Report of the Chief Inspector of Marine Accidents

into the failure of the Lifeboat

Launching Equipment on mv NORSEA

on 5 February 1992

With the loss of 2 lives

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Photograph by courtesy of North Sea Ferries

MV NORSEA

1. SUMMARY

Whilst the ro-ro passenger ferry NORSEA was berthed at Hull on the afternoon of 5 February 1992 the lifeboat launching equipment at No 3 lifeboat station suffered catastrophic failure whilst undergoing operational tests. Damage was extensive and the lifeboat fell into the dock. Of the four men in the lifeboat at the time of the accident, two were killed.

The test was the final one in a series of acceptance tests of a band bowsing system (BBS) which was designed to replace the existing conventional method of tricing and bowsing-in of the lifeboat. The tests were designed to demonstrate to the Department of Transport that the system was a suitable alternative.

The accident happened during operation of the system. Two seamen stationed in the forward and aft hatches of the lifeboat were attempting to release the brakes of the BBS in a controlled manner in order to move the lifeboat away from its embarkation position to its lowering position. During this operation the aft end of the lifeboat suddenly swung away from the ship's side. The dynamic loads induced by the boat's swing and the shifting of the lifeboat falls wire, together with the loading of the BBS, caused the aft davit arm to be forced out of its supporting trackway. Progressive collapse of the davit structure followed.

PART 1 FACTUAL ACCOUNT

2. PARTICULARS OF SHIP AND CREW

2.1 Description of Vessel

NORSEA is a Class II Ro-Ro passenger cargo ferry operating a regular service between Hull and Rotterdam. The Passenger Certificate in force at the time and issued by the Department of Transport (hereafter referred to as the Department) was for 1250 passengers plus 115 crew for Short International Voyages in the North Sea area not North of a line from Newcastle to Elbe and not South of a line from Dover to Calais.

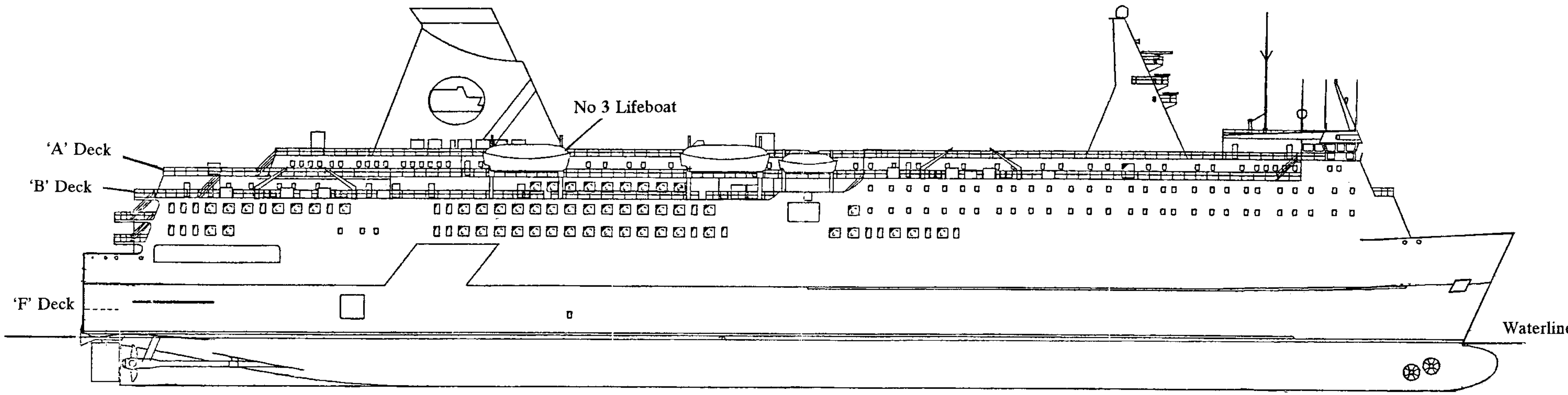
Owners	:	Braham Shipping Ltd, London
Managers	:	North Sea Ferries Ltd, Hull
Port of Registry	:	Hull, UK
Built	:	1987, Govan Shipbuilder Ltd, Glasgow
Length Overall	:	179.2 metres
Beam	:	25.35 metres
Loaded Draft	:	6.184 metres
Gross tonnage	:	31,785
Nett tonnage	:	18,197

The vessel has four 143 person capacity partially enclosed lifeboats and two 24 person capacity totally enclosed rescue/lifeboats.

The lifeboats and rescue/lifeboats are stowed in their respective davits at A Deck level and embarkation takes place on the next deck down at B Deck, (see figure 1). The six boats are identified by Nos 1 to 6. Even numbered boats are positioned on the port side with odd numbered boats on the starboard side. The two most forward port and starboard boats are the rescue/lifeboats.

There are also 44 davit launched liferafts capable of accommodating 1100 persons.

Diagram of Passenger Ferry NORSEA



2.2 Main Design Features of 143 Person Lifeboat

The lifeboats were manufactured by Harding Safety A/S, supplied by Welin Lambie Ltd and built to UK and international regulations and requirements.

The hull and canopies are moulded together to form a single moulding. The buoyancy tanks, thwarts, provision lockers and water tanks are moulded into the hull, forming an integral part of the hull. The buoyancy tanks are filled with polyurethane foam (oil resistant). This design provides good insulation and prevents water from flooding the cabin if the outer shell should be damaged.

The canopies at the forward and aft ends are fixed, while the central area of the lifeboat is covered by a folding canopy which has entrances at both ends and one each side. A hatch is fitted in the fixed canopy forward to enable handling of the hook. The aft fixed canopy incorporates a closed steering tower for the helmsman which has a hatch to enable handling of the aft hook. These hatches can be opened and closed from inside and outside, (see figure 2). The lifeboats are not self-righting.

The lifting hooks are quick release type (on-load), complete with hydrostatic release mechanism in accordance with the 1983 Amendments to SOLAS 1974.

2.3 Design of the Lifeboat Launching Equipment

The lifeboat launching equipment was designed and built by Schat-Davit (UK).

The sets of gravity davits for the lifeboats and rescue boats comprise arms mounted on rollers which engage with and travel down fixed inclined trackways. The controlled launching of a boat is by means of the boat's own weight doing the work to bring about the launch.

The davits are designed to swing out the lifeboat from its stowed position manned by a crew of two persons. The lifeboat is capable of being lowered into the water from the embarkation position with its full complement of persons when the ship has a list either way of up to 20° and a trim of up to 10°.

In the stowed position, the lifeboat is suspended by means of two lifting hooks which are located at the forward and after ends of the lifeboat. A wire rope lower block is connected to each of the lifting hooks. Each lower block is suspended from a horn welded to each of the two davit arm heads. Each davit arm is held in the stowed position by means of a securing lever. The two securing levers are interconnected by a wire rope incorporating a quick release slip.

FIGURE 2

Aft end of Lifeboat showing hatch

The fall wire consists of a single steel wire which is rigged through davit sheaves, two fixed bollards and the lower blocks with each of its two ends wound around the two drums of the davit winch, which is rigidly connected to the ship. The function of the fall wire is to support and control the davit arm in the trackway and to suspend the lifeboat during its embarkation and launch. Such a falls system is known as 'continuous wire falls' (see figure 3).

Unwanted uneven movement of the falls relative to the two arms is resisted by friction forces between the falls and the two fixed bollards. To limit the magnitude of falls movement to within acceptable limits two stoppers are fitted to the falls between the two davit arms. Excessive movement of this nature could affect the safe operation of the lifeboat launching system.

A span wire is shackled between the heads of each davit arm. This wire plays no part in the launching process of the lifeboat and is only for suspending the two rope lifelines which are required by regulation.

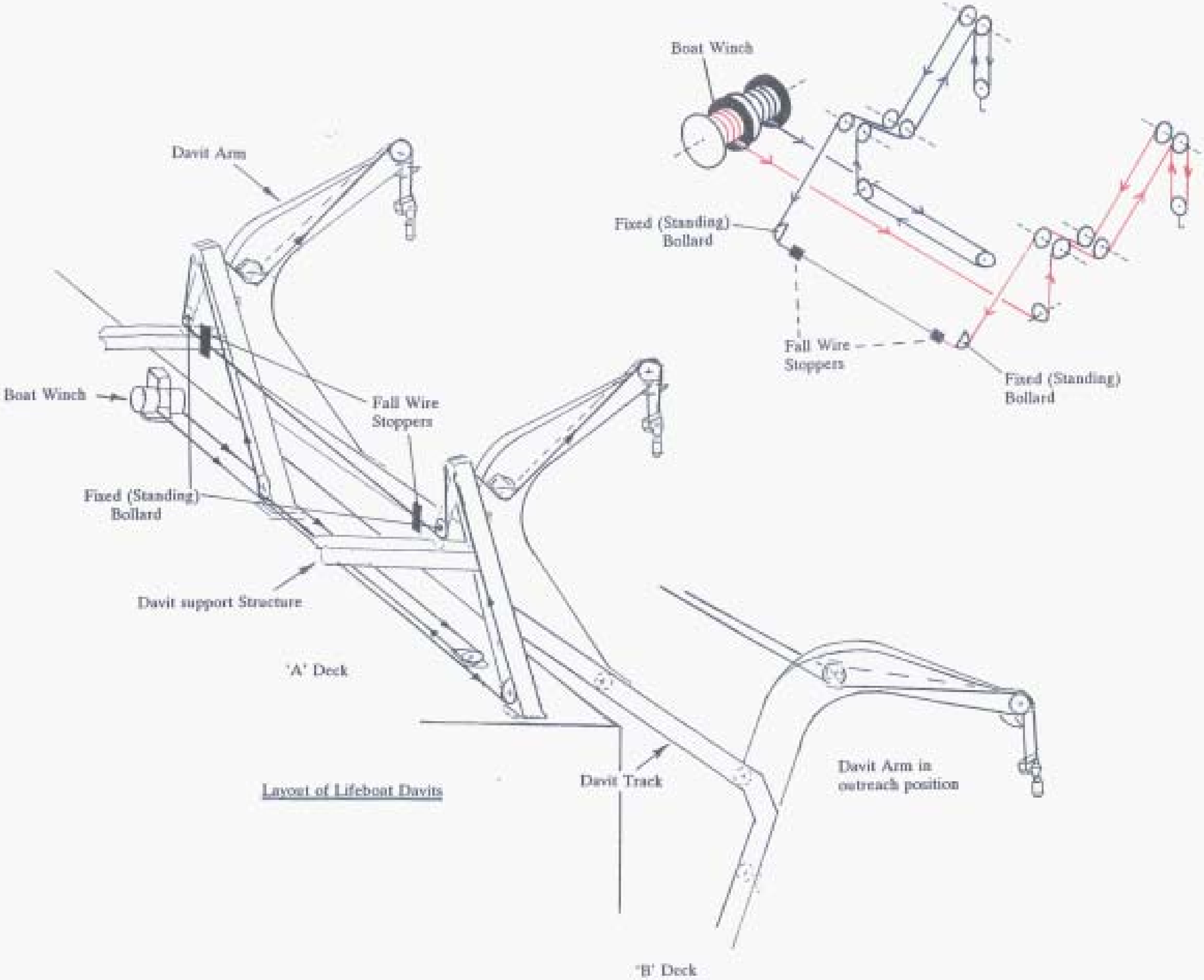
The lifeboat is launched by initially releasing manually the quick release slip in the interconnecting wire between the davit arm securing levers. On release of the winch brake, the wire rope falls slacken thereby allowing the davit arms to move downwards and outwards as their rollers travel down their respective inclined trackways during which time the gripe wire ropes are automatically released. When the lower roller of each davit arm reaches the lower end of trackway, the davit arm heads are located at the outreach necessary both for the blocks to be lowered clear of the davit arm head horns and for the lifeboat to be lowered clear of the ship's side.

