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REVERSE OSMOSIS MEMBRANE ELEMENTS nanoRO series

TECHNICAL DATASHEET AND
OPERATIONAL MANUAL

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1. GENERAL PROVISIONS

1.1. This technical datasheet and operational manual (TDS) covers reverse osmosis spiral wound elements nanoRO KM, KC, KP, K, KH and KCH series produced in accordance with TOR 2292-010-67318131-2012. Reverse osmosis spiral wound membrane elements are designed for application in the reverse osmosis membrane separation units. This technical datasheet and operational manual sets up rules of storage, installation and operation which compliance provides permanent operational readiness of the reverse osmosis spiral wound membrane elements.

1.2. The following models of the reverse osmosis spiral wound membrane elements are being manufactured:

nanoRO KM series models:

KM 2540-T, KM 2540-C,
KM 4040, KM 4040-C, KM 4040-C2, KM 4040-C3,
KM 8040, KM 8040-C, KM 8040-C2, KM 8040-C3.

nanoRO KC series models:

KC 4040, KC 4040-C, KC 4040-C2, KC 4040-C3,
KC 4040-F, KC 4040-F2, KC 4040-F3,
KC 8040, KC 8040-C, KC 8040-C2, KC 8040-C3, KC 8040-F, KC 8040-F2, KC 8040-F3.

nanoRO KP series models:

KP 4040, KP 4040-C, KP 4040-F
KP 8040, KP 8040-C, KP 8040-F,
KP 4040-D, KP 4040-C-D, KP 4040-F-D,
KP 8040-D, KP 8040-C-D, KP 8040-F-D.

nanoRO K series models:

K 1812, K 1812-50, K 2514-T, K 2521-T, K 2540-T, K 2540-C,
K 3012-T, K 4014-T, K 4014-F, K 4021-T, K 4021-F, K 4040,
K 4040-C, K 4040-C2, K 4040-C3,
K 4040-F, K 4040-F2, K 4040-F3,
K 8040, K 8040-C, K 8040-C2, K 8040-C3, K 8040-F, K 8040-F2, K 8040-F3.

K 1812-D, K 1812-50-D, K 2514-T-D, K 2521-T-D, K 2540-T-D, K 2540-C-D,
K 3012-T-D, K 4014-T-D, K 4014-F-D, K 4021-T-D, K 4021-F-D, K 4040-D,
K 4040-C-D, K 4040-C2-D, K 4040-C3-D,
K 4040-F-D, K 4040-F2-D, K 4040-F3-D,
K 8040-D, K 8040-C-D, K 8040-C2-D, K 8040-C3-D,
K 8040-F-D, K 8040-F2-D, K 8040-F3-D.

nanoRO KH series models:

KH 1812, KH 1812-50, KH 2514-T, KH 2521-T, KH 2540-C, KH 2540-T,
KH 3012-T, KH 3837-T, KH 4014-T, KH 4014-F, KH 4021-T, KH 4021-F,
KH 4040, KH 4040-C, KH 4040-T, KH 4040-F,
KH 8040, KH 8040-T, KH 8040-F, KH 8040-C,
KH 8040-C2, KH 8040-C3.

KH 1812-D, KH 1812-50-D, KH 2514-T-D, KH 2521-T-D, KH 2540-C-D,
KH 2540-T-D, KH 3012-T-D, KH 3837-T-D, KH 4014-T-D, KH 4014-F-D,
KH 4021-T-D, KH 4021-F-D.

nanoRO KCH series models:

KCH 1812, KCH 1812-50, KCH 2514-T, KCH 2521-T, KCH 2540-C, KCH 2540-T,
KCH 3012-T, KCH 4014-T, KCH 4014-F, KCH 4021-T, KCH 4021-F,
KCH 4040, KCH 4040-C, KCH 4040-T, KCH 4040-F,
KCH 8040, KCH 8040-F, KCH 8040-F2, KCH 8040-F3, KCH 8040-C, KCH 8040-C2, KCH 8040-C3.

KCH 1812-D, KCH 1812-50-D, KCH 2514-T-D, KCH 2521-T-D, KCH 2540-C-D, KCH 2540-T-D, KCH
3012-T-D, KCH 4014-T-D, KCH 4014-F-D, KCH 4021-T-D, KCH 4021-F-D,
KCH 4040-D, KCH 4040-C-D, KCH 4040-T-D, KCH 4040-F-D,

KCH 8040-D, KCH 8040-F-D, KCH 8040-F3-D, KCH 8040-C-D, KCH 8040-C3-D.

Elements identification:

nanoRO AAA XXYY-ZN-(D)

nanoRO – identification of the spiral wound membrane elements series.

AAA – identification of modification (model) of membrane;

KM – type of membrane - composite high pressure, high rejection polyamide based. Area of application – sea water desalination.

KC – type of membrane – composite high rejection polyamide based. Area of application – brackish water desalination.

KP – type of membrane – composite high rejection polyamide based. Area of application – brackish water desalination.

K – type of membrane - composite polyamide based. Area of application – brackish water desalination.

KH – type of membrane – composite low pressure polyamide based. Area of application – brackish water desalination.

KCH – type of membrane – composite extra low pressure polyamide based. Area of application – brackish water desalination.

XXYY – element sizes in inches:

XX – diameter (first two symbols), **YY** – length (second two symbols).

Z – additional information:

C – fiberglass shell,

T – polypropylene tape wrapped,

F – shrink film wrapped.

N – thickness of feed spacer for elements 8040:

Without any symbol for the elements series nanoRO KM, nanoRO K, nanoRO KC, nanoRO KH thickness of 28 mil (0,71 mm) is taken as a standard.

Without any symbol for the elements series nanoRO KCH thickness of 26 mil (0,66 mm) is taken as a standard.

