Transportation Safety Board of Canada
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Marine Occurrence Report

Fire with the Loss of One Life

in the Cargo Conveyor Tunnel of the Self-unloading Bulk Carrier "HALIFAX" St. Mary's River, Ontario 06 April 1993

Report Number M93C0001

Synopsis

On 06 April 1993, the Canadian self-unloading bulk carrier "HALIFAX" was transiting St. Mary's River, Ontario. Repairs to the unloading system were near completion and the hydraulic system was being tested by the three tunnelmen, when a major fire broke out in the centre tunnel below the cargo holds. A hose to a gate valve was found disconnected after the fire. The fire was successfully extinguished by the crew, but the head tunnelman lost his life.

The Board determined that the fire broke out in the conveyor belt tunnel aboard the "HALIFAX" when the hydraulic oil mist from the disconnected hose was ignited by a halogen lamp that was missing a protective lens cover.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 Particulars of the Vessel

	"HALIFAX"
Port of Registry	Toronto, Ontario
Flag	Canadian
Official Number	313963
Type	Great Lakes self-unloading bulk carrier
Built	1963, Lauzon, Quebec
Gross Tons[1]	20,646
Length	222.56 m
Draught max.	F[2]: 4.87 m A: 7.01 m
Propulsion	Two steam turbine engines, 7,356 kW, 17 knots (kn)
Owners	Canada Steamship Lines Inc. Montreal, Quebec

1.1.1 Description of the Vessel

The "HALIFAX" has the navigation bridge and associated accommodation located forward, and an engine-room and the balance of the accommodation located aft. The 6 cargo holds are served by 17 hatches that are separated by 7 structural but non-watertight transverse bulkheads. The vessel is equipped with two cargo-unloading conveyor belts arranged longitudinally in a hopper-topped tunnel under cargo holds. (For a typical midship cross-section see Appendix A.) A transfer and loop belt conveyor system, located at the after end of the tunnel in a vertical casing on the ship's centre line, serves a swivelling unloading conveyor boom at the main-deck level. Below the hopper is the tunnel which can be accessed from either forward or aft.

The hopper gates and the vibrators are operated by a hydraulic system. The gates feed the cargo on to the conveyor belt, and the vibrators, which are mounted on the saddleback, help to loosen the cargo stuck to it. Manually operated "spool valves" are used to isolate hydraulics to each component. Where necessary, some spool valves are fitted with two independently operated control handles, one to operate the gates and the other to operate the vibrator. The pumps for the system are located on the main deck at the forward end of the aft accommodation.

1.1.2 Tunnel Illumination

In addition to the permanent lighting in the tunnel, portable lighting comprising a cargo cluster light and a halogen lamp (see Appendix B, Figure 1) were used to better illuminate the large work area. The halogen lamp was positioned approximately 0.6 m off the deck on the conveyor belt framing facing the gate some 1.5 m aft of the No. 4 gate valve.

1.2 Chronology of Events

On 06 April 1993, the "HALIFAX", while en route from Nanticoke, Ontario, to Duluth, Minnesota, was in ballast and approaching Sault Ste. Marie Locks, Michigan, United States of America (USA). As the hydraulically operated No. 4

1 Units of measurement in this report conform to International Maritime Organization (IMO) standards or, where there is no such standard, are expressed in the International System (SI) of units.

2 See Glossary for all abbreviations and acronyms.

hopper gate (near frames 42-44) at the after end of the No. 1 hold was not opening, the head tunnelman, tunnelman No. 1 and tunnelman No. 2, had been working on the system for two days. The repairs comprised replacement of the No. 4 gate valve and then of one of the actuating cylinders. The removal of the cylinder required the heating of one of its retaining pins with an oxyacetylene torch. After the work had been completed, the valves at the torch were shut off, leaving the valves at the cylinders open, and the torch was left in the starboard tunnel (see Appendix B, Figure 1). In the interim, one acetylene cylinder was changed late in the morning. At about 1355[3], the area was hosed down with water.

At approximately 1416, under instructions from the head tunnelman, tunnelman No. 2 proceeded to the main deck, a distance of about 140 to 150 m, to activate the hydraulic pumps. In preparation for the hydraulic test, the head tunnelman was positioned in the vicinity of the No. 4 gate valve in the centre tunnel while tunnelman No. 1 was positioned near the No. 4 cylinder in the starboard tunnel. After activating two of the three hydraulic pumps, tunnelman No. 2 returned to the tunnel.

Meanwhile at about 1419, in response to the queries from the head tunnelman, tunnelman No. 1 indicated that the cylinder had not moved. The two men were some 3 to 5 m away from each other with considerable equipment between them, such that their legs were barely visible to the other person. At this time, there was no detectable smell of acetylene.

Tunnelman No. 1 reportedly heard a noise that sounded similar to a vibrator being activated but not as loud, followed, within a couple of seconds, by a large orange flame and then black smoke. He then exited by way of the forward tunnel exit. By the time he reached the forward end of the tunnel (which took some 12 to 15 seconds), he was inhaling thick black smoke.

When tunnelman No. 2 was some 20 to 25 m from the work area in the centre tunnel, he saw a flame, which he associated with some further burning by the head tunnelman, in the vicinity of the starboard belt and not near the oxyacetylene bottles. The bottles were positioned between frames 42 and 43 on the port side of the centre tunnel with the hoses running under the conveyor belt, and the torch was located in the starboard tunnel. Tunnelman No. 2 then observed a "big burst of flame" and associated this with burning oil. Immediately thereafter, he saw a fire-ball that appeared to be moving forward. This was followed rapidly by thick black smoke. He then ran aft and proceeded to shut down the hydraulic pumps; an estimated two to three minutes had elapsed between the

3 All times are expressed in EST (Coordinated Universal Time (UTC) minus five hours) unless otherwise stated.

time the pumps were started and the outbreak of fire.

Upon reaching the main deck, tunnelman No. 1 activated the fire alarm which was followed, a minute later, by the master sounding the general alarm. A count of the crew indicated that the head tunnelman was missing. While the crew attempted to fight the fire, the master contacted the American authorities for assistance. The vessel was granted permission to proceed at full speed. With the assistance of a US tug and two private tugs, the vessel eventually berthed at the Old Carbide dock in Sault Ste. Marie (SSM), Michigan. By the time the vessel berthed, the fire, which had been brought under control, was almost extinguished.

1.3 *Weather Information*

The weather was fine and clear with wind from the east at 10 to 15 kn, and the air temperature was 9°C.

1.4 *Injuries to Persons*

	Crew	Passengers	Others	Total
Fatal	1	-	-	1
Missing	-	-	-	-
Serious	-	-	-	-
Minor	1	-	-	1
None	26	-	-	26
Total	28	-	-	28

Of the three persons in the tunnel, one suffered minor smoke inhalation and the head tunnelman lost his life as a result of asphyxiation and extensive burns.

The autopsy revealed that the victim had second- and third-degree burns to the trunk, abdomen and upper legs, and first- to second-degree burns to the back, but there were no burns on the lower legs below mid-calf. The pattern of burns suggests the possibility of flammable materials being released at the time of the accident which may have saturated the clothing. It also suggests possible loss of consciousness associated with head trauma. Toxicology tests found the carbon monoxide level in the blood to be 37.9 per cent.

At the time the victim's body was retrieved, it was observed that the head tunnelman was burned more severely on the right side.

Studies show that carbon monoxide levels in blood between 30 and 40 per cent generally result in disturbance in judgement and possible confusion.

1.4.1 *Position of Body*

The head tunnelman's body was found approximately 8 m forward of the work area. The body was forward of the oxyacetylene cylinders, to the port side of the centre tunnel, between support pillars. He was lying with his head aft and feet forward in a semi-fetal position. Burnt clothing was found 0.4 m off the deck on the two pillars nearest the body. His rubber boots were off and lying some metres symmetrically beyond his head.

1.5 *Fire Damage*

Examination of the fire area revealed the following:

- The most intense fire-damaged area was in the forward section of the tunnel on the starboard side of the centre tunnel at the after end of the No. 4 hopper under the No. 1 hold. Vertical frames 46 and 49 were warped due to heat, and some 35 m of the rubber conveyor belt had been consumed.

- Metal bulkheads and the metal tray holding the electrical wires were distorted by heat.

