Matching WP 6 Project update:

Task 6.5 - Pressure driven membranes system for recovery of water from unconventional sources

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

October 02-03,2018

Matching workshop

Rome, Italy

Andrea Morandi, Enel Innovation Global Thermal Generation

Content

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

WP 6 : Water Treatment and Recovery

WP overview

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

Cooling Section

RECOVER EVAPORATE

EVAPORATION

6.6 Water recovery from plume

Membrane Condenser

ALTERNATIVE WATER SOURCES

INTAKE WATER

CONDENSER

6.1 CDI Novel membrane based technologies for pretreatment

CDI
Pressure driven (6.4)

Recirculating water

RECOVER BLOWDOWN

BLOWDOWN WATER

REDUCE BLOWDOWN

6.3 Novel membrane based technologies for blowdown recovery

MD

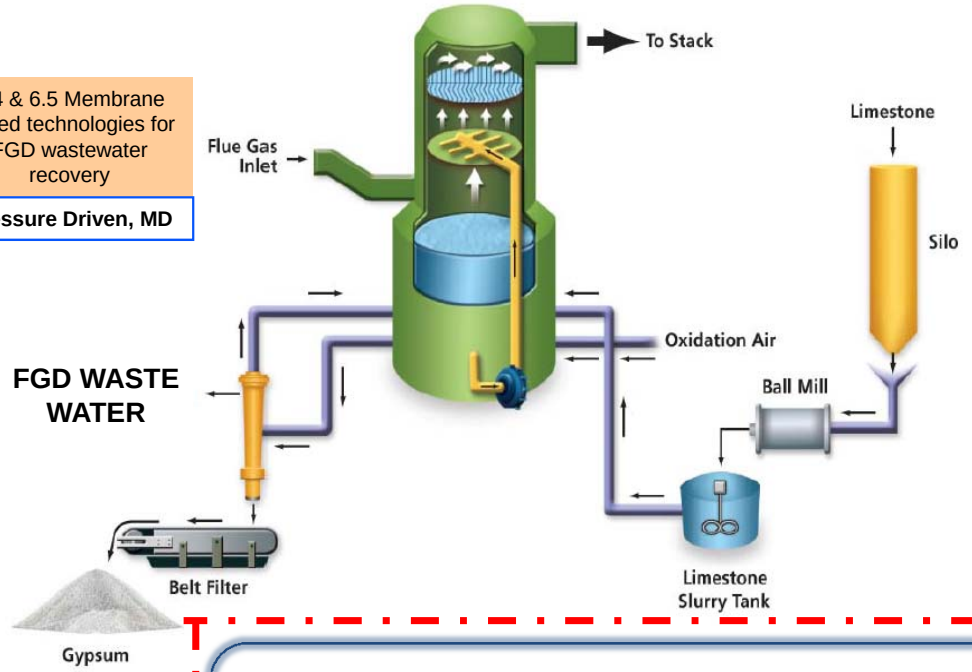
6.2 Novel Circulating water conditioning systems

VPT

Flue Gas Treatment Section

6.4 & 6.5 Membrane based technologies for FGD wastewater recovery

Pressure Driven, MD

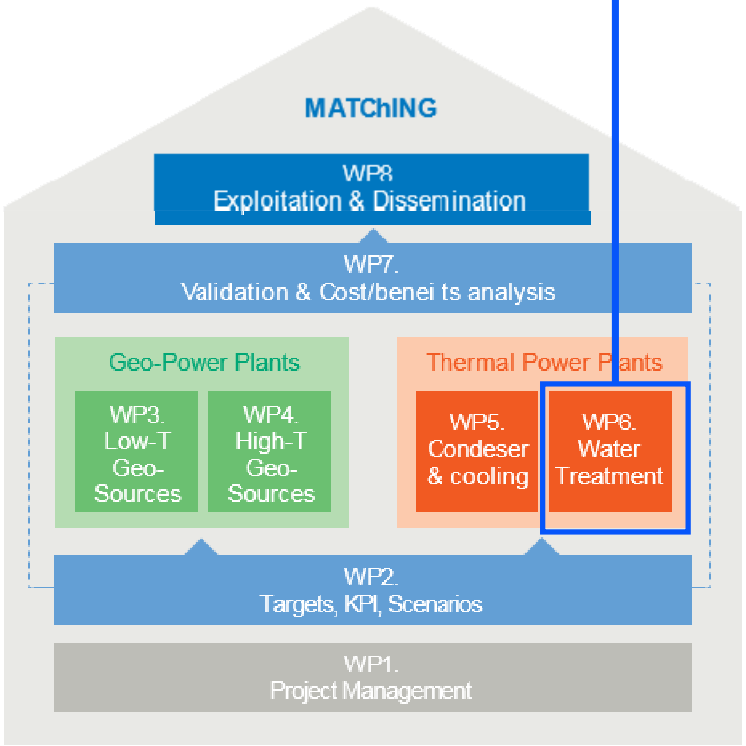


Main targets:

- ❑ **Improve PP sustainability**
- ❑ **Reduce water specific consumption and impact on surrounding environment**

WP6 – Water Treatment and Recovery
Tasks overview

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS



Work Package 6 – Water treatment and Recovery – **WP Leader VITO**

Start Month	**End Month**
2	**38**

Task 6.1	Task 6.2	Task 6.3	Task 6.4	Task 6.5	Task 6.6
Membrane capacitive deionization (MCDI) for CT feed pre-treatment	Vortex degasification technology (VPT) for chemical free CT circulation water treatment	Membrane Distillation (MD) for CT blowdown reuse	Thermally driven membrane (MD) for the recovery of water from unconventional sources	Pressure driven membranes system for recovery of water from unconventional sources	Recovery of water vapor from gas using MC

vito · ENGIE Lab · Aquastill · Pathema Innovatief met Water · enel · EDF · ITM · endesa

Specific Objectives:

- ❑ **Demonstrate the feasibility/profitability to use membrane based technologies to treat different w-FGD wastewater**
- ❑ **Improve waste water recovery by limiting O&M costs**
- ❑ **Simplify waste water recovery processes**

TASK 6.5 – Pressure driven membranes system for recovery of water from unconventional sources

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

Laboratory characterization & process definition | **Performance evaluation at a representative scale** | **Process reliability**

SELECTED TECHNOLOGIES → LABORATORY → PILOT SCALE → LONG RUN TEST

1. Pressure driven membrane technologies: Microfiltration (MF); Nanofiltration (NF); Ultrafiltration (UF) and Reverse osmosis (RO)
2. Thermal driven membrane: Membrane Distillation (MD)

- ❑ Once selected the wastewater to be treated → w-FGD wastewater from Torrevaldaliga Nord PP;
- ❑ Specific lab test will be performed to evaluate the best process configuration characterizing the systems in terms of : Water recovery; energy consumption and permeate quality. → definition of pilot configuration

completed

- ❑ Defined the process configuration a pilot will be designed, realized and installed in ENEL Torrevaldaliga Nord PP.
- ❑ Three months of test to optimize the pilot operation will be performed

