MPMA / BSDA / BBPA RECOMMENDED CODE OF PRACTICE

ENVIRONMENTAL STRESS CRACKING OF ALUMINIUM ALLOY BEVERAGE END SCORES

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DATE OF ISSUE: 14 MAY 2001
1. Introduction

This Code of Practice has been prepared and agreed jointly by MPMA (Metal Packaging Manufacturers’ Association), BSDA (British Soft Drinks Association) and British Beer and Pub Association. It is based on current best practice and will be subject to annual review.

Detailed technical specifications should be agreed between individual suppliers and customers.

2. Technical Explanation

Aluminium alloy beer and soft drink can Ends have been long established as successful components, but can undergo an external corrosion failure process at the score due to reaction with moisture, leading to the tabs popping outwards suddenly. The failure is commonly termed stress corrosion cracking and typically occurs in shrink-wraps or cartons held in warehouses.

Failure risks through stress corrosion are especially high in hot and humid climates e.g. temperatures above 30°C and humidity above 60%rh (relative humidity). Depending on the variations in these conditions and other related factors contained in this technical brief, failures from within 2 weeks to several months after filling may occur.

Figure 1 describes a cross section of an easy-open End and illustrates the area of failure. A typical crack effect is shown in Figure 2. When examined at a microscopic level, different failure modes are identified (see Section 10. Figures).

The fundamental cause of failure is the reaction of moisture with the End alloy at the score region which initiates a localised corrosion process, leading to cracking at the score base and sudden failure. The score is stressed both due to the score forming operation and by the internal pressure of the can contents. The combined action of corrosive attack and stress promotes the accelerated failure. There may be little or no outward indication of the failure developing.

The corrosion process is greatly accelerated by the presence of contaminants such as residual salts, notably chlorides and other halides. Additional processing materials which are known to promote failure risks with aluminium alloys include mineral oils, alcohols and hexane \(^1\), but it has not been established whether failure in these environments is due to moisture. Published work by aluminium suppliers indicates that track lubricants create susceptibility \(^2\), and some of these contain alkyl sulphonates; biocides containing chlorides \(^3\) should also be avoided or require thorough washing off the Ends. Again, some supplier information indicates that close controls on sulphate and nitrate levels in process waters should be applied \(^3\). The score region is vulnerable to attack due to breakdown of the external coating during the scoring operation.

Both ring pull and stay-on-tab Ends are at risk of stress corrosion failures but a higher risk tends to exist with stay-on-tab Ends, because the scored metal is required to be thinner to facilitate ease of opening.
Once corrosion leading to failure is initiated in shrink-wraps or cartons, the moisture released by tab failures is likely to lead to progressive failure of neighbouring packs.

The key measures necessary to minimise failure risks of filled cans are as follows:

- The bodies but especially the Ends need to be thoroughly washed to remove process residues of all types using rinse water with very low salt content.
- It is essential to ensure that bodies and Ends are thoroughly dry prior to packaging.
- Packing should be such as to minimise build up of condensation on the Ends.
- The storage temperature should be below 28°C and above dew point $^4$.
- Temperature variation during storage should be minimised as, in extreme cases, this may lead to fatigue or corrosion fatigue failure.

3. End Manufacturing Factors and Quality Assurance

The manufacturing process for easy open Ends for beers and soft drinks is designed to ensure acceptable quality levels to meet End user requirements under a recognised Quality Assurance System.

The End alloy selected has been established and tested for its suitability for use for the Ends including risks of stress corrosion cracking.

The End score depth adheres to close manufacturing tolerances and is routinely checked, requiring it to maintain pressure resistance and ease of opening of Ends.

Maintenance of overall easy-open End tolerances is in accordance with Customer Product Standard and Industry bodies, for example MPMA (see Recommended Industry Specification for Beer & Carbonated Soft Drink Cans).

It is ensured that materials used in Ends manufacturing meet with their individual specifications via the suppliers.
4. Process / prevention / filling line conditions and equipment specification

Current End making technology cannot fully protect the score from the risk of stress corrosion. The risk can be reduced significantly by adhering to the following recommended conditions:

- No slat lubricant left on the End
- Minimum amount of residual moisture on the End
- Maintaining the temperature of the product above the Dew Point, to prevent condensation occurring before and after secondary packaging of the filled cans.

Ideally, dry lubricant systems should be used. However, if it is necessary to use wet lubricant systems, the amount of lubricant used should be minimised at all times. Only use lubricants with low chloride and sulphate levels. Always dilute to the agreed levels and monitor this dilution level on a daily basis.

Prior to secondary packing of the filled cans, it is necessary to ensure that they are fully rinsed with water such that any residual water left on the can End is low in salts. The rinse water should have the following properties:

- pH between 5 and 8.5
- Chloride level below 10ppm
- Sulphates below 15ppm
- Nitrates below 15ppm

The cans should be in single file, orientated such that the Ends are uppermost and the rinse water directed at the cans through a fan type nozzle. All evidence of slat lubricant must be rinsed off the Ends. Following rinsing of the Ends, they need to be dried efficiently using a modern, specifically designed dryer, where the residual amount of water left on the End is specified.