- The aluminium end housing of the vibrator, which was aft of the No. 4 gate hydraulic controls, had melted away and a large molten glob remained on the deck.

- All wiring showed external heat and fire damage.

- Overall heat and smoke damage extended to the after end of the No. 3 hold.

- Smoke damage throughout the forward accommodation in varying degrees, the worst being near ventilation louvres.

- Previously discontinued hydraulic lines and fittings were scorched within the immediate area of the fire and were hanging askew.

- The regulators on the oxygen and acetylene bottles were partially melted and burned by the fire.

1.6 *Vessel and Personnel Certification*

The vessel was manned, equipped and certificated in accordance with existing regulations.

Recognizing a shortfall in the compliance with the Fire Detection and Extinguishing Regulations in the tunnel space aboard self-unloading bulk carriers, the Ship Safety Branch of the Canadian Coast Guard (CCG) issued a letter dated 04 February 1985. The letter reminded all ship safety surveyors in the Central and Laurentian regions to ensure that the fire hydrants and hoses in the tunnel space were in compliance with the regulatory requirements. It further stated that any shortfall should immediately be brought to the attention of the owners who should correct it as soon as possible, and the Regional Headquarters should also be notified. On 25 March 1992, some seven years later, the "HALIFAX" was issued a SI-7 requiring that hoses and hydrants of regulatory size be fitted in the tunnel to conform with Section 61(1) of the Fire Detection and Extinguishing Regulations. Following another survey, the vessel was issued a Cargo Ship Safety Equipment Certificate on 28 March 1993 without the shortfalls contained in the 1992 SI-7 having been remedied. Until the time of the occurrence, the owners had not rectified the hose and hydrant in the tunnel to meet the requirements.

1.6.1 Personnel History

All tunnelmen had attended a Marine Emergency Duties (MED) course and a company-sponsored welding course highlighting work safety in the tunnel spaces. They had also attended a basic Hydraulic Operations course co-sponsored by the union and the company. The courses also highlighted safe working practices associated with maintenance on self-unloading bulkers. The head tunnelman had served as a tunnelman, in junior and senior capacities, for the past 19 years. He was described as a patient, private individual who took pride in his work and had been commended several times on his performance.

Tunnelman No. 1 and tunnelman No. 2 each had some 10 years' experience working in that position with the head tunnelman. Tunnelman No. 2 had some 23 years of tunnel-work experience.

1.7 Hydraulic System

The three hydraulic pumps are rated at 3.78 L/sec and typically operate at 5,500 kPa (800 psi) with a maximum pressure of 8,270 kPa (1,200 psi). Inspection of the reservoir revealed that the fluid was down about 15 cm indicating that some 400 to 450 L of fluid had been dispensed.

The Parker hydraulic hose in use was suitable for petroleum-based hydraulic fluids and had a minimum working pressure of 13,780 kPa (2,000 psi) with a minimum burst pressure of 55,120 kPa (8,000 psi). There was no evidence to indicate that the hydraulic hose had burst. Photographic evidence of the fire site shows that the hydraulic hose from the main hydraulic line to the input of the No. 4 gate valve was found disconnected after the fire (see Appendix C, Figure 1), and there was no evidence of damage to the threads (see Appendix C, Figure 2).

1.7.1 Hydraulic System Tests

After the No. 4 cylinder was replaced, two tests were conducted on the hydraulic system. During the first test, there was good pressure at the vibrator end, and while the vibrator was functional, the gate was not. The system was then shut down. After being re-examined, the No. 4 cylinder was being tested for the second time when fire broke out in the conveyor belt tunnel.

1.8 Characteristics of Hydraulic Fluid in Use

The hydraulic fluid in use was Esso UNIVIS N-22. According to the UNIVIS product data sheet, the oil has a flashpoint of 155°C. The upper and lower flammable limits of hydraulic oil vary slightly depending on the chemical composition of the oil. A typical hydraulic oil has flammable limits of between 2.5 and 6 per cent. Tests conducted by the National Research Council (NRC) on the sample of used oil from the vessel indicated that the flashpoint and fire point were 174°C and 184°C, respectively. For new oil, these figures were 179°C and 185°C respectively.

In this occurrence, the flammability of hydraulic oil in mist form in the presence of a high-intensity halogen lamp was not fully appreciated in terms of the heat generated by the lamp and of the auto-ignition temperature of the hydraulic oil.

1.9 Properties of Acetylene Gas

According to the Canadian Centre for Occupational Health and Safety, acetylene is a flammable, colourless gas with no or slight garlic-like odour dependent on purity. It warns that one should not draw conclusions based on odour observations alone. However, acetylene of ordinary commercial purity generated from calcium carbide has a distinctive garlic-like odour. Acetylene is slightly lighter than air; relative density compared to air is 0.9. The lower explosive limit (LEL) is 2.5 per cent and the upper explosive limit (UEL) is 81 per cent. The flashpoint of acetylene is -18°C and the auto-ignition temperature is 305°C.

1.10 Halogen Lamp

According to the manufacturer, the type of halogen lamp in use was Canadian Standards Association (CSA) certified for use in outdoor locations. A typical lamp fixture comprises a cast aluminium body which is designed with a specialized heat-dissipating fin system for cooler operation. A parabolic reflector system provides maximum light output and control. The thermal-shock- and impact-resistant glass lens is mounted in a die cast aluminium door frame. A weathertight seal is provided by a high-temperature silicon door gasket, and stainless steel eccentric latches ensure consistent lens pressure. The halogen lamp was mounted on a steel bracket with an electrical junction box attached to the rear of the bracket and an extension cord hardwired into the junction box (see Appendix C, Figures 3A and 3B). In this instance, the halogen lamp fixture in use did not have the protective lens in place.

1.10.1 Halogen Lamp and Ignition Tests

Tests conducted on the halogen lamp recorded surface temperatures in excess of 600°C at the lamp, decreasing to approximately 350°C five centimetres from the lamp surface. Considerable smoke was generated when UNIVIS N-22 hydraulic oil was added directly to the illuminated light, but ignition did not take place.

In a second test, when a mist of UNIVIS N-22 oil was sprayed through a flame source, a substantial fire-ball was produced.

1.10.2 Ship's Electrical Standards

The electrical system and appliances used aboard a Canadian vessel are governed by the CCG Ship's Electrical Standards. Section 18(4) states that the temperature of those parts of the lighting fixtures that can be handled by any individual "shall not exceed 60°C".

In this instance, tests with the lens cover in place also showed that the lens cover reached a steady state temperature of 270°C.

1.11 *Presence of Accelerant in the Tunnel*

At the time of the fire, one full oxygen and two acetylene cylinders, one empty and the other nearly full, were present on the port side of the centre tunnel (Appendix B, Figure 1). One acetylene tank had been changed that morning. With the onset of the fire and with the oxyacetylene cylinder valves open and the hoses burnt, intense fire and heat were generated by the introduction of these flammable materials; the effects of which could be felt on the bridge of the vessel. There was no evidence to suggest explosion within the tunnel due to the presence of acetylene.

1.12 *Oxyacetylene Cylinders*

The carriage of dangerous goods such as acetylene is governed by the Transportation of Dangerous Goods Regulations made pursuant to the *Dangerous Goods Act*. Part VI of the regulations states that:

> No person shall handle or offer for the transport of a cylinder ... containing dangerous goods ... unless the National Standards of Canada ... are complied with.

The Canadian National Standards (CAN/CSA B340-M88 and CAN/CSA B339-88) require all acetylene cylinders to be fitted with a fusible plug. The fusible plug is intended to prevent explosion of acetylene bottles exposed to fire and is constructed of metal which will melt at a temperature of about 68°C.

According to the regulatory agency, the CCG, as the oxyacetylene cylinders were part of the ship's stores, they were not required to comply with either the aforementioned regulations or standards. The two acetylene bottles in the tunnel were not built to Canadian National Standards. The valve of the acetylene cylinder in use was not closed. Since the oxyacetylene cylinder valves were left open, the burnt hoses allowed gases to burn in a controlled manner. Thus, inadvertently, the act of keeping the oxyacetylene valves open effectively served the function of a fusible plug.

The post-fire inspection and/or testing of the oxyacetylene equipment in use revealed the following:

- There was a negligible quantity of oxygen and acetylene in the bottles.

