A Solution for Detecting and Removing Polluted Air from Large-Vehicle Storage Buildings

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ABSTRACT

The control of indoor air quality quite often poses a very challenging problem to designers. This paper presents one solution that was adopted at Canadian Forces Base Montreal, St. Hubert, to improve indoor air quality in an industrial environment situation. The requirement was to ventilate a 43,360 square foot airplane hangar used for parking diesel-powered and gasoline-powered vehicles. The need for ventilation was generated by the belief that symptoms of annoyance experienced by the employees, such as headaches and eye irritations, were related to the odors and a high concentration of polluted air emitted by the vehicles.

In line with energy conservation, a practical system was designed to solve the problem. The solution consisted of five individual systems, each containing four interrelated components including a special polyethylene tubing type make-up air supply unit, continuous carbon monoxide and diesel fume sensors, exhaust fan, and heating thermostat. Each system is area oriented and starts automatically when a signal is received from the sensor. The signal starts the exhaust fan, closes the return air dampers, and opens the motorized shutters supplying outside air to the contaminated area. The outside air introduced together with the air exhausted result in the reduction of the level of pollutants. The other four systems operate when and if necessary. The building's heating system starts automatically to ensure that the heating level is maintained. The system also serves a second purpose, as it can reclaim and recirculate stratified air, providing tempered air throughout the building.

This system has been in operation for the past four years and has provided good ventilation, while complaints of annoyance have not been registered during its operation. Based on these satisfactory results, eight other large buildings have been upgraded with similar systems.

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INTRODUCTION

The Second World War double-land plane hangar, which is 30 feet high, 268 feet long, and 162 feet wide, with open wooden trusses, underfloor concrete heating ducts, and large airplane doors, has stood at this airport for over 40 years. In that time it has served many uses, until several years ago when it was given the role of Base Motor Transport garage. This new use meant the parking of approximately 50 large and small gasoline-powered and diesel-powered military vehicles, and with this new use came the problem of a high concentration of polluted air and irritating odors when the vehicles were moved in and out. Ventilation, being the great waster of heating energy, especially in our climate, gets an extra big "why?" and "what for?" In this case, these questions were easily answered, as the ventilation system was to be implemented as part of a general policy of the department to improve indoor air quality in all its large service buildings.

An engineering study was carried out showing that general ventilation in a building this size would involve excessive operating costs.

On-site inspections and basic sampling techniques were carried out to determine the scope of the problem and to observe the areas where the polluted air was most prevalent. Most complaints came from areas where the drivers awaited their assignments, while others were scattered throughout the building where vehicles were being warmed up and drivers were carrying out first line maintenance.

THE PROBLEM

The project was to design a cost-effective ventilation system for an open building of 43,360 square feet, that would reduce the exposure of workers to air contaminated with gasoline and diesel combustion products.

The Practical Solution

Direct exhaust hoses were rejected as being impractical, as they restricted the in and out movement of vehicles.

Due to the large open area of the building, an attempt would be made to remove the pollutants by zoning the ventilation systems to dilute the contaminated air at the location where it is generated, without loss of total building heat. Figure 1 shows the design, which was made up of five individual systems, each consisting of three major components:

1. Monitoring and control system
2. Fresh air make-up system
3. Contaminated air exhaust system
4. Unit heater (optional)

Since each of these components plays a large role in the overall design, it is necessary to give the following brief description of each:

Monitoring Control System

Carbon dioxide (CO_2) is used as a surrogate for the combined effect of noxious components in the control of diesel fume pollution. The relationship curves established from published research show that by maintaining a CO_2 concentration between 1300 and 2000 ppm, the other pollutants generated by diesel engines would be at acceptable levels.

