REVERSE OSMOSIS (R.O.) UNITS

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CONTENTS

1. INTRODUCTION

1.1 Health and Safety

The R.O. Units use Sodium Bisulphite, Membrane Anti-Scalant and Cleaning-in-Place chemicals for their operation.

See O&M Section 1-07 'Bulk Chemical Handing Systems' for all health and safety instructions, particularly Section 1.4.

The R.O. Units operate at high pressures.

1.2 Reference Documents

See:

- Flow Diagrams - Drawing Nos. CU0464-0001-001 to 021

- Section 1-01 - Water Treatment Plant (WPP) Overview
- Section 1-02 - Actiflo Clarifier & Polymer Makeup Unit
- Section 1-03 - OSFY Multimedia Filters and Poly. Dosing
- Section 1-05 - Rapide / Hipol Three-Bed Demineralisers
- Section 1-06 - Chemical Preparation & Dosing Systems
- Section 1-07 - Bulk Chemical Handling Systems
- Section 1-08 - Motor Control Centre (M.C.C.)
- Section 1-09 - WPP Controls / PLC / HMI
- Section 1-10 - Instrumentation and Process Controls
- Section 1-11 - Manual Operations for Plant Operators
- Section 1-12 - WPP alarms
- Section 1-13 - Fault Finding
- Section 1-14 - Preventative Maintenance
- Section 1-15 - Consumables Schedule
- Section 1-16 - R.O. Normalisation and Cleaning-in-Place (C.I.P.)

- Volumes 2 & 3 - Actiflo AS3 Clarifier & Polymer Makeup Unit Manuals
- Volumes 4 & 5 - Igranic Control Systems
- Volumes 6 - Elga Water Treatment Plant Record Drawings
- Volumes 7 to 11 - Manufacturers' Proprietary Literature
- Volume 12 - Software

1.3 Cleaning-in-Place (C.I.P.)

See:

- Section 1-16 - R.O. Normalisation and Cleaning-in-Place (C.I.P.) Item 3

2. R.O. OPERATION

2.1 Introduction

See drawing numbers: CU0464-0001-010 to -013

2.1.1 Four identical R.O. Unit streams have been provided.

2.1.2 The inlet (feed) supply is filtered by the OSFY Multimedia Duplex Filters – see O&M Volume 1-03.

2.1.3 Treated water (Permeate) from the R.O. Units is supplied to the Degasser Tower.

2.1.4 Concentrate (Reject) wastewater is discharged to the sites drainage system.

2.2 Service (Online)

2.2.1 The common filtered water from the Filtered Water Tank / Filtered Water Pumps are first monitored for conductivity and temperature. Too high water temperature will increase the R.O. Unit's performance – increases the permeate flow – but decreases the usable life of the membranes. Too low water temperature reduces permeate flow. High conductivity reduces the R.O. Unit's performance.

2.2.2 The individual stream feed is then dosed with a R.O. membrane Anti-Scalant to minimise scale deposits within the actual membranes and to keep any suspended solids in a 'mobile' condition – see 2.9.

2.2.3 The feed flow is then filtered down to 10 microns by a Cartridge Filter to minimise membrane fouling by particulates.

2.2.4 The filtered feed water is then dosed with Sodium Bisulphite (see 2.9) to destroy any remaining chlorine (sodium hypochlorite). Chlorine permanently damages the plastic reverse osmosis membranes. ORP/Redox potential measurement is used to check the effectiveness of the de-chlorination.

2.2.5 The dosed filtered feed water then passes to the High Pressure (H.P.) R.O. Feed Pump – see 2.10.

2.2.6 Feed water at high pressure (typically 19 barg) is supplied to the first R.O. stage (#1).

2.2.7 The R.O. process comprises ***two stages*** in a **6:3 membrane** array (M1 to M6:M7 to M10) configuration. Each membrane housing / tube contains ***six*** individual R.O. membranes connected in series.
Provision has been made to increase the number of membrane housings / tubes to an **8:4 membrane array** configuration.

2.2.8 Permeate from all membrane housings/ tubes are ***connected in parallel*** and flow via Permeate flow transmitter and conductivity transmitter to the following Degasser Tower. To check the operating efficiency each permeate line is provided with a separate sample valve.

2.2.9 The stage arrays are ***connected in series*** the reject from Stage #1 passing to the feed of Stage #2. Finally the reject from Stage #2 flows to waste via a modulating Concentrate (Reject) valve and flow transmitter.