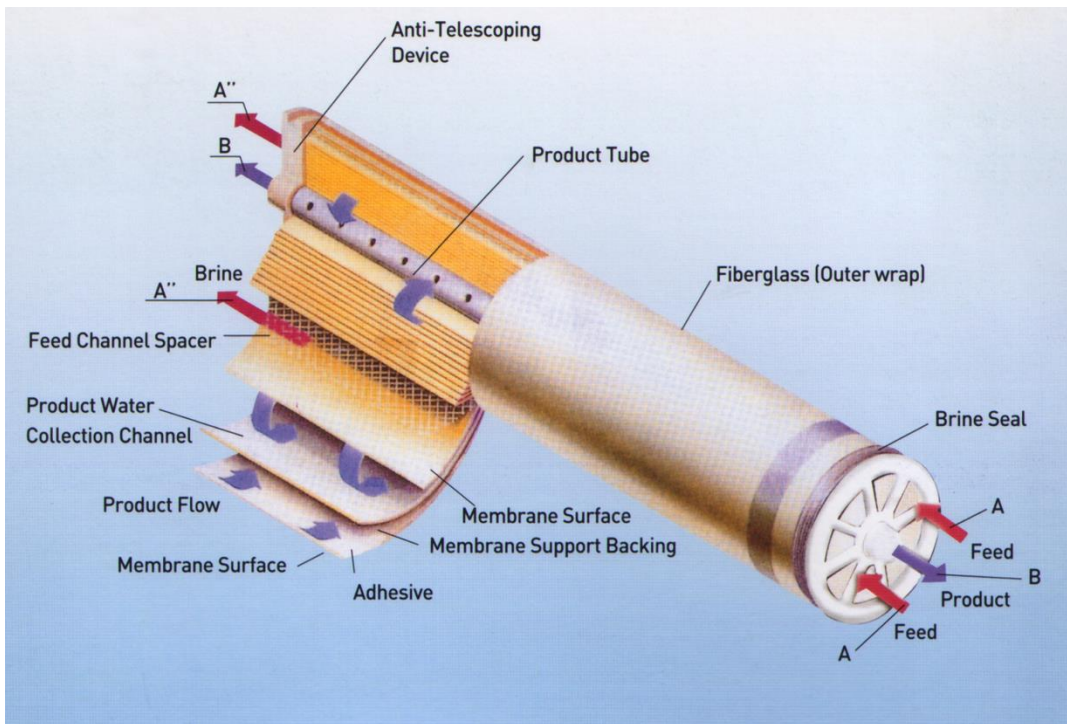
Number 2 means 31 mil (0,79 mm) thickness of feed spacer,

Number 3 means 34 mil (0,86 mm) thickness of feed spacer.

D – identification for dry membrane elements.

1.3. Reverse osmosis spiral wound elements (see picture 1) have cylindrical configuration produced by spiral winding on the perforated tube of the membrane leaves with feed spacer net inside and barrier layer between them. Membrane leaf is sealed by gluing from three inner sides; fourth inner side is open to the tube. Composite membrane acts as a filtrate semipermeable barrier.

Water filtration is carried out by flow-through method. Moving of feed solution above membrane is realized in parallel to the permeate tube axis, concentrate drop is done from the opposite side of spiral element, permeate drop is done through spiral drainage channel to the permeate tube.



Picture 1. Spiral wound membrane element.

1.4. Element's fabrication materials, which are in contact with water, do not exude into the water the contaminants in concentration increasing limits provided in Unified sanitary epidemiological requirements for goods subject to sanitary and epidemiological control, part II section 3 which is confirmed by State Registration certificate # RU.77.01.34.008.E.003690.04.13 dated 30.04.2013.

1.5. JSC "RM Nanotech" supplies spiral wound elements in dry condition and wet. Wet membrane elements are preserved in a solution containing 1% of sodium metabisulphite in order to keep operational characteristics and to prevent microbiological exposure on it.

1.6. Preserved elements are packed in an oxygen barrier film which prevents from oxygen bleeding. Bags are vacuum sealed from both sides in a nitrogen atmosphere.

1.7. Dried out membrane elements supplied in a dry condition are preliminary processed with glycerin which provides presence of residual moisture after drying out.

1.8. Non-tested dry membrane elements are made of membrane flat sheet processed with glycerin which provides presence of residual moisture after drying out.

1.9. Dry membrane elements are kept in barrier bags.

2. APPLICATION

Reverse osmosis spiral wound elements designed for the application in the reverse osmosis membrane separation units in the following areas:

- Sea water desalination;
- Brackish water desalination up to drinking level in agriculture and public utilities;
- Water preparation for thermal energy;
- Ultra-pure water production for radio electronics;
- Wastewater treatment in electroplating industry and extraction of valuable components;
- Technological solutions concentrations in chemical, pharmaceutical, dairy, metallurgical industries and other areas.

3. SHIPPING AND STORAGE

3.1. Elements packed in accordance with technological requirements can be shipped in any roofed type trucks in accordance with cargo transportation regulations at a temperature from + 5°C up to +40°C.

3.2. Storage requirements.

3.2.1. New elements should be stored in manufacturer packaging.

3.2.2. Elements packed in accordance with technological requirements should be stored indoor in a dry area at a temperature from + 5°C up to +35°C, humidity up to 60% and not in direct sunlight.

3.2.3. Elements should be stored horizontally at the shelves or pallets located not less than 1 meter from the heating elements and can be stacked 9 elements high if box is reinforced with additional support and 5 elements high if box has no additional support.

3.2.4 Elements shouldn't have any impacts of aggressive media, thermal radiation or mechanical stress while storage.

3.2.5 Avoid freezing of the elements and storage temperature more than 35°C.

3.3. Wet membrane elements storage procedures

3.3.1 Membrane elements should be inspected **not less than once every 3 months** when stored.

3.3.2. The following procedures should be performed in case of long-term storage (more than 3 months) of the membrane elements.

After 3 months of storage you are required to:

- Open cardboard box;
- Check the integrity of the barrier film;
- Check vacuum inside barrier film;
- Check membrane elements end caps for any discoloring;
- Membrane elements should be re-preserved if bags without vacuum or suspicious elements or elements with biological growth were detected (3.3);
- After inspection, if no declension was detected, put membrane element back in a cardboard box. The date of next inspection should be written outside the box.

