

Lab Design: RO/DI High Purity Water & pH Neutralization Systems

Mark Girgenti



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**Lab Design: RO/DI High
Purity Water & pH
Neutralization Systems**

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Passive Systems
- Single direction Treatment
- Unable to treat strong waste streams

Active Systems
- Can treat in both directions
- Can treat waste of any strength



System Designs

There are three main styles of pH/waste water treatment.

- Flow Through Systems
- Batch Treatments Systems
- Hybrid Flow/Batch Systems

Active vs. Passive Systems



Passive Systems

- Single direction Treatment
- Unable to treat strong waste streams

Active Systems

- Can treat in both directions
- Can treat waste of any strength

Active vs. Passive Systems

pH Range

Active Systems



Passive Systems

Typical Effluent Required Range

Passive Systems

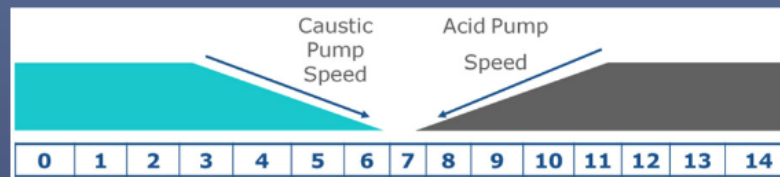
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Active Systems

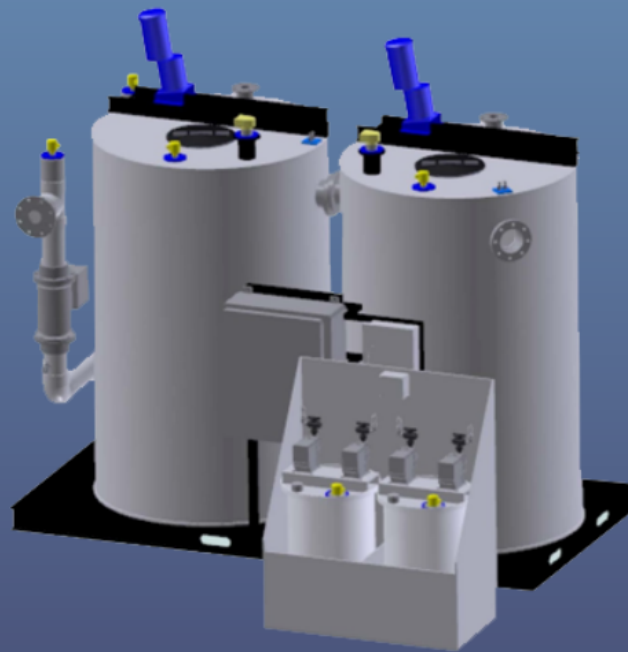
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System Components: Control Schemes

Proportional control is the most common control scheme for pH adjustment systems. It is based on the logarithmic nature of pH and adjusts the chemical addition proportionally to the pH reading or any other waste constituent you can measure in real time.



Major System Components



System Components: Treatment Tanks

The treatment tanks in a pH adjustment system are designed as continuously stirred-tank reactors (CSTR). They are sized and agitated to create ideal mixing so the pH in the tank is equivalent to the pH leaving the tank.

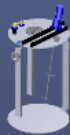


System Components: Tank Agitation

In tank mixers are the ideal choice for tank agitation due to their capacity.

Rate of Mixing:
1.5 x tank volume pumping rate required for well mixed solution.

Due to the ideal model of the CSTR, multiple stages are more efficient than one large stage.



System Components: Chemical Injection

Since a CSTR model allows for uniform pH across the treatment tank, reagent injection must be properly injected into the mixer wash and controlled to avoid swings in pH and to allow for adequate mixing for other reagents. The most common reagents for pH adjustment are sulfuric acid and sodium hydroxide. Additionally, carbon dioxide gas can be used.

Important Considerations

- Turn down for reagent injection proportional to logarithmic pH scale.
- Control not to oversize to avoid instability in controlling pH.
- Other reagents adds on a volumetric basis for additional treatment.



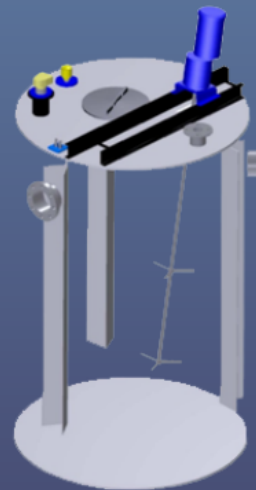
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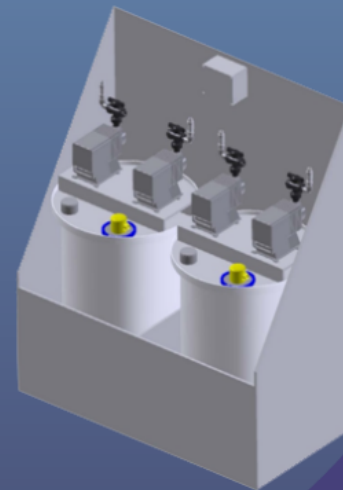


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- Other Reagents adds on a volumetric basis for additional treatment



Case Study 1

Application: Collegiate Biology Building

1st step is develop the flow profile:

Flow profile

The system accepts waste from a 7 floor lab building.

Fixture counts include:

- 100 Lab Sinks
- 50 cup sink
- 12 Fume Hoods
- 2 Cage washers

Using the Sizing Calculations

Calculate Flow

Lab Sink Flow= 1 GPM x 100 Lab Sinks = 100 GPM

Cup Sink = 0.5 GPM x 50 Cup Sinks= 25 GPM

Fume Hood = 0.25 GPM x 12 Fume hoods= 3 GPM

Total Fixture Flow is 128 GPM x 20% diversity factor= 26 GPM

Assuming 1 cage washer operating at 8 GPM,

TOTAL Flow=34 GPM

System selection

Based on 34GPM flow rate over a pH differential of 4 from neutral

400 Gal. CONTINUOUS FLOW SYSTEM

Flow Through Tank Size

Based on 34 GPM and achieve a 15 minute residence time.

34G x 15 Min~ 500 gal. total volume.

