HOT-SMOKE TESTS IN TWO UNDERGROUND RAILWAY STATIONS WITH MOVING TRAINS

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ABSTRACT

Hot-smoke testing in Australia has progressed to the stage where there is an Australian Standard for these tests. The purpose of such tests is twofold: firstly they can validate computer modeling predictions for smoke movement, and secondly they can demonstrate that the smoke control systems and associated fire safety systems function satisfactorily.

Hot-smoke tests were carried out in March 1997 at two of Sydney's underground railway stations, namely St James and Museum.

The purpose of the tests was to demonstrate that the smoke control systems performed their functions as intended. Tests were carried out in the concourses and on the platforms, and trains ran during the tests so that the effect of moving trains on smoke movement could be observed.

A total of five tests were carried out and video recordings were taken of each. This is the first time that hot-smoke tests have been carried out in an underground station with trains running. The paper discusses some of the interesting observations and the problems identified by the tests.

INTRODUCTION

The hot-smoke tests described in this paper are believed to be the first ever to be conducted in an underground railway system with moving trains.

Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) has been carrying out hot-smoke tests since 1989. The tests have been used not only to demonstrate the performance of the smoke control systems, but also to obtain scientific data for the validation of mathematical models.

A hot-smoke test is a simulation of the design fire within a building (the term 'design fire' defines a fire that is assumed to represent a worst-case scenario for the purposes of smoke modelling). The simulation for hot-smoke testing is a smaller fire consisting of a number of trays filled with alcohol. The size of the test fire is dictated by the temperatures of the fire plume at ceiling level, the aim being to prevent heat damage to the ceiling and other installed items such as lights, sprinkler heads and smoke detectors.

An Australian Standard on hot-smoke testing was published in June 1996.

PURPOSE OF THE SYDNEY UNDERGROUND STATION HOT–SMOKE TESTS

Two stations (St James and Museum) were subjected to hot-smoke tests. These stations had recently been provided with smoke control systems and the design specification included a requirement to demonstrate satisfactory performance of the systems by means of hot-smoke tests. The CSIRO provided the specification details relating to the hot-smoke tests.

In the case of St James Station, the hot-smoke tests were intended to demonstrate that:

- in the case of a fire on the concourse level, the smoke control system at that level would minimise the spread of smoke down to the platform level; and
- in the case of a fire at platform level, the smoke control system at concourse level, operating in reverse mode, would provide a sufficient flow of air down the stair to minimise the flow of smoke up from the platform level.

In the case of Museum Station, the hot-smoke tests were intended to demonstrate that:

- in the case of a fire on the concourse level, the smoke control system at that level, in conjunction with fans in the pedestrian tunnels leading to the platforms, would be sufficient to minimise the spread of smoke into the pedestrian tunnels; and
- in the case of a fire at platform level, the fans in the pedestrian tunnels would be sufficient to minimise the spread of smoke from the platform into the pedestrian tunnels.

Neither station had a smoke exhaust system at platform level.

PROCEDURES

Hot-smoke tests in general require a considerable amount of organisation. Planning needs to take into account the proposed date, time and location of the tests, and arrangements need to be made to ensure that the appropriate people are present. In the case of the station tests, those present included the ventilation contractors, the engineering consultants, railway fire services, railway management, station master, train operating staff, train driver, emergency services, railway police, ambulance and the local fire brigade. People such as emergency services personnel, police and ambulance staff attended only to observe and hopefully to benefit from the experience of seeing a station fire simulation. In this context, videos were taken from the train cab to be used for driver training purposes. Other people such as railway management and the engineering consultants were there to assess the performance of the smoke control systems. The CSIRO was there to carry out the hot-smoke tests, assess the performance of the systems and ultimately to prepare a report on the tests.

A number of safety procedures form part of a normal hot-smoke test, namely:

- the use of breathing apparatus by those persons required to be within the smoke;
- briefing prior to the test to ensure that all persons are aware of the exit locations;
- the provision of appropriate fire extinguishers; and
- the protection of furnishings and other items including sprinklers which may be adversely affected by heat.

In addition to the above, another safety measure during these tests was to have observers on the platforms to monitor train movements under the conditions of reduced visibility.

In order to prevent staining the finished building interior, alcohol was used as the fuel. As alcohol burns with a smoke-free flame, artificial non-staining smoke was introduced into the fire plume to facilitate recording of the heat and smoke movement.

In the case of the hot-smoke tests described in this paper, the fire source consisted of eight small trays of alcohol, each tray measuring 0.375 m^2, and the trays were separated in order to create separate plumes. The total perimeter of the trays was 12 m which, in terms of smoke production, represents a fire intensity of approximately 5 megawatts (MW).

