# Water Treatment at AES, Maritza East I TPP

An Overview

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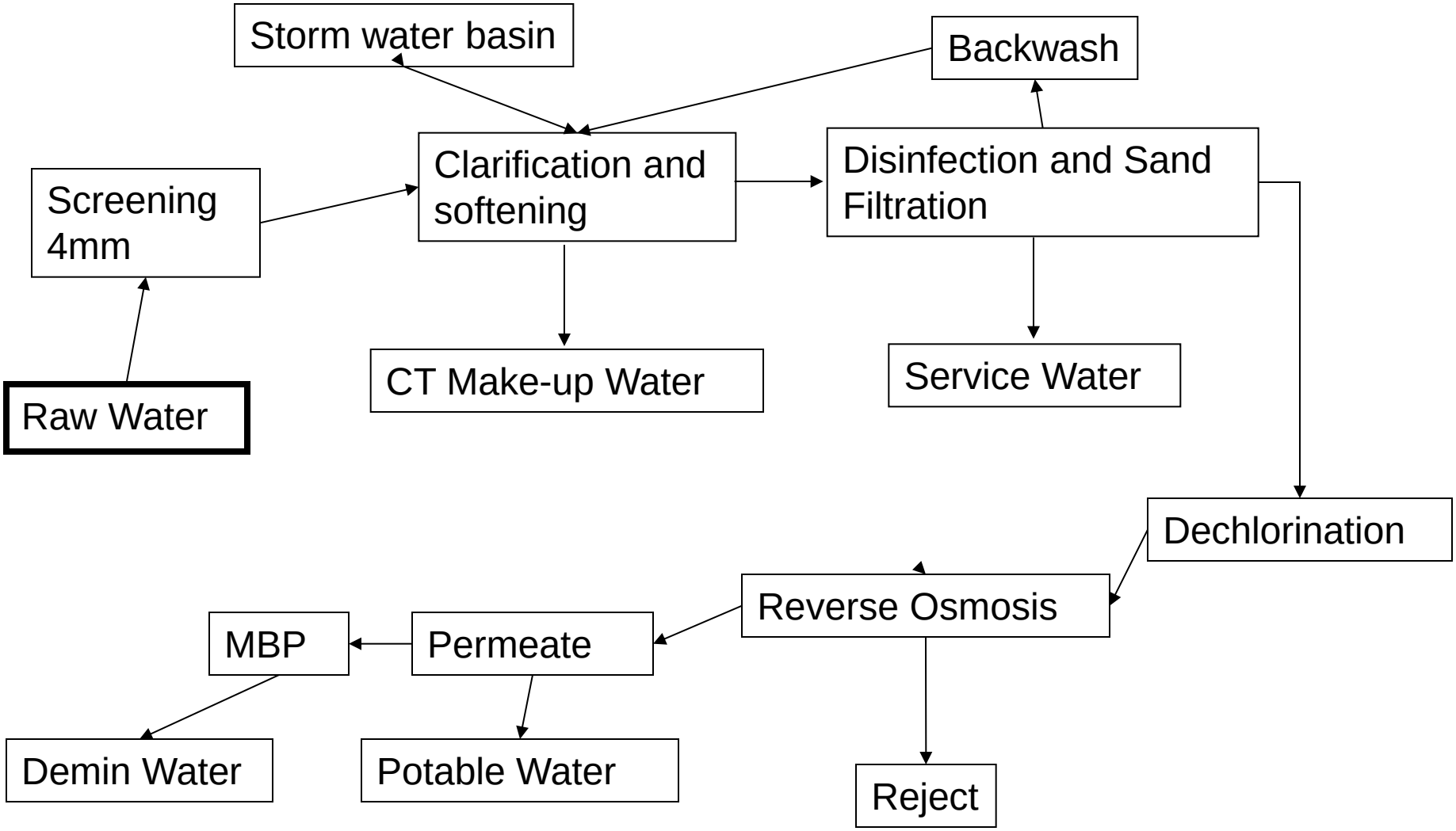
# General Data

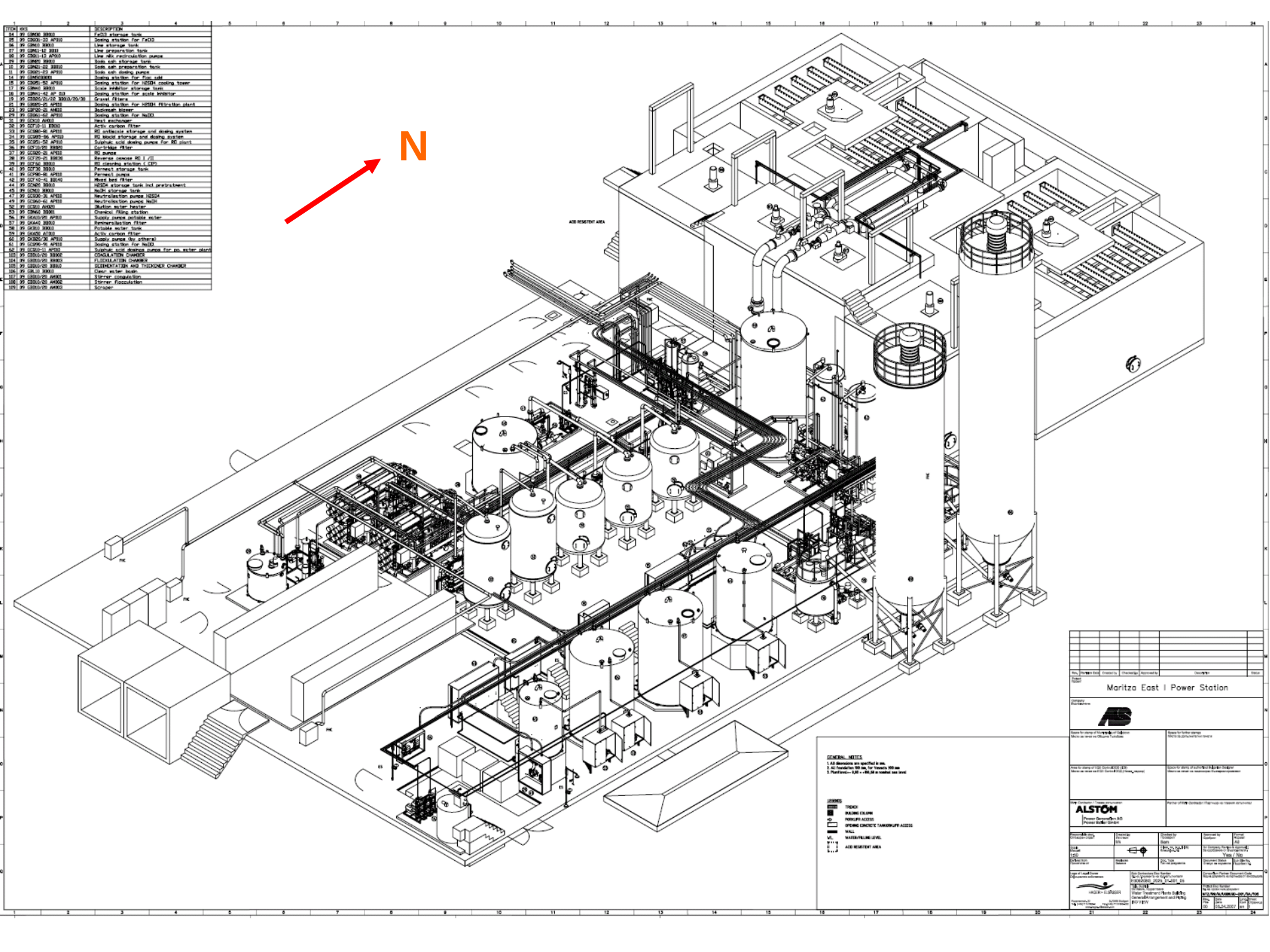
- Lignite Fired power station 2x300 MW Alstom turbines-generators
- 2 Alstom Boilers generating ~ 1022 ton/hour steam @ 544 °C/177 bar each (Maximum Load) with ESP and FGD installations
- Natural draft Cooling tower (61200 m3/hr flow, 16000 m3 system volume, 3-6 cycles of concentration)
- 2 x Condensers with stainless steel (DIN 1.4301) tubes

# EHS

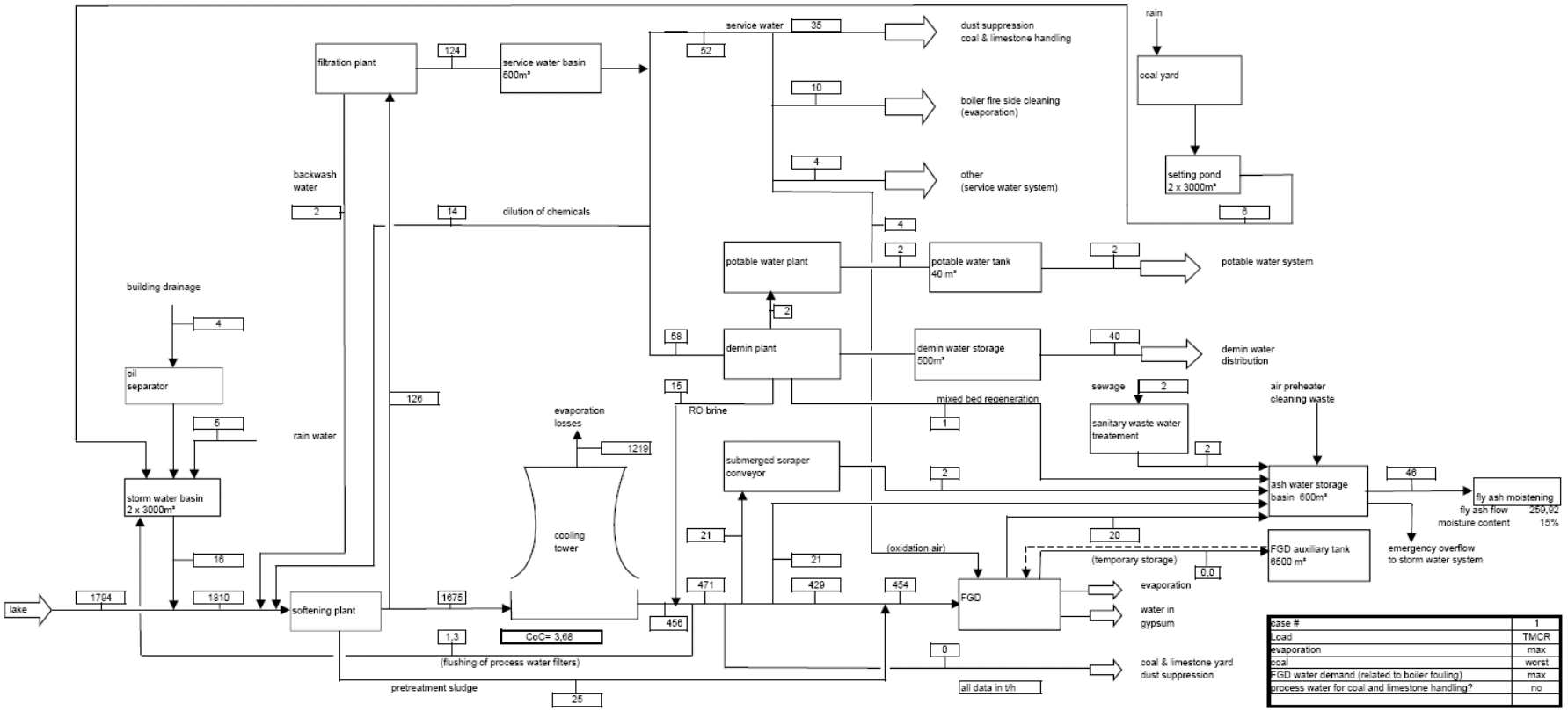
- Zero Liquid Discharge: All waste water streams are recycled.
- Minimal chemical use
  - 96% H2SO4:
    * Before RO technology: 4670 ton/year
    * After RO technology: 875 ton/year
  - 50% NaOH:
    * Before RO technology: 11518 ton/year
    * After RO technology: 73.6 ton/year
- No Harmful chemicals (no Hydrazine)
- All chemical containers bunded and chemical filling is designed with overfill protection
- Safety showers and PPE provided