2nd Step is determining your waste characteristics

Based on review of chemicals in building use and nature of the client the pH range

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Special Waste Considerations:
None



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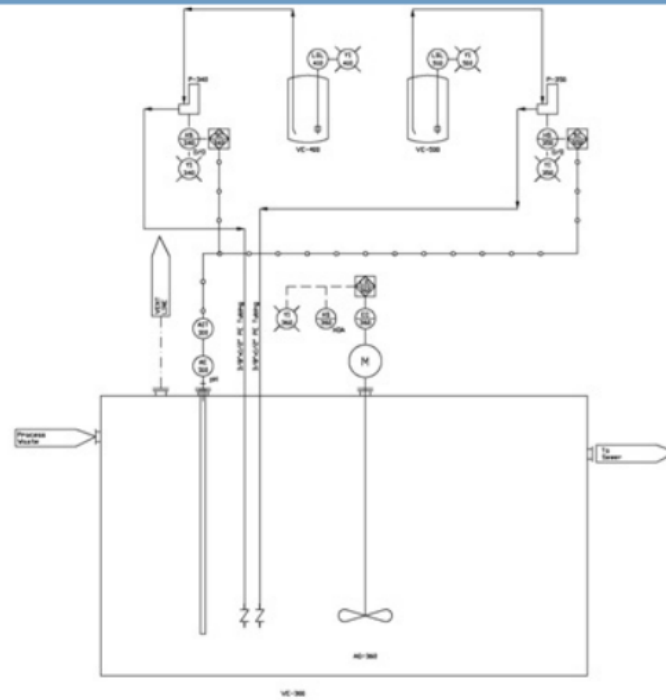
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VC-300

E-340
Process Tank
Quartic Reagent Pump
PULSATION RESISTANT-PTC
3 GPM MAX / 25 psi MAX
120VAC 50 60Hz

25 GALLON VC-400
Quartic Reagent Tank

VC-300
Process Tank
Polystyrene

E-350
Process Tank
Acid Reagent Pump
PULSATION RESISTANT-PTC
3 GPM MAX / 25 psi MAX
120VAC 50 60Hz

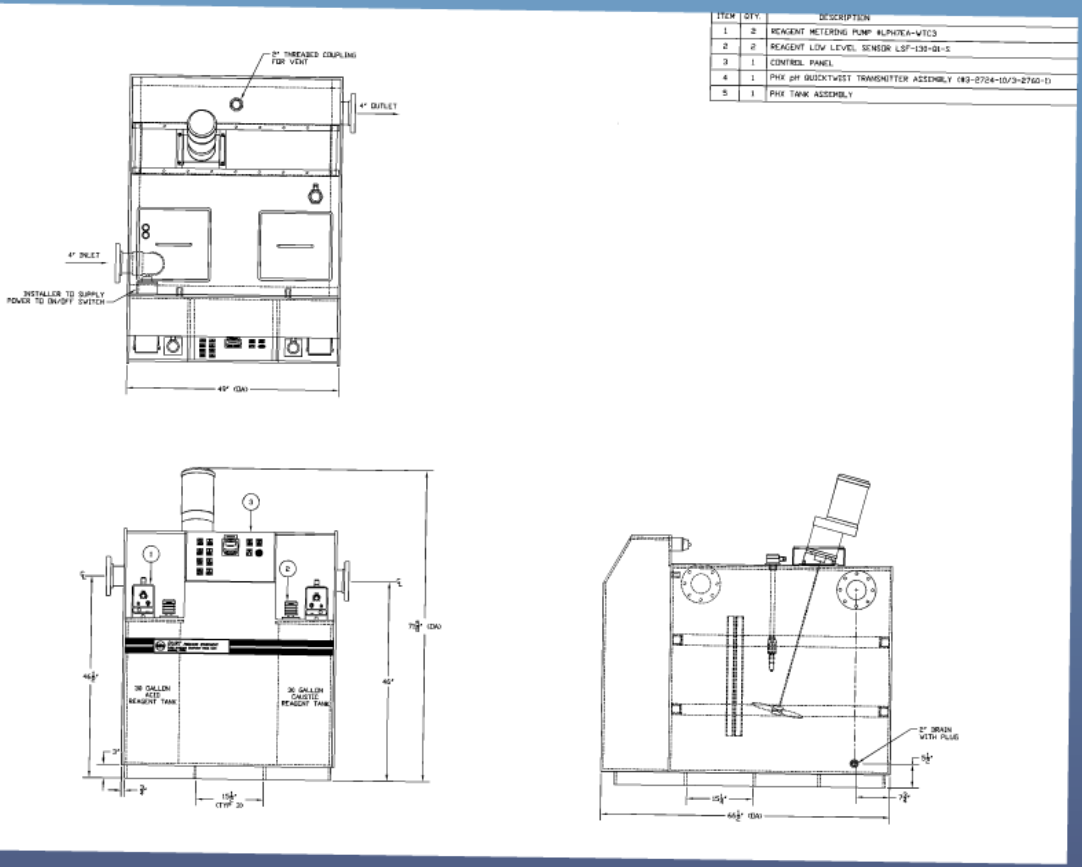
25 GALLON VC-500
Acid Reagent Tank

AC-300
Process Motor

NOTE

1. --- Customer Piping

2. All exterior piping by others.



RODI High Purity Water



Water Quality Standards

ASTM Standards (Types 1-4) (American Society for Testing and Materials)

Parameter	ASTM 1	ASTM 2	ASTM 3	ASTM 4
Conductivity (mS/cm)	0.056	1.0	0.25	5.0
Resistivity (megohm-cm)	18.0	1.0	4.0	0.2
pH	--	--	--	5.0-8.0
TOC (mg/L)	100	50	200	--
Sodium (mg/L)	1	5	10	50
Chloride (mg/L)	1	5	10	50
Nitrate (ppm)	--	--	--	--
Silica (mg/L)	3	5	500	No limit
Bacteria (cfu/mL)	0.01	0.1	10	--

Water Quality Standards

CAP Guidelines (Types 1-3)

(College of American Pathologists)

