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# 1 Content

<b>1</b>	<b>Content</b>	<b>2</b>
<b>2</b>	<b>Summary and background</b>	<b>3</b>
<b>3</b>	<b>General information</b>	<b>3</b>
3.1	The company	3
3.2	The product	3
3.3	Material and assembly details:	3
<b>4</b>	<b>RAGASCO LPG Composite Cylinders – General procedures</b>	<b>4</b>
4.1	General	4
4.2	Special consideration	4
4.3	Emptying the cylinder	4
4.4	Cleaning	4
4.5	Re-valve	4
4.5.1	Clamping during unscrewing and torque	4
4.5.2	Handling of valves with RAGASCO parallel threads/o-ring seal interface.	4
4.5.3	Inspection of cylinder threads	5
<b>5</b>	<b>Procedure for filling</b>	<b>5</b>
5.1	General	5
5.2	Inspection before filling	5
5.3	Filling	5
5.4	After-filling checks	6
<b>6</b>	<b>Procedure for Periodic Inspection</b>	<b>6</b>
6.1	General	6
6.2	Test program for periodic inspection (for details; see later sections)	6
6.3	External Visual Inspection	6
6.3.1	General	6
6.3.2	Preparation	7
6.3.3	<i>Procedure for external visual inspection</i>	7
6.3.4	Visible defects	7
6.4	Procedure for internal inspection	8
6.5	Hydraulic or pneumatic proof testing	8
6.6	Marking of accepted cylinders	8
6.7	Identification of contents	9
6.8	Information to the manufacturer	9
<b>7</b>	<b>Rejection and scrapping of cylinders</b>	<b>9</b>
<b>8</b>	<b>Annex A - Types of damage of cylinders and casing</b>	<b>10</b>

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## 2 Summary and background

This document is a guideline for periodic testing of all variants of the RAGASCO LPG Composite Cylinder, Complet. The instructions are based on experience from the type approval test programs law EN12245, EN14427, ISO 11119-3.2, DOT-SP 12706, TC-SU-5931, ADR/RID, relevant local regulations, filling and retest standards (EN1439, EN1440-1996 and 2008, EN14763, EN14767, ISO11623), and on experience from manufacturing and practical use in service of approximately 4 million cylinders.

Periodic inspection shall consist of check of *external visual conditions*, *check of the internal conditions* and hydraulic or pneumatic pressure test (proof test).

## 3 General information

### 3.1 The company

RAGASCO AS ([www.ragasco.com](http://www.ragasco.com)) is located in Raufoss Industrial Park, about 100km north of Oslo, together with Norsk Hydro, SAPA, Nammo and other companies. The company has more than 15 years of experience with developing and manufacturing fibre reinforced pressure cylinders for markets that acknowledge the special characteristics of composite materials - lightweight, high strength, especially good behaviour in fire and corrosion resistance to mention some.

The main activities today are

- The company manufactures the LPG composite cylinders, COMPLET.
- Developing and manufacturing high-pressure cylinders for cars, trucks and busses.
- Developing and manufacturing products for defence systems

The company is 100% owned by Hexagon Composites ASA ([www.hexagon.no](http://www.hexagon.no)), a Norwegian based company registered on the Norwegian (Oslo) stock exchange market.

### 3.2 The product

Complet is an innovative LPG composite cylinder targeted mainly toward the leisure and fork lift truck market. It can be used for cooking and heating, in caravans and cottages, barbecues, kitchens, on fork lift trucks etc. Main advantages are

- Light weight
- Translucent wall.
- Very good behaviour in fire
- Corrosion resistant
- Easy to handle, and stackable
- The valve is very well protected from impact
- It's easy to clean
- The material is UV-stable with a tough surface to withstand the environmental effects from sun, rain, temperature variations and handling.

