Joint-Stock Company
I. I. Polzunov Scientific and Development Association on Research and Design of Power Equipment

The best solutions for innovation

JSC NPO CKTI

OVERALL JSC NPO CKTI ACTIVITIES PRESENTATION: DIVISIONS, DEPARTMENTS, LABS, SECTORS

Facilities

Headquarters

Address:

3/6 Atamanskaya str.,

St. Petersburg,

191167, Russian Federation

'Lesnoye' Facility

Address:

24 Politekhnicheskaya str.,

St. Petersburg,

194021, Russian Federation

Company History

CKTI was established in 1927, during the implementation of GOELRO plan (Soviet plan for national economic recovery and development). Academician A. F. Ioffe, Associate Members of the Academy of Sciences M. V. Kirpichyov and M. A. Chatelain, professor V. N. Schröter have initiated the creating of new R&D organisation – to provide the research and development (R&D) support for the native energymachinebuilding and energy generation industries.

The name of the institute was altered several times at different stages of its development due to variable structure the boiler and turbine manufacturing industry: Heat Engineering Research Bureau **(BYuTI),** Leningrad Regional Heat Engineering Institute **(LOTI),** Boiler and Turbine Research and Development Institute **(NIKTI),** All-Union Heat and Hydropower Equipment Institute **(VITGEO),** and finally – **since 1935– CKTI or Central Boiler and Turbine Institute (CKTI).**

The main areas of business were defined as: creation of the heat exchange process modelling theory, development of automatic regulation theory and systems, circulation calculation methods, research of heat exchange processes inside boilers, combustion processes, high-velocity flows, research of cascades of turbine profiles, issues of strength and lifetime of power equipment etc.

Fundamental research and development executed in NPO CKTI, created prescriptive calculation methods and design methods have created a basis for the development of the native power plant engineering.

In 1947, the institute was awarded the name of wellknown Russian inventor of heat machine **Ivan Ivanovich Polzunov.**

In 1960, by the ruling of the Government, CKTI was **assigned a role of the leading R&D organisation** of energymacinebuilding industry.

In 1976, by the ruling of the Government, CKTI became a host to the Scientific And Development Association On Research And Design Of Power Equipment – **NPO CKTI.** This Association included Central Boiler and Turbine Institute, CKTI Pilot Factory, branches in Barnaul and Rostov.

In 1977, NPO CKTI was awarded **the Order of the October Revolution** in recognition of its R&D efforts aimed at creating new power equipment**.**

In 1994, the Association was privatised, its structure was reformed and its became the Open Joint-Stock Company NPO CKTI.

In April 2002, the enterprise was reorganized and became **Open Joint-Stock Company I. I. Polzunov Scientific and Development Association on Research and Design of Power Equipment Power Equipment (NPO CKTI JSC)**

NPO CKTI JSC is a leading scientific and engineering center in native power plant engineering. The enterprise is focused on the development and promotion of state-of-the-art technology and innovative products for nuclear, thermal and hydropower plants, industrial and domestic power engineering.

Intellectual potential

NPO CKTI JSC has 815 employees, out of which 524 ones have high education (dyploma engineers) and 80 ones have academic degrees, such as Candidate of Sciences (PhD) or Doctor of Sciences (DR).

In 2004, a quality management system (QMS) was successfully implemented in the NPO CKTI JSC.

Compliance of the quality management system with the requirements of ISO 9001:2008 and the national standard GOST ISO 9001-20011 **is confirmed by the Certificate of Conformity GOST R No. ROSS RU.IS09.K01561**, the international certificate IAF No. 02.154.13 and the international certificate IQNet No. RU-Q01561.

NPO CKTI JSC is a winner of the 2012 Saint Petersburg Government Prize for quality of work.

CKTI NPO JSC has eight operating licenses, including one for nuclear power engineering activities.

CKTI NPO JSC is a member of the Self-Regulated Organization “Non-profit Partnership SOJUZATOMPROEKT”, Noncommercial partnership Centre of Energy Audit, and Self-Regulated Association “Community of Builders of St. Petersburg”.

The enterprise has its own **Power Equipment Testing Center** (ICEO), which was **certified** by the Federal Certification Agency of the Russian Federation and the **State Atomic Energy Corporation Rosatom**.

Intellectual potential

Since 1962, NPO CKTI JSC has been continuously hosting **Doctor's and Candidate's Dissertation Scientific Boards**. Since then, 517 employees of CKTI and various enterprises representing the industry have defended their dissertations in these Boards.

The authority of the Dissertation **Scientific Boards** D 520.023.01 has been extended by order of Rosobrnadzor No. 105nk dated April 11, 2012 for the duration of these scientific and engineering disciplines:

14/05/14 – ***Thermal power plants, their power transmission systems and equipment***;

14/05/03 – ***Nuclear power installations, their design, operation and decommissioning***;

16/05/09 – ***Materials science (mechanical engineering)***.

Intellectual potential

NPO CKTI JSC is a **leader in patented inventions** among enterprises and organizations of Saint Petersburg.

In 2017, NPO CKTI JSC continued developing its inventive activities as planned. The institute received **9 Russian patents** for the inventions and utility models, submitted **9 applications** to Rospatent (Patent Agency of the Russian Federation) for its inventions and utility models, obtained **12 approvals of Russian patents** for the inventions and utility models. Also, **120 Russian patents for the inventions and utility models have been retained.**

	2012	2013	2014	2015	2016	2017
Invention patent applications submitted	7	7	1	4	5	3
Utility patent applications submitted	7	7	9	10	8	6
Total patent applications submitted	14	14	10	14	13	9
Russian invention patents received	3	7	7	4	4	6
Russian utility patents received	10	4	10	8	4	6
Total Russian patents received	13	11	17	12	8	12
Russian invention patent applications approved	6	7	6	3	4	5
Russian utility patent applications approved	5	9	10	10	3	7
Total patent applications approved	11	16	16	13	7	12
Russian invention and utility patents retained	83	94	107	113	119	120

Creation of Scientific and Technical Regulations

- **2006–2017** 102 proprietary standards **(STO)** have been developed by NPO CKTI JSC.
- **1972–1988** 96 technical guides **(RTM)** were developed.
- **1981–2013** 41 guideline **(RD)** was created.
- **1975–2002** 245 industry standards **(OST)** were developed.

OST developed by the NPO CKTI JSC have been purchased and used by the native and international organizations involved in power plant engineering. Besides, the leading native IT companies, such as Norma-CS and Codex, have signed an appropriate license agreements to place the aforementioned OST in their data bases.

Organization Structure

Follow divisions and departments create an organisation structure of NPO CKTI JSC:

- Heat Exchange and Cycle Equipment Division
- Turbine Units Division
- Boiler Units Division
- Advanced Development Department
- Mechanical Integrity and Lifetime Division
- Power Equipment Test Center

Organization Structure

The following auxiliary departments of NPO CKTI JSC work to support scientific and technical activities:

- Power Cogeneration Plant
- Technical Regulation, Licensing and Information Support Department
- Technical Archives Library
- Electronic Technical Archives
- Science and Technology Library
- Non-Standard Equipment Manufacturing Workshop
- Tender and Electronic Procedures Department
- Senior Metrologist Department
- Foreign Relations Sector

Heat Exchange and Cycle Equipment Division

Main Departments and Laboratories

- **Heat Exchange Equipment Department:**
  - *surface heat exchangers for CCP and NPP*
  - *steam turbines regeneration schemes equipment modernization and testing*
  - *mixing heat exchanger, evaporator and auxiliary equipment*
  - *thermal deaerators*
  - *surface heat exchangers for industrial units designed for disrtict heating systems.*
- **Thermal processes for nuclear power plant equipment laboratory**
- **Pump equipment development and research for fossil and nuclear power plants laboratory**
- **Power equipment testing center**
- **Material lifetime assessment and testing materials of welded structures of power equipment at fossil and nuclear power plants department**
- **Development, design and economical analising of thermal power units and systems laboratory**

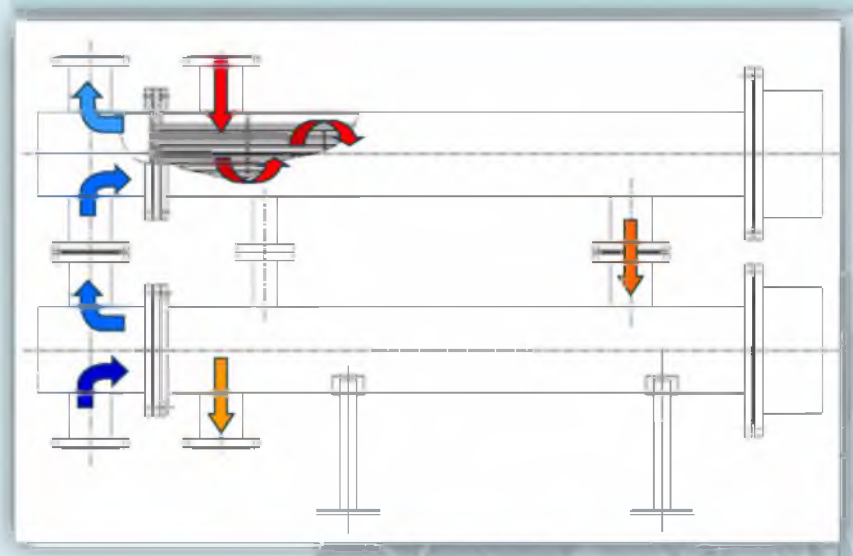
Heat Exchange Equipment Department

Effective and reliable heat exchanger for heat supply systems

Water-water heaters of PVMR type

Features of PVMR heaters:

- floating small-size water chamber;
- small heater footprint and volume;
- removable matrix for annular space cleaning;
- low dirt retention due to increased water flow velocities.



