SECTION 3 - CONCLUSIONS

These conclusions identify the circumstances, cause and factors contributing to the incident, and are not to be taken as apportioning blame or liability.

3.1 FINDINGS

1. The accident took place on board *Island Princess* on 7 December 1997, while at sea off the Italian coast during sea trials following a dry-docking for propeller repairs. [1.3]

2. *Island Princess* was fully manned, had 124 contractors on board but no passengers at the time of the accident. [1.2]

3. Engine room manning and qualifications of engineer officers on board *Island Princess* exceeded international safe manning agreements and requirements of the STCW Convention. [1.11]

4. *Island Princess* had two all welded flat-ended shell-type Aalborg AQ7 economisers, 10 tonnes of water in each and designed to operate full. The design pressure was 9.0bar. [1.4]

5. While in dry-dock, before the accident took place, both economisers were left full when not in use. [1.3]

6. Each economiser was fitted with two safety valves, each set to lift at 9.1bar. [1.4]

7. A conscious decision had been taken to boil off the water in the economisers through jacked open safety valves. [1.3]

8. *Island Princess*'s main engines were running by 0930 on 7 December 1997 and she sailed from Naples at 1030. The port economiser ruptured at 1355. [1.3]

9. Five people were in the immediate vicinity of the economiser when it ruptured. A general purpose seaman was knocked over but managed to crawl to safety and four TEI contractors were affected to varying degrees. [1.3]

10. The most seriously injured contractor, Mr Pickard, received immediate treatment and was later transferred ashore, but died at 1555 the same day. [1.3]

11. Another contractor, Mr Clayton, despite being subsequently air evacuated to the UK, died from his injuries on 20 December. [1.3]

12. The ruptured port economiser on *Island Princess* and an economiser of the same type on *Pacific Princess* had suffered previous steam leaks at the circumferential seam weld of the shell. The cracks were veed out and welded without considering fully why the cracks had occurred. [2.2]

13. There was a reported history of economiser overpressure and safety valve seizure on P&O/Princess Cruises' passenger ships. [1.7]

14. The port and starboard economisers' shell-plate was found to be barrel shaped. The investigation discovered a similar effect on the shell-type economiser on *Pacific Princess*. [1.5]

15. The barrelling of the starboard economiser probably pre-dated the accident to the port economiser. [2.5]

16. Allowing the water to evaporate from the economiser was not good engineering practice since it aggravated the existing problem of unwanted hard scale deposits in the economiser, and increased the risk of seizure of the safety valve. [2.5]

17. The chemical treatment of boiler and feed water was not always able to cope with sea or brackish water and hard potable water. [1.5, 2.3]

18. Princess Cruises did not have a detailed record of economiser safety valve spare parts list. The safety valve body identification plate used to facilitate a correct order for spare parts was found covered in paint and impossible to read. [1.12]

19. Princess Cruises has no record of any economiser safety valve spare parts being ordered or used. [2.4]

20. The safety valve instructions were not detailed sufficiently to enable classification surveyors, engineers and management to accurately judge the acceptability of the safety valves for future use. [2.3]

21. Renewal of damaged safety valve spindles and guides was crucial to reducing the risk of seizure. [2.4]

22. Engineers were unaware of the type of spindle guide bush fitted to the safety valves. [2.4]

23. Spare parts for the safety valve were readily available from the manufacturers and their agents. [1.12]

24. The safety valve springs fitted were for lift pressures of 6.4 to 8.6bar. The springs were not changed to the specified range of 8.6 to 11.5bar, at the time the design pressure of the economiser was upgraded from 8.5 to 9.0bar. [1.12]

25. Both forward and aft safety valves had experienced significant leakage prior to the accident. [1.5]

26. Poor internal condition of the valve body and severe pitting corrosion of the valve cover undersides could also have been consistent with earlier discharging of poor quality water into the valve chamber. [1.5]

27. Fatigue cracks around the top and bottom circumferential joints between the shell-plate and flat-endplates of fired and unfired shell boilers were a widespread problem. [1.8]

28. A significant amount of pre-existing weld defects was apparent in the bottom circumferential weld joint of *Island Princess*'s port economiser. These defects did not contribute to the accident. [1.5]

29. The MCA and LRS have been aware of problems with fatigue cracking at the weld toe of the circumferential joint in shell-type boilers since the 1970s. [1.8, 1.9]

30. Local repairs on circumferential weld joints of the *Island Princes* and *Pacific Princess* economisers were found to be fatigue cracked. [1.5, 2.2]

31. Princess Cruises, the MCA, LRS and GL had been aware of the problems with seizure of safety valves used for steam/water emulsions. [1.7, 2.4]

32. Defects found on the port economiser safety valves were not reported to the classification society or shore management. [1.12]

