| Title | Document number | Revision | Prepared |
|---|---|---|---|
| **Accident investigation report** | **9-237** | **B** | **TH** |
| | Date | | Approved |
| | **2004-06-29** | | **ON** |

# 1 Abstract

This report was written on request by the Swedish accident investigation board that has been appointed to investigate a fatal accident with a paraglider where the rescue parachute malfunctioned as it tore loose from the rig. The purpose is to get an opinion why the seams did not withstand the load. The report is limited to the seam that attaches the rescue parachute's attach point to the rig, as this is the seam that burst.

# 2 Design

The harness's rescue parachute is attached to a loop of nylon tape. The loop's two ends are in turn attached to the harness's upper back part, towards the backside of the wearer's shoulders. The ends are heat sealed and attached with the same seam that holds the back plate to the shoulder straps. This seam is also attached to the shoulder straps with 3 bartacks each.



| **Revision** | *B* | *C* | *D* | *E* | *F* |
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| Date | | | | | |
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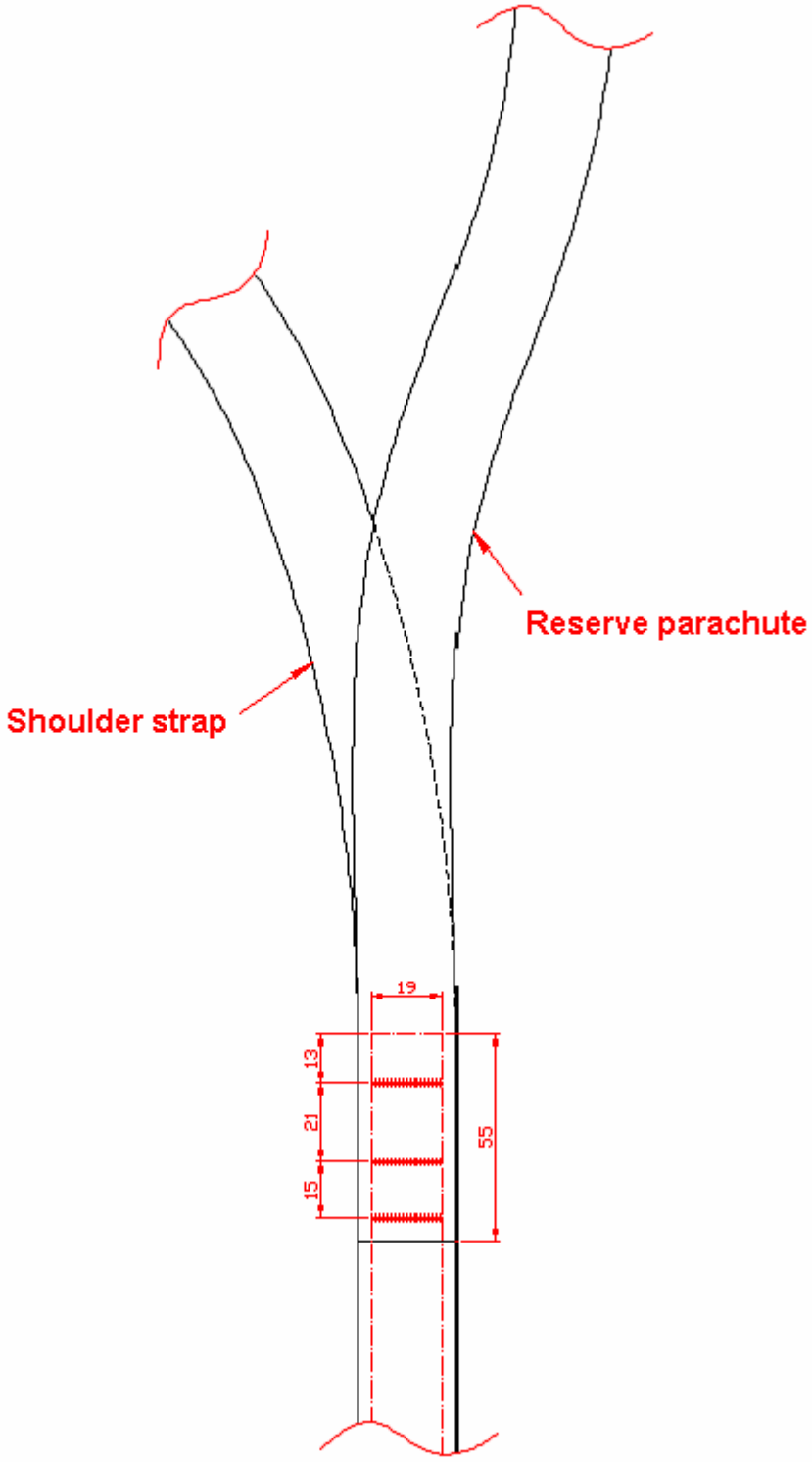
Mellangården 3
S-194 51 Upplands Väsby