Heat Exchange Equipment Department

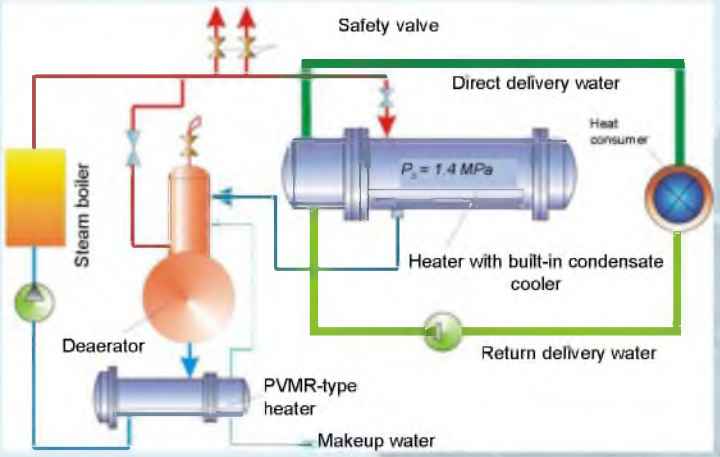
Steam-water heaters with built-in condensate cooler

Improved matrix:

- one-way transverse steam motion through a tube bundle;
- separated cooling zone for steam-air mixture;
- rigid frame and small size free spans of tubes.

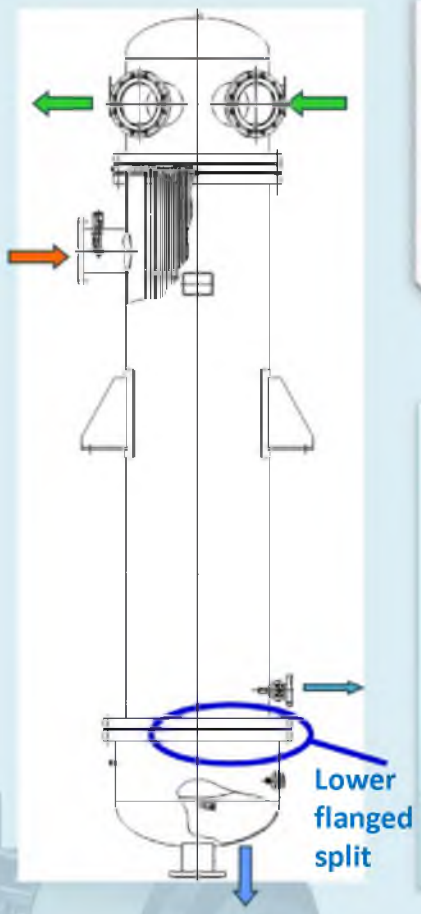
Availability of cooling zone for heating steam condensate allows eliminating the use of external condensate coolers.

Schematic diagram of boiler room when system water heating unit is equipped with heaters with built-in condensate cooler and heater of PVMR type.



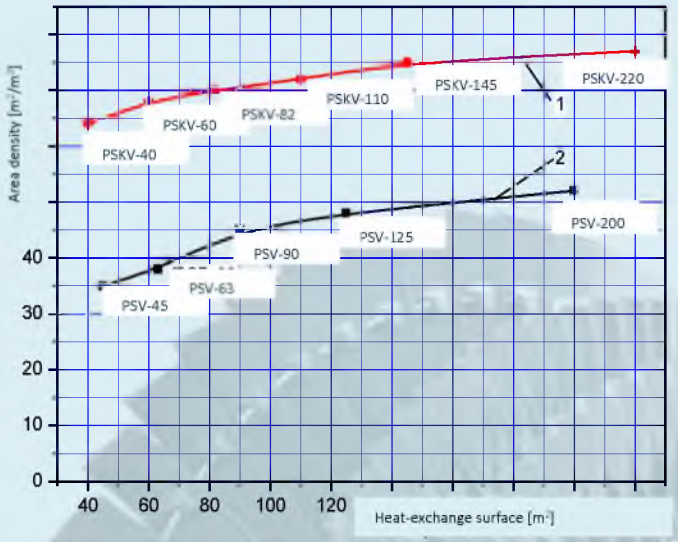
Heat Exchange Equipment Department

New vertical delivery water heaters of PSVK type



Features of PSVK heaters:

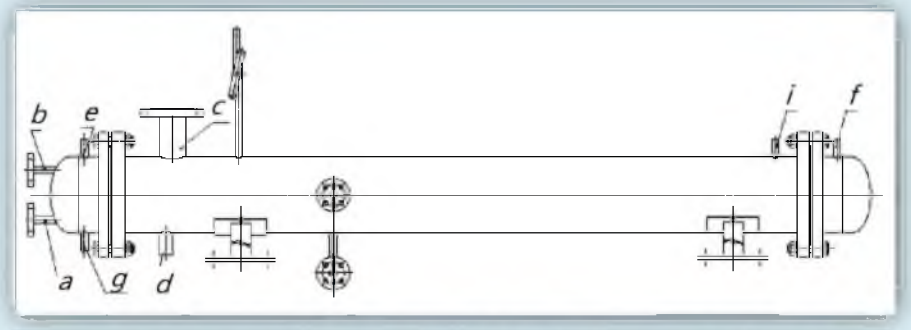
- a flanged split available in the lower part of the shell, which considerably facilitates the maintenance and repairs on the heaters in boiler plants;
- the matrix design provides a higher thermal capacity of the heater at reduced dimensions of its shell;
- the matrix features a high stiffness and anti-vibration reliability.



Heat Exchange Equipment Department

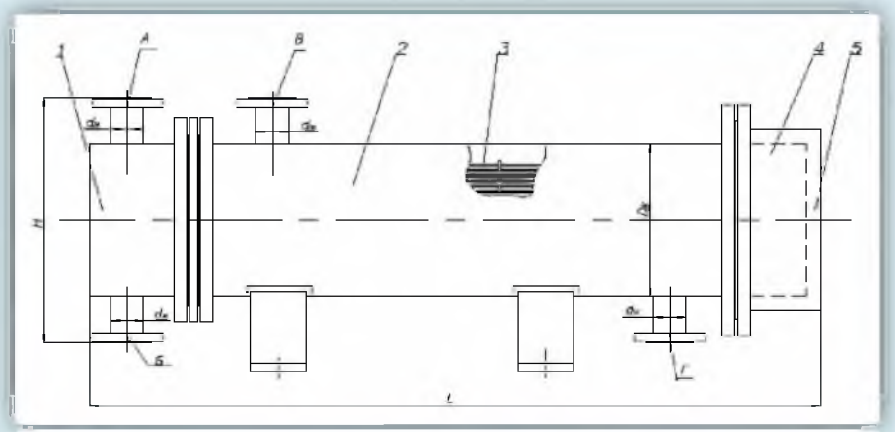
Liquid Fuel heaters

Low capacity steam fuel oil heaters



The heaters have capacity of **250–1600 kg/h**, provide heating of M100 fuel oil at nominal flow rate to the temperature of **70 to 95 °C** at the steam pressure of **10 kgf/cm²**. The heaters are designed for fuel oil pressure of **25 kgf/cm²**. PPM heaters have a built-in cooler of heating steam condensate.

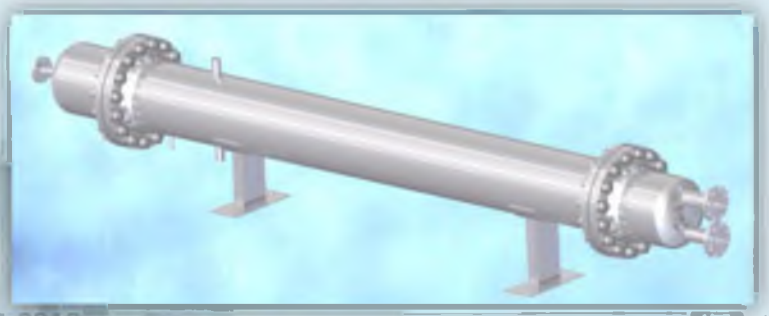
Water fuel oil heaters



Heating medium – water

The heater provides heating of M100 fuel oil to the temperature of **60 to 95 °C**; capacity is 500–2500 kg/h.

Fuel oil heaters with finned tubes, replacing PMR heaters



Heaters of PMRN type provide heating of M100 fuel oil to the temperature of **60 to 135 °C**, have capacity of **6 to 400 t/h**, higher thermal efficiency and lower hydraulic resistance in comparison with PMR heaters (production which is terminated), and practically match by mounting dimensions.

Heat Exchange Equipment Department

Surface heat exchange equipment of combined cycle and nuclear power plants

Main activities:

- development of a new design and testing of low pressure systems;
- development and approval of technical projects for horizontal and vertical low-pressure heaters for turbine plant regeneration systems (LPH) and horizontal and vertical delivery water heaters (PSV) for thermal power plants (TPP);
- thermal-hydraulic design for LPH and PSV;
- rehabilitation and modernization of heat-exchanging equipment;
- testing, condition assessment.

Works performed:

- development of technical design of regenerative surface heaters PND-1, 3, 4;
- development of technical documentation for production of PSG-1 and PSG-2 of the PGU-410T power unit being under construction at the Novo-Salavatskaya Cogeneration Plant (CP);
- design and development of elements for 36 MW steam turbine plant for nuclear icebreakers.

Low Pressure Heater (LPH)

PSV

PSV

Heat Exchange Equipment Department

Steam turbines regeneration schemes equipment modernization and testing

Main activities of the laboratory:

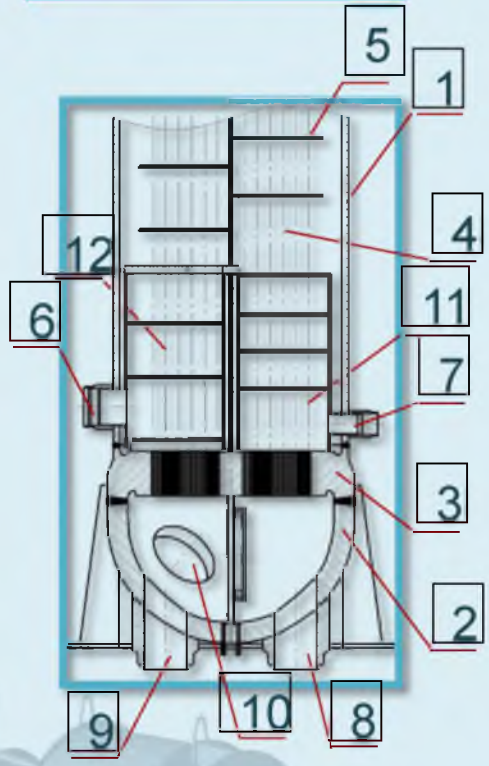
- development of chamber-type high-pressure heaters. Replacement and supply of heaters. Modernization and testing of high-pressure regeneration system;
- development and supply of control valves (**CV**) and main steam isolation valve (**MSIV**);
- development and supply of mixers for various purposes;
- development and supply of throttling devices;
- Analysing of the steam separation and overheating system, of the mixing heater - condensate pump system, of the drain collector - pump for drain water system, deaerator - feed pump system in static and dynamic modes;
- development of repairing documentation for equipment of the steam turbine plant regeneration system;
- development and testing of thermal circuits without deaerator;
- balance, hydraulic and operational tests of heaters; analysis of heater operating modes.

