



FAILURE DETECTION AND RECOMMENDED ACTIONS



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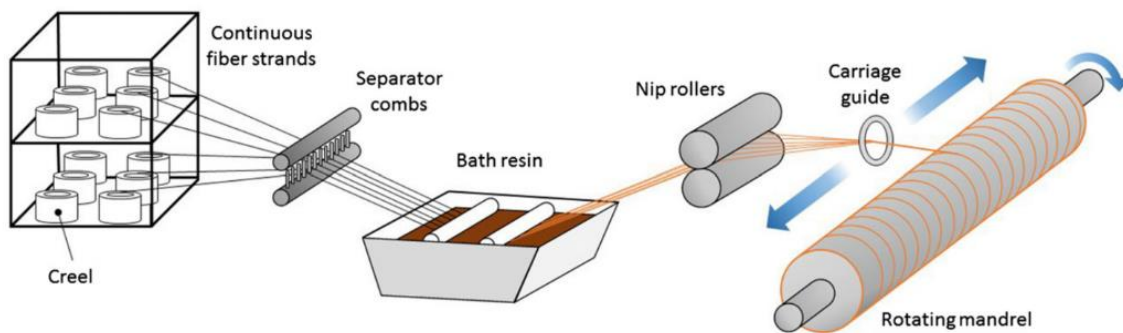
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1.- Introduction

1.1. Manufacturing system

BEL Composite Iberica S.L., in its commitment to safety, develops this document to publicize the technology and the constructive form of its pressure vessels for Reverse Osmosis, in order to facilitate finding failures during operation, determine their degree of severity, and provide guidance on the most recommended corrective actions.

BEL pressure vessels are manufactured using the “Filament Winding” process, through which various fiberglass filaments, dipped in epoxy resin, are wound around a mandrel, which is then subjected to thermal curing to harden the resin. In this way, different materials (heterogeneous to each other) form a single composite material with excellent mechanical properties.



- Filament winding manufacturing process -

To ensure that the mechanical properties are homogeneous throughout the vessel, different winding angles are used in the manufacturing process. This manufacturing method gives our vessels excellent axial and radial strength.

Under normal operating conditions, fiberglass filaments saturated with epoxy resin, will not absorb water at any time, and the strength of the vessel will be not affected.

Which conditions will cause failure?

- 1.- Bad ports alignment.
- 2.- Scratches or damages in the internal surface of the vessel.
- 3.- Working conditions outside the parameters specified by BEL (such as pressure, temperature or pH)
- 4.- Leaks in Endcaps or Side ports due to lack of maintenance

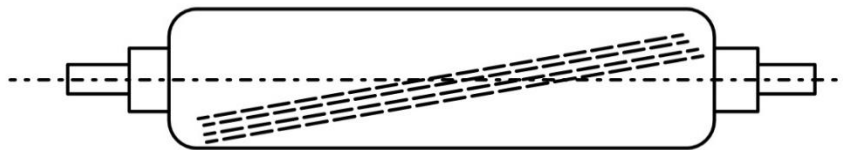
Factors described above will facilitate the vessel being damaged over time, allowing high-pressure water to penetrate into the laminate. The constructive form of BEL pressure vessels prevents the mechanical strength of the vessel no to be immediately affected if water penetrates into laminate.

However, if these factors defined in the previous section are sustained over time, the laminate will weaken over the years, increasing the risk of catastrophic failure.

1.2. Failure behavior

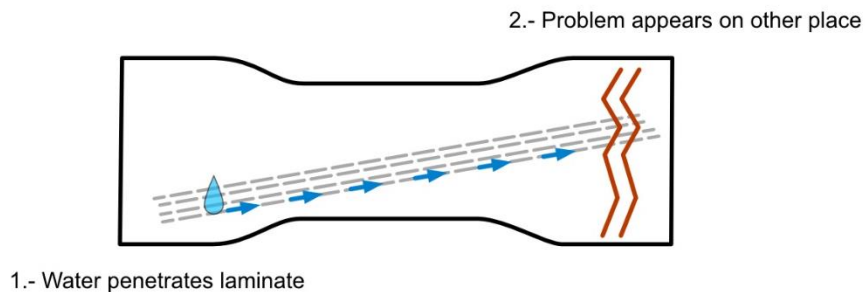
Due to its construction characteristics defined in the previous section, if a water penetration failure were to occur in the laminate, the problem may present symptoms in many different ways, so locating the origin of the failure will be a very difficult task, since water can penetrate the laminate in one part of the vessel, move along the fiberglass filament, and end-up weakening another different part of the vessel.

In the image below we can see how the fiberglass is wound on the rotating mandrel.



- Winding pattern on the mandrel -

Because the fiber is wound throughout the entire vessel, if water penetrates the laminate through a pore or crack inside the vessel, symptoms could appear at the other end of the vessel.



- Water penetration problem behavior inside the laminate -

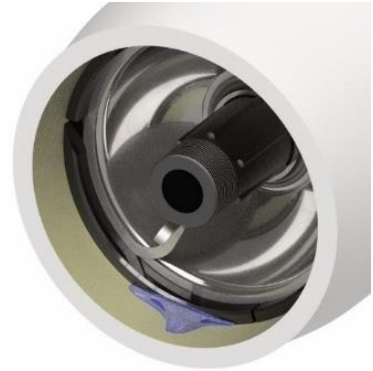
This means that vessels from the same plant can present very different failures from each other.

