Report 96-201

Fishing Trawler *San Manukau*

off Cape Karikari

28 January 1996

Abstract

On Sunday, 28 January 1996, at approximately 0550 hours, the fishing trawler *San Manukau*, enroute from Auckland to North Cape, capsized 15 nautical miles north-north-west of Cape Karikari. One deck-hand was lost, presumed drowned. The vessel was towed into Doubtless Bay where it later sank during attempts to right it. The capsize was caused by the loss of stability due to back-flooding of the fish hold via the vessel's bilge pumping system.

Transport Accident Investigation Commission

Marine Accident Report 96-201

Vessel Particulars:	
Name:	*San Manukau*
Registered:	Auckland
Official Number:	380248
Type:	Trawler
Class:	New Zealand Fishing Ship Class X (unrestricted limits)
Construction:	Steel
Power Plant:	One 559 kW Daihatsu 6PSHTM6EFS diesel engine driving a single fixed pitch propeller through a reversing gearbox
Built:	1979, Kanmon Shipbuilding Co. Ltd, Shimonoseki, Japan
Owner/Operator:	Sanford Ltd
Service speed:	9 knots
Length, over all:	29.26 m
Length, registered:	26.90 m
Breadth, registered:	8.07 m
Gross Tonnage:	223.95 t
Net Tonnage:	80.72 t
Location:	Cape Karikari, east coast, North Island (34° 33 'S 173° 21' E)
Date and time:	28 January 1996 at 0550 hours*
Persons on board:	Crew: 4 Passengers: nil
Injuries:	Crew: 1 fatal
Nature of damage:	Sank, salvaged and declared a total constructive loss
Inspector in Charge:	T M Burfoot

* All times in this report are in NZDT (UTC +13 hours)

1. Factual Information

1.1 History of the voyage

1.1.1 At 0700 hours on Saturday, 27 January 1996, the Master, First Mate and two deck-hands arrived on board their vessel the *San Manukau*, which was moored at the Western Viaduct in Auckland, to prepare the vessel for sea.

1.1.2 The *San Manukau* (see Figure 1) had been moored for a number of days at the Western Viaduct while the vessel was unloaded and maintained by Sanford's shore staff. As was the usual arrangement, the Master and crew were on leave over this period.

1.1.3 The *San Manukau* was an ice fishing trawler which was designed to trawl alone or in tandem (pair trawl) with her sister vessel, the *San Hauraki*. The two vessels were scheduled to depart Auckland on 27 January at approximately 1300 hours bound for fishing grounds off Ninety Mile Beach on the west coast of the North Island.

1.1.4 Prior to departure the *San Manukau* had been refuelled to capacity. It could not be established how much water remained in the number four port and starboard ballast tanks, located aft, as nobody from the crew or Sanford's shore staff sounded them prior to departure. It was estimated by the Master that, on departure, the fuel tanks were 98% full and the ballast tanks approximately half full.

1.1.5 It was normal practice for the crew of the *San Manukau* to press[1] up number four ballast tanks when steaming any distance to fishing grounds. This gave the vessel a stern trim, submerging the propeller deeper in the water for better speed and fuel economy.

1.1.6 The First Mate and the two deck-hands loaded approximately 15 tonnes of crushed ice from a Sanford truck into the *San Manukau's* fish holds. There was an estimated 13 tonnes of ice remaining on board from the vessel's previous trip, making a total of 28 tonnes of ice stowed in various compartments throughout the fish holds (see Figure 4 on page 12). The Master filled the fresh water tanks and assisted the crew in preparing the vessel for sea.

1.1.7 At 1300 hours on Saturday, 27 January 1996 the *San Manukau* left the wharf with the Master, First Mate and two deck-hands on board. The First Mate was also acting as Engineer for that voyage as the permanent engineer was not available. The vessel had a slight port list (lean) when it left the wharf so the Master asked the First Mate to press up the ballast tanks and pump out the fish hold bilges. The Master was standing the watch as the *San Manukau* steamed out of Auckland Harbour and through the Hauraki Gulf, with the *San Hauraki* slightly ahead on their port bow. During this time the First Mate and deck-hands prepared and guided the repaired net on to the net roller.

1.1.8 At approximately 1500 hours, while the two deck-hands continued to secure the vessel for sea, the First Mate proceeded to the engine room and used the "bilge and general service" pump to pump out the fish hold bilges. When fishing it was normal practice to leave this pump running continuously on the fish hold bilges with the sea suction valve "just cracked" open to maintain a flow of sea water through the centrifugal pump ensuring it did not lose suction and run dry when the fish hold bilge emptied; however, as it was going to take the *San Manukau* approximately 24 hours to reach the fishing grounds the Master had reduced the temperature in the fish hold and instructed the First Mate to close the bilge system down.

[1] Overflow using a pump.

Figure 1
Fishing Trawler *San Manukau*

1.1.9 As the First Mate was not going to leave the bilge pump running continuously, he did not use the sea suction valve to prime the pump. He started the pump and proceeded up on deck to observe the overboard discharge. Seeing no water, he assumed the pump had lost suction so, without stopping the pump, he adjusted the valves in the engine room to fill number four port and starboard ballast tanks together. He could not recall with certainty in what order he opened and closed the relevant valves. After approximately 20 minutes the First Mate observed the starboard ballast tank overflowing from its vent on deck. He immediately went down to the engine room and closed the valve for that tank. On returning to the deck he noted water overflowing on deck from the port ballast tank vent so he went down, shut off the pump and, according to the First Mate's recollection, closed all of the bilge and ballast valves. On completion of the ballast and bilge pumping operations the *San Manukau* was listing slightly to starboard (see 1.1.11 below).

1.1.10 The Master stood the bridge watch up to 2200 hours that night and was to resume at 0600 hours the next morning. From 2200 to 0600 hours the bridge watch was divided into three watches, each lasting two hours and forty minutes. The crew cooked and ate their evening meal at approximately 1800 hours and then rested until it was time for their watch. It was a hot, humid night and the forward hatch leading from the deck into the Bosun Store forward and the two weather-tight doors leading from the accommodation to either side of the main deck were left open to supplement the flow of air provided by the accommodation fan vents. The other openings on the main deck, engine room door, fish hold hatch covers and aft peak hatch cover, were secured.

1.1.11 At 2100 hours the Master noticed a slight starboard list (approximately one degree). He could not be sure at this time how long the vessel had been listed or whether the list was getting worse. Usually, after two to three days at sea, the vessel would develop a starboard list due to uneven fuel consumption. Fuel was normally drawn from both port and starboard tanks together but due to the configuration of the pipe work in the engine room the pump would tend to draw more fuel from the port tank, causing the vessel to develop a starboard list. As the vessel had been steaming for only eight hours the Master attributed the list to uneven fuel tanks on departure.

1.1.12 The Master went down to the engine room and shut off the port fuel tank thus drawing fuel from the starboard side only. This action would normally bring the vessel upright again in approximately 12 hours. On his way back up to the bridge the Master spoke to the First Mate and told him that he had just shut down the port fuel tank and asked him to check the list when he went on watch at 0320 hours the following morning. If the vessel was upright then the First Mate was to re-open the port fuel tank suction.

1.1.13 At 2200 hours the first deck-hand, who was the First Mate's brother, took over the watch. The Master had written night orders on the chart stating; "plot the vessel's position every half hour, check the engine room half way through each watch and keep a lookout for small vessels not showing lights". The Master made a brief visit to the bridge at midnight as this was when the vessel was due to make an alteration in course off Cape Brett. The *San Hauraki* was steaming on a parallel course approximately two miles ahead and two points (22.5°) on the *San Manukau's* port bow.

1.1.14 At approximately 0230 hours the second deck-hand checked the engine room and found everything normal. The Master awoke at approximately 0300 hours and went out on deck. He saw the second deck-hand standing on watch and noting that everything appeared to be normal, went back to bed. The Master did not notice anything unusual in the movement or trim of the *San Manukau* at that time. The vessel was "moving easily" to a one metre sea on the port quarter.

1.1.15 At 0320 hours the second deck-hand woke the First Mate and after plotting the vessel's 0330 hour position on the chart he handed over the watch to the First Mate. The second deck-hand then checked the engine room again and, finding everything normal, went to bed. On taking over the watch the First Mate noted that the vessel still had a starboard list of approximately one to one and a half degrees. Light shining up through the Bosun Store hatch on the fore-deck was spoiling his night vision so he went out and closed its hatch cover, securing it with one of the five dogs (cleats).

1.1.16 At approximately 0520 hours the First Mate noticed that the starboard list had become more pronounced in spite of the corrective measures taken by the Master the previous evening. He estimated that the list had increased by one degree over the two hours he had been on watch.

1.1.17 When filling the ballast tanks on the *San Manukau*, at certain levels of trim, air-locks can form in the tanks sending a plug of water up the vent giving a false impression that the tank is full. The First Mate thought this might have been the case on this occasion so, although he had pressed number four port ballast tank full the previous afternoon, he decided to try pressing it further to help correct the list. Having turned the deck light on down aft to illuminate the overflow pipe he proceeded to the engine room, opened the appropriate valves to fill the port tank, and started the bilge and ballast pump.

1.1.18 The First Mate came up from the engine room and waited on deck expecting to see water overflowing on deck from the tank vent. After "five to ten minutes" pumping the tank had not overflowed, but the vessel was upright, so he proceeded back down into the engine room, stopped the pump and closed all the ballast valves, with the exception of the sea suction valve, which he left cracked. He recalled thinking it was strange that the tank had not overflowed, but did not investigate further. He was due to wake the Master in approximately 10 minutes for the 0600 hours watch, and intended to seek his advice on the matter then.

1.1.19 As the *San Manukau* was due to commence fishing later that morning, while he was in the engine room the First Mate decided to start the bilge and ballast pump running continuously on the fish hold bilges; however, he had been absent from the bridge occupied with the ballast for approximately 20 minutes and was concerned about the close proximity of the *San Hauraki,* and the possibility of local small boat traffic mentioned in the Master's night orders. He opened the screw-down non-return valve (NRV) for both of the fish room bilge suctions (numbers 20 and 21) and, with the intention of completing his task after the Master had taken the watch, returned to the bridge. On leaving the engine room, according to the First Mate's recollection, the bilge isolating valve between the sea and the fish hold (number 16) was left closed, the engine room bilge was dry and he closed the engine room door behind him. (See Figure 5 on page 12 for valve positions.)

1.1.20 The First Mate did not call the Master at 0545 hours as requested. At approximately 0550 hours the First Mate was sitting in the bridge chair when he heard the bridge binoculars fall over. It was then that he noticed the vessel had "lurched" approximately 10° to 15° over to port. He stood up, looked aft and observed the port quarter of the vessel submerged with "boiling white water almost covering the net roller on the port side".

1.1.21 Looking aft, the First Mate's initial reaction was that the vessel was "driving itself under" so he instinctively started to reduce the engine speed back to an idle.

1.1.22 The Master, who was asleep, woke up to what he described as a "shuddering and shaking". His initial reaction was that the vessel had run aground. He "leapt" out of bed, noticing that the vessel was listing over to port, and ran up the stairs to the bridge. When the Master arrived on the bridge the First Mate was still reducing engine speed. The Master instructed the First Mate to take the engine out of gear and asked "where are we". The list had increased to approximately 20°. The Master, realising that the vessel was going to capsize told the First

Mate to send out a Mayday. The First Mate had just reached the radio when the Master told him to "tell the others to get out, she is going to go over".

1.1.23 The second deck-hand did not feel any "shuddering and shaking". He awoke to find himself rolled against the bulkhead to which his bunk was attached. Realising that "something was not quite right" he ran out of his cabin toward the stairs leading up to the bridge. His progress was impeded by a torrent of water coming through the open doorway that led out on to the port side main deck. Reaching the foot of the stairs, he had to pull himself up the now near vertical stairs to the bridge.

