Design Considerations

Treated Water Quality and Design Specification

Rob Terrell

ABB

- This module is written from the perspective of water users rather than OEM's
- But the lessons are the same for both parties...

- If the installed plant does not meet the user requirements then, however well designed it is, it will be seen as a failure

- It is important to specify and agree what is wanted before the plant is built
  - "What would good look like?"

1. Treated water quality

Treated water quality

- What will the treated water be used for?
- Where do you find out what quality is required?
- What are the important quality parameters that you should be identifying?
- Can the water quality be too good?
- How do you satisfy multiple duties, each with their own specification?
- What are the consequences of getting it wrong?
- Which determines the treatment technology – raw water quality or treated water quality?

What water quality do you need?

- For most people, water is water is water
  - Potable water is “pure”
  - Cooling water is the same as boiler water
  - The process uses whichever supply of water is closest
  - If the water treatment plant is not working, you use whatever water is available until it is mended
- Sadly this applies to most engineers and chemists too
  - There is very limited formal training

- It is only when you work in Utilities or specific production processes that you learn differently...

What will the water be used for?

- Many of you will have done work in the Power sector, but consider a wider application
- Utility operation
  - LP / MP / HP / VHP steam raising
    - Process heating
    - District heating and cooling
    - Power generation
  - Cooling system make-up
  - Environmental systems make-up – e.g. scrubbers

- Process duties
  - Electronics - wafer manufacture
  - Pharmaceuticals / Healthcare - water for injection
    - manufacturing processes
  - Fine chemicals manufacture - manufacturing
  - Food - product washing
  - Brewing - beer making
  - Dyestuffs - manufacturing
  - Heavy chemicals - process cooling / steam raising
- Do all these duties require the same quality of water?

Where are water quality requirements specified?

- Standards exist for some of these duties, e.g.
  - Steam raising – EPRI, VGB, EN, ASME, JIS, etc
  - US Pharmacopoeia, European Pharmacopoeia
  - Government standards – food processing
  - Shared industry sector experience – heavy chemicals, brewing (“Burtonisation”),
  - Manufacturer’s guidelines / warranties,
  - Product specification, etc
- But often standards are internally set and reflect past experience
  - Fear of changing – even to “improve” water quality

Are water requirements unique to each sector?

- Industry sectors always believe that their requirements for water quality are different from anyone else
  - Which is true, but...
- From water treatment perspective, it is likely that many of the same treatment processes will be used in producing water for different duties
  - So the same treatment process may serve a range of duties
  - As long as we can define what water quality we really need...

Key water quality parameters

- What should we be specifying?
- "Standards" will indicate parameters known to be important for the specific duty e.g.
  - Sodium, Potassium
  - Calcium, Magnesium
  - Iron, Copper, Nickel
  - Chloride, Sulphate, Nitrate
  - Alkalinity
  - Silica
  - TDS / Conductivity / Acid Conductivity
  - pH
  - Colour
  - TSS / Turbidity / Colloids
  - Bacteria, Viruses, Pyrogens
  - TOC, Organic matter
  - Taste
  - Oil & Grease
- Not all of these impurities can or will be removed by ion exchange

Common water systems

- It is quite common to have different water duties on a plant demanding different qualities of treated water
- Should this demand be met by having different treated water qualities available - or is it better to provide one quality for all duties?
- Some are tempted to consider only the minimum water quality needs, i.e. what the system can tolerate, considering this to be the cheapest option
- However it is important also to consider what benefit might result from using better water quality
  - In most cases, improving the treated water quality will do no harm and may be beneficial

Potential benefits of using better water quality

- Typical benefits from improved water quality include
  - Remove need to install “intermediate” water purification processes, distribution systems, control systems, etc.
  - Reduced water consumption by minimising discharge
  - Reduced cleaning / maintenance / inspection
  - Opportunity to minimise chemical treatment, e.g. pH control, antiscalants
  - Opportunity to simplify control system
  - Opportunity to reduce routine analysis
  - Opportunity to treat the waste water from the system locally to recover raw materials and product before further contamination
  - Opportunity to recover water for reuse / recycle
- If these opportunities are not introduced at the feasibility stage in the project, it is unlikely that they will be viable at a later stage.

But beware...

- In some circumstances it is possible for the water quality to be “too good”
- Imagine if demineralised water were used to make your beer instead of raw water?
- Or reverse osmosis was used to remove the colour from water used to make whisky?
- Would you prefer your bottled water to contain well water or reverse osmosis water?

What water qualities do you need?

- It is not practical to produce a wide range of different water qualities to suit each individual water duty
- Recommend producing a simple table identifying the various duties with a simple descriptor of the necessary limitations
  - Table should identify specific plant items and generic duties
- Simple descriptors can be used to focus any further consideration, e.g.
  - Not suitable; Possible; Suitable; Better than needed; etc

Example of Screening Table

Duty	Requirement	Options					
		Softened water	DeAlk + Softener	Reverse Osmosis	Twin Bed Demin water	Polished water	EDI
12 MPa Boiler	VGB Standards	No	No	No	No	Yes	Yes
3 MPa Boiler	ASME standards	Possible	Possible	Possible	Yes	Yes	Yes
1.2 MPa Boilers	Manufacturers standards	Yes	Yes	Yes	Yes	Better than needed	Better than needed
Closed Circuit Cooling System	Low TSS, Low TDS, Disinfected	Possible	Possible	Yes	Yes	Better than needed	Better than needed
Caustic scrubbers	Low hardness	Yes	Yes	Possible	Possible	Better than needed	Better than needed
Acid scrubbers	Low calcium?	Yes	Yes	Better than needed	Better than needed	Better than needed	Better than needed
Etc							
Etc							

