INVESTIGATION INTO THE CAUSE OF CRACKING IN DEAERATORS IN ORDER TO MINIMIZE THE RISK OF COLLAPSING

J.G. Bolten

INTRODUCTION

Numerous incidents of damage to dearators in the USA were reported during 1983, a few of which lead to the collapse of the deaerator and loss of life. In the Netherlands this phenomenon occurred early in 1985.
Stork Boilers, manufacturers of the "sprayer-type" deaerator (fig. 1), have since inspected more than 125 deaerators of different types. Guidelines for inspection and repair have been established in close cooperation between manufacturer, users and Stoomwezen (1). A total review of the phenomenon and the results of inspections are given in (2).
The purpose of this paper is the presentation of our experience with cracking in general and, in particular, with measures to be taken after cracking has been detected. The main purpose of our investigations was to minimize the risk of collapsing and to achieve life-time extension.

HOW DEAERATOR CRACKING MANIFESTS ITSELF

Deaerator cracking is commonly detected in or in the immediate vicinity of internal welds. The majority of the affected areas are found below the water line, where the damage is also more serious. Besides internal stresses caused by the welding process, internal pressure and load variations, the presence of oxygen and chlorides in the feed water appear to have a considerable influence on the deaerator-cracking process.
Deaerator cracking generally manifests itself as cracks perpendicular to the welds and to a lesser degree as longitudinal cracks. Transverse cracks are generally short (10-20 mm) but often treacherously deep. Longitudinal cracks, especially occur in or near fillet welds (heat-affected zones) of nozzles, stiffening rings and welded-on plates, and occasionally near circumferential and longitudinal seams in the vessel. The most effective inspection technique is the wet-fluorescent magnetic-particle testing method (WFMPT) applied on a ground surface.

DAMAGE MECHANISM

Through microscopic examinations of damaged parts insight into the damage mechanism is gained. Apparently many cracks originate from corrosion pits. The cracks run almost perpendicular to the walls, largely growing in a transcrystalline way. All cracks are completely filled with oxides and the

* Stress-Analysis Dept., Stork Boilers, Hengelo, The Netherlands.

tip of the cracks is always blunt. The fracture surfaces sometimes show indications of a discontinuous process.
These facts lead to the conclusion that the responsible damage mechanism must at least result in corrosion and crack propagation. The most probable damage mechanisms are stress-induced corrosion (possibly strain-induced), corrosion fatigue or a combination thereof.

REVIEW OF STORK INSPECTIONS

To date, (March 1988), Stork have inspected more than 125 deaerators manufactured from unalloyed steel (carbon or manganese steel) with outside diameters ranging from 2,000 to 4,500 mm, lengths from 6,000 to 30,000 mm and wall thicknesses from 7 to 22 mm. The safety pressure varied from 0.25 bar to 17 bar gauge. The relationship between service life and damage for 102 of the deaerators inspected is presented in figure 2. The inspection results sorted by material type, pressure rating, decade of manufacture and a classification of the inspection results by damage location can be found in (2).

DAMAGE PATTERN FOR STRESS-RELIEVED DEAERATORS

In 1987, Stork Boilers inspected four deaerators which had been stress-relieved after manufacture. They were manufactured from HII, the diameters varied from 2,100 to 4,000 mm, the wall thicknesses from 18 to 21 mm. The design pressures were 5,5 to 17 bar gauge, the ages of the vessels respectively 15, 20, 25 and 36 years. One deaerator was subjected to a 100% inspection, for the others the inspection (10-20%) covered selected critical spots. None of the deaerators showed typical deaerator cracks. Only at the connections between large baffles and vessel walls fixed by fillet welds, were cracks detected in the longitudinal direction at the baffle/weld transition (stress concentrations caused by rigidity transitions, figure 3a).

