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THE ELECTRICITY COMMISSION OF NEW SOUTH WALES

CENTRAL LABORATORIES TEST REPORT No. MET 342B/81

Test on COMPARISON OF HYDROSWAGE AND ROLLER EXPANSION OF CONDENSER TUBES INTO TUBEPLATES. SUSCEPTIBILITY TO STRESS - CORROSION CRACKING.

Sample from
Date Rec'd
Ref. P/G/Met/IH:SF

1. INTRODUCTION

Minimization of residual stress in the expanded region of condenser tubes is desirable to reduce the probability of stress - corrosion cracking in service. An initial report (Met 342/81) was made on the "HydroSwage" method of hydraulically expanding condenser tubes into the the tubeplates. Tests have now been carried out on HydroSwage and roller expanded tube samples to compare the dimensions of the expanded region and resistance to stress - corrosion cracking in the ammonia vapour test.

2. ORIGIN OF RESIDUAL STRESSES IN EXPANDED TUBE

Magnitude and distribution of residual stress in the expanded tube depend on:

a) The difference in diameter of the tube and tubeplate hole. This difference can be a maximum of 2% of the tube diameter.

b) The force applied to the tube during expansion, which for roller expanding is set to give tube wall thinning of 6% to 8% after the tube contacts the tubeplate.

c) The profile of the expanding mandrel. This profile determines the width of the transition zone between the expanded and unexpanded tube. This contributes to the magnitude and distribution of the residual stress in the transition zone.

d) The type of expander. Roller expanders produce high surface stresses at the tube bore while static pressure produces a more uniform distribution.

The tube 'as manufactured' has a low residual tensile stress because it is given a fine grain anneal without any subsequent cold working. The tube as supplied in the quarter - hard condition must be capable of passing an ammonia vapour test for residual stresses. However current specifications do not nominate that the tubes must be capable of passing this test after expansion into the tubeplate.

3. PROCEDURE

Test samples were made from 180mm lengths of 25.40 mm O.D. x 1.22 mm wall (18 swg) aluminium brass condenser tube expanded into 50 mm O.D. Naval brass blocks. The blocks were machined (1.6umRa) to 1% and 2% above the nominal tube O.D. of 25.40 mm. The remaining wall thickness of the block approximates the ligament size in a typical tubeplate. The HydroSwage installation consisted of lightly expanding the tube to locate it in the block with a 'Tube Lock Tool'. The minimum expansion pressure used was determined by a 690 kPa water pressure leak test applied between the tube and block. The maximum pressure was determined by distortion of the block. These criteria gave a minimum swage pressure of 103 MPa and a maximum pressure of 186 MPa. Swage pressure used for various tests are shown in Table 1.

The roller expanded samples were made using an Elliott three roll expander. The samples were made at Vales Point using the same technique as for the installation of replacement tubes in Unit 3. The rolls were lubricated with a liquid soap and the mandrel penetration set to give tube wall thinning of 6% to 8% after contacting the tube wall.

4. TEST RESULTS

4.1 Dimensions

Tube wall thinning for the roller expanded samples ranged from 2.0% to 4.1% (Table 1), which is less than specified. HydroSwage expanded samples showed the tube wall thinning of 2.0% to 2.2% (Table 1). Tube wall thinning partly arises from expanding the tube until it just touches the tubeplate hole without having applied sufficient pressure to seal the tube to the tubeplate. For a 2% oversize hole this amounts to 2.08% wall thinning. This accounts for most of the wall thinning measured in the samples used.

The width of the transition zone from expanded to non-expanded tube ranged from 4 to 6 mm for the roller expanded samples and 6.5 to 6 mm for HydroSwage samples.

The HydroSwage tube samples undergo less severe local deformation during expansion than roller expanding as indicated by the wall thinning and the length of the transition zone.

4.2 Ammonia Vapour Tests

Ammonia vapour tests generally in accordance with BS2871 Pt3/1972 were carried out on the tube and block assemblies for 24 and 120 hours. The tube as manufactured must be capable of passing the 24 hour test without cracking. The tubes were removed after testing, sectioned and pickled in 40% nitric acid to reveal any cracks and examined up to 10 X magnification. Cracking associated with the cut ends of the tubes or fine cracks across scratches or other inadvertent damage associated with sample preparation were disregarded.

Results are given in Table 1.

Table 1

Ammonia Vapour Test Results

Sample No.	Swage Pressure MPa	Tubeplate Hole Diam. mm	Calculated % Wall Thinning Due to Expansion to Tubeplate	Total % Wall Thinning	Total Time Hrs.	Maximum Crack Penetration
Roller Expanded -						
1.010.5		25.65	1.7	2.1	24	37%
1.020.5		25.90	2.7	4.1	24	50%
1.010.7		25.65	1.7	2.1	120	90%
1.020.7		25.90	2.7	3.1	120	100%
HydroSwage -						
18.24	152	25.90	2.7	2.2	24	None
18.4A	186	25.65	1.7	2.0	120	Less than 5%
18.23	138	25.90	2.7	2.2	120	None
18.22	124	25.90	2.7	3.7	120	20%

4. TEST RESULTS (Contd.)

a) Cracking was primarily transverse in the transition zone (see Fig. 1) and similar in pattern to cracking found in condenser tubes.

b) Original tube size was 25.27 mm O.D. by 1.19 mm wall.

c) Calculated wall thinning of the tube when expanded until the tube just touches the hole assumes that the tube remains a constant length. In practice, the tube may shorten.