The lowering of the lifeboat can be controlled from within the boat or from a position on B deck remote from the winch by using a control wire connected to the winch brake lever. The control wire leads around various pulleys to its two free ends which are operated from their respective remote positions. Lowering can also be controlled by direct hand operation of the winch brake lever.

A tricing pendant, consisting of a wire rope, a hemp lashing and a patent slip, is connected between each lower block and its associated lug welded onto the davit arm. The length of the tricing pendant and the position of the lug on the davit arm are such that, on further lowering of the lifeboat, some load is taken by the pendant which causes the lifeboat to be laterally swung into a position alongside and level with the embarkation deck.

At this point, before embarkation commences, bowsing tackles are rigged and tightened at each end between the lower block and the ship. The ship end of the tackle is mounted on lugs which are fixed to the davit trackways. The tricing pendants are then released, leaving the lifeboat held alongside by the bowsing tackles. After embarkation, the bowsing tackles are manually slackened under control until the lifeboat is again suspended

Schematic of Continuous Falls



Layout of Lifeboat Davits

entirely by the wire rope falls. The bowsing tackles are then removed. The launching operation is completed by lowering the lifeboat to the water and then releasing each block from its respective lifting hook.

2.4 Crew

The vessel carried a total complement of 90: the Master, four deck officers, seven engineer officers, four catering officers and 74 ratings.

3. NARRATIVE

(All times are GMT)

3.1 From the time that NORSEA entered service, use of the conventional tricing pendant and bowsing system had been unpopular with the crew and management. The view was held that crew members were endangered when operating the lifeboat launching system. The lifeboat could only be bowsed-in at the expense of placing a proportionately high load onto the tricing pendant. These problems are explained in detail in Section 4.

Schat-Davit Company BV Holland (hereafter referred to as Schat-Davit BV) had developed and manufactured a band bowsing system (BBS) for incorporation in the davit launching arrangement for a lifeboat. The BBS was regarded by North Sea Ferries as a possibly safer alternative and an operational improvement to the traditional method of bowsing the 143-person capacity lifeboats fitted aboard NORSEA and, in conjunction with Schat-Davit BV, they approached the Department for its approval.

An operational demonstration of the BBS, forming part of the approval procedure required by the Department, was carried out aboard NORSEA on 17 April 1991. The demonstration was conducted using a 143-person capacity partially enclosed lifeboat in a light condition. No 3 lifeboat had been selected for the demonstration and a lug to which the BBS was to be shackled had been welded to each davit arm. The demonstration indicated that there was satisfactory positive control by manual operation of the brake lever of the BBS. The banding was eased out slowly or quickly as required.

A further operational demonstration of the system was scheduled to be undertaken aboard NORSEA on 5 February 1992, while the vessel was in service and alongside in King George Dock, Hull. The demonstration was intended to be conducted again using No 3 lifeboat but, this time, with the lifeboat in a simulated laden condition of 1.1 times its working load. The opportunity was to be taken to conduct a static test with the boat suspended entirely by the BBS (the "first test"). In addition, the Department required an operational test in which the weight was to be transferred from the BBS to the falls (the "second test"). The same BBS that had been used for the first demonstration was to be used in these latest demonstrations.

The manufacturer of No 3 lifeboat advised the Department that the weight of the empty lifeboat with equipment was 7,683 kg and its fully laden weight was 18,408 kg (assuming 75 kg per person). The Department notified North Sea Ferries that the additional weights required for the test should equal 12,565.8 kg.

Water Weights Ltd were instructed by North Sea Ferries to supply 12,566 kg of weights. It had been calculated that 252 water bags would be required. Each bag when filled with sea water would weigh 50 kg. The 252 water bags were to be used for the "first test" to determine the ability of the BBS to support the working load. Four bags were then to be removed for the BBS operational test to account for the weight of the four persons who were to be in the boat for the duration of the test.

3.2 Preparation for the test of the BBS commenced at approximately 0800 hrs on 5 February 1992 while No 3 lifeboat was in its stowed position. Schat-Davit BV representatives detached the two tricing pendants from their respective positions on the davit arm and lifeboat lower block and replaced them with the BBS. The lifeboat was then lowered to embarkation deck level by ship's crew and held alongside the vessel by the BBS in readiness to be loaded with test weights.

3.3 Loading of the lifeboat started at 0900 hrs using water bags filled with dock water from the ship's deck fire main. The amount of water used was monitored by a flow meter fitted in the filling hose line. The filling of the water bags was supervised by two employees of Water Weights Ltd. Two crewmen were appointed to load up the lifeboat. Life-jackets were not worn by personnel in attendance at any stage of the proceedings leading up to the accident.

3.4 The two crewmen placed the water bags evenly throughout the bottom of the lifeboat, both stopping for lunch at midday. The Chief Officer requested two volunteer crewmen from the afternoon team of four ratings to start work at the earlier time of 1230 hrs instead of the normal time of 1300 hrs. All four were informed that they would be in the lifeboat for the test of the BBS. Seaman A and Seaman B volunteered to start work early and continued with the loading of the lifeboat. At 1300 hrs they were assisted by the other two duty ratings, Seaman C and Seaman D. At about 1345 hrs, loading of the lifeboat was complete.

3.5 Meanwhile, Surveyors from the Department observed the final stages of lifeboat loading to ensure that the water bags were evenly distributed in the lifeboat along its entire length and breadth. They were informed that the Schat-Davit BV representatives would be operating the BBS during the demonstration. The Schat-Davit BV representatives explained the operation of the BBS to the Chief Officer who, in turn, explained its operation to the four attending seamen, all of whom were certificated Able Seamen and qualified lifeboatmen.

3.6 Without anyone in the lifeboat, the lifeboat winch brake was released to slacken the fall wires thereby transferring all of the load to the BBS. The davit launching equipment was examined by a Surveyor from the Department for signs of distress but none was found other than minor distortions where the upper roller rested on the trackway, which were present before the test started. When all concerned were satisfied, the slack on the falls was once again taken up, so that some of the weight was taken back onto the falls.

3.7 For reasons which are not clear, it was decided that crew members should operate the BBS, not Schat-Davit BV representatives. Four seamen entered the lifeboat without wearing life-jackets. In readiness to operate the BBS for the test, Seaman A was standing in the forward hatchway and Seaman B was standing in the after hatchway. Seaman D went under the canopy towards the after end of the lifeboat. Seaman C held on to the centre deckhead section in the forward part of the lifeboat and faced the ship.

3.8 At about 1355 hrs the Chief Officer instructed Seaman A and Seaman B to start to operate the BBS. The two seamen were, on the first attempt, unable to move their respective BBS operating levers. Seaman B, positioned in the aft hatch opening, tried to lift the lever with one hand without success. He then used two hands. The after end of the lifeboat moved rapidly away from the ship's side and then dropped vertically. There were no reports of Seaman A (who was in the forward hatch opening for the purpose of effecting release of the forward BBS).

3.9 Seaman A and Seaman C were thrown off-balance by the sudden motion and fell inside the lifeboat. A loud bang was heard together with other loud noises resembling that of parting metal and wire. Personnel in attendance, realising that something was wrong, sought protection by way of the accommodation superstructure. The after davit arm upper rollers came free of the trackway which allowed the arm to rotate outwards about its lower trackway roller pin. Another loud bang was heard and the forward davit arm similarly rotated outwards. Both davit heads continued to rotate until they, and the lifeboat, struck the ship's side. The forward fall wire and BBS parted causing the lifeboat to pivot about and, then, to suspend vertically from its after lifting hook. The resultant high load on the after keel connection caused the entire after lifting assembly to break away from the lifeboat structure, (see figure 4). The lifeboat then dropped bow-first into the water, re-surfaced, and floated upside down in a position parallel to the ship. None of the four men who had been in the boat could be seen.

3.10 A Search and Rescue operation began at once, and is described in Section 11.

Failed Davit Arms suspended from their respective Lower Rollers. The Aft Arm is on the left of the picture

PART II CONSIDERATION OF POSSIBLE FACTORS

4. BACKGROUND TO THE DECISION TO USE THE BAND BOWSING SYSTEM

4.1 History of the Approval of the Launching System

As the keel of NORSEA was laid in 1985 the Merchant Shipping (Life-saving Appliances) Regulations 1980 applied. However, the standards to which the lifeboat davit launching system was assessed were those of The Merchant Shipping (Life-saving Appliances) Regulations 1986, which embody requirements of Chapter III/4 in the 1983 Amendments to the 1974 Safety of Life at Sea (SOLAS) Convention. Under this provision, the Marine Directorate of the Department of Transport approved the lifeboat launching system of NORSEA. In particular, detailed drawings and calculations relating to the strength and stability of the proposed launching appliances on NORSEA were submitted by Schat-Davit (UK) to the Department at the building stage of the ship.

In the case of the davits used for the 143-person capacity lifeboats, a calculation diagram provided information relating to design stresses exerted upon the launching appliance due to an applied load (working load) equating to the weight of a fully loaded lifeboat of 18,700 kg. Design stresses on the davit arms and roller axles were calculated for trim and low-side list conditions of 10° and 20° respectively. The stress calculations afforded a minimum factor of safety of 4.74 having regard to the quality of the construction material. The Regulations require a minimum factor of safety of 4.5 based on the ultimate tensile stress of the material used in construction. The factor of safety calculated for approval purposes is based on the simply supported beam theory.

Design stress on the trackways was calculated for a low-side list condition of 20°. The stress calculation afforded a factor of safety of 5.51 having regard to the quality of the construction material. The load on the trackway in way of the top pair of davit arm rollers was calculated as 17.8 tonnes force. Account was not taken of side loading on the trackway due to trim.

The following tests were among those successfully undertaken as part of the approval procedure required by the Department:

- static winch brake tests were carried out at the makers on 30 June 1986 using a test load of 14,250 kg (representing 1.5 times the maximum designed working load of each winch).

- also lowering winch brake tests were carried out on 30 June 1986 using a test load of 9,200 kg (representing the estimated maximum working load of each winch);

- davit arm and trackway production tests were undertaken by Schat-Davit (UK) on a test rig. Each set of davit arm and trackway were tested individually using a static test load of 20,570 kg (representing 2.2 times a working load of 9,350 kg on the lower block of each davit arm). These loads were pulled in a direction simulating loaded conditions at 10° of trim and 20° of low-side list, and were carried out with each davit arm housed in its respective trackway at the full outreach position and supported by the wire falls. The tests were completed on 16 September 1986. In no case was any permanent deformation of the structure recorded.

- lifeboat lowering installation tests were carried out on board the ship during February, March and April of 1987 at the fitting-out basin of Govan Shipbuilders Ltd. The tests were undertaken with the lifeboats loaded in accordance with the lifeboat lowering test sheets produced by Govan Shipbuilders Ltd and dated 7 January 1987. The test sheets indicate that an additional weight of 13,406 kg was required to be loaded into each lifeboat in order to provide the necessary 10% overload for the tests. The total test load is stated to be 19,751 kg which represents 1.1 times a working load of 17,955 kg.

On 17 February 1987, Govan Shipbuilders Ltd produced revised lifeboat lowering test sheets on the basis of final specifications received from the lifeboat supplier, Welin Lambie Ltd. The test sheets indicate that an additional weight of 14,026 kg was required to be loaded in each lifeboat in order to provide the necessary 10% overload for the tests. The total test load was stated to be 20,949 kg which represents 1.1 times a working load of 19,044 kg; 1089 kg more than the working load used for the 1.1 safe working load (SWL) tests earlier in the year. There is no report of a test having been performed using these revised figures.

