Troubleshooting Guide for Industrial Aquaporin Inside® RO Membrane Elements

This guide contains useful techniques when troubleshooting reverse osmosis (RO) systems. The objective of troubleshooting on RO systems is to identify membrane system irregularities and to investigate modes of membrane system failures, with the intent of eventually restoring membrane performance.

Despite pretreatment and attention to system hydraulics, most RO systems will eventually show degradation in performance due to membrane ageing and fouling. This performance degradation manifests itself as a slow and continuous loss in permeate flow, increase of salt passage, or increase in pressure drop.

If one of these three parameters, or a combination of them, deviates slowly from the normalized value, it may indicate normal fouling and scaling, which can possibly be removed by proper membrane cleaning. However, a fast and/or sudden performance decline indicates faulty system operation and/or operation outside the original system design criteria (e.g., a change in feed water quality, change of pretreatment chemicals, etc.). In these cases, it is essential that the proper corrective measures are taken as soon as possible, as any delay decreases the chance of restoring system performance and may lead to other problems.

A prerequisite for early detection of potential problems is consistent record keeping and performance normalization, including proper calibration of all instruments. Without accurate readings, it may not be possible to detect a problem early and identify the root cause.

After the problem has been detected, the next step is to localize the problem and to identify the causes. This can be done using the data in the record keeping log sheet or additional online measurements. If the data are not sufficient to determine the causes, one or more membrane elements must be taken out of the system and analyzed using either nondestructive or destructive methods.

System Evaluation

Instrument Calibration

Instrument calibration is the first thing to check during troubleshooting as wrong instrumentation can lead to a false alarm or cause a real increase in salt passage to be missed.

Online TDS meters should be verified by measuring feed and permeate TDS manually with a calibrated TDS meter. If the values do not align, recalibrate the online meter according to the manufacturers' instructions. The probe should also be inspected to ensure proper mounting and make sure that accumulated residual material is not interfering with the reading.

Mechanical pressure gauges should be verified using a calibrated pressure gauge. This can be mounted with a quick-connect fitting. Electronic pressure sensors have the potential for greater accuracy. However, they are subject to sensor drift and damage resulting from vibration of the high-pressure pumps. To reduce the effects of vibration, the sensor can be mounted remotely and connected to the high-pressure piping with a length of stainless steel or high-pressure nylon tubing.

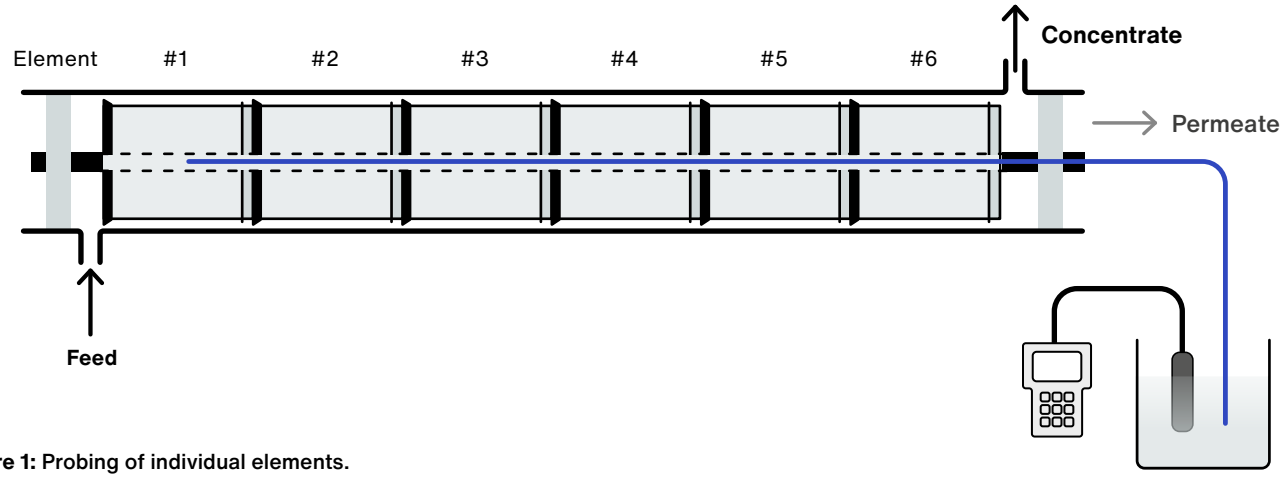

Figure 1: Probing of individual elements.

The pH meters should be verified and, if necessary, calibrated using buffer solutions with a known pH. The temperature readings should be verified with an accurate thermometer.

Visual Inspection

After instrument validation and calibration, a visual inspection of the system is a helpful troubleshooting tool.