- The handle of the oxygen shut-off valve was partially melted.

- The regulator gauges attached to the oxyacetylene cylinders were both partially melted (see Appendix C, Figure 4).

- The regulator fittings had tapered threads and the cylinder valve had straight threads requiring the use of an adapter.

- The hoses originally attached to the regulator were burned off with about 8 m remaining attached to the torch; the torch was located in the starboard tunnel (Appendix C, Figure 5).

- There were no flashback arresters installed on the regulators nor are any required by regulations.

- The knob of the oxygen shut-off valve on the torch was missing and the valve stem was bent requiring a tool to turn the valve stem, but the tests showed the valve to be functioning satisfactorily.

- The acetylene valve on the torch was complete, the valve was closed and operated normally.

- The hose connections at the torch were tight and the tip nut was seated properly and in good condition.

- The hose connections at the torch did not have non-return valves installed nor are any required by regulations.

- The remaining hose, which had been in service for approximately two years, was in relatively good condition with no splices or crazing of the hose.

1.13 TSB Engineering Report

The TSB Engineering Branch report based on the examination and testing of material present at the fire site and other available information concluded, among others, the following:

- The hydraulic hose normally attached to the input of the No. 4 hopper gate valve was, or became, disconnected from the valve for undetermined reasons.

- The pressurizing of the hydraulic system allowed hydraulic oil to be sprayed from the disconnected hose, forming a flammable mist.

- The protective lens cover on the quartz halogen lamp in use was missing.

- The UNIVIS N-22 in a mist form could have ignited when it came in contact with the exposed illuminated quartz halogen lamp.

1.14 Other Considerations

The TSB Engineering Branch report also determined that the conveyor belt involved in the fire was not a primary source of fuel in this case. It was also determined that the oxyacetylene torch, the electrical extension cord, the electrical equipment and the other area lighting were not the source of ignition for the hydraulic oil.

1.15 Fire-fighting Equipment in the Tunnel

The vessel was required to carry fire-fighting equipment in accordance with existing regulations. The equipment on board included a fire main comprising a 51 mm line with fire hoses positioned at various locations within the vessel, fire extinguishers, breathing apparatus and a fireman's outfit. However, the hydrants and hoses in the tunnel, primarily intended for hosing down, were not of regulatory size nor were the hoses manufactured of material approved for a fire-fighting hose; the fire extinguishers were suitably located.

The fire was successfully extinguished by personnel wearing breathing apparatus and fire suits using fire hoses, and the point of entry to the tunnel was from the forward end by way of the laundry area.

1.16 *Fire-fighting*

Most of the fire-fighting effort was conducted by the ship's crew assisted toward the end by the SSM, Michigan, Fire Department and the United States Coast Guard (USCG) with the Canadian Sault Ste. Marie Fire Department standing by.

At approximately 1425, the fire-fighting party, under the direction of the first mate, donned air packs. In the initial stages, two attempts were made to reach the fire site from the laundry room, but they were unsuccessful due to intense heat. Nos. 1 and 2 hatches were then opened and three hoses were directed at the starboard cargo gates and the "saddleback" at about 1444. Tunnel fans were not used for fear of feeding the fire with oxygen. The deluge sprinkling system in the loop belt casing area aft was turned on to inundate the fire with water and to cool the belt. Difficulties were experienced in handling the long lengths of five hoses around corners and obstacles. When the last air bottle had been half-consumed, the first mate informed the master to request back-up. The crew of the USCG vessel "KATMAI BAY", equipped with fire-fighting gear, boarded the "HALIFAX" and provided general assistance. The third mate took charge of the team on deck. By the time the fire chief from SSM boarded the "HALIFAX", the fire had been brought under control. Shortly thereafter, the chief mate and the fire chief recovered the body of the head tunnelman with assistance from another seaman, at about 1506. In the fire-fighting effort, a total of 14 air bottles had been used.

1.17 *Fire Precautions*

The Safe Working Practices Regulations made pursuant to the *Canada Shipping Act* and the Canada Labour Code both require sufficient fire extinguishers to be placed in the vicinity where hot work operations are carried out. In this instance, a fire extinguisher was kept at hand.

1.18 *Clothing Worn by Tunnelman*

The victim, the head tunnelman, wore rubber boots and coveralls made with a material of 65 per cent polyester and 35 per cent cotton. In this instance, the hydraulic oil in conjunction with the soot associated with the fire smoke would have accelerated the burning rate.

Tests conducted show that pure untreated cotton is more fire-resistant than a blend using any percentage of polyester.

1.19 *Work Practices and Safety*

The chief engineer, as head of the engineering department, was responsible for the maintenance of equipment in the tunnel. Periodically, checks would be carried out to monitor the progress of the repairs. The impact of some work practices employed on board the vessel, as reflected in the occurrence, were not fully appreciated and included the following:

- Use of a longer length of flexible hydraulic hose than required to carry out repairs.

- Slacking back of the hydraulic hose connection to check for fluid flow while the system was under pressure.

- Use of a high-intensity lighting fixture, that is intended for outdoor use, in confined spaces; a practice in recent use.

- Practice of keeping the oxygen and acetylene cylinder valves open when the equipment was not in use.

2.0 Analysis

2.1 Reconstruction of Events Leading to the Fire

The reconstruction of events leading to the fire was based on the examination and testing of material evidence as recovered from the fire site, on the evidence as presented by the tunnelmen, in conjunction with on-site observations by personnel after the fire, and on the examination of photographic evidence taken shortly after the fire.

2.2 Reason for the No. 4 Gate Being Non-operational

At the time of the occurrence, the hydraulic system was being tested for the second time. The vibrators were found to be functioning during the first test; this would indicate that the hydraulic system was under pressure, thus eliminating the possibility of air lock in the main hydraulic line. Further, as the TSB Engineering Branch tests conducted on the No. 4 gate valve (in use at the time of the fire) showed the valve to be functioning, the reason for the non-actuation of the No. 4 gate cylinders for a period of some two to three minutes before the fire cannot be explained.

2.3 Hydraulic Hose Disconnection and Initiation of Fire

The fact that the hose was found disconnected after the fire and that the coupling threads were not damaged despite the high pressure within the main hydraulic line suggests that the hose may have been backed off manually and was barely held in position by the threads either with or without possible manual support from the head tunnelman (see Appendix C, Figure 2). Further, with the system pressurized, oil should have sprayed from the coupling the moment the coupling had been loosened. Although the hydraulic system was under pressure, there was a time lag of about two minutes before the pressurized oil was seen to come out from the disconnected hose. Thus, the hydraulic pressure had not reached the No. 4 valve until this stage.

Tunnelman No. 1 reported hearing a weak noise that sounded similar to a vibrator, but different, a couple of seconds before he observed a large orange fire-ball. This is consistent with the hydraulic hose striking against metallic surfaces while spraying fluid in all directions because the hose which was under pressure was disconnected. The instantaneous hydraulic mist so generated then ignited when it came in contact with the halogen lamp which culminated in a substantial fire-ball.

2.4 Significance of the Flame Observed by Tunnelman No. 2

The flame sighted by tunnelman No. 2 and described as having been associated with burning would suggest that the flame was elongated in shape and similar to that produced by oxyacetylene equipment. However, this flame could not have been from the torch which was used in the repairs as the torch was in the starboard tunnel and out of his line of vision. Hence, any acetylene-fed flame had to have been from a minor leak in some other part of the equipment. In the absence of corroborating evidence to substantiate an acetylene leak in the tunnel prior to the onset of the fire and/or a source of ignition, the appearance of the flame described as having been associated with oxyacetylene equipment cannot be explained. Given the rapidity with which the fire progressed and in the absence of evidence to the contrary, it would appear that the flame sighted by tunnelman No. 2, thought to be in the vicinity of the cargo hold, was most likely the initiation of the hydraulic oil fire.

2.5 *Victim's Position and Burn Pattern*

The head tunnelman's last communication with tunnelman No. 1 questioned whether the gate cylinder had moved yet which would suggest that he was preoccupied with the testing of the No. 4 gate. From that position, when the fire erupted, the halogen lamp would have been on his right side and could account for the heavier burns he sustained on that side, and the heavier burns to his chest would suggest that he was facing the fire-ball.