Box 834
S-194 28 Upplands Väsby

Phone: +46-8-594 112 60
Fax: +46-8-590 715 46

Telefon: +46-8-594 112 60
Fax: +46-8-590 715 46

Airsafe Sweden AB | Telefon: 08-594 112 60 | Fax: 08-590 715 49 | E-post: info@airsafe.se




*picture 1. The attachment loop's seams*



Mellangården 3
S-194 51 Upplands Väsby
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S-194 28 Upplands Väsby
Phone: +46-8-594 112 60
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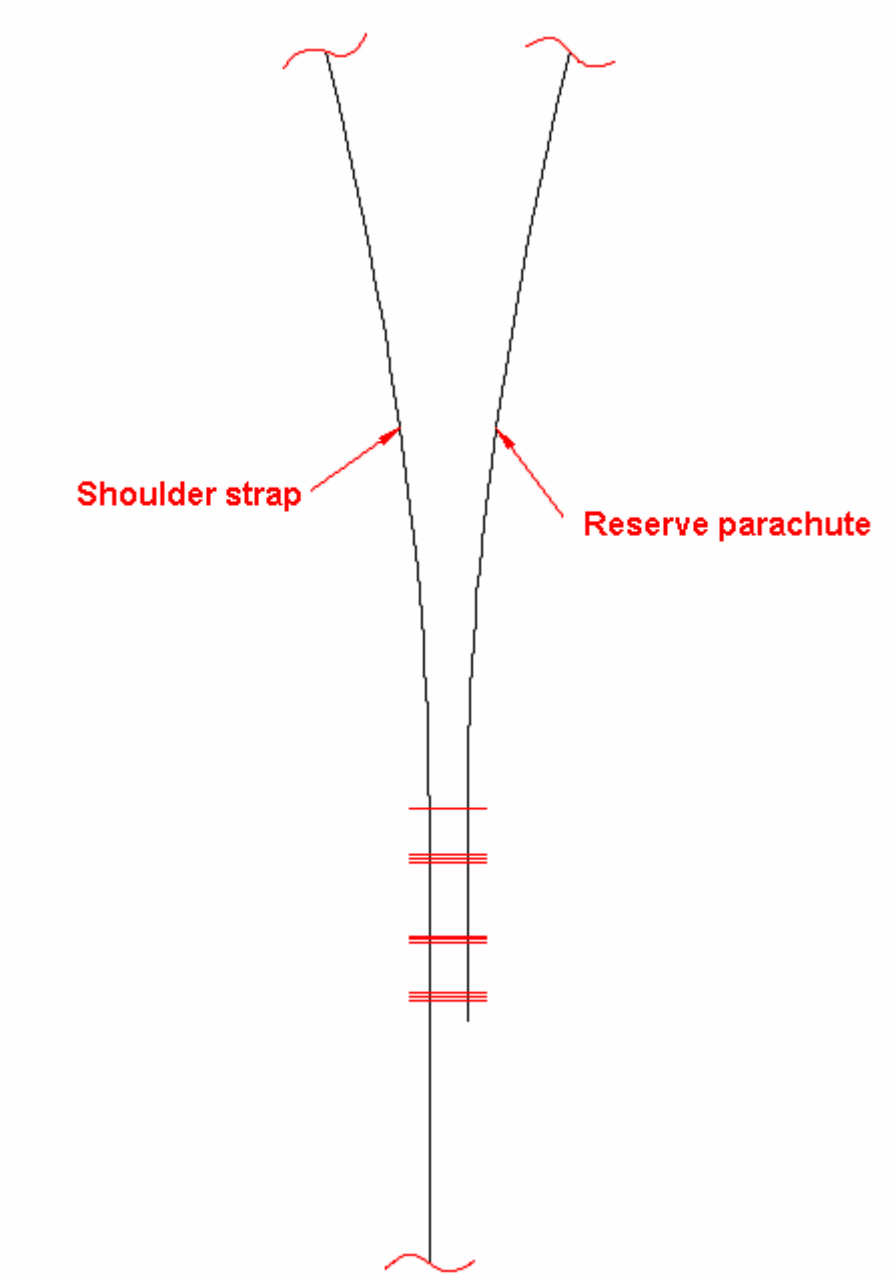


