Report 00-202

Restricted limits passenger vessel *Sweet Georgia*

engine room fire and grounding

Wellington Harbour

10 March 2000

Abstract

On 10 March 2000 at about 2000, the passenger vessel *Sweet Georgia* was on a charter cruise in Wellington Harbour when a fire started in the engine room. The fire was contained by the actions of the skipper but the control cables for the engine were damaged, causing the engine to slowly manoeuvre astern. Other vessels in the vicinity were able to evacuate the 58 passengers and 4 crew without injury. The skipper remained aboard the *Sweet Georgia*. The astern movement of the vessel caused it to ground on reclaimed land, where the fire service boarded and extinguished the fire. The skipper suffered smoke inhalation but nobody was injured.

The principal factor contributing to the fire was a fault in the house battery alternator.

Safety issues identified included:

- substandard marine electrical installations on small craft
- lack of consistency and the adequacy of rules governing standards for marine electrical installations on small craft.

Safety recommendations were made to the owner and the Director of Maritime Safety to address the safety issues.

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Sweet Georgia

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Glossary

aft	rear of the vessel
alternator	AC generator with in-built DC rectifier and voltage regulator
amidships	middle section of a vessel, mid length
bulkhead	nautical term for wall
deckhead	nautical term for ceiling
inverter	converts DC power to AC power
knot	one nautical mile per hour
mayday	radiotelephone distress signal requesting immediate assistance
port	left-hand side when facing forward
rectifier	converts AC power to DC power
restricted inshore	operating limit as defined in Maritime Rule part 20
shunt box	enclosure where battery cables are terminated or joined
starboard	right-hand side when facing forward
track	the path intended or actually travelled by a ship

List of Abbreviations

AC	alternating current
Ahr	amp hour
DC	direct current
HF	high frequency
kg	kilogram
kW	kilowatt
kVA	kilovolt amps
m	metres
mm	millimetres
MSA	Maritime Safety Authority
PVC	polyvinyl chloride
rpm	revolutions per minute
UTC	universal time (co-ordinated)
V	volt
VHF	very high frequency

Data Summary

Vessel particulars

Name:	*Sweet Georgia*
Port of Registry:	Wellington
Type:	charter launch
Operating limit at the time of the accident:	restricted inshore
Passenger limit:	80
Length overall:	19.85 m
Breadth:	5.85 m
Gross tonnage:	84 t
Construction:	timber
Built:	1993 in Picton
Propulsion:	one 387 kW Scania DSI 11 54 M, 6 cylinder diesel engine, driving a single 4 bladed fixed-pitch propeller
Maximum speed:	11.5 knots
Owner/Operator:	Sweet Georgia Cruising Limited

Location:	Evans Bay, Wellington Harbour	
Date and time:	Friday, 10 March 2000 at about 2000[1]	
Persons on board:	crew:	5
	passengers:	58
Injuries:	crew:	1 (minor)
	passengers:	nil
Nature of damage:	extensive to engine room and wiring	
Investigator-in-charge:	Captain W A Lyons	

[1] All times in this report refer to New Zealand Daylight Time (UTC +13 hours) and are expressed in the 24-hour mode.

1. Factual Information

1.1 History of voyage

1.1.1 The *Sweet Georgia* arrived in Wellington at 2230 on Monday 6 March 2000, after completing a voyage from Auckland.

1.1.2 During the trip south the main engine tachometer had developed an intermittent fault. The tachometer derived its speed reference from the starter battery alternator.

1.1.3 The next day the skipper, who was the owner of the *Sweet Georgia*, decided to send both the house and starter battery alternators and the starter motor to a local auto and marine electrical company for servicing. All 3 items had been in operation since the vessel was built without being serviced. The main engine had a total of about 6700 running hours at the time.

1.1.4 At the servicing company both alternators were dismantled and the parts were cleaned and tested, the brushes and bearings were renewed and the alternators were reassembled. Both were then run on a test bench and appeared to be operating correctly.

1.1.5 The equipment was returned to the *Sweet Georgia* on Friday morning and refitted by a contractor. The system was then tested and appeared to be operating correctly but the tachometer still had an intermittent fault. The fault was later found to be in the tachometer gauge.

1.1.6 On Friday 10 March at about 1830, passengers for a charter cruise began arriving at the *Sweet Georgia*. The skipper gave the charterer and the first passengers to arrive a safety briefing and showed them around the vessel. The charterer and a number of the passengers had been on the vessel before so the skipper asked them to pass on the information to other passengers as they arrived.

1.1.7 The *Sweet Georgia* departed Queens Wharf at 1840. On board were the skipper, 4 crew and 58 passengers. Shortly after leaving the wharf the skipper called Beacon Hill signal station on very high frequency (VHF) radio and passed on the number of persons aboard and the planned route. His intention was to cruise the harbour and then anchor in Oriental Bay.

1.1.8 The *Sweet Georgia* proceeded past Point Halswell towards Ward Island at about 6 knots, which was equivalent to about 1250 engine revolutions per minute (rpm). The skipper was steering from the flying bridge. There were no engine or electrical gauges at this steering position.

1.1.9 Owing to the high electrical demand the skipper started the generator. All lights were on and the total electrical load was possibly near the maximum. The main engine and the alternating current (AC) generator were running. As there was an AC supply to the distribution board, the inverter would have been operating in battery charger mode and the alternators would have been float charging their respective battery banks.

1.1.10 The *Sweet Georgia* proceeded down the harbour to Falcon Shoal beacon. The skipper increased the engine revolutions to about 1450 rpm for a brief period before reducing them back to about 1250 rpm. He then turned the vessel and headed passed Kau Bay and into Evans Bay at about 1940. (See Figure 1)

1.1.11 Shortly after entering the bay the skipper asked one of the passengers, who was also a friend of his, to take the wheel while he went below to check the engine room. The skipper proceeded to the engine room and found everything in order. Within 5 minutes he returned to the flying bridge and took over the helm.

