Annex A

Report by the Institute for Industry

Introduction

This report concerns the anchor drop chain locker on the Viking Islay vessel. A briefing meeting and discussion was held with MAIB's on 26th October 2007. A simplified calculation is performed to examine whether corrosion of the exposed locker steelwork and anchor chain steel surfaces could lead to appreciable consumption of oxygen from the atmosphere inside the compartment. An opinion is provided on the feasibility of significant oxygen depletion via corrosion.

Calculations and Notes

A number of assumptions, notes and estimates are made:

a) The anchor drop compartment was essentially sealed for an extended period of time, such that the lower levels of the chain locker experienced a very small air movement. It is known that closed cell polymeric foam was inserted between the anchor chain and its surrounding guide tubes. A sealed manhole cover would then provide an essentially closed compartment from the viewpoint of air movement.

b) Photographs and inspection notes indicate that the internal locker surfaces and anchor chain were covered with red rust; some black oxide was reported under the red rust film (corresponding to a lower oxygen level under the red rust). Seawater ingress has occurred (seawater was noted under the perforated plate in the bottom of the locker) and the surfaces were actively corroding.

c) An estimate of the exposed area of the steel surfaces undergoing corrosion is made. This includes contributions from the anchor chain and internal compartment steelwork.

d) From photographs provided (15 November letter from MAIB, the exposed surface area of the starboard anchor chain can be estimated as 90 m^2. It is assumed that the port anchor chain has a similar area such that the total chain area is 180 m^2. 10% of this value is subtracted to allow for overlap of the chain links, leading to an effective total chain area of 162 m^2.

e) Photographs also indicate that the majority of the internal surfaces of the locker were actively corroding (red rust is evident) and the MAIB have estimated the relevant surface area as 70 m^2. The total estimated area of steel exposed is then 232 m^2.

f) Consumption of oxygen in the compartment air occurred mainly via corrosion of the exposed steel.

g) A constant rate of corrosion with time is assumed.

h) The corrosion of steel is a redox process where simultaneous degradation of iron (by dissolution or oxide formation) together with oxygen reduction occurs. A complex series of corrosion products results from such corrosion but the process may be simplified to formation of an iron(II) hydrated oxide (via a two-electron oxidation of iron) by reaction with oxygen:

$$2Fe^{2+} + 0.5O_2 + 3H_2O = 2FeO.OH + 4H^+$$

i) The reacting quantities are 2 mole (112 g) of iron reacting with 0.5 mole (16 g, 12.4 litres) of oxygen.

j) The density of iron is taken as 7.86 g cm^{-3}.

k) The period for corrosion may be taken as approximately 15 months (between the last known, recorded inspection on 6th June 2006) and the date of the incident (23rd September 2007).

l) The locker enclosed air volume has been estimated by MAIB at 22.9 m^3.

m) A typical averaged corrosion rate of mild steel in a humid, atmospheric seawater environment is taken as 36 microns per year (E. Mattson book). This is equivalent to 36 x (15/12) = 45 microns over a 15 month period.

n) This penetration of steel is equivalent to a metal loss of (7.86 g cm^{-3}) x (0.0045 cm) x (232 x 10^4 cm^2) = 82.1 x 10^3 g steel.

o) Such a mass loss of steel represents an equivalent oxygen consumption of (82.1 x 10^3 / 112.7) x 12.4 litres = 9.0 x 10^3 litres, assuming ideal gas behaviour. The oxygen volume consumed is then 9.0 m^3.

p) The percentage reduction in oxygen level in the enclosed locker is 100 x (9.0 m^3/22.9 m^3) = 39.5 %. This is equivalent to reduction in the oxygen level of the atmosphere from a nominal 21 % by volume to only 12.7 % by volume.

q) In practice, the corrosion rate (hence the degree of oxygen depletion) is likely to have been higher due to parts of the steel being immersed in seawater (rather than simply exposed to a humid seawater atmosphere). The resultant increase in corrosion rate is difficult to estimate but might be a factor of 2, resulting in a lowering of the oxygen level in the tank to just 4.4 % volume - which would not sustain breathing.

Conclusions & Opinion

1. A simplified calculation has been carried out to estimate the possible degree of oxygen consumption from the anchor chain locker due to corrosion of steel components.
2. The results indicate that such corrosion, in a sealed compartment, could lead to sufficient loss of oxygen to result in an air atmosphere which had insufficient oxygen to support continued breathing by personnel.
3. In principle, there are several possible explanations for the deaths experienced in the chain locker, namely, (a) a toxic atmosphere (there was no evidence of toxic gases in the air bag sample taken, (b) displacement of oxygen in the atmosphere by a non-breathable gas (e.g., CO_2 or N_2 – but there is no evidence to support this) or (c) depletion of oxygen, over a period of time, by the corrosion reaction with exposed steelwork.
4. In my opinion, (c) <u>oxygen loss by corrosion of steel is feasible</u> and may have provided a mechanism for substantial depletion of oxygen in the lower levels of the locker, leading to an atmosphere which would not sustain breathing. Death by asphyxiation would then be likely to follow.

