

---

## DEAERATOR CRACKING

WTIA Guidance Note GN 001  
P1-23-98

May 1998  
Supersedes November 1995 issue

---

### 1 SCOPE

- 1.1 This note summarises the results of surveys and investigations of Australian and overseas incidents with deaerators and associated water storage vessels, and makes recommendations for design, fabrication, testing and inspection based on these surveys, research and experience.

### 2 BACKGROUND TO FAILURES

#### 2.1 Extent of Deaerator Failures

In the early 1980s there were overseas reports of failures of deaerators and associated storage vessels. At least 7 of these failures were catastrophic and in one case in 1983, the vessel end was blown off and killed 3 people. Since then, throughout the world and Australia, cracking of a significant number of these vessels has been reported. In the last few years improvements are leading to reduced incidents.

#### 2.2 Nature of Deaerator Cracks

Cracks are found on the internal surfaces and associated with welds, especially circumferential welds but have also been associated with internal and external welded attachments. Cracks occur both perpendicular and parallel to the hoop stress direction and are normally transverse to the weld. They are normal to the plate surface and propagate in a trans-granular fashion; the crack tips are commonly blunt and may exhibit branching as well as being filled with an adherent oxide product (Ref 1).



The WTIA has joined forces with industry and government to create a 3.5 million dollar Technology Support Centres Network. This network will assist industry to identify and exploit world's best technology and manufacturing methods to establish a vibrant Australian industry beyond 2000. Together we will be implementing a step by step process which will lead to ongoing viability and greater profitability for all concerned:

- (1) Determine your technological and manufacturing needs;
- (2) Identify world's best practice;
- (3) Draw upon the network to implement world's best practice at your site.



MEMBER INTERNATIONAL INSTITUTE OF WELDING  
CORE PARTNER CRC FOR WELDED STRUCTURES



Cracks are not limited to deaerators of particular designs, fabrication methods or steels.

Cracking has been detected (Ref 1 and 2) under the following circumstances:

- In deaerators in all industries- paper and pulp, chemical, petroleum and power;
- In almost half of deaerators thoroughly checked;
- In all types of deaerators;
- Mostly in the water storage compartments and at or below the water line;
- On inside surfaces initiating in welds, heat-affected zones, corrosion pits and at the internal surface of the shell plate where an external attachment is welded.

### 2.3 Time for Cracking

Cracking is most often detected between 6 and 18 years of service with 3 years being the shortest time reported for extensive cracking (Ref. 3 & 4).

### 2.4 Mechanism of Failure

The mechanisms of failure are not fully understood but appear to be mainly corrosion fatigue sometimes in association with stress corrosion cracking. Fluctuations in flow and water level, vibration and start-ups and shut-downs are thought to provide cyclic stresses sufficient to fracture the magnetite scale adhering on the crack sides and thus expose fresh metal to corrosion and further cracking.

Water chemistry can exacerbate the occurrence especially where oxygen and chlorides are high.

In some cases stress corrosion cracking has been the mechanism of cracking, resulting from caustic carry-over in condensate return coupled with high local stress.

### 2.5 Origins of Stresses Inducing Cracking

In addition to the stress induced by the pressurised operation of the vessel, high local stresses can result from:

- The use of high design stresses as in Class 1 or any H class vessels;
- The use of higher strength steels e.g. Grade 490 MPa or higher to achieve higher operating stresses and also resulting in higher residual stresses;
- Large diameters where external loads induce significant bending stresses;
- Design and operating procedures which result in flow pulsation or transient thermal stress;
- Local stress concentrations on the inside surface resulting from internal *or external* attachments or poor quality welds;
- Non stress relieved welded joints.

## 3 GENERAL RECOMMENDATIONS FOR ALL DEAERATORS

3.1. Fluctuating thermal or bending stresses should be reduced by steady operation.

- 3.2 Protective surface coatings may be beneficial if they are suitably resistant to steam and hot water (see Ref. 3, Paper 211).
- 3.3 Ensure oxygen scavenger is introduced in a manner that will mix it evenly through the whole storage compartment, for example by injecting into the drop leg between the heater and storage vessel.

#### **4 RECOMMENDATIONS FOR IN-SERVICE INSPECTION OF ALL DEAERATORS**

- 4.1 Internal surfaces at significant stress concentrations should be subject to wet fluorescent magnetic particle examination (MT) using an AC yoke (Ref 7) after a maximum of 4 years service (note that special precautions will be required using mains voltages). High quality surface preparation is essential for the detection of cracking (Ref 6).

Areas to be examined include:

- 100% of areas of significant stress concentration
- Welds and pitting particularly in or near supports;
- At the internal surface in the location of external attachment welds;
- At attachments and openings;
- At areas of high bending stress;
- At 100% of weld T joints, and
- At 50% of the length of each remaining weld seam, with approximately equal amounts from above and below the water line.

The extent of inspection may be reduced for subsequent identical units in the same service if cracking is not found.

