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"Membrane Research, Production and Application in Russia"

CONFIDENTIAL

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SUMMARY:
In the present report, the state of the art about the development of Membrane Science and Technology in Russia is presented. In particular, the membrane research status and the applications of the membrane science and operations in Russia are reported, with particular attention to the Russian companies manufacturing and supplying membranes and membrane devices, mainly in the field of water treatment and gas separation. A significant part of reported information about membrane research and applications has been obtained from Companies' reports and part of the information about the membrane development has been achieved by the web.

KEYWORDS:
Russia, membrane science, membrane technology, membrane devices.

Document history and validation

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Partners acronym list

During the NanoMemPro project, the different organisations will be represented by the following acronyms:

CNRS	Centre National de la Recherche Scientifique	F
Imperial	Imperial College of Science, Technology and Medicine	UK
IBET	Instituto de Biologia Experimentale Tecnológica	P
GKSS	GKSS Forschungszentrum Geesthacht GmbH	D
FORTH/ICE-HT	Institute of Chemical Engineering and High Temperature Chemical Processes - Foundation for Research and Technology Hellas	GR
Vito	Flemish Institute for Technological Research	B
SINTEF	The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology	N
UTwente	University of Twente	NL
UNIZAR	Universidad de Zaragoza	SP
LUT	Lappeenranta University of Technology	FI
ITM-CNR	Istituto per la Tecnologia delle Membrane	I
ICTP	Institute of Chemical Technology in Prague	CZ
DTU	Technical University of Denmark	DK

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1. History of the development of membrane science and technology in Russia

The development of membrane science in Russia started in the early 40s of the last century when different research groups were involved in research about ceramic membranes mainly for gas separations. In the 60s the attention of the Russian researchers focused on the fuel cells system and, for the first time in the world, on the Pd-based membrane reactors for hydrogen production.

The membrane gas separation processes were always a topic of the academic and industrial research, and nearby the development of ceramic membranes; in the 70s different groups investigated the use of the polymeric membranes for gas separation. In the 80s the serial production of commercial membrane gas separation plants was implemented by *Cryogenmash*, a private company in Moscow, while some prototypes of fuel cell bus were proposed. Unfortunately, due to the instability owing to the political processes happening in the country at that time, these projects were never realised. Also research in general had a lot of problems at the end of the 80s due to the collapse of the Soviet Union which reflected also on the Academy of Sciences of the USSR that was divided in different national Academies.

In 1991, with a decree of the Russian President, the Russian Academy of Science (RAS) was restored, inheriting all facilities of the USSR Academy of Sciences in the territory of Russia. The research on membrane started again in the academy and, at that time, different institutes, both private and public, were created and operated in this field. In the 90s the membrane research was also focused on the water treatment. With the new millennium, even though the governmental funds on the membrane processes were not at the level of the European countries, different investors from abroad went in Russia funding research on fuel cells, catalytic membranes and membrane reactors. At the moment, the biggest company working in the membrane field is *STC Vladipor* with its headquarter in Vladimir, the ancient capital of Russia. Other big companies producing membranes are *ASPECT* and *Cryogenmash*. For these three companies a lot of information is available on internet in English.

In particular, *STC Vladipor*, a subsidiary company of *OAO Polymersintez*, was set up in 1998 on the basis of scientific departments and pilot-commercial production facilities of *OAO Polymersintez* (until 1992 known as *NPO Polymersintez*) engaged in the development of membrane products for the period of over 35 years. *NPO Polymersintez* used to be the leading organization within the *Interbranch Scientific-Technical Complex (ISTC) "Membranes"* and coordinated all the research and development work performed in the country in the field of polymeric membranes and membrane processes. Over the period of the activity of *ISTC Membrane*, set up in 1985 in compliance with the decision of the Government, a tremendous growth was observed in the country with respect to scientific research activities and setting up of facilities for the production of polymeric membranes and filtering elements on their basis, as well as the expansion of applications of membrane processes for separating liquid and gaseous mixtures, primarily this can be referred to microelectronics, biotechnology, food industry, pharmaceuticals, etc.

OAO Polymersintez held three All-Union scientific conferences devoted to membrane methods of separating mixtures, the International symposium on membranes designed for gas-vapor separation. The Institute took an active part in domestic and International congresses, symposia, conferences, presented its developments and achievements at the domestic-international exhibitions and trade fairs. *STC Vladipor* participates in the development and realization of a series of all-Russian and regional programs in the field of ecology, gas separation and water preparation as well as in international projects in the field of membrane technologies.

Currently *STC Vladipor* is stuffed with a R&D department composed of four scientific labs and a shop with pilot-commercial and pilot plants designed for producing and testing membranes based on proprietary scientific-technical developments.

STC Vladipor is the owner of the a laboratory building having the area of 7465 m^2 and the shop equipped with pilot-commercial plants having the area of 5595 m^2. *STC Vladipor* maintains cooperation with the scientists of the academic and educational Institutes, scientific centres and a number of branch organizations involved in R&D in the area of membranes and membrane processes. Moreover, scientists of *Vladipor* are the authors of over 150 certificates for inventions, 12 patents (including 3 patented abroad), they published two monographs (one of them was published abroad), over 500 articles including those published in international journals, proceedings of the congresses, conferences, symposia devoted to membranes. In particular, the Vladipor staff takes an active part in arranging and holding domestic and International conferences, symposia being members of organizational committees of over 20 events of this type.

STC Vladipor produces on request the following types of membranes and elements:

- Polymeric membranes (reverse osmosis, nanofiltration, ultrafiltration, microfiltration, gas separation, and pervaporation) based on polyamides, fluroplasts, cellulose acetates and other polymers
- Based on the above membranes, spiral-wound and cartridge filtering elements of various length (250, 350, 475, 500, 750, 950, 1016 and 2000 mm) and diameter, tubular membrane modules, devices for vacuum filtration.

The main application areas of the *Vladipor* membranes and elements are:

- Water softening and treatment of surface water in order to remove low-molecular substances
- Concentration and treatment of salt solutions
- Concentration and treatment of milk raw materials and biopreparations
- Production of apyrogenic water
- Treatment, filtration and analysis of purity of washing and process fluids in precise instrumentation
- Disinfecting filtration of water
- Separation of gas mixtures
- Water quality control
- Oils quality control
- Working fluids control in hydraulic and fuel systems.

As spin-off of the same *OAO Polymersintez* other two companies were created and both of them have the headquarter in Vladimir. These two companies are the *Technofilter* (http://www.technofilter.ru/eng/info/) and *CJSC Membranes* (http://www.memb.boom.ru/) created in 1991 and 1995, respectively. Both these two companies are producing membranes with similar characteristics of the ones produced by *Vladipor*; for this reason in the following only the *Vladipor*'s membranes will be presented and discussed.

The second Russian company working in the membrane field is the *ASPECT*. Association for business cooperation in the advanced complex technologies *ASPECT* has been established in 1991 on the initiative of the leading institutions with the Ministry for Atomic Energy of the Russian Federation. Activity of the *ASPECT* Association is based upon the interaction with its founders and on the agreements with Rosatom and "Rosenergoatom" Concern granting rights for the implementation of high-end projects including the projects with foreign participants.

ASPECT Association is a non-governmental scientific-production and marketing centre providing the development, implementation, and transfer of the state-of-the-art high-end technologies and projects using domestic scientific and production potential. The Association is focused at the development of innovative high-end projects; on the assistance in the manufacturing and selling the high-end products such as membranes; on the development of the international scientific and technical cooperation. *ASPECT* Association is a licensee for operations in atomic industry and possesses its own manufacturing works needed for the production of optional and tailored equipment used in LRW processing complexes; it owns the design and technical documentation for the equipment, holds patents on the basic technological solutions.

