SECTION 4 - RECOMMENDATIONS

IACS, LRS, MCA and IMO, are recommended to:

1. Develop guidelines for the examination of crack defects in shell-to-flat-endplate and furnace-to-flat-endplate welded joints in shell-type boilers, similar to the guidelines published by the Safety Assessment Federation Ltd.

   The guidelines should be submitted to shipowners associations and IMO.

2. Extend the scope of periodical surveys to cover examination for cracking in the region of circumferential weld joints between shell and flat-endplates.

3. Require classification surveyors and ship owners to report:

   i) cases where shell boiler or economiser repairs are necessary because of cracking;

   ii) cases where boiler or economiser safety valves are found to have seized.

   The above should be submitted to IACS for the purpose of trend analysis and the identification of problem types.

4. Review procedures and frequency of testing of safety valves of fully flooded economisers.

5. Review the requirements for remote monitoring of economisers' pressure.

The MCA is recommended to:

6. Publish a marine guidance note on the importance of maintaining safety valves on auxiliary boilers and economisers in operational condition between surveys.

7. Ensure, as part of the MCA's quality audit trail of LRS and other classification societies, appropriate procedures are in place which require every report of boiler and safety valve failure to be followed up.

8. Review the process of safety management system audits to take account of the lessons learned from this accident.

Princess Cruises and the P&O group of companies are recommended to:

9. Develop a boiler installation portfolio to enable management to monitor and assess safety risks, and include it in the safety management system of the ISM Code.

   i) The portfolio should include:

- written reports of boiler and safety valve examinations;
- clear and concise operating procedures needed to operate the system safely;
- special procedures in the event of an emergency;
- standards and frequency of examination of the system;
- an inventory and specifications of safety valve spare parts;
- boiler repair specifications.

ii) Shore management would have to review regularly the management and effectiveness of the portfolio. Audit of the safety management system should be assured that the review takes place.

iii) The portfolio should be updated when new problems are identified that could impact on the safe operation of the installation.

10. Supply sufficient manufacturers' documentation and other data to its ships to assist ship's staff to safely operate and maintain steam generating plant.

11. Introduce an inspection and testing regime for the safety valves of fully flooded economisers to ensure they remain functional between surveys.

12. Review its process of safety management system audits to take account of the lessons learned from this accident.

13 Review its safety management system to ensure that important safety information is retained and communicated effectively between ship and shore management.

14. Develop safety procedures to prevent the possibility of passage of steam and water into boilers which are under repair.

International Maritime Organization, International Chamber of Shipping, MCA, IACS and LR are recommended to:

15. Encourage ship owners to develop a boiler installation portfolio as recommended to Princess Cruises and P&O Group of Companies.

NAF AB, Linköping, Sweden, is recommended to:

16. Review and amend its safety valve maintenance and installation instruction and spare parts list (Fi46.721(2)AGB) to include valve component material specifications. The details required are specified in the NordAmatur's document FK46.72(5)E.

GLOSSARY OF TERMS

blowdown	-	Water removed from a boiler so that feed water may be added to reduce concentration of dissolved solid substances, or so that sediments may be carried to waste. It is also a process of removing this water.
bull-dog fastening	-	a screw clamp fitting to make the eye of a wire.
carry-over	-	Water and solids carried out of an evaporator or boiler with steam, especially at times of foaming or priming.
corrosion fatigue	-	Cracking under the conditions of simultaneous action of a cyclic stress and corrosion. The endurance limit of a metal is considerably reduced when chemical attack is taking place during the alternating cycles of stress. Fracture occurs at lower stress levels or fewer cycles than would be required in the absence of the corrosive environment.
cyclic loading	-	A cyclic increase and decrease in stress levels.
"designated person"	-	Specific person appointed to carry out a task.
dissolved solids	-	Solids in solution in water that would be left if all the water were evaporated.
Document of compliance	-	A document issued by the flag state administration or organisation recognised by it to companies who on completion of an audit, have demonstrated that they comply with requirements of the ISM Code.
fatigue	-	Mechanism of crack growth caused by cyclic loading.
galling	-	Damage due to rubbing together of two metal surfaces.
gouging corrosion	-	Water percolates through the scale deposit in the boiler and and deposits either acidic or very alkali concentrates. Corrosion occurs under the scale, resulting in intergranular damage, tending to gouge out irregular areas of metal.
hardness	-	Term originally used to denote that a water has a property of destroying a soap lather. It is also used to denote certain impurities are present.
Neil Robertson stretcher	-	See **Figure 35**
muff coupling	-	A sleeve like coupling connecting two intermediate propulsion shafts.

non-conformance note	-	A report of any deviation from an SMS procedure instruction, or relevant rules and regulations.
pH	-	A point on a numerical scale designed to show the degree of alkalinity or acidity of a solution. Alkaline solutions have pH values between 7 and 14 and acid solutions have pH values less than 7.
phosphate control	-	Maintenance, by treatment of water in the boiler, of a controlled reserve of phosphate ions.
reserve	-	Excess of conditioning chemicals maintained in a boiler.
Safety Management Certificate	-	Document containing the company policy and objective, a description of the safety management system and all organisational interfaces and responsibilities.