As neither of the two surviving tunnelmen had observed the head tunnelman's movements immediately before and following the onset of the major fire/fire-ball, the precise reason for the position of the victim's body, some distance from the work site, cannot be ascertained.

However, given the circumstances of the case and in the absence of evidence to the contrary, one possible explanation could be that as the head tunnelman was in the vicinity of the fire-ball, its effect would have thrust him in a forward direction and could account for the dislodgement of the boots and the head trauma sustained. The eruption of the fire would have ignited the victim's coveralls drenched in hydraulic oil, accounting for the burn pattern found on his body.

2.6 *Progress of Fire*

As indicated by the tests, hydraulic oil poured on the surface of the halogen lamp could not have ignited, but the mist could. Further, the absence of the glass cover further facilitated the ignition of fire. By the time the hydraulic system was shut off, some 400 to 450 L of hydraulic oil had been dispersed into the tunnel space providing a large quantity of flammable oil. As the fire progressed, it was further fuelled by the oxygen and acetylene gases from the gas-cutting equipment, setting the conveyor belt on fire.

2.7 *Approach to Fight the Fire*

One of the techniques used to fight fire is to starve the fire of oxygen. This is achieved by restricting and/or sealing off ventilation. In this instance, the ventilation to the tunnel was not in use.

The presence of propellants in the tunnel space and the intense heat generated by the fire necessitated the opening of two cargo hatches to facilitate cooling the saddleback and flooding of the tunnel. This proved effective in preventing the fire from spreading. Further, the heavy smoke generated by the burning hydraulic oil and conveyor belt would have created a smothering effect on the fire. Thus, the cumulative effect of the cooling of adjacent metal surfaces and the smothering effect of the smoke generated resulted in effectively extinguishing the fire within a short time frame. The smothering effect from the smoke was diminished, to a certain extent, by the release of oxygen from the oxygen cylinder once the hose was burnt out.

2.8 *Oxyacetylene Cylinder*

Because the torch was being used in the starboard tunnel while the cylinders were positioned in the centre tunnel and the closest connection between the two tunnels was at the entrance to the forward exit, the crew, of necessity, was required to walk a considerable distance to shut off the oxyacetylene valves. As repairs are physically demanding, time-consuming and sometimes frustrating, the crew set practices to facilitate operations.

As the air flow in the tunnel was restricted (mechanical ventilation to compartment not used), any gas/vapour introduced in the tunnel would accumulate creating a potential fire hazard. There is a potential for generating hydraulic oil mist during the hydraulic system test. The oxyacetylene cylinder valves should be closed prior to and during such tests.

In this instance, while the closing of the oxyacetylene cylinder valves prior to the hydraulic system test may not have prevented the onset of fire, the narrow flammable range of the hydraulic oil would probably have made the fire difficult to sustain for any significant period of time. Additionally, the fire would have been of shorter duration and of reduced intensity than in this occurrence.

In view of the hazard associated with the use of oxyacetylene equipment in spaces other than those exposed to open atmosphere, the safe working practices call for compartments where oxyacetylene equipment is used to be well ventilated. In this instance, although the tunnel space was provided with forced air ventilation, it had not been utilized when oxyacetylene equipment was in use.

Owing to the limitations of the fire-fighting equipment (including the absence of fire hydrants and fire-hoses) in the tunnel space, additional safety precautions would have been in order. As the nearest fire hydrant was in another compartment some distance away, a total of four hoses had to be connected to reach the fire site. Further, with the tunnel space limited and confined, handling fire-hoses under pressure was difficult and cumbersome with increased possibility for personnel injury. Hence, as a precautionary measure, a fire-hose with a combination nozzle should have been rigged, kept ready for use with water in the line, and a hydrant valve left open on deck.

3.0 Conclusions

3.1 Findings

1. The head tunnelman was in the vicinity of the No. 4 gate valve at the onset of fire.

2. The hydraulic hoses and fittings used were suitable for use, and there was no evidence to indicate that the hydraulic hose had burst.

3. The hydraulic hose to the No. 4 gate valve was found disconnected after the fire. The cause for the disconnection is unknown.

4. The hose which was under pressure became disconnected, allowing hydraulic oil to be sprayed forming a flammable mist in the tunnel.

5. The hydraulic oil mist was ignited by the bare halogen lamp.

6. A flame observed in the vicinity of the work area by the tunnelman was the initiation of the hydraulic oil fire.

7. The halogen lamp fixture, which was intended for outdoor use only, was being used in the tunnel.

8. The protective lens cover of the halogen lamp fixture was not in place and the illuminated lamp surface temperature was in excess of 600°C.

9. The lens temperature of the type of halogen lamp in use was in excess of the temperature permissible for handling lighting fixtures.

10. The acetylene cylinder in use had replaced an empty cylinder earlier on the day of the occurrence.

11. The acetylene cylinders, being part of the ship's stores, were not required to meet Canadian standards and, consequently, were not required to be fitted with fusible plugs, and they were not so fitted.

12. There is no requirement for the oxyacetylene cylinders to be fitted with flashback arresters or for the hoses to have non-return valves, and they were not so fitted.

13. The valves to the oxyacetylene cylinders were not shut prior to testing of the hydraulic system.

14. The polyester-blend coveralls worn by the victim were less fire-resistant than coveralls made from pure cotton.

15. The hazards associated with the flammability of hydraulic oil mist and the presence of a bare high-intensity halogen lamp were not fully appreciated.

16. The victim lost consciousness due to head trauma and lost his life due to asphyxiation and extensive burns.

17. Difficulties were experienced in handling long lengths of fire-hoses which had to be led from the laundry compartment.

3.2 *Causes*

The fire broke out in the conveyor belt tunnel aboard the "HALIFAX" when the hydraulic oil mist from the disconnected hose was ignited by a halogen lamp that was missing a protective lens cover.

4.0 Safety Action

4.1 Action Taken

4.1.1 *High-intensity Lamps*

Subsequent to the occurrence, the TSB apprised the Canadian Coast Guard (CCG) of the results of its laboratory tests and of the potential fire hazard associated with the installation and use of high-intensity lamps in an indoor environment aboard vessels. The CCG issued Ship Safety Bulletin (SSB) No. 1/95, in January 1995, advising all vessel operators and maintenance personnel of the following:

1. the need for compliance with Ship Safety Electrical Standards (TP 127, Section 18(4)) concerning the use of portable equipment;

2. the need for maintenance of all portable equipment in a safe working condition;

3. use of portable shipboard equipment in a safe environment aboard; and

4. the need for enclosure of fixtures in areas where there is a risk of spray or readily combustible material.