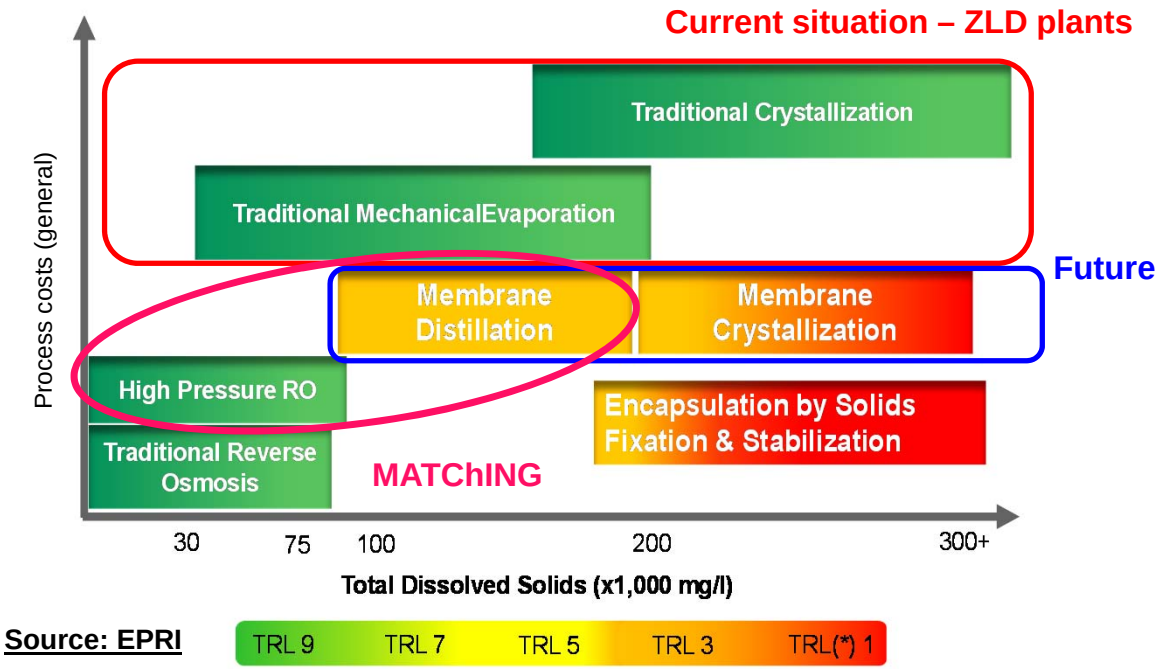
- ❑ Once reached the optimized operating conditions a long run test will be performed to evaluate reliability of the plant;
- ❑ The duration of the test will be around 1 months

Content

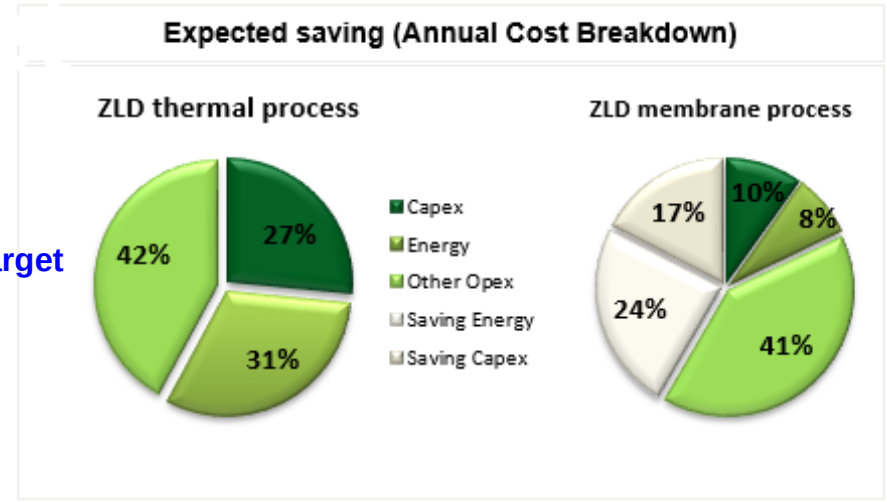
MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

- Matching Project – WP 6 overview
- w-FGD waste water treatment
- Pilot Design, Realization & Installation
- Pilot Commissioning
- Next steps

W-FGD Waste Water Treatment
Framework and targets



Source: EPRI



- Advanced ZLD configuration should assure a significant saving of energy (thermal and electrical) and a saving of Capex
- **Target: water treatment cost reduction from 5 €/m^3 up to 3÷3.5 €/m^3**

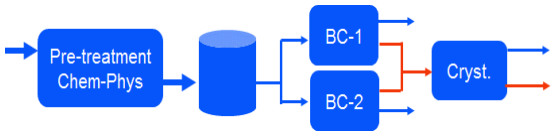
Main Targets:

- ✓ Increase ZLD treatment capacity
- ✓ Substitute thermal BC with membrane based systems
- ✓ Reduce steam consumption
- ✓ Reduce electrical power consumption
- ✓ Increase reliability and availability of the ZLD plant

W-FGD Waste Water Treatment
Process evolution

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

Current ZLD configuration



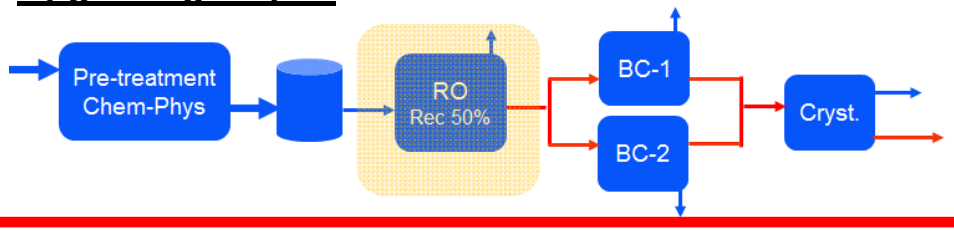
Current ZLD plant: Thermal concentration and crystallization.

1. The upgrade of current configuration, as retrofit of existing plants, could be reached by the introduction of a RO step to reduce the volume of wastewater to be sent to BC. Recovery achievable ~ 50 - 75%.

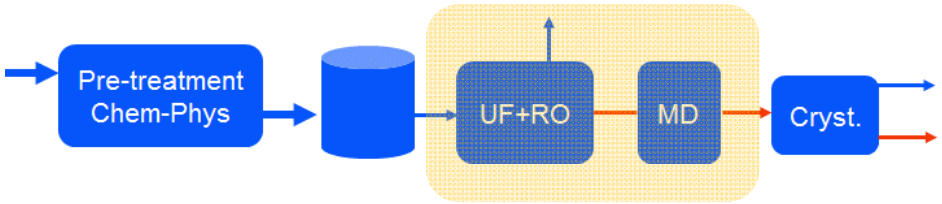
2. An advanced configuration with recovery achievable > 85%. Alternative configuration for new plants or retrofit.

3. New ZLD configuration using only membranes technology. Recovery achievable > 95%

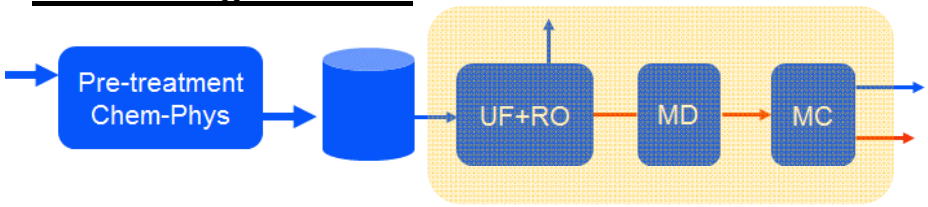
Upgrading step 1:



Upgrading step 2:



Final configuration 3:



Content

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

- Matching Project – WP 6 overview
- w-FGD waste water treatment
- Pilot Design, Realization & Installation
- Pilot Commissioning
- Next steps