2.2.10 The Concentrate (Reject) backpressure is controlled a modulated pneumatically operated valve – with positioner –see 2.11.

Time: As required

Automatic Valves Open – SERVICE (ONLINE)				
Equipment	**Stream 1**	**Stream 2**	**Stream 3**	**Stream 4**
R.O. Inlet	1RO2	2RO2	3RO2	4RO2
Permeate Outlet	1RO6 (1)	2RO6 (1)	3RO6 (1)	4RO6 (1)
Concentrate (Reject) Outlet	1RO9 (2)	2RO9 (2)	3RO9 (2)	4RO9 (2)
Degasser Tower Inlet	V080 (3)			
Filtered Water Pump	PM104	PM204	PM304	PM404
R.O. High Pressure (H.P.) Feed Pump	PM105 (4)	PM205 (4)	PM305 (4)	PM405 (4)
Sodium Bisulphite Dosing Pump	PM106A or PM106B	PM206A or PM206B	PM306A or PM306B	PM406A or PM406B
Anti-Scalant Dosing Pump	PM107A or PM107B	PM207A or PM207B	PM307A or PM307B	PM407A or PM407B

(1) *Mechanically linked to Permeate Flush valve 1RO13 /2RO13 / 3RO13 / 4RO13.*
(2) *Modulated – see 2.10*
(3) *Mechanically linked to R.O. Permeate Recycle valve V081*
(4) Variable speed – see 2.9

2.3 R.O. in Recycle

See also drawing number: CU0464-0001-014

2.3.1 If demineralised water demand – from site – is low, when the water in the Degasser Sump reaches a preset high level the Service (Online) R.O. streams are placed into an ***external recycle*** condition.

2.3.2 The R.O. Units remain in their normal service conditions (see 2.2), except that the Sodium Bisulphite and Anti-Scalant dosing is switched off.

2.3.3 The Degasser Tower inlet linked valves V80/V81 change-over and ***permeate*** is recycled back to the Filtered Water Tank where it is again pumped through the Service (Online) R.O. Units.

2.3.4 The purity of the R.O. feed water increases during the 'R.O. in Recycle' eliminating the need for Sodium Bisulphite and Anti-Scalant dosing.

2.3.5 On demand from the Degasser Sump level the system reverts back to the normal Service condition – see 2.2.

Time: As required

Automatic Valves Open – RECYCLE				
Equipment	**Stream 1**	**Stream 2**	**Stream 3**	**Stream 4**
R.O. Inlet	1RO2	2RO2	3RO2	4RO2
Permeate Outlet	1RO6 (1)	2RO6 (1)	3RO6 (1)	4RO6 (1)
Concentrate (Reject) Outlet	1RO9 (2)	2RO9 (2)	3RO9 (2)	4RO9 (2)
R.O. Permeate Recycle	V081 (3)			
Filtered Water Pump	PM104	PM204	PM304	PM404
R.O. High Pressure (H.P.) Feed Pump	PM105 (4)	PM205 (4)	PM305 (4)	PM405 (4)

(1) *Mechanically linked to Permeate Flush valve 1RO13 / 2RO13 / 3RO13 / 4RO13.*
(2) *Modulated – see 2.10*
(3) *Mechanically linked to Degasser Inlet valve V080*
(4) Variable speed – see 2.9

2.4 Low Pressure Flush on Shutdown

2.4.1 When there is no demand for R.O. Permeate – Degasser Sump full, and following an extended period in Recycle – the R.O. Unit has to be flushed before being shutdown and placed into the Standby condition.

2.4.2 The R.O. membranes are full of highly concentrated feed water that during the Shutdown (Standby) period could precipitate resulting in fouled membranes. This could increase the need to carry out Cleaning-in-Place (C.I.P.).

2.4.3 The R.O. H.P. Pump is slowly set to zero speed. The associated stream Filtered Water Pump remains running.

2.4.4 The Concentrate (Reject) Flush valve is opened and dosed feed water at low pressure flushes away the highly concentrated feed water within the R.O. membranes to drain. The little or no Permeate flow / production at low pressure, flows to drain.

2.4.5 When the conductivity is low or when the set period is complete the R.O. Unit is placed into the Standby (Shutdown) condition – see 2.5.