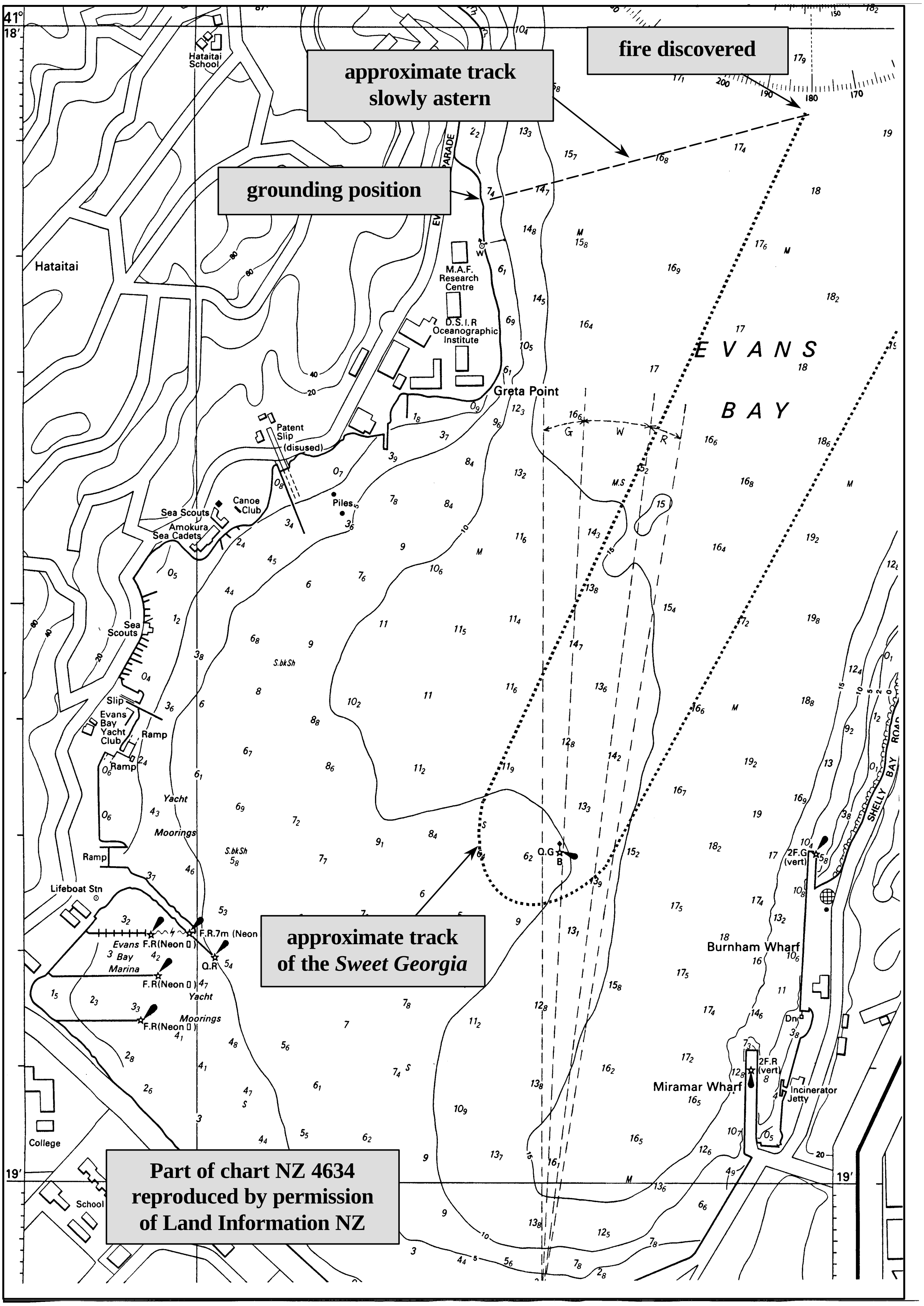

Figure 1
Part of chart NZ 4634 showing approximate track of *Sweet Georgia*

1.1.12 When the *Sweet Georgia* reached the buoy off Burnham Wharf the skipper turned the vessel and headed back up the bay. When the vessel was on a steady course the skipper again asked the passenger to take the wheel while he went below to get a cup of coffee. While down below the skipper noticed the house battery voltmeter, which was situated on the switchboard at the main cabin steering station, was reading off the scale.

1.1.13 One of the passengers who was at the bar later recalled hearing a loud bang about 5 minutes before the skipper came down from the flying bridge. He was not sure of the source and took no further notice.

1.1.14 Realising there was a problem the skipper went back up to the flying bridge to inform the passenger on the helm that he was going to check the engine room again. While on the flying bridge the skipper noticed black smoke coming out of the engine room vents in the radar and antenna arch. The skipper immediately reduced the engine revolutions to idle and went below to investigate the source of the smoke. He lifted the engine room hatch situated in the galley area and was confronted with thick black smoke and flames.

1.1.15 The skipper shut the hatch and transmitted a mayday call on VHF radio. This was received by Beacon Hill signal station at 2001. He informed the passengers in the vicinity of the problem and asked them to move out to the after deck. He also instructed the crew to issue life-jackets to the passengers and to launch the 4.3 m Naiad rigid inflatable boat. The *Sweet Georgia* was in the middle of Evans Bay, north-east of the reclamation at Greta Point at the time.

1.1.16 The skipper then took an 8 kg carbon dioxide fire extinguisher, opened the engine room hatch and discharged about two-thirds of the extinguisher into the engine room before shutting the hatch again. He then isolated the house batteries and gas bottles. He did not close the fire dampers in the engine room vents. The closing devices for these were situated on each side of the main deck.

1.1.17 Meanwhile, the cook/deckhand turned off all the galley appliances. One of the crew, assisted by some passengers, launched the Naiad boat which was stowed on the transom. When the Naiad was launched they began loading passengers on board.

1.1.18 Various vessels had answered the mayday call; others had seen the smoke and proceeded to the *Sweet Georgia* to assist. One of the first vessels to arrive towed the Naiad, loaded with about 15 passengers, to the reclamation. A yacht manoeuvred alongside the *Sweet Georgia* and tied up while the remaining passengers transferred to it.

1.1.19 The fire had burned through the control cables for the engine and as a consequence it was operating slowly astern. While the passengers were boarding the yacht the astern propulsion of the *Sweet Georgia* was moving both vessels slowly toward the reclamation. The fire service and an ambulance had been alerted and were waiting at the reclamation to assist.

1.1.20 When the remaining passengers and crew had boarded the yacht it manoeuvred clear of the *Sweet Georgia*. At this point the *Sweet Georgia* was about 15 m from the reclamation wall and still moving slowly astern. The skipper checked the accommodation for passengers and then remained on the after deck.

1.1.21 At about 2012 the *Sweet Georgia* grounded stern first on the rock wall of the reclamation. The fire service boarded immediately, opened the engine room hatch and extinguished the remaining areas of fire and checked for any hot spots. The skipper went ashore and was treated for smoke inhalation by the ambulance staff.

1.1.22 The engine was still operating astern but the fire-fighters elected not to shut it down as it was holding the *Sweet Georgia* in position against the reclamation wall.

1.1.23 The police launch *Lady Elizabeth 3* arrived at the scene at about 2030. The *Sweet Georgia's* engine was stopped and the *Lady Elizabeth 3* took it in tow. Some of the fire-fighters and the skipper remained aboard the *Sweet Georgia* for the tow.

1.1.24 When the *Sweet Georgia* arrived back at Queens Wharf it was secured at its berth and the fire-fighters made a final check that the fire was extinguished before they and the *Lady Elizabeth 3* departed.

1.2 Personnel information

1.2.1 The skipper of the *Sweet Georgia* had extensive maritime experience on both recreational and charter boats. In 1986 he obtained a Local Launchmaster Certificate, which he upgraded to a Commercial Launchmaster Certificate in 1988 and a Coastal Masters Certificate with a Home Trade Endorsement in 1997. He also held a Second Class Diesel Trawler Engineer Certificate.

1.2.2 He had owned various boats since 1979 and commenced part-time charter operations in 1984. When the *Sweet Georgia* was completed in 1993 he commenced full-time charter work. He had operated mainly around Wellington, Cook Strait and the Marlborough Sounds but on occasions took the *Sweet Georgia* to Auckland for major yacht races.

1.2.3 The deckhand/cook had been employed on a casual basis aboard the *Sweet Georgia* for about 4½years. The barman had been employed for about 4 previous trips and the 2 waitresses had completed one trip each. None held any maritime qualifications.

1.3 Vessel information

1.3.1 The *Sweet Georgia* was built in Picton to survey requirements in 1993. The hull was built to a standard trawler design and constructed of timber. It had 2 decks and a flying bridge. The *Sweet Georgia* had an overall length of 19.85 m and gross tonnage of 84 t. It was powered by a 6 cylinder Scania diesel engine, which gave a maximum speed of about 11.5 knots.

1.3.2 The main deck consisted of a lounge with a bar and galley. The main steering console was situated on the starboard side forward. Adjacent to the steering console was the direct current (DC) distribution board and a locker which contained some electrical equipment and associated wiring.

1.3.3 The forward lower deck consisted of passenger cabins and a conference room. The engine room was situated amidships. Aft of the engine room were more passenger cabins.

1.3.4 Access to the engine room was through a hatch in the deck of the galley area. The engine room was about 4 m square and as well as the propulsion machinery it contained the bulk of the electrical system. On the port and starboard side were the fuel tanks. The space was totally enclosed, with ventilation provided via air intakes on each side of the radar and antenna arch. Fire dampers for these ventilators were operated from either side of the main deck. (See Figure 2)

1.3.5 There was no fixed fire or smoke detection system fitted to the *Sweet Georgia* apart from a household smoke detector in the forward accommodation. There were 3 fire alarms, one each in the fore and aft accommodation and one in the engine room.

1.3.6 The bulkheads and deckhead within the engine room were lined with fire retardant insulation. The wiring and piping ran external to the insulation.

1.3.7 The *Sweet Georgia* had a Safe Ship Management certificate that was issued by Survey Nelson on 20 November 1998 and valid until 28 December 2001. Since the issue of the certificate the *Sweet Georgia* had undergone one hull and valve inspection by the safe ship management company on 24 August 1999.

