6.5 NON-DESTRUCTIVE TESTING SCHEDULE

This NDT Schedule has been prepared on behalf of the Health and Safety Laboratory by:

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Date 20th March 2013

Institution of MECHANICAL ENGINEERS

Argyll-Ruane Ltd
Learning & Development

Non-Destructive Testing Schedule for the Inspection of Safeco Crazy Frog Amusement Device Arms – Fatigue Fracture Risk Critical Areas

Contents

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NDT Schedule for Safeco Crazy Frog Arm Critical Areas

1.0 Introduction

This NDT Schedule has been developed following the failure of one of the arms of a Safeco Crazy Frog amusement device. The subsequent investigation highlighted that the fatigue cracking had initiated from an earlier weld repair from the inside of the arm box section through to the outside in Zone 2 (see Figure 1). Because the cracking had initiated on the inside of the arm box section standard NDT techniques such as visual inspection or magnetic particle testing would not be capable of detecting the cracking at an early stage.

All other arms were inspected using magnetic particle techniques and a serious fatigue crack was located on an arm within Zone 2 running horizontally across the top plate, across the corner and down the horizontal plate.

Further investigation by the Health and Safety Laboratory highlighted higher g-forces than previous assessments with high tensile stresses occurring at the highest point on the arm box section (arm apex) on the inner surface (see Figure 1) and also at the root of the weld attaching the inner stiffening plate to the side walls. The plate runs from about where the ram is attached up to the apex, with the highest stresses near the top. Once again these high tensile stresses could initiate a fatigue crack on the inside surface where standard visual inspection or magnetic particle testing would not be capable of detecting the cracking at an early stage.

Note the NDT specified in this NDT schedule for supplementary inspection of Crazy Frog Arm critical areas is to be carried out in addition to any NDT specified in earlier NDT schedules for inspection of Crazy Frog amusement devices. Therefore this document does not negate the need to follow other existing NDT procedures for inspection of specified areas of Crazy Frog amusement devices for other arm parts.

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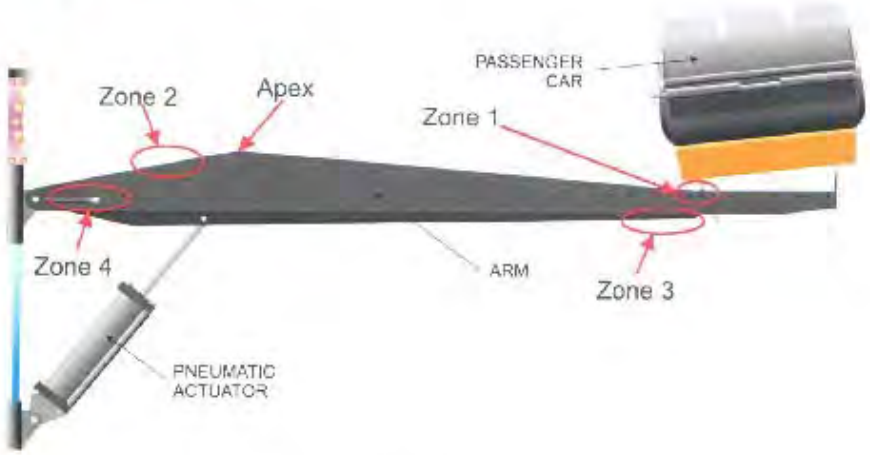


Figure 1 Crazy Frog Arms

3.0 References

BS EN ISO 9934-1: 2001 Magnetic Particle Inspection (General)

BS EN ISO 9934-2: 2002 Magnetic Particle Testing (Detection Media)

BS EN ISO 9934-3: 2002 Magnetic Particle Testing (Equipment)

BS 6072: 1981 Magnetic Particle Flaw Detection

BS EN ISO 3059:2012 Magnetic Particle Testing Viewing Conditions

BS EN ISO 9712: 2012 Qualification and Certification of NDT Personnel

BS 667: 2005 Illuminance Meters Requirements and Test Methods

BS EN ISO 17640:2010 Ultrasonic Testing of Welds

BS EN ISO 11666: 2010 Ultrasonic Testing of Welds Acceptance Levels

BS EN 583-1: 1999 Ultrasonic Examination – General Principles

BS EN 12223: 2000 Ultrasonic Examination – Specification for Calibration Block No. 1