# Block Diagram for WTP




N
ACID RESISTENT AREA
Maritza East I Power Station
ALSTOM
Power Generation AS
Power Boiler GmbH
HAGER + ELSÄSSER
Water Treatment Plants Building
General Arrangement and Piping
1 : 100

# Water balance



# Impurities

- Raw water is brackish (TDS ~ 1000 mg/L), scaling due to hardness (10-14 meq/L), TOC is high ( 5-30 mg/L due to humics and chlorophyll), sulfate is high, Silica, Barium/Ca sulfate is a potential scalant
- Raw water is surface water and hence has bacteria/phytoplankton/algae/fish/mussels (potentially)
- Raw water has turbidity (suspended solids, colloids) / color

# Types of Water (Produced and Waste Streams)

- Raw Water (Rozov Kladenets)
- Main Cooling Tower Make-up Water (clarified and softened)
- Service Water (pH adjusted, disinfected and filtered)
- Process Water (CT Blow-down Water)
- RO Permeate (demineralized service water - 5 mg/L TDS)
- Potable Water (remineralized, A/C treated, disinfected)
- Demin Water for Boiler (RO permeate deionized using MBP's)
- Regeneration waste (from regenerating the MBP's)
- RO reject (recycled into CT make up water)
- Ash Water (FGD blowdown water, neutralization waste, RAPH cleaning waste, treated sanitary water, SSC blowdown)
- Storm water (recycled into clarifier)
- Coal storage yard drain water (recycled into storm water basin)
- Sanitary waste water (treated using STP and used for ash moistening)
- Oil-separator effluent (recycled into Storm water basin)

# Water Treatment Systems

- Clarifiers (FLOCOPAC) for Raw Water Treatment with capacity of 2200 m3/hr: Coagulation, flocculation, chemical softening and settling with recycling of sludge produced into FGD process. Reduce TSS down to 10 mg/L and Hardness down to 1 meq/L
- Sodium hypochlorite dosing (for service water and CT)
- Gravel/Sand Pressure Filters (total capacity = 133 m3/hr) reduce TSS to less than 1 mg/L
- Active Carbon Filters (pre-treatment for RO)
- 5 micron filters (pre-treatment for RO)
- Three-stage Reverse Osmosis Units x 2 / CIP Station
- MBP
- Closed Cooling Water System Chemical Feed System
- Ball cleaning system/self-cleaning filters for the condenser

# Water Treatment Systems

- Boiler feed water and condensate treatment for ~ 1000 tons/hr steam per boiler (Ammonia + backup NaOH)
- Remineralization filter ($CaCO_3$) for potable water
- Oil Separators (Boiler and Turbine area)
- Package Sewage Treatment Plant (Fixed film activated sludge process)
- Storm Water Basin for rain water (which is collected and reused) and Settling basin for coal yard drainage water (the latter is recycled in storm water system)

# Processes/Chemicals

- $FeCl_3$ as coagulant, anionic Polyacrylamide as flocculant and $Na_2CO_3$/$Ca(OH)_2$ for chemical softening
- NaOCl as disinfectant for service water and Main CT water
- Anti-scalant/$H_2SO_4$ for the cooling tower
- Corrosion inhibitor for fire-fighting system
- NaOH and $H_2SO_4$ for regeneration of the MBP
- RO antiscalant and cleaning chemicals: acid clean (citric acid based) and base clean (caustic + surfactant)
- DBNPA for the RO
- SBS for preservation of membranes
- Caustic Soda + Ammonia for WSC

# Raw Water Pumping Station

- Two pumps 100% each
- Traveling Band Screen

(Eimco Water technologies)

# Coagulation, Flocculation, Precipitation and Settling

# **FLOCOPAC**

# FLOCOPAC

Theoretical Aspects

Functional Views

Type of Construction

# Explanation

- Coagulation – Destabilisation of colloidal suspension by addition of chemical reagents (iron III chloride, aluminium sulphates etc.) by nullifying the repulsive forces

- Flocculation – Agglomeration of the neutralized colloids into flocs by adding of flocculant (organic polymer)

- Precipitation/Settling – Chemical precipitation means formation of insoluble compounds by action of appropriate reagents → Elimination of Calcium, Magnesium and Silica by Lime Softening. Settling means settling of flocs by action of gravity.

# Water Quality

- TSS before: 20mg/L (65 in worst case)
- TSS After: < 10 mg/L
- Hardness Before: 10 meq/L (14 in worst case)
- Hardness After: < 1 meq/L

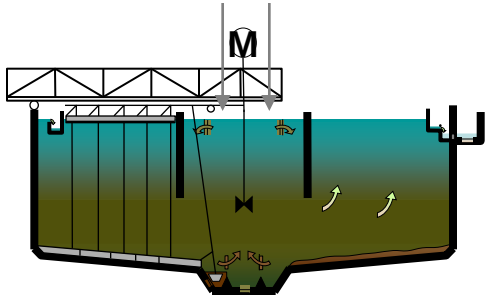
# Explanation

Settling units with **sludge re- circulation**, **sludge blanket** units, **plate settling** and **granular contact** units

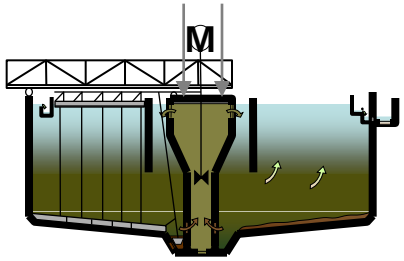
- Sludge re- circulation unit : FLOCOMAT
- Sludge blanket unit : FLOCOPULS
- High efficiency plate type unit with contact sludge upflow reactor : **FLOCOPAC**

# Comparison

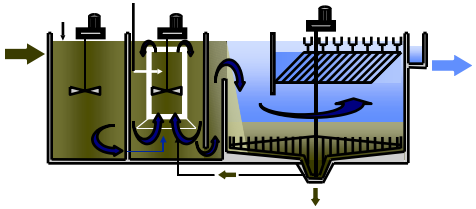
**Flocomat**




**Flocopuls**

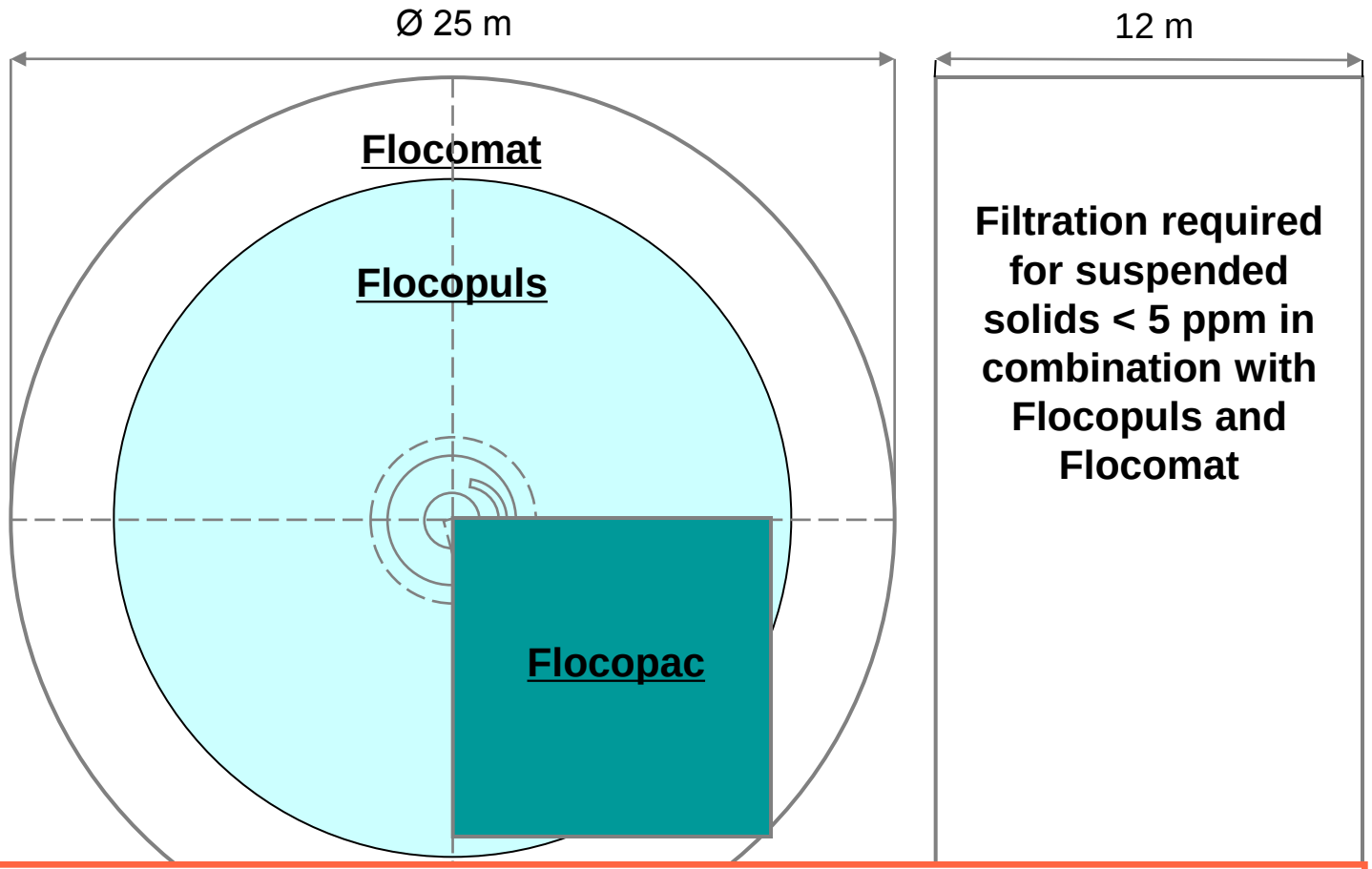



**Flocopac**



| | | | |
|---|---|---|---|
| •Upflow velocity | 1,5 – 1,8 m/h (Flocc)<br>2,8 – 3,5 m/h (Decarb) | 2,0 – 2,5 m/h (Flocc)<br>3,0 – 5,0 m/h (Decarb) | 20-25 m/h (Flocc)<br>30-35 m/h (Decarb) |
| •Solids outlet | **< 10** | **5-10** | **< 2** |
| •Space requirement | **High** | **Medium** | **Low** |
| •Sludge concentration | Low | Medium | High |
| | | | |

