RODataXL Program Manual

January 2015

Hydranautics is pleased to provide our Reverse Osmosis (RO) system performance data management and normalization program. It is recommended that you "normalize" your logged operating data to determine if you have a problem with your system. "Normalization" computer programs, such as RODataXL, graphically represent normalized permeate flow, per cent salt rejection and feed-to-reject pressure drop. These normalized parameters are calculated by comparing a particular day's operations to the first day of operation. Adjustments are made for changes in major operating variables such as temperature, feed TDS, recovery, and pressures. In this way, performance declines unrelated to operating parameters can be identified and treated.

Disclaimer

This normalization program is in compliance with ASTM Standard D 4516-85 "Standard Practice for Standardizing Reverse Osmosis Performance Data".

Operating Notes: The most accurate normalized data is obtained by (1) holding the actual System Operational Data conditions as close as possible to the System Reference Data conditions and (2) by collecting accurate RO data which includes properly calibrated instruments. The true value of normalized data lies not in the calculation of one set of data points but in the trended analysis of these numbers which reflects the impact of fouling on system performance over an extended period of time.

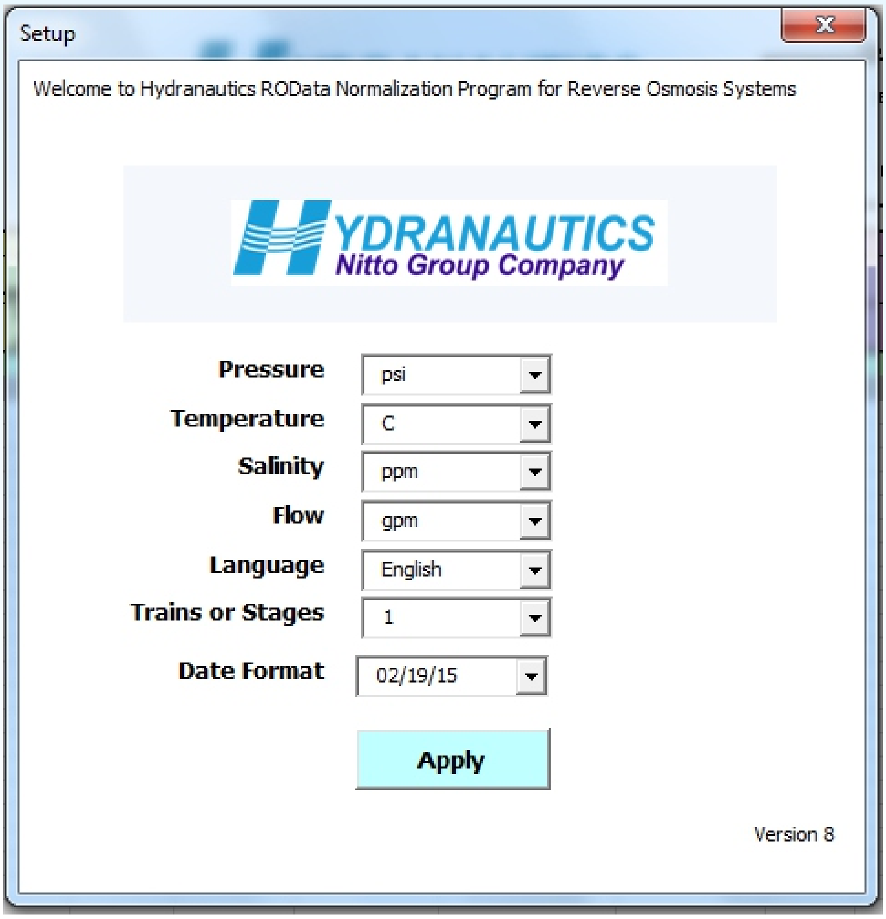
Quick Start: New Project Entry

When you open the RODataXL Microsoft Excel file for the first time, you will:

- Select Display Units to be American or Metric engineering units. The Display Units can not be modified later on in the program so save a copy of the original file. The table below lists the engineering units:

Parameter	American Units	Metric Units
Pressure	psi	bar
Temperature	°F	°C
Salinity	ppm	µS/cm
Flow	gpm	m^3/hr
Element Permeate Flow	gpd	m^3/day