1.1.24 As the second deck-hand reached the bridge, the First Mate was shouting for the two deck-hands to "get out". The first deck-hand shouted down the stairs to wake up the second deck-hand and then followed the Master and First Mate out of the bridge door, which was on the starboard side of the bridge. They climbed across the side of the now horizontal funnel in an attempt to reach the life-raft which was located on top of the bridge, but the vessel capsized before they could reach it and all three were thrown into the water on the seaward side of the upturned hull. The second deck-hand appeared from the direction of the stern having escaped through the open door leading out to the starboard side of the main deck. The Master and two deck-hands were dressed in their underwear, having been asleep, and the First Mate was lightly clad in shorts and a T-shirt. None of the four had time to don a lifejacket.

1.1.25 The crew, who were on the weather side, made several attempts to climb up on to the upturned hull but each time they suffered bruising as they were washed off by the one metre sea that was breaking against the hull. The first deck-hand, who appeared to be in shock, made no attempt to climb up on the hull. The First Mate, seeking shelter in the lee of the hull, swam to the bow and was swept past the hull by a surface current created by the build up of water on the weather side of the hull. Being a strong swimmer he managed to swim back and climb up on the lee side of the upturned hull. The First Mate called out for the other three to do the same.

1.1.26 The Master and the second deck-hand were also swept approximately 10 metres past the bow and struggled back where the First Mate assisted them up on to the hull. The first deck-hand could not swim and as he came around the bow he was carried further than the others by the current. The three on the hull could see he was having difficulty, only just managing to tread water. The First Mate entered the water again and swam to his brother. When he reached him his head was under water. The First Mate pulled him up and started toward the upturned hull. After some time the First Mate, who was becoming exhausted, realised that they were being carried further from the vessel by the current. He turned his brother over and noted that his eyes had rolled back in his head and water was flowing in and out of his open mouth. Realising that he could not save his brother as well as himself the First Mate let him go and struggled back where he was assisted by the others back up on to the hull. The second deck-hand was last seen floating away face down. This was at approximately 0610 hours.

1.1.27 The three survivors used the bilge keel and various appendages to hold on to the upturned hull for approximately one hour. During this time they could not recall seeing any obvious signs of hull damage that might have caused the vessel to capsize.

Rescue

1.1.28 On board the *San Hauraki*, the Engineer had commenced his bridge watch at 0500 hours that morning. When he accepted the watch he noted the *San Manukau* on his radar 2.3 nautical miles back on the *San Hauraki's* starboard quarter, close to the "radar shadow sector" (area of poor radar performance) which was caused by the *San Hauraki's* mast and engine exhaust pipes. The *San Manukau's* navigation lights were visible to him by eye.

1.1.29 The Engineer routinely checked the radar for other traffic in the area. At approximately 0550 hours he noticed the *San Manukau* had disappeared off the radar screen. He adjusted the radar controls to check its performance. As the radar was clearly displaying another ship eight miles away he assumed that the *San Manukau* had drifted further aft into his "radar shadow sector".

1.1.30 Having plotted the *San Hauraki's* 0600 hour position on the chart the Engineer stepped out of the bridge and looked aft expecting to see the *San Manukau's* navigation lights. Surprised that he could not see the *San Manukau* he stepped back into the bridge and called her on the VHF radio. There was no response so he called them on the cell phone. Unable to raise the *San Manukau* the Engineer woke the Master. The Master altered course 120° to starboard to move the radar shadow sector away from where the *San Manukau* should have been. There was still no sign of the *San Manukau* on the radar screen so the Master tried to send a message by satellite communications. The Master then altered course further to starboard towards where the *San Manukau* should have been and increased the *San Hauraki's* engine to full speed.

1.1.31 At 0615 hours the Master of the *San Hauraki* contacted Sanford and informed them that they had lost the *San Manukau*. On instruction from the Sanford contact the Master sent out a "Mayday Relay" using VHF radio. As the *San Hauraki* steamed back her crew stood on top of the bridge and used binoculars to scan the horizon for signs of the *San Manukau*. It was approaching sunrise and although the horizon was clearly visible the water below the horizon was still dark.

1.1.32 At approximately 0625 hours, in the improving light, the crew of the *San Hauraki* were able to make out the upturned hull of the *San Manukau*. After a further 20 minutes the *San Hauraki* arrived on the scene and the Master manoeuvred his vessel in close enough to the *San Manukau* for her crew to throw lines across to the three survivors. The survivors each tied a line around themselves and, with the assistance of her crew, were pulled across and taken on board the *San Hauraki*.

1.1.33 The *San Manukau's* Master indicated to the Master of the *San Hauraki* the area where the first deck-hand was last seen. They immediately started a search of the area. A number of local game fishing boats, three other Sanford fishing boats and a search and rescue aircraft joined the search. The search continued for approximately 14 hours and was abandoned soon after dark. The first deck-hand's body was not recovered.

1.1.34 The next day the three survivors returned to Auckland on the *San Hauraki* while the capsized hull of the *San Manukau* was towed into the sheltered waters behind Point Berghan on the south side of Doubtless Bay. During attempts to right her the *San Manukau* sank in approximately 30 metres of water settling upside down on the sea bed in position 34°55.26' S 173°32.996' E.

1.2 Vessel information

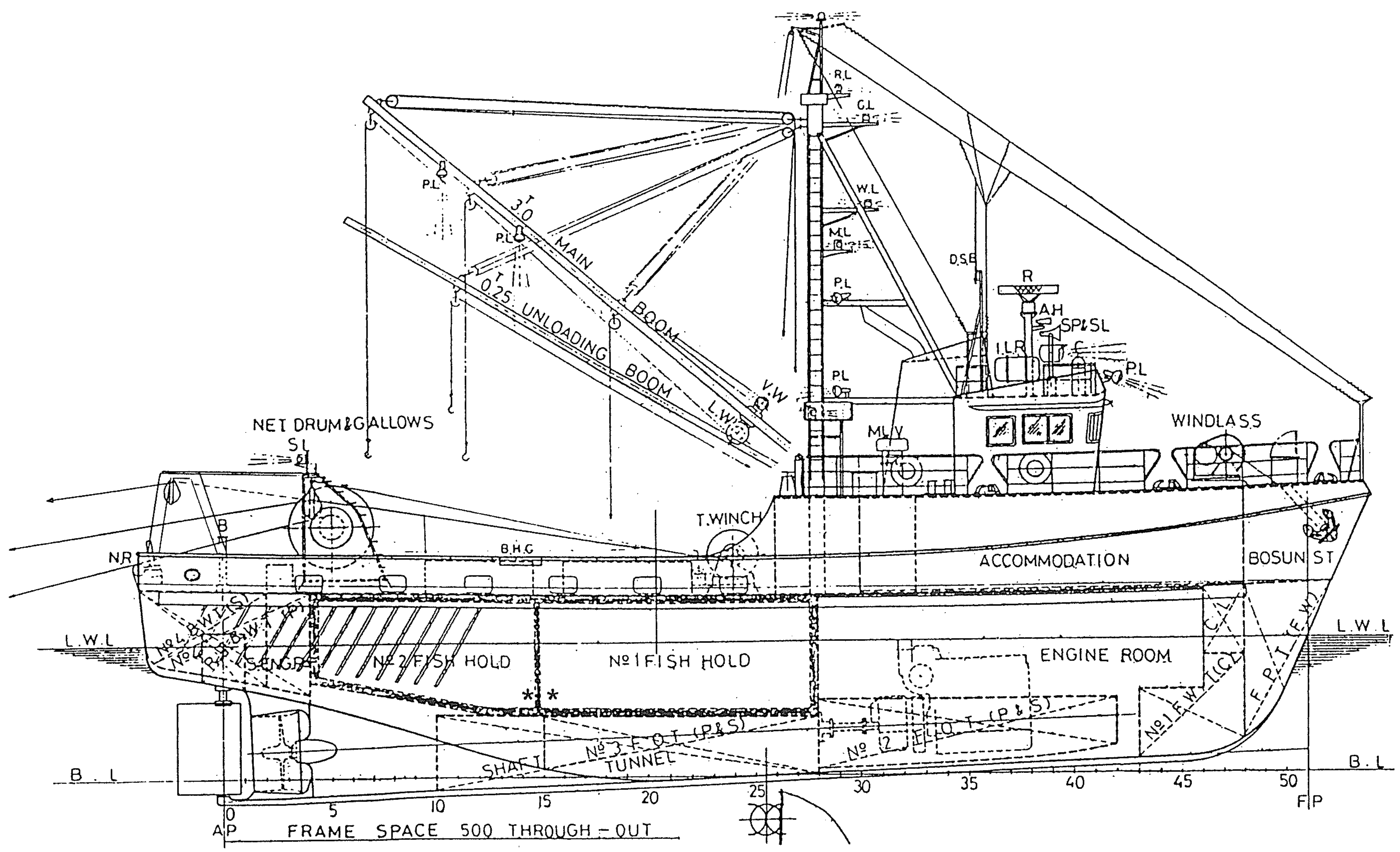
1.2.1 The *San Manukau* was one of four 29 m sister trawlers constructed in steel and powered by one 559 kW diesel engine driving a single, fixed pitch propeller shrouded by a fixed kort nozzle. She was designed to trawl either alone or pair trawl with one of her sister vessels, the *San Hauraki*. Electric power for the vessel was normally supplied by one of two Yanmar diesel driven 60 kVA generators.

1.2.2 The bridge, engine room and accommodation were situated forward. Access to the engine room and accommodation was through weather-tight doors on the main working deck. In the forward part of the accommodation was the Bosun Store which could also be accessed through a stores hatch on the front of the raised fore-deck. Access to the bridge was via a door from the starboard side of the raised fore-deck, or an internal stairway from the accommodation. The fore peak tank, which was used for fresh water, and the main fresh water tank were located forward of the engine room. (See Figure 2.)

1.2.3 Diesel fuel was carried in four tanks, one either side of the engine room and one either side of the shaft tunnel. The shaft tunnel was a water-tight space running back from the engine room under the fish holds near the centreline of the vessel. It accommodated the propeller shaft with its intermediate bearings and bilge/ballast pipelines. The propeller shaft was fitted with a water-tight gland where it passed through the hull of the vessel.

1.2.4 The catch was carried in the two fish holds which were supported on top of the shaft tunnel and the aft fuel tanks. The fish holds were common under deck but could be accessed through separate hatches on the main working deck. Each access was located within a larger working hatch for loading and unloading operations. The aft end of number two fish hold was supported by the solid floors in a void space which followed the line of the hull back from where the shaft tunnel and fuel tanks ended. (See Figure 2.)

1.2.5 The fish hold construction consisted of a layer of high density foam insulation sandwiched between layers of marine plywood and covered by a 10 mm layer of glass reinforced plastic (GRP). Timber bearers transferred the weight on the GRP floor of the hold through to the solid steel floors beneath. The wings (under-runs) of the fish holds were compartmentalised by solid GRP bulkheads into nine "bins" each side but the centreline run was common throughout (see Figure 4). Each compartment in the under-runs could be divided vertically by placing loose wooden boards into steel channel supports at two different levels. Using the same system of boards a working platform was usually constructed approximately one metre above the fish hold floor in the centre run. The platform usually extended from the forward end of number one fish hold back to where the floor of number two fish hold angled up to follow the line of the hull and provided a work area for sorting fish during loading. The space under this platform was often used to store lower grade fish in large bins (slurry tanks). Removable corrugated aluminium shifting plates held the fish bins, or ice, in the under-run compartments. There were no fore and aft watertight bulkheads to counter the effects of liquid free surface in the fish holds, although when the wooden boards and aluminium plates were in place, they would reduce any wave action caused by free liquid in the hold. The total volume of the two fish holds was 196.88 cubic metres. (See Figures 2, 3 and 4.)