- Based on this table, the purest" water required for the new plant can be established
  - Most likely to be for steam raising, but
  - Some process duties demand even better water quality
    - Or "different" purity parameters
- Next consider whether this quality of water could be beneficially used for other less demanding duties, e.g.
  - Demineralised water for LP steam raising
  - Demineralised water for closed circuit cooling system make-up
  - Softened water for caustic scrubber duties
  - Demineralised water for product washing, etc.
- Aim to limit the number of different treated water qualities to 2, maximum 3

- Aim is to establish balance between
  - Number of different water qualities available on the plant and
  - Capital cost of installing additional water purification equipment, distribution systems and control systems and
  - Future operating costs per m^3 water consumed and
  - Beneficial impact (if any) of using better than required water quality
- Rare to see more than 3 purified water qualities used on single plant
- Based on this information, it should be possible to identify each water duty against a specific water quality.
- This information is then used to develop outline specification and sizing for each water purification process.

Consequences of getting it wrong

- The Standards we work to are designed to protect us against the consequences of getting it wrong
  - At the production stage:
    - Equipment failures due to corrosion
    - Heat transfer limitations due to scaling or fouling
    - Microbiological growth
    - Failed batches and off-specification product
    - Non-compliance with manufacturing standards
  - Or at the wider stage:
    - Lost business due to poor quality product, failure to supply
    - Personal injury and fatalities
    - Civil and criminal proceedings

Treated water quality determines process selection

It is the treated water quality that ultimately determines the water treatment process, not the raw water quality

- It may limit your choice of raw water source
  - Potential contamination
  - Variability, especially seasonality
- It should determine what pretreatment stage(s) will be necessary for the selected raw water quality – alongside the treatment technology used
  - Clarification?
  - Media filtration or membrane filtration?
  - Carbon filtration?

- Treated water quality will determine whether ion exchange is a suitable technology
  - Or whether alternative technology such as membranes would be more suitable

  - Ion exchange is not suitable for brackish water or sea water treatment
  - Ion exchange is not designed to remove suspended solids, colloids, bacteria or viruses – and will only partially remove organic contamination (TOC)

  - **Water quality must take priority over cost of production**
    - The Standards represent a wealth of experience of knowledge

Objective

- To define a water quality (or more than one?) which meets the specification for the most demanding duty
- Do not expect the OEM will do this for you – it is not their job!
- Consider all quality parameters – not just a selection
  - Even if you think they are not relevant
- If you are not purchasing a complete treatment train (pretreatment + treatment + polishing), share the details of the other unit operations with the OEM
  - It will affect the final design

- Once you have defined the water quality, it is time to start developing a design specification before talking to the OEM

Design specification

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Design specification

Aim is to install a plant which is:

- Fit for purpose, i.e.
  - produces enough water
    of the required quality
    all the time
    at minimum cost
    reliably
    for the lifetime of the ion exchange resin
- On budget
- On time

Pitfalls of design specification

- If you don't specify the plant, the OEM will provide what they think you want…
  - or what they think you think you want…
- If you over-specify the plant, the OEM will not take responsibility for the future performance of the plant… but will be happy to accept your money

- Trust is good - but it is of little value in negotiating contracts between purchaser and supplier
  - or in claiming on the plant warranty

- Aim of this module is to help you to define what is needed rather than carry out the detailed design

The simplest design specification

- The simplest design specification is to specify the output:
  - "I want X m^3/h of water with a conductivity of < Y $\mu S/cm$ and with a silica concentration of < Z $\mu g/kg$ from the potable water supply to my site."
- The risk is that the plant will not achieve the required design:
  - if the raw water quality is variable or the source changes
  - if the demand quoted is an average demand which ignores variations
  - if the plant is not reliable
  - for more than the warranty period

Must meet the worst case

- Still need to satisfy demand when:
  - Maximum water demand *and*
  - "Worst" raw water quality *with*
  - Four year old resins *with*
  - One stream unavailable *and*
  - Another stream in regeneration
- Performance trials after 3 months give little indication of long-term operation
- Warranty of no value after 12 months
- Important to consider at design stage
  - Unless you want to use mobile water treatment plant…

Elements to consider as part of design specification

- Inputs
- Outputs
- Number of streams
- Plant configuration
- Regeneration
- Effluent neutralisation
- Control and instrumentation
- Mechanical design
- Risk and reliability
- Performance trials

Inputs

Raw water quality

- Source
  - Surface
    - Lake
    - River
  - Borehole
  - Desalination
- Local geology
- Variability
  - Seasonality
  - Impact of rainfall
- Quality
  - Ionic balance
  - Organic material

Condensate recovery

- Temperature
- Quality
  - Corrosion products
    - Iron
    - Copper
  - Contamination
    - Cooling water
    - Organics

Water reuse/recycle

- Source(s)
  - Wastewater
  - Process condensate
- Quality
  - Ionic balance
  - Contamination
- Pretreatment
  - Is there any?
- Availability and Variability
- Control and monitoring
  - On-line

Note: You can never have too much information about the raw water quality!