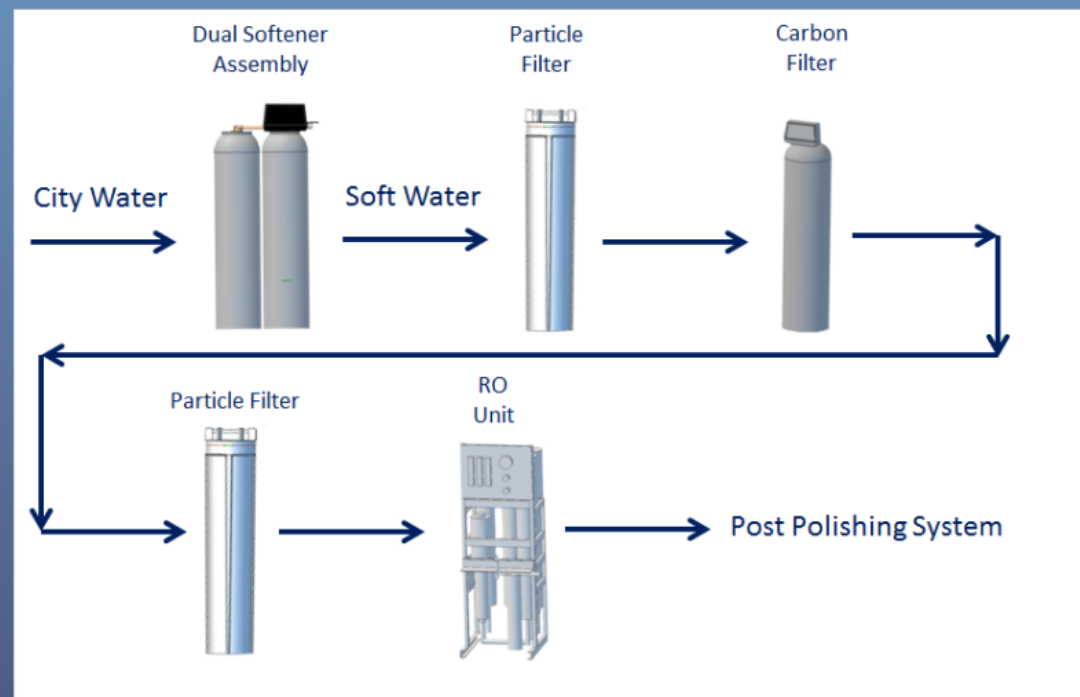
*previously known as the National Committee
for Clinical Laboratory Standards*

Parameter	CAP/NCCLS 1	CAP/NCCLS 2	CAP/NCCLS 3
Conductivity (mS/cm)	< 0.1	< 0.5	< 10.0
Resistivity (megohm-cm)	> 10	> 2.0	> 1.0
pH	--	--	5.0-8.0
Silica (mg/L)	< 0.5	< 0.1	< 1.0

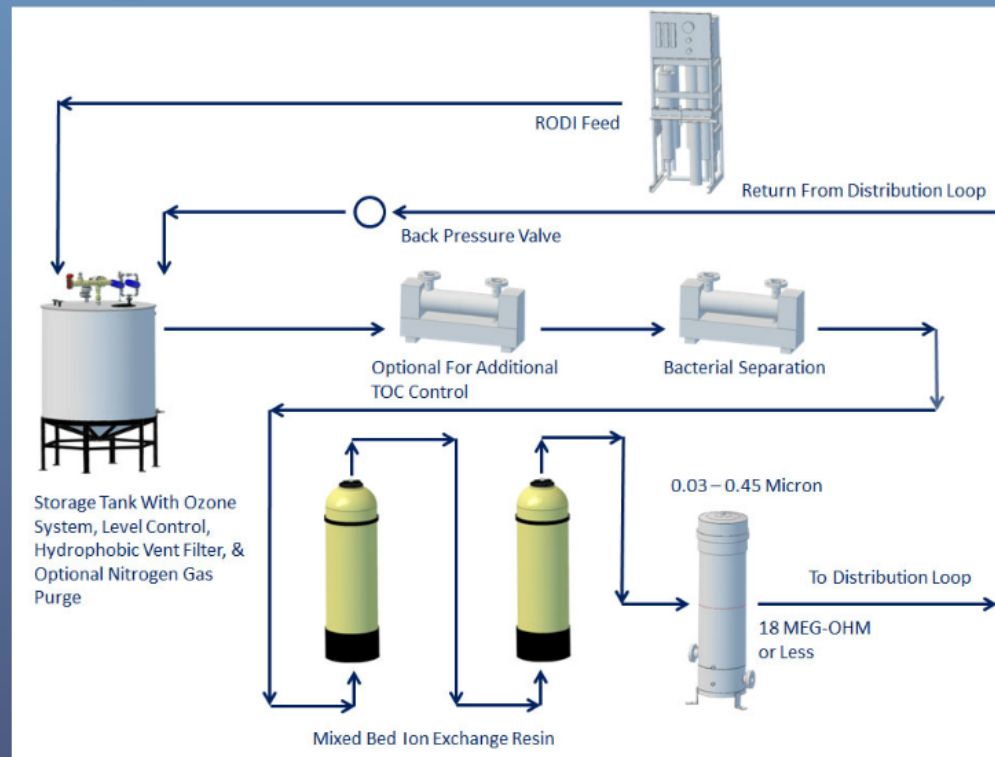
BPE's RODI System Basics

- Pretreatment
- Reverse Osmosis
- Storage Tank
- Recirculation Pump (s)
- Ion Exchange (DI)
- UV (Ultraviolet lamps)
- Final Filter
- Instrumentation
- The Loop (plumbing)

Pretreatment Train



Post RO Polishing System in The Loop



Design Conditions

Parameters	Unit	Values
Cl	ppm	6.0
NO3	ppm	0.33
SO4	ppm	15.2
Ca	ppm	7.2
Mg	ppm	0.7
Na	ppm	22.2
Cu	ppm	0.03
Fe	ppm	0.04
F	ppm	1.0
CO2	ppm	0.03
TOC	ppm as C	1.6
TDS	ppm	58.7
pH (25°C)	-	9.35
Conductivity	μohms-cm	124
Alkalinity	ppm	46
Total Hardness	ppm	21
Free Chlorine	ppm	0.1 - 2.2
Turbidity	NTU	0.7

Parameters	Values (US unit)	Values (SI unit)	Remarks
Pre-treatment	80 GPM	18.2 m ³ /h	(TBD by supplier)
RO Make-up	60 GPM	13.6 m ³ /h	
Recirculation	125 GPM	28.4 m ³ /h	@ 90 psig - 6.4 kg/cm ²

Parameters	Unit	DI Water
Supply Pressure	psig	70 ±10
Temperature	°F	55 - 77
Resistivity @ 25°C	Mohm-cm	≥ 10
TOC	ppb	≤ 300
Bacteria	CFU per ml	< 10