* Position of hold bilge wells

Figure 2
***San Manukau*, profile**

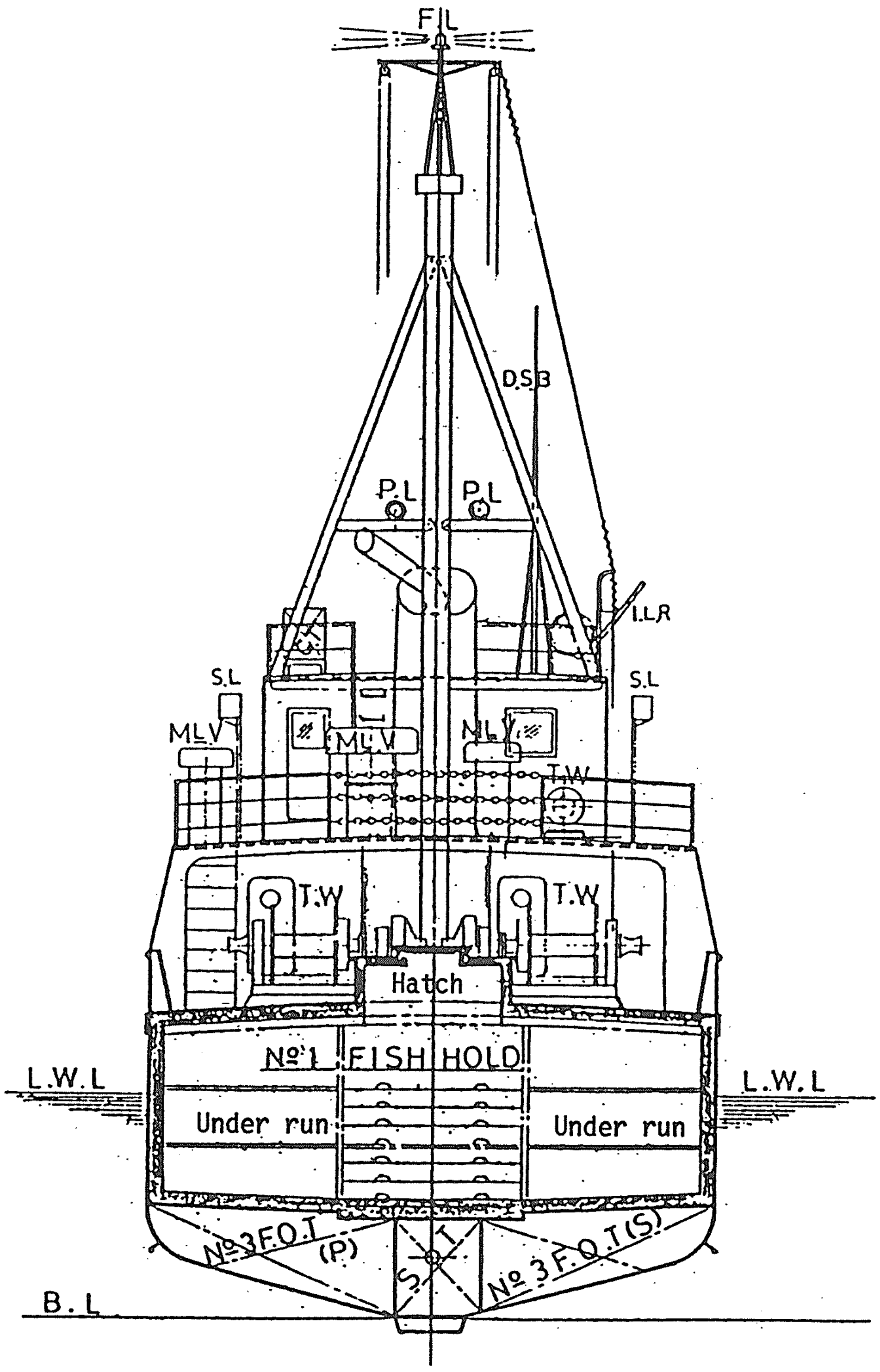
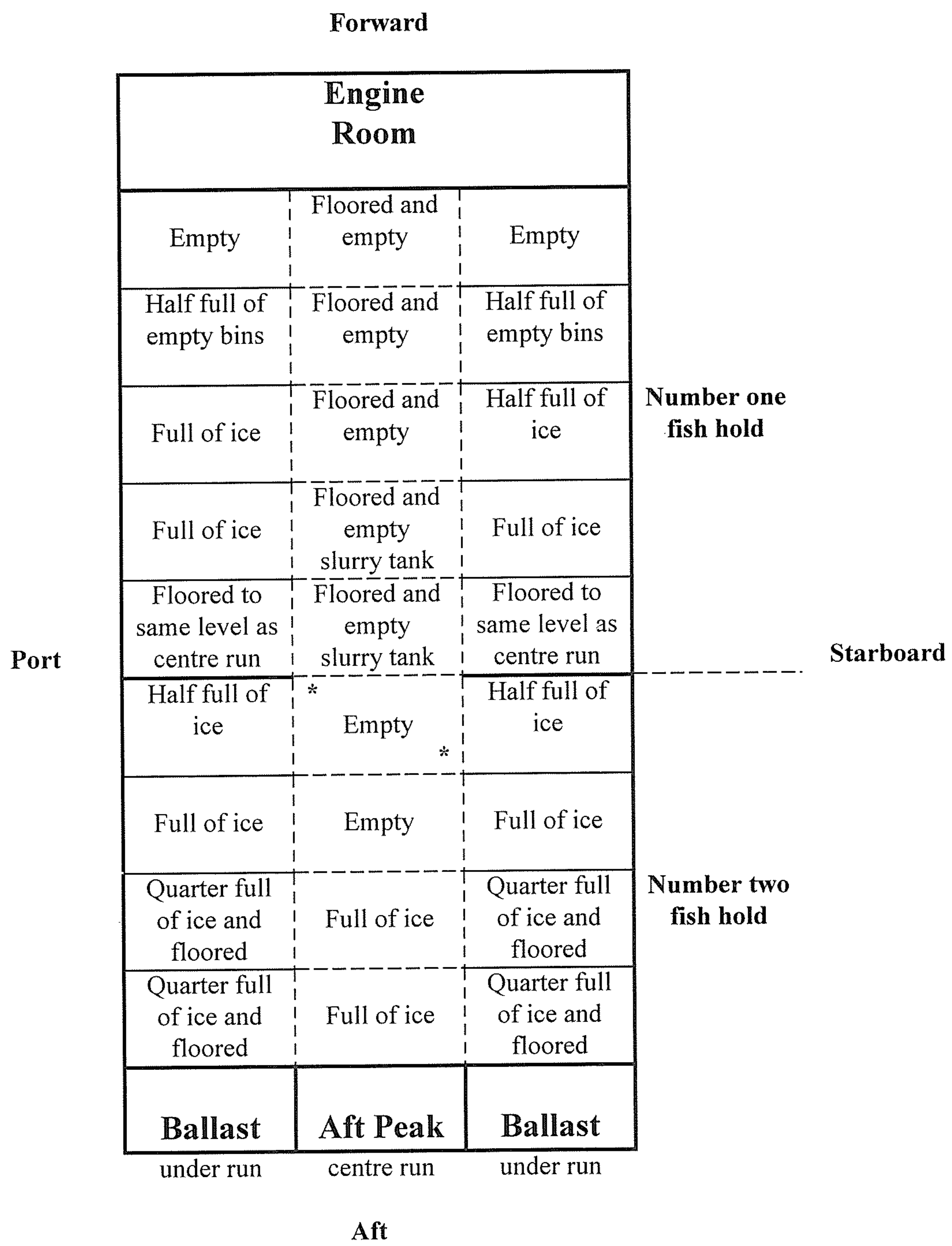


Figure 3
***San Manukau*, midship section**

1.2.6 On the accident voyage the *San Manukau's* fish holds were set up as shown below in Figure 4.



* Approximate position of bilge suctions

Figure 4
***San Manukau* Fish Hold Plan**

1.2.7 The fish holds were kept cool by a refrigeration unit in the engine room. The temperature was usually kept at approximately -1°C which was cold enough to maintain a frozen crust on the ice but leaving it soft enough to be easily moved around using shovels.

1.2.8 The electro-hydraulic steering system and emergency fire pump were located in the aft peak space at the centre rear of the vessel. Two ballast water tanks, one either side of the aft peak, provided a means of adjusting the trim of the vessel (see Figure 4). Access to the aft peak was through a weather-tight hatch on the main working deck. The fill/suction lines for the ballast tanks passed through the aft engine room bulkhead into the shaft tunnel, through the void space and into their respective tanks. The port ballast tank had a capacity of 17.69 cubic metres and the starboard tank 12.3 cubic metres. The difference in capacities was due to the aft peak access trunk passing through the starboard ballast tank.

1.2.9 Deck equipment included a net drum and gallows, two net towing winches and two derricks. The working derrick had a safe working load (SWL) of three tonnes and was used to haul the net and catch on board. The smaller unloading derrick had a SWL of 0.25 tonnes. A second set of gallows located right aft had been added to the vessel. This was to facilitate deep water fishing where the downward angle of the towing wires is greater which caused the wires to chafe on the stern of the vessel.

1.2.10 The bilge and ballast water pumping arrangement was serviced by two centrifugal pumps located in the engine room; the "general service pump", which was rated at 35 cubic metres per hour at 33 metres head, and the "bilge and general service pump", which was rated at 35 cubic metres per hour at 15 metres head. The arrangement was designed so that both pumps could be used to pump from any bilge space, or to fill either of the two ballast tanks; however, only the "bilge and general service pump" could be used to pump from the ballast tanks. Each pump was fitted with a suction gauge which could be used to indicate if the pump was drawing water, air, or if a pipe was blocked, but only if the user was familiar with bilge pumping systems. (See figure 5.)

1.2.11 The bilge spaces that could be pumped on the *San Manukau* were:

- Engine room
- Shaft tunnel
- Fish hold (port)
- Fish hold (starboard)
- Aft peak

1.2.12 An audible and visual "high level bilge" alarm was installed on the bridge to warn the crew if the engine room, shaft tunnel or aft peak bilges became flooded. The alarm in the aft peak had been retrofitted following an incident where it had flooded resulting in a loss of steering. The fish hold did not have such an alarm installed. Other vessels in the Sanford fleet had been installed with high level alarms in the fish hold but their crews regularly disconnected them as they were considered to be a nuisance when they continually alarmed when engaged in fishing. As the pumps could be started and stopped only from the engine room no indicator to show their running status had been installed on the bridge.

1.2.13 The void space under number two fish hold was not fitted with a sounding pipe for detecting the presence of water, nor was there any way the space could be pumped out in the event of it becoming flooded. The entire space and the pipes and fittings that ran through it had been coated at new building with epoxy paint formulated to protect steel in areas likely to be exposed to water and difficult to access for inspection and maintenance.