Raw water characterisation

Remember:
Raw water quality provides the biggest wriggle-room in any contract

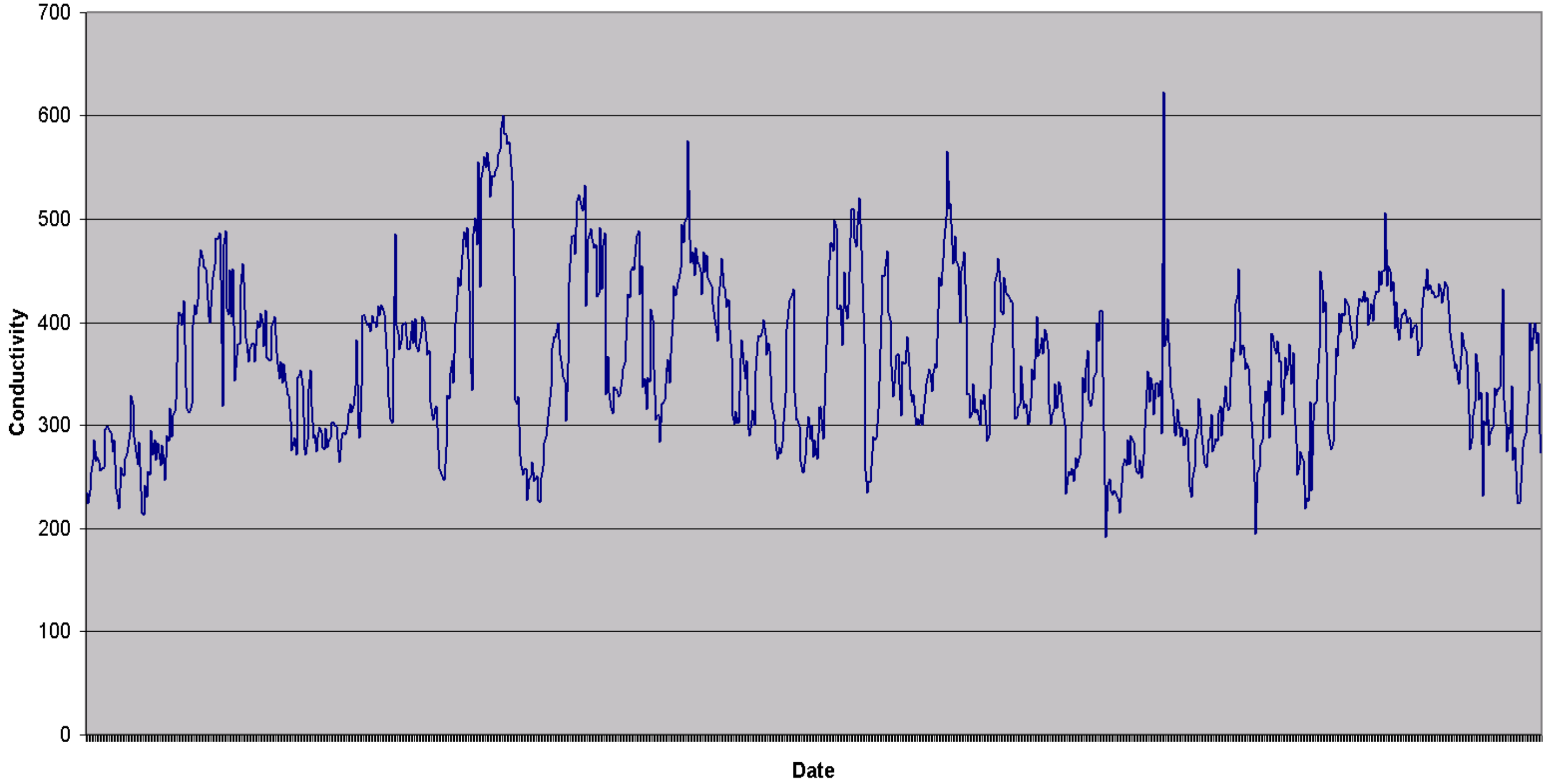
- Provide the OEM with whatever information you have
  - Your own monitoring
  - Water Treatment Company reports
  - Plant data, e.g. for water reuse/recycling
  - Other plants in the area (generally non-contentious)
  - Use available public records
- Minimum period of data should be 12 months, but the more the better
- Be careful not to put limits on the data such as “maximum”
  - Provide all the raw data, not just a summary
  - Use terms such as “maximum recorded”
  - Qualify the values you are uncertain about
  - e.g. potable water quality
- Agree with OEM the interpretation of the data and what allowances to make for missing data or shorter monitoring periods
- Don’t ignore inconvenient data – it may be correct!
- Don’t accept responsibility when you have no control
- Aim is to achieve an ionic balance

