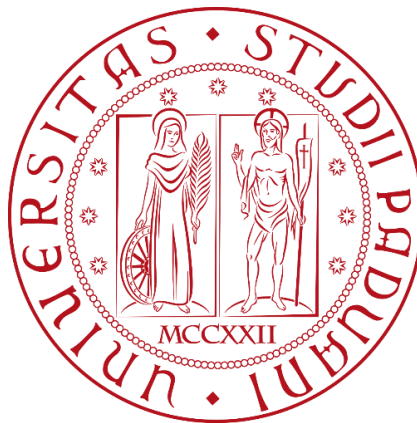


UNIVERSITÀ DEGLI STUDI DI PADOVA
DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

Department Of Industrial Engineering

**Master Degree in Materials Engineering,
Functional Materials**



MASTER THESIS

**DESIGN AND OPTIMIZATION OF A WATER
TREATMENT PLANT FOR PRODUCING HIGH
QUALITY OSMOTIC WATER IN THE FOOD
INDUSTRY**

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Abstract

The project developed consists on the design of a water treatment system to obtain high quality osmotic water intended for feeding a plant for pasta's production, in particular cous cous, located in Algeria, Africa.

The project has been designed and realized by Atlas Filtri, a Company located in the North of Italy, specialized in the production of several components related to water treatment, both for domestic and industrial purposes, and the design of reverse osmosis plants. Most of commercialized products include cartridges, realized in different materials, self-cleaning filters, anti-scale systems, industrial mass filters, UV sterilizers, water softeners and reverse osmosis plants.

Starting from the analysis of the feed water and the technical and mechanical requests presented by the customer, numerous problems will be studied, and several solutions will be reported, with also possible alternatives, both from a technical and economical points of view.

Since the raw water is influenced by the environment, the effects of it must be considered during the design, considering the possibility of several changes in temperature and water parameters, such as turbidity, pH, electrical conductivity, oxygen dissolved and water hardness.

In addition, also the geographical area where the plant will be installed has to be considered: once it has been placed, the installation, control and monitoring of it could be difficult.

For these reasons, before designing, the worse data obtained from the water analysis will be considered, to work with "safety margin".

Then, comparing the data obtained by the water analysis with those reported in the Legislative Decree currently in force, the critical issues of water can be determined and consequently, the most appropriate water treatment plant can be proposed.

Usually, a pre-treatment step is necessary to preserve the life and functionalities of the reverse osmosis membranes, with also the addition of specific chemical products to avoid scale formation and corrosion problems, enhancing the overall efficiency of the plant while reducing the energy consumptions.

Thus, considering the inlet and outlet flowrates and the working pressures, together with the water analysis and environmental parameters, the plant can be designed, verifying that the obtained pure water parameters meet the costumer expectations, while respecting the regulations.

Finally, an analysis of the total costs of the plant will be carried out, considering the final costs of the entire system, in terms of electrical consumption (taking into account the cost of electricity and the working time) and water consumption (considering the inlet flowrate), and the costs related to consumables, such as reverse osmosis membranes, water filtration cartridges, sterilizer filter, chemical products (...).

In conclusion, it will be demonstrated that the purchase of the entire treatment system, fed by well water, is the best solution from a technical and economic point of view, compared with the purchase of a partial treatment system, fed by aqueduct potable water.

Introduction

The project developed consists on the design of an industrial treatment plant to obtain high purity osmotic water, suitable for feeding a pasta producing plant.

The Company appointed to realize this work is Atlas Filtri, a dynamic and flexible modern manufacturing Company based in Padova, in the North of Italy. For fifty years, it has played a leading role in the water treatment sector, thanks to the design, creation and distribution of components and systems for producing water intended for civil and industrial use, both at national and international level, characterized by specific chemical and physical properties.

The wide range of products, constantly updated to offer new and customized solutions, the exclusive technology and the attention to details confirm the reliability and competence of this Company, always oriented towards continuous improvement and widespread distribution throughout the world.

As an Italian Company, it is dedicated to engineering and designing the products in true Italian style, each of which is internationally patented, and all of them are 100% produced in Italy.

Thanks to a modern and efficient corporate organization, closer to the need of new markets and ready to face future challenges, the Company produces and exports to over 90 countries worldwide, comprising Atlas Filtri North America, Atlas Filtri Far East and Atlas Filtri Italia.

Within Atlas Filtri Italia, operates the Atlas Filtri Engineering division, devoted to the development and design of water filtration and treatment systems, standard or customized according to the specific customer requests. This group responds to a constant evolving market, solving particular problems with specific engineered systems, creating tailor-made solutions to improve the quality of water used in industrial, professional and domestic processes. Treatment systems of different sizes and flowrates are manufactured using innovative technologies, applying strict production standards, while ensuring high quality of the products.

In particular, Atlas Filtri designs and realizes standard reverse osmosis plants from 40 l/h to 2500 l/h, and personalized reverse osmosis plants based on the specific request of the costumer, up to 50000 l/h.

The Company also produces systems for brackish water, and single or double stage reverse osmosis systems projected for the use in several industrial sectors, especially in the food field, whenever ultra-pure water is required.

Furthermore, Atlas Filtri Engineering has always invested to the research and development of efficient and long-lasting products, operating with the utmost respect for the environment, implementing production processes aimed at saving energy and building products with objectively ecological features.

The Company prides to be present in more than one hundred countries in all the world, more than 90% of the production is destined abroad, above than 23000 m² of offices, production and logistics, and more than 200 specialized employees. The production is active 24 hours per day, five days a week. Over 280 tons of polypropylene, 520 tons of reinforced polypropylene, 20 tons of recycled polypropylene and 600 tons of PET used every year. Finally, there are 40 injection machines used to produce filters, heads, glasses and other components.

In conclusion, the principal aim of the Company is to enhance the quality of water both for domestic and industrial use, sensitize the public opinion, improving the global access to clean and safe water and protect the planet through sustainable hydro-initiatives, using emerging technologies to achieve both environmental and operational objectives. ^[1]



Fig. 0.1 Operational headquarters of Atlas Filtri company

1. Project's presentation

1.1 Customer's request

The costumer's request consists on the design of a water treatment plant for producing high quality water at the service of a cous cous supplied line of 2400 kg/h and an existing cous cous line of 2400 kg/h, with a final steam drying cycle. Cous cous is a natural product linked to an ancient tradition that requires care and competence to be formed and cooked, according to the rules that make it a healthy and pleasant food. For these reasons, a line capable of returning the best possible to each phase of the process is needed, paying attention to those details that determine great return and better quality of the final product for the same raw material. [2]

The figure below shows an example of a cous cous production plant.



Fig. 1.1 General configuration of a plant for the production of cous cous of 2400 kg/h [3]

The data of each consumption point with the relative pressures, defined by the costumer, are:

- Water flowrate for dough: 1700 l/h at the minimum pressure of 2,5-3 bar (softener water);

- Water flowrate for washing cooker: 3000 l/h (maximum flowrate, batch consumption) at the minimum pressure of 3-4 bar. This consumption must be considered contemporary to the water needed for dough, leaving the second thrust pump on stand-by;
- Osmotic water flowrate: 3000 l/h (degasser loading in the thermal power plant) at the minimum pressure of 3-4 bar. The osmotic water that goes to the degasser must be treated with a specific chemical product.

1.2 Method of planning

In order to design the requested system, the analysis of the raw water, supplied by the customer, has to be analysed, considering the worse scenario. Thus, the higher values of hardness, conductivity and various chemical elements eventually present should be evaluated. Even though bacterial analysis was not performed, the potential presence of bacteria will be considered.

Water analysis performed in February 2024:

- pH: 7.6
- Conductivity: 4120 $\mu\text{s}/\text{cm}$
- Turbidity: limpid
- TH: 198.0 °F
- TAC: 18.2 °F
- Chloride: 269.8 mg/l



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Qualité des produits & matières



Le 05 Février 2024

Suivi de la qualité du forage

Après un prélèvement établi au niveau du l'unité pâte, on a constaté:

(nouveau forage pâte) A 09H00	Ph	7,60
	Conductivité	4120 μs
	Turbidité	Limpide
	TH	198,0 °F
	TA	00 °F
	TAC	18,2 °F
	Chlorure	38,0 °F (269,80 mg/L)

Observation :

-L'eau du nouveau forage est **très dure** et trop **chargée**.

Fig. 1.2 Water analysis performed in February 2024, supplied by the customer

Water analysis performed in September 2024:

- pH: 6.9
- Conductivity: 3610 $\mu\text{s}/\text{cm}$
- Turbidity: limpid
- TH: 200 °F
- TAC: 14 °F
- Chlorine: 260.0 mg/l
- Sulphate: 2187 mg/l

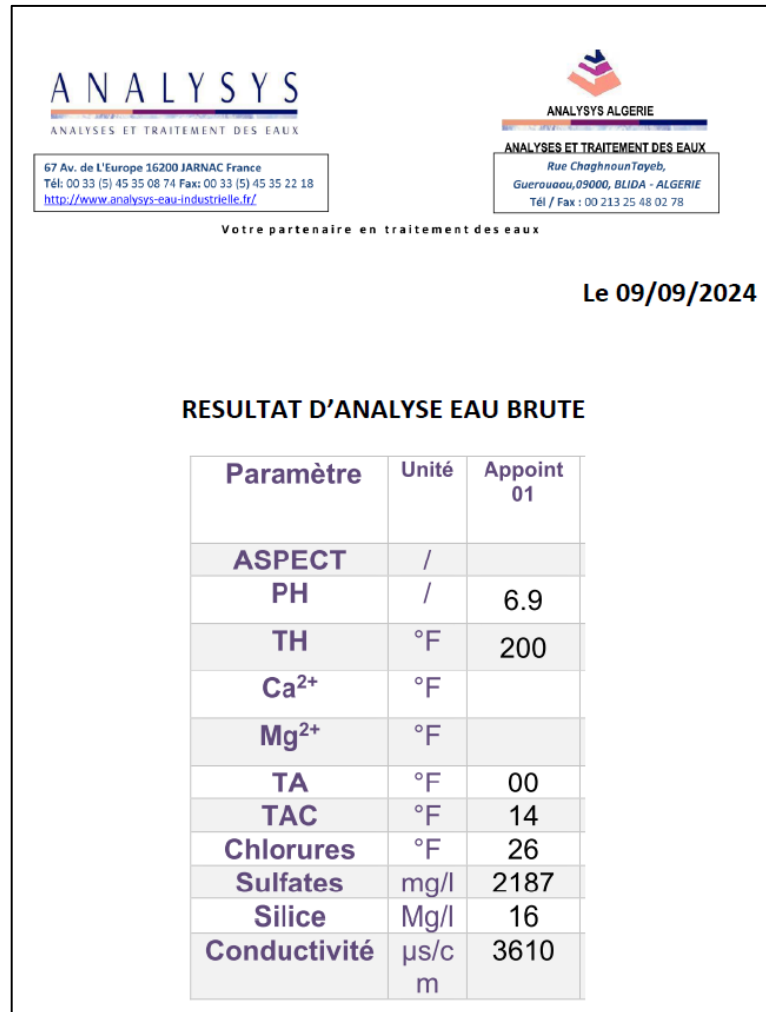


Fig. 1.3 Water analysis performed in September 2024, supplied by the customer

As previously announced, the worse data must be considered:

- pH: 6.9
- Conductivity: 4120 µs/cm
- Turbidity: limpid
- TH: 200 °F
- TAC: 18.2 °F
- Chlorine: 269.8 mg/l
- Sulphate: 2187 mg/l

The design of the water treatment plant starts from these parameters, which have to be compared with those reported in the Legislative Decree 18/2023, in order to determine which of them must to be regulated. Consequently, for each problem, different solutions are proposed, and the needed treatments are defined.

2. Design of water treatment plant

2.1 Water analysis and treatments

On the basis of the guidelines provided by the World Health Organization, the criteria for monitoring and safety of water intended for human consumption have been identified, indicating the limit values of quality parameters. In Italy, the reference legislation is the Legislative Decree 18/2023, which has repealed the Legislative Decree 31/2001 by updating the discipline on potable waters, reviewing the parameters and values of health relevance to the greatest protection of citizens and establishing the hygiene requirements for materials and chemical reagents that come into contact with the potable waters. In detail, the Legislative Decree 18/2023 provides restrictions on 53 parameters, divided as follows:

- microbiological parameters (5 for waters sold in containers or bottles);
- 28 chemical parameters, unwanted and toxic elements, for which restrictive limits of concentration in water are indicated;
- 21 indicators parameters, for which recommended values should not be overcome;
- parameters of radioactivity.

In the tables below, the values of inorganic and organic pollutants or microorganisms are reported, with their respective limits.

Microbiological Parameters:

Tab. 2.1 Microbiological Parameters reported in the Legislative Decree 18/2023 ^[4]

PARAMETER	VALUE (number/100 ml)
Escherichia coli (E. coli)	0
Enterococchi	0

Chemical Parameters:

Tab. 2.2 Chemical Parameters reported in the Legislative Decree 18/2023 ^[4]

PARAMETER	VALUE	UNIT OF MEASURE
Acrylamide	0.1	µg/l

Antimony	5.0	µg/l
Arsenic	10	mg/l
Benzene	1.0	µg/l
Benzo(a)pyrene	0.01	µg/l
Boron	1.0	mg/l
Bromate	10	µg/l
Cadmium	5.0	µg/l
Chromium	50	µg/l
Copper	1	mg/l
Cyanide	50	µg/l
1,2 - dichloroethane	3.0	µg/l
Epiciohydrin	0.1	µg/l
Fluoride	1.5	mg/l
Lead	10	µg/l
Mercury	1.0	µg/l
Nickel	20	µg/l
Nitrate (NO₃)	50	mg/l
Nitrate (NO₂)	0.5	mg/l
Pesticides	0.1	µg/l
Total pesticides	0.5	µg/l
Polycyclic aromatic hydrocarbons	0.1	µg/l
Selenium	10	µg/l
Tetrachloroethylene	10	µg/l
Total Trihalomethanes	30	µg/l

Indicator Parameters:

Tab. 2.3 Indicator Parameters reported in the Legislative Decree 18/2023 ^[4]

PARAMETER	VALUE	UNIT OF MEASURE
Aluminum	200	µg/l
Ammonium	0.5	mg/l

Chloride	250	mg/l
Color	Acceptable for the consumer and without abnormal variations	
Conductivity	2500	μS/cm a 20° C
Hydrogen ion concentration	6.5-9.5	Unità pH
Iron	200	μg/l
Manganese	50	μg/l
Odor	Acceptable for the consumer and without abnormal variations	
Oxidability	5.0	mg/l O ₂
Sulphate	250	mg/l
Sodium	200	mg/l
Taste	Acceptable for the consumer and without abnormal variations	
Colony count at 22°C	Without abnormal variations	
Coliform bacteria at 37°C	0	
TOC	Without abnormal variations	
Turbidity	Acceptable for the consumer and without abnormal variations	
Hardness		
Dry residue at 180°C		
Residual disinfectant	The lower limit is valid for water subjected to	

	softening or desalination treatments	
--	---	--

Consequently, it is possible to identify the water parameters that, exceeding the imposed limits, require a specific treatment.

- Hardness: 200 °F, should be reduced to avoid problems of scale, incrustations and corrosion, resulting in lower efficiency of the system;
- Conductivity: 4120 $\mu\text{s}/\text{cm}$, should be reduced to avoid high quantity of dissolved solids, and consequently hardness and scale problems;
- Iron: not reported, anyway it must be considered. The value must be below 200 $\mu\text{g}/\text{l}$;
- Chlorine: 269.8 mg/l, the value must be below 250 $\mu\text{g}/\text{l}$;
- Sulphate: 2187 mg/l, the value must be below 250 $\mu\text{g}/\text{l}$;

In the case of deep well water, several factors such as pH, temperature, turbidity, colour, odour, and microbiological aspect are easily satisfied, and eventual treatment processes are simplified because the origin and quality of water, which maintains its characteristics over the time.

In the water that comes from deep well sources, are commonly found excessive concentrations of Fe, Mn and very high hardness, due to the presence of high quantities of Ca and Mg, which can be removed through softening treatments.

In this specific case, the plant will be placed in Algeria thus, depending on the season, temperature and weather events, the water could be subjected to changes in microbiological, chemical and indicator parameters. For these reasons, during the design of the pre-treatment and treatment systems, environmental effects must be taken into account. ^[4]

2.2 Block Flow Diagram

In order to better understand the final structure of the water treatment system, the block flow diagram is reported below. As we will see, two stage reverse osmosis system is necessary to obtain ultra-pure water suitable for the uses.

Since the feed water presents various problems (mentioned before), appropriate solutions will be proposed, considering both mechanical and economic reasons.

In the following chapters, each block will be treated in a specific way.

It's important to underline that the design of the entire plant starts from the design of the single reverse osmosis systems and proceeds backwards.

Consequently, the feed water flowrate depends on the permeate at the exit of the first reverse osmosis plant, which depends on the flowrate required at the inlet of the second reverse osmosis system and from the outlets for the two uses requested by the customer.



3. Pre-treatment system

The water entering into the system, coming from a deep well, may contain sand, clay and/or colloidal substances, which must be removed before any treatment, in order to safeguard the plumping system, constituted by valves, pressure switches, taps, and boiler. In the case that water contains sand or solid particles in small quantities, cartridge filters should be used. If the turbidity is due to clay, silt and/or colloidal substances, filtration with multilayer quartz sand filters of different grain sizes is required, being able to retain large quantities of impurities.

The diagram below shows the pre-treatment system for this specific case, constituted by:

- Sand filter, for treating turbidity
- Chlorine dosage, for treating bacteria
- First storage tank, to collect water
- Booster set, to increase the pressure of water at the outlet of the storage tank
- Mars filter, for treating iron and manganese
- Venus filter, for treating chlorine
- Second storage tank, to collect water

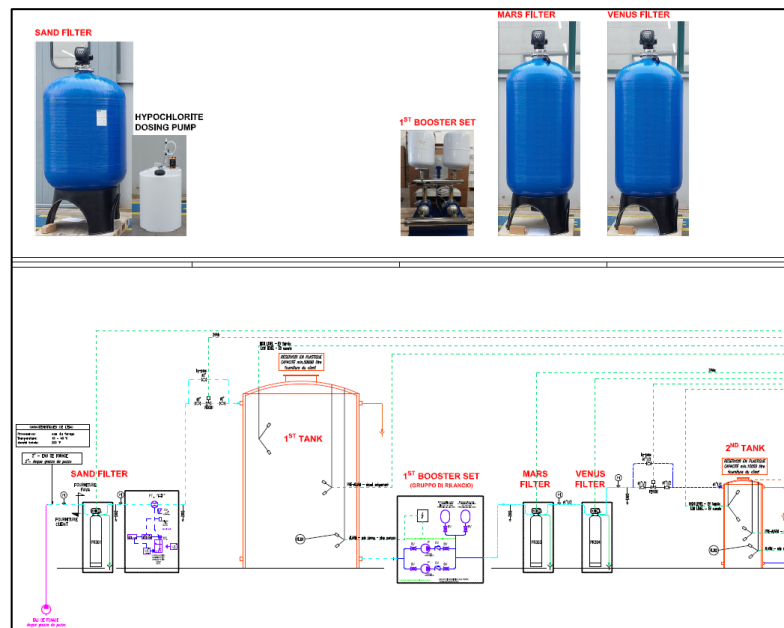


Fig. 3.1 P&I of the pre-treatment system

3.1 Coarse filtration

The total suspended solids (TSS) are constituted by inorganic and organic materials such as sediments, silt, sand, bacteria, plankton and algae. Organic particles from decomposing materials can contribute to increase the concentration of TSS, as the decomposition process of higher algae, plants and animals allows small organic particles to break off and enter the water as suspended solids. Chemical precipitates are also considered a form of suspended solids.

The total solids (TS) are the sum of total suspended solids (TSS) and total dissolved solids (TDS) in the water.

The suspended solids are mostly generated by natural phenomena: organic materials such as algae are naturally present in the ocean, while inorganic materials are put into suspension due to storm water runoff, erosion or resuspension due to seasonal changes in the natural water flow. Some of these suspended solids sediments on the seabed, where heavier particles, such as gravel and sand, often tend to settle when they enter an area of low or no water flow. The remaining particles that do not settle because they are too small and light, are called colloidal or non-divisible solids. Typically, these particles are less than 2 microns.

Total suspended solids (TSS) is a significant factor to evaluate the water clarity because the higher the concentration of solids in the water, the less clear will be the water.

3.1.1 Turbidity

Turbidity and clarity of water are visual properties, based on scattering and attenuation of light. In particular, turbidity is determined by the amount of light scattered by particles, so measurements can be affected by coloured dissolved organic matter, which can cause artificially low turbidity reading, as it absorbs light rather than scattering it.

Water clarity is closely related to sunlight penetration and it is usually determined by human observation. Since suspended particles can originate from soil erosion,

human waste or algae proliferation, the clarity of water is generally considered an indicator of healthy water.

Pollutants such as dissolved metals and pathogens can attach to suspended particles and be carried into water as potential pollution, increasing turbidity. Contaminants include bacteria, protozoa, nitrates and phosphorous, pesticides, mercury and lead. Many of them, especially heavy metals, can be harmful and toxic. [5]

The total suspended solids are quantified in milligrams of solids per litre of water [mg/l]. the most accurate method for determining TSS is filtering and weight a water sample, evaporated in a thermostated oven at 105°C.

The total solids contents given by:

$$Total\ Solids\ [\frac{mg}{l}] = \frac{(M1 - M0) * 1000}{V\ sample}$$

Where:

M_1 = mass [mg] of the capsule and residue after drying;

M_0 = mass [mg] of the empty capsule;

V_{sample} = volume [l] of sample subjected to analysis

Turbidity is usually measured with a turbidity meter and it is quantified in units called nephelometric turbidity units (NTU). In this case, the instrument measures the light scattered by a sample placed at ninety degrees angle with respect to the incident light.

3.1.2 Cartridge filters

Coarse filtration of sediments, clays and/or colloidal substances is usually obtained through the use of filter cartridges, specific for each use, consisting of a tubular filtering net, usually in polyester, and characterized by a double open end. They allow a uniform flow of water and limited pressure losses. They are produced without glue and sealants, by over moulding the rigid structural support on the net.

The washable filter cartridge offers an excellent quality-price ratio, flow rate up to 4000 l/h and nominal filtration of 50 microns, allowing an elevated flowrate keeping low pressure drop. Furthermore, the gasket present combats the problem of bacterial proliferation. Washing the filter septum can restore conditions comparable to those of the new cartridge, with a duration of up to 24 months and maintenance every 3 months, demonstrating greater longevity and resistance over time.

Alternatively, there are cartridges with a plated stainless steel mesh structure, supported by a central polypropylene core that guarantees a high filtration surface. These cartridges have an average life of 3 to 5 years, with maintenance every 3 months, but cannot be used in case of microbiologically impure water or water of unknown quality.

Generally, the cartridges are placed in special filter containers, which offer excellent performance in terms of safety and installation.



Fig. 3.2 Cartridge filters^[1]

3.2 Fine Filtration

Elements such as impurities, fine sands, or elements like Iron and Manganese can be removed through finer and more accurate filtration, in order to avoid negative effects like rust formation, corrosion and scale, with consequent pipes damage, pressure losses and higher energy consumption, resulting in higher costs and lower performance.

The problems related to the presence of iron, calcium and manganese are listed below, with their relative solutions.

3.2.1 Iron, Calcium and Manganese

Iron residues in pipes can result from the oxidation of iron naturally presents in the soil: when rainwater or groundwater passes through the soil, it comes in contact with iron, causing its oxidation, forming layers of rust. Iron pipes can be susceptible to corrosion, especially if they are not properly maintained. Additionally, the presence of iron residues can negatively affect the quality of drinking water: high levels of iron cause unpleasant taste and smell. Furthermore, excess iron can interact with other chemicals present in the water, forming insoluble compounds that enhance turbidity.

Excesses of Calcium and Manganese can occur due to various factors, including the geological composition of the soil and the presence of mineral deposits in the underground water sources. These minerals can accumulate over time, leading to the formation of lime scale residues.

Calcium is an essential mineral for human health however, when it is present in larger quantity in water, it leads to the formation of lime scale residues.

On the other hand, Manganese is found naturally in soils and rocks, but high concentration of this element can negatively affect the human health and contribute to the formation of dark stains and deposits.

Clarifying filters are used to filtrate water and remove turbidity caused by different elements. ^[6]

3.2.2 Clarifying filter

Clarifying filters are characterized by a column containing a permanent multilayer filtering bed, that allows the removal of all suspended substances that cause turbidity, such as silt, mud, colloids. The filtering bed is made of non-toxic materials, suitable for contact with water intended for human consumption., in

particular sand or grit of monocrystalline spherical quartz of alluvial origin with high silica content, selected for civil and industrial use.

The following image shows a general type of filter constituted by a plug with transformer, a control valve, a diffuser tube, the filtering bed containing the treating material and the tank.

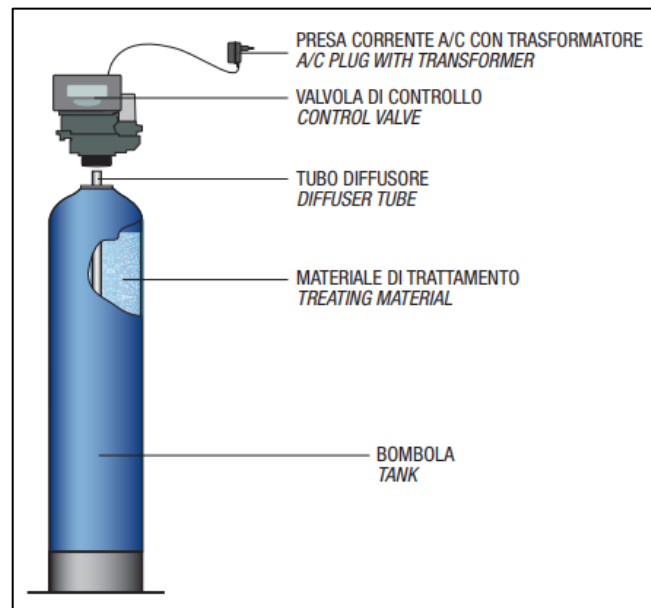


Fig. 3.3 Configuration of a generic mass filter

The process consists in the passage of water through various layers of selected quartzite or other inert material, with different grain size. This filtering bed is contained into a tank, usually made of fiberglass, coated steel or stainless steel.

During the normal flow, water passes through the filtering bed from the top to the bottom, and substances gradually retained on the first upper layer of sand increase the efficiency of the subsequent layers. Obviously, the pressure drops on the filter bed increase continuously as the filtration proceeds. When the pressure drops reach the maximum acceptable value (generally 0.9 bar), it is necessary to clean the filter, performing the regeneration of the filtering bed.

In order to eliminate the retained turbidity and restore the efficiency of the filter, it is sufficient to periodically carry out a backwash of the filtering bed.

The regeneration process consists on backwashing the filtering bed by passing water through the filter, from the bottom to the top, in the opposite direction to

ordinary filtration. In this way, the previously filtered substances are dragged and conveyed to the drain, preventing from further depositions which would otherwise obstruct the passage. The regeneration can be controlled manually or automatically, at pre-set time intervals or based on the pressure drop detected by a differential pressure gauge.

Often the backwash phase is followed by a short co-current washing phase in order to clean the lower layers of the filter bed. This process consists of the passage of water from the top to the bottom and finally to the drain. Usually, this phase is not foreseen when the backwash is performed with the filtered water.

The higher efficiency of the filtration process is obtained when the suspended solids are in flocculated form, therefore it may be necessary to add a suitable chemical conditioner, called flocculant, upstream of the sand filter.

The effectiveness of the filtering action depends mainly on two factors:

- Speed of water crossing through the filter: the slower the flow of water through the filter, the better the filtering action. The speed of water is given by the ratio between the water flowrate, expressed in $[m^3/h]$ and the filter surface, expressed in $[m^2]$. The most suitable filtration speed will be identified for each single case, but generally it is suggested to not exceed 20 m/h.
- Height of the bed layer: the higher the bed, the longer the time needed to cross the filter and the greater the efficiency of the process. ^[7]

Quartz sand exists in five types of different grain sizes:

- 0.4 mm - 0.8 mm
- 0.8 mm - 1.2 mm
- 1.2 mm – 2.0 mm
- 2.0 mm – 3.0 mm
- 3.0 mm – 5.0 mm

The filtering bed of the clarifying filter is generally characterized by three different grain size:

- The first layer is characterized by finer grains, 0.8 – 1.2 mm
- The second layer is characterized by medium grains, 1.0 – 2.0 mm
- The third layer is characterized by larger grains, 2.0 – 3.0 mm

In this way, the sediments will be immediately blocked and they will settle on the most superficial layer of the filter mass, facilitating the washing and backwashing operations and reducing the pressure drops.

For sizing the most appropriate sand filter, it's important to analyse the properties of the quartz grit that characterize the filtering bed:

- Apparent density: 1500 [g/l]
- Layer height: 450 - 750 [mm]
- Filtering speed: 8 - 12 [m/h]
- Backwash speed: 30 – 42 [m/h]

The technical datasheet of the quartz grit is reported below.

Ion exchange resins and filtering media

2024-497

Filter Sand and Gravel

- REF. RA049, RA050, RA051, RA052 and RA053;
- Filter sand and gravel shape of alluvium origin, uncrushed;
- High contents of silica, selected for specific use in water filtration for potable and industrial application;
- Hardness 7° Mohs,

Ref	Description	Fam.	Subfa	Disp.	Stock
RA049	QUARTZ SAND 0,4 - 0,8 BAG 25 KG	65	310	OK	
RA050	QUARTZ SAND 0,8 - 1,2 BAG 25 KG	65	310	OK	
RA051	QUARTZ SAND 1 - 2 BAG 25 KG	65	310	OK	
RA052	QUARTZ SAND 2 - 3 BAG 25 KG	65	310	OK	
RA053	QUARTZ SAND 3 - 5 BAG 25 KG	65	310	OK	

Ref	Description	SIZE (mm)
RA049	QUARTZ SAND 0,4 - 0,8 BAG 25 KG	0,4 - 0,8
RA050	QUARTZ SAND 0,8 - 1,2 BAG 25 KG	0,8 - 1,2
RA051	QUARTZ SAND 1 - 2 BAG 25 KG	1,0 - 2,0
RA052	QUARTZ SAND 2 - 3 BAG 25 KG	2,0 - 3,0
RA053	QUARTZ SAND 3 - 5 BAG 25 KG	3,0 - 5,0

Physical properties	
Colour	white
Specific gravity (g/l)	2650
Bulk density (g/l)	1500
SiO ₂ content	> 96 %
Humidity	0,3 % max
Melting point	1700 g/c
pH	8

Operating conditions	
Bed depth (mm) (sand filter)	450 - 750
Service flow rate (m ³ /h m ²)	8 - 12
Backwash flow rate (m ³ /h m ²)	30 - 42
Backwash bed expansion (%)	5 - 10

Box: WxLxH	Box: Q/ty	Box: Weight	Pallet: WxLxH	Pallet: Q/ty	Pallet: Weight

Certificates	Manufacturer	Sectors
STANDARD EN 12904		Domestic, Commercial, Industrial

Fig. 3.4 Technical datasheet of the quartz grit

There are two possible operating modes:

- **Timer:** the wash control valve has a timed electronic programmer that automatically starts the wash at a time programmed by the user. The device allows you to program both the time and the frequency for washing, from a minimum of 1 wash every 12 hours up to a maximum of 1 wash every 99 days. Alternatively, it is possible to program the wash on fixed days of the week always at pre-set time.
- **Volume:** the washing control valve is equipped with a flow sensor and a turbine counter, to determine the volume of treated water. This version starts the washing at the time set on a day chosen by the electronics based on actual water consumption. The appliance allows the washing to be programmed in the two following ways:
 - **Time-volume:** after reaching the set volume, at the set time;
 - **Pure volume:** immediately after reaching the set volume.

The filter is typically installed as shown in the figure below. The working pressure must be higher than 2 bar and lower than 6 bar. The maximum operating temperature is 50°C.

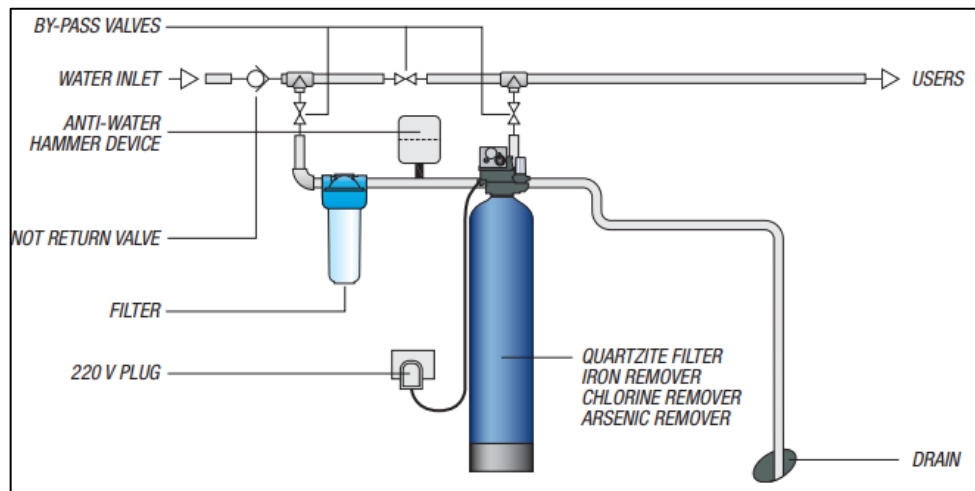


Fig. 3.5 Typical installation of a mass filter

Before starting with the sizing of the clarifying filter, the feed flowrate has to be calculated, starting from the sizing of the reverse osmosis system.

The requested flowrates are the following:

- 3 m³/h of osmotic water for the steam generator, the permeate at the outlet of the second reverse osmosis system;
- 1.7 m³/h of water for dough;
- 3 m³/h of water for cooker washing, batch system.

At the outlet of the second reverse osmosis system, 3 m³/h of osmotic water are needed. Considering the recovery equal to 75%, 7 m³/h will be necessary at the inlet of that system. Opting for a recirculation of 3 m³/h, the final water flowrate is 4 m³/h.

Now, considering the obtained 4 m³/h of water needed at the inlet of the second reverse osmosis process, and 1.7 m³/h intended for the dough and water flowrate of 0,4 m³/h for washing the cooker, the permeate of the first reverse osmosis system must be approximately around 6.12 m³/h. Defining a recovery of 50%, the inlet water must be approximately 12 m³/h

Considering the speed filtration equal to 20 m/h, and the inlet flowrate of 12 m³/h, the required cylinder cross section is:

$$A = \frac{12 \frac{m^3}{h}}{20 \frac{m}{h}} = 0.6 m^2$$

Consequently, the diameter of the cylinder is:

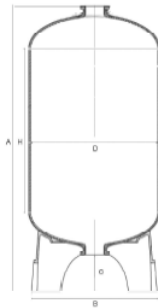
$$d = \left(\frac{4A}{\pi} \right)^{0.5} = 0.92 m$$

Therefore, the suitable tank is 36''x72'', characterized by 1036 litres in volume and 1195 mm in height. Now it is necessary to verify if the height of the filtering bed is compatible with the height of the tank, assuming that the filtering mass should occupy around 2/3 of the total volume of the tank. Since the height of the filtering layer is between 450 mm and 750 mm, the chosen tank results to be suitable for the use.

The technical datasheet of the tank is reported below.



MWG Industrial Pressure Vessels With Flanged Top&Bottom Openings



- Made in China;
- Composite pressure vessels PE liner reinforced with fiberglass and epoxy resin;
- For industrial and potable water treatment systems;
- European 2014/68/EU Directive compliant for pressure equipment (PED);
- Max operating pressure 10 bar;
- Max operating temperature 50°C;
- Top and bottom 6" flange connection;
- Cycle test 100,000 times from 0 to 10,5 bar;
- Burst test to 4 times max operating pressure; Blue colour;
- Warranty 10 years;
- Pressure vessels 30" and bigger are shipped with vacuum breaker;
- **Note:** vacuum breaker and flexible connection mounting are highly recommended,

Ref.	Description	Fam.	Subfa m.	Disp. Stock	
BMWG18068MB	MWG PRESSURE VESSEL 18X68 6" + 6" BLUE	44	422	OK	
BMWG21066MB	MWG PRESSURE VESSEL 21X66 6" + 6" BLUE	44	422	OK	
BMWG24075MB	MWG PRESSURE VESSEL 24X75 6" + 6" BLUE	44	422	OK	
BMWG30072MB	MWG PRESSURE VESSEL 30X72 6" + 6" BLUE	44	422	OK	
BMWG36072MB	MWG PRESSURE VESSEL 36X72 6" + 6" BLUE	44	422	OK	
BMWG42063PB	MWG PRESSURE VESSEL 42X63 6" + 6" BLUE	44	422	OK	
BMWG42072MB	MWG PRESSURE VESSEL 42X72 6" + 6" BLUE	44	422	NO	
BMWG42072PB	MWG PRESSURE VESSEL 42X72 6" + 6" BLUE	44	422	OK	
BMWG48072MB	MWG PRESSURE VESSEL 48X72 6" + 6" BLUE	44	422	NO	
BMWG48072PB	MWG PRESSURE VESSEL 48X72 6" + 6" BLUE	44	422	OK	
BMWG63067MB	MWG PRESSURE VESSEL 63X67 6" + 6" BLUE	44	422	NO	
BMWG63067PB	MWG PRESSURE VESSEL 63X67 6" + 6" BLUE	44	422	OK	
BMWG63086MB	MWG PRESSURE VESSEL 63X86 6" + 6" BLUE	44	422	NO	
BMWG63086PB	MWG PRESSURE VESSEL 63X86 6" + 6" BLUE	44	422	OK	

Ref.	Volume (litres)	External D (mm)	A (mm)	B (mm)	C (mm)	H (mm)	Connection (inch)
BMWG18068MB	264	469	2120 ± 25	480	250	1451	6"
BMWG21066MB	322	544	2010 ± 25	554	260	1254	6"
BMWG24075MB	460	617	2180 ± 25	650	265	1404	6"
BMWG30072MB	716	767	2240 ± 25	815	265	1260	6"
BMWG36072MB	1036	920	2270 ± 25	920	275	1195	6"
BMWG42063PB	1224	1085	2145 ± 25	1060	365	955	6"
BMWG42072MB	1425	1085	2285 ± 25	1060	270	1185	6"
BMWG42072PB	1425	1085	2375 ± 25	1060	365	1185	6"
BMWG48072MB	1746	1220	2270 ± 25	1230	260	1110	6"
BMWG48072PB	1746	1220	2365 ± 25	1230	365	1110	6"
BMWG63067MB	2623	1620	2050 ± 25	1620	265	660	6"
BMWG63067PB	2623	1620	2120 ± 25	1590	330	660	6"
BMWG63086MB	3417	1620	2480 ± 25	1620	265	1100	6"
BMWG63086PB	3296	1620	2465 ± 25	1590	330	1100	6"

Certificates	Manufacturer	Sectors
DM174-2004 ACS KTW CE, EAC	MWG	Industrial

Fig. 3.6 Technical datasheet of MWG industrial pressure vessels with flanges top and bottom openings

Knowing that the tank should be filled for 75% of its entire volume, the volume of filtering mass required is:

$$\text{Liters of quartz grit} = 1036 \text{ liters} \times \frac{2}{3} = 690.67 \text{ liters}$$

In order to calculate the amount of filtering mass expressed in kilograms, the apparent density has to be considered which, in the case of quartz grit, is 1.5 kg/l:

$$\text{Kilograms of Quartz grit} = 690.67 \text{ liters} \times 1.5 \frac{\text{kg}}{\text{l}} = 1036 \text{ kg}$$

Each bag of filtering material contains 25 kg of quartz grit, thus around 42 bags are necessary, divided into three different grain sizes:

- 14 bags of quartz grid of 0.8 – 1.2 mm
- 14 bags of quartz grid of 1.0 – 2.0 mm
- 14 bags of quartz grid of 2.0 – 3.0 mm

Finally, the most appropriate valve can be determined, considering the following parameters:

- Valve operating flowrate
- Required backwash flowrate
- Size of the tank

Thus, it is necessary to calculate the backwash flowrate, knowing the cylinder cross-section, 0.6 m^2 , and the backwash speed of the quartz grit, which is recommended to maintain between 30 m/h and 42 m/h. For simplicity, 30 m/h has been chosen. So the backwash flowrate is:

$$\text{Backwash flowrate} = 0.6 \text{ m}^2 \times 30 \frac{\text{m}}{\text{h}} = 18 \frac{\text{m}^3}{\text{h}}$$

A valve is considered suitable if it is able to ensure a maximum flowrate higher than or equal to the backwash flow rate of $18 \text{ m}^3/\text{h}$.

The selected valve for this use is named WS2CI, characterized by an inlet, for the entering of water to be treated, the outlet, for the exit of the treated water, and the drain, through which the waste water is expelled.

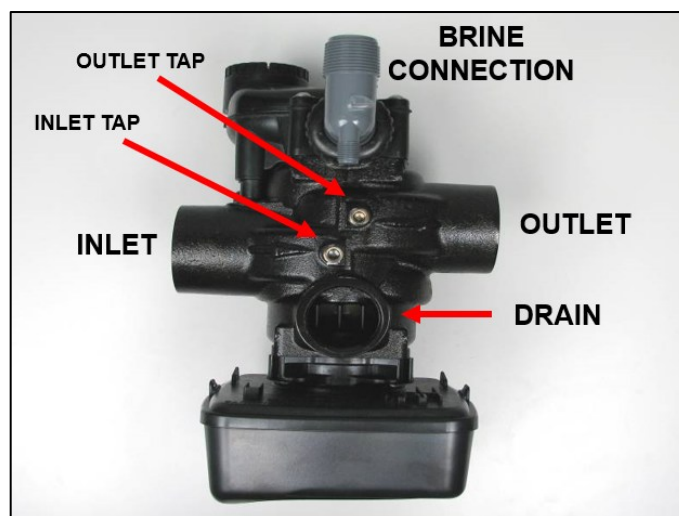


Fig. 3.7 Typical valve configuration

In fact, as indicated in the technical datasheet reported below, it has a maximum flowrate of 18.2 m³/h, and it is suitable for the application of cylinders with dimensions between 12" and 36", usable for both filtration and softening. The regeneration stage is controlled by time and volume.

The following images represent the cycle positions of the control valve regeneration.

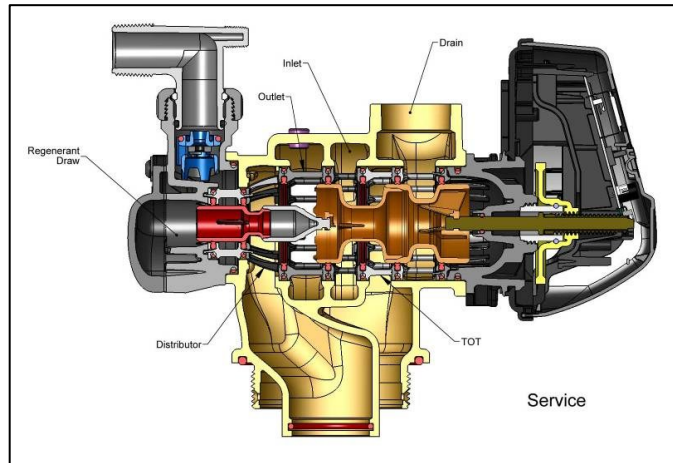


Fig. 3.8 control valve regeneration: service position

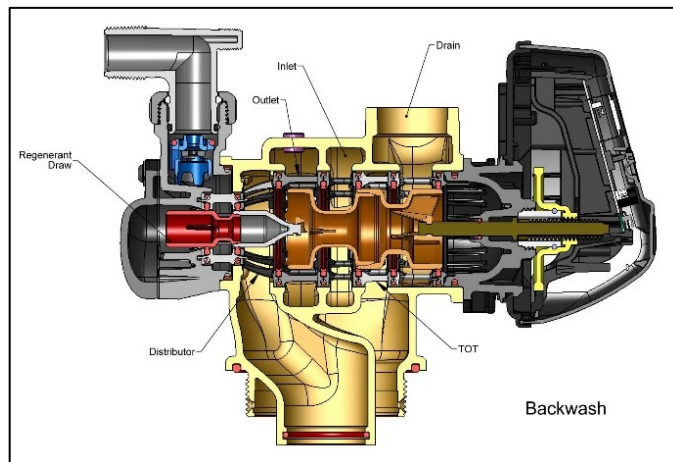


Fig. 3.9 control valve regeneration: backwash position

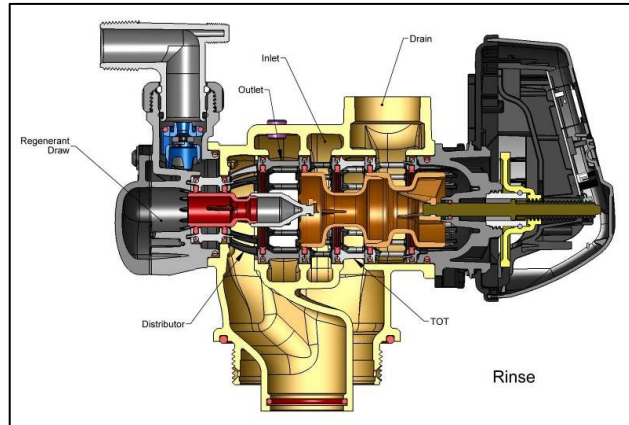


Fig. 3.10 control valve regeneration: rinse position

The operating parameters are fully programmable in order to optimize the system. Up to 9 phases per regenerative cycle can be set and the hardness is programmable both in ppm and °F.

