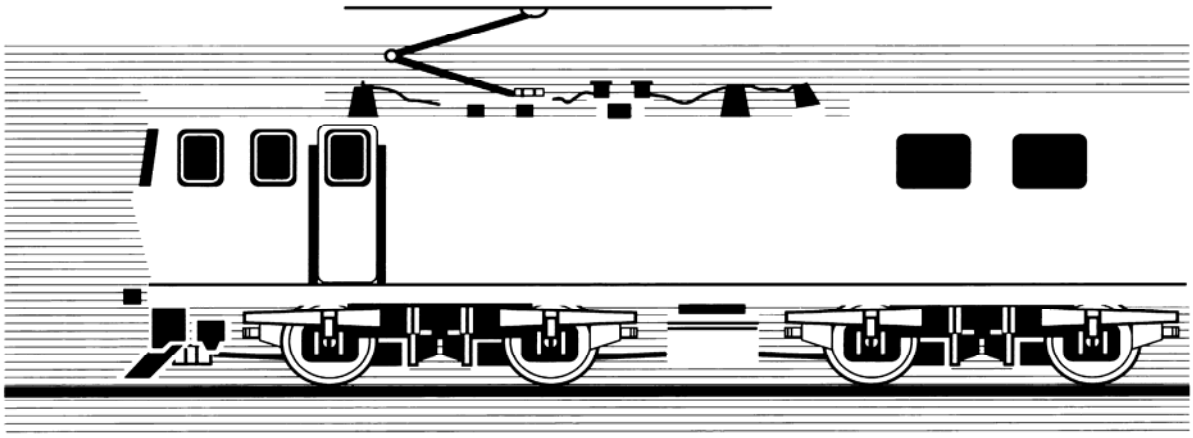
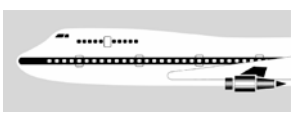
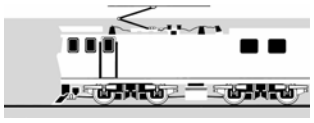


RAILWAY OCCURRENCE REPORT

06-112 **Report 06-112, loss of airbrakes and collision, Tram 244, Christchurch** **November 2006**


TRANSPORT ACCIDENT INVESTIGATION COMMISSION
NEW ZEALAND

The Transport Accident Investigation Commission is an independent Crown entity established to determine the circumstances and causes of accidents and incidents with a view to avoiding similar occurrences in the future. Accordingly it is inappropriate that reports should be used to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

The Commission may make recommendations to improve transport safety. The cost of implementing any recommendation must always be balanced against its benefits. Such analysis is a matter for the regulator and the industry.

Report 06-112

Tram 244

loss of air brakes and collision

Christchurch

21 November 2006

Abstract

On Tuesday 21 November 2006, at about 1120, Tram 244, operated by Christchurch Tramway Limited, lost its air brake after striking a traffic warning cone. The tram then collided with the rear motor vehicle in a line of cars stopped for a traffic signal. The impact pushed the car forward into a nose-to-tail collision with two cars ahead of it.

The tram sustained minor damage and 3 cars were extensively damaged. There were no injuries.

A safety issue identified was the lack of consultation between Christchurch City Council, its contractor and Christchurch Tramway Limited before starting road maintenance work. Safety recommendations covering this issue were made to the Chief Executive of Christchurch City Council, as principal, and the Operations Manager, Christchurch Tramway Limited.

Because of the safety actions taken by Christchurch Tramway Limited to protect the air braking system following this incident, no safety recommendation to improve the system has been made.

A safety recommendation was made to the Director of Land Transport that he inform other tramway operators about the lessons learned from this investigation.

Tram 244 (courtesy Christchurch Tramway)

Contents

Figures

Abbreviations

the Council	Christchurch City Council
Christchurch Tramway	Christchurch Tramway Limited
DC	direct current
km/h	kilometre(s) per hour
kPa	kilopascal(s)
m	metre(s)
mm	millimetre(s)
psi	pounds per square inch
the Code	Transit New Zealand's Code of Practice for Temporary Traffic Management
UTC	coordinated universal time

Data Summary

Train type and number:	Tram 244
Date and time:	21 November 2006 at 1120[1]
Location:	Christchurch
Persons on board:	crew: 2 passengers: about 25
Injuries:	nil
Damage:	minor to tram 3 cars extensively damaged
Operator:	Christchurch Tramway Limited
Investigator-in-charge:	D L Bevin

[1] Times in this report are New Zealand Daylight Times (UTC+13) and are expressed in the 24-hour mode.

Factual Information

1.1 Narrative

1.1.1 On Tuesday 21 November 2006, Christchurch Tramway Limited (Christchurch Tramway) Tram 244 was operating a scheduled tourist service around Christchurch central business district. The tram was carrying about 25 passengers and was crewed by a driver and a conductor.

1.1.2 At about 1120, Tram 244 departed from the Casino stop in Armagh Street and travelled east across Durham Street North. Immediately after crossing the intersection, it approached a road worksite that was close to the tram lines and protected by traffic warning cones.

1.1.3 As the tram entered the worksite it clipped several traffic warning cones positioned near the tram line. At least one warning cone lodged under the running board of the tram and was dragged for a short distance before dislodging. While being dragged, the warning cone hit and forced open the drain cock on the air reservoir. The air reservoir discharged and no air pressure was available to operate the brakes. The tram driver was unaware of this and continued on.

1.1.4 The conductor heard the air escaping and went forward to advise the driver. By this time the tram had crossed the Armagh Street bridge and was travelling down a slight grade and was about 10 metres (m) from the last car in a line of stationary traffic. By this time the driver had realised that he had no air brakes and attempted to apply the handbrake. However, the tram was too close to the last car for the handbrake to be effective and prevent a collision.

1.1.5 The point of impact was about 95 m past the worksite. The impact of the collision propelled the rear car forward in a nose-to-tail collision with 2 cars in front of it. The tram sustained minor damage and the 3 cars were extensively damaged. There were no injuries.

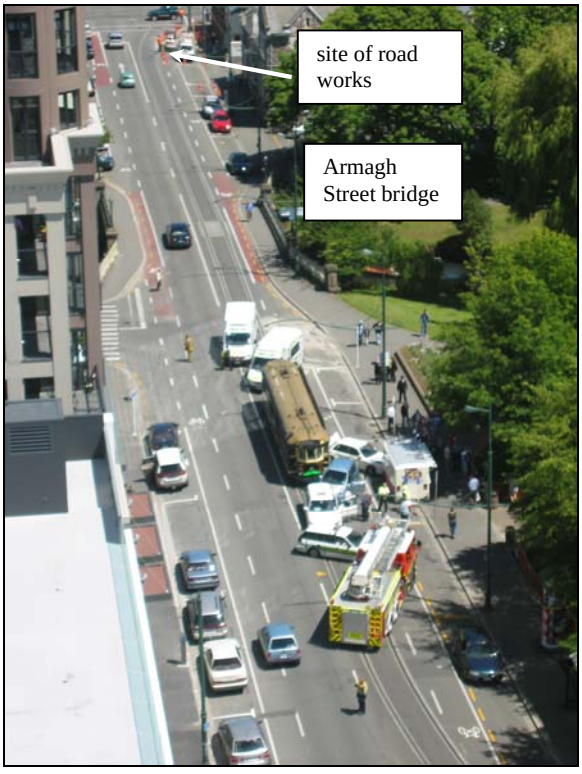


Figure 1
Position of the vehicles after the collision (courtesy Christchurch Tramway)

1.2 Tram information

Operator and route information

1.2.1 Christchurch Tramway operated a fleet of 5 motorised trams and 2 non-powered trailers. The trams carried about 120 000 passengers per annum.

