FRESENIUS MEDICAL CARE
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RO System Distribution Loop Indirect Feed vs Direct Feed

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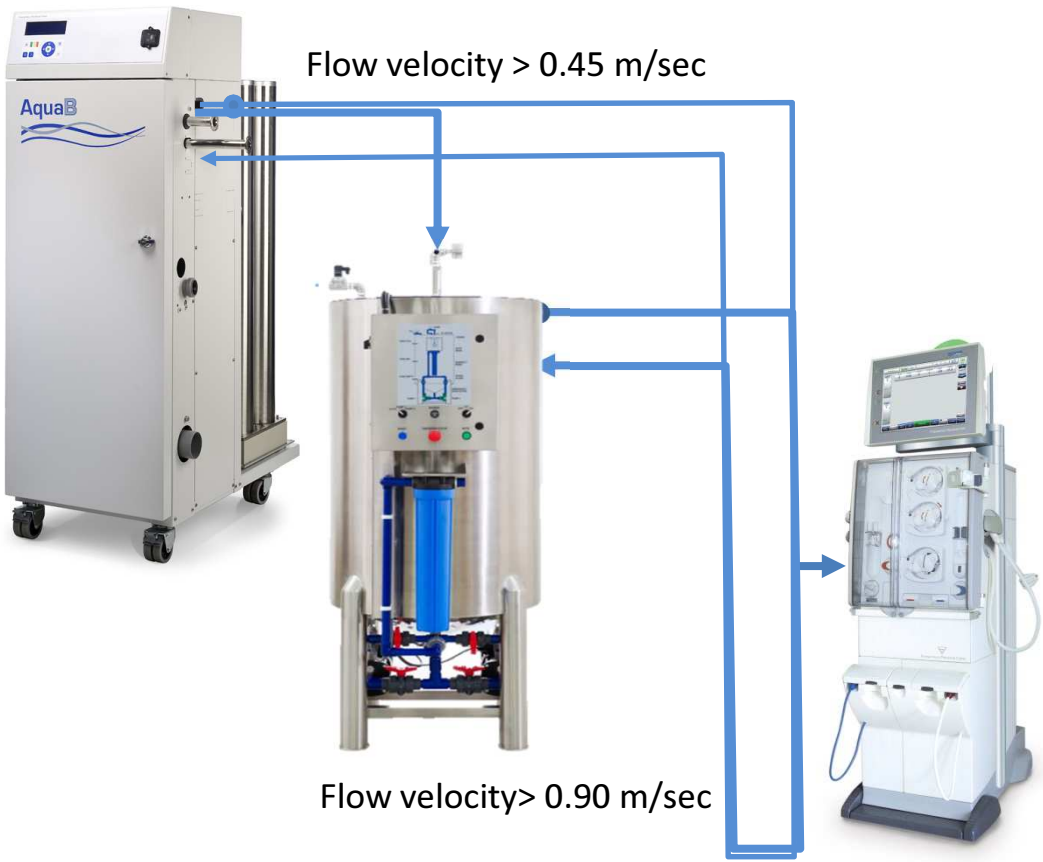
Agenda

Distribution Loop

Definition & Configuration

- ***Definition***
  - The distribution loop is the physical means for the delivery of purified water from the purification equipment to the dialysis equipment
- ***Configuration***
  - **Direct feed**
    - Purified water is delivered from RO Unit to HD equipment
    - Required flow velocity >0.45 m/sec
  - Indirect feed
    - Purified water is delivered from RO Unit to a storage tank and from storage tank to HD equipment
    - Required flow velocity >0.90 m/sec



Distribution Loop

Choice for system configuration depends on:

- *Purity of water required*
  - Must not degrade water quality achieved during purification processes
- *Amount of water required*
  - Delivers purified water at appropriate pressures and flow rates
  - Dependent on number of machines
- *Choice of material depends on*:
  - Cost
  - Availability
  - Inertness to chemicals
  - Lifespan of material