All operating data and service history are saved in a non-volatile memory and they can be recalled at any time in case of system analysis.

The technical datasheet of the chosen valve is shown below.



WS2CI

WATER SPECIALIST CONTROL VALVE




Certified to NSF/ANSI/CAN 61 and NSF/ANSI/CAN 372.

- 2" Top mount control valve suited for commercial/Industrial applications
- Epoxy coated lead free brass valve body
- Economical stainless steel optional meter assembly
- Service flow rate of 435 lpm (26.1 m³/h) (115 gpm), backwash 303 lpm (18.2 m³/h) (80 gpm)
- Solid state microprocessor with easy access front panel settings
- Front panel display for time of day, days until next regeneration, volume remaining and current flow rate.
- Four methods to initiate regeneration; meter immediate, meter delayed, time clock delayed or pressure differential
- Program in ppm, French degrees, German degrees, or cubic meters
- Fully programmable regeneration cycle sequence (maximum 9)
- Programmable regeneration cycle times
- Days override feature; 1-28 days available
- Coin Cell Lithium battery back-up with an 24 hour carry over
- Level VI 15-volt output DC power supply provides safe and easy installation
- Pre or Post treated water regenerant refill
- 24 Hour Clock
- Reliable and proven DC drive
- One piece expanding seal spacer stack assembly
- Linearly reciprocating piston operation



Optional 2" Meter

Fig. 3.11 Technical datasheet of the WS2CI valve

Water Specialist 2" CI Control Specifications

Inlet/Outlet (1)	2" Female BSPT or NPT
Cycles	Up to 9
Valve Material	Lead free brass
Regeneration	Downflow
CONTROL VALVE FLOW RATES	
Service @ 1 bar/15 psi drop	435 lpm (26.1 m ³ /h) (115 gpm)
Backwash @ 1.7 bar/25 psi drop.....	303 lpm (18.2 m ³ /h) (80 gpm)
Cv Service	29.7
Cv Backwash	16.0
OPERATING PRESSURES	
Minimum/Maximum	1.4 - 8.6 bar (20 psi - 125 psi)
OPERATING TEMPERATURES	
Minimum/Maximum	4° - 43° C (40° - 110° F)
METER SPECIFICATIONS	
Accuracy	± 5%
Flow Rate Range.....	5.7 - 568 lpm (1.5 - 150 gpm)
Volume Range	0.02 - 5,700 m ³
Totalizer	1 - 99,999 m ³ (264 - 26,417,000 gallons)
DIMENSIONS & WEIGHT	
Distributor Pilot	
Valve bodies with 2" Female BSPT Inlet & Outlet.....	50mm OD
Valve bodies with 2" Female NPT Inlet & Outlet.....	1.90" OD (1.5" NPS)
Drain Line Connection	1.5" Female NPT
Brine Line Adapters Included.....	1" Male NPT elbow, ¾" x 1" solvent weld elbow and ½" OD Poly Tube Compression
Mounting Base.....	4" - 8 UN
Height From Top Of Tank.....	216 mm (8.5")
Shipping Weight With Meter	13 Kg (29 lbs.)
ELECTRICAL SPECIFICATIONS	
POWER SUPPLY	
U.S. International	
Supply Voltage	100VAC to 120VAC ... 200VAC to 240VAC
Supply Frequency	50/60 Hz ... 50/60 Hz
Output Voltage	15VDC ... 15VDC
Output Current.....	500 mA ... 500 mA
TANK APPLICATIONS	
Water Softener	12" - 48" diameter
Water Filter (2).....	12" - 36" diameter
CYCLES OF OPERATION	
Choose up to nine regeneration cycles, in any order, with a wide range of available values:	
Cycle	Range of values
Backwash	1 - 120 minutes
Rinse.....	1 - 120 minutes
Pause (service).....	1 - 480 minutes
Brine (co-current).....	1 - 180 minutes
Refill (softener).....	0.1 - 99.0 minutes
Refill (filter)	0.1 - 99.0 minutes

Fig. 3.12 Technical datasheet of the WS2CI valve

The final projected Sand filter is illustrated in the image below.



Fig. 3.13 Sand filter

3.2.3 Iron Removal filter

The water used for domestic and industrial purposes, coming from aqueducts or independent supply, can present several problems, including the excessive presence of iron and manganese. Their presence gives the water a yellow-reddish colour and an unpleasant taste, causing deposits that lead to gradual occlusion of the pipes and it is often the principal cause of corrosion in the systems. According to the current legislative decree, water intended for drinking must not exceed the following limits:

- For iron, the limiting value is 200 µg/l;
- For manganese, the limiting value is 50 µg/l;

Iron can be present in water in dissolved form or as precipitate in suspension.

The removal of suspended iron, normally consisting of ferric hydroxide, does not have particular consequences. It can be done by means of normal mechanical

filtration using mechanical filters and/or sand filters. If iron is dissolved in water, in the form of ferrous ion, the removal involves the oxidation to ferric ion and subsequent precipitation. Therefore, after obtaining the suspended form, mechanical filtration is adopted.

From a chemical point of view, dissolved iron in the form of Fe^{2+} must be transformed by oxidation into Fe^{3+} . The pH of water to be treated must have a value higher than the neutrality, as any acidic environment may hinder the precipitation of ferric ion.

There are several iron removal methods:

- If the iron concentration is low, around 0,5-1 ppm, and water $\text{pH} < 7,5$, it is possible to oxidize and precipitate the dissolved iron by blowing air into the water inside a tank before proceeding with filtration. The effectiveness of this method, valid only in very favourable conditions, can be increased by adding an oxidizing agent to the water, such as sodium hypochlorite, then leaving an adequate contact time to complete the oxidation reaction;
- If the water pH is neutral and the iron concentration is greater than 1 ppm, it is preferable to proceed with a catalytic oxidation together with filtration.

In general, filtration is achieved by passing water through a special filtering bed: iron removal filters are characterized by a column containing a filtering bed of manganese dioxide (pyrolusite) of excellent quality and purity, obtained by washing, drying and sifting the mineral selected for the specific catalytic activity. Pyrolusite acts as a catalyst for the oxidation of iron and manganese present in water, but due to its high cost, it is used mixed from 20% to 50% in volume with sand of appropriate grain size. Manganese dioxide is characterized by hardness between 3° and 5° Mohs and the filtering medium is available in 25 kg bags. To ensure the efficiency of filtration, it is sufficient to periodically backwash the filtering bed, done automatically by the head controlled by a volumetric electronic control.

Pyrolusite does not necessarily require regeneration with KMnO_4 , but a chlorine dosage is sufficient, which can be continuous or during backwashing.

The technical datasheet of the Manganese dioxide is reported below.

Ion exchange resins and filtering media

2024-494

Pyrolusite

- PYROLUSITE is manganese dioxide (MnO_2) of very good quality and pureness obtained by washing, drying and screening of mineral selected for the specific catalytic activity;
- Used as catalyst for the reduction of iron and manganese dissolved in the water, by sand filters, mixed 20+50 % with sand 0,4+0,8 / 0,7+1,2 mm;
- Does not require a compulsory regeneration with KMnO_4 , but you can do a continuous chlorination or a chlorination during the backwash;
- Hardness $3^\circ + 5^\circ$ Mohs;
- Available in 25 kg bags.

Ref	Description	Fam.	Subfam.	Disp. Stock	
RA069	MWG PYROLUSITE (MANGANESE DIOXIDE) BAG 25 KG	65	315	OK	

Physical Properties	
Colour	brown
Bulk density (g/l)	2000
Effective size (mm)	0,35 + 0,85
Mn (%)	80

Operating Conditions	
Composition	Mixed 20+50 % with sand 0,4+0,8 / 0,7+1,2 mm
Suggested filtration speed (m/h)	≤ 10
Max backwash speed (m3/h m2)	25
Backwash expansion at 25 m/h (%)	25
Min contact time (min)	6
Range pH	6,5 + 8,5

Box: WxLxH	Box: Q,ty	Box: Weight	Pallet: WxLxH	Pallet: Q,ty	Pallet: Weight

Certificates	Manufacturer	Sectors
STANDARD EN 13752	MWG	Domestic, Commercial, Industrial

Fig. 3.14 Technical datasheet of Pyrolusite

Operating mode:

- **Timed:** the wash control valve has a timed electronic programmer that automatically starts the wash at a time programmed by the user. The appliance allows you to program the time at which the wash takes place and the frequency of the wash, from a minimum of 1 wash every 12 hours up to a maximum of 1 wash every 99 days. Alternatively, it is possible to program the wash on fixed days of the week, always at a pre-set time.
- **Volume:** the washing control valve is equipped with a flow sensor and a turbine counter, to determine the volume of treated water. This version starts the washing at the set time on a day chosen by the electronics based on actual water consumption. The device allows the washing to be programmed in the following ways:
 - Time-volume: after reaching the set volume, at the set time;
 - Pure volume: immediately after reaching the set volume.

In order to proceed with the sizing of iron removal filter, the operating parameters to take into consideration are:

- Optimal filtration speed: < 10 m/h;
- Maximum filtration speed: 13 m/h;
- Maximum pressure drop allowed through the filter: 0.9 bar;
- Backwash water flow rate corresponding to a speed of approximately 25-30 m/h.

In general, the iron removal filter can be integrated with other treatments, such as preliminary oxidation of the iron by means of hypochlorite, which also involves disinfection of water.

In order to correctly choose the most appropriate process, it is fundamental to distinguish between the presence of suspended iron, which mainly influences the sizing of the filtration system, and the dissolved iron, which mainly determines the type of the oxidation method.

Considering the filtration speed equal to 10 m/h, and the inlet flowrate equal to 12 m³/h, the required cross section of the tank is:

$$A = \frac{12 \frac{m^3}{h}}{10 \frac{m}{h}} = 1.2 m^2$$

Consequently, the tank diameter will be:

$$d = \left(\frac{4A}{\pi} \right)^{0.5} = 1.24 m$$

The most suitable tank is 48" x 72", with a volume of 1746 liters, and height of 1110 mm.

The technical datasheet of the selected tank is reported below.

Pressure vessels and accessories

2024-326

MWG Industrial Pressure Vessels With Flanged Top&Bottom Openings

- Made in China;
- Composite pressure vessels PE liner reinforced with fiberglass and epoxy resin;
- For industrial and potable water treatment systems;
- European 2014/68/EU directive compliant for pressure equipment (PED);
- Max operating pressure 10 bar;
- Max operating temperature 50°C;
- Top and bottom 6" flange connection;
- Cycle test 100.000 times from 0 to 10,5 bar;
- Burst test to 4 times max operating pressure; Blue colour;
- Warranty 10 years;
- Pressure vessels 30" and bigger are shipped with vacuum breaker;
- **Note:** vacuum breaker and flexible connection mounting are highly recommended;

Ref.	Description	Fam.	Subfam.	Disp. Stock
BMWG1806MB	MWG PRESSURE VESSEL 18X68 6" + 6" BLUE	44	422	OK
BMWG2106MB	MWG PRESSURE VESSEL 21X86 6" + 6" BLUE	44	422	OK
BMWG24075MB	MWG PRESSURE VESSEL 24X75 6" + 6" BLUE	44	422	OK
BMWG30072MB	MWG PRESSURE VESSEL 30X72 6" + 6" BLUE	44	422	OK
BMWG36072MB	MWG PRESSURE VESSEL 36X72 6" + 6" BLUE	44	422	OK
BMWG42063PB	MWG PRESSURE VESSEL 42X63 6" + 6" BLUE	44	422	OK
BMWG42072MB	MWG PRESSURE VESSEL 42X72 6" + 6" BLUE	44	422	NO
BMWG42072PB	MWG PRESSURE VESSEL 42X72 6" + 6" BLUE	44	422	OK
BMWG48072MB	MWG PRESSURE VESSEL 48X72 6" + 6" BLUE	44	422	NO
BMWG48072PB	MWG PRESSURE VESSEL 48X72 6" + 6" BLUE	44	422	OK
BMWG63067MB	MWG PRESSURE VESSEL 63X67 6" + 6" BLUE	44	422	NO
BMWG63067PB	MWG PRESSURE VESSEL 63X67 6" + 6" BLUE	44	422	OK
BMWG63086MB	MWG PRESSURE VESSEL 63X86 6" + 6" BLUE	44	422	NO
BMWG63086PB	MWG PRESSURE VESSEL 63X86 6" + 6" BLUE	44	422	OK

Ref.	Volume (litres)	External D (mm)	A (mm)	B (mm)	C (mm)	H (mm)	Connection (inch)
BMWG1806MB	264	469	2120 ± 25	480	250	1451	6"
BMWG2106MB	322	544	2010 ± 25	554	260	1254	6"
BMWG24075MB	460	617	2180 ± 25	650	265	1404	6"
BMWG30072MB	716	767	2240 ± 25	815	265	1260	6"
BMWG36072MB	1036	920	2270 ± 25	920	275	1195	6"
BMWG42063PB	1224	1085	2145 ± 25	1060	365	955	6"
BMWG42072MB	1425	1085	2285 ± 25	1060	270	1185	6"
BMWG42072PB	1425	1085	2375 ± 25	1060	365	1185	6"
BMWG48072MB	1746	1220	2270 ± 25	1230	260	1110	6"
BMWG48072PB	1746	1220	2365 ± 25	1230	365	1110	6"
BMWG63067MB	2623	1620	2050 ± 25	1620	265	660	6"
BMWG63067PB	2623	1620	2120 ± 25	1590	330	660	6"
BMWG63086MB	3417	1620	2480 ± 25	1620	265	1100	6"
BMWG63086PB	3296	1620	2465 ± 25	1590	330	1100	6"

Certificates	Manufacturer	Sectors
DM174-2004 ACS KTW CE, EAC	MWG	Industrial

Fig. 3.15 Technical datasheet of the MWG industrial pressure vessels with flanged top and bottom openings

Now it is possible to choose the most suitable valve for the required use, considering the following parameters:

- Valve operating flowrate;
- Backwash flowrate required;
- Size of the tank

Thus, knowing that the section of the tank is 1.2 m^2 and the backwash speed of the Pyrolusite is 25 m/h , the backwash flowrate of the filtering mass can be calculated:

$$\text{Backwash flowrate} = 1.2 \text{ m}^2 * 25 \frac{\text{m}}{\text{h}} = 30 \frac{\text{m}^3}{\text{h}}$$

Since the backwash flowrate results to be too high, requiring the use of a much expensive valve, smaller cylinders can be taken into consideration.

1) Tank 36" x 72":

- Tank diameter: $d = 0.92 \text{ m} \rightarrow$ Tank radius: $r = 0.46 \text{ m}$
- Tank section $A = \pi r^2 = 0.66 \text{ m}^2$

- Filtration speed: $v = \frac{\text{Feed flowrate}}{\text{Tank cross section}} = \frac{12 \frac{\text{m}^3}{\text{h}}}{0.66 \text{ m}^2} = 18 \frac{\text{m}^3}{\text{h}}$
- Backwash flowrate: $Q = \text{backwash speed} * \text{tank section} = 25 \frac{\text{m}}{\text{h}} * 0.66 \text{ m}^2 = 16.5 \frac{\text{m}^3}{\text{h}}$

Since the recommended filtration speed is 10 m/h, this cylinder results to be too small for the required service. Therefore, another option will be considered.

2) Tank 42" x 63":

- Tank diameter: $d = 1.1 \text{ m} \rightarrow$ Tank radius: $r = 0.54 \text{ m}$
- Tank section: $A = \pi r^2 = 0.92 \text{ m}^2$
- Filtration speed: $v = \frac{\text{Feed flowrate}}{\text{Tank cross section}} = \frac{12 \frac{\text{m}^3}{\text{h}}}{0.92 \text{ m}^2} = 13 \frac{\text{m}^3}{\text{h}}$
- Backwash flowrate: $Q = \text{Filtering speed} * \text{Tank cross section} = 25 \frac{\text{m}}{\text{h}} * 0.92 \text{ m}^2 = 23 \frac{\text{m}^3}{\text{h}}$

This tank results to be the most suitable for the requested use, thus the sizing of the filter can proceed.

The selected tank has the following characteristics:

- Tank volume: 1124 litres
- Tank height: 1085 millimetres

Knowing that it must be filled for 2/3 of its total volume, the required amount of filtering ass is:

$$\text{Liters of filtering mass} = \text{Tank volume} * \frac{2}{3} = 1124 \text{ litri} * \frac{2}{3} = 749 \text{ litri}$$

Since the Pyrolusite is very expensive, iron removal filters are generally characterized by a filtering mass constituted of 50% of Pyrolusite and 50% of quartz grit. Therefore, to calculate the amount [kg] of filtering mass, the apparent density of both the components has to be considered:

- Apparent density of Pyrolusite: 2 kg/l;
- Apparent density of quartz grit: 1.5 kg/l.

Thus, the amount of filtering mass required is:

$$\text{Kilograms of filtering mass} = \left[\frac{749}{2} * 2 \right] + \left[\frac{749}{2} * 1.5 \right] = 1124 \text{ kg}$$

Since each bags contains 25 kg of filtering mass, approximately 56 bags are necessary for this use.

The valve must be able to guarantee a maximum flowrate greater than or equal to the backwash flowrate of 23 m³/h. for this purpose, the solenoid valve used is WS2CI/QC.

In fact, as indicated in the technical datasheet, this valve has a maximum flowrate of 19.3 m³/h, and it is suitable for the application of tanks between 12" and 36", with regeneration starts by time and volume, usable for both filtration and softening. The operating parameters are completely programmable in order to optimize the system from every point of view. Up to 9 phases can be set for each regenerative cycle and the hardness can be programmed both in ppm and °F. All the operating data and the service history are stored in a non-volatile memory and can be recalled at any time for a system analysis.

The technical datasheet of the selected valve is reported below.



Fig. 3.16 Technical datasheet of WS2CI/QC valve.

Water Specialist 2" CI/QC Control Specifications

Inlet/Outlet (1)	2" Female BSPT or NPT
Cycles	Up to 9
Valve Material	Lead free brass
Regeneration	Downflow
CONTROL VALVE FLOW RATES	
Service @ 1 bar/15 psi drop	473 lpm (28.4 m ³ /h) (125 gpm)
Backwash @ 1.7 bar/25 psi drop	322 lpm (19.3 m ³ /h) (85 gpm)
Cv Service	32.3
Cv Backwash	17.0
OPERATING PRESSURES	
Minimum/Maximum	1.4 - 8.6 bar (20 psi - 125 psi)
OPERATING TEMPERATURES	
Minimum/Maximum	4° - 43° C (40° - 110° F)
METER SPECIFICATIONS	
Accuracy	± 5%
Flow Rate Range	5.7 - 568 lpm (1.5 - 150 gpm)
Volume Range	0.02 - 5,700 m ³
Totalizer	1 - 99,999 m ³ (264 - 26,417,000 gallons)
DIMENSIONS & WEIGHT	
Distributor Pilot	
Valve bodies with 2" Female BSPT Inlet & Outlet	63mm OD
Valve bodies with 2" Female NPT Inlet & Outlet	2.37" OD (2" NPS)
Drain Line Connection	1.5" Female NPT
Brine Line Adapters Included	1" Male NPT elbow, ¾" x 1" solvent weld elbow and ½" OD Poly Tube Compression
Mounting Base	4" - 8 UN, 6" Flange or Side Mount
Height From Top Of Tank with 4" - 8 UN QC Base	284.5mm (11.2")
Height From Top Of Tank with 6" Flange QC Base	287mm (11.3")
Shipping Weight With Meter	14 Kg (30 lbs.)
ELECTRICAL SPECIFICATIONS	
	POWER SUPPLY
	<u>U.S.</u> <u>International</u>
Supply Voltage	100VAC to 120VAC ... 200VAC to 240VAC
Supply Frequency	50/60 Hz ... 50/60 Hz
Output Voltage	15VDC ... 15VDC
Output Current	500 mA ... 500 mA
TANK APPLICATIONS	
Water Softener	12" - 48" diameter
Water Filter (2)	12" - 36" diameter
CYCLES OF OPERATION	
Choose up to nine regeneration cycles, in any order, with a wide range of available values:	
Cycle	Range of values
Backwash	1 - 120 minutes
Rinse	1 - 120 minutes
Pause (service)	1 - 480 minutes
Brine (co-current)	1 - 180 minutes
Refill (softener)	0.1 - 99.0 minutes
Refill (filter)	0.1 - 99.0 minutes

Fig. 3.17 Technical datasheet of WS2CI/QC valve

The valve WS2CI/QC has several cycle positions, but the most important are the following two:

- 1) Service: when the water, passing through the active carbons, is filtered. This is the normal water flow direction.

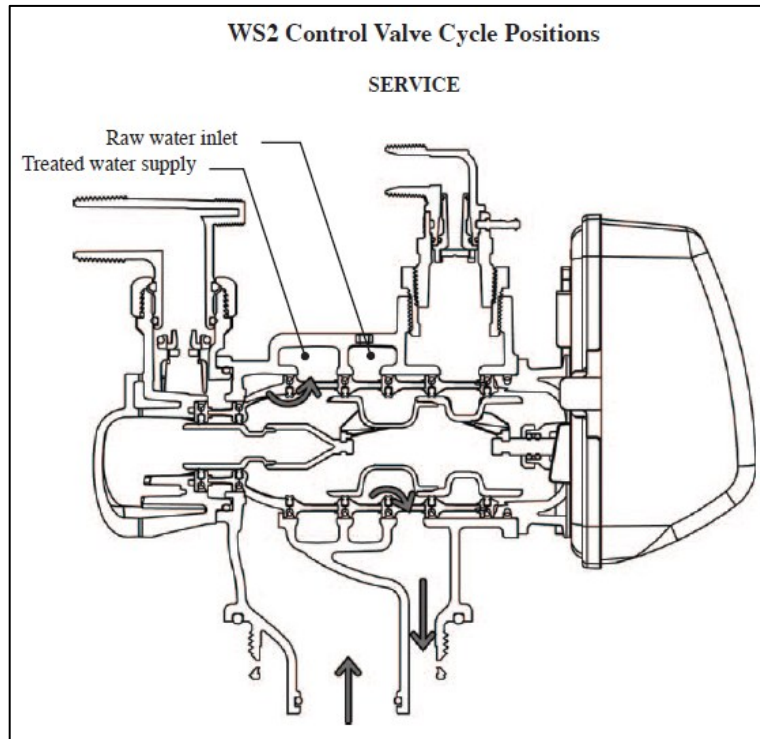


Fig. 3.18 WS2 Control valve cycle position - Service

- 2) Backwash: to ensure a good efficiency of the filter, is necessary to perform a counter-current rinsing of the filtering bed at regular intervals, to raise the filtering bed and delete preferential routes eventually formed.

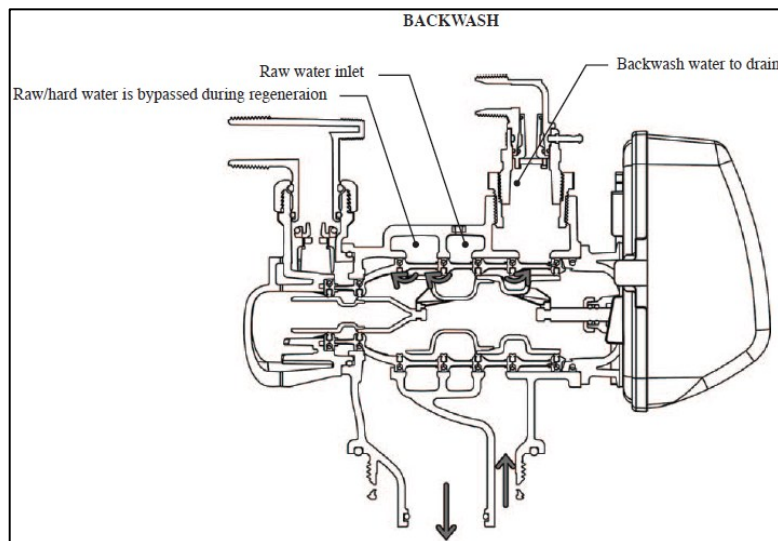


Fig. 3.19 WS2 Control valve cycle position - Service

The final projected Mars filter is illustrated in the image below.



Fig. 3.20 Mars filter

3.2.4 Dechlorinating filter

Dechlorinating filters are designed to remove chlorine, odour, flavour and organic pollutants present in well water, both for domestic and industrial use. All systems are equipped with an automatic backwash system to ensure the filter cleaning and an effective treatment over the long term. This operation is managed automatically, and it is based on time or volume of treated water. The filtering mass is constituted by activated carbon, non-toxic materials suitable for human consumption. Carbon of vegetal or mineral origin becomes “active” through an activation process, carried out in special ovens with high-temperature steam that causes the formation of tiny passages inside the carbon granules, called micropores, whose presence determines its activity. Each type of activated carbon is characterized by:

- Type of origin: vegetal or mineral;
- Granulometry [mm]
- Apparent density [g/l]
- Bet [m^2/g]
- Iodine index [mg/g]
- Ash content (%)

Activated carbons perform their function mainly based on three mechanisms of action:

- 1) Chemical action: catalytic action towards the reduction of some inorganic groups
- 2) Chemical-physical action: the main prerogative of activated carbons is the adsorption power and the ability to retain, in its porosity, particular types of molecules;
- 3) Physical action: ability of the bed of activated carbons to operate mechanical filtration, with similar or better results than those obtained with filtration on sand beds.

Activated carbon is effective also in promoting biological processes of degradation of organic pollutants, with a similar action to that occurs naturally with the infiltration of water into the soil.

In the water purification, active carbons are used for:

- Removal of chlorine, exploiting the catalytic effect that promotes the reduction of chlorine to chloride ion;
- Elimination of unpleasant odours and flavours, by absorbing the organic substances that give rise to them;
- Elimination of pollutants such as chlorinated solvents, insecticides, pesticides, detergents, by absorbing them;
- Filtration, exploiting their filtering action.

In general, it is better to carry out the least number of backwashes possible, in order to avoid mixing of bed, that would bring part of the potentially pollutes carbons to the lower areas. Porosity saturation due to adsorption is generally not removed by backwashing: saturated carbon can be reactivated by a special heat treatment.

However, this operation is economically interesting only with large quantities of carbon. The operating parameters for the use of activated carbons are variable depending on the purpose for which they are intended.

The bed layer height is normally maintained between 80 and 120 cm. in the case of dechlorination, a minimum contact time of two minutes is maintained. By increasing the contact time, it is possible to obtain a longer duration of the carbon together with a lower pressure drop. In fact, the greater the contact time, the higher the surface area of the bed and the lower the linear crossing speed.

In any case, given the same filtering bed composition, the effectiveness of pollutant removal increases as the water flowrate decreases.

In the specific case of dechlorinating filters, the duration of activated carbon in relation to chlorine treatment (reduction to chloride ion) is extremely high: the activated carbon is not selective in the removal of various substances that pass through it. It retains any organic substances that may be present in the treated water. This means that the carbon bed could become saturated due to the absorption of what was not the primary objective of the treatment, and release what had been retained, with a higher concentration than the entrance.

Since this exhaustion is neither predictable nor measurable with systems within the reach of any maintenance technician, it is absolutely necessary to avoid the use of activated carbon dechlorinating filters without adequate pre-treatments, such as sand filtration or chlorination.

The technical datasheet of the filtering material is reported below.

Ion exchange resins and filtering media

2024-495

Activated Carbon

- RA204 activated carbon is not suitable for treatment of water intended for human consumption;
- In granular form;
- Suitable for Chlorine, chemical oxidants, chlorinated compounds and organic contaminants dissolved in water;
- activated carbon require periodic backwashing to eliminate accumulated suspended matters and to regrade the filter bed;
- A good backwashing of the AC filter bed of the start-up is required;
- Mainly bituminous origin coal activated carbons are carefully selected, with a thermal activation process at strictly controlled temperature to obtain a large surface area and a mesoporous structure allowing the adsorption of high molecular weight organic compounds in particular hydrocarbons, atrazine, surfactants;
- Mainly vegetal (coconut base) activated carbons are suitable for applications that need good resistance to the attrition and mechanical shocks; they have a microporous structure allowing the adsorption of low molecular weight organic compounds in particular trichloroethylene, tetrachloroethylene;

Ref	Description	Fam.	Subfam.	Disp. Stock	
RA204	MWG BAG 25 KG CARB. CYLINDRICAL MIN. SC 45 (47 LT.ABOUT)	65	305	OK	
RA201	MWG BAG 25 KG CARB. MIN. GAC 830 M (52 LT.ABOUT)	65	305	OK	
RA202	MWG BAG 25 KG CARB. MIN. GAC 1240 M (52 LT. ABOUT)	65	305	OK	
RA206	MWG BAG 25 KG CARB. GAC 8X30 VEGETAL	65	305	OK	
RA208	MWG BAG 25 KG CARB. GAC 12X40 VEGETAL	65	305	OK	

Ref	Type	Origin	Size(mm)	Bulk density (g/l)	Bet. (m ² /g)	Iodine number (mg/g)	Ash content (%)
RA204	SC45 cylindrical	Mineral	4 x (6 ÷ 12)	590	700	750	15
RA201	GAC 8x30	Mineral	0,6 ÷ 2,4	480	1100	1000	12
RA202	GAC 12x40	Mineral	0,4 ÷ 1,7	480	1100	1000	12
RA206	GAC 8x30	Vegetal	0,6 ÷ 2,4	500	1250	1100	3
RA208	GAC 12x40	Vegetal	0,4 ÷ 1,7	500	1250	1100	3

Operating conditions		
Bed depth (mm) (dechlorination)		650 ÷ 750
Service flow rate (m ³ /h m ²) (dechlorination)		12 ÷ 15
Backwash flow rate (m ³ /h m ²)		24 ÷ 30
Backwash bed expansion (%)		30 ÷ 40

Box: WxLxH	Box: Q.ty	Box: Weight	Pallet: WxLxH	Pallet: Q.ty	Pallet: Weight

Certificates	Manufacturer	Sectors
STANDARD EN 12915-1:2004 (except RA204)	MWG	Commercial, Industrial

Fig. 3.21 Technical datasheet of activated carbon filtering media

The operating mode of the valve can be:

- **Timed:** the wash control valve has a timed electronic programmer that automatically starts the wash at a time programmed by the user. The appliance allows you to program the time at which the wash takes place and the frequency of the wash, from a minimum of 1 wash every 12 hours up to a maximum of 1 wash every 99 days. Alternatively, it is possible to program the wash on fixed days of the week, always at a pre-set time.
- **Volume:** the washing control vale is equipped with a flow sensor and a turbine counter, to determine the volume of treated water. This version starts the washing at the set time on a day chosen by the electronics based on actual water consumption. The device allows the washing to be programmed in the following ways:
 - Time-volume: after reaching the set volume, at the set time;
 - Pure volume: immediately after reaching the set volume.

Now, it is possible to proceed with the sizing of the tank.

Since the filtration speed recommended is between 12 m/h and 15 m/h, 15 m/h will be considered. The feed flowrate is 12 m³/h, so the required tank cross section is:

$$\text{Tank cross section} = \frac{\text{Feed flowrate}}{\text{filtration speed}} = \frac{12 \frac{\text{m}^3}{\text{h}}}{15 \frac{\text{m}}{\text{h}}} = 0.8 \text{ m}^2$$

Consequently, the tank diameter is:

$$d = \left(\frac{4A}{\pi} \right)^{0.5} = 1 \text{ m}$$

The most suitable tank is 42" x 72", characterized by a volume of 1425 litri, and height of 1085 mm. knowing that the tank should be filled for 2/3 of its total volume, the required amount of the filtering media is:

$$\text{Liters of active carbons} = 1425 \text{ liters} * \frac{2}{3} = 950 \text{ liters}$$

In order to calculate the amount of the filtering mass required expressed in kilograms, the apparent density has to be considered, which in the case of active carbons is 0.5 kg/l, thus:

$$\text{Kilograms of active carbons} = 950 \text{ liters} * 0.5 \frac{\text{kg}}{\text{liters}} = 475 \text{ kg}$$

Each filtering media bag can contain 25 kg of active carbons, so 19 bags will be necessary for the use. Usually, two types of active carbons are preferred:

- GAC 8x30, with granulometry between 0.6 mm and 2.4 mm and apparent density of 0.5 kg/l
- GAC 12x40, with granulometry between 0.4 mm and 1.7 mm and apparent density of 0.5 kg/l

At this point, the most suitable valve can be chosen, considering the following parameters:

- Valve operating flowrate
- Required backwash flowrate
- Size of the filtration tank

Then, it is necessary to calculate the backwash flowrate, knowing the tank cross section, 0.8 m^2 , and the backwash speed for the activated carbons, assumed 24 m/h . therefore, the backwash flowrate is:

$$\begin{aligned} \text{Backwash flowrate} &= \text{Tank cross section} * \text{Backwash speed} \\ &= 0.8 \text{ m}^2 * 24 \frac{\text{m}}{\text{h}} = 19.2 \frac{\text{m}^3}{\text{h}} \end{aligned}$$

Since the backwash flowrate results to be too high, an alternative sizing is proposed, based on the fact that activated carbons are more performing for higher filtration speed.

So, in this case a filtration speed of 18 m/h is assumed, and the resulting cross section of the tank will be:

$$\text{Tank cross section} = \frac{\text{Feed flowrate}}{\text{Filtration speed}} = \frac{12 \frac{\text{m}^3}{\text{h}}}{18 \frac{\text{m}}{\text{h}}} = 0.66 \text{ m}^2$$

Thus, the resulting diameter of the tank will be:

$$d = \left(\frac{4A}{\pi} \right)^{0.5} = 0.92 \text{ m}$$

Consequently, the more appropriate valve is $36'' \times 72''$. Considering the backwash speed of 24 m/h and the cross section of the tank 0.66 m^2 , the backwash flowrate will be:

$$\begin{aligned} \text{Backwash flowrate} &= \text{Backwash speed} * \text{Tank cross section} \\ &= 24 \frac{\text{m}}{\text{h}} * 0.66 \text{ m}^2 = 16 \frac{\text{m}^3}{\text{h}} \end{aligned}$$

The suitable valve must be able to guarantee a maximum flow rate greater than or equal to the backwash flowrate of $16 \text{ m}^3/\text{h}$. for this purpose, the selected valve is WS2CI.

In fact, as indicated in the technical datasheet, it has a maximum flowrate of $18.2 \text{ m}^3/\text{h}$, and it is suitable for application of tanks between $12''$ e $36''$, with regeneration start by time and volume, usable for both filtration and softening.

The operating parameters are completely programmable in order to optimize the system from every point of view. Up to 9 phases can be set for each regenerative cycle and the hardness can be programmed both in ppm and $^{\circ}\text{F}$. all the operating

data and the service history are stored in a non-volatile memory and can be recalled at any time for a system analysis.

The technical datasheet of the WS2CI valve is reported below.



WS2CI

**WATER
SPECIALIST
CONTROL
VALVE**



Certified to NSF/ANSI/CAN 61 and NSF/ANSI/CAN 372.



- 2" Top mount control valve suited for commercial/industrial applications
- Epoxy coated lead free brass valve body
- Economical stainless steel optional meter assembly
- Service flow rate of 435 lpm (26.1 m³/h) (115 gpm), backwash 303 lpm (18.2 m³/h) (80 gpm)
- Solid state microprocessor with easy access front panel settings
- Front panel display for time of day, days until next regeneration, volume remaining and current flow rate.
- Four methods to initiate regeneration; meter immediate, meter delayed, time clock delayed or pressure differential
- Program in ppm, French degrees, German degrees, or cubic meters
- Fully programmable regeneration cycle sequence (maximum 9)
- Programmable regeneration cycle times
- Days override feature; 1-28 days available
- Coin Cell Lithium battery back-up with an 24 hour carry over
- Level VI 15-volt output DC power supply provides safe and easy installation
- Pre or Post treated water regenerant refill
- 24 Hour Clock
- Reliable and proven DC drive
- One piece expanding seal spacer stack assembly
- Linearly reciprocating piston operation



Optional 2" Meter

Fig. 3.22 Technical datasheet of WS2CI valve

Water Specialist 2" CI Control Specifications

Inlet/Outlet (1)	2" Female BSPT or NPT
Cycles	Up to 9
Valve Material	Lead free brass
Regeneration	Downflow
CONTROL VALVE FLOW RATES	
Service @ 1 bar/15 psi drop	435 lpm (26.1 m ³ /h) (115 gpm)
Backwash @ 1.7 bar/25 psi drop	303 lpm (18.2 m ³ /h) (80 gpm)
Cv Service	29.7
Cv Backwash	16.0
OPERATING PRESSURES	
Minimum/Maximum	1.4 - 8.6 bar (20 psi - 125 psi)
OPERATING TEMPERATURES	
Minimum/Maximum	4° - 43° C (40° - 110° F)
METER SPECIFICATIONS	
Accuracy	± 5%
Flow Rate Range	5.7 - 568 lpm (1.5 - 150 gpm)
Volume Range	0.02 - 5,700 m ³
Totalizer	1 - 99,999 m ³ (264 - 26,417,000 gallons)
DIMENSIONS & WEIGHT	
Distributor Pilot	
Valve bodies with 2" Female BSPT Inlet & Outlet	50mm OD
Valve bodies with 2" Female NPT Inlet & Outlet	1.90" OD (1.5" NPS)
Drain Line Connection	1.5" Female NPT
Brine Line Adapters Included	1" Male NPT elbow, ¾" x 1" solvent weld elbow and ½" OD Poly Tube Compression
Mounting Base	4" - 8 UN
Height From Top Of Tank	216 mm (8.5")
Shipping Weight With Meter	13 Kg (29 lbs.)
ELECTRICAL SPECIFICATIONS	
	POWER SUPPLY
	U.S. International
Supply Voltage	100VAC to 120VAC 200VAC to 240VAC
Supply Frequency	50/60 Hz 50/60 Hz
Output Voltage	15VDC 15VDC
Output Current	500 mA 500 mA
TANK APPLICATIONS	
Water Softener	12" - 48" diameter
Water Filter (2)	12" - 36" diameter
CYCLES OF OPERATION	
Choose up to nine regeneration cycles, in any order, with a wide range of available values:	
Cycle	Range of values
Backwash	1 - 120 minutes
Rinse	1 - 120 minutes
Pause (service)	1 - 480 minutes
Brine (co-current)	1 - 180 minutes
Refill (softener)	0.1 - 99.0 minutes
Refill (filter)	0.1 - 99.0 minutes

Fig. 3.23 Technical datasheet of WS2CI valve

The final projected Mars filter is illustrated in the image below.



Fig. 3.24 Venus filter

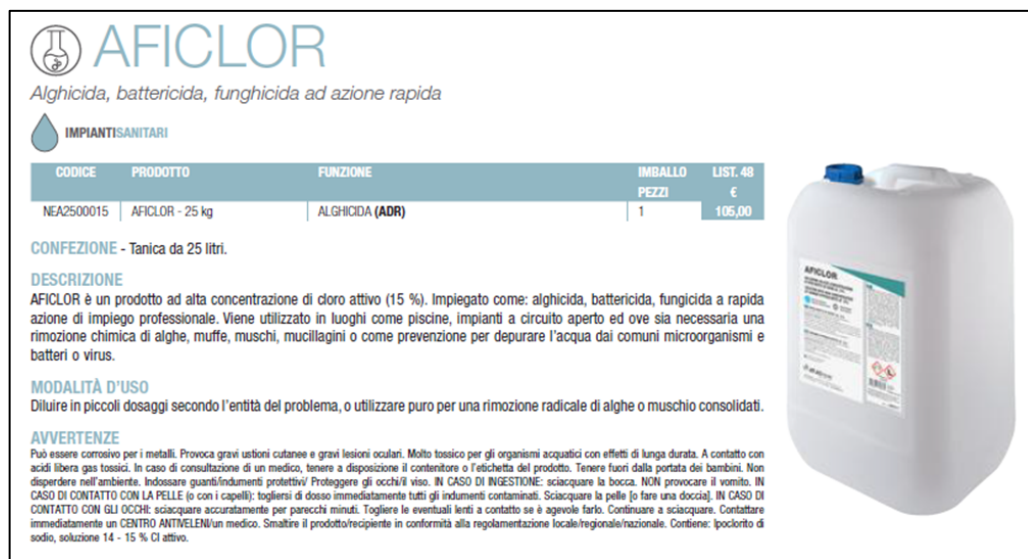
3.3 Sodium Hypochlorite Dosage

This dosage must be placed immediately after the sand filter and before the first storage tank. The purpose of this dosage is to disinfect water from bacteria and to lower the oxidability value of some components. In addition, the Sodium Hypochlorite dosage acts against the bacteria proliferation and removes iron and manganese.

It is added through a system constituted of:

- dosing pump
- container CNT PD 200 l KMSAMF (8 bar; 5.5 lph)
- flow sensor SEFLS
- pulse emitter water meter CATFI 50 (2"; 1 imp/l)
- injection valve 0,3 bar

The dosing pump is connected to the electrical panel of the first reverse osmosis system.



The image shows a technical datasheet for AFICLOR Sodium Hypochlorite. On the right is a photograph of a white plastic jerrycan with a blue cap and a label. The datasheet on the left includes the following information:

- Logo:** A flask icon with a chemical symbol.
- Brand Name:** AFICLOR
- Description:** Alghicida, battericida, fungicida ad azione rapida.
- Category:** IMPIANTISANITARI
- Table:**

CODICE	PRODOTTO	FUNZIONE	IMBALLO PEZZI	LIST. 48 €
NEA250015	AFICLOR - 25 kg	ALGHICIDA (ADR)	1	105,00

CONFEZIONE - Tanica da 25 litri.

DESCRIZIONE
AFICLOR è un prodotto ad alta concentrazione di cloro attivo (15 %). Impiegato come: alghicida, battericida, fungicida a rapida azione di impiego professionale. Viene utilizzato in luoghi come piscine, impianti a circuito aperto ed ove sia necessaria una rimozione chimica di alghe, muffe, muschi, mucillagini o come prevenzione per depurare l'acqua dai comuni microorganismi e batteri o virus.

MODALITÀ D'USO
Diluire in piccoli dosaggi secondo l'entità del problema, o utilizzare puro per una rimozione radicale di alghe o muschio consolidati.

AVVERTENZE
Può essere corrosivo per i metalli. Provoca gravi ustioni cutanee e gravi lesioni oculari. Molto tossico per gli organismi acquatici con effetti di lunga durata. A contatto con acidi libera gas tossici. In caso di consultazione di un medico, tenere a disposizione il contenitore o l'etichetta del prodotto. Tenere fuori dalla portata dei bambini. Non disperdere nell'ambiente. Indossare guanti/indumenti protettivi/Proteggere gli occhi/il viso. IN CASO DI INGESTIONE: sciacquare la bocca. NON provocare il vomito. IN CASO DI CONTATTO CON LA PELLE (o con i capelli): togliersi di dosso immediatamente tutti gli indumenti contaminati. Sciacquare la pelle [o fare una doccia]. IN CASO DI CONTATTO CON GLI OCCHI: sciacquare accuratamente per parecchi minuti. Togliere le eventuali lenti a contatto se è agevole farlo. Continuare a sciacquare. Contattare immediatamente un CENTRO ANTIVELENI/un medico. Smaltire il prodotto/recipiente in conformità alla regolamentazione locale/regionale/nazionale. Contiene: ipoclorito di sodio, soluzione 14 - 15 % Cl attivo.

Fig. 3.25 Technical datasheet of Sodium Hypochlorite

The quantity of chlorine to add on the water flux in order to disinfect from bacteria present depends on the amount of water to be treated. You should prepare a 5% sodium hypochlorite solution inside the container, using only demineralised water to dilute the product.

Taking into account the water analysis provided by the customer, it is recommended to dose 2 ppm of chlorine, because we need 1 ppm of chlorine for the removal of bacteria from the first tank, where we have a certain contact time, and 0.5-1 ppm of free chlorine before the Mars iron remover filter. This value must be measured after the initial storage tank.

In fact, this type of filter has Pyrolusite (MnO_2) as filtering media, which does not require a compulsory regeneration with KMnO_4 , but you can do a continuous chlorination or a chlorination during the backwash.

In addition, the quantity of dosed chlorine is adjustable depending on the water analysis measured instantaneously, so the customer should read the value continuously using the sample grip.

In order to add the chemical product into the water flux, the pressure at which the bactericide is subjected must be higher than the pressure of tubes, which is defined. As a consequence, the pump has to be set as a function of this pressure.

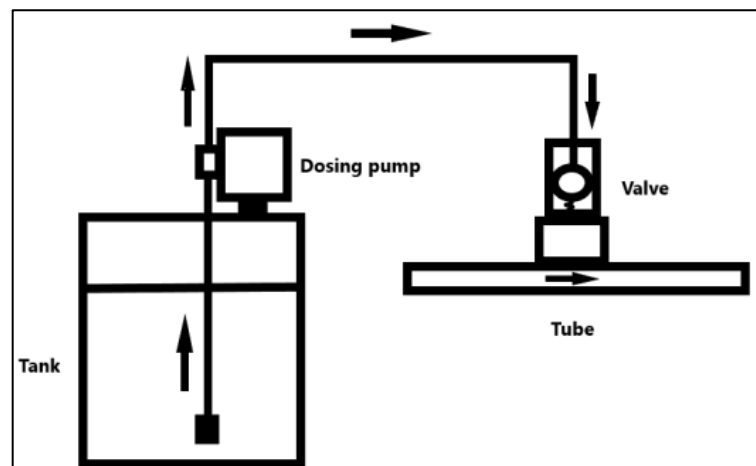


Fig. 3.26 Schematic representation of Sodium Hypochlorite dosage

In this type of systems, it is common to add an expansion vessel, a hydraulic component with the function of containing sudden variations in pressure in the circuit, avoiding sudden changes and water hammer, which otherwise would have absorbed by the system, with possible damage. Due to its construction logic, it can be simply called “lung”, the inflatable membrane that acts as an air chamber.