### 3.3 Material and assembly details:

- RAGASCO type 4 (all composite) cylinder for LPG.
- Inner liner: High Density Poly Ethylene (HDPE). Blow moulded. No joints. Typical burst pressure: >3 bars. Gas barrier. Very ductile, may be collapsed and reshaped with no damage, even in cold temperature.
- Boss (interface between liner and valve): Brass insert with threads. Brass part interlocked with fibres. Injection moulded into HDPE. Hotplate melted to the liner.
- Composite: 75% glass fibre. Fully wrapped, *continuous fibres*, no joints. Resin based on vinyl ester. Individual fibre impregnation control and quality assurance.
- Standard valves used in very large numbers. Threads modified to cylindrical. O-ring seal.
- Outer casing: HDPE. Injection moulded. Covering 75% of the composite cylinder. Protects the valve.
- All production is highly automated and controlled by PLC's and PC's. A large number of manufacturing- and test parameters will be collected for each individual cylinder.
- Rotation of the cylinder in the casing is prevented by friction between cylinder and casing.

## 4 RAGASCO LPG Composite Cylinders – General procedures

### 4.1 General

Acceptance criteria given in this document shall not replace international, national or local official rules/standards. They are to be regarded as RAGASCO recommendations directly related to the properties of the actual product. Local authorities' requirements are legally always superior to this document.

Only trained personnel shall be allowed to carry out the testing.

### 4.2 Special consideration

- As a rule of thumb, always handle the cylinder carefully, both due to safety and visual appearance.
- Impact from drop higher than 1,5m shall lead to the cylinder being inspected by trained /experienced personnel.
- Do not expose the cylinder to temperatures higher than 65°C.
- Do not wash the cylinder with strong acids and/or solvents.
- Due to low electrical conductivity, RAGASCO recommends using the RAGASCO antistatic valve solution and/or adding small amounts of water to the cylinder surface and/or using other means to discharge the polymer surface just before filling. The filling operator shall evaluate the need of special caution during the filling procedure. Do not use the cylinder as a part of the filling equipment ground system.
- Vacuum: Do not store the cylinder with vacuum below 500 mbar absolute pressure. All practical pressure levels resulting from storing pure butane is OK.
- Only use valves with RAGASCO special parallel threads / o-ring seal interface
- Any sign of cracks or heat damage to the casing should lead to thorough investigation of the cylinder. *Damage to the interface area between upper and lower casing ("skirt") and cracks to the lower casing base (**tilt the cylinder to see bottom**) shall be specially focused and, in general, not accepted.*
- Any sign of cut fibres should result in scrapping the product.

### 4.3 Emptying the cylinder

Removing remaining LPG from the composite cylinder should be done in the same way as with traditional steel cylinders. If using vacuum, the cylinders should not experience less than 500 mbar absolute pressure.

### 4.4 Cleaning

Washing the cylinders can be done with standard soaps. RAGASCO recommends using alkaline solution in powder or liquid form, mixed with water. It is important to rinse the soap away after washing. Avoid strong acids and solvents.

### 4.5 Re-valve

#### 4.5.1 Clamping during unscrewing and torque

The maximum force for keeping the cylinder in position by clamping during unscrewing and torque valves should not systematically exceed  $7 \text{ kg/cm}^2$  at any area of the cylinder. Clamping equipment shall be shaped to assure sufficient interface area (thus rounded to fit the cylinder shape). The minimum interface area between clamping equipment and the cylinder surface should be no less than  $20\text{cm}^2$  for every equipment part in contact with the cylinder. The cylinder should not be exposed to a total force more than 200kg in any direction (vertical/horizontal). Clamp to the outer casing / side wall - not to the boss part.

#### 4.5.2 Handling of valves with RAGASCO parallel threads/o-ring seal interface.

Use only valves with RAGASCO special parallel threads / o-ring seal interface.

1. Remove the valve in the same manner as for traditional steel cylinders. Note the above limitations for clamping.
2. Check the O-ring and threads on the valve for dirt and damage. See also "Inspection of threads" below.
3. Check the threads and sealing area in the black boss solution. A soft brush may be used for cleaning.
4. Apply grease onto the o-ring all around the circumference. The grease must be compatible to propane and not contain silicon. If in doubt, please contact RAGASCO (+47 6115 1600, [info@ragasco.com](mailto:info@ragasco.com), [www.ragasco.com](http://www.ragasco.com)).
5. Insert the valve by hand and be sure the threads enter properly by screwing it in a couple of turns.
6. Tighten the valve by controlled torque to 80-120Nm.