1.2.2 The 1435-millimetre (mm) gauge tramway route was a 2.5-kilometre loop linking the central business district with several tourist attractions. The trams operated daily from 0900 to 2100 and at the busiest times were scheduled about 8 minutes apart.

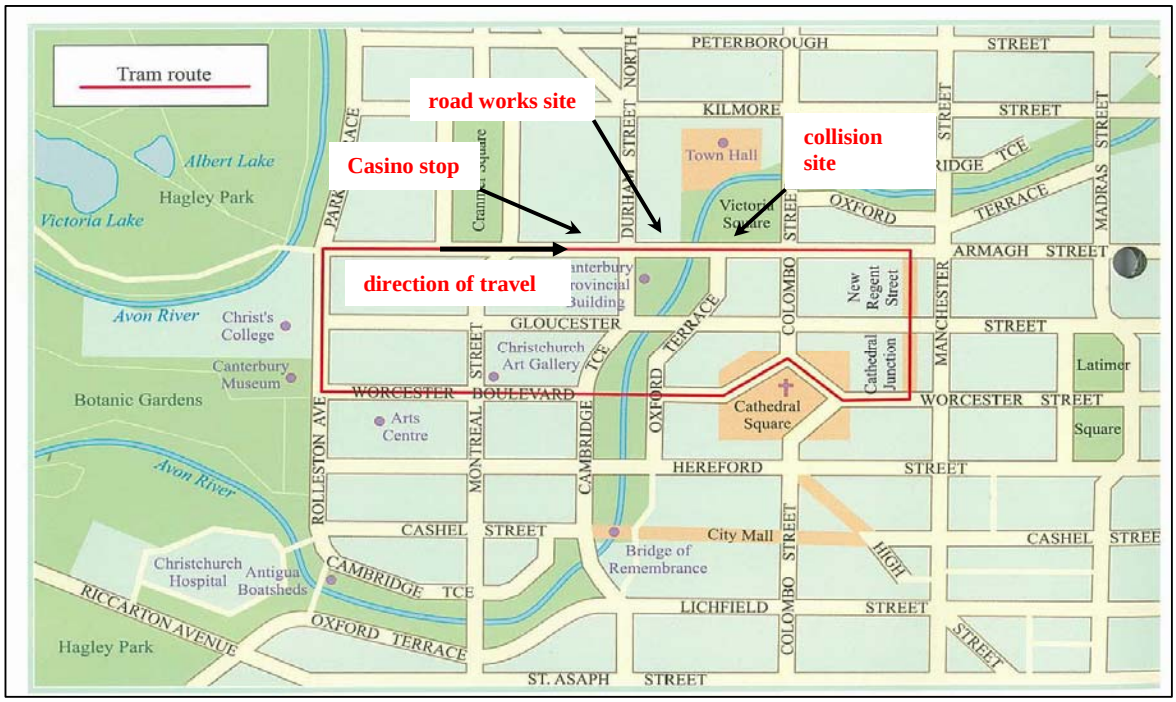


Figure 2
Tram route map (courtesy Christchurch Tramway)

1.2.3 Most of the route was on roads where the trams ran with other vehicles. The trams were required to obey traffic signal indications or special, tram-only, indications at intersections.

1.2.4 The trams were powered by a 600-volt DC overhead power supply.

1.2.5 The infrastructure, including the tram lines and overhead power supply, was owned by the Council.

1.2.6 Under section 15 of the Railways Act 2005, both the Council as access provider[2] and Christchurch Tramway as operator[3] were required to have individual safety cases approved by the Director of Land Transport New Zealand, and be appropriately licensed. Christchurch Tramway had an access agreement with the Council to operate on the tramway.

1.2.7 Christchurch Tramway's safety system section 2.2, Track Design Standards, required a minimum safety clearance of 750 mm outside the tram. The maximum tram width was 2.5 m.

1.2.8 Christchurch Tramway advised that the driver and the conductor training manuals did not include the section of the safety system that related to the 750 mm clearance requirement and

[2] The person who controls the use of that railway line by rail operators.
[3] The person who provides or operates a railway vehicle.

not all of the drivers were aware of the requirement. Tram crews did not have ready access to a copy of the full safety system, and they had not brought the proximity of the worksites to the tram lines to the attention of their operations manager.

1.2.9 Christchurch Tramway received road-closure advice from the Council for planned events, stoppages or parades. These notices were placed on the boards for the information of the tram crews and were used by Christchurch Tramway to plan accordingly. No such advice was received for planned works being undertaken near the tramway corridor.

Tram 244

1.2.10 Tram 244 was one of 2 Melbourne W2 class trams in the fleet. It was built in 1925, weighed 17 tonnes and, at 2.5 m wide, was the widest tram in the fleet.

1.2.11 Tram 244 had commenced operations with Christchurch Tramway in January 1996 and was licensed to carry 52 passengers.

1.2.12 There was a running board secured to the side of the tram to assist passengers with boarding and alighting (see Figure 6). The running board started 3.6 m behind the driver's cab and ran along the outside of the tram for 5.2 m. It was 200 mm wide and was 300 mm above the ground.

1.2.13 Christchurch Tramway advised that Tram 244 had entered service at 0910 on the day of the collision and had completed a circuit of the route about every 25 minutes. The tram had also been in service the previous day.

1.3 Tram 244 air brake system

1.3.1 The air brake used compressed air from a reservoir that was charged by an electrically powered compressor. The compressor was controlled by a governor,[4] which switched off the compressor when the reservoir reached its maximum prescribed pressure of 73 pounds per square inch (psi) (496 kilopascals (kPa)). The compressor switched on again when the reservoir pressure fell to 55 psi (379 kPa).

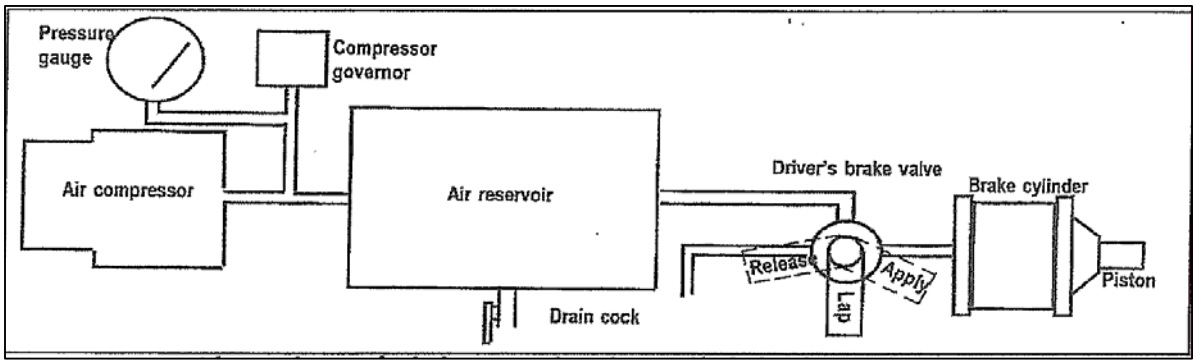


Figure 3
Schematic diagram of the air brake system on Tram 244 (not to scale)

1.3.2 The driver's brake valve handle (see Figure 4) was used to control the flow of compressed air to and from the brake cylinder. A piston actuated the brakes through a system of levers, rods and chains, collectively known as the brake rigging. The brake rigging forced brake blocks onto the rim of the wheel to provide braking action.