33. Because of the existence of poor quality boiler and feed water affecting the safety valves' spindle's resistance to corrosion, there was an added need for greater care and attention when operating and maintaining the valves. [2.4]

34. In 1979 economiser safety valves were found to be prone to seizure. To reduce the risk of seizure, Princess Cruises and the MCA agreed to survey the safety valves annually and to set the lifting pressure with clean steam on a shore-side boiler. The procedures were discontinued. The survey period was increased to 2½ years and the lifting safety valve pressure was set with the valves installed on the economiser. [1.12]

35. The tamper-proof seals and protection covers were missing from the economiser safety valves in contravention of LRS and the MCA requirements. [1.12]

36. There was a possibility of leakage of hot water and steam from the economisers into the port boiler where four contractors were fitting and welding the new tube plate. [2.5]

37. The engine exhaust by-pass was not in operation because it was permanently secured in the closed position. [1.4]

38. The attempt to rescue Mr John Pickard by Mr Hippolyte and the daywork third engineer was courageous. [1.13]

39. Use of the Neil Robertson stretcher slightly delayed Mr Pickard's transfer to the medical centre but did not affect the patient's care. [1.13]

40. P&O's rapid provision of stress counselling showed, in a practical way, their concern for accident victims. [1.13]

41. Stress counselling was of great practical help to victims of the accident. [1.13]

3.2 CAUSE OF RUPTURE OF THE PORT EXHAUST GAS BOILER (ECONOMISER)

1. The port economiser ruptured when it overpressured resulting in over-stressing along the lower circumferential weld joint between the shell-plate and lower endplate. [2.1]

2. The rupture was influenced by the weakening effect of the progressive corrosion fatigue crack growth along weld joint. [2.2]

3. Fatigue crack initiation was accelerated by corrosion grooving at the bottom shell-to-endplate weld toe. [2.2]

4. Water was left in the unvented economiser, and heated by engine exhaust gases to generate steam. [2.5]

5. The overpressure in the economiser was caused by failure of the safety valves to lift to release the steam pressure. [2.1]

6. The safety valves did not lift because the valve spindles were seized in their guides. The seizure was attributed to spindle corrosion damage and the presence of accumulated corrosion products, boiler sludge deposits and other extraneous material at the guide/bush interface. [2.4]

7. The corrosion resistance of the safety valve spindle material was compromised because of poor quality boiler water and leaking safety valves. [2.4]

3.3 CONTRIBUTORY CAUSES

8. The engineers did not realise that the port economiser safety valves had not been jacked open. This was probably influenced by the indicators at the easing gear handwheels which showed the safety valves to be open. [2.5]

9. The engineers failed to monitor the economiser during watches to ensure that it was venting effectively. The reasons were:

   (i) The engineers' pre-occupation with sea trial related work;
   (ii) The engineers' perception that economisers and safety valves posed no significant safety risk;
   (iii) The inconvenience of checking the economisers because of the remoteness of the installation from mainstream systems;
   (iv) Absence of an economiser pressure gauge in the engine control room. [2.5]

10. The ship's engineers were unaware of the detailed specification requirement of the safety valve spindle and bush. [2.4]

11. The safety valves were not maintained in accordance with the manufacturers' care and maintenance instructions. [2.4]

12. Because of the history of seizure of the safety valves there was an added need for greater care and attention when operating and maintaining them. This need was not satisfied. [2.4]

13. Senior management were unaware of past incidents of economisers and safety valve failures. Vital management information on the hazard of overpressurisation of economisers and seized safety valves had been lost or forgotten. [2.4]

14. Because Princess Cruises did not account for previous incidents of safety valve seizures, the hazards associated with them could not be assessed fully. This seriously weakened the effectiveness of the safety management system since developed. [1.12]

15. The safety management system did not encourage the reporting of defective safety valves. Consequently senior management did not realise safety actions to reduce the possibility of seizure. [1.12].

16. The safety management system did not encourage the need to properly challenge and assess the situations with the safety valves and economisers which gave rise to non-standard procedures. [1.12, 2.5]

17. The formation of hard scale and corrosion fatigue cracking made it difficult to locate defects during inspection. [2.3]

18. Contrary to good engineering practice, the ship's engineers did not drain out the economisers and vent them to ensure that it was impossible for any pressure build-up to occur. [2.5]

19. Princess Cruises, the MCA and LRS treated each incident of cracking in the economisers of *Pacific Princess* and *Island Princess* in 1994 and 1995 respectively in isolation. In so doing, this inadvertently fostered a perception that the economisers were low risk. [2.2]

20. LRS considered it unnecessary to inform industry of the possibility of a more widespread problem given previous incidents of rupture and cracking of Princess Cruises' ships' economisers and their knowledge of serious cracking problems on shore-side boilers. [2.2]