Welin Lambie Ltd produced a technical specification for the lifeboats on 10 November 1986. The specification indicates that the total davit load of each lifeboat equated to 18,375 kg. Such a figure excludes the weight of the blocks and falls which is estimated to have equalled 240 kg and would have provided a total working load of 18,615 kg, 660 kg more than that originally specified by Govan Shipbuilders Ltd in January 1987. The additional weight required to provide a test load of 20,477 kg (representing 1.1 times the working load) is calculated to be 13,554 kg (assuming that all of the loose equipment, except the skates, is not present on the lifeboat at the time of testing). Again there is no report of a test having been performed using these figures.

It should be noted that during the time the lifeboat launching system was under consideration by the manufacturers, the shipyard and the Department there was no consistent figure used for the weight of the lifeboat.

The Department's Surveyor who attended the installation tests reported that:

- during demonstrations of the tricing and bowsing arrangements, considerable difficulty was experienced when it was evident that the final boat embarkation position was too low on the ship's side.

- after numerous modifications to the location of the tricing pendant lugs on the davit arm and to the tricing pendant lengths a satisfactory final arrangement was achieved.

The final arrangement, although deemed satisfactory to the Department, still resulted in the gunwale of the lifeboat being located some 50cm lower than the level of the embarkation deck when the lifeboat was positioned at the embarkation point. The geometry and shape of the installed davit was such that a compromise was necessary with respect to the tricing arrangements in order to meet two criteria, namely:

.1 to ensure that the fall blocks were able to clear the davit arm head horns before the lifeboat was bowsed alongside; and

.2 to ensure that the load remained substantially on the fall wires throughout.

In order to assist the embarkation of personnel into the 143-person capacity lifeboats, a portable step was made available at each of the embarkation points.

4.2 Further Problems Arising from the Fitted Design

Since NORSEA entered service the tricing pendant and bowsing-in tackle arrangement, associated with the launching procedure for the 143-person capacity lifeboats fitted aboard NORSEA continued to generate concern from both North Sea Ferries and the Department.

The following problems and difficulties were experienced in service when the lifeboat was positioned at the embarkation point:

- An excessive load was taken by the tricing pendants.

- Crew members found it difficult to take up the slack on the bowsing tackles before releasing the tricing pendants allowing the boat to jump outwards and down on slipping the tricing gear.

- Violent jolting occurred to the davit and lifeboat on release of the tricing pendants causing the lifeboat to move away from the ship's side as load was taken up by the bowsing tackles.

- It was difficult to slacken off bowsing tackles.

- While standing in the lifeboat canopy hatch openings, crewmen had difficulty in handling the bowsing tackle as the hatch openings were too small preventing easy transfer of the bowsing tackle from within the boat to outside.

- It was not possible for crew members to secure the bowsing tackles to the lower fall blocks without climbing on to the outside of the rigid canopy located at each end of the lifeboat.

- Difficulties in handling of the bowsing tackle were compounded when the crew members wore standard life-jackets.

4.3 Suggested use of the Band Bowsing System (BBS)

Schat-Davit BV had developed and manufactured a single system called the band bowsing system (BBS) to replace the traditional tricing pendant for incorporation in the davit launching arrangement for a lifeboat. It had been approved by some flag states and been installed on several foreign registered vessels without any problems. It was regarded by North Sea Ferries as safer and an operational improvement to the existing system.

The BBS comprises three nylon sheaves of an upper block and a lower block to form a six-fold purchase block and tackle arrangement. A polyester woven band is led around the sheaves. The lower block contains a winding crank, a drum around which the band is also wound and a braking mechanism which holds the band. The brake is operated by a spring loaded handle which ensures permanent application of the brake unless physically released, (see figure 5). The brake is released by a crew member leaning out of the boat, through a hatch provided. The lower block can be detached from the lifeboat by the manual release of an associated hook.

The BBS functions as a tricing pendant and bowsing tackle combined. It is set at a predetermined length and like the tricing pendant is connected to a davit arm lug and to the lower block plate. The lifeboat is brought from its stowed to embarkation position and the BBS, acting as the tricing pendant, guides the lifeboat to the ship's side to hold it in place. The lifeboat is now ready for embarkation.

The BBS avoids the cumbersome change over to the bowsing tackle. Unlike its tricing pendant counterpart, it is designed to support the working load of the lifeboat (weight of the lifeboat and equipment plus the weight of the total number of persons). By operating the BBS brake lever from the lifeboat hatch position the band is allowed to pay out. The lifeboat is moved outwards from the ship's side to be supported fully by the fall wire in readiness to be lowered. Before lowering, the BBS is disconnected from the lower block, (see figure 6).

Diagram of Band Bowsing System

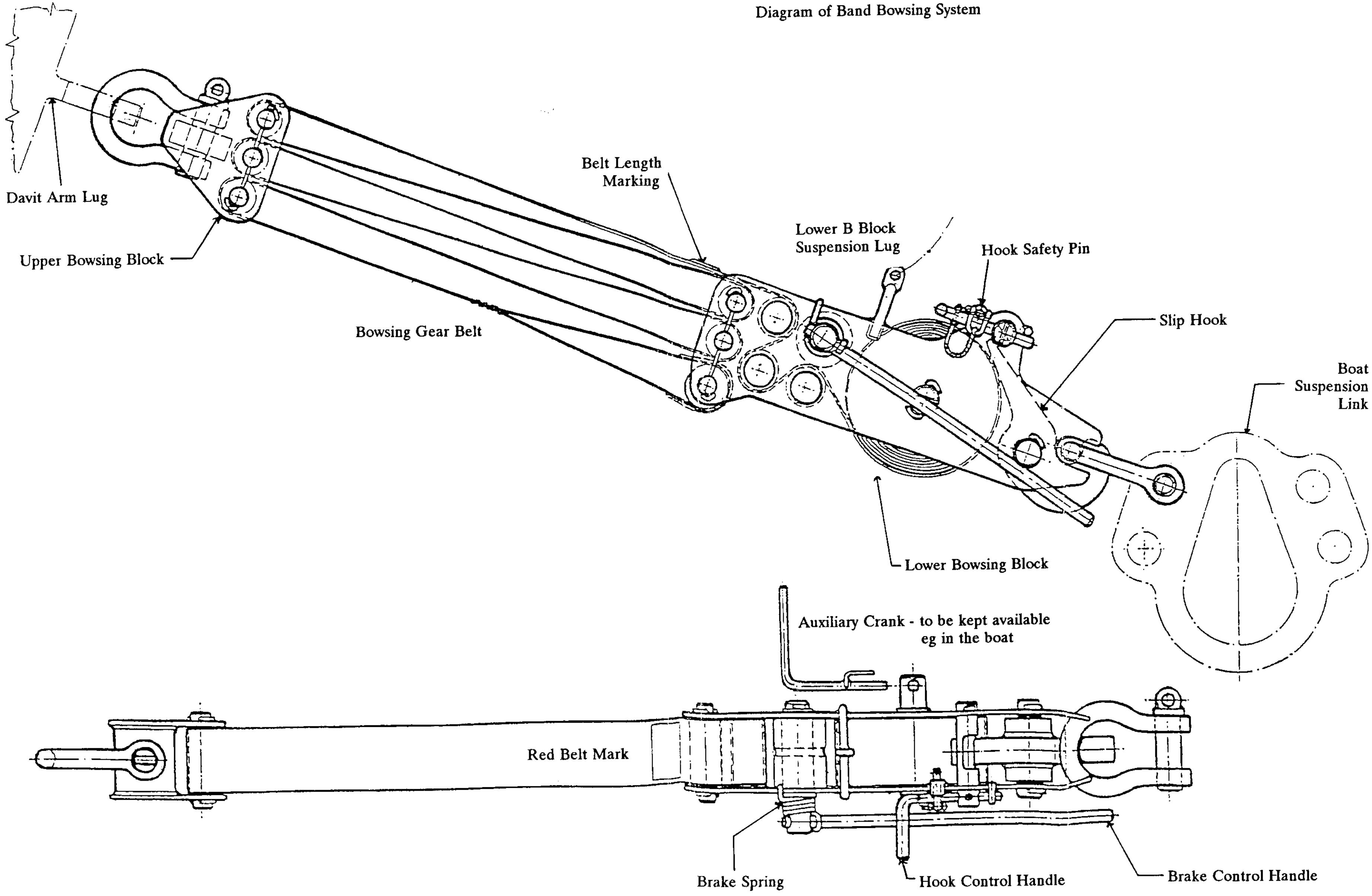


FIGURE 6

Loaded Lifeboat suspended BBS

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As the BBS was new to the Department, before any changes could be made to the existing bowsing system the Department had to be satisfied that Merchant Shipping Regulations would not be breached as a result. They needed assurance of the reliability and effectiveness of the BBS to enable persons to embark safely into the lifeboat, so that its use did not undermine the strength and stability of the davits.

5. EXTENT OF DAMAGE

5.1 The Davit Arms

An inspection of No 3 davit structure after the accident revealed no sign of deterioration due to corrosion but there was extensive damage to various parts.

The upper rollers of both forward and aft arms of the davits were free of their trackways. The lower rollers were still in place on their arms and within their tracks. The head of each arm was resting against the shell plating of the vessel, the horns having damaged the plating, (see figure 4).

The falls on the aft davit arm, its lower block and the BBS were still in place and suspended from the aft arm. Hanging from the aft hook was the stern column of the lifeboat together with the propeller shaft, and keel plate. Hanging between the aft arm and hook plate was the BBS.

The lower block was missing from the forward arm and the forward falls had failed. One block of the BBS was still hanging from the pad eye but the band fabric of this gear together with the other block were missing.

Removal of the davit arms from the ship enabled a closer inspection to be carried out. No significant amount of damage to the arms could be seen but the following was noted:

- Forward arm showed slight twisting towards what would have been the aft direction.

- The lower block stops on both arms were distorted but intact.

- The upper and lower roller axles were intact and showed no signs of damage.

- The remains of the aft falls, where they passed through the lower block stops, showed signs of severe crushing and bending.

Of particular note was that the pad eyes, used for the BBS tackles, were both intact and showed no signs of distress.

5.2 Inspection of No 3 Trackways

The dimensions of the trackway scantlings matched those of the makers drawings but the following was noted:

- Both channels of the aft trackway were splayed symmetrically in way of the position where the upper rollers would be with the davit arms swung out; total splay was in the order of 30mm. There was also local distortion in the same position, consistent with the rollers having been pushed upwards and outwards from the trackway.

- Both channels of the forward trackway displayed signs of local distortion in way of the position where the upper rollers would be with the davit arms swung out. The aft channel showed significant splay towards the aft direction which was consistent with the observed twisting of the forward arm.

- The lower ends of both sets of tracks showed local distortion in way of the arms lower rollers.

No other parts of the trackways, or their supports, showed any signs of distress or overload. However, the handrails either side of the trackways, at the embarkation deck, showed signs of permanent deflection, in the fore and aft direction, sufficient in magnitude to prevent the proper closing of the lifeboat embarkation gates.

5.3 The Falls Wire

The falls wire had failed in the region of the forward arm head and showed signs of stranding over much of its length adjacent to each arm. The aft falls stopper was pushed hard against its fixed bollard, whilst the forward falls stopper was well clear of its fixed bollard. Schat-Davit UK recommend that the fall stoppers be positioned 0.2m from the fixed bollards. The distance between the inner faces of the fixed bollards is approximately 8.0m, therefore the expected distance between the outer faces of the fall stoppers would be approximately 7.6m. The measured distance between the fall stoppers after the incident was approximately 5.9m. These dimensions suggest that the falls wire moved 0.2m till the aft stopper came up against its fixed bollard and then the falls wire possibly moved by approximately 1.7m as a result of passing through the aft stopper, though the actual movement is unknown.