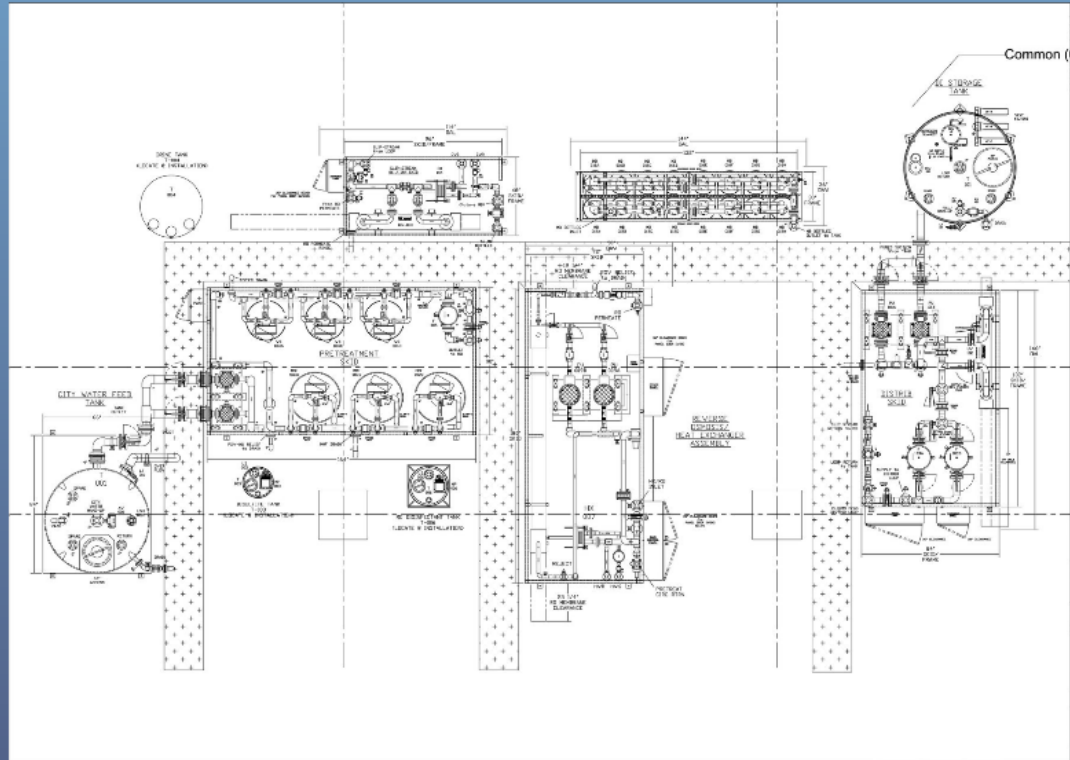
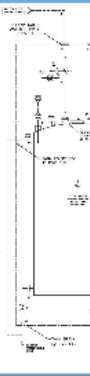
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Na	ppm	22.2
Cu	ppm	0.03
Fe	ppm	0.04
F	ppm	1.0
CO2	ppm	0.03
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TDS	ppm	58.7
pH (25°C)	-	9.35
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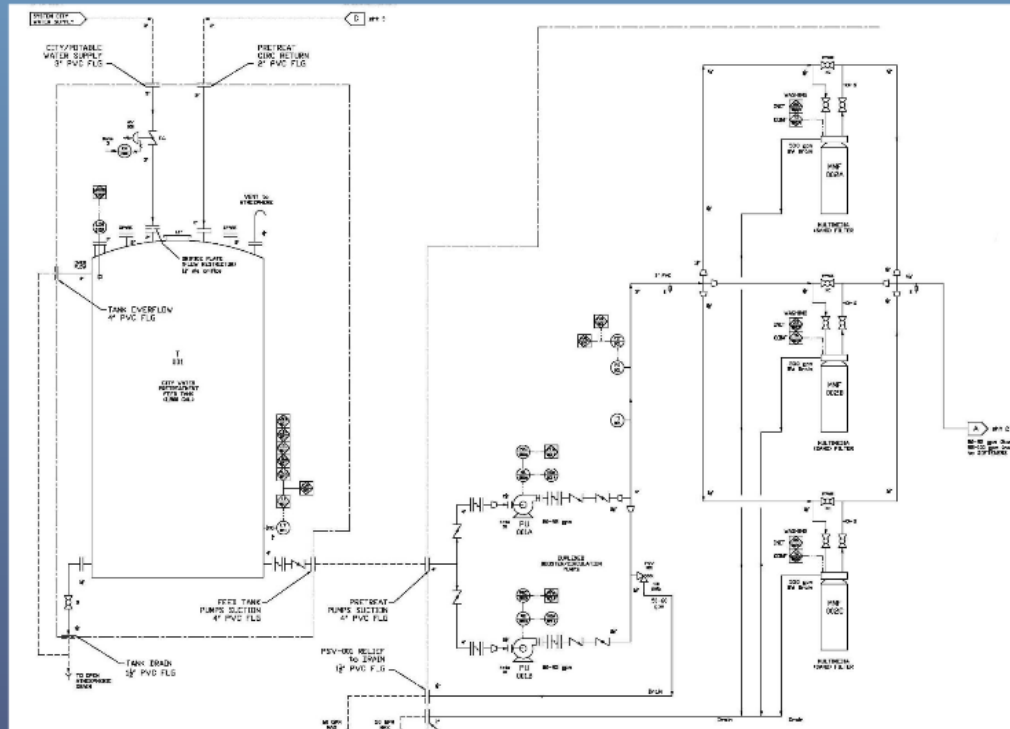
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Parameters	Unit	DI Water
Supply Pressure	psig	70 ±10
Temperature	°F	55 - 77
Resistivity @ 25°C	Mohm-cm	≥ 10
TOC	ppb	≤300
Bacteria	CFU per ml	< 10