The main application areas of the *ASPECT* are:

- Development of the unique metal-ceramic "Trumem" membranes with pore size within the range of 0.1 mm – 4 mm using nano-technologies.
- Creation of the domestic portable fuel cell with metal-carbon-ceramic porous matrices based on "Trumem" membranes used as a carrier for all membrane-electrode assembly components.
- Design and development of the metal-ceramic membrane-based membrane-catalytic reactors combining chemical processing of raw materials with the reaction product separation.

- Set up of the semi-full scale production of different type metal-ceramic ‘Trumem” membranes.
- Development and implementation of new radioactive waste and spent nuclear fuel handling technologies.

The third membrane producer is *Cryogenmash*. Since 1975 *Cryogenmash* has been dealing with the problems in the membrane technology based on selective permeability of gas mixture components through a polymer membrane. In 1976 for the first time in the world practice a pilot commercial plant of capacity 500 m^3/h was put into operation intended for concentration of hydrogen at the Shchekinsky Industrial Association "Azot" for catalytic purification of argon from oxygen.

Since 1980 the serial production of commercial membrane gas separation plants was implemented. In the plants use is made of hollow-fiber modules of new generation. The design features the modular principle of construction that allows, through transformation of unified modules, to provide for necessary productivity.

In comparison with the traditionally used methods in separation of gas and vapor-gas mixtures, the membrane technology, as a rule, requires considerably smaller capital and operational expenses.

Besides, high competitiveness of the membrane processes is provided with a complex of the following properties inherent to them:

- Lower cost and shorter time of payback
- Easy maintenance and minimum attending personnel
- Quick reaching of operating conditions (3-5 minutes)
- Big service life of the membranes – up to 15 years
- Ability of fine and fast regulation of process conditions
- Modular design and high mounting readiness
- Small size
- Ecological cleanliness
- Fireproofness and explosion safety.

The plants are available for various applications: nitrogen plants, plants for enrichment of air with oxygen, plants for hydrogen concentration, plants for creation and regulation of gas atmosphere in refrigeration chambers, in fruit storage facilities, such as "Bars", intended for maintenance of long storage of fruits and vegetables at minimum losses.

Other small companies operating in the field of membranes are present in Russia but the information about their products and their researches are not easily available in English.

2. Introduction to different membrane processes

In this section the different membrane processes studied in Russia are presented and discussed with particular attention to the membrane produced in the three big companies operating in the membrane field.

2.1. Microfiltration process

Both Vladipor and ASPECT are producing different membranes for microfiltration processes. In the following the characteristics of these membranes are presented.

2.1.1. MFAS-B membrane grade

General Characteristic

The Vladipor membranes called MFAS-B grade, are microporous film material based on acetate cellulose mixtures, having pore sizes ranging between 0.05 and 0.2 μm and total porosity of 80-85%.

Application

- Disinfecting filtration of water
- For microbiological, biological, physico-chemical research work.

Operating parameters

- Pleatable in aqueous aerosol
- Withstand autoclave and gamm-radiation sterilization
- Non-toxic
- Are produced unsupported or supported (various types of support) as a band up to 950 mm wide or as discs of various diameters (35, 47, 90, 142, 293 mm), as plates of various sizes.

Operating performance

Membrane grade	MFAS-B-1	MFAS-B-2	MFAS-B-3	MFAS-B-4
Average pore size, μm	0.05	0.1	0.15	0.2
Distilled water flux at 0.05 MPa, mL/cm^2 min.	0.50-0.99	1.00-2.99	3.00-5.99	6.00-9.99
Min. pressure of bubble point through water-wetted membrane, MPa	0.4	0.4	0.4	0.4

2.1.2. MFAS-OS membrane grade

General Characteristics

The Vladipor membranes called MFAS-OS grade, are fine-pored film material based on cellulose acetate mixture, having pore sizes within the range of 0.22-0.8 μm and total porosity of 80-85%

Application

- Clarification and filtration of aqueous media including medicinal preparations, protein media, food-stuffs, etc.
- Electrophoresis of blood serum

- MFAS-OS-1, MFAS-OS-2 membranes are recommended for sanitary-bacteriological analysis of water using membrane technology. The certificate is issued by the Scientific-Research Institute (NII) of ecology and environmental hygiene.

Membranes Vladipor of the MFAS-OS-1 grade as plates are intended for use in electrophoresis analysis of blood serum proteins. They meet the requirements put forward to the goods used in filtration of protein blood preparations. They are recommended for the use in sterilisation filtration of blood preparations due to non toxicity parameter.

Operating parameterss

- Pleatable in aqueous aerosol
- Withstand autoclave and gamma-radiation sterilization
- Are produced unsupported as a band up to 950 mm wide or as discs of various diameters (35, 47, 90, 142, 293 mm), as plates of various sizes.

Operating performance

Membrane grade	MFAS-OS-1	MFAS-OS-2	MFAS-OS-3
Average pore size, μm	0.22	0.45	0.8
Distilled water flux at 0.05 MPa, ml/cm^2 min.	8.0 -12.0	22.0-34.0	80.0-120.0
Min. pressure of bubble point through water-wetted membrane, MPa	0.39	0.23	0.11

2.1.3. Membranes, MFAS-M grade

General characteristics

Vladipor membranes, MFSA-M grade, are fine-pored film material based on cellulose acetate mixture, having pore sizes within the range of 0.4-2.0 microns and total porosity of 80-85%

Application

- Filtration and analysis of fuel and oil purity.

Operating parameters

- Pleatable in aqueous aerosol
- Withstand autoclave and gamma-radiation sterilization
- Non-toxic
- Are produced unsupported as a band up to 950 mm wide or as discs of various diameters (35, 47, 90, 142, 293 mm), as plates of various sizes.

Operating performance

Membrane grade	MFAS-M-1	MFAS-M-2	MFAS-M-3
Average pore size, μm	0.4	0.65	0.9-2.0
Distilled water flux at 0.05 MPa, ml/(cm^{2}min)	20.0-39.0	40.00-89.0	90.00-220.0
Minimum pressure of bubble point through water-wetted membrane, MPa	0.2	0.1	0.05

2.1.4. MFAS-P membrane grade

General characteristics

Vladipor membranes, MFAS-P grade, are fine-pored film material based on cellulose acetate mixture, having pore sizes within the range of 0.05-4.5μm and total porosity of 80-85%.

Application

- Purification, filtration and analysis of purity of washing and process fluids used in precise instrument engineering.

Operating parameters

- Non-toxic
- Are produced unsupported as a band up to 950 mm wide or as discs of various diameters (35, 47, 90, 142 and 293 mm), as plates of various sizes.

Operating performance

Membrane grade	MFAS-P-1	MFAS-P-2	MFAS-P-3	MFAS-P-4	MFAS-P-5
Average pore size, μm	0.05-0.15	0.2-0.5	0.85-1.5	2.4-4.5	0.5-0.85
Distilled water flux at 0.05 MPa, ml/(cm^2 min)	0.50-6.0	6.10-26.0	85.00-180.0	181.0-450.0	26.10-84.9
Minimum pressure of bubble point through water-wetted membrane, MPa	0.4	0.28	0.05	0.03	0.13

2.1.5. Membranes, MFAS-SPA grade

Material

Vladipor membranes, MFAS-SPA grade, are fine-pored film material based on cellulose acetate mixture, having pore size of 3 μm and total porosity of 80-85%.

Application

- Analysis of water quality in terms of parasitological indices.

Operating parameters

- Non-toxic
- Are produced as discs of various diameters (35, 47, 90 and 142 mm).

Operating performance

Membrane grade	MFAS-SPA
Average pore size, μm	3
Distilled water flux at 0.05 MPa, ml/(cm^2 min)	150.0-300.0
Minimum pressure of bubble point through water-wetted membrane, MPa	0,05

2.1.6. MUSA membrane grade

Material

Vladipor membranes, MUSA grade, are fine-pored film material based on cellulose acetate mixture and non-woven lavsan.

