Resource A

PAPER 6

Degradation of an acetal plumbing fitting by chlorine.

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Degradation of an Acetal Plumbing Fitting by Chlorine

by

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Abstract: It has been known for many years that both types of acetal plastic are susceptible to oxidative attack, or stress corrosion cracking (SCC) when in contact with chlorine. It was thought that high levels (>30ppm) of free chlorine in cold water are needed to initiate attack, so that acetal injection moulded fittings could be used quite safely in potable water supplies where free chlorine levels are very much lower (<1 ppm). The case study to be described here of a fracture in a water supply which caused substantial damage, indicates that attack probably can occur at such levels, especially if the fittings exhibit extensive weld lines near stressed zones. High chlorine concentrations can arise due to chlorine surges in the water supply, especially when the water company overdoses the supply after a major leak.

Circumstances of the Accident: A hot water supply system had been installed for about 3 years in the Physics Department at Loughborough University, England. The department occupied the top floor of a large building, immediately above the Computer Sciences department. A leak was detected in early November, 1988, when it was discovered that an injection moulded fitting had fractured some time over the previous weekend, and flooded and destroyed numerous computers in the department below. The fitting was a three-way junction, which controlled the cold water supply to a small water heater, which could supply hot water to the adjacent tap (**Figure 1**). Since the hot water tap had not been used (as far as is known) over the weekend, no movement in the junction had occurred to initiate a crack).

The immediate investigation could find no obvious cause for the fracture, which occurred along a thread on the cold water inlet part of the joint, where it was attached to the copper pipe. The investigator (who had no specific training in plastics technology) thought that over-tightening of the joint may have caused the failure. In addition, it was thought that the water heater itself (which had come free from its single fixing point) may have put excessive loads on the joint.

The junction was still in one piece by the time it came for more detailed study. However, it rolled off his desk top onto the floor, and finally broke into two pieces across the thread. The larger fragment is shown in **Plate 1**. However, the insurers refused to accept the possible cause suggested, which implied that the plumbers had wrongly fitted the junction. The problem moved on to issuing of court proceedings, when the University sued the plumbing company and others involved in the renovation of the facilities (Loughborough University-v-Wm Moss *et al.*).

The Failed Sample: When collected, it was clear that the fracture was very old, because the fracture surface was encrusted with brown salts, as shown in **Plate 2**. They turned out, on analysis, to be identical with the local hard water deposits (also present in a nearby electric kettle), a fact confirmed by the water supply company. The failure had thus progressed slowly with time, and there had been slow leakage of water for many months, if not years. The washer and joint showed that it had not suffered any excessive stresses, so the joint could not have been over-tightened by the plumber or anyone else. The joint had also been wrapped with PTFE tape to prevent seepage of water through the thread. The water heater was loose when examined, but was unlikely to have put excessive loads onto the joint sine they would have been taken by a steel bracket in the system (**Figure 1**). The cause of failure could thus not be explained by over-tightening or other abuse.

Examination of the fracture surface showed several zones of discolouration (**Figure 2**), as well as the new fracture (clearly distinguished by an absence of later deposits). Injection moulding features such as the injection direction and mould parting line (MPL) appeared to show no obvious correlation with the fracture. However, careful inspection at right angles to the fracture showed several crack branches at the edge at the thread root (**Plate 3**). When continued around the edge, it allowed several crack paths to be identified, as shown by the bold arrows in **Figure 3**. There were about five such independent cracks in all. Examination in the optical microscope also showed the presence of many small weld lines on both outer and inner surfaces, and especially at the root of the thread adjacent to the main crack paths. Some were stained deeply by the salts from the water, showing them to be long standing defects.

Injection Moulding: In order to explore the moulding conditions more systematically, a set of new mouldings were requested from the moulder. The fitting was made in a four impression tool, and the acetal resin used was the copolymer version of the material (rather than the end-capped homopolymer).