Re-preservation and re-packing of the membrane elements are required after 6 months of storage (Section 3.3.3.).

3.3.3. Re-preservation of the membrane elements.

First you will require to prepare 1-1,5% solution of sodium metabisulfite. When dissolved in water it generates sodium hydrogen sulfite.

To prepare preservation solution you require to use food grade sodium metabisulfite containing 95% of assay and desalinated or softened water, chlorine-free; preferably reverse osmosis or nanofiltration permeate. Soak elements in preservation solution during 1 hour, keep it in vertical position for 15 minutes to dispose solution and then seal it into an oxygen barrier plastic bag. Put repacked elements in cardboard box and write down the date of next inspection. You can procure oxygen barrier plastic bags from JSC "RM Nanotech".

Re-preservation should be conducted once every 3 months after original manufacturer packaging was opened.

3.3.4. Dry membrane elements storage procedures.

Dry membrane elements should be visually inspected once every 3 months.

The following procedures should be performed in case of long-term storage (more than 3 months) of the membrane elements.

Once every 3 months you are required to:

- Open cardboard box;
 - Check for moisture inside barrier film;
 - Check membrane elements end caps for any discoloring;
 - After inspection, if no declension was detected, put membrane element back in a cardboard box. The date of next inspection should be written outside the box.
 - Membrane elements where moisture was detected inside barrier film or discoloring at the end caps should be re-preserved and re-packed in accordance with section 3.3.3.
- Storage period for dry membrane elements reversed into wet is set for not more than 3 months since the date of re-preservation subject to follow cl. 3.3.2.

4. ELEMENTS LOADING IN PRESSURE VESSEL

4.1. To prepare pressure vessel prior to installation you should remove dust, oil remains, and metal grit and spray it with clean water.

4.2. Unpack the element. Make sure that sealing rubbers are in place and there're no mechanical damages.

4.3. Unpack interconnector which is used for series connection of the membrane elements loading in multi-elements vessel. Interconnector is not used for the loading into single-element vessel.

4.4. Lubricate interconnector O-ring seals and brine seals with glycerin. Use of oil based lubricants (for example silicone) can cause damage of the membrane element.

4.5. Gently and without extra efforts to load element in pressure vessel ensuring tightness between element and vessel's wall.

4.6. You can load successively from 1 up to 3 shrink film wrapped or tape wrapped elements in pressure vessel ("F" and "T" at the end of element identification) and from 1 up to 8 elements reinforced with fiber glass ("C" at the end of element identification). Meanwhile the core tubes are connected with interconnectors which are supplied with each element.

4.7. Prepare interconnectors and special endcaps which connect core tubes of the lead and tail elements with vessel end caps.

Please note! It's forbidden to use interconnectors as endcaps. This can cause feed water leak into permeate and result in membrane element destruction.

Lubricate adapter endcaps sealing rubbers and vessel end plates with glycerin. Install endcaps in vessel and fix it. Tightness between endcaps and permeate tube as well as between endcaps and vessel is provided by the O-rings.

5. OPERATING PROCEDURES

5.1. Reliable operation of spiral wound elements is achieved by the appropriate preparation of feed solution and optimized hydrodynamic modes while operation.

5.2. Feed water requirements:

- TSS 5 microns size shouldn't exceed 1 mg/l;
- Turbidity – not more than 1 NTU;
- Oxidation – not more 5 mgO₂/l;
- Content of active chlorine, organic solvents and strong oxidizers (ozone, bromine, iodine) – not less than 0,1 mg/l;
- Content of solved aluminum – less than 0,1 mg/l (less than 0,05 mg/l in case of silicon presence);
- Content of dissolved iron – less than 0,3 mg/l (less than 0,05 mg/l in case of silicon presence);
- Content of manganese – less than 0,1 mg/l;
- Content of cationic polymers and cationic surfactants – less than 0,1 mg/l;
- SDI – less than 5;
- LSI shouldn't exceed 1,0 for operation without antiscalant and 2,6 for operation with antiscalant.

Excess of any parameter can cause warranty cancelation.

5.3. Chemical compatibility with some materials.

5.3.1 Free chlorine and other oxidizers (permanganate, ozone, bromine, iodine) are not allowed in feed water while reverse osmosis membrane elements operation. Even small amount of free chlorine in feed water can cause an irreversible destruction of the membrane selective layer. End-users should be confident that oxidizer doesn't flow into feed part of the membrane system.

In order to make sure that membrane is not affected by oxidizer, JSC "RM Nanotech" recommends to control oxidation-reduction potential at the feed of the reverse osmosis system in order to continually control presence of oxidizer in the feed water. Oxidation-reduction potential number shouldn't exceed 300 mV except for wastewater application. If oxidation-reduction potential number reached 300 mV the preventive measures to reduce this number should be taken, for example, by dosing into feed water solution of sodium metabisulphite. When oxidation-reduction potential number reached 350 mV, a reverse

osmosis system should be shut down until oxidation-reduction potential number decreases to 300 mV. In case of issues with active chlorine removal from the reverse osmosis system feed water you should request assistance from JSC "RM Nanotech's" Center of technical support.

5.3.2 Catalysts of membrane oxidization with free chlorine are transition metal ions, such as iron and manganese. If presence of such ions is unavoidable in the water you should take measures to remove 100% of free chlorine from the feed water.

5.3.3 Cationic polymers and cationic surfactants can cause irreversible changes of composite polyamide membrane characteristics. It is not recommended to use these materials during operation and chemical cleaning of the reverse osmosis membrane elements.

5.3.4 Glycerin can be used to lubricate the rubber washers. Oil based products application as lubricant can cause membrane elements damage.

Presence of the indicated materials in the feed water can cause warranty cancelation.

5.4. First start-up.

An element should be washed for at least 1 hour at the first launch.