7. *The operator may choose to apply a locking fluid to assure correct torque. If so, RAGASCO recommends Holdtite Optolok 211 (medium strength locking fluid) or equivalent onto 1 thread on the valve. The un-screw torque must not be more than 120-150Nm. Adding seal fluid to the threads will not create a permanent seal. Only the correct implemented o-ring solution will assure a permanent gas barrier.*
8. Leak test is recommended.

#### 4.5.3 Inspection of cylinder threads

This inspection only is relevant in the case of removing the valve due to other required inspections. In general, it should be avoided.

##### 4.5.3.1 Threads

Where the valves (or any other fittings) are removed during re-qualification, the cylinder threads concerned shall be inspected.

##### 4.5.3.2 Internal threads

The internal threads of the cylinder shall be examined to ensure that they are of full form and clean. They shall be checked for burrs, cracks, and other thread damage. If applicable, check that locking fluid and similar is OK. Check o-rings for damage.

##### 4.5.3.3 Damaged threads

Where necessary, and where the design permits, damaged threads may be rectified by a competent person. Alternatively, the cylinder shall be scrapped.

## 5 Procedure for filling

### 5.1 General

The acceptance of the container for filling is to be based upon visible investigation of the outer casing and the parts of the pressure cylinder without protection. The container including outer casing is to be regarded as one total system where every product part is necessary to retain all safety properties and required markings. Removing the casing should not be done, unless expressly agreed with RAGASCO and the local inspector.

If required, the cylinder may be cleaned and have labels, tar oil or other foreign matter removed from its external surface e.g. by water jet cleaning, chemical cleaning or other suitable methods. Strong acids or solvents shall be avoided. Normal soaps are OK. The outer casing shall be kept on during inspection. Care shall be taken to avoid damaging the cylinder. A suitable strong back-light is recommended and will make the inspection more easily apparent.

### 5.2 Inspection before filling

The following shall be checked before every filling.

- Any marking, tags, notes or similar indicating that special handling is required.
- Date for periodic inspection (if due, send to periodic inspection)
- Valve production date. If due time, change valve. Required after a certain time in service (usually 15 years).
- External visual inspection in accordance with table 1.

It is recommended that any visual abnormality (crack or dent, signs of heat, abbreviation, either to the casing or the composite) results in the cylinder being set a side for more thorough investigating – alternatively scrapping. Any sign of cut fibres should result in scrapping the product. *Damage to the interface area between upper and lower casing ("skirt") and cracks to the lower casing base (tilt the cylinder to see bottom) shall be specially focused and, in general, not accepted.*

### 5.3 Filling

Filing should be performed in accordance with local regulations and filling station routines, as for traditional steel cylinders.

Due to low electrical conductivity, RAGASCO recommends using the RAGASCO antistatic valve solution and/or adding small amounts of water to the cylinder surface and/or using other means to discharge the polymer surface just before filling. The filling operator shall evaluate the need of special caution during the filling procedure. Do not use the cylinder as a part of the filling equipment ground system.

#### 5.4 After-filling checks

After-filling checks should be performed as for traditional steel cylinders. Typically this includes visual external inspection, LPG mass check and leakage test in accordance with local requirements. Leak level shall be less than 2g/hr (Note: 1-2 g/hr is the typical accuracy on a filling station leak detector. RAGASCO cylinders shall normally deliver cylinders with no leak above  $1 \times 10^{-4}$  mbarL/s (103g/yr for a 10kg propane cylinder).

*The cylinder contains a gas tight barrier (liner), thus the load bearing composite is not required to be gas tight. Pores in the composite, small air pockets in non-adhesion areas between the liner and composite at the domes/top and small air pockets in the boss/valve interface, might lead to surface bubbles during a soapy water test / water jacket leak test. To check if there is an actual gas leak, store the cylinder for 2 days and test again, or test with a LPG sniffer. Air bubbles will not affect a LPG leak detector.*

## 6 Procedure for Periodic Inspection

### 6.1 General

This procedure fully meets the requirements of ADR/RID and EN1440. Cylinders shall be periodically inspected in accordance with a written format of inspection requirements approved by the national Competent Authority. The format shall specify the interval between inspections and the procedures to be employed.