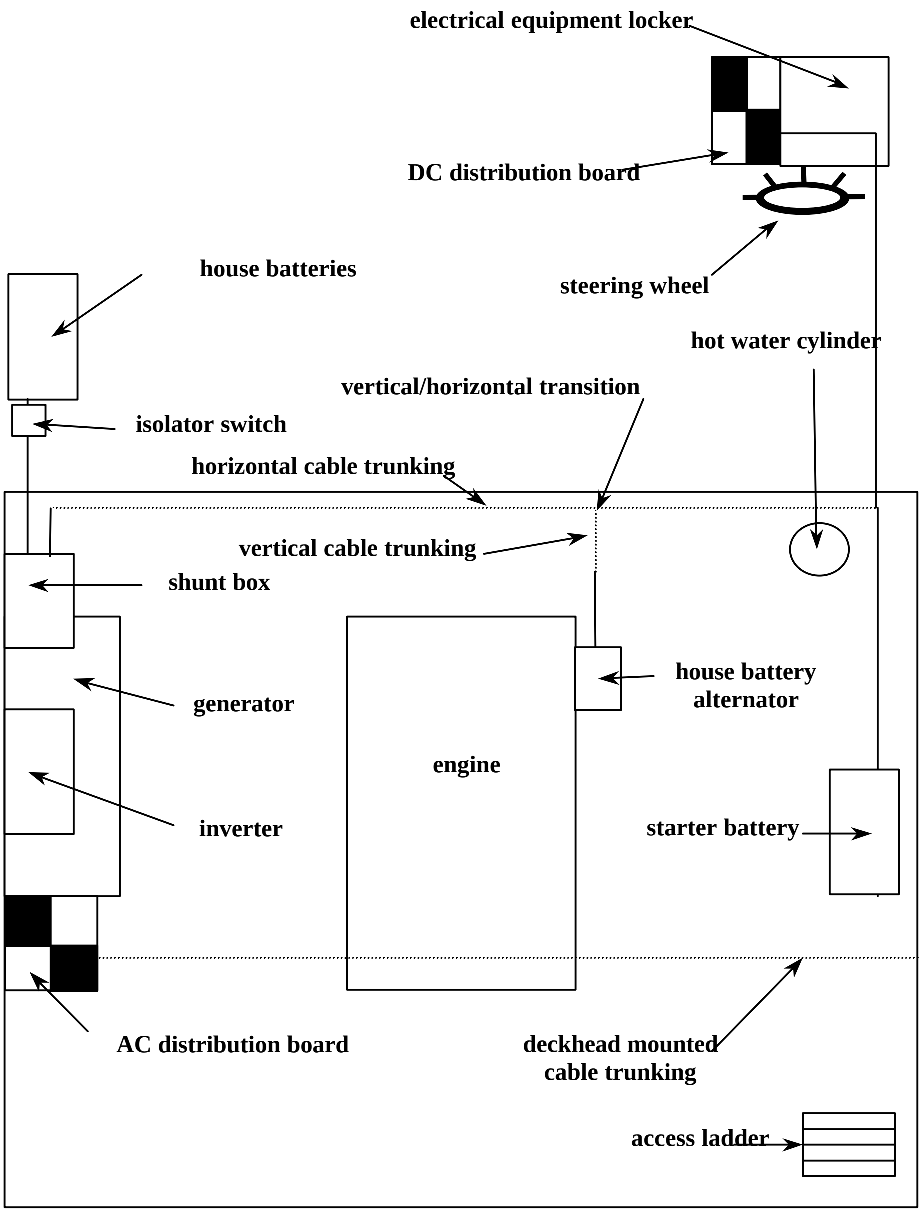

Figure 2
Plan view of engine room

1.3.8 The Maritime Safety Authority (MSA) conducted a flag state inspection of the *Sweet Georgia* in Auckland on 17 February 2000 and found one minor deficiency.

High frequency (HF) radio

1.3.9 The HF radio was an Icom 726 transceiver and was fitted to the vessel about 18 months before the fire. It was a non-marine type HF radio that did not have an isolated antenna earth from the DC power supply.

1.3.10 Marine radios have an isolated antenna earth to avoid the possibility of earth loops and galvanic corrosion.

1.3.11 The radio was not part of the survey requirements. It was installed before the last inspection by a radio surveyor but was not detailed on the radio licence.

1.4 Regulations for marine electrical installations

1.4.1 At the time the *Sweet Georgia* was built the regulations in force that covered the electrical installation were contained in The New Zealand Gazette number 190 under the heading The Ship Construction (Code of Practice for Ships Not Required to Comply With The Safety Convention) Notice 1989. Part VI covered electrical installations.

1.4.2 The regulations in the Gazette also stated that the regulations for the electrical and electronic equipment of ships, which were issued by the Institute of Electrical Engineers, or the equivalent provisions of an approved classification society could be used. The MSA stated that the Requirements for the Construction and Equipment for Fishing Boats Regulations, which were more stringent, could also have been substituted for the above.

1.4.3 To gain approval for the electrical installation the boat builder supplied wiring diagrams of the intended electrical installation to the Marine Division of the Ministry of Transport for approval. After the installation was completed it was inspected by a surveyor to ascertain that the plans and regulations had been adhered to.

1.4.4 The wiring diagrams submitted and approved for the *Sweet Georgia* were 2 photocopies of example wiring diagrams from Section 16 of the Requirements for the Construction and Equipment for Fishing Boats Regulations that had been slightly changed to suit the vessel.

1.5 Electrical system

1.5.1 The low-voltage DC electrical system on board the *Sweet Georgia* consisted of 2 separate 24 V DC battery banks: one dedicated to engine starting, the other to house use. There were two 24 V DC alternators driven by the main engine, one dedicated to the house batteries and the other to the starter batteries.

1.5.2 The AC power system consisted of a single phase 230 V AC distribution board that distributed power from either an 11 kVA 230 V AC single phase diesel generator or the silent running 3 kVA 230 V AC static inverter. There was also the facility for a single-phase shore power connection.

1.5.3 The original electrical installation on the *Sweet Georgia* was completed by a qualified automotive electrician who had extensive experience with marine electrics. It was completed at the builder's yard and approved by a Marine Division surveyor. There had been few changes made to the original system since installation.

DC power

1.5.4 The 24 V house batteries comprised 2 strings of 125 Ahr, 6 V, wet cell lead acid battery blocks. They were stowed in a locker lined with marine ply under a settee on the port side of the lounge area. The handle for the house battery isolation switch was also in the locker; the 2-pole switchgear was mounted behind the partition with the adjoining locker but both poles were exposed and unprotected from accidental contact.

1.5.5 The house battery alternator was belt driven from the flywheel on the main engine. The step up pulley ratio was about 3:1. When the engine was operating at 1000 rpm, the alternator was running at 3000 rpm.

1.5.6 The engine starter batteries and house batteries could be connected under controlled conditions to enable the house batteries to be used to start the main engine if necessary. Each battery bank had a local isolator switch fitted.

1.5.7 The house battery was connected to a shunt box in the engine room. The shunt box served as a DC power connection point for all the main DC cables and contained the meter shunts for the charge and discharge meters fitted to the DC distribution board. DC cables were connected into this junction point from the inverter, the house battery bank, the house battery alternator, the link to the starter battery bank and the dual cable supply to the DC distribution board next to the wheel.

AC power system

1.5.8 The AC distribution board was split into two sections, main and inverter. The power source to the main section was manually selected with the “ship/shore” power switch and then protected and distributed via circuit breakers to all AC powered services.

1.5.9 The inverter section of the board was dedicated to essential AC loads and those required for silent running at night. This section was connected to the main section via a contactor mounted within the static inverter. If AC power was available at the AC distribution board from either the diesel-powered generator or the shore power connection, the inverter contactor connected the two sections of the board and the inverter operated in battery charger mode to float charge the house batteries. If there was no power to the main section, the contactor de-energised and the inverter powered the essential section.

Static inverter

1.5.10 The inverter changed the house battery power to AC and supplied 230 V AC to the distribution board. The inverter was an Ebbett Automation 3 kVA static inverter that was mounted next to the shunt box and connected to the house battery DC supply at the shunt box.

Cable installation

1.5.11 Cables installed in the vessel were generally run in cavities or ductways within the bulkheads and deckheads. All cabling within the engine room was enclosed within plastic cable trunking that was surface mounted on either the deckhead or bulkhead. At the lower levels of the engine room and around the engine the cables were run within flexible PVC conduit.

1.5.12 Two major cable trunking routes were provided within the engine room. One ran horizontally at a height of about 1.6 m above the deck, around the bulkheads from the shunt box, to behind the hot water cylinder. A smaller cable trunking ran vertically down from the horizontal cable trunking to the forward end of the main engine. A secondary cable trunking ran from the AC switchboard, across the deckhead to the starboard side of the engine room.