DESCRIPTION OF ST JAMES STATION

St James Station has a single 'island' platform separating the two tracks. There is a single concourse located above the centre of the platform with which it is connected by a number of open stairways. The ceiling over each railway track is a separate arch except in the centre of the station (below the concourse) where the ceiling is flat.

DESCRIPTION OF MUSEUM STATION

Museum Station has two platforms, one on either side of the twin tracks. The platforms are approximately 160 m long and there is an arch-shaped concrete roof over. At each end of the station there is a single tunnel which accommodates both train tracks.

A system of pedestrian tunnels connects the platforms with the two concourses located at each end of the station.

DESCRIPTION OF THE HOT-SMOKE TESTS

The following hot-smoke tests were carried out:

- Test No. 1 – St James concourse, 2 December 1996, 9 pm;
- Test No. 2 – Museum concourse, north end, 6 March 1997, 12.30 am;
- Test No. 3 – Museum concourse, south end, 6 March 1997, 2.30 am;
- Test No. 4 – Museum concourse, south end, retest, 6 March 1997, 11.30 pm;
- Test No. 5 – Museum platform, 7 March 1997, 12.30 am; and
- Test No. 6 – St James platform, 7 March 1997, 2.30 am.

Test No. 1

Test No. 1 was conducted at St James station concourse in the late evening with trains running normally.

This concourse is connected to the platforms below by means of open stairs. In concourse fire mode, the smoke control system is designed to extract smoke from the concourse while make-up air is supplied from the pedestrian tunnels leading from the concourse to the street.

The fire was located near one of the pedestrian tunnels and the excessive velocity of the make-up air caused the flames and the smoke to swirl, which prevented the formation of a stabilised hot layer. Nevertheless the objective of preventing smoke from flowing into the pedestrian tunnels was achieved, at least until a train approached the station.

The piston effect of a train moving towards the station caused some smoke to flow into the pedestrian tunnels, and when the train departed from the station, the effect was reversed. A train leaving the station also caused some of the smoke in the concourse to be drawn down the stairs to the platform level.

Test No. 2

This test was conducted at the north concourse of Museum Station after normal train operations had ceased. A special train was arranged to run back and forth through the station at the 'emergency speed' of 15 km/h so that the effect of the train on smoke movement could be observed. This train running arrangement was provided for all of the subsequent tests discussed below and was intended to be a realistic simulation of a real fire emergency.

The concourse is connected to the platform level by a series of pedestrian tunnels, each of which was provided with a reversible fan to 'pressurise' the concourse in a concourse fire situation, and to pressurise the platform in the event of a platform fire. Two pedestrian tunnels connecting the concourse with street level also had fans installed.

During this tests, smoke entered the pedestrian tunnels leading to the platform and activated those smoke detectors which were designed to detect a fire within the platform. This caused the tunnel fans to change from concourse fire mode to platform fire mode.

Test No. 3

This test was conducted at the south concourse of Museum Station. The concourse is connected to the platform level by a series of pedestrian tunnels, each of which was provided with a reversible fan to 'pressurise' the concourse in a concourse fire situation, and to pressurise the platform in the event of a platform fire. A pedestrian tunnel connecting the concourse with street level also had a reversible fan installed.

The problem with the smoke detectors in the pedestrian tunnels leading to the platform, as identified in Test No. 2, was overcome for test purposes by starting the fans in the tunnels manually. In this test, a fan in one of the pedestrian tunnels malfunctioned and smoke was drawn into that tunnel.

Test No. 4

This test was a retest of Test No. 3 after the faulty fan operation had been rectified.

Test No. 5

Test No. 5 was located at the south end of the platform level in Museum Station. Smoke detectors at the high arched ceiling activated the fans in the pedestrian tunnels and no smoke entered these tunnels. There was no mechanical smoke exhaust system in the platform area.

Smoke within the platform area flowed along the ceiling to the north end – a distance of approximately 160 m. The smoke remained at high level until the train entered the station. The movement of a train, even at 15 km/h, was sufficient to disturb the hot layer and the whole platform area became smoke-logged. The density of the smoke increased as the test proceeded even though a large proportion of the smoke flowed into the train tunnels at both ends of the station.

Test No. 6

Test No. 6 was located near the centre of the platform area of St James Station, adjacent to the stairs leading to the concourse above.

Smoke detectors at ceiling level activated the concourse level fans which provided a flow of air down the stairs. The smoke accumulated in the high ceiling near the fire and was prevented from flowing under the smoke curtains at the stairs until the train moved through the station. This caused a temporary flow of smoke up the stairs. When the train had passed the make-up air again prevented smoke from flowing into the stair openings.

CONCLUSION

This series of hot-smoke tests demonstrated the performance of the smoke control systems and was invaluable in identifying unexpected problems in the smoke control systems and associated fire systems in underground railway stations. In addition, the experience gained by railway staff, including management, train drivers and emergency personnel, was of considerable importance in the development of safe railway operating procedures and training programs.