4.1.2 *Application and Enforcement of Safety Regulations*

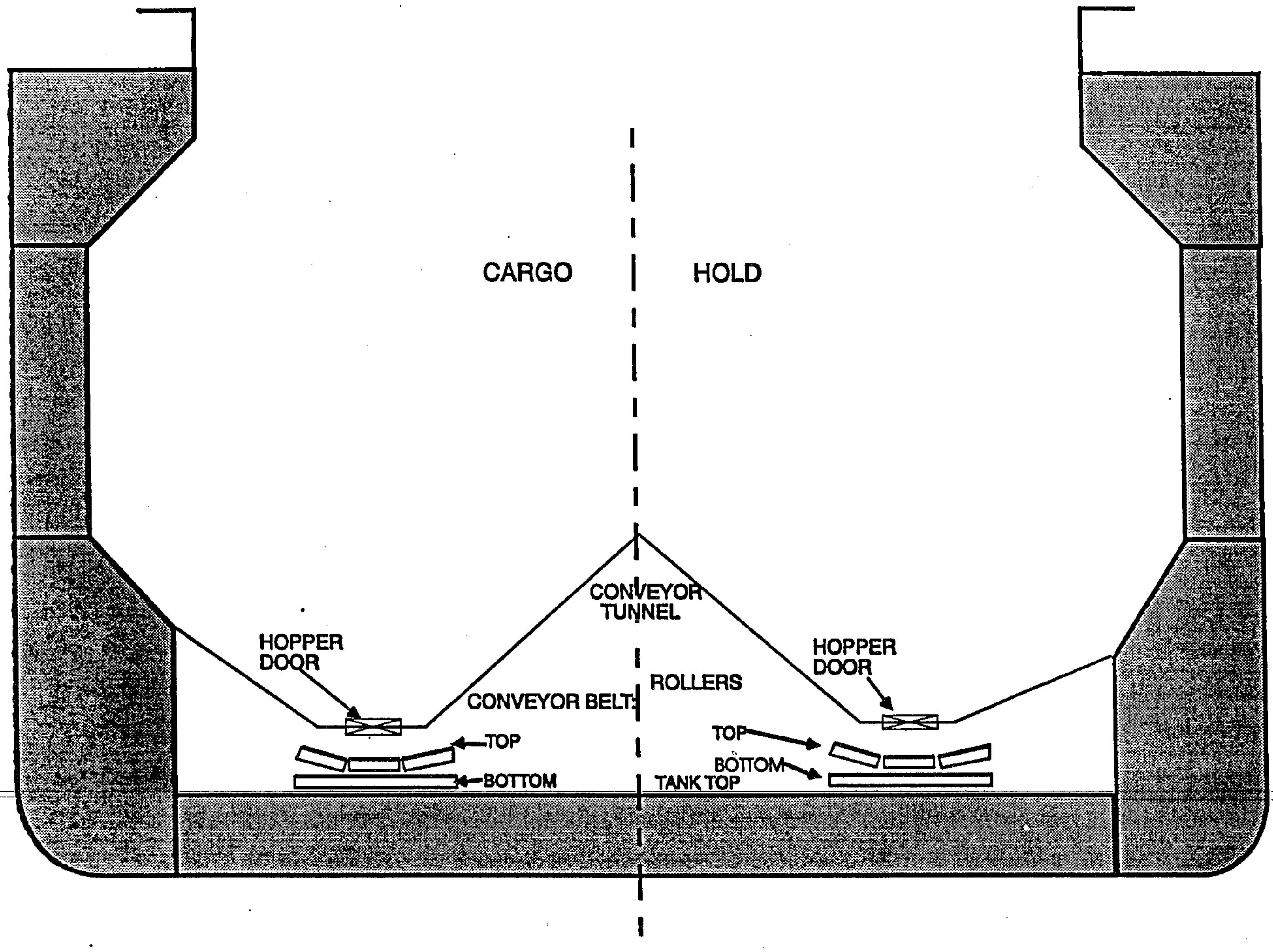
After reviewing comments from persons with a direct interest in the findings, the TSB apprised the CCG of discrepancies in the application and enforcement of safety regulations by regional offices.

4.1.3 *Hot Work Procedures*

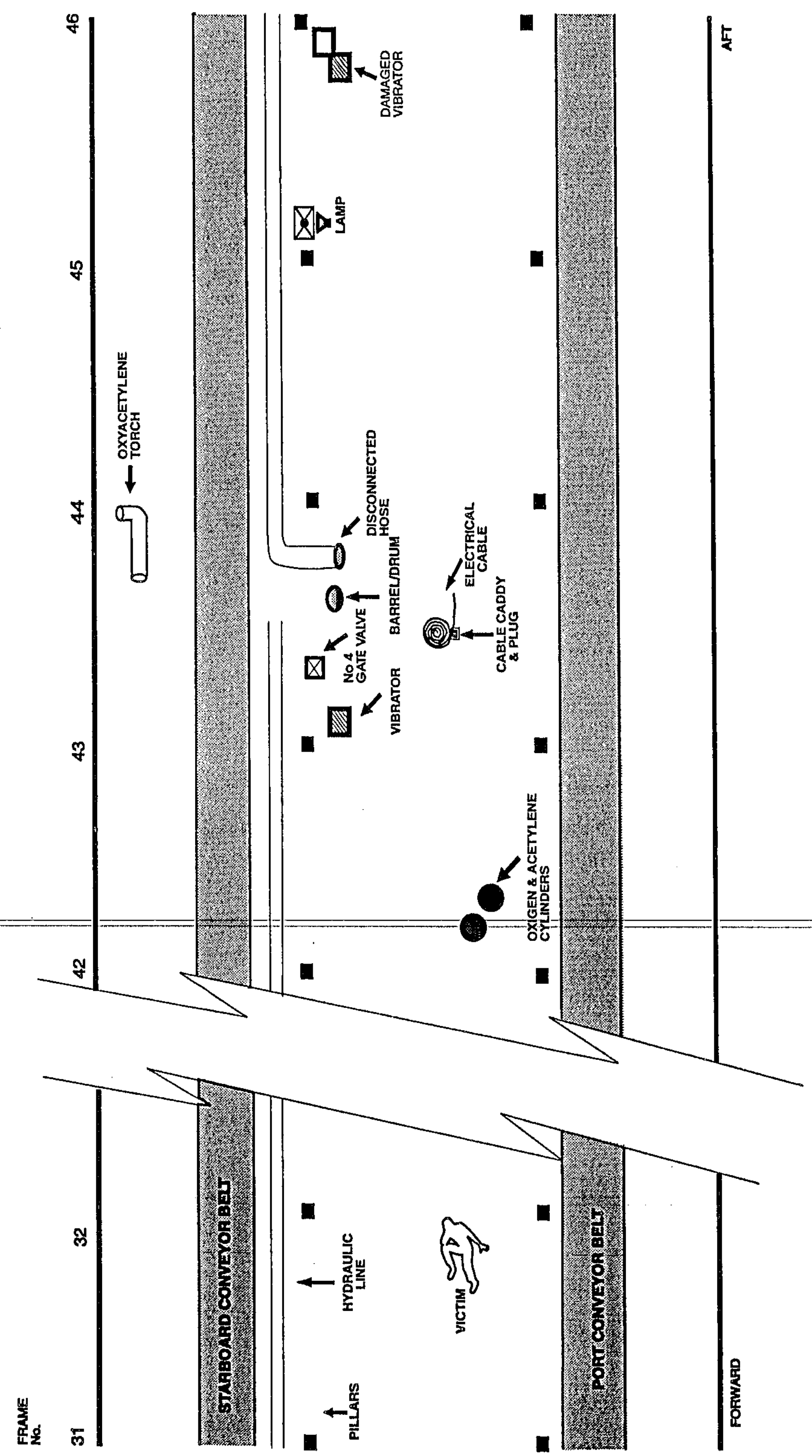
As a result of this occurrence, the owners have reportedly introduced a new procedure for conducting hot work aboard vessels. The hot work permit system is intended to ensure that all safety precautions are taken prior to the commencement of burning, welding, and other hot work using oxyacetylene gas.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson, John W. Stants, and members Zita Brunet and Hugh MacNeil, authorized the release of this report on 07 June 1995.