Table 1 NDT Schedule Crazy Frog Arms Critical Areas

Item	Location/Description	Test Method	Procedure	Frequency of Test
Arm Apex	Top plate transverse weld	UT	Appendix A	Immediately Then 6 monthly
Arm Apex	Top plate and corner edges down on to horizontal plate	MT	Appendix B	Immediately Then 6 monthly
Arm Zone 2	Top plate and corner edges down on to horizontal plate	MT	Appendix B	Immediately Then 6 monthly
Arm Zone 2	Any weld repairs	UT	Appendix C	Immediately Then 6 monthly
Fillet Welds of Arm Stiffening Inner Plates	Root of fillet welds attaching inner stiffening plate to side walls from where ram is attached up to the arm apex	LT	Appendix C	Immediately Then 6 monthly

Appendix A

Procedure for the Ultrasonic Inspection of Crazy Frog Amusement Device Arms – Fatigue Fracture Risk Critical Areas

1.0 Scope

1.1 This procedure specifies techniques for detection of internal fatigue cracks using the manual ultrasonic testing of fusion-welded joints and fusion-weld repairs of Crazy Frog amusement device arms in fatigue fracture risk critical areas with an arm wall thickness of 5 mm. (See note below)

Note: This procedure is generally in accordance with BS EN ISO 17640: 2010 however the standard is written based on metallic materials of thicknesses greater than or equal to 8 mm, as such care should be exercised when using this procedure to locate internal fatigue cracks as the wall thickness of the test area is only 5 mm.

2.0 Qualification and Certification of Personnel

2.1 All personnel working to this procedure shall be qualified and certified to Level 2 in accordance with BS EN ISO 9712 in Ultrasonic Testing method weldments sector, for example PCN Level 2 UT weldments 3.1 & 3.7 and shall have a current vision test certificate.

3.0 Equipment

3.1 General
All equipment shall comply with and be calibrated in accordance with: BS EN ISO 12668 Parts 1 – 3

3.2 Flaw Detectors
Digital pulse echo A-Scan flaw detectors shall be used.

3.3 Probe Parameters
Probes shall be twin crystal shear waves with refracted angles of 45° and 70° 5MHz frequency, 6 mm to 12 mm diameter elements.

3.4 Coupling Media
Couplant used shall be compatible with the materials to be examined; the following are suitable to use in accordance with BS EN 583-1: 1999

- Contact paste
- Oil
- Grease
- Cellulose paste containing water

The same couplant type shall be used for calibration, sensitivity setting, scanning, and evaluation.
After examination is completed, the coupling medium shall be removed.

3.5 Calibration Block
Calibration Block No. 1 in accordance with BS EN 12223: 2000 shall be used to calibrate the flaw detector time base. The time base shall be calibrated such that the metal path from either half skip or 1 ½ skip (see figures 2 & 3) can be displayed on the screen.

3.6 Reference Standard
The reference standard shall be manufactured from ferritic steel acoustically similar to the material to be tested, the thickness of the reference standard shall be the same as the wall thickness of the material to be tested; 5.0 mm. The surface of the reference standard shall be prepared to match the surface of the areas under test i.e. if the test areas are painted, the reference standard shall also be painted. The reference reflector shall be a notch milled to a depth of 1.0 mm, width 1.0 mm and length of 20 mm.

4.0 Safety and Environmental Requirements

4.1 National and local accident prevention, electrical safety, handling of dangerous substances and personal and environmental protection regulations shall be observed at all times.

5.0 Surface Preparation

5.1 Remove all external bolt-on paraphernalia such as panels and lighting from the Crazy Frog arms in the region of the test areas; Arm Apex, Zone 2 and Fillet Welds of Arm Stiffening Inner Plates.

5.2 Areas to be tested shall be free from dirt scale, loose rust, weld spatter, grease, oil and any other foreign matter that may affect the test sensitivity and or acoustic coupling.

6.0 Setting Scanning Sensitivity

6.1 Note due to the wall thickness of only 5 mm it may not be possible to resolve the reference target at half skip (see figure 2), if this is the case locate the reference target at 1 1/2 skip distance (see figure 3).