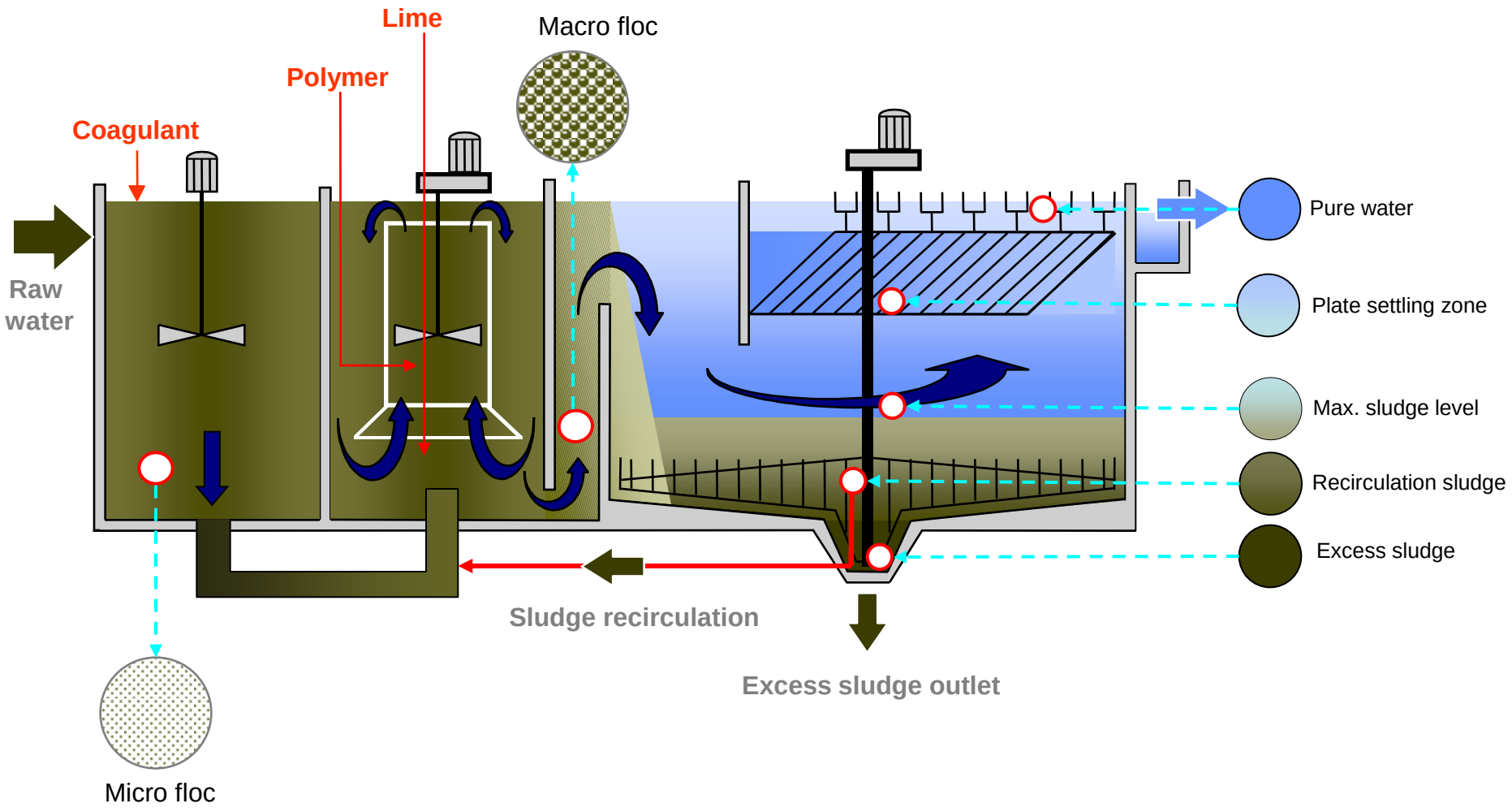
# Comparison Space Requirements
# Example: Flow rate approx. 1.500 m³/h