The samples showed many flow lines, which were exposed by dusting the outer surfaces with fine graphite powder (e.g., **Figure 4**). The four different impressions gave different patterns, which could not be correlated with the pattern from the failed moulding. Moreover, the new mouldings did not possess the very serious and deep weld lines of the failed sample. It was concluded that moulding conditions were probably different for the failed sample. It was also noted that the design had been changed : the original failed moulding showed several different section thicknesses, for example.

Discussion: Failure had probably occurred from a deep weld line in the bore of the moulding. The stress raising effects of deep weld line grooves are well known, but it was felt that this by itself could not explain the failure. There was enough evidence at this stage of the investigation to rebut the Plaintiff's arguments against the plumber, and point to faulty moulding. **Figure 5** shows the sequence of events identified so far in the failure. Stress analysis indicated that water pressure alone could not initiate failure, so some additional failure mechanism was in operation.

However, while preparing a review on Design in Plastics for RAPRA (1), the investigator noted from a single reference that proceedings were taking place in the state of Texas (Babb et al -v- Shell Chemical) (2). The papers in the case were obtained from the Plaintiffs, and the expert reports (3) revealed that acetal copolymer fittings had been analysed for the possible presence of chlorine. It had been confirmed by EDAX analysis that chlorine was present in several failed samples. Very low chlorine levels in the potable water supply could cause SCC of acetal copolymer mouldings. Other materials had failed as well, especially the polybutene pipe systems used in the hot water systems, and the case resulted in a large settlement for the Plaintiffs. Subsequent events have confirmed the problems of using such polymers in hot water suppplies (4).

The failed joint from the current English case was subjected to EDAX analysis and the presence of chlorine in the acetal near the failure site confirmed. In addition, the water supply company reported that chlorine levels in the potable water supply could rise outside normal limits when plugs of chlorine were put into the water after major leaks. The method was employed to prevent any harmful bacteria accidentally entering the supply, for example. A possible cause for the problem was therefore found, although not explored further. The outcome for the English case was settled out-of-court, given the evidence from the USA, with the case against the plumbers dropped in the light of the strong evidence that the cause of failure lay in an SCC mechanism.

Conclusions: The evidence from the failed fitting pointed towards poor moulding practice leading to numerous weld lines at and near the joint which failed. It started cracking soon after installation, and several cracks grew slowly from weld lines, probably by an SCC mechanism under the influence of free chlorine in the cold water supply. The case study illustrates the importance of trans-Atlantic cooperation in publicising case studies of failure so that practising engineers can avoid future product liability disputes.

References:

(1) PR Lewis, Designing with Plastics, RAPRA-Review Reports No 64 (1993).
(2) Anon, Plastic Pipe is Expensive for Industry, Chem Mark Reporter 239, No 11 (18th March, 1991), pp 7/13.
(3) Armstrong, James and Duvall, Plaintiffs Exhibits in Chris and Diane Babb-v-Shell Chemical Company et al, Matagorda County Court, Texas (1992).
(4) eg, Zhou, Chudnovsky and Niu SPE Antec, 1996, p 3265, discussed in PR Lewis, Case Histories of Polymer Product Failures, RAPRA Review reports No 108 (1999).

