Executive Summary

Introduction

1 The tragedy and mystery of the DERBYSHIRE began in September 1980 when that enormous vessel disappeared without trace in the Pacific about 350 miles south east of Japan. She was an oil/bulk/ore carrier (O.B.O.), in length nearly three times the length of the playing area at Wembley Stadium and considerably larger in width than the Titanic or the QE2. All those on board perished – 42 members of crew and two of their wives. She was the largest British ship ever lost at sea.

2 Yet the DERBYSHIRE was only four years old, apparently well maintained and manned by a competent and very experienced master and crew. She had been built by highly reputable shipbuilders, namely, Swan Hunter at their Haverton Hill Yard on Teeside. She was fully classed with Lloyd's Register of Shipping. All her surveys and certificates were up to date.

3 She was on a voyage from Quebec to Japan laden with iron ore concentrates. She was within a few days of arrival at Kawasaki when she encountered a tropical revolving storm known as Typhoon Orchid moving from the east. Her northerly route was crossed by the worst sea conditions associated with the typhoon on 9th September 1980. By 0300z on that day she reported that she was hove to in a violent storm with a force 11 wind and a wave height of 30 feet. The vessel's last radio message was sent at 1019z that day. This Report finds that by 1700z on that day the conditions had deteriorated: the average height of the highest one third of the waves (the significant wave height) was 10.86 metres and the wind speed was over 56 knots.

4 Such conditions are severe but not exceptional amongst north west Pacific typhoons. Vessels of the size and design of the DERBYSHIRE were at the time assumed to be quite capable of withstanding such conditions, even if they had to reduce speed or be hove to. Nevertheless, as a matter of good seamanship, masters would always do their best to avoid coming within 50-75 miles of the storm centre and would generally try to maintain a distance of at least 200 miles.

5 Not surprisingly, the families of those who perished in this tragedy were extremely anxious to know what had caused such a catastrophic loss of life. They wanted a formal investigation. The UK Government took the view that, because of the total absence of material evidence, a formal investigation could not be expected to establish clearly the cause of the loss.

6 The DERBYSHIRE was the last of six bulk carrier sister ships built by Swan Hunter at Haverton Hill Yard. The first – the FURNESS BRIDGE – was completed in September 1971.

7 Following casualties which were sustained by the second of the series of sister ships – the TYNE BRIDGE – in 1972 and by the third of the series – the KOWLOON BRIDGE – in 1986, both involving fractures in way of Frame 65 located at the after end of the No.9 hold, just forward of the superstructure and engine room, the finger of suspicion as to the cause of the loss of the DERBYSHIRE was strongly pointed at a possible design defect in that part of the vessel. Consequently, in December 1986 a Formal Investigation was appointed under Mr Gerald Darling QC as Wreck Commissioner.

8 The hearing of that Formal Investigation took place during 46 days between October 1987 and March 1988 and the Report was issued on 18th January 1989. The formal decision was:

> "For the reasons stated in this Report the Court finds that the DERBYSHIRE was probably overwhelmed by the forces of nature in

Typhoon ORCHID, possibly after getting beam on to wind and sea, off Okinawa in darkness on the night of 9th/10th September 1980 with the loss of 44 lives. The evidence available does not support any firmer conclusion."

9 Amongst the reasons for this conclusion were:

(i) Structural failure due to excessive loading at amidships was highly improbable even under the severe wave loading conditions and since at Fame 65 the vessel was relatively stronger than at amidships and that bending moments were at a maximum close to amidships, it was also highly improbable that there had been structural failure at Frame 65.

(ii) Fatigue cracking was unlikely to have caused the total loss of the ship by failure of the hull girder, either at amidships or in way of Frame 65.

(iii) Separation of the hull at Frame 65 due to brittle fracture must be regarded as very unlikely though some element of uncertainty remained.

(iv) Although the flooding of the bosun's store and chain locker followed by loss of freeboard by the bow and then sequential failure of the No.1, 2 and 3 hatch covers due to hydrostatic loading was a possible cause of the loss, it was not thought probable.

10 The members of the Derbyshire Families Association were greatly disappointed that the Report was so inconclusive. They pressed for an underwater survey but the exact location of the wreckage was not known and until the 1990's there was no adequate technology for obtaining sufficiently clear photographic evidence at a probable depth of some 2½ miles.