The general cleanliness of the RO system should be investigated. Mold and biological growth in tanks and pipes are indicators of biofouling. A wet and slippery surface on the feed side of a pressure vessel indicates biofilm growth. The concentrate side of pressure vessels may show signs of scaling. Torn, damaged, or misplaced O-rings should be replaced immediately.

The efficiency of cleaning agents may indicate the presence of fouling (i.e. if a cleaning solution contains high amounts of foulant when it exits the RO system, fouling is most likely present inside the system). To establish the type of foulant present, analyze and compare samples of the cleaning solution before and after cleaning-in-place (CIP). Please refer to the "Membrane Clean-in-Place (CIP) Guide for Industrial Aquaporin Inside® RO Membrane Elements" for more details.

Localizing High Salt Passage

If an RO system exhibits high salt passage, it is important to localize the source. A drop in salt rejection may be uniform throughout the system, or it could be limited to the front or tail end of the system. It could be a general plant failure, or it could be limited to one or a few individual vessels or elements.

To localize high salt passage, the RO system should be profiled. This requires that the TDS, conductivity, and other relevant quality values are checked on all individual vessels. In a well-designed system, there will be a sample port located in the permeate stream from each vessel where samples can be taken. Care must be taken during sampling to avoid mixing the permeate sample with permeate from other vessels. All permeate samples should be tested with a TDS or conductivity meter to ascertain their concentration of dissolved solids. The permeate samples from all pressure vessels in the same stage should give readings in the same range. Additionally, the feed concentration to each stage must be measured. The resulting salt passage values can then be assigned to the stages and individual vessels, respectively.

If one pressure vessel shows a significantly higher permeate TDS than the other vessels in the same stage, then this vessel should be probed (see **Figure 1**). Probing involves the insertion of a plastic tube (approx. 1/4" for an 8" module) into the full length of the permeate tube. The probe will then divert water from the permeate stream of that vessel when the RO system operates at normal operating conditions. A few minutes should be allowed to rinse out the tubing and allow the RO system to equilibrate. The TDS of the permeate sample from the tubing can then be measured manually. This measurement should reflect the TDS of the permeate being produced by the RO element at that location.

Membrane Element Evaluation

If the causes of plant performance loss are unknown, or they have to be confirmed, one or more elements in the system should be analyzed individually. The element(s) that should be analyzed are those with an increase in their conductivity profile.

When there is a general plant failure, a front-end element or a tail-end element should be selected, depending on where the problem is located. Typical front-end problems are due to fouling; typical tail-end problems come from scaling. Vessels/elements with these problems usually show low permeate flow rate and sometimes a high salt passage from severe fouling and/or scaling.

When the problem cannot be localized, an element from both ends of the system should be taken.

If high salt passage is found only in one or a few elements in one or a few pressure vessels, then it is most likely that the element(s) have mechanical damages, such as punctures on the membrane surface, glue line failure, a cracked membrane centerfold, or damaged O-rings, including brine seals.

Damaged O-rings and brine seals can be verified easily by visually inspecting the failed elements. Damaged membranes and glue line failures can only be visually verified following an autopsy of the elements. Alternatively, physical damages can be verified by running a dye test alongside a salt rejection/flux test by using a small test line containing methylene blue or rhodamine B. If the dye is detected visually or spectroscopically in the permeate, it indicates that there is considerable damage in the membrane or glue line. The element can then be autopsied to assess the cause of the damage.
If membrane damage has been caused by chemicals, such as chlorine or concentrated acid, a high salt passage along with a higher than normal permeate flow rate would occur, usually in all the elements of the first array. If the high dosage of chemicals in the system is not corrected immediately, the membranes in the second array will also be damaged.

Indicators, Causes, and Corrective Measures for Performance Loss

The possible causes of RO system performance decline can be diagnosed through system performance indicators. Normalized permeate flow rate, normalized salt passage, and pressure drop are the three main indicators for identifying the cause of lost membrane performance.

The troubleshooting matrix in **Table 1** shows trends in normalized performance data, their causes and corrective measures, as well as the locations where they commonly occur.

Table 1: RO system troubleshooting guide.

Permeate flow	Salt passage	Pressure drop	Cause	Corrective measure	Usual location
Up	Up*	Stable	Oxidation damage	Replace element Improve pretreatment	1st stage
Up	Up*	Stable	Membrane leak	Replace element	Random
Up	Up*	Stable	O-ring leak	Replace O-ring	Random
Up	Up*	Stable	Leaking product tube	Replace element	Random
Down*	Up	Up	Scaling	Cleaning Scaling control	Last stage
Down*	Up	Up	Colloidal fouling	Cleaning Improve pretreatment	1st stage
Down	Stable	Up*	Biofouling	Cleaning Improve pretreatment	All stages
Down*	Stable	Stable	Organic fouling	Cleaning Improve pretreatment	All stages
Down*	Down	Stable	Compaction	Replace element	All stages

*Main symptom

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