



CRYOGENMASH

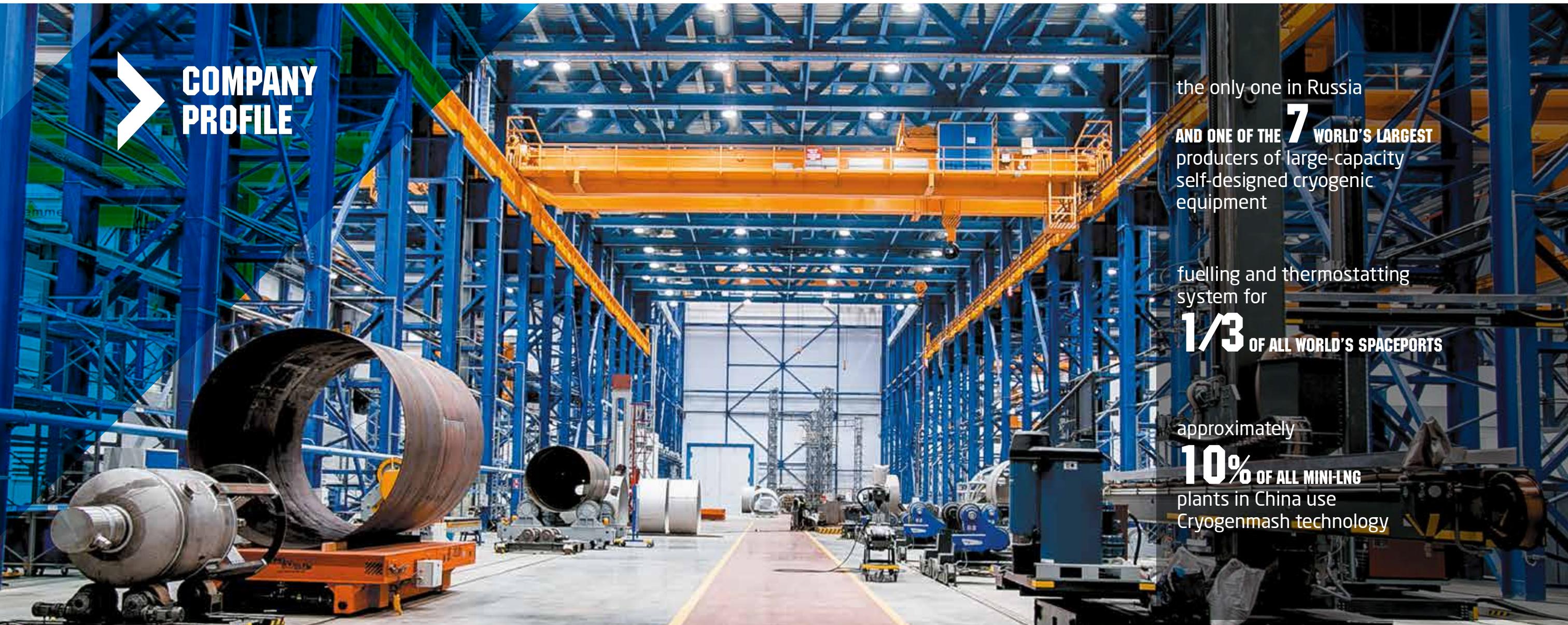
**INTEGRATED SOLUTION
PROVEN RELIABILITY
REAL EFFICIENCY**



**UNITED HEAVY
MACHINERY PLANTS**



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COMPANY PROFILE

the only one in Russia
AND ONE OF THE **7** WORLD'S LARGEST producers of large-capacity self-designed cryogenic equipment

fuelling and thermostating system for
1/3 OF ALL WORLD'S SPACEPORTS

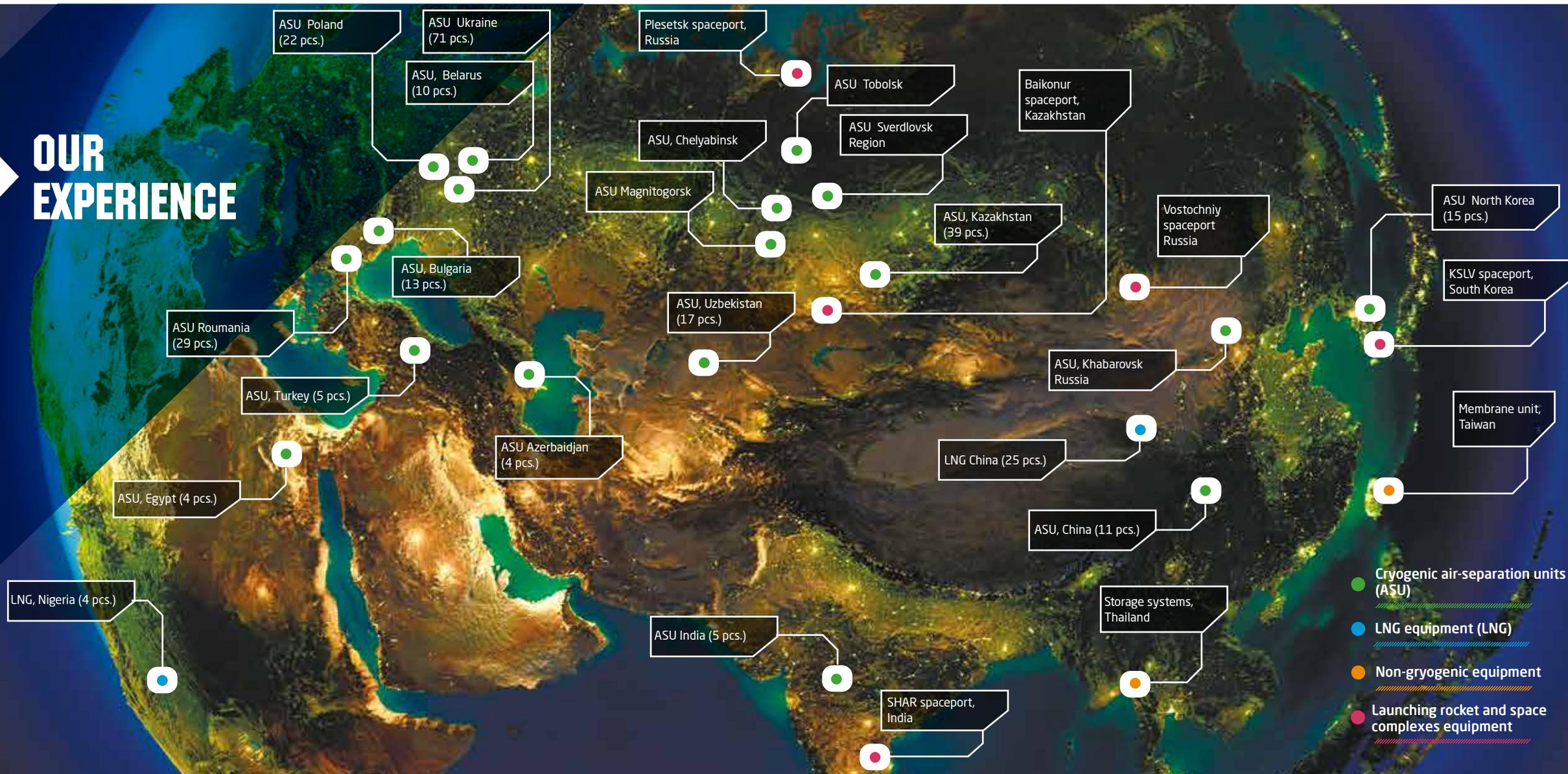
approximately
10% OF ALL MINI-LNG plants in China use Cryogenmash technology