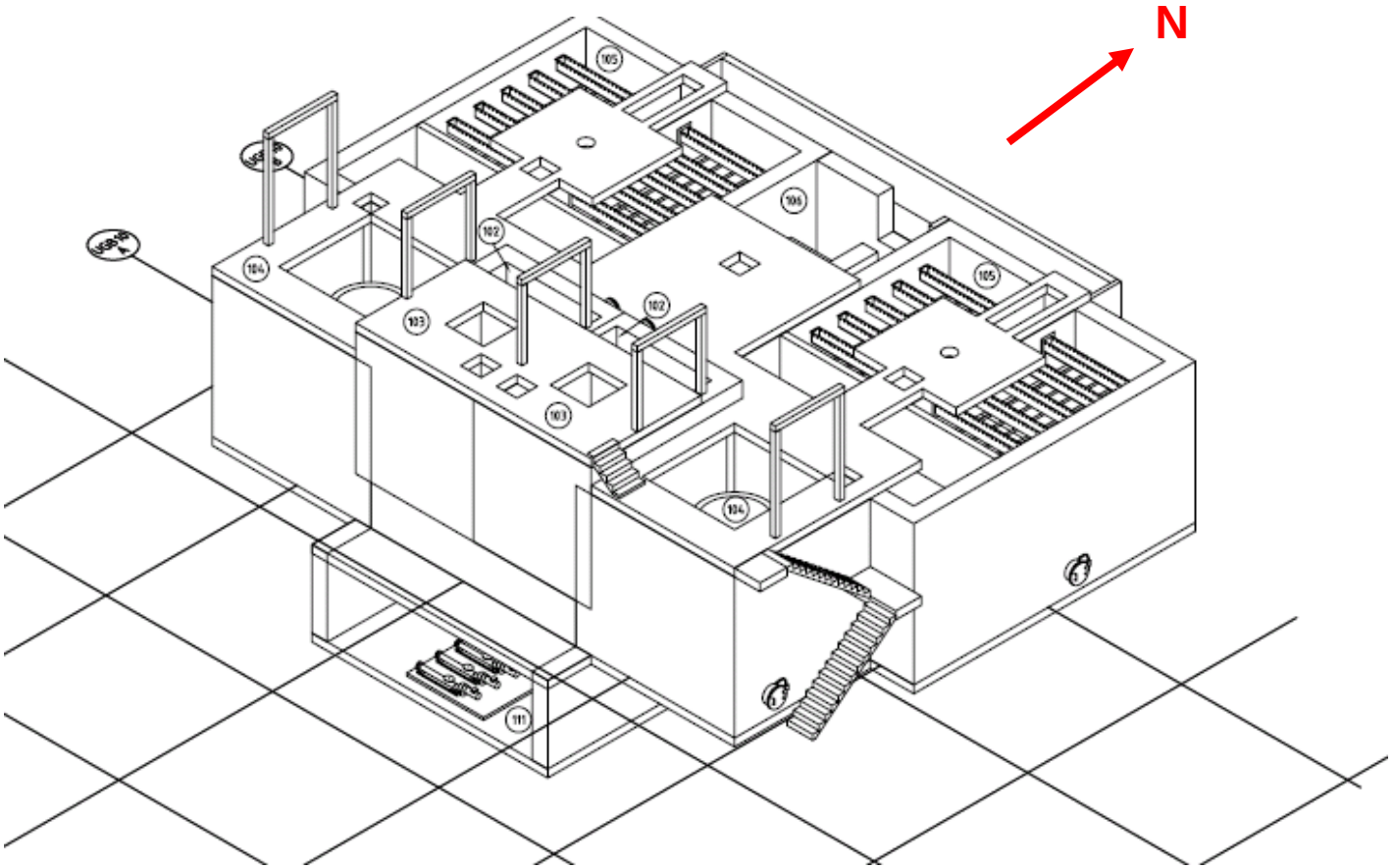

**Flocopac**

- **85% - 90% savings in space**
- **Improvement of water quality**

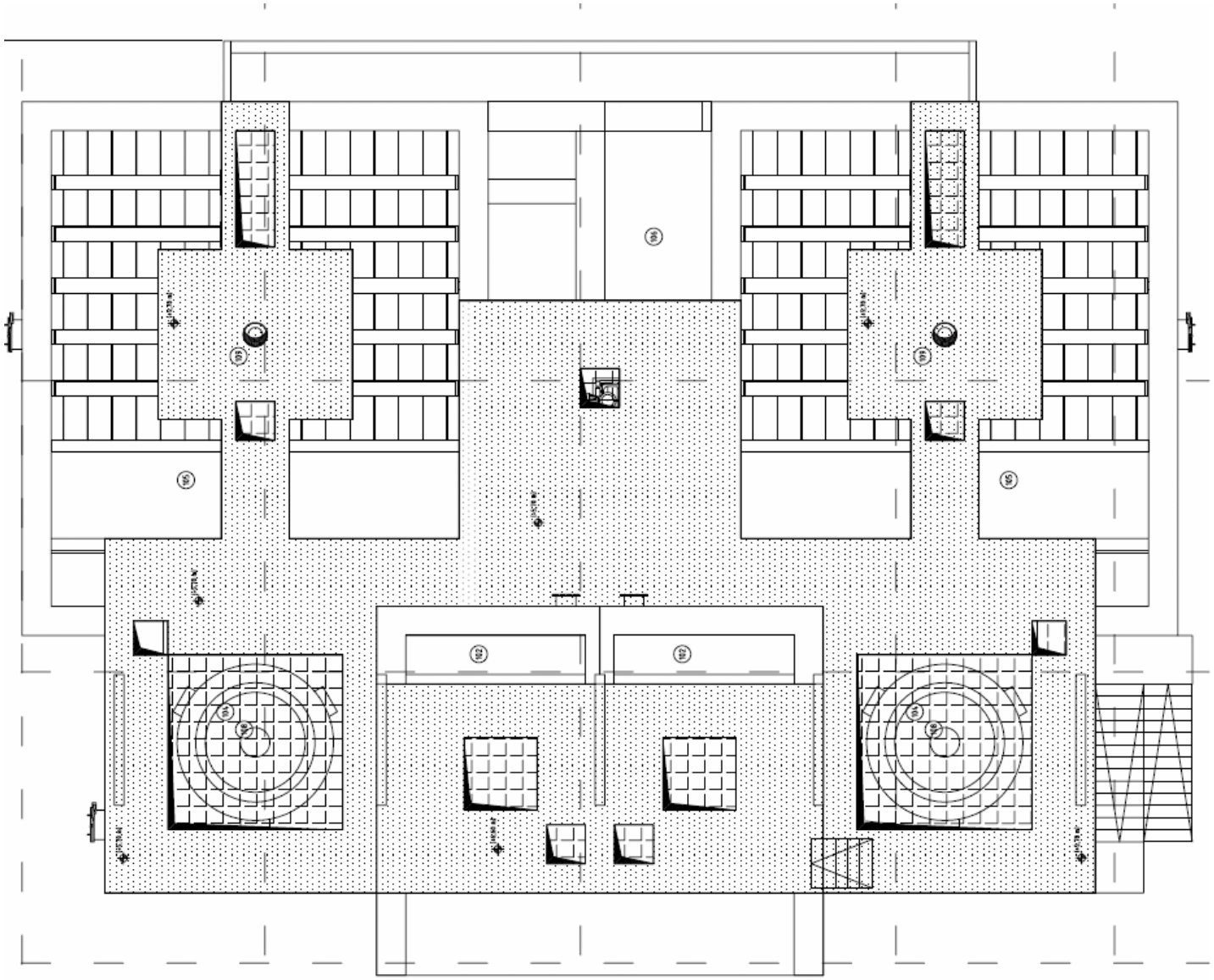
# FLOCOPAC Functional View



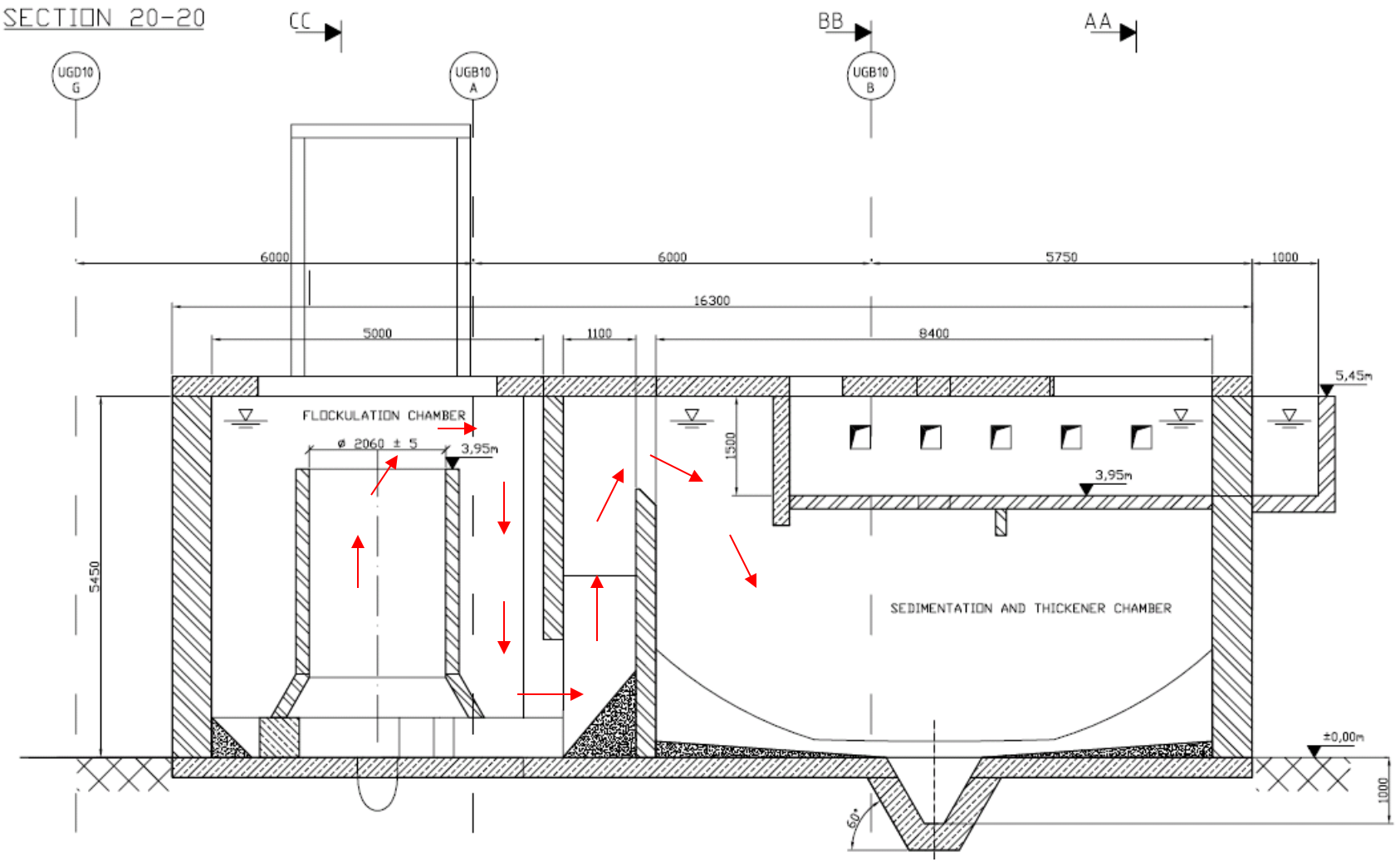
# FLOCOPAC Isometric View



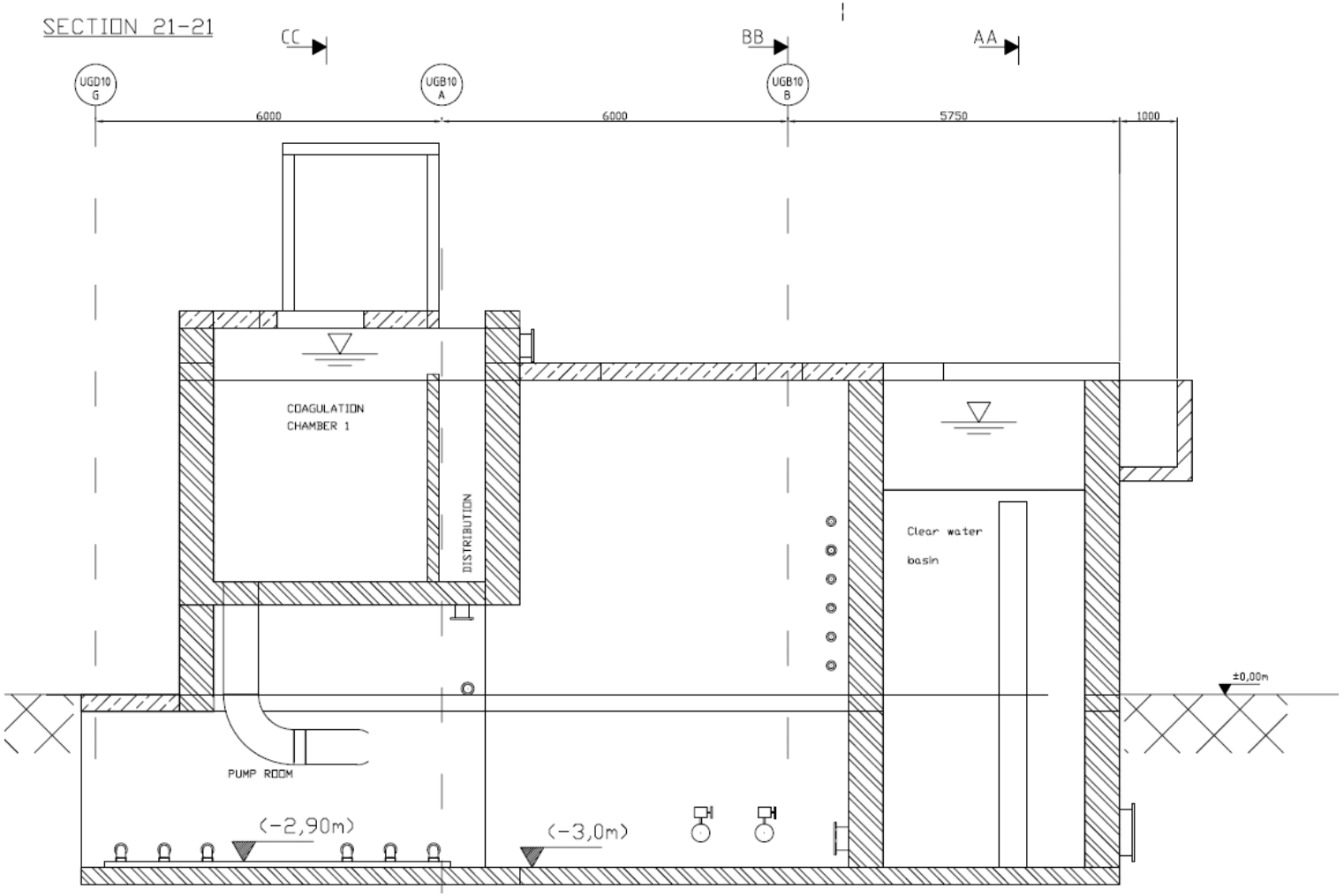
# Arrangement (Top View)