Case study

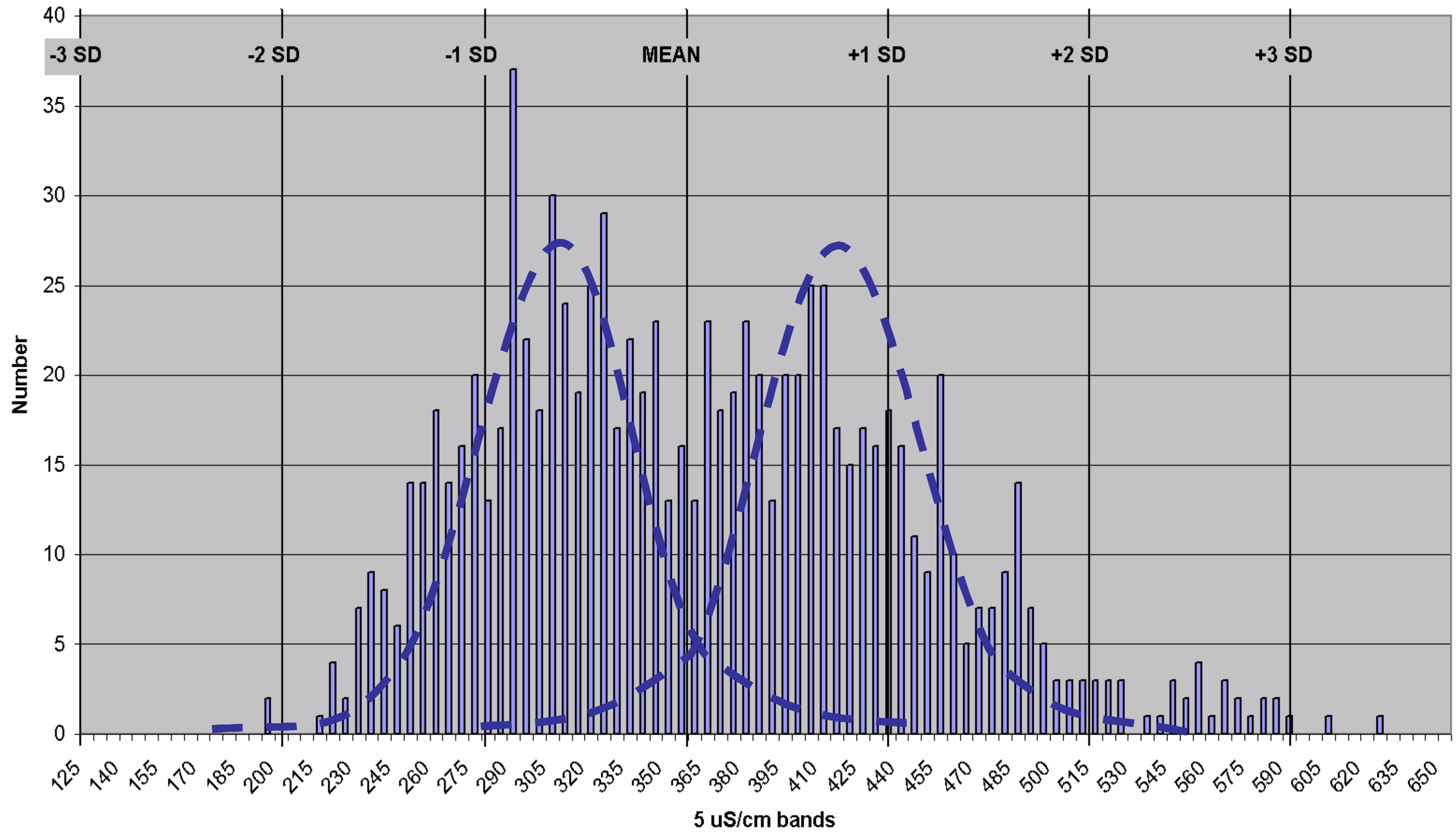
- Large replacement demineralisation plant to be built in the NW of England
  - Increasing site demand
    - Multiple users
    - Highly variable demand
  - Improved water quality required
  - Process and steam raising duties