Cryogenmash is the largest Russian operator in air separation technology and appropriate equipment production, development of comprehensive solutions for casing-head gas, natural gas processing and LNG as well as industrial gases supplier. More than 70% of annual technical gases in Russia are produced with the equipment manufactured by Cryogenmash. PJSC OMZ is the managing company of PJSC «Cryogenmash».

Cryogenmash is a modern and dynamically developing company. Its products are competitive in the international market and approximately 20% of its output is exported. In 2019, Cryogenmash reported 9.9 billion rubles in revenue on the basis of the Russian Accounting Standards. The Company employs approximately 1200 people and its headquarters are in Balashikha, Moscow Region.

The Company consolidates the following assets: Cryogenmash (an institute and machine works), Giprokislorod (a leading specialized design institute). There is the representation office in China. Cryogenmash is a member of OMZ Group.

OUR EXPERIENCE



- Cryogenic air-separation units (ASU)
- LNG equipment (LNG)
- Non-gryogenic equipment
- Launching rocket and space complexes equipment

Company History: Milestones





**INTEGRATED
QUALITY SYSTEM**

CERTIFICATES



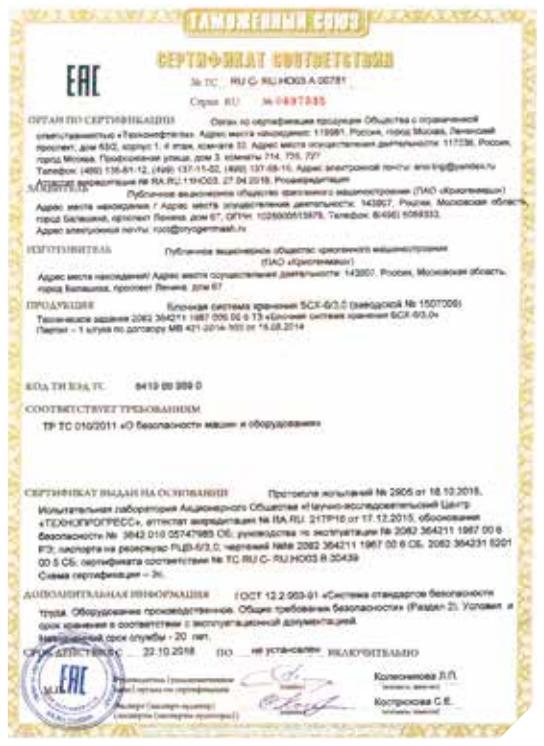
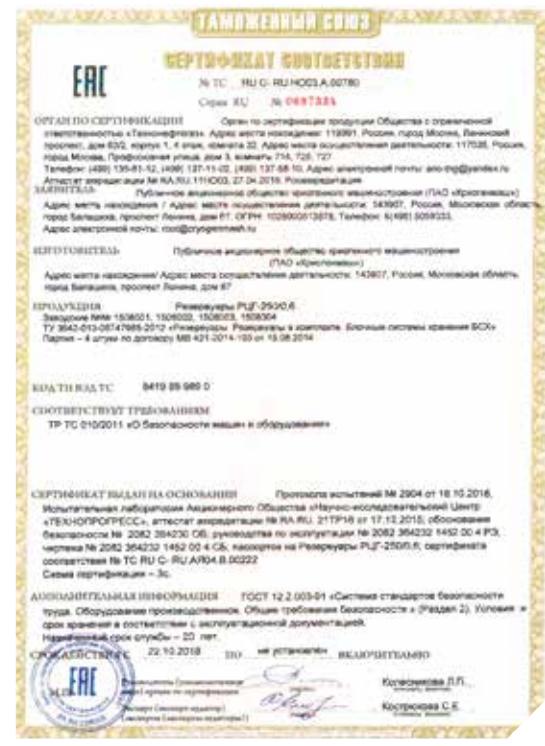
In 2001, Cryogenmash was one of the first to receive a certificate of conformity to the international quality standard ISO 9001:2000 and Russian standard GOST P ISO 9001:2001. Cryogenmash has required Russian licenses (from the Federal Service for Environmental, Technological and Nuclear Supervision, the Federal Service for Defence Order, the Russian Aviation and Space Agency, etc.), and also certificates ISO 9001:2015.



CERTIFICATES



CERTIFICATES



CORE BUSINESS LINES



EQUIPMENT



Equipment deliveries to
35 COUNTRIES OF THE WORLD

Throughout its 70-year history, Cryogenmash has been involved in national-level programs and projects. The adoption of the oxygen converter process for steelmaking, the development of large-scale chemical processes, the creation of large fuelling systems for rockets operated on cryogenic liquid fuel at space launch facilities both domestically and abroad, and innovations in superconductivity – all these were actively contributed by Cryogenmash.

Currently, Cryogenmash manufactures the following equipment for production, processing, transportation and storage of industrial gases:

- › Air separation plants
- › Membrane gas separation plants
- › Pressure swing adsorption units
- › Equipment for natural gas separation, purification and liquefaction
- › Hydrogen and helium systems
- › Cryogenic tanks, storage and gasification systems
- › Transport tankers
- › Cryogenic pipelines
- › Turboexpanders
- › Equipment for rare gases production
- › Equipment for launch of rocket-space systems

SALE OF INDUSTRIAL GASES



on-site projects in Russia

8 IMPLEMENTED

The industrial gases business lies at the heart of Cryogenmash development. Thanks to its long experience, Cryogenmash was able to offer its clients a new form of cooperation – on-site gas supply. Under a long-term contract for industrial gases supply, Cryogenmash builds and operates an air separation facility at the customer’s site to provide the main production with industrial gases. The Company is engaged in eight on-site projects to produce industrial gases for Seversky Tube Works (TMK), Pervouralsk Novotrubny Works (ChTPZ Group), Taganrog Metallurgical Works

(TMK), Izhora Industrial Site, Tomskneftekhim and Zapsibneftekhim (SIBUR), TulachermetSteel and Kirovo-Chepetsk Chemical Works (URALKHIM).

