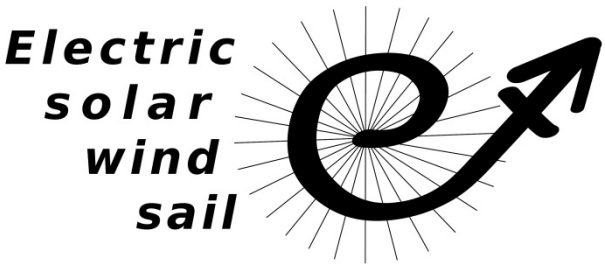

ESAIL D3.1.2
Reeling Test Plan

Work Package: **WP 3.1**

Version: **Version 1.0**

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Issue	Rev.	Date	Pages, Tables, Figures affected	Modification	Name
1	0	30 May 2011	All	Initial issue	Rosta

Table of Contents

Table of Figures

List of Acronym and Abbreviation

DLR	German Aerospace Center (Deutsches Zentrum für Luft und Raumfahrt)
ESAIL	Electric solar wind sail
PTA	Preliminary Test Assembly
ZARM	Center of Applied Space Technology and Microgravity (Zentrum für angewandte Raumfahrttechnologie und Mikrogravitation)

Reference Documents

[RD01]	Esail Document Part B: Description of Work
[RD02]	Requirement Specifications of the Tether Test Reel, D3.1.1, Issue 1, Revision 0

1. Scope of this Document

This report presents the test plan for the tether unreeling tests. The test configuration and the required equipment are described, as well as the test facility in which the tests were performed.
The tests will be performed to show the reliability of the tether deployment mechanism and to verify the assumptions and pre-tests made at [RD02].
The descriptions of the tests to be performed are described in a logical test flow diagram.

2. Test Item Description

2.1. *Heytether*

The tether to be tested is a so called “Heytether”, developed by the University of Helsinki. The design and the manufacturing of the tether is part of the work package 2 [RD01].
The final Heytether consist of a single 50 µm diameter basic wire and three auxiliary wires with a diameter of 25 µm. These auxiliary wires are bonded with an ultrasonic wire to wire bonding technique to the basic wire.
For the tests, described in this document, two different kind of prototype tethers will be used (Figure 1 & Figure 2).
The first test run will be done with a tether which consists of one basic wire and one, loop shaped auxiliary wire. The high of the loops are 9 mm. The Tether is show in Figure 1.

Figure 1: Heytether with one basic wire and one auxiliary tether loop

For the second test run the used Heytether has the same tether design with 20 mm heigh auxiliary tether loops.
In the case that the tether factory is able to produce a 10 m long tether with two auxiliary tether loops until the test starts, the test will be performed in addition with this delivered tether. The first sample of this tether is show in Figure 2.

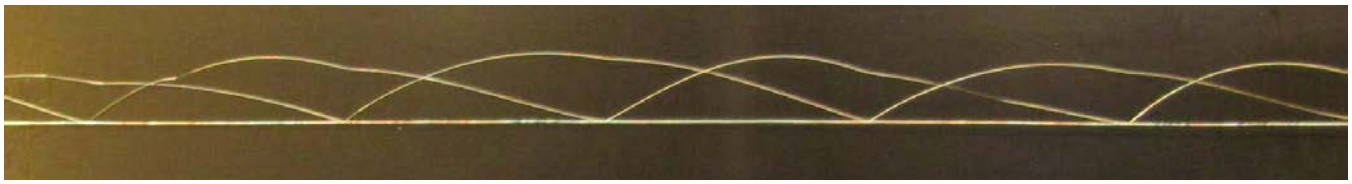

Figure 2: Heytether with one basic tether and two auxiliary tether loops

3. Test Setup

3.1. *Preliminary Test Assembly*

The preliminary test assembly is designed for testing the Heytether unreeling behaviour. The PTA is developed for unreeling tests of the Heytether in the Estcube-1 project. It can be used in three different configurations: with a rectangular shaped-, a round one- and without any specific tether opening.
For the use of the rectangular tether opening it is possible to change the width and the length of the tether opening. It should be mentioned that in case of the usage of the rectangular opening the sharp edges of the opening will have a large influence of the tether performance and eventually damage the wires. This property has detected during preliminary tests, in which the possibility design of the tether opening are investigated.
In Figure 3 the three different possible PTA configurations are shown.