Time: 5 minutes, conductivity controlled

Automatic Valves Open – LOW PRESSURE FLUSH on SHUTDOWN				
Equipment	**Stream 1**	**Stream 2**	**Stream 3**	**Stream 4**
R.O. Inlet	1RO2	2RO2	3RO2	4RO2
Permeate Flush	1RO13 (1)	2RO13 (1)	3RO13 (1)	4RO13 (1)
Concentrate (Reject) Flush	1RO8	2RO8	3RO8	4RO8
Concentrate (Reject) Outlet	1RO9 (2)	2RO9 (2)	3RO9 (2)	4RO9 (2)
Filtered Water Pump	PM104	PM204	PM304	PM404
Sodium Bisulphite Dosing Pump	PM106A or PM106B	PM206A or PM206B	PM306A or PM306B	PM406A or PM406B
Anti-Scalant Dosing Pump	PM107A or PM107B	PM207A or PM207B	PM307A or PM307B	PM407A or PM407B

(1) *Mechanically linked to Permeate Outlet valve 1RO6 / 2RO6 / 3RO6 / 4RO6.*
(2) *Modulated – see 2.10*
(3) Variable speed – see 2.9

2.5 Standby

2.5.1 The R.O. Unit remains in this condition until there is demand for degassed water.

Time: As required

Automatic Valves Open – STANDBY				
Equipment	**Stream 1**	**Stream 2**	**Stream 3**	**Stream 4**
R.O. Inlet	None			
Permeate Outlet	1RO6 (1)	1RO6 (1)	1RO6 (1)	1RO6 (1)
Concentrate (Reject) Outlet	None			
Filtered Water Pump	None			
R.O. High Pressure (H.P.) Feed Pump				
Sodium Bisulphite Dosing Pump				
Anti-Scalant Dosing Pump				

(1) Mechanically linked to Permeate Flush valve 1RO13 / 2RO13 / 3RO13 / 4RO13.

2.6 Low Pressure Rinse

2.6.1 On demand for degassed water the Standby R.O. Unit needs to be flushed to make it ready for service operation.

2.6.2 The pre-service flushing comprises 3 stages:

- i) Low Pressure Rinse – see below
- ii) High Pressure Rinse – see 2.7
- iii) Pre-Service Rinse – see 2.8

2.6.3 The Low Pressure rinse is similar to the Low Pressure Flush prior to shutdown.

Time: 2 minutes

Automatic Valves Open – LOW PRESSURE RINSE				
Equipment	**Stream 1**	**Stream 2**	**Stream 3**	**Stream 4**
R.O. Inlet	1RO2	2RO2	3RO2	4RO2
Permeate Flush	1RO13 (1)	2RO13 (1)	3RO13 (1)	4RO13 (1)
Concentrate (Reject) Flush	1RO8	2RO8	3RO8	4RO8
Concentrate (Reject) Outlet	1RO9 (2)	2RO9 (2)	3RO9 (2)	4RO9 (2)
Filtered Water Pump	PM104	PM204	PM304	PM404
Sodium Bisulphite Dosing Pump	PM106A or PM106B	PM206A or PM206B	PM306A or PM306B	PM406A or PM406B
Anti-Scalant Dosing Pump	PM107A or PM107B	PM207A or PM207B	PM307A or PM307B	PM407A or PM407B

(1) Mechanically linked to Permeate Outlet valve 1RO6 / 2RO6 / 3RO6 / 4RO6.
(2) Modulated – see 2.10
(3) Variable speed – see 2.9

2.7 High Pressure Rinse

2.7.1 Following the Low Pressure Rinse the R.O. H.P. Pump is enabled.

2.7.2 The little or no Permeate flow / production at low pressure, flows to drain.

Time: 1 minute

Automatic Valves Open – HIGH PRESSURE RINSE				
Equipment	**Stream 1**	**Stream 2**	**Stream 3**	**Stream 4**
R.O. Inlet	1RO2	2RO2	3RO2	4RO2
Permeate Flush	1RO13 (1)	2RO13 (1)	3RO13 (1)	4RO13 (1)
Concentrate (Reject) Flush	1RO8	2RO8	3RO8	4RO8
Concentrate (Reject) Outlet	1RO9 (2)	2RO9 (2)	3RO9 (2)	4RO9 (2)
Filtered Water Pump	PM104	PM204	PM304	PM404
R.O. High Pressure (H.P.) Feed Pump	PM105 (3)	PM205 (3)	PM305 (3)	PM405 (3)
Sodium Bisulphite Dosing Pump	PM106A or PM106B	PM206A or PM206B	PM306A or PM306B	PM406A or PM406B
Anti-Scalant Dosing Pump	PM107A or PM107B	PM207A or PM207B	PM307A or PM307B	PM407A or PM407B

(1) *Mechanically linked to Permeate Outlet valve 1RO6 / 2RO6 / 3RO6 / 4RO6*
(2) *Modulated – see 2.10*
(3) *Variable speed – see 2.9*

2.8 Pre-Service Rinse

2.8.1 The R.O. Unit is now operated as if it was in the service condition, except that the little or no Permeate flow / production at low pressure, flows to drain.