In implementing its development strategy, Cryogenmash is striving to become the leading supplier on the industrial gases market. In 2019, sales of industrial gases exceeded 2.8 billion rubles.

Gas projects are implemented by the Company’s subsidiaries LLC Cryogas and LLC Cryogenmash-Gas.

SERVICES



More than **150** of Cryogenmash’s cryogenic **AIR SEPARATION UNITS (ASU)** are operating in the Russian Federation

Services in the field of air separation plants traditionally include turnkey projects, development of feasibility studies, design and project documentation, erection works, civil works, erection supervision, designer supervision, commissioning, training of personnel, service maintenance and modernization .

As a current leader in the Russian market of industrial gas production equipment, Cryogenmash is well positioned to perform any of these works and services.

Cryogenmash’s units for production of oxygen, nitrogen and other industrial gases are operating

almost at all Russian metal and petrochemical works.

To develop its service business, Cryogenmash has acquired a specialized design institute Giprokislorod, established a training center in the field of air separation, and built a unique team comprised of professional engineers, installers, builders and project managers.

Our partners in the field of engineering, construction and installation help us complete turnkey projects with high quality standards and competitive turnaround times.



PRODUCTION CAPACITIES

A WIDE RANGE OF OPPORTUNITIES



The production capacities of Cryogenmash allow for the manufacturing of cryogenic, chemical and petrochemical products with the following max dimensions: 40,000x5,500x4100 mm (LxWxH) and a weight of up to 80 tons for packaged modular equipment, and up to 4,500 mm in diameter, up to 26,000 mm in length, and up to 60 tons in weight for vessels and apparatus.

Our production technologies are certified and qualified and allowed for processing of carbon steel

materials (steel 20, steel 3), low-alloy carbon steel (09G2S), corrosion-resistant steel (12H18N10T), aluminum alloys (AMg, AMts) and their foreign analogues.

The production site provides a full production cycle, from blanking to testing, painting, packaging and shipping to Customer.

WELDING



Our assembly and welding facilities are competent in flat rolled steel products processing with a thickness of 1.0 to 40 mm. The production uses unique technologies, such as robotic plasma cutting of complex geometric profiles and robotic welding of steel and aluminum-alloy critical joints with a thickness of 4 to 40 mm.

We effectively use the technologies of surface preparation for welding using unique biodegradable low-acidity cleaning solutions.

Other technologies used include plasma arc welding of aluminum alloys with thicknesses of 4 up to 25 mm, automatic welding with shielding gas, including orbital welding of corrosion-resistant steel on pipelines with an outer diameter of up to 276 mm, automatic submerged arc welding, manual and semiautomatic welding. We use European welding equipment, such as PEMA, UNIWELD, SBI, FRONIUS and EWM.

MECHANICAL PROCESSING



Mechanical production mainly includes machining centers that use the numerical program control technology and provide for precision mechanical processing (on the order up to 2 microns), with the maximum dimensions of up to 5,000 mm and the maximum workpiece weight of up to 12 tons. The equipment of world leaders of the European and Asian machine tool industry, such as HERMLE, BIGLIA, WELLE, is used.

//////
 The machining facilities of Cryogenmash meet all of its internal needs and ensure precision accuracy.
 //////

QUALITY CONTROL



To control product quality, Cryogenmash uses modern equipment for phased array ultrasonic testing, the X-ray television systems for inspection of welded joints, strength and leakage tests, including vacuum tank tests

Our core laboratory facilities include a metrology and instrumentation laboratory, a test and analysis laboratory and a production laboratory for X-ray and ultrasonic inspection.

The metrology and instrumentation laboratory is accredited to perform metrological evaluation of documents and calibration according to the scope of accreditation.

The test and analysis laboratory is accredited to GOST ISO 17025, with the scope of accreditation covering mechanical tests, metallographic

studies, chemical and spectral analysis, positive material identification of metals and welded joints, physicochemical analysis and testing of non-metallic materials, and industrial hygiene testing.

The production laboratory for X-ray and ultrasonic inspection is certified to perform non-destructive testing (NDT). The scope of certification covers the following types (methods) of non-destructive testing and evaluation:

- › X-ray (radiography and radioscopy);
- › Ultrasound (non-destructive testing and thickness measurements);
- › Acoustic-emission method;
- › Dye penetrant test.

ROBOTIC SYSTEMS



Cryogenmash is the first in Russia to use robotics for welding of critical welded joints in the chemical and petrochemical industry. Robotic systems are used for plasma cutting and deseaming of steel and aluminum alloys, and also for welding of steel and aluminum alloys with shielding gas.

There is a 24.5 m high automated storage and retrieval system equipped with a system to measure the dimensions and define the best location of goods, which provides a connection between the first and second floor of the manufacturing facility.

The pre-welding treatment unit is equipped with robotic autooperators and as such allows for removing human participation from parts processing. A new degreasing technology based on environmentally-friendly biodegradable cleaning solutions is used, reducing the harmfulness of the process.



INNOVATIONS AND R&D

The modern Research and Design Institute of Cryogenic machinery (a structural subdivision of Cryogenmash) is the deserved successor of the scholarly traditions established by Peter Kapitza. The institute employs unique experts, who create complex high-technology equipment, which often excels in its characteristics the foreign competitors' products. Over the last years the company invests actively in the creation of the modern laboratory-stand base, in new products development and learning to use new technologies



Mission of the Research and Laboratory Department: Develop and launch up-to-date cryogenic and gas-separation solutions in the market, and ensure steady growth of Cryogenmash by continuously developing the product line, meeting and excelling Customers' requirements



In the course of development of the Testing Facility, a testing building with total area of more than 1200 square meters was constructed, unique laboratory stands for cryogenic and gas separation equipment testing were developed and manufactured:

- › Test bench for turboexpander sets;
- › Test bench for cryogenic liquids evaporators;
- › Test bench for heat exchangers;
- › Vacuum test benches;
- › Stands for adsorption processes research;
- › Stand for working out new designs of layered-vacuum heat insulation;
- › Vibration stand;
- › Armored chamber.

The IC provides certification and licensing of all Cryogenmash's equipment, and develops conceptual infrastructure, technology and design solutions.

Over the past decades, Cryogenmash has done a good number of comprehensive research on a pilot or full-scale basis.