In order to prevent destruction of the elements the following should be observed:

- Do not allow excessive feed pressure and feed flow above the levels indicated in the specification.
- Take measures for protection of the membrane elements from the back pressure on the permeate side. The pressure on the permeate side under no circumstances must exceed pressure at the feed of the membrane element. Filter valve should be open during launch of the system.
- Avoid hydraulic hammer during start-up, operation and shut down of the reverse osmosis systems.
- During start-up of the reverse osmosis system the feed pressure must be increased up to the operating level gradually within 30-60 second (at the max. rate of 0,1 MPa/sec)
- During shot down of the reverse osmosis system the feed pressure must be decreased from the operating level to zero gradually within 30-60 seconds (at the max. rate of 0,1 MPa/sec)
- Take measures for prevention of membrane elements' operation in dead-end mode without concentrate discharge.
- Feed water, permeate and concentrate tests should be conducted during operation.

5.5. Technical data and operating conditions

5.5.1. General information

Flow of each single element in a lot may vary for $\pm 15\%$. Nominal rejection of 2521 and 2540 membrane elements is achieved after 100 hours of continuous operation on test solution.

Nominal rejection of 4040 and 8040 membrane elements is achieved after 48 hours of continuous operation on test solution.

Each element is tightly packed under vacuum in a polyethylene bag and preserved with a solution containing 1% of sodium metabisulphite. Before RO unit launching all membrane elements should be washed from preservatives during 1 hour followed by permeate drop.

5.5.2. Basic technical information for each type of element is provided in the Attachment 1.

5.5.3. Sizes and dimensions for each type of element is provided in the Attachment 1.

5.5.4. Operating conditions

Recovery for each membrane element 1 m (40 inch) long must not exceed 15% for all types of membrane elements except sea water elements. Recovery for sea water membrane elements must not exceed 10%. For continuous and stable operation of sea water membrane units it is recommended to maintain recovery on each membrane element 1 m long within 6 – 8%.

Operating pressure may vary:

For sea water from 4,5 up to 7 MPa,

For brackish water from 1 up to 4 MPa,

For slightly salted and tap water from 0,5 up to 2,0 MPa depending on the salt content of feed water, temperature, recovery, operation life of the membrane elements.

- Pressure drop must not exceed 0,07 MPa on each element and 0,4 MPa on each pressure vessel.
- Feed water temperature must not exceed 45⁰C. At pH 10 maximum temperature of the feed water must not exceed 35⁰C.
- Time of chemical cleaning of the membrane elements within the range of pH 1-12 shouldn't exceed 4 hours once a month.
- The maximum turbidity of the feed water must not exceed 1 NTU, and SDI<5. For continuous and stable operation of the reverse osmosis units it is recommended to pre-treat feed water to turbidity below 0,2 NTU and SDI down to the level 1-3.

5.5.5. Permeate valve operation.

- Membrane elements should never be affected by pressure from the permeate side (where permeate static pressure exceeds concentrate static pressure) during operation nor during start-up/shot down of the reverse osmosis unit.
- Permeate valve shall never be closed during launch, cleaning, shot down and standard operation of the reverse osmosis unit.
- Closing of the permeate valve during any phase of operation causes a pressure differential across the tail end of the system and will likely result in irreparable damage to the glue lines of the tail element(s).
- Permeate valve may be closed during shutdown only when water off into the system. During start-up of the system the permeate valve should be open first and then concentrate valve prior to re-introducing feed water.

Violation of the above mentioned requirements can cause warranty cancelation.

5.5.6 Concentrate valve operation.

Concentrate valve should be fully open during system start-up. Gradual close of the concentrate valve to create operating pressure and recovery should be started only after the feed water introducing into the system.

5.6. Membrane elements flow rate measuring and temperature compensation.

Passport specifications of the membrane elements are calculated at operation pressure and feed water temperature 25±2 °C. The recovery rate of the membrane element is dropping off while feed water temperature decreasing. Below you can see a table of adjustment factor (K) value for the new membrane element recovery rate calculation depending on the feed water temperature:

Chart #2. Adjustment factor of the temperature offset

t, °C	K _T	t, °C	K _T	t, °C	K _T	t, °C	K _T
10,0	1,71	15,0	1,42	20,0	1,19	25,0	1,00
10,5	1,68	15,5	1,40	20,5	1,17	25,5	0,98
11,0	1,65	16,0	1,37	21,0	1,15	26,0	0,97
11,5	1,62	16,5	1,35	21,5	1,13	26,5	0,96
12,0	1,59	17,0	1,32	22,0	1,11	27,0	0,94
12,5	1,56	17,5	1,30	22,5	1,09	27,5	0,93
13,0	1,53	18,0	1,28	23,0	1,07	28,0	0,92
13,5	1,50	18,5	1,25	23,5	1,05	28,5	0,90
14,0	1,48	19,0	1,23	24,0	1,03	29,0	0,89
14,5	1,45	19,5	1,21	24,5	1,02	29,5	0,88

Recovery rate of the membrane element (Qt) while given temperature (t) is counted according to the formula:

$$Q_t = Q_{25} / K_t$$

Which means that while temperature decreasing from 25⁰C down to 10⁰C, the recovery rate of the membrane element will go down by 1,71 times (see the chart).

A chemical cleaning of the membrane elements is required when the membranes' unit recovery rate decreasing by 1,15 times in comparison with the passport specification data in conversion to the feed water temperature $t=25^{\circ}\text{C}$.

For example: Flow rate of pressure vessel after 48 hours of operation at the temperature 20⁰C was 10 m³/hour. Filtrate normalized flow (in conversion to the feed water temperature 25⁰C, see the chart) will be $Q_{1_{25}}=10*1.19=11,9$ m³/hour.

After 2 months of operation while feed water temperature 10⁰C and the same operating pressure the recovery rate equaled 6 m³/hour, which means $Q_{2_{15}}=6$ m³/hour.

Calculate the recovery rate in conversion to the feed water temperature 25⁰C, i.e. $Q_{2_{25}} = Q_{1_{15}} * K = 6 * 1,71 = 10,26$ m³/hour, where $K=1,71$ (data from the chart).