Heat Exchange Equipment Department

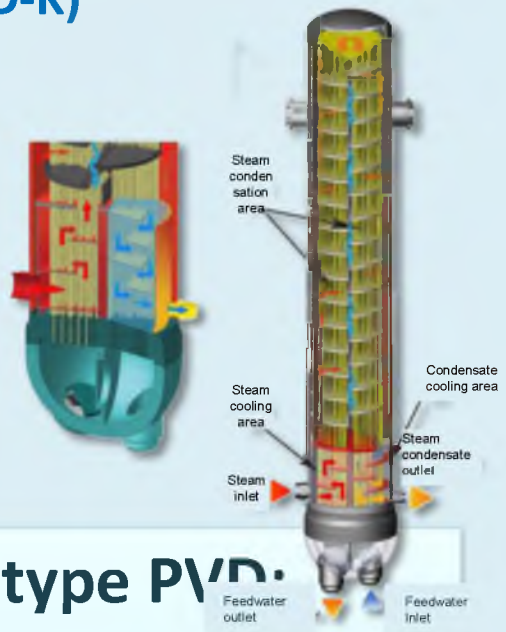
Steam turbines regeneration schemes equipment modernization and testing

Chamber-type high-pressure heaters (PVD-K)

Main structure elements:



1. Steam shell
2. Spherical water chamber
3. Tube sheet
4. Heat exchange tubes
5. Partitions
6. Steam inlet tube
7. Heating steam condensate outlet tube
8. Feed water inlet
9. Feed water outlet
10. Manhole
11. Condensate cooling area
12. Steam cooling area



Advantages of chamber-type PVD:

operation safety:

the chamber PVDs don't feature headers, which can lead to serious accidents at power units and significant destruction in the turbine hall.

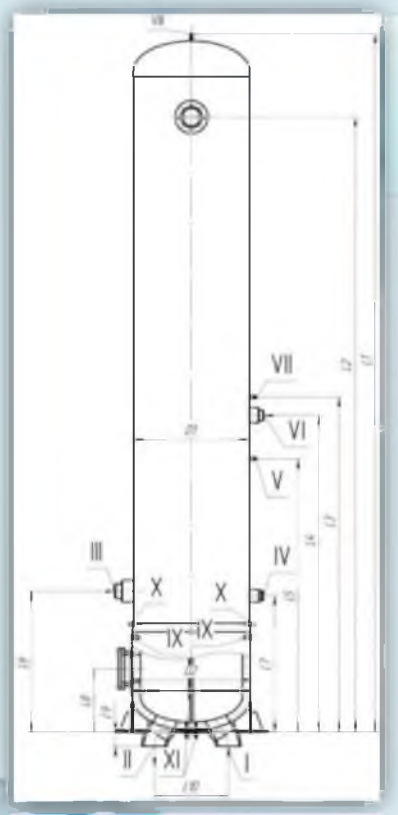
Chamber PVD is designed for simultaneous rupture of 7 nearby tubes, without causing the unit to stop due to PVD fault.

Short payback period.

Heat Exchange Equipment Department

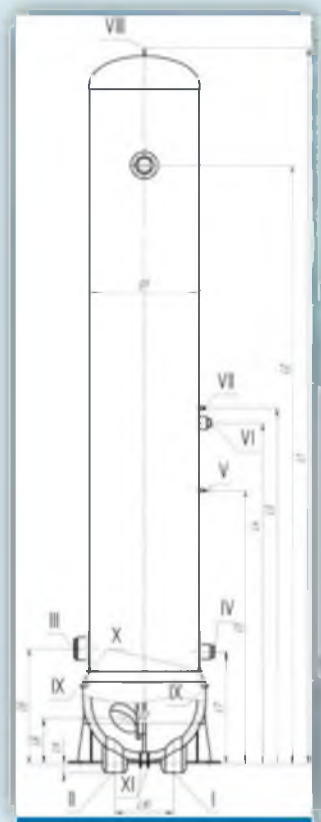
Steam turbines regeneration schemes equipment modernization and testing

Vertical high-pressure heater of chamber type (PVD-K)



PVD-K-360-230-12-II
PVD-K-360-230-25-II
PVD-K-360-230-44-II

Overview of PVD



PVD-K-425-230-13-II
PVD-K-425-230-25-II
PVD-K-425-230-37-II

PVD-K-700-265-13-II
PVD-K-700-265-31-II
PVD-K-700-265-45-II

Overview of PVD

Heat Exchange Equipment Department

Steam turbines regeneration schemes equipment modernization and testing

Closed high pressure heaters for steam turbine regeneration systems

Type and size of chamber heater	The analog of spiral header heater	Heat transfer surface area, total, m^2	Operating pressure**, MPa		Feed water nominal flow rate, t/h	Underheating*, ^0C	Undercooling, ^0C	Hydraulic resistance at nominal flow rate, MPa	Overall dimensions, mm		Weight, t		Turbine type and size (D/BTS)
			Water in the matrix	Steam in the shell					Height	Shell diameter	Dry	Filled with water	
PVD-K-360-230-21-II	PV-350-230-21	360	17.0	1.27	390	0	7	0.1	7500	ø 1250	20.0	26.0	PT-60/75-130/13 LMZ,
PVD-K-360-230-36-II	PV-350-230-36	360		2.55		0		0.11	7500	ø 1250	20.0	26.0	
PVD-K-360-230-50-II	PV-350-230-50	360		4.31		-0.6		0.12	7500	ø 1250	20.0	26.0	
PVD-K-425-230-13-II	PV-425-230-13	425	17.0	1.22	550	0	7	0.1	6400	ø 1400	21.5	28.1	PT-90/110-130/13 LMZ,
PVD-K-425-230-25-II	PV-425-230-25	425		2.28		0		0.1	6400	ø 1400	22.2	28.2	
PVD-K-425-230-37-II	PV-425-230-37	425		3.32		0		0.1	6400	ø 1400	23.7	30.3	PT-100/110 LMZ K-55-90 LMZ T-110/120-130 UTZ
PVD-K-700-265-13-II	PV-775-265-13	700	20.0	1.28	700	-1.0	7	0.12	9380	ø 1400	39.0	50.0	K-210(215)-130 LMZ,
PVD-K-700-265-31-II	PV-775-265-31	700		3.03		0		0.13	9380	ø 1400	39.0	50.0	T-180/210-130 UTZ
PVD-K-700-265-45-II	PV-775-265-45	700		4.41		-1.0		0.13	9380	ø 1400	39.0	50.0	T-185/220-130 UTZ
PVD-K-1400-380-21-II ***	PV-1250-380-21	1400	29.0	2.1	1050	-1.6	7	0.19	13100	ø 1590	61.0	79.0	K-300(330)-240 LMZ K-300(330)-240 KhTZ, T-295(335)-23.5 UTZ, T-250/300-240 UTZ
PVD-K-1400-380-51-II	PV-1700-380-51	1400		5.0		+2.0		0.2	13100	ø 1590	61.0	79.0	
PVD-K-1400-380-70-II	PV-1550-380-70	1400		6.9		-0.6		0.2	13100	ø 1590	61.0	79.0	

* – nominal underheating at rated load of the power unit

** – maximum admissible parameters

*** – possible supply by Violen arrangement with external vapor cooler, and parameters of PVD-K to be specified.

Heat Exchange Equipment Department

Steam turbines regeneration schemes equipment modernization and testing

Characteristics of high-pressure heater connections

Heater type and size	I – Feed water inlet	II – Feed water outlet	III – Heating steam inlet	IV – Heating steam condensate outlet	V – Branch pipe of non-condensable gases	VI – Condensate inlet from the higher stage PVD	VII – Inlet of non-condensable gases from the higher stage PVD	VIII – Air branch pipe from steam shell	IX – Air branch pipe from matrix	X – Shell emptying	XI – Matrix emptying	Turbine type and size
PVD-K-360-230-12-II	ø 273 x 24	ø 273 x 24	ø 219 x 11	ø 108 x 6	ø 57 x 4	ø 108 x 6	ø 57 x 4	ø 38 x 3	ø 38 x 3	ø 38 x 3	ø 38 x 3	PT-60/75-130/13,
PVD-K-360-230-25-II			ø 219 x 11	ø 108 x 6		ø 108 x 6						
PVD-K-360-230-44-II			ø 219 x 11	ø 108 x 6		-						
PVD-K-425-230-13-II	ø 273 x 23.5	ø 273 x 23.5	ø 222 x 13.5	ø 159 x 6.5	ø 60 x 5	ø135 x 11.5	ø 58 x 5.5	M20	ø 16 x 2.5	ø 38 x 3	ø 38 x 3	PT-90/110-130/13 LMZ, PT-100/110 LMZ K-55-90 LMZ T-110/120-130 UTZ
PVD-K-425-230-25-II			ø 222 x 20	ø 159 x 6.5		ø135 x 11.5	ø 58 x 5.5					
PVD-K-425-230-37-II			ø 222 x 20	ø 159 x 6.5		-	-					
PVD-K-700-265-13-II	ø 273 x 24	ø 27 3x 24	ø 273 x 13	ø 219 x 8	ø 57 x 4	ø 159 x 7	ø 57 x 4	ø 38 x 3	ø 38 x 3	ø 38 x 3	ø 38 x 3	K-210(215)-130 LMZ, T-180/210-130 UTZ T-185/220-130 UTZ
PVD-K-700-265-31-II			ø 159 x 9	ø 159 x 7		ø 159 x 7						
PVD-K-700-265-45-II			ø 159 x 9	ø 159 x 7		-						
PVD-K-1400-380-21-II	ø 377 x 50	ø 377 x 50	ø 325 x 15	ø 273 x 10	ø 57 x 4	ø 219 x 9	ø 57 x 4	ø 38 x 3	ø 38 x 3	ø 38 x 3	ø 38 x 3	K-300(330)-240 LMZ K-300(330)-240 KhTZ, T-295(335)-23.5 UTZ, T-250/300-240 UTZ (D/BTS)
PVD-K-1400-380-51-II			ø 219 x 22	ø 219 x 9		ø 159 x 9						
PVD-K-1400-380-70-II			ø 159 x 16	ø 159 x 9		-						