11 Eventually in 1994 the ITF funded an underwater search to try to locate the wreckage. Against all the odds this succeeded. The depth was 4200 metres, some 2½ miles.

12 The Department of Transport then appointed Lord Donaldson of Lymington to carry out an assessment as to what further steps could be taken to obtain evidence as to the cause of the loss, the cost of taking such steps and what benefit to ship safety could be secured if the cause of the loss were established.

13 In his Assessment, Lord Donaldson concluded that the cost of an appropriate underwater survey would be about £2 million and that such a survey ought to be mounted in the interests of international ship safety. His recommendation was accepted by the Minister of Transport and the UK/EC Survey was duly conducted, funded partly by the UK and partly by the EU.

14 That survey was conducted in two phases in 1997 and 1998 respectively by the Woods Hole Oceanographic Institution by means of the United States Research Vessel, THOMAS G THOMPSON. Three Assessors were appointed to oversee the survey and report upon the results, namely Mr Robin Williams, Dr Remo Torchio of Genoa, both naval architects, and Professor Douglas Faulkner, Professor of Marine Architecture and Ocean Engineering at the University of Glasgow.

15 The technical achievement of that survey went far beyond anything in scope and detail that had previously been attempted on any underwater wreck at a comparable depth.

16 In the event, 135,774 individual electronic stills were obtained from a carpet plot of over 98 per cent of the entire wreckage field, which measured 1500 metres x 1000 metres. The result was to identify 2500 separate items of wreckage. By means of the joining up of the separate stills into larger pictures

(mosaicking) it was possible to obtain and usually identify very clear black and white pictures of continuous expanses of wreckage.

17 High definition video filming was also carried out. Some 200 hours of video were made.

18 Two of the three Assessors (Mr Williams and Dr Torchio, Professor Faulkner having resigned) concluded on the basis of the photographic evidence that the vessel's loss had been caused by seawater entering the bow section which caused the vessel to develop a forward trim, thereby exposing its No.1 hatch covers to wave heights great enough to impose loading in excess of their collapse strength. Water then poured into the large empty space above the cargo in the No.1 hold. That put the vessel further down by the bow until No.2 and No.3 hatch covers suffered the same fate sequentially. The vessel would then sink.

19 However, the disturbing aspect of this Report was that the main reason for entry of seawater into the bosun's store in the first place was found to be the failure of the crew to secure the lid to the hatch on the foredeck.

20 This conclusion clearly involved the imputation of serious negligence against the officers and crew. It was deeply upsetting to the families of those on board. However, the conclusion also acquitted the design and construction of the vessel in way of Frame 65 of any causal contribution to the loss.

21 Following that report, on 17th December 1998, the Deputy Prime Minister, The Rt Hon John Prescott, MP announced that there was to be a full re-opening of the Formal Investigation and that this was to be held in the High Court under section 269(1) of the Merchant Shipping Act 1995. I was subsequently appointed to conduct that Investigation. This is the first time that such a reference to the High Court has been made.

22 The hearing commenced on 5th April 2000 and lasted for 54 days, concluding on 26th July 2000. Twenty scientific and technical experts, six master mariners and five other witnesses gave oral evidence. Robes had nothing to contribute to the hearing and were therefore dispensed with. The parties to the Investigation were:

The Derbyshire Families Association

Bibby Tankers Ltd, the shipowners

SHSEGL Realisations Ltd, the successors to Swan Hunter, the ship builders

Lloyd's Register of Shipping, (LRS) the classification society

The Department of the Environment, Transport and the Regions (DETR)

The Attorney General and his counsel acted as in effect counsel to the tribunal.

23 Assessors to sit with the court were not appointed. Instead, Dr P S J Crofton of Imperial College and Professor John van Griethuysen of University College, London, were appointed as its technical and scientific advisers. They took no part in the making of the ultimate decisions expressed in this Report.

24 It is to be recorded that without a high degree of commitment and co-operation between all parties and between the many expert witnesses, it would have been impossible to produce this Report as early as it has been.