[4] A pressure-operated switch.

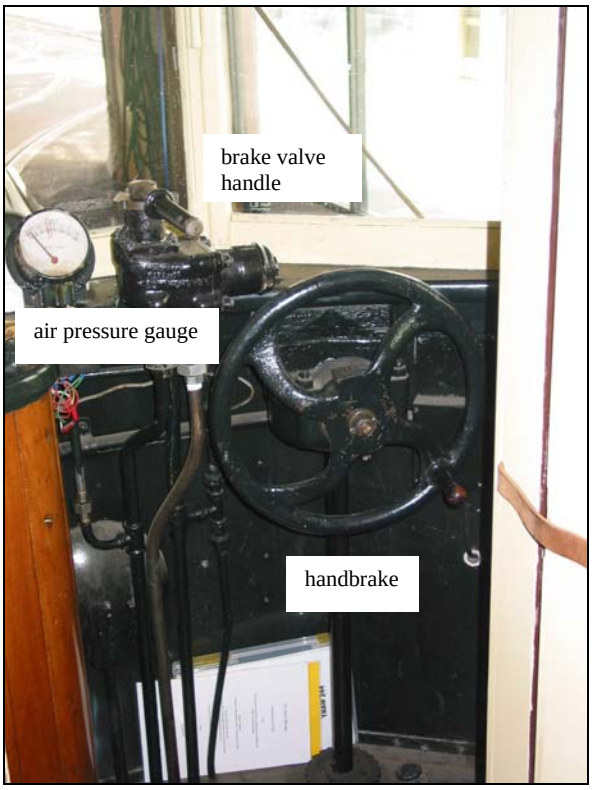


Figure 4
Driver's cab of Tram 244

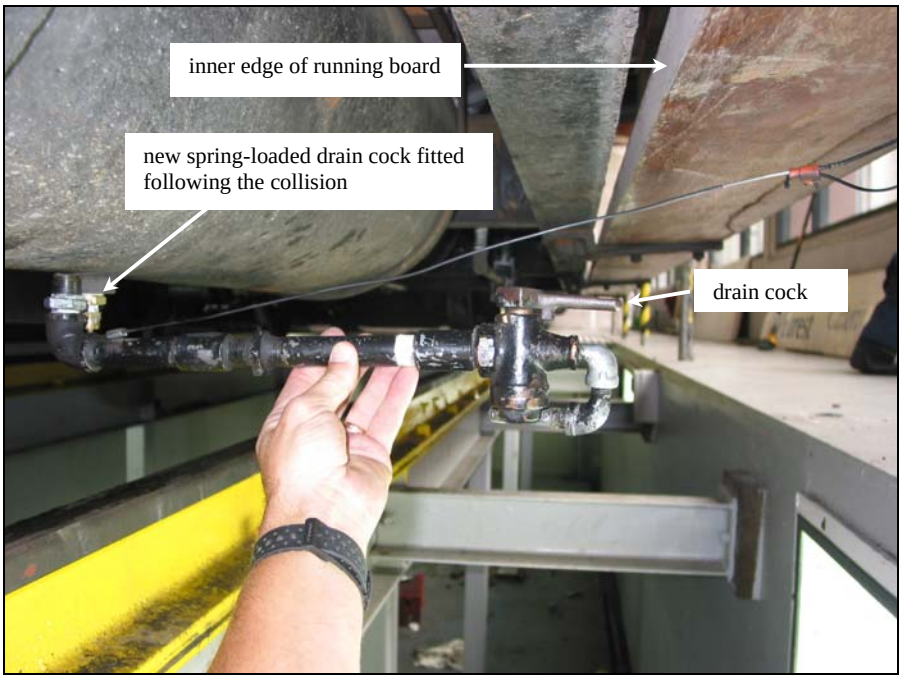


Figure 5
The old drain cock held in position, left-hand side in direction of travel

1.3.3 A drain cock[6] was attached to the air reservoir. The cock was at right angles to the side of the tram, 200 mm in from the outside edge of the running board (see Figure 5). There was an 85 mm clearance between the drain cock and the ground. The drain cock was located 1 m from the start of the running board and was 4.6 m behind the tram driver's cab (see Figure 6).

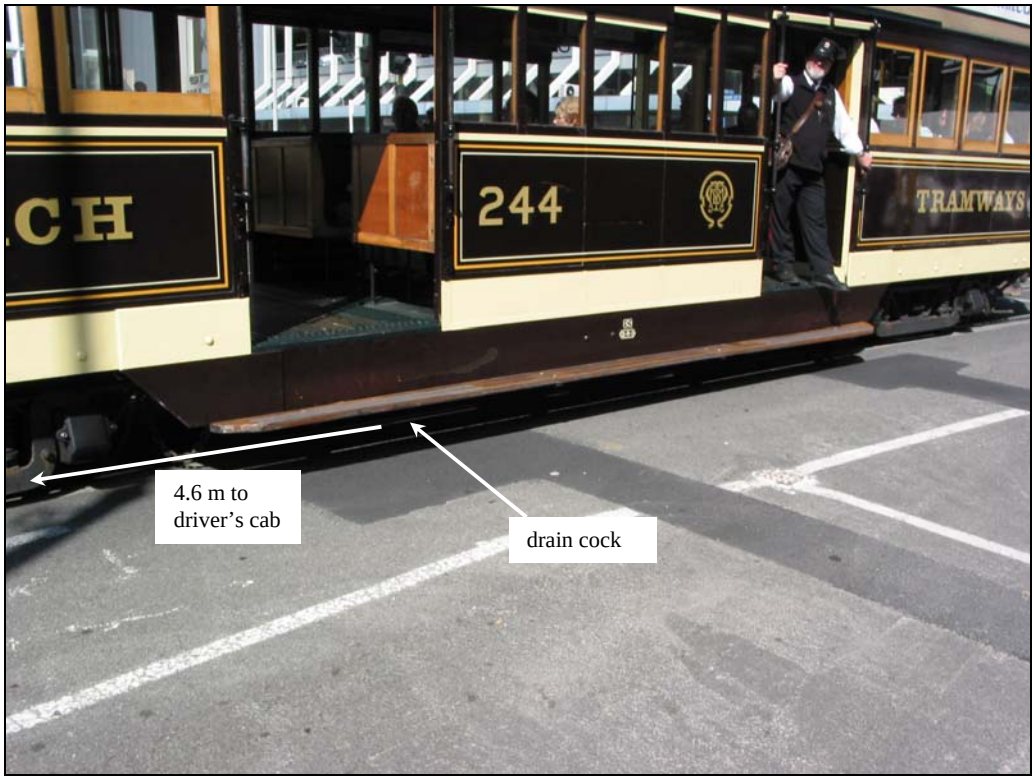


Figure 6
Location of drain cock from outside tram

1.3.4 When the drain cock was open (see Figure 8), the air escaped from the reservoir through a half-inch (nominal 15 mm) diameter valve. The air escaped more quickly than the compressor could compensate for the leakage, with the result that the system ran out of air pressure and the tram had no air brakes. Tests carried out following the collision showed that with the drain cock open the air reservoir drained from 72 psi (496 kPa) to zero psi in 30 seconds.