Worth particular attention among them are the following:

- › Heat exchange, circulation and admixtures deposition conditions in oxygen boiling channels of condenser-evaporators;
- › Unsteady heat exchange and hydrodynamic processes in long-distance multi-hole cryogenic transfer lines;
- › Heat transfer and vacuuming processes in thermally insulated spaces of cryogenic equipment;
- › Heat and mass exchange and flow dynamics in mixtures rectification with high-performance sieve trays and regular packings;
- › Simulation, development of methods and programs for calculation of multi-line plate-fin heat exchangers;
- › Cryogenic liquids subcooling and long-term storage processes;
- › Submerged and circulation SC magnets cooldown and cryostatting;
- › Prevacuum and high-vacuum pumping processes in cryogenic space simulators;
- › Research and development of cryosorption vacuum pumps with porous screens.

R&D



Research results were implemented in some large projects, including:

- › A series of large KA-30 and KtK-35 ASUs (about 90 pcs) for the metallurgy industry
- › Creation of a liquid hydrogen production facility and infrastructure for its delivery to the launch complexes;
- › Space simulators, including the largest ones in Europe (with a capacity of 400, 1,000, 3,000 and 10,000 m³);

- › Cryogenic components storage and filling systems for the following spaceports: Baikonur, Plesetsk, Vostochniy, SHAR (India), Sea Launch (USA), KSLV (South Korea), Kuru (French Guiana);
- › Liquid hydrogen and oxygen storage, subcooling and filling systems of the rocket and space complex «Energia» - «Buran»;
- › Helium liquefiers and refrigerators, SC magnet cryostatting systems for Tokamak-7, Tokamak-15 and IHEP accelerator (Protvino), cryogenic helium pipelines for the CERN..

INDUSTRY 4.0



The present-day industrial production trend is to switch from mass and large-volume production to knowledge-intensive make-to-order production. A new research and industrial complex of Cryogenmash is a shining example of multiproduct single-piece manufacture of large-sized items.

The company realizes the digital production of cryogenic apparatus with elements of Industry 4.0:

- › 3D design development (in Catia v.5) with modeling of projection reference points and views;
- › Automated process design of welding and assembly processes in computer-aided system NATTA;

- › Development of 3D interactive flow charts;
- › Installation of production process navigators with 3D visualization of assembly changeovers at welding and assembly workplaces;
- › Cutting, welding and clean up works using positioners operated by programmable-controlled machines and robotic systems;
- › Deployment of laser projectors and trackers for assembling large-sized units, laser scribing of the cutting and tack points, and geometry control after welding;
- › Implementation of digital production and measurement of pipelines.



PRODUCTS CATALOGUE

EQUIPMENT



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➤ **CRYOGENIC AIR SEPARATION UNITS (ASU)**

The purpose of ASUs is to produce oxygen, nitrogen, argon and mixtures of rare gases from the ambient air by means of low-temperature rectification. Over our history, we have manufactured and supplied more than 600 units of various capacities to 30 countries. For maximum Customer's satisfaction, the Company manufactures air separation units as per individual projects considering the particularities of their production and available infrastructure. The units are based on state-of-the-art circuit designs and engineering solutions, completed with assembly sets and units made by leading domestic and foreign manufacturers, and feature a high level of automation, reliability and low specific power consumption.

The Company manufactures air separation units both for complex extraction of products in gaseous and liquid forms, and for production of individual gases (oxygen and nitrogen) with

the delivery of separation products under normal and/or high pressure and with an adjustable capacity.

Units of low and medium capacity are manufactured as packaged with the maximum operational availability. Cryogenmash provides warranty and aftersale service of its ASUs, and provides spare parts for them throughout the service life.

Read more on our Website:



<http://cryogenmash.ru/en/>

Process oxygen under pressure air separation units (Ktd type)



Processed air, m ³ /hr (0.5 MPa)		30 000	50 000	80 000	120 000	175 000
Products, m ³ /hr (kg/hr)	Gaseous process oxygen (0,35 MPa)	5 950	9 900	16 000	24 000	35 500
	Gaseous nitrogen	1 500	3 000	5 000	8 000	12 000
	Liquid oxygen and nitrogen (in total)	50	150	250	500	750
Specific power consumption to oxygen, kW hr/m ³		0,41	0,40	0,39	0,38	0,37

Designed to produce and deliver process oxygen at a pressure of up to 0.35 MPa directly from the cold box, and also small amounts of liquid oxygen, gaseous and liquid nitrogen. Modifications for process oxygen at a up to 0.6 MPa are possible.

Products purity:

- › Process oxygen: 96% and lower;
- › Liquid oxygen: 99.5 % and higher;
- › Gaseous and liquid nitrogen: oxygen impurities of 5 ppm and less.

Air separation units with complex recovery and internal compression (KdAdAr type)



Processed air, m ³ /hr (0.5 MPa)		30 000	50 000	80 000	120 000	175 000	300 000	500 000
Products, m ³ /hr (kg/hr)	Gaseous oxygen (3.0 MPa)	5 700	9 600	15 500	23 600	34 500	59 000	100 000
	Gaseous nitrogen	5 000	10 000	15 000	24 000	35 000	60 000	100 000
	Liquid argon	180	30	500	800	1 200	2 100	3 500
	Liquid oxygen and/or liquid nitrogen	150	250	450	600	1 000	2 200	3 700
Specific power consumption to oxygen, kW hr/m ³		0,56	0,55	0,54	0,53	0,52	0,51	0,50

Designed to produce and deliver (directly from the cold box) industrial gaseous oxygen, and, if necessary, nitrogen and argon under pressure as required by the customer, and a part of these products as liquid. Large ASUs can produce krypton-xenon concentrate and neon-helium mixture. Modifications without nitrogen and argon production are possible.

Products purity:

- › Oxygen: 99.5 % and higher;
- › Nitrogen: oxygen impurities of 5 ppm and less;
- › Argon: oxygen impurities of 5 ppm and less, nitrogen impurities of 5 ppm and less.

Products pressure: up to 7 MPa and higher.

Air separation units for liquid products (KzhAzhArzh type)



Processed air, m ³ /hr (0.5 MPa)		2 500	5 000	10 000	15 000	20 000
Circuit air, m ³ /hr (3.5 MPa)		6 800	12 500	24 500	35 000	46 000
Products, kg/hr	Liquid Oxygen	660	1 330	2 670	4 050	5 400
	Liquid Nitrogen	3 650	720	1 450	2 180	2 900
	Liquid Argon	30	65	140	210	280
Specific power consumption to oxygen, W hr/kg		0,76	0,72	0,68	0,66	0,65

Designed to produce different amounts of liquid oxygen, nitrogen and argon. Possible modifications include oxygen ASUs without production of nitrogen and argon (or any of them) and nitrogen-only ASUs.

Products purity:

- › Oxygen: 99.5 % and higher;
- › Nitrogen: oxygen impurities of 5 ppm and less;
- › Argon: oxygen impurities of 5 ppm and less, nitrogen impurities of 5 ppm and less.