Application

- Water pretreatment
- Clarifying and sterilizing filtration of medical preparations, juices, wines, etc.
- Filtration of industrial wastes.

Operating parameters

- Withstand deformation and vibration loads
- Withstand hydraulic impact.

Operating performance

Membrane grade	MUSA-1P	MUSA-2P	MUSA-3P	MUSA-4P	MUSA-5P	MUSA-6P
Average pore size (μm)					0.1	0.2
Distilled water flux at 0.05 MPa, ml/(cm^2 min)					1-2	3-9
Distilled water flux at 1.5 MPa, ml/(cm^2 min)	0.03-0.15	0.16-0.49	0.50-1.00	1.10-2.00		
Minimum pressure of bubble point through water-wetted membrane (MPa)					0.4	0.3
Membrane retention, protein components (% min)	95	95	95	95		

Vladipor is also producing microfiltration fluoroplastic composite membranes. The characteristics of these membranes are reported in the following.

2.1.7. Micro-filtration hydrophobic membranes of the MFFK grade

General characteristics

Micro-filtration fluoroplastic composite hydrophobic membrane, MFFK grade, is a porous polymeric film material based on fluoroplastic F42L and produced on a support made of nonwoven materials (polypropylene, lavsan) with pores size 0.05; 0.15; 0.25; 0.45 and 0.60 μm and general porosity 80-85%.

Application

- Micro-processing of aggressive media, including gases
- Micro-processing of alcohols, hydrocarbons, oils, acids, alkalies, organic solvents (excluding ketones, esters, amide solvents).

Technical features

- Pleatable
- Resistant towards strong acids and alkalies
- Withstand autoclave and gamma-radiation
- Treatment with aliphatic alcohols or their aqueous solutions is needed for filtration of aqueous solutions
- Produced on various supports as a band of 600 mm width or as discs of different diameters (22, 35, 47, 90, 142 and 293 mm) and plates of different dimensions
- The membranes are approved by RF Ministry of Health for operating in contact with blood.

Operating conditions

- Maximum temperature: 80^0C
- pH range: 1-13

Operating features

	MFFK-0	MFFK-1	MFFK-2	MFFK-3	MFFK-4
Average pore size (μm)	0.05	0.15	0.25	0.45	0.60
Minimum output, ethyl alcohol, P=0.05 MPa, $dm^3/(m^2h)$, min	100	1100	3200	7500	16000
Bubble point, KPa (kgc/cm^2), limits	300±60 (3.0±0.6)	180±30 (1.8±0.3)	120±40 (1.2±0.4)	56±20 (0.56±0.2)	40±10 (0.4±0.1)

2.1.8. Micro-filtration hydrophilic membranes: MFFK-G grade

General characteristics

Micro-filtration fluoroplastic composite hydrophilic membrane, MFFK-G grade, is a porous polymer film material based on fluoroplast F42L and produced on a support from non-woven material (polypropylene, lavsan) with pore size of 0,15; 0,25; 0,45 and 0,60 μm and general porosity 80-85%.

Application

- Micro-processing of different aqueous solutions, including aggressive
- Disinfecting filtration of water
- Integrated into domestic membrane filters
- Micro-processing of aggressive media, including gases
- Micro-processing of alcohols, hydrocarbons, oils, acids, alkalies, organic solvents (excluding ketones, esters, ethers, amide solvents).

Operating features

- Pleatable
- Non-toxic
- Withstand autoclave and gamma-irradiation sterilization
- Produced on various supports, as bands of 600 mm width or as disks of different diameter (22, 35, 47, 90, 142, 293 mm) and plates of different size.

Operating conditions

- Maximum temperature: 80^{o}C
- pH range: 1-13.

	MFFK-1G	**MFFK-2G**	**MFFK-3G**	**MFFK-4G**
Average pore size (μm)	0.15	0.25	0.45	0.60
Minimum output, water, P=0.05 MPa, $dm^3/(m^2h)$, min	1100	3200	7500	16000
Bubble point, KPa (kgc/cm^2), limits	360±60 (3.6±0.6)	260±60 (2.6±0.6)	110±40 (1.1±0.4)	80±20 (0.8±0.2)

Nearby the Vladipor also ASPECT is producing membranes working on the edge between microfiltration and nanofiltration processes. In particular, Aspect is commercializing the *Trumem*® membranes. The main characteristics of these membranes are reported in the following.

Description and Patents

Thin tubular or flat sheet metal/ceramic two layer or stainless steel single layer membrane. Trumem® membranes are 150-250 μm thick with ceramic layer about 15 μm thick. Trumem® membranes are manufactured under Russian, European and U.S.A. patents (U.S. Patents # 5, 830, 340 and #5, 364, 586). Membrane trademark number is 75-155.401, filed 8-26-1996.

Configurations

Trumem® membranes are available in tubes or flat sheets of various shapes. Tubes are currently available with the ceramic layer on the inside or outside surfaces, in lengths up to 950 mm and diameters as small as 10 mm. Current standard flat sheets are 285 mm x 285 mm, but larger sizes can be easily mounted by "micro" welding sheets together. Membrane housing design is providing support for the tubular or flat sheet filter or sparger.

Pore size and Flux Data

Trumem® membranes operate in the ultra-filtration and micro-filtration range with pore sizes ranging from 0.1 μm to 5 μm and with narrow distribution of pore sizes around a given mean size. With appropriate support provided by the membrane housing, both tubular and flat sheet membranes can withstand up to 10 bar trans-membrane pressure (TMP) drop.

Two layer membranes cover the 0.07 μm to 1 μm mean pore size (diameter) range. Two layer membranes typically consist of a stainless steel substrate and the thin ceramic layer of: TiO_2, TiO_2/Al_2O_3, ZrO_2, or SiO_2. Clean, distilled water flux rates range from 2,800 to 18,000 l/h m² at TMP of 2 bar. Argon gas flux rates for a nominal 0.1 μm mean pore size membrane used as a sparger are around 200,000 l/h m² at TMP of 0.5 bar.

Single layer membranes are made of stainless steel and are currently available with a mean pore size (diameter) range from 2 μmto 5 μm. Clean, distilled water flux rates for 2.5 - 3.0 μm mean pore size membranes ranges from 25,000 to 30,000 l/hm² at TMP of 2 bar. Argon gas flux rates for this membrane used as a sparger are around 150,000 l/ hrm² at TMP of 0.1 bar.

Installation

Trumem® membranes are very malleable and can be easily installed into various housings. Trumem® membranes can be easily installed by means of conventional pressure fittings or by welding or brazing into any assembly. In the tubular configuration, ends of tubes can be non-porous stainless steel of a specified diameter or attached to most any customer specified bushing.

Operating ***Environment/Capabilities***

Trumem® membranes have high mechanical strength, long lifetime, high porosity and superior flow rates. Membranes are not affected by bacteria and by selection of the appropriate ceramic; they will be resistant to aggressive media. Trumem® membranes can be regenerated by back flushing or by heat treatment (up to 300°C in the air and up to 800°C in an inert or reducing atmosphere).

Membranes can be treated by high temperature steam or most any other sterilizing solution. Typically, Trumem® membranes will provide enhanced performance for applications wherever polymer membranes are traditionally used. For example:

- Oil/water emulsion separation
- Cell debris filtration
- Beer tank bottoms cleaning
- Fruit juice clarification
- Waste water cleaning.

2.2. Ultrafiltration process

2.2.1. Cellulose acetate membranes

General characteristics

Vladipor membranes, UAM series, are polymeric porous semi-transparent or white films based on cellulose acetates on supports: polypropylene, woven and non-woven lavsan.