It is recommended that the interval between periodic inspections shall be at least 10 years, based on decision from Norwegian Competent Authority (DSB), German Competent Authority (BAM) and Notified Body TÜV, confirmed in the TPED certificate.

The below procedure shall be performed at time of Periodic inspection

### 6.2 Test program for periodic inspection (for details; see later sections)

- Look for any indication of necessary special handling.
- Cylinder to be cleaned and have labels, tar oil or other foreign matters removed from its external surface.
- Serial number identification
- External visual inspection
- Check of the internal conditions.
  - A) *Normally, internal visual inspection is required from the local authorities. If so;*
    - Empty the cylinder
    - Remove the valve
    - Check cylinder threads
    - Internal inspection
    - Proof testing with a gas or hydraulic.
    - Marking
  - B) *If the filling procedure and gas quality are iaw EN1439, and the cylinder is operated by professional organization with a certified quality system for such operation, it is technically justifiable to perform the check of internal conditions by evaluating the internal surface from outside through the transparent wall. This is typically done with a strong backlight, and un-normal shades, signs of foreign materials and major signs of internal discolouring, shall lead to internal inspection from inside. One should not expect a clear visual image, but more an indication of un-normalities. This method must be approved in advance with the relevant national authority.*
- Proof testing with a gas or hydraulic, with or without valve.
- Marking

(An example checklist for inspection company preparations, is given in Annex B)

### 6.3 External Visual Inspection

#### 6.3.1 General

The acceptance of the container during retesting shall be based mainly upon visible investigation of the outer casing and the parts of the pressure cylinder accessible through openings in the casing. The container including outer casing is to be regarded as one total system where every product part is necessary to retain all safety properties and required marking. Removing the casing should not be done, unless specially agreed with RAGASCO and the local inspector. If replacing the casing due to maintenance, both the casing and the inner cylinder must be inspected.

### 6.3.2 Preparation

Before cleaning, look for *damage* or a sign of the composite pressure vessel was turned within the casing other than during valve positioning. If rotated unintentionally, the cylinder shall be investigated in agreement with RAGASCO and the local inspector. *In case of damage, evaluate if the damage investigation is more efficient before or after cleaning.*

If required, the cylinder may be cleaned and have labels, tar oil or other foreign matter removed from its external surface e.g. by water jet cleaning, chemical cleaning or other suitable methods. Strong acids or solvents shall be avoided. Normal soaps are OK. The outer casing shall be kept on during the main inspection. Care shall be taken to avoid damaging the cylinder. A suitable strong back-light is recommended and will make the inspection more easily apparent.



### 6.3.3 Procedure for external visual inspection

The entire surface of the outer casing, and composite wall available in the cutaway portions of the casing, shall be inspected for:

- a) Cuts, gouges, bulges, cracks or de-laminations applying the guidelines for acceptance criteria in table 1.
- b) Defects e.g. depressed bung, fire/heat damage applying to the guidelines for acceptance criteria in table 1.
- c) Integrity of all permanent attachments.

Any cylinder rejected by the competent person shall be segregated for reconditioning or scrapping.

### 6.3.4 Visible defects

Rejection criteria guidelines for physical and material defects on the cylinder shell/casing are contained in the acceptance/rejection criteria in Table 1.

**Table 1 —Acceptance/Rejection criteria**

Type of damage	Description	Rejection if
Abrasion damage or damage from cuts (Casing and composite).	<p>Abrasion damage is caused by wearing, grinding or rubbing material away by friction, see figure 1, Annex A.</p> <p>Cuts or gouges are caused by contact with sharp objects in such a way as to cut into the composite, reducing its thickness at that point, see figure 2, Annex A.</p> <p>If it cannot be established that the cylinder is unaffected, the cylinder shall be put aside for further investigation.</p>	<p><b>Casing damage:</b></p> <ul style="list-style-type: none"> <li>. Any small and large damage to the upper casing “skirt” typical &gt;20mm<sup>2</sup>, depending on depth and mode.</li> <li>. Cuts/cracks to the lower casing base</li> <li>. Abrasion / cut through casing.</li> <li>. Total length of non-penetration cuts &gt;50 % diameter of the cylinder.</li> <li>. Total damaged area maximum diameter is more than 50 % of the diameter of the cylinder</li> </ul> <p><b>Composite damage:</b></p> <ul style="list-style-type: none"> <li>. Any cut or otherwise damaged fibre</li> </ul> <p>Note 1: the maximum diameter of the damage area is the diameter of the smallest circle that includes the damaged area.                      Note 2: Intra-laminar hairline cracks (between fibres, typically on the circumference after proof testing) is allowed if not in combination with impact damage.                      Note 3: Scratches that do not sever a fibre are not included in the above.</p>