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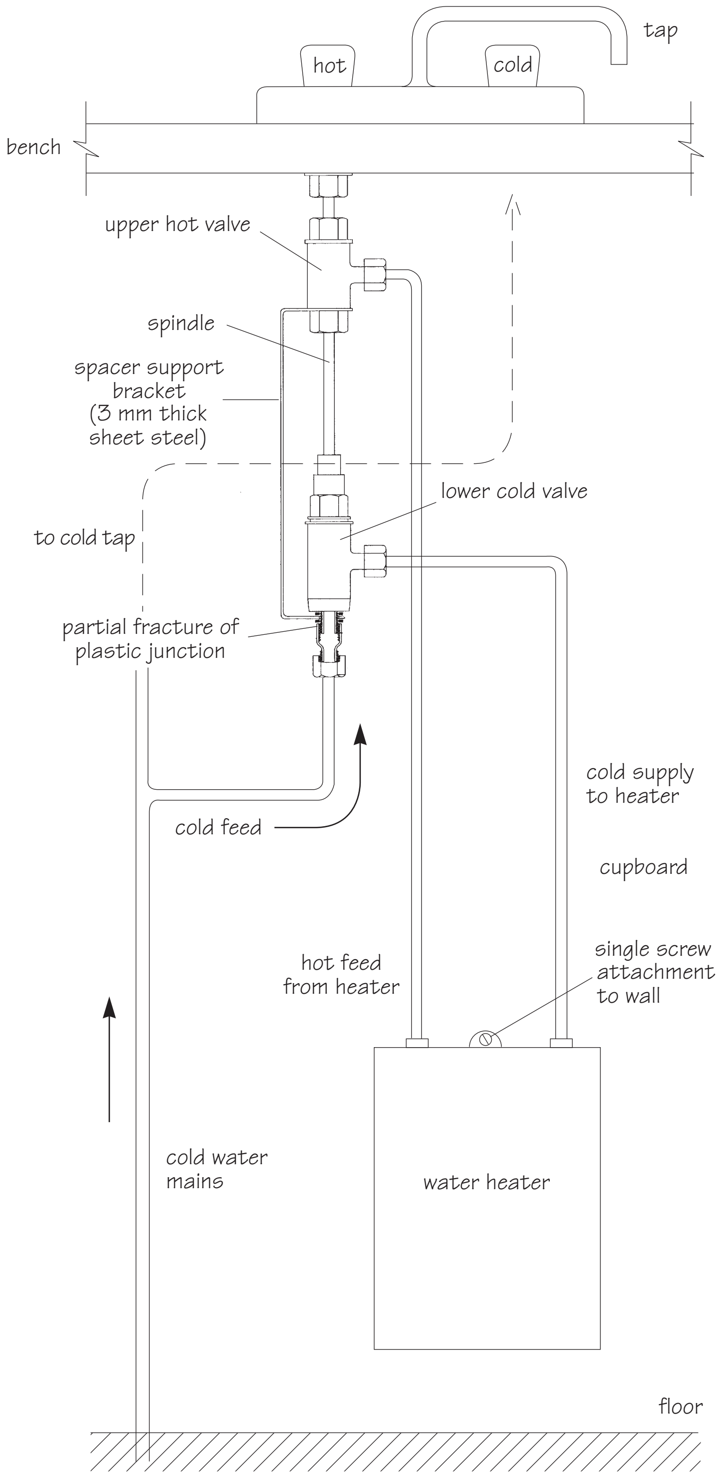
tap
hot
cold
bench
upper hot valve
spindle
spacer support
bracket
(3 mm thick
sheet steel)
lower cold valve
to cold tap
partial fracture of
plastic junction
cold supply
to heater
cold feed
cupboard
hot feed
from heater
single screw
attachment
to wall
cold water
mains
water heater
floor

