Reverse Osmosis and the AS4187 Sterilisation Standard

Sven Denton : Principle Consultant

AquaKlar
Melbourne
Speaker: Sven Denton
12:30 to 12:55  Monday 23rd September

• Principle Consultant and Director - AquaKlar (14 years)
• Water Chemist (30 years)
• M.AIRAH (4 years)
• B.Sc (Hons) Applied Chemistry
• Consulting in Water and Energy Matters
• And we do lots of other stuff!

• Site Audit and water efficiency assessment of water systems for over 300 cooling systems within Australia
• EnHealth Risk Assessments
• Statistical process control evaluation of water treatment analysis and testing
• Generation of Water Treatment Tender Specifications
• Water Treatment Tender Specification Evaluation
• Waste water consultancy: monitoring, design, modifications
• Water Chemistry Assessment and Analysis
• Microbiological Risk Assessment and Consulting for Cooling and Warm Water Systems
• Water Treatment Risk Assessment and Analysis Consultancy
• Boiler System Water and Energy Optimisation Studies
• Corrosion Monitoring and Water Treatment Performance Monitoring
• Steam Boiler and Condensate System Water Treatment Management
• Greening our Hospitals
• Cert 2 trainer for water efficiency
• NGER submission for major Victorian health care networks
• EEO reporting
• EREP reporting
• NPI Reporting
• AIMS reporting
• Water Map reporting
• Compliance Reporting
• Energy and Water auditing
• Risk Management Plans and Reviews
• Chemical and Physical Water Treatment
The AS4187 Standard

• Original AS 4187—1994
• Revision AS 4187—1998
• Revision AS/NZS 4187:2003
• AS 4187:2014 – Introduction of table 7.2

• Aust. Comm on Safety and Quality in Health Care: Advisory No: A16/03 – by 2021 (published June 2016)

• AS4187 Amendment May 2019 (see next slide)
c. Demonstrate progress toward implementing the plan, noting health service organisations are permitted to:
- Return to or maintain pre AS/NZS 4187:2014 water quality input requirements and water quality monitoring requirements
- Revise or delay implementation plans until the Commission clarifies the minimum requirements to comply with Action 3.14 in November 2019.
The AS4187 Standard - Current
The Key Requirements……..by 2021

TABLE 7.2
FINAL RINSE WATER—MANUAL CLEANING
MANUAL DISINFECTION AND
WASHER-DISINFECTORS

<table>
<thead>
<tr>
<th>Substance</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>5.5–8.0</td>
</tr>
<tr>
<td>Conductivity at 20°C</td>
<td>≤ 30 µS/cm</td>
</tr>
<tr>
<td>Total hardness</td>
<td>≤ 10 mg CaCO₃/L</td>
</tr>
<tr>
<td>Chloride</td>
<td>≤ 10 mg/L</td>
</tr>
<tr>
<td>Iron</td>
<td>≤ 0.2 mg/L</td>
</tr>
<tr>
<td>Phosphates (molybdate reactive)</td>
<td>≤ 0.2 mg/L</td>
</tr>
<tr>
<td>Silicates (molybdate reactive)</td>
<td>≤ 1.0 mg/L</td>
</tr>
<tr>
<td>Total viable count (see Note)</td>
<td>≤ 100 cfu/100 mL</td>
</tr>
<tr>
<td>Endotoxin</td>
<td>≤ 0.25 EU/mL</td>
</tr>
</tbody>
</table>

NOTES:
1 Table 7.2 applies to the quality of water used in the types of washer-disinfectors included under the scopes of ISO 15883-1 and ISO 15883-2.
2 ISO 15883-1 is the umbrella (i.e. horizontal) standard that applies to all WDs. Specific or altered requirements are given in each of its subsequent parts (i.e. vertical standards) for different types of WD. See Table 7.3 for specific requirements for WDs used to reprocess thermolabile endoscopes.
3 For TVC, test methodology should be in accordance with ISO 15883-1 and the HTM 01-01 series.

(a) Water hardness no greater than 150 mg/L.
    NOTE: This specification may need to be lower, depending on the RMD being reprocessed, to reduce the risk of deterioration to the RMD.
(b) Chloride no greater than 120 mg/L.
    NOTE: This quality of water may be suitable for use in the final rinse of washer-disinfectors within the scopes of ISO 15883-3, ISO 15883-6 and ISO 15883-7.