[6] Used to bleed air from the reservoir.

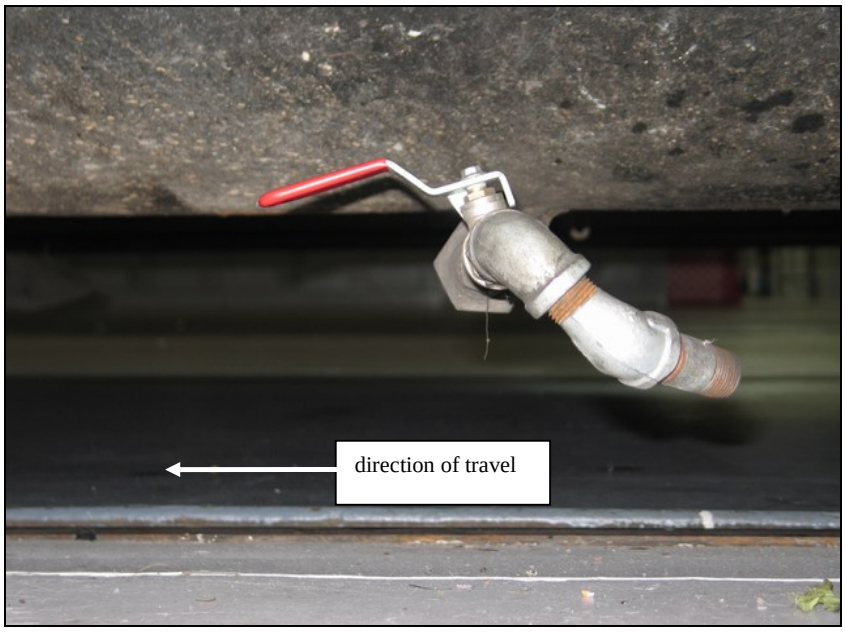


Figure 7
Drain cock on Tram 244 in the closed position (courtesy Christchurch Tramway)

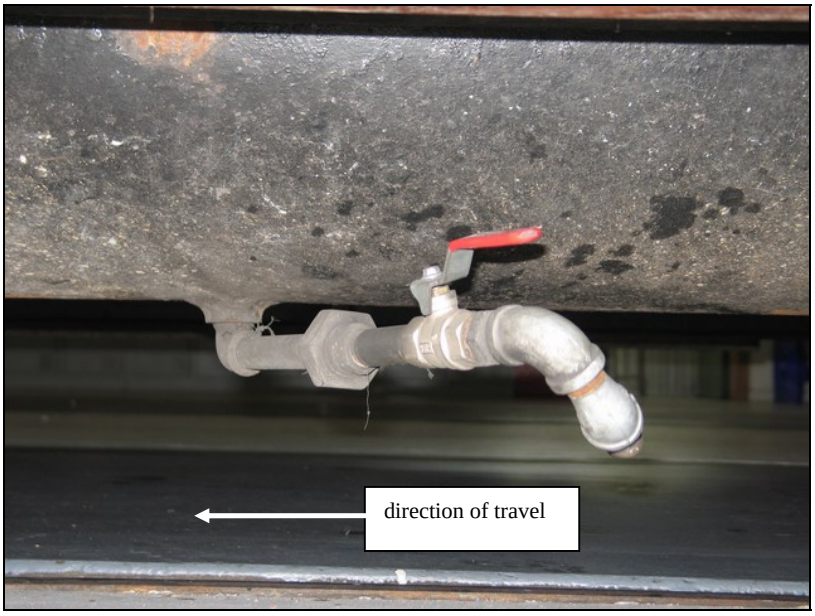


Figure 8
Drain cock on Tram 244 in the open position (courtesy Christchurch Tramway)

1.3.5 Tram 244 was not equipped with an emergency air reservoir, unlike most other trams in the fleet.

1.4 Site information

Christchurch City Council

1.4.1 The Council had authorised the contractor to carry out the cable trenching work near the accident site. The Council had adopted Transit New Zealand's Code of Practice for Temporary Traffic Management (the Code), which contained traffic management plans for traffic disruption situations.

1.4.2 The contractor had developed several generic traffic management plans from the Code. Providing the temporary traffic management plan complied with one of these generic plans there was no need for the Council to issue an authority to work. However, if the work did not comply with a generic plan, the contactor had to obtain a road-opening notice from the Council. This was an authority for the work to be carried out. The contractor had the responsibility for determining that the planned work fitted with a generic traffic management plan.

1.4.3 The Council had a copy of Christchurch Tramway's safety system and was aware of a 750 mm minimum clearance requirement (see 1.2.6) for obstructions placed near the tram lines. However, the Council said that the contractor was working under the authority of one of its own generic traffic management plans, none of which included reference to the presence of the tram lines near the worksite.

1.4.4 The road works near the intersection of Durham Street North and Armagh Street involved trenching work and installing cable ducting under the tram carriageway and pedestrian footpaths. The worksite had been protected by traffic warning cones (see Figure 9).

Figure 9
Worksite at the intersection of Armagh Street and Durham Street North

1.4.5 Road works had been continuing near the tram lines at several sites along Armagh Street during the morning. Figure 10 shows a previous worksite and the falling grade from Armagh Street bridge to the point of impact. The downhill grade was about 4 degrees and was 20 m long. There were no road works being carried out at this site at the time of the collision.