Appendix A - Typical Midship Cross-section of Vessel



Appendix B - Elevated and Plan Views of the Tunnel



SKETCH DEPICTING DISPOSITION OF EVIDENCE RELEVANT TO THE CASE

FIGURE 1

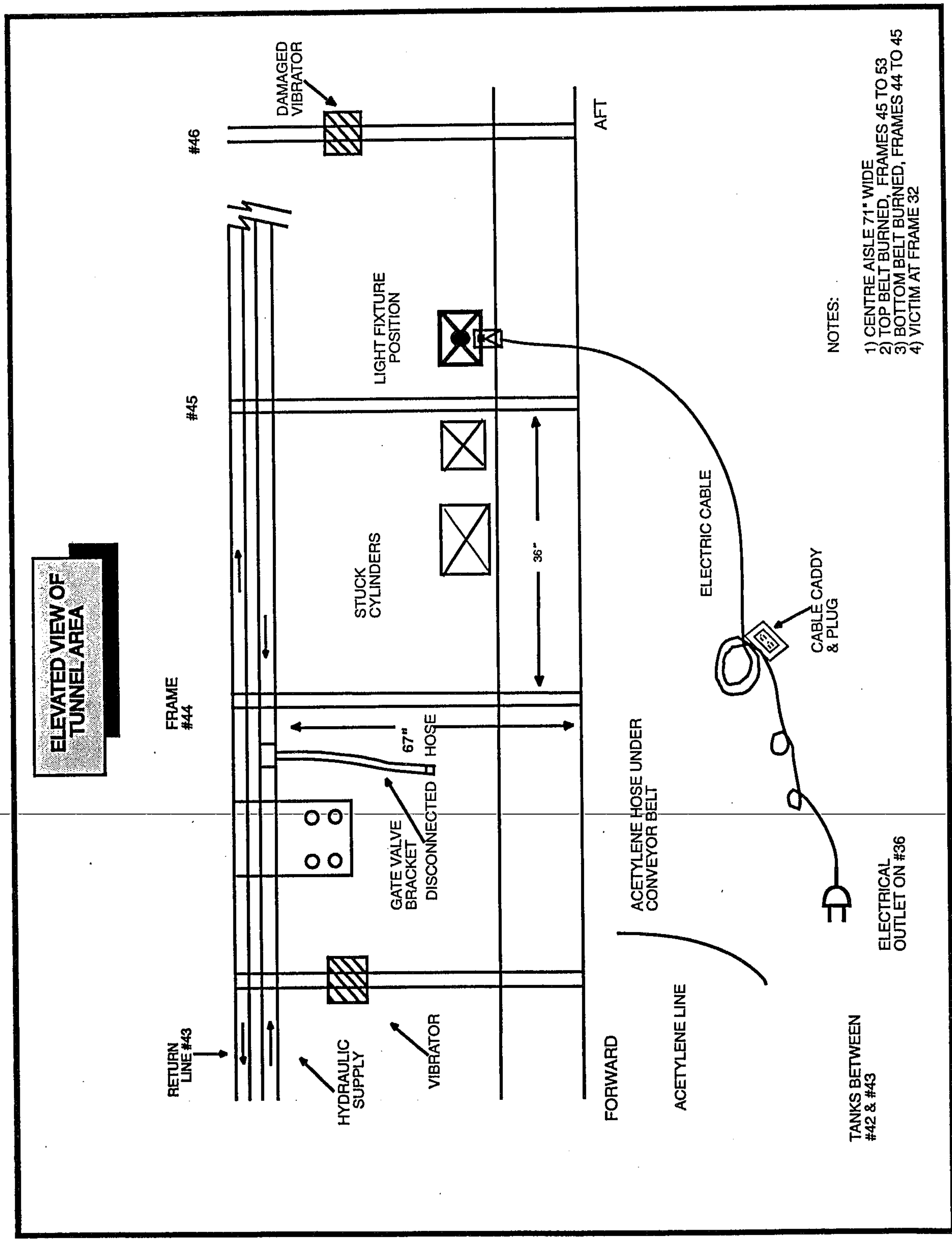
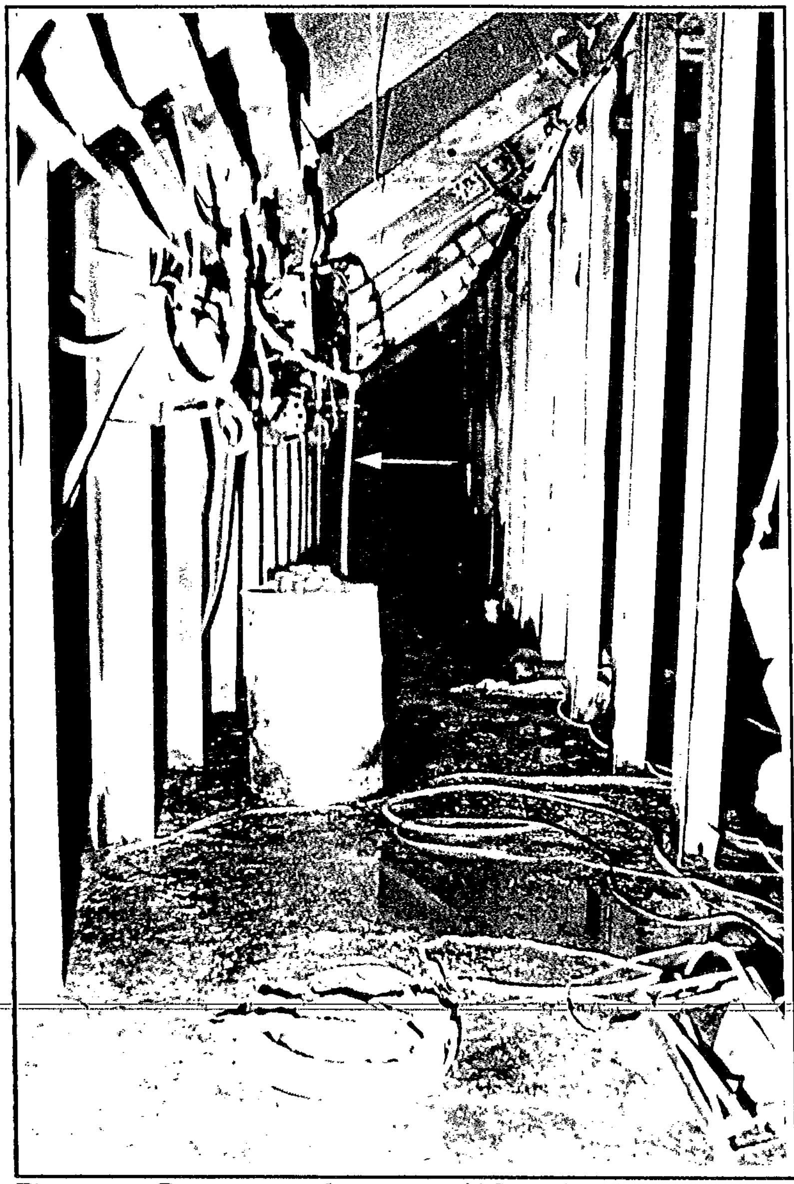

ELEVATED VIEW OF TUNNEL AREA
RETURN LINE #43
HYDRAULIC SUPPLY
VIBRATOR
FRAME #44
#45
#46
DAMAGED VIBRATOR
GATE VALVE BRACKET
DISCONNECTED HOSE
67"
36"
STUCK CYLINDERS
LIGHT FIXTURE POSITION
FORWARD
AFT
ACETYLENE LINE
ACETYLENE HOSE UNDER CONVEYOR BELT
ELECTRIC CABLE
CABLE CADDY & PLUG
ELECTRICAL OUTLET ON #36
TANKS BETWEEN #42 & #43
NOTES:
1) CENTRE AISLE 71" WIDE
2) TOP BELT BURNED, FRAMES 45 TO 53
3) BOTTOM BELT BURNED, FRAMES 44 TO 45
4) VICTIM AT FRAME 32

FIGURE 2

Appendix C - Photographs



Disconnected hydraulic hose

Figure 1 - Centre tunnel in way of No. 1 hold, No. 4 gate valve, looking aft in tunnel. Note: Halogen lamp, lower right; extention cord and caddy, lower centre (courtesy of CSL).