<p><i>Delamination and impact damage on the composite surface that is not covered by the casing.</i></p>	<p>An Inter-laminar delamination is a separation of layers of strands<sup>a</sup>. An intra-laminar delamination is a separation between strands within the same layer<sup>b</sup>. Impact damage may appear as hairline cracks in the resin or delamination or cuts of the composite<sup>c</sup>. It may also appear as a whitish patch like a blister or air bubble beneath the surface. See annex A, figure 3</p>	<ul style="list-style-type: none"> <li>• Any delamination in combination with surface damage,</li> <li>• Cut fibres.</li> <li>• Delamination covering more than 30 % of the cylinder.</li> </ul> <p>Note 4. A delamination that is not in combination with outer damage and not covering more than 30 % of the cylinder is acceptable. Note 5. Areas with no adhesion between liner and over wrap shall not be regarded as delaminated.</p>
<p>Chemical damage</p>	<p>Chemical attack would appear as the dissolution of the resin matrix surrounding the fibres, the cylinder surface feeling sticky when touched. The cylinder shall be rendered unserviceable.</p>	<p><i>Chemical attack on the casing, resin or fibres resulting in damage to the materials, such as sticky or discoloured surface.</i></p>
<p>Heat/fire damage of the casing or composite</p>	<p>Heat or fire damage may be evident by discolouration, scarring or burning of the composite overwrap, casing, labels and non-metallic components of the valve. Cylinders with this type of damage shall be rendered unserviceable<sup>d</sup>.</p>	<p>Visible damage from heat and/or fire. See fig. 4. Heat damage to the boss =&gt; scrap.</p>
<p><sup>a</sup> see annex A, figure 3. <sup>b</sup> It may also appear as a whitish patch like a blister or an air bubble beneath the surface. See annex A, figure 3. <sup>c</sup> see figure 3, Annex A. <sup>d</sup> see figure 4, Annex A.</p>		

#### 6.4 Procedure for internal inspection

- Position the cylinder in strong back-light or use internal light. Any equipment used for steel cylinders may be used. Look for colour shading, loose objects, contamination, scratches, material loss etc.
- In case of abnormal findings, evaluate to find the cause.
- In case of contamination, dirt etc – clean the cylinder.
- In case of colour shading or delamination, see Table 1.
- In case of material loss, scrap the cylinder.

Note: During education and start up with this type of cylinder, RAGASCO recommends cutting open a few cylinders with “abnormal” internal colours, dirt, whitening etc. (if any is found) to investigate for educational purposes.

#### 6.5 Hydraulic or pneumatic proof testing

- To be performed as for steel cylinders, in accordance with ADR/RID or relevant local regulations. (See example checklist in Appendix B).
- Re-valving in accordance with the above section “Re-valving”
- Safety note: A pneumatic test is only acceptable if prepared so that safety for the test personnel is assured even in the unlikely event of a cylinder burst during the pressure test.

#### 6.6 Marking of accepted cylinders

After successful completion of the re-qualification, each cylinder shall be legibly and durably marked with the following information:

- The symbol of the re-qualification test station and the identification number of the inspection body;
- The year (minimum) of next re-qualification: the marking heights shall be at least 5 mm.



Where cylinders are not under the full control of any marketing organizations, test results may be kept on record by the organization responsible for re-qualification. The marking shall as a minimum be stamped or melted into the top ring of the handle or as required by the local inspector. If needed, extra marking might be added as sticker, ink-jet, ink stamp etc, for readability.

#### **6.7 Identification of contents**

The cylinder content shall be identified, e.g. commercial propane.

#### **6.8 Information to the manufacturer**

In order to gather experience, RAGASCO urges the party doing retesting to send to [info@ragasco.com](mailto:info@ragasco.com) a summary of findings from retesting. If cylinders that could be of special interest are detected, it would be appreciated if they are stored until after contacting RAGASCO, due to possible testing.