1.5.13 The horizontal cable trunking was approximately 75 mm wide and 60 mm deep and appeared to have been full of cables. It was attached to the bulkhead at each vertical frame so was clear of the flat bulkhead surface. It contained:

- 50 mm² rubber insulated DC single core battery cables
- 16 mm² PVC insulated DC single core alternator cables
- 1 mm² PVC insulated double core DC lighting cables
- 2.5 mm² 230 V AC triple core general power tough plastic sheath cables.

1.5.14 The two 16 mm² power cables that joined the house alternator to the house batteries were run up the vertical cable trunking. They then turned through a right angle bend with a radius of about 25 mm towards the port side. To facilitate the change in direction of the cable from vertical to horizontal a hole was cut in the side of the vertical cable trunking. The cables then ran in through the bottom of the horizontal cable trunking via the gap between the bulkhead surface and the bottom of the cable trunking.

1.5.15 There was no additional support provided for the 16 mm² cable within the vertical cable trunking. The weight of the two 1.6 m lengths of cable was supported by the rough-cut edge of the trunking penetration at the right angle bend in the cables.

1.5.16 A few of the DC power cables within the horizontal cable trunking were cable tied together but in general the cables were loose and were not supported. The deckhead mounted cable trunking relied on the snap-on lid to stop the cables from falling out. Cables within the trunking were not physically segregated by voltage. DC cables rated at less than 100 V were run adjacent to 230 V AC cables.

1.5.17 The 16 mm² cable was PVC insulated welding cable with a maximum conductor current rating of 92 amps. The 50 mm² cable had vinyl nitrile rubber insulation and was industrial flex with a maximum conductor current rated at 165 amps.

1.6 General damage

1.6.1 The morning after the fire the Commission’s electrical consultant and a New Zealand Fire Service safety officer inspected the scene.

1.6.2 The fire was contained within the engine room. The insulation was burnt away along the forward bulkhead and across the deckhead. The major burn damage was above the horizontal cable trunking on the forward bulkhead and in each forward corner of the space. Below that height there was virtually no heat damage.

1.6.3 The seat of the fire appeared to have been at the intersection of the vertical and horizontal cable trunking, forward of the main engine.

1.6.4 The deckhead had been charred but not as severely as the forward bulkhead. It appeared that hot gases from the forward bulkhead had flowed across the deckhead and melted the plastic on the exposed surfaces of the inverter, AC distribution board, light fittings and the PVC cable trunking mounted on the deckhead. The weight of the cables contained within the trunking had forced the cap off, allowing the cables to drop down from the trunking and hang suspended from their terminations or penetrations on either side of the engine room.

1.6.5 The forward bulkhead of the engine room was constructed of timber frames and marine ply which were badly charred. The deck was covered in burnt material that had fallen from the deckhead and bulkheads. There was little damage caused in extinguishing the fire.

1.6.6 Damage to the *Sweet Georgia* as a result of the grounding was minimal.

1.7 Damage to cable trunking and wiring

1.7.1 The fire damage to the cable trunking was concentrated in the area where the horizontal and vertical trunking intersected. It initially appeared to be caused mainly by the external application of heat. On closer inspection a severed end of a 50 mm^2 DC submain to the distribution board was protruding out of the bottom of the horizontal trunking, and its mating end was hanging free just to starboard. This cable appeared to have been severed by an electrical fault, which was evident by the molten copper at the broken ends. (See Figure 3)

1.7.2 When the cable loom within the horizontal trunking was further separated and pulled further apart, signs of insulation failure were more obvious. Severe charring was discovered within the loom and several bare copper conductors were visible. The cables at the back of the loom were bonded to the trunking and adjacent cables by the molten insulation. Another 50 mm^2 submain cable, at the back of the loom, to the DC distribution board was discovered to have been severed by an electrical fault. (See Figure 4)

1.7.3 The two 16 mm^2 cables connecting the house alternator to the house batteries rose vertically from below the horizontal cable trunking. They were then bent at right angles to enter the trunking and ran to the shunt box on the port side. Both of these cables were severed at the bend by an electrical fault. A section about 300 mm long towards the shunt box was completely missing from each cable. It appeared, from the coppery and blue copper sulphate coloured deposits within the loom and on the cable trunking, that these missing sections of cable had been vaporised under severe electrical fault conditions.

