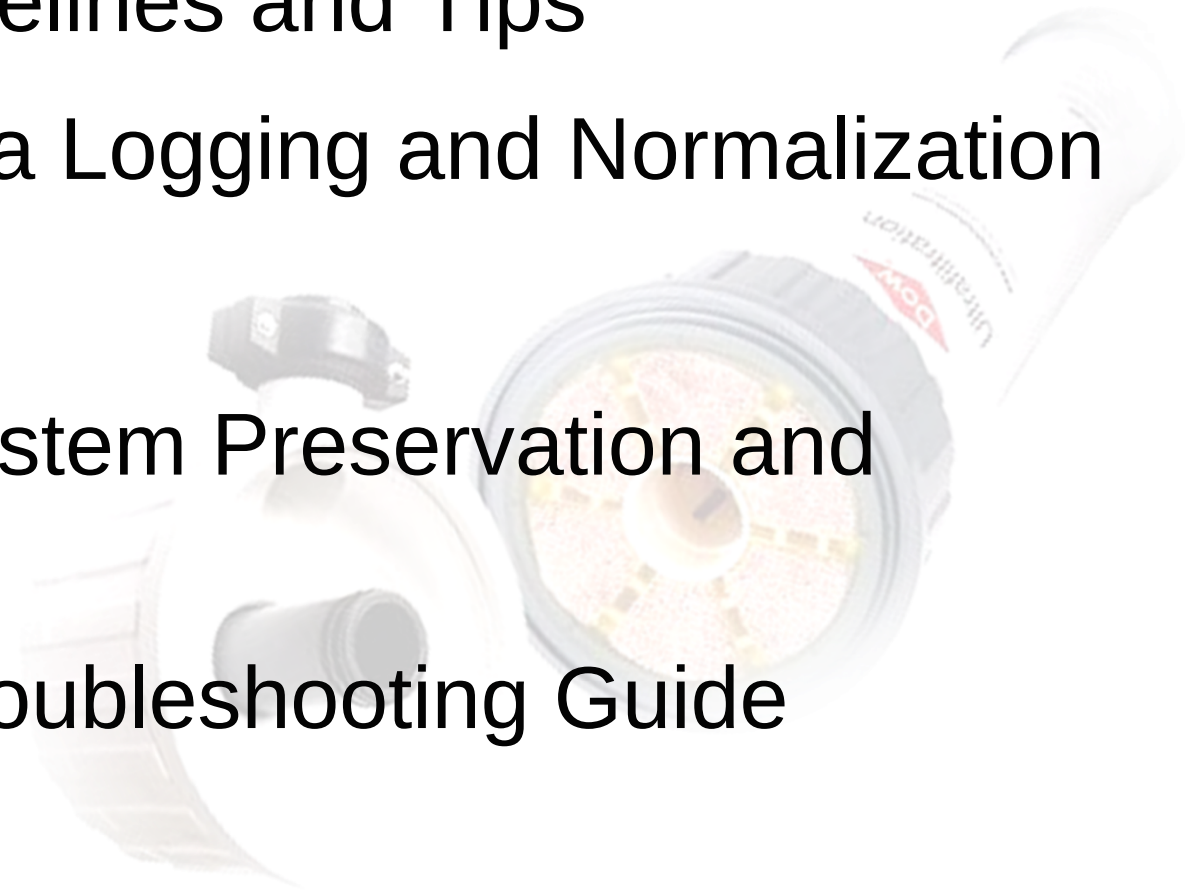
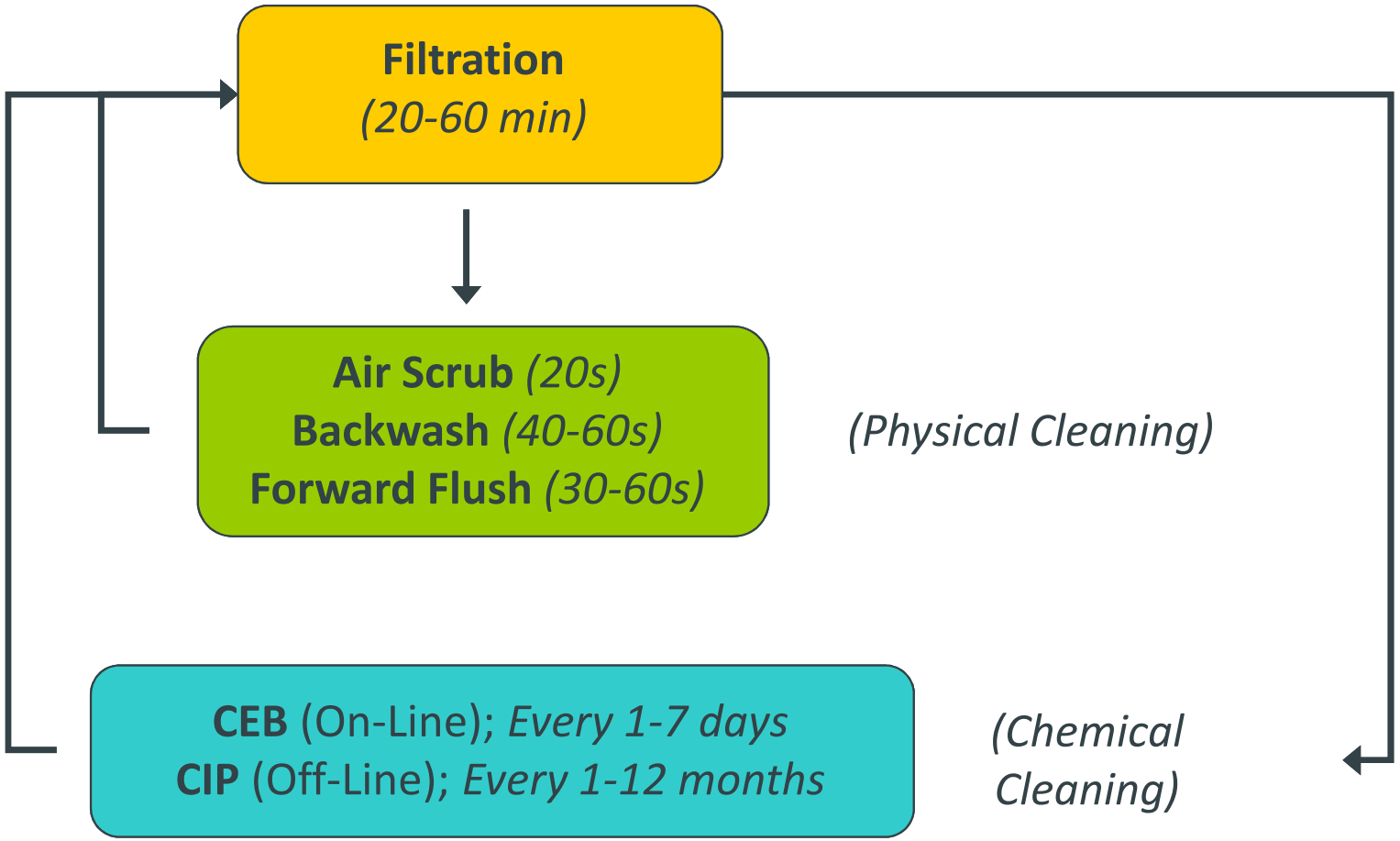
DOW™ Ultrafiltration Operation & Troubleshooting

