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PERFORMANCE OF THE SMOKE CONTROL SYSTEM, LIBRARY BUILDING, UNIVERSITY OF OTTAWA

by

C. Y. Shaw and G. T. Tamura

Internal Report No. 403
of the
Division of Building Research

Ottawa
April 1973

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PREFACE

The Division has been studying the factors affecting the migration of smoke through multi-storey buildings for the past several years, and has developed a number of approaches to the control of smoke in the event of fire. Buildings incorporating these concepts are now being constructed and it is of great value to be able to determine how they perform. This report presents the results of one such series of tests that were made on the Library at the University of Ottawa. The Division is very appreciative of the University's co-operation in permitting these tests to be made and also of the assistance that was obtained from the consulting engineers, Pageau Morel Lefebvre (Ottawa) Ltd., who designed the smoke control system for the Library.

The results of these tests, and other similar ones, will provide design and application data that can only be obtained by such direct experience. This kind of information is needed as a basis for rational building code regulations and for the design of systems that will meet the code requirements.

This report is a private record of what was done and of the results that were obtained: the information will ultimately be published in a form that better suits the needs of designers and code officials.

Ottawa
April 1973

N. B. Hutcheon
Director

Central Control Station

The central control station is located at the first floor.

Smoke Shaft

Shaft Construction: One T-shaped shaft of concrete construction with a total internal cross-sectional area of 48 ft^2.

Smoke dampers:
Concourse to 6th Floor: Two multiple blade dampers located side by side in the smoke shaft opening. The total open area is 16.6 ft^2.

Basement: Branch air ducts of the return air system serve as intake ducts to the smoke shaft.

Exhaust fan: an exhaust fan with a capacity of 40,000 cfm is installed at the top of the smoke shaft. Back draft dampers are provided at both sides of the fan. A motorized hatch door controlled by a thermostat is also located at the top of the shaft.

Controls: The dampers and hatch door are operated by electric controllers.

Operation (see Figure 2)

Automatic actuation with either smoke detector or pull alarm is found at each floor.

Smoke dampers on each floor can be opened with switches provided on the panel of the central control station.

Main supply air system switches to 100% outside air. (The system is designed for operation at outside air temperature of -40°F.)

The return air fan is shut down with return air dampers closed.

The smoke damper on the fire floor is opened and the smoke exhaust fan is activated.

Alarm is sent to the central heating plant.

When the temperature inside the smoke shaft rises to about 120°F, the hatch door is opened.

Other Provisions

Communication system: intercom and loud speaker.

Elevator: key operated switch for independent service.

Alarm system.

TESTS

First Test: Pressure Measurements

Tests were conducted with the 4th floor selected as the fire floor.

Test A1: A/C system in operation.
With the A/C system operating normally, pressure differentials across emergency stair and elevator doors at concourse, 4th and 6th floors were measured. Also pressure differentials from 1st floor to main stairwell and from main stairwell to outside were measured.

Test A2: A/C system shutdown.
With both the A/C systems and the smoke control system not operating, pressure differentials across emergency stair and elevator doors at concourse, 4th and 6th floors were measured. Also pressure differentials from 1st floor to main stairwell, and from main stairwell to outside were measured.

Test A3: Air conditioning system operating in smoke control mode with no venting. With the smoke exhaust fan shut down manually, and the damper opening at the fire floor sealed, pressure differentials from 1st floor to main stairwell and main stairwell to outside were measured. This test was conducted to determine the amount of pressurization provided by the supply air system.

Test A4: Smoke control system in operation without mechanical venting.
With the smoke control system operating, the smoke exhaust fan shut down manually and the seal removed from the damper opening at the fire floor, the following measurements were taken:

Test A4-a: all stair and exit doors closed

i. Air flow into the smoke shaft through the damper opening.

ii. Pressure differentials across floor constructions between the 4th floor and floors above and below.

iii. Pressure differentials across elevator and emergency stair doors at the 4th floor.

iv. Pressure differentials from 1st floor to main stairwell and from main stairwell to outside.

Test A4-b: exit door in one emergency stairwell open

i. Pressure differentials across the stair door of the SW emergency stairwell at the 4th floor with the exit door of this stair shaft open to outside. All other stair doors closed.

ii. Pressure differentials across the stair door of the SE emergency stairwell at the 4th floor with the exit door of this stair shaft open to outside. All other stair doors closed.

Test A5: Smoke control system with mechanical venting. With the smoke control system operating and with the smoke exhaust fan activated, the following measurements were taken:

Test A5-a: all stair and exit doors closed

i. Air flow into the smoke shaft through the damper opening.

ii. Pressure differentials across floor constructions between the 4th floor and floors above and below.

iii. Pressure differentials across elevator and emergency stair doors at the 4th floor.

iv. Pressure differentials across the stair doors of the NE emergency stairwell at the concourse, 4th and 6th floors.

v. Pressure differentials from 1st floor to main stairwell and from main stairwell to outside.