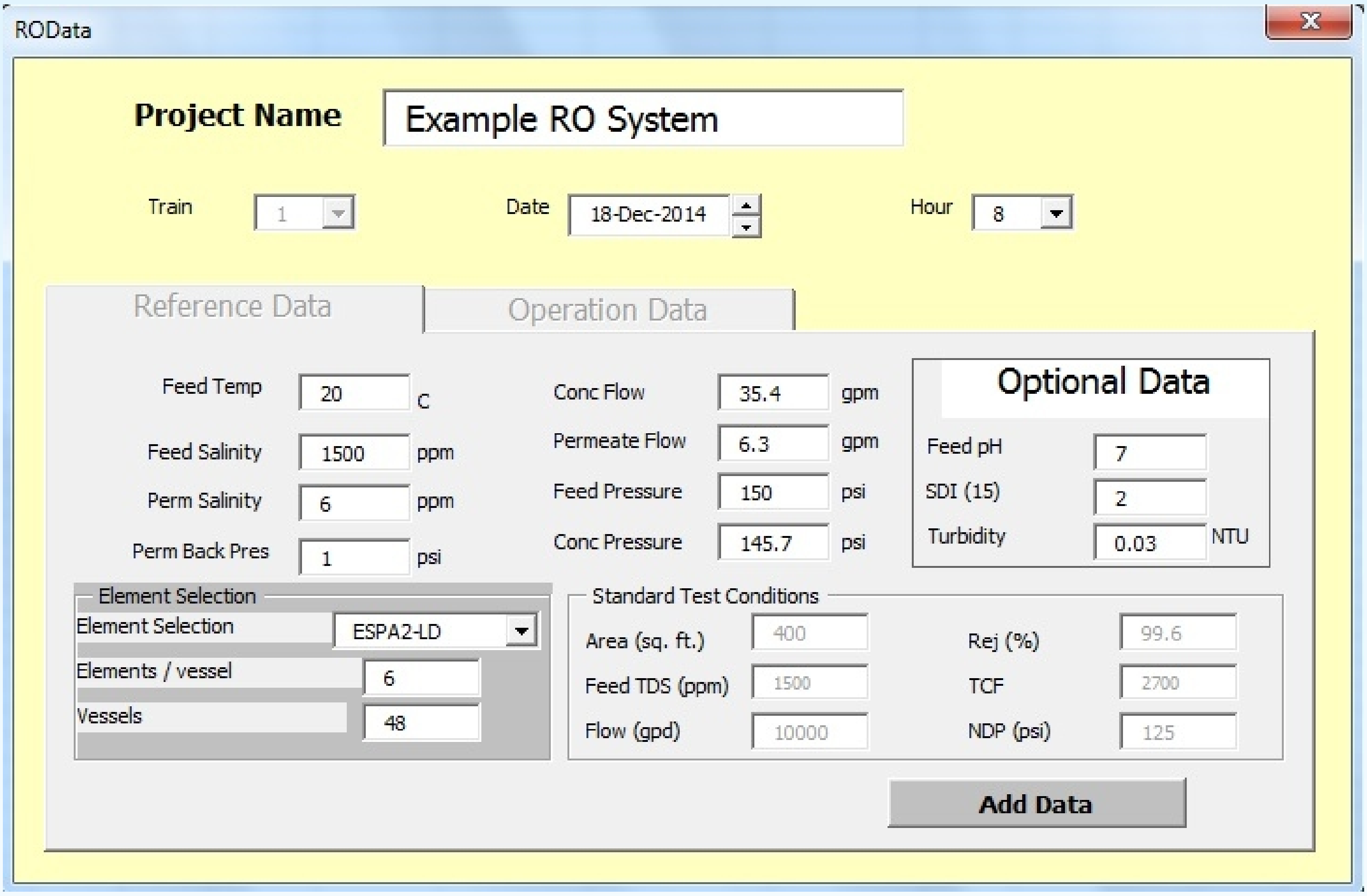
- Select Language
- Select the number of trains or stages in the system
- Select Date Format (10/27/14 or 27/10/14)
- Click Apply



Reference Data

This brings up the System Reference Data entry screen for your new project. Only one set of System Reference Data is allowed for each Train or Stage of a Project.