5.4 The Band Bowsing System

The bottom shackles which were in place on both forward and aft lower block hook plates were rated at 4.75 tonnes SWL, although Schat-Davit BV specified these to be 9.5 tonnes. The pins of these shackles displayed signs of distortion and it proved impossible to remove these pins without the application of substantial effort. Subsequent tests performed on these shackles, but fitted with new pins of similar material, indicated that a load of at least 18 tonnes would have been required to produce the pin distortion observed.

The banding of both forward and aft BBS displayed signs of stranding. The side plates of the forward BBS block, mounted on the arm pad eye, were distorted and one pin was displaced at one end. Also the banding on the forward BBS had parted and been carried away with the lower block.

After recovery of both BBS and close examination, it was possible to determine that the aft BBS had increased in length by approximately 771mm from an original pre-launch setting of approximately 1994mm: the forward BBS would have been increased in length by approximately 396mm from its pre-launch setting.

5.5 **Recovery of Water Bags**

During the recovery operation of the lifeboat from King George Dock a total of 221 Water Weights Ltd water bags were recovered and many of these were damaged.

6. SEQUENCE OF FAILURE

6.1 The evidence of witnesses to the exact sequence of events leading to the failure of the equipment does vary. However, the majority stated that there was an initial movement of the after end of the lifeboat away from the ship which was followed by a rapid movement outwards. Some described it as moving rapidly, others as swinging rapidly. This rapid movement was in turn followed by the collapse of the davit structure. The great majority of witnesses also stated that after initial attempts in moving the BBS lever, Seaman B finally succeeded in releasing the BBS causing the rapid movement of the after end of the lifeboat away from the ship's side.

One witness reported that Seaman B then moved the brake lever in the opposite direction, effectively applying the brake and that he succeeded in releasing the BBS a second time causing a further swing outwards. However, it is unclear why he should have made this second attempt before Seaman A had succeeded in releasing his brake. It is therefore considered unlikely that more than one attempt was actually made. The aft davit arm top roller pulled away from the trackway and sequential collapse of the davit structure followed. Seaman B's counterpart, Seaman A, who was stationed in the forward hatchway, was unable to operate the BBS throughout the proceedings.

Damage to the aft trackway comprised splay in both channels and distortion of the track flanges was symmetrical indicating that the trackway failed in this area due to the top roller of the aft davit arm pushing out in a normal direction to the plane of the trackway flanges.

The local damage to the forward trackway flanges showing significant splay in the aft direction in way of the position where the upper rollers would be with the davit arm swung out matched the effect of the forward davit arm twisting out in the aft direction.

It cannot be said that there was no fore and aft loading on the aft trackways. But any such loading during failure must have been relatively small as there has been no non-symmetrical permanent splay in the aft tracks. This compares with the significant non-symmetrical splay found on the forward tracks when the effect of twisting is considered to have been a major cause of its failure.

This pattern of damage on each trackway along with evidence of witnesses, indicates a probable sequence of events leading to final collapse of the davit structure as follows. Subsequent to the operation of the BBS during the "second test" the upper roller of the aft davit arm applied a load to the trackway flanges causing the tracks to splay open. As the aft davit arm fell away while pivoting on its lower rollers, the span wire attached to each of the davit arm heads pulled the forward davit arm aft and downwards. This twisted the forward davit arm upper rollers out of the trackway, resulting in the arm falling away.

7. POSSIBLE REASONS FOR STRUCTURAL COLLAPSE OF THE LIFEBOAT DAVITS

7.1 Introduction

It has been deduced that collapse of the davit was initiated when the supporting trackway in way of the top rollers splayed so that support for the rollers was lost. It is the Inspectors' considered opinion that a load was induced on the aft trackway at the point of upper roller support as the after end of the lifeboat swung away and the weight of the boat was rapidly transferred from the BBS to the fall wire. This load was outside design limits and beyond the load which was applied during the 2.2 SWL production tests of the structure at the makers works. This overload was the primary cause of trackway splay and loss of support for the aft davit. A possible contributory factor was the influence of possible loss of load bearing capacity due to local plastic deformation of the trackway which might have occurred during previous service and/or the "first test". In order to find out why this happened detailed examination of how the davit was loaded on the day of the test is necessary, but before examining the davit loading, consideration should be given to causes which on investigation have been eliminated.

7.2 Winch Failure

The possibility of whether a failure of the lifeboat winch contributed to the accident has been examined. At the time of collapse, a ship's officer who was in the cargo office situated below the lifeboat embarkation deck may have heard the lifeboat being lowered followed by a sound of the lifeboat winch stopping. The possibility of inadvertent release of the lifeboat winch brake was therefore investigated.

Incidents of uncontrolled lowering of lifeboats resulting in structural damage of davits have occurred in the past and have been investigated. In many cases the cause has been due to malfunction of the winch brake system and/or its associated clutch.

Inadvertent brake release has been reported on ships because of malfunction of the remote lowering wire which, when pulled, operates the lifeboat winch brake. Malfunction can occur due either to incorrect adjustment of the wire or to it snagging in its winding arrangement as the lifeboat is being launched or recovered. These possibilities were dismissed on the grounds that the lifeboat was lowered from the stowed to the embarkation position in readiness for the operational test of the BBS. After moving the lifeboat for embarkation, the load was removed from the fall wires by releasing the winch brake momentarily; this was later followed by re-tensioning the fall wires before the men embarked the lifeboat. All these operations were carried out without incident.

To establish the probability of the winch operating and initiating the incident, the winch was removed to the manufacturers works and placed on a test bed. Tests conducted consisted of sporadically applying increasing loads on the winch, up to 1.5 SWL, the maximum load applied at the original proving tests. The clutch and brake did not slip. The two assemblies were dismantled after the load tests and found to be in good order.

From the results of the tests and inspection of the winch it was concluded that the winch did not initiate or influence the catastrophic failure of the lifeboat davit structure.

7.3 Overloading of the Lifeboat

The possibility that the loading of the lifeboat was in excess of the specified test weight and could have led to overloading of the structure was considered. 12,565.8 kg was specified to be placed in the lifeboat in order to achieve a load of 1.1 times the working load on the davits. This would have given a loading greater than applied during the 1.1 times SWL applied during the vessel's construction. However this load is less than the designed, and approved, maximum working load of the davits.

Water bags, supplied by Water Weights Ltd, were used to apply the required loads. Each bag was marked to hold 50 kg. Tests were performed on behalf of the Inspectors to examine any possible margin of error in the weight of water bags used. A margin of error of approximately minus 2.9% was measured on one bag, assuming a sea water density of 1012 kg/m^3 the density of water as measured from King George Dock. These bags were calibrated for a sea water density of 1025 kg/m^3.

There is no documentation to support witness evidence to the effect that 252 water bags were placed in the lifeboat. As only 221 water bags were recovered from the dock it is assumed that some were lost. However, assuming the figure of 252 is correct, any error in the total weight of the water bags used would appear to be slight and on the light side, therefore the total weight used for the test was not in excess of the prescribed weight.

7.4 Twisting out of the Aft Davit Arm

A further possibility considered was that the aft davit arm had twisted out of the trackway. The swinging away of the lifeboat on release of the aft BBS brake would have induced a twisting motion on the aft davit arm. Evidence of witnesses and examination of the damaged aft BBS and aft trackway indicates that this twisting motion was well within that expected when the system was subjected to the 2.2 SWL proof test which included a 10° trim load. It is concluded that loading on the trackway due to this twisting motion was insignificant and that the motion was insufficient to cause the upper rollers of the davit arm to twist out of the trackway resulting in progressive collapse of the davit structure.

7.5 **Failure due to Overload of the Structure**

With the elimination of the various possibilities just discussed, it was necessary to consider whether the failure of the structure was due to overloading. Investigation into the loading pattern generated on the davit structure during each test was based on information on drawings supplied by Schat-Davit (UK) and Schat-Davit BV to the Department for the purpose of the original approval of the davits and for approval of the BBS. The dimensions and geometry of the davit indicated on the drawings were later confirmed by an Inspector taking measurements from No 5 davit installation and the damaged No 3 aft davit arm. North Sea Ferries confirmed the probable length of the aft BBS as set before commencement of the tests.

7.5.1 **Loading of the Davit during the "First Test"**

The test was conducted with the ship in the upright position (no list). The water bags were placed evenly throughout the lifeboat while bowsed into the ship's side and the BBS sharing the weight of the boat with the fall wire.

Photographic evidence indicates that at the start of the "first test" the davit arms were in the full outreach position with the lifeboat held against the ship's side lying inwards with its gunwales at an angle of approximately 9 ° to the horizontal, and suspended by the BBS with the fall wires slack. The angle taken by the BBS is shown to be approximately 22 ° to the vertical, (see figure 6). In this condition and using the lifeboat manufacturers specified position of centre of gravity, the loads in the BBS and top rollers would be 9.36 tonnes and 29.422 tonnes respectively.

The loading on the top rollers when the lifeboat is suspended by the BBS and held into the ship's side with the fall wires slack is therefore much higher than that load expected when the davit is subjected to 1.1 times the working load. This test is performed in the conventional manner with the lifeboat hanging on the fall wires in the vertical position ready to be lowered. The loading is, however, within range of the 2.2 times working load proving test of the davit.

7.5.2 **Loading on the Davit Structure During the "Second Test"**

After completing the "first test" the weight was replaced onto the fall wire using the davit winch. The total weight of the lifeboat was then shared between the fall wire and the BBS with the lifeboat held against the ship's side. In this condition it was possible for the falls to support an approximate maximum of 70% of the total weight. However, it is difficult to judge how much weight would have been placed on the fall wire once tightened. It was reported that the fall was "bar tight", but this observation does not necessarily mean that it had taken its maximum share of the weight. It is possible that the actual share could have been substantially less.

The aft davit arm collapsed as the aft end of the lifeboat swung away from the ship's side subsequent to the release of the BBS. Loads induced on the arm due to the swing outwards are affected by a combination of factors.

These factors are:

- rate of swing out of the lifeboat;

- the load in the BBS during the swing;

- the amount and timing of "fall shift";

- the pull back load on the fall wire.

Rate of Swing

If it is assumed that the aft end of the lifeboat swung freely as a simple pendulum, it is estimated that the dynamic load on the aft arm top roller was 0.87 times its SWL. Whilst it is accepted that a somewhat higher loading could be calculated by working on the basis of a conical pendulum motion, nevertheless it is concluded that the effect of free swing alone was not the primary cause of davit failure.

Load in the BBS during the Swing

The effect of release of the aft BBS would have caused the aft end of the lifeboat to swing outwards and down. The aft BBS was inspected by an independent organisation after the accident and they reported that it had increased in length by approximately 771mm from its original setting of 1944mm.

For the BBS load to have been significant at any time during the swinging out of the boat, the BBS brake would need to have been re-applied. This re-application would have been due to either a positive action on the part of the seaman in pushing the brake lever down or due to his release of the lever which would have allowed it to drop under the influence of the return spring and gravity. Exactly what happened will never be known since the seaman was killed. Like his two surviving colleagues, he was probably thrown off balance and fell as the lifeboat suddenly swung away when he operated the brake lever.

As a result he probably lost his grip on the lever allowing the brake to return automatically to the "on" position. The amount by which the aft BBS payed out during this period is uncertain. Given the increase in length of 771mm, this would have been due to the brake being released, slipping and the subsequent gross overloading as a consequence of the davit arm collapsing. The proportion of the BBS extension due to each of these factors cannot be established. Tests indicate that when the BBS brake is applied using only the assistance of the lever return spring, slipping would occur at loads of the order of 6 to 8 tonnes. Positive re-application of the brake by the seaman would have caused the brake to slip at a greater load than this. However, it is considered unlikely that he was able to re-apply the brake, having fallen over, suggesting that the BBS load of 6 to 8 tonnes was the most probable.