Both the rinse water supply and the dryer must be interlocked to the line such that the line cannot operate unless these are operational.
5. Test Method for Assessing the Dryness of Can Ends

5.1 Equipment required:

1. A balance that is accurate and repeatable to at least 0.001g.
2. Air tight containers and swabs.
   Either a. Sterilin tubes and cotton wool buds
   or b. Sealable polythene bags and filter papers

5.2 Test Procedure:

1. Weigh swabs in the sealed containers to an accuracy of 0.001g. Record the weights.
2. Take samples from the line directly after the dryers and swab immediately.
3. Carefully use the swab to remove all residual water from each individual End, including under the tab and in the countersink and score.
4. Reseal the swab into the container.
5. Reweight container and swab. Record the weights.
6. The difference in weight is taken as the amount of moisture remaining on the End.

5.3 Test Frequency

Recommended daily, but should be continually reviewed depending on consistency of results and process capability.

5.4 Points to note:

1. The time between sampling and testing should be kept to a minimum.
2. If drying in single lane take 4 samples from each lane.
3. If drying in bulk take 4 samples evenly across the belt.
4. Prevention of contamination of the items to be weighed is important to avoid spurious results.
5. The swabs should be out of containers for the minimum time between weighings to prevent moisture pick up / loss.
5.5  **Standard to be achieved:**

The objective is to achieve zero residual moisture on the Ends but the following is a minimum practical operating standard based on available modern equipment.

<table>
<thead>
<tr>
<th>Recommended Operating Standard</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target average less than 3mg per End</td>
<td>Recheck, if within standard continue, if not, establish cause &amp; rectify. Recheck to ensure standard is achieved</td>
</tr>
<tr>
<td>Single End between 9 and 14mg</td>
<td>Establish cause &amp; rectify. Recheck to ensure standard is achieved</td>
</tr>
<tr>
<td>Single End 15mg or greater</td>
<td>Establish cause &amp; rectify. Recheck to ensure standard is achieved</td>
</tr>
<tr>
<td>4 can average 7 mg or greater per End</td>
<td>Establish cause &amp; rectify. Recheck to ensure standard is achieved</td>
</tr>
</tbody>
</table>

Visual checks should be carried out on an ongoing basis to verify drying performance is maintained.

6. **Secondary Packaging**

**Trays / Corrugated cases / Multi-packs**

It is suggested that, where possible, perforated shrink-film is used to aid ventilation and drying. Packs should also be open at each end to allow airflow through the pack.

It should be noted that boardless shrink-wrap packs present more risk of moisture retention.

7. **Environment / Post manufacture / Distribution and Storage**

- Perforated shrink film will aid pack ventilation and assist moisture evaporation.
- Packs should be open at each end to allow good air flow through the pack
• Any secondary packaging developments should be evaluated to ensure that they do not restrict ventilation of the can and End.

• Plastic coverings on the top of the filled pallet should be avoided as this will restrict ventilation.

• Pallets should be stored with air gaps between rows to allow air circulation, thus minimising condensation and assisting the evaporation of any residual moisture.

• Cyclic storage temperatures should be minimised, as this will encourage condensation and add further stresses to the End, thus promoting corrosion.

• Regular inspection of filled stock is recommended and any leaking/damaged packs should be removed immediately.

• Whatever the mode of transport/distribution, there should be ventilation of the pallets and room for air circulation (not block stacked). This is especially important on long distance shipping through varying climates.

8. Training and education

The Customer Technical Services functions within the supplier companies are able to advise on means to reduce risks of Environmental Stress Cracking failures, thereby ensuring that the requirements for filled pack life of products are met.

9. Reference documents
(Copies of these documents are available from MPMA)


3 Information derived from Alcoa checklist, appended to a presentation by Francine Bovard and Darl Boysel referring to their work in 1996. Much of this data contained in Crown Cork & Seal documentation, including:

4 See Crown Cork & Seal report referred to in ref. 3 above.

10. Figures

The Figures illustrate the configuration of Easy open End and Score and different modes of failure.

Figures 3, 4 & 5 show the differences between fracture resulting from Environmental Stress Cracking, Fatigue failure and Bursting due to overpressure.

Description of figures

Fig.1  Configuration of Stay-on-Tab Easy-open-End and Score
Fig.2  Environmental Stress Crack development in Aluminium End Score
Fig 3  Environmental Stress Cracking: Fracture Surface of Aluminium End Score.
Fig.4  Fracture of Aluminium End Score showing fatigue effects.
Fig 5  Fracture of Aluminium End Score physically induced by pressurising to bursting strength.
Fig. 1: Configuration of Stay-on-Tab Easy-Open-End and Score

Figure 1a
EO End Exterior Plan View

Figure 1b
Scored Region

Figure 1c Score Section profile

Material Thickness  Score Residual Thickness

Section B - B
Environmental stress crack showing typical branching progressing from pit beneath score exterior. Secondary sites of corrosion and crack development are present at the left-hand edge of the score. Field of view width \( \approx 200\mu m \).
Fig. 3: Environmental Stress Cracking: Fracture Surface of Aluminium End Score

Environmental stress cracking: Surface of score residual fracture showing fan shaped cleavage cracks. Secondary cracks typical of environmental stress cracking are also visible. Field of view width = 230µm.
Fracture surface of aluminium end score showing horizontal striations indicating fatigue effects. Field of view width = 180µm.
Fig. 5: Fracture of Aluminium End Score Physically Induced by Pressurising to Bursting Strength

Fracture surface of unused aluminium end score blown under pressure showing ductile cup/cone physical failure effects. Field of view width = 190µm.