Furthermore, the expansion vessel can be open, putting the fluid in contact with the air, or closed, consisting on a rigid container divided into two chambers with

variable volume, one containing the circuit fluid and the other containing air or gas pre-charged to a certain pressure by means of a special valve. It requires periodic maintenance to verify the correct pressure inside the membrane and that no water has entered between the lung and the container. The seal of the inflation valve is also an element to be checked periodically. A drop in water pressure in the system is often caused by insufficient air pressure in the membrane or, worse, water infiltrations inside it. [8]



Fig. 3.27 Expansion vessel [9]

3.3.1 Dosing pump

The water coming from municipal supplies or from autonomous sources required for potable, sanitary or industrial use may present various issues such as microbial contamination, excess in acidity, alkalinity, hardness and/or presence of algae. In these cases, it is necessary a water treatment with specific chemical products using dosing pumps which deliver the chemical products with the required amount, perfectly measured and regulated. The installation of dosing pumps is very simple and normally arranged upstream the water treatment equipment or plants to be protected.

There is a wide range of dosing pumps, with constant or proportional dosing mode, making it possible to respond every kind of requirement in water treatment for house and industry, for small and large equipment and plants. All dosing pumps can be supplied stand alone or assembled on dedicated tanks. The dosing pumps are

manufactured using top quality materials to obtain the best performances and operate within the highest safety.

In our specific case we install dosing pump of series “KMS MF” made from glass-filled polypropylene, which provides suitable protection against the damaging effects of chemicals and the environment. It is a digital multifunction pump with seven different possible operating modes, stand-by and flow sensor input, alarm output and level control.

The pump working modes are:

- Constant: the pump doses at constant frequency in relation to the values of “SPH” (strokes per hour), “SPM” (strokes per minute) or “LPH” (litres per hour)
- Divide: the pulses supplied by a motor connected to the pump are divided by the value set during programming and determine the dosing interval
- Multiply: the pulses supplied by a motor connected to the pump are multiplied by the value set during programming and determine the dosing interval
- Ppm: the pulses supplied by a motor connected to the pump determine dosing based on the set ppm value. The concentration of product dosed, the quantity for each single stroke and the pulse/liter values of the connected meter must be set during programming.
- Perc: the pulses supplied by a meter connected to the pump determine dosing according to the set PERC value (%). The concentration of the product dosed, the quantity for each single stroke and the pulse/liter values of the connected meter must be set during programming.
- MLQ: the pulses supplied by a meter connected to the pump determine dosing according to the set MLQ (millilitres per quintal) value. The concentration of the product dosed, the quantity for each single stroke and the pulse/litre values of the connected meter must be set during programming.

- Batch: the pulse supplied by an external contact starts dosing the amount of product set during programming.
- Volt: the voltage supplied to the pump, by means of the input signal, determines proportional dosing based on the two minimum and maximum values that have been set for the strokes/minutes during programming.
- mA: the current supplied to the pump, by means of the input signal, determines proportional dosing based on the two minimum and maximum values that have been set for the strokes/minutes during programming.
- Timer: weekly working mode with customised dosing repetition of up to 16 programs per week.

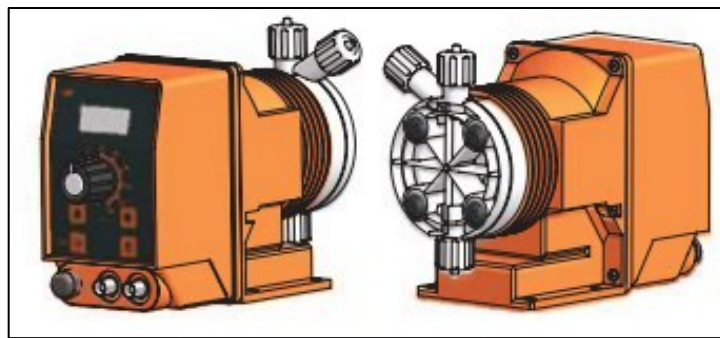


Fig. 3.28 Typical representation of a dosing pump

The 6 series of solenoid-driven dosing pumps are able to meet any dosing requirement and can be implemented in numerous sectors, in combination with control systems and accessories. The models vary by type of venting, ability to work with liquids of varying viscosities, LCD display, dosing system, materials, control parameters, inputs or types of function available. Each has versions with different flow rate (l/h) and working pressure (bar).

The different models of the series, correspond to various dosing parameters to be combined with the pH reading, while the R series pumps, ideal for use in systems such as car washes, as well as the AMS AC and T AC models, differ in their compressed air supply. Reliability and precision are guaranteed by the use of microprocessor technology, double ball valves and hydraulic parts in PVDF

(polyvinylidene fluoride). MF type solenoid-driven pumps provide an even higher level of control. The solenoid-driven dosing pumps are also customisable, with a choice of colours in addition to those offered as standard. The logo and graphics on the polycarbonate front of each pump can be customised to suit the customer.

In general, the K series of horizontally mounted solenoid-driven pumps are economical, reliable and very versatile. They are constant and/or proportional dosing with multifunction. The series includes an MF version with multifunctional software and a LPV version for viscous liquids. They are also available with automatic venting.



Fig. 3.29 Typical representation of KMS MF dosing pump

Technical and electrical specifications:

- Number of injections per minute: 0 – 180
- Maximum Suction hose height: 5 metres
- Toom temperature for operation: 0 – 45°C

The main two models of KMS pump are:

- 1) KMS MF: multifunctional series that allows to set different working modes, such as Constant, Divide, Multiply, ppm, perc, mlq, batch, volt, mA, Timer. In addition, you can:
 - set automatic re-priming, with a flow sensor installed
 - enable the lost strokes recovery system
 - set an upkeep dosing in case of system downtime

The pump is equipped with stand-by input, self-input (flow sensor), level input (level control) and alarm contact output. Pump dosing is determined by the number of pulses and the capacity per single injection. Single injection adjustment is linear only over values between 30% and 100%. The operating and control parameters are shown on an LCD display and managed via a keypad.

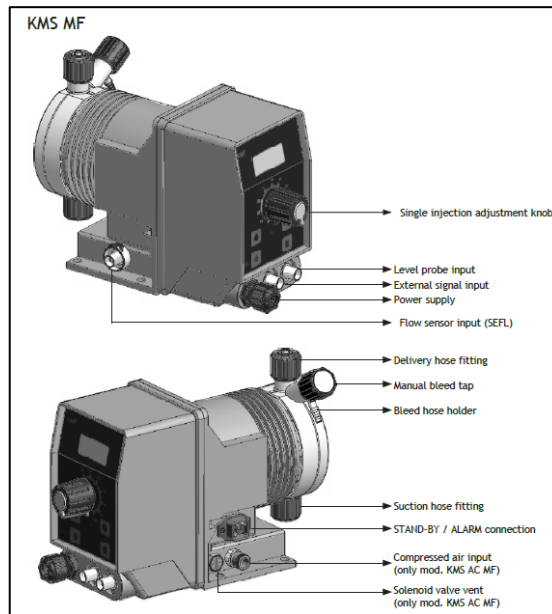


Fig. 3.30 Representation of several functionalities of KMS MF dosing pump

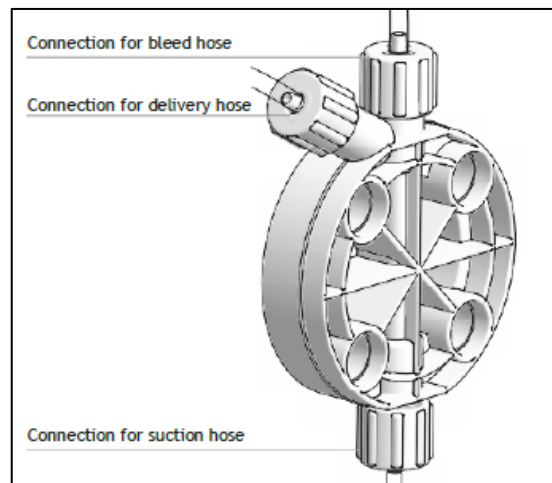


Fig. 3.31 Description of the self-purging pump body (KMSA MF pump)

- 2) KMSA MF: dosing pump with the self-purging pump body, necessary for dosing gas-generating chemicals such as hydrogen peroxide, ammonia, sodium hypochlorite at certain temperatures.

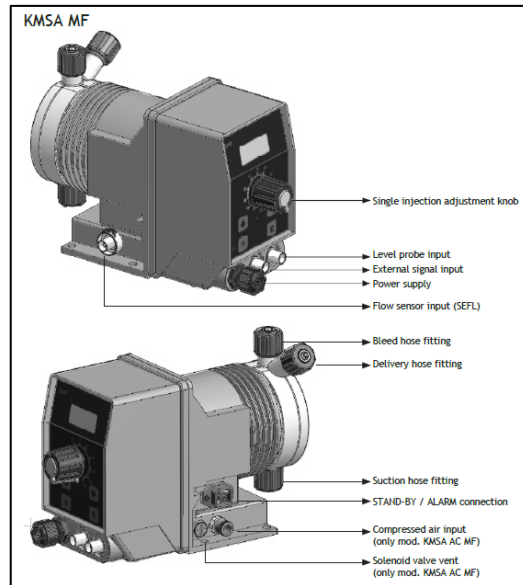


Fig. 3.32 Representation of several functionalities of KMSA MF dosing pump

The following image shows the tables with the data related to KMS MF and KMSA MF models.

INFORMATION											
KMS MF KMS MF LPV ¹	FLOW RATE				cc / pulse ²		Maximum pressure		imp/min	Hoses	Pump body
	min cc/h	max l/h	Min GPH	Max GPH	min	max	bar	PSI			
2001	0.03	1	0.000008	0.26	0.03	0.09	20	290	180	4 x 6	I
1802	0.06	2	0.000016	0.53	0.06	0.19	18	261	180	4 x 6	L
1504	0.11	4	0.000029	1.06	0.11	0.37	15	217	180	4 x 6	L
1005	0.14	5	0.000037	1.32	0.14	0.46	10	145	180	4 x 6	L
0808	0.22	8	0.000058	2.11	0.22	0.74	8	116	180	4 x 6	L
0510	0.28	10	0.000074	2.64	0.28	0.93	5	72	180	4 x 6	L
0501	0.03	1	0.000008	0.26	0.03	0.09	5	72	180	4 x 6	I
0301	0.03	1	0.000008	0.26	0.03	0.09	3	43.5	180	4 x 6	I
0218	0.50	18	0.00013	4.76	0.50	1.67	2	29	180	6 x 8	M

INFORMATION											
KMSA	FLOW RATE				cc / pulse ²		Maximum pressure		imp/min	Hoses	Pump body
	min cc/h	max l/h	Min GPH	Max GPH	min	max	bar	PSI			
1801	0.03	1	0.000008	0.26	0.03	0.09	18	261	180	4 x 6	LA
1503	0.08	3	0.000021	0.79	0.08	0.28	15	217	180	4 x 6	LA
103.5	0.10	3.5	0.000026	0.92	0.10	0.32	10	145	180	4 x 6	LA
100.5	0.02	0.5	0.01	0.13	0.02	0.05	10	145	180	4 x 6	JA
085.5	0.15	5.5	0.000040	1.45	0.15	0.51	8	116	180	4 x 6	LA
057.5	0.21	7.5	0.000055	1.98	0.21	0.69	5	72	180	4 x 6	LA
0213	0.37	13	0.000098	3.43	0.37	1.20	2	29	180	6 x 8	MA

¹ The indicated flow rates refer to measurement with water. Flow rates may vary depending on viscosity.

² cc per pulse: calculated with the mechanical flow rate adjustment knob set to 100%

Fig. 3.33 Technical datasheet of KMS MF and KMSA MF dosing pumps

All flows rate indications refer to measurements made with H₂O at 20 °C at the indicated back pressure. The dosing accuracy is +/- 2% at constant pressure of +/- 0.5 bar. Below the KMS MF and KMSA MF flow rate curves are reported.

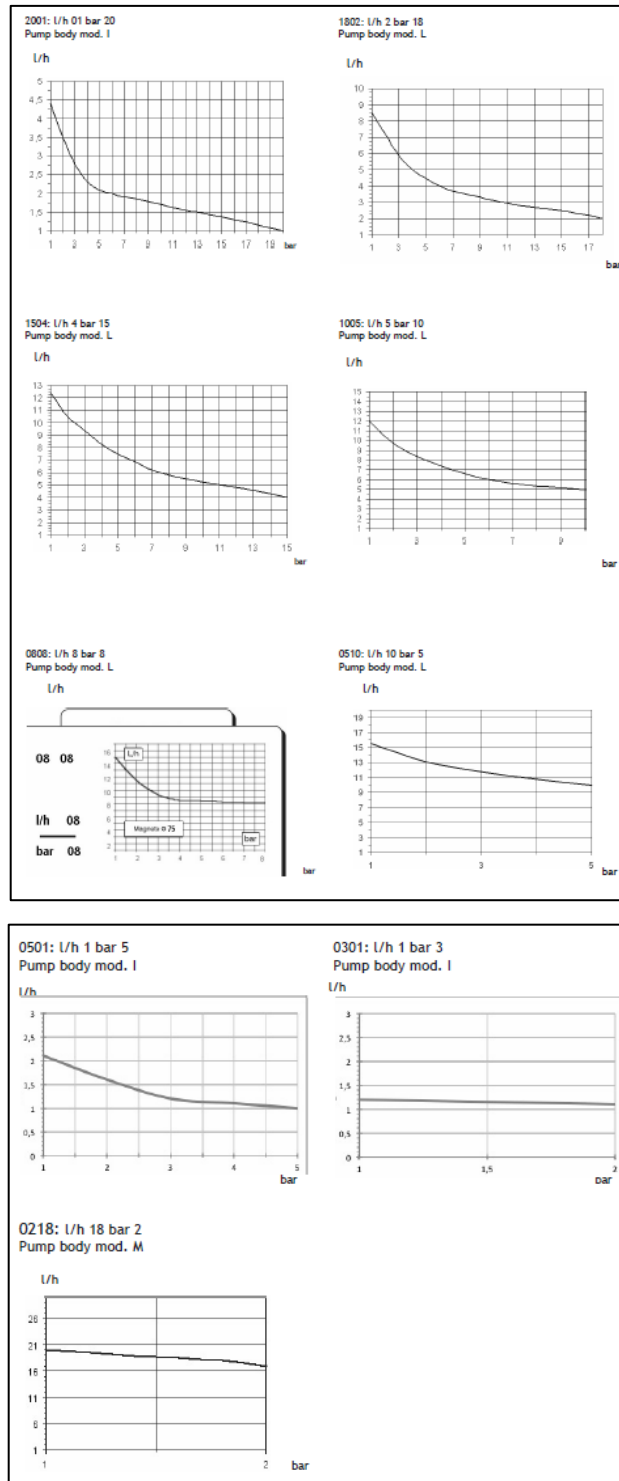


Fig. 3.34 Representation of KMSA MF flowrate curves

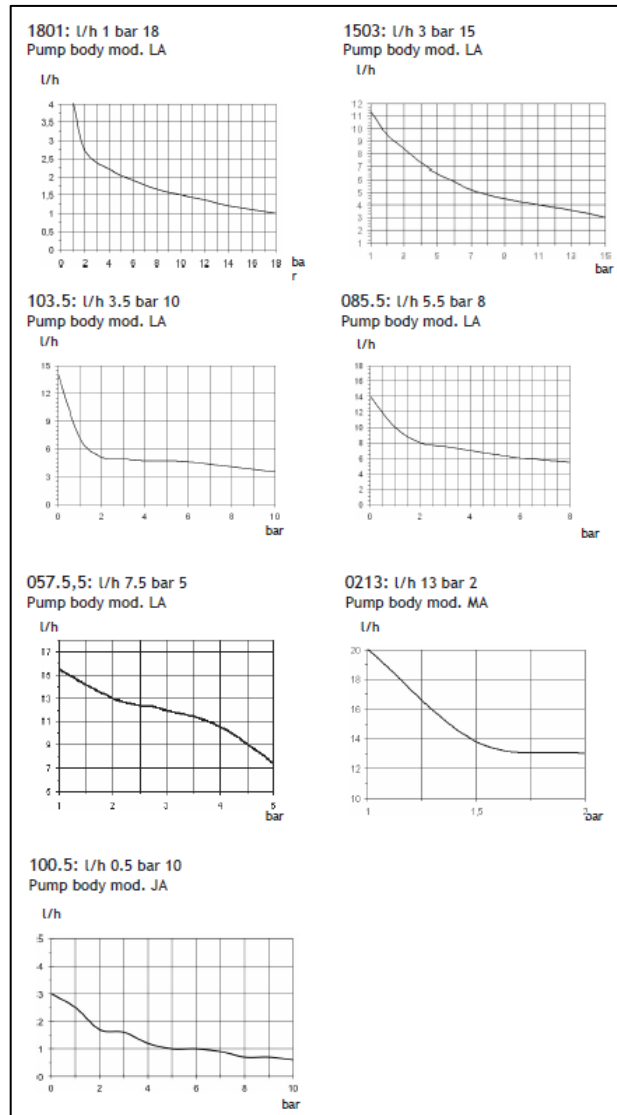


Fig. 3.35 Representation of KMSA MF flowrate curves

Dosing pumps are widely used for dosing chemical products and you can select the most suitable material for the liquid to be dosed in the “Chemical Compatibility Table”.

The data contained in the table are based on information provided by the manufacturers and their experience. Since the resistance of materials depends on many factors, this table is provided as an initial guide only. In general, the pump is made of PVDF, PP, PVC, SS 316, PMMA, PTFE, FPM, EPDM, NBR, PE.

Product	Formula	Ceram.	PVDF	PP	PVC	SS 316	PMMA	Hastel.	PTFE	FPM	EPDM	NBR	PE
Acetic Acid, Max 75%	CH ₃ COOH	2	1	1	1	1	3	1	1	3	1	3	1
Concentrated hydrochloric acid	HCl	1	1	1	1	3	1	1	1	1	3	3	1
Hydrofluoric acid 40	H ₂ F ₂	3	1	3	2	3	3	2	1	1	3	3	1
Phosphoric acid, 50%	H ₃ PO ₄	1	1	1	1	2	1	1	1	1	1	3	1
Nitric acid, 65%	HNO ₃	1	1	2	3	2	3	1	1	1	3	3	2
Sulphuric acid 85%	H ₂ SO ₄	1	1	1	1	2	3	1	1	1	3	3	1
Sulphuric acid 98.5%	H ₂ SO ₄	1	1	3	3	3	3	1	1	1	3	3	3
Amines	R-NH ₂	1	2	1	3	1	-	1	1	3	3	1	1
Sodium bisulphate	NaHSO ₃	1	1	1	1	2	1	1	1	1	1	1	1
Sodium carbonate (Soda)	Na ₂ CO ₃	2	1	1	1	1	1	1	1	2	1	1	1
Ferric chloride	FeCl ₃	1	1	1	1	3	1	1	1	1	1	1	1
Calcium hydroxide	Ca(OH) ₂	1	1	1	1	1	1	1	1	1	1	1	1
Sodium hydroxide (Caustic soda)	NaOH	2	3	1	1	1	1	1	1	2	1	2	1
Calcium hypochlorite	Ca(OCl) ₂	1	1	1	1	3	1	1	1	1	1	3	1
Sodium hypochlorite, 12.5%	NaOCl + NaCl	1	1	2	1	3	1	1	1	1	1	2	3
Potassium permanganate 10%	KMnO ₄	1	1	1	1	1	1	1	1	1	1	3	1
Hydrogen peroxide, 30%	H ₂ O ₂	1	1	1	1	1	3	1	1	1	3	3	1
Aluminium sulphate	Al ₂ (SO ₄) ₃	1	1	1	1	1	1	1	1	1	1	1	1
Copper sulphate	CuSO ₄	1	1	1	1	1	1	1	1	1	1	1	1

Fig. 3.36 Chemical compatibility table

3) KCL PLUS: constant or proportional dosing pump with level control for chemical feeding into water, in particular:

- In the constant dosing mode, the pump doses a constant quantity regularly as configured by the user.
- In the proportional dosing mode pump doses a quantity proportionally to an input signal, digital (voltage free contact) or current (mA).

We have seven working modes available:

- constant
- constant, with 1-10 pulses divider
- multiplier, with 1-10 pulses divider
- divider, with 1-10 pulses divider
- divider, with 1-100 pulses divider
- divider, with 1-1000 pulses divider
- mA current signal (0/4 mA = 0 pulses: 20mA = maximum pulses)

The flow rate is determined by the stroke length (from 0 to 100%) and by the stroke speed.

However, dosing accuracy is guarantee within an adjustment range from 30% to 100%.

In the specific case of KCL PLUS dosing pump, it works in constant mode and has got level control. The pump can be set to work in constant or constant with 1-10 speed reducers.

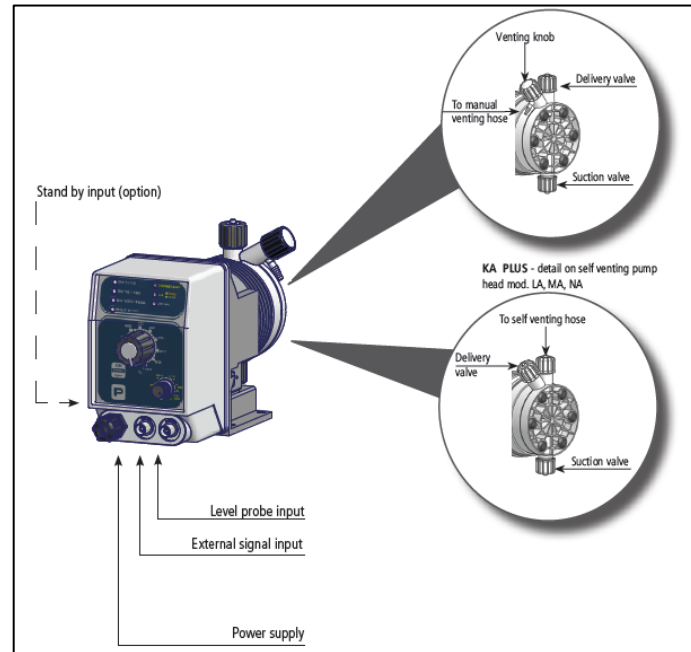


Fig. 3.37 Representation of K Plus and KA Plus pumps

In the following table we can find the capacity of manual and self-venting pumps.

CAPACITY														
Mod. K PLUS K PLUS LPV ¹	Flow				cc per stroke ²		pulse/ min	Max pressure		peak Amps (A)		Delivery hose (PVDF)	Suction hose	Pump head
	min cch	max l/h	Min GPH	Max GPH	min	max		bar	PSI	230 VAC	115 VAC			
2001	0,03	1	0,000008	0,3	0,03	0,09	180	20	290	2,7	1,45	4 x 6	4 x 6	I
1802	0,06	2	0,000016	0,53	0,06	0,19	180	18	261	2,7	1,45	4 x 6	4 x 6	L
1504	0,11	4	0,000029	1,06	0,11	0,37	180	15	217	2,7	1,45	4 x 6	4 x 6	L
1005	0,14	5	0,000037	1,32	0,14	0,46	180	10	145	2,7	1,45	4 x 6	4 x 6	L
0808	0,22	8	0,000058	2,11	0,22	0,74	180	8	116	2,7	1,45	4 x 6	4 x 6	L
0510	0,28	10	0,000074	2,64	0,28	0,93	180	5	72	2,7	1,45	4 x 6	4 x 6	L
0501	0,28	1	0,000008	0,3	0,03	0,09	180	5	72	2,7	1,45	4 x 6	4 x 6	L
0218	0,50	18	0,00013	4,76	0,50	1,67	180	2	29	2,7	1,45	6 x 8	6 x 8	M
Mod. KA PLUS	Flow				cc per stroke ²		pulse/ min	Max pressure		peak Amps (A)		Delivery hose (PVDF)	Suction hose	Pump head
	min cch	max l/h	Min GPH	Max GPH	min	max		bar	PSI	230 VAC	115 VAC			
1801	0,03	1	0,000008	0,26	0,03	0,09	180	18	261	2,7	1,45	4 x 6	4 x 6	LA
1503	0,08	3	0,000021	0,79	0,08	0,28	180	15	217	2,7	1,45	4 x 6	4 x 6	LA
103.5	0,10	3,5	0,000026	0,92	0,10	0,32	180	10	145	2,7	1,45	4 x 6	4 x 6	LA
085.5	0,15	5,5	0,000040	1,45	0,15	0,51	180	8	116	2,7	1,45	4 x 6	4 x 6	LA
057.5	0,21	7,5	0,000055	1,98	0,21	0,69	180	5	72	2,7	1,45	4 x 6	4 x 6	LA
0213	0,37	13	0,000098	3,43	0,37	1,20	180	2	29	2,7	1,45	6 x 8	6 x 8	MA

¹ Flow rates indicated refer to a measure with water. flow may change according to viscosity.
² cc per stroke: referred to cc/stroke with stroke length knob on 100%.

¹ Flow rates indicated refer to a measure with water; flow may change according to viscosity.
² cc per stroke: referred to cc/stroke with stroke length knob on 100%.

Fig. 3.38 Capacity (manual and self-venting models)

The flow rate indicated is for H₂O at 20°C at the rated pressure. Dosing accuracy +/- 2% at constant pressure +/- 0.5 bar.

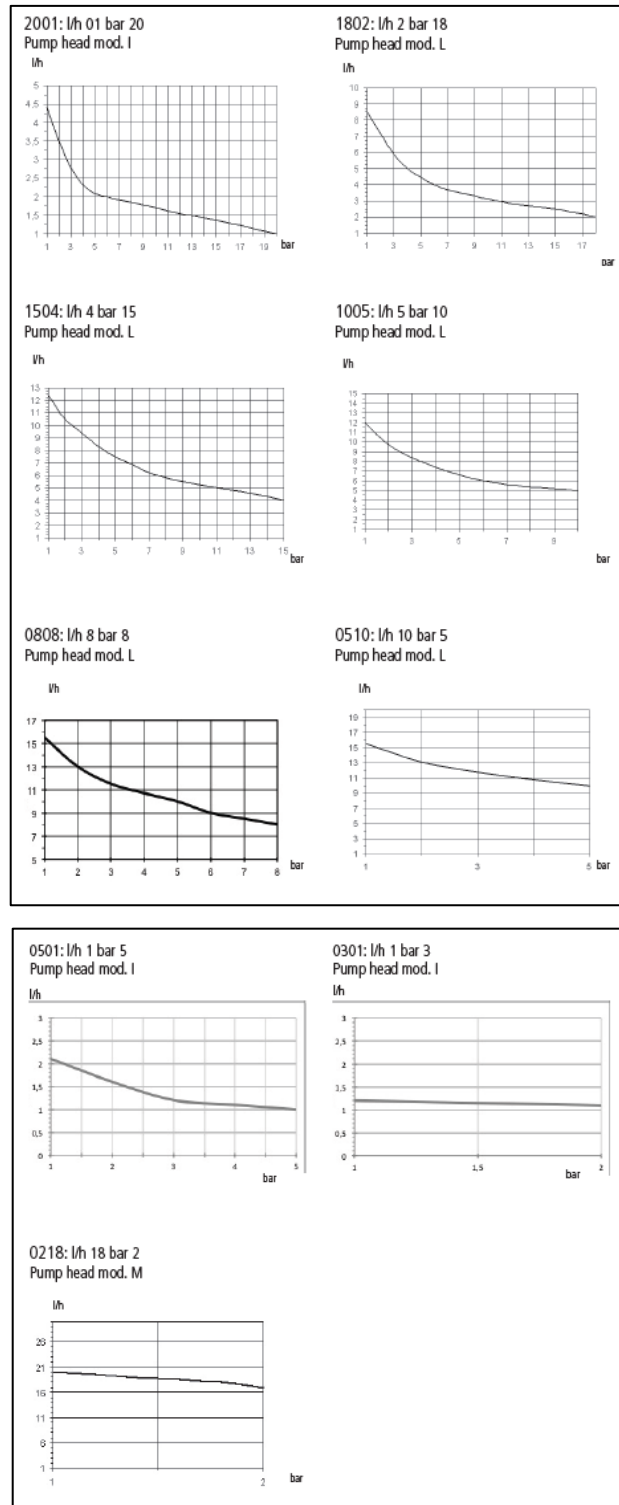


Fig. 3.39 Representation of KCL Plus flowrate curves

The solenoid driven metering pumps are widely used to dose chemical fluids and it is important that most suitable material in contact with fluid is selected for each application. The compatibility table serves as a useful help in this respect and all

data are based on manufacturer's data and its own experience but since the resistance of any material depends by several factors this list is supplied only as an initial guide.

The pump is made of PVDF, PP, PVC, SS 316, PMMA, PTFE, FPM, EPDM, NBR.

Product	Formula	Ceram.	PVDF	PP	PVC	SS 316	PMMA	Hastel.	PTFE	FPM	EPDM	NBR	PE
Acetic Acid, Max 75%	CH ₃ COOH	2	1	1	1	1	3	1	1	3	1	3	1
Hydrochloric Acid, Concentrate	HCl	1	1	1	1	3	1	1	1	1	3	3	1
Hydrofluoric Acid 40%	H ₂ F ₂	3	1	3	2	3	3	2	1	1	3	3	1
Phosphoric Acid, 50%	H ₃ PO ₄	1	1	1	1	2	1	1	1	1	1	3	1
Nitric Acid, 65%	HNO ₃	1	1	2	3	2	3	1	1	1	3	3	2
Sulphuric Acid, 85%	H ₂ SO ₄	1	1	1	1	2	3	1	1	1	3	3	1
Sulphuric Acid, 98.5%	H ₂ SO ₄	1	1	3	3	3	3	1	1	1	3	3	3
Amines	R-NH ₂	1	2	1	3	1	-	1	1	3	3	1	1
Sodium Bisulphite	NaHSO ₃	1	1	1	1	2	1	1	1	1	1	1	1
Sodium Carbonate (Soda)	Na ₂ CO ₃	2	3	1	1	1	1	1	1	2	1	1	1
Ferric Chloride	FeCl ₃	1	1	1	1	3	1	1	1	1	1	1	1
Calcium Hydroxide (Slaked Lime)	Ca(OH) ₂	1	1	1	1	1	1	1	1	1	1	1	1
Sodium Hydroxide (Caustic Soda)	NaOH	2	3	1	1	1	1	1	1	2	1	2	1
Calcium Hypochlorite (Chlorinated Lime) ¹	Ca(OCl) ₂	1	1	1	1	3	1	1	1	1	1	3	1
Sodium Hypochlorite, 12.5%	NaOCl + NaCl	1	1	2	1	3	1	1	1	1	1	2	3
Potassium Permanganate, 10%	KMnO ₄	1	1	1	1	1	1	1	1	1	1	3	1
Hydrogen Peroxide, 30% (Perrydrol)	H ₂ O ₂	1	1	1	1	1	3	1	1	1	3	3	1
Aluminium Sulphate	Al ₂ (SO ₄) ₃	1	1	1	1	1	1	1	1	1	1	1	1
Copper-II-Sulphate (Roman Vitriol)	CuSO ₄	1	1	1	1	1	1	1	1	1	1	1	1

¹ Calcium Hypochlorite (Chlorinated Lime): WQA test was based on 1% Calcium Hypochlorite solution.

Fig. 3.40 Chemical compatibility table

The pump is able to dose the necessary quantity of chemical product based on the flowrate of water in the pipeline, thanks to a device called pulse meter, characterized by a turbine and a magnet inside. When the water passes through the turbine, it begins to move, depending on the inlet flowrate and consequently the magnet, applied to the turbine begins to turn.

These movements are identified and counted by a sensor placed on the device. Thank to this mechanism, it is possible to measure the instantaneous flowrate of water present in the pipeline.

Therefore, pulse meter is used in conjunction with dosing pups to dose chemical substances in quantities proportional to litres of water measured.

There are various types of pulse meters, more or less precise:

- Single jet turbine model, in which a single jet of water hits the blades of a turbine mounted radially inside the body of the meter;
- Multiple jet turbine model, in which the jet of water is distributed symmetrically ion the blades of the turbine.

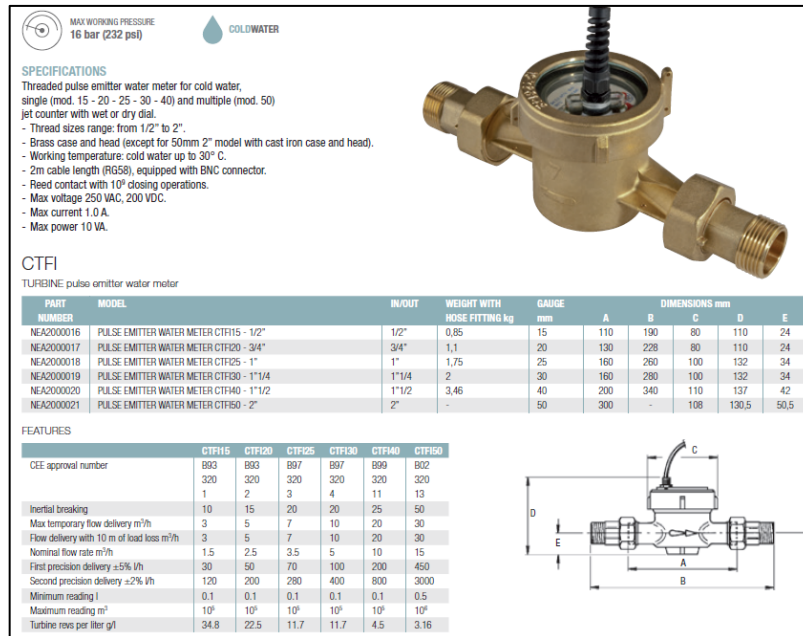


Fig. 3.41 Turbine pulse emitter water meter

Alternatively, the flanged Woltmann model is mainly used in industrial and irrigation applications, and it is characterized by a mechanical turbine. Working conditions:

- Temperature: 0-50 °C
- Pressure: < 16 bar.

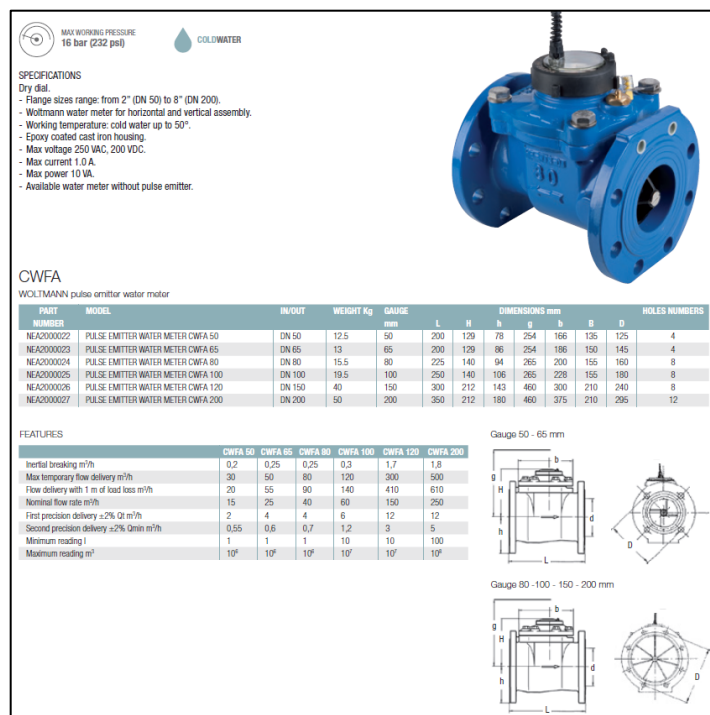


Fig. 3.42 Woltmann pulse emitter water meter

Each model of pulse emitter water meter is defined by a specific alphanumeric code.
For example:

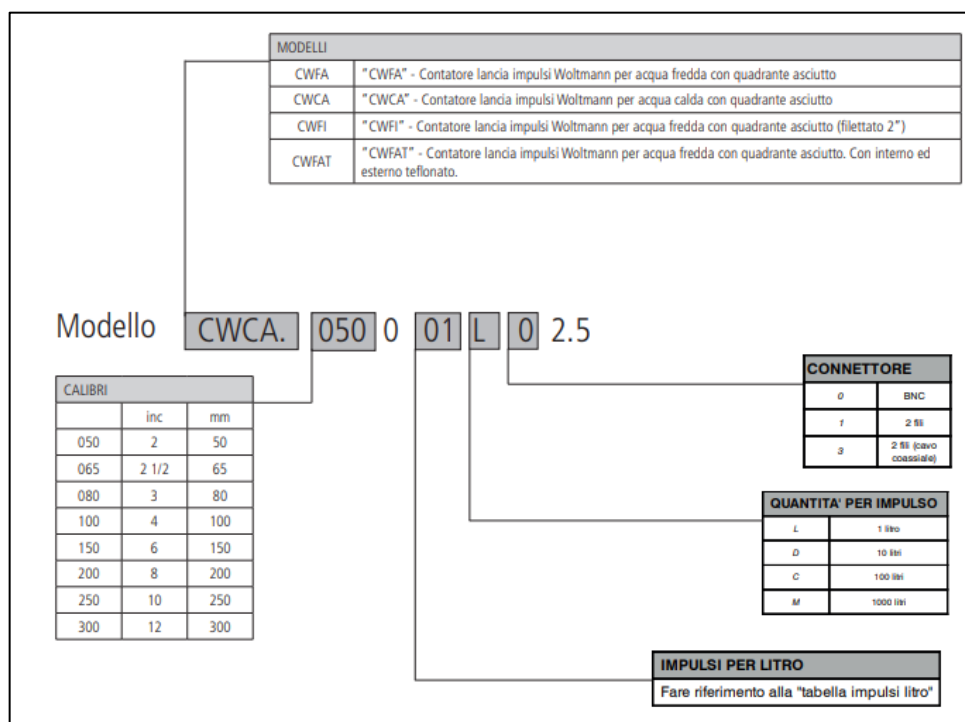


Fig. 3.43 Example of alphanumeric code of a pulse emitter water meter

Two codes have most importance:

- "01": indicates the number of impulses per litre
- "L": indicates the amount of water for each impulse

Usually 4 pulses/litre are chosen because it allows a rather safe and precise dosage.

To choose the pulse meter model, refer to the following table:

IMPULSI PER LITRO

Impulsi litro contatori serie CWFA / CWF1 / CWFAT								
	Calibro contatore							
	50 - 2"	65 - 2.5"	80 - 3"	100 - 4"	150 - 6"	200 - 8"	250 - 10"	300 - 12"
Impulsi per 10 lt	1-2-4	1-2-4	1-2-4	n/a	n/a	n/a	n/a	n/a
Impulsi per 100 lt	1-2-4	1-2-4	1-2-4	1-2-4	1-2-4	n/a	n/a	n/a
Impulsi per 1000 lt	1-2-4	1-2-4	1-2-4	1-2-4	1-2-4	1-2-4	1-2-4	1-2-4
Impulsi per 10000 lt	n/a	n/a	n/a	1-2-4	1-2-4	1-2-4	1-2-4	1-2-4

DIMENSIONI

CALIBRO	(mm)	50	65	80	100	150	200	250	300	CWF1 50
	(inch)	2	2 1/2	3	4	6	8	10	12	CWF1 2
L - lunghezza (mm)		200	200	230	250	300	350	450	500	200
B - larghezza (mm)		165	185	200	200	283	340	406	460	-
H - altezza (mm)		214	228	234	250	310	338	438	465	175
h - altezza (mm)		70	84	90	106	130	158	258	330	-
Peso (kg)		12	13	15.5	19	35	47	75	95	5

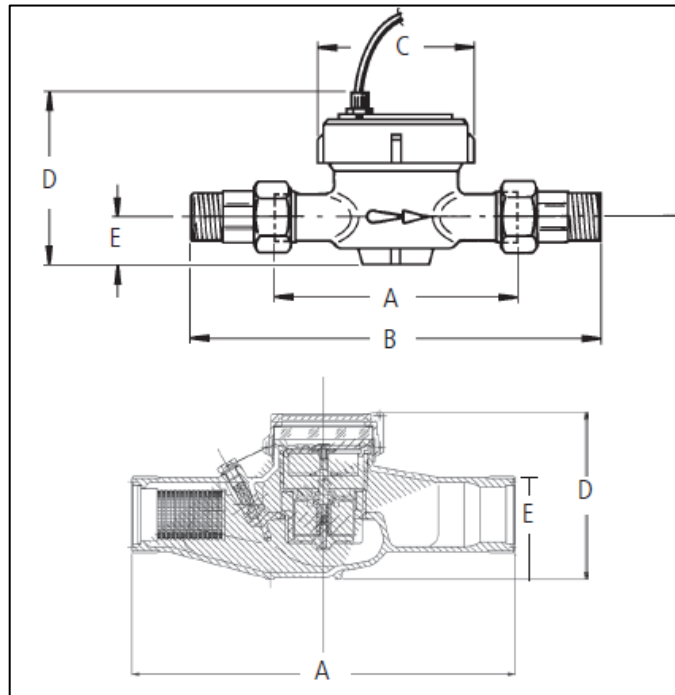


Fig. 3.44 Tables concerning the principal characteristics of a pulse emitter water meter

Other components to take into consideration are the tank and the safety baffles.

The tanks for chemicals dosing are made of reinforced polyethylene, with cylindrical-vertical shape and flat bottom side. The upper side is available for dosing pumps, suction lances and mixers installation. They are also equipped with chemical load hatch and level indicator.

The technical datasheet of tanks is reported below.

TANKS					
PART NUMBER	MODEL	CAPACITY (Lt)	DIMENSIONS mm		
			A	H	S
NEA2000028	SERBATOIO CNT50	50	Ø 420	505	1/2" F
NEA2000029	SERBATOIO CNT110	120	Ø 495	735	1/2" F
NEA2000030	SERBATOIO CNT200	250	Ø 610	850	1/2" F
NEA2000031	SERBATOIO CNT500	500	Ø 780	1200	1" F

Fig. 3.45 Technical datasheet of Tanks

Safety baffles are cylindrical container made of self-supporting vertical polyethylene with a flat bottom, the upper part of which is open to the sky, and has a reinforced upper edge. It is designed to prevent the dispersion of the chemical compound outside the container, ensuring the safety of the system.

The technical datasheet of safety baffles is reported below.

SAFETY BAFFLES for CNT container					
PART NUMBER	MODEL	CAPACITY (Lt)	DIMENSIONS mm		
			A	B	H
NEA2000032	VASCA DI SICUREZZA COS60	60	510	430	425
NEA2000033	VASCA DI SICUREZZA COS110	120	545	520	615
NEA2000034	VASCA DI SICUREZZA COS200	300	695	660	875
NEA2000035	VASCA DI SICUREZZA COS500	600	840	820	1095

Fig. 3.46 Technical datasheet of Safety baffles

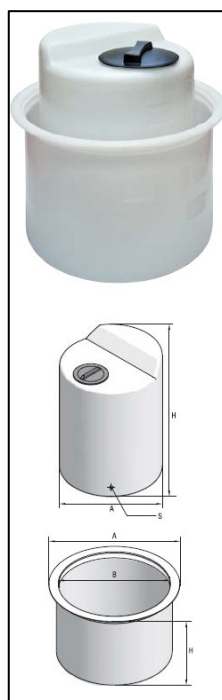


Fig. 3.47 Tanks and Safety baffles

Suction lances are level probes with a valve and a bottom filter made of PVC. On the other hand, injection lances, are used to remove injection valves with the pipeline under pressure and are equipped with a ceramic ball valve. They are bale to reduce chemical deposits and crystalline formations at the injection point.

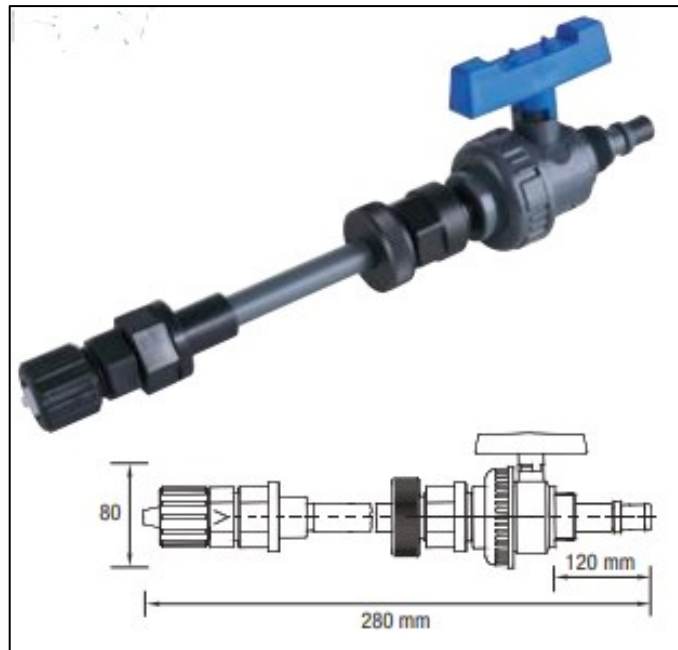


Fig. 3.48 Injection lances

3.4 Pre-treatment section testing

Testing the systems is a fundamental procedure to ensure the correct installation and functioning of the system and its elements. The system is made of an electrical, hydraulic and pneumatic component, which will be subjected to final checks in order to ensure that the system parts and components function correctly.