- Materials not to be used include:
  - Brass, Copper, Aluminum and Zinc

Distribution Loop

Acceptable Materials

Material	Description	Cost	Installation	No. of fittings	Risk of stagnation	Availability	Inertness to chemicals	Resistance to heat	Life span
PVC Type 1	Polyvinyl chloride	Low	Medium	High	High	Easy	Yes	No	5 – 10 years
ABS	Acrylonitrile butadiene styrene	Medium	Medium	High	High	Medium	Yes	No	10 years
PP-R	Polypropylene Random	High	Medium	High	High	Difficult	Yes	Yes	10 years
SS	Stainless Steel	High	Difficult	Low	Low	Difficult	Yes	Yes	25 years
PEX	**Cross-linked Polyethylene**	**Low**	**Easy**	**Low**	**Low**	**Easy**	**Yes**	**Yes**	**15 – 20 years**

Distribution Loop

Design suggestions	Comments
• Reduce elbows and fittings during installation	• ABS, PP-R, and PVC require many fittings, increasing the risk of bacterial contamination
• Only install machine connections that are required	• Each connection is a risk for stagnations
• Fresenius Medical Care recommends opaque PEX (RAUPEX)	• PEX is flexible – meaning less fittings required and can be installed quickly
• Min. 6 monthly chemical disinfection	• More frequent disinfection is recommended
• Weekly heat disinfection is recommended if system is capable	• Heat disinfection is a preventive measure

Distribution Loop - Disinfection

Chemical Disinfection	Heat Disinfection (>85°C)
• Reactive measure	• Proactive measure
• Frequency: 6 monthly	• Frequency: weekly
• Eliminates existing bacteria	• Prevents bacteria growth
• High risk if biofilm	• Low risk of biofilm
• Chemical is not environmental friendly	• Environmental friendly
• High risk to operator	• Low risk to operator
• Manual process, requires manpower	• Automated process
• Longer process as chemicals need to flush out	• Shorter process – only cool down required
• Lower initial cost	• Higher initial cost

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Pro's & Con's of Indirect Feed

Pro's	Con's
• Smaller Reverse Osmosis (RO) Systems could be used, avoiding peak load periods • Water saving, as RO stops when Tank is FULL -> no Reject to drain • Dialysis Water buffer if: – Raw water supply is unreliable – RO System is unreliable • Longer Distribution Loop can be installed • RO System can be located on different floors (more than 1)	• Dialysis Water no longer purified • Disinfection and maintenance is more difficult and often impossible • Higher power consumption due an extra pump • Poor tank designs may lead to: – Stagnation – Contamination (inadequate air filter) – Biofilm • No patient protection if Dialysis Water out of specification (no direction to drain) • Higher risk of Bacterial contamination