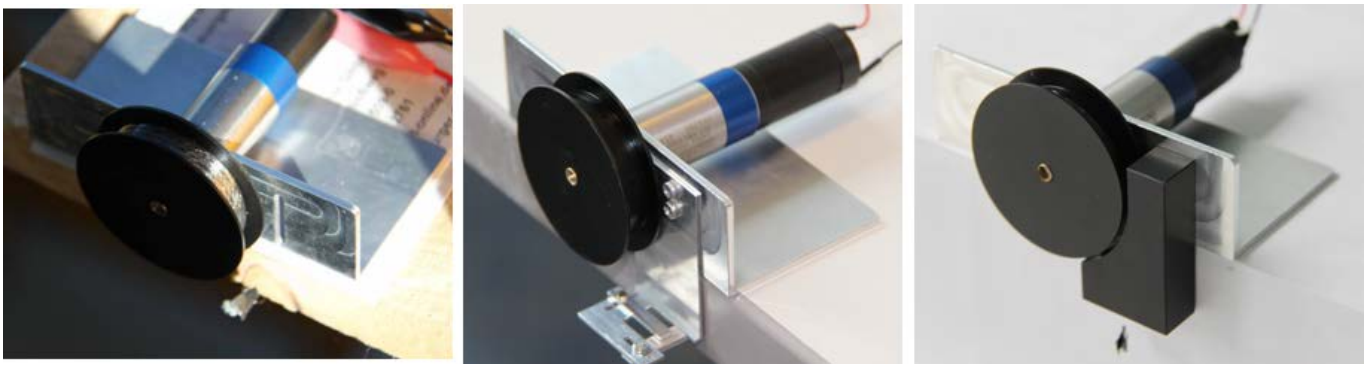

Figure 3: Different PTA configurations. On the left side without -, in the middle with the rectangular - and on the right side with the round tether opening

The PTA comprise of:

- **The clamp**
  The clamp holds the e-motor, the tether opening and establishes the interface for mounting to different test facilities.
- **The e-motor**
  The used motor is a Faulhaber DC- Micromotor, Series 1724 024 SR, connected to a Faulhaber planetary gear, Series 20/1, with a gear reduction of 415:1
- **The tether opening**
  To simulate the tether opening tow configuration are possible. For the rectangular - and round opening, the distance between the motor axis and the tether opening is adjustable. Thus it is possible to study the effect of different distances to the satellite sidewall on the tether deployment.
  - Rectangular opening
    - Width variation
      With the width variation it is possible to simulate different width tether openings, so the effect of the tether can study.
    - Length variation
      With the length variation it is possible to simulate different length tether openings, so the effect of the tether can study.

- Round opening
  For the new tether design with the auxiliary loop height of 20 mm a new round opening is designed. The design changes are only related to the adaption to the new width of the tether reel.

- **Tether reel**
  The tether reel has changed as well as the round opening. To be able to reel the new tether on the reel the contact surface has changed to 30 mm. One additional reel is modified with a rounded shaped reel edge. The detailed description is written in [RD02]

The above mentioned parts of the PTA are shown in Figure 4.