2.8.1 When the conductivity is below the normal operating limit the R.O. Unit is placed into the Service condition.

Time: 6 minutes, conductivity controlled

Automatic Valves Open – PRE-SERVICE RINSE				
Equipment	**Stream 1**	**Stream 2**	**Stream 3**	**Stream 4**
R.O. Inlet	1RO2	2RO2	3RO2	4RO2
Permeate Flush	1RO13 (1)	2RO13 (1)	3RO13 (1)	4RO13 (1)
Concentrate (Reject) Outlet	1RO9 (2)	2RO9 (2)	3RO9 (2)	4RO9 (2)
Filtered Water Pump	PM104	PM204	PM304	PM404
R.O. High Pressure (H.P.) Feed Pump	PM105 (3)	PM205 (3)	PM305 (3)	PM405 (3)
Sodium Bisulphite Dosing Pump	PM106A or PM106B	PM206A or PM206B	PM306A or PM306B	PM406A or PM406B
Anti-Scalant Dosing Pump	PM107A or PM107B	PM207A or PM207B	PM307A or PM307B	PM407A or PM407B

(1) *Mechanically linked to Permeate Outlet valve 1RO06 / 2RO06 / 3RO06 / 4RO06.*
(2) Modulated – see 2.10
(3) Variable speed – see 2.9

2.9 Dosing

See also O&M Section 1-06

2.9.1 Each R.O. Unit stream is supplied with Sodium Bisulphite and Anti-Scalant dosing systems.

2.9.2 Each dosing system is provided with duplex Dosing Pumps.

2.9.3 Chemical preparation is a manual operator operation

2.10 H.P. (High Pressure) Feed Pumps

2.10.1 One pump is provided for each R.O. stream – PM105/PM205/PM305/PM405.

2.10.2 The R.O. H.P. Pump motor is fitted with a Variable Speed Drive (VSD / Inverter):

2.10.3 The R.O. H.P. Pump motor speed controls the feed pressure to the inlet of membrane Stage #1, monitored by Pressure Transmitter PIT114 / PIT214 / PIT314 / PIT414.

2.10.4 The pump speed is varied to maintain a preset pressure, value set in software.

2.10.5 The control parameters are operator settable – within limits – via the Human Machine Interface (HMI) – see O&M Section 1-09

2.11 Modulated Concentrate (Reject) Valves

2.11.1 These are pneumatically operated ported slide valves. The actuators are fitted with current to pneumatic controllers and positioners.

2.11.2 The valve position is controlled by 4-20mA analogue signals from the PLC. The valve position maintains the required design Recovery for varying feed temperatures – see Process Data – 7.

2.11.3 The control parameters are operator settable – within limits – via the Human Machine Interface (HMI) – see O&M Section 1-09.

2.11.4 Condensate (Reject) Valves – 1RO9/2RO9/3RO9/4RO9 operate as follows:-

Operation:	Modulated to maintain a recovery of between 73% to 70% for a temperature range of between 5^0 to 27^0 Celsius.
Shutdown (Standby):	Fully open
Cleaning-in-Place (C.I.P.):	Fully closed

3. CLEANING-IN-PLACE (C.I.P.)

3.1 R.O. Normalisation – see O&M Section 1-16

This sets the limits on flow, pressure and / or quality for when a C.I.P. is required. This is based on trails and variations in feed water qualities, and can change with time or demand.