- Potable water supply
  - Plus steam condensate
  - Plus process condensate

Case study
Water quality over five year period



Case study
Water quality over five years



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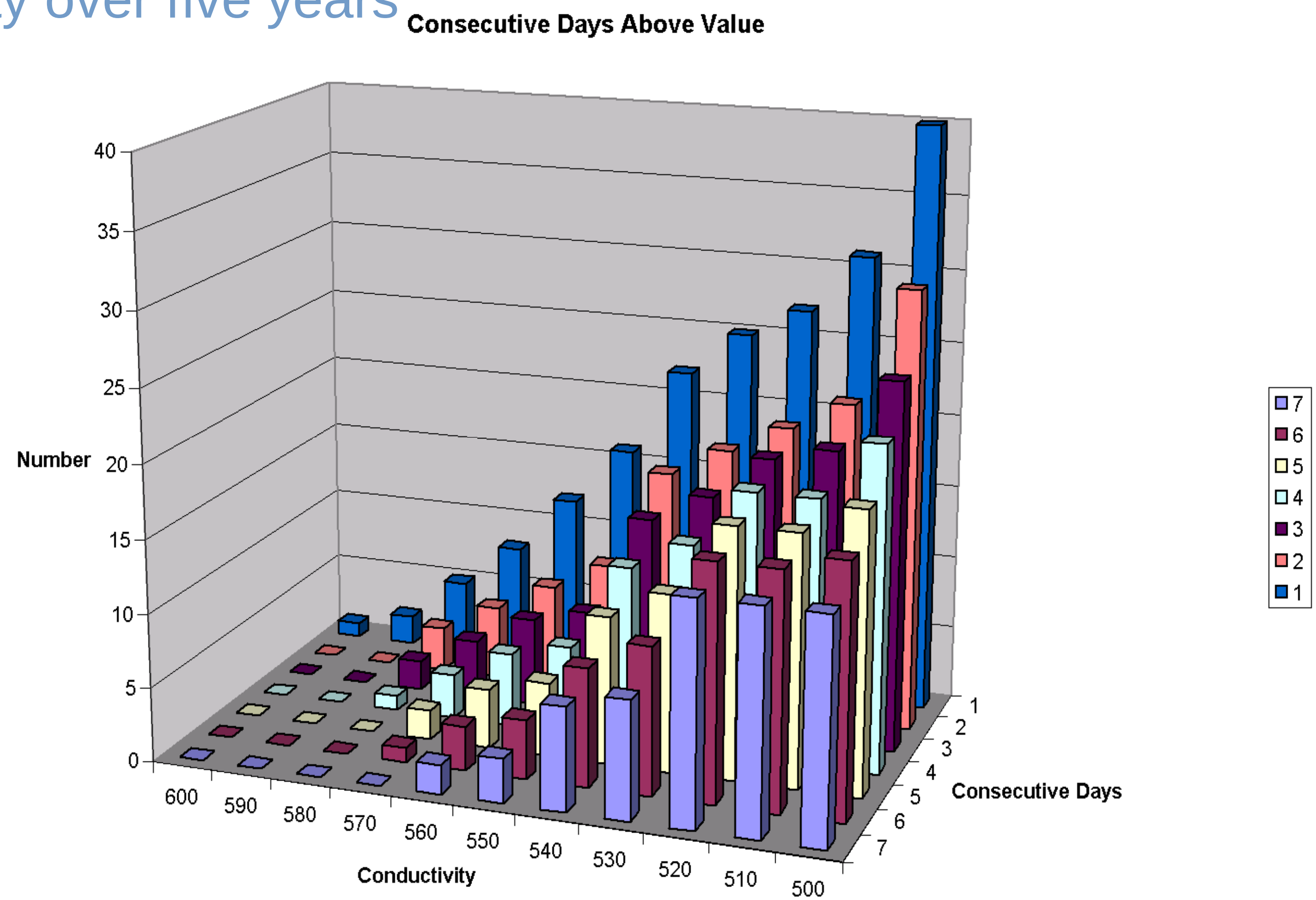
Case study
Water quality over five years



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Outputs

- Flow
  - Maximum, Minimum, Typical
  - Gross capacity - gross water production when in service
  - Net capacity - net water production over service cycle allowing for regeneration demand)
- Pressure
  - At point of delivery
- Quality
  - Standard parameters - conductivity, sodium, silica, pH
  - Additional parameters - chloride, sulphate, organics, etc
  - Industry specific standards, - e.g. pharmaceuticals, electronics, power,
  - Process specific needs, - e.g. fine chemicals
  - Zero demand operation - Recycle? Or first flush to drain?

Specify supply or demand?

- Important to characterise demand to ensure plant can meet requirements
  - Monitor usage vs time
    - Short enough time period to show peaks and troughs
  - Consider abnormal conditions
    - Plant outages
    - Start-ups
    - Unavailability
      - e.g. need to dump condensate due to contamination
- May be simple for small plant with single duty, e.g. steam raising
- More critical for large, multi-plant site

Number of streams

- There is a trade-off between the number of streams and installed storage
- Factors for consideration include:
  - Variability of raw water (short service runs)
  - Variability of demand
  - Cost of additional streams Vs storage tank
  - Available space
  - Effluent neutralisation capacity
  - Stream outage for vessel inspection, resin change
  - Consideration of likely failure modes and repair times
    - Control system? Regeneration equipment?

Case study
Examined operating cases

Service Life	83.4	h	Resin Age	0	y
			Resin Capacity	100	%
			Design Service Life	27	h

Gross Flow	129.9	m3/h
Net Output	125.00	m3/h
Raw Water Quality	300	S/cm

Raw Water Qualities

Design Influent	450	S/cm
Worst Dee	530	S/cm
Average Dee	286	S/cm
Average Influent	170 - 230	S/cm

Design Regen Time	2.5	h
Age Factor	0.00	h
Regen Time	2.50	h

Design Regen Water Usage	96	m3 based on standard regen procedure
Age Factor	0	m3
Regen Water Usage	96	m3

