

# Aquaporin Inside® Reverse Osmosis Flat Sheet Membrane Operation Guide

## 1. Introduction

This document outlines the procedures for users to follow, from receiving the Aquaporin Inside® Reverse Osmosis Flat Sheet membrane (RO FS) products until their application. This guide covers information such as unpacking and repacking of the RO FS rolls, as well as the correct usage of the RO FS during testing and application. This guide is generic and not exhaustive as there are differences in the applications of each customer. Please contact Aquaporin A/S if there are any doubts not listed in this guide.

## 2. Information and Instructions before Unpacking

When receiving the RO FS shipment from Aquaporin A/S, users shall:

### 2.1. Check the Certificate of Analysis (CoA)

Check and verify the CoA results such as flux, rejection, etc., recorded against the performance specifications listed to ensure all CoA results pass the specifications. Please contact Aquaporin A/S should there be any discrepancies or Out of Specification (OOS) found when checking against the CoA before opening the package. Only proceed to unpack the package after the discrepancies are clarified.

### 2.2. Check the package's outer appearance and labelling

The RO FS is susceptible to physical, chemical, and biological damages, and these could occur during shipment and handling. Inspect and identify any abnormalities with the carton or package, such as crushing, punctures, tears, wet carton, presence of mold, crushed pallet, cartons in the wrong orientation, etc. After the packaging inspection, check the label and the information on the label, such as product name, product type number, length, etc. Make sure it fulfils the label specification between Aquaporin A/S and the customer. Please contact Aquaporin A/S immediately if any of the abnormalities described above are identified.



Aquaporin Inside®	
Product Name	AQP-G1 40" Flat Sheet
Product Item no.	20033B  5 744000 980898
Total Length (m)	500
Effective Length (m)	498
Flux (GFD)	25.0
Rejection	98.9%
 Roll ID# FG0923045	

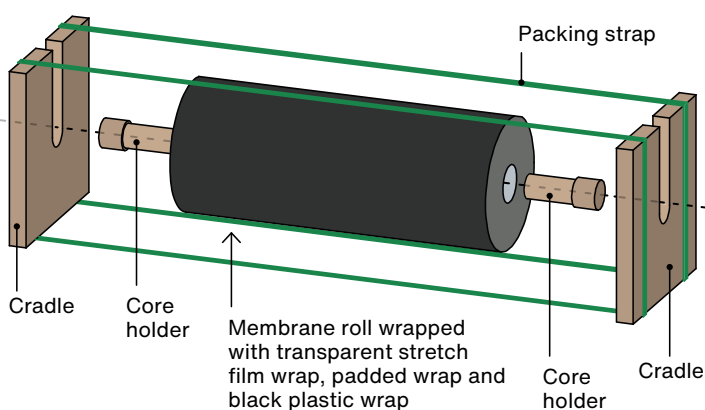
Figure 1: An example of RO FS package label

### 3. Unpacking and Cutting Instructions

Users may proceed to unpack the RO FS for use with the following steps, if there are no issues found during the CoA and package inspection.

#### 3.1. Unpack the RO FS from the carton box

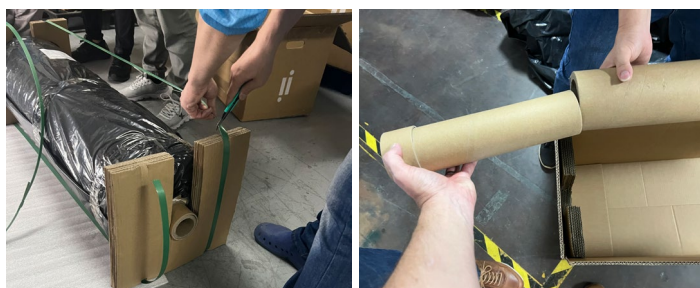
Unload the carton box from the stacked package or pallet to the workstation. For safety consideration, always manoeuvre the heavy carton box and RO FS roll with two persons. Always maintain the carton box in its original orientation. Use a pen knife to cut the tape on the top of carton to open the box. The items contained in the box are shown in **Figure 2**. Two persons should grab the inner packing straps and lift the roll out from carton box (**Figure 3**) together. Cut



**Figure 2:** Sketch diagram of inner packaging of carton containing RO FS roll.



**Figure 3:** Unpacking the RO FS roll: lift the roll from the carton box using the packing straps



**Figure 4:** Packaging pieces: side cardboard cradle (left); side core holder (right)

the strapping with a pen knife or a pair of scissors. Pull off the side cardboard cradles (**Figure 2** and **Figure 4**) and place the RO FS roll down gently on a flat surface and take out the side core holders (**Figure 2** and **Figure 4**). Insert the user's roll core support, lift the roll and load it into the RO FS preparation machine. Once the roll is in the preparation machine, remove the black plastic wrap, the padded wrap, and followed with the transparent stretch wrap.