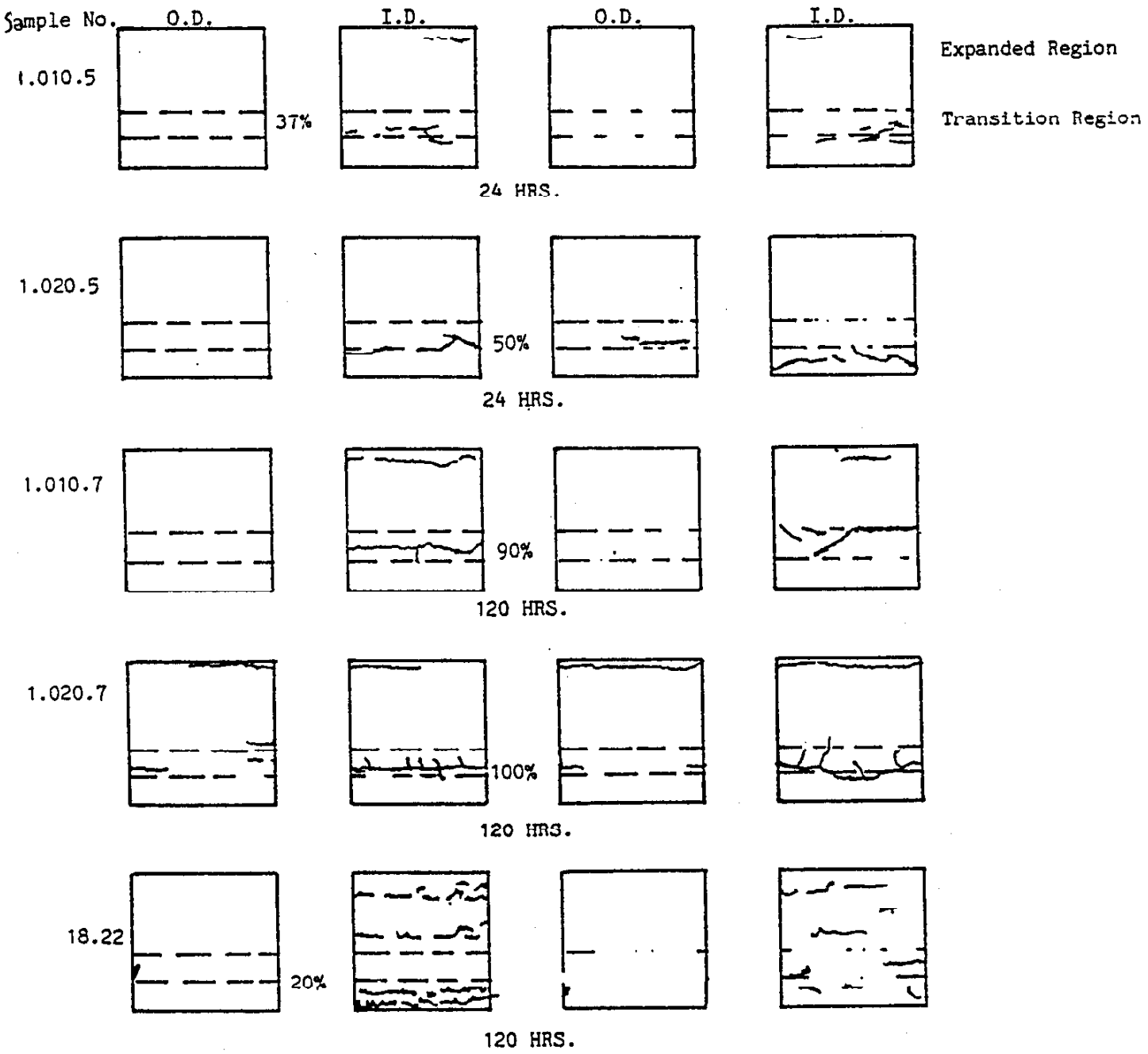
5. FINDINGS

5.1 For the samples tested, the HydroSwage tube installation procedure reduces the susceptibility to stress - corrosion cracking of aluminium brass condenser tubes in ammonia vapour testing. HydroSwage specimens were able to pass the 24 hour ammonia vapour test specified for new tube without cracking, whereas roller expanded tubes cracked in the tests.

5.2 Further tests need to be done to compare sealing effectiveness and pull out strengths of HydroSwage and roller expanded tubes.

FIGURE 1

DISTRIBUTION OF CRACKS IN AMMONIA VAPOUR TESTS
MAXIMUM CRACK PENETRATION (%) SHOWN



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