"Fall Shift"

In order to explain the factor of "fall shift" it is necessary to make comparison between the load present in the fall wire when either conventional type bowsing gear or BBS is in use.

With conventional bowsing gear, such as the equipment originally fitted on NORSEA, the lifeboat is embarked when held into the ship's side by the bowsing-in tackles. The tackles are rigged so that the bowsing load applied to each fall wire lower block acts in a direction very close to the horizontal plane when the vessel is upright. As the vessel heels, this bowsing load moves away from the horizontal by an angle equal to an angle of heel. With davits such as those on NORSEA that are rigged with a continuous fall wire, (a single fall wire instead of two) release of one of the two bowsing-in tackles will, from static load considerations only, result in differences of loads in the falls between each of the two davit arms. This would induce a tendency for the wire fall to shift towards the davit arm having its bowsing gear still in place. This tendency is present both in the upright and low-side list conditions, although of decreasing severity as low-side list angles become greater. Thus, the falls at the davit arm where the bowsing gear has been released would have a smaller load than at the other end. Any possible downward movement of the boat due to movement of the falls would occur at the opposite end from where the gear was released.

It should be noted that in normal operation of this type of bowsing gear, because it is impossible to significantly unload the falls, the forces tending to shift the falls are small, particularly in the low side list condition. Thus the fall shift is adequately resisted by the potentially large friction forces generated between the falls and the fixed bollards.

The BBS is designed to apply bowsing loads to the lower block plates of the lifeboat, with a line of action at a substantial angle to the horizontal plane. Thus, whenever the BBS is in operation it must, by design, support a proportion of the lifeboat's weight. Should the BBS load be released at one end when the lifeboat is in the bowsed-in condition, then again from static considerations only, the load in the falls at the end released becomes greater than at the end which remains bowsed-in. Any potential movement of the fall wire induced by this difference of load will be towards the davit arm at which the BBS has been released.

This effect is present from the upright ship condition to the extreme 20° low-side list condition. The greater the list the greater this load difference becomes until at 20° low-side list the load difference becomes equal to half the weight of the boat. However, with continuous falls this situation cannot be sustained by any friction between the fall wire and fixed bollards: without a significant load in the fall wire due to loads on both lower blocks, the wire will experience no significant friction force to oppose the tendency for the falls to shift. The amount of free-movement that takes place is dependent on the gap setting between the stopper on the falls and the fixed bollard on the davit.

One should note that, as with the conventional bowsing gear, this shifting action of the fall wires will only take place when the davit is rigged with a continuous fall wire. No 3 davit on NORSEA was rigged in such a manner.

There is thus a fundamental difference in the way the two types of bowsing gear affects the falls system. Essentially, conventional bowsing-in tackles produce a system which is stable, whereas under certain conditions the BBS can cause an unstable system to be generated.

When the BBS suddenly payed out on the NORSEA davit, a shift of the fall wire is considered to have taken place causing the aft end of the lifeboat to drop by an amount dependent on the stopper gap distance. The gap setting on No 3 lifeboat davit is unknown but the setting recommended by Schat-Davit (UK) is 200mm. On the other NORSEA davits the gap distances were measured by North Sea Ferries and found to vary between 250mm to 20mm. From this examination it is reasonable to assume that a gap existed on No 3 davit.

Inspection of the damaged davit indicates that this movement of the fall and stopper occurred. Such a movement of the fall wire would allow the boat to move. This motion would continue until the fall wire stopper met its fixed bollard. This sudden arrest of the wire's motion would induce a dynamic load into the wire, arm and trackway.

The Inspectors have attempted to estimate the order of magnitude of these loads induced in the davit but the complex nature of the motion makes an accurate analysis impossible.

Pull Back Load

Inspection further indicated that the aft fall wire stopper had moved some distance along the wire. It is not known when this movement occurred but the possibility exists that part or all of this movement took place during the shift of the falls and resulted in the generation of a dynamic load. If this stopper movement is to be assumed it would have allowed the aft end of the boat to fall and the forward end to rise. Should this forward end rise have been sufficient to allow the forward wire block to meet its stop, then a dynamic load would have been generated in the system. The effect of this load on the arms would have been to increase the top roller load on the aft arm and to reduce the top roller load on the forward arm.

Although this interpretation is possible it is considered unlikely because the proportion of the total extension of the aft BBS which occurred before the davit failure indicates that the total fall wire shift was less than that required to allow the forward lower block to hit its stop.

It is recognised there is a possibility that, simultaneously with the dynamically induced load caused by the "falls shift", an adverse moment of the aft arm may have occurred caused by the BBS brake load and this may have been further superimposed on the pendulum load.

The cumulative effect of the total load generated on the davit makes it impossible to predict with accuracy, but its magnitude was sufficient to cause local distortion of the flanges and spring of the trackway channels at the point of support in way of the top pair of rollers. The circumstances of this effect were extraordinary in that using the conventional bowsing system the effects of the "falls shift" and the BBS induced moment would not have developed.

7.5.3 Possible Influences on Load Bearing Capacity of Trackway

Any deterioration of the trackways which occurred between the 2.2 SWL test at the manufacturers in September 1986 and the test of 5 February 1992 is likely to have affected their load bearing capacity. Inspection of the trackway for lifeboat Nos 4, 5 and 6, indicated some opening and splaying of a permanent nature. Some of this distortion may have occurred during the manufacturing process. However, the pattern of distortion points to most of this having occurred during service, notwithstanding the fact that following the 1.1 load test at the builders yard the equipment was only ever operated with unladen lifeboats.

The nature of this distortion indicates that the trackway channels in way of the top rollers were subjected to spreading and twisting giving rise to an increased gap between adjacent channel flanges. The effect is at its greatest on the upper flanges which support the arm top rollers. The measured increase in the upper flange gap is up to a maximum of 13mm. Thus increased clearance would lead to greater lateral movement of the arm and overhang of the rollers on the trackway flanges. The cumulative effect of manufacturing clearances and the measured trackway distortions have caused roller overhangs, beyond the edge of the flanges, of up to 20mm to occur.

The effect of such roller overhangs would be to further increase trackway deflection for any particular davit load. During the "first test" the distortion, elastic and possibly plastic, would have been superimposed on any existing distortion. The sum of all these distortions is likely to have been difficult to identify without careful measurement. The Surveyor from the Department assigned to inspect the davit during this test reported minor distortions being present at the point where the upper roller rested on the trackway before the "first test" commenced. Once the load of the "first test" was applied, further inspection by the Surveyor indicated no further deflection visible to the naked eye or signs of cracking of the paint coating which would have indicated local deformation of the trackway material.

Post accident investigation by a firm of consultants, on behalf of North Sea Ferries, calculated total splay of the trackway channels due to the estimated top roller loads acting at the time of the "first test" as 32mm. This degree of splay is in conflict with the observations made during the "first test" by the Surveyor from the Department.

It is considered that splay of 32mm would most likely have been identified by eye without the need for direct measurement. Although some distortion during the "first test" was inevitable, the report of the Department's Surveyor suggests that it was not as severe as predicted by the analysis of the consultants. It is recognised that some doubt exists as to the exact magnitude of plastic distortion present, but any plastic deformation induced locally during the "first test", or during previous service, would have reduced the ability of the trackways to withstand the loads it would have ultimately experienced during the "second test".

PART III FURTHER COMMENT AND DISCUSSION

8. OPERATION OF THE BAND BOWSING SYSTEM BRAKE

The forward and aft BBS units are a matched pair in order that the brake levers face the operators in the forward and aft hatches of the lifeboat. In other words, the brake lever for the forward BBS faces aft, whilst that for the aft BBS faces forward. Also the levers of both units need to be operated in the same direction. It has been verified from photographs taken during the "first test" that the units were connected correctly so that the operation of the brake levers was common for both forward and aft BBS, but there is no clear indication on the equipment in which direction the lever has to be moved to release the brake.

The purpose of the BBS brake is two-fold: it prevents the BBS from slipping so that the lifeboat remains bowsed while persons embark; it acts as a control device to allow the BBS to pay out in a controlled manner so placing full weight of the lifeboat onto the fall wires.

Mechanical failure (breakage) of the BBS was not expected. Following the "first test" the BBS was examined and there was no sign of failure. This was not surprising since the breaking load of the BBS was specified to be 51.3 tonnes. The SWL specified was 10 tonnes and Schat-Davit BV claimed that the BBS was designed to take the full load of the boat with sufficient mechanical safety. Their view was that the BBS could not be overloaded to such an extent to cause mechanical failure since the brake would slip first. This view is probably correct.

In the "first test", full weight of the lifeboat was applied to the BBS with the fall wire slack and the BBS brake held. Calculations indicate that the load in the BBS was approximately 10 tonnes. To prevent the BBS from inadvertent slipping the brake needs to be able to resist the largest force applied to it in service and to enable the operator to effectively control the paying out of the BBS and stop it when necessary.

With the help of Schat-Davit BV an Inspector conducted tests of the performance of the BBS. The tests indicated that the slipping load characteristics of the BBS brake were not constant but varied between 4.5 and 11.7 tonnes depending on the amount of effort put into moving the lever to apply the brake. However the amount of effort required was not always directly proportional to the slipping load. For example, the slipping load of the BBS varied between 9.58 and 11.2 tonnes for the same applied effort to move the brake lever. Findings of this test conflicted with Schat-Davit BV specifications of the slipping load originally stated to be 11.5 tonnes and later revised to a range between 13.7 and 18.7 tonnes, the maximum value achieved by hard application of the brake with hammer blows to the lever.

The Inspector also found that control of the BBS is sensitive to the amount of effort placed by the operator in moving the brake lever and concluded that it may be possible to achieve this sensitivity given hands on experience of the equipment. However, despite this conclusion training alone may be insufficient to ensure effective control and locking of the BBS under all conditions of use.

If the brake lever is not set to resist the maximum expected load, inadvertent slipping is a possibility. Although the davit structure should be designed to withstand any BBS induced loads including those imposed due to slipping there is the danger that should slippage occur the lifeboat could move away from the ship's side making any further embarkation impossible.

If, on the other hand, maximum locking force is achieved by hammering the lever in the locked position, all sensitivity may be lost thus preventing the operator from achieving any control of paying out of the banding.

The design of the BBS like that used on NORSEA needs to be reviewed. The locking of the BBS and control of paying out of the band must be assured at all times. Specification of the slipping load is incomplete and could lead to potentially unsafe operating conditions.

9. APPROVAL OF LIFEBOAT LAUNCHING SYSTEM

9.1 Introduction

Using the BBS imposed loads on the lifeboat launching system causing it to fail. Although approval of the system as originally installed on NORSEA is discussed in Section 4.1 of this Report, it is necessary to consider this in more detail, and particularly in respect of the effect of fitting the BBS.

9.2 Implications of using the BBS

Operation of the BBS using No 3 empty lifeboat had been successfully demonstrated to the Surveyors from the Department. One of the Surveyors, and a representative from Schat-Davit BV, operated the BBS brakes and the demonstration indicated that there was satisfactory positive control by manual operation of the brake lever. The banding eased out slowly or quickly as required. However, the Surveyors raised questions about the weight being taken by the BBS when the lifeboat was held alongside the ship. The winchman, when bringing the lifeboat out from its stowed position had to take care not to make the fall wires slack. Nevertheless, it was accepted by the Department, Schat-Davit BV and North Sea Ferries that this situation could not always be avoided. The Department was also concerned that the BBS brake could slip suddenly causing the lifeboat to jerk so endangering passengers when boarding.