Reference

E. Mattson, Basic Corrosion Technology for Scientists and Engineers, 2nd edition, The Institute of Materials, 1996 (Appendix 1).

Extract from *Viking Islay* Risk Assessment

RISK ASSESSMENT

No. 37

RISK RATING (R) See explanations at right		LIKELIHOOD OF OCCURRENCE (L)				
		V.LOW	LOW	MED	HIGH	V.HIGH
HAZARD SEVERITY (S)	NEGLIGIBLE	LOW	LOW	LOW	LOW	MED
	MODERATE	LOW	LOW	LOW	MED	
	SERIOUS	LOW	LOW	MED		
	MAJOR	LOW	MED			
	CATASTROPHIC	MED				

RISK RATING (R)	
LOW	No immediate action required. Proceed with care.
MEDIUM	Hazard to be investigated in conjunction with Ships Safety Officer/HoD with a view to reducing the risk

LOCATION	ON BOARD	JOB	CONFINED SPACE ENTRY

TASK (1)	HAZARD (2)	PERSONS AFFECTED (3)	RISK (4) L	RISK (4) S	RISK (4) R	CONTROL MEASURE (5) List those provided and required	RISK (6) L	RISK (6) S	RISK (6) R
Tank/space entry	Asphyxiation	Person(s) involved in task	High	Major	High	Toolbox talk. Competent person in charge. Proper PPE to be worn. Permit to work to be completed before entry. Space to be well ventilated. Space to be isolated and sign posted. Emergency procedures in place. B.A. sets at hand. Minimum persons in the space to do the task. Accesses to be kept clear. Good communication. Only enough persons to do the task enters	Low	Moderate	Low
Tank/space entry	Fire / Explosion	All crew	Medium	Major	High	Ensure that space atmosphere has been tested for oxygen and gases. Fire extinguisher at hand, fire mains charged up.	Low	Moderate	Low
Tank/space entry	Fall	Person(s) involved in the task	Medium	Major	High	Ensure that ladders inside space are in good order. Safety harness to be worn. PPE to be worn.	Low	Moderate	Low
Tank/space entry	Poor lighting	Person(s) involved in the task	Medium	Serious	Medium	Ensure lighting to the space is adequate. Extra lighting if required	Low	Moderate	Low

ASSESSOR (S)				MASTERS SIGNATURE
		DATE ASSESSED	24/01/05	
		REVIEW DATE	08/06/06	
		SHEET		
		REVISION		

VIKING

K ASSESSMENT Continuation Sheet

No. 37

LOCATION	ON BOARD	JOB	CONFINED SPACE ENTRY

TASK (1)	HAZARD (2)	PERSONS AFFECTED (3)	RISK (4)			CONTROL MEASURE (5) List those provided and required	RISK (6)		
			L	S	R		L	S	R
						TANKS MUST NOT BE ENTERED UNTILL CHEMIST HAS ENSURED SPACE IS GAS FREE, AND OXYGEN LEVEL SUFFICIENT.	Low	Negligible	Low
							Low	Negligible	Low

Forms and Emergency Checklists

<u>**Forms and Emergency Checklists**</u>

EMERGENCY CHECK LIST – ENCLOSED SPACE RESCUE

SHIP NAME	**DATE**		
ACTION	**PERSON**	**✓ X N/A**	**TIME**
Inform bridge/sound alarm	Witness/oow		
Muster all personnel	All		
Do not enter space	Witness		
Brief 1st officer	Witness		
Don breathing apparatus/lifeline	Two trained personnel		
Check atmosphere	1st officer		
Ascertain reason for casualty (Illness, Fall, Electric Shock)	1st officer		
Reach casualty as soon as possible	Team		
Give air to casualty or get casualty to air (if atmosphere unsafe)	Team		
If atmosphere safe identify cause	Team		
Do not move if badly injured and atmosphere safe	Team		
Arrange first aid	1st officer/AMA		
Get medical advice	Master		
Arrange stretcher	Cook		
Place casualty on stretcher if safe	Team		
Continue supplying air/first aid	Team		
Report to company	Master		
Arrange evacuation	Master		

Signed: - ______________________________
Responsible Officer

For Drill Purpose ☐
Tick Box
Form VOSL/S08/12/01