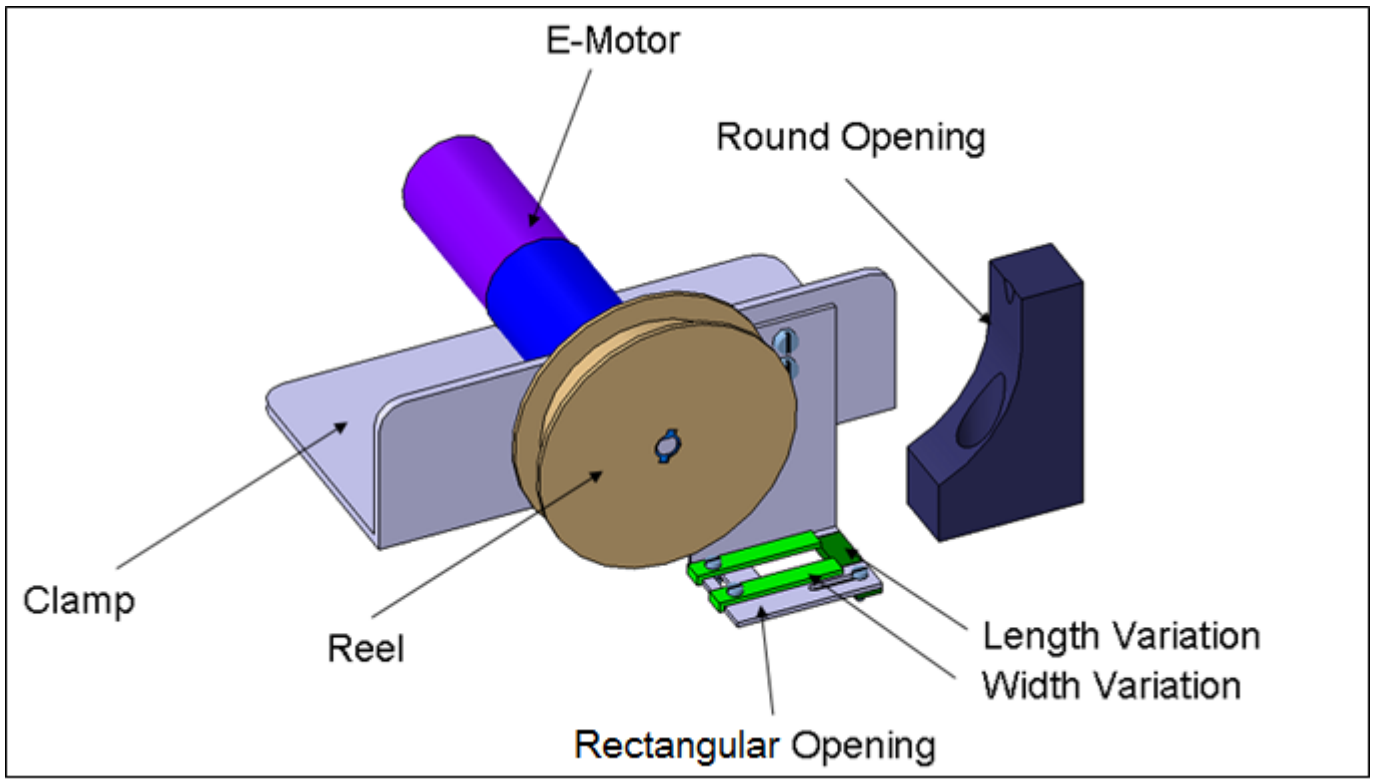

Figure 4: CAD -Model of PTA with several parts description

3.2. *Test Facility*

The Facility for the test campaign is located in the ZARM laboratory building, which is rented by DLR for multiple hardware tests. This indoor facility has the possibility to mount the PTA in the required overall height of 10 m which represents the maximum manufacture length of the actual tether factory. To reach this height the facility has two options:

- In the first one, the PTA can be mounted on a man carrying platform and lifted up to a height of 10 m.
- The second is to mount the PTA on an available maintenance platform inside of the Facility. The height of the platform is 10 m.

3.3. *Test Equipment*

During the tests the following equipment is needed.

- **Laser Range**
  Laserliner, LaserRange-Master 40, measuring range 40 m, precision 3 mm. The Laser range is used to measure the height in which the PTA is positioned. This is mainly needed if the man carrying platform is used to perform the tests; otherwise the height is only approved.

Figure 5: Laserliner, Laser Range-Master 40

- **Camera**
  Canon EOS 500D, 15 Megapixel, Full HD Movie with 20 fps. The camera is used to document the tests procedure. With this device it is possible to make picture and video documentation

Figure 6: Canon EOS 500D

- **White Plate**
  The white plate, with the dimensions of 1 m by 2 m, is positioned on the ground below the tether to have a high contrast of the tether end-mass and the ground of the facility floor. With this plate it is possible to determine the tether position.

3.4. *Test Configuration*

The test configuration shows the position of the equipment and the position where the PTA is mounted. The Figure 7 shows the test configuration in the case of the usage of the man carrying platform. The configuration of the test equipment on the maintenance platform is the same.