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Storage Tank Requirements

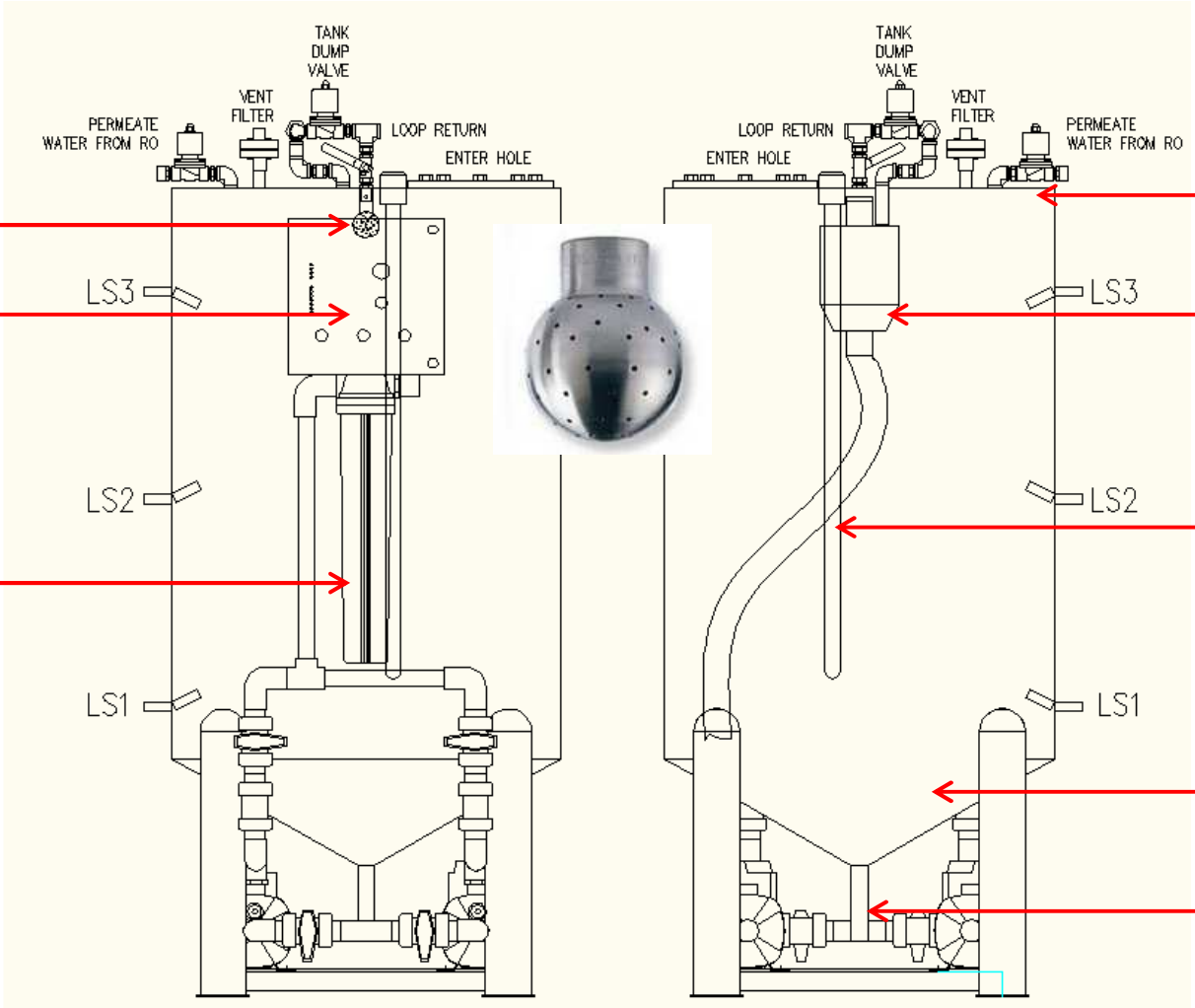
Spray Ball mechanism to eliminate stagnation & ensure complete disinfection of tank

Automatic disinfection program

Properly sized Bacterial filter on water outlet.

Small undersize filter housing and filters suffer from pressure loss and bypass issues

Please note:
Filters do not prevent endotoxins from entering the system, UV radiation is required



Sealed Lid with adequate air vent

Sealed Overflow in case of malfunction

UV Disinfection Lamp, lamp replaced every year

Conical or bowl shape

Drainage from lowest point

Storage Tank - Pitfals

Experience for the Field

- Storage Tank does not conform with ISO26722
- Poor design & installation of Storage Tank
- Very difficult to disinfect Tank connection pipe
- Inappropriate filter used or not replaced regularly

Please note: If UV monitor is used, it needs to be a calibrated ultraviolet intensity meter, the minimum dose of radiant energy should be at least 16 mW sec/cm2

Easier and more economical is to replace the lamp as per the manufacturers guidelines (12 monthly)

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Pro's & Con's of Direct Feed

Pro's	Con's
• Patient Safety as Dialysis Water is constantly monitored & sent to drain if unsuitable • Continues purification of unused Dialysis Water • Reduced risk of bacterial contamination • Easy to disinfect as Loop & RO are disinfected together • Faster flush out of chemicals • Additional protection against bacterial contamination if RO is equipped with UV sterilizer • No need for an extra recirculation pump	• RO System must be sized to fulfil max. demand • Higher water consumption due to continues reject to drain (**not with MX Eco**) • If RO System is unreliable, all dialysis stops as there is no buffer of purified water – Tank Buffer only lasts for ~1 hour • Distribution loop length limitation • RO System must be located on the same floor (± 1) as the dialysis unit

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Distribution Loop Examples

Direct Feed (PEX)

Dialysis Unit information:

- Number of HD Machines = 16
- Number of Reuse Device = 2

Dialysis Water required:

HD Machines * max dialysis flow + Reuse Device * max flow rate

= 16*0.5+2*2 = 12 L/min

Required RO is **MX Eco 3** with **15 L/min**

Choice of distribution Loop (PEX)