Application

- Concentration of dilute solutions of high-molecular compounds, removal of impurities
- Fractionation of substance mixtures
- Filtration of industrial wastes
- Water pretreatment
- For producing spiral-wound elements.

Operating parameters

- High hydrophility and rigidity of polymer ensure prolonged stability and retaining of operating characteristics
- Non-toxic
- Safe in operation.

Operating conditions

- Maximum temperature: 50 °C
- Operating pH range: 3-8
- Cl resistance (mln^{-1}, min): 5

Operating performance

Operating parameters	**UAM grade**					
Type	50П	100П	150П	300П	500П	1000П
Minimal retention, %						
Mioglobine (12700 D)	98.5	95.0	90.0			
Albumin (67000D)				97.0	98.5	
Gamma-globulin (150000D)						98.5
Operating pressure, MPa	0.15	0.15	0.15	0.15	0.15	0.15
Minimum distilled water flux, dm^3/m^2 h (ml/cm^2 min)	12 (0.002)	6 (0.01)	14.8 (0.028)	66 (0.11)	186 (0.31)	1200 (2.0)

2.2.2. Polysulfonamide membranes

General characteristics

Vladipor membranes, UPM series, are polymeric porous films based on aromatic polysulfonamide "Sulfone-T" on support (polypropylene, woven and non-woven lavsan).

Application

- Concentration and purification of ferment solutions, raw dairy produce, biologically active substances (viruses, blood preparations, etc.)
- Completing specific ultrafiltration plants.

Operating parameters

- Improved thermal and aggressivity resistance
- Non-toxic
- Explosion-proof.

Operating conditions

- Maximum water temperature: 100 °C
- Working pH range: 2-12

Operating parameters	**UPM grade**							
	10	20	50	50M	100	200	П	ПП
Operating pressure (MPa)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Minimum distilled water flux, (dm^3/m^2 h), ((ml/cm^2 min))	15 (0.025)	60 (0.1)	72 (0.12)	180 (0.3)	840 (1.4)	1560 (2.6)	100 (0.16)	100 (0.16)
Min. retention, %								
Cytochrome (12700)	95							
Mioglobine (17000)		95						
Gemoglobine (64500)			98	97				
Protein components of milk raw materials							95	95
Albumin (67000)			97					
Gamma-globulin (150000)					98	90		

2.2.3. Phenylon membranes

General characteristics

Vladipor membranes, UFM series, are polyamide-supported polymeric films based on polyamide. As supports, polypropylene, woven or non-woven lavsan can be used.

Application

- Uultra-filtration of raw dairy produce, biopreparations, ferment solutions, and food raw material
- Dairy, food, pharmaceutical and medicinal industries
- Biotechnology and microbiology.

Features and advantages

- Non-toxic
- Improved aggresion and thermal resistance
- Low-burnung and safe in operation
- Explosion-proof.

	UFM grade				
	20	50	100	П	ПТ
Operating pressure, MPa	0.1	0.1	0.1	0.1	0.1
Minimum distilled water flux, dm^3/m^2 h (ml/cm^2 min)	100 (0.16)	240 (0.4)	900 (1.5)	150 (0.25)	240 (0.4)
Min. rejection, % in terms of					
Gemoglobine (64500 D)		98		98	98
Mioglobine (17000 D)	95				
Gammo-globulin (150000 D)			98		

2.3. Nanofiltration process

2.3.1. OPMN membrane grade

General characteristic

Vladipor membranes, OPMN and OFMN series, are polyamide-supported porous polymeric films on a polyamide support.

Application

- Separating organic materials and salts containing polyvalent anions from monovalent salts in aqueous solutions
- Water softening and surface water treatment in order to remove low-molecular substances
- Concentration and purification of salt solutions
- Purification and concentration of food and biological raw materials
- Completing domestic membrane desalination plants.

Operating parameters

- Production of high-quality potable water
- Low-burning
- Non-toxic
- Safe in operation.

Operating conditions

- Maximum temperature: 45°C
- Operating pH range: 2-12
- Operating pH range : 3 –8 (for AMN-P)

Grade	**OPMN (OFMN) P**	**OPMN К**	**AMN P**
Operating parameters			
Operating pressure, MPa	1.6	1.6	1.6
Minimum water flux at 25 ^{0}C, dm^3/m^2 h	100	100	40
Retention, %			
0,2% $MgSO_4$, min	98.5	93	98.0
0,15% NaCl, min	55.0	25.0	60.0
Cl resistance, mln^{-1} , min	1	1	5

2.3.2. Charged ultra- and nano-filtration membranes Vladipor based on fluoroplast

General characteristic

Charged ultra-nanofiltration membranes Vladipor are porous polymeric film materials which are produced on the basis of fluoroplast F42L and on a support made of non-woven materials (polypropylene, lavsan) with a separating ultra and nano filtration diaphragm.

Application

- Desalination of oligomeric product
- Water softening and removing of dyeing low molecular compounds from surface waters
- Hot water filtration
- Ultra filtration processing of aqueous media
- Disinfecting filtration of water
- Installation into domestic water processing systems
- Concentration and processing of salinated solvents

Operating features

- Presence of polymers with charged chemical groups in the diaphragm
- Retention of hydrophilic properties
- Non-toxicity
- Withstand autoclave and gamma-radiation sterilization
- Produced on various supports

Operating conditions

- Maximum temperature: 900°C
- pH range: 1 -11

Charged ultrafiltration membranes (UFZ)			
	UFZ-2кD	**UFZ-6кD**	**UFZ-10кD**
Output, water, P=0,1 MPa, $dm^3/(m^2h)$, min	14	22	50
Retention			
molecular mass (cut-off), kD	2	6	10
Selectivity, %			
vitamin B12 (0.15% mass)	> 50	65	33
dye “chromium black” (0.2% mass)	>90	60	30
Charged nanofiltration membranes (NFZ)			
	NFZ-1	**NFZ-2**	**NFZ-3**
Output, water, P=0.5 MPa, $dm^3/(m^2h)$, min	50	35	25
Selectivity, %			
NaCl (0.15% mass)	15	25	35
$MgSO_4$ (0.2% mass)	>30	>90	>95
$CaCl_2$ (0.1% mass)	15	45	65

2.4. Reverse Osmosis process

2.4.1. Reverse-osmotic cellulose acetate membranes

General characteristics

Vladipor membranes, MGA series, are porous polymeric semi-transparent or white films based on cellulose acetate, on support (polypropylene, woven and non-woven lavsan).

Application

- Desalination of brackish or salt waters with salt content of up to 20 g/l
- Treatment of waste waters and processing of effluents to remove hazardous impurities
- Extraction of valuable substances from aqueous solutions
- For installation into spiral-wound filter elements.

Operating Parameters

- High hydrophilicity and rigidity of polymer ensures prolonged service life of membranes
- Non-toxic
- Safe in operation.

Operating conditions

- Maximum temperature: 50°C
- Operating pH range: 3-8
- Cl resistance, mln-1, min: 5

Operating parameters

Grade	**MGA**					
	70П	80П	90П	95 П-Н	95 П-Т	100П
Operating parameters						
Operating pressure, MPa	5.0	5.0	5.0	5.0	3.0	5.0
Minimum water flux (in terms of filtrate), dm^3/m^2 h, t= 25^0C	92	63	42	33	35	25
Retention, %						
0.15% NaCl, min					95.0	
0.5% NaCl, min.	70.0	80.0	90.0	95.0		97.0

2.5. Pervaporation process

2.5.1. Hydrophilic pervaporation composite membranes Vladipor

General characteristics

Hydrophilic pervaporation composite membrane of the Vladipor type is a porous polymer film material based on fluoroplast F42L and produced on support made of non-woven materials (polypropylene, lavsan) with a separating hydrophilic diaphragm.

