturation). There is also important evidence that exposure to lower CO concentrations, producing COHb levels below 5%, affects the nervous system and causes changes in visual alertness, response time, and fine judgment.

At lower altitudes exposure at the current OSHA standard for CO of 50 ppm for 90 minutes may cause chest pain for persons with angina (chest pain related to heart disease); exposure for 2 hours may make leg cramps worse for persons who have leg cramping associated with vascular disease. The effects of CO exposure, including the more common symptoms of headache, dizziness, and nausea, are made worse by heavy labor and a high temperature in the work area.

Non-smoking, non-exposed persons have an average COHb level of 1%. Non-smokers exposed to 50 ppm (50 parts per million of CO, the OSHA standard) for six to eight hours have COHb levels of 8 to 10%. NIOSH recommends an exposure limit of 35 ppm for an 8-hour time-weighted average, and a ceiling limit of 200 ppm. This recommendation is based on the concentration necessary to produce a COHb level of not more than 5%. At "very high altitudes (e.g., 5,000 - 8,000 feet above sea level), the permissible exposure stated in the recommended standard should be appropriately lowered to compensate for loss in the oxygen-carrying capacity of the blood." Symptoms such as headache and nausea may be seen above 15% saturation, but usually not at lower levels. At 25%, there may be electrocardiographic evidence of heart effects, and 40% usually results in collapse.

These recommendations do not consider the smoking habits of workers since the COHb levels in smokers has generally been found to be in the 4 to 5% range, but may run as high as 10 to 15% in heavy smokers. Therefore, smokers who already have a blood level of 5%, and then are exposed in a work place with an average concentration of 35 ppm will have a total COHb of about 10%.

Although CO binds to the hemoglobin over 200 times as strongly as does oxygen, when exposure ceases the CO will slowly be replaced by oxygen from the air restoring the oxygen carrying capacity of the hemoglobin. Even with fairly severe exposures, prompt removal to fresh air (oxygen if available) will usually be followed by complete recovery.

V. RESULTS AND DISCUSSION

A. Environmental

During the walk-through inspection of the building, the following features important to ventilation were seen and/or called to the investigators attention:

1. The offices were located on two floors at the west end of the building. The structure was tightly constructed with a

forced air heating system without fresh air intake. Return air ducts are located in the lower offices. It is common practice to open the sliding door from the upper offices onto a balcony in the rink area, although on the day of the study it was closed. On warm days it is also usual to open the outside door on the first floor. This occurred in the afternoon of the study day. There are exhaust vents in the rest rooms.

2. The main rink area was originally open to the outside above a partial wall. It has since been enclosed with windows, but there are obvious air leaks between the window frames and the wall. Recently a reflective fabric ceiling has been installed which will undoubtedly modify heating requirements. There are gas fired radiant heaters along the periphery of the rink and in the bleacher area. These are vented to the outside.

3. The bleachers are located at the east end of the rink over the ice surfacing machine room and the area where the refrigeration machinery for the rink ice is located. The bleachers are open in back to the equipment area and there is a large exhaust fan located at the peak of the ceiling in this area. Airflow 1 foot from the fan was 125 feet per minute (fpm) but only 10 fpm by the 10 feet from the fan. There was some channeling of air flow under the ceiling ridge. At the time of the study the venting for the refrigeration machinery had just been relocated and the old venting openings were not sealed.

4. The ice surfacing machine was kept in a small, unvented room under the bleachers. Full width and height doors open onto the rink at one end and into the machinery area at the other end. It was the usual practice to warm up the surfacing machine in this room.

5. There was a large door at the west end of the building through which the ice surfacing machine is driven outside to unload. It is often open when weather permits. Besides the refrigeration machinery in this area, there is a vented gas hot water heater in a lower level by a tunnel which goes to the west end of the rink, a locker room, and some storage rooms.