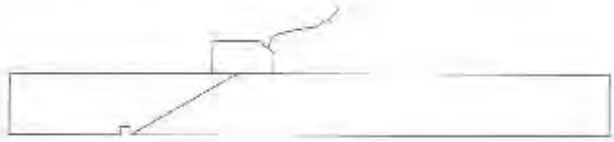


Figure 2 Locating Reference Target at Half Skip Distance

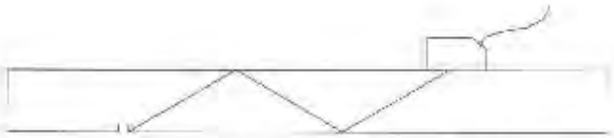


Figure 3 Locating Reference Target at 1 1/2 Skip Distance

6.2 Locate and maximise the response from the reference target in accordance with 6.1 and adjust the gain setting to set the amplitude from the reference target to 80% of full screen height. Note the gain setting, this is the reference sensitivity. When scanning the test areas add 6dB, to evaluate indications remove the 6dB added to scan and use the reference sensitivity.

6.3 At least every four hours or at the end of the test, check the sensitivity using the reference target. If the amplitude from the reference target has fallen below 80% of full screen height at the reference sensitivity established in 6.2 then the sensitivity shall be re-established and all test areas inspected since the previous acceptable sensitivity check shall be re-tested.

7.0 Testing Techniques

7.1 The areas to be tested (see table 1) are welds and weld repairs that are transverse to the length of the Crazy Frog arms, specifically looking for fatigue cracks that have initiated from the weld root. Subsurface planar discontinuities perpendicular to the testing surface are difficult to detect with single angle probe techniques therefore scan the test areas with two probes: 45° and 70° refracted shear waves.

7.2 On butt welds; arm apex top plate transverse welds and all weld repairs, establish the test standoff distance on the test surface between the probe emission point to the point above the weld root on both sides of the weld using the following:

Standoff = Tan θ x plate thickness

Where:
θ is the probe angle either 45° or 70°
plate thickness is 5 mm for half skip distance or 15 mm for 1 ½ skip distance

Note the standoff distance will depend on which skip distance is being used; either half skip or 1 ½ skip distance see section 6.1 and table 2 below.

	45° Refracted Angle	70° Refracted Angle
Standoff at Half Skip Distance	5 mm	13.7 mm
Standoff at 1 ½ Skip Distance	15 mm	41.2 mm

Table 2 Nominal Standoff Distances

7.3 On the fillet welds of arm stiffening inner plates there are two roots from which to establish standoff test distances, see figure 4 below:

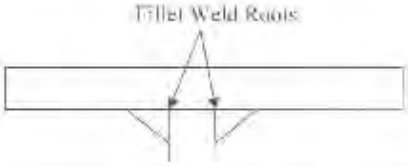


Figure 4
Fillet Weld Roots

7.4 At each test area use a suitable marker to mark across the arm parallel to the weld roots on both sides of the weld at the relevant test standoff distances obtained from table 2 for both probe angles on both sides of the weld.

Note 1: it may not be possible to test across the full width of the arm as a longitudinal cable conduit may be tack welded down the length of the arm, if this is the case test as much of the width of the inspection area as possible.
Note 2: check the actual probe angles using Calibration Block No. 1 and the actual plate thickness which can be measured using a normal probe at a point adjacent to the weld and if these parameters are different to nominal adjust the standoff distance accordingly.

7.5 At each test area place the 45° probe emission point on the relevant marked standoff line with the beam interrogating the weld root and carefully scan the probe across the arm keeping the emission point on the marked standoff line using the scanning sensitivity established in section 6.2 using a maximum

scanning speed of 100 mm per second. During the scan along the standoff line a slight swivelling movement up to an angle of approximately 10° on either side of the nominal beam direction shall be applied to the probe. Repeat the scan of the test area along the standoff line on the other side of the weld with the probe interrogating the weld root.