PORT EXHAUST GAS BOILER (Economiser)

Type	:	Aalborg AQ7
Manufacturer	:	Aalborg Vaerftas, Denmark
Year of manufacture	:	1970
Maximum throughput	:	3 tonnes per hour
Test pressure	:	12.5bar
Safety valve setting	:	9.1bar
Working pressure	:	upgraded to 9.0bar in 1989
Area of heating surface	:	230 m^2
Outer diameter (excluding insulation)	:	2.16m
Height	:	3.10
No of tubes (common)	:	484
Outside diameter	:	51mm
Wall thickness	:	3.6mm
No of tubes (stay)	:	102
Outside diameter	:	51mm
Wall thickness	:	8.0mm
Quantity of water held in economiser	:	10 tonnes
Shell wall thickness	:	12mm
Tube plate thickness	:	22mm

Main Fittings:

1	Main steam valve	:	100mm
2	Safety valves (duplex)	:	65mm
2	Feed water circulating valves	:	50mm
1	Vent valve	:	15mm
1	Manometer valve	:	15mm
1	Pressure gauge		

OIL-FIRED BOILERS

Type	:	Down-fired OF19
Manufacturer	:	Senior Green Ltd
Year of manufacture	:	1989
Rated	:	4 tonnes per hour
Test pressure	:	12.5bar
Operating pressure	:	7.5bar
Outer diameter, excluding insulation	:	2100mm
Height	:	3950mm

PORT EXHAUST GAS BOILER (ECONOMISER) SAFETY VALVES

The specification of the NAF 546348 safety valve is:

Manufacturer	:	NordAmatur, Linköping, Sweden
Type	:	Nak 65/100 NP16 Duplex
No	:	546348
Max temperature	:	425°
Max pressure (gauge)	:	15bar
Capacity	:	10500 kg/hr

Principal dimensions:

- nominal steam pipe inlet diameter 2x65mm
- nominal steam out pipe diameter 2x100mm
- seat diameter 2x40mm
- throat diameter 2x38mm

Pressures:

- design pressure 16bar

Materials:

- body and bonnet: cast carbon manganese steel
- valve seat: 17% chrome molybdenum stainless steel welded into body and machined formed to 1.5mm set width.
- spindle (made up to 1975): 0.18-0.25 C, 13%Cr, 0.9-1.2Mn, 0.20S, 0.2-0.4Si. This was a Swedish standard steel numbered 2390.
- spindle and lid (made after 1975): 0.28-0.38C,12.5-14.0%Cr,1.0Mn,1.5Si,1.0-1.5Mo.
- spindle guide: a glacier split plain bearing; sintered bronze/PTFE/lead lining on a soft steel backing **(Figure 7)**.

Machine tolerances:

- spindle diameter (30mm nominal) made up until 1975: 30 to 29.948mm
- spindle diameter (30mm nominal) made between 1975 & 1976: 29.89 to29.76
- spindle diameter (30mm nominal) made from 20 December 1976: 29.9 to 29.96mm
- bush housing diameter (34mm nominal): 34.00 to 34.025mm

Laboratory analysis of the spindle and lid fitted to the port economiser safety valves indicated stainless steel specification pre-dating 1975.

Glacier bearings specification:

- spindle diameter (30mm nominal): 29.98 to 29.96mm
- housing diameter (34mm nominal): 33.985 to 33.976mm

Surface roughness of spindle (30mm nominal diameter):

- average roughness, Ra, less than 0.40 (micro millimetres)

Maximum temperature at working pressure 10bar: 350°C

EXPERIENCE GAINED FROM 50 YEARS OF MARINE FAILURE INVESTIGATION, J S CHARLTON AND I BANTHAM Trans. I.Mar.E. Vol 110, Part 1, page 29

The propensity for crack growth is influenced by the environment due to the deleterious effect of corrosion when combined with stress. If the stresses are sensibly constant, as for example in a pressure vessel, the corresponding failure mechanism is usually termed stress corrosion cracking, whereas the term corrosion fatigue is applicable when cyclic stresses are predominant. In practice, such clear distinctions are unusual because all components experience some stress fluctuations and significant residual tensile stresses can be induced by manufacturing processes. All environments are corrosive to some degree, even air and pure water, and it is interesting to note that the fatigue strength of samples is increased if they are tested in a vacuum. The crucial function of the corrosive action is its contribution in overcoming the stronger microstructural barriers during the early stages of crack growth. Such action is a chemical function (fluid composition, pH value, electropotential) and is consequently time dependent, which helps to explain why there is no conventional cyclic stress limit for corrosion fatigue conditions. Furthermore, fatigue life is not related solely to the number of stress cycles and the results of corrosion fatigue tests are influenced by the frequency of the applied loads. Corrosive agents include both acidic and alkaline embrittlement mediums: chlorine, sodium and sulphur are commonly encountered in marine and industrial failures which are caused by corrosion assisted cracking.