Figure 1

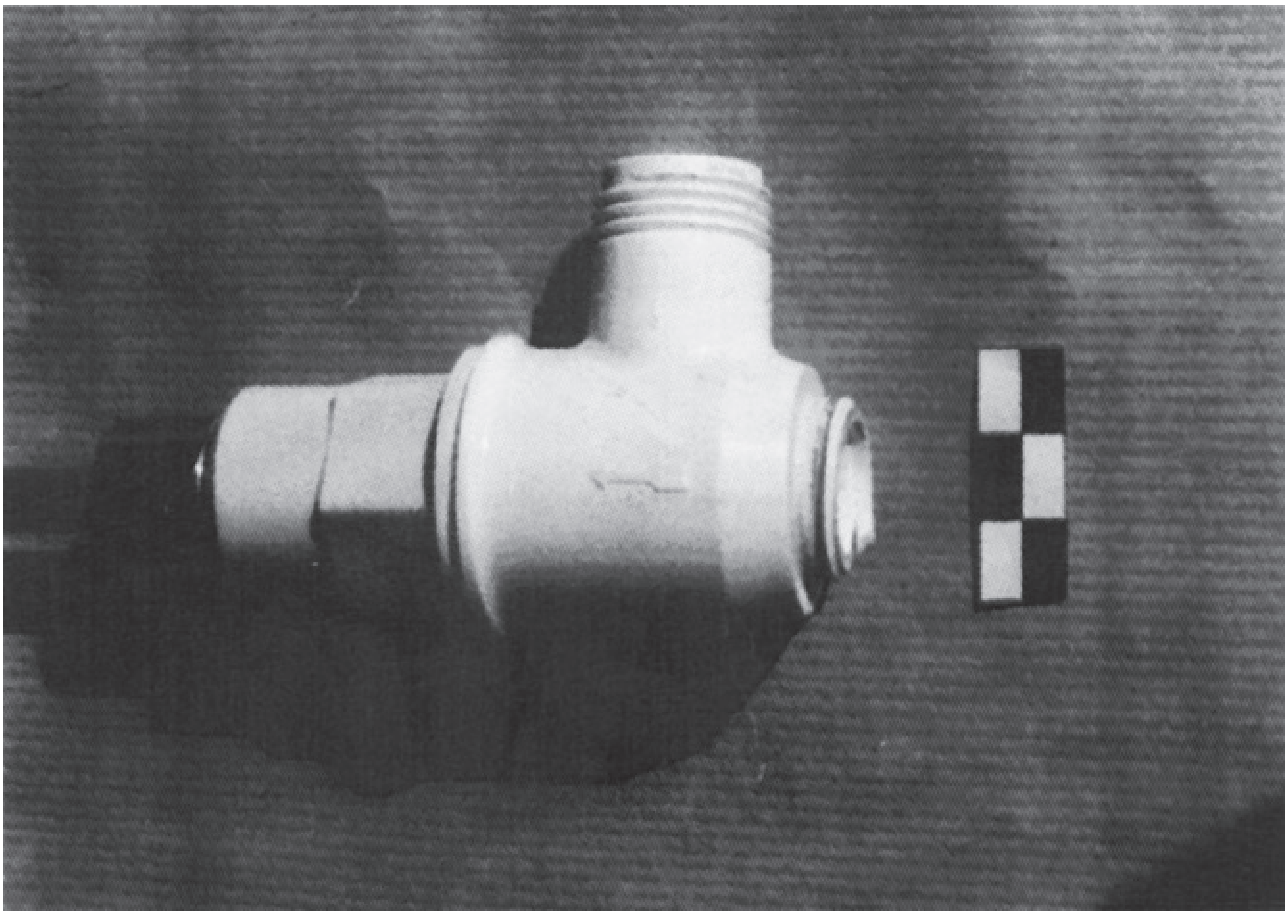

Plate 1