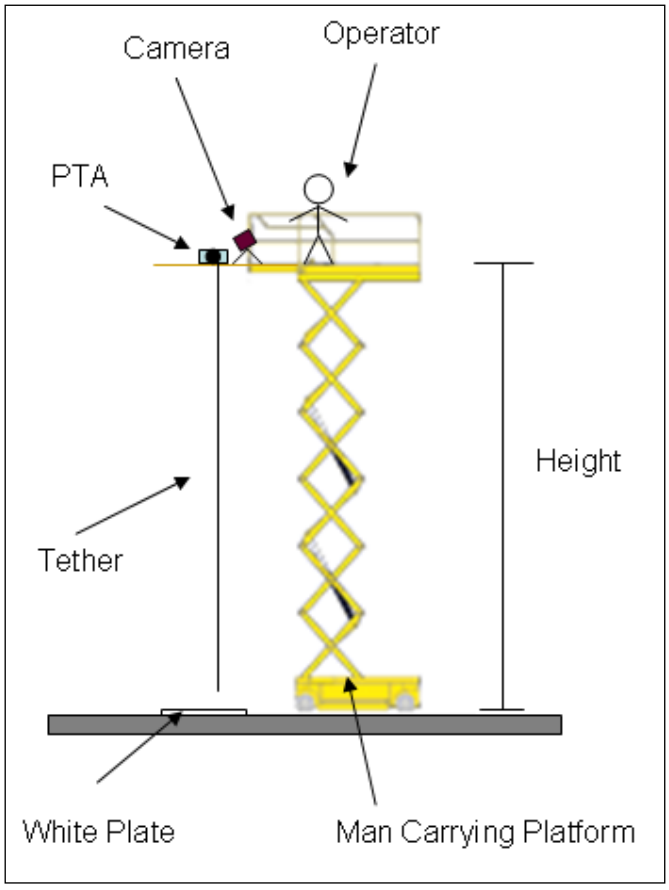

Figure 7: Test configuration

4. Test Overview

4.1. *General considerations*

The tests will be performed in order to investigate following key issues:

- Tether unreeling behaviour
- Damaging caused on the tether
- Damaging caused by the round opening
- Reliability of the unreeling

4.1.1. Features to be Tested

This is a list of components to be tested. This list of features is applied for both tether designs.

Components	Features to be tested
Tether	Tether unreeling.
Tether	Behaviour of the tether during un- and upreeling.
Tether behaviour	How different layer number on top of each other influence the reeling behaviour.
Tether behaviour	How the unreeling is influenced by the tether if they are side by side, tether guidance during the upreeling.
Tether behaviour	How the unreeling is influenced by the tether if the upreeling is done without tether guidance.
Tether behaviour	The unreeling of the tether in the case that the PTA is equipped with the round opening.

4.1.2. Features not to be Tested

This is a list of components NOT to be tested.

Components	Features not to be tested
E-motor	Function of the motor.
Tether	The conductivity of the Tether.
Tether	The unreeling in a vacuum environment.
Tether behaviour	Unreeling behaviour with rectangular opening equipped PTA.

4.1.3. Motor Calibration

The used motor for the PTA is a brushless Faulhaber DC-Motor. The Motor is equipped with a Faulhaber planetary gear and has a reduction of 415:1.
To know which supply voltage is needed to have a reeling speed of 3 mm/s and 6 mm/s the tether reel was equipped with a reference point. With this pointer it was possible to measure the time for one revolution and results from this measurement the needed voltage is calculated.
The supply voltages are:

- 0.9 V for 3 mm/s
- 1.8 V for 6 mm/s

4.2. *Test Program Sequence*

The overall unreeling test sequence can be split in four different test sequences. They are listed in Figure 8.