3.2 C.I.P.

See O&M Section 1-16 for full details

4. SILT DENSITY INDEX (SDI) TESTING - see Figure 1.

(Sometimes referred to as fouling index or pluggage test)

4.1 SDI

4.1.1 The SDI is calculated from the percentage of flow decay over a period of time through a 0.45µ (micron) Millipore filter at 2 barg (30 psi) applied water pressure. There is almost a direct relationship between the Silt Density Index number and the rate at which colloidal and particulate fouling will occur. Due to the fact that large particulates in tap water effect the SDI the least when compared to the rapid pluggage typically caused by smaller particles and colloids when filtering through a 0.45µ filter, it is assumed that the test is mostly a measurement of colloidal concentration. The SDI warranty requirements for RO Membranes are as follows:

4.1.2 Hollow Fibre/Composite - Maximum SDI = 5.0

4.2 Symptoms Caused by Excessively High SDI

4.2.1
- i) Excessive decrease in rated permeate flow vs. time.
- ii) Increase in membrane feed pressure versus Reject (Concentrate) pressure differential.
- iii) Loss of percent salt Reject (Concentrate)ion.

Effect: Blockage of the Reject (Concentrate) and product channels.

4.2.2 IMPORTANT - CAUTION:

Colloidal/particulate fouling can induce many other causes of membrane failure due to uneven flow distribution and concentration factors within the cartridge.

4.3 Suggested Remedies

1. Ultrafiltration
2. Softener *
3. Sand prefiltration
4. Carbon prefiltration
5. Nominal micron prefilters
6. Manganese greensand
7. Flocculation/Filtration

* *Does not reduce the SDI, but may reduce fouling of the membrane by stabilising colloids.*

4.4 Equipment Required

4.4.1 To perform the pluggage test, you will need a Fouling Index Test Kit. This kit should contain a Millipore Filter Disc Holder, pressure regulator, pressure gauge, tweezers, filter discs, valves and fittings required to test for Fouling Index (Silt Density Index). You will need to provide your own timing device (stop watch or watch with second hand). Figure 1 illustrates the typical test kit apparatus.

4.5 Test Procedure

See also drawing number: CU0464-0001-005

1. Connect up the SDI tester to the OSFY Multimedia Duplex Filters common outlet sample valve ***V658***. Any R.O. Unit should be running at its correct feed flow rate when running the SDI, or the final test results will be invalid.

2. Hook up the SDI tester without a 0.45μ filter in it.

3. Turn on the water and open the valve on the tester. Allow water to flow through the tester for several minutes to flush out the tester and the tubing and valve that may be feeding it.

4. Close the valve on the tester and using tweezers place a 0.45μ white Millipore filter (shiny side up) in the filter holder and gently tighten the thumb nuts to hold it in the housing.

5. Partially open the sample valve and, while water is flowing through the tester, slowly unscrew one or two of the thumbnuts and allow water to flood the filter housing and flow out of the filter cavity to expel all air.

6. With the water still flowing out of the filter cavity gently retighten the screws once you are sure that there is not air entrapped in the filter housing. Open the valve fully and adjust the pressure regulator so that the pressure reads 2 barg (30 psi). Once you have the pressure set, turn off the sample valve.

7. Use a suitable container to collect the water sample. The actual volume is not important, as long as the same volume is used throughout the test. Any volume between 100 and 500ml can be used. Various containers have been used such as cylinders, beakers, coffee cups, Coke bottles, etc.

8. Open the sample valve fully and with a stopwatch immediately measure the time required to collect a volume of 100 ml and record that time as T(0) = ___ sec., leaving the valve open and the water flowing after the 100 ml mark has been reached.

9. Allow the water to keep flowing and, immediately at five minutes of elapsed test time, measure the amount of time in seconds it takes to fill the graduated cylinder to the 100 ml mark and record as T(5) = ___ sec., leaving the sample valve ***V658*** open and the water flowing.

Repeat this procedure at ten minutes and fifteen minutes of elapsed test time. After the T(15) time measurement has been made, the test can be stopped and the index calculated, although on some waters it may be desirable to continue the test to T(20), T(30) etc. Some tests have been run to T(60) although this is very unusual.

a) CALCULATION

1. Check that the value for the starting time divided by the 15 minute time is greater than 0.2. If it is not, then see later Section on High Index Water.

2. Deduct the above value from 1 and then multiply by 100.

3. Divide by 15 to obtain the Silting Index/Fouling Index value.

Silting Index/Fouling Index =

$$\frac{\left[1 - \frac{t_0}{t_f}\right] \times 100}{T_f}$$

Where :

to = time (in seconds) for the collection of the initial 100 ml

tf = time (in seconds) for the collection of the 100 ml sample at time Tf

Tf = time (in minutes) at which the 100 ml collection tf was taken

b) HIGH INDEX WATERS

For these waters, it will be impossible to obtain even a 5 minute reading and still have a to/tf ratio greater than 0.2.