Following the initial demonstration, a sample unit of the BBS type was tested to destruction in Holland on 8 May 1991. The unit broke at a load of 51.27 tonnes force (503kN). During other tests it was determined that the brake of the BBS unit type was found to slip at a load of approximately 13.7 tonnes. When the brake handle was tightened with the aid of a hammer the brake started to slip at approximately 18 tonnes. Prior to the tests, Schat-Davit BV specified the slipping load as 11.5 tonnes.

The Department performed an assessment which considered the loads taken by the davit arm mounted BBS lug. Based on those calculations an acceptance factory test on a sample davit arm lug was conducted with the lug welded to a fixed structure. The test conditions were intended to simulate the exact lug dimensions, the penetration of weld, and the method of welding intended to be employed on the davit arms. The test was conducted in order to satisfy a Department requirement that the lug should be capable of successfully withstanding a load of 23.43 tonnes, 2.2 times the working load anticipated on the lug. No calculations were made involving trackway or davit arm loadings.

It was then agreed between the three parties that a 1.1 SWL test of the lifeboat should take place to demonstrate the capability of the BBS to hold the full weight of the lifeboat into the ship's side with the fall wires slack.

The Department also required a demonstration to show that the BBS could be payed out smoothly in order to bring the lifeboat from the ship's side and place full weight of the boat onto the fall wires in readiness for the lifeboat to be lowered, though it is unclear when the requirement for this additional demonstration was made known.

The Department's Surveyor at Hull advised Schat-Davit BV and his headquarters in London of his concern that the system had implications on the strength of the davit and therefore required investigation. The design of the davits is such that in the outreach position of the davit arm the weight of the lifeboat and its occupants cause a clockwise turning out moment of the davit arm. The load in the fall wire due to this weight acts as a counterbalancing moment - the greater the weight the greater the counterbalance. This is an important feature of the design, and allows for a lighter davit construction than would otherwise be permitted should this counterbalance not exist. Use of the BBS could result in elimination of this vital counterbalancing moment as the fall wires become unloaded.

A different load regime is therefore imposed on the davit structure using the BBS compared to that imposed using the conventional method of tricing and bowsing. It is therefore essential to thoroughly assess this new pattern of loading to ensure that the strength of the davit is not compromised.

The Department requested Schat-Davit BV to make an assessment of the implication of loading on the davit using the BBS under the condition of slack falls. When making the assessment Schat-Davit BV allowed for the ship having a 20° low-side list together with 10° of trim. The heaviest loaded top roller was considered under this condition without the BBS in use and, separately, with the BBS in use with slack falls and working under a maximum BBS slipping load of 13.5 tonnes. This method of analysis, although assessing a different criteria to the Department's usual approved methods, appeared to be reasonable and proper. These calculations indicated that this single roller maximum load was of a similar magnitude in each case. From this result Schat-Davit BV advised the Department that the davit structure would not be endangered by using the BBS. No calculations or drawings were submitted to support this conclusion but the Department accepted that they could be submitted later after the tests scheduled for the 5 February. Final approval of the BBS was subject to the Department's evaluation of these submissions.

Davits of this type have been in use for decades and it has always been assumed that the most onerous condition is when the ship lists on the low side. This assumption is justified using the conventional bowsing-in system but it was not fully appreciated that this is not necessarily valid using the modified version of bowsing-in the lifeboat. With the conventional system the lifeboat is embarked after the tricing pendant has been released, which is only possible when any slack is taken out of the falls, and with the bowsing tackle positively holding the lifeboat against the ship's side. Use of this system ensures that the fall wire continues to support most of the boat's weight during embarkation.

The geometry of the BBS and fall wire, as employed on NORSEA, can generate situations where it is necessary for the fall wire to become slack during embarkation of the lifeboat. In the 20° low-side list condition the BBS is vertical and totally supports the weight of the lifeboat. When in this position it is intended that the gunwale of the lifeboat be in contact with the ship's side but this contact may be lost if any load is taken by the fall wire. If, however, during an emergency evacuation of a vessel conditions change the vessel may experience a reduction of list angle. The lifeboat could then be at embarkation position, supported on the BBS and the fall wire slack, but with the vessel in or near the upright condition.

Operating the BBS however changes the position at which the most unfavourable loading on the davit structure occurs. This loading condition arises during the course of the bowsing operation and when the falls are slack with full working load on the BBS as designed. What is more, the load regime on the davit structure is different, and the load in way of the trackways is higher when the full working load is taken by the BBS. In terms of upper roller loading the most unfavourable condition is the upright ship's state. However, when bending moment induced stresses in the trackway are considered, the 20° low-side list would be the most onerous. There would appear to be a conflict between these two criteria.

Also use of the BBS has the potential to impose greater loads on the trackway structure than would be experienced using the conventional system. In the upright ship condition the upper roller load is magnified by a factor of 1.8 times the approved loading of 17.8 tonnes. Whenever the BBS is in use, between the upright ship and 20° low-side list condition with slack falls and a fully laden lifeboat, the bending stresses induced in the trackway produce a factor of safety less than that required by regulations. It is considered possible that had this factor been known, the advisability of proceeding with the tests would have been reviewed.

9.3 Method for Calculating the strength of the Davit

The design of the davits had been approved using long established and accepted techniques. The approval calculations for the strength of the davits which are submitted to the Department are of a method accepted by other Administrations and Classification Societies.

The calculation generally accepted for approval purposes considers the effects of trim induced loads on the davit arms and roller axles only, but not on the davit trackways. Neither does it predict the splay inducing effects of transverse loads on the trackways.

The method employed to assess the stress in the trackway assumes that the trackway behaves as a simply supported beam, to which simple beam theory applies. The technique has the potential to predict direct stresses due to applied bending moments but cannot predict stresses induced by local or point loads, ie loads in way of the rollers. Further errors may occur in the analysis as it neglects the fixing moments on the trackways where they are secured to the deck. The calculations are performed in the 20° low-side list condition which conventionally has been considered the most onerous condition.

As already stated, this method of calculation does not consider the influences on trim induced loads on the trackway, although they are taken into account when calculating davit arm and roller axle stress. Although it is important for these trackways to maintain their geometry in order to retain the davit arms in position, no deflection predictions are made at the approval stage.

In an attempt to overcome the limitations of this type of analysis proof tests are required of the completed structures before installation in the ship. In the case of the lifeboat launching appliances the proof tests are 2.2 times SWL performed in the condition which gives a maximum stress concentration. As required by Regulation proof load test for the NORSEA davits was performed at 20° low-side list combined with 10° trim.

The investigation into this accident noted damage to the trackways, in that splay was observed both on the trackways of No 3 davits and to a much lesser extent on the other davit trackways. This damage suggests that a re-appraisal of techniques used to assess stresses in davit structures is required. Computer programs do exist which investigate the strength of a structure and predict stresses and deflections. The reliability of these programs would need to be validated before their application to the approval of the strength of the lifeboat davits is justified.

9.4 Factor of Safety

A minimum Factor of Safety (FOS) of 4.5 is applied to all davit and winch structural members. This FOS is based on the ultimate strength of the material. When the design of the davits on NORSEA was considered for approval by the Department the calculation diagram showed that, for those stresses which were considered, the FOS exceeded 4.5. This FOS is based on the Ultimate Tensile Stress (UTS) of the material thus:

$$\text{FOS} = \frac{\text{UTS}}{\text{Maximum Working Stress}}$$

When the wider applications of engineering design are considered, it is found that the vast majority of loaded engineering components are designed to operate within the elastic range of the material from which they are produced. Provided the stress in the component does not exceed a value known as the Elastic Limit or Yield Stress, the component will regain its original geometry on removal of the applied stress. As most engineering components are intended to be capable of accepting fluctuating or cyclic loading, often through very many cycles of repeated application of the load, it is obviously essential that such components are never loaded beyond the Elastic Limit.

Due to the necessity of maintaining working stresses below the Elastic Limit so that components suffer no permanent deformation, the failure of such items is often defined in terms of the Yield Stress of the material. Therefore, failure may be considered to have occurred when a component is loaded so that it experiences a permanent deformation or 'set'.

The values of UTS and Yield Stress for typical commercially available structural steels vary slightly and depend on preparation and composition. UTS values vary between 410 and 520 MN/m^2 and Yield Stress between 225 and 260 MN/m^2: ratios of Yield Stress/UTS for such steels covering the range of 0.5 to 0.75.

The material from which the davit trackways on NORSEA are fabricated is a steel to British Standards specification BS 4360 Grade 43A, having a composition of 0.2% Carbon (maximum) and 1.6% Manganese (maximum) giving properties of:

UTS	-	430 to 510 MN/m^2
Yield Stress	-	245 MN/m^2 (minimum)

Approval calculations, and thus FOS, were based on a UTS value of 430 MN/m^2 (4390 kg/cm^2) giving a relationship between UTS and Yield Stress of:

$$\frac{\text{Yield Stress}}{\text{UTS}} = \frac{245}{430} = 0.569 \text{ say } 0.57$$

In the case of the NORSEA davit trackways, using the Yield Stress as the criteria, the FOS would be a minimum of $4.5 \times 0.57 = 2.565$ - say 2.6.

This FOS would be further depleted by dynamic loads and deficiencies of the stress analysis.

As part of an investigation into a fatal lifeboat accident on a tanker in 1990, a major shipping company carried out extended experimental work into the dynamic loadings on lifeboat davits due to sudden stopping of raising or lowering operations. These tests showed that a load magnification of two was achieved. It was found that dynamic loads generated in the fall wire exceeded twice the weight of the lifeboat.

On this basis the review of calculation techniques suggested in Section 9.3 should include the advisability of basing FOS on Yield Stress.

In the NORSEA incident the excessive displacement of the trackways was a major factor in the collapse of the system. However, no part of the davit structure failed in the sense of breakage; failure which did occur was a functional failure of the trackway to retain the arms. Thus the review of calculation techniques suggested above should consider the elastic displacement of trackways in all planes which are likely to induce a functional failure of the system, together with the corresponding stresses and take due consideration of the possibility of failure due to plastic deflections.

9.5 Lifeboat Launching System Design

The request for use of the BBS system highlights operational problems with large semi or fully enclosed lifeboats. These problems are only revealed once the launching equipment and lifeboat has been fitted to the ship in readiness for service.

Documented evidence of experience in some passenger ships shows similar problems to those of NORSEA which involve difficulty in bowsing of the lifeboat effectively and safely; semi-enclosed and enclosed lifeboats make it difficult for seamen to operate bowsing equipment. Also, because of the geometry of the davit arm relative to the ship, a dangerously high load is imposed on the tricing pendant further affecting safe operation of the bowsing equipment. Safety of embarkation is affected, such as on NORSEA, where the gunwale of the lifeboat is in the unsatisfactory position of being below embarkation deck level.

The design and approval of lifeboat launching equipment should be considered in the context of the vessel to which it is to be fitted. If the system is viewed as a complete entity, then the risk to personnel and to the launching equipment can be assessed as a whole and the risks reduced. Such an overview should be undertaken both during initial design of the system and when modifications are considered, which may be inevitable during the life of a ship.

10. SAFETY OF MEN IN THE LIFEBOAT

The tests of 5 February were acceptance tests and therefore an element of risk was implicit. It is therefore necessary to consider whether proper regard was had for the safety of those involved.

The purpose of the "first test" was to examine the strength of the davit and the BBS with the lifeboat loaded to 1.1 times the working load. Care was taken to ensure that personnel were not in the boat when the full weight of it was taken by the BBS with the fall wire slack. No secondary means of support existed to safeguard personnel in the event of failure of the launching system while the weights were being placed in the lifeboat, but at that time the boat was still partially supported by the fall wire.