Supply Water Quality to Reprocessor Washers

TABLE 7.3
FINAL RINSE WATER—WASHER-DISINFECTORS
IN ACCORDANCE WITH ISO 15883-4
FOR THERMOLABLE ENDOCOPES

<table>
<thead>
<tr>
<th>Substance</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total viable count (see Note)</td>
<td>≤ 10 cfu/100 mL</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>Not detected/100 mL</td>
</tr>
<tr>
<td>(Atypical) Mycobacterium sp.</td>
<td>Not detected/100 mL</td>
</tr>
<tr>
<td>Chemical purity</td>
<td>In accordance with WD manufacturer’s recommendations</td>
</tr>
<tr>
<td>Endotoxin</td>
<td>≤ 30 EU/mL</td>
</tr>
</tbody>
</table>

NOTE: For TVC, test methodology should be in accordance with ISO 15883-1 and the HTM 01-01 series.

Table 7.2 – For Reprocessor Washers

Table 7.3 – For Scope Washers
The AS4187 Compliance

Reprocessor Washers Spec

Typical Melbourne Water

<table>
<thead>
<tr>
<th>Substance</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>5.5–8.0</td>
</tr>
<tr>
<td>Conductivity at 20°C</td>
<td>≤ 30 µS/cm</td>
</tr>
<tr>
<td>Total hardness</td>
<td>≤ 10 mg CaCO₃/L</td>
</tr>
<tr>
<td>Chloride</td>
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</tr>
<tr>
<td>Iron</td>
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<tr>
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<td>≤ 0.2 mg/L</td>
</tr>
<tr>
<td>Silicates (molybdate reactive)</td>
<td>≤ 1.0 mg/L</td>
</tr>
<tr>
<td>Total viable count (see Note)</td>
<td>≤ 100 cfu/100 mL</td>
</tr>
<tr>
<td>Endotoxin</td>
<td>≤ 0.25 EU/mL</td>
</tr>
</tbody>
</table>

Conductivity – 80 to 150 uS/cm
Total Hardness 15 to 30 mg/L
Chloride – 10 to 30 mg/L
Silicates – 4 to 6 mg/L
Total Viable Count (HCC) – Occasionally >100cfu/ml
Endotoxins - >0.25 (2 to 8) EU/mL

What is the Fix : use Reverse Osmosis!
Other options are economically unviable or mechanically unsuitable
Reverse Osmosis

Key Concepts

• **Permeate**
  (The treated water)

• **Concentrate**
  (The water left behind)

• **Permeate Flow**
  (Flow rate of cleaned water)

• **Differential Pressure**
  (Between inlet and outlet)

• **Percent Rejection**
  (Ratio of permeate to concentrate flow or concentration)
Best Practice Configuration

Typical RO System Setup – Key Elements

- Dechlorination (particularly reqd. with Thin Film Composite (TFC) membranes)
- Softening (particularly when hardness is >100mg/L)
- Filtration to 0.2micron
- UV post RO
- Loop filter to 0.2 micron
- Aseptic sampling points
- Online monitoring (incl Flows)
- Protected storage
- Facility to sterilise

My thanks to Craig Marshall (Focus Energy) for providing schematic
<table>
<thead>
<tr>
<th>Equipment</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prefiltration</td>
<td><img src="image1" alt="Prefiltration Image" /></td>
</tr>
<tr>
<td>0.22micron Filter</td>
<td><img src="image2" alt="0.22micron Filter Image" /></td>
</tr>
<tr>
<td>UV Disinfection</td>
<td><img src="image3" alt="UV Disinfection Image" /></td>
</tr>
<tr>
<td>Filtration</td>
<td><img src="image4" alt="Filtration Image" /></td>
</tr>
<tr>
<td>Pressurisation Pumps</td>
<td><img src="image5" alt="Pressurisation Pumps Image" /></td>
</tr>
<tr>
<td>Washer RO Unit</td>
<td><img src="image6" alt="Washer RO Unit Image" /></td>
</tr>
<tr>
<td>Laboratory RO Unit</td>
<td><img src="image7" alt="Laboratory RO Unit Image" /></td>
</tr>
<tr>
<td>Holding Tank (with Air Filtration)</td>
<td><img src="image8" alt="Holding Tank Image" /></td>
</tr>
</tbody>
</table>
What do they Look Like (B)?

Prefiltration
Filtration
UV Disinfection

1.0 and 0.35 micron Filtration

Pressurisation Pumps
Washer RO Unit
Holding Tanks
Holding Tank
What do they Service?
Myths, Do’s and Don'ts?

- **Myth**: RO units are just fancy filters.
  - **Truth**: RO units will always have to lose water. Efficiency is optimised by minimising water loss without fouling the RO membrane.

- **Myth**: All RO installations are the same
  - **Truth**: Membranes vary (Thin Film Composite vs Cellulose Acetate). TFC is more flexible but cannot handle chlorine. Pretreatment options are important.