Also, the behavior of each failure is unpredictable, which makes estimating the expected lifetime after detecting a failure in a vessel, a very complicated task. This document aims to provide guidance on the types of failures and their severity, as well as some recommended actions for each type.

2.- Failure types

2.1. Endcap leaks

- **Description:** the vessel presents some water leaks through the endcap.
- **Actions to be taken:** replace endcap sealing as soon as possible (no type of leakage is tolerable). If the issue is solved, it should not be considered a serious problem. If it keeps leaking after replacing the sealing, see point 2.3.
- **Severity level:** Low (if leak is detected soon)
- **Expected lifespan:** Not affected



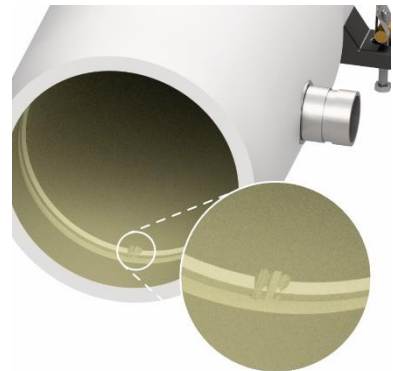
2.2. Side port leaks



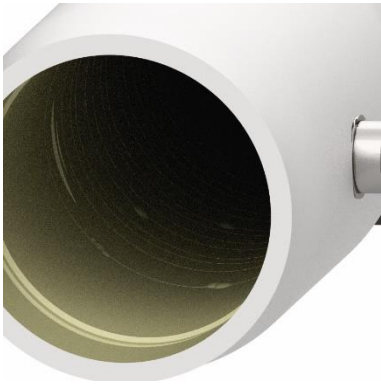
- **Description:** the vessel presents leaks through the side port.
- **Actions to be taken:** replace the side port sealing as soon as possible (no type of leakage is tolerable). If the issue is solved, it should not be considered a serious problem. If it keeps leaking after replacing the sealing, see point 2.5 and 2.6.
- **Severity level:** Low (if leak is solved soon)
- **Expected lifespan:** Not affected

2.3. Damage in the sealing groove

- **Description:** the vessel presents scratches or surface defects in the sealing groove.
- **Actions to be taken:** repair according to manual. For cracks in the sealing groove please see point 2.6
- **Severity level:** Medium
- **Expected lifespan:** Not affected if solved soon and correctly. Do close monitoring and watch out for new symptoms.



2.4. Damage in internal surface



Description: the vessel presents scratches, white bubbles or other kind of damage in the inner face.

Actions to be taken: not repairable. Water has penetrated in the inside of the laminate. The extent of the damage cannot be determined

Severity level: Medium/high, depending on the quantity and size.

Expected lifespan: Close monitoring and replacement plan replacement

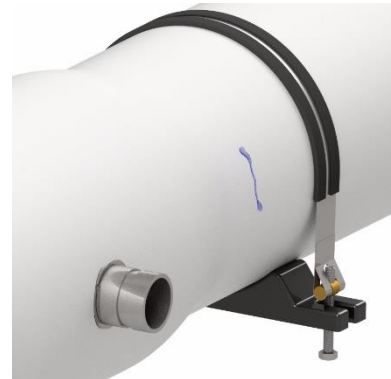
2.5. Body leaks

Description: vessel shows leakages through the body.

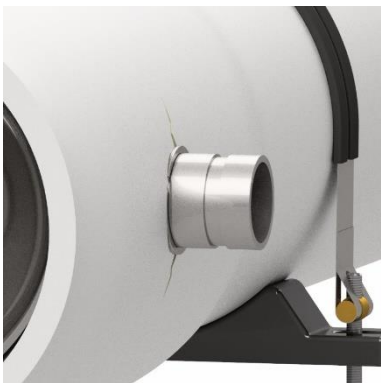
Actions to be taken: never repair or block these leaks with resin. Water has penetrated in the inside of the laminate. The extent of the damage cannot be determined. Replace the vessel immediately

Severity level: High

Expected lifespan: Close to catastrophic failure risk.



2.6. Cracks



Description: Cracks are found, starting from the side port drill in the bell, or in the inner groove of the vessel.

Actions to be taken: Replace the vessel immediately

Severity level: High

Expected lifespan: Immediate catastrophic failure risk.



3. Summary

As a summary, the following table shows the defects arranged in order of severity.

ID	Kind of failure	Severity Level	Actions to be taken
2.1	Endcap leaks	Low	Replace sealings
2.2	Side port leaks	Low	Replace sealings
2.3	Damage in the sealing groove	Medium	Repair according to manual
2.4	Damage in internal surface	Medium / high	Plan replacement of vessel
2.5	Body leaks	High	Replace the vessel immediately
2.6	Cracks	High	Replace the vessel immediately

4. Note

The images shown in the document are an exaggeration of reality. Some defects may be shown in a more discreet way

It is important to remember that no leak is tolerable.

Operating outside the design conditions (such as pressure, temperature or pH), seriously damages the service life.

If any defect is found, please do not hesitate to contact us and we will support you.

The contents of this document are intended to assist in the maintenance of the plant and do not modify or diminish BEL's liability as outlined in the original agreement and BEL's general T&C.