- Direct feed must be >0.45 m/sec

- **Choice of pipe size = 20 mm**

Dialysis Water Flow Rate	PEX (SDR 7.4) Diameter mm	Velocity Metres/sec	Pressure Drop per 100 m (Straight)
5	20 (14.5)	0.50	0.3 bar
5	25 (18.2)	0.32	0.1 bar
10	20 (14.5)	1.01	1.01 bar
10	25 (18.2)	0.64	0.34 bar
15	20 (14.5)	1.51	2.08 bar
15	25 (18.2)	0.96	0.70 bar
20	20 (14.5)	2.01	3.49 bar
20	25 (18.2)	1.28	1.16 bar

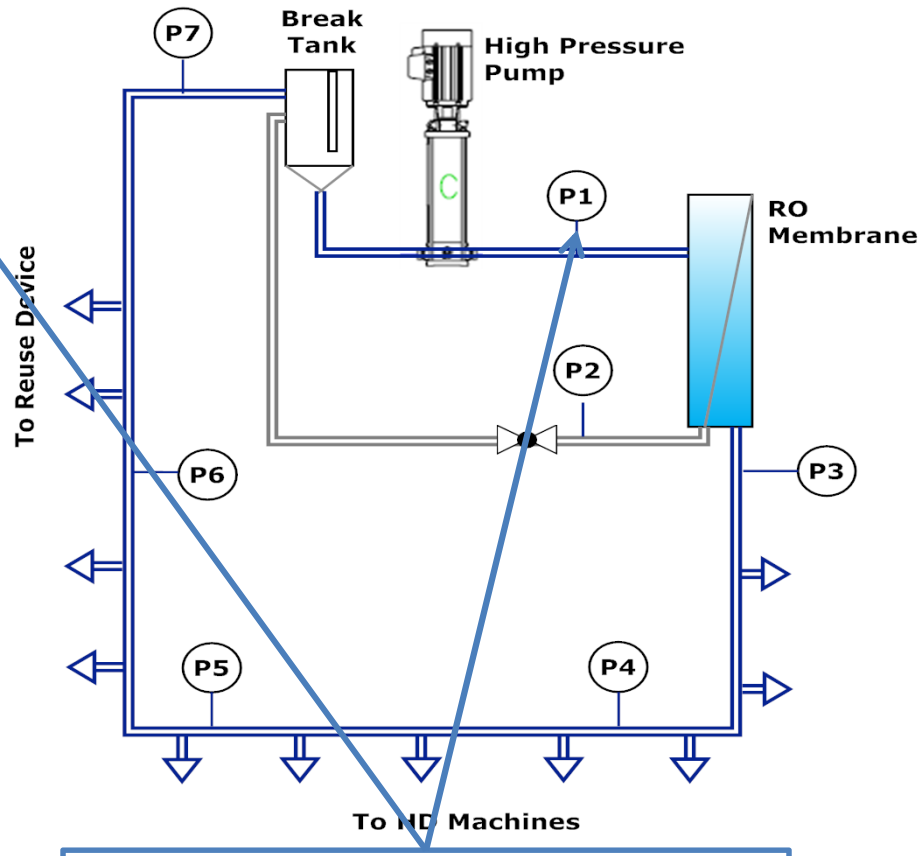
PEX tubing absolute roughness = 0.007 mm

For other material:
- Velocity may be lower
- Pressure drop may be higher

Distribution Loop Examples

Direct Feed (PEX) – 100 m

- P1 – Before RO Membrane
  - Feed Pressure = 8 bar
- P2 – Reject Line
  - Reject pressure = 7 bar
- P3 – After RO Membrane
  - Loop pressure = 4 bar
  - HD machines = 0
  - Dialysis water flow = 15 L/min
  - Velocity = 1.51 m/s
- P4 – After 30 m of Loop
  - Loop pressure = 3.37 bar
  - HD machines = 4
  - Dialysis water flow = 13 L/min
  - Velocity = 1.31 m/s
- P5 – After 50 m of Loop
  - Loop pressure = 3.05 bar
  - HD machines = 8
  - Dialysis water flow = 11 L/min
  - Velocity = 1.11 m/s
- P6 – After 70 m of Loop
  - Loop pressure = 2.81 bar
  - HD machines = 12
  - Dialysis water flow = 9 L/min
  - Velocity = 0.91 m/s
- P7 – End of Loop
  - Loop pressure = 2.64 bar
  - HD machines = 16
  - Reuse machine = 2
  - Dialysis water flow = 3 L/min
  - Velocity = 0.3 m/s