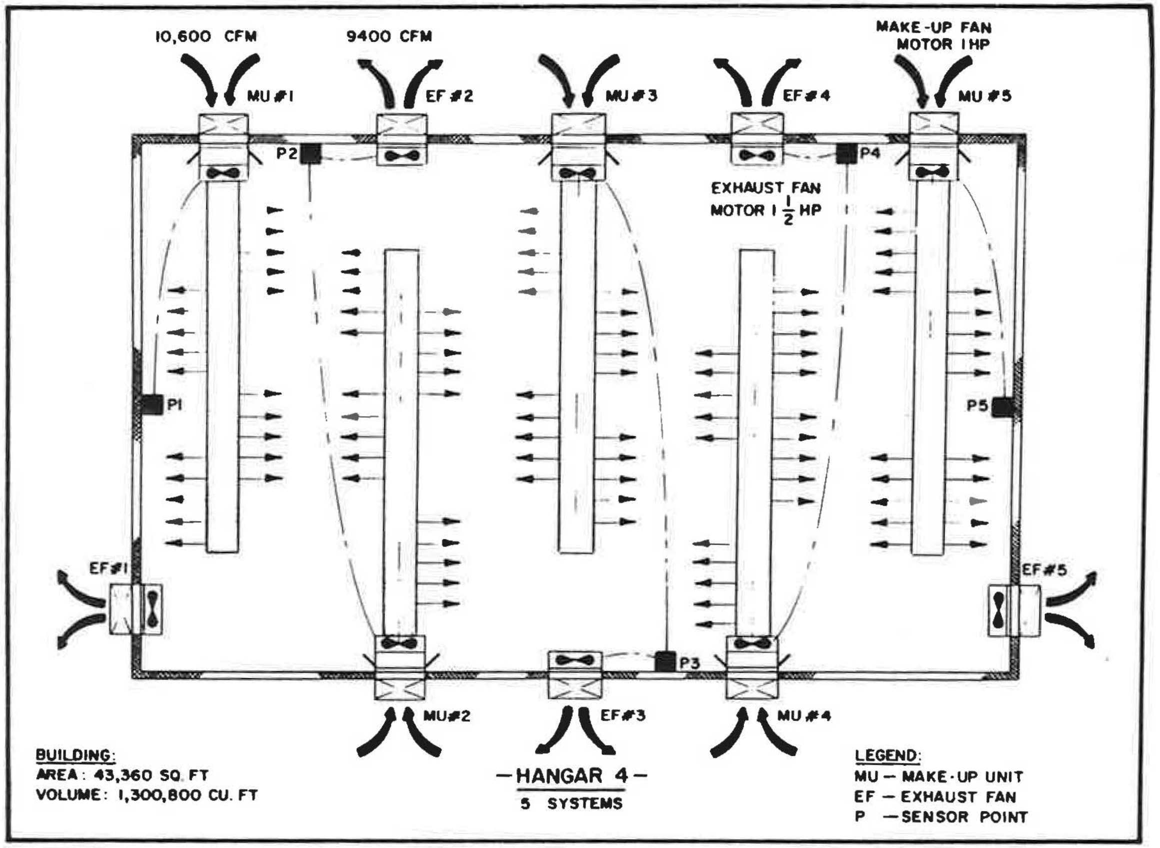

Figure 1 System layout

The control system shown in Figure 2 was designed for all spaces where there is a mixture of vehicles with diesel and gasoline engines. The design is modular for easy checking and replacement of components and does not require highly trained specialists for operation and maintenance.

Each sampling point consists of a small independent pump that draws air into a carbon monoxide sensor sampling chamber. The output of the sensor is connected to a carbon monoxide module that has two set points—operating level and alarm level. The air is then exhausted through a three-way solenoid valve, which diverts one sample at a programmed time to the carbon dioxide infrared analyzer. The central processor unit acquires the output of the infrared analyzer and produces one operating output and one alarm output.

The outputs from the combined modules produce a logic of operation for ventilation as demanded by a particular zone.