Repeat the test, measuring the 100 ml collection at 1 minute intervals. Apply the appropriate values into the preceding formula to obtain the Silting Index/ Fouling Index value.

c) LOW PRESSURE MEASUREMENTS

At times, it may not be possible to undertake the test at (2 barg) 30 psi, therefore, set the test pressure to one of those given below and apply the correction factor to the calculated result:

Test Pressure	Correction Factor
(0.70 barg) 10 psi	2.7
(1.00 barg) 15 psi	1.9
(1.37 barg) 20 psi	1.4

The application of these correction factors will introduce certain errors. Therefore, whenever possible, (2 barg) 30 psi should be used for the tests.

EXAMPLE:

Total Time (minutes)	100 ml Sample Time (seconds)
0	6
5	11
10	20
15	28

$$to/tf = \frac{6}{28} = 0.21$$

This value is over 0.2 therefore Silting Index/ Fouling Index is:

$$\frac{(1 - 0.2) \times 100}{15} = 5.3$$

Total Time (minutes)	100 ml Sample Time (seconds)
0	8
1	14
2	27
3	35
4	57
5	83

Because of the 0.2 rule, the 3 minute time is the one to use.

Silting Index/Fouling Index =

$$\frac{\left[1 - \frac{8}{35}\right] \times 100}{3} = 25.7$$

Note:

It is advisable to run two or more S.D.I. Tests so that results can be compared. If there is a large difference between the first and second test when taken one right after the other, further testing should be done.

Caution:

If pH adjustment equipment is in use, at least one S.D.I. should be run with it on and one with it off, to see if pH adjustment is causing any dissolved solids to become un-dissolved, thus altering the S.D.I pH adjustment, by acid feed or Cation blend, has been known to increase the S.D.I. value by three to five times its original value due to certain substances whose solubilities are highly pH dependent.

5. GENERAL SAMPLING

5.1 R.O. Service Condition

When sampling the R.O. Unit should be in its normal Service condition otherwise results may be invalid.

5.2 Sample Tundish

The majority of the sampling points collected together in a Sample Tundish at the end of the R.O. Skid. The water should be allowed to flow for at least ***1 minute*** to ensure a representative sample.

5.3 Sample Points

Valve Numbers	Sample Point	Use
1RO19 / 2RO19 /3RO19 /4RO19	H.P. Pump Suction	Feed conductivity & chlorine Feed dosing levels
1RO25 / 2RO25 /3RO25 /4RO25	Stage #1 Housing M6	Housing Permeate conductivity
1RO26 / 2RO26 /3RO26 /4RO26	Stage #1 Housing M1	Housing Permeate conductivity
1RO27 / 2RO27 /3RO27 /4RO27	Stage #1 Housing M2	Housing Permeate conductivity
1RO28 / 2RO28 /3RO28 /4RO28	Stage #1 Housing M3	Housing Permeate conductivity
1RO28 / 2RO29 /3RO29 /4RO29	Stage #1 Housing M4	Housing Permeate conductivity
1RO30 / 2RO30 /3RO30 /4RO30	Stage #1 Housing M5	Housing Permeate conductivity
1RO31 / 2RO31 /3RO31 /4RO31	Stage #2 Housing M9	Housing Permeate conductivity
1RO32 / 2RO32 /3RO32 /4RO32	Stage #2 Housing M7	Housing Permeate conductivity
1RO33 / 2RO33 /3RO33 /4RO33	Stage #2 Housing M8	Housing Permeate conductivity
1RO34 / 2RO34 /3RO34 /4RO34	Permeate Outlet	R.O. Stream Final Permeate conductivity
1RO35 / 2RO35 /3RO35 /4RO35	Concentrate (Reject) Outlet	R.O. Stream Final Concentrate (Reject) conductivity
V078	Common R.O. Units Outlet to Degasser Tower	R.O. System Common Outlet Permeate conductivity