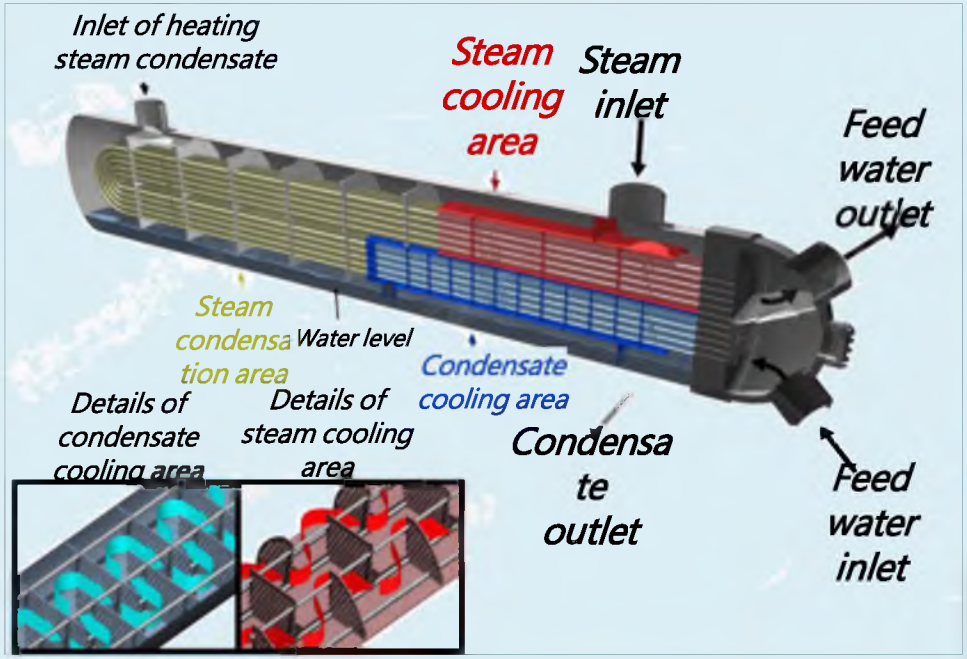
Dimensions of tubes and their boring can be specified for a specific turbine plant and wiring diagram.

D – thermal circuit with deaerator; BTS – thermal circuit without deaerator.

Heat Exchange Equipment Department

Steam turbines regeneration schemes equipment modernization and testing

Horizontal high-pressure heater of chamber type (PVG-K)



Main structure elements:

- casing;
- spherical water chamber;
- tube sheet;
- heat exchange tubes;
- Partition;
- steam inlet tube;
- heating steam condensate outlet tube;
- feed water inlet;
- feed water outlet;
- manhole;
- condensate cooling area;
- steam cooling area.

Absence of water mass in the steam space of the heater is advantage of horizontal design. It decreases a possibility of moisture entering the turbine and turbine rotor overspeed, i. e. overall reliability of the turbine increases.

Chamber-type high-pressure heaters (PVD-K)

Heat Exchange Equipment Department

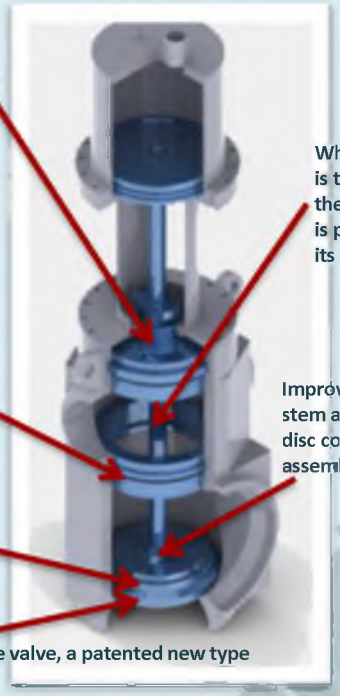
Steam turbines regeneration schemes equipment modernization and testing

Development and supply of control valves (CV) and fast safety device (FSD)

Control valves (CV)

Fast sefety device (FSD) for high pressure heaters (PVD)

Improved design and process solutions:



FSD valves (inlet and outlet)

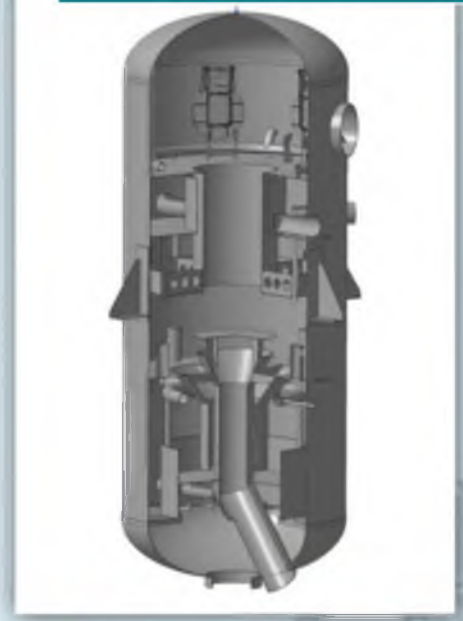
Heat Exchange Equipment Department

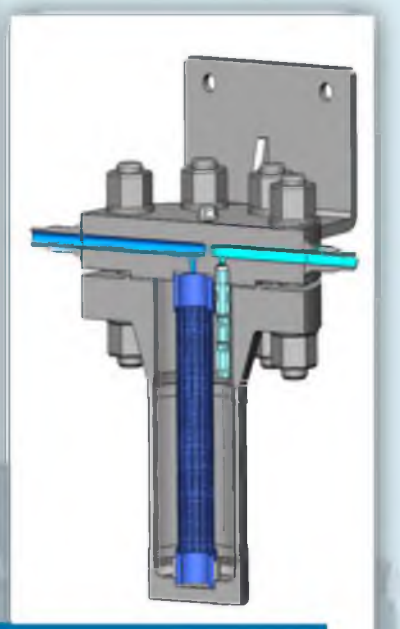
Mixing heat exchanger, evaporator and auxiliary equipment

Main activities of the laboratory:

1. Development, manufacturing, supply, commissioning, testing, modernization and restoration:
   - of the new generation of mixing-type heat exchangers in the low-pressure regeneration circuit for Fossil Fuel Power Plants;
   - mechanical filters intended for coarse and fine cleaning of impurities in heat supply systems and in process circuits of various production, as well as purging water of steam generator;
   - continuous blowdown separators, drainage expansion units and steam coolers.
2. Single-stage projects of deaerators in condensate collectors of condensators.

Vertical regeneration mixing heater of PNSV type (invention patent)





Filter for steam generator purge water cleaning (utility patent)

Heat Exchange Equipment Department

Thermal deaerators sector

Main activities of the sector:

- development of new and non-standard equipment (for the facility);
- development of installation diagrams and selection of equipment (for atmospheric and vacuum deaerators);
- modernization and rehabilitation of equipment and installation diagrams;
- consultations of the developer;
- manufacturing of equipment including: deaerator tanks, deaerator columns, vapor coolers, safety devices, etc.;
- technical support at installation and commissioning;
- service life extension for deaerators after the expiration of the specified service life or breakdown in accordance with the current normative documentation, including:
  - development of individual programs for technical diagnosis and its implementation;
  - examination of industrial safety and issue of an technical approval;
  - implementation of strength designs;
  - development (if required) of technical documentation for deaerator strengthening, repair and improvement.

Heat Exchange Equipment Department

Thermal deaerators sector

High-pressure deaerator DP-1000/120

The deaerator design is based mainly on well-known and proven solutions. The use of a jet nozzle as a low-pressure water distributor at the top of the column allows creating an additional contact surface of the water and vapor phases to improve heat and mass transfer and thereby improve performance of the deaerating column. Use of two jet stages in the column and the flooded bubbling device in the tank can guarantee the required water heating and deaeration.

Prototype of deaerator DP-1000/120 was manufactured by LLC Sibenergomash-BKZ in 2005 and installed in 300 MW turbine unit circuit at Wong Bi TPP in Vietnam later.

According to NPO CKTI JSC, it is reasonable to develop proposals for **creation of a series of new high-pressure deaerators** for use in circuits of new power units and modernization of existing ones with a capacity of **200–300 MW**, aimed to:

- increase of maneuverability of the power unit operation;
- reduce vertical dimensions and simplify the deaerator design;
- ensure reliable operation of the deaerator at sliding pressure under starting and transient modes;
- improve the operating economy of the turbine plant by increasing operating pressure in the deaerator and working at sliding parameters depending on the turbine load.

Heat Exchange Equipment Department

Thermal deaerators sector

High-pressure deaerator DP-1000/120

NPO CKTI JSC developed high-pressure deaerator DP-1000/120 with a capacity of 1000 t/h for use in power unit circuits with capacity of 200–300 MW.

The deaerator consists of a horizontal column mounted on the deaerator tank.

