RESEARCH HIGHLIGHT

October 2002 Technical Series 02-133

Positive Pressure Ventilation for High-Rise Buildings

INTRODUCTION

Positive pressure ventilation (PPV) is a smoke control strategy used by Fire Departments during and after fire emergencies in buildings. PPV is used to clear and maintain access to fires, to clear smoke from exits to facilitate evacuation and to vent smoke after a fire is extinguished. A PPV system consists of a portable high volume fan-motor set that is used to establish airflow and pressure regimes in areas where smoke must be cleared or where smoke proliferation has to be minimized. In high-rise apartment buildings, PPV could be used to pressurize stairwells and corridors.

While there has been much experience with PPV systems in low rise residential and commercial structures, particularly in the United States, the ability of PPV systems to control and vent smoke in multi-unit residential buildings had not been assessed. Accordingly, Canada Mortgage and Housing Corporation, the Ottawa Fire Department, Tempest Technology Corporation, the Co-operators Insurance and the National Research Council undertook a joint research project to investigate the use of PPV to clear smoke from fires in a high-rise building.

The research was conducted to determine the effectiveness of the PPV system for specific fire-fighting operations, including both post-fire salvage and fire-attack scenarios. Cold weather performance was also assessed as the ability of PPV systems to successfully vent smoke under high stack pressure conditions had not been explored.

RESEARCH PROGRAM

The tests took place at the National Research Council's 10-storey fire-test facility near Almonte, Ontario. The facility was set up to duplicate corridor, apartment and stairwell conditions in a high-rise residential building.

The test facility contained all the shafts and other features needed to simulate the patterns of air and smoke movement in the centre core of a typical multi-story building. The researchers could set variable openings in the exterior walls and the walls of the vertical shafts to provide leakage areas comparable to those in typical buildings. A blower door test of the tower stairwell was conducted by CMHC to determine the air leakage characteristics of the test facility so that comparisons could be made with actual multi-unit residential buildings.

The tests used a variety of commercially available PPV fan sets. The characteristics are detailed in Table 1 (next page).

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Table 1 PPV Fan Characteristics

Fan	Weight (kg)	Power	Fan Diameter (mm)	Nominal Flow Capacity (m^3/s)
1	38.6	Gas	600	8.0
2	40.4	Electric	600	6.1
3	34.9	Gas	530	8.9
4	13.6	Hydraulic	530	6.6

During the tests, a PPV fan was placed in the doorway of the exterior door to the bottom of the stair shaft so that outside air was delivered to the stairwell. A series of tests involving propane burners, burning residential furniture (sofas and beds) and a sprinklered heptane pan fire were conducted to compare the smoke-clearing capabilities of the PPV system, in both the stairwell and adjacent corridors, for fires with different characteristics under a variety of venting conditions.

TEST PROCEDURE

The researchers conducted a series of baseline tests using the 600 mm gas and the 600 mm electric fans to determine the quantity of airflow that each fan could deliver through the open exterior stair shaft doorway under non-fire conditions. The distance from the doorway and the tilt angle of the fans was varied to assess the impact on airflow through the doorway. The two fans produced similar airflows through the exterior door of the test facility. However, the most stable airflow characteristics (4.1- 4.8 m^3/s average flow) were produced with the fans at a distance of 1.8 m from the doorway. This was the distance used for all the venting tests. A fan tilt angle (up from horizontal) between 5° and 12° was found to produce the most stable airflows.

During a second series of baseline tests, researchers used propane burners to establish repeatable conditions of temperature and CO_2 concentrations in the stairwell prior to venting. Using this set-up, the impact of various venting arrangements (including vent location, size, variable leakage area between corridors and stairwells, open stairwell doors etc.) and PPV operation on smoke movement and concentrations was assessed. Twenty-two tests using the propane burner were conducted. They provided the initial fire conditions used to investigate the impact of various parameters on the effectiveness of the PPV system.

After the baseline measurements were recorded, the researchers conducted tests to determine the effectiveness of the PPV system in venting smoke generated by furniture (sofas and beds) fires and sprinklered heptane pan fires. The latter investigated the effectiveness of the PPV system in venting cool smoke that could be produced when sprinklers are activated.