Ensure sample Tundish drain valve V649 / V650 / V651 / V652 are open

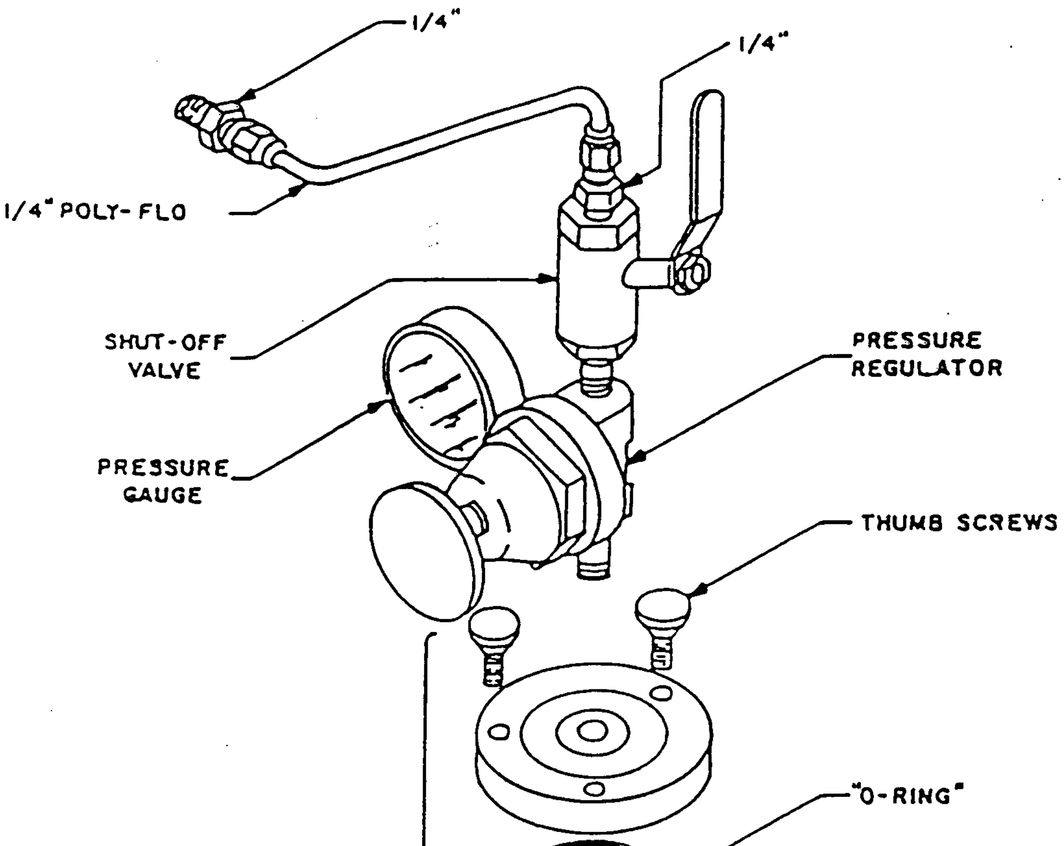

Figure 1

6. PROCESS DESCRIPTION

6.1 Introduction

Osmosis is a natural process involving fluid flow across a semi-permeable membrane barrier. It is the process by which nutrients feed the cells in our bodies and how water gets to the leaves at the top of trees.

If you separate a solution of salts from pure water using a basic thin semi-permeable membrane like a sausage skin, the pure water passes through the membrane and tries to dilute the salt solution. If the salt solution is connected to a vertical pipe then the progressively diluted solution will fill the pipe until the 'osmotic pressure' drawing the pure water though the membrane is the same as the head of solution.

This process can be reversed - hence 'Reverse Osmosis' - by applying a higher pressure to the salt solution. Pure water will then pass the other way through the membrane in a process that is easy to visualise as 'filtration' where the filter will only let through the small water molecules and retain almost all of the other molecules.

The mechanism of water and salt separation by reverse osmosis is not fully understood at the 'atomic' level. Current scientific thinking suggests two transport models: porosity and diffusion. That is, transport of water through the membrane may be through physical pores present in the membrane (porosity), or by diffusion from one bonding site to another within the membrane. The theory suggests that the chemical nature of the membrane is such that it will absorb and pass water preferentially to dissolved salts at the solid/liquid interface. This may occur by weak chemical bonding of the water to the membrane surface or by dissolution of the water within the membrane structure. Either way, a salt concentration gradient is formed across the solid/liquid interface. The chemical and physical nature of the membrane determines its ability to allow for preferential transport of solvent (water) over solute (salt ions).

6.2 Membrane Construction

The semi-permeable membrane for reverse osmosis applications consists of a thin film of polymeric material a fraction of a millimetre thick cast on a fabric support. Commercial grade membranes have high water permeability and a high degree of semi-permeability; that is, the rate of water transport is much higher than the rate of transport of dissolved ions.