Summary of the Presentation

- DOW™ UF UF System Operation
- Cleaning Guidelines and Tips
- Operating Data Logging and Normalization
- Integrity Test
- UF Module/System Preservation and Storage
- UF System Troubleshooting Guide



UF System Operation



CEB

Acid

- Typically HCl or H_2SO_4 @ approx. 500 mg/L (target pH 2)
- Frequency is typically every 72 hours or when necessary.
- Removes colloids and inorganic salt plugging both inside and outside of membrane.

Alkali

- NaOH @ approx. 500 mg/L (target pH 12)
- Generally combined with NaOCl @ approx. 350 mg/L
- Frequency is typically every 12-24 hours or when necessary.
- Removes organics and biofoulants from membrane.

CIP

Acid

- HCl, H_2SO_4 up to 2,000 ppm
- Oxalic / Citric acid @ 2%
- Target pH 2

Alkali

- NaOH @ 1,000 ppm
- NaOCl @ 2,000 ppm
- Target pH 11.5-12

- Frequency is typically every 1-3 months.
- Flow rate of 1.5 to 2.0 m^3/h/module.
- Duration is typically 120-150 minutes.
- Triggered by transmembrane pressure rise (rule of thumb: TMP_0 + 1 bar).

CEB vs CIP

CEB	CIP
Maintenance cleaning.	Intensive cleaning.
Shorter in duration (but higher frequency).	Longer in duration (but lower frequency).
Require less operator involvement. Automatic.	Manually initiated.
It is done with ultrafiltrate.	Chemical solution is prepared with demin/RO water, usually at higher concentrations.
Chemical solution is flushed out from the system.	Chemical solution is recirculated through the system.
Cleaning occurs at ambient temperature.	Heating of the cleaning solution is recommended.

CIP – General Guidelines

Cleaning Solution → / Type of Fouling ↓	0.2% (W) HCl pH 2, 35C	2% (W) Citric Acid pH 2, 35C	2% (W) Oxalic Acid pH 2, 35C	0.2% (W) NaOCl 0.1% (W) NaOH pH 11.5-12, 35C
Inorganic	**Preferred**	Alternative	Alternative	
Organic				**Preferred**
Metal Oxides (Fe, Mn)	Alternative	**Preferred**	Alternative	
Colloids / Particles		Alternative	Alternative	**Preferred**
Silica				**Preferred**
Biological				**Preferred**
Coexistence polivalent cations / metals & organic complexes		**Preferred**	**Preferred**	

Main Causes of Membrane Fouling

- Changes in feedwater composition, e.g., organics, solids,
- Insufficiently designed pretreatment system, e.g., strainer selection, chemicals carryover,…
- Failure of chemical dosing systems
- Improper operational control (e.g. too high flux, too long cycles, etc.)
- Slow build-up of precipitates over extended periods
- Seasonal algal blooms
- Inadequate backwash and chemical enhanced backwash (CEB) programs
- Inappropriate shutdown and preservation procedures
- Improper materials selection (pumps, piping, etc.)

CIP Procedure

- **Make-Up cleaning solution**. Preheat cleaning solution to desired temperature. RO permeate is preferred for the CIP make-up solution.
- **Regular backwash, pre-CIP**. Conduct a regular backwash of the UF skid to remove loose contaminants prior to the CIP.
- **Drain out water in the UF skid**. Residual water in UF skid will dilute the concentration of cleaning solution.
- **Low-flow pumping**. Pump cleaning solution through the feed side of the UF modules at conditions of low flow rate.
- **Recycle**. Recycle the cleaning solution at the recommended flows (e.g. 1.5 m^3/h for 2860/2880). Typically 1 hour duration.
- **Soak**. Typically 2 hours.
- **Flush out**. RO permeate preferred to prevent reaction of impurities in the flush-out water with the remaining cleaning solution.
- **Regular backwash, post-CIP**.
- **Return to Service**.

*Note: Technical Bulleting "**Cleaning in Place (CIP) Procedure for DOW™ UF Modules**" available.*

CIP Tips

- Often it is required a **two-step cleaning program: alkaline cleaning followed by acid cleaning**. Acid cleaning should only be applied as the first cleaning step if it is known that only calcium carbonate or iron is present on the membrane surface.
- **Measure the pH during cleaning**. If the pH varies more than 1 pH units during cleaning, add more chemical.
- **Inspect the appearance of the CIP solution** at various points during the recycle and soak steps.
- **Long soak times**. It is recommended to circulate the solution regularly in order to maintain the temperature and add chemicals if the pH needs to be adjusted.
- **Fresh cleaning solution** needs to be prepared when the cleaning solution becomes turbid.
- **Intermittent air scour** during soaking can benefit the cleaning effectiveness.
- **Thermal Shock** should be considered in cold water environments, to prevent damage to UF modules and piping systems.
- **Use the least harsh cleaning solution** possible, including cleaning parameters of pH, temperature, and solution strength.