# FLOCOPAC Sectional Views - I



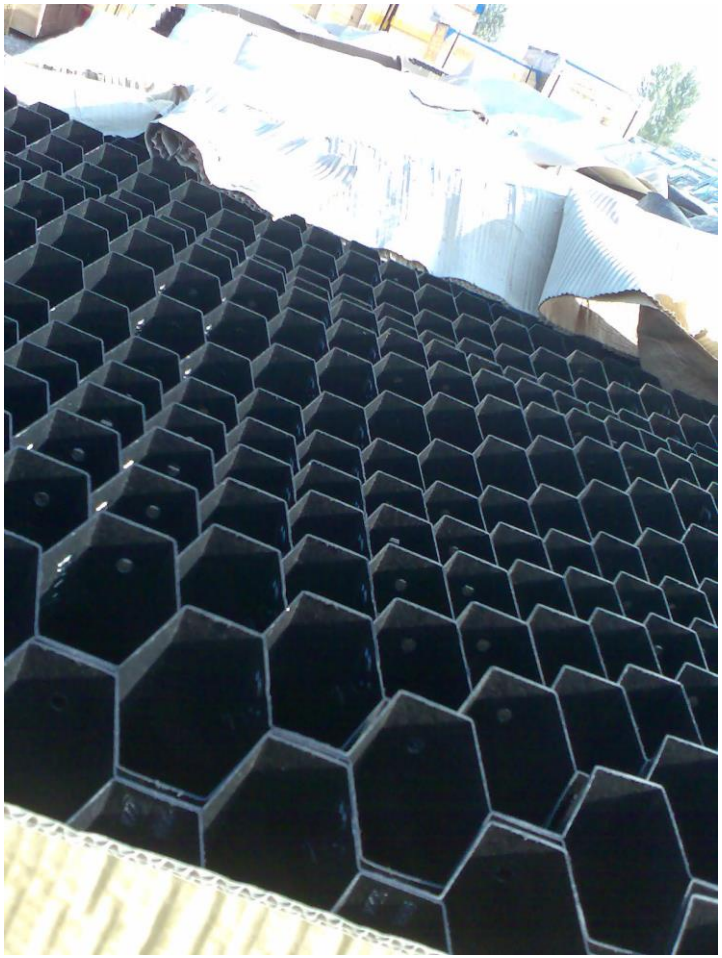
# FLOCOPAC Sectional Views - II



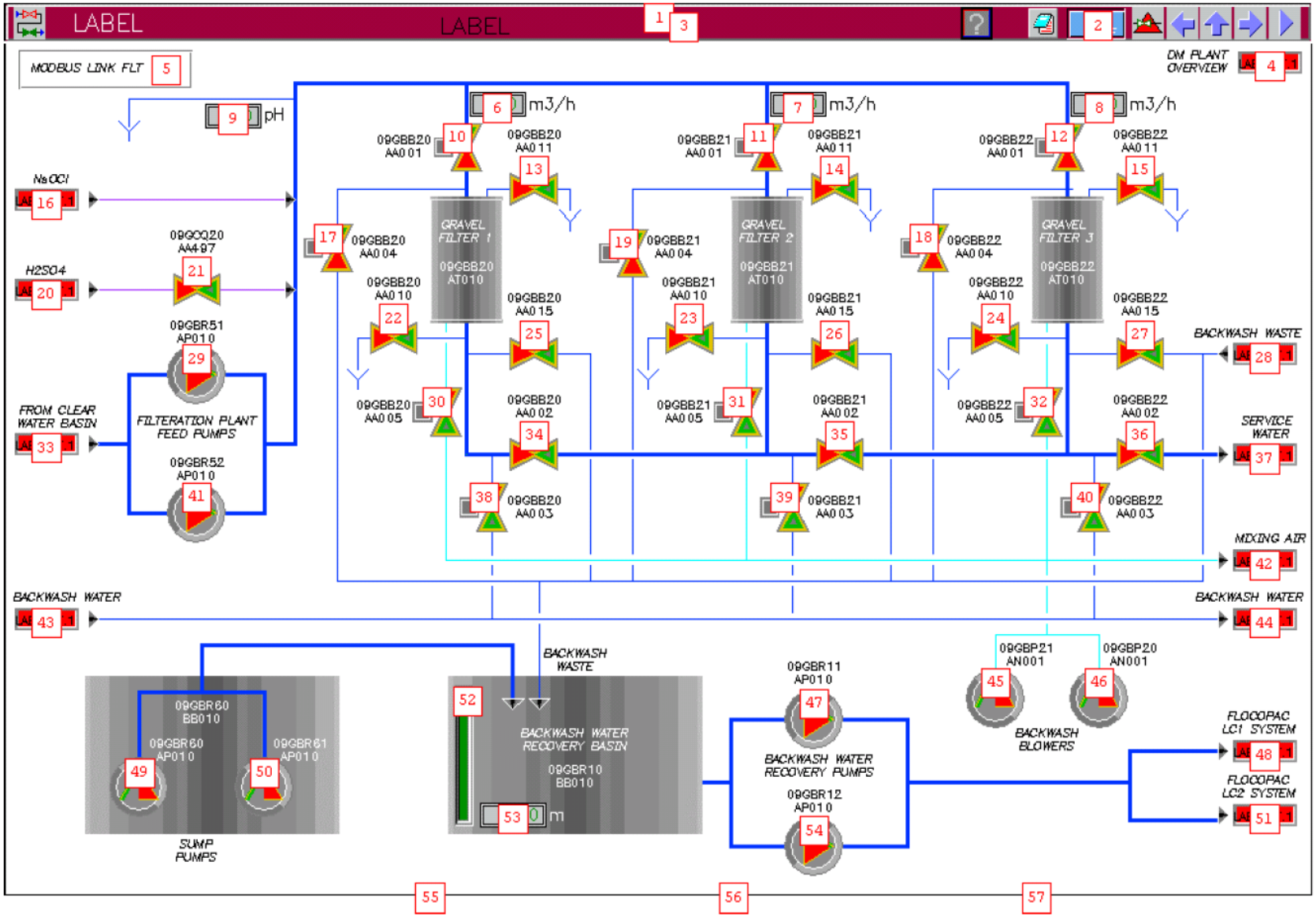
# FLOCOPAC Scraper

# Clear Water Channels

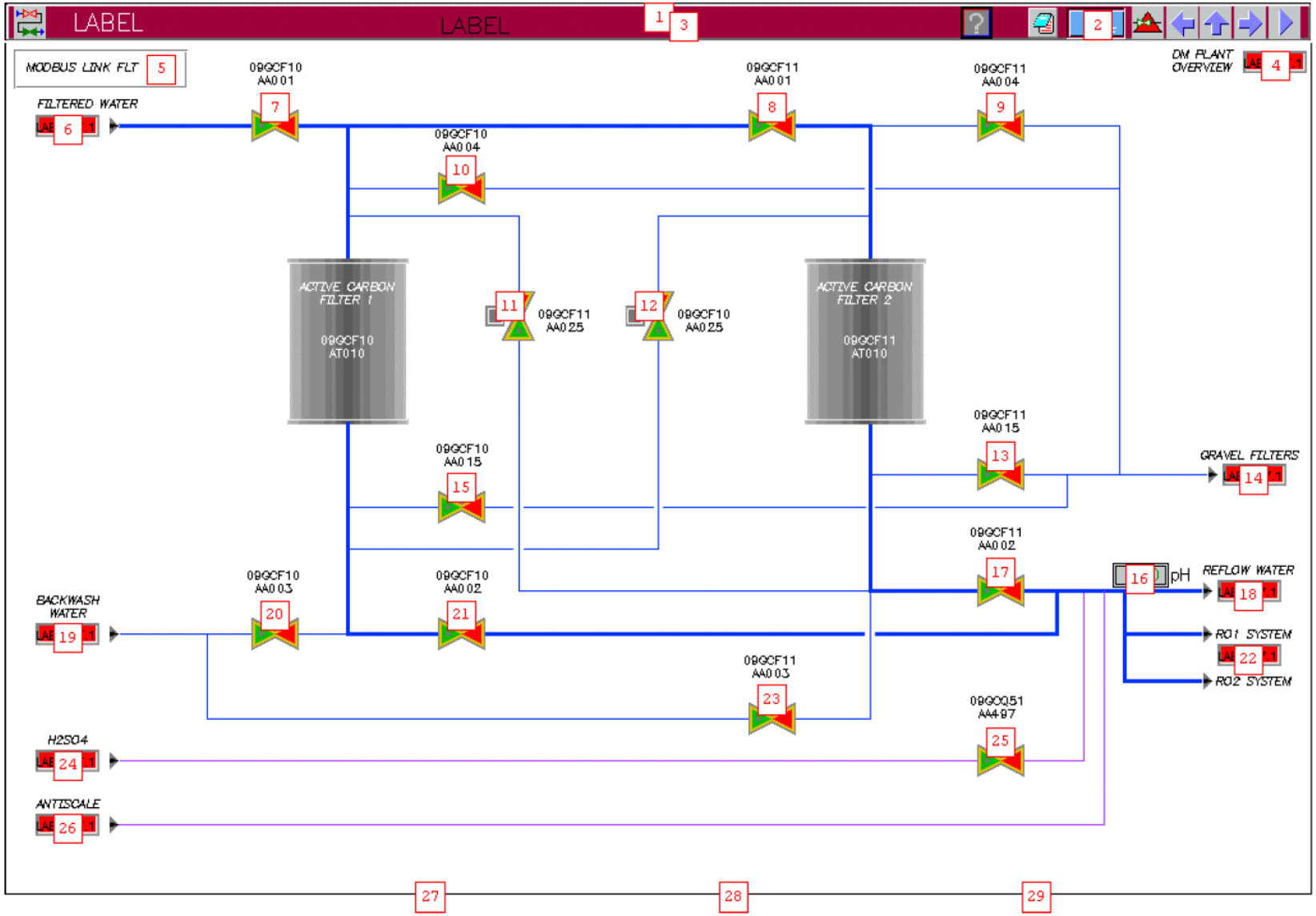
# Lamella Modules



# Gravel Filters (TSS < 1 mg/L)

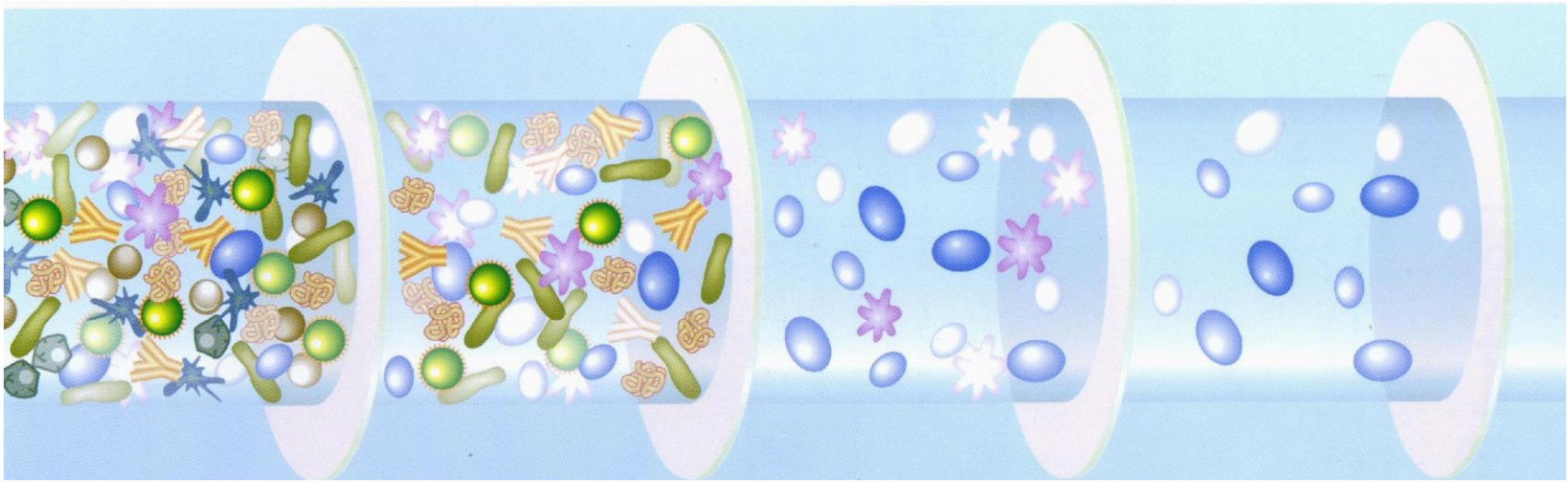


# AC Filters


LABEL
LABEL
1
3
2
MODBUS LINK FLT
5
DM PLANT OVERVIEW
4
FILTERED WATER
6
09GCF10 AA001
7
09GCF11 AA001
8
09GCF11 AA004
9
09GCF10 AA004
10
ACTIVE CARBON FILTER 1
09GCF10 AT010
11
09GCF11 AA025
12
09GCF10 AA025
ACTIVE CARBON FILTER 2
09GCF11 AT010
09GCF11 AA015
13
GRAVEL FILTERS
14
09GCF10 AA015
15
09GCF11 AA002
17
16
pH
REFLOW WATER
18
BACKWASH WATER
19
09GCF10 AA003
20
09GCF10 AA002
21
RO1 SYSTEM
22
RO2 SYSTEM
09GCF11 AA003
23
09GCQ51 AA497
25
H2SO4
24
ANTISCALE
26
27
28
29