Test A5-b: exit door in one emergency stairwell open

Pressure differentials across elevator and stair doors at the 4th floor with the exit door of the NE stairwell open.

Test A5-c: exit door and 4th floor stair door in one emergency stairwell open

i. Pressure differentials across elevator and stair doors at the 4th floor with both the exit door and the 4th floor stair door of the NE stairwell open.

ii. Air flow through the open stair door at the 4th floor.

All measurements are listed in Table I. Because of the fluctuations in pressure difference readings caused by wind and movement of elevator cars, readings given in the Table are approximate mean values.

DISCUSSION OF PRESSURE MEASUREMENTS

With the air conditioning system off (Test A2), pressure measurements indicate that the neutral plane of the elevator shafts is found at approximately the 4th floor level with flow into the shafts below the neutral plane and flow out of the shaft above it. Air flow is out of the stair shafts at both lower and upper levels with flow into the shaft at mid levels. This was probably caused by the inflow of outside air through the leakage openings of the bottom exit door. The comparison of the pressure difference between the 1st floor and outside with the air conditioning system on (Test A1) and off (Test A2) indicates a pressurization of about 0.02 in. of water. With pressurization, the direction of flow as shown in Table I is into the stair shafts from all floor spaces. The flow pattern across the walls of the elevator shafts, however, indicates the characteristic flow pattern caused by stack action as indicated previously. With the air conditioning system operating in the smoke control mode but with the smoke shaft inoperative (Test A3), the supply air system provided building pressurization of 0.31 in. of water.

The objective of the smoke control system of this building is to lower the pressure in the fire floor to such an extent that air enters from the surrounding areas into the fire floor. This is achieved by venting gas in the fire floor to outside through a smoke shaft. Tests A4-a and A5-a were therefore conducted to check the flow pattern across the fire floor enclosure with the smoke control system in operation. Test A4-a was conducted with the smoke exhaust fan shut down so that air was exhausted to outside through the smoke shaft due to building pressurization and stack effect. Test A5-a was conducted with the smoke exhaust fan in operation. Both tests clearly show that air flow directions originate from the adjacent areas into the fire floor and from the fire floor to outside via the smoke shaft. These tests indicate that the operation of the smoke control system under the conditions specified (low temperature fire) will thus prevent smoke spread from the fire floor to its surroundings.

Air flow rates into the smoke shaft at the fire floor were taken during Tests A4-a and A5-a with rates of 9,400 cfm and 15,500 cfm respectively. The comparison of pressure readings taken during the two tests shows that the reduction in pressure in the fire floor relative to adjacent spaces increased with the venting capacity of the smoke shaft as expected. The rate of air flow into the smoke shaft in Test A4-a was taken with the hatch door at the top of the shaft closed and with the exhaust fan shut down. By opening the hatch door, the air flow rate increased to 17,800 cfm, an increase over Test A5-a where the exhaust fans were on and the hatch door closed.

The rate of air flow into the shaft at the fire floor obtained in Test A5-a was 15,500 cfm which is much less than the rated fan capacity of 40,000 cfm. This was probably caused by the following factors:

(1) Visual observations which indicated that there were large gaps between damper and damper frame as well as between individual damper blades. The leakage area is estimated to be roughly 15 per cent

of the damper opening. On this basis the total leakage area is approximately 105 per cent of the vent opening at the fire floor indicating that the total leakage flow might have been as high as 15,000 cfm.

(2) Leakage through the shaft walls.

(3) Frictional pressure drop inside the shaft due to the T-shaped cross section.

Test A5-b differs from Test A5-a in that the exit door of the NE emergency stairwell was opened to outside. Pressure difference readings across the 4th floor stair door of the stairwell indicates that the opening of the exit door caused a reversal in the direction of leakage flow; that is, from the fire floor into the NE stairwell and through the stairwell to outside. When the stair door of the NE stairwell at the 4th floor was also opened, as in Test A5-a, the measured air flow rate through this door into the stair shaft was 7100 cfm. The reversal in the flow direction as a result of opening the exit door is verified by the pressure measurements obtained in Test A4-b.

Second Test: Smoke Test

Eight 3-minute smoke bombs were placed at the fire floor (4th floor), two in each corner. With the A/C system in normal operation (Test A1) the smoke bombs were ignited; after 5 minutes smoke detectors distributed in the open ceiling area activated the smoke control system (Test A5-a). Observation of smoke movement indicated that no smoke entered either the stair shafts or the elevator shafts at the 4th floor with all doors closed. When both the exit door and the 4th floor stair door of the NE stairwell were opened, however, significant amounts of smoke entered this stairwell. The smoke test provided a visual proof of the conclusions that were drawn from the results of the pressure measurements.