DESIGN BASIS

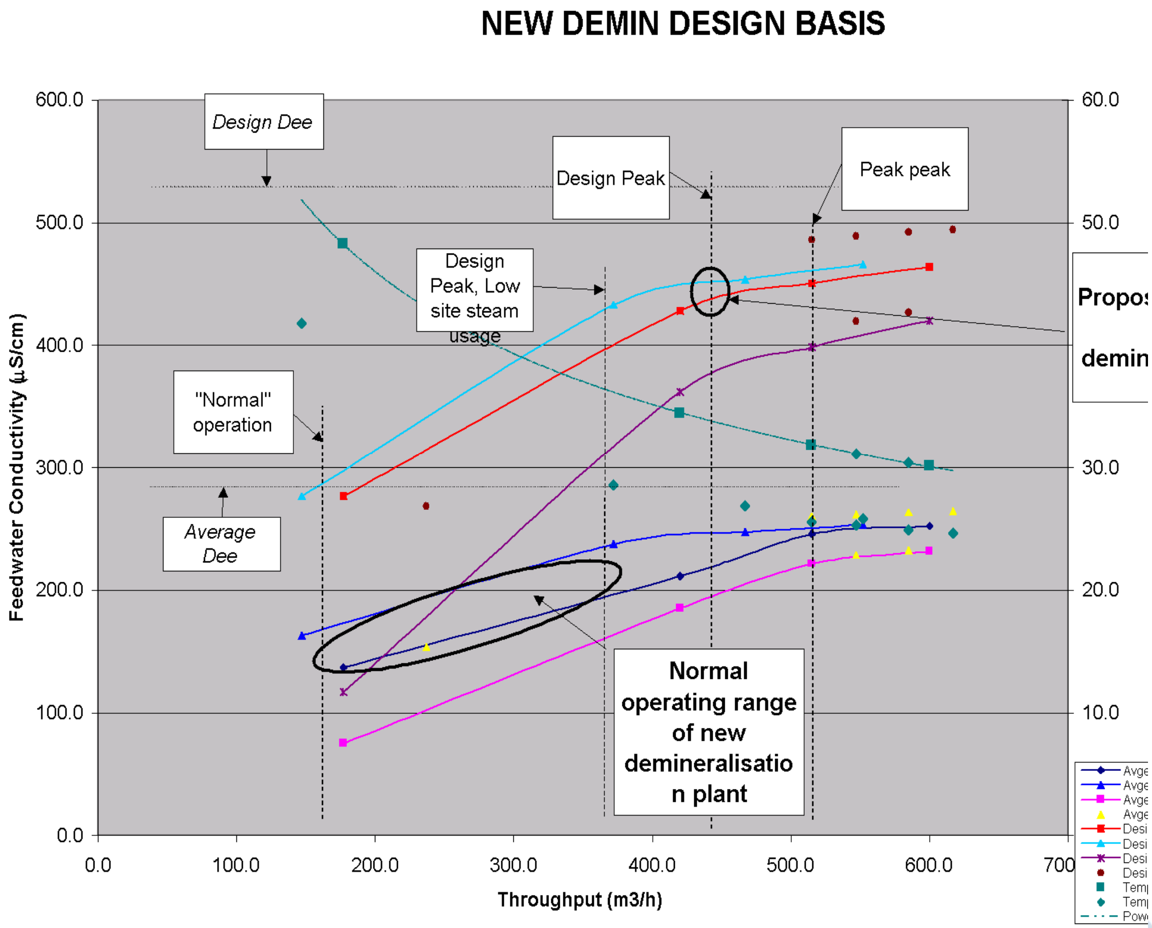
Total Cycle Time	**85.93**	**hours**
Maximum water demand	250	m3/h
No of streams	2	
Net flow/stream	125	m3/h
Gross flow needed	**129.9**	**m3/h/stream**
Max production with one stream off	125	m3/h

OPERATION

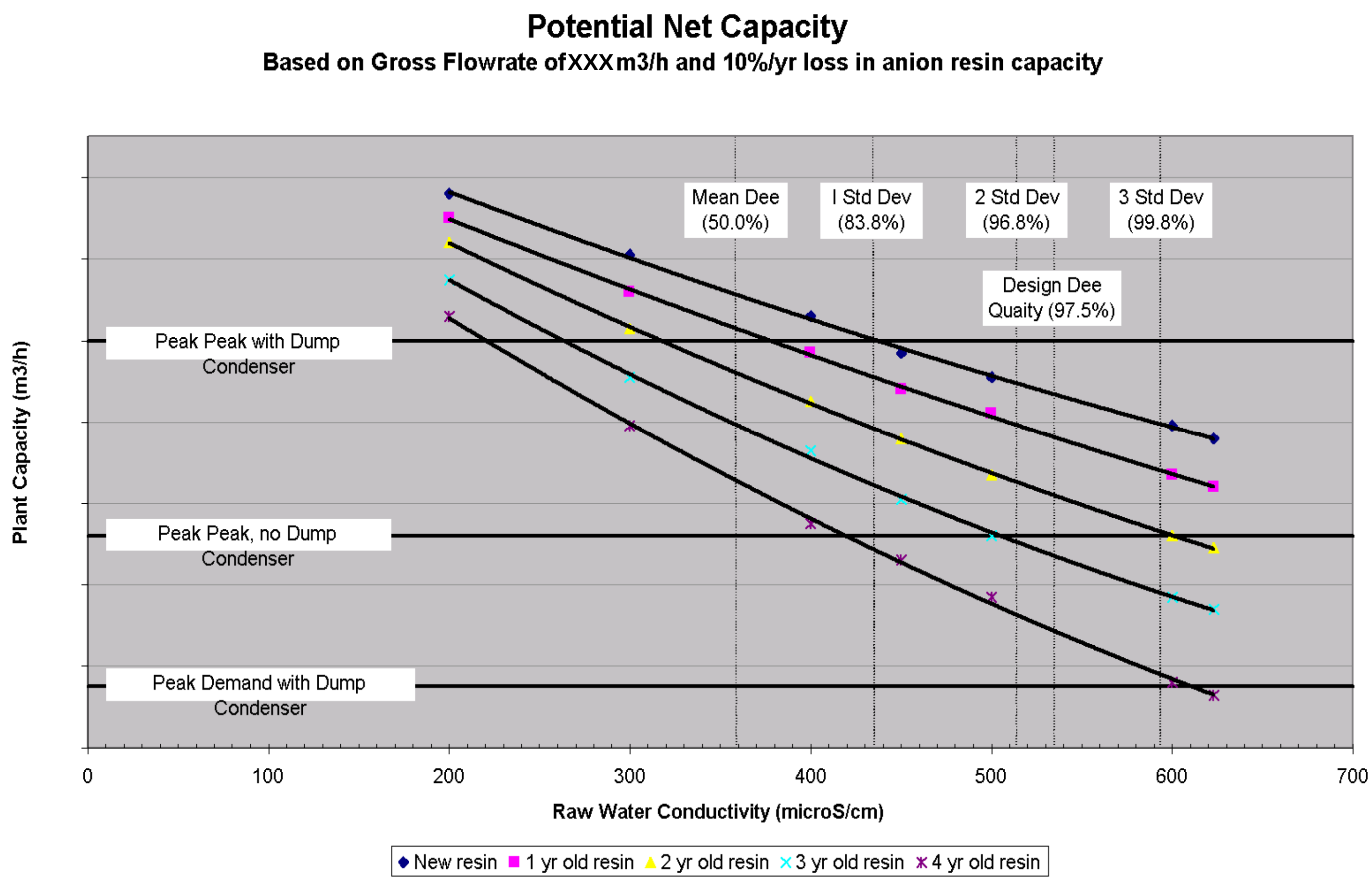
Overall net demand	250	m3/h
Calculated Service Life	83.4	h
Cycle Time	85.9	h
Streams available	2	
Time for effluent neut. & dischge	3	h
Interval between regenerations	43.0	h