The Cause of the Loss

25 The DERBYSHIRE would certainly not have been lost had it not encountered extremely severe seas close to the centre of Typhoon Orchid. The first question to be answered is therefore why the vessel ever found itself in these conditions.

26 This Report concludes that, whereas the vessel would have avoided the typhoon if, on 7th September or up to about 1000z on 8th September, the master had altered course to the west south west or south west, instead of proceeding on a northerly course towards Japan, his failure to do so almost certainly arose from his belief that the sea conditions along his route on 8th and 9th September would enable him to maintain sufficient speed to keep well ahead of the typhoon which was then advancing on an east-west track.

27 The vessel was receiving weather forecasts from the United States Navy/Air Force Joint Typhoon Warning Centre broadcast by Guam radio and from the Japanese national weather forecasting service over Tokyo radio. The vessel was also receiving occasional weather reports from Oceanroutes, a routeing agency appointed by the charterers. One such report was sent at 2146z on 5th September, before Typhoon Orchid had developed, and the next at 0113z on 8th September.

28 At no time did Oceanroutes advise the master to alter course to avoid the typhoon.

29 The forecast track of the typhoon given by Guam radio on 7th and 8th September differed substantially from that given by Tokyo radio: on 7th September Guam put the track curving north west on 8th and 9th September, whereas Tokyo radio put the track much further to the west. Further, the Guam forecasts between 1200z on 7th September and 0600z on 8th September very substantially under-estimated the windspeeds ahead of the centre of the typhoon. One of several unusual characteristics of Typhoon Orchid was that

the wind field and area of consequential high swell running in front of it were abnormally extensive. Another unusual feature was its extremely long duration.

30 The continuing under-prediction by the Guam forecasts of the extent of the wind field running before the typhoon and their failure to anticipate that the vessel would encounter 50 knot winds over 200 nautical miles ahead of the storm centre and 30 knot winds over 400 nautical miles ahead of it would have led the master to believe not only that the DERBYSHIRE would be able to maintain sufficient speed to keep ahead of Orchid but that, if, on 8th September, it became necessary to change course to the south west or west south west, that option would not be lost due to the danger of turning beam on in severe sea conditions.

31 Further, the fact that Oceanroutes at no stage advised the master to alter course would have been understood by him to be a tacit endorsement of his keeping to his present course.

32 Since the master could not reasonably have anticipated from the local wind, sea and isometric conditions in the period from 1200z on 7th to 1000z on 8th September that the vessel would not be able to maintain sufficient speed to keep ahead of the typhoon, then closing from the east south east as much as 250 nautical miles from the vessel, no criticism can be attached to his decision to hold to his rhumb line course or subsequently at some stage after 0300z on 8th September to take a slightly more northerly course probably in order to put the sea 4 points off the starboard bow.

33 The DFA has strongly criticised Oceanroutes for failing properly to perform its duty as a routeing agency in as much as it failed on 7th and early on 8th September to provide the vessel with adequate information as to the track of the typhoon and to advise the master to alter course to the west south west or south west.

34 This Report accepts that the message sent to the vessel by Oceanroutes at 0113z on 8th September was seriously deficient in information. However, this Report does not accept that it has been established that Oceanroutes were negligent or otherwise at fault in failing to advise the master to alter course. In as much as it has not been shown to be negligent for a typhoon forecasting service to have failed to anticipate the unusual forward projection of the wind field of Typhoon Orchid, it was not unreasonable for a routeing agency to continue to endorse the vessel's present course up to 1000z on 8th September. Failure to anticipate the extent of the wind field and the unusually distant spread of heavy swell running before the storm centre is not shown to have been professionally negligent. Even if the message sent at 0113z on 8th September had contained adequate information then available, that information would not have caused the master to change course. It can therefore be concluded that the vessel's encounter with the most severe sea conditions of the typhoon arose without the fault either of those on board or of Oceanroutes.

35 However, the brochure issued to masters by Oceanroutes in which it set out what routeing services it would provide in respect of typhoons was obscurely worded. If Oceanroutes intended to suspend positive routeing advice in such conditions, that should have been much more clearly expressed.

36 The vessel encountered such severe conditions by about 1800z on 8th September that she was hove to, that is to say the master's speed would be the minimum necessary to maintain steerage, so as to keep the seas on the vessel's starboard quarter. From that time onwards, as the storm centre closed on her course from the south east, she was inevitably going to be subjected to very severe sea conditions.