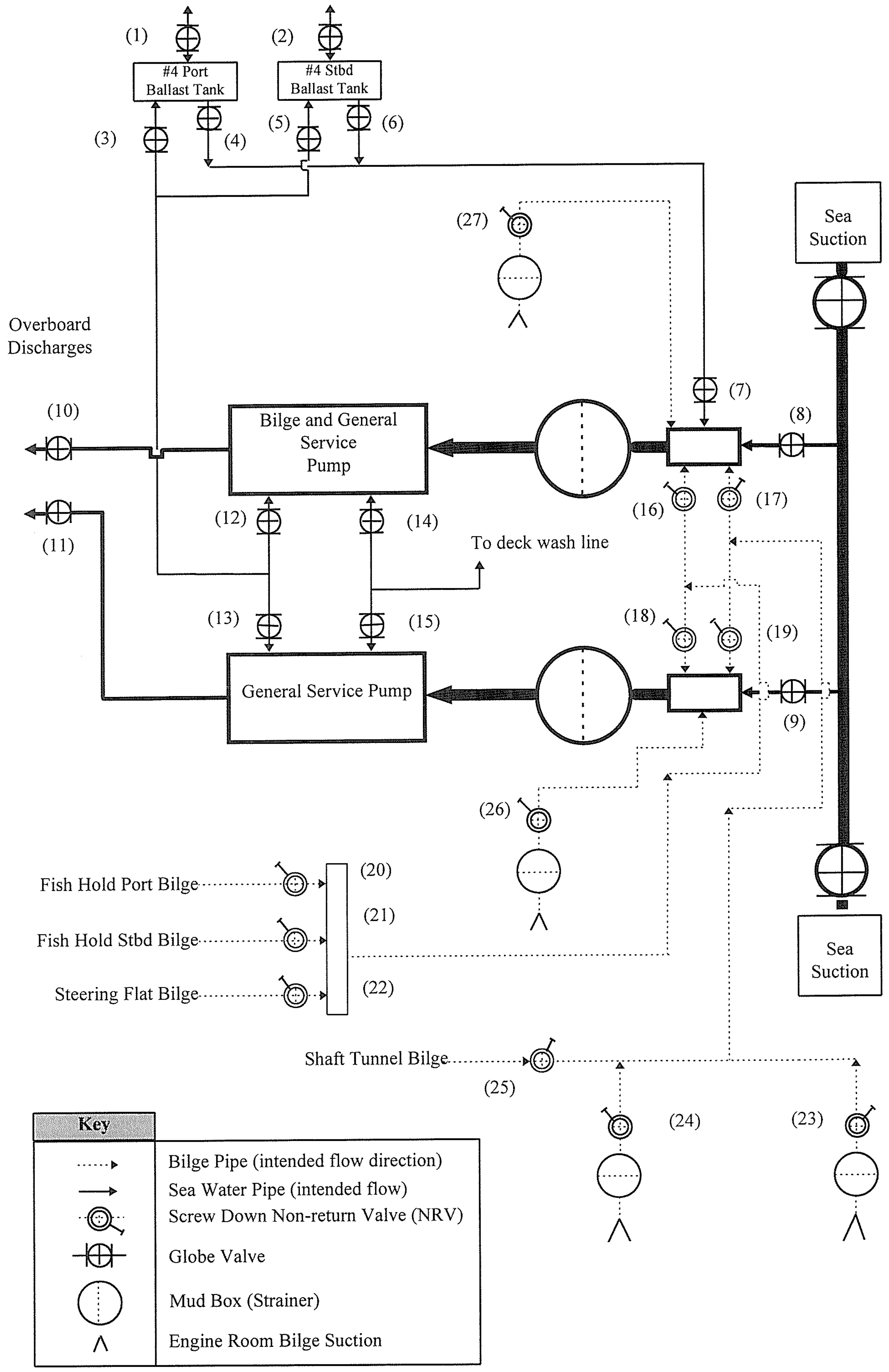


Figure 5
Schematic Sea Water and Bilge Water Piping Plan in Engine Room, *San Manukau*.
(See 1.5.6 for details of valve functions)

1.2.14 It was known that water collecting on the floor of the fish hold readily permeated through cracks and repaired sections of the GRP into the void space. On occasions when the *San Manukau*, and other sister vessels, altered their trim by the head significantly, water would, over a period of time, accumulate in the fish room bilges. It can be seen from Figure 2 that if the vessel had a stern trim with the void space full and the trim was adjusted to "even keel", this would create a "water-head" pressure on the underside of the fish hold insulation resulting in the water permeating back through the insulation into the fish holds. Permeation would stop when the water level in the void equalled the level in the fish hold (the spaces were common). When fishing, the crew would mistake this water as having come from melting ice and fish slurry.

1.2.15 Water would have been present in the void space for the later part of the vessel's working life, once the quality of the GRP had deteriorated with time and use and allowed water to permeate through it. Calculations show that the capacity of the void space was 21 cubic metres. It is estimated that the void space would hold approximately 10 tonnes of water when there was no surface water on the floor of the fish hold with the vessel on "even keel". No allowance had been made for this space in the vessel's trim and stability book.

1.3 Crew information

1.3.1 The Master of the *San Manukau* had been fishing for a total of 18 years. He obtained his "New Zealand Coastal Master" Certificate in 1984, "Mate of Deep Sea Fishing Boat" Certificate in 1992 and "Skipper of Deep Sea Fishing Boat" Certificate in 1994. He also held a "Second-class Diesel Engineer" Certificate and had completed most of his "First-class Diesel Trawler Engineer" Certificate. He had been serving as Master on Sanford fishing trawlers for five years, the last 14 months of which was served on board the *San Manukau*.

1.3.2 The First Mate had been fishing for 22 years. He obtained his "Mate of Deep Sea Fishing Boat" Certificate in 1986 and had been sailing as First Mate on a variety of trawlers since then. He had been sailing on the *San Manukau* and her other three sister ships for approximately eight years. The First Mate also held a "Second-class Diesel Trawler Engineer" Certificate. He was also "Acting Engineer" for the accident voyage as the vessel's permanent engineer was on leave. This was a position that he was qualified to hold, but he did not have any significant experience, as he was normally involved in deck operations.

1.3.3 The first-deck-hand had been employed in the New Zealand merchant navy for a short period and in the late 1970's he began a career in the fishing industry. He held a "New Zealand Coastal Master" Certificate and a "Second-class Diesel Trawler Engineer" Certificate and had been employed on various fishing boats "on-and off" over the ensuing years.

1.3.4 The second deck-hand had 13 years experience in the fishing industry. He obtained his "Qualified Fishing Deck Hand" Certificate in 1987 and had since been employed on a variety of Sanford and other fishing vessels as either deck-hand or Bosun.

1.3.5 Although Sanford was the crew's employer, Sanford's company policy was to leave the selection of the crew to the Master. The Master usually recruited crew with whom he was familiar, resulting in a close knit team approach to life on board. The *San Manukau's* Master, Mate and first deck-hand had fished together on numerous occasions over the previous 10 years. The second deck-hand was temporarily employed to make up the numbers while the permanent engineer was on leave. The Master had sailed with the second deck-hand in the past.

1.3.6 The manning level on the *San Manukau* met the requirements of the Shipping (Manning Of Fishing Boats) Regulations 1986.

1.4 Weather information

1.4.1 The weather forecast current for the sea area off Cape Karikari was for south-east winds of 25 knots, a three metre south-easterly swell, easing, and fine.

1.4.2 The weather conditions at the time of the capsize were described as fine with very good visibility. A 15-20 knot south-south-east wind was causing a one metre sea to come from behind on the port quarter. There was no significant swell. The *San Manukau* was "moving easily" and taking spray across the stern but was not shipping seas on deck. The air temperature was described as "hot" during the day and "warm" at night.

1.4.3 The average sea water temperature for the area was approximately 21° C.

1.5 Salvage operations/damage to the vessel

1.5.1 The Master and crew could not recall, from their time spent sitting on the upturned hull of the *San Manukau* awaiting rescue, seeing any damage to the hull that may have contributed to the capsize. Analysis of video footage taken from sea and air rescue craft confirmed this.

1.5.2 The second deck-hand's personal video camera was salvaged from the *San Manukau*. He had been taking video footage of the *San Manukau* as they were steaming past Kawau Island, shortly after the First Mate had pressed the ballast tanks. Analysis of the video confirmed that the *San Manukau* had an approximate 1.5° starboard list at that time.

1.5.3 When the *San Manukau* sank and landed upside down on the sea floor, the main mast was bent sideways but remained attached. The vessel was resting in an unstable position supported by the gallows aft and the funnel and mast structure forward.

1.5.4 A salvage team using air bags managed to raise the vessel to the surface where it rolled over and sank again, landing upright on the sea bed. The vessel sustained some bottom damage where it landed on rocks protruding from the sandy sea bed.

1.5.5 Over the next nine weeks fuel oil was removed from the hull to reduce the risk of pollution during the continuing salvage operation. The vessel was raised off the bottom and towed in stages into shallow water. Several compartments in the hull, including the fish hold, were sealed and filled with air to add to the buoyancy provided by the air bags to lift the vessel off the sea bed. During the process more bottom damage was sustained as the vessel was lowered back on to the sea bed after each stage. In order to seal off the various compartments salvage divers had to close several valves in the engine room. Where this was done, the status of the valves before moving them was recorded. The two fish room bilge suction valves in the engine room were found in the open position. This was consistent with the First Mate's testimony.

1.5.6 The *San Manukau* was re-floated on Thursday, 4 April 1996 and towed into Manganui Harbour. Inspection of the bilge and ballast valves in the engine room, and diver records, revealed the following (see Figure 5 for the position of the valves in the system):

Valve #	Valve function	Valve status
1	# 4 port ballast tank main valve	closed
2	# 4 starboard ballast tank main valve	closed
3	# 4 port ballast tank filling valve	closed
4	# 4 port ballast tank suction valve	closed
5	# 4 starboard ballast tank filling valve	closed
6	# 4 starboard ballast tank suction valve	closed
7	Ballast suction isolating valve	closed
8	Bilge and GS pump sea suction	open 2 of 6 turns
9	General service pump sea suction	fully open
10	Bilge and GS pump overboard discharge	closed
11	General service pump overboard discharge	closed
12	Bilge and GS pump ballast cross-over	closed
13	General service pump ballast cross-over	closed
14	Bilge and GS pump fire line/deck wash cross-over	closed
15	General service pump fire line/deck wash cross-over	fully open
16	Bilge and GS pump hold bilge isolating NRV	fully open
17	Bilge and GS pump engine room isolating NRV	closed
18	General service pump hold bilge isolating NRV	closed
19	General service pump engine room isolating NRV	closed
20	Fish hold port bilge suction NRV	fully open
21	Fish hold starboard bilge suction NRV	fully open
22	Steering flat bilge suction NRV	closed
23	Engine room forward bilge suction NRV	closed
24	Engine room aft bilge suction NRV	closed
25	Shaft tunnel bilge suction NRV	closed
26	GS pump direct engine room bilge suction NRV	closed
27	Bilge and GS pump engine room direct bilge suction NRV	closed

1.5.7 On Sunday, 7 April the *San Manukau* left Manganui under tow bound for Auckland. On Tuesday, 9 April she was slipped in Auckland to undergo examination, assessment and partial repair. (See Figure 6.)

1.5.8 The number four port and starboard ballast tanks and their associated pipe work were pressure-tested and closely inspected to determine why the port tank had lost the unknown quantity of water that was initially thought to have caused the increasing starboard list prior to the capsize. A sister vessel had previously encountered problems with ballast pipes leaking ballast water into the void space and fish hold. The problem on the sister vessel was traced to a leaking pipe, where vibration had caused the pipe to chafe and corrode where it passed through an opening in a solid floor in the void space. Sections of the *San Manukau's* fish hold floor were cut out to allow for inspection of the void space and pipe lines running through it. The void was found to be full of water up to a level just under the number one fish hold floor. The *San Manukau's* ballast tanks and pipe work were found intact and in very good condition.