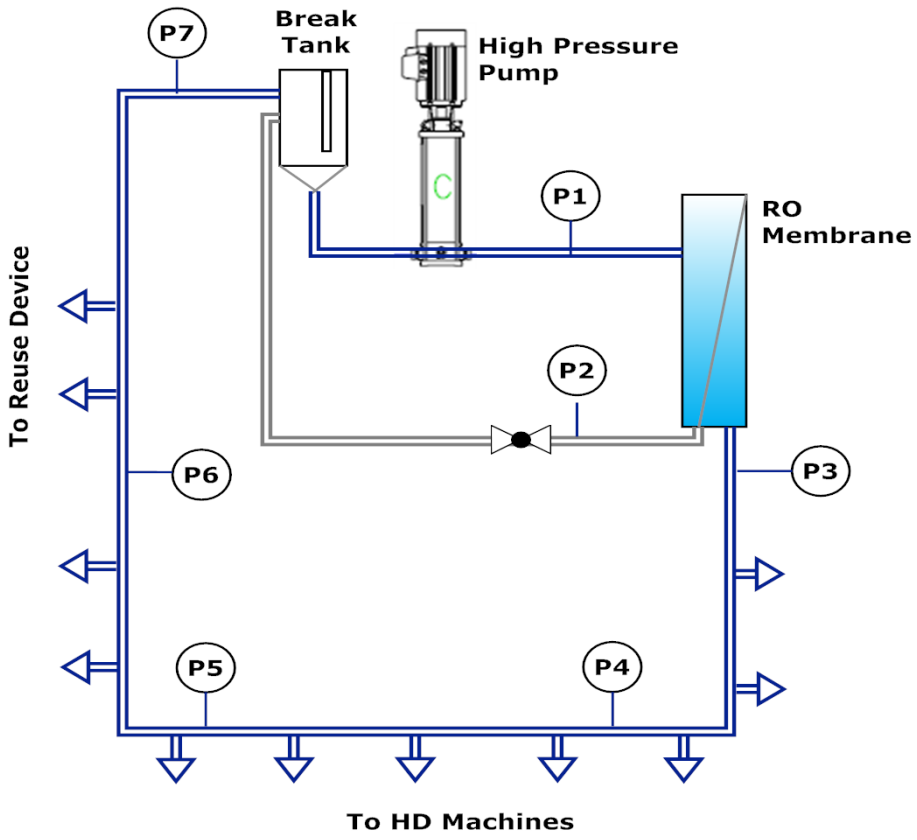


Applied pressure (P1) as per manufacturer's recommendations

Distribution Loop Examples

Direct Feed (PEX) – 250 m

- P1 – Before RO Membrane
  - Feed Pressure = 8 bar
- P2 – Reject Line
  - Reject pressure = 7 bar
- P3 – After RO Membrane
  - Loop pressure = 4 bar
  - HD machines = 0
  - Dialysis water flow = 15 L/min
  - Velocity = 1.51 m/s
- P4 – After 75 m of Loop
  - Loop pressure = 2.44 bar
  - HD machines = 4
  - Dialysis water flow = 13 L/min
  - Velocity = 1.31 m/s
- P5 – After 125 m of Loop
  - Loop pressure = 1.63 bar
  - HD machines = 8
  - Dialysis water flow = 11 L/min
  - Velocity = 1.11 m/s
- P6 – After 175 m of Loop
  - Loop pressure = 1.03 bar
  - HD machines = 12
  - Dialysis water flow = 9 L/min
  - Velocity = 0.91 m/s
- P7 – End of Loop
  - Loop pressure = 0.61 bar
  - HD machines = 16
  - Reuse machine = 2
  - Dialysis water flow = 3 L/min
  - Velocity = 0.3 m/s



Distribution Loop Examples

Indirect Feed (PEX)

Dialysis Unit information:

- Number of HD Machines = 16
- Number of Reuse Device = 2

Booster Pump CM3-5:

Flow rate @ 4.0 bar ~ 23 L/min

Dialysis Water consumption = 12 L/min

Choice of distribution Loop (PEX)

- Direct feed must be >0.90 m/sec

- **Choice of pipe size = 25 mm**

In Indirect Feed; flow rate & pressure are controlled by the booster pump!