Low pressure air separation units with complex recovery (KAAr type)



Processed air, m ³ /hr (0.5 MPa)		30 000	50 000	80 000	120 000	175 000	300 000	500 000
Products, m ³ /hr (kg/hr)	Gaseous oxygen (3.0 MPa)	5 700	9 600	15 500	23 600	34 500	59 000	100 000
	Gaseous nitrogen	5 000	10 000	15 000	24 000	35 000	60 000	100 000
	Liquid argon	180	30	500	800	1 200	2 100	3 500
	Liquid oxygen and/or liquid nitrogen	150	250	450	600	1 000	2 200	3 700
Specific power consumption to oxygen, kW hr/m ³		0,56	0,55	0,54	0,53	0,52	0,51	0,50

Designed to produce industrial gaseous oxygen and pure nitrogen under slight overpressure and a part of these products as liquid. Large ASUs can also produce krypton-xenon concentrate and neon-helium mixture. Modifications without production of nitrogen and argon are possible.

Products purity:

- › Oxygen: 99.5 % and higher;
- › Nitrogen: oxygen impurities of 5 ppm and less;
- › Argon: oxygen impurities of 5 ppm and less, nitrogen impurities of 5 ppm and less;
- › Krypton-xenon concentrate (Kr + Xe): 0.5 %;
- › Neon-helium mixture (Ne + He): 40%.

Process oxygen low pressure air separation units (KtA type)



Processed air, m ³ /hr (0.5 MPa)		50 000	80 000	120 000	175 000
ΠProducts, m ³ /hr (kg/hr)	Process gaseous oxygen	10 500	16 800	25 300	36 500
	Gaseous nitrogen	10 000	16 000	25 000	35 000
	Liquid oxygen	300	500	800	1 500
	Liquid nitrogen	200	300	400	500
Specific power consumption to oxygen, W hr/m ³		0,34	0,32	0,31	0,30

Designed to produce gaseous process oxygen and pure nitrogen at a slight overpressure and some of these products in the liquid state. Large ASUs can also produce krypton-xenon concentrate and neon-helium mixture.

Modifications with production of part of industrial gaseous oxygen without nitrogen are possible.

Products purity:

- › Process oxygen: 96 % and lower;
- › Industrial oxygen: 99.5 % and higher;
- › Nitrogen: oxygen impurities of 5 ppm and less.

Pure gaseous nitrogen under pressure air separation units (Ad type)



Parameters		Standard ASUs				ASU with increased nitrogen content			
Products	Processed air, m ³ /hr (0,5 MPa)	1 750	3 600	6 000	10 000	15 000	20 000	30 000	50 000
	Gaseous nitrogen, m ³ /hr (0,75 MPa 5 ppm O ₂ and less)	660	1 400	2 400	4 000	8 000	10 700	16 500	28 000
	Liquid nitrogen, kg/hr	40	80	150	250	150	200	300	500
Specific power consumption to nitrogen, kW hr/m ³		0,28	0,27	0,26	0,25	0,18	0,17	0,16	0,15

Designed to produce and deliver (directly from the cold box) pure gaseous nitrogen at a pressure of up to 0.75 MPa, and also a small amount of liquid nitrogen. The units are available in packaged design with full operational

availability of individual packages. Modifications of large nitrogen ASUs with double-column rectification unit and increased degree of nitrogen recovery are possible.



CRYOGENIC EQUIPMENT FOR LIQUID NATURAL GAS (LNG)



One of the priority development areas of Cryogenmash is to design new original cryogenic technologies and create equipment for natural gas liquefaction, storage, transportation and use.

Cryogenmash has been developing LNG equipment since the 1980s. Drawing on its capabilities and experience, Cryogenmash offers to provide the Customer with design, manufacture and supply of necessary cryogenic equipment for LNG technology implementation, including installation and commissioning works.



LNG EQUIPMENT

LNG LIQUEFACTION UNIT
OF **0,3** UP TO **4** T/HR

LNG DELIVERY RADIUS OF
UP TO **1000** KM

20+
SUCCESSFUL REFERENCES IN CHINA

Low-capacity LNG production solutions



Cryogenmash's technology – the throttle-ejector cycle (0.3 to 4 tons of LNG per hour per line) – is optimal for the creation of mini LNG plants, as an alternative to gas pipelining, to supply natural gas to remote infrastructural facilities and gas engine vehicles within a radius 150 – 1,000 km:

- › The units are based on a sufficiently efficient and simple high-pressure refrigeration cycle for gas liquefaction;
- › The external freon pre-cooling at the temperature of 40°C below zero is used for increasing the thermodynamic effectiveness of liquefaction;

- › Ejectors are used instead of the throttle for high-pressure gas expansion, allowing to use efficiently gas pressure energy to build the circulating refrigeration circuit at a back flow overpressure;
- › The combination of straight flow high pressure and back flow overpressure reduces convertibility losses in the heat exchanger and specific power consumption to liquefaction per kilogram of LNG;
- › Three-stage separation of the two-phase flow allows to separate efficiently and remove low-boiling hydrogen, helium and nitrogen admixtures from the refrigeration circuit without methane loss

Characteristic	Unit	Amount			
		1,0	1,5	2,5	3,0
Natural gas liquefaction system capacity	t/hr	1,0	1,5	2,5	3,0
Process cycle		Throttle-ejector cycle			
Gas flow rate at system inlet	Hm ³ /hr	1 578	2 367	3 946	4 735
Energy consumption	kW	700	1 050	1 750	2 100
Energy intensity	kW/kg	0,7			
Range of capacity control	%	70 - 110			
Specified service life	years	20			



Solution advantages for mini LNG plant



- › Modular design with sizes suitable for transportation both by truck and by train;
- › Full shop assembly of the cold box with a full range of factory tests passed, including strength and leakage tests, verification of valves, accessories and probes, welded joints control and other similar procedures;
- › All apparatus and pipelines are mounted on a skid, heat-insulated and housed in aluminum jackets to ensure safety during transportation, installation and maintenance;
- › The module is equipped with a special lifting beam for handling and erection;
- › The unit is fully ready for installation, which includes mounting on the foundation and connection of supply lines;
- › Easy of start up;
- › Quick time to the LNG deliverability mode, the rated level in a discharged scrubber is achieved within 30 minutes;
- › The unit does not require manual control or continuous presence of an operator;
- › The unit can be set outdoors under a shelter;
- › The unit operates automatically and is controlled remotely from the central computer control panel of the liquefaction complex;
- › Automatic adjustment to the liquefiable gas parameters for pressure, temperature and gas composition.