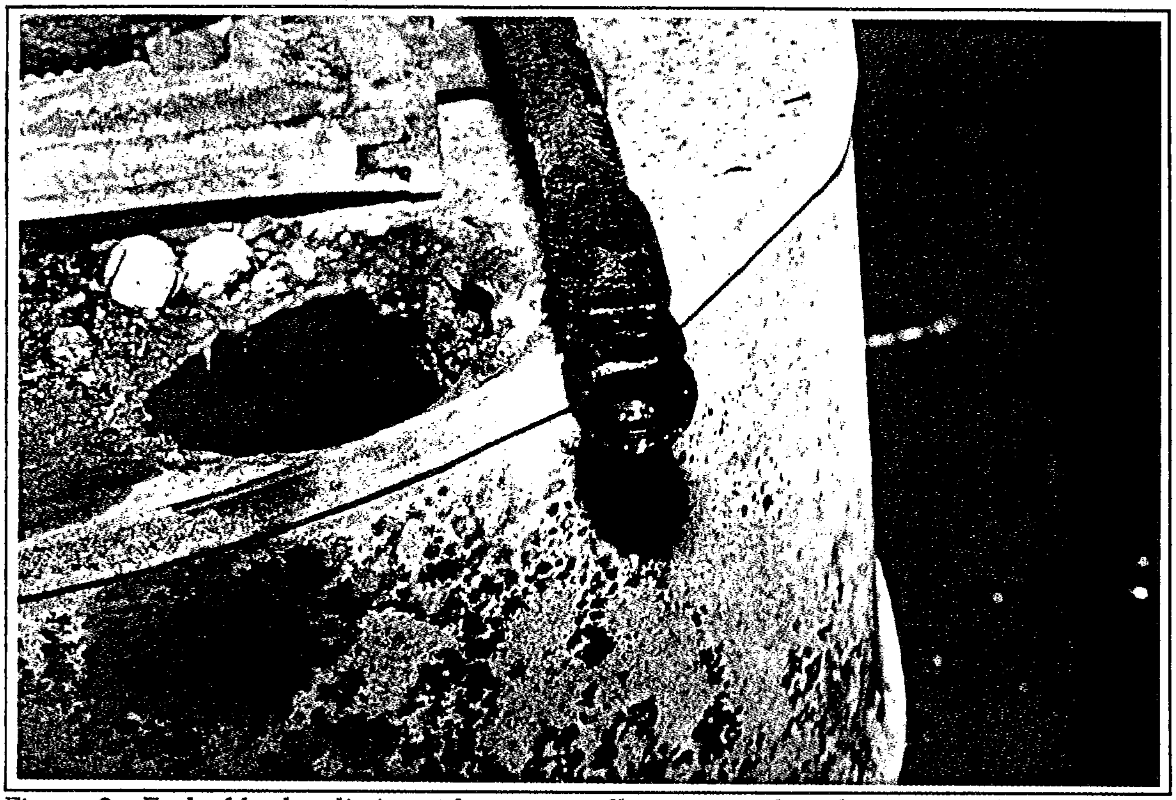


Figure 2 - End of hydraulic input hose normally connected to the input reducer.
Note: The absence of any thread damage.

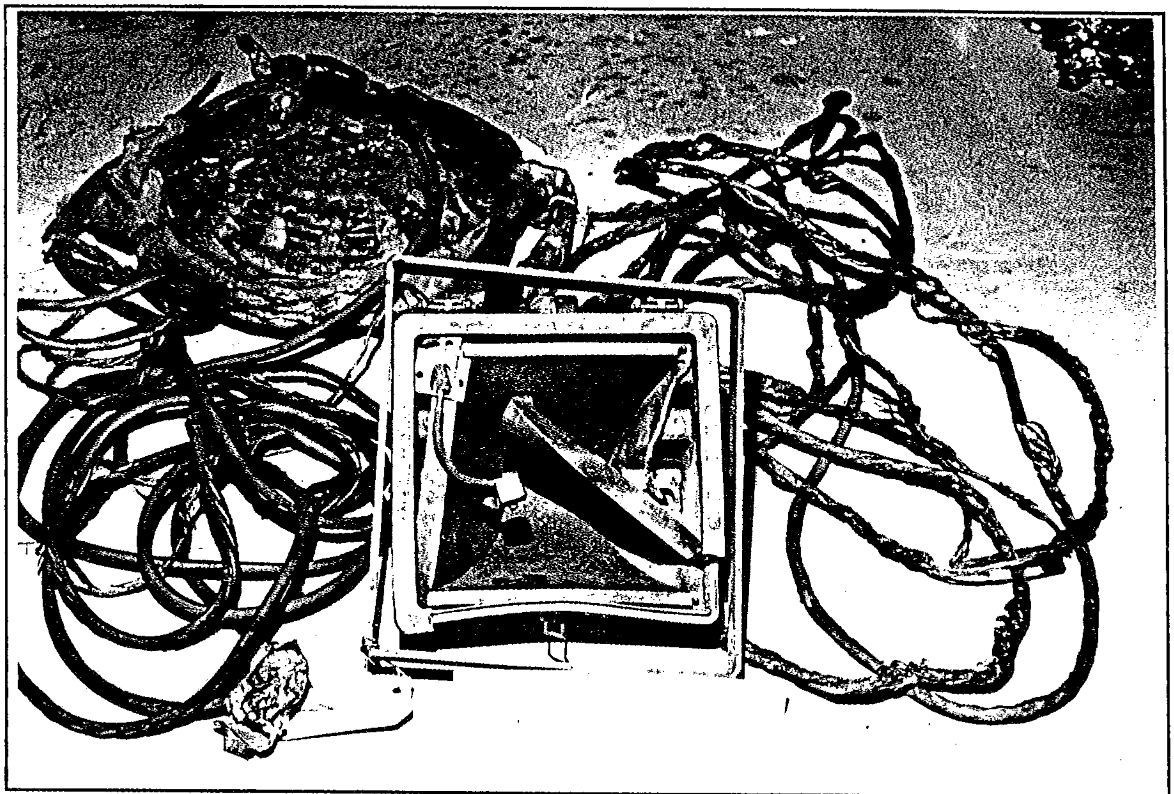


Figure 3A - Front view of the halogen lamp.

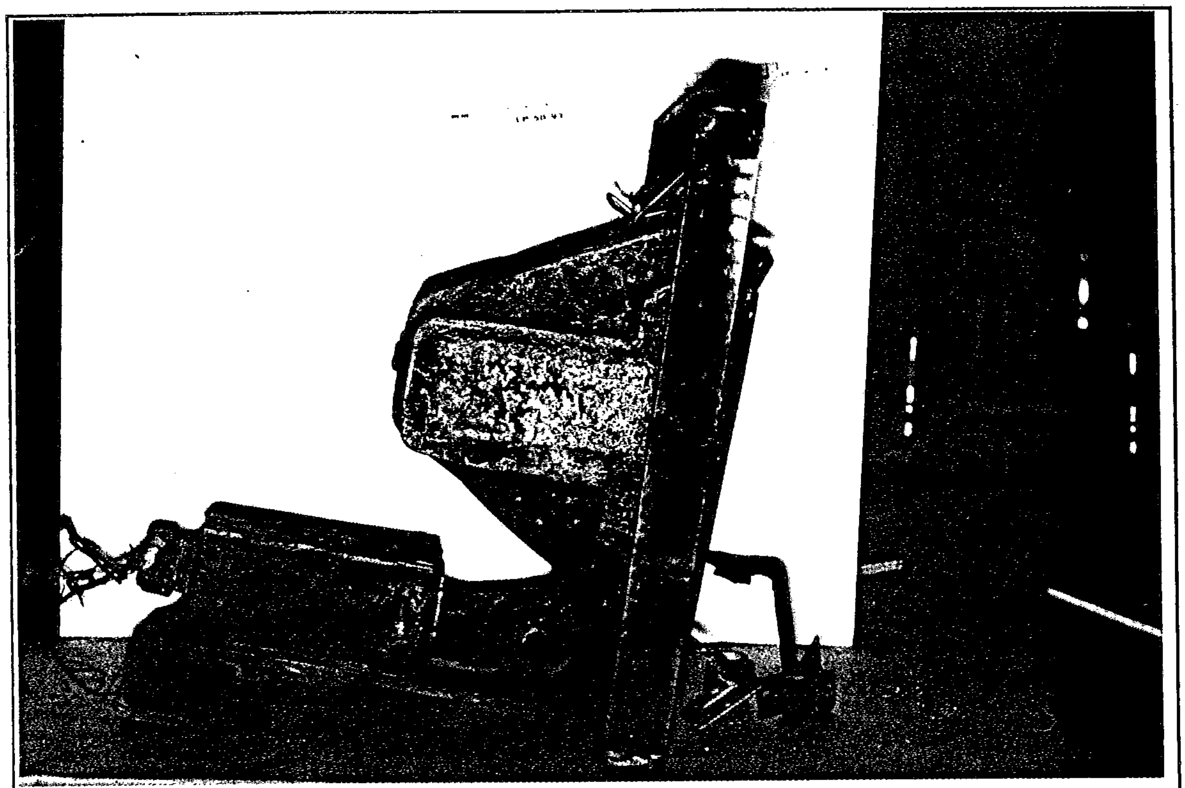


Figure 3B - Side view of the halogen lamp showing junction box.