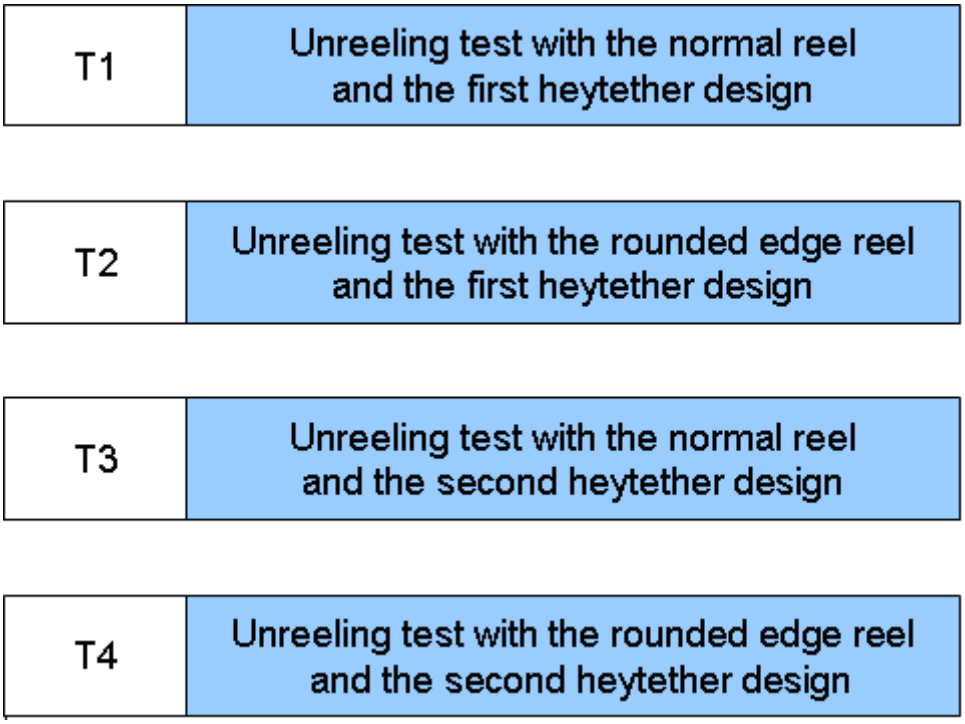

Figure 8: Test program sequence

4.2.1. Test procedure

The following general procedure applies for each test:

1. Verify that the item to be tested and the needed equipment are ready to be used (connected to the power supply, the motor control is adjusted to the correct rotation speed, the PTA has the required configuration and the end mass is unlocked.)
2. Logbook to be filled out at each test run– see below
3. Perform the test runs
4. Document the Unreeling behaviour, tether damage and success criteria

Test Number	Date	Reeling Speed [mm/s]	End mass [g]	Unreeling behaviour	Tether damages	Success/Fail Criteria

5. Test Sheets

The aim of the tests is to investigate the tether unreeling behaviour under different conditions and to approve the reliability of the unreeling procedure.
The four different test sequences will be performed in the same procedure. This procedure is the following:

- Install the needed equipment for the test run (reel and tether outlet)
- Set the motor voltage level to the required value to reach the unreeling speed of 3 mm/s, the upreeling speed is 6 mm/s.
- Install the camera for video/picture documentations
- Run test according to:
    1. Unreel the tether to 10 m
    2. Take a picture form the tether and the end mass position
    3. Upreel the whole tether without guidance, in case that the tether will get over the reel side wall, a manual hand-guidance must be done by the operator
    4. Redo step 1 to 2
    5. Upreel the whole tether with guidance
    6. Reconfigure the PTA with the round tether opening
    7. Redo step 1 to5
    8. Redo step 1 to 7 with a unreeling speed of 6 mm/s

The test flow for the above described test sheet is show as test flow in Figure 9.