Generally, there are two types of testing:

- Static testing, aimed to verify the stability and the resistance of the building structure;
- System testing, aimed to verify the operations of the system and their performance.

For water systems, it is necessary to verify that the sizing of pipes and mechanical equipment is carried out in a consistent manner with what is foreseen in the project, and in compliance with the conditions and requests of the users.

In particular, it is necessary to verify that materials comply with current regulations and that safety systems have been installed and function correctly. In addition, it is necessary to carry out leak and pressure tests, and verify the energy efficiency of the system. The tester must verify compliance with regulations on the quality of drinking water, and, if present, the correct installation and operation of wastewater purification systems. ^[10]

4. Treatment system

4.1 Reverse osmosis

Direct osmosis is a phenomenon that occurs normally in nature, in the cells of all living organisms, and is the process by which two solutions with different concentrations, divided by a semipermeable membrane that allows the passage of water but not salts, the more diluted solution tends to naturally go towards the more concentrated solution, until the concentration of the two solutions are equivalent. The pressure that is generated on the membrane due to this flow is called osmotic pressure, which depends on the difference between the solutions in contact. In particular, the osmotic pressure is the minimum pressure which needs to be applied to a solution to prevent the inward flow of its pure solvent across a semipermeable membrane.^[11]

The potential osmotic pressure is the maximum osmotic pressure that could develop in a solution if it were separated from its pure solvent by a semipermeable membrane.

Jacobus van 't Hoff found a quantitative relationship between osmotic pressure and solute concentration, expressed in the following equation:

$$\Pi = i * C * R * T$$

where Π is the osmotic pressure, i is the dimensionless van 't Hoff index, c is the molar concentration of solute, R is the ideal gas constant, and T is the absolute temperature usually in Kelvin. This formula is applied when the solute concentration is sufficiently low, thus the solution can be treated as a dilute and ideal solution.^[12]

Exploiting this principle, the process can be reversed applying an equal and opposite pressure on the concentrated solution to obtain a solution with lower concentration. The osmotic membrane, which implements the highest level of filtration achievable, behaves as a barrier against the salts and inorganic substances that constitute the saline composition of the water, and the organic substances such

as pesticides, pyrogens, viruses and bacteria. In particular, against the latter, it is possible to achieve a nominal rejection of 100%.

The higher the difference between the applied pressure and the osmotic pressure, the greater the quantity of water produced per unit of semi-permeable membrane surface.

Reverse osmosis systems can lead to dissolved solids removal over 90%. Together with organic ions, they can remove:

- Residual organic molecules;
- Metals, such as Lead, Arsenic (99%);
- Fluorine;
- Turbidity;
- Radionuclides (94%);
- Bacteria and viruses.

Osmotic pressure depends on the concentration of salts in the feed water: the higher the TDS, the higher the osmotic pressure, and consequently the higher the feed pressure to apply.

- 100 ppm TDS → around 1 psi osmotic pressure;
- 1000 ppm TDS → around 10 psi osmotic pressure;
- 35000 ppm TDS → around 350 psi osmotic pressure.

Therefore, depending on the type of water and the salinity to be treated, the range of required feed pressures varies:

- Raw water from 2-3 up to 18-20 bar;
- Brackish water from 7-8 up to 34-40 bar;
- Sea water from 50-55 up to 70-85 bar.

A reverse osmosis system is characterized by:

- A feed, raw water to be treated;
- A product, pure and low in salts, the permeate;
- A discharge, rich in salts, the concentrate.

Solvent flux (usually water): $Q_w = K_w(\Delta P - \Delta \pi)$

Where:

- K_w = membranes permeability;
- ΔP = pressure drop;
- $\Delta \pi$ = osmotic pressure difference.

Salts flux: $Q_s = K_s(\Delta C)$

Where:

- K_s = salts permeability;
- ΔC = concentration difference.

The most important operating parameters that affect the water flux and salt rejection are:

- Feed pressure: considering temperature, recovery and TDS constant, the higher the feed pressure, the higher the water flux and the salt rejection;

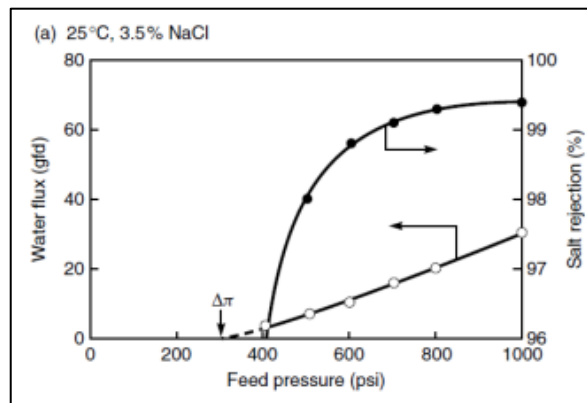


Fig. 4.1 Water flux as a function of the applied pressure

- Concentration of salt in the feed solution: considering pressure, temperature and recovery constant, the higher the salts concentration in the feed solution, the lower the water flux and the salts rejection;

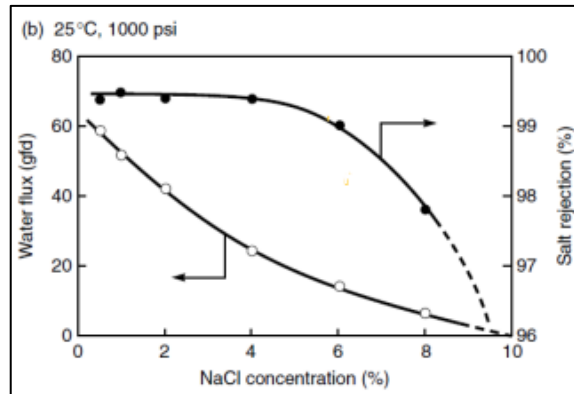


Fig. 4.2 Water flux as a function of the salts concentration

- Temperature: considering pressure, recovery and TDS constant, increasing the temperature of the feed water, the water flux increases while the salt rejection decreases.

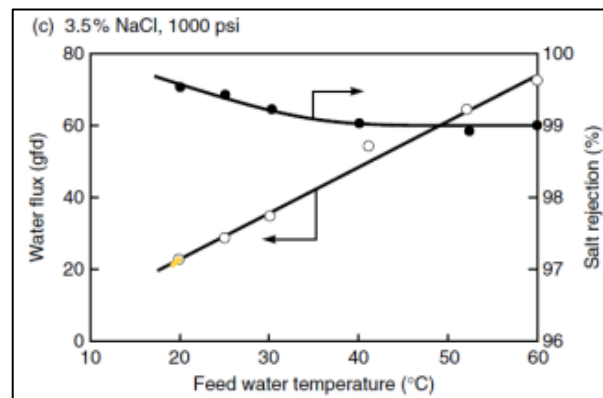


Fig. 4.3 Water flux as a function of the feed water temperature

The influence of pH on the water flux is not so relevant: keeping constant pressure, temperature, TDS and pH between 2 and 12, permeate flux and salt rejection does not change so much. Talking about recovery, considering temperature, pressure and TDS constant, permeate flux and salts rejection decrease.

The following parameters are indices of the efficiency of an osmotic pressure membrane:

- Recovery (%) = (Permeate flowrate/ Feed flowrate) x 100
- Salt passage (%) = (Salts concentration in the permeate / Salts concentration in the concentrate) x 100
- Salts rejection (%) = 100 – Salt passage

Polyvalent ions, such as Calcium and Magnesium, are rejected up to 99%, while monovalent ions, such as Sodium, up to 95%. A reverse osmosis membrane cannot remove salts by 100%, however today can reach up to 99,5%. ^[13]

4.1.1 Reverse osmosis membranes

Pre-treatments of the feed water are always required to remove turbidity before entering in the reverse osmosis system, due to suspended solids and minerals dissolved in water (in particular Fe, Mn and colloids) which could obstruct the pores of the membrane.

The performance of these membranes on pre-treated water are around 95%. As a function of the quality of water to be treated, the discharge of retentate can vary between 10 and 50%, with performances between 50% and 99%.

Due to very low content of salts dissolved in water, a certain amount of feed water can be mixed with the treated water, through a by-pass, to in order to re-stabilize an adequate value of salts in the permeate.

Reverse osmosis technology has undergone a rapid, technological, industrial and economic development in recent years: today it is able to guarantee compact, simple, versatile systems characterized by constant yields in terms of both production and water quality. Furthermore, the permeate must meet specific chemical-physical requirements, dictated by production and legislative needs.

The membranes mostly employed in reverse osmosis processes are:

1. Asymmetric Cellulose Acetate membranes, characterized by a dense layer around 0.1 μm in thickness, and total membrane thickness around 100 μm .
2. Non-cellulosic Polymer membranes: for example, aromatic polyamide use by Du Pont in its Permasep B-15 hollow fine fibres, which have good seawater salt rejections of up to 99.5%, good fluxes but susceptible to degradation by chlorine because of their amide bonds. Otherwise there are membranes based on sulfonated Polysulfone and substituted polyvinyl alcohol, characterized by high flux and low rejection, mostly employed in water softening applications thank to their chlorine resistance.

3. Interfacial polymerization membranes: characterized by a microporous Polysulfone support to which a liquid reactant is added. Polymerization occurs in the pores at the membrane/solution interface. ^[13]

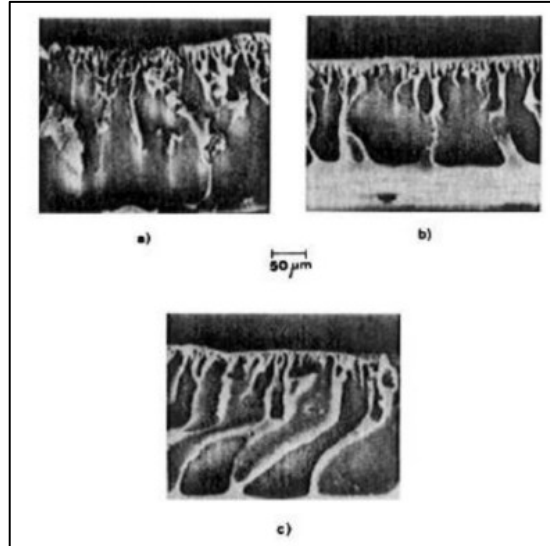


Fig. 4.4 SEM images of membrane cross-section prepared from a) 12% cellulose acetate in DMAc, b) 12% polyamide in DMSO, c) 12% Polysulfone in DMF

The image above represents the scanning electron micrographs of membrane cross sections prepared from three different polymer-solvent systems by precipitation in water:

- 12% Cellulose Acetate in DMAc;
- 12% Polyamide in DMSO;
- 12% Polysulfone in DMF.

The following picture shows the SEM cross section image of thin film composite membranes for reverse osmosis processes and its microstructure.

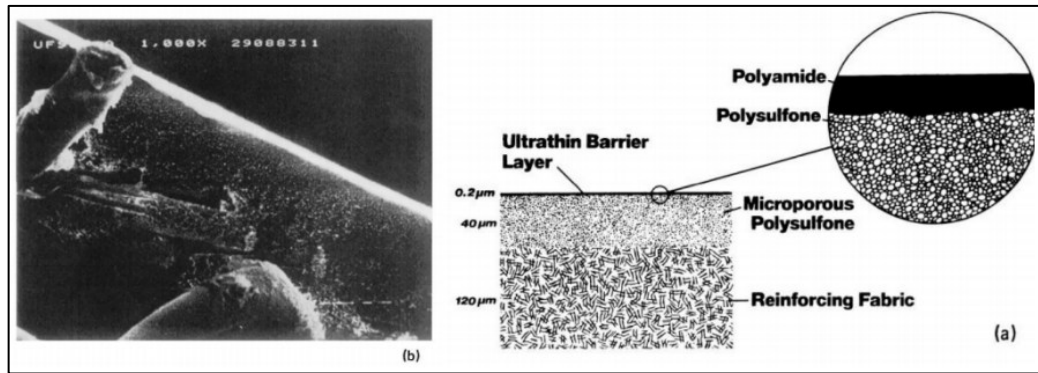


Fig. 4.5 a) SEM images of thin film composite membrane cross-section prepared from, b) Microstructure of reverse osmosis membrane

The table below compares the technical features of thin film composite membranes and cellulose acetate membranes. The first have a higher salt rejection but frequent cleaning is required.

Parameter	Thin-Film Composite Membranes	Cellulose Acetate Membranes
Salt rejection, %	Higher (>99.6%)	Lower (Up to 99.5%)
Net driving pressure, bars	Lower (10–15 bars)	Higher (15–30 bars)
Surface charge	Anionic (limits use of cationic pretreatment coagulants)	Neutral (no limitations on pretreatment coagulants)
Chlorine tolerance	Poor (Up to 1000 ppm-h) feed dechlorination needed	Good; continuous feed of 1–2 ppm of chlorine is acceptable
Cleaning frequency	High (weeks to months)	Lower (months to years)
Pretreatment requirements	High (SDI < 4)	Lower (SDI < 5)
Organics removal	High	Relatively lower
Biogrowth on membrane surface	May cause performance problems	Limited—not a cause of performance problems
pH tolerance	High (1–13)	Limited (4–6)

Fig. 4.6 Comparison between the technical features of thin film composite membranes and cellulose acetate membranes

Usually, the osmotic membranes used have two different types of configuration: Flat or Tubular. The lower area into which membranes can be packed is called modulus. We could have:

- Flat membranes, divided into Plate and Frame and Spiral wound
- Tubular, divided into Tubular, Capillary and Hollow Fibres

Actually, 8 inches in diameter and 40 inches in length spiral-wound modules are the type most commonly used for reverse osmosis, while hollow fibres modules are

not used anymore. Five to seven modules are housed inside a filament-wound, fibres-glass-reinforced plastic tube.

Hollow fibres and Capillary modules require less costs due to lower operating pressure, in addition they can be easily cleaned with back-flushing. On the other hand, Tubular and Plate and Frame modules operate at higher operating pressure, higher energy pumping and larger stripper, thus they require higher energy consumption, but they can be used when high fouling resistance is required.

One-half of the reverse osmosis systems currently installed are desalinating brackish or seawater plants. Around the 40% of these systems produce ultrapure water for the electronics, pharmaceutical and power generation industries.

As we will see later, in this specific implant the following membranes will be used:

- LOW2-HR_8040, characterized by “Spiral Wound” configuration, made of Composite Polyamide as membrane polymer and Polypropylene as Brine Spacer material, with a salt rejection of 99.65%. In addition, they are characterized by a total length of 40 inches (1016 mm) and a diameter of 8 inches (200mm). Nominal area of 400 ft², Permeate flow of 9500 gpd and solution NaCl of 1500 ppm, applied pressure of 150 psi at 25°C, with a permeate recovery of 15% in a pH range of 6.5-7.
- LOW4_8040, characterized by “Spiral Wound” configuration, made of Composite Polyamide as membrane polymer and Polypropylene as Brine Spacer material, with a salt rejection of 99.2%. In addition, they are characterized by a total length of 40 inches (1016 mm) and a diameter of 8 inches (200mm). Nominal area of 400 ft², Permeate flow of 12000 gpd and solution NaCl of 500 ppm, applied pressure of 100 psi at 25°C, with a permeate recovery of 15% in a pH range of 6.5-7.

4.1.2 Concentration polarization and Fouling

There are several types of resistance towards mass transport across a membrane.

During a separation process, the performance of the system can change a lot with time and, as a consequence, the flux decreases over the time, as shows in the following graph:

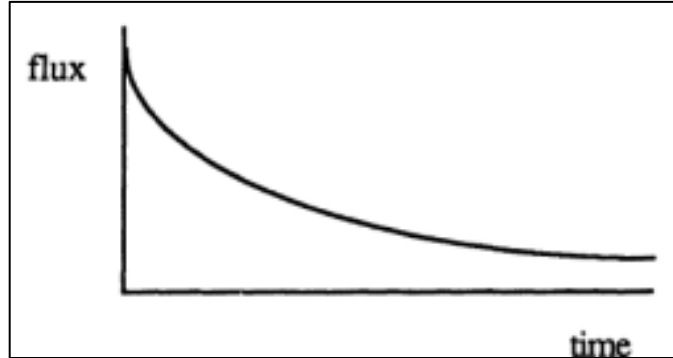


Fig. 4.7 Water flux across a membrane as a function of time

The flux is given by the ratio between the driving force and the viscosity, multiplied by the total resistance, thus, as the total resistance increases, the flux decreases. In particular, for pressure driven processes:

$$J = \frac{\Delta P}{\eta * R_{tot}}$$

The importance of concentration polarization depends on the membrane separation process. Reverse osmosis can be significantly affected by this phenomenon but it is usually well controlled in industrial systems. However, there are no insights about concentration polarization and membrane properties relationship. In addition is not possible to estimate a priori the magnitude of concentration polarization.

There are several factors that affect the modulus of concentration polarization:

- Turbulence: increasing the turbulence, the flow velocity increases and the concentration polarization decreases. However, the energy consumption of the pumps and the pressure drops give a practical limit to the turbulence.
- Membrane enrichment: increasing the membrane enrichment, the concentration polarization increases.
- Membrane flux: increasing the flux, the concentration polarization increases.

- Solute diffusion coefficient: increasing the solute diffusion coefficient, the concentration polarization decreases.

Membrane fouling is another type of resistance towards mass transport across a membrane, which occurs mainly in microfiltration and ultrafiltration processes, where porous membranes, much susceptible to fouling are used. In fact, a narrow size distribution can reduce fouling. There are three types of foulant that can be distinguished:

- Organic precipitates, such as macromolecules or biological substances
- Inorganic precipitates, for example metal hydroxides and calcium salts
- Particulates

The following image shows the two phenomena as a function of flux and time.

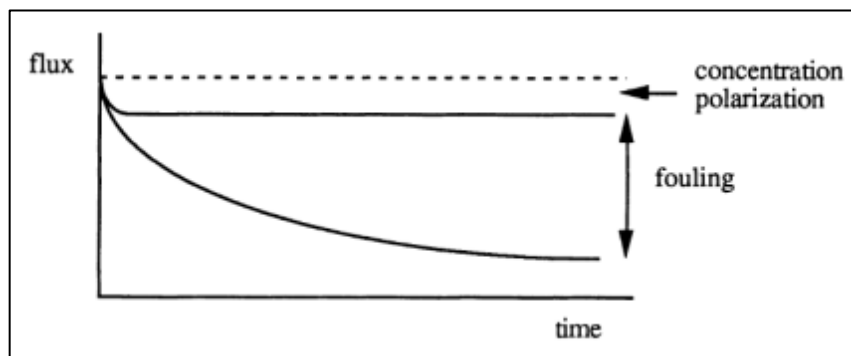


Fig. 4.8 Water flux across a membrane affected by fouling and concentration polarization as a function of time

To measure the tendency of fouling, we can perform fouling tests such as silting index, plugging index, fouling index or membrane filtration index.

In general, the preferred method to reduce this phenomenon is to perform a pre-treatment of the feed solution, which may consist on:

- Heat treatment;
- pH adjustment;
- Addition of complexing agents;
- Chlorination;
- Adsorption onto active carbon;
- Chemical clarification.

Also cleaning is usually performed, which can be hydraulic, mechanical, electric and chemical cleaning, with acids, alkali detergents, enzymes, complexing agents and disinfectants.

The following graph shows how the flux decreases over the time with and without back-flushing. With back-flushing, fouling is reduced because precipitates and particulates, previously deposited on the membrane surface, are removed, thus the resistance to flow across the membrane is reduced and the decreasing of the flux over the time is much less.

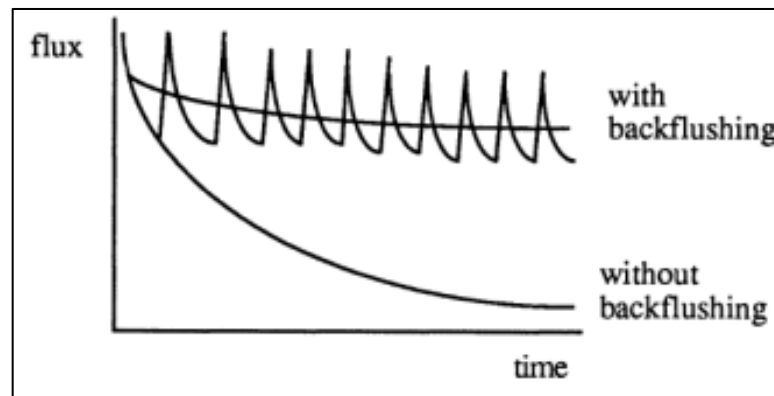


Fig. 4.9 Comparison of the behaviour of water flux as a function of time with and without backflushing

Fouling can be induced by two main causes:

- Silts, particulates, bacteria and organics controlled by a suitable pre-treatment procedure. This type of fouling affects the first modules in the plant. Silt is formed by suspended particulates, such as organic colloids, iron corrosion products, algae and fine particulate matter, that accumulate on the membrane surface. In order to determine the tendency of the feed water to producing fouling by scale can be determined by calculating the silt density index (SDI). For values of SDI lower than 1, the reverse osmosis system can run for several years. For values of SDI between 3 and 5, fouling starts to be a problem, so frequent cleaning is required. For SDI values higher than 5, pre-treatments are required.
- Scaling, that affects more the last modules of the plant because they are exposed to the most concentrated feed solution. Scale is caused by the precipitation of dissolved metal salts in the feed water on the membrane surface. As salt-free water is removed in the permeate, the concentration of

ions in the feed increases until the solubility limit is exceeded. Then the salt precipitates on the membrane surface as scale. The tendency of a feed water to produce fouling by scale can be determined by performing the analysis of feed water, calculating the expected concentration factor in the brine. ^[13] The following graph represents the behaviour of the concentration factor as a function of the recovery rate: the higher the recovery rate, the higher the concentration factor.

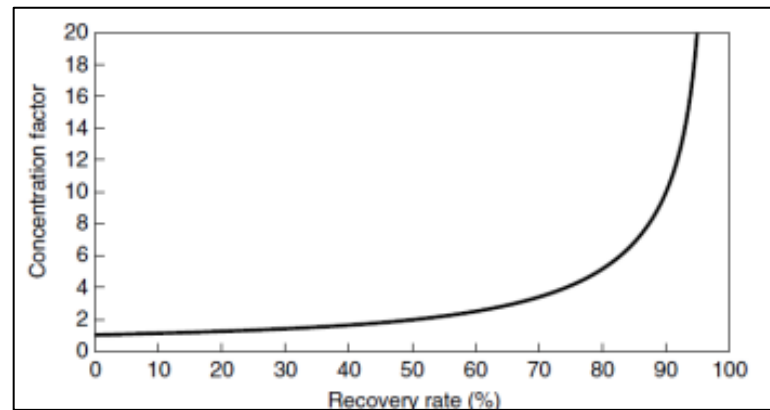


Fig. 4.10 Behaviour of concentration factor as a function of the recovery rate

4.2 First reverse osmosis system

In order to obtain 3 m³/h of osmotic water for the steam generator, two reverse osmosis systems will be needed. The sizing will be performed starting from the second reverse osmosis system and then for the first one, taking into account the output water flowrates requested by the customer.

These systems use reverse osmosis technology to improve the quality of water intended for industrial use: thanks to the passage of water through the osmotic membrane, the resulting water produces is free from salts, harmful substances such as pesticides, insecticides and heavy metals, bacterial load like viruses and pyrogens, odours and flavours. Based on the analysis of the source water and the treatment needs, adequate pre-treatment and dosing systems are proposed. Reverse osmosis systems are equipped with a double conductivity probe (inlet and permeate) and visual indicators of the permeate, discharge and recirculation flowrate.

The feed water flowrate entering in the first plant is 12 m³/h, while at the exit the water must be suitable for washing the cooker and dough, as the customer asked.

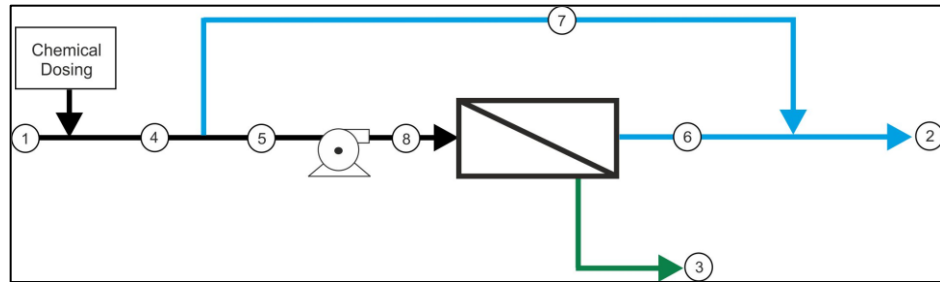


Fig. 4.11 Configuration of the first reverse osmosis system obtained by the software Sirio

For each point, the software calculates the water flowrate:

- Point 1: 11850 [l/h]
- Point 2: 6050.9 [l/h]
- Point 3: 5800 [l/h]
- Point 4: 11850 [l/h]
- Point 5: 11600 [l/h]
- Point 6: 5800 [l/h]
- Point 7: 250 [l/h]
- Point 8 = 11600 [l/h]

The pressure at the point 8 is 11.8 bar, while at the point three is 9.8 bar, thus tubes constituted of stainless steel are here suggested. In the other parts, tubes made of PVC can be used.

In order to obtain good quality water, two stages are used, each containing three elements per vessel, for a total of six membrane modules. For this specific application, LOW2-HR_8040 membranes are chosen. The technical datasheet of these membranes is reported below.

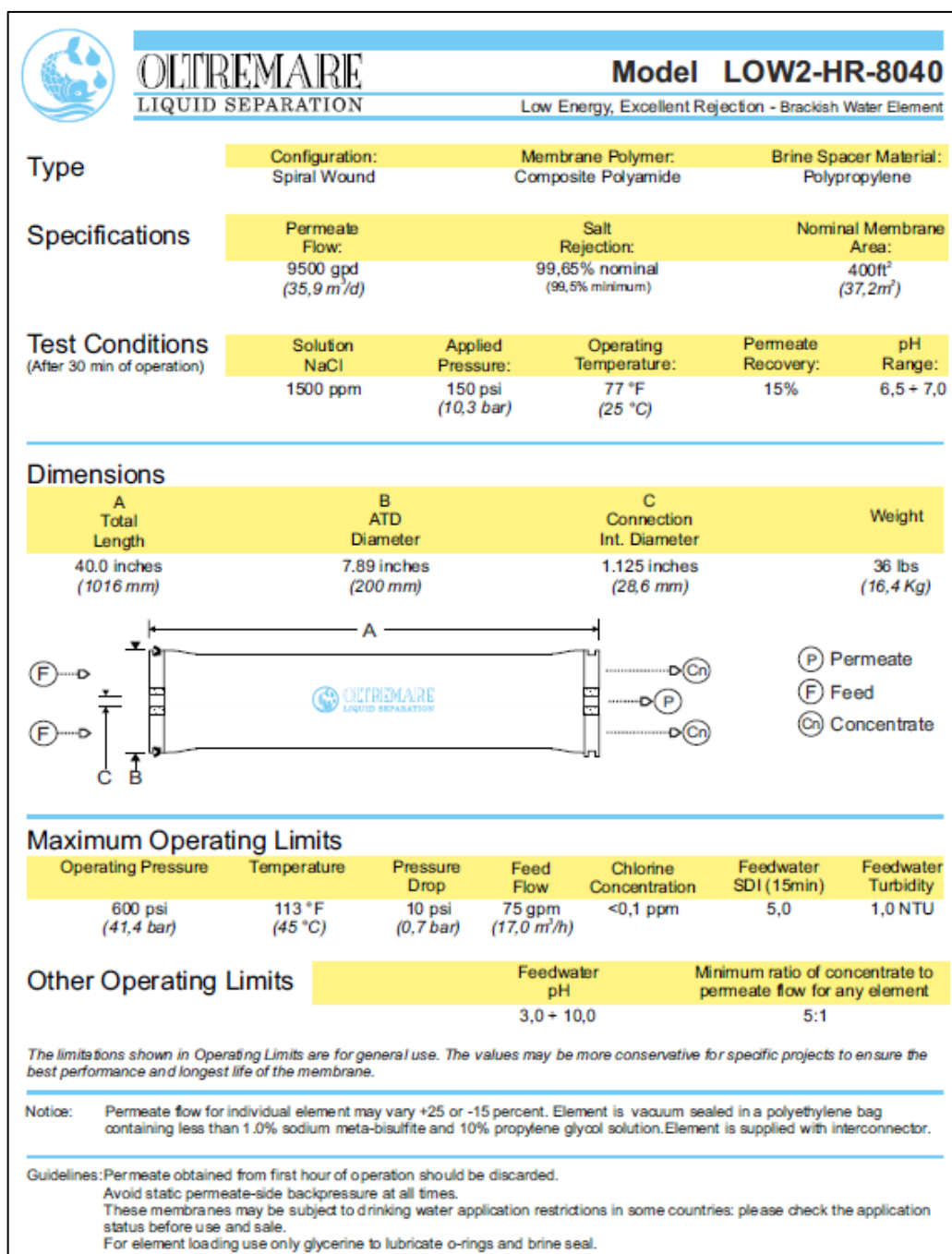


Fig. 4.12 Technical datasheet of LOW2-HR_8040 membranes

Working with a recovery of 50%, the obtained permeate has the following characteristics:

- TDS: 13.5 ppm
- Conductivity: 25 µs/cm
- pH: 5.7

This water is suitable for washing the cooker and dough, but not for water entering in the steam generator, for this reason a second reverse osmosis plant will be necessary.

The concentrate is characterized by the following values:

- TDS: 7383.8 ppm
- Conductivity: 11561 $\mu\text{S}/\text{cm}$
- pH: 7.7

Due to very high salts concentration, the concentrate will be completely discharged. The chemical analysis of the raw water, permeate and concentrate is reported below, obtained from the simulation with the software “Sirio”.

Plant Data							
Type of RAW water	Well Water		Membrane age	2	years		
SDI	3		Flux decline factor	8			
Temperature	18	°C	TDS increase factor	5			
RO Feed Pressure	11.7	bar	Recirculate	0.0	l/h		
H.P. Pump Flow	11600.0	l/h	Blend Permeate	250.0	l/h		
Average Perm. Flux	26.0	l/m ² /h	Chemical Dose	N.A.	ppm of	N.A.	
Recovery	50	%	Ion-exchange softening	No			

Water Details							
Name	RAW (1)	With chem.dosing (4)	Feed N.A.	Permeate (2)	Blended (7)	Concentrate (3)	Unit
NH4	0.0			0.0	0.0	0.0	ppm
K	18.8			0.7	1.4	36.9	ppm
NA	334.2			1.9	16.0	682.8	ppm
MG	194.5			0.4	8.5	388.6	ppm
CA	481.0			1.0	20.8	961.2	ppm
SR	0.0			0.0	0.0	0.0	ppm
BA	0.0			0.0	0.0	0.0	ppm
CO3	2.5			0.0	0.0	6.6	ppm
HCO3	220.0			1.9	11.9	478.1	ppm
NO3	25.0			1.1	2.1	48.9	ppm
CL	190.2			1.2	9.1	379.2	ppm
F	0.0			0.0	0.0	0.0	ppm
SO4	2187.0			5.1	95.2	4369.6	ppm
SiO2	16.0			0.1	0.7	31.9	ppm
B	0.0			0.0	0.0	0.0	ppm
CO2	22.4			6.6	6.6	8.1	ppm
Total TDS	3669.2			13.5	165.8	7383.8	ppm
Conductivity	6109			25	326	11561	uS
pH	7.0			5.7	6.4	7.7	
Flow	11850.0			5800.0	6050.0	5799.1	l/h
Pressure	11.7					9.8	bar
Osm.Press.	1.3			0.0	0.1	2.4	bar
LSI	0.23					1.56	
S&D	-0.90					0.43	
Ionic Strength	0.098			0.000	0.004	0.198	
CaSO4 saturat.	106.2					225.7	%
BaSO4 saturat.	0.0					0.0	%
SiO2 saturat.	28.6					37.9	%
SrSO4 saturat.	0.0					0.0	%

Fig. 4.13 Chemical analysis of water for each step of the process

The final configuration of the first reverse osmosis system is reported in the following P&I.

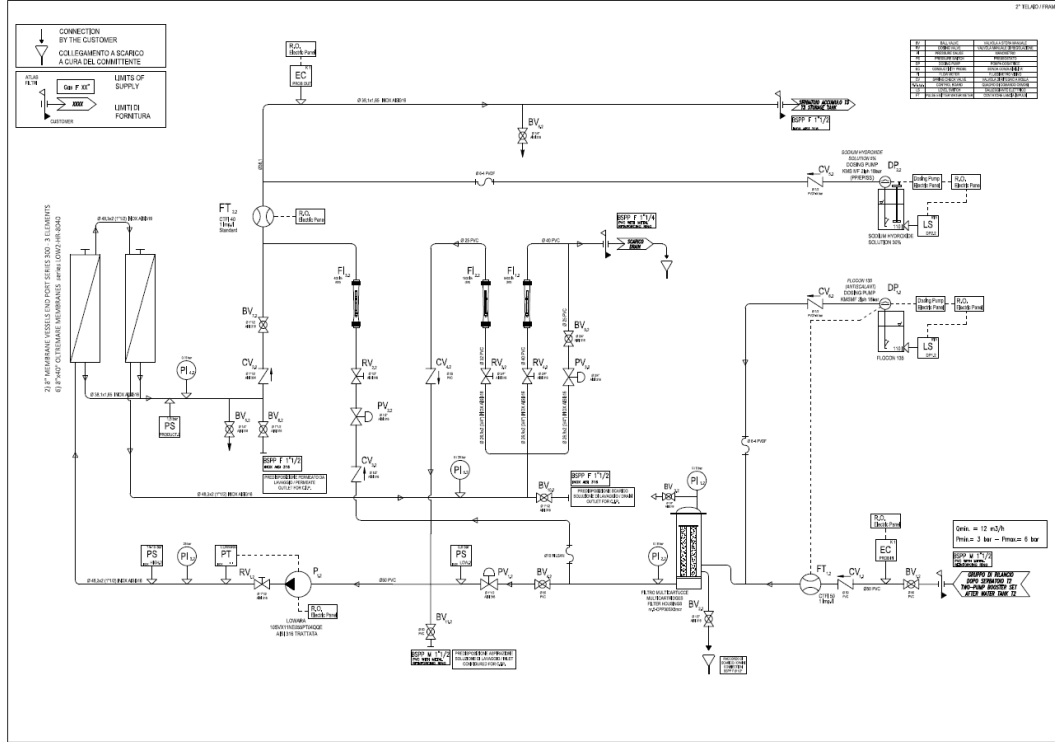


Fig. 4.14 Detailed P&I of the first reverse osmosis system

4.2.1 Addition of anti-scale chemical product

Before entering in the first reverse osmosis system, the water requires the addition of a chemical product for the maintenance and protection of thermal systems. Operating in a localized, simple and effective way, the formation of scale, corrosion and the proliferation of algae and bacteria can be prevented. This protective action is necessary to comply with conditions of boiler and steam generator, reduce energy waste and maintenance costs and ensure the functionality of new high-efficiency systems. In this specific case, the anti-scale product used is Flocon 135, added at the inlet of the first reverse osmosis system.



Fig. 4.15 Flocon 135

Flocon 135 is an aqueous solution of a specialised phosphinocarboxylic acid, highly effective in controlling the deposition of inorganic scale forming salts on membrane surfaces. Its main characteristics are:

- Excellent control of carbonate and sulphate scales for cost effective operation
- Compatible with all major membranes
- International potable water approvals
- Dispersant
- Iron tolerant

In addition, this chemical product is an aqueous solution of an organic acid and as such is corrosive in its concentrated form. Corrosion resistant dosing equipment should therefore be used. Examples of suitable materials are 316L stainless steel, or plastics such as GRP, PVC and PE.

Flocon 135 is miscible with water in all proportions. It may be applied as the neat product, or as a solution in permeate, but the minimum dosing solution strength of 10% w/w is recommended. The chemical product should be dosed continuously and proportionately to the feed water flow, to maintain the recommended dose level and guarantee that the water is always treated.

Thus, the purpose of this dosage is to avoid the sedimentation of water hardness, and so the formation of scale on the equipment's surface and prevent the damaging

of membranes in a few time. In addition, scale could lead to higher energy consumption and corrosion problems.

The dose level required is dependent on the quality of the feed water and the saturation indices of the various scale forming species present in the concentrated brine. The dosing station is constituted by:

- RO electric panel, connected to a dosing pump electric panel and a Level switch (LS)
- Dosing pump KMSMF (18 bar; 2 lph)
- Container CNT PD 110 l
- Pulse emitter water meter CTFI 50 (2", 1 imp/l)
- Injection valve 5 bar

The pump is correctly connected to the electrical panel of the first reverse osmosis system. Flocon 135 must be diluted inside the supplied tank only with osmotic water, making a 1:20 dilution, in particular 1 kg of product for every 19 litres of osmotic water. Taking into account the water analysis provided by the costumer, a dosage of 1,5 ppm of pure Flocon 135 is recommended.

In order to determine the required amount of chemical product to add to water, "Flodose", a specific software, will be used after the design of the reverse osmosis plant.

This software requires the following data:

- Type of feed water: brackish water;
- Chemical analysis of water, with appropriate balances;
- Feed flowrate: 11.60 m³/h
- Permeate flowrate: 5.80 m³/h
- Concentrate flowrate: 5.80 m³/h
- Recirculate flowrate: 0 m³/h
- Type of membranes: thin film high rejection membranes
- Recovery: 50%

The simulation obtained with “Flodose” is reported below, with the relative chemical analysis of non-treated and treated water, permeate and concentrate flowrates.

Plant Data				
Feedwater Type:	Brackish Water		Concentrate Flow:	5.80 m³/h
Feedwater Flow:	11.60 m³/h		Recycle Flow:	0.00 m³/h
Permeate Flow:	5.80 m³/h		RO Recovery:	50.00%
System Recovery:	50.00%		Membrane Rejection:	99.22%
RO Membrane Type:	Thin Film High Rejection			

Product Recommendation: – Flocon 135		
Recommended Dose Rates:	1.18 mg/l - Feed	2.35 mg/l - Conc.
Est. Product Usage (100%):	0.33 kgs/day	0.12 MT/yr

Acid Dosing		
Est. Acid Dose (100%):	0.00 mg/l - Feed	
pH Control Method:	None	
Est. Acid Usage (100%):	0.00 kgs/day	0.00 MT/yr

mg/l at 18.0°C	Raw Water	Treated Feed	Product	Concentrate
Ca ²⁺	481.00	481.00	1.55	960.28
Mg ²⁺	195.00	195.00	0.65	389.27
Na ⁺	334.00	334.00	3.64	664.17
K ⁺	18.80	18.80	0.22	37.37
NH ₄ ⁺	0.50	0.50	0.00	1.00
Ba ²⁺	0.02	0.02	0.00	0.04
Sr ²⁺	0.02	0.02	0.00	0.04
Fe ²⁺ /Fe ³⁺ /Mn ²⁺	0.200	0.200	0.001	0.399
Al ³⁺	0.00	0.00	0.00	0.00
HCO ₃ ⁻	220.00	220.00	2.85	436.44
Cl ⁻	190.83	190.83	2.08	379.47
SO ₄ ²⁻	2,187.00	2,187.00	7.64	4,365.54
F ⁻	0.00	0.00	0.00	0.00
NO ₃ ⁻	35.00	35.00	0.80	69.16
PO ₄ ³⁻	0.00	0.00	0.00	0.00
SiO ₂	16.00	16.00	0.13	31.87
CO ₃ ²⁻	0.22	0.22	0.00	1.05
CO ₂	31.66	31.66	30.70	31.61
TDS	3,678.59	3,678.59	19.56	7,336.10
Ionic Strength	0.10	0.10	0.00	0.20
pH	7.00	7.00	5.22	7.27

Saturation Index (SI)	Raw Water	Treated Feed	Concentrate	% Max SI of Flocon 135
LSI	0.160	0.160	0.931	33.25%
SDSI	N/A	N/A	N/A	N/A
CaSO ₄	0.974	0.974	2.276	45.52%
BaSO ₄	3.497	3.497	7.584	6.32%
SrSO ₄	0.002	0.002	0.005	0.02%
CaF ₂	0.000	0.000	0.000	0.00%
SiO ₂	0.144	0.144	0.287	23.93%
Iron/Manganese	4.000	4.000	7.985	13.31%
Aluminium	0.000	0.000	0.000	0.00%

Fig. 4.16 Water chemical analysis obtained with Flodose for Flocon 135 addition at the first reverse osmosis system

At this point, the program provides a series of alternatives that can be chosen depending on preferences. The choice of one chemical product instead of another depends on the specific needs, for example if the removal of iron is preferred rather than sulphates.

In this case, the choice falls on Flocon 135, specifically:

- Inlet concentration: 1.18 mg/l;

- Concentrate concentration: 2.35 mg/l.

The graph below describes the saturation in concentrate with a recovery of 50% for each chemical species prone to fouling. The saturation in concentrate without the addition of chemical is shown in red, while the saturation in concentrate with the addition of Flocon 135 at 1.18 mg/l is shown in blue. As the graph highlights, the addition of the chemical product reduces dramatically the saturation in concentrate of several scaling species.

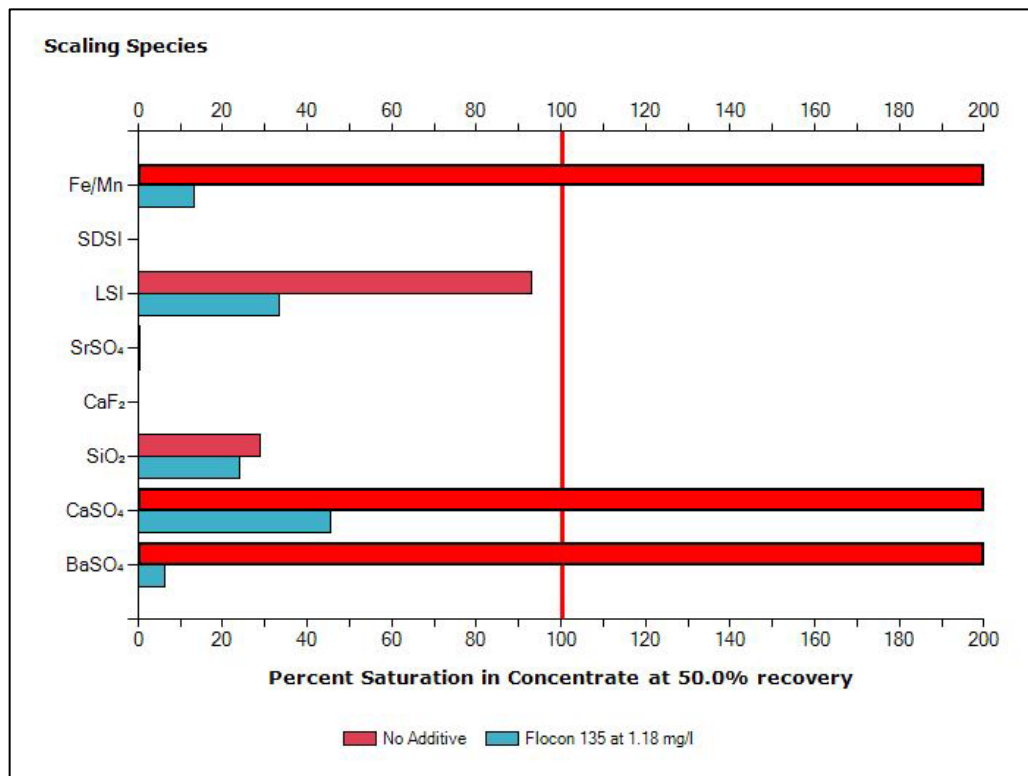


Fig. 4.17 Saturation in concentrate at 50% recovery for several scaling species with and without the addition of Flocon 135

In this specific case, the pump's operating mode is proportional, so the pump automatically adjusts the dosing frequency based on the actual flowrate, passing through the tube.

Thanks to the use of a pulse counter water meter, it is possible to dose the correct amount of chemical product: the number of pulses generated by the meter is directly proportional to the instantaneous flowrate passing through the tube.

In this specific plant, the inlet flowrate is 12000 l/h and the amount of chemical product added is 1.18 mg/l, thus the amount of Flocon 135 needed is around 14160

mg/h. Considering the density of chemical product equal to 1 kg/l, the system requires 0.01416 l/h of chemical product.

Consequently, the most suitable pump is MSA MF (sewage truck, digital version) 1801, which works at a maximum pressure of 18 bar and a maximum flowrate of 1 l/h.

Since the pressure on tubes is 0.1 bar, lower than 18 bar, and as previously calculated, the required amount of Flocon 135 is 0.01416 l/h, less than 1 l/h, the chosen pump results to be suitable for the specific use.

The dimensions of KMSA MF pump are reported below.