LNG LINE WITH CAPACITY
OF **5** UP TO **100** T/HR

LOCAL CONTENT
NO LESS THAN **70** %

Medium capacity solutions for LNG



Cryogenmash's technology – the nitrogen expander cycle – is optimal for projects on comprehensive supply of natural gas to regions, as an alternative to gasification programs involving construction of main and local gas pipelines, and for the creation of LNG export terminals:

- › The units are based on the nitrogen refrigeration circuit with turboexpander-compressor sets and plate-fin heat exchanger for cooling and liquefaction of natural gas;
- › Experience using a similar refrigeration circuit in large ASUs: more than 600 projects completed in 25 countries all over the world;

- › Opportunities to improve efficiency thanks to the number of expansion stages and by changing their switching on scheme;
- › Advantages of using compact and high performance PFHE instead of CWHE;
- › No fluid and double-phase flow rate and non-uniformity problems;
- › Feed natural gas and LNG subcooling parameters suitable for adjustment;
- › Complete fire and explosion safety of the entire refrigeration circuit;
- › The cost of the equipment is lower comparing to mixed refrigerant solutions.

Characteristic	Ед.	Значение		
Natural gas liquefaction system capacity	t/hr	5,0	7,0	10,0
Process cycle		External nitrogen expander cycle		
Gas flow rate at system inlet	Hm ³ /hr	7 892	11 049	15 785
Energy consumption	kW	3000	4200	6000
Energy intensity	kW/kg	0,6		
Range of capacity control	%	70 - 110		
Specified service life	years	20		



LNG transportation



It is proposed to use road tankers and ISO tank containers to transport LNG from an LNG plant to other infrastructural facilities. In addition to transportation solutions, we offer a solution for mobile filling systems based on road tankers. A semi-trailer tanker consists of a tanker on chassis board, a pressurization evaporator and a valve rack where all control and monitoring instruments are installed.

Intermodal ISO tank containers are designed for LNG transportation by sea (river), by rail and by road. The transportation in tank containers is carried out on a door-to door basis without intermediate product transfer in case of any change of the mode of transport, which provides increased security and safety of cargo.

CryoPAGZ is a tanker mounted on a chassis board with a cryogenic pump and a fiscal metering unit. CryoPAGZ reservoir's configuration is similar to that of a transport tank reservoir. In addition to the transport tank solution, the valve cabinet is provided with flow rate meter which is used to directly measure the mass flow rate, density and temperature and calculate the volumetric flow rate. CryoPAGZ is also fitted with a centrifugal electric pump with an electric control box for pumping LNG into customer's tanks, and metal hoses for connection with customer's tanks.



➤ **CRYOGENIC STORAGE AND GASIFICATION SYSTEMS**

COMMERCIAL SOLUTIONS WITH
A CAPACITY OF **3** UP TO **1400** M³

LIQUID CRYOPRODUCTS:
O₂, N₂, AR, H₂, HE, LNG

Storage and gasification systems



Cryogenmash has a 65 years experience in manufacturing systems for cryogenic products storage, transportation and gasification which are operated successfully by numerous companies in metallurgy, mechanical engineering, chemical industry, oil & gas industry and medicine in the Russian Federation, the CIS countries, as well as internationally.

We manufacture storage systems for liquid cryogenic products with a capacity of 3 up to 1400 m³ and working pressure of 1.7 MPa. Cryogenic products storage, transportation and gasification systems offered by Cryogenmash are produced on the basis of the latest research and development results using high-tech materials, including stainless steel, for manufacture of the inner vessel and control, shut-off and safety valves.

The systems are designed for receipt, storage, transportation and gasification of liquid cryogenic products:

- › nitrogen;
- › oxygen;
- › argon;
- › hydrogen;
- › helium;
- › LNG.

For customers' convenience, Cryogenmash manufactures standard compact storage systems in vertical and horizontal versions. Compact storage systems are supplied ready-to-operate upon their installation to the foundation.

For customers who need to transport liquid cryogenic products, Cryogenmash manufactures transport tankers of 8, 22, 30, 45 and 50 m³ capacity.



➤ **TRANSPORTATION SYSTEMS.
GASIFIERS**

SEMI-TRAILER TANKER OF
22, 45 AND 50 m³

**GASIFIERS WITH A CAPACITY
OF 3 UP TO 26 m³**



Cryogenmash manufactures transport tankers designed for liquid cryoproducts transportation, short-term storage and delivery to customers.

The tankers are cryogenic tanks with high-performance vacuum screen insulation and valve cabinets containing equipment and instruments required for the process operations performance. Semi-trailers tankers (PPTs) have vehicle type approvals AT (PPTs 22/0,35 and PPTs 22/035M) and FL (PPTs 45/1,0) as per the European Agreement concerning the International Carriage of Dangerous Goods by Road and are certified as compliant with the UN ECE Codes No. 105-03, No. 13-09, No. 48-02, No.73-00 and No. 58-01. The cryoproducts pumpless delivery technology is used in tankers PPTs-22/0,35M and PPTs-45/1,0.

One of Cryogenmash's lines of business is to create gasification systems for liquid cryogenic products (oxygen, nitrogen, argon). These systems are designed to Customer's requirements with the optimal use of different gasifier models.

The systems are intended for the receipt of liquid cryogenic products, their long-term minimum-loss storage, gasification and delivery of gaseous product through atmospheric evaporators to consumer. Gasifiers are available with a capacity of 3, 5, 10, 25 or 26 m³. They are completely autonomous in operation, do not require exterior power sources and use atmospheric air heat for gasification. A significant advantage of our gasifiers is automatic control of the product delivery mode. GH and GHK gasifiers comprise compact storage systems and product atmospheric evaporators.

Cryogenmash can design and manufacture systems for cryoproducts storage, transportation and gasification with the required parameters (storage capacity, working pressure, flow rate) according to the Customer's specification, with manually or remotely controlled valves.



Cryogenmash has a vast proven experience in manufacturing large-capacity engineering tanks for storage of the following cryogenic products:

- › Process gases (nitrogen, argon, oxygen);
- › Carbon dioxide;
- › Liquefied natural gas;
- › Hydrogen.

The advantages of engineering tanks manufactured by Cryogenmash are as follows:

- › The tanks can be manufactured in a horizontal version to reduce production man-made risks;
- › The tanks can be transported by standard transport (road, rail and sea);
- › Large-capacity tanks of up to 1,400 m³ capacity can be manufactured and mounted at the Customer's site;
- › The use of the most efficient screen-vacuum insulation helps to prevent loss of cryoproducts during storage;
- › The tanks are manufactured in compliance with the Russian industrial safety requirements, European Directive 97/23/CE, AD 2000 regulations and the US ASME standards;

› The tanks have been successfully used for space programs and large-scale industrial programs.

Engineering tanks made by Cryogenmash can be completed with:

- › Pressurization evaporation (for pressure buildup in the tank);
- › Required manually and remotely controlled shut-off, control and safety valves;
- › Instrumentation and attachments for fastening to foundations.