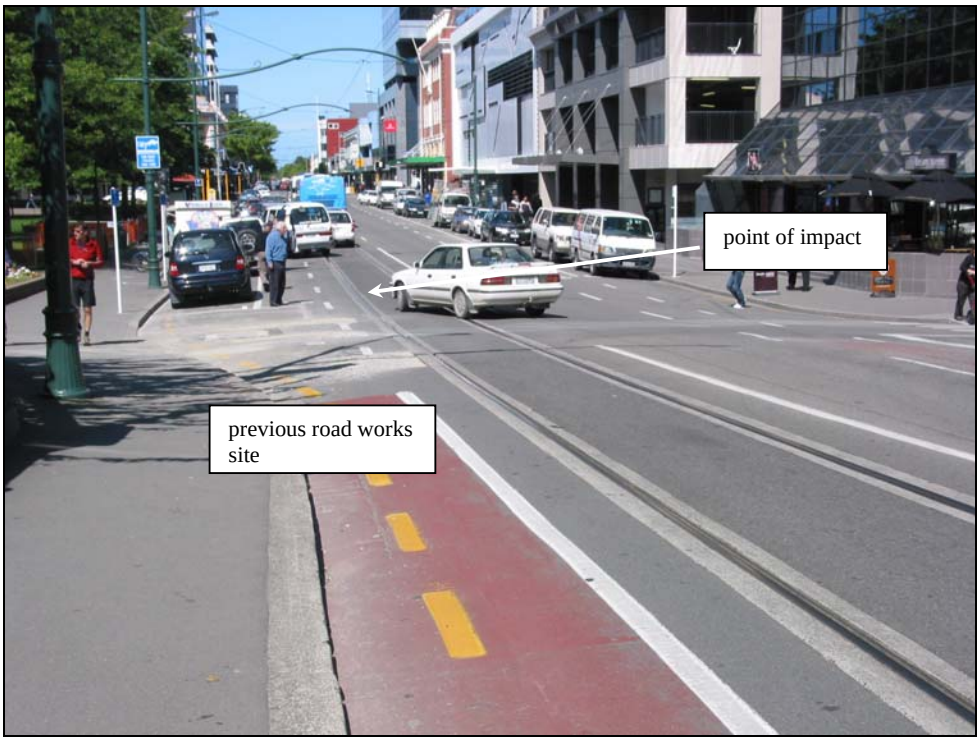


Figure 10
Point of impact

Site plan and measurements

1.4.6 Figure 11 shows Tram 244 passing the worksite after the work and resealing had been completed. The worksite consisted of 2 separate trenches from the duct adjacent to the tram line to the kerb. The first trench was 5 m from the intersection of Durham Street North and Armagh Street and the other about 6 m along Armagh Street.

1.4.7 The darker shade of grey shows the location of the trenches after resealing. The edge of the new seal was closer to the tram line than the edge of the trenches had been. At the closest point, the edge of the trench was 843 mm from the edge of the tram line (1.610 m from the centreline) (see Figure 11), which allowed for the traffic warning cones to be placed between the edge of the trench and the side of the tram. The cones were 944 mm high and extended 370 mm from the edge of the trench towards the tram line, at the base of the cone.

1.4.8 The trenches were of a depth that the workmen climbed out when trams approached.

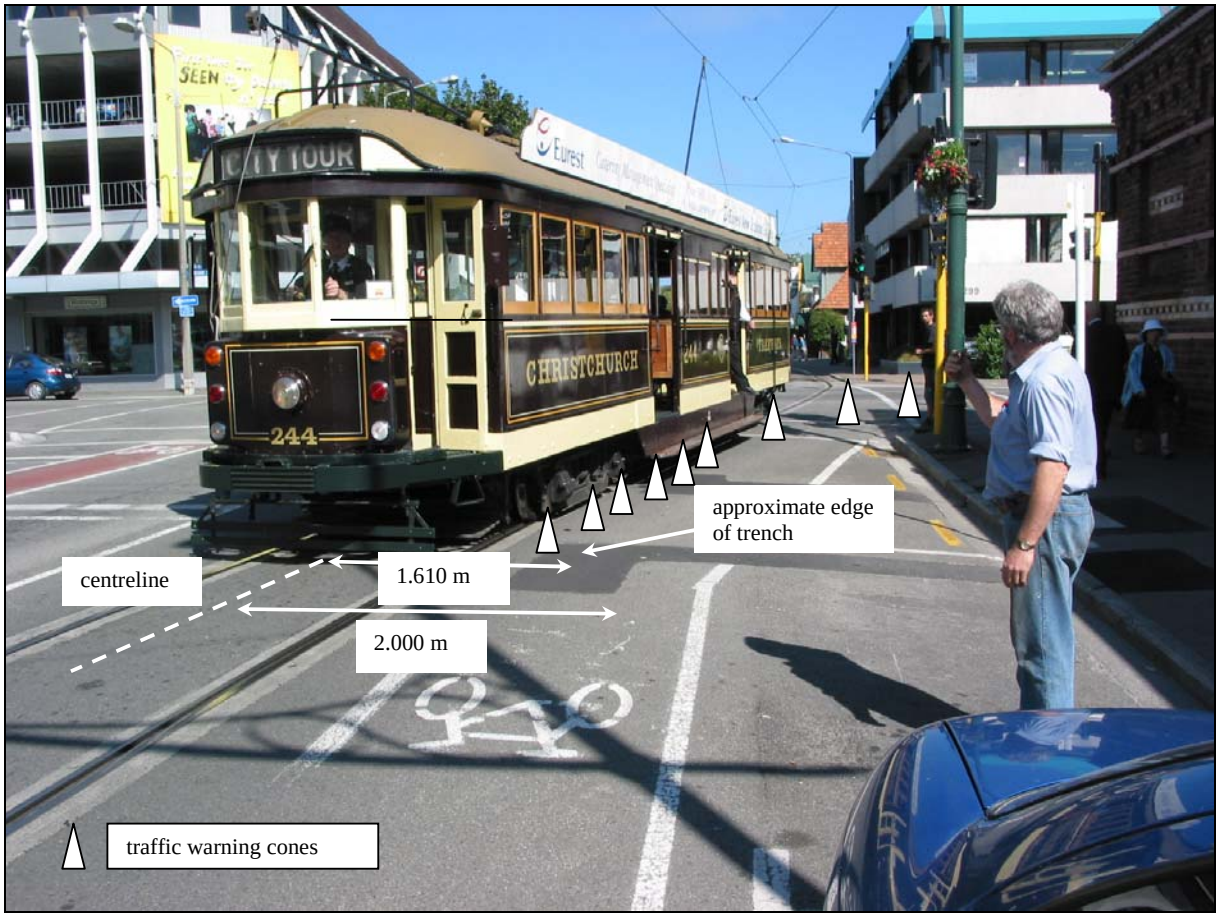


Figure 11
Tram 244 passing the worksite following completion of the work

1.5 Static post-incident examination

1.5.1 A static post-incident examination of the position of the traffic warning cone against the running board of Tram 244 was undertaken at the tram depot. The measurement from the running board to the surface of the concrete walkway was confirmed as 300 mm, the same as at the worksite.

1.5.2 Figure 12 shows the traffic warning cone flush against the side of the running board, with the bevelled leading edge of the running board clearly visible.

Figure 12
Traffic warning cone in the vertical position

1.5.3 Figure 13 shows the traffic warning cone in the horizontal position alongside the running board.

Figure 13
Traffic warning cone in the horizontal position

1.5 Personnel

The tram driver

1.5.4 The driver of Tram 244 had been driving trams for 33 years. He had worked on a regular part-time basis at Christchurch Tramway since its opening in February 1995. He also drove trams at a tram museum in Christchurch.

1.5.5 He had started his shift at 1000. He said that during the morning, road works were being carried out at 3 different locations along Armagh Street and he was aware that warning cones had been placed close to the tram line. The road workers had been removing the cones to allow the trams to pass then replacing the cones. He said that Tram 244 was the widest tram in the fleet.

1.5.6 The driver said that after departing from Stop 8 (Casino) in Armagh Street he had crossed the intersection with Durham Street North and moved slowly through the road works site.

1.5.7 He said he was unaware that the tram had lost its air until he attempted a brake application to slow as he approached a line of cars ahead of him. There was no response, so he looked at the air gauge and saw that there was no air pressure. At this time the conductor arrived and advised him of the loss of air but it was too late for him to do anything.