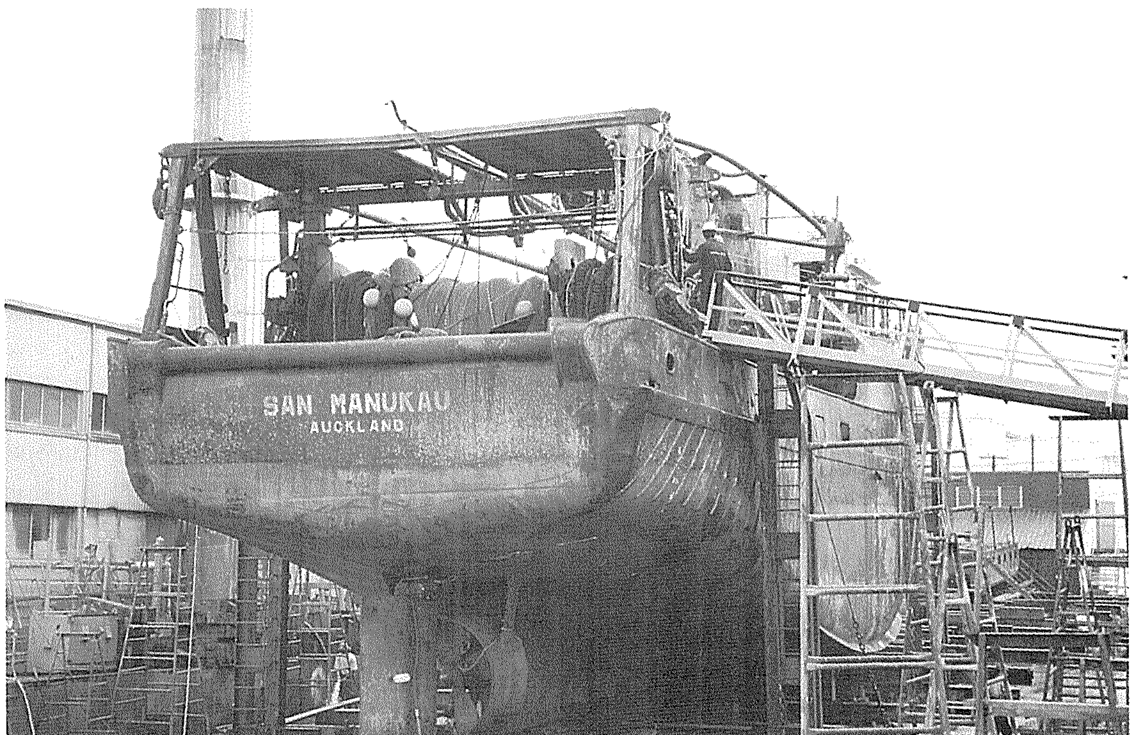


Figure 6
***San Manukau* on the slip after salvage**

1.5.9 All of the valves associated with the ballast system were dismantled and inspected. Valves number 3 to 9 and 12 to 14 (inclusive) had a build-up of scale on the valve seat consistent with approximately one year in use without service. These valves "weeped" if not closed tight. Valves number 1, 2 and 15 were in slightly worse condition consistent with approximately one year in use without service, but not having been opened and closed as frequently as the other valves. These valves leaked slightly under pressure even when closed tight.

1.5.10 The bilge NRVs associated with the fish hold (numbers 20 and 21) and steering flat (number 22) were dismantled and inspected. All the valves, with exception of the steering flat bilge suction valve, were found with their internal "check" valve seized on to its spindle by scale and fish residue. This meant that the valves were acting as a normal globe valve allowing water to flow in either direction when open i.e. allowing water to flow back into the bilges when they were in the open position. The aft peak bilge suction NRV was operating normally.

1.5.11 The setting and condition of the NRVs, as found, meant that sea water had a free path back into the fish hold bilges at the time of the capsize.

1.5.12 The *San Manukau* was subsequently declared by her owners and underwriters as a total constructive loss. Their effort, involving considerable time and expense, put into the salvage operation to determine the cause of the capsize when the vessel was likely to be declared a total loss, should be acknowledged.

1.6 Company and vessel procedures

1.6.1 The company policy was for the Master to take responsibility for his vessel and crew while at sea, and the company took over the vessel responsibility while it was in port (at the wharf).

1.6.2 While the vessel was at sea the crew were expected to carry out minor repairs to maintain the seaworthiness of the vessel. All running maintenance and major repair work was carried out by the company's repair and service network located in their main ports of call around New Zealand. If major mechanical repairs were required while the vessel was at sea, assistance was sought from ashore.

1.6.3 The "Company's Instructions to Masters" included the following;

> Sanford expects and requires all Masters to:
>
> - Implement instructions
> - Ensure compliance with legal requirements
> - Report maintenance needs and vessel requirements.
> - Generally maintain safe navigation and seamanship practices on board and ensure that crews are provided a safe working environment.

1.6.4 At the end of each voyage the Master completed a "Trawler Log Sheet" on which was listed any repairs, service, and stores that were required. On arrival at the wharf the Master handed the sheet along with other voyage documentation to the vessel's "Husband" (superintendent). The Master and crew would then go on leave until the vessel had been unloaded, stored and, where necessary, repaired ready for the next voyage.

1.6.5 The "Husband" arranged for the vessel to be serviced according to the "Trawler Log Sheet" and the company's repair and maintenance system. He made out "Fleet Operations Work Orders" which were passed on to the relevant Sanford division. Outside contractors were regularly used for specialist work. The work reports and invoices were collated back in the office. There was no written feedback to the vessel's Master on what work had, or had not, been undertaken.

1.6.6 The length of voyages undertaken by the *San Manukau* varied from a few days to 2-3 weeks depending on the location and nature of the fishing operations. During a voyage the aft (number three) fuel tanks were used to off-set the stern trim the vessel acquired as the fish hold was filled. The forward (number two) fuel tanks were not often used though all tanks would usually be filled to capacity. Refuelling was carried out by Sanford's shore staff. The tanks were not usually sounded after filling and, depending on the list and trim of the vessel, air locks could and did form in the filler pipe giving the false impression that the tank was full.

1.6.7 Unloading of the vessel's catch was undertaken by Sanford's shore staff. As they discharged the fish the vessel would acquire a negative trim (bow down attitude) causing any slurry from the melting ice and fish, and water permeating through the insulation from the void space, to collect in the forward part of the hold, away from the bilges which were located toward the rear, in number two fish hold. To facilitate pumping out the fish hold during discharging operations, the number four port and starboard ballast water tanks were, on occasions, partially filled to achieve a stern trim. This was sometimes carried out by Sanford's shore staff.

1.6.8 The shore staff, on completion of unloading, were responsible for cleaning of the fish hold and its bilge spaces in preparation for "icing" the vessel prior to her departure. This involved hosing down the space and pumping the mixture of water and fish residue out using the vessel's bilge pump. Most of the solid fish residue and scales were filtered out by the stainless steel mesh that covered the bilge; however some fish residue would slip through and be pumped out through the bilge system, often causing blockages in the lines, valves or pump strainer. When a blockage occurred the shore engineer would attend the vessel to clear the bilge system. Only the "used" ice slurry was removed from the fish hold. The unused ice was left on board for the next voyage.

1.6.9 When fishing, or carrying fish on board, the relatively warm temperature of the fish and the opening and closing of the fish hold hatch cover would cause the ice to melt. It was normal practice on board the *San Manukau,* and her three sister vessels, to run the "bilge and general service" pump drawing continuously from the fish hold. Water in the bilge would automatically be picked up by the pump and when the bilge ran dry, pump suction was maintained by the flow of sea water from the pump's partially open sea water suction valve.

1.6.10 If the vessel was going to engage in fishing soon after leaving port the bilge pump was normally started on leaving the wharf. This was normally the case. On several occasions Masters had experienced difficulty pumping the fish hold bilges at some time during the voyage. This was usually due to fish residue from the fish holds blocking the bilge strainer or valves in the engine room. "Old" ice stowed in compartments from previous voyages often developed gaps between the ice and the compartment walls due to melting. Fish would sometimes become wedged in these gaps, out of sight, when being sorted in the hold during loading. After the unloading gang had cleaned the fish hold and the vessel had been sitting at the wharf for a period of time, the fish could become dislodged from the gaps and gravitate into the bilges giving the impression that the holds had not been cleaned properly. On other occasions the fish holds had not been properly cleaned.

1.6.11 If the Master experienced problems pumping out the fish hold early on in a voyage, steps were taken on board to rectify the problem, either by back-flushing the bilge lines to the fish hold or clearing blocked valves in the engine room. If the vessel was due to enter port, the problem was often left and noted down on the trawler log sheet for actioning by Sanford shore staff. Inspection of company records confirms this practice.

1.6.12 The last recorded problem with pumping of the *San Manukau's* fish hold was in December 1995, one and a half months prior to the accident. Company records show the Master's request on the trawler log sheet worded "Fish Hold not pumping properly - suspect blocked sumps". A Fleet Operations Work Order was made out which among other jobs, was worded " 4) F/Hold not pumping". There is no record of why the fish hold would not pump, or what work was carried out on the fish hold pumping arrangement.

1.6.13 There had been a number of reported incidents over the years involving back-flooding of the fish hold via the bilge system on various company vessels. The most common cause was crew, or shore staff, leaving the NRVs open after pumping out their fish hold bilges. It was common knowledge around most of the fleet personnel that fish hold NRVs were prone to failure in this manner. This knowledge was either gained from experience, or by oral instruction from the company.

1.6.14 At the start of a voyage the Master and crew would rejoin their vessel in sufficient time to prepare the vessel for sea. The Master of the *San Manukau* usually checked his own copy of the "Trawler Log Sheet" to see what jobs had been completed. In the absence of documented feedback he often relied on the "debris" left by the workmen as an indication that a job had been undertaken.

1.6.15 The Master of the *San Manukau* did not usually sound the tanks prior to departure. He could usually see if his vessel had been refuelled by "how the vessel was sitting in the water". The crew were responsible for "icing" the vessel prior to departure. The amount of ice taken on board varied depending on the type of fishing operation, the amount of ice remaining from the previous voyage and each individual Master's preference. The crushed ice was loaded from trucks and distributed in alternate compartments in the under-runs leaving the hatch squares free to facilitate the loading and icing of the fish during fishing operations.

1.6.16 During normal working hours the Master could contact the Sanford shore staff to confirm what repairs, maintenance and servicing of his vessel had been completed during that period in port. After hours numbers were provided for this purpose; however, according to the Master, the relevant people could not always be contacted in time, particularly when the vessel's time of departure was critical due to tidal and weather conditions over harbour bars.

1.6.17 The absence of a formal hand-over between the company superintendent and the Master sometimes resulted in the vessel putting to sea with the Master not being totally aware of the state of his vessel.

1.6.18 The company produced a "Skipper's Declaration and Instructions to Masters" booklet which all Masters signed and a copy of which was placed on board each vessel. From time to time a "Memorandum" would be circulated to all Masters addressing certain safety or operational issues. The memoranda were not numbered and carried no instruction on how to store, or dispose of them nor the procedure for their implementation. Verbal communication was often relied on to pass on safety messages arising from incidents, accidents and problems encountered on other company vessels.

1.6.19 It has been suggested by several witnesses directly involved with the fishing industry that, in general, due to many fishermen's antipathy to written instruction, verbal communication is usually the most effective method of passing on safety messages.

1.7 *San Manukau* stability information

1.7.1 A full and comprehensive set of stability documents was placed on board which included several sample stability calculations for key conditions. The sample conditions showed that the *San Manukau* had ample reserve stability for all intact conditions. No sample "damaged stability" calculations were provided in the vessel's trim and stability booklet, nor were they required to be. The Master of the *San Manukau* had read through the stability documents when he first took command of the vessel and had satisfied himself that the vessel was inherently stable. Stability calculations were rarely made before or during a voyage.

1.7.2 The *San Manukau's* statical stability was portrayed as good at normal angles of trim; however, her relatively low freeboard aft, and thus reserve buoyancy aft, meant that when the vessel was trimmed significantly by the stern, deck edge immersion occurred at relatively small angles of heel and consequently her range of stability decreased accordingly.

1.7.3 Using the trim and stability data supplied with the *San Manukau,* number one and two fish holds were treated as separate compartments and added weights were calculated as being placed in the centre of each hold. This would give a fairly accurate result of transverse stability assuming the added weights were secured and not left free to move within the holds.

1.7.4 Number one and two fish holds were common through the centre run and extended from side to side of the vessel. In the event of flooding, water was free to flow from one side of the vessel to the other, as the vessel was heeled by external forces (wind and sea). The inertia effect of the water as it flowed would vary depending on the amount of fish on board and the number of retainer boards keeping the fish and ice in place but, regardless of this, the water was able to flow in both fore and aft and athwartships direction.

1.7.5 The natural tendency for a Master is to trim the vessel by the stern for better fuel economy and control of the vessel, and to allow any liquids accumulating in the fish hold to naturally gravitate back to the fish hold bilges which could be pumped out. This scenario works well so long as the water is pumped out on a regular basis and not allowed to accumulate on the floor of the fish hold.

1.7.6 If water was allowed to accumulate in the fish hold, it would naturally gravitate aft thereby increasing the stern trim and lowering the freeboard near the stern. This, combined with the effect of free surface on transverse stability would erode the vessels residual stability; or area under the GZ curve (its ability to return to the upright when heeled). (See Appendix A.)