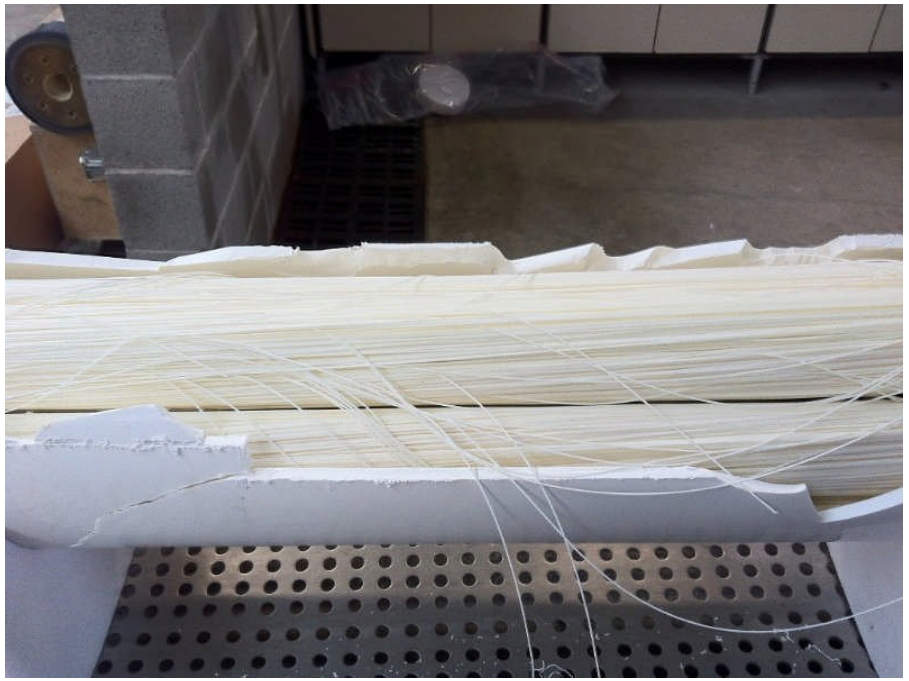
Examples of membrane fouling

Examples of membrane fouling

Examples of membrane fouling

Example of Effective Cleaning

Before Cleaning



After Cleaning

Note: Two different UF modules from same plant

Key elements for UF Design & Operation

1. **Qualified feed water**
   - Design range
   - Selected Operating Parameters
2. **Proper backwash interval,** to avoid:
   - Fouling more rapid
   - High operating pressures
   - Reduced net production
3. **Timely chemical cleaning,** to prevent:
   - Lower permeability
   - Irreversible Fouling
4. **Temperature Impact on Design**

Experienced Operators Say:

"With MF/UF – Finished Water Quality is Easy. Maintaining Capacity is the Challenge"

Operating Limits

Parameter	Unit	Recommended	Maximum Allowable
Turbidity, NTU	NTU	<50	300
TOC, mg/l	mg/l	<10	40
Particle Size	micron	<150	300
COD_{Mn}	mg/l	< 20	60
Oil & Grease	mg/l	0	< 2
pH continuous		6-9	2-11
pH cleaning		1-12	1-12
Temperature	°C	25	40[b]
Feed Pressure	bar	3	6
TMP	bar	0.2[a]	2.1
Cl2 continuous	mg/l	0.5[c]	200
Cl2 cleaning	mg/l	2,000	5,000
TSS	mg/l	<20	100

Operating Data Logging

- **Feed water Temperature and pH -** Continuously
- **Feed water and Filtrate Pressure -** Continuously
- **Product water Flow rate -** Continuously
- **Feed and Filtrate Turbidity -** Continuously
- **Feed and Filtrate SDI –** 2-3/ day
- **Feed and Filtrate TOC, TSS, BOD/COD, CFU, Iron, Manganese, Silica, O&G, Color, etc. –** 1-2 / week

Operating Data Logging

DOW™ Ultrafiltration Data Log Sheet			
Customer:			
System Information: (pretreatment process, chemical feed type and dosages, etc):			
UF Module Type:	Number of Skids:	Number of Modules/skid:	Membrane Area:
Date:	Time:	Cumulative hours of operation:	Recorded By:
Parameters	**Unit**	**Recorded Value**	**Comments**
Data Collected			
Temperature (T)	°C or °F		
Pre-filter Inlet Pressure	Psi or bar		
Pre-filter Outlet Pressure	Psi or bar		
UF Feed Pressure (P_f)	Psi or bar		
UF Filtrate Pressure (P_p)	Psi or bar		
UF Concentrate Pressure (P_c)	Psi or bar		
UF Filtrate Flow / skid (Q_p)	gpm or m³/hr		
UF Backwash Flow / skid (Q_{BW})	gpm or m³/hr		
UF Forward Flush / skid (Q_{ff})	gpm or m³/hr		
Filtration time per cycle (t_f)	minutes		
Backwash time per cycle (t_{BW})	seconds		
Forward flush time per cycle (t_{ff})	seconds		
Air Scour time per cycle	seconds		
CEB Alkali frequency	hours		
CEB Alkali pH	---		
CEB Acid frequency	hours		
CEB Acid pH	---		
UF Feed Turbidity	NTU		
UF Filtrate Turbidity	NTU		
UF Feed TSS	ppm or mg/L		
UF Filtrate TSS	ppm or mg/L		
UF Filtrate SDI_{15}	---		
Performance			
Gross Flux (J)	Gfd or lmh		
Transmembrane Pressure (TMP)	Psi or bar		
Permeability ($L_{N,\,20}$)	Gfd/psi or lmh/bar		
Equations to Calculate Performance			
Transmembrane Pressure (TMP) = P_f - P_p			
Recovery (R) = (Q_p* t_f - Q_{BW}* t_{BW}) / (Q_p* t_f + Q_{ff}* t_{ff}) * 100			