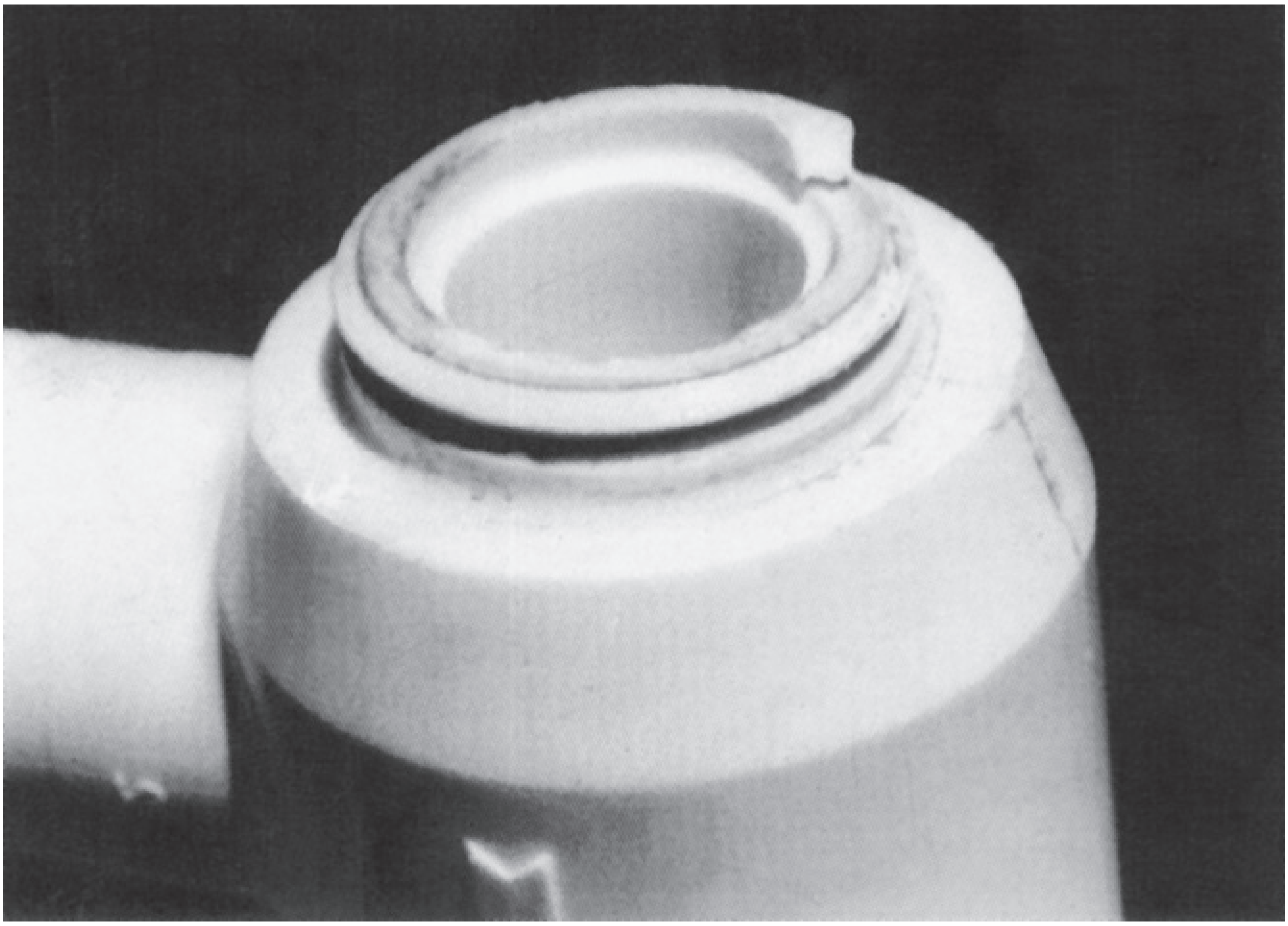

Plate 2

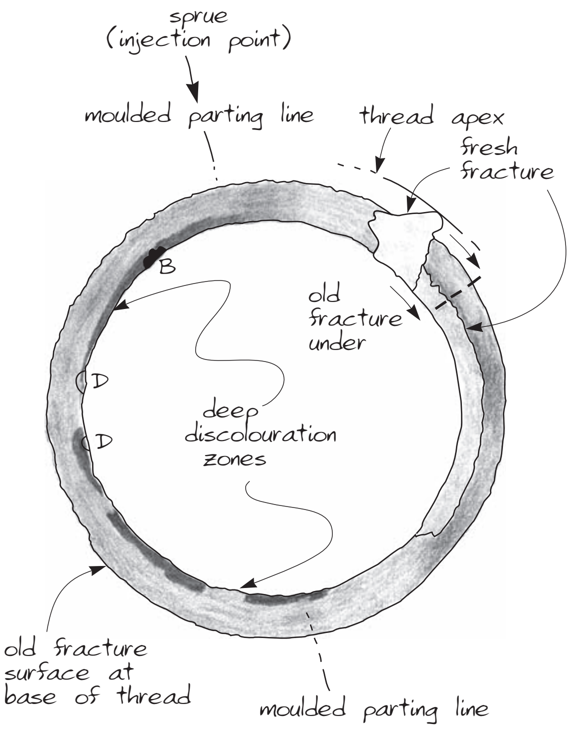