# Reverse Osmosis

# Membrane Separation

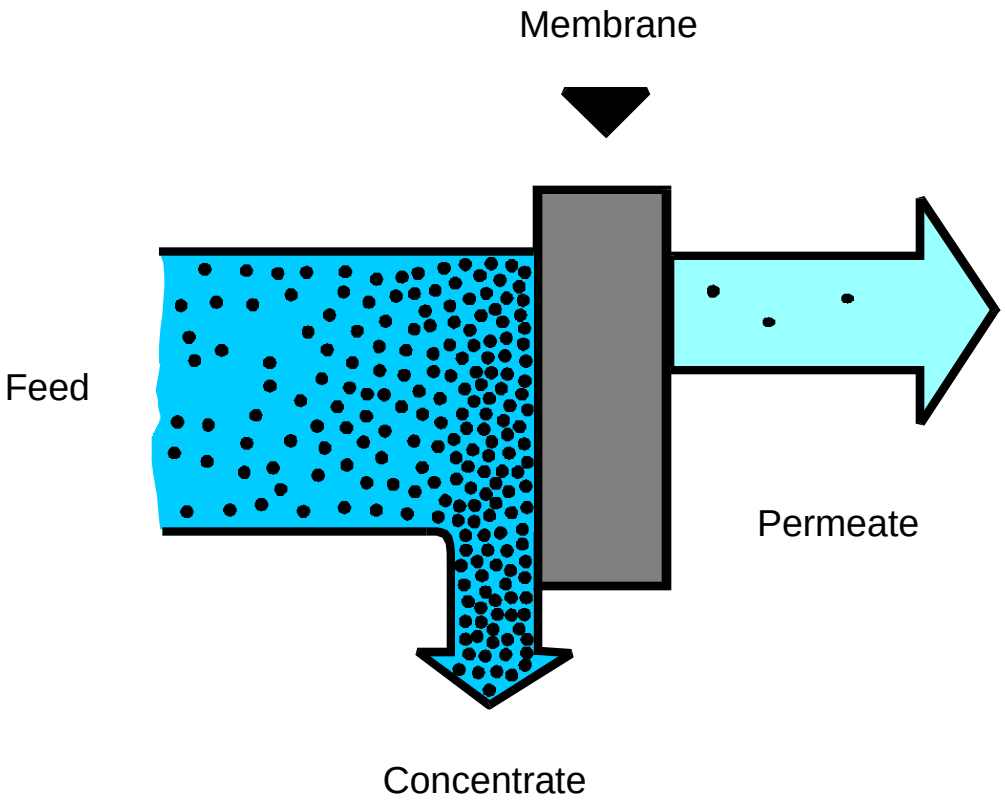


| Mikrofiltration | Ultrafiltration | Nanofiltration | RO |
|---|---|---|---|
| > 0,1 µm | 0,1 - 0,01 µm | 0,01 - 0,001 µm | < 0,001 µm |
| - turbidity<br>- Suspended solids<br>- algae | - Colloidal substances<br>- Micro organism | - Organics<br>- Pesticides<br>- CaSO4 | - Ions |

# Reverse Osmosis

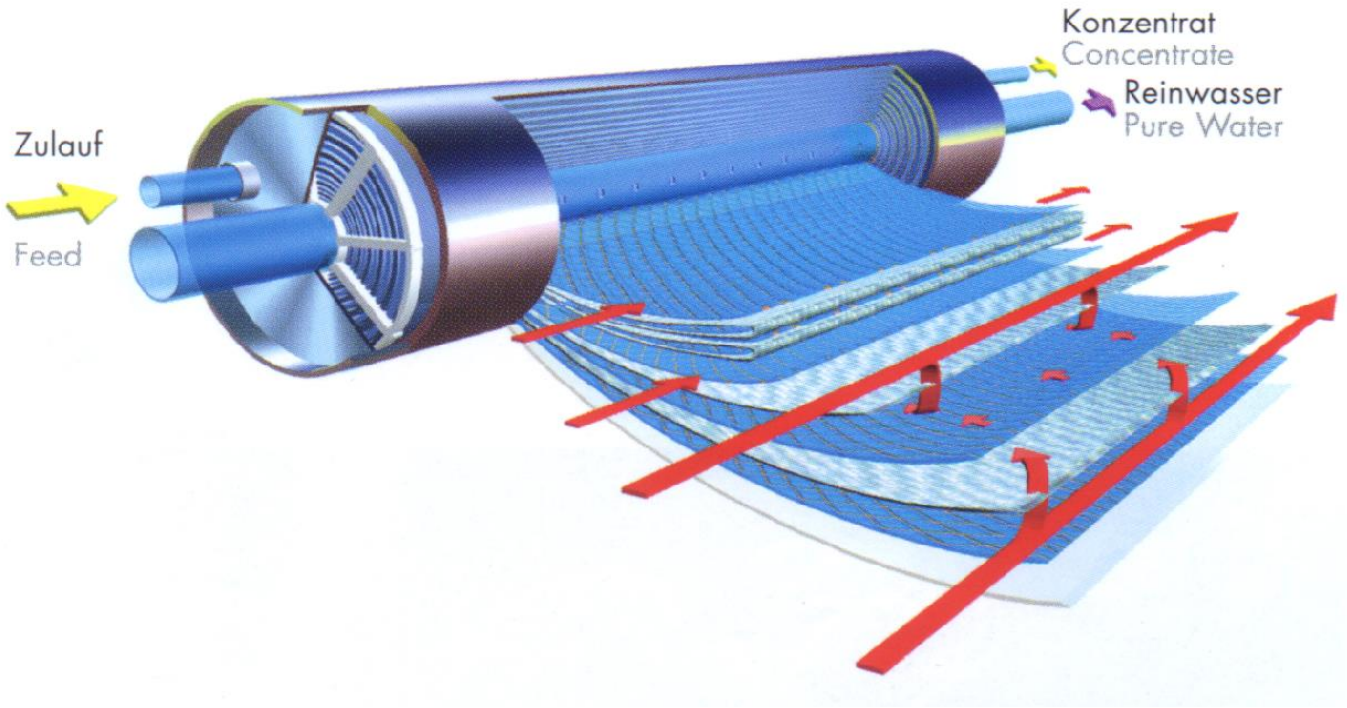
- Membrane solids separation technology
- Pressure driven process through a semi-permeable membrane
- Retention of salts, organics (down to 100 amu) and micro-organisms
- Cross-flow operation mode
- Continuous process

# Principle of RO



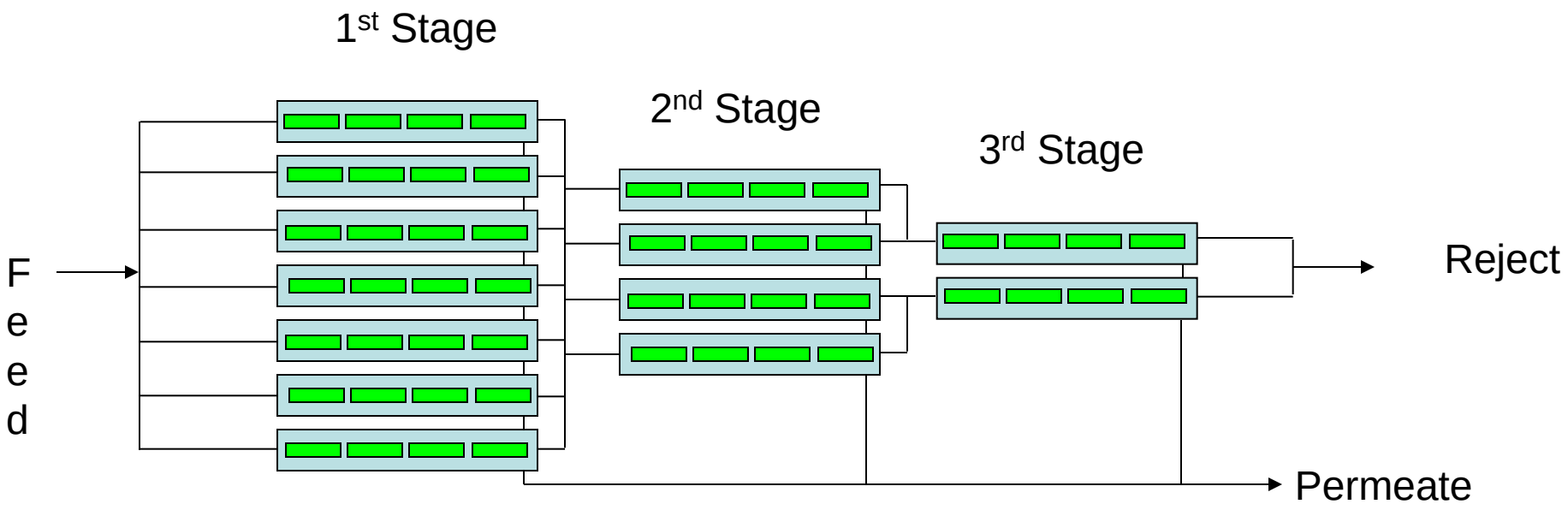

- Cross-flow filtration for continuous desalination
- Separation of feedwater into concentrate and permeate
- Average concentration factor 4-5

# Reverse Osmosis Modules



# R.O. Configuration at AES ME1

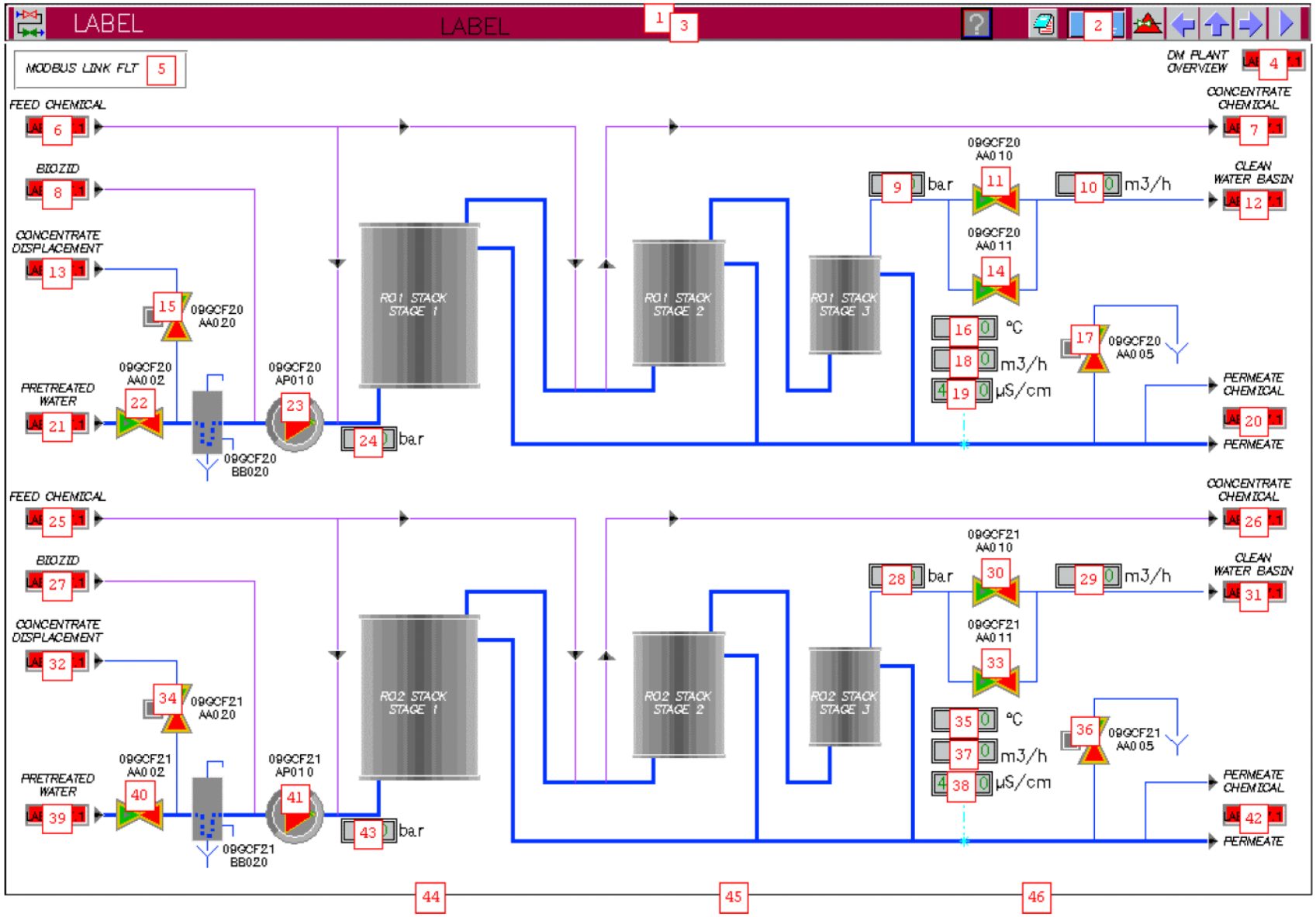
- 7-4-2 Concentrate Staging Configuration