- **Do** measure recovery rate (cycles of concentration) and differential pressure – SIMPLE!
- **Do** (try to) measure normalised permeate flow – COMPLICATED!
- **Don’t** use larger micron prefilters if they are plugging too quickly. This is probably a microbial problem.
- **Don’t** use RO on its own. It will always need pre-treatment. Use Ion Exchange when hardness is greater than 100mg/L (not an issue in Victoria)
  - Use can even consider chemical scale inhibitor treatment with very challenging water
- **Do** sample correctly (see AS2031)
Water and Savings

Calculations

Cycles \( n \) = \( \frac{\text{Concentrate Conductivity}}{\text{Supply Conductivity}} \)

Feed conductivity = 100 uS/cm  
Concentrate Conductivity = 400 uS/cm  
Cycles of concentration = \( \frac{400}{100} = 4 \)

Cycles of less than 3 are common in RO water systems!

Assume 4 Cycles Currently: (250 litres)

Assume 10 Cycles possible: (100 litres)

Saving: 150 litres for 1 m\(^3\) of makeup
Water and Savings

Percent Rejection = \frac{\text{Feed Conductivity} - \text{Permeate Conductivity}}{\text{Feed Conductivity}}

Feed conductivity = 100 \text{ uS/cm}
Permeate Conductivity = 3
Percent rejection = \frac{97}{100} = 97% 

But this is too good!

In Melbourne it is normally Silicates which govern percent rejection (for AS4187):

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Typical supply Concentration</th>
<th>AS4187 Spec</th>
<th>Percent Rejection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductivity</td>
<td>uS/cm</td>
<td>100</td>
<td>30</td>
<td>70%</td>
</tr>
<tr>
<td>Total Hardness</td>
<td>mg/L</td>
<td>20</td>
<td>10</td>
<td>50%</td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/L</td>
<td>30</td>
<td>10</td>
<td>67%</td>
</tr>
<tr>
<td>Silicate</td>
<td>mg/L</td>
<td>5</td>
<td>1</td>
<td>80%</td>
</tr>
</tbody>
</table>
Water and Savings

Normalised permeate flow calculation is a bit complicated! (but it is the most sensitive in telling you membrane is failing)

Equation 1 gives the Normalised permeate flow:

$$Q_N = Q_t \times \left( \frac{NDP}{NDP_0} \right) \times \left( \frac{STCF}{STCF_0} \right)$$

Where:
- $T$ is water temperature in °C,
- $K$ is linear temperature coefficient
- $TCF = \exp \left\{ K \times \left[ \frac{1}{273} (T + 273) \right] \right\}$

Equation 2 gives the formula for Net Driving Pressure:

$$NDP = P_f - \frac{1}{2} \delta P_f - P_{om}$$

Where:
- $P_f$ is Feed pressure
- $\delta P_f$ is Pressure drop between $P_f$ and $P_b$
- $P_{om}$ is Osmotic pressure

The log mean concentration factor is given by:

$$\log_{10} C_{tp} = \log_{10} C_f - \frac{1}{2} \log_{10} C_r$$

Where:
- $C_f$ is Feed concentration
- $C_r$ is Recovery Concentration

The salt passage of a system can be normalised to standard conditions by the following equation:

$$\%SP_{st} = \left( \frac{SP_{at}}{SP_{st}} \right) \times 100$$

Where:
- $SP_{at}$ is Actual Salt Passage
- $SP_{st}$ is Salt Passage at standard conditions

The log mean concentration factor is given by:

$$C_{tp} = C_f \times \exp \left( \frac{\log_{10} C_r}{2} \right)$$

Where:
- $C_f$ is Feed concentration
- $C_r$ is Recovery Concentration

Finally, the Temperature Correction Factor is given by:

$$STCF = \exp \left[ \frac{1}{273} (T + 273) \right]$$

Where $T$ is water temperature in °C.
Performance - Sampling

• Water sampling has been desirable since 2014 – Introduction of Table 7.2
• Sampling should be Monthly
• Sampling as per AS2031:2012 or as per manufacturers recommendations (if exceeds AS)
• We recommend following Table 1, row (a).

<table>
<thead>
<tr>
<th>Purpose (see above)</th>
<th>Water type</th>
<th>Remove attached devices and inserts</th>
<th>Disinfect</th>
<th>Flush</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>In the distribution main</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>b)</td>
<td>As it is delivered to the tap</td>
<td>Yes</td>
<td>Yes</td>
<td>No (minimal)</td>
</tr>
<tr>
<td>c)</td>
<td>As it is consumed</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

\[a\] Flush briefly only to overcome influence of disinfection of the tap.