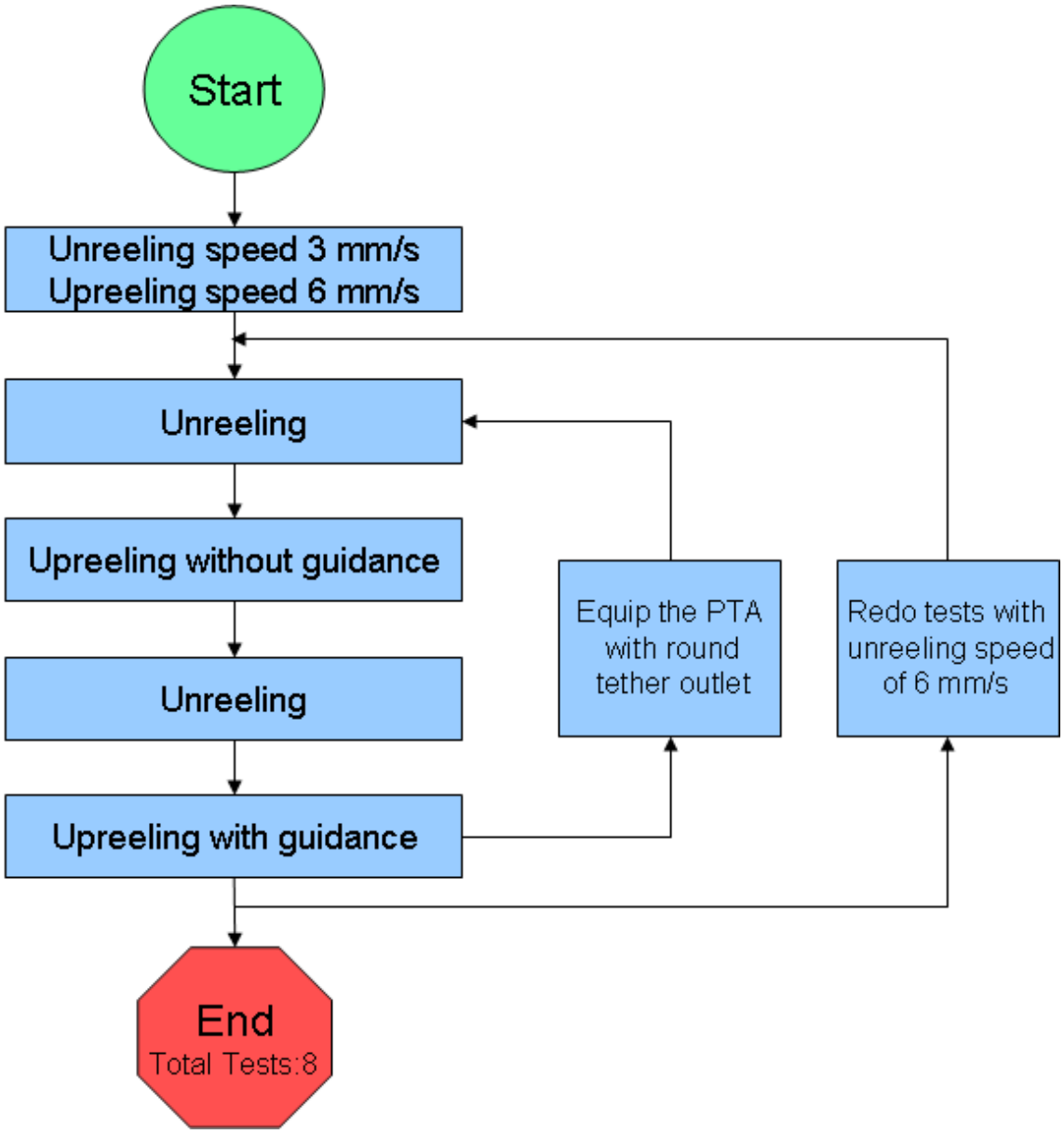

Figure 9: Test Flow

6. Release Criteria

6.1. *Item Success/Fail Criteria*

Success:

- If the tether was unreeled to the full length of 10 m

Fail:

- If the tether or the loops jammed into other tether loops and avoid continuing the unreeling

The following table shall be filled out after each test sequence.

Test Number	Unreeling behaviour	Tether damages	Success/Fail Criteria

6.2. *Possible Tether Damage Consequents*

The possible consequents of the damage are listed and discussed in this chapter

Damage	Description	Possible consequents
Broken main tether	The main tether is broken.	The broken main tether can lead to a shortening of the tether length, if the pull strength of the auxiliary wires is not enough to avoid a complete disruption. A shortening of more than the half of the whole tether length can result in a test abort.
Broken auxiliary loops	The loop is broken between the two welding points.	The broken loops can get stuck into the tether opening or they can jam into the unreeling tether.
Broken welding	The loop is broken on the welding point	Same as above, The broken aux. wire can also jam into another tether layer on the reel.
Broken neck	The loop is broken directly over the welding point.	Same as above.