Case study
Developed design basis

- Complex operation with many “consumers” on the site
  - Demand pattern highly variable
  - Variable condensate returns
- Needed to develop “supply management” model
  - Variable feedwater quality
  - Ageing ion exchange resin



Case study
Resin life



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Plant configuration - 1

- It is tempting to leave this to the “experts”
- But it is always wise to have your own view of what the plant will look like
  - Use the IEX2012 training notes to help you…
  - Speak to the Ion Exchange manufacturer

- What have you had before – and what were its limitations?
- What do your neighbours have?
- Has the raw water quality changed?

- Have a preliminary discussion with potential suppliers to understand the options

Plant configuration - 2

- Is a “standard” Cation + Anion configuration good enough?
  - Or would you benefit from using a more sophisticated design
    - WAC? WBA? Stratified Bed?
  - Would the operational benefits override the increased complexity

- Is it a known Fouling water with high / seasonal concentrations of natural organics?
  - Do you need a pretreatment stage to protect the resin?
  - Have you good or bad experience with different resin types?

- Co-flow regeneration or counter-flow regeneration?

Plant configuration - 3

- Do you need a Degasser?
  - Will it pay for itself?
    - Consider both Capex and Opex
  - Do you have room?

- Do you need a Mixed Bed Polisher to achieve the required quality
  - Or would a polishing cation unit do the job?

- If it is a large capacity plant, would you benefit from separating cation and anion pairs?
  - How would you manage effluent neutralisation?

Regeneration - equipment

- How many sets of regeneration equipment?
  - Cost Vs reliability
  - Consider consequences of failure / delays
    - e.g. double regenerations, brine wash
- Day tanks
  - Dilution
  - Level controls
  - Interlocks
- Ejectors Vs injection pumps
  - Accuracy
  - Reliability
  - Safety

Remember:
The most common fault in demineralisation plants is the failure to regenerate

Regeneration – control

- Most new plants have automatic regeneration, but can choose:
  - Fully automatic regeneration, including initiation
  - Fully automatic regeneration with manual initiation
  - Automatic regeneration with hold points, e.g. after rinse
  - Automatic with Manual step-through capability
  - Simultaneous Vs Consecutive

- When do you want to initiate regeneration?
  - Time?
  - Throughput?
  - Quality?
  - Throughput with Quality override?
  - Manually?

Regeneration – control (2)

- Regeneration may also need interlocks
  - Other stream(s) being regenerated
  - Regenerant Day Tank levels
  - Treated Water tank / Regenerant Water tank
  - Effluent Neutralisation tank

- Facility to adjust regeneration sequence
  - Backwash times and flowrate
  - Regenerant injection times
  - Regenerant displacement times
  - Rinse times
  - Regeneration levels
  - Quality set points

Regeneration – regenerants - acid

- Sulphuric
  - Cheaper
  - Poor at removing iron
  - Longer, more complex regeneration
  - Risk of calcium sulphate precipitation
  - More concentrated (96%)
  - Smaller storage tank or less frequent deliveries
  - Quality generally consistent
- Hydrochloric
  - More expensive
  - Good at iron removal
  - Simpler, quicker regeneration
  - No risk of precipitation
  - Less concentrated (36%, 28%)
  - Larger storage tank or more frequent deliveries
  - > 30% HCl fumes - may require scrubber
  - MUST be High Grade acid

Note: Nitric acid is not used as it is an oxidising acid and will destroy the resin

Regeneration – regenerants - alkali

- Caustic
  - Generally 45 to 47% strength, can get lower strength
    - If high strength Tank may require heating to prevent freezing
  - Quality generally good,
    - but beware iron, mercury, chloride
    - depends on source and manufacturing process

Regeneration – additional facilities

- Do you need additional facilities? e.g.
  - Caustic brine washing facility to remove organic contamination from anion resin?
    - Brine tank
    - Caustic injection
    - Dwell time
  - Cation resin cleaning facility
    - Hydrochloric acid injection or sodium dithionite
    - Dwell time
  - Double regeneration facility
    - Repeat acid and caustic injection stages without having to complete rinse after first regeneration
  - Chlorine removal with SMBS injection