DOW™ Ultrafiltration CIP Record Sheet				
Customer:				
System Information: (pretreatment process, chemical feed type and dosages, etc)				
UF Module Type:	Number of Skids:	Number of Modules/skid:	Cumulative hours of operation:	Total number of cleaning:
Date:	Time:	Cumulative hours of operation after last cleaning:		Recorded By:
Item	**Unit**	**First Solution**	**Second Solution**	**Remarks**
Pre-cleaning Air Scour and Backwash				
Backwash Water Source	---			
Backwash Flux	LMH or gfd			
Air flow rate per module	Nm³/h or scfm			
Cleaning Chemicals				
Volume of cleaning solution	Liters or gallon			
Acid (also list type used)	Liters or gallon			
Caustic soda (%)	Liters or gallon			
Sodium hypochlorite (%)	Liters or gallon			
Others Chemicals	Liters or gallon			
CIP Operating Conditions				
Solution concentration	%			
pH	---			
Temperature	°C or °F			
Circulation flow rate	m³/h or gpm			
Duration of initial circulation	Minutes			
Soaking period	Minutes			
Duration of final circulation	Minutes			
Final Backwash or Flush/Rinse				
Source of water	---			
Flow rate	m³/h or gpm			
Duration	Minutes			
pH of waste streams	---			

Normalization Tool

DOW UF Normalización - Font Salem.xlsx - Microsoft Excel

Ultrafiltration

DOW™ Ultrafiltration Normalization Tool

Last Revised: June 7, 2011

Plant Name	Font Salem
Plant Location	Spain
Train ID	Tren A
Start-Up Date	Junio 2010
Modules / Train	15
Module Type	2860
Available Surface Area Per Module	51 (m²)
Units of Measure	Metric

Raw Data to be Entered

Graphs (Automatic):

1a – Normalized Permeability vs. Date
1b – Normalized Permeability vs. Operating Hour
2a – Normalized TMP vs. Date
2b – Normalized TMP vs. Operating Hour
3a – Norm Filtrate Flux / Temperature vs. Date
3b – Norm Filtrate Flux / Temperature vs. Operating Hour
4a – UF Filtrate SDI / Turbidity vs. Date
4b – UF Filtrate SDI / Turbidity vs. Operating Hour

Date	Time	Date, Time	Operating Time (Hour)	Feed Temperature (°C)	Feed Flow (m³/hr)	Conc. Bleed Flow (m³/hr)	Filtrate Flow (m³/hr)	Feed Pressure (bar)	Conc. Pressure (bar)	Filtrate Pressure (bar)	Feed Turbidity (NTU)	Filtrate Turbidity (NTU)
10-Jan-2011	8:00:00	01/10/11 08:00		16.00	66.10			1.68		1.15	0.150	0.038
11-Jan-2011	8:00:00	01/11/11 08:00										
12-Jan-2011	8:00:00	01/12/11 08:00										
13-Jan-2011	8:00:00	01/13/11 08:00		16.00	64.00			1.63		1.12	0.100	0.049
14-Jan-2011	8:00:00	01/14/11 08:00										
15-Jan-2011	8:00:00	01/15/11 08:00										
16-Jan-2011	8:00:00	01/16/11 08:00		15.00	65.26			1.64		1.13	0.120	0.050
17-Jan-2011	8:00:00	01/17/11 08:00										
18-Jan-2011	8:00:00	01/18/11 08:00										
19-Jan-2011	8:00:00	01/19/11 08:00										
20-Jan-2011	8:00:00	01/20/11 08:00		15.00	64.72			1.65		1.15	0.073	0.049
21-Jan-2011	8:00:00	01/21/11 08:00										
22-Jan-2011	8:00:00	01/22/11 08:00										
23-Jan-2011	8:00:00	01/23/11 08:00										
24-Jan-2011	8:00:00	01/24/11 08:00										
25-Jan-2011	8:00:00	01/25/11 08:00		15.00	63.79			1.70		1.14	0.078	0.050
26-Jan-2011	8:00:00	01/26/11 08:00										
27-Jan-2011	8:00:00	01/27/11 08:00										
28-Jan-2011	8:00:00	01/28/11 08:00										
29-Jan-2011	8:00:00	01/29/11 08:00										
30-Jan-2011	8:00:00	01/30/11 08:00										
31-Jan-2011	8:00:00	01/31/11 08:00										
1-Feb-2011	8:00:00	02/01/11 08:00		16.00	65.02			1.64		1.12	0.065	0.049
2-Feb-2011	8:00:00	02/02/11 08:00										
3-Feb-2011	8:00:00	02/03/11 08:00										
4-Feb-2011	8:00:00	02/04/11 08:00										
5-Feb-2011	8:00:00	02/05/11 08:00										
6-Feb-2011	8:00:00	02/06/11 08:00		15.50	63.90			1.63		1.11	0.104	0.050
7-Feb-2011	8:00:00	02/07/11 08:00										
8-Feb-2011	8:00:00	02/08/11 08:00										
9-Feb-2011	8:00:00	02/09/11 08:00										
10-Feb-2011	8:00:00	02/10/11 08:00		15.00	64.25			1.66		1.12	0.068	0.049
11-Feb-2011	8:00:00	02/11/11 08:00										
12-Feb-2011	8:00:00	02/12/11 08:00										