1.5.8 He estimated the tram was travelling at about 15 kilometres per hour (km/h) at this time and he thought that there were about 4 seconds before impact. He tried to apply the handbrake but had not completed that action before the tram collided with the closest stationary car.

1.5.9 The driver said that had he known earlier that the tram had lost its air brakes he could have put the tram into reverse, but he doubted whether this would have had any effect on the situation he was in, because of the closing distance between the tram and the car in front.

1.5.10 After the collision he and the conductor found the drain cock open, so he closed it to prevent the air from the compressor escaping. He did not recall seeing a warning cone or any other obstruction under the tram at that time.

1.5.11 He said he had never had any problems with the braking system on Tram 244 prior to the collision.

The conductor

1.5.12 The conductor had worked as a part-time tram driver and conductor for 18 months.

1.5.13 She said that as they approached Stop 8 she had been aware of cables being laid close to the tram lines in several locations. After they left the stop the driver had requested that she watch for the warning cones.

1.5.14 The conductor said she leaned out of the tram through a doorway as they passed the warning cones and saw one cone get clipped and fly away from the tram, but she did not see one go under the tram.

1.5.15 Shortly after they had passed the cones, she heard air escaping so she went forward to advise the driver. However, when she got to the driver the tram was on the bridge and the driver was trying to apply the handbrake. She realised the tram was not going to stop before colliding with the cars in front, so she called to the passengers to hold on.

1.5.16 She said there were about 10 cars queued in front of the tram, which was more than usual. Had there been only about 5 cars she felt the tram would have stopped before colliding with the cars. The tram had been travelling slowly and from the time she heard the air escaping until she got to the driver it had probably travelled between 25 m and 30 m.

1.5.17 The conductor said that the air reservoir was positioned underneath the tram, about half-way along, and it was unlikely the driver would have heard the air escaping as he was in the enclosed driving cab and delivering a commentary to the passengers at the time.

1.5.18 She said she thought there were about 25 passengers on the tram at the time of the collision and said there were no injuries to them or crew members.

Christchurch Tramway's maintenance engineer

1.5.19 The tram maintenance engineer (the engineer) said that some time prior to the incident a person visited him and said he had a contract to install manholes next to the tram lines. He told the person that the best time to do the work was between midnight and 0900, outside the hours of operation of the trams. The engineer said that a process had been implemented at similar worksites near to the tram lines that required machinery to stop work and clear the vicinity of the tram lines before the tram was permitted to pass.

1.5.20 The engineer said there had been no further contact with the contractor and he was unaware that the work had commenced until he was advised of the incident. He said he would have expected the contractor to return and talk to him about site requirements before the work commenced. Also, he said that if working outside the hours of tram operation was not suitable, the contractor should have come back to arrange a workable alternative.

1.5.21 The engineer said he had not at the time fully appreciated the work the contractor wanted to do and had not realised they would be working so close to the tram lines. He was now concerned about the presence of other contractors who may use the manholes for inspections or for connecting other services.

The contractor's network manager

1.5.22 The contractor's network manager (the manager) said they had been working for about a month laying a 100 mm duct that ran along the tram lines. On the day of the incident the contractors had arrived at the intersection of Durham and Armagh Streets early in the morning and set up their traffic management zone as they had to secure parking. Once established, traffic had flowed freely and several trams had passed through the worksite.

1.5.23 The manager said that the Council was aware of the general area in which the work was being undertaken but not the specific sites being worked on at any particular time. The contractor had submitted a work plan before work commenced, which detailed their safety plan when working through the central business district. The contractor had also met with Christchurch Tramway and he believed that from that meeting he had its approval to commence work. He had not personally attended the meeting with Christchurch Tramway but was aware of who had represented the company at the meeting, although he was unsure of when the meeting had taken place.

1.5.24 He said they had considered doing the work outside the hours of tramway operation, but it was not an option because of the timeframe of the project. The contractors were familiar with working in close proximity to the trams. They had previously worked at 4 or 5 other sites without incident. He said they had had problems with the wider tram but were aware of its increased width, as were the tram drivers, and everything had gone well.

1.5.25 He said the work was carried out under generic temporary traffic management plans developed from the Code. These plans were approved by the Council and were the contractor's authority to operate. The work was covered by generic traffic management plans 5 and 7. Plan 5 did not cover the intersection of Durham and Armagh Streets, so a more detailed traffic management plan, designed for layout at the site especially for the instruction of the contractor's staff, had been developed to do so. He said that neither of the plans provided for the running of trams through or near the worksite.

1.5.26 He said he personally was unaware of Christchurch Tramway's requirement for a 750 mm clearance from the outer edge of the widest tram to obstructions such as work construction equipment. He said he did not prepare the generic traffic management plans; that was done by one of the contractor's traffic management staff, who then had them approved by the Council.

1.5.27 He said he was at the worksite when Tram 244 collided with the warning cones. He said the running board was wider than on other trams and had a bevelled edge on the leading and trailing ends. If the running board had clipped the cones it would have done so in such a way that they would tilt a slight degree then revert to the vertical position.

1.5.28 The preferred option was that if the cones could be clipped they were moved away. This time had been different from previous times when Tram 244 had clipped the cones because, after clipping the first cone, the driver had increased speed and knocked over the next 2 or 3 cones.

1.5.29 The manager said he saw some of these cones get caught, but they didn't go any further under the tram than the running board. The cones were dragged between 1 m and 2 m before being ejected. After the tram had gone, the workers stood the cones back up.

1.5.30 He said it was usual for a tram to approach and pass the worksite slowly so that the workers could judge the spaces of the cones and move them away from the tram. After 3 or 4 trams had passed without hitting the cones, the workers did not take so much notice of the approaching trams but they remained aware that the wider tram would appear at some time. This had worked well previously and there had been no problems with the trams hitting the cones.

1.5.31 He said that the tram drivers were aware of the cones and that they had to use caution when proceeding through the worksite, which was why he was surprised when the driver on this particular occasion powered through and hit the cones.

1.5.32 He said that it was not a case that Tram 244 would always hit the cones; rather it was a matter of placing the cones and rearranging them further away when the tram got close to them. There was room at every site for the cones to be placed clear of Tram 244, but in this instance they may have been shuffled around while the work was being done and the tram had come through and clipped them. He said there was not a situation where the cones could not be positioned outside the kickboard. Tram 244 set the margins on where the cones could be placed, although it was often difficult to judge until Tram 244 appeared.

1.5.33 He said that no particular person among the workers was responsible for placing the cones but, because they were working close to the tram lines, there was always someone keeping a lookout for the trams and telling the other workers when one was approaching. Work always stopped for the passage of a tram, and if the tram driver had not seen the workers move away from the site he would stop.

1.5.34 He said he wasn't sure how many times Tram 244 had been through the site prior to clipping the cones, although he had been on site for about an hour and a half. He said that if the tram had passed earlier in the day, the only difference between clipping the cones and not clipping them would have been the speed of the tram through the worksite.

1.5.35 He maintained that there had been an excellent working relationship between his staff and the tram crews and no other difficulties had been experienced.