1.7.7 The void space under the fish hold also extended from one side of the vessel to the other. Although the space was divided athwartships by four intercostal girders (plate running fore-and-aft between the solid floors) these acted as "wash bulkheads" only. Water could flow through the lightening and drain holes in the girders from one side of the vessel to the other.

1.7.8 Calculations were made to determine the *San Manukau's* stability condition (intact) before flooding of any spaces. As no calculation was made before departure from Auckland most of the tank levels were estimated. The following results were obtained:

Trim	0.387 m
Displacement	444.91 tonnes
Corresponding mean draft	3.378 m
KG	3.285 m
GM	0.918 m
Free surface correction	0.094 m
GoM	0.824 m
Maximum GZ (righting lever)	0.364 m at 42.5° heel
Range of stability	0° to over 60° heel

1.7.9 A computer model was made of the *San Manukau* and her response to loaded conditions analysed. The analysis was extended to consider the progressive flooding of the fish hold and void space by the mass transfer method to deduce the quantity of water in these spaces required to produce instability, and the manner in which the instability occurred.

1.7.10 Results show that when the fish holds were flooded with sea water to 50% of the total volume this produced a stability curve where positive stability vanished at 12° angle of heel. The maximum positive GZ would have been 0.016 metres at 5° angle of heel. This meant that if the vessel was heeled by external forces (wind, sea or both) to an angle of 12° or more the vessel would become unstable and begin to capsize.

1.7.11 Fifty percent of the combined volume of number one and two fish holds equates to 98 tonnes of water. Calculations indicate that it would take approximately 8.7 hours for this amount of water to flood back through the bilge system with the valve setting and condition as found. This figure may vary depending on the attitude of the vessel in the water and resultant driving force of the water through the bilge system. At the time of the vessel's capsize she had been at sea for 17.8 hours.

1.7.12 Figure 7 shows the GZ curves for the *San Manukau* before, during and after flooding of the void space and fish hold.

2. Analysis

2.1 The weather conditions as described at the time of the *San Manukau's* capsize could not have caused the vessel to capsize. The vessel was not engaged in fishing and therefore had no fishing gear extended into the water. The vessel was approximately 15 nautical miles from the closest known navigational hazard and there was no evidence to suggest that it had suffered any hull damage that would affect her watertight integrity. The intact stability as calculated after the capsize showed that the vessel should have been well within allowable limits and should not have capsized without other significant external or internal forces acting upon her.

2.2 As there was no evidence of undue external forces acting upon the *San Manukau* at the time of her capsize it is believed that she experienced a progressive flooding of internal spaces resulting in a loss of stability sufficient for her to capsize.

2.3 The manner in which the *San Manukau* was observed to capsize (corkscrew over to port and by the stern) suggested that the internal space, or spaces, that were flooded would have been aft of her longitudinal centre of gravity. Examining each of these spaces in turn;

2.3.1 **The ballast tanks -** The starboard tank was full and therefore was not considered. The port ballast tank had been full and appeared to have lost an unknown quantity of water which was later replaced when the First Mate filled it again. This will be addressed later in the analysis but the tank itself is considered to have contributed to the loss of stability. Both these tanks and their associated pipe work were tested after salvage and found to be intact.

2.3.2 **The aft peak -** Calculations show that the flooding of this space alone could not have caused the capsize. If this space had become flooded the bilge alarm would have sounded on the bridge, and the vessel would have lost steering when the electrics associated with the electro-hydraulic steering system became immersed. There was no reported loss of steering or bilge alarm sounding before the capsize.

2.3.3 **The shaft tunnel -** Calculations show that flooding of this space alone could not have caused the capsize. As with the aft peak, this space was also fitted with a bilge alarm which was not activated prior to the capsize.

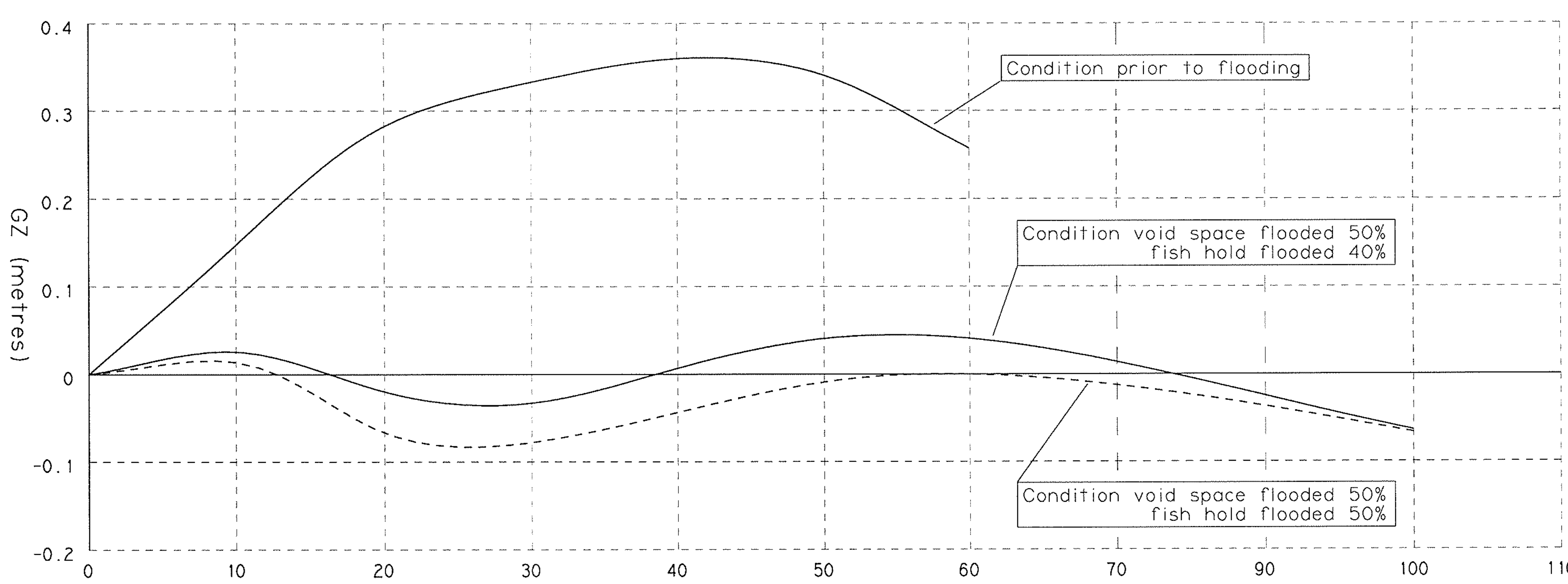


Figure 7

San Manukau Diagrams of righting lever (GZ curve) for intact and flooded conditions

2.3.4 **The engine room** - This space is forward of the tipping centre of the vessel and if flooded, would have trimmed the vessel by the head. It too was fitted with a bilge alarm which was not activated prior to the capsize. Approximately 10 minutes before the capsize the First Mate had been in the engine room and recalled the bilge level as being "normal".

2.3.5 **The void space** - As it was known that water would gradually permeate through the fish hold insulation it is considered likely that this space had been permanently flooded to about 50% of its total volume (approximately 10 tonnes). This would have the effect of reducing the vessel's stability due to free surface and reduction of freeboard aft. The crew would not be aware of this as there was no means provided for sounding, pumping or entering the void space without cutting through the fish hold floor.

2.3.6 **The fish hold** - Number one and two fish holds were common and have been combined when considering the effects of free surface and "mass transfer" of liquids within them. Calculations have shown that the effect of 98 tonnes (50% of capacity) of water in the hold, when combined with the effect of approximately 10 tonnes of water in the void space, would be enough to reduce the *San Manukau's* residual stability to a point where she would capsize with very little influence from outside forces.

2.4 Given the weather conditions at the time it is unlikely water entered the fish hold through its hatch covers, which were found secured. Similarly, the bilge and ballast lines that passed through the void space to other compartments were found intact discounting this as a possible source of water ingress.

2.5 When considering the combined effect that water in the fish hold and void space had on the vessel's stability, and the position and state of the fish hold bilge NRVs, it is considered that water entered the fish hold through the bilge system ultimately leading to the *San Manukau* capsizing.

2.6 The First Mate stated that on the day before the capsize he used the pump to draw directly from the bilges without priming the pump with sea water. The vertical distance between the pump in the engine room and the fish hold floor is 1.5 metres. When the First Mate was preparing the valves for pumping out the fish room the following morning (approximately 10 minutes before the capsize) he opened both of the fish hold bilge suction valves. It could be reasonably assumed that he intended to pump both of the bilges at the same time.

2.7 A centrifugal pump will have difficulty picking up suction on a dry bilge line without being primed first. This difficulty would be accentuated if two bilge lines were open to the pump (doubling the chance of drawing air). If the First Mate had used the same procedure the previous afternoon, it is unlikely that the pump ever gained suction on either of the fish hold bilges. Alternatively, the bilge strainer may have been blocked by fish residue remaining in the fish hold. In either event the use of the suction gauge would have provided the First Mate with more information on how the pump was performing. It is not known how much water was in the fish holds at that time as no soundings were taken and nobody entered the fish hold thereafter.

2.8 The First Mate was not the permanent engineer on board the *San Manukau* and therefore was not, and could not be expected to be, as familiar with the bilge and ballast pumping arrangement as the permanent engineer. When he had satisfied himself that the fish hold bilges were empty he left the pump running and adjusted the valves to fill both ballast tanks. This would have involved opening and closing 10 valves in the right sequence to avoid undue wear on the pump caused by loss of suction or closing off on the discharge side of the pump. It is possible that one or more of the bilge and ballast valves were left open, or not fully closed, during the First Mate's attempts to effect the change.

2.9 There is some doubt as to how long the fish hold had been progressively flooding. According to the First Mate's statement he closed down all of the bilge and ballast valves after pumping out the fish hold bilges and pressing up both ballast tanks between 1500 and 1600 hours on the Saturday. If all of the valves had indeed been closed as stated by the First Mate, then it is unlikely that progressive flooding of the fish hold would have occurred over the ensuing 13 hours. For this to happen water would have had to pass through three closed valves. It is not uncommon for one valve to leak when foreign bodies become trapped between the valve and valve seat at the time of closing, and on very rare occasions two consecutive valves may leak, but it would be most unlikely for three consecutive valves to leak in this manner.

2.10 The port ballast tank was pressed up at 1530 hours the afternoon before the capsize. If an air lock had formed in the tank when filling, then it may have only been approximately 98% full. When the First Mate pumped for "5 to 10 minutes" into that same tank the following morning (just prior to the capsize) he would have pumped approximately 4.5 cubic metres of sea water into a tank that was supposed to have been full. Assuming the best case scenario (where the tank was just about to overflow when the First Mate stopped the pump) the tank had lost 4.5 cubic metres of ballast water over 13.5 hours at a rate of 5.5 litres/minute.

2.11 As the ballast tank and ballast pipe work were tested and found intact, the lost ballast water can only have leaked back through the valves and into the suction chamber of the bilge and ballast pump. From here it could have either leaked back to sea through number 8 sea suction valve or, if number 16 bilge isolating valve was open, ballast water would have chosen this easier path and pressurised the bilge line leading to the two fish hold bilge suction valves numbers 20 and 21. If either of these valves was leaking, or had been left open, then the 4.5 cubic metres could have found its way into the fish hold over that 13.5 hours.

2.12 When ballast valve numbers 1 to 6 were subsequently opened, inspected and tested under pressure, each was found to be weeping; however, when two valves were closed in line, they successfully held water against the head of a full ballast tank. It is likely that one or more of these valves were left open, or not closed properly, allowing water to leak back to the pump overnight. It should be noted that valves number 4, 6 and 7 associated with deballasting would not have been touched by the First Mate that voyage so their status at the beginning of the voyage was not known. This was an alternative path the water could have taken back to the pump suction chamber.