Figure 1
Normalized Permeability

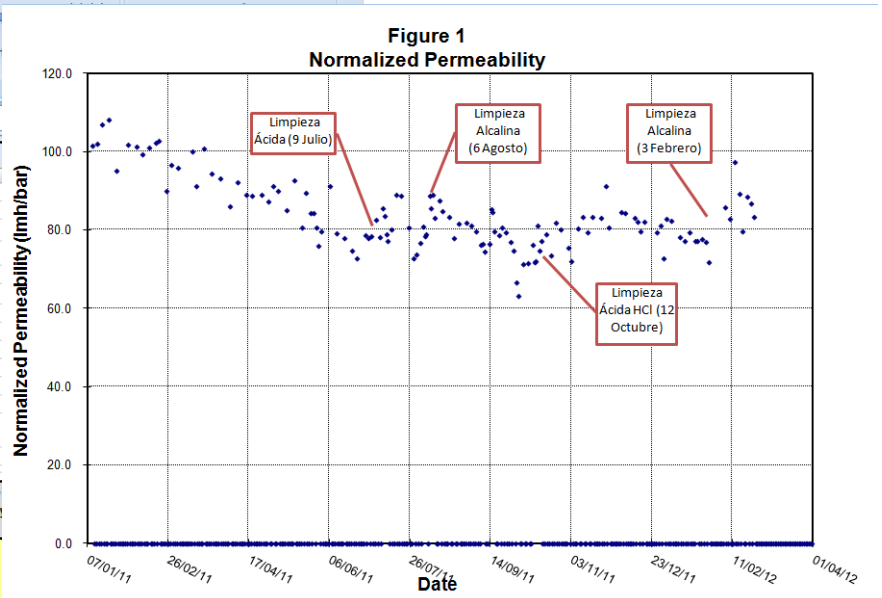
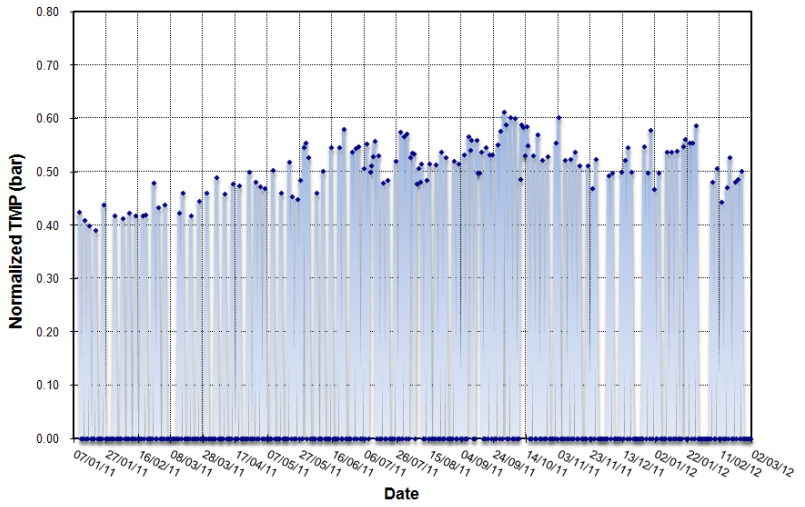


Figure 2
Normalized TMP



Integrity Testing

Main Causes of Fiber Breakage:

- Excessive vibrations during shipping, handling or installation.
- Foreign/Abrasive matter entering the UF system (e.g. sand)
- Excesive TMP operation (e.g. at low temperature).
- Operation at Flux and/or Temperature above guidelines.
- Water surges (e.g. air trapped in the system).
- Failure of previous repairs.
- Thermal shock (e.g. during CIP).
- Chemical attack (e.g. too extreme pH cleaning)

Integrity Testing

Direct Test Methods: Physical tests applied to a membrane unit to *detect* leaks.

- **Pressure Decay test**
- **Diffusive Air Flow test**
- **Water Displacement test**
- **Marker-Based Integrity test** (seeding)

Diagnostic Tests: Tests applied to a membrane unit to *identify* leaking module.

- **Visual Inspection** (through transparent pipe)
- **Bubble test** (module end-cap is removed)
- **Sonic test**
- **Single Module testing**

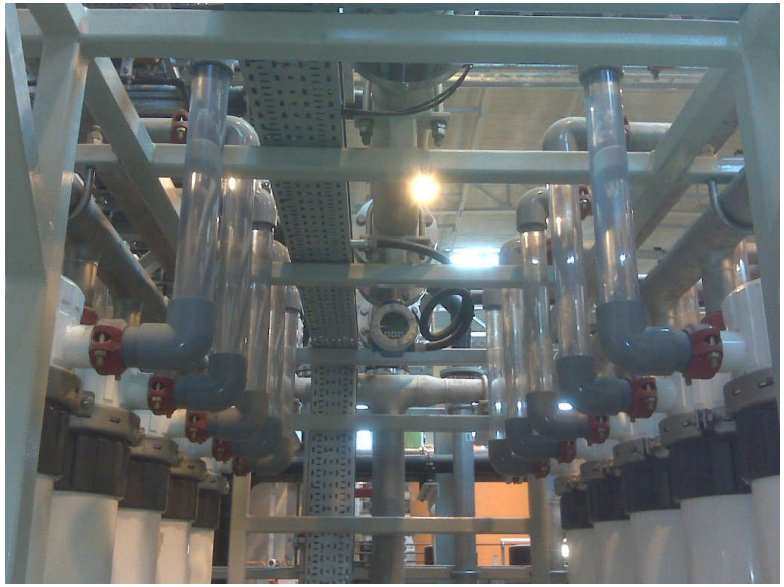
Integrity Testing

Indirect Test Methods: Filtrate water quality is monitored to detect compromised membrane units.