Fresh Air Make-up System

The drawing of the make-up air system shown in Figure 3 and in the actual installation in Figure 4 is a relatively new ventilating concept. It utilizes some basic aerodynamic principles for supplying, tempering, and distributing make-up air for buildings in cold weather. It offers more efficiency, economy, and comfort than most conventional make-up air units. The unit consists of a specially designed air supply fan, housing two motorized air shutters, one for outside air and one for recirculated air. A long length of special polyethylene tubing attached to the unit completes the system. The tubing has precision holes punched on both sides at specific intervals along its length and has one end closed off. Each fan, housing an inlet shutter, is mounted to an opening in the upper area of the building wall. The polyethylene tubing is attached to the discharge end of the supply fan and extends horizontally throughout the upper region of the building, supported by a tight wire. When make-up air is needed, the motorized inlet shutter opens and the supply fan turns on and draws in fresh air, blowing it down the tube and inflating it for its full length. The air discharges from the punched holes in the tube as small high-velocity jets that create turbulent mixing with the warmer stratified building air. The resulting throw of air from the jets, combined with the mixing action, effectively tempers the make-up air before it reaches the worker occupancy level to produce a uniformly distributed, draft-free make-up air system. Several systems are usually required for large buildings; the number will depend on the amount of make-up air required, the size of the models selected, and the size of the area to be supplied. Supplementary heat, when needed to counter the action of cold make-up air, may be provided by the existing heating system or by some additional conventional space heaters positioned at convenient locations in the general area of the tubes. When no dilution air or destratification is needed, the fan is stopped and the motorized inlet shutter closes to prevent the entrance of cold air into or the loss of warm air from the building. The deflated polyethylene tube hangs from the support wire ready for use again when needed. Infiltration around the large doors and windows exceed the fresh air requirements of the personnel working in the building.

Exhaust Fan

The heavy-duty propeller fan and ductwork shown in Figure 5 were chosen for the design because they provide ruggedness and stable performance. The main purpose of the exhaust fan is to capture at source and exhaust gasoline and diesel combustion fumes. Since carbon monoxide is slightly lighter than air and carbon dioxide is heavier than air,