2 Analysis

2.1 The tram lost air pressure in the brake system because of the design and positioning of the air reservoir drain cock. The drain cock was in such a position that if its tap was knocked by an obstacle under the tram, the cock would go to the open position and bleed the reservoir of air pressure, thereby removing the tram's braking ability. Because the tram was not equipped with an emergency air reservoir, there was no back-up air pressure for the braking system.

2.2 The drain cock was in the closed position when the handle was pointing in the direction of travel of the tram and in the open position when the tap was turned 90 degrees and pointed at right angles to the direction of travel of the tram. It was most likely that when the traffic warning cone became jammed under the tram's running board, it came in contact with the drain cock tap and, while being dragged along, pushed it to the open position.

2.3 The drain cock was positioned close to the side of the tram to allow staff easy access to bleed off the air reservoir when necessary. However, its location and proximity to the ground created the potential for it to be knocked open by any obstruction passing under the tram or the running board. The spring-loaded drain cock that was fitted by the operator after the incident ensured that if the cock were accidentally opened the handle would immediately swing back to the closed position, unless it was jammed open, thereby retaining sufficient air pressure in the reservoir to operate the brakes. In view of this action taken, no safety recommendation covering this issue has been made.

2.4 If the air reservoir had been at full capacity when the drain cock handle was forced open, and the speed of the tram had increased to 10 km/h after leaving the worksite, the tram would have travelled a distance of about 84 m by the time the reservoir was depleted. This would have put the tram about 9 m onto the downhill slope off the bridge and 11 m from the closest stationary motor vehicle. Allowing for the tram increasing speed as it travelled down the slope, the driver would have had about 4 seconds to respond to the loss of air brakes before the impact. This was insufficient time for him to take evasive action, although he did attempt to apply the handbrake.

2.5 Tests carried out on the air reservoir showed that it could be depleted of air pressure in 30 seconds. As the tram crossed the intersection and approached the worksite, it was not travelling very fast and the air reservoir may not have been at full capacity because of recent brake applications, in which case it would have taken less time for the reservoir to lose its air pressure.

2.6 The replacement of the original nominal 15 mm drain valve with a 6 mm drain valve meant that the compressor was able to compensate for the air loss and even rebuild the air pressure back up to normal while the valve remained open. Therefore, if for any reason the drain cock was accidentally opened and did not swing back to the closed position immediately, the compressor would ensure that sufficient air pressure was retained in the air reservoir so that the brakes could be operated. In view of this action taken, no safety recommendation covering this issue has been made.

2.7 The first time that the driver became aware of the loss of air was when he attempted to make a brake application as the tram descended the slope from the bridge towards the line of stationary cars. He would have been able to see the line of cars forming as he travelled down Armagh Street and, at the speed he was travelling, he obviously had no concerns about his ability to stop short of the last vehicle once he began to descend the slope from the bridge. There was an air pressure gauge in the driving cab that would have alerted him to the reducing brake system air pressure if he had referred to the gauge, which he did only after his unsuccessful brake application to confirm that there was no air pressure. There was no aural warning system installed to attract the driver's attention to reducing brake system air pressure.

2.8 Continual reference to the air pressure gauge was probably not normal driving technique and it was therefore understandable that the tram driver had not referred to it earlier. Aural warning

devices have since been installed on all the trams in Christchurch Tramway's fleet to attract the drivers' attention to a loss of air pressure. In view of this action taken, no safety recommendation covering this issue has been made.

2.9 The tram driver would not have heard the air escaping from the reservoir after the drain cock tap had been opened. His attention would have been focused on firstly getting across a busy intersection before approaching and passing through the worksite, while at the same time delivering a commentary to the passengers. He then had to concentrate on stopping short of the line of cars. The reservoir was located under the floor of the tram with the drain cock 4.6 m behind the semi-enclosed driver's cab. This, together with the noise of the compressor trying to replace the escaping air, the sounds of the in-motion tram and his commentary, would have drowned out the sound of the escaping air.

2.10 The cone that had lodged under the running board probably dislodged before the conductor looked out of the tram, so she would not have seen what had occurred. The cones she had seen moving towards the kerb would probably have been those the tram had clipped earlier. It was likely that had the conductor not put her head out of the tram, she would not have heard the air escaping.

2.11 An informal meeting had taken place between a member of the contractor's staff and Christchurch Tramway's engineer regarding the nature of the work. However, both parties took conflicting understandings from the meeting and no written record had been kept to confirm arrangements. The engineer understood that the work would take place outside the hours of tram operations, if it took place at all, while the contractor's representative only understood that agreement had been reached on the commencement of the work.

2.12 There was no requirement for the parties to meet and formalise the work programme before it commenced and, as a result, there was no effective coordination between the constraints of the operator, including the requirements of its safety system, and the needs of the contractor to get the work done. The lack of such a requirement was a significant contributing factor to this incident and a safety recommendation covering this issue has been made to the Operations Manager, Christchurch Tramway and to the Chief Executive of the Council which, as owner and provider of the tramway infrastructure, was responsible for any work undertaken within the tramway corridor.

2.13 The engineer's recommendation that the work be done outside the hours of operation of the trams indicated he probably considered that, even though he did not have a full understanding of the work to be done, it could have interfered with the tram operation. There was a process that could have been implemented if necessary to enable work to be undertaken in conjunction with the tram operation, but the contractor had not come back seeking this option. This probably confirmed to the engineer that if the work were going ahead it would be outside the tram operating hours.

2.14 To undertake the work the contractors needed access to the ducting near the tram line. Because of this it was necessary for obstructions, such as the work trenches and the traffic warning cones, to encroach within the minimum clearance distances specified in Christchurch Tramway's safety system. It was difficult to understand how this work could be carried out in such close proximity to the tramway infrastructure without both Christchurch Tramway and the Council being involved. The Council was aware of the 750 mm minimum clearance as specified in the Christchurch Tramway safety system, but the contractor was not. The temporary traffic management plans, under which the Council's contractor was working, should have provided for the movement of the trams through the worksites but it did not. However, in view of the action since taken by the contractor, in conjunction with the Council, no safety recommendation covering this issue has been made.

2.15 Prior to the incident the network manager was aware that Tram 244 was the widest tram and, as such, set the standard for the trams to clear the traffic warning cones. It was not the accepted

practice for the cones to be left where they would be clipped by Tram 244; rather the procedure was that the cones were rearranged for the passage of the tram as it approached. That this procedure was being followed earlier on the day was confirmed by the fact that Tram 244 had passed through the worksite previously without knocking over the cones. However, the last time it did so the cones had been left close to the tram lines and in the area of conflict with the tram's running board.

2.16 From the static post-incident examination it appeared most likely that the cones were struck by the bevelled leading edge of the tram running board. Some warning cones were deflected away but at least one had lodged under the running board. Although the base of the cone was slightly higher that the running board, the pressure brought to bear as it went under would probably have been enough to disfigure the base sufficiently for it to be squeezed under the running board and be held captive, at least for a short time. The examination confirmed that the cone, while in the horizontal position, could have stretched back and contacted the drain cock.