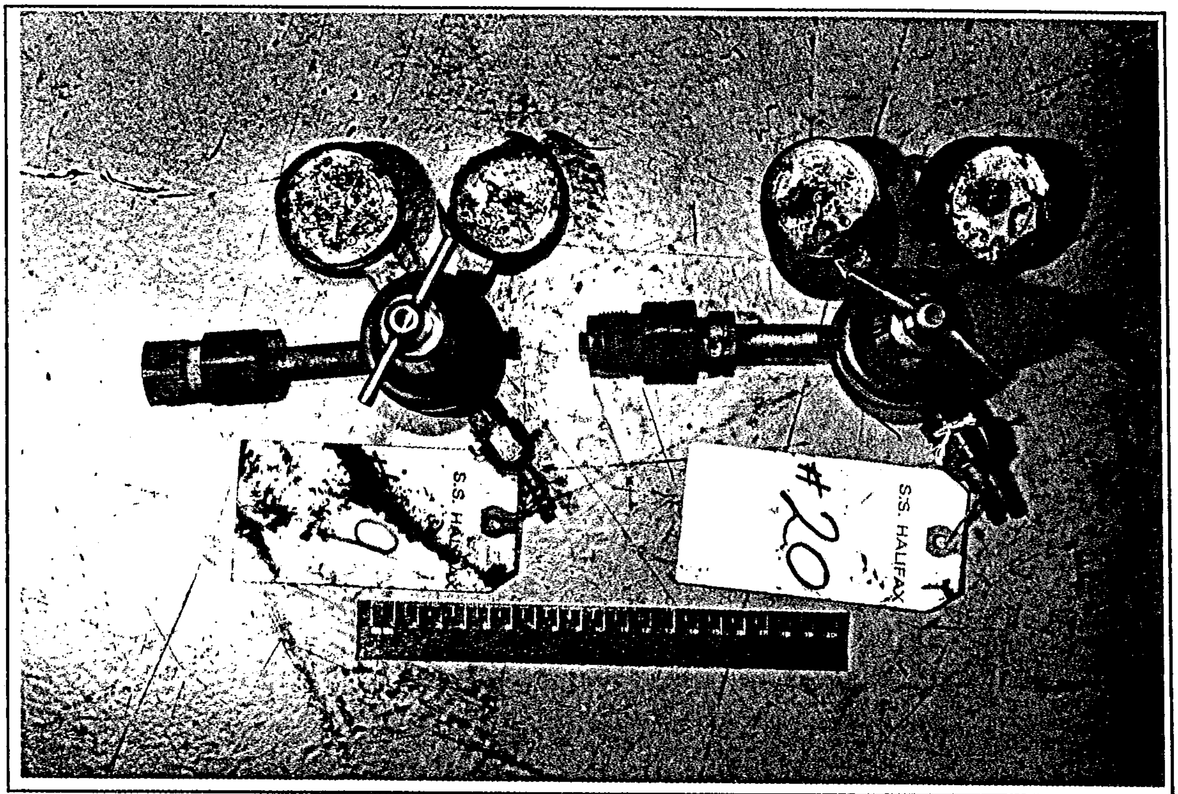
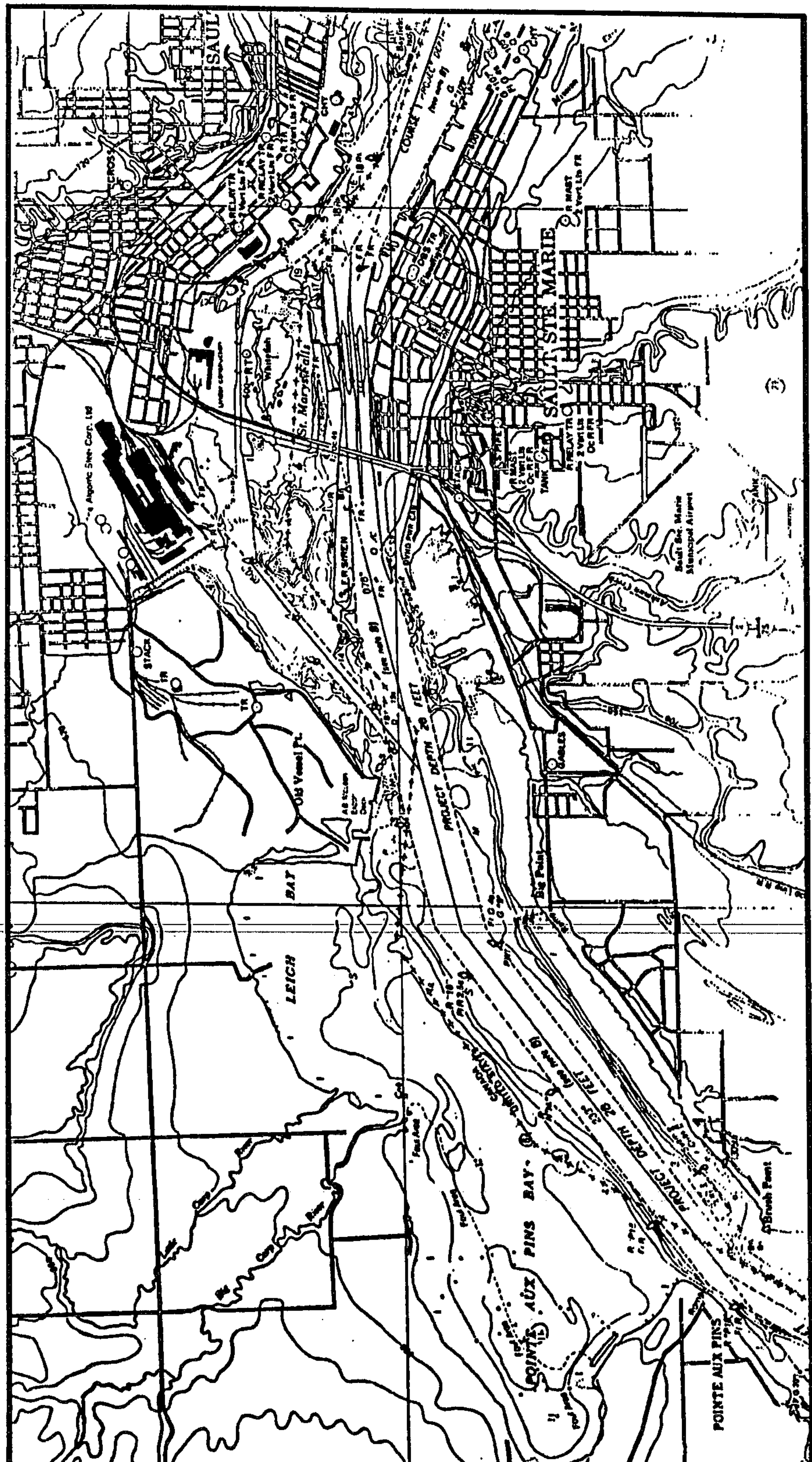


Figure 4 - Regulators and gauges removed from oxyacetylene tanks.

Figure 5 - Oxyacetylene torch as found in the starboard side of the tunnel after the fire (courtesy of CSL).

Appendix D - Sketch of the Area of Occurrence



Appendix E - Glossary

auto-ignition temperature	The lowest temperature required to initiate or cause self-sustained combustion in the absence of a spark or flame.
C	Celsius
CCG	Canadian Coast Guard
CHS	Canadian Hydrographic Service
cm	centimetre(s)
EDT	Eastern daylight time
explosive range	All concentrations of a mixture of flammable vapour or gas in air in which a flash will occur or a flame will travel if the mixture is ignited.
fire point	The lowest temperature at which a liquid in an open container will give off enough vapours to continue to burn once ignited.
flammability limits	See "explosive range"
flashpoint	The temperature at which vapour from oil, etc. will ignite in air.
IMO	International Maritime Organization
kn	knot(s): nautical mile(s) per hour
kPa	kilopascal(s)
kW	kilowatt(s)
L	litre(s)
L/sec	litre(s) per second
LEL	Lower Explosive Limit - lower limit of concentrations of mixture of flammable vapour or gas in air (usually expressed in percentage by volume) in which a flash will occur or a flame will travel if the mixture is ignited.
LFL	Lower Flammable Limit - the limit below which the mixture is too lean to ignite.
m	metre(s)
mm	millimetre(s)
NRC	National Research Council
psi	pound(s) per square inch
SI	International System (of units)
SSB	Ship Safety Bulletin
SSM	Sault Ste. Marie, Michigan
UEL	Upper Explosive Limit - upper limit of concentrations of mixture of flammable vapour or gas in air (usually expressed in percentage by volume) in which a flash will occur or a flame will travel if the mixture is ignited.

UFL	Upper Flammable Limit - a limit above which the vapour mixture is too rich to ignite.
US	United States
USCG	United States Coast Guard
UTC	Coordinated Universal Time
°	degree(s)