COLLAPSE OF DEAERATORS

Generally, deaerators are manufactured from unalloyed materials having excellent ductility characteristics. The applied welding processes are not very complicated and according to the design codes extensive inspection of the welds was and still is not necessary. Especially in the past, simple weld details were often applied, e.g. for circumferential and longitudinal welds and nozzle joints. In the old low-pressure type deaerators regularly one-sided, non-root penetrated joints are found.
Sometimes poor root penetration (figure 3b) similar to a longitudinal crack, becomes visible after the internal weld surfaces have been ground flat. Next to these imperfections

existing since the manufacture, the above-mentioned deaerator cracks originate in or near welds.
However, only in very few cases has the deaerator exploded and in a few cases were the dearators found to leak. Until now dangerous cracking has only been detected in:

- circumferential seams, particularly in shell/head joints and in longitudinal seams with large longitudinal cracks of a considerable depth in addition to transverse cracks (figure 3b).
- Fillet welds of a circumferential stiffener, of large nozzles or manholes, transverse and longitudinal cracks local to the heat-affected zone in the shell (figure 3c respectively 3d).

The consequences of a sudden rupture of these joints can be disastrous, depending on volume (average 150 m^3), pressure (1-17 bar) and location of the deaerator in the installation. Carrying out fracture mechanics analysis, research into reliable methods for crack-growth monitoring, and tests simulating crack growth will in future lead to a better understanding of the origin and the consequences of cracking. In view of the great number of cracks of unknown depth, however, grinding out and if necessary reconditioning by welding will often be the only practical solution.

REPAIR PROCEDURES FOR DEAERATORS

After repair, the deaerator should be crack-free. All indications detected have to be removed by grinding out. If the required residual thickness is insufficient reconditioning by welding will be necessary. In cases of serious damage the complete welds and adjoining parts will be replaced. If possible, fully root-penetrated joints are applied instead of fillet welds. A reinspection by WFMPT should be carried out after 4 years, at critical spots after 2 years. The first reinspections two years after repair have resulted in:

- new cracks in old welds.
- New cracks in or near repaired spots in welds.
- Only a few cracks in completely new welds.
- Incidental cracks in welds, stress-relieved after repair.

CONCLUSIONS

The main conclusions of this paper are:

- extensive cracking has been detected in approximately 65% of the inspected deaerators, 50% thereof necessitating major repairs or replacement.
- The cracking phenomenon is independent of manufacture, type, material and pressure rating.
- There is no reliable relation between cracking pattern and age.

- Stress-relieving of new deaerators is a precautionary measure against cracking.
- Appliance of fracture-mechanic techniques and research into crack growth may result in improved deaerator monitoring in the future.
- An expertly performed repair can extend the life time of the deaerator, but the damage mechanism will remain.

REFERENCES

(1) Report of the Dutch working group deaerators, "Status and recommendations", (in Dutch, to be published), Stoomwezen the Hague.

(2) Bolten, J.G. and Jansse, L.W., "Cracking in deaerators, results of inspection and measures for lifetime extension", Int. Conf. on Life-time assessment, June 13-15 1988, The Hague, Netherlands.