Application

- Dehydration of organic solvents
- Dehydration of air and gaseous mixtures.

Technical features

- High selectivity of separation
- Presence of polymers with charged chemical groups in the separating layer
- Retention of hydrophilic properties
- Non-toxic
- Withstand autoclave and gamma-radiation
- Produced on various supports as a band of 600 mm width or as disks of various diameter (22, 35, 47, 90,142, and 293 mm) and as plates of different dimensions.

Operating conditions

- Maximum temperature: 80^{o}C
- pH range: 2-8
- Concentration of water in the starting mixture – below 30% (mass)

Operating characteristics

Separated mixture *	**Ethanol/water 94/6**	**Iso-propanol/water 88/12**	**Tert-butanol/water 95/5**
Output, permeate, kg/(m^{2}h), min	0.2	0.65	0.30
Water content in permeate, % mass, min	95	99	99

* Test conditions: temperature of the feeding mixture – 60^{o}C; permeate pressure – 10 mmHg.

2.5.2. Lyophilic pervaporation composite membranes Vladipor

General characteristic

Liophilic pervaporation composite membrane Vladipor is a porous polymer film material based on fluoroplast F42L and produced on a support made of non-woven material (polypropylene, lavsan) with a separating lyophilic diaphragm.

Application

- Processing of water and removing organic solvents
- Processing of air and gas mixtures and removing organic solvents.

Operating features

- Highly selective separation
- Non-toxic
- Withstand autoclave and gamma-radiation sterilization
- Produced on various supports as a band of 600 mm width or as discs of different diameters (22, 35, 47, 90, 142, and 293 mm) and as plates of different dimensions.

Operating conditions

- Maximum temperature: 80°C
- pH range: 2-8

Operating characteristics

	Water/ethanol 95/5	**Water/methylene chloride 98.5/1.5**
Output, permeate, kg/(m^2h), min	0.25	0.25
Organics content in permeate, %mass, min	40	75

2.6. Gas Separation process

2.6.1. Gas separation composite membranes Vladipor: MDK grade

General characteristics

Gas separation composite membrane Vladipor of the MDK type is a porous polymer film material based on fluoroplast F42L film material on a non-woven support (polypropylene, lavsan) with a thin diaphragm made of organic silicon polymer.

Application

- As a separating element in different gas separation systems
- In membrane oxygenerators
- In air separation and air enrichment installations.

Operating features

- Non-toxic
- Withstand autoclave and gamma-radiation sterilization
- Produced on supports of various types as a band of 600 mm width or as discs of different diameters (22, 35, 47,142 and 293 mm) and plates of different dimensions.
- Approved by Ministry of Health for works with blood.

Operating conditions

- Maximum temperature: 80^{o}C
- pH range: 2-8

Operating characteristics

	MDK-1	**MDK-1**	**MDK-1**
Output, oxygen, $dm^3/(m^2h\ MPa)$, min	1500	2200	2600
Selectivity O_2/N_2, min	2.0	2.0	2.0

2.7. Composite membranes

2.7.1. Vladipor composite membranes

General characteristics

Vladipor membranes, OPAM,OFAM, OPM and OFM series, are porous polymeric films based on polyamide on support (polypropylene, woven and non-woven lavsan).

Application

- Concentration and purification of salt solutions with salt content below 35 g/l
- Concentration and purification of raw dairy produce and biopreparations
- Production of apyrogenic water
- Completion of domestic membrane desalination plants.

Operating parameters

- High flux
- Improved chemical resistance
- Resistance to biodestruction
- Explosion-proof
- Low-burning
- Safe in operation
- Non-toxic.

Operating conditions

- Maximum temperature: 45°C
- Operating pH range: 2-11

Grade	**OPAM**	**OFAM**		**OPM**		**OFM**
	КН	**КН**	**К**	**КМ**	**КМТ**	**КМ**
Operating parameters						
Operating pressure, MPa	1.5	1.5	3.0	5.0	5.5	5.0
Minimal water flux (in terms of filtrate), T= 25^0, dm^3/m^2 h	35	35	80	50	20	50
Retention, %						
0,15% NaCl, min	95.0	95.0	96.0	98.5		98.5
3,0% NaCl, min					97	
Maximum Cl resistance, mln^{-1}, max.	0.01	0.01	0.01	0.1	0.1	0.1

2.8. Membrane reactors

The Russian scientists have a long experience on membrane reactors. For example, early in 1935, Kobosev (Moscow University) investigated the hydrogenation on palladium membranes by hydrogen supplied as a gas to other surfaces. After that, a mile stone in the membrane reactors area was placed in 1964 by the Academician Prof. Vladimir Gryaznov (Moscow University) first proposed a method for carrying out simultaneously the evolution and the consumption of H_2 in a dense tubular palladium reactor, where palladium is permeable to H_2 only and also serves as a catalyst. The reaction studied was cyclohexane dehydrogenation to benzene. Different academic groups are making research on this topic. Considering the industrial projects, very interesting is the one coordinated by *ASPECT*. In fact, one of the most large-scale and "breakthrough" applications for the *ASPECT* nanoporous membrane materials is development and design of so-called catalytic nanomembrane reactors (i.e. devices capable of combining the chemical processing of raw materials and reaction products separation).

As it is well known, the combination of a membrane and a catalyst within one module may open new opportunities for improving selectivity of raw material utilization and reducing power consumption at the stage of catalytic synthesis.

Gradient porous ceramic membranes are "groups of nanosized channels" with a density of up to $1{,}0x10^{10}$ per 1 cm² of the membrane. With catalyst applied to inner walls of such membrane channels, the membrane becomes a set of nanosize reactors.

When such reactors are switched to filtration mode, the temperature inside them goes quickly down to create favorable conditions for running the reaction while changing its selectivity This equipment makes it possible to carry out oxidizing transformation of methane and its homologous compounds in an explosion-proof and environmentally friendly manner.

Catalytic membrane-based multireactor units have the following key advantages:

- Minimum number of energy consumptive stages of separation
- Higher output of the target product owing to continuous discharge of one or more products from the reaction zone
- Possibility to carry out oxidative transformation of light hydrocarbons under explosion-proof conditions
- Lower capital costs required for building such units
- Easy exchangeability of units and flexible flow sheets
- Higher selectivity of chemical processes at reasonable temperatures.

The new flexible technologies allow:

- To bring refinery of hydrocarbon raw material (like natural gas, crude oil, associated petroleum gas) to a new level of effectiveness
- For the first time in history to bypass difficult-to-overcome stages of process scaling
- To significantly reduce raw material consumption and power costs.

Besides effective solution of environmental problems, a revolutionary new technology for utilization of associated petroleum gas, which was developed by *ASPECT* Association and scientific research institutes of the Russian Academy of Sciences, now makes it possible to meet an increasing demand for olefins (ethylene, propylene and butylenes) and benzene hydrocarbons (benzyl, methyl benzene etc.) on the market of oil refinery products and in parallel to start producing high-purity hydrogen as a fuel for hydrogen power engineering purposes. In 2005–2007 it is planned to perform a number of works on testing and mass producing catalytic nanomembrane-based systems, which would simultaneously act as a reactor for converting a mixture of saturated hydrocarbons into olefins or aromatic compounds and a device for separating these products from hydrogen. In Russia this project is being carried out at the order of the Russian Federal Agency for Science and Innovations.

2.9. Fuel Cells

As already stated in the introduction, the Russian scientists were already working and patented on fuel cell systems in the 80s. Nowadays the fuel cell field is one of the most funded membrane field in Russia. Different industrial partners are involved in this research area. The biggest project is the so-called “New Energy Projects” (NEP).