• Disinfection by alcohol or flame (preferred) – from an aseptic sampling point
# Performance – Real Data (A)

<table>
<thead>
<tr>
<th>CURRENT SPEC:</th>
<th>Chloride</th>
<th>Conductivity @ 25°C</th>
<th>Endotoxin &lt;0.25</th>
<th>Total Viable Count &lt;100</th>
<th>Metals &lt;0.2</th>
<th>pH 5.5 to 8.0</th>
<th>Phosphate &lt;0.2</th>
<th>Silicate &lt;1</th>
<th>Total Hardness &lt;10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>POOR RO EXAMPLE</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2017</td>
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<td></td>
</tr>
<tr>
<td>&lt;13/06/2017</td>
<td>2.1</td>
<td>14.0</td>
<td>High</td>
<td>22,000</td>
<td>0.0</td>
<td>6.7</td>
<td>0.1</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td><strong>2018</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qtr 2</td>
<td>1.5</td>
<td>14.0</td>
<td>High</td>
<td>440</td>
<td>0.0</td>
<td>7.0</td>
<td>0.0</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td>Qtr 3</td>
<td>2.9</td>
<td>20.0</td>
<td>High</td>
<td>25,000</td>
<td>0.0</td>
<td>7.0</td>
<td>0.1</td>
<td>0.1</td>
<td>10</td>
</tr>
<tr>
<td>Qtr 4</td>
<td>4.0</td>
<td>24.0</td>
<td>High</td>
<td>25,000</td>
<td>0.0</td>
<td>7.0</td>
<td>0.0</td>
<td>0.1</td>
<td>3</td>
</tr>
<tr>
<td><strong>2019</strong></td>
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<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Qtr 1</td>
<td>1.6</td>
<td>13.0</td>
<td>High</td>
<td>9,500</td>
<td>0.0</td>
<td>7.4</td>
<td>0.0</td>
<td>0.1</td>
<td>2</td>
</tr>
<tr>
<td>Qtr 2</td>
<td>88.0</td>
<td>428.0</td>
<td>High</td>
<td>6,800</td>
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<td>6.8</td>
<td>0.0</td>
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<td>120</td>
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<tr>
<td>Qtr 3</td>
<td>1.7</td>
<td>10.4</td>
<td>High</td>
<td>5,600</td>
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<td>6.7</td>
<td>0.0</td>
<td>0.1</td>
<td>0</td>
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<tr>
<td><strong>GOOD RO EXAMPLE</strong></td>
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<tr>
<td>Qtr 2</td>
<td>1.0</td>
<td>3.9</td>
<td>None</td>
<td>1</td>
<td>0.0</td>
<td>7.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0</td>
</tr>
<tr>
<td>Qtr 3</td>
<td>1.0</td>
<td>3.1</td>
<td>None</td>
<td>3</td>
<td>0.0</td>
<td>6.7</td>
<td>0.0</td>
<td>0.5</td>
<td>0</td>
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<tr>
<td>Qtr 4</td>
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<td>3.9</td>
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<td>0.1</td>
<td>0</td>
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<tr>
<td><strong>2018</strong></td>
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<tr>
<td>Qtr 1</td>
<td>1.0</td>
<td>3.9</td>
<td>None</td>
<td>1</td>
<td>0.0</td>
<td>7.0</td>
<td>0.0</td>
<td>0.1</td>
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<tr>
<td>Qtr 2</td>
<td>1.0</td>
<td>3.5</td>
<td>None</td>
<td>1</td>
<td>0.0</td>
<td>7.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0</td>
</tr>
<tr>
<td>Qtr 3</td>
<td>1.0</td>
<td>4.5</td>
<td>None</td>
<td>1</td>
<td>0.0</td>
<td>7.0</td>
<td>0.0</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td>Qtr 4</td>
<td>1.0</td>
<td>8.0</td>
<td>None</td>
<td>1</td>
<td>0.0</td>
<td>6.7</td>
<td>0.0</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td><strong>2019</strong></td>
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<tr>
<td>Qtr 1</td>
<td>1.0</td>
<td>5.7</td>
<td>None</td>
<td>1</td>
<td>0.0</td>
<td>6.9</td>
<td>0.0</td>
<td>0.1</td>
<td>0</td>
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<tr>
<td>Qtr 2</td>
<td>1.0</td>
<td>3.4</td>
<td>None</td>
<td>1</td>
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<td>6.9</td>
<td>0.0</td>
<td>0.1</td>
<td>0</td>
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<td>Qtr 3</td>
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<td>3.3</td>
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<td>1</td>
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<tr>
<td><strong>MODERATE RO EXAMPLE</strong></td>
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<td></td>
</tr>
<tr>
<td>Qtr 3</td>
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<td>150</td>
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</tbody>
</table>
Performance – Real Data (B)

Observations

- Sample points are typically poor
- Routine (none AS4187) performance analysis is uncommon
  - (Water rejections as high as 90% have been recorded when data is captured).
- AS4187 Analysis:
  - Mineral removal efficiency is typically “too good”
  - None compliance is typically microbial (not mineral)
  - Once a system is infected it is very challenging to disinfect effectively
THE END

Thank you for Listening!
Any Questions?