Note: The data entered in this screen is very important to the calculation of normalized data as it is the base point from which all other operational data points in the future will be referenced to. The RO system should be allowed to reach a stable operation, which usually occurs within the first day or two after start-up.



Train or Stage (XX): Identify the train or stage using numbers. You can have any number of Trains or Stages you want for a Project, with each Train or Stage having its own System Reference Data.

Date (XX/XX/XX): Enter the date by using the drop-down calendar or by manual entry.

Hour (XX): Enter the hour the data point was logged using military time of 0 to 23 hours.

Note: The Reference Data section items listed below are used in the calculation of system Normalized Permeate Flow, Normalized % Salt Passage, and Normalized Delta P. The Element section items listed after the Reference Data section are used in the normalization calculations of the Water Transport Coefficient and Salt Transport Coefficient. The Normalized Permeate Flow and Normalized % Salt Passage in most cases is a better indicator of actual system performance as they are based on the actual "real-world" initial operation of the elements at the site

Feed Temp (XXX.X): Enter the temperature of the RO feed. The temperature range allowed is 33 to 122°F or 1 to 50°C.

Note: The correct feed temperature is absolutely essential for the generation of meaningful normalized data due to its significant impact on feed pressures and permeate quality.

Feed Salinity (XXXXX.X): Enter the salinity of the RO feed as it enters the 1st stage of the RO. The feed salinity is a measurement of the TDS (Total Dissolved Salts) content and is reported as **ppm** (American) or **µS/cm** (Metric). PPM (Parts per Million) is also known as **mg/l** (milligrams per liter). MicroSiemens/cm (µS/cm) is also known as micromhos/cm (µmhos/cm) in parts of the world.

Perm Salinity (XXXXX.X): Enter the salinity of the RO permeate. The Permeate Salinity is a measurement of RO permeate quality and is reported as **ppm** or **µS/cm**. The Permeate Salinity has to be a lower value than the Feed Salinity.

Perm Back Pressure (XXXX.X): Enter the Permeate Back Pressure as it leaves the RO. American units are **psi** (Pounds per Square Inch) and Metric units are **bar**.

Note: The Permeate Back Pressure reading is important in that it is subtracted from the Feed Pressure and Concentrate Pressure for the calculation of NDP (Net Driving Pressure). The Net Driving Pressure is the remaining feed pressure available to force water through the membrane once osmotic back-pressure and permeate back-pressure have been overcome.

Conc Flow (XXXX.X): Enter the concentrate flow of the RO. Concentrate flow is also known as Reject or Brine flow. American units are **gpm** (Gallons Per Minute) and Metric units are **m3/hr** (Cubic Meters per Hour).

Perm Flow (XXXX.X): Enter the permeate flow of the RO. Permeate flow is also known as Product flow. American units are **gpm** (Gallons Per Minute) and Metric units are **m^3/hr** (Cubic Meters per Hour).

Note: The Feed flow is calculated by the program by adding up Concentrate flow plus Permeate flow.

Feed Pressure (XXXX.X): Enter the Feed Pressure as it enters the 1st stage of the RO. American units are **psi** (Pounds per Square Inch) and Metric units are **bar**.

Conc Pressure (XXXX.X): Enter the Concentrate Pressure as it exits the last stage of the RO. American units are **psi** (Pounds per Square Inch) and Metric units are **bar**.

Note: The Concentrate Pressure is subtracted from the Feed Pressure by this program to determine the Delta P (Pressure Drop) of the system. In the situation where the user uses a Delta P gauge to monitor the feed-to-concentrate pressure drop, it is recommended to log the feed pressure gauge reading and that the concentrate pressure is logged by the operator by deducting the Delta P from the feed pressure. An increase in the calculated Pressure Drop is an indication of fouling of the feed spacer.

Optional Data: Feed pH, SDI, and Turbidity are optional data. These data are not used in normalization calculations; however, you may want to record these data for future trouble-shooting purposes.

Feed pH (XX.X): Enter the pH of the RO feed as it enters the 1st stage of the RO. The pH range allowed for entry is 1 to 14.