The inner vessel is made of cold-resistant austenitic steel grades, and the outer jacket is made of high-grade carbon steel. Additionally, on customers' request, the tanks can be completed with vacuum piping, atmospheric and other kinds of evaporators, other equipment necessary for solving the full range of problems encountered by customers when storing liquid cryoproducts.



MEMBRANE GAS SEPARATION UNITS

NITROGEN
OF **10** UP TO **10000** M³/HR

HYDROGEN
OF **500** UP TO **50000** M³/HR

NITROGEN
OF **93** UP TO **99,9** %

HYDROGEN
OF **95** UP TO **99,8** %



Since 1975, Cryogenmash has been dealing with the membrane technology based on selective permeability of gas mixture components through a polymeric membrane.

In 1976, for the first time in the world, a pilot production unit for hydrogen concentration with a capacity of 500 m³/h was put into operation at the Shchekino Production Association «Azot».

Compared to the traditional methods of gas and steam-gas mixtures separation, the membrane technology requires much less capital and operating expenses.

Cryogenmash uses the most perfect new generation hollow-fiber membranes to produce gas separation units, with the service life of membranes exceeding 10 years. The construction is based on modularity that helps to ensure the required product capacity by transformation of unified modules

Cryogenmash manufactures membrane units for various applications:

- › Hydrogen concentration from the exhaust gases of catalytic reforming and petrochemistry waste gases;
- › Nitrogen recovery for providing an inert atmosphere and ensuring fire and explosion safety while storing hazardous substances, petroleum products and liquefied hydrocarbons, fire extinguishing in mines, and providing proper conditions for long-term storage of food products;
- › Oxygen enrichment of air for medical applications and technological processes in metallurgy.

Cryogenmash's membrane units have the following range of capacity:

- › Hydrogen concentration: 500 up to 50000 nm³/hr; H₂ concentration: 95 up to 99.8 %, depending on the base mixture;
- › Nitrogen recovery: 10 up to 10,000 nm³/hr, N₂ concentration: 93 - 99,9 %;
- › Air oxygenation 10 up to 2,000 nm³/hr, O₂ concentration: up to 45 .



Purification, liquefaction, storage and transportation systems



The manufacture of cryogenic complexes for hydrogen liquefaction, long-term storage and transportation by rail and road started in the 1960s. First of all, this was due to the wide use of liquid hydrogen as a fuel for space-rocket systems.

Cryogenmash has created numerous cryogenic complexes for ground treatment of rocket engines and stages, rocket fueling at start positions, and transportation facilities for liquid hydrogen over large distances. These systems can form a basis for the development of hydrogen energetics using hydrogen as a unique and environmentally friendly energy carrier.

Cryogenmash has the required research and engineering capabilities, production facilities and wide experience to ensure comprehensive supply of liquefied hydrogen equipment:

- › Large-capacity liquefaction units with a capacity of 180 up to 700 kg of hydrogen per hour;

- › Hydrogen liquefaction units with the helium cooling cycle and turboexpanders;
- › For small consumers of liquid hydrogen, throttle liquefiers with a capacity of 20 l/hr are available;
- › Factory-built liquid hydrogen storage tanks with a capacity of 5 up to 250 m³;
- › Field assembly tanks of 1,400 m³;
- › Hydrogen gasification systems;
- › Road tankers for hydrogen transportation with a capacity of 25 or 45 m³;
- › Hydrogen rail tankers of 100 m³ capacity. These are completed with a valve rack and transportation safety devices;
- › Cryogenic pipelines for hydrogen transportation;
- › Hydrogen purification systems, turbo-expanders, heat-exchangers, valves, etc.;
- › Cryogenic equipment for steam-gas mixture separation during polycrystalline silicon production.



HELIUM EQUIPMENT

MORE THAN **10**
LARGE-SCALE HELIUM COMPLEXES

HELIUM LIQUEFIERS WITH A CAPACITY
OF **200** UP TO **2400** L/HR



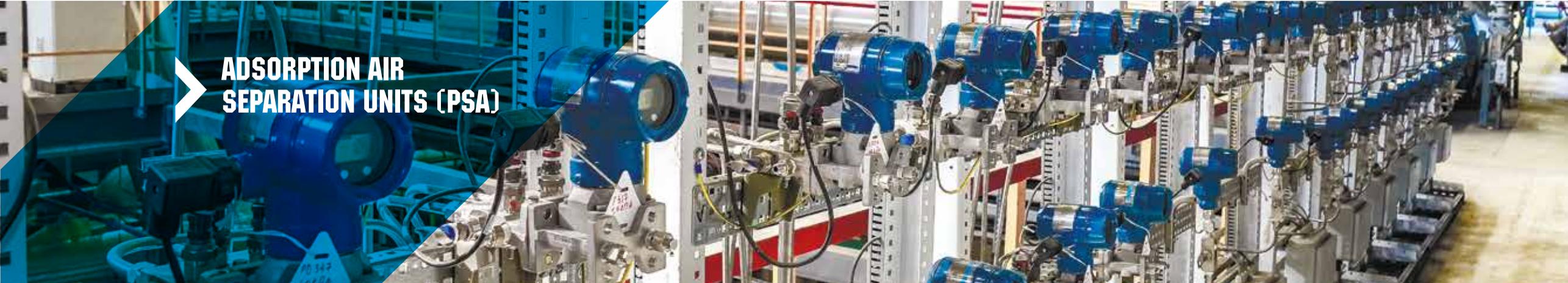
Development of advanced scientific technologies and research in fundamental physics, energetics, superconductivity effect, cosmonautics and instrument engineering predetermined the national economy's demand for cryogenic helium systems. Cryogenmash is one of the pioneers in their creation and application in practice. We have made the basis for designing new helium systems of free configuration on the ground of our own research and technology achievements tested in practice.

Today, the Company is ready to carry out a complete package of work to design, manufacture and commission equipment of the helium systems:

- › Helium liquefiers with a capacity of 200 up to 2400 l/hr;
- › Refrigerators with a cooling capacity of 50 up to 3000 W at a temperature of 1.8÷4.5 K°;
- › Cryostats with a capacity of 100 m³ and more, including the cryostats with lead-in wires;

- › Cryogenic helium tanks with a capacity of 1.25, 16 and 40 m³, highly-performance insulation and a nitrogen screen;
- › Cryogenic helium pipelines with additional heat-insulation screens;
- › Cryogenic shields of superconducting cables of rigid and flexible design;
- › Cryogenic equipment for superconducting motors and generators, energy accumulators and magnetohydrodynamic generators with superconductive magnets;
- › Systems for helium compression, purification and disposal, heat exchange equipment, turboexpanders and valves.

Cryogenic helium equipment of Cryogenmash is supplied to the customer at the maximum factory availability for mounting, and is operated successfully both in Russia and abroad.