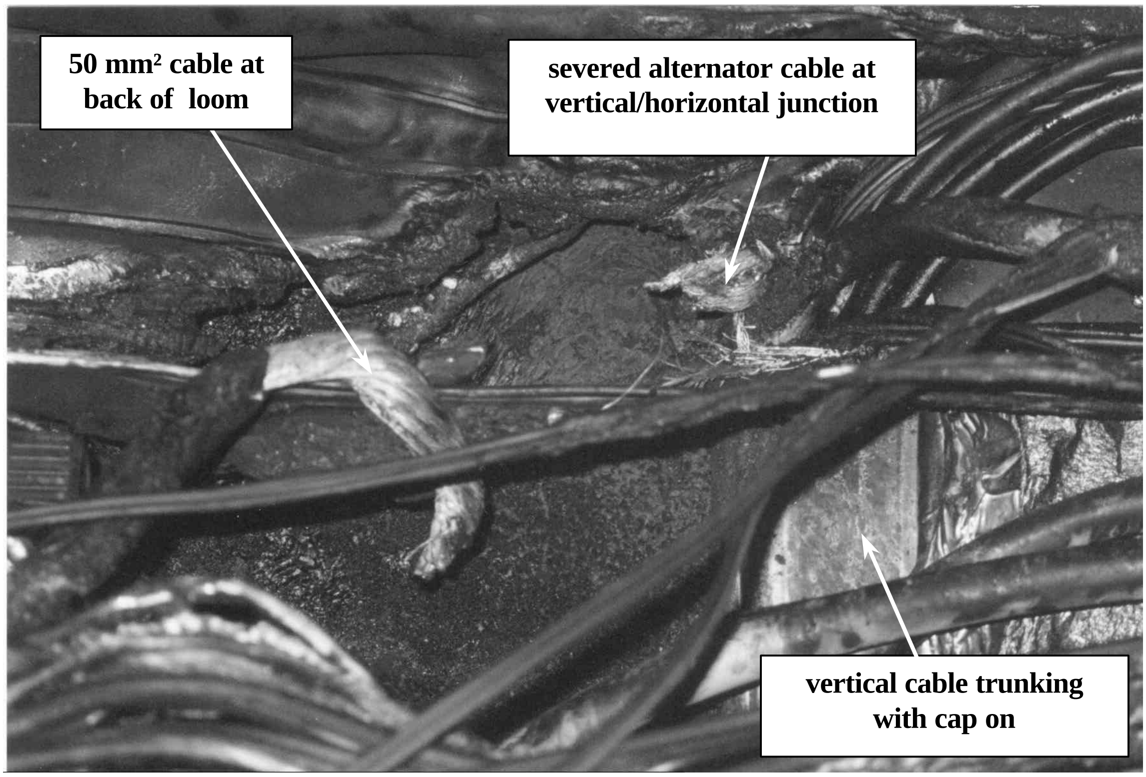

Figure 3
Photograph showing severed 50 mm² DC submain cable

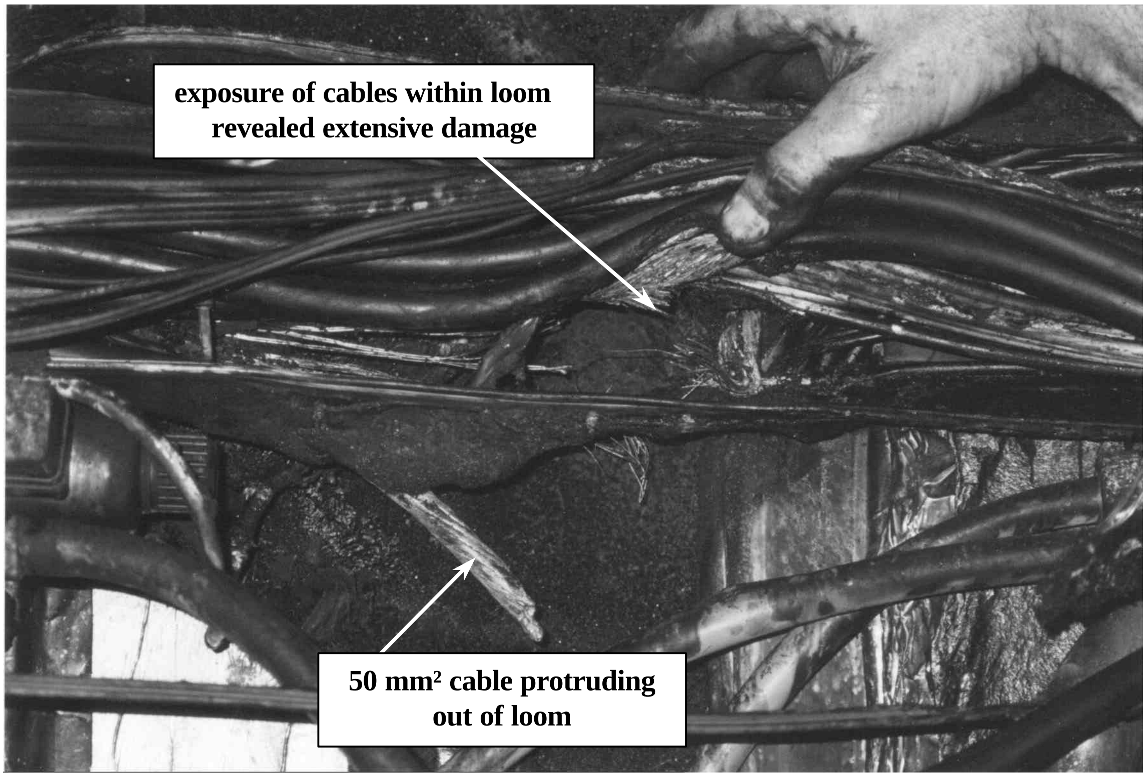

Figure 4
Photograph showing damaged cables in horizontal cable trunking

1.7.4 Sections of the PVC base of the cable trunking adjacent to the vertical to horizontal transition point had been burnt to charcoal and some of it had completely burnt away. The base of the cable trunking was burnt from the inside out, which indicated that the heat source was inside the cable trunking loom and had burnt through to the outside where the cable trunking faced the bulkhead.

1.7.5 The vertical cable trunking cap was removed and the cables examined. Insulation on the alternator cables within the cable trunking showed signs of extreme heat damage. The external surface of the cable trunking was relatively clear of soot with no signs of burning or heat damage. The heat damage to the cable had been caused by a sustained excess current flow within the cable. The only current that was able to flow along this section of cable would have been sourced from the alternator (see Figure 5).

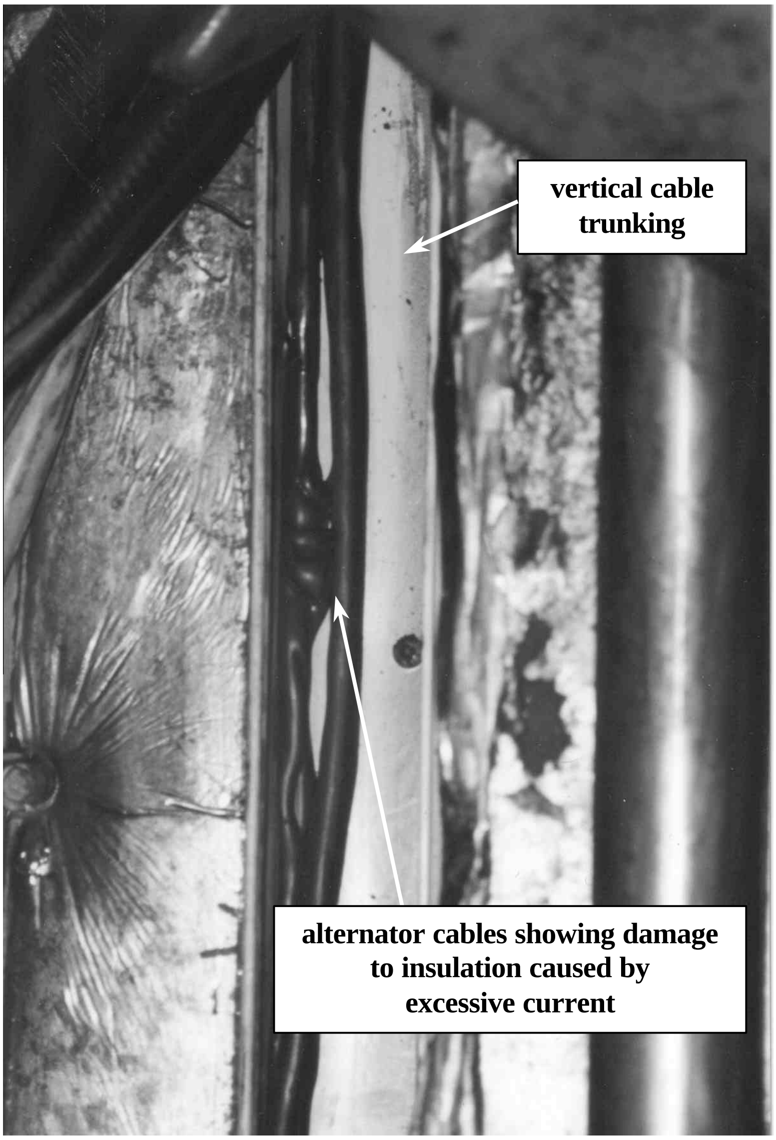

Figure 5
Photograph showing heat damage to alternator cables

1.8 Battery damage

1.8.1 The house batteries were removed and examined. The cases had bulged unnaturally due to excessive internal pressure and the electrolyte level was well below the plates in most cells. The electrolyte that remained was discoloured.

1.9 Post fire house battery alternator tests

1.9.1 The house battery alternator was tested immediately after the fire by the company that had serviced it. The regulator had failed which caused the output voltage to increase in proportion to the revolutions. A replacement regulator was fitted and the alternator was retested and appeared to be operating correctly.

1.9.2 After the fire damage was repaired, the house battery alternator was refitted and tested. The tests revealed that the output voltage would still increase uncontrollably with the increase in revolutions. The alternator was again removed and returned to the servicing company's workshop.

1.9.3 The house battery alternator was again tested by the servicing company and an independent marine electrical company. Both subjected the alternator to standard bench tests which showed no fault on the alternator.

1.9.4 Further tests on board the vessel revealed an alternative earth loop that was causing the regulator to lose voltage control of the alternator output. The earth loop was caused by the negative DC supply to the HF radio being directly connected to the HF radio antenna earth. The antenna earth consisted of a copper plate on the outside of the hull in contact with the sea water. The earth loop was completed through the sea water to the sacrificial anode and the engine block. When the earth plate connection cable from the HF radio was disconnected, the alternator worked correctly.

1.9.5 The radio was removed and tested by a marine and industrial electronic company and was found to be in good working order. However, it confirmed that the radio was a non-marine type and that it did not have the standard marine equipment isolation between the input DC connections and the antenna earth.

1.9.6 A new alternator was installed on the *Sweet Georgia* and the HF radio was removed. Tests on board confirmed that the original alternator was faulty but that the fault had not been detected during the tests conducted at the workshops.

1.9.7 The original alternator was further tested by a marine electrical company in Auckland. It carried out a range of predefined static and dynamic tests then methodically disassembled the alternator while checking for damage. The static tests revealed that the rectifier diodes were all operational. Dynamic tests proved that the regulator was working correctly over the full range of speeds and output loads.

1.9.8 While the alternator was in operation on the test bench, a jumper lead was connected between the alternator negative output terminal and the case; the fault symptoms immediately re-appeared. Removal of this jumper lead immediately returned the alternator to its correct and normal operation.

1.9.9 The disassembly of the alternator revealed that the wires from the rotor coil to the slip ring were being forced against the sharp edges of the wire channel within the rotor shaft. The wires had been pinched and flattened, damaging the insulation. This had been caused by the slight misalignment of the slip ring when assembling the alternator after it had been serviced just before the fire (see Figure 6 and Figure 7).