CONCLUSION

Both the pressure measurements and smoke test demonstrated that the smoke control system is effective in preventing smoke spread from the fire floor to its surrounding areas provided that there is no direct connection to outside via the exit routes. With direct connection to outside, as in the case of a stairwell with both the exit door and the stair door of the fire floor open however, smoke contamination of the stairwell can be expected. This occurrence can be prevented by operating the smoke control system with the A/C system shut down for the following reasons:

Since the building height is low it is expected that the adverse pressure differential across the walls of the vertical shafts caused by stack action would be small.

The smoke shaft is provided with a mechanical exhaust so that its operation does not depend on either stack effect or building pressurization. It is expected that the exhaust capacity is sufficient to create adequate suction pressures in the fire floor to prevent smoke spread into adjacent spaces including the condition of open exit stair doors. Massive window breakages can reduce the effectiveness of mechanical venting. The window area of this building, however, constitutes a small portion of the exterior wall area; hence, massive window breakages are unlikely.

The stairwells can also be protected by pressurization. As the stairwells are located adjacent to the supply air ducts in this building it is possible to divert air from the supply air ducts into the stairwells without undue difficulties.

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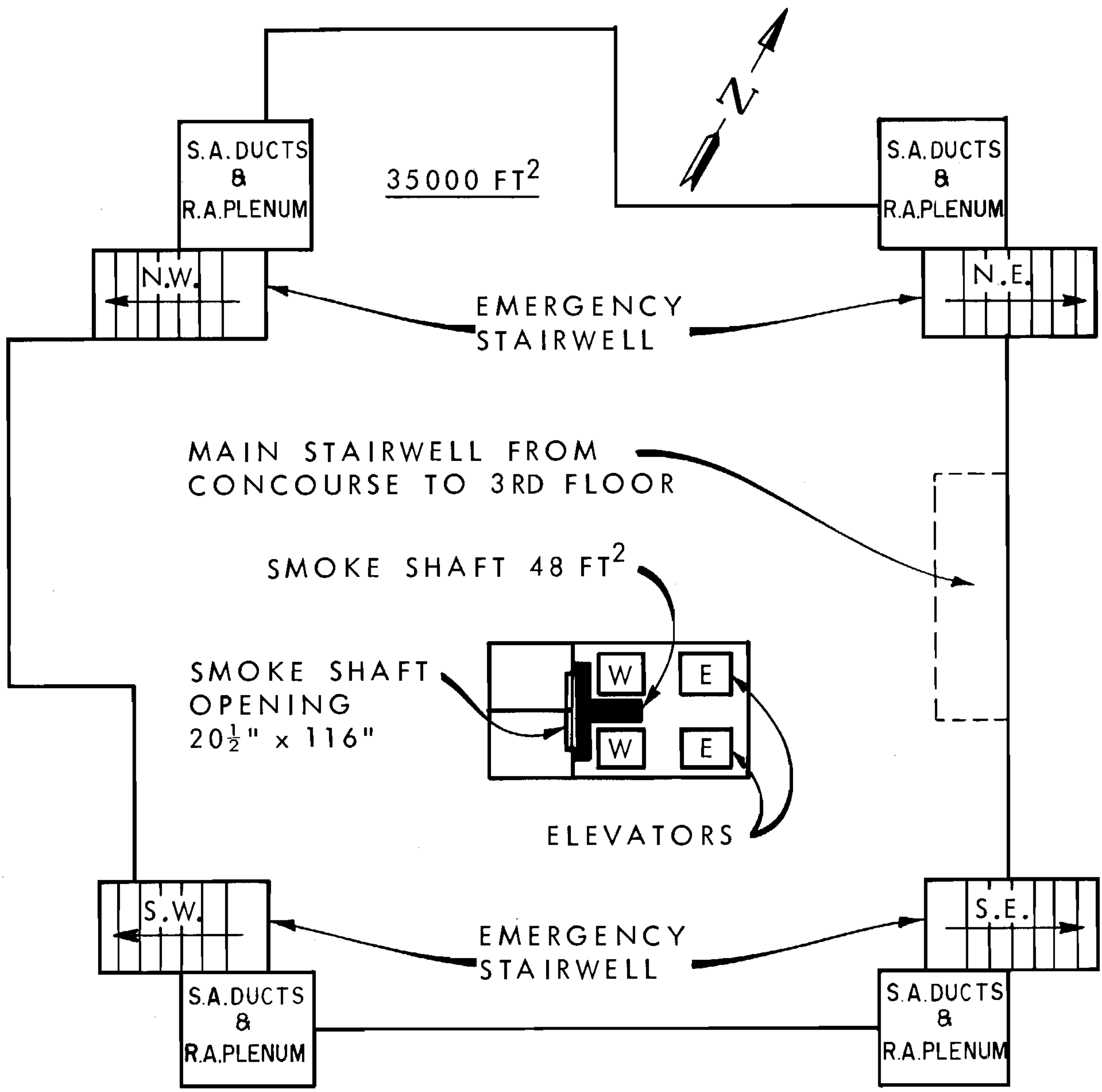