37 These conditions had deteriorated in the course of 8th and 9th September. The hindcast evidence is to the effect that for about 12 hours from 0500z on 9th September the route of the DERBYSHIRE experienced significant wave

heights above 9.5 metres, rising to a peak of 10.85 metres by 1700z. The vessel's average forward speed in these conditions would be in the range 1.50 to 2 knots over the ground depending on wave drift forces. That would have taken the vessel to the wreckage site by about 1700z to 2000z on that day.

38 When a vessel is near to head on to the waves it will be subjected mainly to pitching effects. The extent of these effects is dependent on the relationship between the length of the vessel and the wave length. It will also be dependent on the damping characteristics of the vessel's configuration, notably the relationship of draught to beam. When the wave frequency is relatively low and the wavelength relatively large, the vessel will tend to follow the slope of the waves with the effect that there will be little relative vertical motion. By contrast, where there is a high wave frequency and a short wave-length relative to the vessel's length, the vessel will not respond to the waves in terms of pitch and heave, thereby creating relative vertical motion broadly equal to wave elevation. However, between those positions, as the wavelength shortens, the slope of waves of the same wave height increases. That causes the vessel's pitch response to increase. There eventually comes a point when the wavelength is broadly equal to the length of the vessel. It is at this point that the vessel experiences maximum relative vertical motion. A pattern of movement is thereby created which involves the vessel pitching head-down into the trough of a wave and then, before its bow has lifted back to horizontal, meeting the next wave crest.

39 Where the waves are very high, they tend to have very steep wave fronts which allow little time for a ship to rise above them. The effect of the vessel's pitching in the manner described is to increase the relative vertical motion of the vessel quite substantially. Where relative vertical motion exceeds the local freeboard, green water will begin to load the vessel's bow. The more the relative vertical motion, the greater will be the head of green water on the bow.

40 The length of the DERBYSHIRE (at 294.1 m overall) was slightly less than the wavelength (about 300 m) that would typically have prevailed during the period 1700z to 2000z on 9th September. The conditions therefore gave rise to accentuated pitching and considerable amplification of relative vertical motion to wave amplitude, so exposing the bow and forward hatch covers to heavy and repeated green water loading; a response by the vessel strongly evidenced by the model tests.

41 These model tests were conducted at the MARIN Research Institute, Wageningen, Netherlands, and were designed to measure the magnitude of green water impacts on the No.1 hatch cover in different conditions of trim and at different significant wave heights. The various conditions of trim were designed to ascertain what difference it made to green water loading on the No.1 hatch cover that water had entered the bosun's store and machinery spaces, the forepeak ballast tank and the forepeak fuel tank. They were also directed to ascertaining the rate of seawater entry to those spaces if ventilators and air pipes or their covers had been destroyed.

42 The results of those tests indicated that at speeds of zero or 2 knots, without water ingress, at the peak significant wave height of 10.85 metres, and even at 12.5 metres, the maximum loading on No.1 hatch would be well below the collapse strength. However, in the damaged condition, with the bow flooded, the maximum measured impacts on No.1 hatch at a significant wave height of 10.85 metres exceeded its collapse strength, even at zero speed.

43 In order to ascertain the probability of the No.1 hatch being subjected to green water loading in excess of its collapse strength in sea conditions during periods of time comparable to those experienced by the vessel and in different states of bow flooding, it was necessary to extrapolate from the new model test data by statistical methods. This exercise was conducted by the court-appointed expert Professor Jonathan Tawn of the University of Lancaster. His extrapolations indicate that at the most probable speeds of 70% maximum and

2 knots, there was a very substantial risk of a hatch-breaking wave at an un-enhanced significant wave height when both the stores and the ballast tank had been flooded and a considerable risk when the ballast tank alone had been flooded, whereas there was no risk if the stores alone had been flooded. Obviously, the magnitude of the risk would be commensurately reduced if there were only partial flooding of the ballast tank together with full flooding of the stores.