Consequently, the membrane elements pressure vessel recovery rate decreasing adjusted with the feed water temperature while constant operating pressure is equal to $11,9/10,26 = 1,16$ times, i.e. chemical cleaning of the membrane elements should be carried out.

6. CLEANING GUIDELINE

This paragraph provides general information about common contaminants which affect the reverse osmosis composite polyamide membrane elements operational characteristics and methods of their removal. This information applies to the membrane elements with a diameter 2.5, 4, 8 inches.

Note 1: The reverse osmosis composite polyamide membrane elements should be at no circumstances affected by the organic solvents and oil based products. Any of such impact will cause the membrane irreparable damage. Careful disinfection of the piping and equipment is required; when preparing cleaning solutions you should make sure that there's no even a trace chlorine in feed water provided to RO membrane elements. If you doubt regarding chlorine presence, we recommend to conduct chemical testing. Residual chlorine should be neutralized with sodium bisulfite solution and make sure of contact duration for the complete dechlorination.

Note 2: During warranty period it's recommended to conduct reverse osmosis membrane elements cleaning in coordination with JSC "RM Nanotech" Center of technical support specialists. If needed JSC "RM Nanotech" specialists can visit your site to provide cleaning technical support. Please, address your inquiry to check service fees.

Note 3: You should avoid using cationic surfactants which can cause in irreversible decrease of the membrane elements recovery rate.

6.1 Reverse osmosis membrane elements contaminants

Eventually in the course of standard operation the reverse osmosis membrane elements are subject to contamination with the suspended or low-solubility products which can present in feed water. The most common materials deposited on the membrane elements surface are: calcium carbonate, calcium sulfate, metal oxides, silica, organic or biological deposits.

Character and speed of the salt scale on the membrane element surface depend on the feed water composition. Salt scale is a progressive factor and if not to control it at the early stage it can have negative impact on the reverse osmosis membrane elements performance characteristics within a relatively short period of time.

Regular monitoring of overall system performance is an essential step to identify membrane elements fouling. Fouling influence on the membrane flow is a gradual process and depends on the contaminant nature. In chart 1 you can see anticipated contaminants influence rate on the membrane elements performance.

6.2 Contaminants removal

Cleaning, washing or system operational parameters changes are required to remove contaminants. Contaminants removal usually should be carried out in the following conditions:

- Normalized filtrate flow (reduced to 25 ⁰C, see cl. 5.4) dropped by 15% compare to the calculated flow under normal pressure.
- Permeate electrical conductivity was increased by 15% (salt passage was increased by 15%).

- Pressure drop in the RO pressure vessel while the product water constant flow and recovery was increased by 15%.

Excess of these parameters during operation can cause warranty obligations cancelation.

6.3. Below is a description of common contaminants and methods of their removal (chart 1).

6.3.1 Calcium carbonate scale.

Calcium carbonate deposits mostly from any type of feed water if there is a failure in the antiscalant addition system or in the acid injection pH control system that results in high pH level in feed water. An early detection of the calcium carbonate scaling is absolutely essential to prevent damage caused by crystals on the active membrane layers. Calcium carbonate scale that has been detected at the early stage can be removed by lowering the feed water pH to 3.0 - 5.0 for one or two hours. Longer resident accumulations of calcium carbonate scale can be removed by recycling of 2% citric acid and pH not less than 4.0 through the membrane elements of the solution 1.

Note: Make sure that pH level in any cleaning solution doesn't go below 2. Otherwise reverse osmosis membrane elements will be damaged particularly at the elevated temperatures. pH maximum level should be less than 12. To increase pH level use ammonium hydroxide, to decrease it – sulfuric acid or salt acid.

6.3.2 Calcium Sulfate scale

The best way of calcium sulfate scale removal from the reverse osmosis membrane element is to apply Solution 2.

6.3.3 Metal Oxides foulants

Precipitated hydroxides (e.g., ferric hydroxide) are usually removed by using calcium carbonate scale removal method.

6.3.4 Silica scales

Silica scales which are not related to metal hydroxides or organic substances can be removed using special cleaning methods only. Please contact JSC "RM Nanotech" Center of technical support for the instructions.

6.3.5 Organic deposits

The best method to remove organic deposits (e.g., microbiological gum, mold) is to apply Solution 3, 4 or 5. To reduce further foulants' growth it's recommended to treat membrane element with biocidal solution approved by JSC "RM Nanotech". This requires continuous effective treatment: a biocidal solution will have higher efficiency when blocked or cascade type RO system designed for the reserved stand for more than 3 days. For more details please contact JSC "RM Nanotech" Center of technical support.

6.3.6 Silicon (silicon – organic)

Small deposits of silicon can be removed using solution 5. In case of severe contamination silicon's deposits can be removed using special cleaning methods. Please contact JSC "RM Nanotech" Center of technical support for the instructions.

Chart 1: Signs of RO membrane elements contamination

Contaminant	Common features	Contaminant's removal measures
1. Calcium precipitates (carbonates and phosphates which are usually detected at the end of the system concentrate)	Significant decreasing of salt rejection and small increase of ΔP between feed flow and concentrate. There is also a slight decrease in the system performance.	To conduct system chemical cleaning with Solution 1
2. Hydrated oxides (iron, nickel, copper and etc.)	Salt rejection fast decreasing and ΔP fast increase between feed flow and concentrate. There is also fast decreasing in system performance.	To conduct system chemical cleaning with Solution 1
3. Mixed organic/mineral colloids (iron, organic substances and silicates)	Salt rejection gradual decreasing and gradual increase of ΔP between feed flow and concentrate. There's also gradual decrease of system performance in the course of several weeks	To conduct system chemical cleaning with Solution 2. In case of high contamination level to apply Solution 4.
4.Silicon	Salt rejection gradual decreasing and gradual increase of ΔP between feed flow and concentrate. There's also gradual decrease of system performance in the course of several weeks	To conduct system chemical cleaning with Solution 5.
5. Calcium sulfate (usually detected at the tail elements of system concentrate)	Salt rejection considerable decreasing and ΔP small/moderate increasing between feed flow and concentrate. There's also small decreasing of system performance	To conduct system chemical cleaning with Solution 2.
6. Organic deposits	Salt rejection possible decreasing and ΔP gradual increasing between feed flow and concentrate. There's also gradual decreasing of system performance	To conduct system chemical cleaning with Solution 2. Solutions 3, 4 or 5 are recommended for high fouling rates
7.Bacteriological contamination	Salt rejection possible decreasing and ΔP notable increasing between feed flow and concentrate. There's also system performance considerable decreasing	To conduct chemical cleaning with any type of solution depending on possible mixed contamination. Use solution 4 or 5 at high contamination level

Note: At any circumstances it's important to eliminate the cause contamination origin. Please contact JSC "RM Nanotech" Center of technical support.