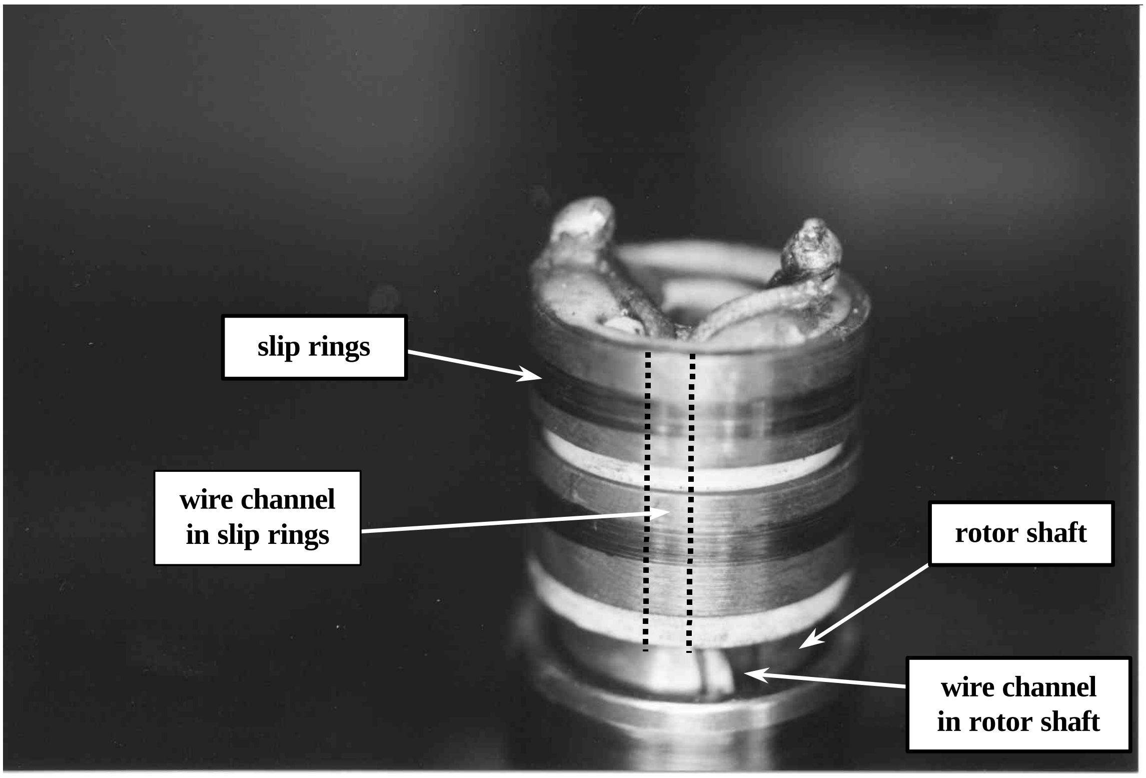

Figure 6
Photograph showing misaligned wire channels

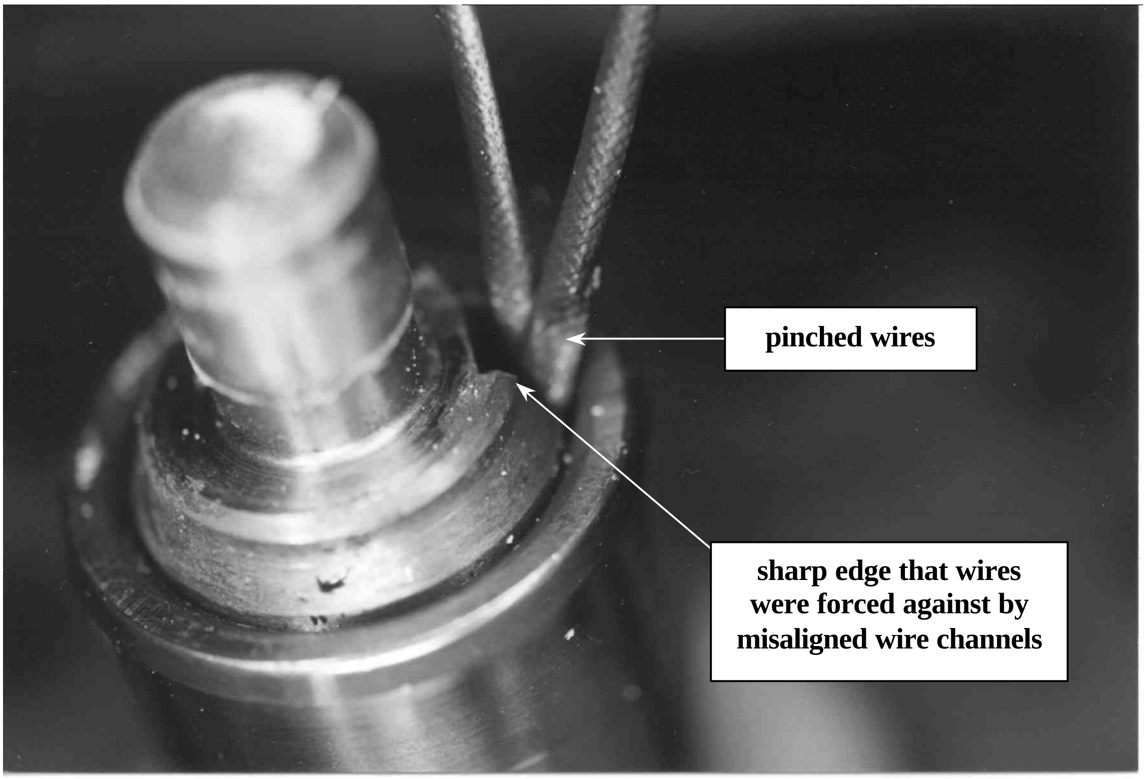

Figure 7
Photograph showing pinched wires with slip rings removed

1.9.10 The damaged insulation created a low resistance current path between the rotor coil and the alternator case. Whenever current was able to flow through this low resistance path the regulator lost control of the output voltage. If no current flowed then the regulator worked normally. Current flow was completely dependent upon the existence of an external circuit path to one of the 2 isolated output terminals from the case. An earth loop through the HF radio created this path to the negative terminal of the alternator.

1.9.11 The regulator circuit diagram was not available but the alternator fault appeared to have occurred because the additional load of the low resistance path to the case depressed the regulator output voltage to the rotor and diverted a portion of the rotor current through the earth loop. When the rotor voltage was depressed in this manner the regulator was fooled into acting as if the alternator output voltage was also too low. As a result the regulator increased the current to the rotor coil to raise the alternator output voltage. The effect was to initially step up the alternator output voltage and eventually lose voltage regulation. As the alternator speed increased the output voltage also increased.

1.9.12 An earth loop DC current had been able to flow from the stator winding, through the exciter diodes, through the low resistance path to the alternator case and down through the engine mounting to the earth plate near the propeller shaft. From there the current passed via the sea water to the HF radio via its earth plate and then back to the stator windings via the negative DC battery cables. This current had adversely affected the alternator's voltage regulation (see Figure 8).