Matching pilot plant 1 m³/h
Feed composition and expected performance

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

	UdM	Reference composition	Max	Min
Azoto ammoniacale(come NH4)	mg/l	60,00	92,4	12,42
Potassio (k)	mg/l	166	412	65
Sodio (Na)	mg/l	4081	1000	1206
Magnesio (Mg)	mg/l	61	446	1
Calcio (Ca)	**mg/l**	**425**	**1000**	**255**
Sr	mg/l	2,9		
Ba	mg/l	0,018		
CO3	mg/l	214,7		
HCO3	mg/l	136,6		
NO3	mg/l	131	52,06	15
Cloruri (come Cl-)	mg/l	5137	20000	2180
F	mg/l	15,61		
Solfati (come SO4--)	**mg/l**	**2107**	**3500**	**450**
SiO2	mg/l	<0,1	2	0
Boron	mg/l	89,18		
CO2	mg/l	0,01		
TDS	**mg/l**	**12627**	**30000**	**4185**
pH	Unità	10,11	10,5	10
Alcalinità totale	mg/l CaCO3	1000		

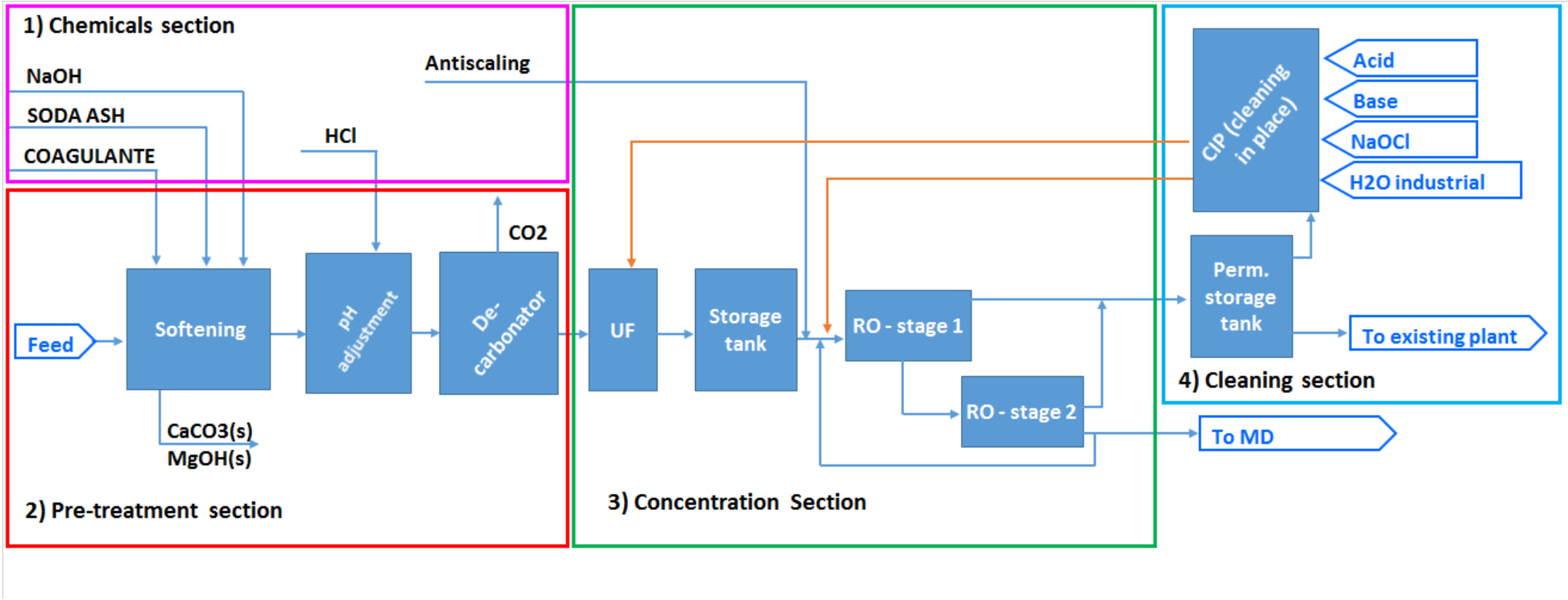
Expected output with feed reference composition	
Ca removal (softening)	≥90 %
Mg removal (softening)	≥73 %
SDI(*) downstream UF	≤5
% Recovery reverse osmosis	≥75%
TDS first stage RO	<300 mg/L
TDS second stage RO	<1500 mg/L

Plant performance are mainly affected by:

- ❑ **Water hardness → scaling**
- ❑ **Total salinity → recovery**
- ❑ **Unfortunately these parameters are the most variable**

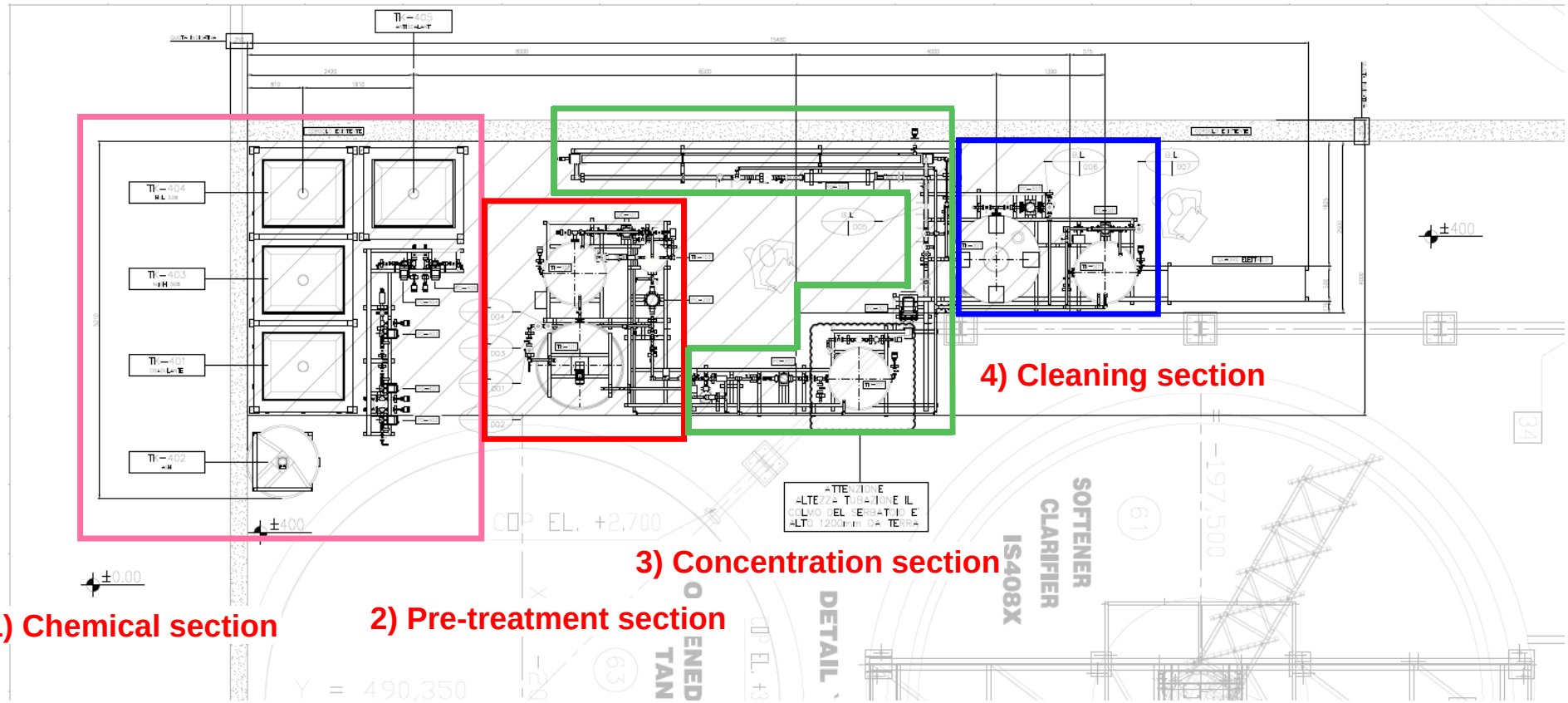
Matching pilot plant 1 m³/h
Principle layout