*picture 2. The attachment loop's seams*



Mellangården 3 | Box 834 | Phone: +46-8-594 112 60 | www.airsafe.se
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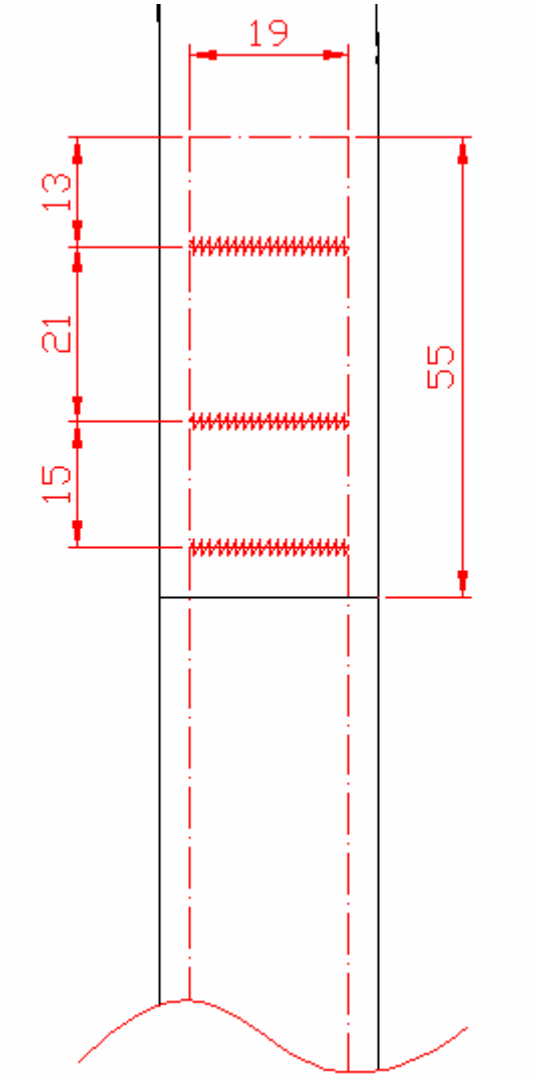


*picture 3. The attachment loop's seams - measurements*



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# 3 Calculations

A typical bartack seam consists of 27 stitches size E thread. There are different stitch patterns, but only with slight differences. The single row stitching is sewn with some sort of common thread (Size 3, 4 or 5) with about 5 stitches per inch. Every stitch consists of two threads. We have calculated with two bartacks to get a seam dense enough.
Size E thread has a breaking strength of 37,8 N (8,5 lbs). Size 3 thread has a breaking strength of 106,8 N (24 lbs).