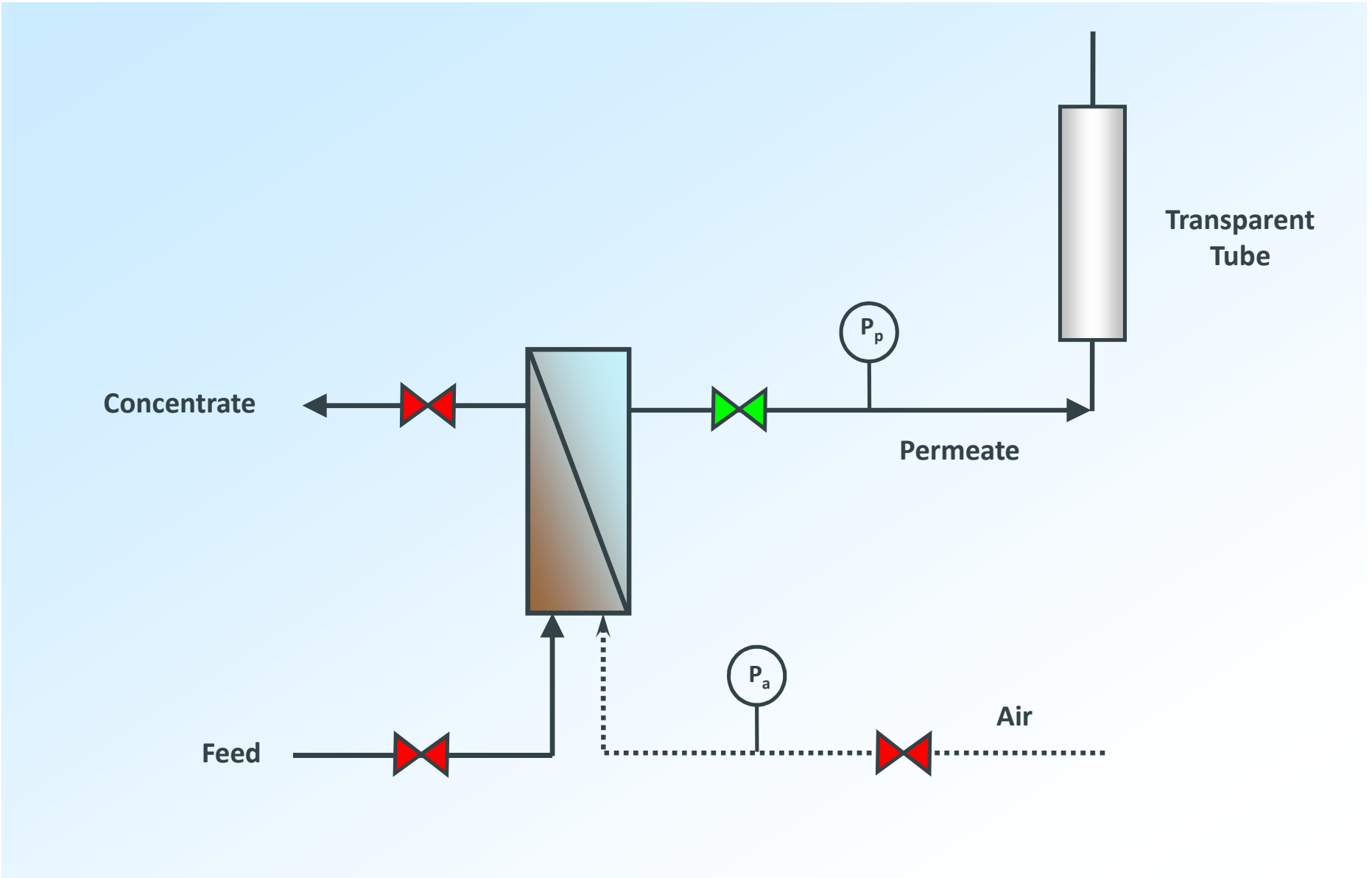
- **Turbidity Monitoring**
- **Particle Counting** (counts and groups particles by size)
- **Particle Monitoring** (does not count or measures size)
- (**SDI** not valid as it is non-continuous!)

Disadvantages: Not as sensitive as Direct Integrity Methods.

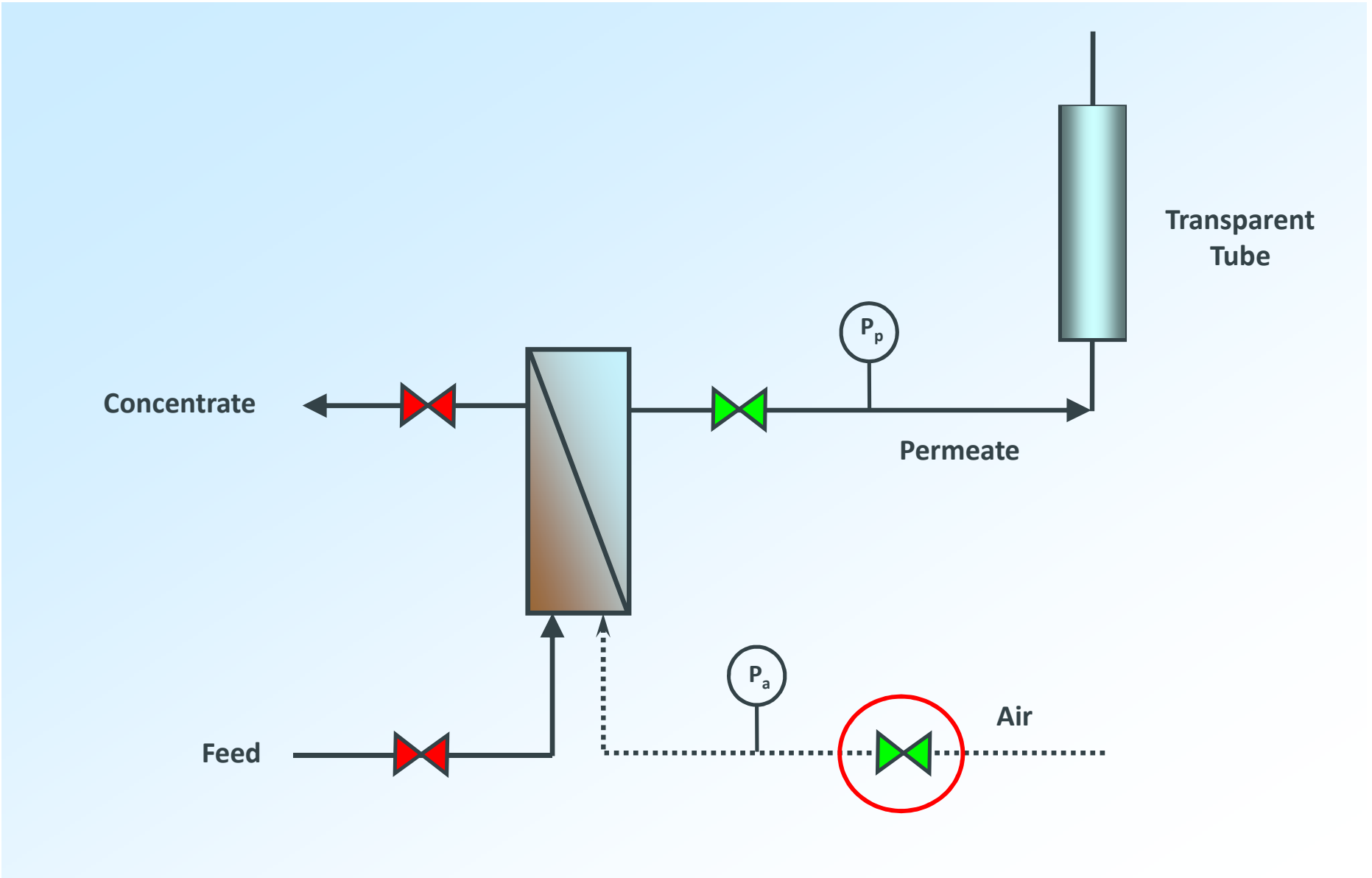
Advantages: Membrane unit does not need to be taken off-line. Continuous monitoring provides real-time integrity indication.