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS



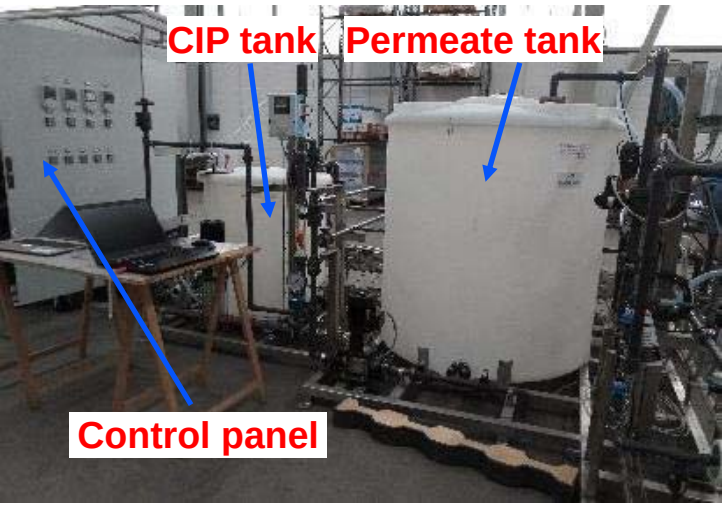
Matching pilot plant 1 m³/h
Top view

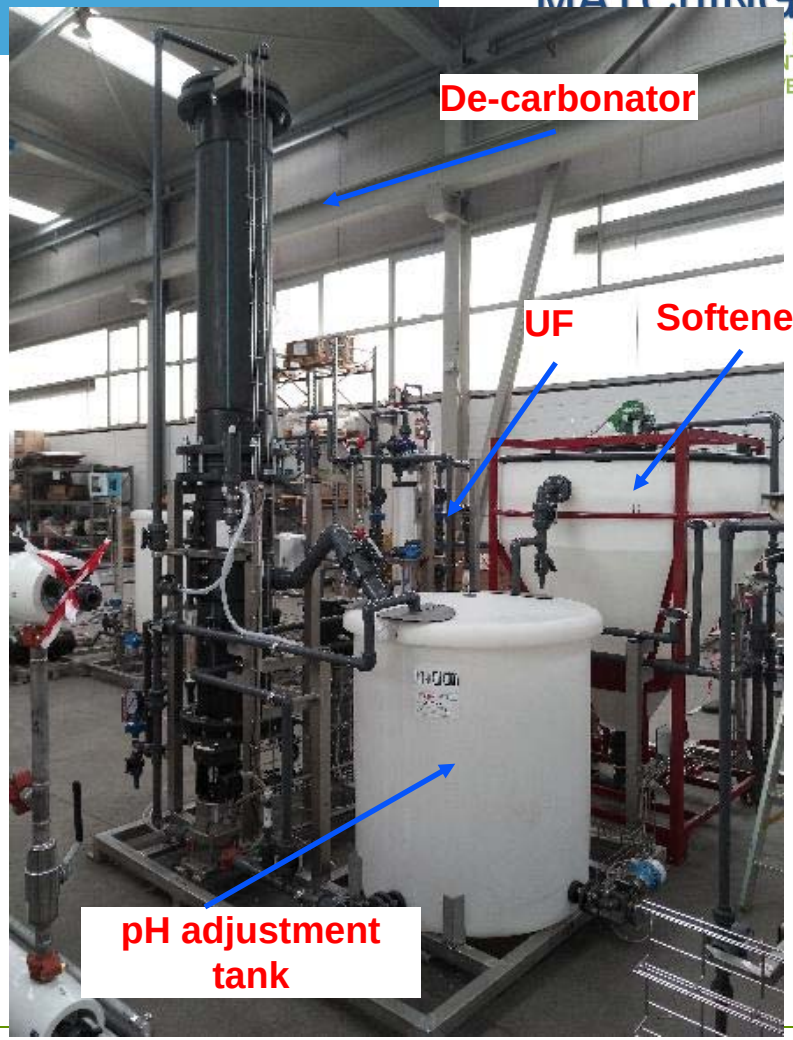
MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS



Matching pilot plant 1 m³/h

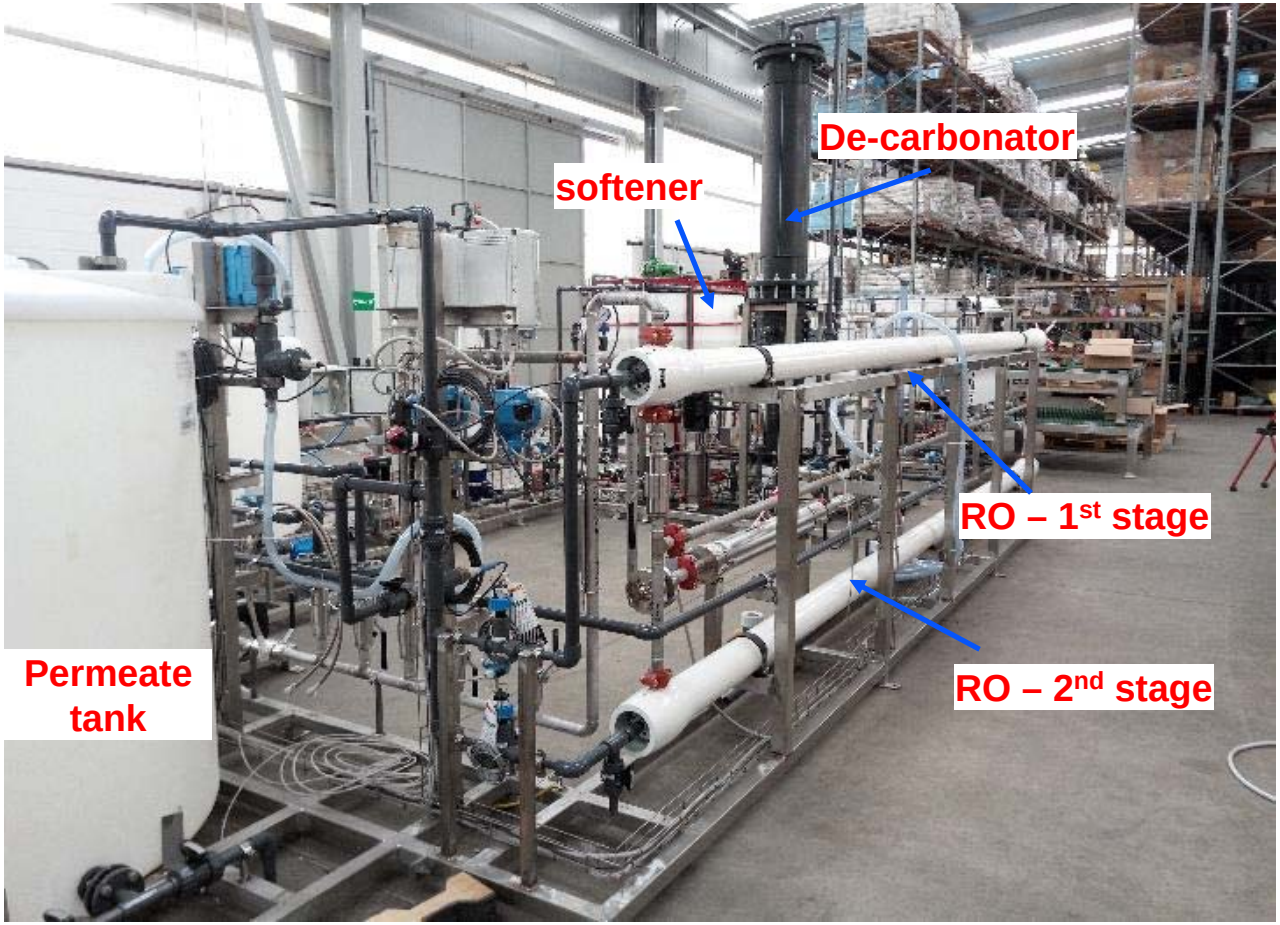
Plant overview- pretreatment + UF + Permeate collection





