Queensland Civil and Administrative Tribunal

Application No. QR:128-07

Applicant: SHAFSTON UNIVERSITY MANSIONS PTY LTD CTS29747

First Respondent: QUEENSLAND BUILDING SERVICES AUTHORITY

Second Respondent: BROOKFIELD MULTIPLEX LIMITED

Leakage of Copper Pipes at Shafston University Mansions

JOINT STATEMENT OF EXPERTS

Mr Bruce Dan, Dr Jeff Gates

1. INTRODUCTION

1.1 Mr Dan is a hydraulic services and fire and risk engineer.

1.2 Mr Dan prepared a report titled "Shafston University Mansions Hot Water Pipe Failure", dated June 2007 (JWP Pty Ltd, report 070231-001).

1.3 Dr Gates is a metallurgical engineer with expertise in component failure investigations. He has been instructed by Minter Ellison acting for Brookfield Multiplex.

1.4 Dr Gates prepared a report titled "Leaks in Copper Pipe at Shafston Mansions", dated 30 October 2008 (UQ Materials Performance, report 41204).

2. POINTS OF AGREEMENT – MECHANISM OF FAILURE

2.1 The failure of the copper tubes occurred by a mechanism known as erosion-corrosion.

2.1.1 Erosion-corrosion is a damage mechanism caused by the conjoint action of a corrosive environment and fluid flow. Neither the environment nor the fluid flow on their own would be sufficient to cause premature failure; it is only their conjoint action which leads to premature failures.

2.1.2 In the case of erosion-corrosion of copper pipes carrying hot water, the failure mechanism consists of damage to the protective oxide layer followed by accelerated corrosion attack of the copper.

2.2 In general the main factors affecting the rapidity of development of erosion-corrosion of copper in hot water piping are as follows:

2.2.1 Water velocity (general flow velocity) – that is, the speed of water flow, in this case expressed in units of metres per second (m/s);

2.2.2 Proportion of the time that these velocities are experienced (hence continuously recirculating hot water systems are more prone to erosion-corrosion than on-demand only systems);

2.2.3 Water turbulence – created by any features of the pipe which interrupt the smooth flow, such as bends, elbows and branches, or internal irregularities such as joints, beads of solder, etc.;

2.2.4 Water temperature.

2.3 With regard to the water velocity:

2.3.1 Based on a survey of industry standards documents and scientific literature, the recommended maximum water velocity for continuously recirculating hot water systems at temperatures above 60°C is probably 0.5 m/s but certainly no higher than 0.6–0.9 m/s.

2.3.2 There is considerable evidence to suggest that in the Shafston system the water velocities used were higher than the above guidelines. The evidence comes from the following:

2.3.2.1 A letter by Ralph Engineering Concepts to Multiplex refers to specifications calling for flow rates of 1.5 L/s, which translates to velocity of 1.5 m/s in a 40 mm diameter tube.

2.3.2.2 The hydraulic services specification (page 47 section 003.03, dot point 1) included a specified velocity for noise limitation of 1.5 m/s.

2.3.2.3 The hydraulic services Finishes Schedule (Page 54 Section 004 sub-section 9) specifies the hot water recirculation pumps duty as 1.5 m/s.

2.3.2.4 Measurements using an ultrasonic flow meter, as recorded in a report by Ralph Engineering Concepts, indicated velocities of 1.4 – 1.45 m/s when the pumps were set to low speed and 2.0 – 2.1 when the pumps were set to high speed. Moreover, the report states that when Ralph Engineering Concepts inspected the pumps on 22 November 2006, both pumps were set to the highest speed.

2.3.2.5 Hydraulic calculations by Mr Dan suggest that velocities in some parts of the system were routinely higher than 1.5 m/s, and that if two pumps were operated simultaneously the velocity would be 2.8 m/s.

2.3.2.6 The physical examinations of tube samples obtained from Shafston Mansions show erosion-corrosion damage and clearly indicate the action of excessive water velocities.

2.3.3 In view of the above we believe that excessive water velocity was a major causative factor in the failures.

2.4 With regard to water temperature:

2.4.1 Literature indicates that increasing temperature significantly above 60°C, for example up to 75–80°C, can be expected to result in an increase in the rapidity of development of erosion-corrosion.

2.4.2 Measurements made by UQ Materials Performance on 10 September 2008 indicated heater outlet temperatures ranging from 54°C to 80°C. At that time there were seven heaters operating (out of a total of eight). These heaters feed into a manifold in which the waters mix, resulting in some averaged temperature. If the flow rates from the various heaters are equal then the average temperature should be approximately 65°C.

2.4.3 A temperature of 65°C is not regarded as excessive in a hot water recirculation system. Therefore excessive temperature cannot be deemed to be a contributory factor in the failures.

2.5 With regard to turbulence:

2.5.1 While local turbulence might have contributed to some of the failures, significant erosion-corrosion has been observed in locations with no bends or irregularities that would cause turbulence. Hence it is concluded that the primary cause was the systemic high velocity.