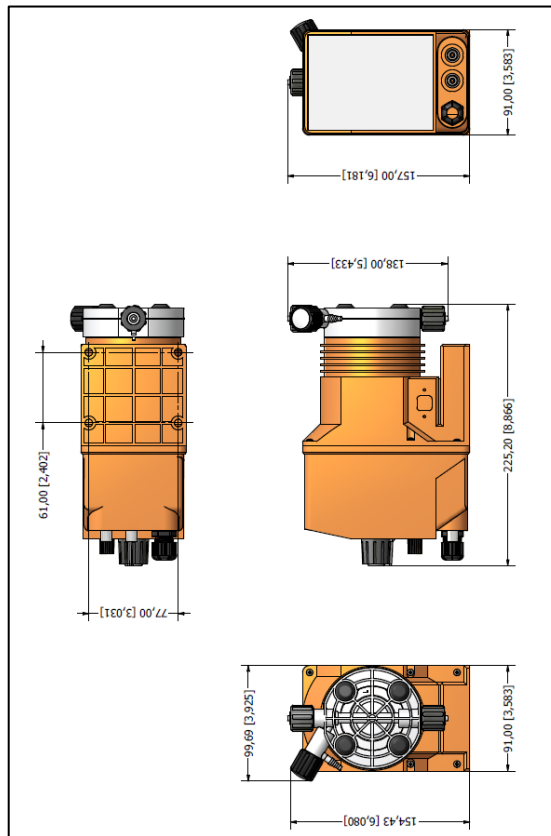


Fig. 4.18 KMSA MF pump dimensions

At this point, the number of pulses per hour sent by the counter water meter is calculated considering the water flow rate in the tubes, 12000 l/h, and 4 pulses/l generated by the counter water meter, obtaining 48000 pulses/h. The following pump curve can be observed:

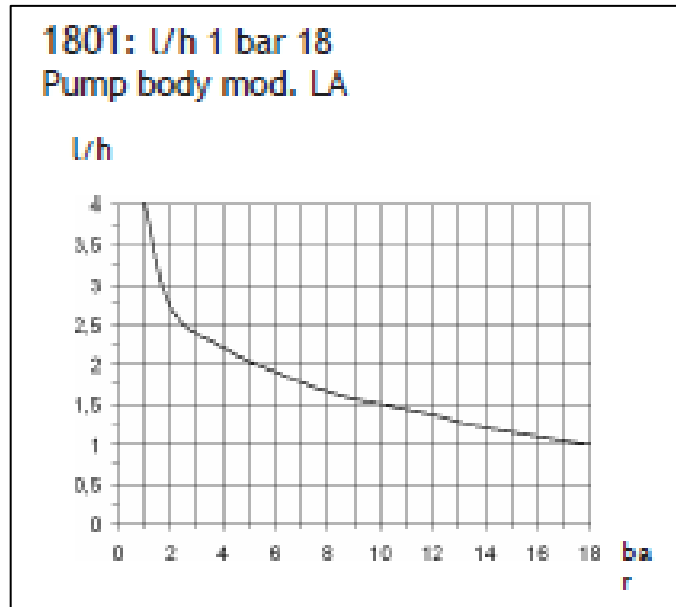


Fig. 4.19 KMSA MF 1801 flow rate curve

Theoretically the pump works at a maximum pressure of 18 bar at 1 l/h, however the tubes are subjected to a lower pressure (atmospheric pressure), therefore the “real” flowrate delivered by the pump at this working pressure is significantly higher. Adopting a pressure of 1 bar, the pump can deliver 4 l/h of water. This large safety margin guarantees the effectiveness of the pump even in more extreme conditions than those considered.

From the technical datasheet of KMSA MF 1801 it is possible to identify two important characteristics of the pump: the maximum number of pulses per minute and the cubic centimetres per stroke distributed by the pump. In particular:

- Minimum number of pulses per hour: 1 pulses/hour
- Maximum number of pulses per minimum: 180 pulses/minute
- Minimum number of cubic centimetres per pulse: 0.03 cc/pulse
- Maximum number of cubic centimetres per pulse: 0.09 cc/pulse

The technical datasheets of the selected pump are reported below.

KMS								
Models	Regolazioni impulsi		Linearietà della regolazione meccanica	Assorbimento medio alla massima portata (230 VAC)	Assorbimento medio alla massima portata (115 VAC)	Assorbimento medio alla massima portata (24 VAC/VDC)	Assorbimento medio alla massima portata (12 VDC)	Peso
	min imp/ora	max imp/min						
2001	1	180	dal 30% al 100%	19 Watt	24 Watt	12 Watt	8.8 Watt	4.1 Kg (9.02 Lbs)
1802	1	180						
1504	1	180						
1005	1	180						
0808	1	180						
0510	1	180						
0501	1	180						
0218	1	180						
KMSA								
1801	1	180	dal 30% al 100%	19 Watt	24 Watt	12 Watt	8.8 Watt	4.1 Kg (9.02 Lbs)
1503	1	180						
103.5	1	180						
100.5	1	180						
085.5	1	180						
057.5	1	180						
0213	1	180						

Fig. 4.20 Technical datasheet concerning the pulses regulation for KMSA-1801 pump

KMSA								
Model	PORTATA				cc per impulso		Pressione massima	
	min cc/h	max l/h	Min GPH	Max GPH	min	max	bar	PSI
1801	0,03	1	0,000008	0,26	0,03	0,09	18	261
1503	0,08	3	0,000021	0,79	0,08	0,28	15	217
103.5	0,10	3,5	0,000026	0,92	0,10	0,32	10	145
100.5	0,02	0,5	0,01	0,13	0,02	0,05	10	145
085.5	0,15	5,5	0,000040	1,45	0,15	0,51	8	116
057.5	0,21	7,5	0,000055	1,98	0,21	0,69	5	72
0213	0,37	13	0,000098	3,43	0,37	1,20	2	29

Fig. 4.21 Technical datasheet about flowrate, cc per pulse and maximum pressure for KMSA-1801 pump

Thus the average value of cubic centimetres per pulse will be considered, 0.06 [cc/pulse] and the pump will be regulated according to this value.

It is important to verify that the number of pulses per minute is lower than 180, to avoid that the pump works at too high stress. In this case, it results 4 stroke/min, thus the selected pump results to be suitable. So 14,16 cm³/h of chemical product have to be dosed.

Knowing the average value of cubic centimetres, 0,06 [cc/stroke] it is possible to calculate the number of stroke per hour: 236 [stroke/h].

Finally, the “Divisor” can be determined from the ratio between the number of pulses per hour, 48000 [pulses/h] and the number of stroke per hour, 236 [stroke/h], thus the “Divisor” results 203, and indicates the number of pulses, received from the pulse counter meter, performed by the pump during a stroke. This value will be set up during the programming of the pump

4.2.2 Multi-cartridge filter

In order to preserve and protect the reverse osmosis membranes, it is always recommended to add a filter to remove any fine sediments that may be suspended in water and causing several problems such as fouling, pressure drop and lower efficiency. The choice of cartridges is based on the type, quality and quantity of water to be treated. In this case, the water quality is very good thanks to the previous mass filtration steps. For this reason, the choice falls mainly on depth cartridges, having maximum capacity to retain fine sediments.

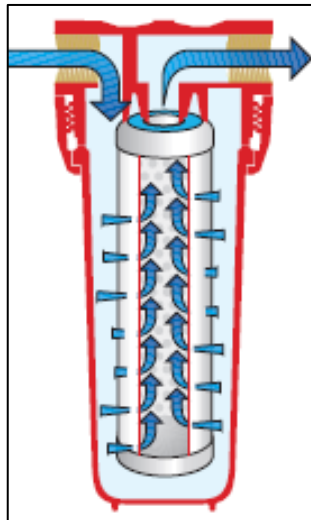


Fig. 4.22 Mechanism of action of cartridge filter for depth filtration

In particular, two types of cartridges are taken into consideration.

1. Wound wire filter cartridges (FA): filter cartridges made with polypropylene thread wound on polypropylene or reinforced polypropylene inner core that guarantees stability. They are available in a wide variety of filter rates, heights, diameters and configurations, with a maximum flowrate of 5000 l/h. Wound thread cartridges are a standard as heavy-duty sediment

filter to remove sand, lime, rust, scale and others suspended sediments. FA wound cartridges are made of uniform and consistent polypropylene thread, strong and homogenous, which makes a compact cartridge construction resulting in a larger filtration surface with improvement in filtration efficiency and in life-span, resulting in higher cost/effective ratio. The inner rigid core is made with particular solutions to achieve the maximum rigidity for every height from 4” to 40”. Furthermore, polypropylene is suitable for many industrial applications due to its wide chemical-physical compatibility to a variety of water based solutions.



Fig. 4.23 Wound polypropylene thread cartridges with double open end

2. Melt-blown polypropylene cartridges: high efficiency cartridges manufactured in specific plant which includes the standardization of production with dedicated software at every process' stage, thermal insulation at controlled temperature, full automation of the whole production line, from the raw-material loading to the finished product packing, without operator direct contact with the product, guaranteeing full hygienic safety. Certified raw material, high productivity and quick delivery time, flexibility of production and custom made products complete the benefits of the range. CPP cartridges are made to comply with the most stringent regulations for applications in drinking water. Furthermore,

polypropylene is suitable for many industrial applications due to its wide chemical-physical compatibility to a variety of water based solutions.



Fig. 4.24 CPP melt-blown polypropylene

Considering that the water flowrate passing through the filter cartridges is high, to guarantee the longest possible duration and the least possible frequency of maintenance, the CPP 30 cartridges are chosen. In fact, it has been noted that, over the time, the thread constituting the FA cartridges tend to get damaged and consequently the filtering capacity decreases. Furthermore, to preserve the cleanliness of subsequent reverse osmosis membranes, cartridges capable of filtering sediments of up to five microns are usually used.

Once the type of filter cartridges suitable for the specific system and their filtering capacity have been identified, the choice of size is made, starting with filter cartridges with a nominal height of 10", which are able to treat up to 2000 l/h. The nominal flowrate is defined by considering the incoming water to be completely clean, free of any sediment and new filter cartridges not yet used. For these reasons, it is necessary to assume a safety coefficient of two in order to ensure the correct functioning of cartridges and guarantee an output water quality consistent with what is declared.

- Cartridges with nominal height of 10", can treat up to 1000 l/h of water;
- Cartridges with nominal height of 20", can treat up to 2000 l/h of water;
- Cartridges with nominal height of 30", can treat up to 3000 l/h of water;
- Cartridges with nominal height of 40", can treat up to 4000 l/h of water.

Since the water flowrate at the inlet of the first reverse osmosis system is 12000 l/h, 5 filter cartridges CPP 30 SX 5 micron, which can treat up to 15000 l/h, are used.

The main characteristics of these filtering cartridges are listed below:

- Maximum operating temperature: 80°C (176°F);
- Minimum operating temperature: 4°C (39°F);
- Average duration: 3- 6 mesi;
- Maintenance: none;
- Suitable for potable water;
- Not suitable in case of microbiological impure water, contaminated or unknown quality.

The water flowrate at the inlet of the second reverse osmosis system is 7000 l/h. In this case five cartridges with nominal height of 20", which can treat up to 10000 l/h of water, are, theoretically, sufficient. But, in order to simplify the maintenance, filter cartridges with nominal height of 30", which can treat up to 15000 l/h of water, are preferred.

The technical datasheet of the polypropylene melt-blown smooth cartridges with double open end is reported below.

CPP SX							
POLYPROPYLENE MELT-BLOWN SMOOTH CARTRIDGES WITH DOUBLE OPEN END (DOE)							
CODE	MODEL	NOMINAL HEIGHT	NOMINAL FILTRATION MICRON	RECOMMENDED FLOW RATE l/h	DIMENSIONS MM		
	OD 2,40" x ID 1,10"				A	B	C
RA5703506	CPP 4 SX 1 mcr	4"	1	800	101	61	28
RA5703508	CPP 4 SX 5 mcr	4"	5	800	101	61	28
RA5703509	CPP 4 SX 10 mcr	4"	10	800	101	61	28
RA5703511	CPP 4 SX 25 mcr	4"	25	800	101	61	28
RA5703514	CPP 4 SX 50 mcr	4"	50	800	101	61	28
RA5704506	CPP 5 SX 1 mcr	5"	1	1000	125	61	28
RA5704508	CPP 5 SX 5 mcr	5"	5	1000	125	61	28
RA5704509	CPP 5 SX 10 mcr	5"	10	1000	125	61	28
RA5704511	CPP 5 SX 25 mcr	5"	25	1000	125	61	28
RA5704514	CPP 5 SX 50 mcr	5"	50	1000	125	61	28
RA5705506	CPP 7 SX 1 mcr	7"	1	1400	173	61	28
RA5705508	CPP 7 SX 5 mcr	7"	5	1400	173	61	28
RA5705509	CPP 7 SX 10 mcr	7"	10	1400	173	61	28
RA5705511	CPP 7 SX 25 mcr	7"	25	1400	173	61	28
RA5705514	CPP 7 SX 50 mcr	7"	50	1400	173	61	28
RA5706506	CPP 10 SX 1 mcr	10"	1	2000	250	61	28
RA5706508	CPP 10 SX 5 mcr	10"	5	2000	250	61	28
RA5706509	CPP 10 SX 10 mcr	10"	10	2000	250	61	28
RA5706511	CPP 10 SX 25 mcr	10"	25	2000	250	61	28
RA5706514	CPP 10 SX 50 mcr	10"	50	2000	250	61	28
RA5706706	CPP 20 SX 1 mcr	20"	1	3000	505	61	28
RA5706708	CPP 20 SX 5 mcr	20"	5	3000	505	61	28
RA5706709	CPP 20 SX 10 mcr	20"	10	3000	505	61	28
RA5706711	CPP 20 SX 25 mcr	20"	25	3000	505	61	28
RA5706714	CPP 20 SX 50 mcr	20"	50	3000	505	61	28

Fig. 4.25 Technical datasheet of polypropylene melt-blown smooth cartridges with double open end

The graph below describes the water flowrate as a function of the pressure drop. Considering as filtering power of 5 microns, and a minimum water flowrate of 2000 l/h, the pressure drop is less than 0,1 bar. Increasing the water flowrate keeping the same cartridge filtering capacity, the pressure difference increases.

Furthermore, filter cartridges have an average lifetime between three and six months. If they are not replaced when necessary, there is an increase in pressure losses because cartridges are full of sediments and impurities, which reduce the flow of incoming water, with a consequent drop in the performance of the filtering system.

This phenomenon can be easily controlled by reading the pressure indicated by the pressure gauge, usually installed before and after the multi-cartridge filter. If the pressure increases, it means that the filter cartridges must be replaced.

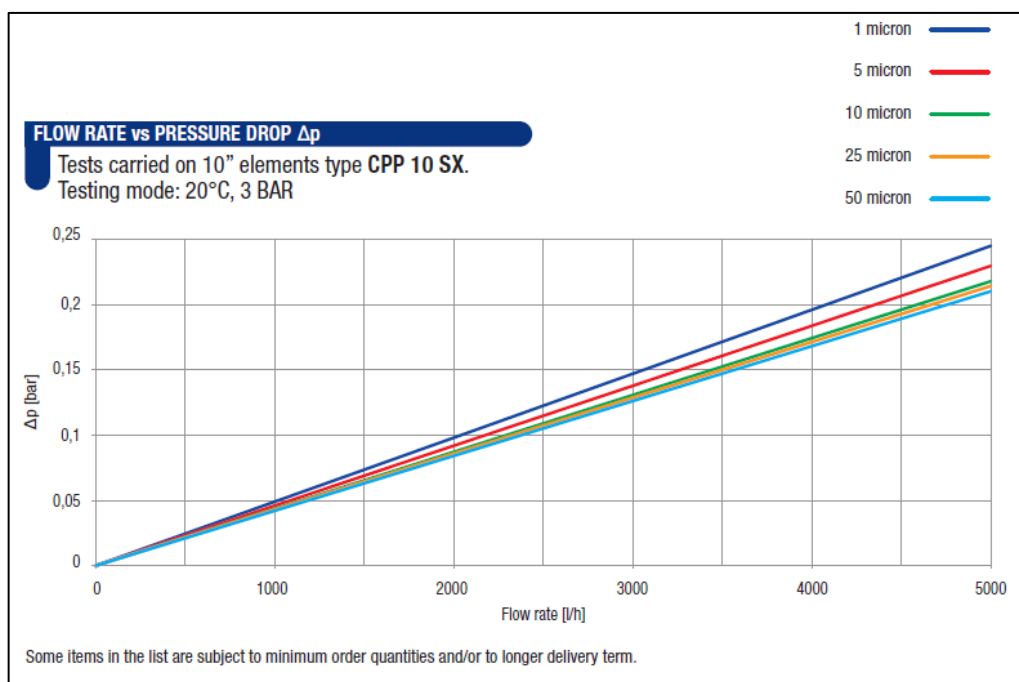


Fig. 4.26 Graph representing the water flowrate as a function of pressure drop for CPP cartridge filters

The previously described filter cartridges will be placed inside a multi-cartridge container capable of treating medium-high flowrates, made with the best materials for a constant search of innovative processing technologies and continuous control to guarantee the absolute quality of products.

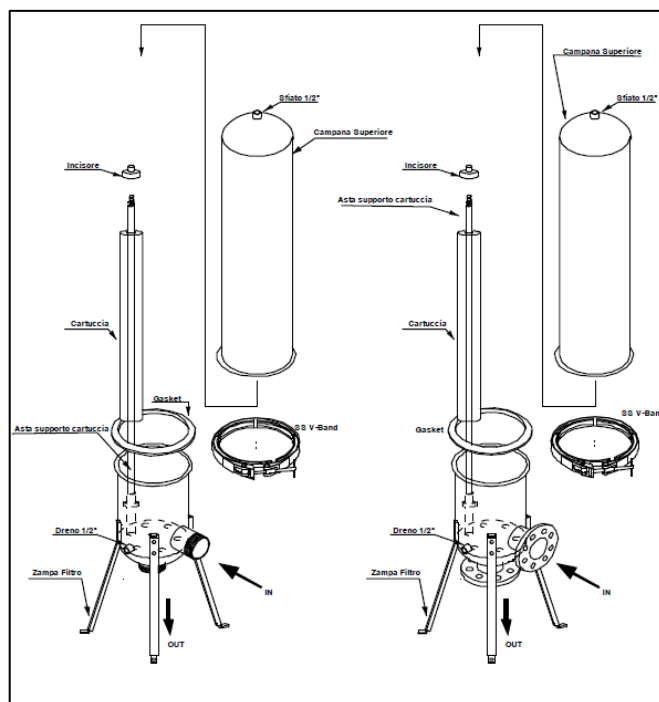


Fig. 4.27 Schematic configuration of a generic multi-cartridge container

There are two main types of containers used for high flowrates filtration systems: FT multi-cartridge containers, made of painted steel, and Hydros, constituted of AISI 306 stainless steel.

- 1) FT: carbon steel container, type Fe360/B subjected to protective hot-dip galvanizing treatments and painted externally with sky blue polyurethane paint. They are used to treat large water flows, especially in industrial applications where reliability and high performance are required;
- 2) Hydros: AISI 316 stainless steel container to prevent corrosion and facilitate cleaning. The internal sealing details are designed to house filter elements in the most common configurations. This container can house any type of SX filter elements and the most recent products in melt-blown polypropylene microfiber, or pleated cartridges with a high filtering surface.



Fig. 4.28 Hydros multi-cartridge container

Obviously, the dimensions of multi-cartridge containers depend on the number and nominal height of filter cartridges, determined considering the flowrate of water that needs to be treated.

In this specific case, Hydros multi-cartridge container is chosen, because it is made of stainless steel which is more suitable for the contact with water intended for food and/or drinking use.

Operating conditions:

- Maximum operating pressure: 9 bar (130 psi)
- Maximum operating temperature: 80°C (176 °F)
- Minimum operating temperature: 4°C (39°F)

The technical datasheet of Hydros container is reported below.

HYDROS contenitori multicartuccia in acciaio inox AISI 316					
CONTENITORI CON FILETTATURE TIPO BSP					
MODELLO	NUMERO CARTUCCE	ALTEZZA CARTUCCE	ATTACCHI IN/OUT	DIMENSIONI mm	
A				A	B
HYDROS 32 A	3	20"	1"1/2	1040	180
HYDROS 52 A	5	20"	2"	1040	213
HYDROS 53 A	5	30"	2"	1420	213
HYDROS 54 A	5	40"	2"	1630	213
HYDROS 62 A	6	20"	2"	1040	213
HYDROS 63 A	6	30"	2"	1420	213
HYDROS 64 A	6	40"	2"	1630	213

Fig. 4.29 Technical datasheet of Hydros multi-cartridge container

4.2.3 Addition of pH corrector chemical product

In the frame of the first reverse osmosis plant, there is a dosing system for the addition of sodium hydroxide solution for pH adjustment. The equipment consists of:

- RO electric panel, connected to a level switch (LS) and a dosing pump electric panel;
- Dosing pump;
- Spring check valve.

In order to determine the required amount of caustic soda to add to water, where the permeate is mixed with the blended, the water analysis at this point has to be considered.

Water Details							
Name	RAW (1)	With chem.dosing (4)	Feed N.A.	Permeate (2)	Blended (7)	Concentrate (3)	Unit
NH4	0.0			0.0	0.0	0.0	ppm
K	18.8			0.7	1.4	36.9	ppm
NA	334.2			1.9	16.0	682.8	ppm
MG	194.5			0.4	8.5	388.6	ppm
CA	481.0			1.0	20.8	961.2	ppm
SR	0.0			0.0	0.0	0.0	ppm
BA	0.0			0.0	0.0	0.0	ppm
CO3	2.5			0.0	0.0	6.6	ppm
HCO3	220.0			1.9	11.9	478.1	ppm
NO3	25.0			1.1	2.1	48.9	ppm
CL	190.2			1.2	9.1	379.2	ppm
F	0.0			0.0	0.0	0.0	ppm
SO4	2187.0			5.1	95.2	4369.6	ppm
SIO2	16.0			0.1	0.7	31.9	ppm
B	0.0			0.0	0.0	0.0	ppm
CO2	22.4			6.6	6.6	8.1	ppm
Total TDS	3669.2			13.5	165.8	7383.8	ppm
Conductivity	6109			25	326	11561	uS
pH	7.0			5.7	6.4	7.7	
Flow	11850.0			5800.0	6050.0	5799.1	l/h
Pressure	11.7					9.8	bar
Osm.Press.	1.3			0.0	0.1	2.4	bar
LSI	0.23					1.56	
S&D	-0.90					0.43	
Ionic Strength	0.098			0.000	0.004	0.198	
CaSO4 saturat.	106.2					225.7	%
BaSO4 saturat.	0.0					0.0	%
SiO2 saturat.	28.6					37.9	%
SrSO4 saturat.	0.0					0.0	%

Fig. 4.30 First reverse osmosis system water analysis

From this analysis, it can be observed that the pH is 6.4, slightly below the recommended limit, which should be between 6.5 and 7.5. In addition, this water has to be employed on food industry for pasta production, so the potable limits imposed by laws must be respected: the value of pH must be increased, otherwise corrosion problems could arise and water could be no more potable.

In order to determine the correct quantity of Caustic Soda to be dosed, the pH definition should be considered:

$$pH = -\log_{10}(a_{H^+}) \approx \log_{10}([H^+])$$

Where a_{H^+} is the activity of hydrogen ions in the solution, $[H^+]$ is the equilibrium molar concentration of H^+ in the solution expressed in $M = [\text{mol/L}]$.

At 25 °C (77 °F), solutions of which the pH is less than 7 are acidic, and solutions of which the pH is greater than 7 are basic., while solutions with pH of 7 at 25 °C

are neutral, so they have the same concentration of H^+ ions as OH^- ions. The neutral value of the pH depends on the temperature and is lower than 7 if the temperature increases above 25 °C. The pH range is commonly given as zero to 14, but a pH value can be less than 0 for very concentrated strong acids or greater than 14 for very concentrated strong bases. ^[14]

In conclusion, according to the water analysis, the system requires the addition of 0.1 ml/m³ of solution, but having 6 m³ of treated water at the exit of the first reverse osmosis implant, the final amount of caustic soda to be dosed is 0.6 ml.

Finally, we can design and select the correct pump for this use.

4.2.4 Dosing pump

In order to dose correctly the caustic soda into the treated water, we use the KMS MF 1802 pump, just mentioned in the previous paragraphs.

Having 0,6 ml/h of NaOH 5%, we regulate the pump at the minimum number of cubic centimetres per stroke, so 0.06 [cc/stroke]. Thus, we determine the number of strokes per hour:

$$\frac{stroke}{h} = \frac{0.6 \text{ ml/h}}{0.06 \frac{cc}{stroke}} = 10 \text{ stroke/h}$$

Remembering that 1 cc = 1 cm³ = 1/1000 l = 1 ml. Considering a dilution of 1:100, we have:

$$\frac{stroke}{h} = 10 \frac{stroke}{h} * 100 = 1000 \text{ stroke/h}$$

Since we have 6000 l/h of water at the exit of the first reverse osmosis implant and 4 imp/l from the pulse emitter water meter, we obtain:

$$\frac{imp}{h} = 6000 \frac{l}{h} * 4 \frac{imp}{l} = 24000 \text{ imp/h}$$

Finally, we can calculate the divisor according to the following equation:

$$N = \frac{24000 \text{ imp/h}}{1000 \text{ stroke/h}} = 24 \text{ imp/stroke}$$

For this purpose, the KMS MF pump has been selected. It is a digital multifunction pump with seven operating modes made of glass-filled polypropylene that provides suitable protection against the damaging effects of chemicals and environment.

Horizontal-mounted dosing pump specifications:

- Minimum stroke per hour: 1;
- Maximum strokes per minute: 180;
- Stroke length range reliability: from 30% to 100%;
- Power consumption at maximum flow: 19 Watt;
- Power supply: 230 VAC

Further informations can be found in the following technical datasheet:



KMS MF

Digital multifunction pump (Constant, Divide, Multiply, PPM, Batch, Volt, mA), stand-by and flow sensor input, alarm output and level control.



SPECIFICATIONS

Min strokes hour: 1
Max strokes minute: 180
Stroke length range reliability: from 30% to 100%
Power consumption at max flow (230VAC): 19 Watt
Power supply: 230 VAC (190÷265 VAC)

LIQUID ENDS

Head: PVDF
O-rings: Viton®
Body valves: PVDF
Balls valves: Ceramic
Diaphragm: PTFE
Delivery hoses: PVDF
Suction hoses: PVC
Viscosity max CPS: 100
Other material configurations available on request

Viton® is a registered trademark DuPont Dow Elastomers.



KMS MF

DIGITAL MULTIFUNCTION PUMP

CODE NUMBER	MODEL	HOSES	PUMP HEAD	FLOW				CC PER STROKE		MAX PRESSURE	WEIGHT
				MIN CC/H	MAX L/H	MIN GPH	MAX GPH	MIN	MAX		
NEA2000001	DOSING PUMP KMS MF 1802	4x6	3/8"	0.06	2	0.000016	0.53	0.06	0.19	18 bar / 261 psi	4.1 Kg
NEA2000002	DOSING PUMP KMS MF 1005	4x6	3/8"	0.14	5	0.000037	1.32	0.14	0.46	10 bar / 145 psi	4.1 Kg
NEA2000003	DOSING PUMP KMS MF 0808	4x6	3/8"	0.22	8	0.000058	2.11	0.22	0.74	8 bar / 116 psi	4.1 Kg

Protection rating IP65 (NEMA4x)

"KMS DIGITAL" series dosing pumps are made from glass-filled polypropylene, which provides suitable protection against the damaging effects of chemicals and the environment.

DESCRIPTION

Horizontal-mounted dosing pump with microprocessor, LCD display, multi-functions: proportional with analogue/digital signals with level control, dual flow regulation, dosing intervals and single injection programmable in 7 different models.

7 OPERATING MODES

CONSTANT. The pump doses at constant intervals.

DIVIDE. Pulses supplied by a water meter connected to the pump are divided by the value entered during programming and determine its dosing interval.

MULTIPLY. Pulses supplied by a water meter connected to the pump are multiplied by the value entered during programming and determine its dosing interval.

PPM. Pulses supplied by a water meter connected to the pump determine dosing based on the set PPM value. The concentration of the product dosed and amount per stroke must be set during programming.

BATCH. The pulse supplied by an external contact starts dosing of the amount of product set during programming.

VOLT. The voltage supplied to the pump (by means of the input signal) determines proportional dosing based on the two minimum and maximum values that have been set for the strokes/minute during programming.

mA. The current supplied to the pump (by means of the input signal) determines proportional dosing based on the two minimum and maximum values that have been set for the strokes/minute during programming.

Mains frequency synchronization so that the magnet receives the same energy every time, providing greater dosing accuracy and longer magnet life.

POWER SUPPLY: 230 V. Other power ratings available on request.

Other models with different pressure / flow rate available on request.

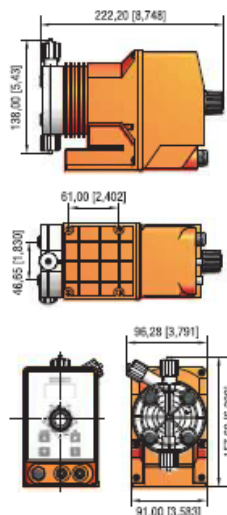


Fig. 4.31 Technical datasheet of KMS MF dosing pump

The dosing pumps for the addition of anti-scale agent and NaOH, with their relative tanks, are reported in the following image, from the forward view.



Fig. 4.32 Anti-scale agent and NaOH dosing pumps with their relative tanks

The first reverse osmosis plant projected is reported in the image below, from the forward view.



Fig. 4.33 First reverse osmosis plant – forward view

4.3 First Outlet: Water for Cooker washing

The cooking system guarantees a deep treatment of the product for the time necessary to produce couscous of the highest possible quality. Uniform cooking is achieved by injecting steam above and below the product, guaranteeing deep and uniform cooking. ^[3]

The water at the exit of the first reverse osmosis plant is suitable for being directly used. In fact, it is sufficient to ensure low water hardness and conductivity to avoid scale problems and absence of bacteria due to food contact.

The washing of the cooking system requires batch consumption at the maximum flowrate of 3000 l/h at the minimum pressure of 3-4 bar. As asked by the customer, this consumption must be considered contemporary to the water intended for dough, leaving the second booster pump on stand-by.

The following images shows the line for couscous production from the cooker to the dryer.



Fig. 4.34 Couscous line from the cooker to the dryer ^[3]

4.4 Second outlet: water for dough

The centrifugal pre-mixer guarantees a perfect pre-mixing of water and raw material. Each grain of flour will receive a film of water on its surface which will then penetrate inside it, completing the hydration phase. It is suitable for all grain sizes, it has very fast transit time without damaging the raw material and it is very easy to clean. The mixing group allows to easily optimize the formulation of the desired granulometry. ^[3]

The customer has required 1700 l/h of softened water at the minimum pressure of 2,5-3 bar.

The water at the outlet of the first reverse osmosis system cannot be directly used, but requires a further step: the removal of possible bacteria present in the water, due to potable reasons and food contact. Therefore, UV sterilizer filter is required.



Fig. 4.35 Mixing tank and cyclones of the couscous production line [3]

4.4.1 UV Sterilizer

The small part of electro-magnetic spectrum having wave lengths included between 100 and 400 nm (thousandths of micron) is defined as the space of the ultra-violet irradiation. The UV-C are part of the subspace characterized by the wave lengths included between 100 and 280 nm. Electro-magnetic waves with different wavelength and width induce interactions with the matter of different nature; the UV-C irradiation with wavelength of 254 nm is particularly interesting thanks to its marked germicidal power.

The high germicidal power of this wavelength must be sought in DNA and in the link of its fundamental components. DNA is a macromolecule present in all living organisms in which all information necessary for life and reproduction reside. The

alteration, induced by the UV-C irradiation, of some chemical links present among nucleotides can change the information contained and conveyed by DNA, these alterations prevent its normal activity, and this irreversibly leads to the cellular death.

For being effective in the disinfection, an electro-magnetic wave, besides being of a certain kind (wavelength equal to 254 nm) it must possess also a minimum value of intensity to be able to ensure a minimum dose to water. A UV sterilizer, if correctly sized, can give water a dose sufficient for reducing almost all the commonest micro-organisms present in water.

Normally a UV disinfection system must have a UV dose higher than 300 J/m^2 . UV-C rays are produced with the help of special fluorescent lamps containing mercury fumes, these lamps are made of a very pure quartz (>99.99% SiO_2) transparent to the UV-C light which they emit in an almost monochromatic form (>95% of $\lambda = 254 \text{ nm}$).

Working conditions:

- Ambient temperature: $5\text{-}45^\circ\text{C}$;
- Water working temperature: $5\text{-}50^\circ\text{C}$;
- Peak until 70°C .

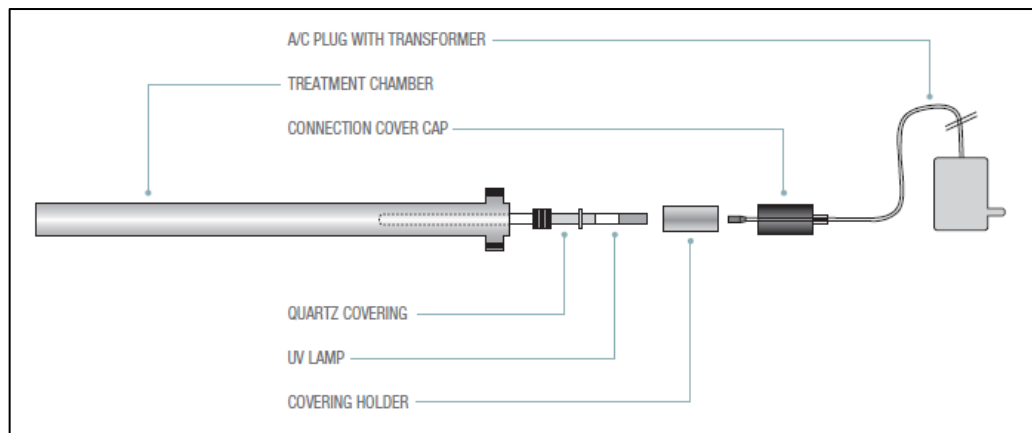


Fig. 4.36 General UV sterilizer configuration

In order to obtain high efficiency sterilizer system, the water to be treated must have high transmittance. Transmittance in optics and spectroscopy represents the ability of a material to allow part of the incident light to pass through it. Therefore, being the ratio between the intensity of the transmitted radiant flux and the intensity of

the incident radiant flux, it is a dimensionless quantity. Materials can be classified based on the transmittance value that characterizes them:

- Exclusively reflective or absorbent materials: transmittance value equal to 0;
- Weakly transmitting materials: transmittance coefficient less than or equal to 0.35;
- Strongly transmitting materials: transmittance coefficient greater than 0.35.

UV-C rays are produced with the help of special fluorescent lamps containing mercury vapours, which are excited by the discharge and emit radiation that is converted by the fluorescent coating of the lamp. Breakage, deterioration or replacement with another type of filter leads to a damage in the characteristics of the radiant source and the consequent possibility of undesirable effects or damage. UV water sterilizers allow the removal of bacteria through the action of ultraviolet germicidal radiation. They can be used as a treatment step in water treatment systems, allowing effective water disinfection without the addition of chemicals. Furthermore, these systems do not require maintenance, except for periodic replacement of lamps.

The customer requires 1700 l/h of softened water intended for the dough, thus UV 2800 LCD sterilizer has been selected, which can treat up to 2800 l/h of pre-treated water.

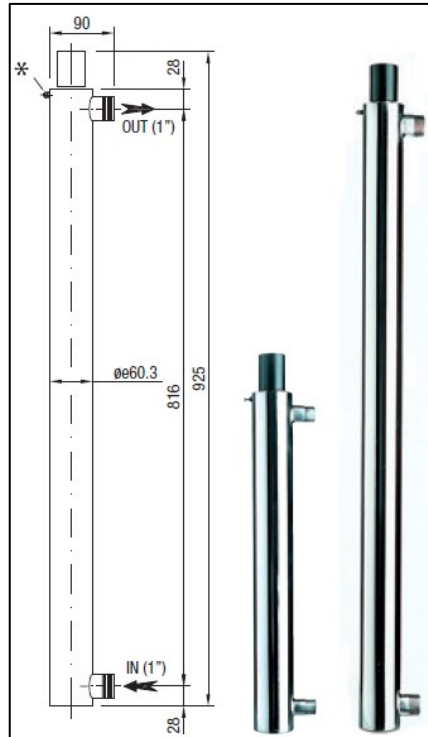


Fig. 4.37 UV 2800 LCD sterilizer

The UV filter is characterized by the following operating characteristics:

- Working pressure: 9 bar (130 psi);
- Lamp life-span: 9000 hours;
- Electrical panel: LCD/LCD PLUS;
- UV chamber materials: AISI 304 or AISI 316L.

The UV sterilizer is powered by an electrical panel equipped with a display that shows the working hours of the lamps, any anomalies, the temperature and the irradiation. These electrical panels have small dimensions to facilitate installation and maintenance operations.

The technical datasheet of UV sterilizers with LCD/LCD PLUS electrical panel is reported below, valid with transmittance 99% at 1 cm, 20°C, after 9000 hours.

PART NUMBER	MODEL	MAX FLOW RATE	UV LAMP	NUMBER OF UV LAMP	ELECTRICAL ABSORPTION	IN/OUT
NEA3500003	UV 1200 LCD	1200 l/h	30W	1	30 W	3/4"
NEA3500004	UV 2800 LCD	2800 l/h	40W	1	40 W	1"
NEA3500009	UV 1200 LCD PLUS	1200 l/h	30W	1	30 W	3/4"
NEA3500010	UV 2800 LCD PLUS	2800 l/h	40W	1	40 W	1"

Fig. 4.38 Technical datasheet of UV sterilizers with LCD/LCD PLUS electrical panel

4.5 Second reverse osmosis system

Knowing that the permeate flowrate at the exit of the second reverse osmosis system must be $3 \text{ m}^3/\text{h}$ as requested by the customer, with the proper chemical and physical properties suitable for feeding the steam generator, the water flowrate at the inlet of that system is $4 \text{ m}^3/\text{h}$, with a recovery of 75%. The simulation obtained with “Sirio” is reported below.

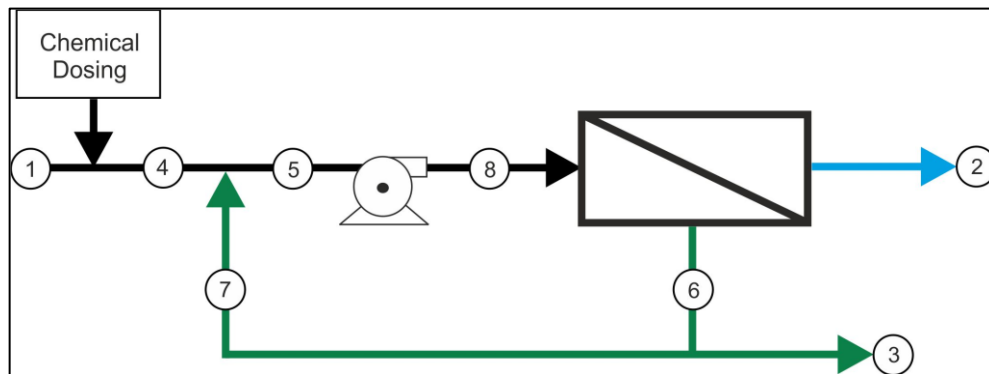


Fig. 4.39 Configuration of the second reverse osmosis plant obtained with the software “Sirio”

Each point is characterized by a certain flowrate:

- Point 1: 4000 [l/h]
- Point 2: 3000 [l/h]
- Point 3: 1000 [l/h]
- Point 4: 4000 [l/h]
- Point 5: 7000 [l/h]
- Point 6: 4000 [l/h]
- Point 7: 3000 [l/h]
- Point 8: 7000 [l/h]

The pressure at point 8 is 5.7 bar, while at point 3 is 4.5 bar, thus the material used for tubes is PVC. In order to obtain the lower possible conductivity and TDS value, three stages are necessary, each of one containing one element per vessel, resulting in 3 membranes LOW4_8040, characterized by 4” in diameter and 40” in length. The technical datasheet of the selected membranes is reported below.

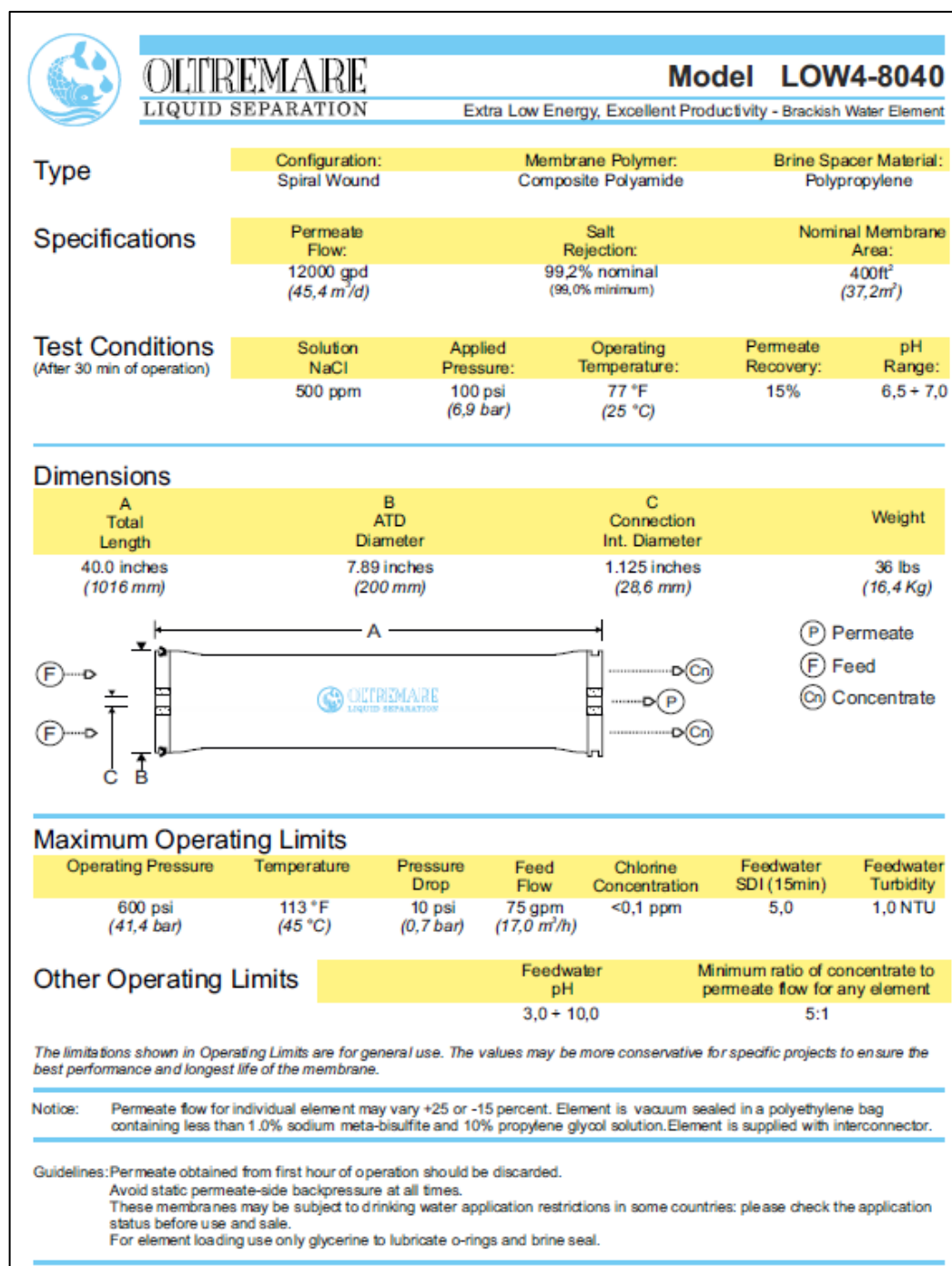


Fig. 4.40 Technical datasheet of LOW4-8040 membranes

Working with a recovery of 75%, it is possible to obtain a water suitable for the use, which permeate is characterized by the following properties:

- TDS: 6 ppm;
- Conductivity: 11 µs/cm;
- pH: 5.9.

The concentrate has the following characteristics

- TDS: 676.7 ppm;
- Conductivity: 1330 $\mu\text{S}/\text{cm}$;
- pH: 7.5.

Since the concentrate TDS is not so elevated for water intended for dough and washing the cooker, it is possible to re-use this flowrate at the first reverse osmosis system, re-insert it into the second storage tank.

The chemical analysis of the feed, permeate and concentrate water flowrates, obtained with the software “Sirio” is reported below.