7.6 At each test area place the 70° probe emission point on the relevant marked standoff line with the beam interrogating the weld root, and carefully scan the probe across the arm keeping the emission point on the marked standoff line using the scanning sensitivity established in section 6.2 using a maximum scanning speed of 100 mm per second. During the scan along the standoff line a slight swivelling movement up to an angle of approximately 10° on either side of the nominal beam direction shall be applied to the probe. Repeat the scan of the test area along the standoff line on the other side of the weld with the probe interrogating the weld root.

8.0 Characterisation and Acceptance

8.1 Any indication interpreted as a crack shall be considered unacceptable.

9.0 Compliance to Procedure

9.1 If this procedure cannot be complied with fully do not carry out any testing and inform the Health and Safety Laboratory immediately.

10.0 Test Report

The test report shall include at least the following information:

- Identification of the Crazy Frog amusement device under test
- Identification of the specific arm and weld under test
- Dimensions of test areas
- Surface conditions
- Reference to this procedure
- Place and date of testing
- Identification of test organisation and identification and certification of operator
- Make and type of flaw detector used with serial number
- Make, type, frequency, size, actual refracted angle and serial number of probes
- Identification of reference blocks used
- Couplant type
- Extent of testing
- Time base range

- Gain setting for reference levels
- Result of test including sizes of any cracks located

Appendix B

Procedure for the Magnetic Particle Inspection of Crazy Frog Amusement Device Arms – Fatigue Fracture Risk Critical Areas

1.0 Qualification and Certification of Personnel

1.1 All personnel working to this procedure shall be qualified and certified to Level 2 in accordance with BS EN ISO 9712 in Magnetic Particle Inspection method for example PCN Level 2 and shall have a current vision test certificate.

2.0 Safety and Environmental Requirements

2.1 Magnetic particle testing may require the use of toxic, flammable and/or volatile materials. In such cases, working areas shall therefore be adequately ventilated and far from sources of heat or flames. Extended or repeated contact of detecting media and contrast paints with the skin or mucous membranes shall be avoided.

2.2 Testing materials shall be used in accordance with the manufacturer's instructions. National and local accident prevention, electrical safety, handling of dangerous substances and personal and environmental protection regulations shall be observed at all times.

7 Surface Preparation

7.1 Remove all external bolt-on paraphernalia such as panels and lighting from the Crazy Frog arms in the region of the test areas - arm apex and Zone 2.

7.2 Areas to be tested shall be free from dirt scale, loose rust, weld spatter, grease, oil and any other foreign matter that may affect the test sensitivity

7.3 Non-ferromagnetic coatings up to approximately 50µm thick, such as unbroken tightly adherent paint layers, do not normally impair detection sensitivity. Thicker coatings reduce sensitivity. Under these conditions, the sensitivity shall be verified. If suitable sensitivity cannot be achieved strip the paint layer down to bare metal.

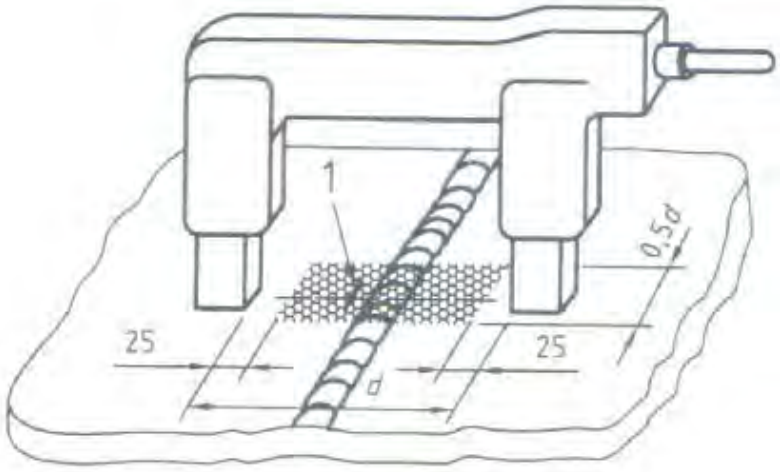
7.4 There shall be a sufficient visual contrast between the indications and the test surface. It may be necessary to apply a uniform, thin, adherent layer of approved contrast paint.

8 Magnetisation Technique

8.2 Portable Electromagnet (Yoke) – The poles of an a.c. electromagnet (yoke) are placed in contact with the test area as shown in Figure 5. The test area shall not be greater than that defined by a circle inscribed between the pole pieces and shall exclude the zone immediately adjacent to the poles.