2.13 The First Mate "thought it strange" that he was able to pump for "5 to 10 minutes" into the port ballast tank which he had seen overflow the previous afternoon. It is likely that he made sure all the valves were closed tight at this time with the exception of the number 8 sea suction valve which he left "cracked" in preparation for pumping the fish hold bilges. He then opened the two fish hold suction valves and left the engine room for the bridge thinking that the number 16 bilge isolating valve was closed. If it had been left open the previous afternoon then an open path was set for sea water to enter the fish hold back through the failed NRVs at this time. This, combined with the ballast water from the port tank and sea water already collected in the hold, would have been sufficient to cause the vessel to capsize.

2.14 The accident voyage of the *San Manukau* did not differ substantially in some respects from most other voyages that she had undertaken over the previous 17 years. There have been several known past incidences of the *San Manukau's* fish hold being flooded back through the bilge system. To the Commission's knowledge these have all occurred when the vessel was tied up at the wharf under sheltered conditions.

2.15 The practice of running the bilge and ballast pump continuously drawing from the fish hold bilges while the vessel was at sea, primed by the open sea suction valve was, in itself, an unsafe one. On the *San Manukau* there was no indicator on the bridge to show the running status of the pump, other than the watch keeper looking over the side at the overboard discharge. If the pump stopped, unnoticed by the sole watch keeper at night, it would be left up to the action of the NRVs to prevent sea water flooding back into the fish hold. The condition of the NRVs for the fish hold bilges indicated that they were not overhauled (freed) in December 1995, the last time work was carried out on the bilge system. It is likely that the problem was "blocked sumps" and that this was attended to before the vessel sailed. The NRVs may not have been blocked at this time but it is unlikely that they were operating effectively as a NRV either.

2.16 NRVs are placed in a system to assist the pump to gain suction and to stop the inadvertent return flow of water back through the system. They are a relatively simple device but require regular maintenance, especially if liquids containing debris pass through them.

2.17 It should be common knowledge to a prudent, appropriately qualified mariner that NRVs should never be relied upon to stop the back flow of water for long periods. The crew of the *San Manukau* were appropriately qualified and were aware of this danger, even though it was not documented in company policies and procedures. Sanford state that this was a subject of oral instruction.

2.18 Ironically, if the bilge pump had been left running continuously on the accident voyage, as it normally was, the fish hold would probably not have flooded and the vessel would not have capsized.

Probable sequence of events leading to the capsize

2.19 The *San Manukau* left the wharf in Auckland with a port list. The ballast tanks were partly full and there would have been an unknown amount of water in the fish hold bilges. The Master instructed the First Mate to pump out the fish hold and press up the ballast tanks.

2.20 The First Mate set up the bilge and ballast pump to pump directly from the two fish hold bilges together. The bilge pump probably never gained suction on the bilges and what water was in them remained there. The First Mate, seeing no water coming from the overboard discharge, assumed that the bilges were dry. He then went back to the engine room and adjusted the valves to start pressing up the port and starboard ballast tanks together. The bilge valves were either forgotten or not properly closed.

2.21 When both ballast tanks overflowed on deck the First Mate proceeded to the engine room, stopped the pump and, according to him, closed down all the valves. One or more of the ballast valves associated with the port ballast tank was either left open or not properly closed.

2.22 After filling the ballast tanks the *San Manukau* had a slight starboard list (approximately 1.5°). The Master attributed this list to uneven fuel and went down and closed the suction for the port fuel tank, leaving instructions with the First Mate to check the list when he went on watch the next morning.

2.23 During the night, ballast water from the port ballast tank, and sea water through the sea suction valve slowly gravitated down past the failed NRVs in the bilge system and into the fish hold. This caused a gradual, increasing listing moment to starboard as the water collected in the starboard side of the fish hold. The starboard listing moment would have been partially offset by the fuel being drawn from the starboard fuel tank. The trim of the vessel would not have altered significantly at this stage but the range of stability for the vessel would have been reducing due to free surface effect of the water collecting on the floor of the fish hold.

2.24 As can be seen from Figure 4 a large proportion of the ice was carried in number two fish hold in the area where the warm sea water was collecting. As the sea water level rose a good proportion of the ice would have rapidly turned to ice slurry. This slurry, which was treated as a fixed weight in the original stability calculation, would have contributed to the increasing free surface effect which was reducing the *San Manukau's* range of stability. This would have explained the increase in starboard list observed by the First Mate over the first two hours of his watch in spite of the corrective measure taken by the Master to reduce the starboard list the previous evening.

2.25 The wind blowing across the port quarter of the *San Manukau* would have created a small heeling moment to starboard throughout the night.

2.26 The First Mate was aware that the Master had taken measures to reduce the starboard list by fuel management. When he noticed the starboard list increasing, he should have been concerned that something was amiss and taken steps to determine the cause. It would have been prudent for him to have called the Master at that time before attempting to rectify a situation of which he was unsure.

2.27 The First Mate refilled the port ballast tank until the *San Manukau* was upright. The stability of the vessel was probably finely balanced at that stage. Even though the First Mate "thought it strange" that he was able to pump for longer than expected into the port tank, he still did not call the Master and continued making preparations to pump out the fish hold bilges.

2.28 According to the First Mate the bilge system was set up for pumping when he proceeded back to the bridge, with the exception of the number 16 bilge isolating valve. This valve was probably still open from the previous afternoon and by opening the two fish hold bilge suction valves the path was further opened for sea water to back-flow past the failed NRVs into the fish hold.

2.29 When the First Mate, according to his statement, went back up to the bridge, he had only to open one more valve and push the start button for the pump to commence continuous pumping from the fish hold. Considering that he had already been off the bridge for approximately 20 minutes, it was surprising that he did not complete his task before proceeding back to the bridge. If this had been done the partially flooded hold would have been pumping out, improving the vessel's stability and there would have been no damage other than the loss of some ice.

2.30 Over the next 10 to 15 minutes back flooding would have continued until the vessel had such a small range of stability that the action of the sea, or lull in the wind, caused the vessel to heel over to port past her angle of vanishing stability and she began to capsize. As the vessel capsized progressive down-flooding occurred, firstly into the accommodation through the open weather-tight doors, and eventually into the engine room through the open engine room skylight and vent. If the weather-tight doors leading into the accommodation had been closed this would have slowed the rate of the capsize, possibly long enough for the crew to launch a life-raft or don life-jackets.

2.31 The rate of capsize would have slowed when the list angle reached 50° as the *San Manukau* almost reached an angle of neutral stability (angle of loll), but continuing down-flooding would have caused the capsize to continue.

2.32 The vessel settled at an angle of approximately 160° to port of upright, and remained in this position until the following day, when slow down flooding of the remaining enclosed spaces caused her to sink before she could be stabilised and righted.

2.33 The *San Manukau* took approximately two minutes to capsize and once started, the situation was irretrievable.

2.34 The "shuddering vibration" that woke the Master remains largely unexplained. At about the time the Master woke, the First Mate was pulling back the engine lever. It is possible the vibration caused by the main diesel engine reducing through a critical RPM range, or the shifting of wooden boards and fish bins in the fish hold as the vessel listed, may have woken him.

Procedures

2.35 The distribution of weights, and in particular liquids, around a vessel is vital to her stability and seaworthiness. It is essential that the person responsible for the safety and operation of the vessel be familiar with the effect that loading, discharging or shifting of weights on board will have on the vessel's trim and stability.

2.36 For that person to have a true grasp of what is happening with the vessel he/she must be aware of tank levels and weight distribution on board at all times. The routine of loading, unloading, ballasting and fuelling of a vessel can often lead to complacency and a reliance on what "looks about right". Under normal conditions a vessel may operate in this way and survive, with or without incident, for a long period of time. The procedure where the *San Manukau* had a "change of command" each time she arrived at, or departed the wharf with no formal hand-over nurtured an environment for complacency to creep in.

2.37 When the *San Manukau* departed Auckland on the accident voyage, neither the Master, nor Sanford's shore staff, knew the exact levels in the fuel and ballast tanks, or the state of the bilges. When the vessel left the wharf with a slight port list, the Master told the First Mate to pump the fish hold bilges and press up the ballast tank to see what effect that would have, and because that was what they would normally do. When the First Mate had completed this, or was thought to have completed this, the *San Manukau* had a slight starboard list. The Master assumed this to be caused by uneven fuel tanks so he adjusted the fuel to draw from the starboard side only. The Master's actions, while logical, were based on assumptions that everything was normal.

2.38 The First Mate's actions showed a general lack of understanding for the dynamics involved in vessel stability and an overall unfamiliarity with the engine room bilge and ballast system.

2.39 The lack of formal hand-over of the vessel from the company to the Master did not preclude the Master's responsibility to ensure the seaworthiness of his vessel before departing the wharf. It has been established that the fish hold was flooding back through its bilge lines during the 15 minutes immediately before the capsize; however, this was not sufficient time for 98 tonnes of sea water to have entered the fish hold from this source; therefore it would appear that the flooding was the result of a succession of cumulative failures.

2.40 The responsibility for maintenance of Sanford vessels rested with their shore staff. This included the cleaning of fish holds. By the very nature of the operation, it is reasonable to expect that bilge pumping arrangements for fish holds will be prone to infiltration by fish residue, regardless of how clean the fish holds are on the vessel's departure from the wharf. This fish residue will, in time, affect the operation of NRVs in the system. Although the NRVs should not be totally relied upon, their function is to provide a defence against accidental flooding and they should therefore be functional at all times. Regular inspection and maintenance of such valves would be prudent.

2.41 It could not be determined from records when the NRVs were last serviced on the *San Manukau*. Several references were made on trawler log sheets "unable to pump fish hold" over the previous year. This type of problem could relate to any one of a number of causes, including blocked NRVs. It is understood that all valves are overhauled during the annual slipping of the vessel, which the *San Manukau* had undergone in May 1995, and was due to undergo approximately one month after the accident.

3. Findings

3.1 The *San Manukau* was manned and certificated as required for fishing vessels of her class.

3.2 The *San Manukau* suffered a loss of stability sufficient for her to capsize in the prevailing light conditions.

3.3 The flooding of the vessel's fish hold was the main factor contributing to the loss of stability.

3.4 Water in the void space below the fish hold would have contributed to the loss of stability, but to a lesser degree.

3.5 Water had probably been present in the void space for some years prior to the capsize.

3.6 The flooding of the fish hold was caused by the malfunction of three non-return valves in the bilge pumping system.

3.7 The company repair and maintenance system was insufficient to detect the failure of the three non-return valves to function correctly.

3.8 The First Mate's reliance, intentional or unintentional as it may have been, on the effectiveness of the non-return-valves was contrary to verbal instruction from the company, and was a contributing factor to the flooding.

3.9 The First Mate's unfamiliarity with the engine room bilge and ballast pumping arrangement was a contributing factor to the flooding.

3.10 The Master and First Mate did not fully appreciate the stability condition of the *San Manukau* on departure from the wharf, nor during the subsequent flooding of the fish hold.

3.11 Company procedures did not allow for an adequate flow of information between shore and ship when responsibility for the vessel was handed over. This may have contributed to the Master's and First Mate's lack of appreciation of the state of repair and stability of their vessel.

3.12 The operation of a high level bilge alarm in the fish hold of the *San Manukau* could have avoided her capsize, provided the crew were aware of its importance.

3.13 The quick and decisive action taken by the Master in waking the remaining crew and giving the order to abandon ship allowed all four crew to escape into the water unharmed.

3.14 The first deck-hand's inability to swim and insufficient time to don a life-jacket were factors contributing to his drowning. The First Mate's efforts to try and save his brother at considerable risk to himself should be acknowledged.

3.15 The vigilance of the watch-keeping engineer on the *San Hauraki* and her Master's quick response to the situation probably avoided any further injury to the three survivors and should also be acknowledged.