Figure 2

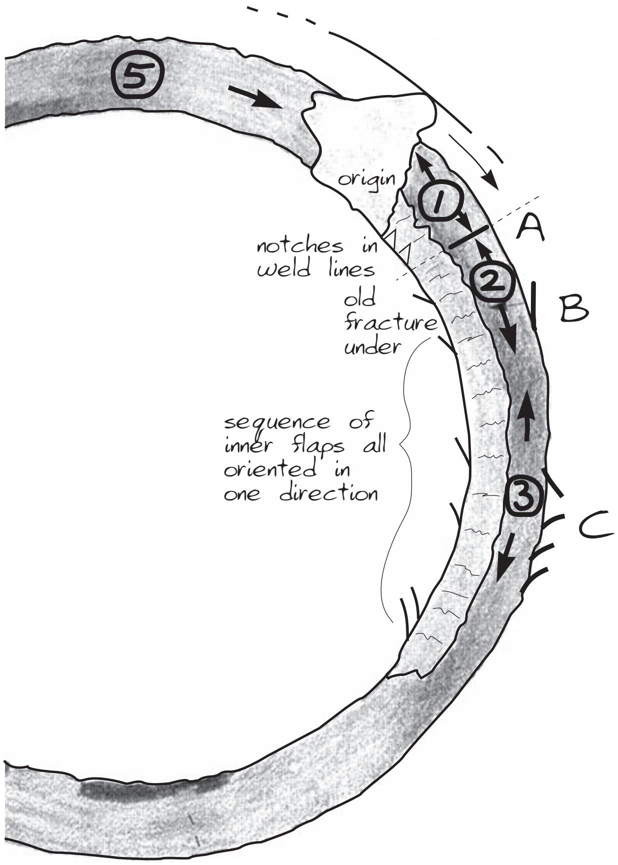

Figure 3