Matching pilot plant 1 m³/h
Reverse osmosis section

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS



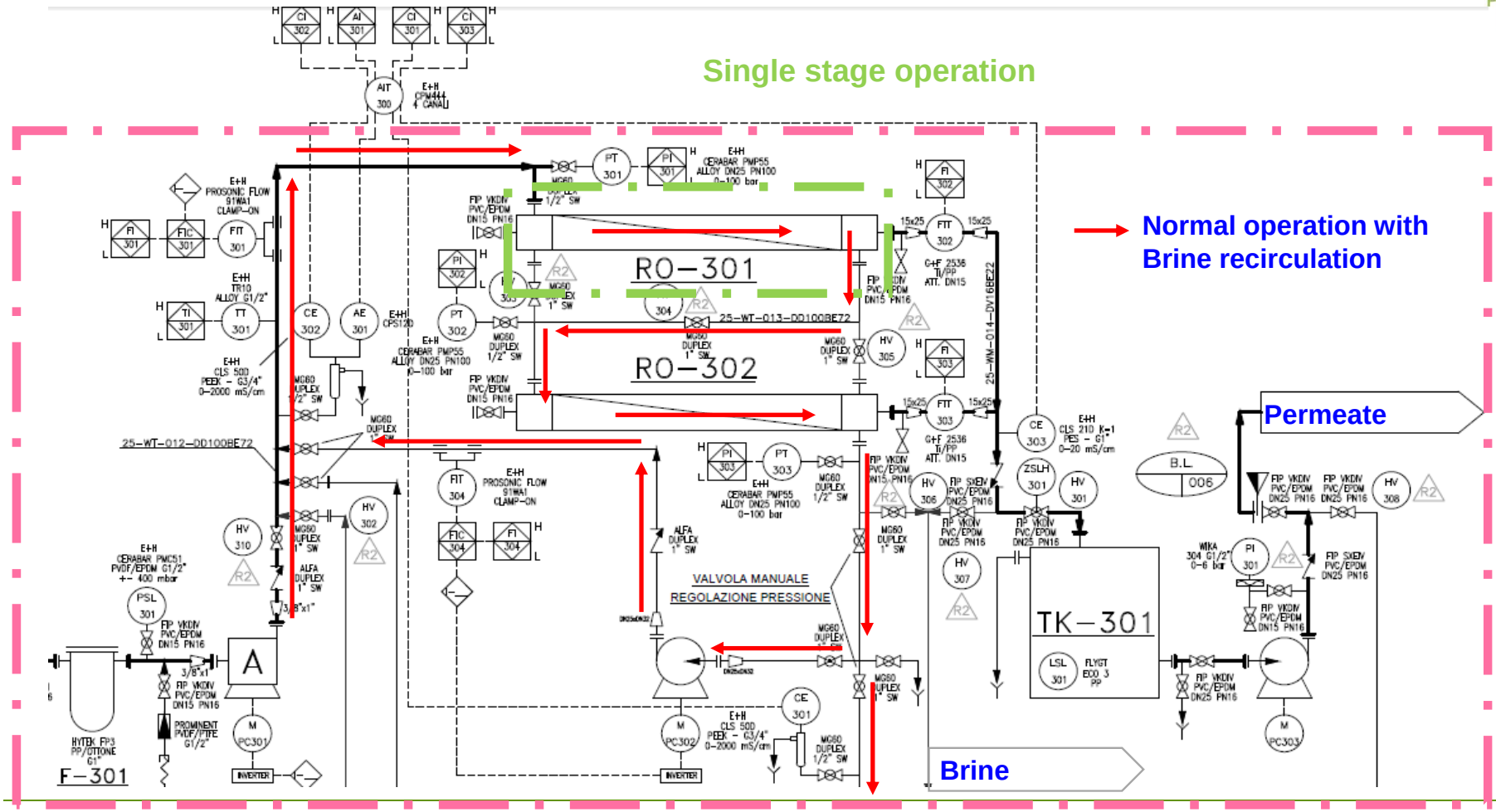
Matching pilot plant 1 m³/h
Chemicals dosing stations

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

Matching pilot plant 1 m³/h
Reverse Osmosis - details

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

Single stage operation



Two stage operation with Brine recirculation

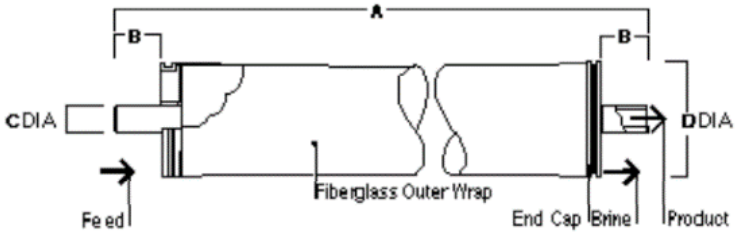
Matching pilot plant 1 m³/h

RO Membranes specifications - DOW Filmtec SW30 4040 (4")

Product	Maximum Feed Flow Rate gpm (m³/h)	Dimensions – Inches (mm) A	B	C	D
SW30-4040	16 (3.6)	40.0 (1,016)	1.05 (26.7)	0.75 (19)	3.9 (99)

- Membrane Type — Polyamide Thin-Film Composite
- Maximum Operating Temperature — 113°F (45°C)
- Maximum Operating Pressure — 1,000 psi (69 bar)
- Maximum Pressure Drop — 15 psig (1.0 bar)
- pH Range, Continuous Operation[a] — 2 - 11
- pH Range, Short-Term Cleaning[b] — 1 - 13
- Maximum Feed Silt Density Index — SDI 5
- Free Chlorine Tolerance[c] — <0.1 ppm

a Maximum temperature for continuous operation above pH 10 is 95°F (35°C).
b Refer to Cleaning Guidelines in specification sheet 609-23010.
c Under certain conditions, the presence of free chlorine and other oxidizing agents will cause premature membrane failure. Since oxidation damage is not covered under warranty, DOW FILMTEC recommends removing residual free chlorine by pretreatment prior to membrane exposure. Please refer to technical bulletin 609-22010 for more information.