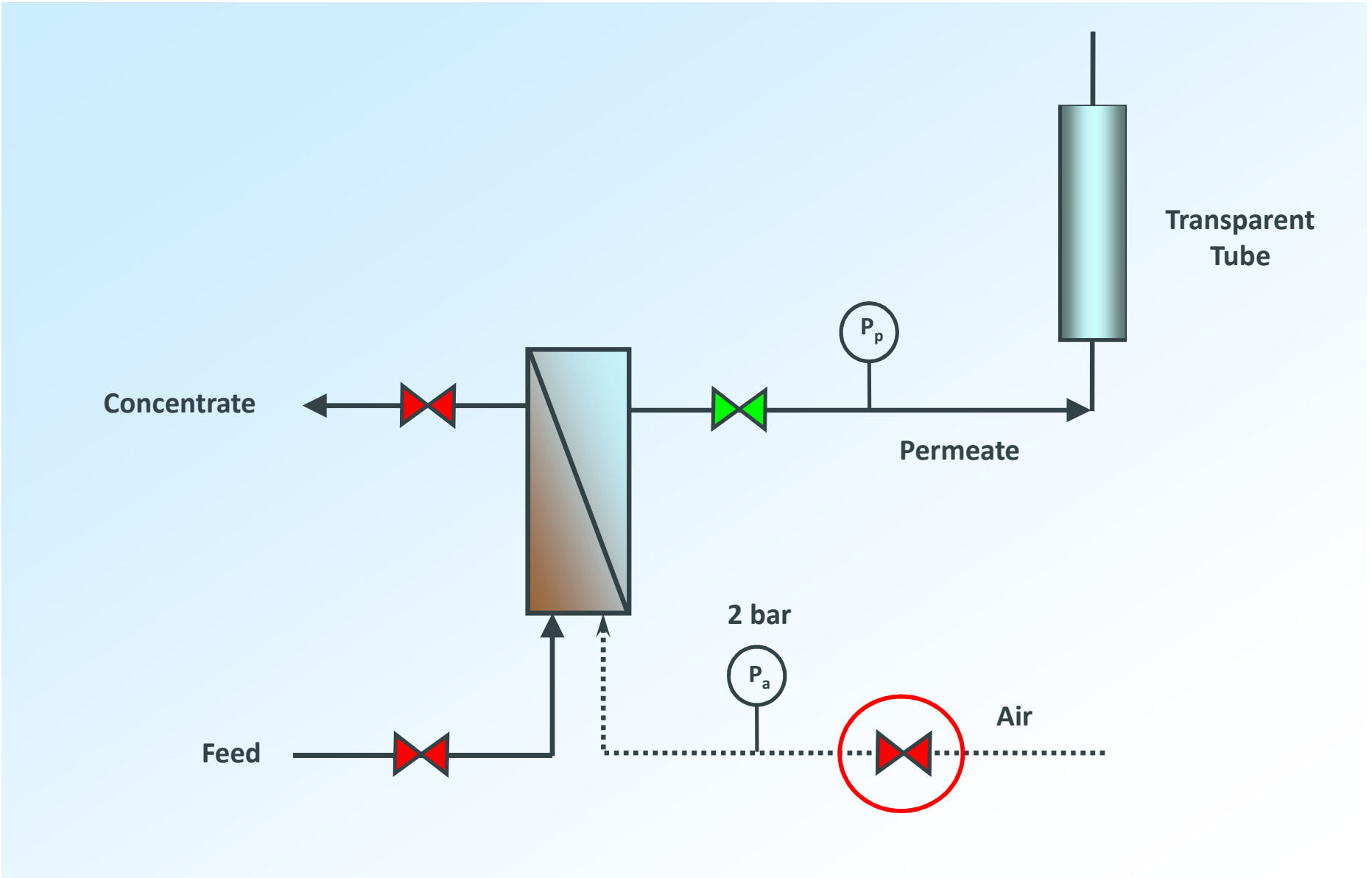
Integrity Testing (Visual Inspection)