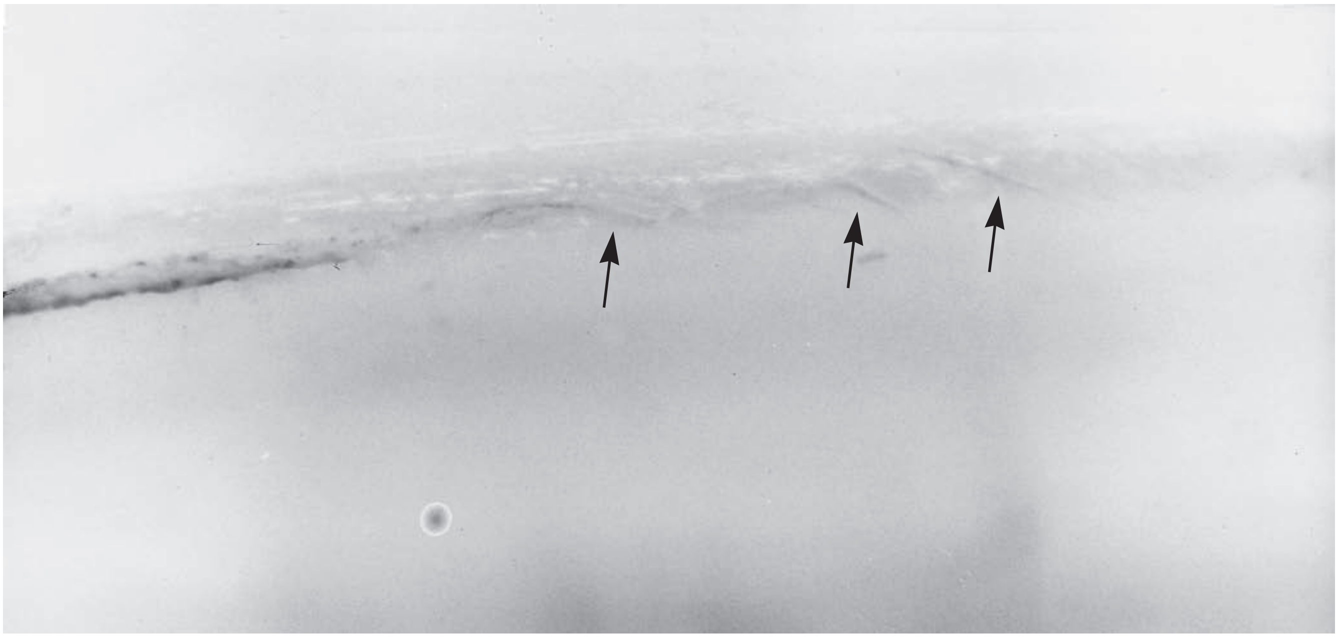

Plate 3

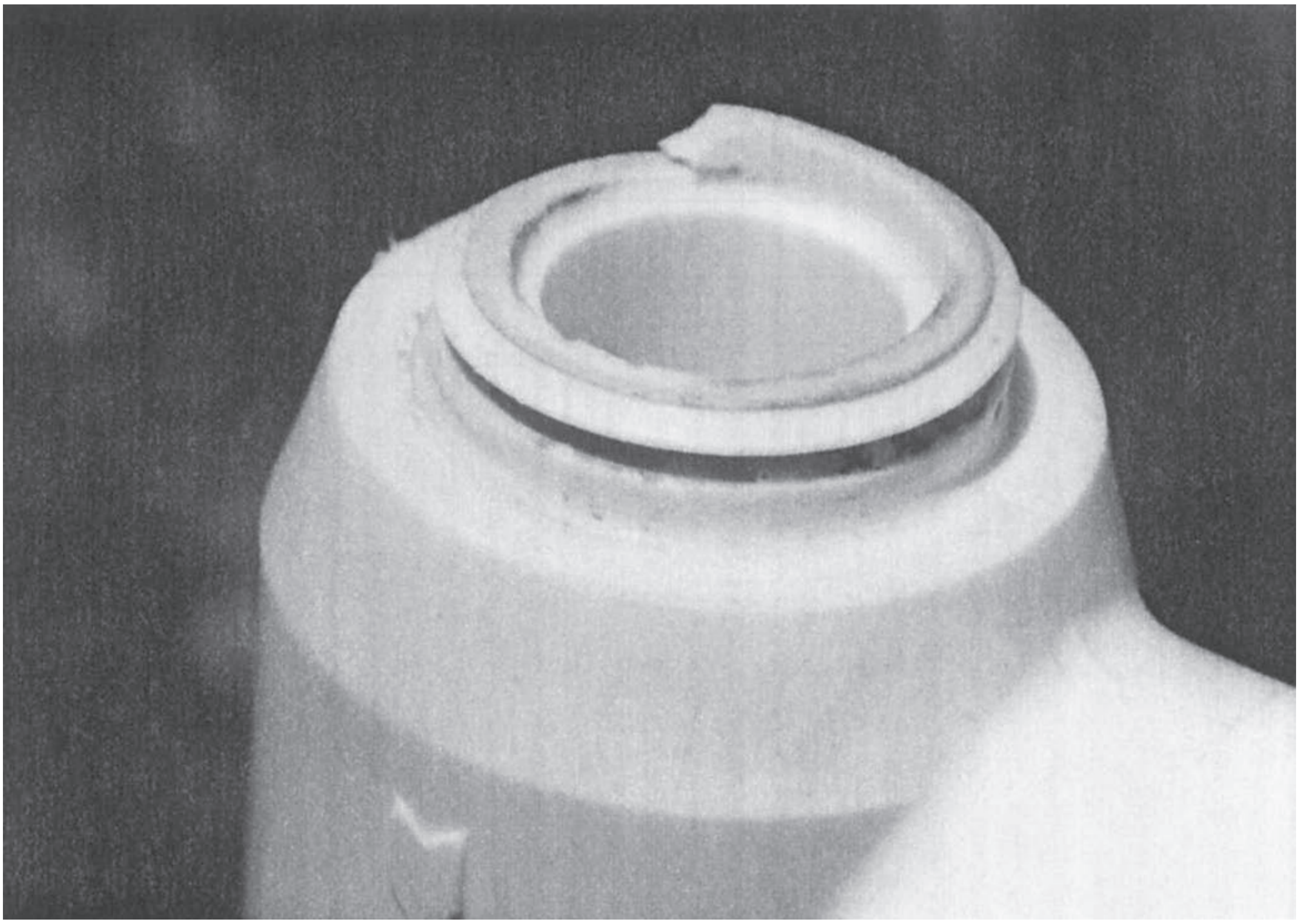