6.4 Cleaning Solutions

Chemical solutions recommended for the cleaning of RO membrane elements are listed below in chart 2. Solution suitable for cleaning can be determined by chemical analysis of the contaminant. A detailed study of analysis's results will provide key information to determine the best cleaning method. Registration of the applied methods and obtained results will provide information (useful for the development of methods and solutions) which is the most suitable for the available feed water conditions.

Chart 2. List of recommended cleaning solutions

Solution	Component	Concentration, %	pH correction	Temperature
1.	Citric acid	2-4	Adjust to pH 2 using sulfuric or salt acid	35-40 °C
2.	Sodium tripolyphosphate Tetrasodium salt of ethylenediaminetetraacetic acid (Na ₄ EDTA)	2 1	Adjust to pH 10,5-11,0 (see chart 3) using sulfuric acid or salt acid	30-35 °C
3.	Sodium tripolyphosphate Sodium dodecylbenzene sulfonate	2 0,025	Adjust to pH 10 (see chart 3) using sulfuric acid or salt acid	30-35 °C
4.	Alkaline NaOH Sodium laurel sulfate	0,1 0,025	Adjust to pH 11,0 -11,5 (see chart 3) using alkaline or tetrabutyl ammonium hydroxide (up), sulfuric acid or salt acid (down)	35 °C max
5.	Alkaline NaOH	0,1	Adjust to pH 11,0 -11,5 (see chart 3) using alkaline or tetrabutyl ammonium hydroxide (up), sulfuric acid or salt acid (down)	35 °C max

Other special cleaning solutions besides the above mentioned can be allowed for application after coordination with JSC "RM Nanotech". All solutions are designed for the use at the highest temperatures up to 35-40°C (see the chart) during cleaning time up to 60 minutes (solution 1) and up to 30 minutes (solutions 2-4).

Solutions should be prepared on the basis of chemical agent's measuring based on the quantity of water to be used during cleaning. Free chlorine desalinated water (permeate) should be used for the solutions mixing. Mix solutions extensively before use. pH-meter should be regularly gauged. Typical time for chemical cleaning with each solution depending on the temperature is 30 minutes – 2 hours, see chart 3.

Chart 3. pH, temperature and time limits for membrane elements chemical cleaning

Membrane element type	Continuous operation		Max temperature during chemical cleaning		
	36- 45 ⁰ C	Up to 35 ⁰ C	36- 45 ⁰ C	26- 35 ⁰ C	Up to 25 ⁰ C
nanoRO KM	3-10	2-10,5	2-10,5	1-11	1-12
nanoRO K	3-10	2-10,5	2-10,5	1-11	1-12
nanoRO KC	3-9,5	2-10	2-10,5	1-11	1-12
nanoRO KH	3-9,5	2-10	2-10,5	1-11	1-12
nanoRO KCH	3-10	2-10,5	2-11	1-11,5	1-12,5
Chemical cleaning time, minutes			Not more than 30	30-60	60-120

In case of continuous operation or chemical cleaning at the temperature level more than **45⁰C** please consult JSC “RM Nanotech” Center of technical support.

6.5 Membrane elements cleaning and flushing

Reverse osmosis membrane elements in pressure vessels are flushed by cleaning solution recycling from the feed side at low pressure and at a relatively high flow. A system of chemical cleaning of the membrane elements is required for this purpose. Chemical cleaning frequency shouldn't exceed one time per month¹. Otherwise parameters of the pretreatment before RO system should be changed.

Violation of the above mentioned requirements of the chemical cleaning frequency can cause warranty cancelation.

6.5.1 General procedures for the reverse osmosis membrane elements cleaning:

1. To flush pressure vessel by pumping clean free chlorine produced water from the cleaning tank (or an equal source) for a few minutes.
2. To mix fresh volume of the selected cleaning solution in the cleaning tank using produced water. Volume of the cleaning solution is determined based on the quantity and sizes of the membrane elements (see chart 4). This volume doesn't include volume required for the feed water driving out and volume of pipes, filters and etc.

Chart 4. Volume of cleaning solutions for one membrane element.

Size of membrane element	Solution volume, liters
2540	3
4040	10
8040	40

3. To circulate the cleaning solution through the pressure vessels for approximately one hour, or within a required period of time at the flow rate 7-10 m³/h for vessel with 8040 elements and at the rate 2-2.5 m³/h for 4040 elements.
4. It's recommended to control temperature and keep required pH level of the cleaning solution in accordance with chart 2 and 3.
5. To drain and wash the cleaning tank after flushing; to fill it with the produced clean water for washing.
6. To flush the membrane elements by pumping clean free chlorine produced water from the cleaning tank (or equal source) for a few minutes.
7. After reverse osmosis system flushing, launch the system with the filtrate and concentrate valves opened until clean water free of any foam or residuals from the cleaning substances runs (usually within 15-30 min).

Note: Alkaline cleaning should be conducted first before a combined acid based chemical cleaning.

¹ **Except elements designed for waste water treatment, food and dairy industry.**

7. Preservation of the membrane elements

Membrane elements should be stored wet after use.

7.1. The following procedures should be applied if membrane system is shut down for more than 48 hours max. For shorter shut downs we recommend regular cleaning.