ADSORPTION AIR SEPARATION UNITS (PSA)

OXYGEN OF 50 UP TO 2000 M ³ /HR	NITROGEN OF 100 UP TO 3000 M ³ /HR	OXYGEN PURITY UP TO 93 %	NITROGEN PURITY 99,99 %
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Cryogenmash designs and manufactures Pressure swing adsorption (PSA) units for the production of gaseous air separation products with specific parameters required by the Customer:

- ▶ For oxygen: producing capacity is from 50 up to 2 000 m³/hr with the product purity of 93% of the volume of O₂;
- ▶ For nitrogen: producing capacity is from 100 up to 3 000 m³/hr with the product purity of 99.9% of the volume of N₂.

Oxygen production by means of the Company's PSA units is efficient in scrap recycling, repair and machine building, glass-blowing industry, medicine, fish farming, as well as in mobile gas-plasma metal welding, brazing and cutting stations in building organizations.

The gaseous oxygen production units being designed by the Company are indispensable for ironworks, nonferrous industry, chemistry and petrochemistry, biological waste-water treatment stations, industrial and domestic waste incineration plants, and ozonization stations for potable water treatment.

PSA units for nitrogen production are widely used in the petrochemical, chemical and food industries, in metallurgy, power engineering and agriculture.



**SPECIALIZED SYSTEMS.
CRYOTHERMOVACUUM
SYSTEMS**

THE EQUIPMENT IS INSTALLED
AT **1/3** OF THE WORLD'S SPACEPORTS

THE EQUIPMENT WORKS
IN **6** COUNTRIES OF THE WORLD



Since 1959, Cryogenmash is the largest manufacturer of systems for supply of oxygen, nitrogen and hydrogen to domestic launching rocket complexes and space motors test facilities.

Cryogenmash designs and manufactures unique cryogenic-vacuum complexes and vacuum plants for centers and enterprises involved in space research and exploration programs.

Cryogenmash has set up production of cryogenic-vacuum units of 1 to 10,000 m³ capacity with working pressure of 1x10⁻³ to 1x10⁻⁸ mm Hg, a high speed of evacuation and sterility of the product surface. About 600 specialized units have been adopted for various applications.

Cryogenic-vacuum process units manufactured by Cryogenmash are intended for thermal vacuum tests of large-capacity assemblies and space vehicle units under simulated space conditions (vacuum of 1x10⁻⁴ ... 10⁻⁷ mm Hg at temperatures of 80...423 K).

Among the simulators, a special place is occupied by the KVI complex, Europe's largest space simulator of 10,000 m³ capacity and with 1x10⁻⁵ mm Hg working pressure, which is designed for full-scale tests of spaceships and crafts.

Cryogenmash has created specialized cryothermovacuum units for scientific research and experiments in cosmonautics. The units feature super-high vacuum conditions (up to 5x10 mm Hg) and universal design, i.e. the same unit is used to carry out a wide research program.

The test centers of Cryogenmash have been provided with a variety of cryogenic vacuum and vacuum chambers for testing air locking and spacewalk systems, flight crew rescue aids, space suits as well as for preflight preparation and training of spacecraft crews and flight personnel.



Since 1975 Cryogenmash has been offering a wide range of cryogenic turboexpanders, that fully meet both the Company's internal needs and any customer's demands.

Low- and medium-pressure turboexpander-compressor sets, the production of which started in 1993, are successfully operated in Russia and China. Their high thermodynamic effectiveness, combined with the expander capacity for additional compression of working gas in the compressor stage, improves essentially the engineering and economic performance of the modern ASUs.

Turbosets similar in design and equipped with a brake compressor were widely used in various thermostating systems, particularly as a part of the Sea Launch space launch system.

In 1996, Cryogenmash started to produce ASU turboexpanders on gas bearings, which were previously used in turbomachines of helium

liquefiers only. Positive operating experience gives evidence of their high quality and safety.

The Company has developed and implemented a special procedure for on-site upgrading of the turboexpanders already operated by Customers. Substitution of the flow channel elements for improved ones and the bearings for more safe ones, makes it possible not only to extend the turboexpanders service life, but also to improve the ASU performance substantially.

The concept for turboexpander creation currently adopted by Cryogenmash is to develop compact sets equipped with modern performance control systems with the minimum scope of mounting and commissioning works.



➤ **CRYOGENIC PIPELINES**

PIPELINES WITH A DIAMETER
OF DN **10** TO DN **750**



Cryogenmash designs and manufactures cryogenic pipelines of DN10 up to DN750 for transportation of liquid cryogenic products (nitrogen, oxygen, argon and liquefied natural gas) with the minimum heat gains from the environment.

A cryogenic pipeline is a coaxial double-walled pipeline with vacuum screen insulation.

According to the georeferencing, a cryogenic pipeline route is completed with the following components:

- Cryogenic pipeline sections;
- Compensator elements (expansion joints, metal hoses);

- Connection elements (couplings, lenses, etc.);
- Adsorption sections;
- Vacuum ports for connection of evacuation and vacuum control devices;
- Supports, membrane safety devices and protective grounding devices.

Cryogenic pipeline sections are interconnected by welding.

At present, the Company has designed and manufactures pipeline sections for oxygen, nitrogen, argon, hydrogen and helium.



In Russia, the cryogenic industry was originally created on the basis of the latest scientific achievements in the 1940s-1950s. It was for a reason that this project was entrusted to a future Nobel Prize Winner, Peter L. Kapitsa.

An autogenous plant which became the prototype of a future high-powered Research and Industrial Association Cryogenmash, was founded in Balashikha in 1949. Prior to 1963, the research and development were carried out by a research institute in Moscow. Later, it was decided, to consolidate the research, design and production capacities into a single whole on a single territory, and this has proved to be a good solution.

Nowadays, the Company's core product is exclusive customized equipment. That's why the development and application of new technologies, new parts and assembly systems are rather a rule than an exception for Cryogenmash, and this is actively contributed to not only by researchers and designers, but also by process engineers and production people. A link between science and production is essential for building competitive equipment.

Cryogenmash is one of few engineering companies in Russia who managed not only to keep, but also to substantially develop its scientific component. Thanks to its groundbreaking engineering and scientific developments, Cryogenmash is successfully competing with other manufacturers on the high-tech equipment markets.

Besides, the competition has urged the Company to upgrade. It was necessary to change all the technological limits, carry out full-scale modernization of the production facilities, liquidate the redundant production spaces and optimize the provision of infrastructural resources. To meet these challenges, Cryogenmash has built a new, modern production facility on its grounds.

Nowadays, Cryogenmash markets the products that are cost-effective, use effective technologies and, most importantly, are able to assure the Company's customers of its potential for innovation.



CRYOGENMASH

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