Dialysis Water Flow Rate	PEX (SDR 7.4) Diameter mm	Velocity Metres/sec	Pressure Drop per 100 m (Straight)
10	20 (14.5)	1.01	1.01 bar
10	25 (18.2)	0.64	0.34 bar
15	20 (14.5)	1.51	2.08 bar
15	25 (18.2)	0.96	0.70 bar
20	20 (14.5)	2.01	3.49 bar
20	25 (18.2)	1.28	1.16 bar
30	20 (14.5)	3.03	7.27 bar
30	25 (18.2	1.92	2.41 bar

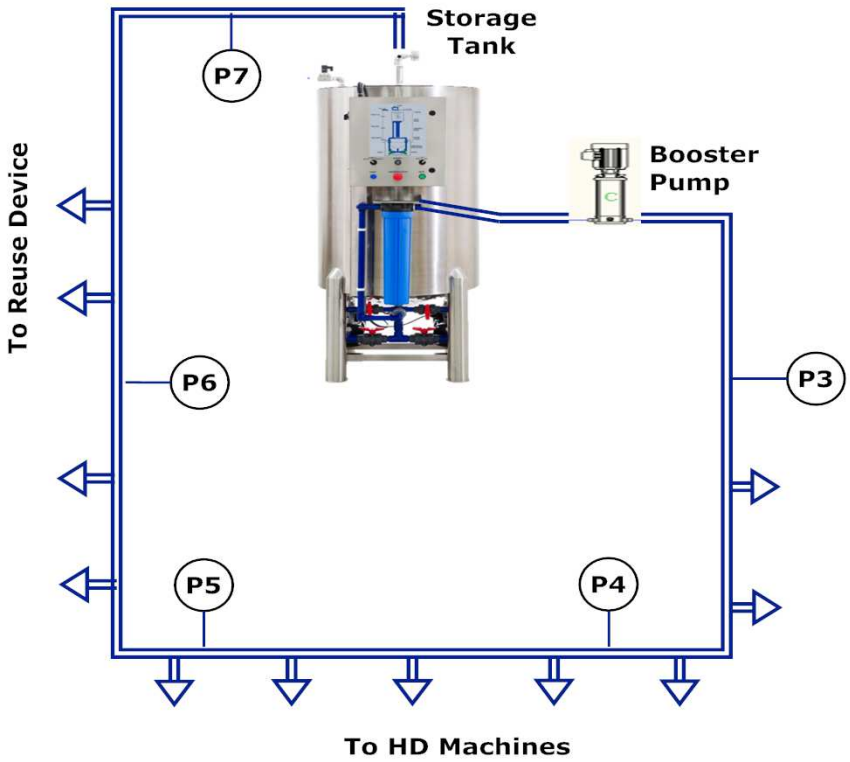
PEX tubing absolute roughness = 0.007 mm

For other material:
- Velocity may be lower
- Pressure drop may be higher

Distribution Loop Examples

Indirect Feed (PEX) – 250 m

- Booster Pump CM3-5
  - Feed Pressure = 4 bar
  - Dialysis water flow ~ 23 L/min
- P3 – Start of Loop
  - Loop pressure = 4 bar
  - HD machines = 0
  - Dialysis water flow = 23 L/min
  - Velocity = 1.47 m/s
- P4 – After 75 m of Loop
  - Loop pressure = 2.88 bar
  - HD machines = 4
  - Dialysis water flow = 21 L/min
  - Velocity = 1.35 m/s
- P5 – After 125 m of Loop
  - Loop pressure = 2.24 bar
  - HD machines = 8
  - Dialysis water flow = 19 L/min
  - Velocity = 1.22 m/s
- P6 – After 175 m of Loop
  - Loop pressure = 1.71 bar
  - HD machines = 12
  - Dialysis water flow = 17 L/min
  - Velocity = 1.09 m/s
- P7 – End of Loop
  - Loop pressure = 1.35 bar
  - HD machines = 16
  - Reuse machine = 2
  - Dialysis water flow = 11 L/min
  - Velocity = 0.7 m/s