7.2. A chemical cleaning of the membrane elements should be done before preservation of the system. For this purpose clean elements successively with solution 4, then with desalinated water, then with solution 1 and again with desalinated water in accordance with section 6.4. Preservation should follow right after the cleaning and disinfection within maximum 12 hours between cleaning/disinfection and preservation.

7.3. Preservation is carried out by recycling of 1 - 1,5% of sodium metabisulfite solution using chemical cleaning block. Solution should be recycled through the system for around 1 hour. It is recommended to verify that system is deaerated and airproof from outside during preservation.

7.4. Close all valves at the system. Any contact of sodium metabisulfite solution with oxygen will oxidize SMBS and pH level will reduce.

7.5. Regular pH control of the preserved membrane system is required. pH level must never drop below 3. Re-preservation is mandatory when pH level is lower than 3. Preservation solution should be replaced not less than once every 3 months.

7.6. Maximum temperature must not exceed 35°C during shut down, but should not be less than 0°C. The storage optimum temperature is 5-15°C.

7.7. To restart system it should be washed from preservatives for at least 1 hour.

8. General Information

8.1. End-user bears responsibility for chemicals applying which are not recommended for operation with membrane elements.

8.2. Customer's failure to follow recommendations of operating membrane elements may result in withdrawal of the warranty obligations.

9. Terms of Warranty obligations

9.1. JSC "RM Nanotech" provides warranty for materials, workmanship and reverse osmosis membrane elements¹ performance subject to follow the operation requirements and RM Nanotech recommendations in accordance with the following provisions:

9.2. Storage warranty period of wet membrane elements is 6 months from the date of delivery subject to follow membrane elements storage procedures described in section 3.

Storage warranty period of wet membrane elements depending on temperature is provided in chart 1.

Storage temperature, C	5-15	16-35	More than 35
Storage warranty period of wet membrane elements	6 months	3 months	1 month

Storage period of wet membrane elements shouldn't exceed 12 months if procedures described in section 3 were followed.

9.3. Storage warranty period of dry membrane elements is 12 months from the date of shipment subject to follow membrane elements storage procedures described in section 3.

Storage period of dry membrane elements shouldn't exceed 18 months if procedures described in section 3 were applied.

Storage warranty period of dry membrane elements depending on temperature is provided in chart 2.

Storage temperature, C	5-15	16-35	36-45	More than 45
Storage warranty period of dry membrane elements	12 months	6 months	3 month	1 month

9.4. JSC "RM Nanotech" warrants the performance of the elements during 12 months provided that new elements were run into operation not later than 6 months from the date of shipment.

9.5. JSC "RM Nanotech" provides warranty on the materials, workmanship, and performance of its spiral-wound reverse osmosis and nanofiltration elements, when installed and operated in accordance with current operational manual and JSC "RM Nanotech's" specifications.

9.6. JSC "RM Nanotech" warrants that the elements supplied to the Buyer have the initial minimum permeate flow and initial minimum salt rejection as specified in catalogues and performance passports of the elements. These parameters are determined under standard test conditions specified by JSC "RM Nanotech". Flow of each single element in a lot may vary $\pm 15\%$. Nominal rejection of 1812, 2521 and 2540 dry membrane elements is achieved after 100 hours of continuous operation on test solution. Nominal rejection of 4040 and 8040 dry membrane elements is achieved after 48 hours of continuous operation on test solution. Nominal rejection of 4040 and 8040 wet membrane elements is achieved after 2 hours of continuous operation on test solution.

¹ Elements designed for sulphates removal, waste water treatment, food and dairy industry are not covered by this warranty.

9.7. Buyer bears responsibility for the spiral wound membrane elements maintenance during transportation, storage and installation in the pressure vessels. The customer's failure to follow recommendations for transportation, storage and installation in pressure vessels (see section 3 and 4) may result in withdrawal of the manufacturer's warranty obligations.

9.8. Buyer bears responsibility for the use of chemicals not recommended for operation with membrane elements. End-user disregard of the membrane elements operation recommendations may result in withdrawal of warranty obligations.

9.9. Buyer bears responsibility to provide end-users with the appropriate operational manuals, to instruct system operators and service personnel, to provide possibility of the appropriate cleaning and diagnostic procedures.

9.10. An element should be washed from the preservatives for at least 1 hour at the first launch. A report should be drafted based on the washing results. The following data should be summarized in operational report after 2 hours of the reverse osmosis unit operation: feed pressure, concentrate and filtrate pressure, pressure drop in the unit and at all steps, feed water/concentrate/permeate flow, feed water and permeate analysis. All initial parameters of the unit should be sent to the manufacturer of the membrane elements. Failure to provide such data at the first launch may result in withdrawal of the manufacturer's warranty obligations.

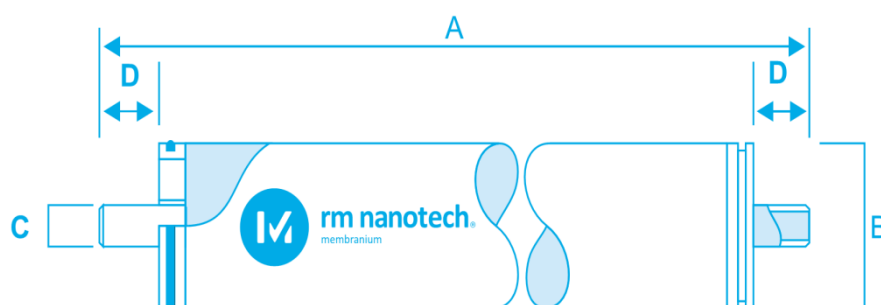
9.11. Buyer should make sure that operational characteristics of the reverse osmosis system in accordance with section 5 and 6 were regularly recorded and analyzed. This information should be available for JSC "RM Nanotech" and membrane elements supplier in case a claim for compensation is pursued in accordance with the warranty. Refusal to provide to JSC "RM Nanotech" an open access to the operational characteristics of the reverse osmosis system where JSC "RM Nanotech's" membrane elements are installed will result in complete withdrawal of warranty obligations except those for materials and components.