SDI (15) (XX.X): Enter the Silt Density Index value at 15 minutes of the RO feed.

Turbidity (XX.X): Enter the turbidity value in NTUs

Element Type: Select the model of the RO element from the drop down screen. The Standard Test Conditions screen will automatically be filled in when an element is selected. The Standard Test Conditions data for the listed elements cannot be modified.

# of Elements/Vessel (XXX): Enter the Number of RO Elements per Pressure Vessel. Normally the maximum is eight elements per vessel.

# of Pressure Vessels (XXX): Enter the total Number of RO Pressure Vessels for the entire Train or Stage. The program calculates the system flux by multiplying the # of Elements/Vessel by the # of Pressure Vessels by the available membrane area of each element.

Add: By clicking on the Add button, the System Reference Data is recorded and the file is formed for the new Train or Stage of this Project. The user can proceed to entering System Operational Data once the System Reference Data has been entered.

Continue to add data by clicking the Data Entry button in the top left corner of the spreadsheet (Cell A1).

Normalization Calculations

Units for Calculation: When only one unit is designated for a parameter, for example 0°C, then the subsequent calculations require that only that unit be used to achieve the correct value. When two units are designated, for example gpm or m^3/hr, then American or Metric values can be used for subsequent calculations but you must stay with either American or Metric to achieve the correct values.

The value of the RODataXL Normalization Program by Hydranautics becomes apparent after a review of the calculations performed. However, the user should remember that the true value of normalized data lies not in one set of data but in the trended values of the normalized data over time.

Equations used in the program are listed in the spread sheet under the “Help File” tab. These equations match the code which can be viewed by entering visual basic and going to the main module “ModMain” and going to the subroutine “Formulas”

Graphs

The operator can choose to view a number of graphs of the system operating data and normalized data. The graphs are automatically generated and the data is plotted relative to time. If there is more than one set of data for a particular day, the data set with the lowest Hour value will be plotted. The graphs plot a straight line between data points.

The graph types include:

- **Permeate Flow vs. Time:** This graph plots the actual permeate flow in **gpm** or **m^3/hr**.
- **Feed Pressure vs. Time:** This graph plots the actual RO feed pressure in **psi** or **bar**.
- **Permeate Salinity vs. Time:** This graph plots the actual permeate salinity (quality) in **ppm** or **µS/cm**.
- **Salt Passage vs. Time:** This graph plots the actual per cent salt passage for the entire system. The calculated value is the actual permeate salinity divided by the "average" salinity of the RO feed and concentrate. The average feed salinity calculation estimates the concentrate salinity based on system recovery and then calculates the "arithmetic average" of the feed and concentrate salinity.

  Note: The % Salt Passage in this case is not simply permeate salinity divided by feed salinity.

- **Normalized Salt Passage vs. Time:** This graph plots the normalized per cent salt passage of the system relative to the System Reference Data at start-up.
- **Normalized Permeate Flow vs Time:** This graph plots the normalized permeate flow in gpm or m^3/hr, relative to the System Reference Data at start-up.
- **Normalized Delta P vs. Time:** This graph plots the normalized feed-to-concentrate pressure drop in psi or bar relative to the System Reference Data at start-up. The normalized Delta P value reflects adjustments to pressure drop due to varying feed and concentrate flows.
- **Salt Transport Coefficient vs. Time:** This graph plots Salt Transport Coefficient **(STC)** for "membrane technophiles". The importance of this number is that it measures the efficiency of the membrane in how fast it allows the passage of salts. **The value is reported as m/sec (meters per second).** This number allows the comparison of membranes from site to site, independent of what the on-site operating conditions are. This number will be affected by changes in the ionic makeup of the feed water. For example, an increase in divalent ions (like hardness or sulfate) will result in a lower Salt Transport Coefficient.
- **Water Transport Coefficient vs. Time:** This graph plots the Water Transport Coefficient **(WTC)** for "membrane technophiles". The importance of this number is that it measures the efficiency of the membrane in how fast it allows the passage of water. **The value is reported as m/sec-kPa (meters per second per kilopascal.** This number allows the comparison of membranes from site-to-site, independent of what the on-site operating conditions are.