#### 3.2. Cutting RO FS for coupon testing, element rolling, or other applications

It is recommended to put the RO FS membrane roll onto the core roller for easier operation, and users may apply their respective cutting and preparation procedures according to the machinery or equipment they own. Otherwise, for generic procedure, simply pull out the RO FS gently, with active surface (rejection layer) facing up, then use a pen knife to cut a cross-web membrane sample with the dimensions sufficient for the user's applications. Ensure that there are no scratches or physical damage caused to the membrane surface when sampling/cutting the RO FS for applications. Please refer to the **Shipping, Handling, and Storage Guide** for further information on RO FS handling.

Optional: For folded RO FS membrane to be applied for element rolling, please secure the stack of folded RO FS membrane with weights and/or supports surrounding it to prevent loose placement and subsequent damage due to stack sliding and/or falling.

#### 3.3. Repacking the opened RO FS roll after use

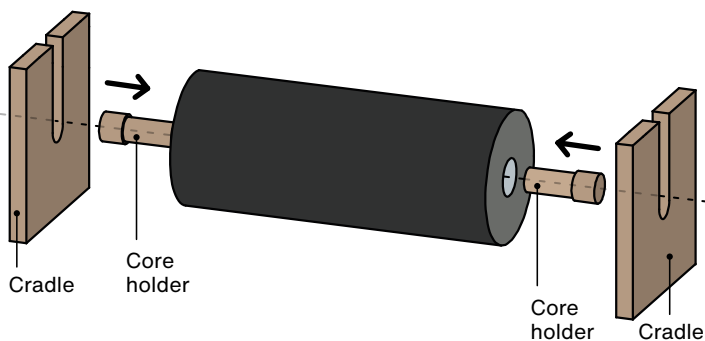
The opened RO FS rolls should be fully consumed as soon as possible, as the membrane is sensitive towards environmental factors which may deteriorate the membrane's functionality. If the RO FS is not immediately consumed, users shall repack it in the original packaging. The repacking may be done with the following steps:

- Wrap the RO FS roll with stretch film wrap. Make sure the roll is fully covered with no exposed membrane area.
- Place the padded wrap around the roll after the stretch film wrap.
- Wrap the roll with black plastic wrap. Make sure the roll is fully covered with no exposed membrane area.
- Insert the side core holders into both ends of the roll core, then support the roll by placing the side cardboard cradles under the side core holders on both ends.

- e. Place the packaged roll back into the carton box. Ensure that the two side cardboard cradles are oriented with their openings at the top of the carton box, so that the roll will be suspended by the side cardboard cradles when the carton box is oriented correctly according to the carton box labelling.



**Figure 5:** Repacking the RO FS roll: wrap the RO FS roll with stretch film wrap and replace the padded wrap around the roll (left); replace the black wrap around the roll (right).



**Figure 6:** Reassemble the RO FS roll with core holders and cradles before placing the roll back to the original box.

## 4. Information for Element Rolling Application

### 4.1. Compatibility of adhesive glues

Users shall conduct compatibility testing between the glue and RO FS prior to use of the membrane for scaled element production. The glue compatibility testing can be performed manually with RO FS coupons, manually rolled test elements, or with test elements rolled on production equipment. During the glue compatibility testing, users shall control the RO FS working environment to a temperature of  $25 \pm 5$  °C,

and Relative Humidity (RH)  $60 \pm 10\%$ . A proper and accurate glue mixing ratio shall be maintained during the glue compatibility testing. During glue application, users shall maintain a consistent glue application amount and line width using their equipment. During rolling, the glue line must be kept even and straight, without deviating from the glue line target. After the elements are rolled, glue must be properly cured before evaluation. Test leaves or rolled elements will be placed in a curing room/environment for a specified minimum period to harden the glue before the element glue line trimming process. After the glue hardening process and any necessary element trimming has taken place, the membrane glue penetration and adhesion strength shall be evaluated.

It is crucial to ensure the compatibility of the glue with the RO FS. Incompatible glue may cause severe element defects such as a high vacuum decay rate or significantly lowered rejection. Please contact Aquaporin A/S for more information or recommendations on compatible glues for the Aquaporin Inside® RO FS.

### 4.2. Environment of rolling workshop

Users shall control the environment in the workshop for rolling applications (including trimming FS, folding, glue application, and rolling etc.) to a temperature of  $25 \pm 5$  °C, RH  $60 \pm 10\%$ . Exposure of RO FS under lower RH environment will cause dehydration, which leads to poor vacuum decay result of rolled element or negatively affect the glue compatibility with the RO FS. Additionally, exposing RO FS to a high RH environment will cause excessive membrane moisturisation, where then the sticky membrane surface results in rolling difficulty or negatively affects glue compatibility with RO FS. Since RH and temperature have a strong dependence, maintaining a stable temperature environment will help to ensure stable moisture content in the air, keeping the moisture content of membrane within an optimal range to avoid potential RO FS or element quality issues.

### 4.3. Element rolling process and machine design

The active layer of the RO FS consists of a nanometer-scale biomimetic dense layer, which acts as the rejection layer in the filtration process. The active layer is fragile even though it is coated with a thin protection film. Ideally, users should avoid touching or contacting the active layer, as any form of touching or contacting may cause damage to the layer. In element applications, certain contact with the active layer

surface is inevitable when there is membrane folding or contact with feed spacer. Users should minimise this face side contact, and control its contact area, position, and intensity. Users should touch the active layer as gently as possible within the non-effective area or non-performance affecting area, such as glue line area or the area to be trimmed out after rolling. When handling the RO FS, users shall always wear protective gloves.