On November 10th, 2003, the President of the Russian Academy of Sciences and an academician, together with the General of *Norilsk Nickel MMC* (the world's largest producer of palladium and nickel, one of the leading platinum producers and one of the top 10 copper producers), signed a General Agreement on cooperation between the Russian Academy of Sciences and Norilsk Nickel MMC in the field of hydrogen power and fuel cells. To implement the Agreement and the Investment Program a national innovation company named *New Energy Projects* was founded.

According to Yuri Osipov, the President of the Russian Academy of Sciences: “A very important agreement has been signed, one which I hope will be a long-term agreement in the field of hydrogen power. The interests of large Russian business and those of Russian science have concurred. We hope to fill this agreement with more specific content. Let it serve the best interests of Russia.”

According to Mikhail Prokhorov, the General Director and Chairman of the Board of Directors of Norilsk Nickel MMC: “For Norilsk Nickel this agreement has a strategic value. It will make the basis that will enable our country to convert from a great supplier of raw materials to a great technological power. The basis of this agreement is high technology, which will be the basis for development of the world economy as a whole over the next 10 years.

The company “New energy projects” conducts research and development work for the settling of the challenging issues regarding the Fuel Cells. The main purpose of these investigations is the prospective native PEMFC and PEMFC components having the parameters higher than the best foreign materials and systems. The creation of high-efficient membrane electrolyte, electrocatalysis, gas-diffusion and active layer materials is foreseen. The new techniques and technology for the MEA formation are under development. The main attention is paid to the MEAs structural, electrochemical and construction properties optimization.

Also concerning the Alkaline fuel cells (AFC), the NEP is making research for answering to the main problem for the AFC technology effective commercialization which are low specific parameters (mainly for the flowing electrolyte systems) and insufficient operation resource partly concerned with the harmful influence of the impurities in the reactants (For the power plant economically proved is the lifetime more than 40000 hours).

Finally, concerning the Solid oxide fuel cells (SOFC) technology, the NEP develops following projects in the field of SOFC technology:

- Tubular SOFC with bearing anode development. The project is devoted to the technologies of the SOFC with the bearing metal anode production elaboration. These technologies will allow thin-layered cathode and electrolyte using. The experimental series of fuel cells manufacturing and selective SOFC testing will create the basis for the industrial manufacturing technology elaboration.
- New cathode materials for the SOFC development. The main limiting stage of the hydrogen electrochemical oxidation process in the fuel cell is the oxidant feed to the reaction area. In the framework of this project new electrode materials are under development. These materials possess specific properties and are able to increase the three-phase boundary area without material strength and electric conductivity decrease. The expected result of the project implementation is the choice of the low-cost cathode material which will be able to significantly improve fuel cell parameters without significant fuel cell cost increase.

2.10. Housing and installation

Beside the membrane production, another aspect well studied in Russia is the problem related to the housing and the installation of the membrane and membrane modules. Hereafter, the main modules used in the Russian membrane industry are reported.

2.10.1. Membrane Spiral-Wound Elements

2.10.1.1. ERU series elements

Material

Elements of the ERU series are produced on the basis of Vladipor membranes, UPM and UFM series, offering variable molecular weight cut off values (20000, 50000 Dalton). Under special order ERU series elements may be produced using UPM and UFM membranes having molecular weight cut off values of 10 000, 100 000, 200 000 Dalton.

Application

Concentration and treatment of biologically active products (viruses, blood preparations), ferment solutions, dairy produce, proteins, cottage cheese and cheese serum, skimmed milk, etc.

Operating conditions

- Maximum pressure, MPa: 1.0
- Working pH range: 2-11
- Maximum temperature: 55°C
- Resistance to Cl, mln^{-1}: 1.0

Grade	**P-100-508 (20000)**	**P-100-1016 (20000)**	**P-61-508 (50000)**	**P-100-1016 (50000)**
Operating parameters				
Operating pressure, MPa	0.2	0.2	0.2	0.2
Flux, dm^3/h	200	400	400	800

2.10.1.2. ERN series elements

Material

Elements of the ERN series are based on nanofiltration Vladipor membranes of OPMN, OFMN and AMN series.

Application

- Separating organic matters from salts in aqueous solutions, for water softening and treatment of surface water to remove low-molecular sunstances, for concentration and purification of salt solutions in biotechnology, water preparation, in dairy, food, chemical and electronic branches of industry.
- Completing domestic devices and plants of the “Rucheek” series.

Advantages

- Water softening
- Tertiary treatment of potable water to remove low-molecular impurities under relatively low pressure.

Operating conditions

- Maximum pressure, MPa: 2.5 (for ERN-B-45-350 0.8)
- Working pH range: 2-11
- Maximum temperature: 45°C
- Resistance to Cl, mln^{-1}: 1.0

Grade	B-45-350	КР-100-1016	КР-200-1016	КР-96-950
Operating parameters				
Operating pressure, MPa	0.5	1.6	1.6	1.6
Flux, dm^3/h	8	500	2000	400
Rejection, % in terms of:				
0.2% $MgSO_4$	90	97	95	97
0.15% NaCl		60	50	60

2.10.1.3. ERO series elements

Material

- Elements of ERO-B, ERO-K,ERO-KN,ERO-KM are produced on the basis of Vladipor composite membranes.
- Elements of ERO series are produced on the basis of cellulose acetate Vladipor membranes.

Application

- Biotechnology
- Desalination of sea water
- Medical industry
- Dairy industry
- Food industry
- Chemical industry
- Electronic industry.

Low-pressure osmosis

Grade	B-45-310	KN-100-1016	KN-200-1016	KN-96-950	KNI-100-1016	KNI-200-1016
Operating parameters						
Operating pressure, MPa	0.8	1.6	1.6	1.6	1.05	1.05
Flux, dm^3/h	10	250	1000	200	400	1700
Minimum 0,15% NaCl rejection, %	80	90	90	90	98.5	98
Maximum Cl resistance, mln^{-1}	0.01	0.01	0.01	0.01	0.1	0.1
Operating conditions						
Maximum pressure, MPa,	1.0	2.0	2.0	2.0	2.5	2.5
Operating pH range	2-11	2-11	2-11	2-11	3-10	3-10
Maximum temperature, °C	45	45	45	45	45	45

Medium-pressure osmosis

Grade	K-100-1016	100-1016	200-1016
Operating parameters			
Operating pressure, MPa	3.0	3.0	3.0
Flux, dm^3/h	400	150	700
Minimum по 0,15% NaCl rejection, %	90	92	92
Maximum Cl resistance, mln^{-1}	0.01	5	5
Operating conditions			
Maximum pressure, MPa,	3.5	3.5	3.5
Operating pH range	2-11	3-8	3-8
Maximum temperature, °C	45	45	50

High-pressure osmosis

Grade	KM-100 -1016	KM-96-950	KM-MO -100-1016	96-475	96-950	100-475	100-1016
Operating parameters							
Operating pressure, MPa	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Flux, dm^3/h	230	200	80	60	180	70	210
Minimum rejection, % in terms of:							
0.15% NaCl	98	98		90	92	92	92
3.0% NaCl			97				
Maximum Cl resistance, mln^{-1}	0.1	0.1	0.1	5	5	5	5

Operating conditions							
Maximum pressure, MPa,	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Operating pH range	2-11	2-11	2-11	3-8	3-8	3-8	3-8
Maximum temperature, °C	45	45	45	45	45	45	45

2.10.2. Tubular Membrane Modules

General characteristics

Tubular modules designed for ultra- and micro-filtration consist of 7 open-porous tubes of 2 m length having a membrane applied on their inner surface. The ends of the tubes are filled with a sealing compound forming securing casings of 60 mm diameter.

Application

Ultra (BTU) and micro (BTM) modules are designed for separation, concentration and purification of the components of liquid mixtures and waste waters (solutions of high-molecular substances and colloidal solutions, finely divided suspensions, low-coalescing emulsions). They are perfectly suited for treating solutions containing particles and high viscous solutions or solutions becoming viscous during treatment.