44 If, however, there were a 10% increase in the significant wave height, not only was it certain that there would be a hatch-breaking wave when the stores and ballast tank were flooded, but there was a 1% to 10% risk that such a wave would eventuate if, at 70% maximum speed, the stores alone were flooded (Dam Stores single max) and a 4% to 42% risk of such a wave in that condition if a speed of 2 knots were assumed. The expert evidence as to the hindcast wave height was subject to a 10 per cent probability range.

45 The evidence derived from the underwater survey of the wreckage and the inferences to be drawn from it can be summarised as follows:

(i) The wreckage of the bow section was found approximately 590 metres from that of the stern section with most of the wreckage of the hatch covers within a corridor between the two sections about 230 metres wide. That pattern suggests that no substantial section of the hull and none of the hatch covers separated from the main part of the vessel on the surface.

(ii) All hatch cover panels located in the wreckage exhibited a similar initial mode of failure and some exhibited a similar secondary mode of failure. In particular, their initial mode of failure consisted of a symmetrical pattern of bending inwards along an axis transverse to the hull located at or forward of the centre girder. The secondary mode of failure consisted of an asymmetrical

pattern of inward bending along a longitudinal axis very close to the centre line of each panel. The transverse inwards bending occurred before the longitudinal inwards bending. This condition is consistent with the initial mode of failure being caused by green water loading from the forward end and inconsistent with the vessel having developed any significant list by the time sinking began. Sea water would have entered the holds once the transverse bending had occurred.

(iii) The hatch covers were in good condition with seals not excessively worn. It was unnecessary for the centre line catches to be secured, provided that the quick acting cleats were secured, which was the case.

(iv) Ventilators and air pipes located on the foredeck and leading into the bosun's store, machinery space, ballast tank and possibly in one case, the fuel tank, were in damaged condition and had sustained that damage prior to the commencement of sinking.

(v) The seals on the spurling pipes were destroyed. This probably occurred before sinking. Water would thereby enter and flood the chain lockers.

(vi) Seawater would therefore have entered the bosun's store, the machinery space, the ballast tank and, possibly, to a lesser extent the forward fuel tank

(vii) Seawater could not have entered the fuel tank prior to sinking either by reason of the collapse of the floor of the bosun's store or through the manholes leading from the store. The covers to those manholes would not have been left open. Nor would water have entered the ballast tank through the access manhole from the

bosun's store, for it is distinctly improbable that it would have been opened much less left open in the course of the voyage.

(viii) The lid to the foredeck bosun's store hatch was missing from the wreckage of the bow section. The after side of the hatch coaming was severely dented and split. The toggle wing nuts on that hatch were found in various conditions and at differing positions on their threaded shanks, with some missing altogether.

(ix) The condition of the store hatch as found does not suggest that the lid was left unsecured by the crew or that the lid could not properly be closed because a rope was protruding from the hatch. On the whole of the evidence the lid was adequately secured both by properly tightened toggles and by a complicated roping device designed to prevent the lid coming loose because the wing nuts had ridden up the toggle shanks with the motion of the ship. The rope seen in the wreckage to emerge from the hatch was a mooring rope one end of which was originally attached to the inside of the hatch lid. This Report rejects the Assessors' conclusion that the crew had left the hatch lid inadequately secured prior to the DERBYSHIRE entering the typhoon.

(x) The starboard windlass is shown to have become detached from the foredeck. Its position on the seabed suggests that severance occurred immediately before or soon after the commencement of the sinking process. This was probably caused by its being subjected to a succession of powerful waves the impact of which initiated low cycle fatigue cracks in the welding where the windlass was joined to its bed. These would eventually open when subjected to subsequent intense wave loading. This probably occurred after the commencement of water entry to the bow

through damaged ventilators and air pipes and may well only have occurred after the failure of the No.1 hatch cover.

(xi) The loss of the lid to the bosun's store hatch and the loss of the rope leading from it were probably caused by the impact of the whole or part of the starboard windlass after the latter had become detached from its seating and after seawater had already begun to flood the store, machinery space and probably the ballast tank.

(xii) The condition of bulkhead 339 as found in the wreckage does not support the proposition advanced by the UK/EC Assessors that the bow spaces and particularly the fuel oil tank ullage space were substantially full of seawater when the vessel began to sink. Rather its condition is consistent with the deep fuel tank and perhaps part of the ballast tank having been substantially empty of water when sinking commenced, but having admitted additional water during sinking.