9.12. JSC "RM Nanotech" reserves the right to inspect the defected membrane elements and reverse osmosis units at the facility of End-user or to request buyer to conduct test and send results back to JSC "RM Nanotech".

9.13. Membrane elements can be returned not later than 90 days after shipment if they were not used and are in original manufacturer's packaging otherwise it can be refused or additional fees will be required to restore ready-for-sale condition. Customer should receive consent to return elements before sending elements for warranty inspection. Transportation fees for the returned membrane elements are covered by sender, JSC "RM Nanotech" will cover expenses for the transportation to the buyer of the elements replaced under the warranty. Elements should be kept moist and clean at all the time; elements should be placed in a moisture proof packaging before return.

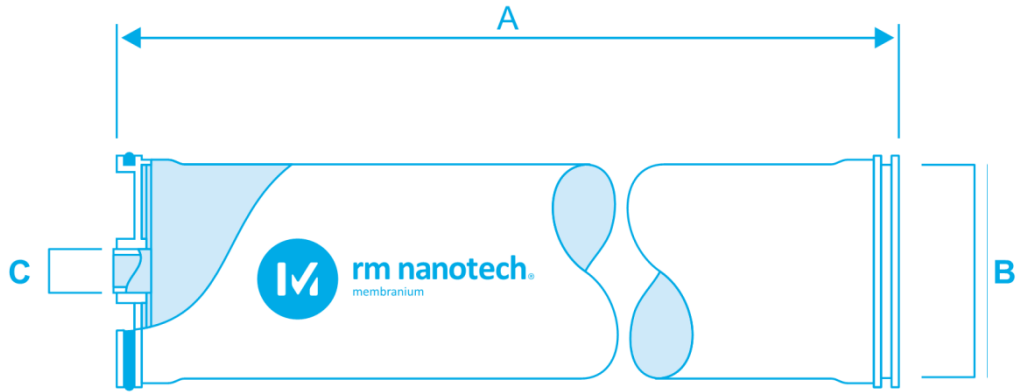
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DIMENSIONAL DRAWING OF THE MEMBRANE ELEMENT
 nanoRO series KM, KC, KP, K, KH, KCH models 1812, 2521, 2540, 4014, 4021, 4040



Model	A, mm	B' (with brine seal), mm	B _(ATD) mm	C, mm	D, mm	Weight, kg	
						Gross	Net
1812	298	55	45	17		0,22±0,02	0,19±0,02
2514-T	533,4	63,5	61,25	19,1	30,5	0,50±0,05	0,40±0,05
2521-T	533,4	63,5	61,25	19,1	30,5	0,60±0,05	0,50±0,05
2540-C	1016	63,5	61,25	19,1	30,5	2,0±0,2	1,8±0,2
2540-T	1016	63,5	61,25	19,1	30,5	1,4±0,1	1,2±0,1
4014-T	355,6	101,6	100,0	19,1	30,5	1,2±0,1	1,0±0,1
4014-F	355,6	101,6	100,0	19,1	30,5	1,2±0,1	1,0±0,1
4021-T	533,4	101,6	100,0	19,1	30,5	1,4±0,1	1,2±0,1
4021-F	533,4	101,6	100,0	19,1	30,5	1,4±0,1	1,2±0,1
4040-C	1016	101,6	100,0	19,1	26,7	4,5±0,3	4,1±0,3
4040-T	1016	101,6	100,0	19,1	26,7	3,6±0,3	3,2±0,3
4040-F	1016	101,6	100,0	19,1	26,7	3,5±0,3	3,1±0,3
1812-D	298	55	45	17		0,22±0,02	0,19±0,02
2514-T	533,4	63,5	61,25	19,1	30,5	0,50±0,05	0,40±0,05
2521-T-D	533,4	63,5	61,25	19,1	30,5	0,60±0,05	0,50±0,05
2540-C-D	1016	63,5	61,25	19,1	30,5	1,9±0,2	1,7±0,2
2540-T-D	1016	63,5	61,25	19,1	30,5	1,3±0,1	1,1±0,1
4014-T-D	355,6	101,6	100,0	19,1	30,5	1,2±0,1	1,0±0,1
4014-F-D	355,6	101,6	100,0	19,1	30,5	1,2±0,1	1,0±0,1
4021-T-D	533,4	101,6	100,0	19,1	30,5	1,4±0,1	1,2±0,1
4021-F-D	533,4	101,6	100,0	19,1	30,5	1,4±0,1	1,2±0,1
4040-C-D	1016	101,6	100,0	19,1	26,7	3,5±0,5	3,1±0,5
4040-T-D	1016	101,6	100,0	19,1	26,7	2,8±0,5	2,4±0,5
4040-F-D	1016	101,6	100,0	19,1	26,7	2,9±0,5	2,5±0,5

DIMENSIONAL DRAWING OF THE MEMBRANE ELEMENT
 nanoRO series KM, KC, KP, K, KH, KCH, model 8040



Model	A, mm	B' (with brine seal), mm	B _(ATD) , mm	C, mm	Weight, kg	
					Gross	Net
8040-T	1016	203	200,1	28,6	15,4±0,5	13,7±0,5
8040-F	1016	203	200,1	28,6	15,5±0,5	13,8±0,5
8040-C	1016	203	200,1	28,6	16,5±0,5	14,8±0,5
8040-T2	1016	203	200,1	28,6	16,4±0,5	12,7±0,5
8040-F2	1016	203	200,1	28,6	16,5±0,5	12,8±0,5
8040-C2	1016	203	200,1	28,6	17,5±0,5	15,8±0,5
8040-T3	1016	203	200,1	28,6	15,9±0,5	12,2±0,5
8040-F3	1016	203	200,1	28,6	16,0±0,5	12,3±0,5
8040-C3	1016	203	200,1	28,6	17,0±0,5	15,3±0,5
8040-T,F(2,3)-D	1016	203	200,1	28,6	12,5±1,0	11,0±1,0
8040-C(2,3)-D	1016	203	200,1	28,6	13,5±1,0	12,0±1,0