For example, when placing feed spacer onto the active layer, avoid dragging of brine spacer along the active layer. Position it vertically above the active surface and place it gently down to avoid direct friction between spacer and active layer. When creasing membrane leaves, users should only apply moderate force to prevent damage to the active layer at the crease area. Some industrial elements with higher rejection requirement may require a protective tape at the crease area. Whenever handling RO FS for the activities such as cutting membrane sheets, folding membrane leaves, etc., always place the RO FS on a flat and clean table or surface, with the membrane active layer facing upwards. Do not place the RO FS with the active layer contacting the work surface, as it can cause damage to the active layer.

Several precautions shall be taken during the rolling process, especially the tension setting of the rolling process. The tension of the rolling machine and winding up pressure should be moderately set, and generally not higher than 0.3 MPa. This setting is applicable to smaller and larger elements based on the experience of Aquaporin A/S, however it might not be applicable to every user, and will depend on each users' machine designs and operation conditions. It is recommended that users reduce membrane tensions or applied pressures as much as possible while executing their element rolling operations. Excessive tension may cause unnecessary indentation of the brine spacer on the membrane active layer and damage it. Users shall ensure that there is no sliding of the brine spacer inside the membrane leaves during rolling as this potentially damages the active layer.

Design and selection of equipment, such as FS slitting machines, trimming machines, folding machines and element rolling/gluing machines should be carefully considered to eliminate or minimise the risks of membrane damage during the FS slitting and element rolling process. It is recommended to have rollers that rotate smoothly (both idler and motor-

driven). The rollers should have straightness less than 0.06 mm/m, surface roughness less than Ra 0.4, runout less than 0.06 mm, and membrane tension between rollers should be controlled below 15kg. It is also recommended to avoid or minimise contact between the roller surface and the membrane active layer, as this may potentially damage the membrane or compromise the performance.

For slitting machines, users are recommended to control the line speed below 30 meter per min (m/min). Fast line speed can cause issues such as wrinkles and membrane sliding, which may damage the membrane or compromise the performance.

## 5. General Guidelines for Membrane Testing

This section outlines the general guidelines on RO FS and element testing. The guidelines provided are based on the general requirements from Aquaporin A/S, and it may vary accordingly among users. Users should always refer to the agreement with Aquaporin A/S on the testing conditions and requirements.

### 5.1. Quality of feed solution

There are certain requirements for the feed solution to RO FS and elements. Silt Density Index (SDI) must not exceed 5 and pre-treatment is generally required to minimise fouling. Free chlorine in feed solution should be lower than 0.1ppm under normal conditions, as continual contact will degrade the desalting capacity of membrane due to oxidative damage. It will not be covered under warranty. Therefore, it is recommended to implement pre-treatment in the RO system to completely remove free chlorine in feed solution.

Users shall also be aware of the adverse effects of contact with chemicals besides known oxidative chemicals like chlorine. Refer to the **Shipping, Handling, and Storage Guide** for more details.

### 5.2. General testing conditions for FS and residential elements

Users shall test the membrane, either RO FS or residential elements under the conditions agreed by users and Aquaporin A/S. The standard quality control (QC) testing conditions for drinking water RO FS are shown in **Table 1**.

**Table 1:** Standard QC Testing Conditions for RO FS.

Product	Pressure (bar)	Feed solution	Temperature (°C)	pH
Aquaporin Inside® DWRO® Flat Sheet				
Aquaporin Inside® DWRO® HF Flat Sheet	4.9	NaCl, 500ppm	25 ± 0.5	7-7.5
Aquaporin Inside® DWRO® XHF Flat Sheet				
Aquaporin Inside® DWRO® HR Flat Sheet	10	NaCl, 1500ppm	25 ± 0.5	7-7.5

Refer to the **Coupon Performance Test Guide** for detailed guidelines on FS coupon test.

For residential elements, test according to the design parameter of users or machine. Generally, municipal tap water (ranging from 50-800 ppm TDS) is used as feed. Operating pressure range should fall within 5.5-6.9 bar, pH approximately 7, feed temperature of ambient temperature (~25C), and recovery range not exceeding 70%. If users are in doubt about the element operating condition limits, users shall check with Aquaporin A/S.

## 6. Troubleshooting Method – Dye Stain Test

A dye stain test is commonly used as a defect identification method for both FS and elements. It identifies the physical damage on the membrane active layer which leads to rejection issues. Rhodamine B, 500 ppm solution (CAS number: 81-88-9) can be used as the dye solution. It can be executed by placing the RO FS, active layer facing downward, on a pan with dye solution (floating on dye solution with dye solution avoided on the membrane backside) for specific interval and rinse the membrane active layer with water to remove remaining dye solution after removing it from the dyeing pan. Pink color dots/area/pattern will be observed at the damaged area on membrane active layer. For element, users may operate it with pressurised dye solution and observe the permeate. Pink permeate indicates damaged active layer and element autopsy should be performed to find out the location of dye passage.