Nominal (rated) deaerator capacity, kg/s	277.78
Design pressure (absolute), MPa	1.08
Design (gage) pressure, MPa	1.02
Design temperature, K	473.15
Water heating in the deaerator at rated output, K	306.15
Range of deaerator output changing, % of design output	30–100
Specific vapor flow rate from the deaerator at design capacity, kg/t d. w. (deaerated water)	1.5
Dissolved oxygen content in deaerated water, µg/kg, max.	
deaerator outlet	7
deaerator inlet	20
Deaerator tank geometric capacity, m^3	186
Deaerator tank effective capacity, m^3	120
Required pressure drop at the water distribution unit, MPa, max.	0.147

Table – Deaerator key features

Heat Exchange Equipment Department

Advantages of Equipment Produced

The equipment produced is adapted for severe operating conditions:

- possible absence of water treatment;
- possible absence of deaeration;
- District heating pipeline of carbon pipes;
- low maintenance level.

The equipment produced has high consumer properties:

- modern thermal efficiency;
- reliability;
- complete maintainability (dismountable);
- small size;
- field maintenance and repair capability;
- available consumables and spare parts.

The equipment owner does not depends on supply of unique and expensive spare parts

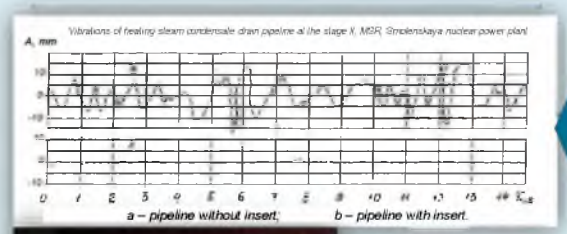
Thermal processes for nuclear power plant equipment

Main activities of the laboratory:

- **homogenizing inserts** for eliminating vibrations in pipelines with two phase flow (vaporing);
- **inserts for limiting** the two-phase and one-phase flows and other non-standard equipment for nuclear power plant pipelines;
- highly efficient heat exchangers with heat-transmitting surface, shaped with **dimples**;
- **condensing systems** for confinement systems in NPP failure case;
- equipment element tests at **extremely low temperatures**;
- complex solution to scientific problems related to storage and transportation of used nuclear fuel and fissile material;
- research related to **modernization of operating equipment,** such as moisture separators-reheaters (MSR) of units with RBMK reactors (High Power Channel-Type Reactors), as well as acceptance tests of modernized equipment at the site;
- research of **aerosol transport** processes in power-generating equipment of nuclear power plants in case of severe accidents;
- thermal hydraulics of elements of the **International Thermonuclear Experimental Reactor** (ITER);
- test research of **liquid metal coolers**;
- **protective coatings** of turbine condenser tube bundles;
- modelling of **transition** on low-boiling coolants.

Thermal processes for nuclear power plant equipment

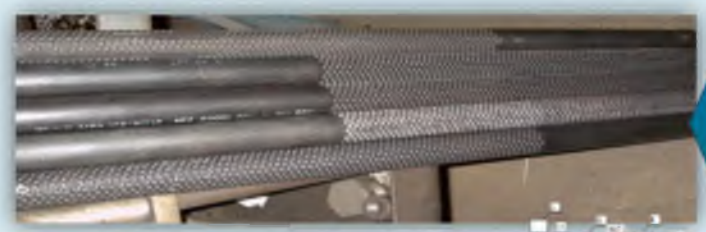
Main work completed by the laboratory



Homogenizing inserts for eliminating vibrations in pipelines with two phase vaporing flow

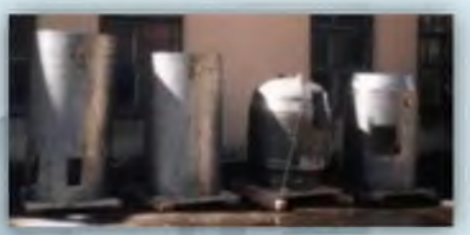
Inserts for limiting the two-phase and one-phase flows and other non-standard equipment for nuclear power plant pipelines

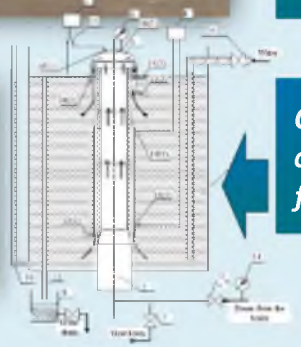
The laboratory has developed a device that eliminates vibrations in pipelines that transport boiling liquids to the nuclear and thermal power plants. The device allows rearranging a structure of a two-phase flow – it eliminates a slug flow, which is dangerous due to vibrations created by it. Industrial tests of inserts on condensate drain pipelines at stages I and II of SMR to the deaerator at Khmelnitskiy, Kalininskiy, Smolenskiy and Kurskiy nuclear power plants, as well as Kozloduy nuclear power plant in Bulgaria allowed lowering the vibration amplitude by 3÷5 times, making the vibration level safe.



Highly efficient heat exchangers with heat-transmitting surface, shaped with dimples

The dimpled pipe production technology has been developed. Currently, tubular plate-type heat exchanger with dimpled plates are undergoing preparations for testing.





Condensing systems for confinement systems for PPT failure case

The laboratory has designed a new injection condenser for SOVA-TK system (radioactive release limitation system for the event of pressure channel rupture) at the Kurskaya nuclear power plant.

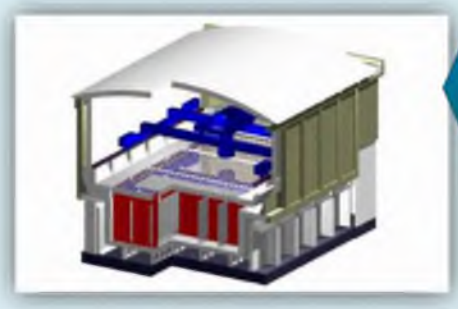
Thermal processes for nuclear power plant equipment

Main work completed by the laboratory

Equipment element tests at extremely low temperatures

The laboratory has a 15-cubic meter cooling chamber. Refrigeration capacity – 12 kW at the temperature inside the chamber – negative 58 °C. The chamber is designed for determining the operating performance and life tests of heating equipment elements.

Storage of used nuclear fuel and fissile material



The laboratory has conducted a large experimental research thermal hydraulic features of Russian Fissile Material Storage Facility and ISFSI (Independent Spent Fuel Storage Installation, see the figure).

Dropping the TUK-129 (TUK-128/1) full scale model cover side down on a steel rod (IAEA requirement)

Fall of the TUK-128 (TUK-128/1) model by its cover onto a pintle (according to the IAEA requirements)

Transportation of spent nuclear fuel and radioactive waste

Drop test with a full scale model of TUK-128 (IAEA requirement)

- The laboratory has conducted a research of heat removal from spent fuel elements placed for transportation and storage in vertical and horizontal protective containers; the laboratory has developed their thermal and strength design methods that comply with IAEA requirements.
- The laboratory has completed thermal (and strength) design of the transport package TUK-6 for 30 spent fuel assemblies (SFA) of VVER-440 reactor, at well as TUK-10 and two types of TUK-13 for 6 and 12 assemblies of VVER-1000 reactor accordingly. The specified transport packages are still in operation and ensure uninterrupted work of domestic nuclear power plants with water-water reactors.
- In cooperation with the State Research Center CNIITMASH and Petrozavodskmash plant, the laboratory conducted a research of ductile iron with spherical graphite aimed to determine its suitability for casting TUK shells (a 40-ton container shell was cast and specifications were released for ductile iron with spherical graphite).

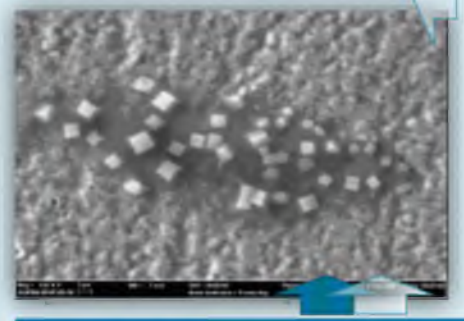
Thermal processes for nuclear power plant equipment

Main work completed by the laboratory

Work performed at nuclear power plants

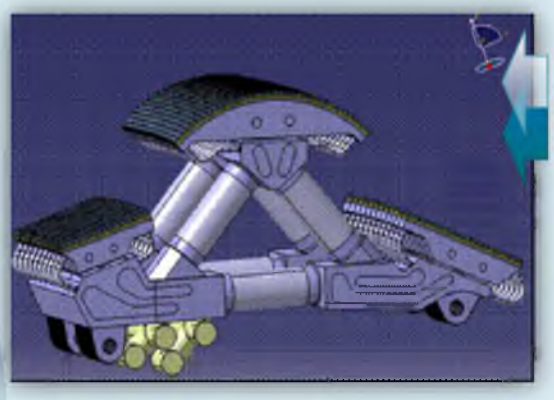
- The laboratory conducts complex research of performance characteristics of heat exchanging equipment at nuclear power plants. When measuring temperature and flow characteristics the laboratory uses standard equipment (thermocouples, resistance thermometer, ultrasonic flowmeter, etc.).
- To measure humidity of steam flows the laboratory developed a small-size throttling calorimeter (see the figure), which allows determining humidity of saturated steam with minimum consumption of measured medium (less than 15 kg/h).

Research of aerosol transport processes in power-generating equipment of nuclear power plants in cause of severe accidents



Deposits structure (a photo from an electronic microscope). Typical particle size – 2 μm

The aerosol deposition and entrainment processes are studied on a special test bed using generators of liquid and hard aerosol. Air velocity in deposition experiments reaches 40 m/s; in entrainment experiments – more than 100 m/s.