The area carbon monoxide (CO) monitoring obtained by the Aspen-Pitkin County Environmental Health Officer in the rink area are given in Table I. Four sections of the data appeared suitable for calculating decay rates, which ranged from 0.57 to 0.81 air changes per hour (mean 0.71 + 0.11). The old ice resurfacing machine was in use at the time. The NIOSH results from the two office areas, midrink, the bleachers, and from the two resurfacing machines are given in Table II. For the rink area decay curves showed 1.02 and 1.40 air changes per hour, and for the bleachers, 1.36. These exchanges were calculated against CO free outside air which could infiltrate through the numerous cracks and, except to a slight extent in the bleachers, would not be influenced by the exhaust fan. Readings at the edge of the rink showed highs of 55 and 65 ppm when the new ice surfacer was run and a high of 90 ppm when the old surfacer was run. CO levels decayed between times.

During the morning, the outside door in the office area was closed, as was the door from the second floor office into the rink area. Although the initial reading in the downstairs office was only 2 ppm, it had risen to 12 ppm after the first morning resurfacing and stayed at about that level until the outside door was opened for the after- noon. (The initial reading is suspect as the lowest level of CO in exhaled air on individual tests was 9 ppm and it seems unlikely that all cars leak CO.) In the afternoon with the door open, decay showed 1.32 air changes per hour measured against outside air. Evidently the air did not exchange overly freely with the rink as the level in the office did not rise much during the second resurfacing and only moder- ately following the afternoon resurfacing with the old machine.

Carbon monoxide readings in the upstairs office was started at 9:00AM. They ran a fairly constant level of 10-13 ppm CO with a small rise to 18 ppm on one occasion unrelated temporally to resurfacing activity.

The ice resurfacing/polishing machines produced some high concentrations of carbon monoxide. Peak levels were 250-400 ppm and averaged about 140-175 ppm for the new ice resurfacing and polishing machine. The older machine had a peak level of 500 ppm and an average of 200 ppm.

B. Medical

Eight persons had their breath monitored for CO on reporting to work and again before quitting time. Initial exhaled CO averaged 12.1 $\pm$ 2.5 ppm which corresponded to 2.29 $\pm$ 0.68 % carboxyhemoglobin saturation (% COHb). This is a little higher than would be expected considering six of the eight were non-smokers and the others had not smoked recently. Possible explanations include exposure to auto exhaust on the way to work, or an eleva- ted background level in the test area. The latter seems more likely even though the initial instrument reading was low.

Everyone's %COHb levels rose during the day. The lowest being 1.0% in an individual who arrived after the first resurfacing and the highest being 4.7% in the individual who ran the resurfacing machines. For the 7 individuals who were in the building all day, end of day exhaled CO averaged 26.3 $\pm$ 4.7 ppm corresponding to 5.67 $\pm$ 1.00 %COHb for a rise in %COHb of 3.26 $\pm$ 1.23. At the time of the study there were no health complaints which could be attributable to CO exposure, although at least one worker had some respiratory complaints which may in part have related to exposure to resurfacer exhaust.

VI. CONCLUSIONS

1. At the time of this study, individual exposure to CO was slightly greater than desirable as average %COHb by the end of the day was over 5%. The new ice resurfacer generated less CO than the old one.

2. The office area has almost no fresh air unless the outside door is open.

3. The building surrounding the rink is not overly tight allowing for moderate air turnover. Considering CO levels generated by the resurfacing machines, a somewhat higher turnover would be desirable. Increasing the output of the exhaust fan would not accomplish this.

VII. RECOMMENDATIONS

1. The room where the ice resurfacing machine is stored should be fitted with an exhaust system and a flexible hose which can be attached to the machine exhaust during warm-up.

2. The resurfacing machines should be well maintained to keep CO emission as low as possible.

3. One person who is very familiar with its operation should operate the ice resurfacing machine. This would make the procedure quicker and help eliminate some CO exposure.

4. Introduce fresh air into the ventilating system for the offices and maintain the offices at a slight positive pressure over the rink. This should virtually eliminate CO exposure in the offices, and would also introduce CO-free air into the west end of the rink.