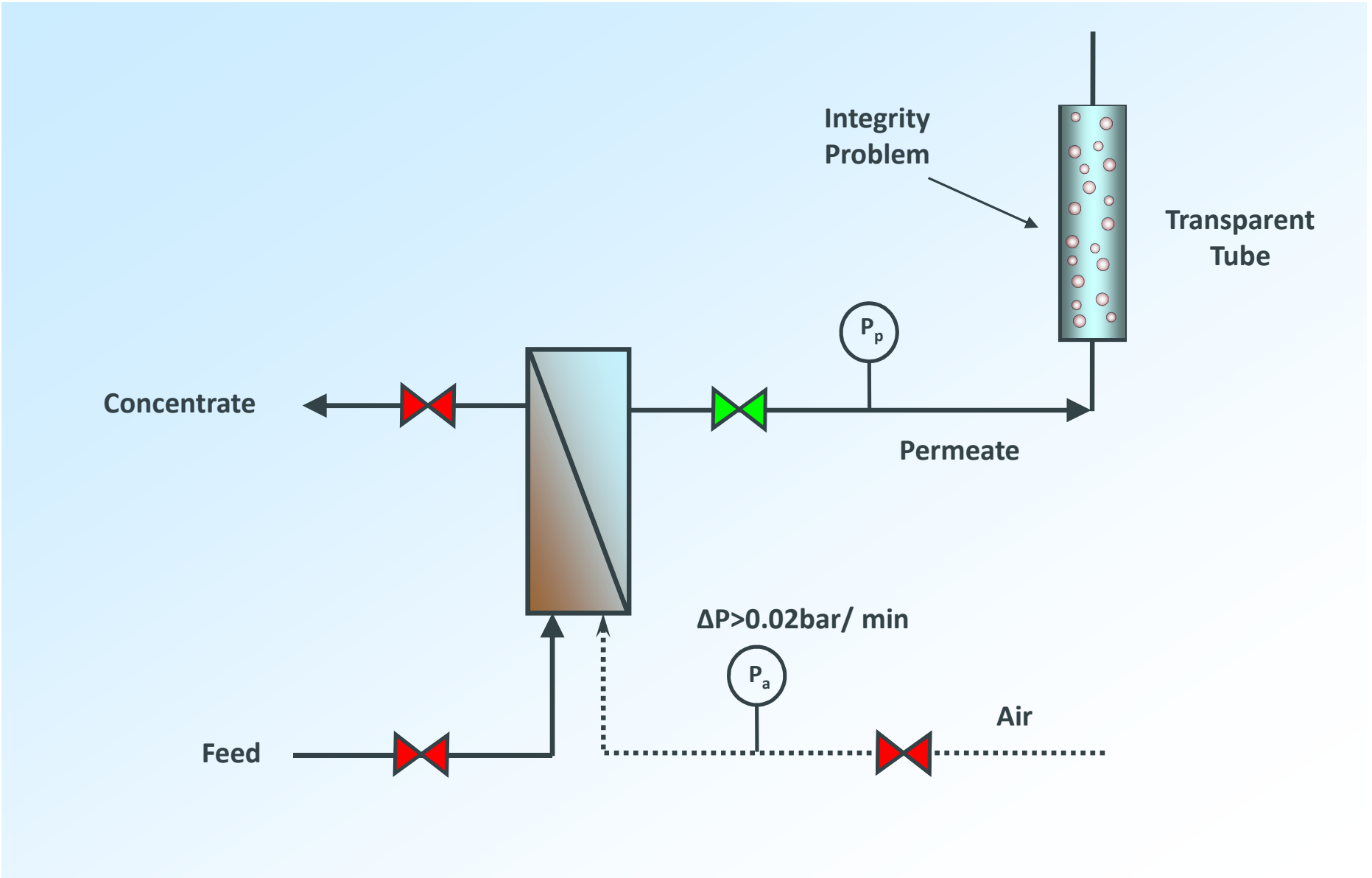
Integrity Testing (Visual Inspection)



Integrity Testing (Visual Inspection)



Integrity Testing (Visual Inspection)



Fiber Repair

UF Module/System Preservation and Storage

Storage of New Modules	• Keep modules in original factory packaging, in horizontal position. • Store inside a cool and dry area (20-35C). • Modules must be protected from freezing or excessive heat. • Sealed modules may be stored up to 1 year.	
Used Modules	**Short Term Shut Down (< 4 days)**	**Long Term Shut Down (> 4 days)**
Off-Skid Storage	• Carry out CEB/BW if available. • Remove modules, fill with clean water (35 liters for 2860; 40 liters for 2880). • Add glycerin if exposed to freezing conditions. • Keep modules horizontal position and sealed.	• Conduct CEB/CIP. • Remove modules and introduce 1% SMBS food-grade (4 liters for 2860; 6 liters for 2880). • Add glycerin if exposed to freezing conditions. • Keep modules in horizontal position and sealed. • Check pH regularly so that it is > 3.
On-Skid Storage	• Carry out CEB/BW if available. • Conduct CIP with clean water and keep system filled. • Add glycerin if exposed to freezing conditions.	• Conduct CEB/CIP. • Fill system with 1% SMBS food-grade via CIP. • Add glycerin if exposed to freezing conditions. • Check pH regularly so that it is > 3.

*Note: Technical Bulleting "**Handling, Preservation & Storage for DOW™ UF Modules**" available.*

UF System Troubleshooting Guide (1/2)

Problem	Possible Cause	Corrective Action(s)
TMP increase rapidly before or after CIP	Membrane scaling/fouling	Carry out CIP immediately.
	Fiber aging or drying	Contact DOW
	Flow rate too high (beyond design capacity)	Reduce accordingly (by feed pump outlet isolation valve).
	Inefficient cleaning	Carry out CIP again, and prolong soaking time, change chemical if necessary (Contact DOW)
	Raw Water quality changed	Check the source water quality.
	Unsuitable chemical dosing or frequency	Adjust (contact DOW if in doubt)
CIP 5 um Filter pressure drop high	Approaching Retention Capacity	Replace filter .
	Flow rate too high (beyond design capacity)	Reduce accordingly (by pump outlet isolation valve).
	Pollutants removed from fiber surface	Check tank (inspect retained water in the tank). Replace CIP solutions if necessary.
CIP pump can not start	Pump breaker off	Turn on breaker
	Current too high	Adjust power
	Magnetic contactor broken	Replace
	Level switch installed wrong	Turn level switch over
Feed/Backwash pump can not start	Pump breaker off	Turn on breaker
	Current too high	Adjust power
	Magnetic contactor broken	Replace
	Tank level low	Refer to Alarm

UF System Troubleshooting Guide (2/2)

Problem	Possible Cause	Corrective Action(s)
UF system can't start in AUTO	Tank level low	Refer to Tank level low
	Switch on Manual mode	Switch to auto mode
	Inlet to pump is blocked	Check inlet side valve and piping
	Backwash pump is blocked	Check inlet side valve and piping
	TMP high	Process CIP
Pipe leakage (system)	Pressure too high	Reduce accordingly
	Normal wear and tear	Contact DOW
	Water hammer effect	Open and close all valves slowly to reduce effect.
Valve failure to open/close	Compressed air pressure low	Increase pressure
	Improper place of cap in valve status monitor	Open actuator cap and adjust it
	No lubrication in actuator	Inject lubrication to actuator

Thank You

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