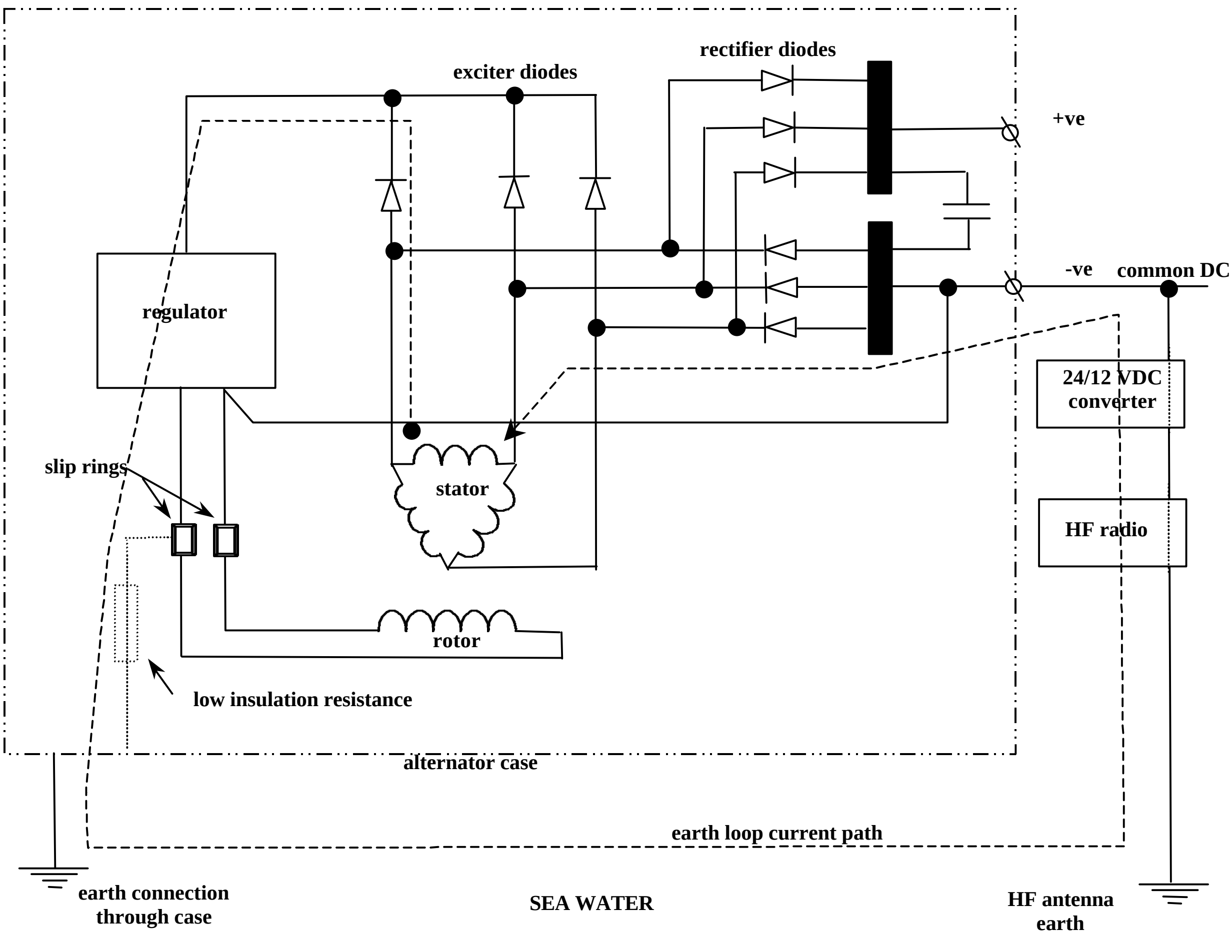

Figure 8
Earth loop current path

2. Analysis

2.1 The trip

2.1.1 When the *Sweet Georgia* sailed the electrical load would have been high due to the requirements of the DC lighting, bar, galley and band. The skipper was aware of this and checked the engine room about one hour after the vessel sailed and found everything in order. Although there was no indication of any problem at the rpm the engine was operating at, the alternator output would have been well above 28 V DC. This condition would have caused excessive current flow from the alternator that would have been causing the wiring to slowly heat up. The DC voltmeter would also have been at full deflection but the skipper would not have been aware of this, as there was no voltmeter on the flying bridge.

2.1.2 By the time the skipper noticed the DC voltmeter at full deflection the fire had already taken hold. A fire detection system or a DC voltmeter at the steering position on the flying bridge would have alerted him to the problem much earlier.

2.1.3 As soon as the skipper realised there was a fire he acted quickly and appropriately by sending a mayday, organising the crew and passengers, isolating the batteries and gas, and fighting the fire. If he had closed the dampers on the engine room ventilators, the effect of the engine still running and the carbon dioxide fire extinguisher may have smothered the fire completely.

2.1.4 The engine continuing to operate astern caused the vessel to ground on the reclamation and facilitate easy access for the waiting fire-fighters. If the engine had stopped earlier the vessel would have been adrift in the bay awaiting the arrival of the fire-fighters on the *Lady Elizabeth 3*. Any air entering the space in the meantime could have reignited the fire.

2.1.5 It was fortunate that the fire occurred in calm conditions, early in the evening, close to assistance from the shore and other vessels. Inspection of the engine room after the fire showed that the timber bulkheads and deckhead had ignited and the fire was close to engulfing the entire engine room.

2.2 Electrical installation

2.2.1 When the *Sweet Georgia* was built there were several different sets of regulations regarding the electrical installation that could have been adhered to. The basic regulations were contained in the Gazette. The electrical installation aboard the *Sweet Georgia* did not comply with some aspects of these regulations. These deficiencies were not noted and rectified by the surveyor at the completion of building or at subsequent surveys and inspections.

2.2.2 If the electrical installation had been installed in an appropriate manner and fitted with overload protection the fire probably would not have occurred. The result would have been a tripped circuit breaker or blown fuse and temporary loss of power.

2.2.3 The cable used for the house battery alternator appears to have been 16 mm^2 PVC insulated welding cable with a maximum continuous current rating for the conditions, of approximately 92 amps. The alternator feeding into this cable was capable of 175 amps continuous output, significantly more than the cable was designed to safely conduct. The nature of the alternator fault would have caused its output current to increase towards maximum and thus exceed the cable rating. The alternator output current was likely to be self-limiting so a cable rated for at least its maximum output would have been adequate for this situation rather than fuse protecting the cable from an alternator short circuit fault. However, it would have still been necessary to fuse protect the alternator cable from a battery short circuit because the battery cables had a significantly higher load current capacity than the alternator cables.

2.2.4 The standard of the low-voltage DC electrical installation aboard the *Sweet Georgia* would not have met land-based regulations. Once the combination of a faulty alternator and the earth loop set up an excess current condition the electrical installation allowed a relatively simple electrical fault to develop into a fire. The conditions that facilitated this situation included:

- the cramped cable trunking that caused excessive heat build-up which led to insulation failure
- the cable bending radius being less than the manufacturer had recommended which caused damage to the insulation
- the sharp unprotected edges damaging the cable insulation
- the unsupported vertical cable run that did not have gravitational stress relief and caused damage to the insulation
- DC power sources not provided with automatic excess current protection at the source
- the house battery alternator cable being under rated for the maximum current it was expected to carry
- the failure of the plastic cable trunking system to retain the cables when the temperature of the engine room rose due to the fire
- cables carrying different voltages run in the same cable trunking without suitable insulation or isolation from each other
- the cable types used on the *Sweet Georgia* were commonly used in New Zealand marine situations but were not designed nor very suitable for this purpose.

2.2.5 This particular marine electrical installation was similar to low-voltage DC systems found in the automotive industry, as some cables connected directly to the battery were not fuse protected. The automotive practice of not providing overload protection for certain cables may be suitable for the single 12 V battery system commonly used in road vehicles, but a marine installation comprising several batteries in parallel, multiple power sources, longer cable runs and the added risk of not being able to stop on the side of the road if a problem occurs, requires higher standards. Potential fault currents in a marine situation are considerably higher than automotive situations and they are capable of explosive cable damage that can lead to a fire, as occurred aboard the *Sweet Georgia*.

2.2.6 The house batteries were situated in the lounge but the locker had no ventilation or acid-resistant lining. The switchgear for the isolation switch in the adjacent locker was not protected; any metal equipment stowed in this locker could have caused a short circuit across the terminals. These basic deficiencies had not been addressed since the vessel was built even though it had been subjected to several surveys and inspections in the interim.

2.3 Alternator tests

2.3.1 The house battery alternator was put on a test bench 3 times by 2 different service companies. Neither identified the fault. If they had tested the insulation between the case and both output terminals the fault would have been identified immediately.

2.3.2 Simple tests could have been conducted that would have identified the existence of an earth fault. This suggests that the nature of marine earth currents and subsequent problems with galvanic corrosion may not be well known within the wider marine electrical industry, where many of the trades people have traditionally come from an automotive background.

2.3.3 When the alternator was returned to the *Sweet Georgia* after the initial service it was fitted to the engine and tested while the vessel was alongside the wharf but the fault was not evident at low engine revolutions. Post fire tests in Auckland identified that the fault did not show until the alternator revolutions reached about 2000 rpm.

2.3.4 Except for a short period, the *Sweet Georgia* travelled at about 6 knots until the fire was noticed. At this speed the engine revolutions were about 1250 rpm. At this rpm the house battery alternator revolutions would have been about 3750 rpm. Tests after the fire showed that with a 100% resistive load at this speed the alternator would have been producing about 130 amps, but with the earth fault affecting the regulator output, the alternator output voltage and current would have been considerably higher.

2.4 The fire

2.4.1 The seat of the fire was within the horizontal trunking cable loom on the forward engine room bulkhead.

2.4.2 The house battery alternator was operating correctly but due to the effect of the earth loop current that was flowing, its output voltage rose above the normal value. This caused the house battery voltmeter to go to full-scale deflection (above 30 V DC) and the house battery to be overcharged. The house battery alternator cables in the vertical cable trunking overheated from excess current flowing though them, which then led to insulation failure at the vertical to horizontal transition point. A short circuit or very low resistance occurred between the alternator cables at the transition point, which then carried the full output current capacity of the alternator. The alternator cable insulation within the vertical cable trunking melted and the regulator probably failed causing the alternator output to rise uncontrollably. As the engine was still running the alternator continued to feed current into the short circuit.