The object of the "second (fatal) test" was to verify the practical effectiveness of the BBS. This could only be achieved by operating the equipment, and for this purpose it was necessary to have men in the lifeboat: the BBS could not be operated from outside the lifeboat. The test was a necessary complement to the first test since the Department needed to be satisfied that the new system was not only safe in terms of strength but also practicable in use. Although the lifeboat was still loaded to 1.1 times its working load, there was no apprehension of breakage, for the first test had been successful and was considered to have adequately demonstrated the strength of the davits and the strength and holding ability of the BBS. Placing men in the boat did not, therefore, appear at the time to put them in hazard.

The original intention was that Schat-Davit personnel would operate the BBS, but in the event it was decided that crew members should do so. It is not entirely clear why this change was made: the most likely explanation is that, once the lifeboat had been lowered into the water the weights would need to be removed before the boat could be recovered and stowed. Four seamen would be needed to do this work, and to make it easier it may have been considered convenient for them to be in the lifeboat for the test in readiness to unload once the boat was waterborne. However, the seamen were unfamiliar with the operation of the BBS, and had had no training or instruction in its use save that handed down from Schat-Davit personnel through the ship's Chief Officer on the day.

Neither safety helmets nor life-jackets were worn by the crew on the day of the accident. It is common and accepted practice to wear safety helmets while working with lifeboats but it is impossible to conclude that lives would have been saved had helmets been worn. Standard SOLAS life-jackets were not worn because they severely restricted the wearer's movement within the hatchway of the lifeboat when operating the bowsing equipment. This was in accordance with "The Code of Safe Working Practices for Merchant Seamen" which states (in relation to drills) that:

"life-jackets may be removed at the Master's discretion if they would impede or make unduly onerous the ensuing practice, provided they are kept ready-to-hand".

Life-jackets were to hand. Again, it is impossible to conclude that wearing them would have saved the lives of the two seamen. It will be noted that the two survivors of the accident who were trapped inside the upturned lifeboat escaped by ducking into the water and swimming down under the boat gunwale before resurfacing outside the boat. If life-jackets had been worn this means of escape may not have been possible, and in the opinion of the two men they would not have survived had they been wearing life-jackets.

During the tests, in addition to the ship's staff, the Fleet Safety Officer from North Sea Ferries, Surveyors from the Department and representatives of Schat-Davit BV were present. It was not made clear who was in direct control. The Department's Surveyors, who attended to witness the tests, advised the Fleet Safety Officer as to what was required to satisfy them but it was not their role nor was it within their authority to take charge of the tests' execution. The representatives of Schat-Davit BV provided advice as manufacturers of the BBS but again had no authority to direct the operation. While it was proper for advice to be sought of and given by both the providers of the equipment and the Department's Surveyors, control of the actual conduct of the tests should have been clearly exercised either by the ship's Chief Officer or by the Fleet Safety Officer on behalf of the owners. Without the line of command being firmly agreed and made clear, the exercise of control fell short of that which should be manifest in an operation such as the conduct of these tests. It should, however, be stressed that it is most unlikely, given the circumstances, that the accident would have been avoided had control been executed differently.

11. SEARCH AND RESCUE

11.1 Sequence of Search and Rescue

Immediately following the accident, preparations were commenced for lowering No 5 lifeboat. On being informed of the accident the Master telephoned the Dock Master at approximately 1400 hrs and informed him that a lifeboat had dropped into the dock and had landed upside down with two persons trapped underneath. The Dock Master immediately contacted the emergency services, and also telephoned Northern Divers (Engineering) Ltd requesting them to send their emergency diving team.

The Master of HUMBER RANGER, a survey vessel berthed at No 7 Quay, on hearing the noise and seeing the upturned lifeboat in the water, with the assistance of three shore workers let go his moorings and proceeded towards NORSEA.

The Fire Brigade arrived at King George Dock at 1405 hrs to be met by the Second Officer of NORSEA in a position on the quay near the stern of NORSEA. The Ambulance Service arrived one minute later.

When HUMBER RANGER arrived alongside the upturned lifeboat two men jumped onto the hull. They both knocked generally all over the hull and heard a return knocking apparently emanating from the forward section of the lifeboat. They reported the fact to the Master of HUMBER RANGER. Two ropes were passed from HUMBER RANGER, one of which was secured at the forward end and the other at the after end of the starboard bilge rail of the lifeboat. The painter, which was still connecting the lifeboat to NORSEA, was then cut. Attempts were then made to right the lifeboat but these were unsuccessful.

The Dock Master then requested that the lifeboat be gently moved to No 7 Quay in order to allow access by the emergency services and divers.

A Fire Brigade vehicle arrived at No 7 Quay with the Second Officer of NORSEA. The senior fire officer present assumed command of an attempt to rescue the crew members who were reportedly trapped inside the lifeboat. It was his intention to either turn or lift the lifeboat and, to this end, he made a request by radio for diving equipment and a dockside crane.

By 1411 hrs, the lifeboat had been manoeuvred alongside and secured to No 7 Quay. A ladder was lowered from the quay to the upturned hull of the lifeboat and two firemen descended. The firemen attempted to cut a hole into the hull into which the hook of a mobile crane hook could be inserted. However the air-driven cutting equipment was ineffective in cutting into the fibreglass material of the hull. The attempt was abandoned when someone advised the senior fire officer that such action might result in the escape of any remaining air available to the persons trapped inside the lifeboat.

The Second Officer had advised the Dock Master that there had been four persons in the lifeboat and the Dock Master requested HUMBER RANGER to conduct a search in the immediate vicinity of NORSEA. No persons were observed in the water and HUMBER RANGER returned to No 7 Quay. In the meantime the divers had arrived and were preparing to enter the water.

At 1415 hrs the body of Seaman D was sighted floating in a position between NORSEA and No 7 Quay. HUMBER RANGER proceeded towards the body but those on board were unable to lift the body out of the water due to its heavy weight. It was therefore decided to manoeuvre the body to No 7 Quay where an ambulance crew attempted resuscitation, which was unsuccessful.

Meanwhile two chains had been lowered to the lifeboat from the quay and connected to opposite ends of the starboard bilge rail. The mobile crane was used to heave on the chains but this resulted in the bilge rail fastenings to the hull becoming detached. The chains were then hooked onto a section of the rail which was still fixed to the hull and the crane then just took the weight with the intention of preventing the lifeboat from sinking.

The senior fire officer requested longer chains. The Dock Master advised of his concern with respect to the possible weight of the lifeboat against the lesser lifting capacity of the crane in use and organised for a mobile crane of a larger lifting capacity to be made available.

At about 1425 hrs, divers entered the water and commenced a search. Again knocks were heard from the upturned hull of the lifeboat. The divers attempted to secure additional chains at each end of the lifeboat but their progress was hampered and endangered by the presence of resultant debris and the large number of water-filled bags located inside and around the upturned hull.

The divers finally succeeded in securing chains to the forward part of the lifeboat in way of the lifting hook arrangement and to the after part in way of the cockpit canopy.

At approximately 1500 hrs, a replacement mobile crane heaved on the chains which had the effect of raising the forward end of the lifeboat. As the gunwale cleared the water, Seaman A and Seaman C swam out from under the lifeboat. After being assisted to the quay they were taken to hospital by ambulance.

The lifeboat was then lifted higher and divers commenced the removal of water-filled bags in an attempt to gain access into the lifeboat. This operation was suspended due to the hazard imposed upon the divers by the presence of the bags. A wire rope was then attached to the lifeboat in way of the canopy structure in order to assist in righting the lifeboat.

The lifeboat was righted at 1528 hrs, the divers then resumed their search of the lifeboat for the remaining missing crew member.

By 1538 hrs, it was determined that the remaining missing crew member was not inside the lifeboat. The search was then extended to the surrounding water area. At 1550 hrs, an initial search was commenced in the vicinity of where the lifeboat had entered the water. At 1615 hrs, divers of the Police Underwater Search Unit were in attendance.

At 1800 hrs, the search for the remaining missing crew member was continuing with diving teams from both Northern Divers (Engineering) Ltd and the Police Underwater Search Unit.

At 2215 hrs, the search was suspended for the night.

The search was resumed at 1000 hrs on the next day. At 1305 hrs, in a position approximately 15 metres from the dock side and in a depth of 10 metres, the body of Seaman B was located and brought to the surface.

11.2 Comments on Search and Rescue Operation

The senior fire officer present correctly assumed command of the rescue attempt in accordance with normal procedure.

The Fire Brigade are accustomed to handle all types of emergencies but they receive no specific training with respect to the rescue of persons from capsized water craft. However with the expertise available from non-fire brigade personnel who were present the rescue operation was a success.

There can be no criticism of anybody involved in the rescue operation, only admiration for all concerned.

12. MANAGEMENT OF THE PROJECT

As pointed out in Section 10, the responsibility for the control of the conduct of the tests lay with the owner who should have ensured that it was clear who was in charge of the operation.

It is quite clear there is a need for an assigned individual to have an overall controlling function for a complex operation of this nature. Such control, to be fully effective, needs to commence during the earliest stages of planning the operation and continue until completion. In this incident, it does not appear that any one person performed such a role.

In March 1993 The Engineering Council issued a Code of Professional Practice, entitled "Engineers and Risk Issues". The aim of the Code is to encourage greater awareness, understanding and effective management of risk issues and addresses the subject under ten separate headings. Although not all of those headings are necessarily applicable to the management of a project such as one aiming to replace the conventional method of tricing and bowsing-in of the lifeboat with the BBS, a number of the points are pertinent. In particular the Code emphasizes the need for a systematic approach to be taken to risk issues; monitoring during all phases of the project to ensure effective management of risk; and assessment of the risk implications of alternatives.

It is considered that with similar projects in the future management and control should, in general, be undertaken by the organisation which initiates the project. An assessment should be made of the safety issues involved and the Code may be a useful guide when making that assessment: a formal submission of the assessment should then be made to all the parties involved in the project who should be satisfied that it is complete.

13. EVENTS SUBSEQUENT TO THE ACCIDENT

As a result of the accident, the Department suspended the vessel's passenger certificate as they are required, under the Merchant Shipping Acts, to be certain the safety equipment on board the vessel is safe, and to be assured as to the safety and integrity of the other davit structures on board the vessel.

Examination of the trackways of the remaining davits revealed some minor opening and splaying of a permanent nature in way of the elbow joints at the position supporting the upper rollers - the point of failure in the accident, (see Section 7.5.3).

Schat-Davit UK, the designers and installers of the equipment, proposed that strengthening pieces be welded to all remaining trackways in accordance with a drawing prepared by them and approved by the Department. These strengthening pieces were installed and in the subsequent days static load tests were successfully carried out on all of the remaining davits, coupled with satisfactory testing of all ancillary equipment. NORSEA resumed service on 15 February following the reinstatement of her passenger certificate by the Department. The vessel operated with a reduced passenger limit until 23 April when the No 3 lifeboat and davits etc were replaced.

Calculations carried out by the firm of consultants acting on behalf of North Sea Ferries Limited show that the strengthening pieces reduce possible elastic splay to about one-tenth of that which could have been predicted with the original equipment.

Following the accident, the Department agreed that when the vessel resumed service it would be permissible for the bowsing equipment to be operated from the ship rather than the lifeboat. The lifeboat equipment has been operated in this way ever since with the result that a number of the previous operational problems have been resolved.