8.3 The poles shall be repositioned after each area has been magnetised and inspected such that sufficient overlap between test areas as defined in 4.1 ensures the arm areas of interest are fully inspected.

Dimensions in millimetres



Key

1 Flaw

Figure 5 Inspection using Portable Electromagnet (Yoke)

9 Detection Media

9.2 The characterisation of detection media shall be in accordance with BS EN ISO 9934-2

9.3 The detection media shall be a suspension of black ferromagnetic particles in a carrier fluid

10 Application of Detecting Media

10.2 Magnetisation shall be accomplished using the continuous method where the detecting media shall be applied immediately prior to and during the magnetisation. The application shall cease before magnetisation is terminated. Sufficient time shall be allowed for indications to develop before moving or examining the component or structure under test.

10.3 During application of a magnetic ink, it shall be allowed to flow onto the surface with very little pressure so that the particles are allowed to form an indication without being washed off.

10.4 After applying ink, the component shall be allowed to drain so as to improve the contrast of any indications.

11 Viewing Conditions

11.2 For inspection the illuminance at the test surface shall be 500 lux or greater even illumination with daylight or artificial light, this shall be checked using a photometer calibrated to BS 667

11.3 The entire surface under test shall be viewed before preceding to the next stage in the testing procedure. Where viewing is obstructed, the component or equipment shall be moved to permit adequate viewing of all the test area. Care shall be taken to ensure that indications are not disturbed after magnetisation has stopped and before the component has been inspected and indications recorded.

12 Overall Performance Test

12.2. The strength of the portable electromagnet (a.c. yokes) shall be assessed by measuring the lifting power or the pull-off force.

12.3 The lifting power shall be equivalent to not less than 4.5 kg for a pole spacing of 300 mm or less, and the pull-off force shall have a value equivalent to not less than 2.25 kg for the same pole spacing.

12.4 The strength of the portable electromagnet shall be assessed at intervals not to exceed 6 months; results of the performance test shall be documented.

13 Test Areas

13.1 Arm Apex: The test area for the arm apex shall be across the full width of the arm apex top plate including the corners down onto the horizontal plates and for 200 mm along the arm in both directions. Position the portable electromagnetic yoke poles such that they are aligned with the direction of the arm, such that transverse cracks can be detected. Note it may not be possible to test across the full width of the arm as a longitudinal cable conduit may be tack welded down the length of the arm, if this is the case test as much of the width of the inspection area as possible.

13.2 Zone 2 (See Figure 1): The test area for the arm zone 2 shall be across the full width of the zone 2 arm top plate including the corners down onto the horizontal plates. Position the portable electromagnetic yoke poles such that they are aligned with the direction of the arm, such that transverse cracks can be detected. Note it may not be possible to test across the full width of the arm as a longitudinal cable conduit may be tack welded down the length of the arm, if this is the case test as much of the width of the inspection area as possible.

14 Interpretation and Recording of Indications

14.1 Care shall be taken to differentiate between true indications and spurious or false indications, such as scratches, changes of section, boundary between regions of different magnetic properties, or magnetic writing. The NDT inspector shall carry out any necessary testing and observations to identify and, if possible, to eliminate the reason for such false indications.

14.2 All indications which cannot be confidently discounted as false shall be classified as linear or rounded, and shall be recorded on the test report.

14.3 Linear indications are those indications in which the length is more than three times the width. Rounded indications are indications that are circular or elliptical and where the length is less or equal to three times the width.

15 Acceptance Criteria

15.1 No linear indications: for example cracks are permitted.

16 Cleaning

16.1 After testing and acceptance all test areas shall be cleaned to remove detecting media.

17 Compliance to Procedure

17.1 If this procedure cannot be complied with fully do not carry out any testing and inform the Health and Safety Laboratory immediately.

18 Test Report

Record the following as a minimum:

- Name of the company
- Work location
- Description and identity of the test areas
- Reference to this procedure
- Description of equipment and detection media/contrast paint used
- Magnetisation technique including pole spacing
- Surface preparation
- Viewing conditions
- Indications located
- Date of test
- Name, qualification and signature of the person performing the tests