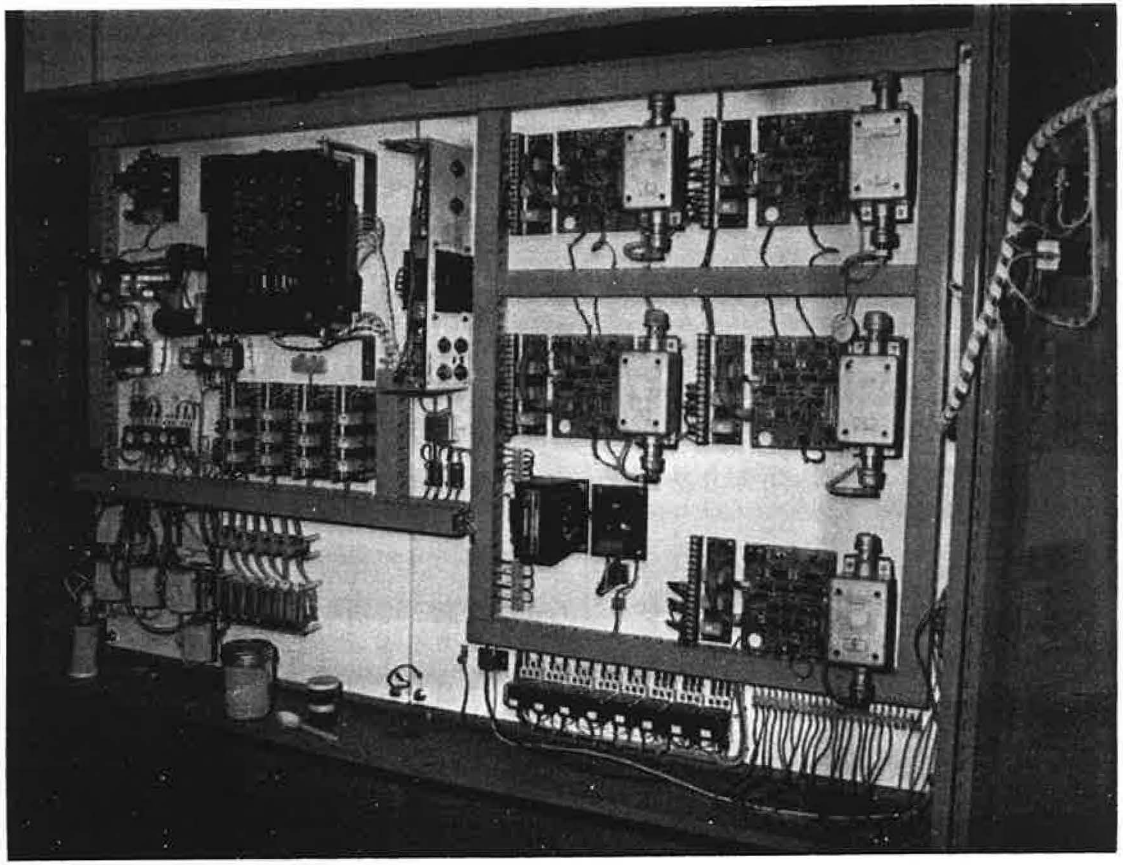

Figure 2 CO/diesel fumes monitoring and control panel

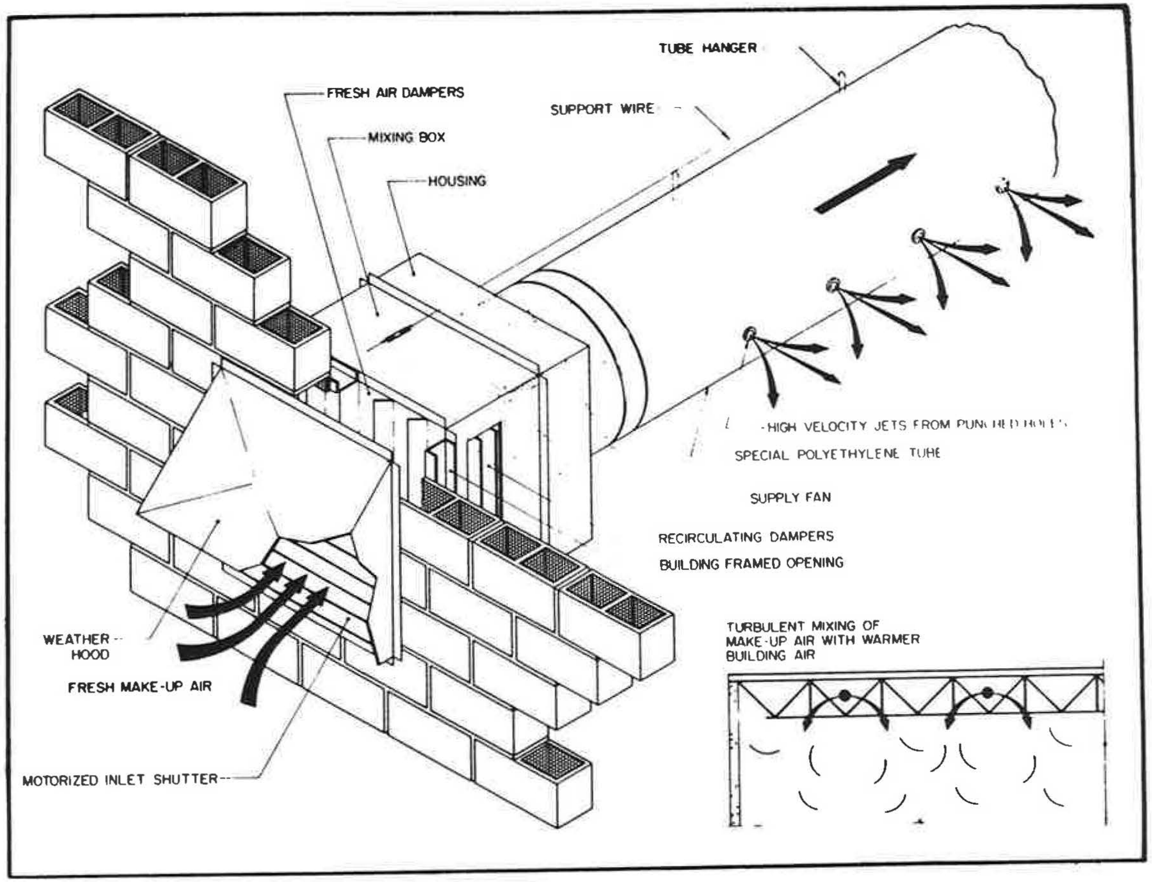

Figure 3 Make-up air system

Figure 4   Actual installation of make-up air system

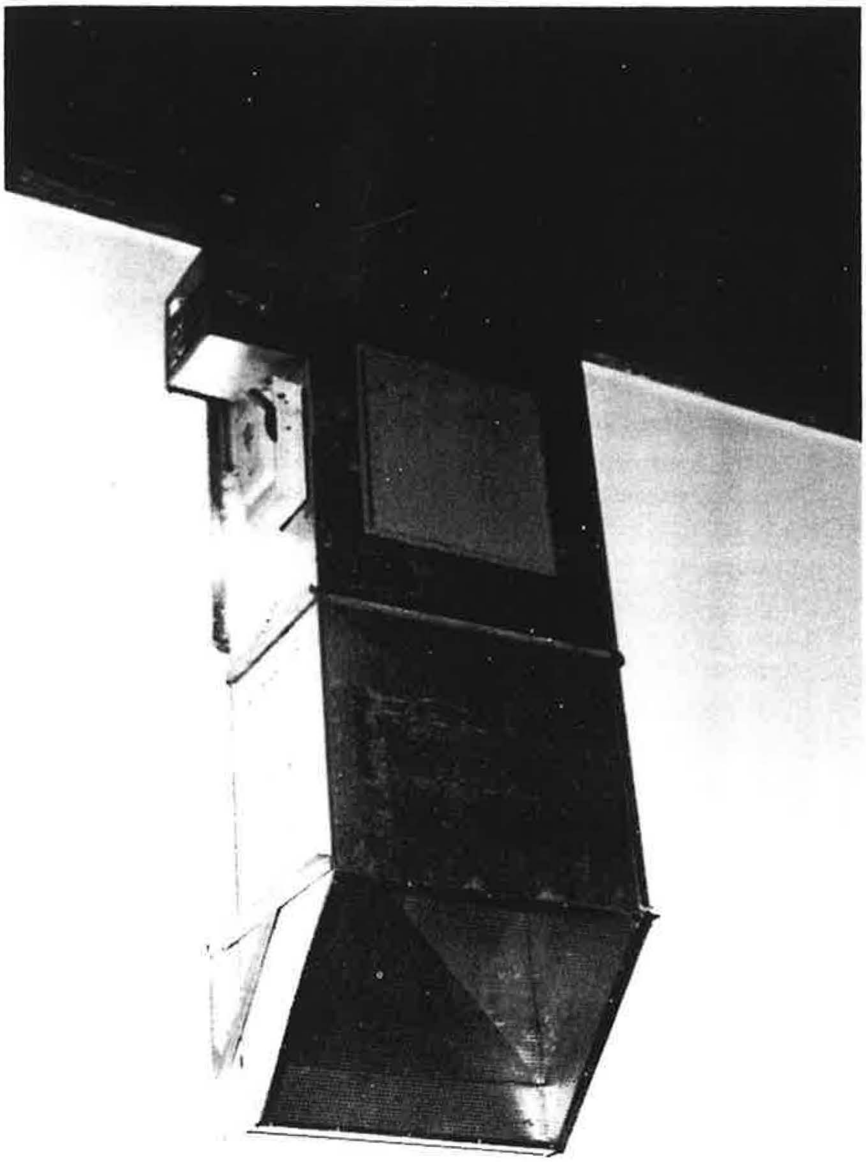

Figure 5 Exhaust fan and ductwork mounted in place

it was necessary to design ductwork from the exhaust fan down the inside building wall to collect the rising warm contaminated air at eye level.

Unit Heater

The unit heater is an optional component in this system and is only used where the building heating system cannot sustain the required temperature with the fresh air make-up system on 100% outside air. If extra heat is required additional unit heaters should be installed in close proximity to the air make-up supply tube. Control is orchestrated by the main control panel.