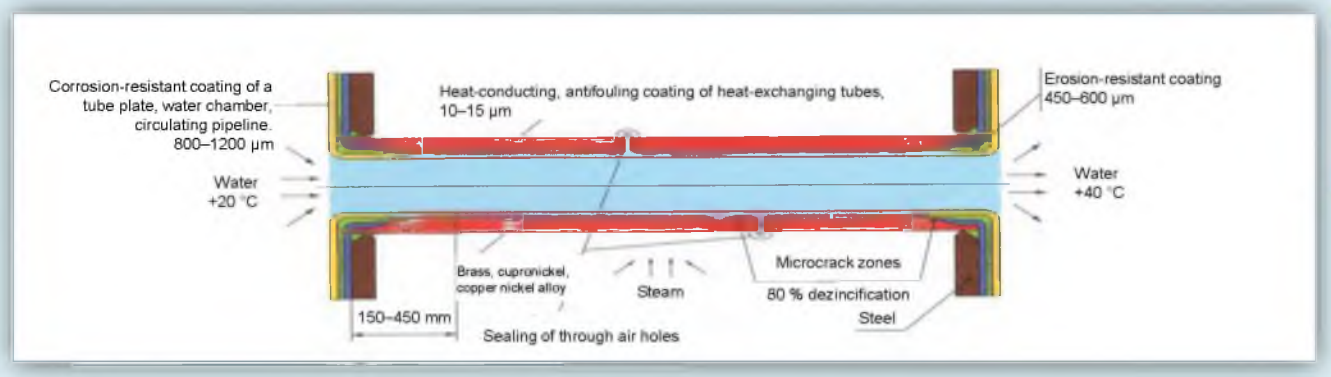


Thermal hydraulics of elements of the International Thermonuclear Experimental Reactor (ITER)

The research conducted at the remote control section allowed developing the coolant flow measurement using a thermal imaging camera.

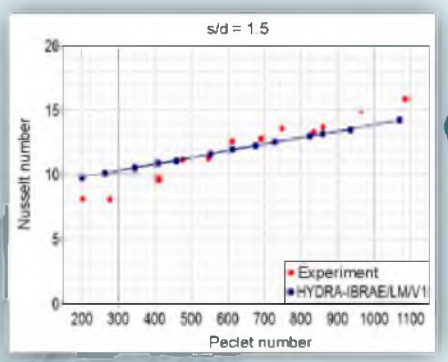
Thermal processes for nuclear power plant equipment

Main work completed by the laboratory



Protective coatings of turbine condenser tube bundles

- Protective coatings allow preventing corrosion, restore damaged tubes, extend service life of low-pressure condensers, prevent emergency shutdowns of power units caused by tube damage.
- In cooperation with coatings designer NPO ROCOR the laboratory conducted a comprehensive research aimed to solve thermophysical problems that occur when protective polymeric coatings are applied to the inner surfaces of low pressure condenser tubes. In particular, heat conductivity of coating material was increased.



Test research of liquid metal coolers

- The laboratory has completed a huge volume of research on natrium, lead-bismuth alloys and indium-gallium-stannum alloys.
- The obtained recommendations have been included in international and domestic technical guidelines.

Pump equipment development and research for fossil and nuclear power plants

Main activities of the laboratory:

- development of new pump units and modernization of operating ones;
- industrial tests of prototypes and upgraded samples of pump equipment at operating power facilities;
- research, analysis and development of recommendations for improving reliability, technical and economic performance and increasing the competitiveness of pump equipment;
- development of detail documentation and factory manufactures of certain types and sizes of pumping and shutoff-regulating equipment;
- development of pump equipment and supervision of works (designer supervision) performed by power machine-building plants when mastering its production;
- technical expertise of pump equipment performed by other organizations;
- development and supply of non-standard equipment (pumps and spare parts) for power units of thermal power plants, nuclear power plants and other industrial facilities;
- R&D, testing, commissioning and supervision of works at industrial facilities of pump equipment.

The main advantage of NPO CKTI JSC is the long-term experience in production of pumps with hydroturbine drive for pumping of high-temperature media on saturation line.

The hydroturbine drive provides the following benefits:

- optimizes the rotation speed of the unit;
- allows significantly reducing its size and metal consumption;
- allows simplifying the design of seals between the pump and hydraulic drive;
- to adjust in the most rational way – by changing the speed of rotation and using guide bearings operating with the working medium of the hydraulic drive, to create sealed pump units (in such a case, external sources of oil supply for bearings and seals are excluded from the turbo pump design).

A feature of the hydroturbine drive is the utilization of energy losses in the drive due to return of working water heated in the pump which is the source of the working water and in the hydraulic turbine to the power unit cycle.

Pump equipment development and research for fossil and nuclear power plants

Hydroturbine driven pumps for power units of Thermal Power Plants and Nuclear Power Plants

NPO CKTI JSC **was the pioneer in the power plant industry** in the creation of pumps with a hydroturbine drive for power units of Thermal Power Plants and Nuclear Power Plants. High-speed electric and gas turbine driven repressuring pumps were created in cooperation with JSC Klimovand JSC Votkinsky Zavod for oil production.

General view of the assembled CPHTD pump unit 850–400 A before installation of thermal insulation

Pumps with a hydroturbine drives designed by NPO CKTI JSC have the following benefits in comparison with traditional pumps of similar parameters **at equal efficiency**:

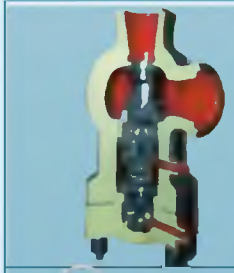
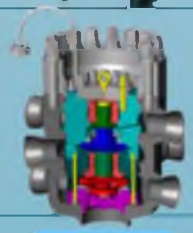
- significantly smaller dimensions;
- are mounted on pipelines without special foundations;
- require no auxiliary lubrication systems.

The CPHTD type pump 850–400 (displacement of 850 m^3/h, head of 400 m) for the turbine plant K-1000-60/3000 by LMZ JSC has a **weight of less than 3 tons**, diameter of 780 mm, height of 1200 mm.

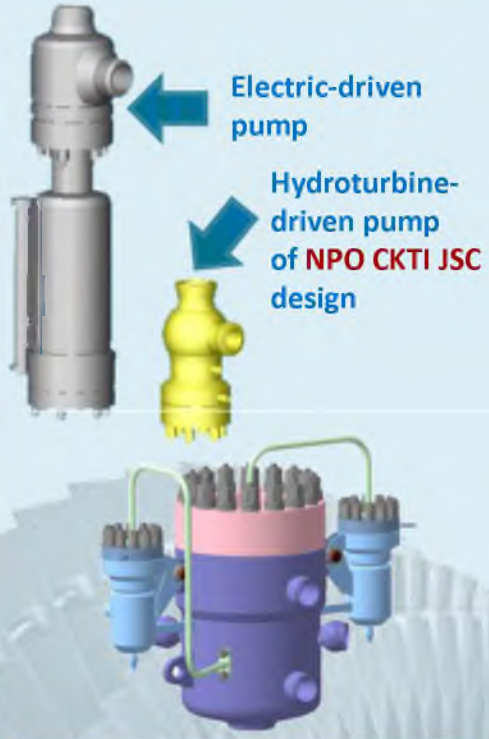
Preliminary studies of electric driven pump with similar parameters show that the weight of such unit is about 10 tons.

Pump equipment development and research for fossil and nuclear power plants

Hydroturbine driven pumps for power units of Thermal Power Plants and Nuclear Power Plants

	The pump designed by NPO CKTI JSC and its analog	Basic parameters	Specific metal content	Installation and operation site
	RGTN-type circulating water-turbine pumps for boiler units	Q = 500–1350 m³/h; H = 150 m; T_{op} = 400 °C;	4.9 kg/kW	Thermal stations with 250–300 MW power units, CP-28 by Mosenergo
	Hayward Taylor (UK) circulation pump		39 kg/kW	
	Condensate hydraulic turbine pumps of CPHTD type for turbine units of nuclear power plants	Q = 400–800 m³/h; H = 300–400 m; $T_{operating}$ = 300 °C;	3.4 kg/kW	NPPs of Russia, Ukraine, China, India, Iran
	Condensate electric pump		13 kg/kW	
	Repressuring maintenance pumps GTNZ 180-1500 VTsNS 25-1400	Q = 180 m3/h; H = 1500 m; Q = 25 m3/h; H = 1400 m;	0.36 kg/kW 2.2 kg/kW	Geoilbent LLC, oil production companies in Udmurtia and Tatarstan
	Pump TsNS 180-1420		11.1 kg/kW	

Comparative overall dimensions of circulating pumps for boiler units of equal parameters



NPO CKTI JSC develops and supplies non-standard make-to-order pumping equipment for power engineering, oil production and other industries.

Pump equipment development and research for fossil and nuclear power plants

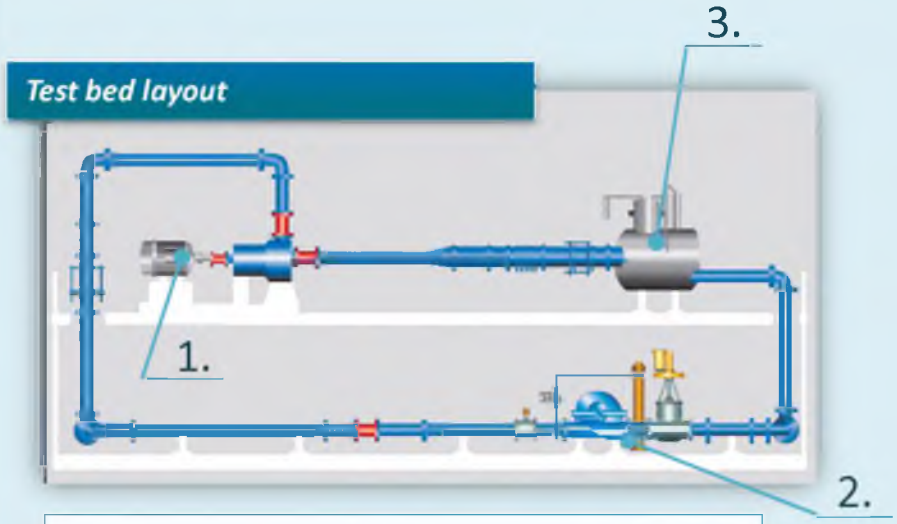
Laboratory test bed

The test rig is sealed, operates in a closed-loop configuration and meets all the requirements of GOST 6134-2007 for parametrical test rigs. Working medium – cold water for industry.