The tests with the three sources of fire (sofa, bed and sprinklered heptane pan) used three ignition and venting sequences. The sofa fires were located on the 2nd floor, and the bed fires and the sprinklered heptane pan fires occurred on the 7th floor. The sofa fires and the bed fires were conducted in both the winter and summer to assess the impact of stack effect on PPV capabilities.

Each fire was set in the fire compartment, simulating an apartment, on the fire floor. Three test sequences were then used to simulate the opening of the apartment-corridor door, the stairwell-corridor door and fire fighter activities and stairwell venting options.

TEST MEASUREMENTS

For each test, the researchers plotted the following nine sets of data:

1. CO_2 and CO concentrations in the stair shaft at the 2nd, 6th, 8th and 10th floors.
2. Smoke obscuration.
3. Pressure differences between the stair shaft and the corridors for floors 2, 4, 6, 8 and 10.
4. Pressure differences between the stair shaft and building exterior at floors 2, 4, 6, 8 and 10.
5. Temperatures in the stair shaft for floors 1-10.

6. Temperatures on the fire floor including the fire compartment and in the stair-shaft doorway.
7. Temperatures in the north corridor on the fire floor.

Similar plots were made from the results of the tests for the bed fire and the sprinklered heptane pan fire. However, for the bed fire and the sprinklered heptane pan fire, the final three data plots included:

8. Temperatures in the stair shaft doorway on the fire floor.
9. Temperatures in the north corridor on the fire floor.
10. Temperatures in the fire compartment.

FINDINGS

Some of the major findings of the PPV venting tests with the three fire sources were as follows:

1. The PPV system was effective in venting smoke from the stair shaft. For the sofa burn tests on the 2nd floor, the times required for venting (clearing of smoke to acceptable levels) were comparable to those for the propane burner tests (2-3 minutes). For the bed and sprinklered pan fires on the 7th floor, the times were typically less than 2 minutes.
2. In the tests during the winter, the venting was comparable to, or faster than, those in the summer. There was also more smoke in the stair shaft in the winter, but this did not affect the time required for venting.
3. When a stair shaft door to a floor above the fire floor was open during the test, smoke was diverted into the building.
4. The time needed to vent the stair shaft was increased when both the stair shaft and the corridor on the fire floor were vented. However, the amount of smoke that leaked into the stair shaft during venting was minimized if the corridor was vented.
5. Venting the stair shaft temporarily increased the amount of smoke at the 10th floor as the venting moved smoke to this location faster than would have otherwise occurred without venting.
6. For fires located on lower floors, the amount of smoke on the 10th floor could exceed tenability limits during venting. However, with the faster venting provided by the PPV system, the smoke exposure would be less than it would be with natural venting.
7. When the fires were located on the 7th floor, smoke accumulated on the 10th floor before venting was started. During the venting, there was an initial increase in smoke levels, but the predominant effect was to clear the smoke from the area.
8. Using the PPV system with the corridor vented could reduce temperatures in the corridor on the fire floor. The cooling was faster when only the corridor was vented (not the stairwell). However, the corridor could be cooled, at a lesser rate, if the stair shaft was also vented.
9. For the bed fires, the PPV system increased the burning rate by supplying combustion air to the fire. The potential increase in the fire size due to venting should be considered if PPV is to be used during fire-attack.

The research indicated that PPV could be used to improve conditions on the fire floor and provide improved accessibility during a fire attack. However, the PPV system can provide increased combustion air to the fire. This has the potential to allow the fire to grow: thus the use of PPV for a fire attack should be used with caution. Adjoining compartments and vent exposures should be protected by charged firefighting hoselines.

The PPV system was also very effective in clearing smoke from the building in situations simulating post-test salvage operations. However, smoke could be pushed into adjacent areas through available intentional and unintentional openings.

It was also noted that doors to the stair shaft above the fire floor should be closed before venting begins because smoke could be diverted into other parts of the building through these openings.

IMPLICATIONS FOR THE HOUSING INDUSTRY

PPV systems represent a measurable improvement in smoke control in high-rise residential buildings. As smoke inhalation is the leading cause of death in apartment building fires, PPV systems can increase the safety of occupants during fire emergencies while improving the ability of firefighters to access fire locations.

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Housing Research at CMHC

Under Part IX of the ***National Housing Act***, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

This fact sheet is one of a series intended to inform you of the nature and scope of CMHC's research.

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Printed in Canada
Produced by CMHC 11-12-06
Revised: 2006

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