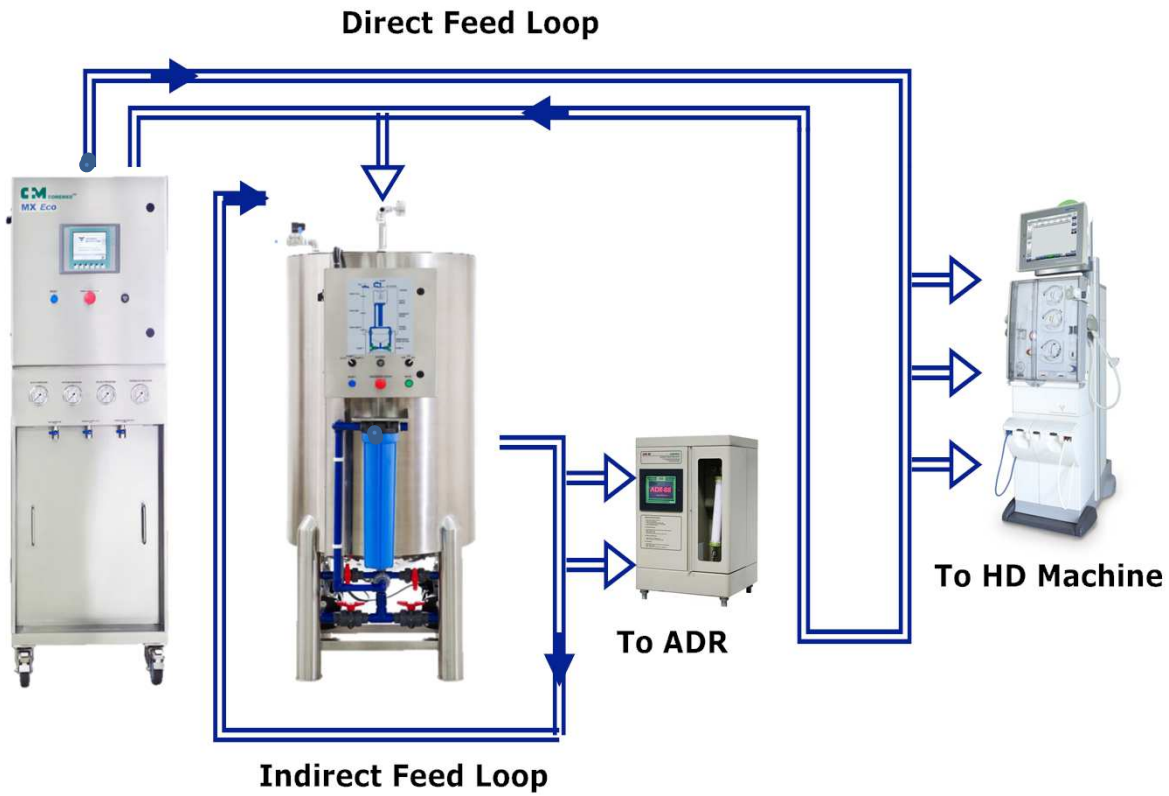
With Indirect Feed, flow rate and pressure are controlled by the booster pump!

In some installations we mix pipe size to ensure sufficient velocity at the end of the loop!

Distribution Loop Examples

Mixed Loop

- Direct feed to HD Machine
  - Reduced risk of bacterial contamination
  - Continues purification of dialysis water
  - Ease of disinfection
  - Ro Sized to fulfil HD Machine water requirements
- Indirect feed to ADR
  - Peak consumption covered by storage tank
  - Operation id independent of direct feed
  - Ease of disinfection and maintenance



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Summary

Distribution Loop - What is the right configuration?

- **Direct Feed** is recommended, however, choice depends on:
  - Location & local requirements
  - Loop length
  - Peak consumption
- **Indirect Feed** has a higher risk of bacterial contamination though:
  - Non-compliant Storage Tanks
  - Ineffective disinfection
- Economy through **Indirect Feed**
  - Only true for less advanced RO Systems
  - Fresenius Medical Care MX Eco system, with dynamic Recovery
    - Water consumption does NOT increase in **Direct Feed**
    - Energy consumption is similar in both configurations
    - MX Eco can achieve Recovery of up to 90%
- Specific configuration (Direct/Indirect) **shall not** be directed, as it depends on local factors

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Thank you for your kind attention

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