Plant Data							
Type of RAW water	Well Water		Membrane age	2	years		
SDI	3		Flux decline factor	8			
Temperature	18	°C	TDS increase factor	5			
RO Feed Pressure	5.7	bar	Recirculate	3000.0	l/h		
H.P. Pump Flow	6999.9	l/h	Blend Permeate	0.0	l/h		
Average Perm. Flux	26.9	l/m ² /h	Chemical Dose	3.1	ppm of	NaOH	
Recovery	75	%	Ion-exchange softening	No			

Water Details							
Name	RAW (1)	With chem.dosing (4)	Feed (5)	Permeate (2)	Blended N.A.	Concentrate (3)	Unit
NH4	0.0	0.0	0.0	0.0		0.0	ppm
K	1.4	1.4	2.9	0.4		4.7	ppm
NA	16.0	18.1	40.3	0.8		70.0	ppm
MG	8.5	8.5	19.2	0.2		33.4	ppm
CA	20.8	20.8	47.1	0.4		82.2	ppm
SR	0.0	0.0	0.0	0.0		0.0	ppm
BA	0.0	0.0	0.0	0.0		0.0	ppm
CO3	0.0	0.0	0.1	0.0		0.2	ppm
HCO3	11.9	17.3	38.3	1.1		66.1	ppm
NO3	2.1	2.1	4.0	0.6		6.6	ppm
CL	9.1	9.1	20.2	0.4		35.1	ppm
F	0.0	0.0	0.0	0.0		0.0	ppm
SO4	95.2	95.2	215.5	2.0		375.7	ppm
SiO2	0.7	0.7	1.6	0.0		2.8	ppm
B	0.0	0.0	0.0	0.0		0.0	ppm
CO2	6.5	2.7	2.7	2.6		2.7	ppm
Total TDS	165.8	173.2	389.2	6.0		676.7	ppm
Conductivity	326	334	753	11		1330	uS
pH	6.5	7.0	7.3	5.9		7.5	
Flow	4000.0	4000.0	6999.9	3000.0		999.9	l/h
Pressure	5.7	5.7	5.7			4.5	bar
Osm.Press.	0.1	0.1	0.2	0.0		0.3	bar
LSI	-2.82	-2.11	-1.14			-0.48	
S&D	-4.06	-3.35	-2.34			-1.67	
Ionic Strength	0.004	0.004	0.010	0.000		0.017	
CaSO4 saturat.	0.5	0.5	2.6			6.9	%
BaSO4 saturat.	0.0	0.0	0.0			0.0	%
SiO2 saturat.	0.6	1.3	2.4			3.8	%
SrSO4 saturat.	0.0	0.0	0.0			0.0	%

Fig. 4.41 Second reverse osmosis system water analysis

The final configuration of the second reverse osmosis system is reported in the P&I below.

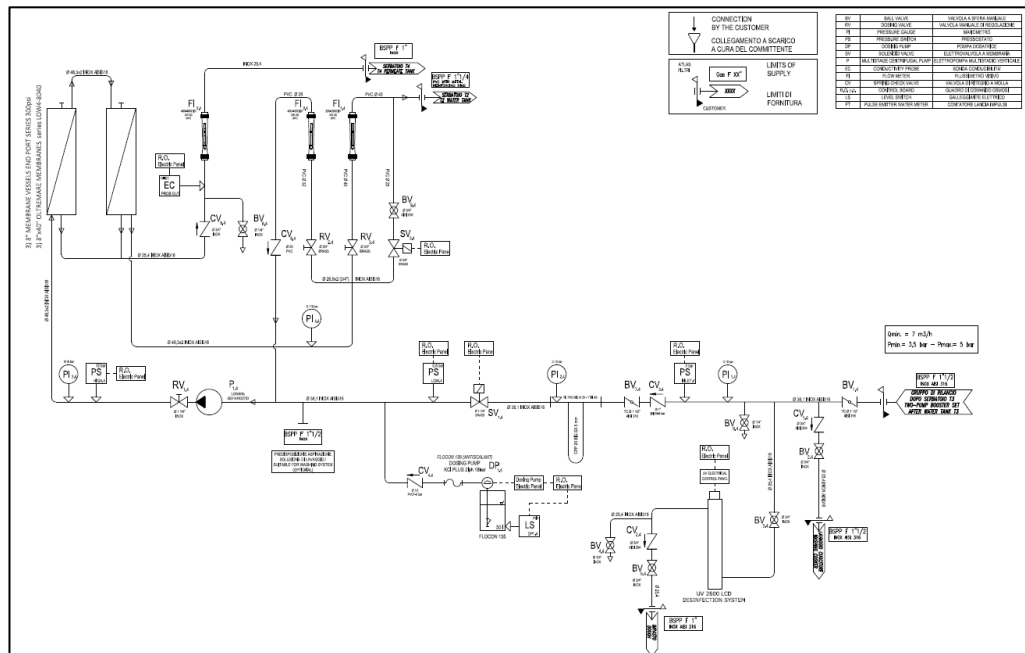


Fig. 4.42 P&I of the second reverse osmosis plant

4.5.1 Addition of anti-scale chemical product

The chemical product used is Flocon 135, previously described. The amount of chemical product to add to water depends on the quality and quantity of treated water, thus the water chemical analysis of the first reverse osmosis system should be considered.

The water at the exit of the first reverse osmosis plant has good quality, however it has 9°F of hardness and $\text{pH} = 6.4$ so, in order to be considered safe, it is recommended to add a chemical product, to avoid the formation of lime scale, damage of membranes and corrosion problems. In addition, since the first reverse osmosis system provides a blending of 250 l/h, the customer could not respect this indication, for example by increasing the flowrate of untreated water added to osmotic water, worsening the quality of water coming into the second system.

As in the previous case, the software “Flodose” is used to determine the amount of required chemical product. This software requires the following parameters:

- Type of feed water: waste water;

- Water chemical analysis, with proper balances;
- Feed water flowrate: 4.00 m³/h
- Permeate flowrate: 3.00 m³/h
- Concentrate flowrate: 1.00 m³/h
- Ricirculate flowrate: 3.00 m³/h
- Type of membranes: thin film high rejection membranes
- Recovery: 75%

The chemical water analysis obtained with the software is reported below, also concerning the recommended dose rates of the chemical product.

Plant Data				
Feedwater Type:	Waste Water		Concentrate Flow:	1.00 m³/h
Feedwater Flow:	4.00 m³/h		Recycle Flow:	3.00 m³/h
Permeate Flow:	3.00 m³/h		RO Recovery:	42.86%
System Recovery:	75.00%		Membrane Rejection:	99.22%
RO Membrane Type:	Thin Film High Rejection			

Product Recommendation: – Flocon 135		
Recommended Dose Rates:	0.50 mg/l - Feed	2.00 mg/l - Conc.
Est. Product Usage (100%):	0.05 kgs/day	0.02 MT/yr

Acid Dosing		
Est. Acid Dose (100%):	0.00 mg/l - Feed	
pH Control Method:	None	
Est. Acid Usage (100%):	0.00 kgs/day	0.00 MT/yr

mg/l at 20.0°C	Raw Water	Treated Feed	Product	Concentrate
Ca²⁺	24.58	24.58	0.17	97.76
Mg²⁺	9.99	9.99	0.07	39.72
Na⁺	21.66	21.66	0.50	85.08
K⁺	1.59	1.59	0.04	6.24
NH₄⁺	0.00	0.00	0.00	0.00
Ba²⁺	0.00	0.00	0.00	0.00
Sr²⁺	0.00	0.00	0.00	0.00
Fe²⁺/Fe³⁺/Mn²⁺	0.060	0.060	0.000	0.239
Al³⁺	0.00	0.00	0.00	0.00
HCO₃⁻	21.64	21.64	0.60	84.19
Cl⁻	10.70	10.70	0.25	42.04
SO₄²⁻	112.38	112.38	0.84	446.73
F⁻	0.00	0.00	0.00	0.00
NO₃⁻	2.26	2.26	0.11	8.70
PO₄³⁻	0.00	0.00	0.00	0.00
SiO₂	2.00	2.00	0.03	7.90
CO₃²⁻	0.04	0.04	0.00	0.65
CO₂	1.14	1.14	1.12	1.13
TDS	206.90	206.90	2.61	819.26
Ionic Strength	0.01	0.01	0.00	0.02
pH	7.50	7.50	5.98	8.07

Saturation Index (SI)	Raw Water	Treated Feed	Concentrate	% Max SI of Flocon 135
LSI	-1.250	-1.250	0.374	13.36%
SDSI	N/A	N/A	N/A	N/A
CaSO₄	0.009	0.009	0.098	1.96%
BaSO₄	0.000	0.000	0.000	0.00%
SrSO₄	0.000	0.000	0.000	0.00%
CaF₂	0.000	0.000	0.000	0.00%
SiO₂	0.017	0.017	0.056	4.70%
Iron/Manganese	1.200	1.200	4.770	7.95%
Aluminium	0.000	0.000	0.000	0.00%

Fig. 4.43 Water chemical analysis of second reverse osmosis system

At this point, the program provides a series of alternatives for the choice of a chemical product rather than another, according to the specific needs, for example if you prefer the removal of iron rather than sulphates.

In this case the choice falls on Flocon 135, specifically:

- In the feed flowrate: 0.5 mg/l
- In the concentrate flowrate: 2.00 mg/l

The graph reported below describes the percentage of saturation of concentrate with a recovery of 75% for each chemical scaling species. The percentage of saturation in the concentrate without the chemical product is represented in red, while the percentage of saturation in the concentrate with the addition of Flocon 135 at 0,5 mg/l is represented in blue.

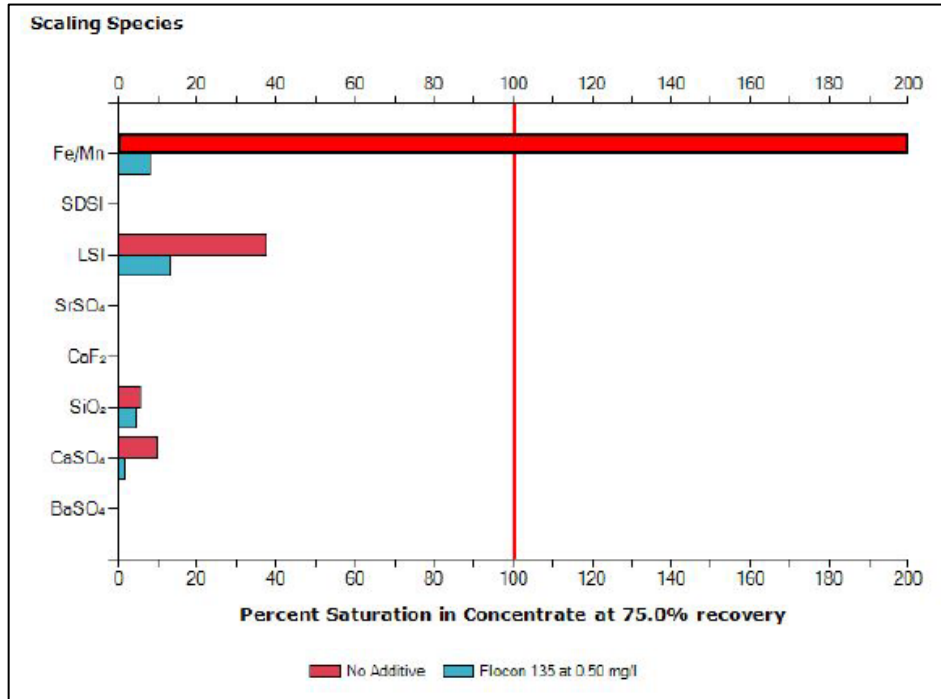


Fig. 4.44 Graph representing the percentage saturation in concentrate at 75% recovery for different scaling species

The feed flowrate of the second reverse osmosis plant is 6000 l/h, which corresponds to the permeate flowrate at the outlet of the first reverse osmosis plant. The required amount of chemical product to add to the flowrate, according to the software “Flowdose”, is 0.5 mg/l, thus:

$$\text{Flocon 135} \left[\frac{\text{mg}}{\text{h}} \right] = 0.5 \left[\frac{\text{mg}}{\text{l}} \right] * 6000 \left[\frac{\text{l}}{\text{h}} \right] = 3000 \left[\frac{\text{mg}}{\text{h}} \right]$$

Considering the density of the chemical product equal to 1 kg/l, the required amount of Flocon 135 is:

$$\text{Flocon 135} \left[\frac{l}{h} \right] = \frac{0.003 \left[\frac{kg}{h} \right]}{1 \left[\frac{kg}{l} \right]} = 0.003 \left[\frac{l}{h} \right]$$

Obviously, if the water entering into the second reverse osmosis plant has a worse quality, for example if the blending at the first reverse osmosis system is higher than the considered, the quantity of required anti-scale product is higher. In fact, having a higher value of the total TDS in the raw water, the resulting value of LSI index is too high, and the software recommends to add a higher quantity of anti-scale product. Consequently, also the quantity of NaOH required increases.

The analysis of water, in the worst case, obtained from the simulation with “Sirio” is reported below.

Plant Data							
Type of RAW water		Well Water		Membrane age		1	years
SDI	3			Flux decline factor	8		
Temperature	18	°C		TDS increase factor	5		
RO Feed Pressure	5.5	bar		Recirculate	3000.0	l/h	
H.P. Pump Flow	6999.9	l/h		Blend Permeate	0.0	l/h	
Average Perm. Flux	26.9	l/m ² /h		Chemical Dose	4.6	ppm of	NaOH
Recovery	75	%		Ion-exchange softening	No		

Water Details							
Name	RAW (1)	With chem.dosing (4)	Feed (5)	Permeate (2)	Blended N.A.	Concentrate (3)	Unit
NH4	0.0	0.0	0.0	0.0		0.0	ppm
K	1.6	1.6	3.2	0.4		5.4	ppm
NA	18.7	21.7	48.7	0.8		84.6	ppm
MG	10.0	10.0	22.7	0.2		39.5	ppm
CA	24.6	24.6	55.8	0.3		97.4	ppm
SR	0.0	0.0	0.0	0.0		0.0	ppm
BA	0.0	0.0	0.0	0.0		0.0	ppm
CO3	0.0	0.0	0.2	0.0		0.6	ppm
HCO3	13.9	21.6	48.1	1.1		82.9	ppm
NO3	2.3	2.3	4.5	0.6		7.5	ppm
CL	10.5	10.5	23.7	0.4		41.1	ppm
F	0.0	0.0	0.0	0.0		0.0	ppm
SO4	112.4	112.4	254.9	1.8		444.8	ppm
SiO2	0.9	0.9	1.9	0.0		3.3	ppm
B	0.0	0.0	0.0	0.0		0.0	ppm
CO2	6.7	1.0	1.1	1.1		1.3	ppm
Total TDS	194.8	205.5	463.7	5.5		807.2	ppm
Conductivity	383	396	894	9		1545	uS
pH	6.5	7.5	7.8	6.3		7.9	
Flow	4000.0	4000.0	6999.9	3000.0		999.9	l/h
Pressure	5.5	5.5	5.5			4.3	bar
Osm.Press.	0.1	0.1	0.2	0.0		0.3	bar
LSI	-2.64	-1.45	-0.49			0.11	
S&D	-3.87	-2.68	-1.69			-1.07	
Ionic Strength	0.005	0.005	0.012	0.000		0.021	
CaSO4 saturat.	0.7	0.7	3.6			9.1	%
BaSO4 saturat.	0.0	0.0	0.0			0.0	%
SiO2 saturat.	0.7	1.1	2.2			3.5	%
SrSO4 saturat.	0.0	0.0	0.0			0.0	%

Fig. 4.45 Analysis of a worse quality water performed with the program “Sirio”

In this specific case, the pump named “KCL PLUS” has been selected. It is a constant or proportional dosing pump with level control for chemical feeding into water.

In the constant dosing mode, the pump doses a constant quantity regularly as configured by the user, while in the proportional dosing mode pump doses a quantity proportionally to an input signal, digital (voltage free contact) or current (mA).

There are several working modes available:

- constant
- constant with 1-10 pulses divider
- multiplier with 1-10 pulses divider
- divider with 1-10 pulses divider
- divider with 1-100 pulses divider
- divider with 1-1000 pulses divider
- mA current signal (0/4 mA = 0 pulses: 20mA = max pulses)

The flow rate is determined by the stroke length, adjustable from 0 to 100%, and by the stroke speed. However, dosing accuracy is guarantee within an adjustment range from 30% to 100%.

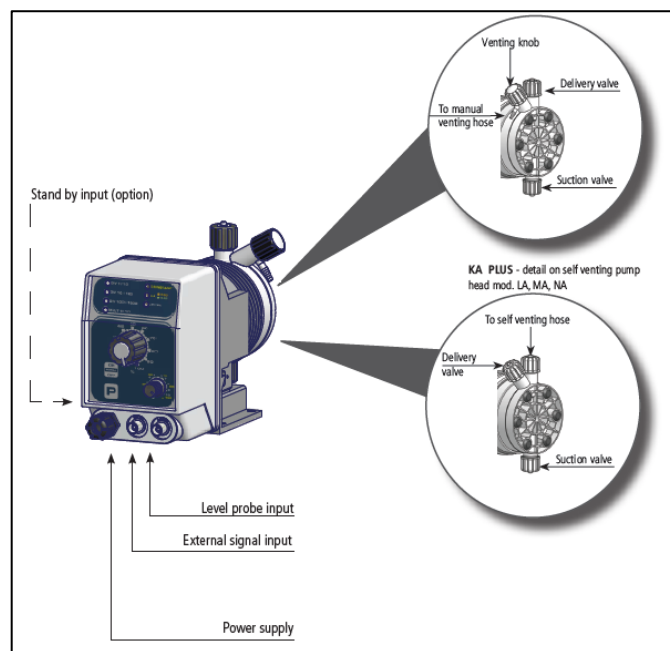


Fig. 4.46 KCL PLUS dosing pump configuration

In particular, the selected pump has a maximum flowrate of 2 l/h and a maximum pressure of 18 bar. Since the pressure inside the tubes is 0.1 bar (lower than 18 bar) and as previously calculated, the required quantity of Flocon 135 to add is 0.003 l/h (lower than 2 l/h), the selected pump is suitable for the use.

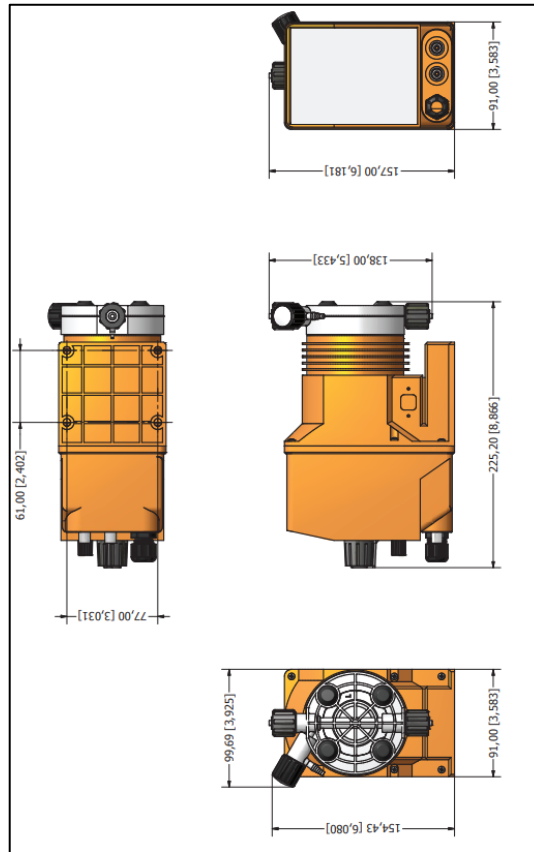


Fig. 4.47 KCL PLUS dosing pump dimensions

At this point, the number of pulses per hour sent by the pulse emitter water meter as a function of the water flowrate can be easily calculated: considering 6000 l/h of feed water, and 4 pulses/l generated, 24000 pulses/h are obtained.

$$\left[\frac{\text{pulses}}{\text{hour}} \right] = 6000 \left[\frac{\text{l}}{\text{h}} \right] * 4 \left[\frac{\text{pulses}}{\text{l}} \right] = 24000 \left[\frac{\text{pulses}}{\text{h}} \right]$$

Now, the pump curve can be observed:

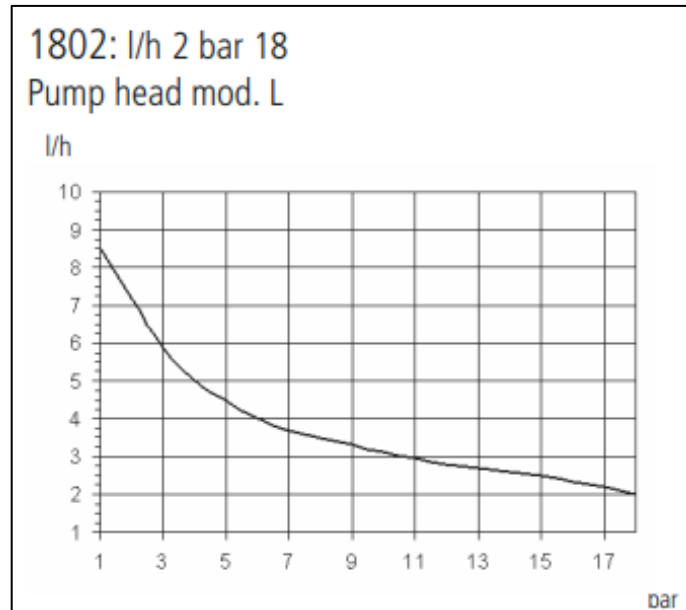


Fig. 4.48 K PLUS delivery curve

From the graph above, theoretically the pump works at a maximum pressure of 18 bar at 2 l/h, but the tubes are subjected to a pressure lower than 1 bar, so the “real” flowrate payable by the pump, at this working pressure, is much higher.

Considering the pressure of 1 bar, the pump is able to provide around 8.5 l/h. This wide safety margin guarantees the efficiency of the pump even at extreme conditions with respect to those considered.

From the technical datasheet of the pump K CL PLUS 1802, it is possible to identify two important characteristics: the maximum number of pulses per minute and the cubic centimetres per stroke payable by the pump.

In particular:

- Minimum number of pulses per hour: 18 pulses/hour
- Minimum number of pulses per minute: 180 impuls/minuto
- Minimum number of cubic centimetres per pulse: 0.06 cc/pulse
- Minimum number of cubic centimetres per pulse: 0.19 cc/pulse

The technical characteristics of the pump are reported below:

CAPACITIES				
K			Hoses	Pump head
2001	1 l/h at 20 bar	0.26 GPH at 290 PSI	4 x 6	I
1802	2 l/h at 18 bar	0.53 GPH at 261 PSI	4 x 6	L
1504	4 l/h at 15 bar	1.06 GPH at 217 PSI	4 x 6	L
1005	5 l/h at 10 bar	1.32 GPH at 102 PSI	4 x 6	L
0808	8 l/h at 8 bar	2.11 GPH at 116 PSI	4 x 6	L
0510	10 l/h at 5 bar	2.64 GPH at 58 PSI	4 x 6	L
0218	18 l/h at 2 bar	4.76 GPH at 29 PSI	6 x 8	M
KA			Hoses	Pump head
1801	1 l/h at 18 bar	0.26 GPH at 261 PSI	4 x 6	LA
1503	3 l/h at 15 bar	0.79 GPH at 217 PSI	4 x 6	LA
103.5	3.5 l/h at 10 bar	0.92 GPH at 102 PSI	4 x 6	LA
100.5	0.5 l/h at 10 bar	0.13 GPH at 102 PSI	4 x 6	JA
085.5	5.5 l/h at 8 bar	1.45 GPH at 116 PSI	4 x 6	LA
057.5	7.5 l/h at 5 bar	1.98 GPH at 58 PSI	4 x 6	LA
0213	13 l/h at 2 bar	3.43 GPH at 29 PSI	6 x 8	MA

Fig. 4.49 Technical datasheet of several pumps (K and KA types) representing the available pressure range

CAPACITY								
K PLUS	FLOW				cc per STROKE		Maximum pressure	
	min	max	Min	Max	min	max	bar	PSI
	cc/h	l/h	GPH	GPH				
2001	30	1	0,01	0,26	0,03	0,09	20	290
1802	60	2	0,02	0,53	0,06	0,19	18	261
1504	120	4	0,03	1,1	0,1	0,37	15	217,5
1005	150	5	0,04	1,3	0,1	0,46	10	145
0808	240	8	0,06	2,1	0,2	0,74	8	116
0510	300	10	0,08	2,6	0,3	0,93	5	72,5
0501	30	1	0,01	0,3	0	0,09	5	72,5
0218	540	18	0,14	4,8	0,5	1,67	2	29

Fig. 4.50 Technical datasheet of several K PLUS pumps representing the available flowrate, cubic centimetres per stroke and maximum pressure ranges

The considered average value of cubic centimetres per pulse is 0.125 [cc/pulse] and the pump will be adjusted according to this value. It is necessary to check that the number of pulses per minute is less than 180, in order to avoid that the pump works at too high stress.

In this case, it results 0.4 strokes per minute, so the pump is suitable for that use.

Therefore, 3000 mg/h = 3 g/h = 3 cc/h of chemical product must be dosed. Knowing the average value of cubic centimetres per stroke, 0.125 [cc/stroke], it is possible to calculate the number of strokes per hour, which is 24 [strokes/hour].

$$\text{Number of strokes per hour} = \frac{3 \left[\frac{\text{cc}}{\text{h}} \right]}{0.125 \left[\frac{\text{cc}}{\text{stroke}} \right]} = 24 \left[\frac{\text{strokes}}{\text{h}} \right]$$

In conclusion, the “Divisor” can be calculated as the ratio between the number of pulses per hour, 24000 [pulses/h] and the number of strokes per hour, 24 [stroke/h], which results:

$$\text{Divisor} = \frac{24000 \left[\frac{\text{pulses}}{\text{h}} \right]}{24 \left[\frac{\text{stroke}}{\text{hour}} \right]} = 1000$$

This value will be set during the pump regulation, and it identifies at which number of pulses received by the pulse emitter water meter the pump performs a stroke.

The dosing pump for the addition of anti-scale chemical product is reported below, with its relative tank.



Fig. 4.51 Anti-scale product dosing pump with its relative tank

The second reverse osmosis system projected is reported in the images below, respectively from forward and backward views.



Fig. 4.52 Second reverse osmosis plant – forward view



Fig. 4.53 Second reverse osmosis plant – backward view

4.6 Third Outlet: water for steam generator

The third and last outlet required by the customer is 3000 l/h of osmotic water intended for degasser in thermal power plant. This water must be treated with a specific chemical product that prevents from several problems, such as:

- corrosion of thermal exchange surfaces;
- incrustations, especially if water was not adequately treated;
- presence of sulphite, not suitable for the contact with food and possible formation of NaCO_3 deposits in the presence of CaCO_3 and MgCO_3 ;
- explosions, due to overheating of thermal exchange surfaces.

4.6.1 Addition of oxygen scavenger chemical product

Since the costumer requires a suitable osmotic water before entering into the steam generator, the concentration of oxygen must to be reduced, otherwise it could cause several problems. In particular, if the water crossing the tubes and heating surfaces presents residual hardness, it could lead to corrosion and explosion phenomena, due to the overheating of surfaces.

Residual hardness leads also to the formation of salts depositions, with a consequent development of a “white coat” on tubes and surfaces, which can lead to higher energy requirements and lower performance of the system.

In order to prevent these problems, the feed water, before entering in the degasser, is added with “Riducen CV”, a chemical product that acts a disincrustant and deoxygenating agent for steam boilers, which can work at pressures up to 63 bar.

It's important to choose a product that respects the FDA (Food and Drug Administration) specifications for steam production in the food industry.

FDA is a government agency responsible for protecting the public health by ensuring the safety, efficacy, and security of human and veterinary drugs, biological products, and medical devices. It also ensures the safety of nation's food supply, cosmetics, and products that emit radiation. In addition, FDA has responsibility for regulating the manufacturing, marketing, and distribution of tobacco products,

advancing the public health by helping to speed innovations that make medical products more effective, safer, and more affordable and by helping the public get the accurate, science-based information they need to use medical products and foods to maintain and improve their health. ^[15]

The reference legislation is UNI EN 12953-10, which defines the quality and characteristics of the feed water entering into the steam generator.

An important parameter reported in this lay is the feed water direct conductivity, that can be higher or lower than 30 $\mu\text{S}/\text{cm}$. According to this reference value, we will choose the most appropriate deoxygenating agent.

The detailed legislation UNI EN 12953-10 is reported below.

Table 5-1 — Feedwater for steam boilers (except attemperator spray water) and hot water boilers				
Parameter	Unit	Feedwater for steam boilers		Make-up water for hot water boilers
Operating pressure	bar (= 0,1 MPa)	> 0,5 to 20	> 20	total range
Appearance	—	clear, free from suspended solids		
Direct conductivity at 25 °C	µS/cm	not specified, only guide values relevant for boiler water see table 5-2		
pH value at 25 °C ^a	—	> 9,2 ^b	> 9,2 ^b	> 7,0
Total hardness (Ca + Mg)	mmol/l	< 0,01 ^c	< 0,01	< 0,05
Iron (Fe) concentration	mg/l	< 0,3	< 0,1	< 0,2
Copper (Cu) concentration	mg/l	< 0,05	< 0,03	< 0,1
Silica (SiO ₂) concentration	mg/l	not specified, only guide values for boiler water relevant, see table 5-2		—
Oxygen (O ₂) concentration	mg/l	< 0,05 ^d	< 0,02	—
Oil/grease concentration (see EN 12953-6)	mg/l	< 1	< 1	< 1
Organic substances (as TOC) concentration	—	see footnote ^e		
^a With copper alloys in the system the pH value shall be maintained in the range 8,7 to 9,2.				
^b With softened water pH value > 7,0 the pH value of boiler water according to table 5-2 should be considered.				
^c At operating pressure < 1 bar total hardness max. 0,05 mmol/l shall be acceptable.				
^d Instead of observing this value at intermittent operation or operation without deaerator if film forming agents and/or excess of oxygen scavenger shall be used.				
^e Organic substances are generally a mixture of several different compounds. The composition of such mixtures and the behaviour of their individual components under the conditions of boiler operation are difficult to predict. Organic substances may be decomposed to form carbonic acid or other acidic decomposition products which increase the acid conductivity and cause corrosion or deposits. They also may lead to foaming and/or priming which shall be kept as low as possible.				

Fig. 4.54 Legislation UNI EN 12953-10 – Feed water for steam boilers and hot water boilers

Parameter	Unit	Boiler water for steam boilers using			Boiler water for hot water boilers
		Feedwater direct conductivity > 30 $\mu\text{S/cm}$		Feedwater direct conductivity $\leq 30 \mu\text{S/cm}$	
Operating pressure	bar (= 0,1MPa)	> 0,5 to 20	> 20	> 0,5	total range
Appearance	—	clear, no stable foam			
Direct conductivity at 25 °C	$\mu\text{S/cm}$	< 6 000 ^a	see Figure 5-1 ^a	< 1 500	< 1 500
pH value at 25 °C	—	10,5 to 12,0	10,5 to 11,8	10,0 to 11,0 ^{b, c}	9,0 to 11,5 ^d
Composite alkalinity	mmol/l	1 to 15 ^a	1 to 10 ^a	0,1 to 1,0 ^c	< 5
Silica (SiO ₂) concentration	mg/l	pressure dependent, according to figure 5-2			—
Phosphate (PO ₄) ^e	mg/l	10 to 30	10 to 30	6 to 15	—
Organic substances	—	see footnote ^f			—

^a With superheater consider 50 % of the indicated upper value as maximum value,

^b Basic pH adjustment by injecting Na₃PO₄, additional NaOH injection only if the pH value is < 10.

^c If the acid conductivity of the boiler feedwater is < 0,2 $\mu\text{S/cm}$, and its Na + K concentration is < 0,010 mg/l, phosphate injection is not necessary. Under the conditions AVT (all volatile treatment, feedwater pH $\geq 9,2$ and boiler water pH $\geq 8,0$) can be applied, in this case the acid conductivity of the boiler water is < 5 $\mu\text{S/cm}$.

^d If non-ferrous materials are present in the system, e. g. aluminium, they may require lower pH value and direct conductivity, however, the protection of the boiler has priority.

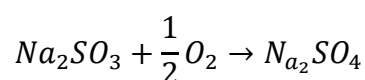
^e If coordinated phosphate treatment is used; considering all other values higher PO₄-concentrations are acceptable (see also clause 4),

^f See ^a in table 5-1.

Fig. 4.55 Legislation UNI EN 12953-10 – Boiler water for steam boilers and hot water boilers

Riducen CV is an aqueous formula suitably stabilized and added up with antifoaming agent, salt sequestering agents and hydrazine free. Its function is to eliminate oxygen formation inside the heating plants and stimulating the formation and maintenance of magnetite (Fe₃O₄) which, adhering to the ferrous surfaces, prevents their corrosion.

As reported below, Riducen CV is based on EDTA, ethylene – diamine - tetra acetic acid, approved as an additive for boiler water systems according to FDA specifications. The deoxygenating action is done by sodium sulphite, which reacts with oxygen producing sulphate sodium, according to the following chemical reaction:



The chelating agents have the ability to complex and prevent the deposition of many cations in the boiler water. The best approach for the control of iron oxides is a combination chelator-polymer. The adsorption of anionic polymers increases the negative charge, reducing their tendency to agglomerate and inhibiting the formation of deposits, which could lead to corrosion and incrustation problems.

The following measures should be taken into account during the use of this chemical product:

- Increasing the bleeding of the boiler in order to check the concentration of dissolved solids;
- Maintaining always an excess of sulphite sodium;
- Keeping the reaction in the pH range between 8,3 and 9,5

According to the technical data sheet, pure Riducen CV has to be dosed in the ratio of 50 - 60 mg/l per ppm of oxygen dissolved in the feed-water, preferentially into the boiler feeding tank downstream the deaerator, or through the boiler expansion tank.

In order to calculate the concentration of oxygen [ppm] dissolved in the feed water, the table on the product safety material data sheet should be considered. This table reports the concentration of oxygen as a function of temperature of the feed water entering into the boiler, which should be known.

In addition, it's recommended to keep the pH range between 8.3 and 9.5 and keep at least 15 to 30 ppm of non-reacted sulphite in the circuit water. ^[16]

The technical data sheet of the chemical product is reported below.

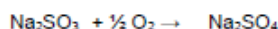
RIDUCEN CV

DEOXYGENATING/SCALES REMOVER FOR STEAM SYSTEMS



APPLICATIONS:

RIDUCEN CV is a scales remover and deoxygenating agent (one drum formulation) for heating systems working up to 63 Bar pressures also under FDA specifications for the production of pure steam. Deoxygenating action is done by sulfite sodium. Its reaction with oxygen can be schematized as follows:



(sulfite sodium) (sulphate sodium)

For a correct use of the product it is necessary to take the following measures:

- Increase the bleeding of the boiler in order to check the concentration of dissolved solids;
- Always maintain an excess of sulphite sodium;
- Make the reaction happen in the following pH range: $8,3 \leq \text{pH} \leq 9,5$.

The active ingredient used in "RIDUCEN CV" is EDTA - ethylene-diamine-tetraacetic acid - approved as an additive for boiler water systems according to FDA specifications. The chelating agents have the ability to complex and prevent the deposition of many cations (hardness and heavy metals) in the conditions of the boiler water. The best approach for the control of iron oxides is a combination chelator-polymer

It should be dosed into the system a sufficient amount of chelating agent to complex hardness and soluble iron and give to the polymer the conditioning and dispersion of all other forms of iron oxides.

DISPERSING/DEFLOCCULANT EFFECT:

The adsorption of anionic polymers increases the negative charge that normally characterizes airborne particles, reducing their tendency to agglomerate and, through its continued suspension, inhibits the formation of deposits.

DOSAGE:

We suggest to measure out $50 \div 60$ RIDUCEN CV ppm for each O_2 ppm dissolved, leaving at least 15-30 ppm of unreacted sulfite into water circuit (to extract the value use a sulfites kit).

In order to protect the entire system (including economizers), it is suggested to dose the product into the feed tank or under the degasser (if present).

CHEMICAL-PHYSICAL FEATURES:

Physical status: limpid liquid

pH > 12,0

Shelf life: 1 year, at environment temperature

Active principle: sulphite sodium – chelator agents – polycarboxylic-phosphine acid



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Fig. 4.56 Technical data sheet of deoxygenating and scale remover agent for steam systems

OXYGEN SOLUBILITY AND PRODUCTS DOSAGE FOR HEATING PLANT

The quantity of oxygen in the water depends on its partial pressure and temperature. At environment pressure and temperature, one liter of water contains from 8 to 10 milligrams of O₂. This concentration decreases while temperature increases however, the solubility of oxygen in the water does not vanish at any temperature. Therefore, even at high temperature, pressurized water can contain significant amounts of dissolved oxygen.

The following table shows the oxygen content according to different temperatures:

OXYGEN CONCENTRATION (ppm)	TEMPERATURE (°C)
9,09	20
7,49	30
6,41	40
5,94	45
5,50	50
4,69	60
3,81	70
2,81	80
2,20	85
1,59	90
0,86	95

PRODUCTS DOSAGE FOR HEATING PLANT:

To locate the correct quantity to be entered in the circuit, multiply the concentration of oxygen corresponding to the temperature of the boiler feed water, for the dosage indicated on the technical note of the recommended product.

Matches: 1 ppm = 1 mg/litre = 1 gram/ton.

Example:

- Inlet water temperature = 85 °C
- From the table we find 2.20 ppm of oxygen dissolved in water

Therefore → 50 ppm of RIDUCEN CV x 2,20 ppm di O₂ = 110 gr/m³

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Fig. 4.57 Technical data sheet of deoxygenating and scale remover agent for steam systems

The use of a chemical product based on sodium sulphite has some negative aspects:

- It can be an allergen, so it cannot be suitable for the food use;
- In the presence of Calcium Carbonate (CaCO_3) and Magnesium Carbonate (MgCO_3) forms Sodium Carbonate (Na_2CO_3) which can lead to encrustations.

On the other hand, it is widely used because it is cost effective.

As an alternative to sulphite, Ascorbate could be used, which has several positive aspects:

- Passivation, which consists of the creation of a magnetite layer that protect the surfaces exposed to hard water from encrustations;
- Rapid deoxygenating action;
- Conditioning of sludge;
- It is not an allergen, it can be freely used in the food industry and it is much employed when we have direct production of steam, in contact with the feed water;
- It's a liquid of easy use and analysis.

Even if it has a higher cost, it requires lower dosing quantity into the boiler, so it lasts more than the sulphite.

In order to select properly the better deoxygenating agent for our use, some important parameters should be taken into account:

- Type of treatment: with or without FDA approval;
- Conductivity of the feed water: lower or higher than $30 \mu\text{S}/\text{cm}$;
- Treatment of condensate: expected or not;
- Type of deoxygenating agent: Sulphite, Ascorbate, DEHA or Carbohydrazide;
- Treatment with one or two chemical product.

The generated vapour has a low pH value due to the presence of CO_2 , resulting in an aggressive environment which could damage the metallic parts of lines. For this reason, condensate should be treated using a specific chemical product, in order to prevent corrosion of the plant.

On the other hand, this could not be in agreement with FDA requirements, thus the pasta manufacturing plants usually avoid their addition.

The following tables show the selection of the most suitable chemical product according to the parameters cited above.

In case of treatment with two products:

Tab. 4.1 Deoxygenating agents (DEHA or Carbohydrazide) suitable for treatment without FDA approval, divided according to feed water conductivity

	Treatment without FDA (ok volatile deox)	
	Feed conductivity > 30 $\mu\text{S}/\text{cm}$	Feed conductivity < 30 $\mu\text{S}/\text{cm}$
DEHA	SWT 276 + SWT 244	SWT 272/273 + SWT 244 (SWT 278 + SWT 244)
Carbohydrazide	SWT 276 + SWT 283	SWT 272/273 + SWT 283 (SWT 278 + SWT 283)

Tab. 4.2 Deoxygenating agents (Sulphite or Ascorbate) suitable for condensate treatment with FDA approval, divided according to feed water conductivity

	Treatment with FDA (not volatile deox)	
	Condensate treatment	
	Feed conductivity > 30 $\mu\text{S}/\text{cm}$	Feed conductivity < 30 $\mu\text{S}/\text{cm}$
Sulphite	SWT 265 + SWT 203/229	SWT 264 + SWT 272/273 + SWT 203/229
Ascorbate	SWT 208 + SWT 203/229 SWT 207 + SWT 276	SWT 272/273 + SWT 207

Tab. 4.3 Deoxygenating agents (Sulphite or Ascorbate) suitable for treatment with FDA approval, without condensate treatment, divided according to feed water conductivity

	Treatment with FDA (no volatile deox)	
	No condensate treatment	
	Feed conductivity > 30 $\mu\text{S}/\text{cm}$	Feed conductivity < 30 $\mu\text{S}/\text{cm}$
Sulphite	SWT 264 + SWT 276	SWT 264 + SWT 272/273
Ascorbate	SWT 205/206 + SWT 276	SWT 205/206 + SWT 272/273

In case of treatment with only one product:

Tab. 4.4 Deoxygenating agents (Sulphite, Ascorbate, DEHA, Carbohydrazide) suitable for treatment with/without FDA approval, with/without condensate treatment

	Treatment with FDA (not volatile deox)		Treatment without FDA (ok volatile deox)
	Condensate conditioning	No condensate conditioning	Condensate conditioning
Sulphite	SWT 260	SWT 265 (SWT 220)	
Ascorbate	SWT 209	SWT 208	
DEHA			SWT 525
Carbohydrazide			

From the previous tables and according to the mentioned parameters, different types of chemical product could be adopted, such as SWT 205, 208, 209, 272.

The deoxygenating agent chosen is SWT 208, a passivating and conditioning agent of sludge for thermal circuits. It is specific for boiler treatments that operate at low/medium pressure according to UNI ENI 12953-10.

This chemical product contains organic acid that reacts with oxygen, eliminating it completely from water and promoting the formation of a passivating layer of magnetite. In addition, due to the use of specific conditioning polymers with high efficiency, represents a complete treatment of boiler's water for the use of vapour in direct contact with the process.

SWT 208 has been chosen because it is a mono-product that contains both dispersing and alkalizing agent without the need of splitting-up the process. This is good in case of low vapour production per unit of time and vapour in contact with the final product.

In addition, a pasta manufacturing plant should not include the recovery of condensation because it could be not in agreement with the FDA requirements.

SWT 208 has to be dosed as function of the content of oxygen in the feed water, maintaining a constant residue of product in the boilers' water. It can be dosed pure or diluted by using a common dosing pump.

The technical datasheet of the chemical product SWT 208 is reported below.

Unfortunately, all the technical datasheets are available only in Italian language, because the supplier company actually works only with the Italian market.

SCHEDA TECNICA

SWT 208

**DEOSSIGENANTE, PASSIVANTE E CONDIZIONANTE DEI FANGHI PER
CIRCUITI TERMICI**

DESCRIZIONE GENERALE

SWT 208 è un deossigenante e condizionante dei fanghi, specifico per il trattamento di caldaie che operano a media/bassa pressione in accordo con le norme **UNI EN 12953-10**. **SWT 208** contiene un acido organico che reagisce rapidamente con l'ossigeno, eliminandolo completamente dall'acqua e promuovendo la formazione di uno strato passivante di magnetite. Inoltre, grazie all'utilizzo in formulazione di specifici polimeri condizionanti dei fanghi, di estrema efficacia, rappresenta un trattamento completo delle acque di caldaia, laddove sia richiesta l'approvazione **FDA** per uso di vapore a diretto contatto con il processo.

- Rapida azione deossigenante
- Promuove la formazione di magnetite
- Condizionante dei fanghi
- **Le sue materie prime sono incluse nella lista GRAS della F.D.A.**
- Liquido di facile impiego e di semplice analisi

DOSAGGIO

SWT 208 si dosa in funzione del contenuto di ossigeno nell'acqua di alimento. Il suo dosaggio deve essere tale da mantenere un costante residuo di prodotto nell'acqua di caldaia. Il nostro consulente autorizzato Vi suggerirà il dosaggio ideale per il Vostro impianto.

SWT 208 viene dosato tal quale o diluito tramite una normale pompa dosatrice.

CARATTERISTICHE CHIMICO FISICHE

Aspetto	liquido chiaro bruno
Densità (g/cm ³)	1,14 a 20°C
pH	circa 12,0

ISTRUZIONE SICUREZZA

Prodotto alcalino. Evitare il contatto con la pelle e gli occhi. In caso di contatto accidentale lavare abbondantemente con acqua. Per irritazioni persistenti affidarsi alle cure di un medico.

IMBALLAGGIO

Il **SWT 208** viene fornito in:

- Taniche 27 Kg.
- Fusti 230 Kg.
- Cisterne 1.000 Kg.

Fig. 4.58 Technical datasheet of SWT 208 chemical product

As an alternative to SWT 208, other deoxygenating agents could be used. For example, in the case of FDA treatment, without volatile deoxygenating agent and without the condensate treatment, SWT 205 could be adopted, which is a deoxygenating agent based on ascorbate, in combination with SWT 272, that is a sludge conditioner.

SWT 205 is a deoxygenating agent based on ascorbate that reacts rapidly with oxygen, eliminating it from water and promoting the creation of a passivating layer of magnetite. The use of SWT 205 with SWT 276 represents a complete treatment for the boiler's water, when the FDA approval is required. It is dosed as a function of the content of oxygen dissolved in the feed water, maintaining a constant residue of product into the water alimenting the boiler.

The technical data sheet of SWT 205 is reported below.

SCHEDA TECNICA

SWT 205

DEOSSIGENANTE E PASSIVANTE PER CIRCUITI TERMICI

DESCRIZIONE GENERALE

SWT 205 è un deossigenante a base di ascorbati che reagisce rapidamente con l'ossigeno, eliminandolo completamente dall'acqua e promuovendo la formazione di uno strato passivante di magnetite. Inoltre, l'impiego di **SWT 205** insieme a **SWT 276** rappresenta un trattamento completo delle acque di caldaia laddove sia richiesta l'approvazione FDA per uso di vapore a diretto contatto con il processo.

- Rapida azione deossigenante
- Promuove la formazione di magnetite
- **Le sue materie prime sono incluse nella lista GRAS della F.D.A.**
- Liquido di facile uso

DOSAGGIO

SWT 205 si dosa in funzione del contenuto di ossigeno nell'acqua di alimento. Il suo dosaggio deve essere tale da mantenere un costante residuo di prodotto nell'acqua di caldaia. Il nostro consulente autorizzato Vi suggerirà il dosaggio ideale per il Vostro impianto.

SWT 205 viene dosato tal quale o diluito tramite una normale pompa dosatrice.

