This bulletin explains and quantifies lubrication flow in the PX™ energy recovery device in the context of overall energy recovery device performance and reverse osmosis plant performance. The reader is referred to Energy Recovery, Inc.'s Operations and Maintenance manuals, other technical bulletins and numerous technical papers posted on ERI's website for detailed consideration of the pressure transfer mechanism and the hydraulic performance of PX technology.

Reverse Osmosis with PX Pressure Exchanger Energy Recovery Devices

In a reverse osmosis (RO) system equipped with PX Pressure Exchanger™ (PX™) energy recovery devices, illustrated in Figure 1, the membrane reject [G] is directed to the membrane feed [E]. A rotor, moving between the high-pressure and low low-pressure streams, removes the reject concentrate [G] and replaces it with feed water [B]. Pressure transfers from the high-pressure concentrate stream to a feed stream. The rotor spins freely, driven by the flow at a rotation rate proportional to the flow rate and lubricated by high-pressure process water. Unlimited capacity is achieved by arraying multiple PX devices in parallel.

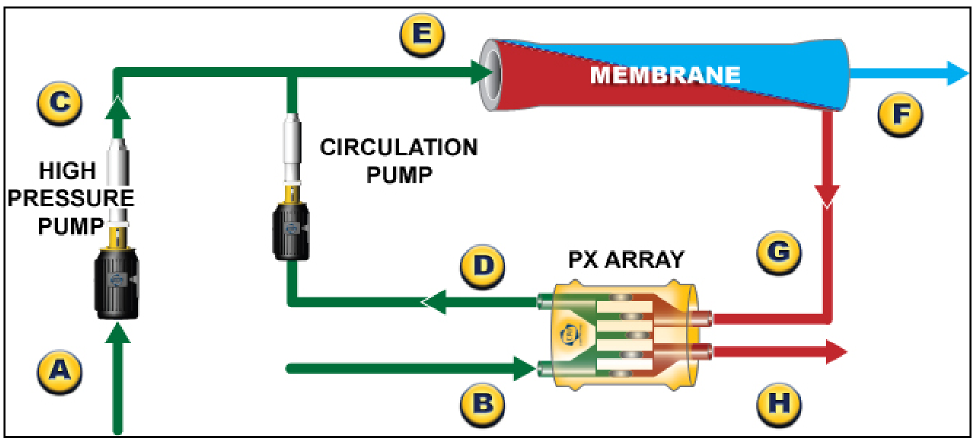

Figure 1 – Schematic Diagram of a Typical PX Device-Equipped RO Process

The PX device seals the high-pressure portion of the RO process as illustrated in Figure 1. The flow rate of permeate [F] nearly equals the flow rate from the high-pressure pump [C]. The pressure with in the high-pressure portion of the process [E-G-D] drives some flow – typically 1 to 2% of the high-pressure pump output – through the PX device to the low-pressure reject stream [H]. This small flow serves an important purpose in the mechanism of the PX device and must be taken into consideration by RO process designers and operators.

Lubrication Flow

A film of water surrounds the rotor within the PX device assembly. This film serves as a hydrodynamic bearing that "floats" the rotor and lubricates its rotation, preventing contact between the rotor and the components that surround it. This film must flow to be renewed while the rotor is turning. This occurs naturally and continuously while the PX device is pressurized.

The lubrication flow rate is a function of the system pressure, the PX device flow rate and the feed water temperature. Figure 2 shows how lubrication flow varies with system pressure for a

PX-220 device. Lubrication flow also increases slightly as the bulk flow rate and water temperature increase.