(xiii) The wreckage evidence is inconsistent with cracking of the deck or hull in way of Frame 65 having made any causal contribution to the loss. However, there is shown to have been a substantial misalignment of longitudinal bulkheads at bulkhead 65. This error in construction when added to the design discontinuity at this position created a very low additional safety risk on account of the danger that it would cause fatigue cracks in the after bulkhead of No.9 hold which could cause oil leakage into the pumproom followed by explosion.

46 On the basis of the condition of the wreckage and of the data derived from the model tests conducted at MARIN, it can be concluded with reasonable confidence that the initiating cause of the loss was the destruction of some or all of the ventilators and air pipes located on the foredeck by sustained green

water loading over many hours in the course of 8th and more probably 9th September 1980. Water was thereby able to enter the bosun's store, machinery spaces and probably the ballast tank in substantial quantities and possibly to a minor extent the fuel tank. The DERBYSHIRE then developed a trim by the bow which, although imperceptible from the bridge, had the effect, as the bow dropped lower and lower, of accentuating green water loading on the No.1 hatch cover as the sea conditions became more severe in the course of that day. By about 1700z those conditions had deteriorated so greatly that there was likely to have been green water loading in excess of the collapse strength of No.1 hatch cover. Once that hatch cover gave way, water would enter the No.1 hatch, very rapidly filling the large ullage space above the cargo and thereby causing the vessel to go still further down by the bow by another 3.7 metres. It is estimated that the filling of No.1 hold might take as little as 5 minutes or as much as 16.5 minutes.

47 This flooding in turn caused the green water loading on No.2 hatch cover progressively and rapidly to increase until it exceeded the collapse strength of that hatch cover and water then entered No.2 hold.

48 No.3 hatch suffered the same fate. At that point the vessel was irretrievably lost.

49 Although it is possible that the No.1 hatch cover collapsed under excessive green water loading before there had been flooding of any of the bow spaces, this is very unlikely indeed.

50 There is no reasonable likelihood that any of the other possible causes considered by Lord Donaldson or by the UK/EC Assessors' Report in any way contributed to the loss of the vessel. If, which is extremely improbable, the vessel ever went beam on to the wind and sea, as suggested as a possibility by the Report of the Formal Investigation, that circumstance did not cause the loss of the vessel.

International Ship Design Regulation and Design Standards: Recommendations

51 The DERBYSHIRE was designed in compliance as to freeboard and hatch cover strength with the regulations made by the United Kingdom Government in 1968 – the Load Line Rules – which gave effect to most of the provisions of the International Load Line Convention 1966, (ILLC 66), in particular Regulation 16(2).

52 Bulk carriers were permitted to maintain a minimum freeboard of a dry cargo vessel reduced by 60 per cent of the difference between the lower permissible tanker freeboard and the higher permissible dry cargo vessel freeboard, subject to having adequate internal flooding protection, so that the vessel could survive one compartment flooding. Mild steel forward hatch covers were required to have a minimum strength capable of loads of not less than 1.75 tonnes per square metre. This loading would give a collapse strength of 42 kPa. Bulk carriers designed by reference to these requirements were known as B-60 carriers.

53 Although, in the course of the international conference which gave rise to ILLC 66, the United Kingdom delegation put forward proposals for increased minimum forward hatch cover strength of about 2.1 tonnes per square metre, these proposals were dropped in view of the opposition of a majority of the 52 delegations. Having regard to the limited state of contemporary knowledge as to the effect of green water loading, the UK Government cannot be criticised for failing to secure agreement to its proposals.

54 The contemporary state of knowledge as to wave loading on forward hatch covers which existed when the design for the DERBYSHIRE was developed in 1968 and up to 1974 when the keel was laid did not suggest that the minimum hatch cover strength requirements prescribed by ILLC 66 were deficient or that a vessel designed to do no more than comply with those

requirements might be unsafe. In that state of knowledge competent architects could in 1974-76 properly rely on the requirements of ILLC 66 as a design benchmark.