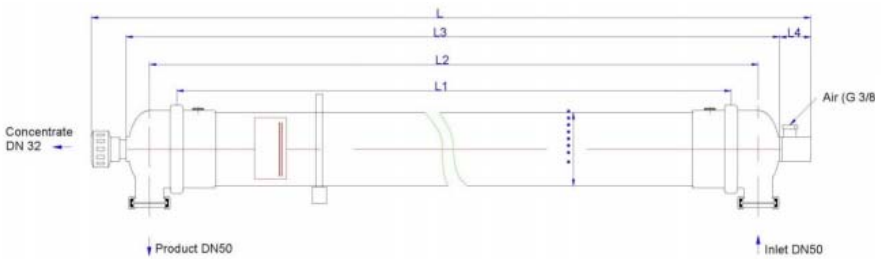


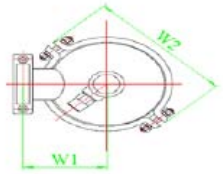
2 stage RO section – 5 membranes (4") in each Vessel (stage)

Matching pilot plant 1 m³/h

UF membranes specifications

Properties	Length				Diameter	Width	
Units	L	L1	L2	L3	D	W1	W2
SI (mm)	1863	1500	1610	1710	165	125	250
US (inch)	73.2	59.1	63.4	67.3	6.5	4.9	9.8





Model	DOW SPF-2660
Operating mode	dead end
Type of filtration	OUT-IN
Molecular cut	80kDa
Fiber type	Hydrophilich PVDF
Active area	33 m2
lenght	1863 mm
Diameter	250 mm
Net fluid volume	16 L
Empty weight	25 kg
Working weight	41 kg

	SI units	US units
Filtrate Flux @ 25°C	40 – 90 l/m²hr	24 – 53 gfd
Flow Range Per Module[1]	1.3 – 3.0 m³/hr	5.9 – 13.1 gpm
Temperature	1 – 40°C	34 – 104°F
Max. Inlet Module Pressure (@ 20°C)	6.25 bar	93.75 psi
Max. Inlet Module Pressure (@ 40°C)	4.75 bar	68.89 psi
Max. Operating TMP	2.1 bar	30 psi
Max Operating Air Scour Flow	12 nm³/hr	7.1 scfm
Max Backwash Pressure	2.5 bar	36 psi
Operating pH	2- 11	
NaOCl (max.)	2,000 mg/L	
Particle Size (max.)	300 µ	
Flow Configuration	Outside in, dead end flow	
Expected Filtrate Turbidity	≤0.1 NTU	
Expected Filtrate SDI	≤2.5	

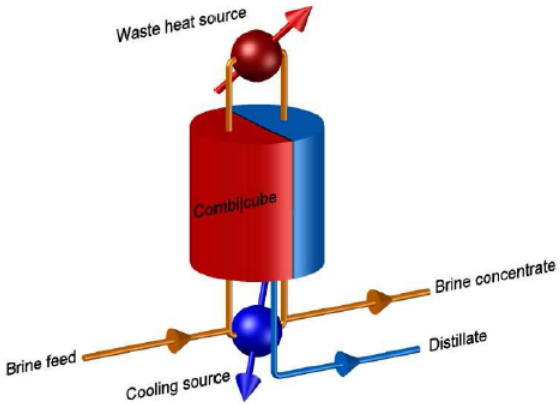
Single module – one way filtration

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

Membrane Distillation
Design data

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

MD specs	
Configuration	AGMD (Air Gap Membrane Distillation)
Membrane surface	7,2 m2
Channel length	1500 mm
Membrane material	PE standard membrane
Feed flow	30 l/h
Expected Recovery	> 40%
Expected permeate quality	< 200 µS/cm
Heater	9 kW submerged heating elements



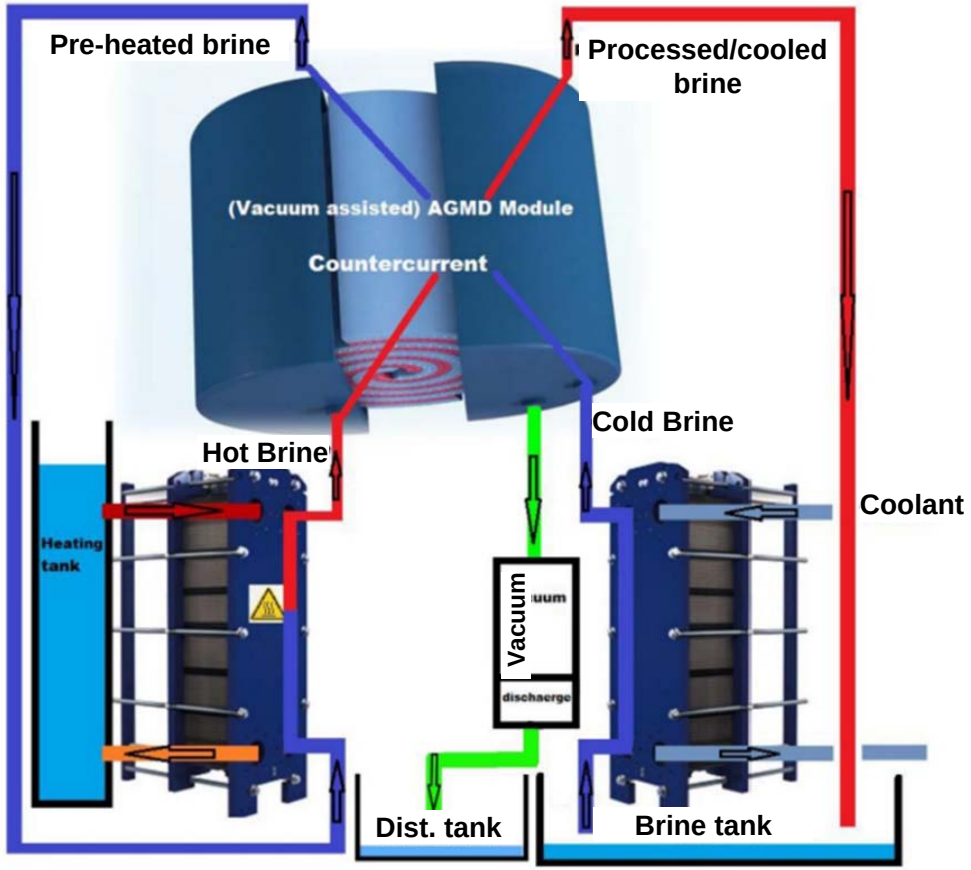
Reference feed composition

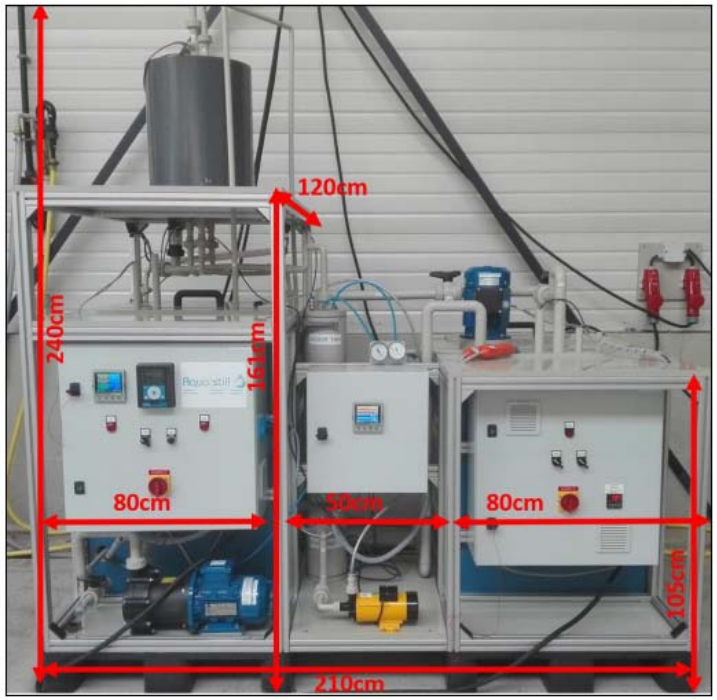
Name	Value (ppm)
NH4+ + NH3	142.59
K	603.08
Na	16995.21
Mg	95.77
Ca	570.63
Sr	0.00
Ba	0.07
CO3	0.15
HCO3	5.05
NO3	453.63
Cl	21438.55
F	59.43
SO4	8791.34
SiO2	0.38
Boron	214.04
CO2	0.12
TDS	50379.19
pH	7.30