14. DECISIONS MADE BY SCHAT-DAVIT FOLLOWING THE ACCIDENT

Tests carried out on the BBS system by all concerned prior to 5 February 1992 indicated that the system was safe. However, since the accident Schat-Davit BV have taken a number of measures with regard to the design of the trackways, the BBS and the requirements for its installation.

It is not appropriate for this Report to go into great detail as to those changes, except to record:

- brackets will be fitted to trackways in way of the upper roller swung out position;

- an automatic BBS, with back load to the tracks, is to be used with new davit installations;

- when a BBS is to be installed on existing davit installations with continuous wire falls, the stopper arrangements are modified;

- design changes have been made to the brake system of the BBS for ease of operation.

PART IV CONCLUSIONS

15. FINDINGS

The Inquiry carried out by the Inspectors has covered great detail. It is inevitable in an accident such as this that when one of the main witnesses, the operator of the after BBS, sadly loses his life a certain amount of supposition is necessary.

North Sea Ferries commissioned research work of their own into the causes of the accident and readily made available that information to the Inspectors. During their Inquiry the Inspectors received the full co-operation of all concerned, particularly from North Sea Ferries, Schat-Davit (UK), Schat-Davit (BV) and the Department, without which their Inquiry would have been made more difficult.

The Inspectors findings, with which I concur and which follow, are consistent with sound investigatory work.

The immediate cause of the accident was:

15.1 **An overloading of No 3 davit structure resulting from the testing of the band bowsing system (BBS), a type of combined tricing/bowsing arrangement.**

The davit structure collapsed due to failure of the after trackway brought about by a combination of local distortion of the flanges and splay of the trackways in way of the davit arm upper support rollers causing loss of support for the arm. Progressive collapse of the structure followed resulting in the lifeboat falling upside down into the water, with the loss of two lives.

The overload of the davit structure was induced by the cumulative effects of the 'fall wire shift' and the BBS induced moment.

Contributory factors were:

15.2 It is possible that the effects of top roller overhang and the plastic distortion of the trackways during previous service and the first load test carried out immediately prior to the fatal test contributed to the failure of the trackway to withstand the overload.

15.3 Operation of the existing tricing and bowsing arrangements which cause difficulties with the handling of equipment and the sudden transfer of load when the tricing pendants are slipped led to the decision to try the BBS system.

Other findings:

15.4 The control of the BBS brake is sensitive to the amount of effort applied by the operator to the brake lever and the operator was unable to achieve the necessary sensitivity of the brake control.

15.5 Specification of the BBS slipping capacity was insufficiently complete so as to lead to potentially unsafe operating conditions.

15.6 The shackles used on the BBS for the lower block hook plates were rated at 4.75 tonnes SWL, not 9.5 tonnes as specified by Schat-Davit BV.

15.7 A pre-test assessment of the ability of the davit structure to withstand the loads imposed by the use of the BBS, showed that, with the combined effects of list and trim, the BBS would induce no greater top roller load on a single channel than would have been present with the conventional bowsing system.

15.8 No Bending Stress analysis was performed on the davit structure when considering the use of the BBS, as was carried out for the original approval procedure for the davits. Had such a calculation been performed it would have indicated a Factor of Safety in the trackway which, under certain conditions, was below the value of 4.5.

15.9 During davit approval procedures it is standard practice to assume the most onerous condition for the davit to occur at the 20° low-side list state with the lifeboat fully swung out from the ship's side ready for lowering. However, when the BBS is employed the most onerous condition will occur before the lifeboat lowering position has been achieved. The worst state is when the full weight of the lifeboat is taken on the BBS with slack falls.

15.10 In terms of upper roller loading when the BBS is employed the most unfavourable condition is in the upright ship state. When bending induced stresses are considered the 20° low-side list condition will be the most onerous.

15.11 Calculations were not performed, nor are required, during approval of the davit structure, or when modifications of the bowsing system were considered, to predict deflection of the structure.

15.12 The Factor of Safety calculated during the approval procedure of these davits was based on the Ultimate Tensile Stress of the material used, as is required by Regulations. It is considered that local stresses on the davit structure during service may have exceeded Yield Stress of the material.

15.13 Safety may be jeopardised by only considering the component parts of lifeboat launching systems as separate entities, and not as the total entity, until trials after installation.

15.14 The need for an assigned individual to have continuous overall control of safety related projects, from the earliest planning stage, was not appreciated.

15.15 If life-jackets had been worn by those in the lifeboat the two who survived might not have been able to escape from the upturned boat. However it is not possible to conclude that the other two crew members would have been saved had they been wearing them.

16. RECOMMENDATIONS

In the course of the Inquiry an interim recommendation was issued to all Administrations which were known to have vessels on which combined tricing and bowsing-in systems were in use. For completeness it is repeated below:

> Interim Recommendation
>
> "Static and dynamic stresses imposed by any type of tricing and bowsing arrangement on davit lifeboat launching equipment under all conceivable operational conditions should be considered.
>
> Particular consideration should be given to loads induced by combined tricing and bowsing systems."

The intent of this interim recommendation is not changed in any way by the final recommendations which follow.

Further Recommendations

The completed Inquiry into this accident and the findings of the Inspectors result in a number of further recommendations being made which, if implemented, should generally improve safety of life at sea.

The recommendations are divided into two categories, firstly those that relate to lifeboat davit structures and secondly those that relate to combined tricing and bowsing systems. Although a number of the findings of the Inspectors relate to the operation of the band bowsing system (BBS) being tested on NORSEA they consider that the principle of the system is sound although there were a number of failings in the particular one in use. They also consider that any combined tricing and bowsing system, which although not of the band bowsing type, can have significant advantages over the traditional tricing pendant and bowsing tackle system but can lead to potential problems. Recommendations 4, 5, and 6 are addressed to resolving those failings and problems.

1. The Marine Directorate of the Department of Transport should initiate a research project into the calculation techniques used when approving lifeboat davit structures. Calculations should consider the elastic displacement of the structures in all planes which are likely to produce a failure of the system, together with the corresponding stresses. Calculations should also take due consideration of the possibility of failure due to plastic deflections. The findings of the research, if warranted, should be brought to the attention of the International Maritime Organization (IMO) with a view to an amendment of the SOLAS Convention in respect of the approval procedures for lifeboat launching appliances.

2. The Marine Directorate of the Department of Transport should review the design and approval process for the lifeboat launching system, in conjunction with the vessel to which its fitting is intended, with the view to ensuring from the earliest design stage, and before the launching equipment is installed, that for all required conditions of list and trim:

- account is taken of the geometry and shape of the davit in relation to the ship structure.

- the load on the tricing pendant and bowsing tackle and on the fall wire is assessed for the full sequence of the lowering and loading operation.

- the load remains substantially on the fall wires throughout the period of operation of the launching system.

- when the lifeboat is brought into the ship's side at the embarkation position and the tricing pendants are released, violent jolting of the davit structure and the lifeboat is avoided and the moving away of the lifeboat from the ship's side is prevented as the holding load is taken up on the bowsing tackles.

- seamen can safely secure the bowsing tackles to the lower fall blocks and are able to easily slacken off the bowsing tackle with the weight of a full complement of persons in the lifeboat.

- the level of the lifeboat relative to the embarkation deck is assured for safe embarkation of the lifeboat.

3. The Marine Directorate of the Department of Transport should consult with representatives of the Marine Industry with a view to producing a Merchant Shipping Notice (M Notice) on the use of project management when it is intended to make significant modifications to the safety equipment on board a ship. The M Notice should contain advice on the following:

- The appointment of a project manager to oversee the forward planning and co-ordination of the project throughout its life.

- The roles and relationships of all personnel involved in the project.

- The importance of forward planning, co-ordination of actions and monitoring of the project.

- The importance of testing, verification and acceptance procedures.

- The need for full documentation throughout the life of the project.

- The importance of the health and safety aspects of the project.

4. The Marine Directorate of the Department of Transport should ensure that any band bowsing systems (BBS) of a similar type to that used in this incident, for which their approval is sought in the future, is fitted with a brake that will hold for unexpected conditions of loading during the operation of the lifeboat launching appliance. Also the sensitivity of operation of the brake lever should be assured. Further, maximum application of the brake lever should be within the capacity of the operator applying reasonable force to the brake lever without recourse to additional force being necessary.

5. The Marine Directorate of the Department of Transport should ensure that on UK registered vessels, whether already fitted or to be fitted in the future with a combined tricing and bowsing system, the load regimes generated by both static and dynamic forces due to operation of the system do not surpass calculated design stresses of the structure. They should be satisfied that any deflection of the structure caused by this loading is within safe limits.

6. The Marine Directorate of the Department of Transport should, through the International Maritime Organization (IMO), bring to the attention of other Administrations the problems which can be encountered with combined tricing and bowsing systems, and in particular the problems highlighted in recommendations 4 and 5.

APPENDIX

Alternative Text

Regulation 9(4) and (5) of the Merchant Shipping (Accident Investigation) Regulations 1989 provide that any person whose reputation is likely to be adversely affected by the Report shall have the opportunity to comment on that part of the Report before it is submitted to the Secretary of State. If, following representations, passages in the Report remain in issue that person can provide an alternative text for the part in issue which must be included with the Report as an appendix.

The manufacturers of the band bowsing system (BBS), Schat-Davit (BV), have exercised their rights in this respect with regard to the last four paragraphs of Section 8 of the Report, and have submitted the following text to replace the paragraphs in question.

"8. **Operation of the Band Bowsing System Brake**

The initial concept and design of the Band Bowsing System was conceived by Schat-Davit Company BV after a continuous stream of complaints from ship crews regarding the operation of the classical bowsing/tricing systems when performing an operational test on lifeboat launching equipment.

The majority of complaints related to the handling of large 150 person capacity life/tenderboats. The general complaints were:

1) The large forces coming into the tricing pendant caused a potentially dangerous situation when opening the tricing pendant due to the occurrence of shocks.

2) The necessity of putting the manilla rope around the bollards manually before disembarkation of the ship into the lifeboat can begin.

3) The magnitude of loads occurring in the manilla rope from the bowsing when releasing the bowsing with a fully manned boat were such that its safe operation could not be guaranteed. Furthermore, there was a lack of control when handling these loads.

4) Before opening of the tricing gear the operating crew had to always ensure that part of the load was taken on by the main wirefall, ie tension had to be put in the wirefalls by means of the winch.

The introduction of the BBS has made the following improvements to the traditional bowsing/tricing system:

1) The use of the BBS's automatic bowsing system makes a separate tricing system redundant.

2) The lifeboat comes automatically to the embarkation position and no manual actions from within the lifeboat are required to bring the lifeboat to the ship's side.

   The BBS also saves time because embarkation can take place immediately after the lifeboat comes along the ship's side.

3) The BBS is controlled by a brake lever. The brake lever can be operated by hand which enables the operator to have a good control over and a good feel for the movement of the loads. After some training the operator should be able to operate the handle with one hand leaving his other hand free for holding on to the lifeboat.

   The brake is designed to start slipping if the maximum force is exceeded. This prevents mechanical failure if overloading should occur. This slipping load depends on the force applied to the brake lever. As in a car which has wet brakes due to rain, it is necessary to adjust the amount of force applied to the brakes. With proper training, the operator of the BBS should be able to make appropriate adjustments and ensure effective control of the brake lever.

Notwithstanding the improvements which have been made to the traditional bowsing/tricing system, Schat-Davit Company BV, as a major supplier of life-saving equipment, advise that all crew who have to operate the BBS, whether in a practice drill or in an emergency, should undergo regular training.

Whilst it may be advisable to give some further consideration to the possibility of improving the operational ease of the present system, the BBS provides a good and safe way of moving a fully laden lifeboat from embarkation position to lowering position and is a safer alternative to the traditional method of tricing and bowsing in of the lifeboat."