CARATTERISTICHE CHIMICO FISICHE

Aspetto	Liquido bruno
Densità (g/cm ³)	1,07 a 20°C
pH	5,0

ISTRUZIONE SICUREZZA

Prodotto acido. Evitare il contatto con la pelle e gli occhi. In caso di contatto accidentale lavare abbondantemente con acqua. Per irritazioni persistenti affidarsi alle cure di un medico.

IMBALLAGGIO

Il **SWT 205** viene fornito in :

- Taniche 25 Kg.
- Fusti 220 Kg.
- Cisternette 1.000 Kg.

Confezioni a perdere.

Fig. 4.59 Technical datasheet of SWT 205 chemical product

In general, a steam generator requires to different products:

- A deoxygenating agent, mentioned before;
- A chemical conditioner for boiler sludge, which maintains the pH value at basic level, in order to neutralize the acidity of the osmotic water and reduce the salts precipitates.

A part of the generated steam, called “Reinstatement”, turns to the liquid state and it is not employed in the steam production. In case of pasta factory this amount consists on around 10-30% that is re-integrated into the process. Since this part is at elevated temperature, the water in the tank before the boiler will be at higher temperature too. In the calculation of the oxygen concentration, we will use this

temperature value. The higher the temperature, the lower the concentration of oxygen and so the lower will be the required amount of deoxidizing agent.

Another part of the system is characterized by the Purge, which consists on a flux of water enriched with salts, that could concentrate due to the increasing of conductivity. This can be done through:

- Time valve, that discharge the water at pre-set time intervals;
- Conductivity probe, that according to the value of conductivity measured discharge the related amount of water.

Finally, there is an Economizer, that recovers the heat from the boiler fumes in order to increase the temperature of the feed water. As a consequence, several improvements can be achieved:

- Lower required energy;
- Higher water temperature;
- Reduced gas consumption;
- Lower amount of chemical product required.

As an alternative to the Economizer, the direct injection of vapour could be performed, in order to increase the temperature. However, this option is not well recommended because it is hazardous due to the poor control of the process.

The use of a chemical product in addition to the degasser is defined by UNI ENI 12953-10:2005, a technical regulation that specifies the requirements related to the quality of feed water and water within the boiler. It must be performed a chemical conditioning very low, according to the temperature of the feed water, because the boiler acts as a salts concentrator, due to the higher temperature, which leads to salts depositions and encrustations.

According to the temperature of water entering in the boiler and considering the technical data sheets of Riducen CV, 50 ppm of chemical product for each ppm of oxygen dissolved should be dosed.

Consequently, two different values of the oxygen concentration and also two different amounts of dosed Riducen CV are obtained:

- For temperature around 60°C, we will have approximately 4.69 ppm of oxygen, so it requires 234.5 ppm of deoxygenating agent.
- For temperature around 80°C, we will have approximately 2.81 ppm of oxygen, so it requires 140.5 ppm of deoxygenating agent.

These results underline that the lower the temperature, the higher the amount of chemical product to add into the feed water. For this reason, it is preferred to integrate some hot water from the steam generator. ^[17]

An example of sludge conditioner is SWT 272, an optimized mixture of phosphates and inorganic alkalinizers for pH control and sludge conditioning in the boiler water. Any trace of hardness introduced with the feed water precipitates in the form of hydroxyapite, also named incoherent sludge. It prevents the particles from sticking to the generator walls and facilitating their removal with the usual sludge removal operations.

In addition, the alkalinizing activity is obtained without the use of alkaline hydroxides, in accordance with the UNI EN 12953-10 standard. Defined for the treatment of smoke tube steam generators with low conductivity feed water. SWT must be dosed in order to ensure a constant phosphate reserve in the boiler water.

The technical data sheet of SWT 272 is reported below.

SCHEDA TECNICA

SWT 272

CONDIZIONANTE DEI FANGHI ED ALCALINIZZANTE PER ACQUE DI CALDAIA ESENTE DA IDROSSIDI ALCALINI

DESCRIZIONE GENERALE

SWT 272 è una miscela ottimizzata di fosfati ed alcalinizzanti inorganici per il controllo del pH ed il condizionamento dei fanghi nelle acque di caldaia. Eventuali tracce di durezza introdotte con le acque di alimento vengono precipitate sotto forma di idrossiapatite (fango incoerente), impedendo che le particelle si attacchino alle pareti del generatore e favorendone l'allontanamento con le usuali operazioni di defangazione. L'attività alcalinizzante, sinergica con il fosfato, è ottenuta senza impiego di idrossidi alcalini, in accordo a quanto indicato nella norma UNI EN 12953-10 per il trattamento di generatori di vapore a tubi di fumo con acque di alimento a bassa conducibilità.

- Inibisce le incrostazioni ed i depositi da durezza
- Mantiene pulite le superfici ed ottimizza gli scambi termici
- **Approvato FDA**
- Non contiene idrossido di sodio o di potassio
- Conforme alla norma UNI EN 12953-10 per il trattamento di generatori di vapore a tubi di fumo
- Liquido di facile impiego e di semplice analisi

DOSAGGIO

SWT 272 deve essere dosato in modo da garantire una costante riserva di fosfato nell'acqua di caldaia. Il nostro consulente autorizzato Vi suggerirà il dosaggio corretto per il Vostro impianto. **SWT 272** può essere alimentato direttamente tal quale o diluito, impiegando delle normali pompe dosatrici.

CARATTERISTICHE CHIMICO FISICHE

Aspetto	liquido incolore - giallo chiaro
Peso specifico (g/cm ³)	1,02 - 1,08 a 20 °C
Punto di congelamento	-5 °C
pH tal quale	11,0 - 13,0

ISTRUZIONE SICUREZZA

Evitare il contatto con la pelle e gli occhi. In caso di contatto accidentale lavare| abbondantemente con acqua. Per irritazioni persistenti affidarsi alle cure di un medico.

IMBALLAGGIO

Il prodotto **SWT 272** viene fornito in:

- Taniche 26 kg
- Fusti 220 kg
- Cisternette 1.000 kg

Fig. 4.60 Technical datasheet of SWT 272 chemical product

Coming back to the treatment with only one product, respecting the FDA requirements and adopting a condensate conditioning, the appropriate deoxygenating agent in this case could be SWT 209.

This deoxygenating agent is based on ascorbate, which reacts rapidly with oxygen, eliminating it completely from water, promoting the formation of a passivating layer of magnetite.

In addition, thanks to the presence of neutralizing amines and specific substances that act against encrustations and dispersions, SWT 209 allows a correct treatment of steam and condensate lines, where the FDA approval is required, avoiding the formation of deposits in the boiler.

It is dosed according to the content of oxygen dissolved in the water, keeping a constant residue of product into the boiler's water and a pH value in the condensate higher than 0,8.

The technical data sheet of SWT 209 is reported below.

SCHEDA TECNICA

SWT 209

DEOSSIGENANTE, ANTINCROSTANTE E NEUTRALIZZANTE DELLE CONDENDE PER CIRCUITI TERMICI

DESCRIZIONE GENERALE

SWT 209 è un deossigenante a base di ascorbati che reagisce rapidamente con l'ossigeno, eliminandolo completamente dall'acqua e promuovendo la formazione di uno strato passivante di magnetite. Inoltre, grazie alla presenza di ammine neutralizzanti e specifiche sostanze antincrostanti e disperdenti, SWT 209 permette un corretto trattamento delle linee vapore e condense, laddove sia richiesta l'approvazione FDA per l'uso di vapore a diretto contatto con il processo ed evita la formazione di depositi in caldaia.

- Rapida azione deossigenante
- Promuove la formazione di magnetite
- Condizionante dei fanghi
- **Le sue materie prime sono incluse nella lista GRAS della F.D.A.**
- Liquido di facile impiego e di semplice analisi

DOSAGGIO

SWT 209 si dosa in funzione del contenuto di ossigeno nell'acqua di alimento. Il suo dosaggio deve essere tale da mantenere un costante residuo di prodotto nell'acqua di caldaia ed un pH superiore a 8,0 nel condensato. Il nostro consulente autorizzato Vi suggerirà il dosaggio ideale per il Vostro impianto.

SWT 209 viene dosato tal quale o diluito tramite una normale pompa dosatrice.

CARATTERISTICHE CHIMICO FISICHE

Aspetto	liquido da giallognolo a bruno
Densità (g/cm ³)	1,08 a 20°C
pH	circa 11,5

ISTRUZIONE SICUREZZA

Prodotto alcalino. Evitare il contatto con la pelle e gli occhi. In caso di contatto accidentale lavare abbondantemente con acqua. Per irritazioni persistenti affidarsi alle cure di un medico.

IMBALLAGGIO

Il **SWT 209** viene fornito in :

- Taniche 25 Kg.
- Fusti 220 Kg.

Fig. 4.61 Technical datasheet of SWT 209 chemical product

4.6.2 Calculation of oxygen scavenger's consumptions

Since several parameters about the functionality of the boiler are unknown, they will be supposed. In the calculations below, the following values have been considered:

- Average production of the boiler: 3 t/h;
- Operating mode: 16 hours per day for 6 days, for 52 weeks, resulting in 4992 hours per year;

- Feed water temperature: 95°C;
- Oxygen content: 0.8 ppm.

The conductivity of feed water coming from the second reverse osmosis system is 11 µs/cm, as previously reported in the simulation obtained with the software “Sirio”, which is lower than the limit value of 30 µs/cm. In addition, FDA treatments will be performed, using only one product, with respect to the reference legislation UNI EN 12953-10.

The following table represents the amount of oxygen dissolved in water as a function of temperature and the consequent DEHA dosing:

Tab. 4.5 DEHA consumption as a function of the amount of oxygen dissolved, related to water temperature

Feed water temperature (°C)	Dissolved oxygen (ppm)	DEHA consumption (ppm)
100	< 20 ppb	0,25
95	0,8	1,5
90	1,6	3,25
85	2,2	4,5
80	2,9	5,75
75	3,4	6,75
70	3,9	7,75
65	4,3	8,75
60	4,7	9,75
55	5,2	10,5
50	5,6	11,25
45	6,1	13,25

Consequently, the consumptions of the selected product can be calculated:

- Generated steam, defined as the product between the average boiler’s production and the hours per year in which the boiler works:

$$\text{Produced steam} = \frac{\text{average boiler's production}}{\text{working conditions}}$$

Practically, the following result is obtained:

$$\text{Produced steam} = 3 \left[\frac{t}{h} \right] * 4992 \left[\frac{h}{\text{year}} \right] = 14976 \left[\frac{t}{\text{year}} \right]$$

- Dosing of the deoxygenating agent: from table 7, considering the temperature of feed water equal to 95°C, 1.5 ppm of DEHA will be

consumed, and assuming the active DEHA's concentration of 4% into the product, we obtain:

$$\text{Dosing of deoxygenating agent} = \frac{100}{4} * 1.5 \text{ [ppm]} = 37.5 \text{ [ppm]}$$

- Product consumption, obtained multiplying the dosage of the chemical product by the content of oxygen dissolved in the feed water:

$$\text{Product consumption} = \text{chemical dosage} * \text{oxygen concentration}$$

Practically, the following result is obtained:

$$\text{Product consumption} = 37.5 \text{ [ppm]} * 0.8 \text{ [ppm]} = 30 \left[\frac{g}{t} \right]$$

- Annual consumption of product, calculated from the product consumption divided by 1000 and multiplied by the steam production:

$$\begin{aligned} \text{Annual product consumption} \\ = \frac{\text{product consumption}}{1000} * \text{produced steam} \end{aligned}$$

Practically, the following result is obtained:

$$\begin{aligned} \text{Annual product consumption} &= \frac{30 \left[\frac{g}{t} \right]}{1000} * 14976 \left[\frac{t}{\text{year}} \right] \\ &= 449 \left[\frac{kg}{\text{year}} \right] \end{aligned}$$

The adopted dosing pump for the addition of deoxygenating agent is reported in the image below.



Fig. 4.62 Deoxygenating agent dosing pump with its relative tank

4.6.3 Deaerator

A deaerator is a device used for the removal of dissolved gases such as oxygen from a liquid.

In particular, thermal deaerators are used to remove dissolved gas in the feed water before going to the steam-generating boilers^{[18] [19]}. In fact, the presence of oxygen dissolved in the feed water causes serious problems to the boiler, because this gas attaches to the walls of the equipment, and in particular metal piping, forming oxides which lead to the formation of rust. Furthermore, dissolved carbon dioxide tend to combine with water forming the carbonic acid, which may cause additional corrosion.

For these reasons, most deaerators are designed to remove oxygen down to seven parts per billion by weight, completely eliminating carbon dioxide.^[20]

Another type of deaerators, named vacuum deaerators, are used to remove dissolved gases from products like food, personal care and cosmetic products, chemicals and pharmaceuticals.^[21]

Their aim consists on:

- increasing the dosing accuracy in the filling process;
- increasing the product shelf stability;
- preventing oxidative effects such as discolouration, changes of smell or taste, rancidity;
- altering the pH;
- reducing the packing volume

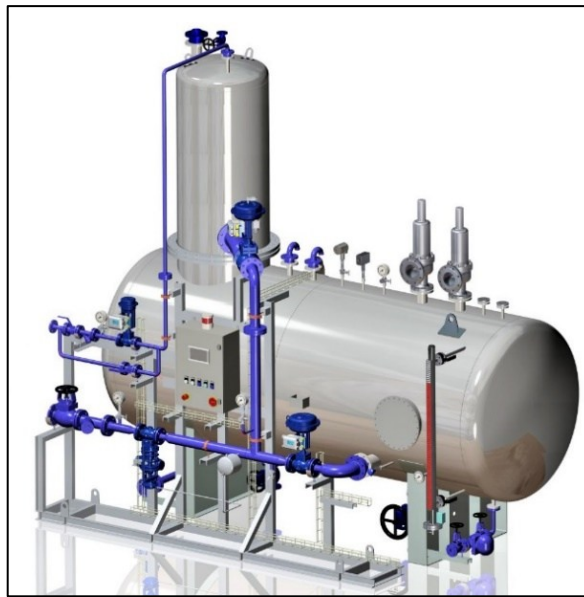


Fig. 4.63 General illustration of a thermal deaerator ^[22]

Oxygen and Nitrogen are two non-condensable gases that are removed by deaeration. In particular, thermal deaeration is based on the principle that the solubility of a gas in water decreases as the water temperature increases, until it approaches its boiling point. In the deaerator, water is heated up closed to its boiling point, with a minimum pressure drop and minimum vent.

A temperature of about 105 °C and an operating pressure around 0.2 bar are actually commonly adopted in low-pressure slide-in degassers.

The following diagram shows the content of dissolved oxygen in the pure water [mg/l] as a function of different temperatures [°C] and absolute pressures [bar].

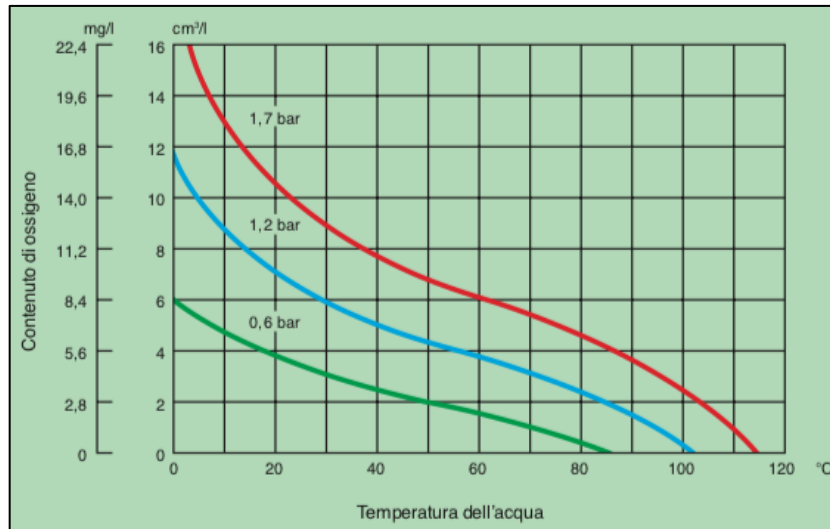


Fig. 4.64 Oxygen solubility in pure water at different temperatures and absolute pressures ^[22]

Looking at the graph, it can be seen that at the boiling temperature of 105°C defined for the operating pressure of 0.2 bar, there is no more oxygen dissolved in the water. Deaeration is done by spraying the feed water into a chamber to increase its surface area, and may involve flow over multiple layers of trays. This stripping steam is fed to the bottom of the deaeration section of the deaerator. When steam contacts the feed water, it heats up to its boiling point. In this way, dissolved gases are released from the feed water and vented from the deaerator through the vent. The treated water falls into a storage tank below the deaerator. ^{[23] [20]}

Oxygen scavenging chemicals are very often added to the deaerated boiler feed water to remove any last traces of oxygen that were not removed by the deaerator. The type of chemical added depends on whether the location uses a volatile or non-volatile water treatment program.

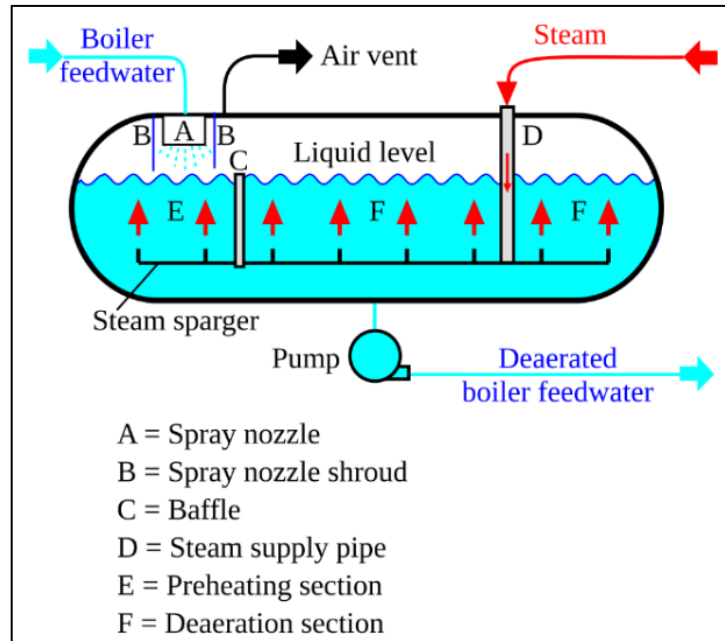


Fig. 4.65 Schematic diagram of a typical spray-type deaerator^[23]

The most commonly used oxygen scavenger for lower pressure systems is sodium sulfite (Na_2SO_3), that is very effective and rapidly reacts with traces of oxygen to form sodium sulfate (Na_2SO_4), which is non-scaling. In case of higher pressure systems (higher than 650 psi) and all systems where highly alloyed materials are present, Hydrazine (N_2H_4) is commonly used as oxygen scavenger in these volatile treatment programs.

4.6.4 Steam generator

The steam generator is a heat exchanger used to convert the feed water into steam, which will drive the turbine. In order to increase the amount of heat transferred and the power generated, the heat exchange surface must be maximized: this is obtained by using tubes. While the secondary fluid is always water, the reactor coolant (carbon dioxide, sodium, helium) depends on the reactor type. ^[24]

The steam generator is usually composed of a burner, a combustion chamber, where the natural gasses are burned, a chimney and a purge or blowdown. The system is pressurized because the osmotic feed water is contained within a tank, at low pressure (around 2 bar) while the steam generator works at about 10 bar. For this reason, we need a fourth booster set.

This device can be subjected to several problems:

- Corrosion of heat exchanger surfaces, due to the presence of oxygen or other gasses;
- Encrustations and scale formation, if the feed water has not been properly treated;
- Presence of chemical products that are not recommended for the food use;
- Explosions, due to overheating of heat exchanger surfaces when they are crossed by water that has not been properly treated.



Fig. 4.66 Pure steam generator used for sterilization and disinfection in the food industry [25]

4.6.5 Calculation of purge costs

In order to calculate the daily costs for the purge, several parameters must be taken into account. Most of them are supposed because of unknown data, since the system is owned by the costumer.

The following calculations have the purpose of comparing the reverse osmosis system with the softener option, considering the difference between the two costs of the purge. For this reason, we have two different cases: the first for methane and osmotic water, the second for methane and softener water.

In general, a steam generator placed after a double pass reverse osmosis system is able to purge around 2-3% of vapour. Also the value of recovered condensate is low, around 10% in case of pasta manufacturing plant.

The following table is used as a guide for the chemical conditioning of water from fire tube boilers according to standard UNI EN 12953-10, where:

- ¹ in case of feed water conductivity $\leq 30 \mu\text{s/cm}$
- ² in case of feed water conductivity $> 30 \mu\text{s/cm}$

Tab. 4.6 Guide for water chemical conditioning from fire tube boilers according to standard UNI EN 12953-

10

Product	Description of the treatment	Control limits	Approval	Notes
SWT 264 + SWT 272	Non-volatile deoxygenating agent based on Sulphite + Phosphate Coordinated	Sodium sulphite reserve	FDA	Presence of total hardness in the feed water
		20 - 30 ppm SO_3	EN 12953-10	< 1 ppm CaCO_3
		¹ 6-15 ppm PO_4 ² 10-30 ppm PO_4		
SWT 205 + SWT 272	Non-volatile deoxygenating agent based on ascorbate + sodium phosphate Passivating action	Sodium ascorbate reserve	FDA GRAS	Presence of total hardness in the feed water
		0,5 - 1 ppm	EN 12953-10	< 1 ppm CaCO_3
		¹ 6-15 ppm PO_4 ² 10-30 ppm PO_4		
SWT 207 + SWT 272	Non-volatile deoxygenator based on ascorbate + coordinated amine + phosphate	Sodium ascorbate reserve	FDA	Presence of total hardness in the feed water
		0,5 - 1 ppm		≥ 1 ppm CaCO_3
		¹ 6-15 ppm PO_4 ² 10-30 ppm PO_4		
SWT 269 + SWT 272	Complete thermal cycle treatment based on sulphite + DEHA + coordinated phosphate	Sodium sulphite reserve		Suitable for temperatures of feed temperatures < 70°C
		20 - 30 ppm SO_3		DEHA condensation > 100 ppb
		¹ 6-15 ppm PO_4 ² 10-30 ppm PO_4		DEHA boiler > 150 ppb
SWT 244 + SWT 272	Complete thermal cycle treatment based on DEHA + amines + coordinated phosphate	DEHA condensation > 100 ppb		
		DEHA boiler > 150 ppb		
		pH condensation 8,3 - 9,5		
SWT 2221	Monofunctional treatment non-volatile based on sulphite + phosphate + polymers	Sodium sulphite reserve		
		20 - 30 ppm SO_3		
		¹ 6-15 ppm PO_4 ² 10-30 ppm PO_4		

The following picture shows a generic plants characterized by a cold osmotic water inlet and two small tanks containing the deoxygenating agent and the chemical conditioner, both placed before the water tank. Here the water is mixed with steam at high temperature, resulting in hotter water that goes to the steam generator.

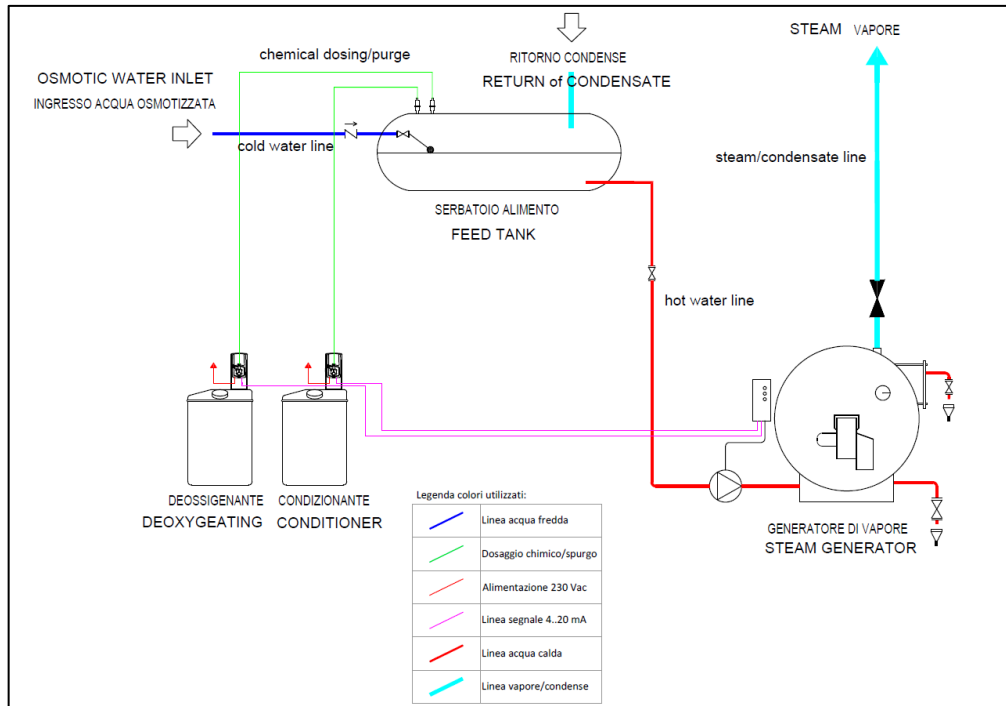


Fig. 4.67 Schematized plant of a steam generator system fed by osmotic water treated with deoxygenating and conditioning agents

The water entering into the tank, placed before the steam generator, comes from the double-pass reverse osmosis system, thus its chemical characteristics are reported in the water analysis obtained by the simulation performed by the software “Sirio”. The alkalinity of the make-up water is 1.1 ppm but we assume a higher value, 5 ppm, as safety factor. Usually for pasta manufacturing plants, the working pressure ranges between 10 bar and 12 bar.

Case 1: osmotic water

- Vapour production: assumed 3000 kg/h;
- Working pressure: assumed 12 bar;
- Temperature of the feed water: assumed 95°C;
- Condensate recovery: assumed 10%;
- Reinstatement: assumed 90%;
- Boiler efficiency: assumed 95%;
- Lower calorific value: taken 8570 Kcal/Nm³;
- Daily exercise: assumed 16 hours;

- Alkalinity of make-up water: assumed 5 ppm;
- Fuel cost: assumed 0.45 €/Nm³;
- Sensible heat of boiler water: taken 193 Kcal/kg;
- Sensible heat of feed water: taken 95 Kcal/kg.

From these values, the following calculations are done to obtain the final daily cost for purge. Calculation of the percentage of purge based on the alkalinity of make-up water:

$$\% \text{ purge} = \frac{\text{alkalinity of make up water} * \text{reinstatement}}{250 - (\text{alkalinity of make up water} * \text{reinstatement})} * 100 = 1.8\%$$

Where the value of 250 ppm is the maximum alkalinity of boiler water admitted by the legislation UNI EN 12953-10. Calculation of the amount of purge produced per hour:

$$\text{Purge production} = \frac{3000 \frac{\text{kg}}{\text{h}} * \% \text{ purge}}{100} = 55 \frac{\text{kg}}{\text{h}}$$

Calculation of heat content for purge production:

$$\begin{aligned} \text{Heat content} &= (\text{sens. heat boiler} - \text{sens. heat feed}) * \text{purge prod.} \\ &= 5390 \text{ Kcal/h} \end{aligned}$$

Calculation of fuel consumption for purge production:

$$\begin{aligned} \text{Fuel consumption} &= \frac{\text{heat content for purge}}{\left[\frac{\text{lower calorific value} * \text{boiler efficiency}}{100} \right]} \\ &= 0.7 \text{ Nm}^3/\text{h} \end{aligned}$$

Calculation of cost of the purge per hour:

$$\text{Hourly purge cost} = \text{fuel consumption for purge} * \text{fuel cost} = 0.3 \text{ €/h}$$

Calculation of the purge per day:

$$\text{Daily purge cost} = \text{cost of purge per hour} * \text{daily exercise} = 4.8 \text{ €/day}$$

Case 2: softened water

The same calculations are applied in the case of softener water. The only parameter that changes with respect to the previous case is the alkalinity of make-up water, which is obviously higher. During this evaluation, the value assumed is 220 ppm. In this case, the value of the maximum alkalinity of boiler water admitted by law is no more assumed to be 250 ppm, as reported in UNI EN 12953-10, but 1000 ppm as the past legislation (UNI CTI 7550) admits, otherwise the cost of the purge produced per day would be very high. Other differences between the two legislations arises:

- From the point of view of the chemical conditioner, both the laws support that the steam generators must be subjected to chemical treatment. In addition, according to the newest law, in order to avoid corrosion problems, NaOH should be used only if the addition of phosphate is not sufficient.
- From the point of view of the pressure for the subdivision of generators, the two laws report different reference pressures:
 - UNI CTI 7550: < 15 bar, 15-25 bar;
 - UNI EN 12953: 0.5-20 bar, > 20 bar;
- From the point of view of the feed water, it is defined by the two laws in a different way:
 - Water entering in the feed pump;
 - Water obtained by mixing of make-up water and condensate;
- Hardness: the admissible value is reduced from 0.5°F to 0.1°F;
- Iron: from boilers from 0.5 to 20 bar the limit is raised from 0.1 to 0.3 ppm;
- Silica: the limits set by the UNI CTI 7550 standard are modified and made a function of operating pressure and alkalinity value;
- UNI CTI 7550 standards set a maximum limit of 30 ppm regardless of the operating pressure. UNI EN 12953 do not set maximum limits if coordinated phosphate treatments are used

- The working range for generators changes with water conductivity:
 - lower than 30 $\mu\text{S}/\text{cm}$ is 10-30 ppm of PO_4 ;
 - greater than 30 $\mu\text{S}/\text{cm}$ is 6-15 ppm of PO_4 .

As a consequence, the following results are obtained:

- % purge = 25%;
- Purge production = 740 kg/h;
- Heat content = 72584 Kcal/h;
- Fuel consumption = 9 Nm^3/h ;
- Hourly purge cost = 4 €/h;
- Daily purge cost = 64 €/day.

From these calculations, it can be observed that the use of a water softener instead of a reverse osmosis plant is not suitable, due to very high costs of purge. In fact, in case of softened water it is around 24000 €/year, while in case of osmotic water is around 1800 €/year.

Thus, adopting the double pass reverse osmosis configuration, the ROI (Return On Investment) is largely higher than the case of water softener.

4.7 Booster sets

The booster set is composed by:

- Two pumps
- Two ball valves for each pump, that allow closing, opening and flow reduction. The operation is based on the 90° rotation of a spherical shutter equipped with a cylindrical cavity coaxial to the flow. ^[26]
- One spring check valve for each pump, used to prevent the direction of flow from reversing, having a one-way flow direction and they are automatic. ^[27]
- Two ball valves linked to two hydro-accumulators. These devices guarantee a constant and stabilized flow, controlling the pressure of water. ^[28]

The design starts with the selection of the most appropriate pump, consequently, some theoretical aspects regarding the pumps and their functionalities should be analysed.

The characteristic curve of a pump identifies the capacity of a pump to generate flux with respect to a determined prevalence. Each pump has its own characteristic curve.

The pump withdraws the mechanical energy from a motor and transforms it into kinetic energy, thanks to the action of the impeller blades. Then, it changes the kinetic energy into pressure energy at the pump discharge. This pressure energy dissipates when the fluid moves through a system. Thus, the pump performance characteristic curve defines how much energy is available at a given flow rate, impeller diameter, and shaft speed for each pump size.

The figure below shows the pump head-capacity curve and the system curve. For a certain capacity Q_p and a certain head H_p , the point of pump operation can be obtained.

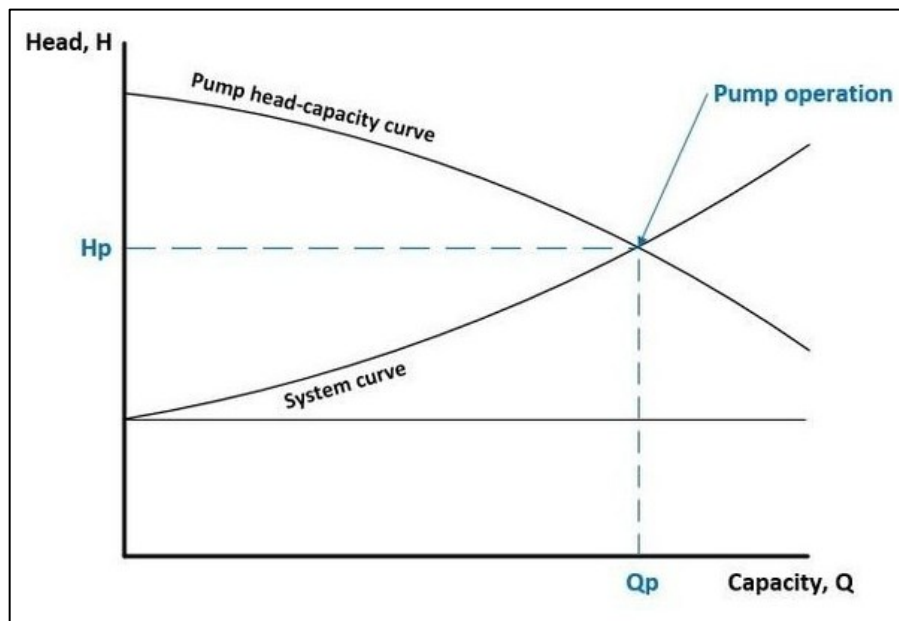


Fig. 4.68 Characteristic curve of a generic centrifugal pump ^[29]

The most important parameters that define the characteristic curve of a pump are:

- Flow: the flow of a pump, expressed in cubic meters per hour, is defined as the volume of fluid that is transferred by the pump, and it varies inversely proportional to the head, expressed in meters. So, when the flow increases, the head decreases;
- Head: it is the mechanical energy added to the fluid through a centrifugal force, expressing the energy content of the liquid per unit weight of liquid. For a given pump running at a given speed and handling a given volume of fluid, the energy transferred is the same for any fluid, independently from its density. The head applied to centrifugal pumps is commonly expressed in feed of liquid and is used to represent the vertical height in feed, or meters of a static column of liquid;
- Efficiency: the relationship between the power supplied to the water and the power input to the hydraulic part of the pump. The efficiency of the pump depends on the operating point, which ensures that the pump is operating in the area that offers the most efficient flow rate. The BEP is the best efficiency point, which corresponds to the point in which the efficiency of the pump is at the maximum, at an ideal value of the flow. When the pump has to be projected, is recommended to project the pump in order to work as much as possible near to the BEP;
- Required power: a pump demands a certain quantity of energy to move the fluid, calculated as follows: $\text{bkW} = \text{wkW} / \text{pump efficiency} = Q \times H \times \text{specific weight} / \text{pump efficiency} \times 367$;
- Diameter of impeller of the pump;
- Velocity of the centrifugal pump;
- Operating conditions: pressure, temperature;
- Properties of fluid: viscosity and specific weight of the pumped fluid.

4.7.1 First Booster Set

In order to select the most suitable pump, an appropriate software called “Xylem Solver” is used, where the following parameters must be selected, grouped into:

- 1) Pumping details:

- Station discharge pressure: 3 bar;
- Suction pressure: 0.1 bar,
- Total flow: 12 m³/h;
- Total head: around 30 m;
- Frequency: 50 Hz;
- System units: metric;
- Nominal speed: 750-3000 RPM;
- Number of stages: 3.

2) Fluid and operating conditions:

- Fluid type: water;
- Fluid temperature: 20°C;
- Stand by pump: 1.

The stand by pumps are backup pumps in addition to operating pumps and used only as substitute for any operating pump. Hydraulics are based on the number of operating pumps only, thus the total pumps are operating pumps plus stand by pumps.

To complete the pump configuration, the following parameters must be selected:

- Non-return valve in delivery side (instead of non-return valve in suction side);
- Pump size: 10HM.

Also the motor characteristics should be configured:

- Frequency: 50 Hz;
- Power: 1.5 kW;
- Phase: three (instead of one);
- Voltage: 380 - 460 V. ^[30]

Once inserted these data, the software gives a series of possible results. Looking to the maximum overall efficiency, pump efficiency and maximum operating point obtainable, the most appropriate pump can be selected.

In this case the SMB series variable speed booster sets have been chosen, which are designed for water pressure boosting and transfer.

The variable speed SMB booster sets are designed for water transfer and pressurization in various industrial applications and each pump is equipped with an e-SM frequency drive that ensures the variable speed operation on all electric pumps. These types of systems improve the comfort of the end user, reducing the noise emissions and the water hammer, thanks to the gradual switching off of the pumps. ^[30]

There are three types of SMB booster set series:

- SMB10: the pump is connected to a 5-way fitting by a non-return valve. The control panel is available as accessory;
- SMB20, SMB30: the pumps are installed on a single base and connected to each other by means of suction and delivery pipes. The pumps are connected to the manifolds by means of on-off valves and non-return valves. The control panel is secured to the same base by means of a bracket.

The SMB series booster sets are certified for potable uses and they are available with a wide range of electric pumps to satisfy the different needs of every system. In fact, the system for regulating the speed of the electric motors are used in the following cases:

- Systems with a lot of users, where the consumption varies frequently and in different periods;
- When it is necessary to obtain constant pressure;
- Systems with supervision, where the performances of booster sets can be controlled. ^[30]

In this specific case, the chosen model is SMB20/10HME03S15/4.

The performance point on the head-capacity curve of the selected pump, corresponding to a specific value of flow [m^3/h] and head [m], is 68.7%, as shown in the figure below.

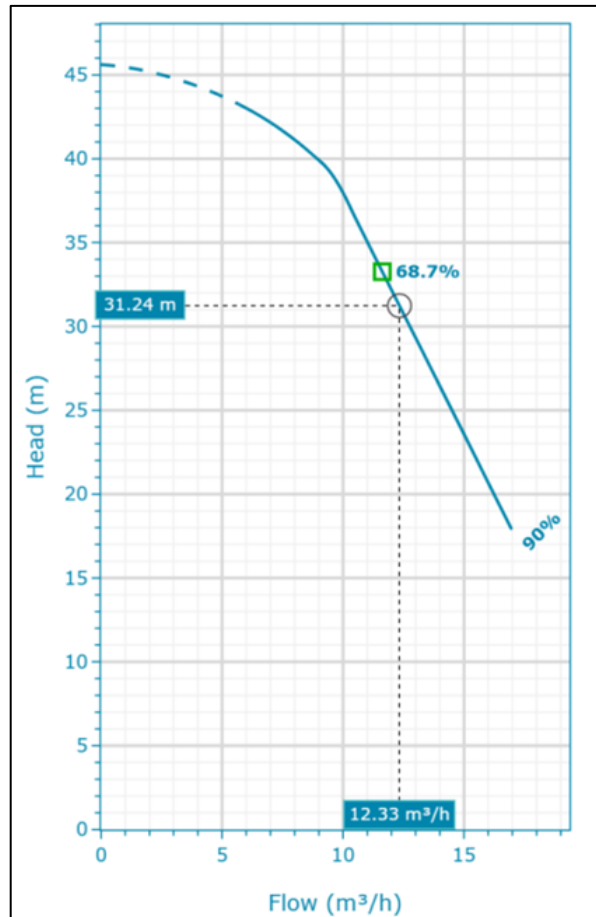


Fig. 4.69 Performance point of the pump according to head[m] and water flow [m³/h] ^[30]

Analysing the graph and looking to the point of maximum efficiency of the pump, it is possible to understand if the selected pump is suitable for the specific application and if it is the best choice among others alternatives.

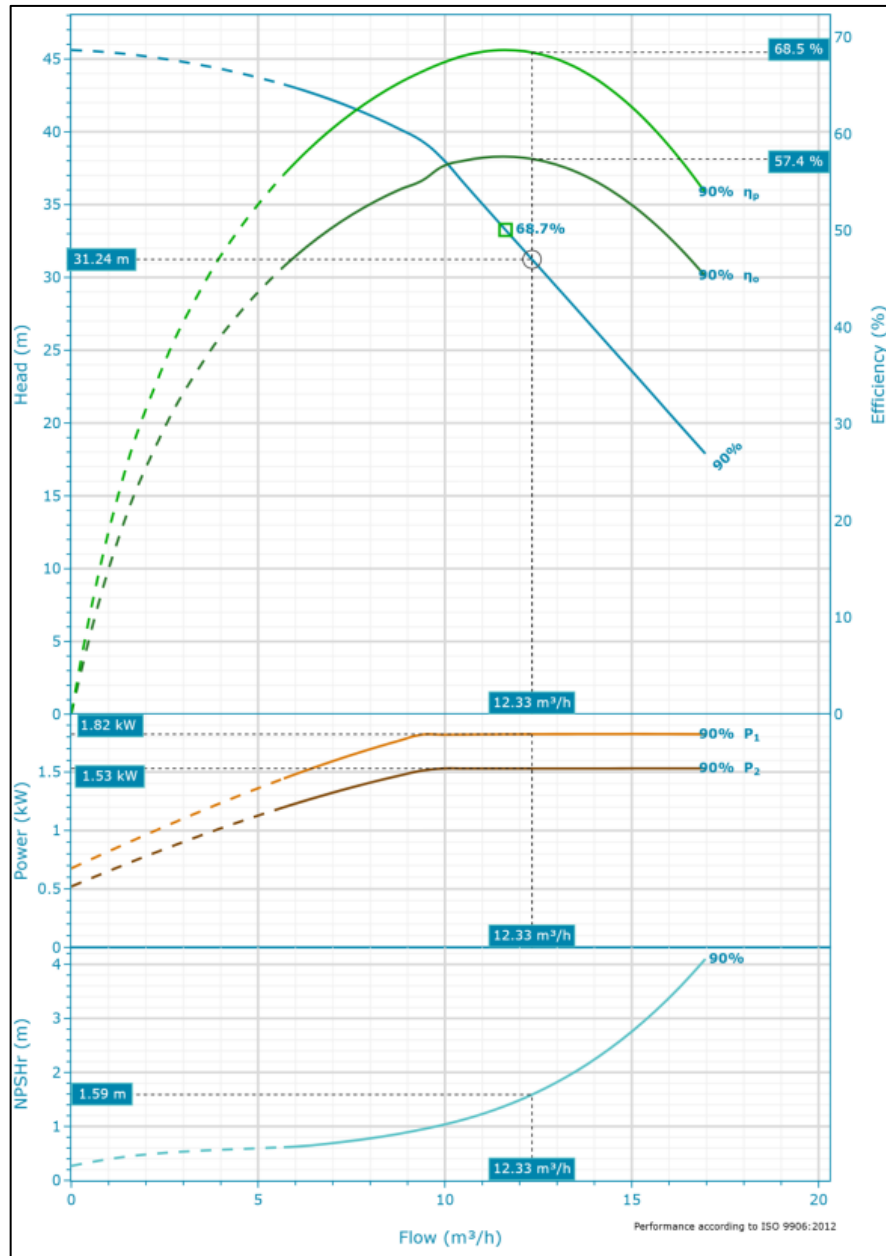


Fig. 4.70 Graphs representing respectively Head [m], Power [kW] and NPSH [m] as a function of the water flow [m³/h] for the SMB20/10HME03S15/4 pump ^[31]

Having the water flow equal to 12.33 [m³/h] and the head equal to 31.24 [m], the maximum performance obtained is 68.7%. The power of the first pump, related to a water flow of 12.33 [m³/h] is 1.82 Kw, while that of the second one is 1.53 kW. Finally, the value of NPSH at 12.33 [m³/h] is 1.59 [m]. The drawing of the first booster set is reported below.

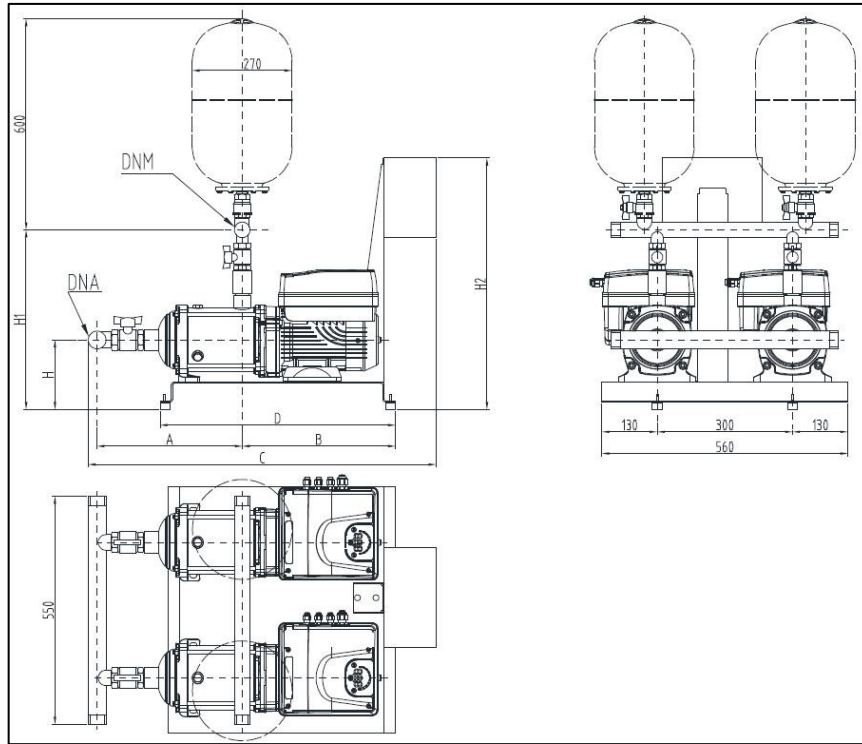


Fig. 4.71 Technical representation of the first booster set

The construction materials used are:

- AISI 304: for manifolds, pressure transmitters, caps/plugs, and welded flanges in contact with the liquid;
- AISI 316: for caps/plugs and fittings;
- AISI 301: for pressure switches;
- Brass: for non-return valves;
- Galvanized steel: for pressure switches, bracket, and sliding/blind flanges not in contact with the liquid
- Painted steel: for bracket and base;
- Nickel-plated brass: for on-off valves.