Figure 4

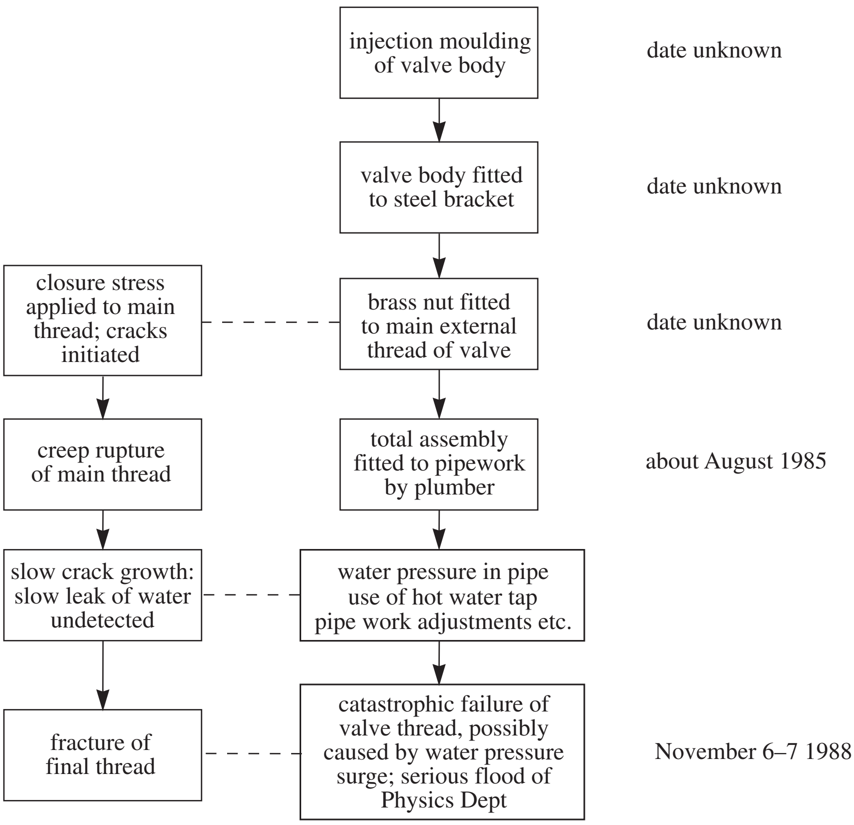

Figure 5