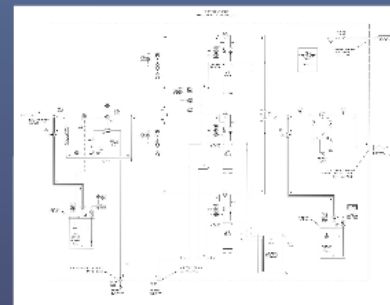


RODI Case Study



RODI Case Study

Softener Capacity Calc's		Softener Capacity Calc's	
C-100E		C-100E	
80.0 gpm	80.0 gpm	80.0 gpm	80.0 gpm
100 ppm (CaCO ₃)	150 ppm (CaCO ₃)	150 ppm (CaCO ₃)	150 ppm (CaCO ₃)
10 ft ²	10 ft ²	10 ft ²	10 ft ²
24 inches	24 inches	24 inches	24 inches
15 lbs salt / ft ² resin	15 lbs salt / ft ² resin	15 lbs salt / ft ² resin	15 lbs salt / ft ² resin
29,200 (grains / ft ² resin)	29,200 (grains / ft ² resin)	29,200 (grains / ft ² resin)	29,200 (grains / ft ² resin)
293 k-grains capacity	293 k-grains capacity	293 k-grains capacity	293 k-grains capacity
50,162 gallons	33,441 gallons	33,441 gallons	33,441 gallons
10.5 total hours in service	7.0 total hours in service	7.0 total hours in service	7.0 total hours in service
150 lbs salt / regen	150 lbs salt / regen	150 lbs salt / regen	150 lbs salt / regen
60.0 gal conc. Brine	60.0 gal conc. Brine	60.0 gal conc. Brine	60.0 gal conc. Brine
161.3 gal dilute Brine	161.3 gal dilute Brine	161.3 gal dilute Brine	161.3 gal dilute Brine
101.3 gal diluten Water	101.3 gal diluten Water	101.3 gal diluten Water	101.3 gal diluten Water
30 minutes	30 minutes	30 minutes	30 minutes
2.00 gpm	2.00 gpm	2.00 gpm	2.00 gpm
2.38 gpm	2.38 gpm	2.38 gpm	2.38 gpm
5.38 gpm	5.38 gpm	5.38 gpm	5.38 gpm
8.00 gpm / ft ²	8.00 gpm / ft ²	8.00 gpm / ft ²	8.00 gpm / ft ²
39.8 inches	39.8 inches	39.8 inches	39.8 inches
3.01 ft ²	3.01 ft ²	3.01 ft ²	3.01 ft ²
26.56 gpm / ft ²	26.56 gpm / ft ²	26.56 gpm / ft ²	26.56 gpm / ft ²
8.00 gpm / ft ²	8.00 gpm / ft ²	8.00 gpm / ft ²	8.00 gpm / ft ²
15.1 gpm	15.1 gpm	15.1 gpm	15.1 gpm
30.1 gpm	30.1 gpm	30.1 gpm	30.1 gpm
gallons / yr	gallons / yr	gallons / yr	gallons / yr
lbs salt / yr	lbs salt / yr	lbs salt / yr	lbs salt / yr

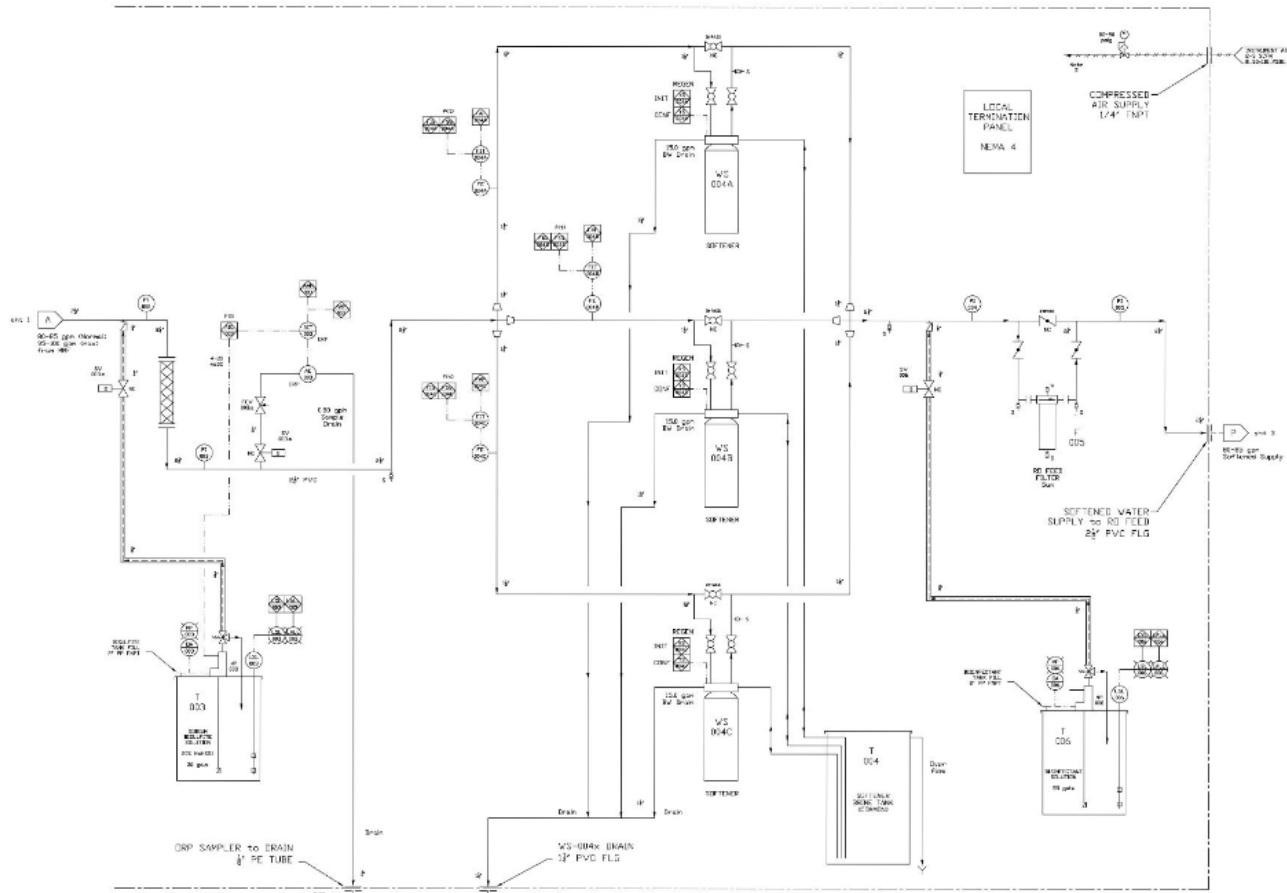


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100 ppm (CaCO ₃)		150 ppm (CaCO ₃)	
10 ft ³		10 ft ³	
24 inches		24 inches	
15 lbs salt / ft ³ resin		15 lbs salt / ft ³ resin	
29,300 (grains / ft ³ resin)		29,300 (grains / ft ³ resin)	
293 k-grains capacity		293 k-grains capacity	
50,162 gallons		33,441 gallons	
10.5 total hours in service		7.0 total hours in service	
150 lbs salt / regen		150 lbs salt / regen	
60.0 gal conc. Brine		60.0 gal conc. Brine	
161.3 gal dilute Brine		161.3 gal dilute Brine	
101.3 gal dilution Water		101.3 gal dilution Water	
30 minutes		30 minutes	
2.00 gpm		2.00 gpm	
3.38 gpm		3.38 gpm	
5.38 gpm		5.38 gpm	
8.00 gpm / ft ³		8.00 gpm / ft ³	
39.8 inches		39.8 inches	
3.01 ft ²		3.01 ft ²	
26.56 gpm / ft ²		26.56 gpm / ft ²	
8.00 gpm / ft ³		8.00 gpm / ft ³	
15.1 gpm		15.1 gpm	
30.1 gpm		30.1 gpm	
gallons / yr		gallons / yr	
- lbs salt / yr		- lbs salt / yr	