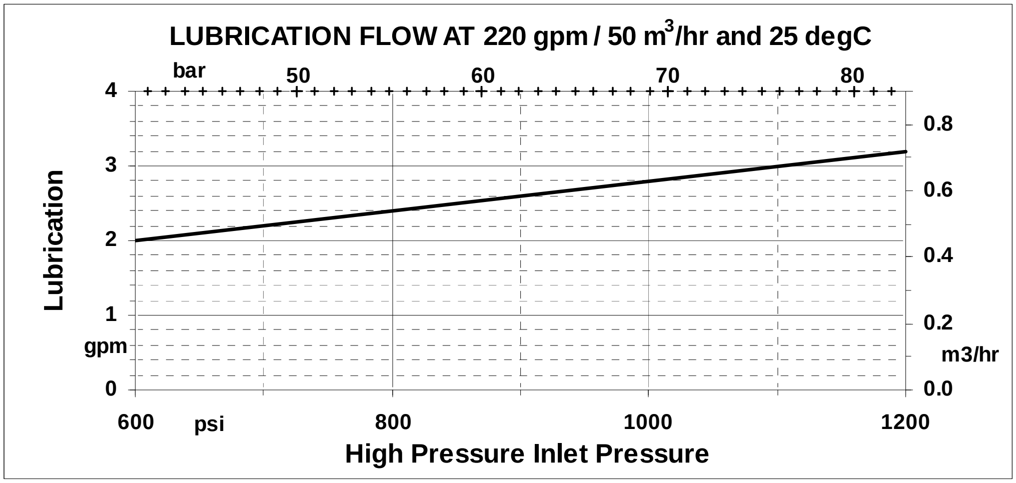

Figure 2 – Typical Lubrication Flow Curve for a PX-220

The lubrication flow rate at seawater RO operating pressures is typically 1 to 2% of the high-pressure pump flow rate. It can be calculated using process measurements and any of the following equations:

(1) Lubrication Flow = high-pressure pump flow rate minus the permeate flow rate [C - F]

(2) Lubrication Flow = PX HP IN minus PX HP OUT [G - D]

(3) Lubrication Flow = PX LP OUT minus PX LP IN [H - B]

Since lubrication flow is a volumetric loss, it affects the efficiency of the PX device. The equation for PX device efficiency in terms of the lubrication flow rate is:

$$\text{EFFICIENCY} = ((F_{HPin} - F_{lube})*P_{HPout} + (F_{LPin} - F_{lube})*P_{LPout}) / (F_{HPin}*P_{HPin} + F_{LPin}*P_{LPin})$$

where F = flow, P = pressure and the subscripts indicate measurement locations around the PX device or device array. Since lubrication flow is provided by the high-pressure pump, lubrication flow needs to be considered when selecting the capacity of the high-pressure pump.

Excess Lubrication Flow

PX devices act as extremely robust and predictable high-pressure seals. Monitoring lubrication flow of a PX device or array is a good way to ensure that the PX device seals are performing properly. If the lubrication flow rate, measured in accordance with the equations above, exceeds about 2% of the total high-pressure pump flow rate, this is an indication of a leak in the high-pressure portion of the process. Lubrication flow is supplied by the high-pressure pump in the RO process, so such a leak is a direct loss of high-pressure pump energy and should be rectified as soon as possible.

Assuming no leaks are visible or otherwise apparent, a high lubrication flow rate is an indication of an internal leak or flow meter error. Such a leak can occur through a valve or through a damaged seal inside a PX device. If a PX device has been disassembled and an o-ring seal has been damaged or incorrectly installed, the resulting leak would be indicated as excess lubrication flow. Alternately, damaged mating surfaces between the rotor and the surrounding ceramic components can allow high-pressure water to leak into the low-pressure regions in the PX device and escape the RO process as a leak. The ceramic material used in PX devices is extremely hard and durable. However, it is possible to damage ceramic with excess flow or low outlet pressure leading to cavitation or with debris in the high- or low-pressure streams feeding the device.

Minimum Lubrication Flow

Lubrication flow is essential in a PX device to assure that the rotor remains lubricated while rotating. Without it, the rotor could come into contact with the ceramic components that surround it, possibly resulting in permanent damage. Ceramic on ceramic contact may occur. Because lubrication flow is passive, there is no direct means to control it. However, because it is pressure-driven, lubrication flow occurs naturally whenever the RO system is pressurized. Caution should be exercised, however, when the RO process is operated without pressure such as during startup, shutdown or flushing.

If the high-pressure pump is not on, the lubrication flow necessary to keep the PX rotor spinning can be provided by osmotic (suck-back) flow through the membranes. However, if the RO process is fully depressurized while flow is being applied to the PX device, the lubrication flow necessary to maintain the hydrodynamic bearing must be either pushed through the high-pressure pump by the supply pump or injected through some other point in the high-pressure loop such as a clean-in-place (CIP) inlet. Typically, the fresh water flush pump provides sufficient head to drive lubrication flow required for successful operation. If the flush water has very low salinity, the lubrication flow may exit the process through the membranes under low trans-membrane pressure. In this case, it may be necessary to block permeate flow to divert lubrication flow through the PX devices.

Conclusions

PX Pressure Exchanger energy recovery devices are lubricated by RO process water. This water forms a hydrodynamic bearing around the PX rotor that minimizes friction between the components, essentially preventing wear. Lubrication flow should be monitored as an indication of the integrity of the high-pressure seals in the RO process, including the seals within the PX device. Lubrication flow occurs naturally, driven by pressure. However, if the RO system is depressurized, the flow necessary to lubricate the rotor may need to be applied deliberately. Lubrication flow serves an important purpose in the mechanism of the PX device and must be taken into consideration by RO process designers and operators.

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