Aqua|still

Membrane Distillation
Details

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

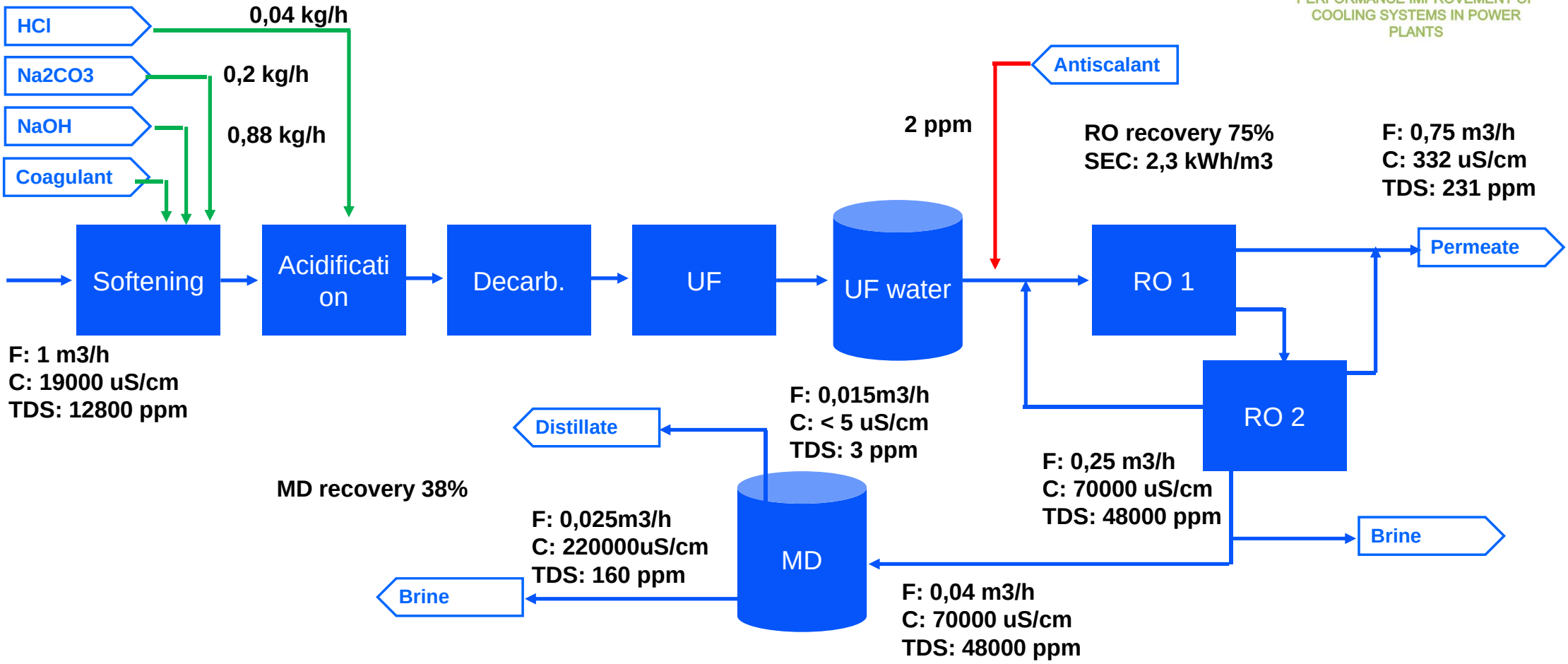




Aquastill

Heating: waste heat **Cooling**

Matching pilot plant 1 m³/h
Simulation design conditions

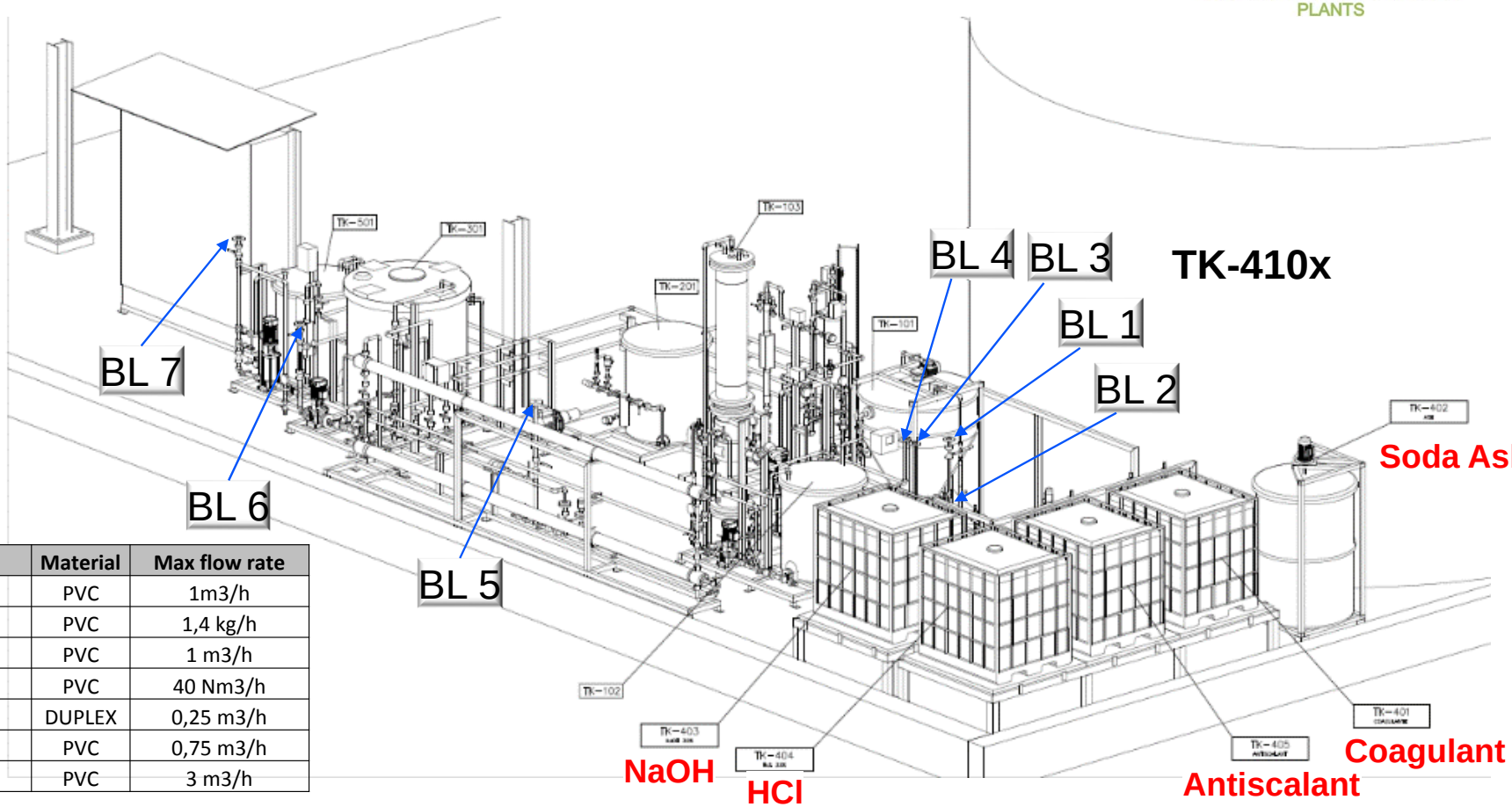


Matching pilot plant 1 m³/h
Installation

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

Matching pilot plant 1 m³/h
General arrangement and Battery Limits

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS



BL	Battery Limits description	Size	Material	Max flow rate
1	Feed water	1"	PVC	1m3/h
2	Softener sludge discharge	1"	PVC	1,4 kg/h
3	Industrial water supply	1"	PVC	1 m3/h
4	Compressed air	1"	PVC	40 Nm3/h
5	Brine restitution	1"	DUPLEX	0,25 m3/h
6	Permeate restitution	1"	PVC	0,75 m3/h
7	CIP discharge	1"	PVC	3 m3/h