PRETREATMENT
SOFTENERS / SANITIZING



RODI Case Study

Sodium Bisulfite (NaHSO_3) Injection

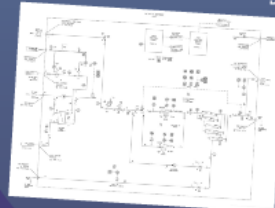
ENTER THE DATA REQUIRED IN YELLOW

80.0	Flowrate (gpm)
2.50	Feed Cl_2 (Free Chlorine) Concentration (ppm) ¹
757.00	mass flow rate of Cl_2 (mg/min)
35.0%	NaHSO_3 Concentration (%)
2271	mg/min Na_2SO_3 Required
2.47	gal/day of 35.00% NaHSO_3 Required *or*
0.103	gal/hr of 35.00% NaHSO_3 Required
30	Tank Volume (gallons)
12.2	Tank service prior to refilling (days)

NOTES

- 1 = Based on an estimate of typical city water
- 2 = Design basis provided

RODI Case Study



RODI Case Study

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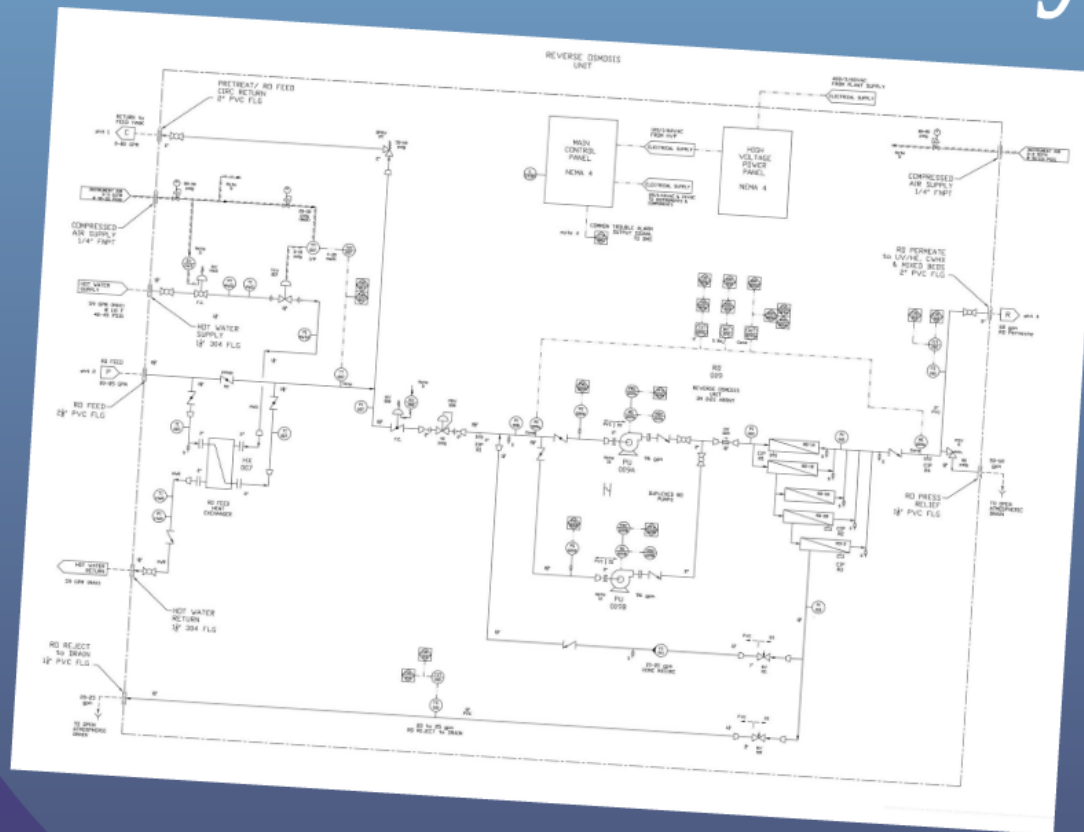
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RODI Case Study



RODI Case Study

Case-specific: Case 1 - 60 gpm BW30-400-IG 2:2:1 array 3M

System Details

Feed Flow to Stage 1	96.00 gpm	Pass 1 Permeate Flow	60.00 gpm	Osmotic Pressure:	
Raw Water Flow to System	80.00 gpm	Pass 1 Recovery	75.00 %	Feed	5.06 psig
Feed Pressure	255.46 psig	Feed Temperature	55.0 F	Concentrate	19.67 psig
Flow Factor	1.00	Feed TDS	481.16 mg/l	Average	12.36 psig
Chem. Dose	None	Number of Elements	15	Average NDP	215.27 psig
Total Active Area	6000.00 ft ²	Average Pass 1 Flux	14.40 gfd	Power	16.42 kW
Water Classification: Surface Supply SDI < 5				Specific Energy	4.56 kWh/kgal

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	BW30-400-IG	2	3	96.00	250.46	16.00	69.65	233.79	26.35	15.81	45.00	0.00	2.35
2	BW30-400-IG	2	3	69.65	228.79	0.00	46.18	218.74	23.47	14.08	45.00	0.00	4.12
3	BW30-400-IG	1	3	46.18	213.74	0.00	36.00	197.26	10.18	12.21	45.00	0.00	6.92