FIGURE 1 TYPICAL FLOOR PLAN 8A5060

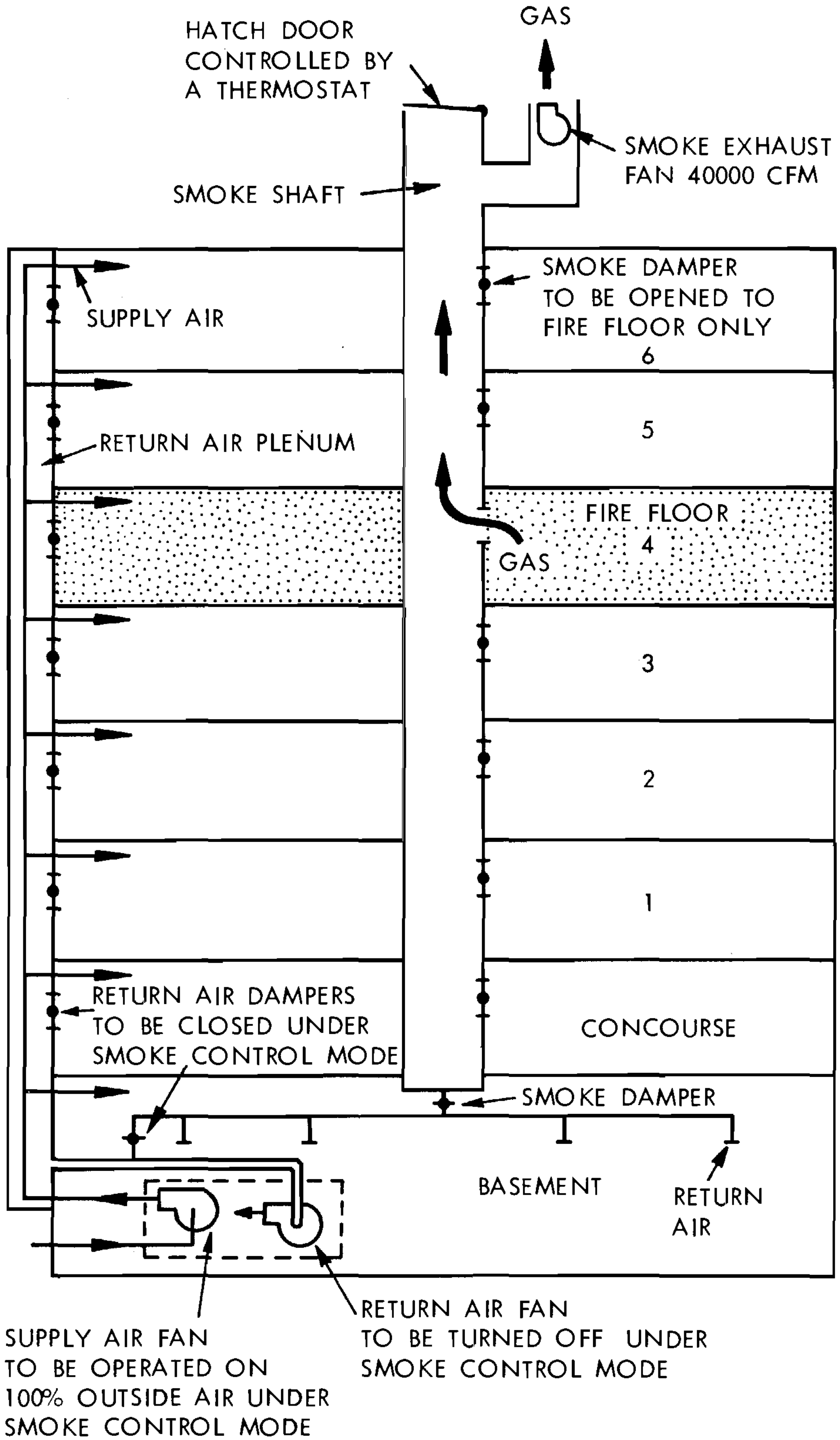

FIGURE 2 SMOKE CONTROL SYSTEM

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