2.4.3 The heat from the short circuit travelled along the copper conductor of the house alternator cable and damaged the 50 mm^2 cable insulation of the battery submain to the DC distribution board. Eventually the battery cables in the horizontal cable trunking were short circuited by a section of hot alternator cable and the explosive cable separations occurred. This was probably the source of the bang the passenger recalled hearing. The energy stored in the battery would have continued to discharge into the short circuit until the battery was flat, manually isolated, or the exposed conductors had blown apart and removed the short circuit. The fire had started sometime during this sequence. A fuse at the house battery could have safely disconnected the battery under this scenario and possibly avoided the fire.

2.4.4 Cable damage indicated that the maximum possible unprotected fault current from the house battery had been conducted through short circuits in this area. The magnitude of the fault current and resulting magnetic forces had separated the 50 mm^2 battery cables with an explosive force that severed the cables and thrust the molten ends out of the cable trunking. Without a protective device to limit the battery fault current, it appears that a section of the smaller 16 mm^2 alternator cable within the cable trunking may have acted as a fuse.

2.4.5 Damage of this nature would not occur without some other complementary existing preconditions such as a lack of current limiting devices or poor installation methods. The skipper had observed the house battery voltage meter being hard over at full-scale deflection at the time of the fire, which indicated that the alternator was still connected to the house battery at the time. The molten alternator cables in the vertical cable trunking indicated that the excessive alternator current situation had existed for a longer term (probably in terms of minutes). This current had been sufficiently in excess of the alternator cable current rating for it to melt the insulation and allow it to flow in liquid form.

2.4.6 The battery damage was also indicative of the battery being overcharged by the alternator output voltage being higher than it should. This would generate an internal gas pressure that seems not to have been vented quickly enough to prevent the battery case from bulging.

2.4.7 The sustained electrical overload went unnoticed until the fire developed. From tests on the alternator after the fire, it was established that an earth loop leakage current had caused the regulator to increase the alternator output voltage well above a safe limit for the house battery. This would have led to excessive current flowing in the alternator cables, heat build-up in the cable trunking and overcharging of the house battery. The regulator fault, which was repaired after the fire, seems likely to have occurred as a result of the alternator operating incorrectly but this was not determined conclusively. The regulator was a sealed unit manufactured in America and sold as a unit to the alternator manufacturer.

2.4.8 The alternator had a dormant fault but otherwise worked correctly at the marine and auto electricians and would have worked correctly on the vessel if the earth loop had not existed. The coincident existence of the secondary earth loop through the HF radio and the dormant alternator fault caused the house battery alternator to operate incorrectly. Neither the alternator nor the HF radio would have caused any obvious problems if they had not both been present at the same time. Once the dormant alternator fault was enabled, the alternator output current increased beyond a safe limit for the alternator cables and the poor wiring installation became the weakest point of failure. If an overload protective device had been installed the situation could have been made safe before any serious damage would have occurred.

2.4.9 The Commission investigated another electrical fire aboard a small commercial vessel (Report 98-211). That report concluded that the regulations and guidelines for marine electrical installations of low-voltage DC systems in small commercial operations were incomplete and ambiguous. The general low-voltage electrical installation practices that were evident on the *Sweet Georgia* were still not equivalent to standard safety practices commonly found in land-based electrical regulations or clearly defined in marine regulations in order to protect cables and ensure that their insulation would remain intact under all operational conditions.

2.4.10 It is of concern that there may be many other vessels operating in New Zealand with substandard electrical installations, particularly as many are licensed to carry passengers. There were many basic improvements that could have been made to the electrical installation aboard the *Sweet Georgia* at limited expense that would have significantly reduced the likelihood of fire, and enhanced the safety of those aboard.

2.4.11 A previous safety recommendation (008/99) to the Director of Maritime Safety read that he:

> Conduct a random survey of New Zealand passenger vessels to determine the extent of the problem regarding substandard electrical and machinery installations, and initiate a strategy involving all Maritime Safety Authority approved surveyors to progressively upgrade the New Zealand passenger fleet to comply.

2.4.12 The Director of Maritime Safety replied:

> The Maritime Safety Authority does not intend to implement this recommendation. It is our belief that a more practical response would be to ensure that Safe Ship Management company inspectors and surveyors follow up on the reissue of the Circular Letter mentioned above [number 76] by paying particular attention to the standard of electrical wiring during their inspections/surveys of boats.

2.4.13 In view of the findings in this report it may be appropriate for the Director to reconsider this safety recommendation.

3. Findings

3.1 The *Sweet Georgia* was operating under a safe ship management system and had a current maritime document at the time of the fire.

3.2 The skipper was suitably qualified for his position.

3.3 The regulations governing the standard of electrical installation for vessels such as the *Sweet Georgia* when it was built were various, not clearly defined and interpreted differently by those in the industry.

3.4 The fire started at the right angle bend in the house battery alternator cables due to the overheating and subsequent failure of the insulation.

3.5 The fire was caused by an electrical fault that required a combination of 3 conditions, which all had to be present for the electrical fault to develop into a fire, namely:

- inadequate mechanical and electrical protection of the low voltage DC cables
- the installation of a non-marine type HF radio
- the dormant house battery alternator insulation fault.

3.6 There were numerous examples of poor standards of electrical installation on board the *Sweet Georgia,* some of which were permitted under the existing legislation.

3.7 The action of the skipper and the crew after the fire was discovered was timely and appropriate but the engine room ventilator dampers should have been closed.

3.8 A fire detection system and monitoring gauges on the flying bridge would have alerted the skipper to the potential fire earlier and may have prevented serious damage.

3.9 It is probable that the *Sweet Georgia* is only one of many existing passenger vessels operating in New Zealand with substandard low-voltage DC electrical installations.

3.10 The existing marine electrical regulations still permit recommended basic safe practices for low-voltage DC installations commonly found in other industry sectors to be ignored in the small commercial marine sector.

3.11 There appears to be the need for an industry training standard to make automotive electricians aware of the peculiarities of marine electrical installations.

4. Safety Recommendations

4.1 On 19 September 2000 it was recommended to the owner of *Sweet Georgia* that he:

4.1.1 Install a fire detection system in the engine room of the *Sweet Georgia* and ensure that the poor electrical installation standards identified in this report are rectified. (074/00)

4.2 On 19 September 2000 it was recommended to the Director of Maritime Safety that he:

4.2.1 Implement safety recommendation 008/99 made by the Commission in report 98-211 which reads as follows:

Conduct a random survey of New Zealand passenger vessels to determine the extent of the problem regarding substandard electrical and machinery installations, and initiate a strategy involving all Maritime Safety Authority approved surveyors to progressively upgrade the New Zealand passenger fleet to comply. (008/99)

(075/00)

4.2.2 Develop an industry training standard that would enable automotive electricians to learn the basic safety requirements and peculiarities of marine electrical installations. (077/00)

4.3 On 2 October 2000 the Director of Maritime Safety replied:

4.3.1 **Recommendation 075/00**

The Maritime Safety Authority has reconsidered the recommendation based on the events of this report and the identical recommendation (008/99) contained in TAIC report 98-211. MSA does not intend to adopt this recommendation for the following reasons.

We would note that the appropriate point for compliance checking of electrical system installation is during construction, or when a vessel is inspected for inclusion in a Safe Ship Management System. Considering the small number of incidents resulting from poor electrical installation that have occurred on vessels whilst in service in relation to the total number of vessels operating, we do not support the proposal for random auditing nor believe that the costs involved in conducting this audit would be justified.

We do, however, intend to advise operators of these incidents and the need for routine inspections to ensure that the installation is compliant and maintained to the electrical standard applicable at the time of construction or when the vessel is entered into a Safe Ship Management System.

Recommendation 077/00

The Maritime Safety Authority does not support this recommendation for similar reasons to recommendation 075/00.

Further, the Maritime Rule 40 series which details the Design, Construction and Equipment of non-SOLAS ships has detailed electrical standards which will apply during the construction of any new vessel, or acceptance of a vessel into Safe Ship Management after 1 February 2001.

All contractors and surveying bodies involved in the installation or inspection of electrical systems on board vessels will need to comply and work to these standards from that date.

Approved for publication 27 September 2000

Hon. W P Jeffries
Chief Commissioner