### **7 Rejection and scrapping of cylinders**

The decision to reject a cylinder may be taken at any stage during the re-qualification procedure. With the agreement of the owner, a rejected cylinder shall be rendered unserviceable so that it cannot be re-issued into service as a pressure vessel. Rendering cylinders unserviceable is performed by drilling as a minimum, one hole of diameter at least 20 mm in the cylinder or equivalent.

It is recommended to deliver the scrapped cylinders with the 20mm hole and without valve, to destruction by high temperature burning in a facility for destruction and energy re-cycling, regrinding for construction fill material or other purposes.

### 8 Annex A - Types of damage of cylinders and casing

Examples of types of damages of cylinders and casing are represented in Figure 1 to 7 (see Table 1).



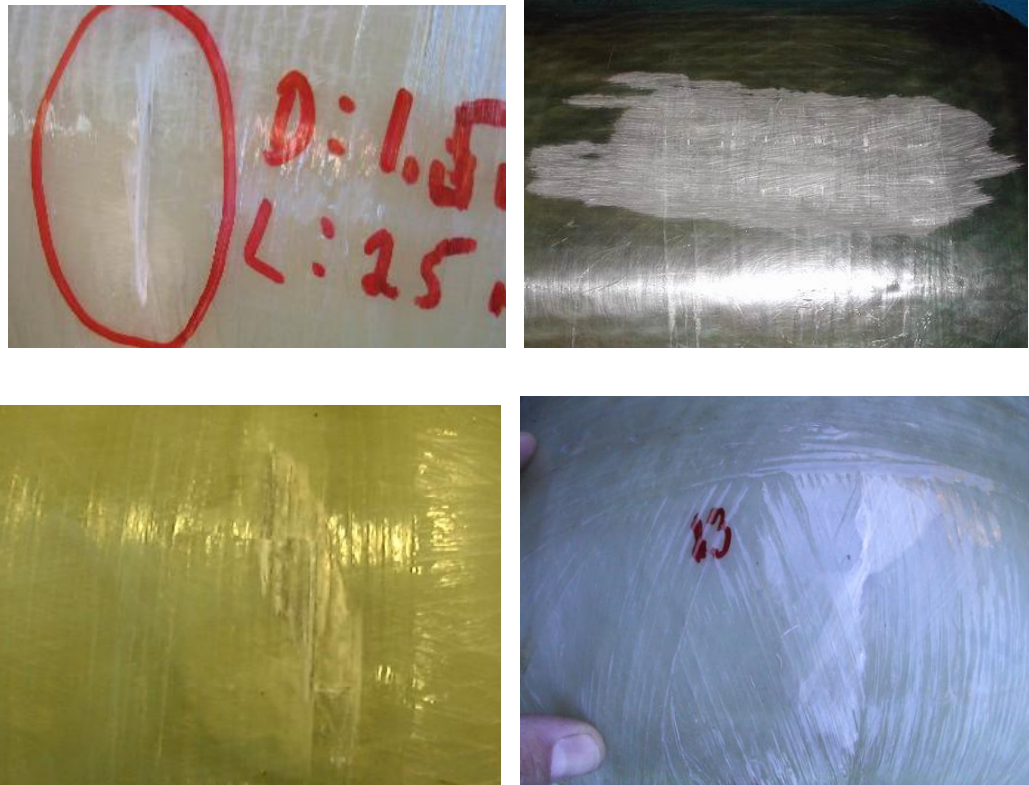
Figure 1a — Damage on casing “skirt”– not acceptable