55 In the course of the 1980s the rising incidence of loss of bulk carriers caused classification societies, in particular LRS, to investigate the adequacy of hatch cover strength in conjunction with other design features of bulk carriers. The International Association of Classification Societies (IACS) set up its Working Party on Strength in 1992. By 1997 IACS had agreed a series of ten unified requirements directed to single side skin bulk carriers of over 150 metres in length. Amongst these UR S21 laid down minimum load and strength requirements for hatch covers. There underlay the adoption of these new classification requirements the belief, at least on the part of some members of IACS, that the ILLC 66 requirements for hatch cover strength were not adequate.

56 The effect of UR S21 was, in substance, to increase the minimum permissible forward hatch cover strength from 42 kPa under ILLC 66 to 83 kPa, equivalent to a corroded value collapse load of 8.3 metres, assuming good design and application of the specified safety factor on first yield. The DERBYSHIRE's collapse strength was 4.2 metres.

57 This requirement was to take effect for bulk carriers contracted for construction on or after 1st July 1998, but it was not to apply to existing vessels or vessels under construction or already contracted for construction.

58 UR S21 expressed the minimum strength requirements for hatch covers by means of a formula which quantified the minimum strength by reference to the height of the freeboard.

59 Had the DERBYSHIRE been laden down to her marks, thus operating on her minimum permissible freeboard, there would have been an unacceptably high risk of her No.1 hatch being subjected to green water loading in excess of its

collapse strength, even at zero speed or at a speed as low as two knots and even without flooding of the bow spaces, when encountering wave heights of a similar order of magnitude to those met in Typhoon Orchid.

60 It can be concluded that the requirements of ILLC 66 are set at a minimum level in relation to which there is a substantial risk of exceedance at the forward hatch covers if a vessel such as the DERBYSHIRE is caught in a typhoon similar to Orchid or in similar conditions and making any speed over the ground and some risk if it is not. Consequently, these requirements could only be regarded as "adequate" if that risk were very substantially discounted because of the low incidence of loss experience since ILLC 66 came into force and/or because of the additional cost that would be involved in increasing the level of protection for new buildings and for existing vessels.

61 Taking fully into account the lack of hard evidence of loss experience, the likely additional cost of fitting stronger hatch covers and the technical and mechanical problems to which that might give rise, this Report is unable to accept in the light of the loss of the Derbyshire that modern concepts of appropriate safety standards for vessels and those on board can accommodate as acceptable the level of risk of exposure to potentially catastrophic consequences presented by ILLC 66.

62 This Report concludes that the minimum hatch cover strength requirements laid down for forward hatches in ILLC 66 in conjunction with the prescribed minimum permissible freeboard for B-60 bulk carriers of similar size to the DERBYSHIRE are seriously deficient in the context of present day concepts of acceptable safety levels. The precise extent of that deficiency should be ascertained by means of a programme of further model tests to be conducted at MARIN with reference to realistic extreme sea conditions.

63 Such a test programme has been agreed between the DETR and IACS and is currently in progress. With a proper regard to the United Kingdom's

leadership in matters of international maritime safety this programme of tests is being funded by the DETR.

64 Although the results of those tests are not yet known the strong probability is that the ILLC 66 hatch strength requirements will be found to be very seriously deficient. In these circumstances, it is important that the United Kingdom should press strongly and urgently for the Convention to be amended by the introduction of a new formula for the calculation of minimum hatch cover strength in relation to minimum permissible freeboard. This amendment should be applicable not only to new buildings but to existing bulk carriers. The present world population of such vessels is about 476 of which 68 are of similar length to the DERBYSHIRE.

65 It is unsatisfactory that there should be the present dual level regulatory regime in respect of minimum hatch cover strength – that under ILLC 66 and that operated by those classification societies which are members of IACS, particularly as 96 per cent of the world's bulk carrier fleet are entered with such members. The evidence before this Investigation has at least raised serious doubts as to whether even the UR S21 formula provides for an adequate minimum strength requirement. Those doubts can only be resolved by the further model test programme now in progress. There is strong evidence that the UR S21 formula includes certain conceptual inadequacies in addition to any question of deficient strength requirements, which suggests that it ought to be re-formulated in any event. What is clear beyond doubt, however, is that the inapplicability of this formula for enhanced hatch cover strength to vessels built or contracted to be built before July 1998 is a very serious short-coming. The exposure to risk of those bulk carriers of the size of the DERBYSHIRE whose hatch covers do no more than comply with ILLC 66 poses an unacceptable risk to the safety of those vessels and their crews.