Assembly (Figure 1)

1. The building was divided into five equal sections across its length, covering approximately 8670 square feet each.
2. An individual system was placed in each section.
3. Each tube was 150 feet long.
4. The make-up tubes were placed as high in the building trusses as possible so that the fresh air would mix with the heated stratified air under the roof.
5. An exhaust fan was installed on the outside building wall at the closed end of the tube.
6. Collector ducts were installed on the wall and ran from each exhaust fan down to a collection point 10 feet above the floor. This dimension was maintained to clear the movement of buses and large vehicles.
7. The sensor was located at eye level on the wall below the make-up fan unit.
8. The full control center was installed on the wall near the center of the building and enclosed with a security fence.
9. Destratification thermostats were installed under the building roof.
10. No unit heaters had to be added in this design.

Sequence of Operation

1. All controls were set on automatic operation.
2. When the ceiling thermostat reaches its set point, it opens the return air dampers and starts the make-up fan, recirculating tempered air down to the work area. Destratification operation is shown in Figure 6.
3. Figure 7 shows the logic of operation of this system. If the carbon monoxide level reaches 50 ppm or the carbon dioxide level reaches 1400 ppm, the system control overrides the thermostat, starts the exhaust fan, closes the recirculating dampers, opens the outside fresh air dampers, and starts the make-up air fan. The system as shown in Figure 8 thereby automatically removes the polluted air, supplies fresh air, mixes it with stratified air at roof level, and supplies it as tempered air to the work level.
4. If the concentration of carbon monoxide or carbon dioxide continues to rise, the system control causes the neighboring ventilation unit to start.