52 membrane elements in each train

# RO At ME I

# ALSPA Process Monitoring



# RO Membrane Fouling/Deterioration

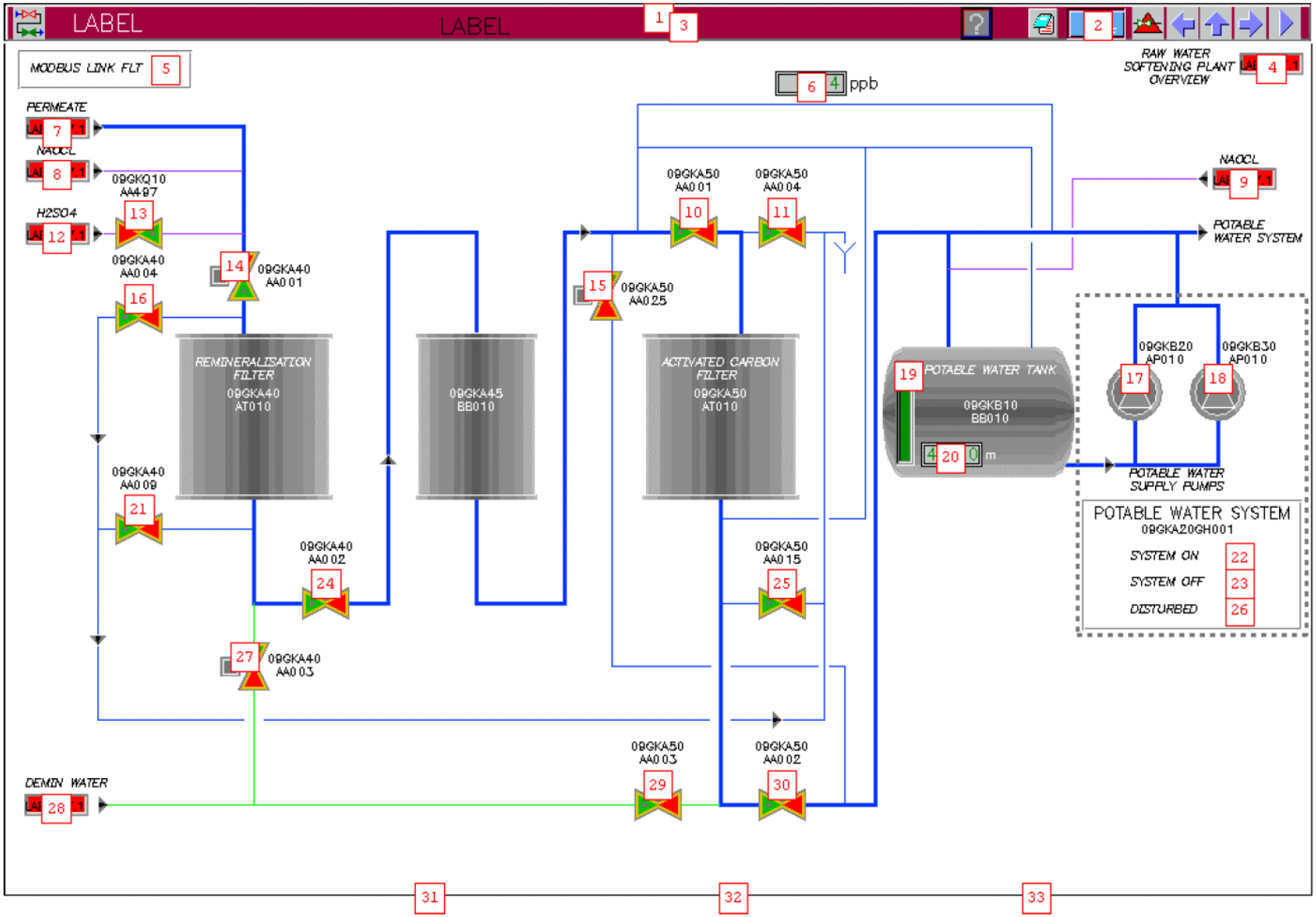
- Scale
- Colloids
- Oxidants
- Color
- Bacteria
- High/Low pH
- Sudden Pressure
- Organic solvents

# RO CIP

# Monitoring the RO

- Ionic composition (weekly)
- Alkalinity (daily)
- Hardness (daily)
- Chlorine (daily)
- T, pH (per shift)
- Conductivity, SDI (per shift)
- TOC, Color (daily)
- Bacteria count (every 3 days)
- Silica (weekly)
- Humic/Fulvic acid (weekly)
- H2S (weekly)
- Boron (daily)
- Oil and Hydrocarbons (weekly)

# Potable Water Treatment

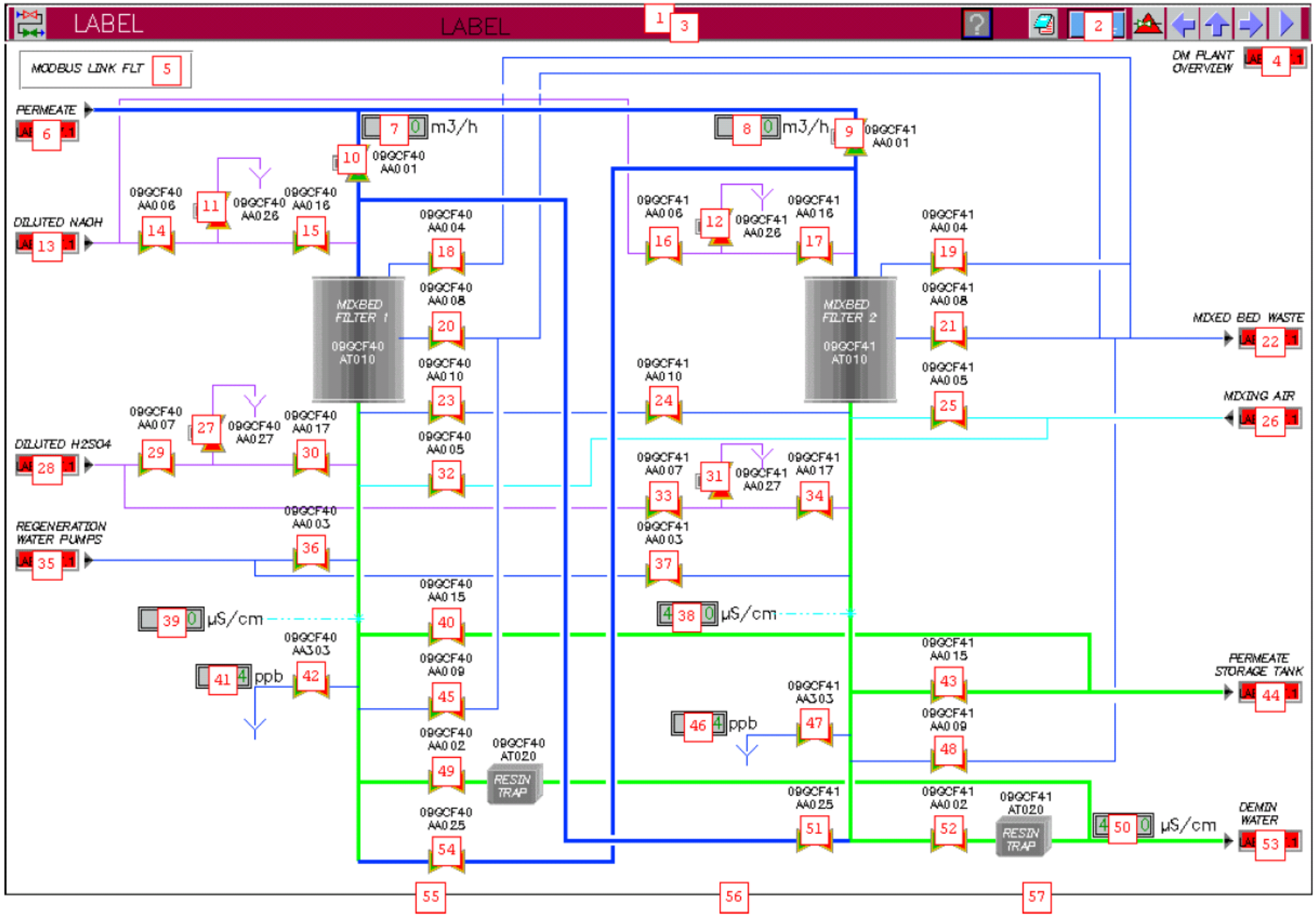


# Mixed Bed Polisher

# Mixed Bed Polisher

- Two vessels with 1-2/2-1 operation
- Strong cation and strong anion Rohm and Haas Amberlite (Amberjet 1200 H and Amberjet 4200 Cl) resin.
- Regeneration with $H_2SO_4$ and NaOH every ~ 48 hours.
- Online monitoring of Conductivity and Silica

# MBP at ME 1 WTP



# Minimum Water Quality for Demineralized Water

- Total Dissolved Solids (TDS) < 0.025 mg/L (Conductivity < 0.08 µS/cm = 12.5 MΩ.cm resistivity)
- Silica as $SiO_2$ < 0.01 mg/L
- Total Organic Carbon (TOC) < or = 0.3 mg/L
- D.O. guarantee at Economizer inlet: 10 ppb (without hydrazine)

# Dosing Regime for WSC

- Based on VGB-R 450 Le
- No Copper materials hence pH can be higher than 9.3
- $O_2$ level of 10 ppb at econ. inlet w/o Hydrazine
- Dosing facilities for solid alkalizing agent (dosed at econ. inlet according to pH in SD) and ammonia (downstream condensate extraction pumps according to pH at econ. inlet )