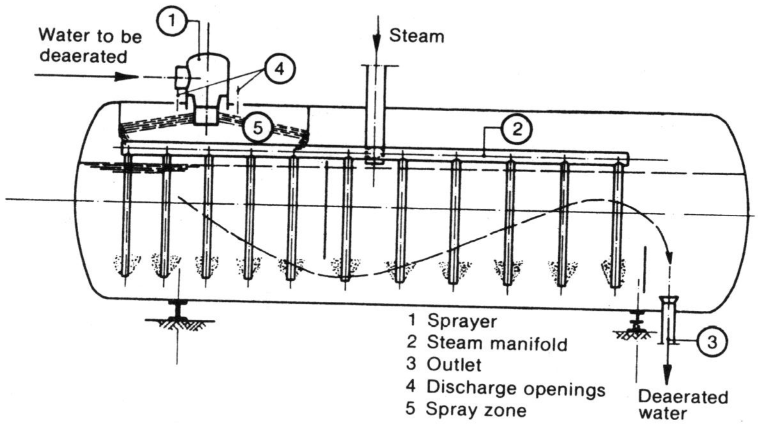

Figure 1 Principle of Stork deaeration system

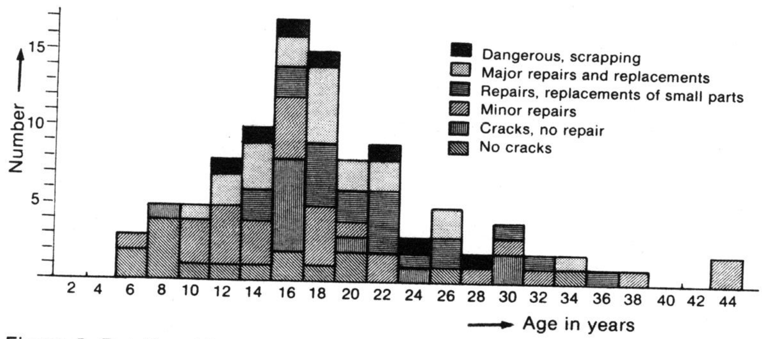

Figure 2 Relationship of service life-extent of damage for 102 deaerators.

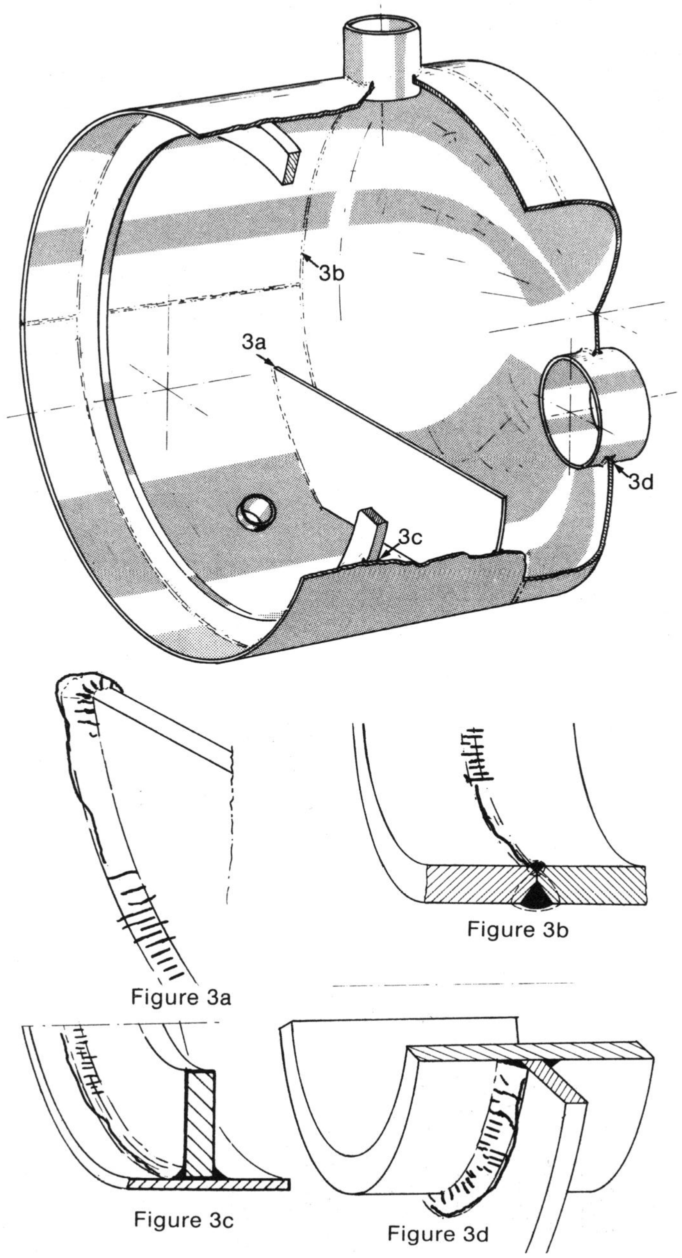

Figure 3 Review of most critical welding details in dearators