Operating parameters

- Number of tubes per module: 7
- Tube hydraulic diameter, mm: 13,3
- Length, mm: 2000
- Diameter along casings, mm: 60
- Filtration area, m^2: 0,5
- Tube material carbon, glass or organic plastic

2.10.2.1. TUBULAR ULTRA-FILTRATION MODULES : BTU SERIES

Membrane material	**Cellulose acetate(CA)**	**Poly-sulfone (PS)**	**Polysulfoneamide (PSA)**	**PolyamidePA 6,6)**	**Polyvinyl-chloride (PVC)**	**Fluoroplast (F)**
Technical characteristics						
Approximate molecular weight of the substances being rejected, K Dalton	20	30	30	30	30	70
Desalted water permeability (at P=0,2 MPa, T=25^0C after 1 hour testing) l/m^2 hч	150	300	600	450	300	700

Operating performance						
Recommended operating pressure, MPa	For modules of 0,1 – 0,5					
pH	4-8	1-13	2-11	2-11	1-12	1-12
Operating temperature, ^{o}C	0-30	0-80	0-60	0-40	0-60	0-60
Chlorine resistance at desinfection, mg/l	10	300	0	0	300	300
Recommended flow rate over the membrane surface, m/s	4-5	4-5	4-5	4-5	4-5	4-5

2.10.2.2. TUBULAR MICROFILTRATION MODULES : BTM SERIES

Membrane material	**Polysulfone (PS)**	**Polysulfoneamide (PSA)**	**Fluoroplast (F)**
Technical characteristics			
Average pore size, μm	0,2 - 0,45	0,2 - 0,45	0,2 - 0,6
Pure water permeability after 5 hours of testing at P=0,1 MPa, T=25^{0} C. l/m^{2} h	200 - 250	300 - 600	250 - 600
Operating performance			
Recommended operating pressure, MPa	0,1 - 0,1	0,1 - 0,1	0,1 - 0,1
Recommended flow rate over the membrane surface, exceeding, m/s	2,5 - 2,5	2,5 - 2,5	2,5 - 2,5

2.10.3. Filtering elements: EPM.K grade

General characteristic

The cartridge elements of the EPM.K grade based on polyamide membranes with pores in the range of 0.1 - 3 microns are close analogs to the elements ULTIPOR and NYLAFLO of the PALL firm and BIOFLOW of the PTI TECHNOLOGIES INC (USA) firm.

Application

Membrane filtering elements of the EPM.K grade are intended for the finishing stage in filtration of aqueous, neutral and aggressive media (compatible with polypropylene and the membrane material) and can be applied in:

- Medicine and pharmaceutics for fine, clarifying and sterilizing filtration of medicinal preparations, blood protein preparations, bacterial and enzymatic media, pharmaceutical liquids
- In food industry for cold sterilization and clarification of beverages and wine, purification of technological, drinking, mineral water and polishing filtration of vodka
- In electronic, radio and chemical industry for finishing purification of deionized water, photoresists, solvents and other media compatible with the material of the element
- In other branches of industry for fine purification and removing particles of 0.1 micron and above.

Operating parameters

Membrane material	**Polyamide (nylon)**						
Average pore size, microns	0.1	0.2	0.45	0.65	0.8	1.0	1.2
Min. pressure of bubble point through water-wetted membrane, MPa	0.43	0.33	0.24	0.17	0.12	0.10	0.8
Initial output, distilled water, t 20^0C and P – o,o5 mPa, m^3/h, min	0.5	1.0	1.8	2.4	3.1	4.0	4.8
Maximum pressure grade, mPa	0.4						
Maximum reverse pressure grade, mPa	0.05						
Maximum operating temperature, ^{0}C	50 (70 momentary)						
pH range	3 - 12						
Number of sterilization cycles, temperature 121^0C, min	10						

2.10.4. Filtering elements: EPM.F grade

General characteristics

The cartridge elements, EPM.F grade, on the basis of hydrophobic and hydrophilic fluoroplast (fluoroplast, 42 grade) membranes are close analogs of the elements DURAPORE of the MILLIPORE firm (USA).

Application

- In medicinal industry for water filtration at complexes of washing machines, for sterilizing filtration of air and gases.
- In food industry for finishing stage of water pretreatment, technological air and carbon dioxide.
- In electronic, radio and chemical industries for finishing purification of deionised water, liquid and gaseous chemical media, including aggressive acids, alkalies compatible with the material of the element.

Operating characteristics

	Hydrophobic and hydrophylic				
Average pore size, μm	0.15	0.25	0.45	0.65	1.0
Min. pressure of bubble point through water-wetted membrane, MPa	0.30	0.21	0.10	0.07	0.05
Initial output, distilled water, t 20°C and P – o,o5 MPa, m^3/h	0.9	1.5	2.7	4.0	7.0
Retention, aerosol particles of 0,3 microns size, front speed V=1 cm/s Q – 1,0 cm^3/cm^2 sec, % for gases, min	99.995	99.99	99.92	98.00	97.0
Max. pressure grade, MPa	0.4				
Recommended max. reverse pressure grade, MPa	0.5				
Max. operating temperature, ^{0}C	60 (80 momentary)				
Number of sterilization cycles at t 121°C, P – 0,11 MPa for 45 min, min	10				

3. *Development and prospect of membrane technology in Russia*

The membrane research organisation in Russia is actually divided between the Institutes of the Russian Academy of Science (RAS) and some Academic groups in Universities.

In particular the main institutes working in this field are:

1) *Institute of Synthetic Polymeric Materials (ISPM) of RAS*

Recent directions of ISPM's scientific activity are:

- R&D investigations in the field of new generation of thermostable synthetic polymers and high-strength composite polymericmaterials
- Research of synthetic polymeric materials with special complex of electrical, magnetic, optical, acoustic and other physical properties
- R&D of high-filled heterogeneous composite polymeric materials
- R&D of flame-retardant polymers for different applications
- R&D of solid-state reaction chemistry depending on outer factor influence like high pressure, shear rate, ultrasound vibrations andothers
- Research in the field of scientific background for high-temperature superconductive polymeric materials design
- Co-ordinations of some State Scientific Research Projects dealing with new polymeric materials R&D.

ISPM comprises 8 scientific laboratories. Big laboratories are subdivided into some scientific groups.

2) *Institute of Macromolecular Compounds (IMC) of RAS*

The Institute of macromolecular compounds was organized in 1948 under the government decree with the aim of conducting basic and applied research in chemistry, physical chemistry, and physics of polymers. It has united prominent specialists in these fields with corresponding member of the Academy of Sciences of the USSR S.N. Ushakov as a director.

The Institute has more than 20 laboratories and scientific groups and an analytical center. Some laboratories deal with the synthesis and chemical modification of polymers and biologically active compounds and investigate polymer formation mechanisms. Other laboratories and groups study the physics and physical chemistry of macromolecules. The structure of thermally stable and self-organizing polymer systems, physico-chemical properties, conformational statistics and chromatography of polymers are also being investigated.

3) *Boreskov Institute of Catalysis (SB) of RAS*

The Institute of Catalysis was founded in 1958 as a part of the Siberian Branch of the Russian Academy of Sciences. The founder and the first Director of the Institute till 1984 was academician Georgii Konstantinovich Boreskov, an eminent scientist and science manager, an expert in the field of catalysis and chemical technology. In 1992, the Institute was named after academician G.K. Boreskov. Academician Kirill Il'ich Zamaraev, an outstanding Russian physical chemist and a talented teacher, was the second Director of the Institute in 1984 to 1995. Since 1995, the Institute has been headed by academician Valentin Nikolaevich Parmon.