# Quality Requirements – Feed Water

| Parameter | Unit | N | A1 | |
|---|---|---|---|---|
| pH | - | 9,2 – 9,4 | 9,2 | 9,8 |
| Conductivity (only valid for ammonia dosing) | µS/cm | 4,3 – 8,6 | 4,3 | 18 |
| Acid conductivity | µS/cm | < 0,10 | 0,2 *) | |
| Oxygen (O2) | µg/kg | 5 - 20 | 2 | 100 |
| Silica (SiO2) | µg/kg | < 5 | 20 | |
| Iron (Fe) total | µg/kg | < 10 | 30 | |

# Quality Requirements – Steam Drum

a) AVT (Alkaline Treatment)

| Parameter | Unit | N | A1 |
|---|---|---|---|
| pH | - | pH is controlled by pH of the feed water (pH of feed water to be > 9,5) | |
| Acid conductivity | µS/cm | < 1 | 1 |
| Silica (SiO2) | µg/kg | < 75 | 300 |

b) Caustic Soda dosing to HP drum

| Parameter | Unit | N | A1 | |
|---|---|---|---|---|
| pH | - | 9,4 – 9,6 | 9,3 | 9,7 |
| Conductivity | µS/cm | 6 – 10 | 5 | 12 |
| Acid conductivity | µS/cm | < 30 | 30 | |
| Silica (SiO2) | µg/kg | < 75 | 300 | |

# Quality Requirements – Live Steam

| Parameter | Unit | N | A1 |
|---|---|---|---|
| Acid conductivity | µS/cm | < 0,10 | 0,2 *) |
| Silica (SiO2) | µg/kg | < 5 | 20 |
| Sodium (Na), if boiler water treatment AVT or caustic | µg/kg | < 2 | 5 |
| Sodium (Na), if boiler water treatment with phosphate | µg/kg | < 5 | 10 |
| Iron (Fe) total | µg/kg | < 5 | 20 |
| Copper (Cu) total | µg/kg | < 1 | 3 |

*) Higher values may be defined if the increase of acid conductivity can be attributed to carbon dioxide from air inleakage but organic decomposition products can be excluded

# Monitoring

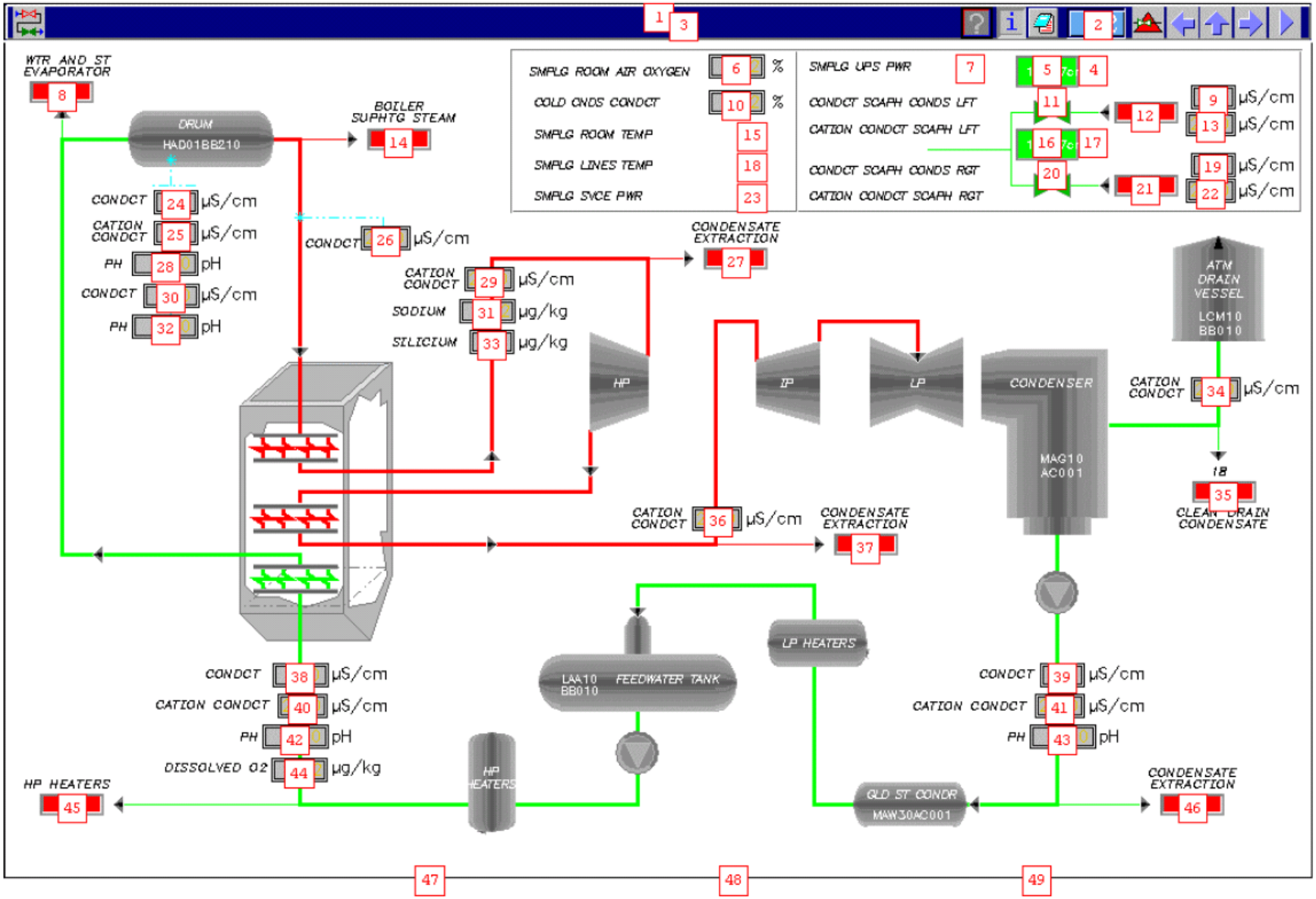
- Water/Lignite/FGD analysis lab for grab samples:
  - Inorganics (heavy metals, phosphates, nitrates, chlorides, etc.), pH, COD, turbidity, hardness, chlorine, ammonia, SDI
  - Lignite: LHV, ash, moisture, volatiles, C/S-content, sieve analysis and boiler/ESP by-products
  - FGD raw materials/byproducts
- Online monitoring (for clarifier, RO, MBP, WSC and CT): pH, turbidity, sludge density, Na, Silica, DO, Conductivity, Cation Conductivity, Chlorine.

# Online Monitoring WSC

| Sampling point | parameter | Measuring range | Remarks |
|---|---|---|---|
| Condensate after condensate extraction pumps | Direct conductivity | 0 – 80 µS/cm | |
| | Acid conductivity | 0 – 2 µS/cm | |
| | Calculated pH | 7 – 12 pH | No analyser, calculated from acid conductivity and direct conductivity |
| | (Dissolved oxygen) | (0 – 400 µg/l $O_2$) | Analyser for measurement for feed water at economizer inlet may be manually interchanged to this sampling point |
| Feed water, at economiser inlet | Direct conductivity | 0 – 80 µS/cm | |
| | Acid conductivity | 0 – 2 µS/cm | |
| | Calculated pH | 7 – 12 pH | No analyser, calculated from acid conductivity and direct conductivity |
| | Dissolved oxygen | 0 – 400 µg/l $O_2$ | (Shared analyser, may be used also for condensate measurement after condensate extraction pumps |
| | Hydrazine | 0 – 20 µg/l $N_2H_4$ | |
| Main steam | Acid conductivity | 0 – 2 µS/cm | |
| | Silica | 0 – 40 µg/l $O_2$ | |
| Saturated steam | | | Sample line interconnected to main steam sampling point to use analysers installed at this sampling line |

# Monitoring WSC

| Sampling point | parameter | Measuring range | Remarks |
|---|---|---|---|
| Reheat steam | Acid conductivity | 0 – 2 µS/cm | |
| Boiler drum water | Acid conductivity, continuously | 0 – 150 µS/cm | Split range output |
| | Direct conductivity | 0 – 150 µS/cm | |
| | pH measurement | 4 – 12 pH | |
| Cold condensate tank | Direct conductivity, continuously | 0 – 80 µS/cm | |
| Condensate return | Acid conductivity | 0 – 2 µS/cm | |


1
3
2
WTR AND ST EVAPORATOR
8
DRUM
HAD01BB210
BOILER SUPHTG STEAM
14
SMPLG ROOM AIR OXYGEN
6
%
COLD CNDS CONDCT
10
%
SMPLG ROOM TEMP
15
SMPLG LINES TEMP
18
SMPLG SVCE PWR
23
SMPLG UPS PWR
7
CONDCT SCAPH CONDS LFT
CATION CONDCT SCAPH LFT
CONDCT SCAPH CONDS RGT
CATION CONDCT SCAPH RGT
4
5
11
12
9
13
16
17
20
21
19
22
µS/cm
CONDCT
24
µS/cm
CATION CONDCT
25
µS/cm
PH
28
pH
CONDCT
30
µS/cm
PH
32
pH
CONDCT
26
µS/cm
CONDENSATE EXTRACTION
27
CATION CONDCT
29
µS/cm
SODIUM
31
µg/kg
SILICIUM
33
µg/kg
HP
IP
LP
CONDENSER
MAG10 AC001
ATM DRAIN VESSEL
LCM10 BB010
CATION CONDCT
34
µS/cm
18
35
CLEAN DRAIN CONDENSATE
CATION CONDCT
36
µS/cm
CONDENSATE EXTRACTION
37
LP HEATERS
LAA10 BB010
FEEDWATER TANK
CONDCT
38
µS/cm
CATION CONDCT
40
µS/cm
PH
42
pH
DISSOLVED O2
44
µg/kg
HP HEATERS
45
HP HEATERS
CONDCT
39
µS/cm
CATION CONDCT
41
µS/cm
PH
43
pH
GLD ST CONDR
MAW30AC001
CONDENSATE EXTRACTION
46
47
48
49

# Automation/PLC

- PLC system controls all automation in water treatment plant
- Opening/closing of valves for various sequences and turning pumps on/off
- Flow control for chemical dosing pumps
- Process DCS Simulation (ALSPA system) displays process parameters in Main Control Room (HMI)

# Main Equipment

- +GF+ PP and PVC piping and tanks
- Steel tank for H2SO4 and steel pipes for steam
- Gemu/Georg Fischer butterfly/membrane valves
- Toray RO Membranes
- KSB, Sterling, Apollo, Munsch, Seepex and Wilo pumps
- Grundfos Chemical dosing pumps
- Spirax Sarco heat exchangers and steam valves
- Nord/KSB motors
- Kaiser blowers
- Endress hauser flow meters/LI's
- Jumo electrodes (pH/Conductivity)

STERLING PUMPS

GRUNDFOS

WILO

sismat

STEINLE INDUSTRIEPUMPEN GMBH

spirax sarco

KAESER

TORAY GROUP U.S.A. www.torayusa.com

GEMÜ

KSB

Endress+Hauser People for Process Automation

seepex.com all things flow

MUNSCH Kunststoffpumpen für aggressive Medien

# The AES Vision

- Bulgarian efficient, clean power generated with social responsibility

- AES Values:
  - Safety
  - Excellence
  - Commitment (to employees, clients and society)
  - Integrity
  - Fun