- 4.2 If cracking is not detected, inspections should be repeated at a maximum interval of 4 years but the extent of each inspection may be reduced to 30-50% of the amount specified in clause 4.1. If after the second inspection cracking is still not detected, the inspection interval may be increased to a period not exceeding the sum of the first two inspection intervals. After 8 years of crack free service the inspection interval may be increased to a maximum of 8 years dependent on consistent water quality.
- 4.3 If cracking is detected, the cause should be determined by a competent person and further consideration given to inspection of the remaining welds. Cracks should be removed by grinding taking care not to induce stresses during grinding. The minimum calculated wall thickness according to AS 3788 (Ref 8) should be determined to ascertain the need for remedial action such as weld repair. Repair should be with low hydrogen welding consumables, and postweld heat treatment of weld repairs is recommended..
- 4.4 Weld repairs should be designed taking note of the requirements of clauses 5.2 and 5.3. On completion they should be ground smooth (taking care not to induce stresses) and WFMT inspected with an AC yoke (note that special precautions will be required using mains voltages).
- 4.5 Weld repairs should be rechecked after 1-2 years operation.
- 4.6 As an alternative to repair by welding, the design pressure of the vessel may be de-rated where an engineering critical assessment has been used to demonstrate the vessel is safe. Precautions should be taken as outlined above to reduce further crack growth, and such potential crack growth should be monitored.

- 4.7 Note that some older vessels were constructed to poor standards of workmanship, for example by using partial penetration butt welds with no edge preparation. This can result in an unfused zone of nearly the same thickness as the welded plates themselves. Comparatively minor cracking could be of great significance in such cases, and grinding such welds smooth or flush could have potentially disastrous consequences. Where doubt exists, non-destructive examination should be carried out to determine the nature and integrity of the weld. Manufacturing defects that have not propagated should be evaluated by competent personnel (Ref 8).

## 5 RECOMMENDATIONS FOR NEW DEAERATORS

- 5.1 Future deaerators should be designed and constructed to AS 1210 (Ref 9). At the design stage low operating stresses should be specified to reduce the risk of corrosion fatigue and stress corrosion cracking. It is also recommended that the specified maximum tensile strength of the steel and welding consumables should not exceed 490 MPa (Ref 5).

Alternatively the vessel could be over designed such that the maximum operating stress of the vessel is low (<30% of the specified minimum yield strength of the steel).

- 5.2 Low hydrogen welding processes should be used, preferably with high heat input to control hardness. Weld quality should be high with minimum undercut. Weld reinforcement should be minimised and sufficiently smooth to enable subsequent magnetic particle or ultrasonic inspection to be carried out without spurious indications occurring. The weld area should then be subject to 100% magnetic particle testing on the inside surface after cleaning the test surfaces. Spot radiographic examination of welds is also recommended if weld quality is suspect.

- 5.3 Residual welding stresses should be reduced by such means as:

- Postweld heat treatment, particularly for steels in a higher strength range, 490 MPa and above; or
- Peening of welds and adjacent parent plate on the inside of the vessel to induce compressive stresses on the inner surface may be performed where appropriate, but it should be noted that subsequent grinding for inspection may remove the compressed layer leaving the area susceptible to cracking; or
- Hydrostatic testing to a general hoop stress equal to approximately 90% of the specified minimum yield strength of the parent metal.

- 5.4 The recommendations of section 3 also apply to new vessels, and they should be inspected in-service as recommended in section 4.

## 6 REVIEW

- 6.1 The guidance given in this note is subject to on-going review by the WTIA Technical Panel 1 *Pressure Vessels*. This is a technical group organised and administered by the Welding Technology Institute of Australia (WTIA) on behalf of its members and industry. For further information or comments contact the WTIA.

- 6.2 Experiences with deaerator cracking may be reported to the WTIA.

## REFERENCES

The following documents are referred to in the text, however some recommendations are made from experience not found in the literature. For example, tests made on one particular deaerator indicated that cracking revealed by WFMT using an AC yoke was not found using DC, or by penetrant inspection etc.

- 1 BULLOCK, J.H Understanding and Eliminating Crack Extension Behaviour in Feed Water Deaerator Systems- A Critical Review. Int.J.Pres.Ves & Piping 53 (1993) 1-21.
- 2 LOVE, C. 'Deaerating Heater/Storage Tanks': Locomotive pp 130-134, 1987. (Hartford Boiler Insurance Co, USA.)
- 3 Various papers presented at the National Association of Corrosion Engineers, USA Conference- 'Corrosion 87' San Francisco, March 1987, i.e. Nos. 138, 211, 212, 213, 14, 302, 304, 305, 309.
- 4 FRANCO, RJ. and BUCHHEIM, GM. 'Case Histories of Deaerator Failure Analysis'. (Materials Performance, October 1986, NACE, USA.)
- 5 National Association of Corrosion Engineers - NACE standards RP0590-96 Item No. 21046 Recommended Practice for Prevention, Detection and Correction of Deaerator Cracking.
- 6 AS 1627.2 Metal finishing - Preparation and pretreatment of surfaces - Power tool cleaning.
- 7 AS 1171 Non-destructive testing - Magnetic particle testing of ferromagnetic products, components and structures.
- 8 AS/NZS 3788 Pressure equipment - In-service inspection.
- 9 AS 1210 Pressure vessels.

## DISCLAIMER

While every effort has been made and all reasonable care taken to ensure the accuracy of the material contained herein, the authors, editors and publishers of this publication shall not be held to be liable or responsible in any way whatsoever and expressly disclaim any liability or responsibility for any loss or damage costs or expenses howsoever incurred by any person whether the purchaser of this work or otherwise including but without in any way limiting any loss or damage costs or expenses incurred as a result of or in connection with the reliance whether whole or partial by any person as aforesaid upon any part of the contents of these Deaerator Cracking Guidance Notes.