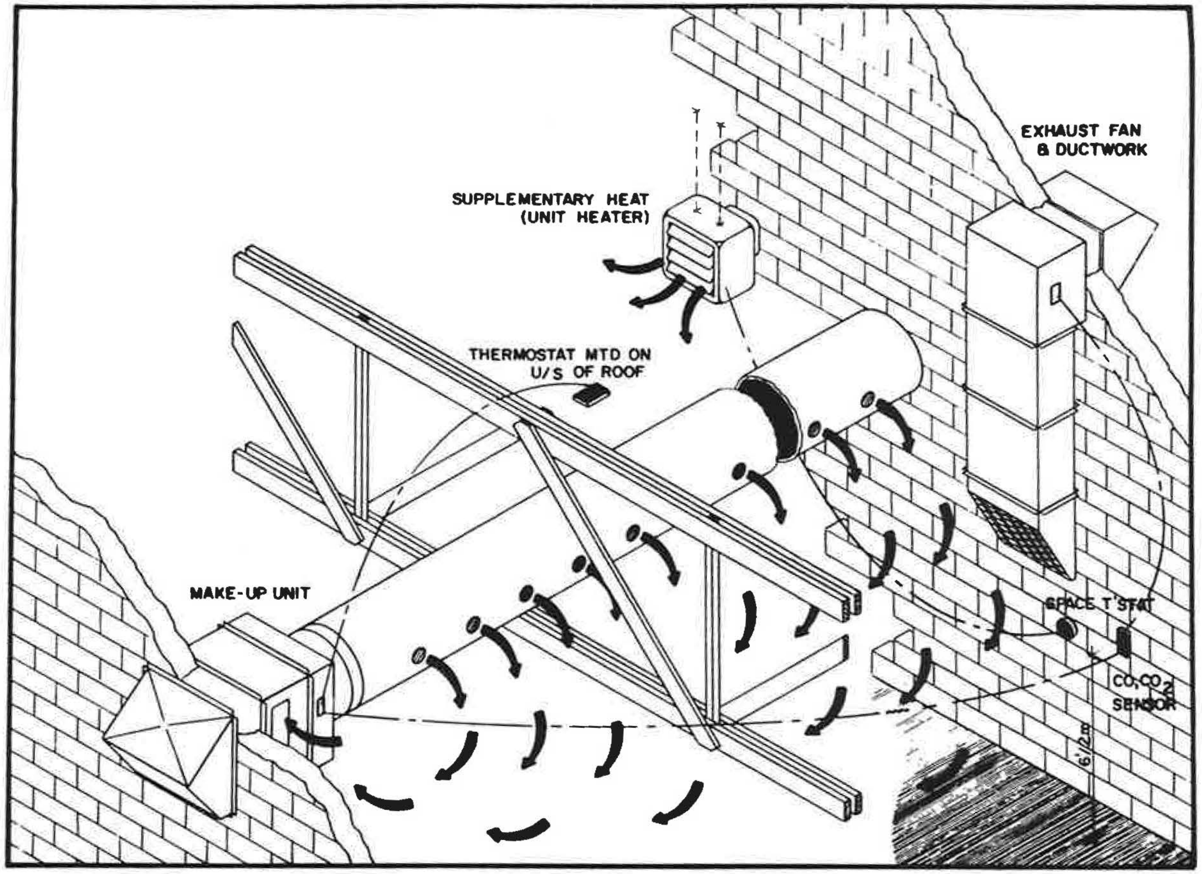

Figure 6 Destratification operation of system

LOGIC OF OPERATION															
ZONE SAMP. LOC.	CONCENTRATION: CARBON MONOXIDE		CONCENTRATION: DIESEL FUMES LOW LEV.	DIESEL FUMES HIGH LEV.	EXHAUST FAN					MAKE-UP AIR UNIT				
	50PPM	100PPM	1400PPM	1900PPM	1	2	3	4	5	1	2	3	4	5
P1	X		X		X					X				
		X		X	X	X				X	X			
P2	X		X			X					X			
		X		X		X	X				X	X		
P3	X		X				X					X		
		X		X			X	X				X	X	
P4	X		X					X					X	
		X		X				X	X				X	X
P5	X		X						X					X
		X		X				X	X				X	X

A 30min. CONTINUOUS CONCENTRATION OF 100 PPM CO CAUSES ALL 5 SYSTEMS TO GO TO RUNNING POSITION.

A CONCENTRATION OF 2400 PPM CO_2 CAUSES ALL 5 SYSTEMS TO GO TO RUNNING POSITION.

IN BOTH CASES THE CONTROL PANEL SHALL BE ON VISUAL AND AUDIBLE ALARM.

Figure 7 Logic of system operation

5. If the concentration is not reduced after 30 minutes' operation of two units, all ventilation units will go to the running position, and visual and audible alarms located at the control center will be energized.

Advantages Over Exhaust and Conditioned Air Make-up System

1. Offers greater savings in initial purchase and operating costs.
2. Does not produce hot or cold blasts of air but provides a gentle and uniform air distribution.
3. Supplies more make-up air with less horsepower, since the friction loss through a heat transfer system is completely eliminated.