The Boreskov Institute of Catalysis (BIC) is now one of the largest research centers worldwide specialized in catalysis. BIC's affiliations are in cities St-Petersburg and Volgograd. The permanent staff consists of ca. 1000 employee, among which 350 are research scientists.

4) *Topchiev Institute of Petrochemical Synthesis (TIPS) of RAS*

TIPS is the leading scientific research institution in the Russian Academy of Sciences in chemistry and chemical engineering. TIPS incorporates 29 scientific laboratories with 450 staff, which include 40 professors and 190 PhD. TIPS carries out diverse research activities in chemistry and physics of macromolecular compounds, homogeneous and heterogeneous catalysis, high-energy chemistry, chemistry of organosilicon compounds, in membrane science and technology and its applications in petrochemistry, chemistry and biotechnology. TIPS carries out its research according to the Programmes of Fundamental Studies of RAS and the Russian State Scientific and Technical Programmes “Ecologically safe Processes for Chemistry and Chemical Technology”, “Advanced Materials” and “National Technical Basis”. The research works of TIPS are supported by international research foundations: INTAS, CRDF, NATO, Juco-Copernicus, TNO-NWO. The Institute has established close business relations with a number of industrial companies: Bayer AG (Germany), Haldor Topsoe, A/S (Denmark), Samsung (South Korea), DuPont (USA), Amoco (USA).

The Laboratory of Selective Permeable Polymer Synthesis, headed by Dr. V.S. Khotimsky, takes part in this project. Laboratory works in A.V. Topchiev Institute of Petrochemical Synthesis from 1979. The research activities of the Laboratory are mainly focussed on:

- Synthesises of high-molecular selective permeable glassy polymers using polymerization, based on vinyl and acetylenic monomers.
- Polymer modification for development of specific membrane materials, including preparation of random, block- and graft copolymers with optimal complex of membrane properties, chemical modification of glassy polymers by incorporating of specific functional groups.
- Development of most perspective prepared polymers for industrial production includes contacts with industry for development of the polymerization technology and production of monomers.

The works include the participation in the main fundamental research programs of the Russian Academy of Sciences, the projects in Russian scientific-technical programs. At last time Laboratory takes part in the projects supported by international research funds – INCO (NISIW, new membranes and integral hybrid membrane systems for VOCs removal from industrial contaminated water), INTAS (MOLSEL, new polymeric materials based on unsaturated silyl hydrocarbons enhanced with selective transfer properties towards organic gases and vapours), NATO (Integrated bioreactor, new materials for membrane for microbial combustible gases production), NWO-RFFI (polymers for membranes for gas absorption at high pressure).

The laboratory has the long experience on polymer synthesis and characterization, and on polymer membrane materials development. The laboratory works on syntheses of high permeable glassy acetylenic polymers which are especially important for this project.

5) *Mendeleev University of Chemical Technology*

Mendeleev University of Chemical Technology (MUCT) is the Russia's leading higher education establishment to train specialists for the chemical industry.

6) *Moscow state University*

One of the oldest Russian institutions of higher education, Moscow University was established in 1755. In 1940 it was named after Academician Mikhail Lomonosov (1711 - 1765), an outstanding Russian scientist, who greatly contributed to the establishment of the university in Moscow.

Other groups are making research on membrane. A complete list can be found in the website of the RAS (www.ras.ru).

The results of the research on the membrane technology are generally presented in both international and national journals. Concerning the national journals the Russian Academy of Science with other Institutes is publishing a Journal called “Membranes” in Russian, which presents the newest information and the main directions of the current state and development of Russian and foreign membrane technologies. Also an international conference called “Membranes” is organised periodically by the Russian Academy of Science.

Funded by the national membrane Industries and by foreign investors, different projects in the membrane field are in progress.

A list of the main projects in the field of membranes and membrane reactors are reported in the Figure 1.

Figure 1. List of the main projects in the field of membranes and membrane reactors in Russia.

№	Institute	Head of the project or study	Subject	Character of work	Address
1	Association Aspect	Dr. L.I. Trusov	Mass producing of catalytic nanomembrane-based systems, which would simultaneously act as a reactor for converting a mixture of saturated hydrocarbons into olefins or aromatic compounds and a device for separating these products from hydrogen. The creation of a Russian design of the portable fuel cell.	Industrial	Russia, Moscow, 119571, 86, Vernadskogo avenue Telephone: +7(095) 434-80-91 Tel./Fax: +7(095) 936-88-45 e-mail: smol@gcnet.ru www.aspect.ru
2	Chernogolovka Institute of Problem of Chemical Physics, Chemphyst company, Federal State Unitary Enterprise “Moscow Special Alloys Processing Plant”	Prof. V.V. Barelko	A process for the production of ultra thin foils for hydrogen filtration based on palladium alloys has been developed and the manufacture of pilot batches of the foils has been started. The industrial process for the production of ultra thin hydrogen filtration foils based on palladium alloys was elaborated and pilot batches of the foils were produced.	Scientific, pilot	JSC "Chemphyst" 142432 Chernogolovka MO, IPCP RAC, Tel +7(096)522 1817; Fax +7(096)522 1260; e-mail: info@chemphyst.ru Internet: www.chemphyst.ru by e-mail to barelko@icp.ac.ru lbik@icp.ac.ru or by phone +7-495-2265446.
3a	Topchiev Institute of Petrochemical Synthesis RAS	Prof. M.V.Tsodikov, Prof. V.V. Teplyakov, Prof. I.I.Moiseev	Modification of ceramic membranes with catalytic particles. Membrane reactors for C_1 –compounds and hydrocarbons transformation.	Scientific	Leninsku av., 29, Moscow, Russia, 119991 www.ips.ac.ru
3b		Prof. G.F. Tereshchenko, Prof. V.V. Volkov Dr. V.I. Lebedeva	Membrane reactors -contactors for catalytic oxygen removal from water.	Pilot plant	
4a	Boreskov Institute of Catalysis SB RAS	Prof. A.A. Khasin	The permeable composite active materials as contactor membranes for Fischer-Tropsch synthesis.	scientific	Prosp. akademika Lavrentieva 5, Novosibirsk, Russia 630090 E-mail: www@catalysis.ru

	Prof. B.N. Parmon				
6 4b		Prof. V.A. Sobyanin	Development of fuel cell systems with solid H^+ and O^{2-} conducting electrolytes to perform various catalytic reactions, methane conversion to valuable chemicals in particular.	scientific	
4c		Prof. O.M. Ilinich	The experimental studies in the fields of gas separation with polymeric membranes, membranes-assisted homogeneous and heterogeneous catalytic processes, as well as those on catalytic membrane reactors.	scientific	
5	Scientific Center "Kurchatovski Institute"	Dr. D. M. Amirkhanov, Dr. O.K. Alekseeva	High temperature catalytic active ceramic tubular membrane elements on the basis of alumina supports for the processes with hydrogen participation.	scientific	
6	Mendeleev University of Chemical Technology	Prof. N.Digurov Dr. V. Skudin	Propane dehydrogenation in molybdenum containing catalytic ceramic membrane reactor.	Scientific, lab. plant	Miusskaya sq., 9, Moscow, Russia, 125047+7(499)9788839 E-mail: skudin@muctr.edu.ru
7	Institute of the Solid Chemistry and Mechano-chemistry SB RAS	Dr. A.P. Nemudry	Materials (perovskites) for oxygen permeable membranes for methane oxidation to syngas.	Scientific	18, Kutateladze str., Novosibirsk, Russia, 630128
8	Institute of Solid Chemistry of UB RAS	Prof. V.L. Kozhevnikov	Ferrites as oxygen permeable membranes for methane oxidation to syngas.	Scientific	Pervomaiskaya, 91, Ekaterinburg, Russia, 620041 +7(343)374-52-19