The test rig consists of:

- experimental plant (allows performing parametrical tests of pump stages and drive turbine stages);
- pressure pump (creates head during power tests of water turbine stages; shuts off by a shut off valve during parametrical tests of the pump stages);
- measurement area (for determining the flow);
- separator tank with vacuum pump connectivity (capability to lower the pressure in the circuit up to the deep vacuum during cavitation tests);
- shut off valves;
- instrumentation;
- foundations and supports;
- filter, water feed and drainage pipelines with appropriate valving;
- heating element (heats the working water during cavitation tests).

The goal of tests is to determine the power and head parameters and compare the received data with the default parameters. Obtaining the rated values of head and consumed (produced) power of the stages. Tests on a test bed and processing of measurement results are conducted according to a specially designed program and test procedure.



1. Pressure pump
2. Pilot plant
3. Separator tank

Power Generating Equipment Testing Center

Main activities of the Department

- Testing and validation of energy equipment (acceptance and validation tests, qualification tests, routine tests, certification tests, type tests, thermohydraulic tests, etc.).
- Marine valving tests
- Oil and gas valving tests
- Tests of recirculation cooling units, recirculation ventilation units, air conditioners and other corrugated-pipe heat exchangers.
- Tests of dismountable plate heat exchangers.
- Tests of brazed plate heat exchangers.
- Tests of plate and shell heat exchangers.
- Tests of tube and shell heat exchangers.
- Test research of thermohydraulic processes and hydrodynamic stability at a large-scale model of natural circulation circuit for LAES-2 (Leningrad Nuclear Power Plant 2) that passively removes heat through the steam generator (SPOT PG).
- Test determination of hydraulic and cavitation parameters of valving.
- Development of programs and procedures for thermal hydraulic tests of heat exchanging equipment.
- Development of thermohydraulic design software for heat exchanging equipment.
- Conducting heat, hydraulic and aerodynamic design procedures for heat exchanging equipment and valving.

Power Equipment Testing Center

Main activities of the Department

- Tests of equipment included in main steam valve units of nuclear power plants and other products which must comply with nuclear power safety requirements.

Isolation valve NT.001 for the first unit of LAES-2.
DN = 400/300 mm; P_{op} = 7.5 MPa;
T_{op} = T_r = 293 °C ; height 2 m;
weight 4.2 t

Pilot-operated safety valve of pressurizer DN 100 UF50024-100-15 with additional control line for LAES-2

Main steam isolation valve NI.006 for the first unit of LAES-2. DN = 600 mm;
P_{op} = 7 MPa; T_{op} = T_r = 286 °C ; height 3.5 m; weight 10 t

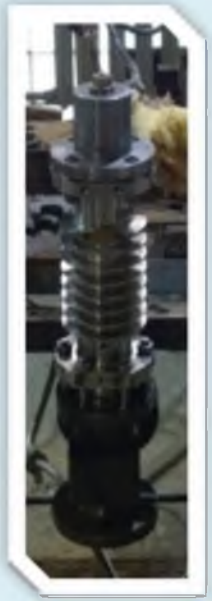
Main safety valve P59504-450.
DN = 300/400 mm;
P_{op} = 8.5 MPa; T_{op} = T_r =300 °C ; height 2,5 m; weight 4.5 t

Power Equipment Testing Center

Main activities of the Department

- Marine valving tests.

Straight-through shut-off valve with single-cavity drive and manual control



Bellows-operated angle-type isolation valve IUKL.492244.026

ZZT C965-type pneumatic drive valve

- Oil and gas valving tests.

Ball valve DN 300, PN 10 MPa

Power Equipment Testing Center

Main activities of the Department

- Tests of recirculation cooling units, recirculation ventilation plants, air conditioners and other corrugated-pipe heat exchangers.

Recirculation ventilation plant RUB-60 for the Novovoronezhsk Nuclear Power Plant-2

Recirculation cooling plant RCP-6.3 EMK.0155.000.00.000 for the third unit of the Rostov Nuclear Power Plant (emergency mode emulation)

- Tests of dismountable plate heat exchangers.

Heat exchangers NT150 SH/CD-16/15 and NT100 THV/CDL-10/15 for the Belarus Nuclear Power Plant

- Tests of brazed plate heat exchangers.

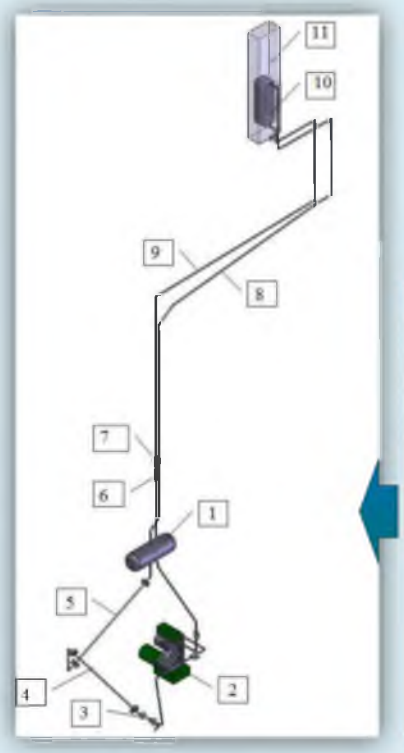
FPB 025 type heat exchanger for LAES-2

Power Equipment Testing Center

Main activities of the Department

- Tests of plate and shell heat exchangers.

Gas blow-off processing system heat exchanger KKS 10KPL11AC002 with a stack of brazed plates Plate Stack XPSP 50 for the Belarus Nuclear Power Plant



- Test research of thermohydraulic processes and hydrodynamic stability at a large-scale model of natural circulation circuit for LAES-2 (Leningrad Nuclear Power Plant 2) that passively removes heat through the steam generator (SPOT PG).

Large-scale model SPOT PG of the reactor unit LAES-2. Coolant heat capacity and power scale (1:110)

1 – steam generator/separator
2 – circulation pump
3, 7 – throttling flow meters
4, 5 – electric heaters
6 – main steam isolation valve
8 – steam pipeline
9 – condensate pipeline
10 – emergency cooling heat exchanger
11 – emergency heat removal tank

- Tests of tube and shell heat exchangers.

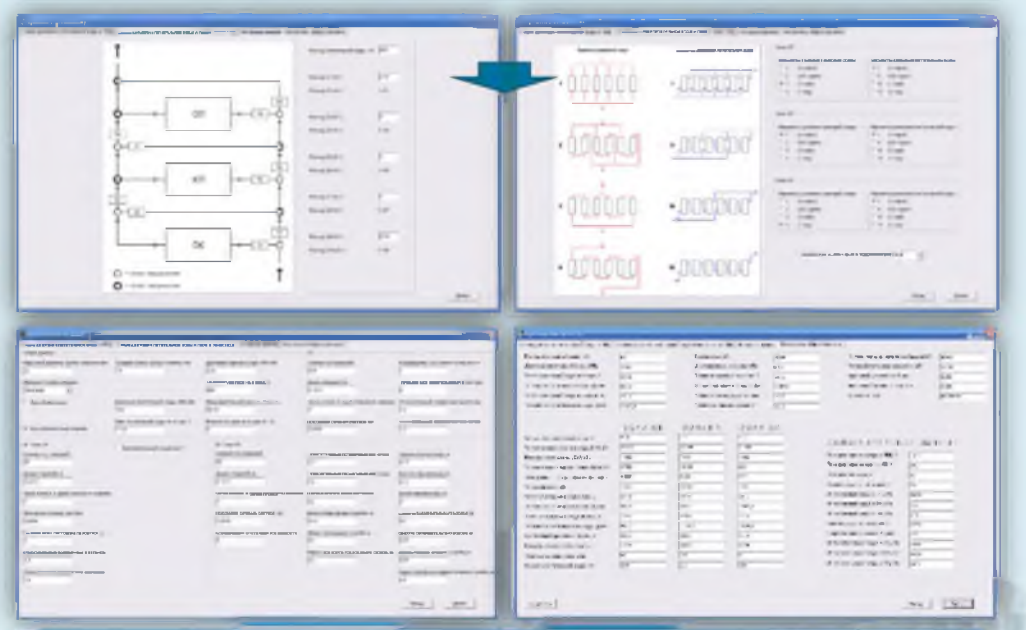
Power Equipment Testing Center

Main activities of the Department

- Experimental evaluation of hydraulic and cavitation parameters of valving.
- Development of programs and procedures for thermal hydraulic tests of heat exchanging equipment.
- Development of thermohydraulic design software for heat exchanging equipment.

Main safety valve of the first production unit of steam generator pilot-operated relief valve ND.002 for LAES-2

Isolation valve NT.001 for LAES-2



Screenshots of spiral case PVD recalculation software developed on request by NPO CKTI JSC

- Conducting heat, hydraulic and aerodynamic design procedures for heat exchanging equipment and valving.

Power Equipment Testing Center

Test rigs of the Center

The department has a large and unique experimental facility.

- A test rig reaching the height of 37 m and occupying the area of 12x33 m².
- two proprietary superheated steam regenerator units supporting the pressure up to 20 MPa at the temperature up to 570 °C.
- 40 MPa air compressor.

High design parameters of the installed equipment **(P = 32 MPa, t = 600 °C):**

- ***30-meter*** *high circulation circuit;*
- *circulation and feed pumps with flow control (**up to 6 kg/s**);*
- *electric heaters with a total power **up to 8 MW**,*

- Pressure compensation valves.
- Heat exchangers.

Some models support stem temperature **up to 600 °C.**

- State-of-the art instrumentation and data gathering system.

Control panell of the Complex Test Rig KS10606

On of the testing spots of the Complex Test Rig KS10606 BZOK-600 and IPU PG are put on the test rig.