2.17 What had changed to bring the cones into conflict since the tram's previous run through the worksite was difficult to determine. The profile of Tram 244 was constant, and there was unlikely to be any side-to-side sway at the height of the running board as the tram travelled along the tram lines. The slow speed of the tram, even if it had accelerated while passing through the worksite, was unlikely to have created sufficient sway for the running board to reach the cones if they had been arranged in their usual position for the passage of the tram. Therefore, it was more likely that the cones had been rearranged closer to the tram lines since the last passage of Tram 244 through the worksite, but had not been repositioned back before it returned. In that position they would still have been clear of the narrower trams as they passed.

2.18 The safety system requirement of a minimum 750 mm clearance to obstructions from a tram profile of 2.5 m wide was not included in the training manuals for tram crews, nor was a copy of the safety system readily available to them. As a result, most of the crews were probably unaware of this safety requirement. It was therefore not surprising that the worksites being in such close proximity to the tram lines had not raised concerns amongst the crews and had not been reported to the operations manager.

2.19 The most effective way to ensure that this safety-critical part of the safety system was adhered to by contractors, or other work gangs in the vicinity of the infrastructure, was to have the tram crews observing the worksites during their circuits and reporting any non-compliance. However, this could only be done if the crews were aware of the standards. The action since taken by Christchurch Tramway to include this information in the crew training manuals and to make a copy of the safety system available to crews will ensure they are better equipped to monitor this aspect of the operation. No safety recommendation covering this issue has been made.

2.20 There are currently 4 tramways in New Zealand operating Melbourne W2 class trams, and because the lessons learned from this incident should be addressed with those operators, a safety recommendation covering this issue has been made to the Director of Land Transport New Zealand.

3 Findings

Findings and safety recommendations are listed in order of development and not in order of priority.

3.1 Tram 244 was being operated by a qualified driver and conductor.

3.2 The loss of air brakes on the tram occurred when its air reservoir lost all pressure after its drain cock tap was forced open by a traffic warning cone.

3.3 The driver was not alerted to the loss of brake system air pressure in time to prevent a collision.

3.4 The air reservoir drain cock was positioned close to the side of the tram and this, together with its proximity to the ground, allowed the tap to be knocked open by the warning cone after it lodged under the running board.

3.5 With the drain cock open, the compressor could not recharge the air reservoir quickly enough to prevent loss of air pressure.

3.6 The tram driver's only means of being aware of the loss of brake air pressure was by the pressure gauge in his cab.

3.7 The traffic warning cones had probably been rearranged to be within the conflict area following the previous passage of Tram 244, but had not been moved outside the conflict area, in accordance with the worksite practice, before the tram returned to the worksite.

3.8 Work had been carried out at various worksites alongside the tram lines, within the minimum obstruction clearance distance specified in the operator's safety system, without formalised agreement between all parties.

3.9 There was no requirement for the Council to authorise the work of the contractors provided the work was covered under an approved generic temporary traffic management plan developed by the contractor from the Code.

3.10 The contractor was not aware of the clearance of obstructions clause in Christchurch Tramway's safety system.

3.11 The generic temporary traffic management plans under which the contractor was working did not provide for the operation of the trams during the work.

3.12 Although an initial meeting had taken place between the contractor and the operator regarding the work, no plan regarding time and conditions when the work was to be done had been mutually agreed.

3.13 Because the tram crews were unaware of Christchurch Tramway's safety system requirement of a 750 mm clearance from obstructions, the crews could not report any irregularities.

4 Safety Actions

4.1 Christchurch Tramway advised that following the collision it had carried out the following:

- the nominal 15 mm drain cock valve on Tram 244 had been replaced with a 6 mm valve
- during testing of the 6 mm valve the air reservoir had been pumped up to full pressure of 72 psi (496 kPa). After the compressor cut out, the drain valve was opened and the pressure dropped to 55 psi (379 kPa) when the compressor cut back in. The drain valve was kept open while the compressor pumped back up to cut-out pressure again. This took about 60 seconds. Following the satisfactory results of the tests, the new drain valves had been fitted to all the trams in the fleet
- since the collision the drain cock tap on Tram 244 had been replaced with a spring-loaded tap which that swung back to the closed position unless physically held in the open position. This change was proposed for all trams in the fleet
- an audible low- air- pressure warning buzzers had now been installed in the drivers' cabs on in all trams in the fleet
- emergency air reservoirs will be fitted to the 2 trams that were not equipped with this feature. Tram 244 was one of those
- a copy of the approved safety system has been made available for tram crews and information relating to the 750 mm clearance requirement will also be included in the Tram Route Driving Procedures manuals.

4.2 On 9 March 2007 the contractor advised that he:

- had met with Christchurch Citythe Council regarding traffic management planning, specifically concerning working in close proximity to the tram lines. At that meeting the Council's Asset Protection Engineer, Transport, outlined the requirements and safe working distances required under the Christchurch Tramway's safety system. It was agreed that all temporary traffic management plans for proposed work within those safe working distances would now be submitted to the Council for approval before commencement of the work
- was considering doing any work on the ducting, which ran along the tram lines, outside the hours of operation of the trams.

5 Safety Recommendations

5.1 On 7 March 2007 the Commission recommended to the Director of Land Transport that he:

> distribute the Commission's report 06-112 to all tramway operators so that the lessons learned from this investigation are understood and recommend they take such actions as appropriate to prevent similar incidents. (001/07)

5.2 On 21 March 2007 the Director responded in part:

> As recommended, we intend to distribute the Commission's Report 06-112 to all tramway operators as soon as we receive the report.

5.3 On 20 March 2007 the Commission recommended to the Chief Executive, Christchurch City Council that he:

> in conjunction with Christchurch Tramway Limited, develop formalised procedures to be followed before any work is undertaken which conflicts with the requirements of the Christchurch Tramway Limited safety system. (003/07)

5.4 On 17 April 2007 the Council advised that, in conjunction with Christchurch Tramway, it was developing an application form to be completed by all contractors before commencing any work on roads that carry the tramway system. This form must be approved by both Christchurch Tramway staff and the Council. The Council was also in the process of writing the above conditions into the Christchurch City Council Construction Standard Specification CSS Parts 1-7 2002.

5.5 On 3 May 2007 the Council advised that, in conjunction with Christchurch Tramway, the implementation of the use of the "Application to Work Near Tram Tracks" form had been approved.

5.6 On 7 May 2007 the Commission wrote to the Chief Executive, Christchurch City Council in part:

> The Commission is satisfied that the recommendation has been acted upon and the status of the safety recommendation is closed-acceptable.

5.7 On 20 March 2007 the Commission recommended to the Operations Manager, Christchurch Tramway Limited that he:

> in conjunction with the Christchurch City Council, develop formalised procedures to be followed before any work is undertaken which conflicts with the requirements of the Christchurch Tramway Limited safety system. (00/07)

5.8 On 1 May 2007 Christchurch Tramway Limited advised that, in conjunction with the Christchurch City Council, implementation of the use of the "Application to Work Near Tram Tracks" form had been approved.

5.9 On 8 May 2007 the Commission wrote to the Operations Manager of Christchurch Tramway Limited in part:

> The Commission is satisfied that the recommendation has been acted upon and the status of the safety recommendation is closed-acceptable.

Approved for Publication 21 June 2007

Hon W P Jeffries
Chief Commissioner

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