The membranes are stable over a wide range of pH and temperature, and have good mechanical integrity. The stability of these properties over a period of time at field conditions defines the commercially useful membrane life, which is in the range of 3 to 5 years. There are a number of different materials used for membranes and several ways of constructing them. This system uses composite polyamide spiral wound membranes.

In a spiral wound configuration two flat sheets of membrane are separated with a permeate collector channel material to form a leaf. This assembly is sealed on three sides with the fourth side left open for permeate to exit. A feed/brine spacer material sheet is added to the leaf assembly.

A number of these assemblies or leaves are wound around a central plastic permeate tube. This tube is perforated to collect the permeate from the multiple leaf assemblies. The feed flow through the elements is a straight axial path from the feed end to the opposite feed end, running parallel to the membrane surface. The feed channel spacer induces turbulence and reduces concentration polarisation.

The spiral membrane is then enclosed by wrapping with glass reinforced resin into which is bonded an adapter cap at each end. The membrane is then housed in reinforced pressure tube / housing with seals at each end. Water under pressure is introduced into one end of the housing / membrane assembly so that it runs between the feed channel spacer and the concentrate and Permeate output piped away at the other

6.3 High Pressure (H.P.) Feed Pump

In order to develop sufficient water pressure to overcome the Osmotic Pressure of the feed water and produce an acceptable volume of permeate, a vertical multistage pump is used to boost the feed water pressure from the Filtered Water Pumps

6.4 Recovery

The 'recovery' of a Reverse Osmosis System is a measure of the proportion of the total input water that is converted to high quality Permeate. A recovery ratio of 10% means that only 1 part in ten of the input water is converted to permeate. At 50% recovery, half of the input water is converted. At 75% recovery, three quarters of the input water is converted to permeate.

The recovery ratio on the R.O. Unit is adjustable, and its setting will affect the final water quality. At high recovery ratios, the amount of solids in the concentrate water as it exits the membrane will be high which will result in a higher level of solids in the permeate. However by reducing the recovery, the operating pressure in the system will also be reduced, which in turn can also result in a raised level of solids in the permeate since rejection rates are better at higher pressures.

A balance of the optimum water quality and volume is usually found at recovery ratios of typically 70%-75% - see 7.

6.5 Rejection

The rejection ratio is a measure of the amount of solids dissolved in the raw water that are 'rejected' by the membrane. A rejection rate of 99% means that that only 1% of the dissolved solids will pass through the membrane, and these are usually of low molecular weight.

At 99% rejection on a feed water supply of say 400 ppm, you would therefore expect a permeate quality of 4 ppm. However by running single membranes at high recovery levels with considerable recirculation will mean that the membrane actually 'sees' a raw water of 1000-1500 ppm which could give a product water quality of 10-15 ppm. This is still very pure water, but needs additional polishing through the Rapide / Hipol Three-Bed ion-exchange resin to produce ultra-low TDS (Total Dissolved Solids) water is needed boiler feed.

6.6 Flush

In order to remove fouling that accumulates during service it is essential to periodically flush the membrane at a high water flow.

The PLC will automatically flush the membrane at the end of a service run – see 2.4

6.7 Pre-Treatment

For a Reverse Osmosis plant to function as efficiently as possible, the raw water feeding the system needs to have its hardness reduced by a water softener, or inhibited with special chemicals that are dosed in to the supply up-steam of the system.

The Composite Polyamide membranes used in high output Reverse Osmosis systems do not tolerate high levels of Chlorine. This removed by dosing Sodium Bisulphite.

7. PROCESS DATA

Design Feed Flow:	52.81m^3/h
Design Feed Pressure:	19 barg (maximum)
Set Feed Pressure:	___ barg for PIT114 / PIT214 / PIT314 / PIT414.
Design Permeate Flow:	38.55m^3/h
Design Concentrate (Reject) Flow:	14.26m^3/h
Design Water Temperature:	5^0 to 27^0 Celsius
Design Recovery:	73 to 70% at above temperature range
Flush Flows:	~ 53m^3/h
Total Number of Housing / Tubes:	9 (as installed – see 2.2.7)
Membrane Type:	BW30-36SFR
Total Number of membranes:	216 (as installed – see 2.2.7)

For C.I.P. flows and temperatures see O&M Section 1-16