## 3.1 Straight pull

At straight pull (as the harness is designed to be used) the tension is greater at the start and the end than in the middle. This is an effect of the elastic properties of the materials. The formula below is a model describing the distribution of the tension in the seam and the total breaking strength.

$$\underbrace{\left[3\times 2\times 106{,}8+\frac{2\times 11\times 2\times 106{,}8}{2}\right]}_{Single row stitching}+\underbrace{\left[\frac{55/2-13}{55/2}\times 2\times 27\times 2\times 37{,}8\right]}_{Upper\cdot bartack}+\underbrace{\left[\frac{21+13-55/2}{55/2}\times 2\times 27\times 2\times 37{,}8\right]}_{Middle\cdot bartack}+$$

$$+\underbrace{\left[\frac{15+21+13-55/2}{55/2}\times 2\times 27\times 2\times 37{,}8\right]}_{Lower\cdot bartack}\approx 3000+2150+960+3190\approx 9300N$$

## 3.2 Tear

If the rescue parachute is activated when the user is improperly aligned, this can tear the seam apart. For example, this will happen if the loop for the rescue parachute is pulled straight out from the body, or downwards. When the seam is torn apart only the outermost part of the seam is loaded, and becomes significantly weaker. The seam's breaking strength is limited to the strength of one bartack seam with the following magnitude:

$$\left[2\times 27\times 2\times 37{,}8\right]\approx 4080N$$

Notice that this formula requires the load to be evenly distributed over the stitches.



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# 4 Experimental tension test

In order to verify the above calculations three test samples were constructed. Samples 1 and 2 are constructed to evaluate the strength of the seam when exposed to a tearing force. Sample 2 is constructed in such a way, that the seam is only exposed to 50 % of the force. Sample 3 is used as a reference to validate the breaking strength of the seam when exposed to a straight pull.

## 4.1 Sample 1

When pulling sample 1 the seam was torn bit by bit, with slightly increasing force for each bartack. The last bartack was torn apart at a pulling force of 194 kg.

## 4.2 Sample 2

When pulling sample 2 the seam was torn bit by bit, with slightly increasing force for each bartack. The last bartack was torn apart at a pulling force of 368 kg, which corresponds to about 184 kg in the seam.

## 4.3 Sample 3

The last sample was pulled to break at 938 kg (9200 N). The calculated strength was 9300 N. The nylon tape rather than the seam caused the break. However this result is sufficient, since it shows that the seam can take even higher loads.

# 5 Conclusions

When dimensioning parachutes and similar systems a design factor of about 3 is applied to the calculations. The design factor is multiplied to the intended load (i.e. weight of jumper) in order to determine the strength requirements of the parachute assembly. The design factor is intended to compensate for a number of uncertainty factors such as asymmetrical load distribution and fatigue of seams etc. Consider a parachute jumper weighing 100 kg:

$$calculated\ load = weight\ of\ \ jumper \cdot 9.81 \cdot G_{load}$$

$$breaking\ strength = design\ \ factor \cdot calculated\ load \Rightarrow \frac{breaking\ strength}{design\ \ factor} = calculated\ load \Rightarrow$$

$$\Rightarrow \frac{breaking\ strength}{weight\ of\ \ jumper \cdot 9.81 \cdot design\ \ factor} = G_{load}$$

$$\frac{9300 \cdot 2}{100 \cdot 9.81 \cdot 3} \approx 6.32$$

$$\frac{4080 \cdot 2}{100 \cdot 9.81 \cdot 3} \approx 2.77$$

This estimation shows that the seams of the attachment loop are designed for about 6 g. However, in the case of a non-favourable deployment the seams will break at less than half the force. It is worth mentioning that most reserve parachutes are designed for 10-12 g.

Due to the flexibility of textile materials, the strength of seams and particularly the bartacks are difficult to calculate. The result of the tension test does not really give much information about the original seam



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strength, but it clearly shows the difference between a straight pull and a tearing force. A tearing force of less than ¼ magnitude compared to a straight pull was enough to break the seam. The reason that the seam was torn apart is probably that the reserve parachute was not activated in a normal way and/or at an unusually high velocity resulting in a higher stress than expected.

# 6 References

## 6.1 Drawings

The three different samples can be found in the following drawings:

Sample 1 2-1191 A
Sample 2 2-1192 A
Sample 3 2-1193 A

## 6.2 Protocol

| | |
|---|---|
| Test device: | M3 Dragrigg manuell |
| Certificate of calibration: | MTmP301129-15, valid for 2004-11-15 |



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