The final project can be represented by the following image:



Fig. 4.72 First booster set ^[31]

4.7.2 Second Booster Set

The second booster set is completely equal to the first one, so the related calculations and the obtained pump curves are identical. For the references, see paragraph 4.7.1.

4.7.3 Third Booster Set

The third booster set is composed by:

- Two pumps;
- Two ball valves for each pump;
- One spring check valve for each pump;
- Two ball valves linked to two hydro-accumulators.

Refers to the paragraph 4.7 for further details.

The design starts with the selection of the most appropriate pump. Consequently, some theoretical aspects regarding the pumps and their functionalities should be considered.

In order to select the most appropriate pump, an appropriate software called “Xylem Solver” is used, where the following parameters should be selected, grouped into:

1) Pumping details:

- Station discharge pressure: 3 bar;
- Suction pressure: 0.1 bar;
- Total flow: 6 m³/h;
- Total head: around 30 m;
- Frequency: 50 Hz;
- System units: metric;
- Nominal speed: 750-3000 RPM;
- Number of stages: 4.

2) Fluid and operating conditions:

- Fluid type: water;
- Fluid temperature: 20°C;
- Stand by pump: 1.

In order to complete the configuration of the pump, the following parameters should be selected:

- Non-return valve in delivery side (instead of non-return valve in suction side);
- Pump size: 1-5SV.

Also the motor characteristics should be configured:

- Frequency: 50 Hz;
- Power: 0.75 kW;
- Phase: three (instead of one);
- Voltage: 380 - 460 V. ^[30]

Once inserted these data, the software gives a series of possible results. Looking to the maximum overall efficiency, pump efficiency and maximum operating point obtainable, the most appropriate pump can be selected.

Also in this case, the SMB series variable speed booster sets have been selected, which are designed for water pressure boosting and transfer. In particular, the chosen model is SMB20/5SVE04F007/4.

The performance point on the head-capacity curve of the selected pump, corresponding to a specific value of flow [m^3/h] and head [m], is 67.6%, as shown in the figure below.

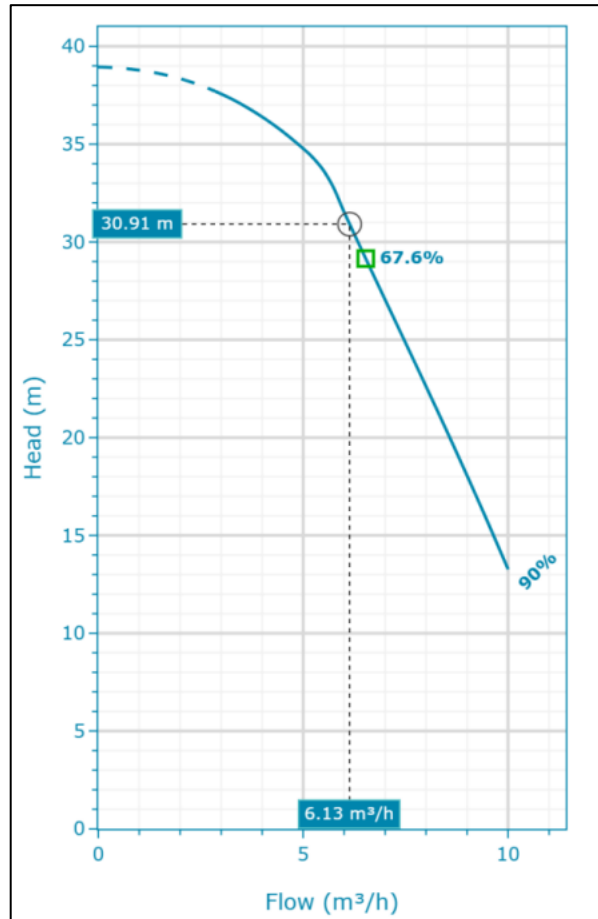


Fig. 4.73 Performance point of the pump according to head[m] and water flow [m^3/h] ^[31]

Analysing these curves and looking to the point of maximum efficiency, it is possible to understand if the selected pump is good for the specific application and if it is the best choice among the others alternatives.

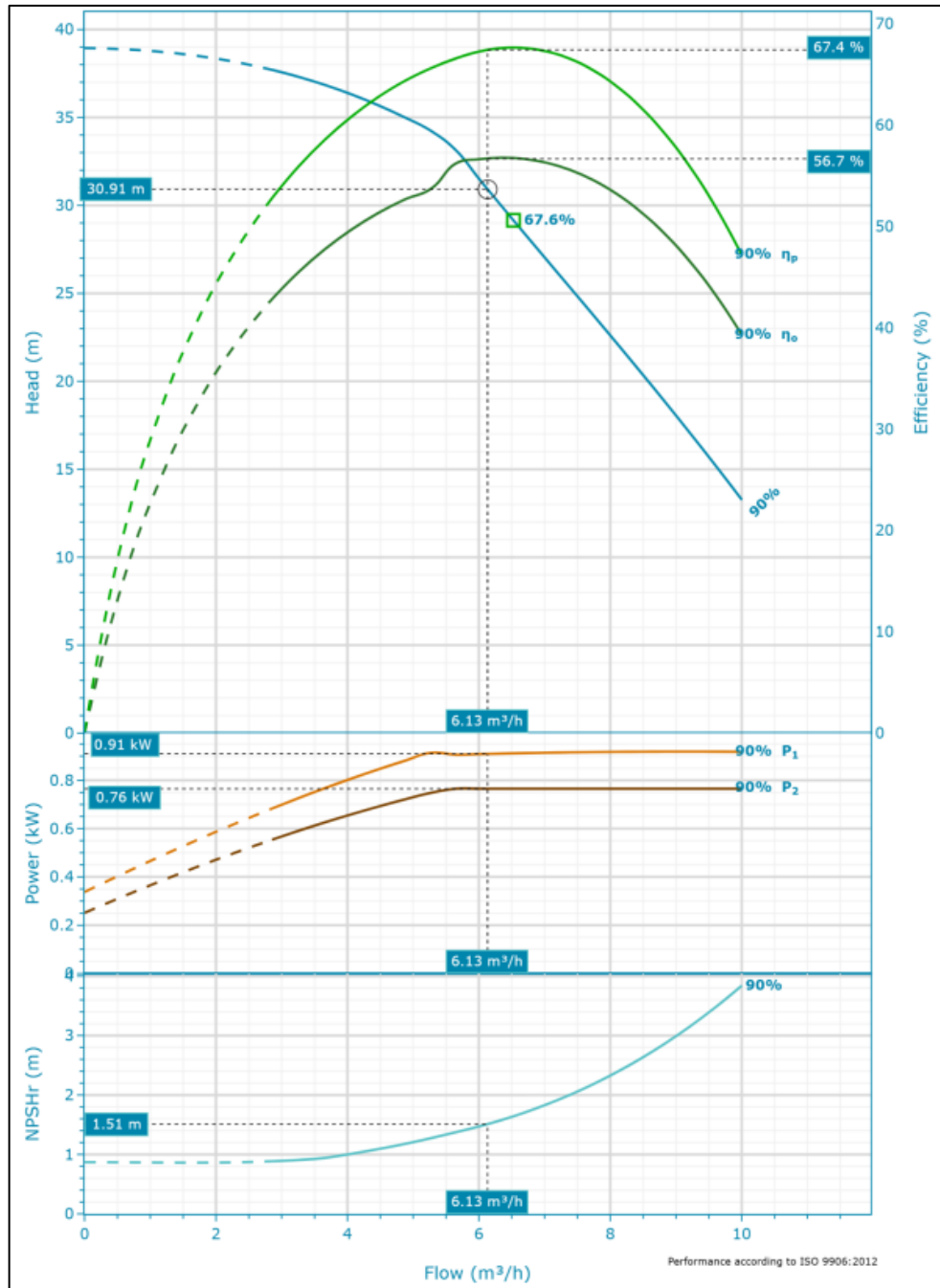


Fig. 4.74 Graphs representing respectively Head [m], Power [kW] and NPSH [m] as a function of the water flow [m^3/h] for the SMB20/5SVE04F007/4 pump ^[31]

As shown in the curves above, having the water flow equal to $6.13 \text{ m}^3/\text{h}$ and the head equal to 30.91 m , the maximum performance obtained is 67.6% . The power of the first pump is 0.91 kW while that of the second one is 0.76 kW . Finally, the value of NPSH at $6.13 \text{ m}^3/\text{h}$ is 1.51 m .

The drawing of the third booster set is reported below.

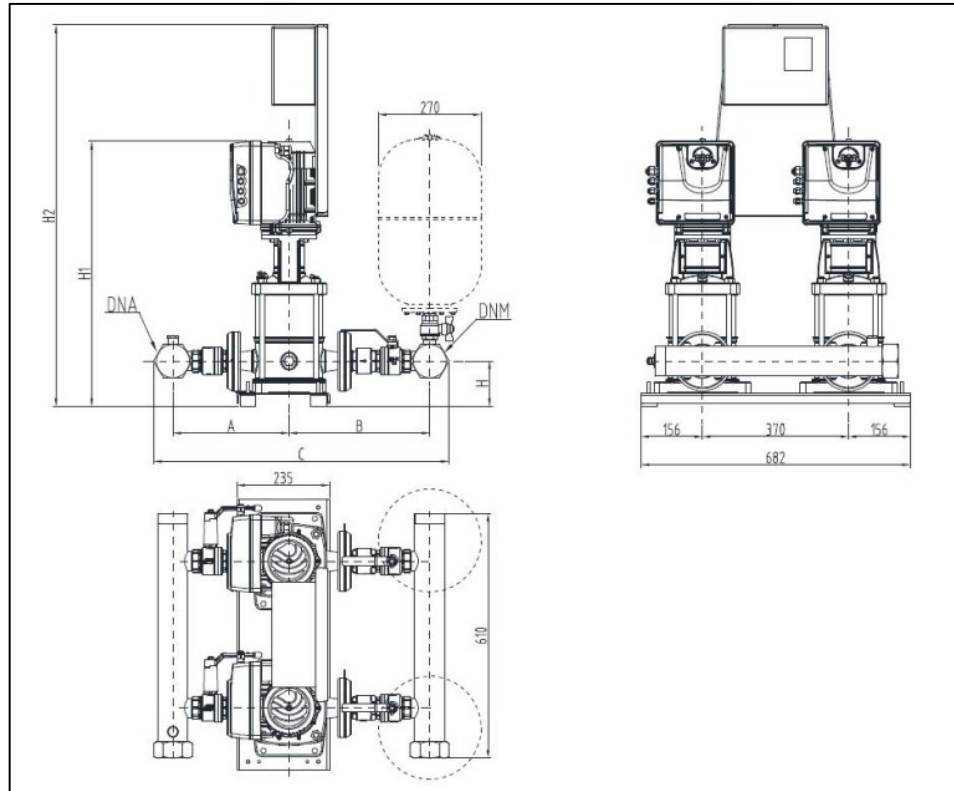


Fig. 4.75 Technical representation of the third booster set

The construction materials used are:

- AISI 304: for manifolds, pressure transmitters, caps/plugs, and welded flanges in contact with the liquid;
- AISI 316: for caps/plugs and fittings;
- AISI 301: for pressure switches;
- Brass: for non-return valves;
- Galvanized steel: for pressure switches, bracket, and sliding/blind flanges not in contact with the liquid;
- Painted steel: for bracket and base;
- Nickel-plated brass: for on-off valves. ^[30]

The final project can be represented by the following image:



Fig. 4.76 Third booster set [30]

4.7.4 Fourth Booster Set

The booster set is composed by:

- Two pumps
- Two ball valves for each pump
- One spring check valve for each pump
- Two ball valves linked to two hydro-accumulators

Refers to the paragraph 4.7.1 for further details.

The design starts with the selection of the most appropriate pump. Consequently, some theoretical aspects regarding the pumps and their functionalities.

In order to select the most appropriate pump, an appropriate software called “Xylem Solver” is used, where the following parameters should be selected, grouped into:

1) Pumping details:

- Station discharge pressure: 4 bar;
- Suction pressure: 0.1 bar;
- Total flow: 3 m³/h;
- Total head: around 30 m;
- Frequency: 50 Hz;
- System units: metric;

- Nominal speed: 750-3000 RPM;
- Number of stages: 7.

2) Fluid and operating conditions:

- Fluid type: water;
- Fluid temperature: 20°C;
- Stand by pump: 1.

The stand by pumps are backup pumps in addition to operating pumps and used only as substitute for any operating pump. Hydraulics are based on the number of operating pumps only, thus the total pumps are operating plus stand by pumps.

Then we have to complete the configuration of the pump by selecting the following parameters:

- Non-return valve in delivery side (instead of non-return valve in suction side);
- Pump size: 3HM.

Also the motor characteristics should be configured:

- Frequency: 50 Hz;
- Power: 0.75 kW;
- Phase: three (instead of one);
- Voltage: 380 - 460 V. ^[30]

Once inserted these data, the software gives a series of possible results. Looking to the maximum overall efficiency, pump efficiency and maximum operating point obtainable, the most appropriate pump can be selected.

In this case the SMB series variable speed booster sets have been selected, which are designed for water pressure boosting and transfer. In particular, the model chosen is SMB20/3HME07S07/4.

The performance point on the head-capacity curve of the selected pump, corresponding to a specific value of flow [m³/h] and head [m], is 59.3%, as shown in the figure below.

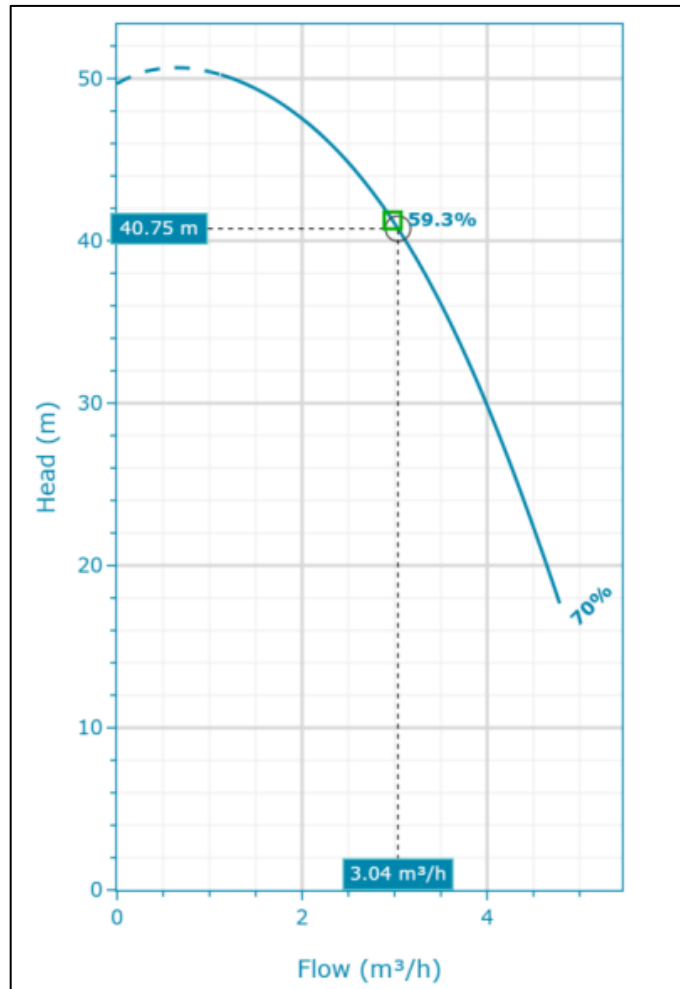


Fig. 4.77 Performance point of the pump according to head[m] and water flow [m³/h] ^[31]

Analysing these curves, we can understand if the selected pump is good for the specific application and if it is the best choice among others alternatives, looking to the point of maximum efficiency of the pump.

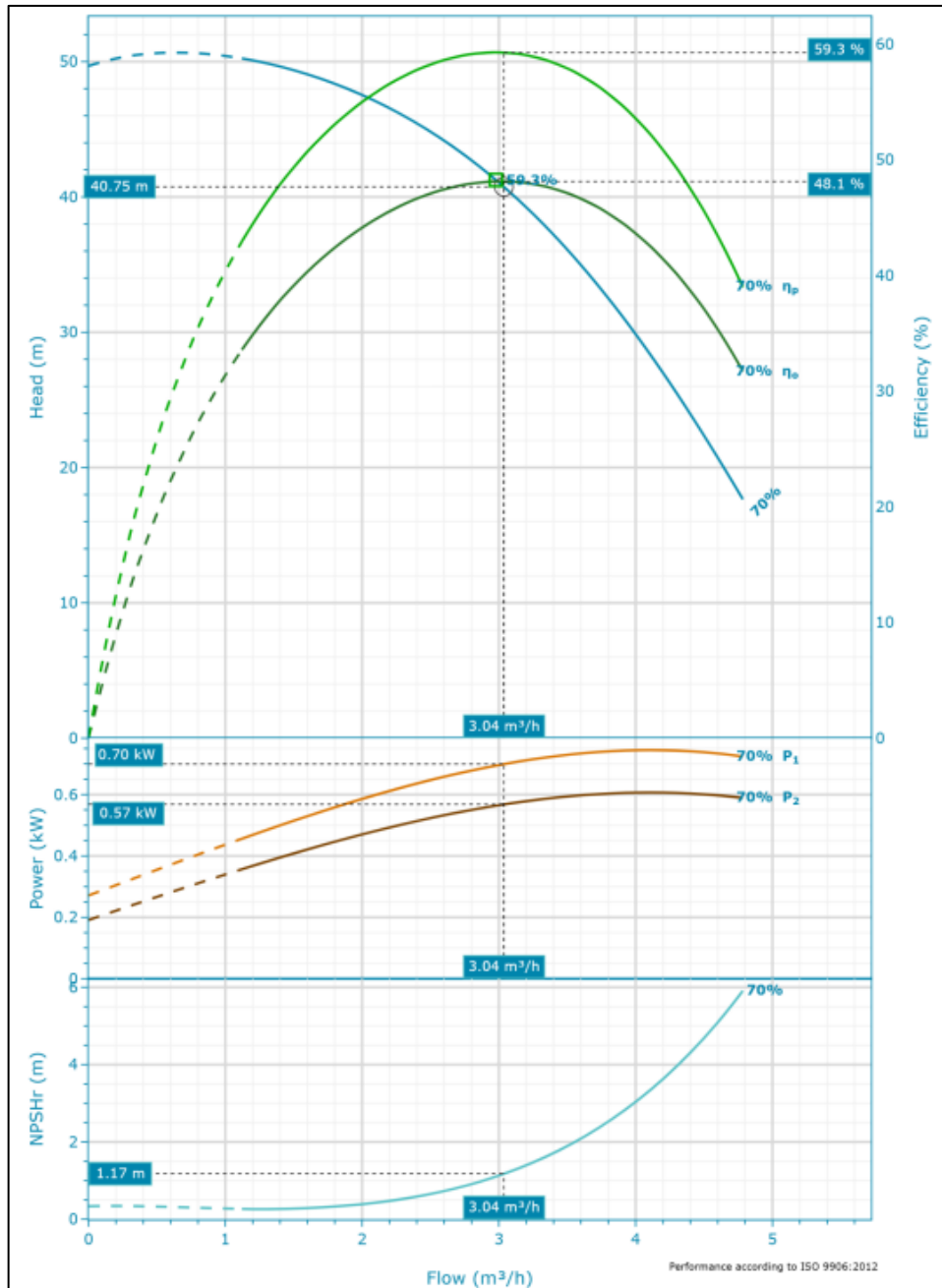


Fig. 4.78 Graphs representing respectively Head [m], Power [kW] and NPSH [m] as a function of the water flow [m^3/h] for the SMB20/3HME07S07/4 pump ^[31]

As shown in the curves above, having the flow = $3.04 \text{ m}^3/\text{h}$ and the head = 40.75 m , the maximum performance obtained is 59.3%, the power of the first pump is 0.70 kW while that of the second one is 0.57 kW. Finally, the value of NPSH at $3.04 \text{ m}^3/\text{h}$ is 1.17 m .

The drawing of the fourth booster set is reported below.

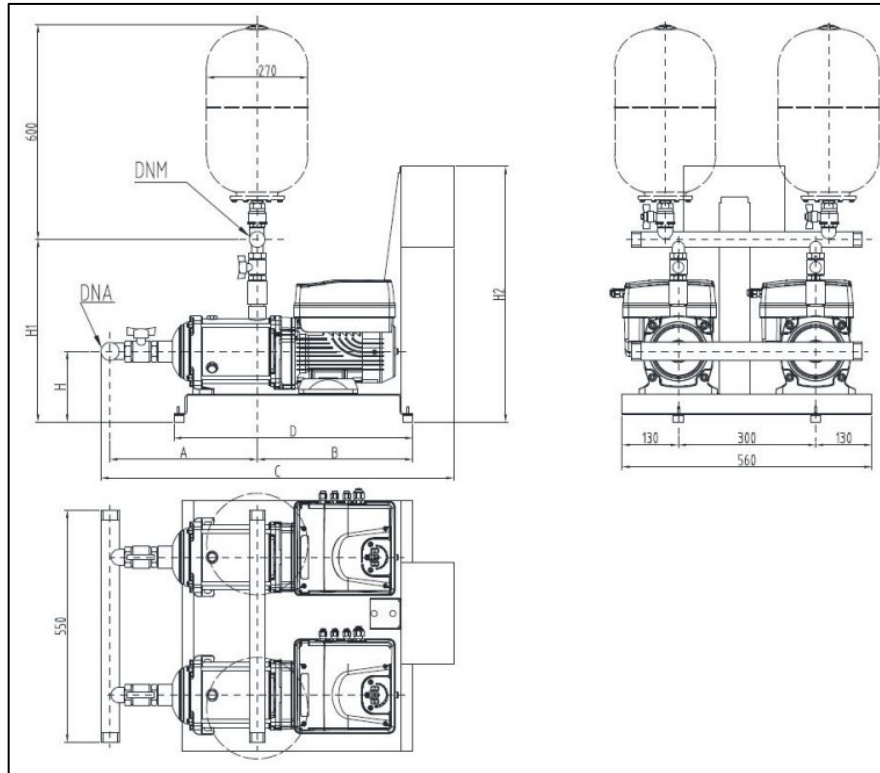


Fig. 4.79 Technical representation of the fourth booster set ^[31]

The construction materials used are:

- AISI 304: for manifolds, pressure transmitters, caps/plugs, and welded flanges in contact with the liquid;
- AISI 316: for caps/plugs and fittings;
- AISI 301: for pressure switches;
- Brass: for non-return valves;
- Galvanized steel: for pressure switches, bracket, and sliding/blind flanges not in contact with the liquid;
- Painted steel: for bracket and base;
- Nickel-plated brass: for on-off valves. ^[30]

The final project can be represented by the following image:



Fig. 4.80 Fourth booster set ^[31]

4.8 Testing and programming before start-up

Before being shipped to the customer, the system is tested in order to identify possible construction and/or assembly defects, and to verify the correct functioning of the electrical system. Several tests can be performed:

- Leak test: tests with compressed air (6 bar) to verify possible defects of the welded parts and tightness control under normal operating conditions. A leak-detection foam is used for identifying non-tight areas, micro-leaks and hairline cracks safely and quickly. The formation of bubbles highlights the presence of defects;
- Electrical test: tests performed to verify the correct functioning of alarms, signals and messages that should appear in the display of the electrical panel, and the contact operating logic (normally open/ normally closed).
- Visual and connection control;
- Power light control;
- Continuity and isolation tests;
- Complete functioning control.

For example, the signal related to the opening of air compression valve of the first reverse osmosis system appears like an announcement, illustrated in the following image:

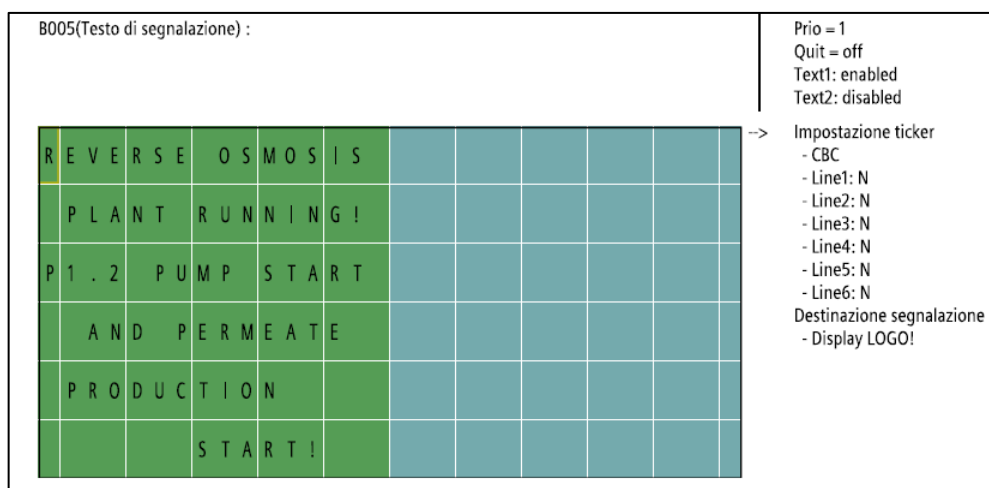


Fig. 4.81 Electrical signal of reverse osmosis plant, pump and permeate production starter

The warning concerning low water level in the first tank, which suggests to check the water supply and the filter of interest, is represented in the figure below.

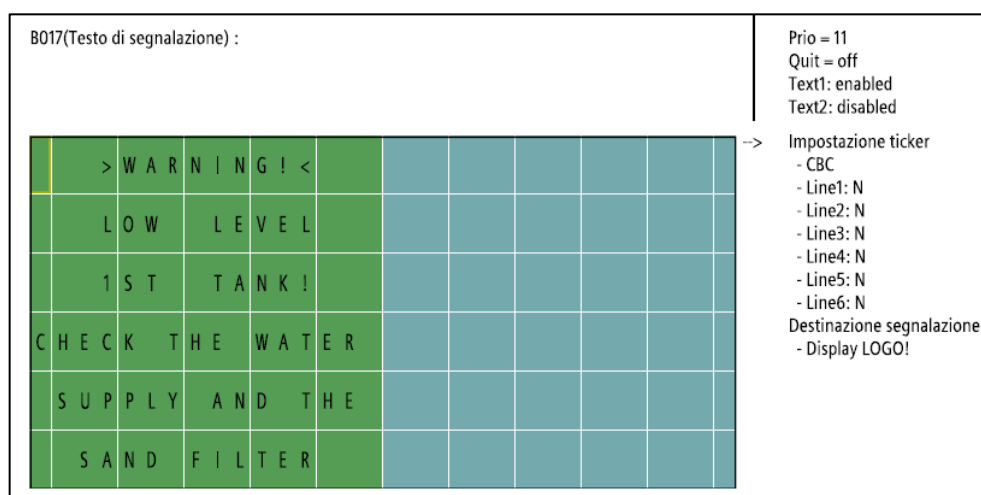


Fig. 4.82 Electrical signal of low water level at the first tank

The entire system will stop if the malfunctioning of a component is verified, producing an alarm in the electrical panel. For example, if the anti-scale dosing pump presents a problem, the alarm appears like in the figure below, suggesting to check the tank level.

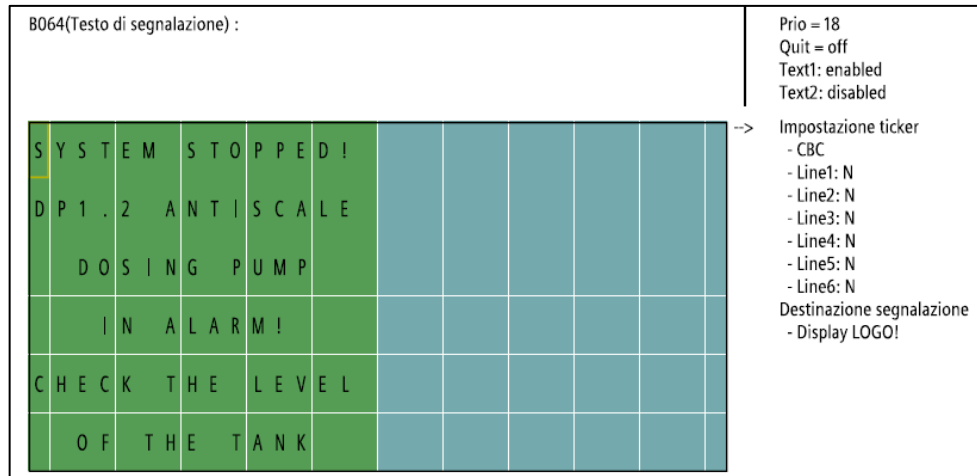


Fig. 4.83 Electrical signal of anti-scale dosing pump malfunctioning

In addition, valves are programmed based on previous technical evaluations:

- Programming of filters valves: Sand, Mars and Venus filters valves are programmed in order to determine the time at which normal flow, backflow and regeneration take place.
- Programming of dosing pumps: Chlorine, NaOH, anti-scale and deoxygenating agents dosing pumps are programmed to regulate the flowrate and frequency of each product injection, depending on valve's operating mode;
- Low pressure switch calibration: the pressure switch is configured setting a certain minimum value of pressure, under which the system cannot work. If the pressure is below this limit, the water is no more flowing, and a signal is sent to the electrical panel to stop the system.

Finally, the serial numbers of each component will be collected in order to be recognizable and traceable. In addition, the weight and dimension of each component will be reported in the final document. The final test module is reported in the figure below.

		MODULO COLLAUDO FINALE			File 66 MCF Rev. 1	
MATRICOLA IMPIANTO		2505026/2025				
DESCRIZIONE IMPIANTO		NEA4000220 – IMP. TRATT. H2O RIUNITO SU TELAIO-R.341270				
APPL.	CONTROLLI ESEGUITI	SI	NO	ESEGUITO DA	DATA	NOTE
v	Controllo Visivo e Connessioni	X			13/02/25	
v	Controllo Impianto Elettrico vedi man. Istruzioni operative par.3.2 e 3.3	X			13/02/25	
v	Controllo Accensione	X		U.T	13/02/25	
v	Controllo Programmazione e Parametrizzazione	X		U.T.	13/02/25	
v	Controllo Tenuta a Regime	X			13/02/25	Aria 6 bar
v	Prova di CONTINUITA' vedi man. Istruzioni operative par.3.5	X			13/02/25	
v	Prova d'ISOLAMENTO vedi man. Istruzioni operative par.3.6	X			13/02/25	
	Controllo Funzionale COMPLETO					

Fig. 4.84 Final test module of the plant

5. Technical and economic analysis of the plant

5.1 Comparison between chemical product and water softener costs

In order to demonstrate why the addition of the chemical product, instead of a water softener, results to be the best choice from an economical and practical point of view, a comparison between their relative costs will be developed. Each result is approximate.

The required dosing amount of Flocon 135 is given by the product between the water flowrate, 12000 l/h, and its dosage (calculated at paragraph 4.2.1) 1.18 mg/l:

$$\text{Flocon 135} \left[\frac{g}{h} \right] = 12000 \left[\frac{l}{h} \right] * 1.18 \left[\frac{mg}{l} \right] = 14.16 \left[\frac{g}{h} \right] = 0.014 \left[\frac{kg}{h} \right]$$

Thus, considering 24 hours for 350 days of work per year, resulting in 8400 working hours per year, around 120 [kg/year] of chemical product will be necessary.

$$\text{Flocon 135} = 0.014 \left[\frac{kg}{h} \right] * 8400 \left[\frac{h}{year} \right] = 120 \left[\frac{kg}{year} \right]$$

Knowing that the chemical product is available in tanks of 25 kg each, around 5 tanks of Flocon 135 will be required. Since each tank costs around € 250, the annual costs for the dosage of Flocon 135 result to be around € 1200. To this result, should be added the cost related to the electrical consumption of anti-scale dosing pump for the first and second reverse osmosis systems, which corresponds to around € 6.00 each.

These results are calculated considering exclusively the price for the company's customer, not for the end user, which will be subjected to additional costs.

Alternatively, a water softener could be adopted for water treatments in domestic and industrial systems. It uses special resins, regenerated from salts, to reduce the hardness, and consequently scale, present in water coming from aqueduct or independent supply, for drinking, sanitary and industrial use. According to their dimensions and characteristics, they can be installed in different spaces. In

particular, the water softener exchanges calcium and magnesium ions with sodium ones, by flowing water through a bed of strong cationic resin enriched of sodium ions. In this way, hard water is filtered and ions responsible for lime scale deposits are retained on the surface of resin and replaced by sodium ions, whose slats do not cause deposits.

A multifunctional control head managed by an electronic timer/volumetric control periodically regenerates the filter bed using saturated brine solution (NaCl). This regeneration ensures treatment efficiency over time.

In order to calculate the amount of required resin, the following calculations are carried out:

Resin

$$= \frac{\text{Hardness } [^{\circ}\text{F}] * \text{Daily consumption } \left[\frac{\text{m}^3}{\text{day}} \right] * \text{Interval between 2 regen. [day]}}{\text{Resin exchange capacity } \left[\frac{^{\circ}\text{F}}{\text{l}_{\text{resin}}} \right]}$$

Considering the water hardness equal to 200 °F, a daily consumption of 12 m³/h for 24 h (288 m³/day), one day between two regenerations, and resin exchange capacity 5,5 °F/litres, the following result will be obtained. Each value is approximate.

$$\text{Resin } [\text{l}_{\text{resin}}] = \frac{200 [^{\circ}\text{F}] * 288 \left[\frac{\text{m}^3}{\text{day}} \right] * 1 [\text{day}]}{5.5 \left[\frac{^{\circ}\text{F} * \text{m}^3}{\text{l}_{\text{resin}}} \right]} = 10500 [\text{l}_{\text{resin}}]$$

Since the cost of resin is 2,4 €/l, the final cost will be around € 25000.

In addition, the salt consumption for each cycle is:

$$\text{Salt consumption [kg]} = \text{Resin [litres]} * \text{Regenerative level } \left[\frac{\text{kg}}{\text{litres}} \right]$$

Considering a regenerative level of 0,18 [kg/l] and the obtained value of resin volume 10500 [l], the salt consumed for each regeneration cycle will be:

$$\text{Salt consumption [kg]} = 10500 [\text{l}] * 0.18 \left[\frac{\text{kg}}{\text{l}} \right] = 2000 [\text{kg}]$$

Since the salt is sold in tanks of 25 kg each, 80 tanks will be necessary, each at € 12,00. Thus the final cost for the salt will be around € 1000.

In conclusion, the cost for a water softener of these dimensions is around € 60000, considering that there will be necessary at least 5 tanks to satisfy this extreme large amount of resin, resulting in a multi-tank water softener. So, the final annual cost of the water softener will be around € 85000.

Due to very high volume of resin required and large amount of salt needed for the regeneration, the costs related to water softener will be enormous and the space required by its large dimensions will be exaggerated.

For this reasons, the addition of a chemical product results to be the most practical, economic and efficient choice.

Usually, the water softener is preferred in case of low water flowrates and moderate water hardness.

5.2 Calculation of final plant costs

In order to give an economic overview of the entire plant, several calculations will be carried out, considering the costs related to:

- Electrical consumptions, which include filters, dosing pumps, booster sets, reverse osmosis systems, and electrical panels;
- Water consumption, related to the inlet flowrate;
- Consumables, which include chlorine, anti-scale products, NaOH, reverse osmosis membranes, cartridge and UV filters, and deoxygenating agent.

Starting from the initial sale price of € 161500 and considering a gross margin of 44%, the hypothetic final user price will be around € 290700.

In terms of electrical consumptions, the cost of each component will be defined according to:

- Electrical consumption [kW];
- Working time [h/year];
- Electrical consumption per year [kWh/year];
- Electricity cost [€].

The annual cost of each component is calculated multiplying the electrical consumption per year [kWh/year] for the electricity cost [€]. Finally, summing each of them, the total cost for the electrical consumption is around € 7000.

In terms of consumables, the cost of each component will be defined according to:

- Quantity consumed [kg/h];
- Working time [h/year];
- Consumable consumption per year [kg/year];
- Consumable cost [€].

The annual cost of each component is calculated multiplying the consumable consumption per year [kg/year] for its cost [€]. Finally, summing each of them, the total cost for the consumables is around € 26000.

In terms of water consumption, the following parameters will be considered:

- Water inlet flowrate [l/h];
- Working time [h/year];
- Water consumption per year: [l/year];
- Water cost [€].

Since the cost of well water is € 0,00, the final cost for water consumption is zero.

In conclusion, the final cost of the entire plant, considering an amortisation in five years, will be around € 92000.

The following table shows the calculations done.

Initial costs entire plant							annual cost of the entire plant
Sale price	€ 161.500,00						
Hypothetic final user price	€ 290.700,00	(gross margin 44%)					€ 58.140,00
Electrical consumptions		consumption [kW]	working hours/year	KWh/year	KWh cost [€]	annual cost [€]	
Sand filter		0,025	8400	210	€ 0,03	€ 6,72	
Chlorine dosing pump		0,02	8400	168	€ 0,03	€ 5,38	
First booster set		4,5	8400	37800	€ 0,03	€ 1.209,60	
Mars filter		0,025	8400	210	€ 0,03	€ 6,72	
Venus filter		0,025	8400	210	€ 0,03	€ 6,72	
Second booster set		4,5	8400	37800	€ 0,03	€ 1.209,60	
1 RO system	Antiscalant dosing pump	0,02	8400	168	€ 0,03	€ 5,38	
	NaOH dosing pump	0,02	8400	168	€ 0,03	€ 5,38	
	Electrical panel	0,5	8400	4200	€ 0,03	€ 134,40	
	Pump	5,5	8400	46200	€ 0,03	€ 1.478,40	
Third booster set		3	8400	25200	€ 0,03	€ 806,40	
2 RO system	UV	0,04	8400	336	€ 0,03	€ 10,75	
	Antiscalant dosing pump	0,02	8400	168	€ 0,03	€ 5,38	
	Electrical panel	0,5	8400	4200	€ 0,03	€ 134,40	
	Pump	2,2	8400	18480	€ 0,03	€ 591,36	
Fourth booster set		5,25	8400	44100	€ 0,03	€ 1.411,20	
Deox dosing pump		0,02	8400	168	€ 0,03	€ 5,38	
						€ 7.033,15	€ 7.033,15
Consumables		Quantity consumed [kg/h]	working hours/year	[kg/year]	cost/kg	annual cost [€]	
Chlorine		0,16	8400	1344	€ 3,80	€ 5.107,20	
1 RO	Antiscalant	0,01416	8400	118,944	€ 22,00	€ 2.616,77	
	NaOH	0,0006	8400	5,04	€ 3,20	€ 16,13	
	Cartridge filters					€ 1.200,00	
	Membranes					€ 3.900,00	
2 RO	UV					€ 140,00	
	Antiscalant	0,002	8400	16,8	€ 22,00	€ 369,60	
	Cartridge filter					€ 900,00	
	Membranes					€ 2.175,00	
Deoxygenating agent		0,09	8400	756	€ 13,00	€ 9.828,00	
						€ 26.252,70	€ 26.252,70
Water consumption		l/h	working hours/year	l/year	cost/l	annual cost	
Inlet flowrate	12 m ³ /h	12000	8400	100800000	€ 0,00	€ 0,00	€ 0,00
							€ 91.425,85

Fig. 5.1 Final plant cost calculation in case of well water

5.2.1 Calculation of final plant cost in case of potable water

In order to demonstrate that the purchase of the entire plant is more convenient than buying potable water from the local aqueduct, further calculations will be carried out.

In this second case, the water does not need the pre-treatment step and the first reverse osmosis system, being already potable. Thus the plant will be constituted only by the first and fourth booster sets, the second reverse osmosis system and the deoxygenating dosing pump.

Starting from the initial cost of the plant, the electrical, consumables and water consumptions costs will be taken into account for the calculation of the final plant cost, as done in the previous case.

Initial costs considering an amortisation in five years:

- First booster set: € 3600;
- Second reverse osmosis plant: € 5000;
- Fourth booster set: € 2400;
- Deoxygenating agent dosing pump: € 580.

In terms of electrical consumptions, the cost of each component will be defined according to:

- Electrical consumption [kW];
- Working time [h/year];
- Electrical consumption per year [kWh/year];
- Electricity cost [€].

The annual cost of each component is calculated multiplying the electrical consumption per year [kWh/year] for the electricity cost [€]. Finally, summing each of them, the total cost for the electrical consumption is around € 3400.

In terms of consumables, the cost of each component will be defined according to:

- Quantity consumed [kg/h];
- Working time [h/year];
- Consumable consumption per year [kg/year];
- Consumable cost [€].

The annual cost of each component is calculated multiplying the consumable consumption per year [kg/year] for its cost [€]. Finally, summing each of them, the total cost for the consumables is around € 13000.

In terms of water consumption, the following parameters will be considered:

- Water inlet flowrate [l/h];
- Working time [h/year];
- Water consumption per year: [l/year];
- Water cost [€].

Considering the water flowrate of 12000 l/h, for a working time of 8400 hours/year and a cost of 0.0015 €/l, the annual cost of potable water is around € 150000.

In conclusion, the final cost of the entire plant will be around € 180000.

The following table shows the calculations done.

Second case initial cost							annual cost of the second case
First booster set	18.000 €						€ 3.600,00
2 RO	25.500 €						€ 5.100,00
Fourth booster set	12.200 €						€ 2.440,00
Deox dosing pump	2.900 €						€ 580,00
Second case electrical consumption		consumption [kW]	working hours/year	KWh/year	KWh cost [€]	annual cost [€]	
First booster set		4,5	8400	37800	€ 0,03	€ 1.209,60	
2 RO system	UV	0,04	8400	336	€ 0,03	€ 10,75	
	Antiscalant dosing pump	0,02	8400	168	€ 0,03	€ 5,38	
	Electrical panel	0,5	8400	4200	€ 0,03	€ 134,40	
	Pump	2,2	8400	18480	€ 0,03	€ 591,36	
Fourth booster set		5,25	8400	44100	€ 0,03	€ 1.411,20	
Deox dosing pump		0,02	8400	168	€ 0,03	€ 5,38	
							€ 3.368,06
Second case consumables		Quantity consumed [kg/h]	working hours/year	[kg/year]	cost/kg	annual cost [€]	
2 RO	UV					€ 140,00	
	Antiscalant	0,002	8400	16,8	€ 22,00	€ 369,60	
	Cartridge filter					€ 900,00	
	Membranes					€ 2.175,00	
Deoxygenating agent		0,09	8400	756	€ 13,00	€ 9.828,00	
							€ 13.412,60
Second case water consumption		l/h	working hours/year	l/h	cost/l	annual cost	
Inlet flowrate	12 m ³ /h	12000	8400	100800000	€ 0,0015	€ 151.200,00	
							€ 179.700,66

Fig. 5.2 Final plant cost calculation in case of potable water

From these calculations results that, the purchase of the entire plant, instead of buying potable water, allows a saving of around € 90000, considering an amortisation in five years.

6. Conclusions

The proposed system has been designed for the production of high quality osmotic water, intended for feeding a pasta production plant that will be placed in Algeria, Africa. The project has been studied from a technical, practical and economical point of view, taking into consideration the influence of several environmental factors, which may change according to the period of time on which the water analysis has been performed, on the final structure of the plant.

Starting from the specific requests presented by the customer, and according to the quality of feed water, a pre-treatment stage and a following treatment step result to be necessary.

The pre-treatment system consists on a set of appropriate filters to treat water coming from an independent source (well water) in order to preserve reverse osmosis membranes and eliminate potential dangerous elements. It consists on a Sand filter, constituted by three layers of sand with different particles size to reduce water turbidity due to clay, sand or colloidal substances, a chlorine dosing station for the elimination of bacteria and algae, a Mars filter, for Iron and Manganese removal, and a Venus filter, constituted by active carbons to remove chlorine, odour, taste, pesticides and other contaminants present in well water.

A first reverse osmosis system is required to produce 6 m³/h of osmotic water with reduced hardness, suitable for dough and cooker washing. It is characterized by six high rejection membranes (40 inches in length and 8 inches in diameter) divided into two stages. Before entering into the membranes, water passes through a multi-cartridge filter to remove possible suspended substances that could damage the membranes. An anti-scale chemical product will be added before the filter to prevent scale formation, and caustic soda will be dosed after the reverse osmosis treatment to neutralize water pH and prevent corrosion phenomena. The system is equipped with a UV sterilizer filter to ensure the complete absence of bacteria or others pathogenic agents, since water is intended for feeding food production plants. A second reverse osmosis system is necessary to produce 3 m³/h of osmotic water with extremely low water hardness, intended for feeding a steam generator. It is characterized by three membranes (40 inches in length and 8 inches in diameter)

divided into three stages. A deoxygenating agent will be added to prevent corrosion and scale problems.

To complete the plant, four tanks will be used to collect treated water and consequently four booster sets will be used to increase the water pressure at the outlet of each tank.

Before being sold, the system has been subjected to several tests in order to verify the correct functioning of the components.

Thanks to an economic evaluation, it has been demonstrated that the purchase of the entire system proposed is more convenient than buying potable water from aqueduct, considering an amortisation in five years.



Fig. 6.1 Final realized plant

Sitography

The water analysis, the initial data, and all the reported technical characteristics of plant components, datasheet, and tables have been taken from Atlas Filtri's database and website.

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