Content

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

- Matching Project – WP 6 overview
- w-FGD waste water treatment
- Pilot Design, Realization & Installation
- Pilot Commissioning
- Next steps

Commissioning & Start up
First result and criticalities

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER

In June the pilot has been commissioned:

- ❑ Water quality has changed sensibly from design and historical data
  - × Conductivity more than double than design
  - × Hardness (Ca) more than three times the design value
  - × Chloride content more than double than design
- ❑ Difficulties in control pH downstream the softener → pH control loop to be adapted
- ❑ Difficulties in precipitate $CaCO_3$ in the softener → dosing (Na_2CO_3/NaOH/coagulant) to be optimized
- ❑ Some $CaCO_3$ precipitation on the UF protective filter → optimize dosing in the softener
- ❑ Stabilization of single stage RO operation
- ❑ Not stable operation of two stage operation
- ❑ **RO recovery in single stage 35 %**
- ❑ Permeate conductivity not stabilize around 800 uS/cm

New water composition simu.:
Max Ca removal 60 % → Increase Antiscalant dosing → Max RO recovery 60 %

		Design	Hystorical analysis						May 2017	June 2018
pH		10,11	5,82	6,04	5,92	4,88	3,1	4,68	10	9,75
Conductivity	mS/cm	18183	28170	20200	22100	17120	17150	22000	16528	35700
Ca	ppm	425	569	255	384	403	367	284	425	1842
K		166	202	116	226	166	147	201	166	590,3
Mg		61	82	3,5	39	27	14	28	61	135
Na		4081	6253	5574	4790	3424	3174	4378	3668	8000
Si		<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	0,56
F		15,61	14	20	18	14	16	19	16	8,14
Cl		5137	10122	7100	7600	5700	5900	8250	4954	12047
NO3		131	36	32	29,5	23,1	28,5	35,9	131	287
SO4		2107	1732	940	1240	980	570	660	2107	2718
TDS		12627	19049	14057	14345	10740	10256	13926	11528	25627

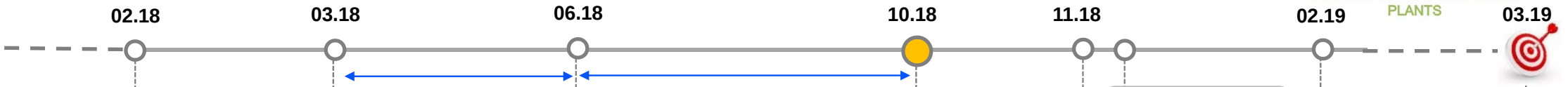
Content

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

- Matching Project – WP 6 overview
- w-FGD waste water treatment
- Pilot Design, Realization & Installation
- Pilot Commissioning
- Next steps

Next steps
Test program

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS



Pilot realization completed and FAT

Pilot installation

Plant modification + PP ZLD out of service

Commissioning & start up

- Water composition changed respect to design → higher TDS and alkalinity
- Issues in stabilize softening
- pH control loops to be optimized
- Reached stable operation of direct RO operation
- Not stable operation of 2 stage RO operation with brine recirculation

- **New water analysis & lab test**
- **New process simulation**
- **Check of dosing with pilot supplier and chemicals supplier**
- **Pilot adaptation & preparation for re-start**
- **Definition of a new contract for pilot operation**

Pilot restart

UF+RO test

- Pretreatment optimization
- Test increasing RO recovery

MD installation

UF+RO+MD test

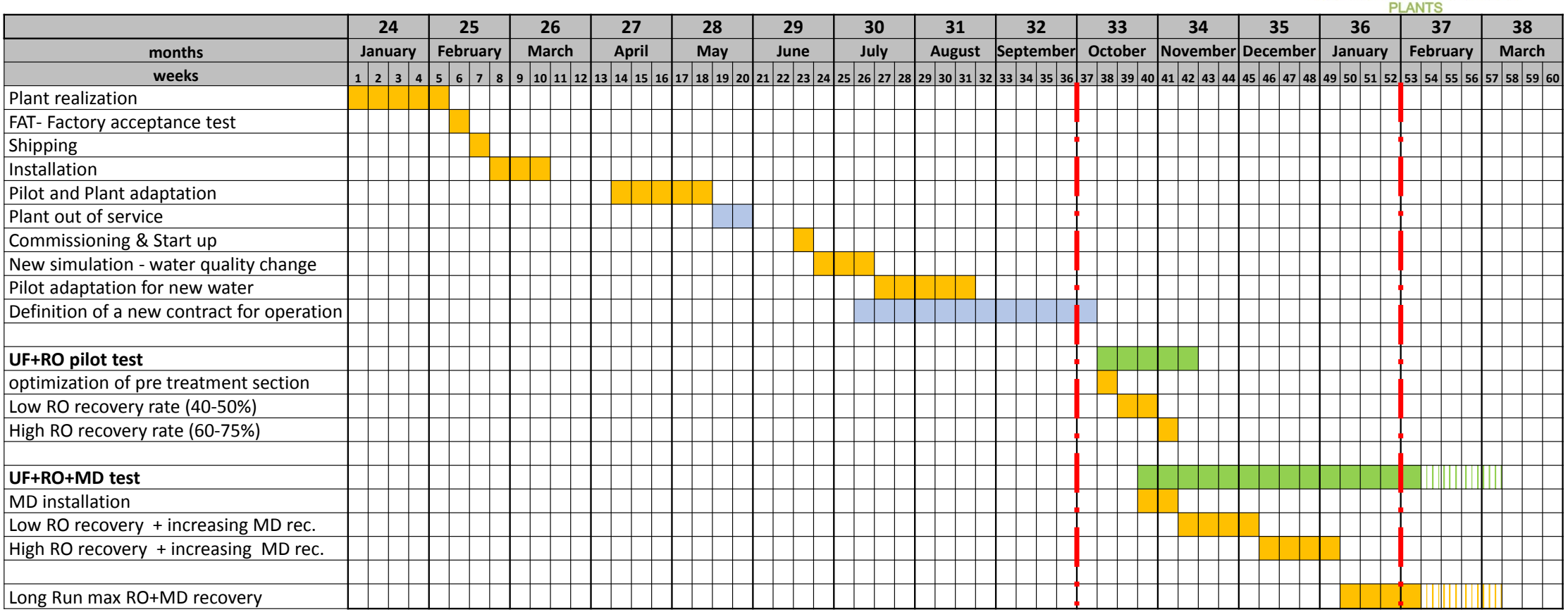
- Low RO recovery + increasing MD recovery
- High RO recovery + increasing MD recovery

Long run tets

- Long run test conclusion
- Final process evaluation

Next steps
Detailed Test program

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS



Acknowledgement

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

Thanks to all MATChING Partners and our Stakeholders Community:

Acknowledgement

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

Thanks to all MATChING Partners and our Stakeholders Community:

Follow us on

www.matching-project.eu

MATChING Group on LinkedIn

Main Coordinator Contacts:

enel

daniela.galla@enel.com;

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

Thank you