Pass Streams (mg/l as Ion)											
Name	Feed	Adjusted Feed			Concentrate			Permeate			Total
		Initial	After Recycles	Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3		
NH4+ + NH3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	3.70	3.70	5.52	7.59	11.40	14.58	0.05	0.09	0.16	0.08	
Na	50.00	175.51	262.89	362.10	545.46	699.03	0.69	1.31	2.29	1.20	
Mg	30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Ca	60.00	0.10	0.15	0.21	0.31	0.40	0.00	0.00	0.00	0.00	
Sr	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Ba	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
CO3	3.47	3.47	5.74	8.39	13.31	17.44	0.01	0.02	0.03	0.02	
HCO3	30.00	30.00	44.35	60.58	90.52	115.57	0.18	0.33	0.55	0.30	
NO3	1.00	1.00	1.45	1.96	2.89	3.63	0.08	0.15	0.26	0.14	
Cl	60.00	225.92	338.39	466.10	702.12	899.80	0.88	1.68	2.95	1.54	
F	2.82	2.82	4.22	5.82	8.76	11.22	0.01	0.02	0.04	0.02	
SO4	28.30	28.30	42.41	58.43	88.05	112.88	0.07	0.14	0.25	0.13	
SiO2	10.00	10.00	14.98	20.63	31.08	39.84	0.04	0.07	0.10	0.06	
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
CO2	0.24	0.02	0.03	0.05	0.07	0.09	0.00	0.00	0.00	0.00	
TDS	279.42	481.16	720.46	992.14	1494.21	1914.69	2.35	4.12	6.92	3.82	
pH	9.30	9.30	9.31	9.30	9.27	9.24	9.29	9.27	9.23	9.28	

*Permeate Flux reported by ROSA is calculated based on ACTIVE membrane area. DISCLAIMER: NO WARRANTY, EXPRESSED OR IMPLIED, AND NO WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, IS GIVEN. Neither FilmTec Corporation nor The Dow Chemical Company assume any obligation or liability for results obtained or damages incurred from the application of this information. Because use conditions and applicable laws may differ from one location to another and may change with time, customer is responsible for determining whether products are appropriate for customer's use. FilmTec Corporation and The Dow Chemical Company assume no liability, if, as a result of customer's use of the ROSA membrane design software, the customer should be sued for alleged infringement of any patent not owned or controlled by the FilmTec Corporation nor The Dow Chemical Company.

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Design Warnings

-None-

Solubility Warnings

-None-

Stage Details

Stage 1 Element Recovery		Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.09	4.53	2.01	48.00	720.46	250.46
2	0.10	4.39	2.33	43.47	795.32	244.06
3	0.11	4.26	2.74	39.08	884.32	238.52
Stage 2 Element Recovery		Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.12	4.04	3.33	34.82	992.14	228.79
2	0.13	3.91	4.05	30.79	1121.83	224.79
3	0.14	3.78	5.04	26.87	1284.57	221.46
Stage 3 Element Recovery		Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.08	3.55	5.96	46.18	1494.21	213.74
2	0.08	3.39	6.89	42.63	1618.13	207.59
3	0.08	3.24	8.00	39.24	1757.28	202.12

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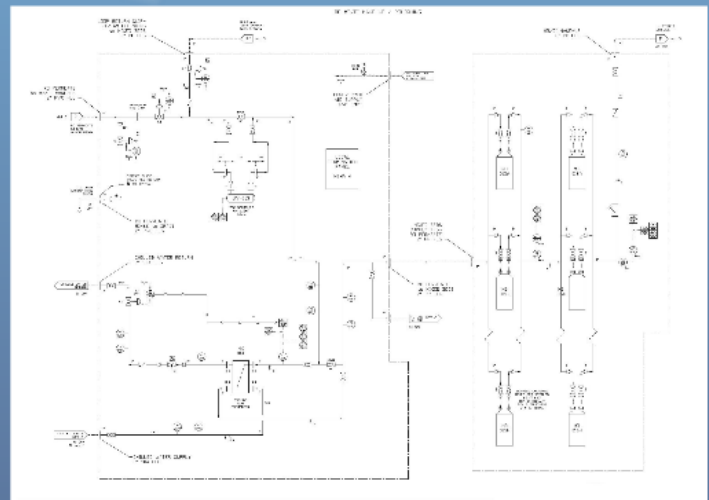
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Scaling Calculations

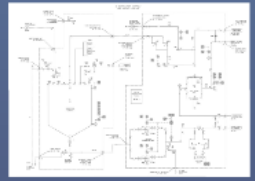
	Raw Water	Adjusted Feed	Concentrate
pH	9.30	9.30	9.24
Langelier Saturation Index	0.73	-2.07	-1.01
Stiff & Davis Stability Index	1.42	-1.34	-0.77
Ionic Strength (Molal)	0.01	0.01	0.03
TDS (mg/l)	279.42	481.16	1914.69
HCO ₃	30.00	30.00	115.57
CO ₂	0.02	0.02	0.09
CO ₃	3.47	3.47	17.44
CaSO ₄ (% Saturation)	0.43	0.00	0.01
BaSO ₄ (% Saturation)	46.66	0.00	0.00
SrSO ₄ (% Saturation)	0.07	0.00	0.00
CaF ₂ (% Saturation)	63.43	0.11	6.69
SiO ₂ (% Saturation)	4.15	4.15	17.14
Mg(OH) ₂ (% Saturation)	4.09	0.00	0.00

To balance: 165.92 mg/l Cl added to feed.