Figure 2b — Damage on casing base – not acceptable



Figure 3c — Damage on casing cylindrical area – not acceptable



**Figure 4b — Damage from abrasion and cuts— not accepted**



**Figure 3a — Impact damage in combination with delamination and surface defects – not acceptable**



Figure 3b — Delamination and no surface damage - acceptable

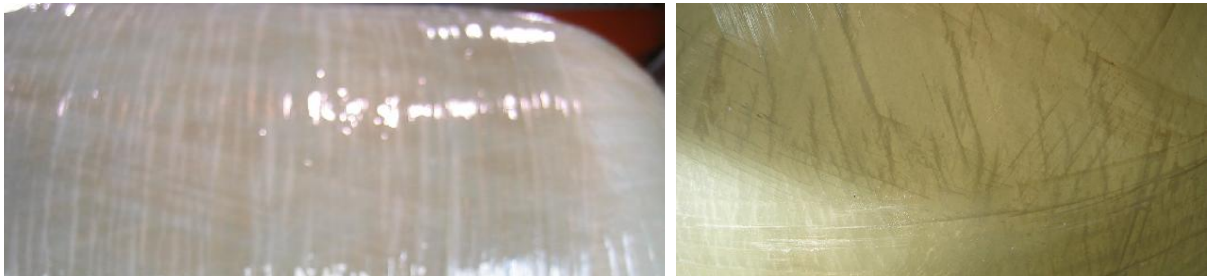


Figure 3c — Intra-laminar lamination due to pressure cycling >12000 cycles to proof pressure - not acceptable damage, even though burst pressure is still above 90 bars.  
If less than approximately 100 hairlines, it is acceptable.



Figure 4 — Heat damage. This type of damage is not acceptable in any form

## Annex B – Example check list for preparation to retest Program 2 (w/pressure test)

This list covers some additional check points for preparing to retest. Please refer to the rest of the document for further details – it is necessary to study the full document for safe, efficient and complete testing.

### Check-list

- Assure safe handling in the process. More than 90% of impact related damages are caused by hard handling and transportation with fork lift trucks at filling stations and retest facilities. *Always perform a visual inspection as described in case of cylinders falling.*
- Check the transportation system at the retest station – does the cylinder fit to pallets, transportation chains etc.
- Pre sorting – major damage sorted out
- External visual inspection is done on the casing and the composite in the open slots in the casing. Cracks in any part of the casing should lead to scrapping (or investigation by RAGASCO approved experts). **No cut fibres are allowed.**
- Emptying cylinder – do not apply vacuum above spec.
- Clean, remove labels etc. Avoid strong chemicals.
- Dismount the valve. Check if there is remaining LPG. The liner is soaked with LPG, thus the pressure might increase if storing it after emptying, due to dissipation from the liner into the cylinder. Do not clamp with load exceeding the spec. An additional smell of styrene is normal.
- Check the threads, the o-ring (no damage) and o-ring seal surface (feel with a finger, look with a light).
- Mount in the pressure test fixture. Special adapter is needed. Ticking sound of surface resin micro cracking is normal – it does not affect the mechanical properties of the cylinder. Ticking should stop during the 30 sec.
- Pressurize to test pressure for 30 seconds with water or air. A certain pressure drop (approximately 1 bar) is normal during the 30 sec. If pressurizing longer, the pressure drop will stop.  
**Safety note:** A pneumatic test is only acceptable if prepared so that safety for the test personnel is assured even in the unlikely event of a cylinder burst during the pressure test.
- Look for leaks and abnormal behaviour.
- Empty the cylinder. Due to internal neck design, the cylinder will not be totally empty by turning it upside down. Use vacuum cleaner, moderate heat or “sponge on a stick” to dry.
- Lack of adhesion between liner and composite does not affect mechanical properties. It has minor effect on permeability and some effect on translucency. The same is valid for delamination within the composite layer. Lack of adhesion / delamination may be seen as areas with different colour shading. It is recommended that the area does not exceed 30% of the total surface of the cylinder.
- Use external and/or internal strong light for optimizing internal visual inspection. Remains from the LPG (white/yellow/brownish crystals/"butter" is normal, but not always present). In the lower end, there are internal bulges from the manufacturing process. This is normal. Cracks and cavities are not acceptable.
- Valve mounting. Check threads, o-ring (greased, un-damaged, right size) and o-ring seal surface. *[Text removed]*. **Torque to 80-120Nm** only. For positioning the outlet, hold the casing by the handles and turn the pressure vessel within the casing *in a controlled* manner until positioned.
- Do not vacuum purge.
- Mark the approved cylinder by a stamp or melting into the outer casing top ring”. Further labels and paperwork.
- Assure safe transportation by proper packaging / strapping.