Effluent neutralisation

- **Local Vs Central facility**
- **Pits Vs Tanks**
  - Materials of construction?
  - Lining?
- **How many pits/tanks do you need?**
- **How big?**
  - 1 or 2 regenerations?
  - Mixed Bed regeneration?
  - Caustic brine discharge?
- **Local acid/caustic tanks?**
- **Mixing?**
  - Jet mixers?
  - Circulating pumps?
- **Sizing of acid/caustic pumps**
  - Trimming pumps?
- **Monitoring and control**
  - pH measurement
  - Control algorithm
  - Links to DCS/SCADA system
- **Discharge control**
  - Interlocks

Control and instrumentation - 1

- **Controller**
  - PLC? – preferred supplier
    - Mimic screen vs text screen
  - DCS? - preferred supplier
  - SCADA?
  - Links to existing plant systems
- **Data storage**
  - How much? How long for?
- **Control facilities**
  - Specify what you want
    - Step through regeneration capability
    - Copy of control program
    - Facility to modify program, e.g. to fine tune regeneration sequence
    - Interrogation / fault tracing
    - Interlocks with plant operation

Control and instrumentation - 2

- Instrumentation
  - Sodium)
  - Silica)
  - Conductivity)
  - ?)

  - preferred supplier?
  - temperature compensated?
  - data storage?
  - multiple instruments / voting system?
- Location of instruments
  - Raw water?
  - In bed vs outlet?
  - After cation unit?
  - After anion unit?
  - After mixed bed polisher?
  - Common outlet?

Mechanical design - 1

- Vessels
  - Where is your plant located?
    - Footprint
    - Indoors vs. outdoors?
    - Weather protection
    - Containerised – pre-plumbed and pre-wired, tested off-site
  - Materials of construction
    - FRP? Lined carbon steel?
    - Lining material?
  - Design standards
    - Where will it be constructed?
    - Quality control
  - Access
    - Manways? Walkways?
  - Sight glasses?

Mechanical design - 2

- Distributors
  - Laterals Vs nozzle plates
  - Materials of construction
    - Stainless steel?
    - Plastic?
    - Lining?
  - Screw fittings or bayonet fittings?
  - Internal supports?
- Valves
  - Preferred supplier?
  - Local indication?

Mechanical design - 3

- Additional features
  - Resin traps
  - Sample points
  - Pressure gauges
  - ?

Risk and reliability - 1

- Demineralisation plants are often the weakest link on a production facility
  - If the demineralisation plant fails, production stops
- Important to critically examine the way in which the plant can fail and try to eliminate possible events at the design specification stage.

- Recommend to conduct a full Hazard and Operability Study starting at the design stage
  - Make sure you involve people who understand the importance of the plant

Risk and reliability - 2

- Topics for consideration include:
- Has the risk to production been assessed?
  - How much would it cost the business if the demineralisation plant was out of action?
- Number of streams vs. storage
  - Storage gives you a guaranteed shut-down period – assuming you keep it full
  - But if the storage tank is contaminated, how do you recover?
  - Additional streams give more purification capacity – but only if they are available
  - But if the common regeneration system fails, you can't produce any water
- Number of neutralisation tanks
  - However many streams you have, if you can't discharge the effluent you can't produce any water!

Risk and reliability - 3

- Common mode failures
  - Are there any single items which, if they failed, would prevent the plant from operating?
    - PLC controller?
    - Valves?
    - Vessels? – both ion exchange and regenerant
- Time for repair
  - If a failure did occur, how long would the plant be out of action?
- Technical service contract
  - Do you have the necessary expertise to assess the performance of the plant or do you need a contract with the OEM?
- Maintenance contract
  - Can you do all the maintenance yourselves or do you need a contract in place with the OEM?

Risk and reliability - 4

- Resin change strategy
  - How long will your resin last before it needs replacing?
  - How will you know when to replace it?
  - What is the lead time on the availability of resin for your plant?
- Spare charges / storage
  - Do you need to keep some spare resin on site (YES!)
  - How should it be stored so that it does not deteriorate?
- Mobile facility
  - If all else fails, could you bring a mobile demineralisation facility on site?
  - How many trailers would you need?
  - Where would you park them?
  - Do you have the necessary pipework connections?
  - Do you have the required power available?
  - Have you negotiated a supply contract with them?

Acceptance trials

- Need to plan your acceptance trials early
- Define what you need from the plant and ensure it is included in the Design Specification
  - What?
  - When?
  - By whom?
- No problems may be apparent in the first few months, but can you predict the future performance as the resin ages or fouls?

Conclusions

Check List
Maximum demand
"Worst" raw water quality
Four year old resins
One stream unavailable
Another stream in regeneration

- A bit of thought early in the Design Process can save a lot of problems later on
- Make sure you know what you want and discuss the options with your OEM(s) and Resin Suppliers
- Don't specify what you don't know – you will become responsible for it
- Be prepared to ask intelligent questions
- Don't cut corners!
- If your OEM is reluctant to talk to you about the detail, then find another OEM!
- Remember that cheap and good is cheap, but cheap and nasty is just nasty.
- You can ask for a plant which will produce "X m^3/h of water with a conductivity of < Y $\mu S/cm$ and with a silica concentration of < Z $\mu g/kg$ from the potable water supply to my site."

  – or you can ask for a plant which meets your needs...

And finally

"You can't always get what you want…

But if you try sometimes well you just might find

You get what you need"

– Rolling Stones

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