4. Safety Recommendations

4.1 It was recommended to the Group Fleet Manager for Sanford Ltd that he:

4.1.1 Introduce a system on all Sanford vessels for recording on board, all operational, safety and maintenance checks/tasks carried out by the crew or Sanford's shore staff. A work record book with signed entries each time a task or check is completed would serve this purpose. (026/96)

4.1.2 Introduce a system for a formal hand-over of company vessels from Master to company and back to Master. The system's purpose is to ensure that both the Master and the company are aware of aspects of operation, safety and maintenance for the vessel before the vessel departs the wharf and upon its return. The work record book could form part of the system. (027/96)

4.1.3 Introduce a system for producing, circulating and keeping on board fleet safety and operational memoranda. The above system should be aimed at informing all crew of such matters. (028/96)

4.1.4 Circulate a memorandum to reiterate the following points:

- Masters and crew check their vessels in accordance with the new hand-over system.
- No-one relies on non-return valves as a stop for water flooding back into bilges.
- Bilge alarms are maintained and tested regularly and it is a danger to the vessel and her crew to disconnect them.
- Bilge pumps are not left running continuously on bilge spaces where there is no indication of the pump's running status unless the bilge is under constant surveillance.
- Watch-keepers do not leave the bridge unmanned for long periods while they complete other tasks.
- Crew do not leave weather-tight doors open at night or in inclement weather. (029/96)

4.1.5 Introduce a program of regular inspection and servicing of bilge non-return valves on all Sanford vessels. (030/96)

4.1.6 Install high level bilge alarms in the fish hold of all Sanford vessels that do not already have one fitted. (031/96)

4.1.7 Install a running/stopped indicator light for bilge pumps on the bridge of all Sanford vessels that do not already have one fitted. (032/96)

4.1.8 Install a sounding pipe for the void space on the sister vessels to the *San Manukau* and some means for pumping this space out when it becomes flooded. (033/96)

4.2 The Group Fleet Manager for Sanford Ltd responded as follows:

It has always been our practice and recommendation to implement the highest safety standards and working conditions on all of our vessels....

4.2.1 026/96 This recommendation is accepted and has already been implemented.

4.2.2 027/96 This recommendation is accepted and has already been implemented.

4.2.3 028/96 The practice referred to in this recommendation is already followed; we are considering ways in which to improve its system.

4.2.4 029/96 This recommendation is accepted and will be implemented as soon as practicable; in any event, not later than the end of August 1996.

4.2.5 030/96 This recommendation is already followed. Whilst the recommendation is unnecessary, we are reviewing our practice in terms of the intervals between each inspection of the non-return valves.

4.2.6 031/96 This recommendation is accepted in part; however, it is not considered practicable for many of the smaller vessels.

4.2.7 032/96 This recommendation is accepted in part and will be installed on vessels of a similar size to *San Manukau.*

4.2.8 033/96 This recommendation is accepted. A method for pumping out the void space when it becomes flooded on the sister vessels to the *San Manukau* has already been installed. Sounding pipes will be installed by the end of August 1996.

23 October 1996

M F Dunphy
Chief Commissioner

Appendix A

Stability terminology and principles

1. The centre of gravity "G", of a body or vessel, is the point through which the force of gravity is considered to act vertically downwards with a force equal to the weight of the body or vessel. The centre of gravity will move within a vessel as weights are loaded, discharged or moved within. Liquids within a vessel, if free to move around in their compartments, will cause the centre of gravity to move with the flow of the liquid. This has the same effect as raising the centre of gravity within a vessel (decreasing its stability) and is referred to as a "virtual rise in centre of gravity".

2. The centre of buoyancy "B" is the point through which the force of buoyancy is considered to act vertically upwards with a force equal to the weight of the water that the vessel displaces. It is the centre of gravity of the underwater volume of the body.

3. To float at rest in still water, a vessel must displace a volume of water equal to the weight of the vessel, and the centre of gravity "G" must be in the same vertical line as the centre of buoyancy "B" (see Figure 1). The letter "K" denotes the keel.

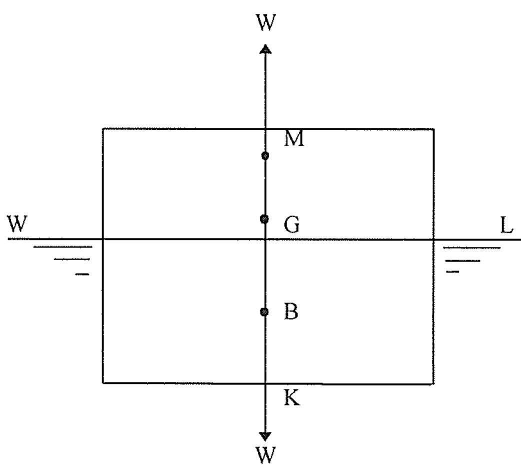


Figure 1

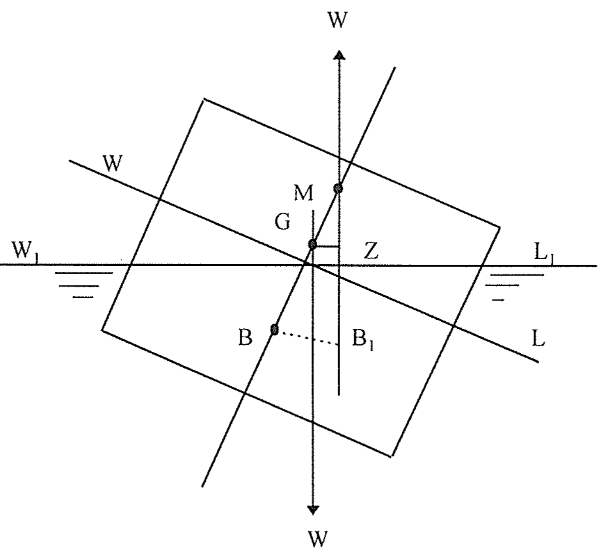


Figure 2

4. If the vessel is inclined by an external force to a small angle as shown in Figure 2 the centre of gravity G will remain static (assuming there is no internal shifting of weights) and the weight of the vessel "W" is considered to act vertically through this point. The centre of buoyancy "B", being the centre of gravity of the underwater volume, will move from B to B_1.

5. For angles of heel up to about 15°, the vertical through the centre of buoyancy may be considered to cut the centre line at a fixed point. This point is known as the initial metacentre "M".

6. The height of the initial metacentre above the keel depends on the vessel's underwater form and the surface water plane area. M is considered to remain stationary for small angles of heel. When a large angle of heel, or an excessive change in trim, significantly changes the underwater form and the water plane area, then the position of M will change and calculations are made using the more complicated "large angle stability" method.

7. The vertical distance between G and M is referred to as the metacentric height "GM". As long as G remains below M the vessel has a positive metacentric height, or positive "GM".

8. A ship is in stable equilibrium if, when inclined, it tends to return to the initial position. For this to occur G must remain below M.

9. Figure 2 shows the vessel inclined at a small angle. The centre of buoyancy moves from B to B_1 to take up a new centre of gravity of the underwater volume and the force of buoyancy is considered to act vertically upwards through B_1 and the metacentre M. If the forces acting around G are summed, then there is a force or moment acting to return the vessel to the upright position. This force or moment is referred to as "the moment of statical stability" and is equal to the product of the force W and the length of the imaginary righting lever GZ.

10. When a vessel, which was inclined to a small angle of heel tends to heel still further, it is in "unstable equilibrium" where the centre of gravity is above the metacentre and has a negative GM. The ship will not stop inclining until G and M coincide (see Figure 3). While G stays above M, the imaginary lever GZ now forms a capsizing lever.

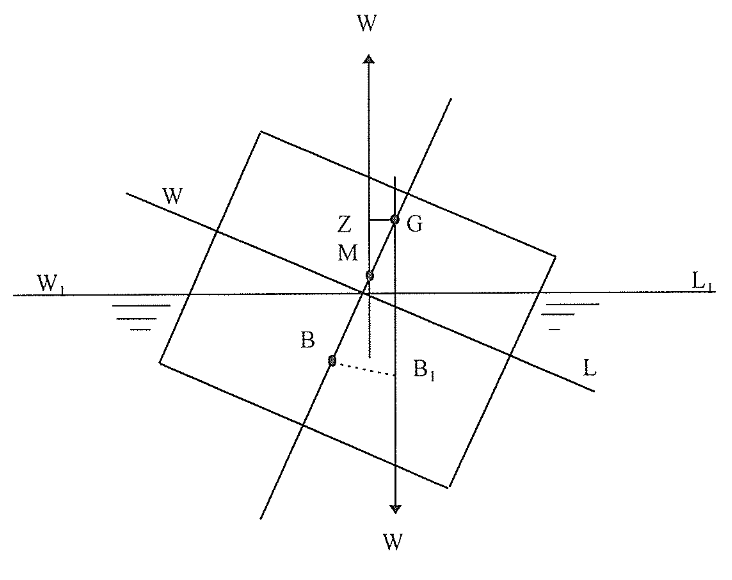


Figure 3

11. The distance GM or metacentric height is sometimes referred to as a measure of a vessel's stability but this will apply only to small angles of heel when GM can be considered to be constant. A better measure of stability is the GZ lever. For small angles of heel Ø, GZ = GM sin Ø and GZ is thus zero when the heel is zero. GZ increases as the heel increases (as long as the formula holds good) showing that the vessel's stability varies with angle of heel. GM, however, remains constant.

12. This measure of a vessel's stability can be represented by plotting a graph of the value of GZ, the righting lever, in metres, against various angles of heel in degrees. This plot is known as the "GZ curve" and the area under the curve, in metre-degrees, is used in various regulations as a parameter by which to specify requirements for a vessel's stability.

13. From the GZ curve can be determined:

- The range of stability and the angle of vanishing stability.
- The maximum GZ, the angle at which it occurs and the righting moment.
- The GZ and righting moment at any angle.
- The angle of deck-edge immersion.
- The initial value of GM.

14. The range of stability is the range over which the vessel has positive righting levers. The angle of vanishing stability is the angle of heel at which the sign of the righting lever changes from positive to negative.

15. The angle of heel at which the deck-edge becomes immersed provides a point of inflexion on the GZ curve. This is where the rate of increase, or slope, of the curve reaches its maximum value, i.e. where the slope (gradient or tangent) reaches its steepest.

Glossary of Marine Terms

AC	Alternating current
Aft	Rear of the vessel
Beam	Width of a vessel
Bilge	Space for the collection of surplus liquid
Bridge	Structure from where a vessel is navigated and directed
Bulkhead	Nautical term for wall
Bus	An arrangement of copper conductors (Bus bars) within a switchboard, from which the circuits are supplied
Cable	0.1 of a nautical mile
Chart datum	Zero height referred to on a marine chart
Command	Take over-all responsibility for the vessel
Conduct	In control of the vessel
Conning	Another term for "has conduct" or "in control"
DC	Direct current
Deckhead	Nautical term for roof
Dog	Cleat or device for securing water-tight openings
Draft	Depth of the vessel in the water
EPIRB	Emergency Position Indicating Radio Beacon
Even keel	Draft forward equals the draft aft
Freeboard	Distance from the waterline to the deck edge
Free surface	Effect where liquids are free to flow within its compartment
Freshet	Term used to describe an increase of water level in the river due to rain in the mountains
Focsle	Forecastle (raised structure on the bow of a vessel)
GM	Metacentric height (measure of a vessel's statical stability)
GoM	Fluid Metacentric height (taking account the effect of free surface)
GPS	Global Positioning System
GS	General service
Heel	Angle of tilt caused by external forces
Hove-to	When a vessel is slowed or stopped and lying at an angle to the sea which affords the safest and most comfortable ride
Hz	Hertz (cycles)
IMO	International Maritime Organisation
KG	Distance in metres from a vessel's keel to its centre of gravity
kW	Kilowatt
List	Angle of tilt caused by internal distribution of weights
m	Metres
MSA	Maritime Safety Authority
Point	Measure of direction (one point = 11¼ degrees of arc)

SOLAS	Safety Of Life At Sea convention
Sounding	Measure of the depth of a liquid
SSB	Single-side-band radio
Statical stability	Measure of a vessel's stability in still water
Supernumerary	Non-fare-paying passenger
Telegraph	Device used to relay engine commands from bridge to engine room
Ullage	Distance from the top of a tank to the surface of the liquid in the tank
V	Volts
VHF	Very high frequency radio
Windlass	Winch used to raise a vessels anchor