What Is Normalization?

The majority of Reverse Osmosis (RO) systems normally will operate under fairly steady conditions over long periods of time if operating parameters remain constant, fouling does not occur, and membrane damage is avoided. Unfortunately, operating parameters (e.g. temperature, feed TDS, permeate flow, recovery) do change and fouling of the membrane and element feed path can occur. Complicating the issue of determining whether the RO is performing as expected is that more than one operating parameter may change. The value of a Normalization Program is the ability to recalculate the instantaneous system performance at some point in time and compare its performance to the Reference Data operating conditions. Stated another way, if you were to remove the RO elements at some point in time (say 100 days after start-up) and replace the new RO elements you used on the day you started up, you could project what the permeate flow and quality would have been using the aged elements. If these 100 day old elements resulted in a lower flow or poorer quality permeate, you could draw the conclusion that they are fouled or damaged in some fashion.

The following changes in operating parameters will decrease the actual permeate flow of a system:

- A decrease in feed water temperature with no change in feed pump pressure.
- A decrease in RO feed pressure by throttling down the feed valve.
- An increase in permeate back pressure with no change in feed pump pressure.
- An increase in the feed TDS (or conductivity) since this increases the osmotic pressure that has to be overcome to permeate water through the membrane.
- An increase in the system recovery rate. This increases the average feed/concentrate TDS which then increases the osmotic pressure.
- Fouling of the membrane surface.
- Fouling of the feed spacer that results in an increase of feed-to-concentrate pressure drop (delta P) which starves the back-end of the system of net driving pressure (NDP) to produce permeate water.

The following changes in operating parameters will result in actual lower quality permeate water, as indicated by an increase in permeate TDS as ppm or conductivity:

- An increase in feed water temperature with the system adjusted to maintain the same permeate flow (or flux).
- An decrease in the system permeate flow, which reduces the water flux, and results in less permeate water to dilute the amount of salts that have passed through the membrane.
- An increase in the feed TDS (or conductivity) since the RO will always reject a set percentage of the salts.
- An increase in the system recovery rate since this increases the average feed/concentrate TDS of the system.
- Fouling of the membrane surface.
- Damage to the membrane surface which allows more salts to pass.

The changes in operating parameters that were listed above that resulted in the reduction of permeate flow and quality are normal and would have been projected to occur with normalized data, except for changes due to membrane fouling, membrane damage or fouling of the element's feed spacer.

Normalized data that is graphed will show not only the instantaneous condition of the RO system at any given time, but also shows the detailed operating history. These graphs can be a useful tool for troubleshooting.

The normalized data presented in the Hydranautics RODataXL Normalization program are:

- **Normalized Salt Passage vs. Time:** This graph plots the normalized per cent salt passage of the system relative to the System Reference Data at start-up.

- **Normalized Permeate Flow vs Time:** This graph plots the normalized permeate flow in gpm or m^3/hr, relative to the System Reference Data at start-up.

- **Normalized Delta P vs. Time:** This graph plots the normalized feed-to-concentrate pressure drop in PSI or Bar relative to the System Reference Data at start-up. The normalized Delta P value reflects adjustments to pressure drop due to varying feed and concentrate flows.

- **Water Transport Coefficient vs. Time:** This graph plots the Water Transport Coefficient (WTC) for "membrane technophiles". The importance of this number is that it measures the efficiency of the membrane in how fast it allows the passage of water. The value is reported as m/sec-kPa (meters per second per kilopascal. This number allows the comparison of membranes from site-to-site, independent of what the on-site operating conditions are.

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Action should be taken before the normalized data shows the following changes from start-up

- Normalized permeate flow decrease is greater than 10%

- Normalized permeate quality decrease is greater than 10%

- Normalized pressure drop, as measured between the feed and concentrate headers, increase is greater than 15%

Any one of these changes in normalized data may indicate membrane fouling. Hydranautics recommends troubleshooting by downloading our Technical Service Bulletin 107 – Foulants and Cleaning Procedures for composite polyamide RO membrane elements (ESPA, ESNA, CPA, LFC, NANO, and SWC) from our website www.membranes.com.