RODI Case Study



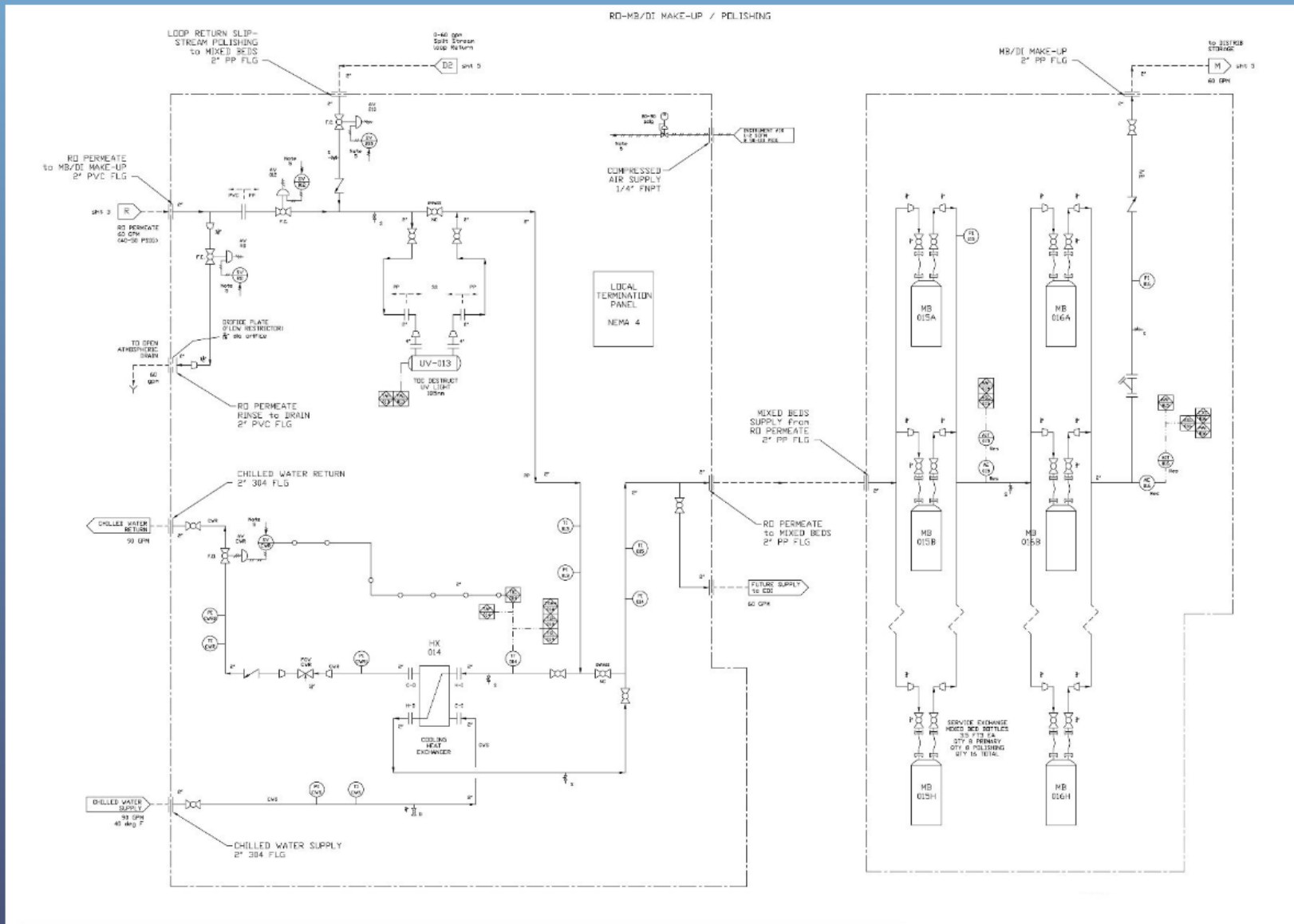
RODI Case Study



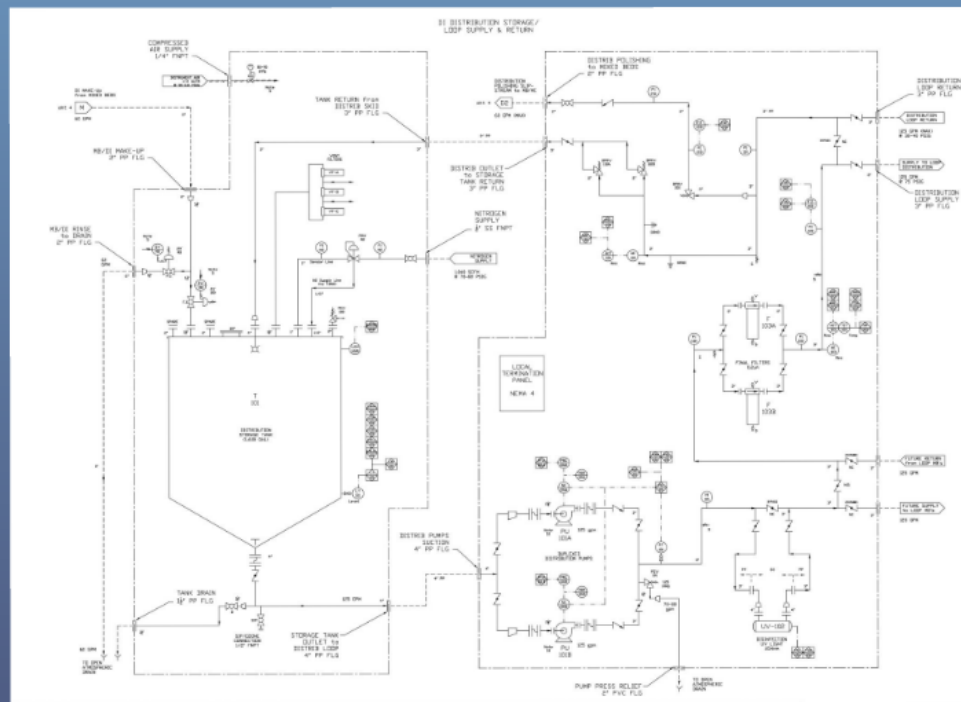
RODI Case Study



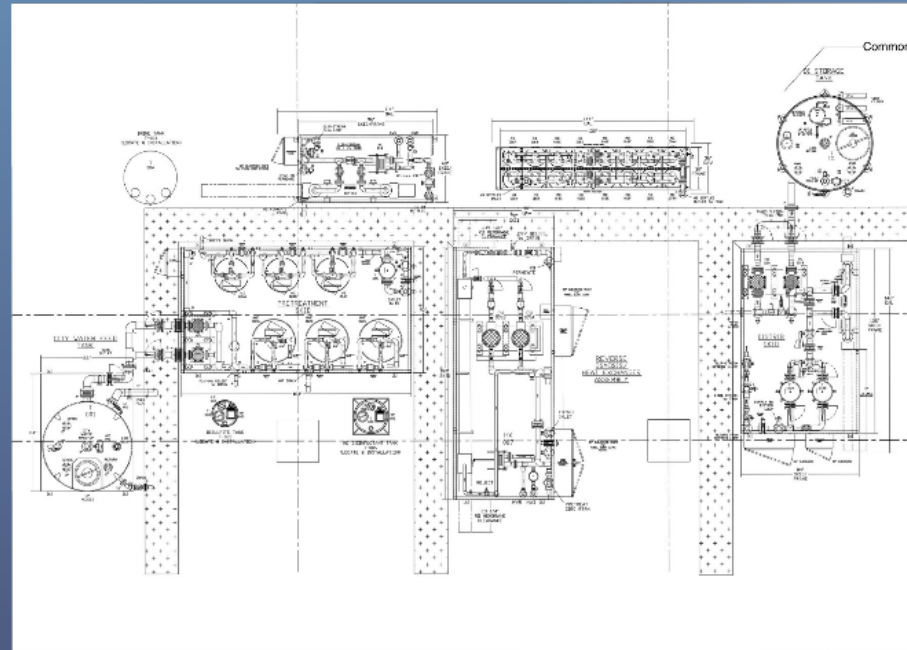
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EQUIPMENT

Thank you for viewing!