66 Accordingly, this Report recommends that as soon as possible after the results of the present model test programme have been obtained and analysed, IACS

should consider the adequacy of UR S21 and should replace it with a formula which provides for adequate minimum strength requirements for the hatches of bulk carriers. That formula should apply both to new buildings and to existing vessels. The flexibility intrinsic to a formula which establishes a relationship between required hatch cover strength and minimum freeboard should make its retrospective introduction more acceptable to the shipping industry. Evidence as to the likely additional costs that would be involved in strengthening the hatches of existing vessels does not suggest that this requirement will subject the operators of such vessels to unacceptably large expenditure. Since any amendment of ILLC 66 to introduce such a formula, particularly with retrospective effect, is likely to take 4 to 5 years to come into effect, it is strongly recommended that IACS should in the meantime urgently bring into operation its own revised formula.

67 The DETR, in conjunction with IACS, should use its best endeavours to persuade all parties to ILLC 66 to agree to amend the Convention to introduce a new formula providing for adequate minimum hatch cover strength requirements for bulk carriers. That formula should apply retrospectively.

68 This Report does not recommend that the UK Government should act unilaterally in introducing statutory requirements for enhanced minimum hatch cover strength. Nor does it recommend that LRS should unilaterally take this course.

69 These are the most far-reaching recommendations included in this Report.

Other Recommendations as to Improved Ship Safety

70 Many other recommendations for improved ship safety are to be found in Sections 12 and 13: Towards Improved Ship Safety: Navigation and Towards Improved Ship Safety: Other Matters. They relate to the following matters:

(1) Compulsory daily reporting of position by all vessels.

(2) Amendment of the Mariners' Handbook advice on navigation in tropical storms.

(3) Advice to masters of bulk carriers on the dangers of bow flooding.

(4) Wider participation in the World Meteological Organisation's Voluntary Observing Ships scheme.

(5) Explicit advice to masters by weather routeing agencies as to the scope of their functions.

(6) A research programme to investigate minimum strength requirements for ventilators and air pipes.

(7) Electronic indication of open or damaged ventilators and air pipes.

(8) A research programme to investigate improved securing devices for stores hatch lids.

(9) Electronic indication of displacement of foredeck hatch lids and of their being unsecured.

(10) Improvements to hatch cover operating manuals.

(11) Electronic indication that hatch securing devices are in place.

(12) Automated hatch opening, closing and securing.

(13) Improvements in the sealing of spurling pipes.

(14) Access to chain lockers.

(15) Research into and development of minimum strength requirements for securing fittings to the foredeck.

(16) Installation of lighting and video cameras on the foredeck of capesize bulk carriers.

(17) Electronic indication on the bridge of bilge levels in forward spaces.

(18) Research into independent pumping systems for dealing with forward space flooding.

(19) Introduction by classification societies of improved design approval and survey procedures for new buildings.

(20) Maintenance ashore by shipowners of accurate construction plans showing the vessel as built and as subsequently altered.

(21) Establishment of a marine accident data base covering storm damage.

(22) The fitting of a VDR (black box) system on all existing cargo vessels and new buildings.

71 This Re-opened Formal Investigation could not have taken place but for the perseverance of the Derbyshire Families Association which led to the location of the wreckage by the ITF survey in June 1994 and the immensely impressive scientific and technical achievement by the Woods Hole Oceanographic Institution of the United States in the conduct of the underwater survey. This

report concludes that until 1994 the Department of Transport was entirely justified in taking the view that there did not exist photographic and filming equipment capable of obtaining evidence of sufficient clarity and accuracy to provide evidence of the cause of the loss. The long delay after the Formal Investigation in organising an underwater survey cannot be the basis of any criticism of the UK Government.

72 The present policy of the DETR in deciding whether to conduct underwater surveys as described in Section 15 is entirely appropriate. The fact that the Department is now co-operating under a research agreement with Woods Hole on further research into the development of a new underwater remotely operated vehicle is a course which this Report strongly endorses in the interests of ship safety.