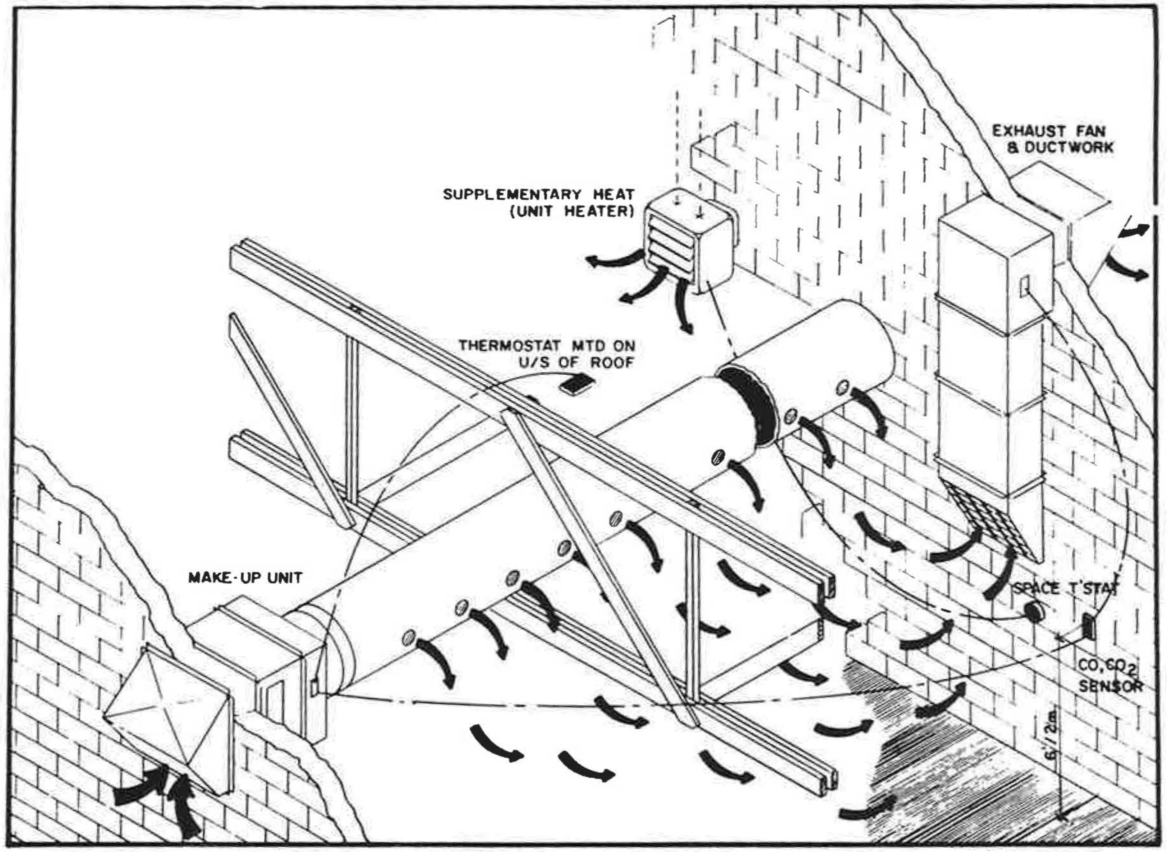

Figure 8 Make-up air operation of system

4. Is less costly to install due to its light weight.
5. Eliminates coil freeze-up problems.
6. Reclaims warm stratified air trapped in upper regions of building.
7. Can be maintained by regular building maintenance personnel.
8. Combines carbon monoxide and diesel fume detection.
9. Is suitable for new and existing buildings.
10. Uses the advanced microprocessor technology.
11. Saves operating costs by running only when required.
12. Displays visual indications of conditions and operation on the system control panel.

POSSIBLE APPLICATIONS

The rugged construction of this system makes it suitable for installation in:

1. Parking garages of mixed diesel and gasoline vehicles.
2. Parking and service garages for buses, sanitation trucks, heavy construction equipment, and trucks of any kind.
3. Parking and service garages for tanks and other military vehicles.
4. Platforms in bus and truck terminals.
5. Control of ventilation in vehicular tunnels

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DISCUSSION

C. Lawson, New Port Richey, FL: How does this system of tubes work in high humidity areas?

A.A. Curnew: If the system is installed in one building humidity should not be a problem. However, if the tubes were to run from a warm building to the outside and back into another building, a condensation problem may occur. In this case, it would be advisable to slope the tubes and provide a bottom drain.

S. Matos, New York City Department of Health: Is CO of 50 ppm too high for people undergoing physical exertion as a standard?

Curnew: Carbon monoxide in any quantity for any length of time is injurious to a person's health. In this application, very little physical exertion was being expended. Fifty ppm is acceptable over an 8-hour period; 100 ppm is not acceptable beyond one hour.

Matos: Have you evidenced any CO stratification due to temperature difference in the building?

Curnew: Specific gravity of CO is 0.998, therefore any stratification of the air would carry along some CO. In this case the system automatically comes on when vehicles are started and moved, thus removing the CO.

T. Sinks, NIOSH, Cincinnati, OH: Was the technique evaluated in terms of actual exposure to workers and CO exposure? The level of 50 ppm of CO to trigger the system seems too high for worker safety.

Curnew: There was no continual exposure to CO in this project. The natural ventilation provided dilution so that the CO level usually remained below the 50 ppm level which starts the ventilation system automatically.