5. It would probably help air turnover in the rink if fresh air was forced in at the west end of the rink. There would then be a slight airfow towards the exhaust fan at the east end. This would be most valuable following each ice resurfacing.

VIII. REFERENCES

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X. DISTRIBUTION AND AVAILABILITY

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Information Resources and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Service (NTIS), Springfield, Virginia. 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. Aspen Ice Rink.
2. U.S. Department of Labor/OSHA - Region VIII.
3. NIOSH - Region VIII.
4. Colorado State Health Department.

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

TABLE I

Aspen-Pitkin County Carbon Monoxide (CO) Monitoring Results
Average Parts Per Million (ppm) for Stated Time Period

Aspen Ice Rink
Aspen, Colorado

March 6 & 29, 1984

March 6th Time Interval min.	March 6th Location # 1 ppm CO	March 29th Time Interval min.	March 29th Location # 2 ppm CO	March 29th Location # 3 ppm CO
12	1.6	60	3.2	2.6
6	0.9	60	0.6	0.6
Start:	Decay Curve 1	60	0	1.9
21	49.9	60	36.1	49.0
39	31.3	60	32.1	43.3
60	20.2	60	53.3	59.7
60	10.7	60	34.0	36.3
60	5.1	60	17.7	21.3
40	2.0	60	42.3	80.5
20	1.0	60	56.0	54.3
End:	Decay Curve 1	Start:		Decay Curve 4
53	0.2	60	32.6	71.7
60	0	Start:	Decay Curve 3	
7	1.6	60	53.6	63.3
25	30.5	60	31.3	34.5
35	34.5	60	17.5	22.2
60	28.7	60	10.2	13.1
1	19.9	60	5.1	7.1
59	45.9	60	1.8	3.8
19	40.3	End:	Decay Curve 3	
41	56.1	60	0	1.4
3	55.8	End:		Decay Curve 4
57	41.9	60	0	1.0
4	28.5	60	0.3	2.1
34	43.7	60	0.8	2.9
22	48.0	60	0.2	9.3
45	37.2	60	24.9	36.1
15	38.7	60	16.1	17.5
Start:	Decay Curve 2	60	8.5	11.5
60	67.4			
10	36.4			
50	27.3			
60	22.1			
60	8.3			
60	5.7			
60	1.0			
End:	Decay Curve 2			
60	0.4			
60	0			

	Air Changes per Hour	
Decay Curve 1	0.81	
Decay Curve 2	0.79	
Decay Curve 3	0.67	
Decay Curve 4	0.57	
Average for Rink	0.71	± 0.11

TABLE II

NIOSH Carbon Monoxide (CO) Monitoring Results
Parts Per Million (ppm) at Stated Time

Aspen Ice Rink
Aspen, Colorado

June 19, 1984

Time	Downstairs Office ppm CO	South Mid-Rink ppm CO	East Bleachers ppm CO
	Ecolyzer # 1	Detector Tubes	Detector Tubes
07:30	2		
08:00		ND	
08:00-08:12	New Zamboni run - Peak CO 400 ppm, average about 175 ppm		
08:12		50	
08:20		55	
08:30	12	35	
08:45	14	30	
09:15		20	
09:35	13		
09:45		10	
10:00-10:06	New Zamboni run - Peak CO 250 ppm, average about 140 ppm		
10:06		65	
10:12	14		
11:16	11		
	Ecolyzer # 1	Ecolyzer # 2	Detector Tubes
13:00			trace
13:10	8		
13:20-13:29	Old Zamboni run - Peak CO 500 ppm, average about 200 ppm		
13:30			45
13:36		90	
13:55	26		
14:00		48	20
14:05	23.5		
14:15	21.0		
14:25	18.0		
14:30			10
14:32		28	
14:35	15.5		
14:45	10.0		
15:00		12	6

DECAY CURVES (air changes per hour)

Downstairs Office	South Mid-Rink	East Bleachers
14:05 - 14:45	8:30 - 9:45	13:30 - 15:00
1..32	1.02	1.36
	13:36 - 15:00	
	1.40	