2.6 The collected evidence indicates that in the Shafston system the primary cause of premature failures was excessive water velocity.

3. Points of Agreement – Root Cause Factors

3.1 For a given pipe size, water flow velocities in the pipes are controlled by the following factors:

3.1.1 The capacity of the pumps (loosely described as the 'size' or 'power' of the pumps);

3.1.2 The speed to which each pump controller is set;

3.1.3 The number of pumps operating at any given time;

3.1.4 Whether or not balancing valves and bypass lines are installed and correctly adjusted.

3.2 The speed to which the pump controllers were set could potentially be influenced by any of the following factors:

3.2.1 The operational specifications laid down by the system designers;

3.2.2 The controller settings made at the time of commissioning (at completion of building);

3.2.3 Any subsequent adjustments to the controller settings that might have been made by operators or owners.

3.3 With regard to the operational specifications laid down by the system designers, we understand that the specification called for a maximum flow velocity of 1.5 m/s (see paragraphs 2.3.2.1 to 2.3.2.4 above, in particular paragraph 2.3.2.2).

3.4 With regard to the appropriateness or otherwise of this specification, our opinion is as follows:

3.4.1 Had the specification called for a maximum flow velocity of 1.5 m/s under the specific circumstance of probable simultaneous flow demand, this could have been deemed appropriate.

3.4.2 However, a specification which calls for a flow velocity of 1.5 m/s under the circumstance of continuously recirculating flow must be regarded as excessive and likely to promote erosion-corrosion.

3.5 With regard to the question of what should have been known about flow velocities and the risk of erosion-corrosion by a competent engineer designing a recirculating hot water system at the time the Shafston building was being designed:

3.5.1 The risk of erosion-corrosion and the role of water velocity and temperature have been known and published in specialist water distribution literature (notably the American Water Works Association) since about 1985.

3.5.2 In 1999 when the Shafston building was designed, this information had not been transferred either to applicable national standards governing hot water systems (such as AS3500.4[1] or BS6700), nor to authoritative metallurgical handbooks such as the ASM Handbook.

3.5.3 At the time the Shafston building was being designed, "best practice" for flow velocities in the design of recirculation systems for hot water above 60°C would have been:

- Maximum water velocity for continuous recirculation — preferably 0.5 m/s and certainly no higher than 0.6–0.9 m/s [see paragraph 2.3.1 above];
- Maximum flow velocity for short-term simultaneous flow demand — 1.5 m/s [see paragraph 3.4.1 above].

3.5.4 However, we are not in total agreement concerning "what a competent engineer should have known" concerning flow velocities when designing a recirculating hot water system, at the time the Shafston building was being designed.

4. POINTS OF DISAGREEMENT

4.1 The only point of disagreement between our opinions that we have identified is in respect of "what a competent engineer should have known" concerning flow velocities when designing a recirculating hot water system.

4.2 Mr Dan's opinion in this respect can be stated as follows:

4.2.1 It is clear both what would have been regarded as "best practice" and "what a competent engineer should have known" when designing recirculation systems for hot water.

4.2.2 That is, a competent engineer designing recirculating hot water systems should have been familiar with best practice as set out in paragraph 3.5.3 above.

4.3 Dr Gates' opinion in this respect can be stated as follows:

4.3.1 It is not clear whether or not a competent engineer designing recirculating hot water systems in Australia in 1999 could be expected to have been familiar with the specialist water distribution literature referred to in paragraph 3.5.1 above.

4.3.2 If an engineer in 1999 had consulted all of the then-current versions of AS3500.4, BS6700 and the ASM Handbook, that engineer would not have been alerted to the

[1] AS3500.4–1994, *National Plumbing and Drainage Code Part 4: Hot water supply systems* (First published 1990, 2nd edition 1994); Revised and redesignated AS/NZS 3500.4.2:1997; Now-current version AS/NZS 3500.4:2003, *Plumbing and drainage, Part 4: Heated water services*, Published 15-Dec-2003, Amendment 1 published 1-Nov-2005.

need to limit flow velocities to no more than 0.5–0.9 m/s. Such guidelines did not enter the ASM Handbook until 2005, and even the now-current version of AS/NZS 3500.4 does not contain such guidelines.

4.3.3 A competent engineer might reasonably have regarded familiarity with the guidelines given in all of AS3500.4, BS6700 and the ASM Handbook as being sufficient to permit appropriate selection of design parameters such as maximum water velocity.

5. POINTS OF UNCERTAINTY

5.1 We have not been provided with commissioning records, from which to determine the pump controller settings at the time of building completion.

5.2 We have no information pertaining to instructions for the hot water recirculation system pumps or pumps' controller that would normally be provided in an Operation & Maintenance Manual format to the operators or owners.

5.3 We have no information about any adjustments to the controller settings that might have been made by operators or owners.

20/04/'10
....
Mr Bruce Dan

....
Dr Jeff Gates 29/4/2010