Material service life assessment and testing for welded structures of power equipment at thermal and nuclear power plants

Main activities

- Research of main and welding materials of welded structures.
- Development of welding technologies, including the ones eliminating the need for heat treatment.
- Participation in design of welded structures consisting in development of weld assemblies from varying domestically produced and imported steel grades which ensure the mandatory service life.
- Evaluation of various features, such as static and dynamic strength, fatigue strength, brittle strength, fracture resistance, stability loss of welded structures.
- Modelling of welding processes and evaluation of processing strength to prevent formation of hot and cold cracks during processing and heat treatment.
- Industrial safety assessment of engineering devices which are supervised by Rostechnadzor (Federal Service for Environmental, Technological, and Nuclear Supervision).
- Investigation (assessment) of destruction of power-generating equipment elements and units, including the court cases.
- 3D modelling of welding technologies to optimize the welding technology, streamline the technology development and prevent the formation of crack in the process of welding; forecasting the changes in features of various welding areas.
- Development of heat treatment technologies.
- Certification research of welding technologies and issuing of expert reports on compliance of weld metal with the requirements set by the official supervising bodies.
- Retrofitting of structures by welding, including cast body parts, beams, vessels, etc.

Material service life assessment and testing for welded structures of power equipment at thermal and nuclear power plants

Research of main and welding materials of welded structures

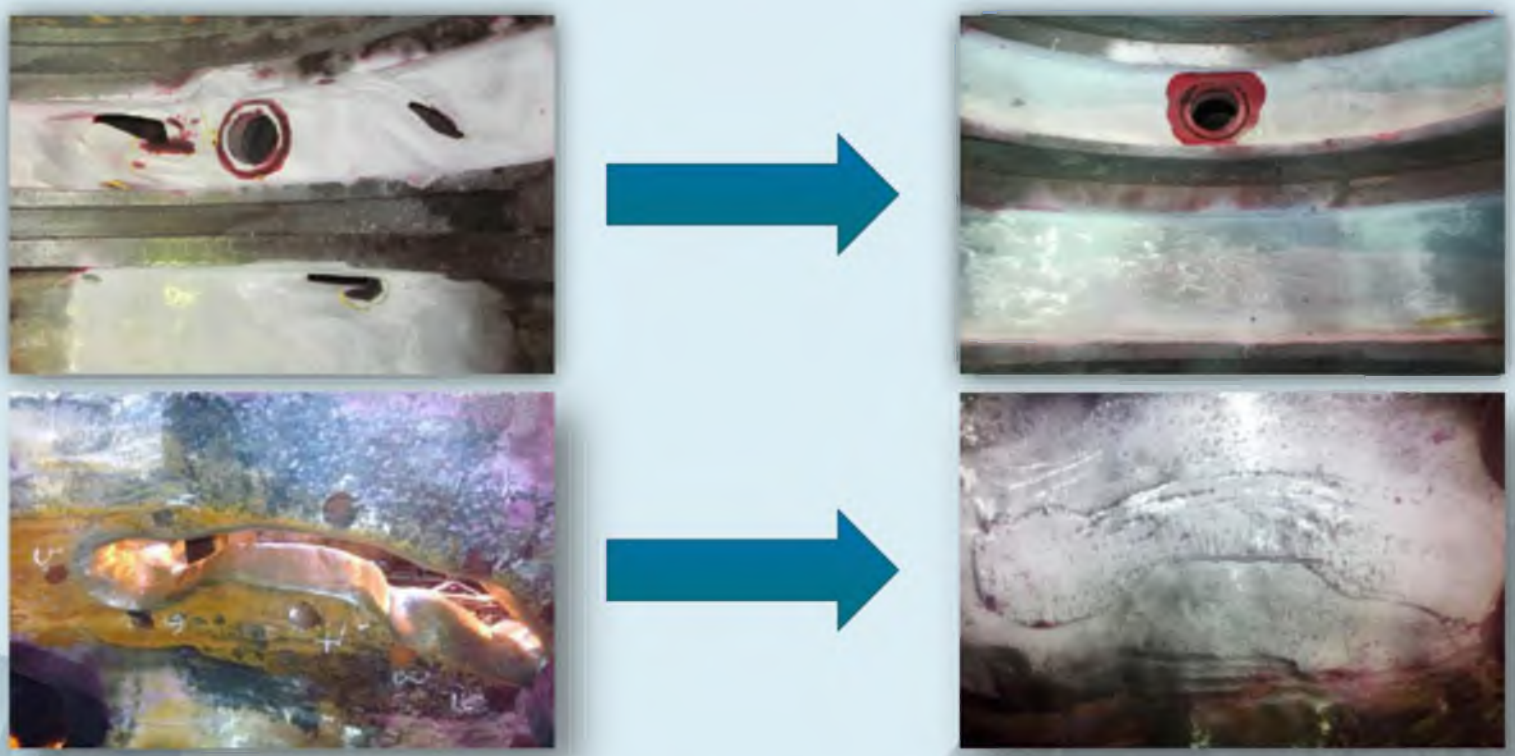
- **Performance of static tests:**
  - tensile test at the temperature of negative 100 °C to 900 °C;
  - bending, shearing and torsion test;
  - evaluation of crack resistance of materials and welds at the temperature from negative 100 °C to 400 °C;
  - drift and flattening tests of pipes;
  - impact toughness tests with evaluation of ductile-to-brittle temperature Tk^{50};
  - research of metal heterogeneity based on the hardness evaluation data;
- **Performance of dynamic tests:**
  - evaluation of nil-ductility temperature (NDT);
  - evaluation of crack resistance of metal at dynamic loads (K_{Id});
- **Creep-rupture strength tests:**
  - evaluation of stress rupture strength and ductility;
  - evaluation of creep crack resistance (K_{Icth});
- **Evaluation of crack resistance at stress release (K_{Irth});**
- **Research of corrosion crack resistance (K_{Iscc});**
- **Performance of full-scale welds and welding samples;**
- **Evaluation of fatique limit and cyclical crack resistance (K_{Itn}, K_{Ifc}) at cyclical load;**
- **Research of macro and microstructure of metal and welds;**
- **Fractographic research of fractures occurred due to accidents and element failures – with evaluation of values of loads at the moment of rupture (accident);**
- **Research of weld deposition and coatings on metal.**

Material service life assessment and testing for welded structures of power equipment at thermal and nuclear power plants

Welding Technology Development

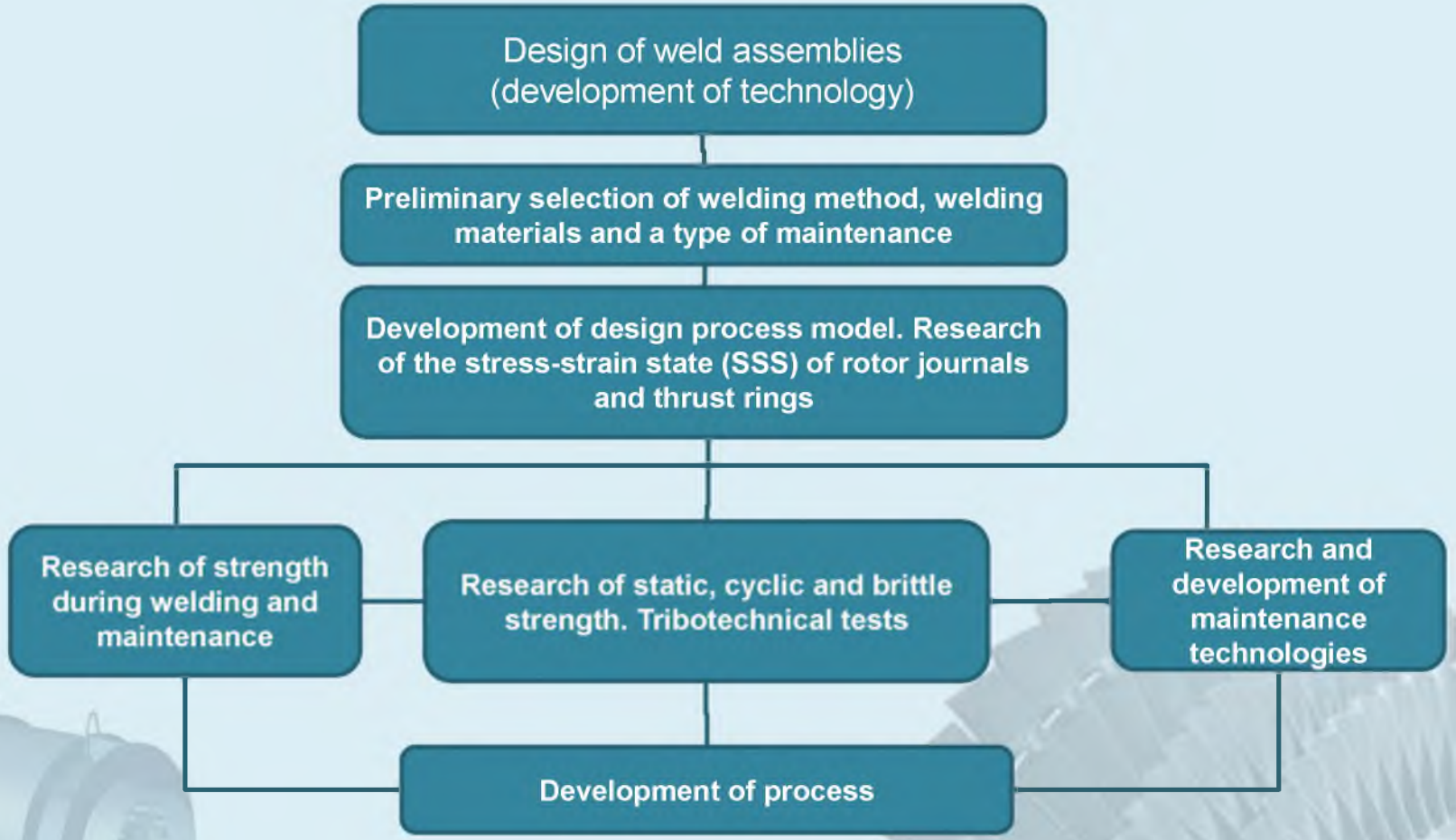
Using the developed welding technology, the laboratory has successfully repaired cast shells of turbines, the shells of emergency regulating valves, LPH, rotors, etc.

Through cracks in cast shells of high pressure cylinders (HPC) before and after welding



Material service life assessment and testing for welded structures of power equipment at thermal and nuclear power plants

Design of weld assemblies



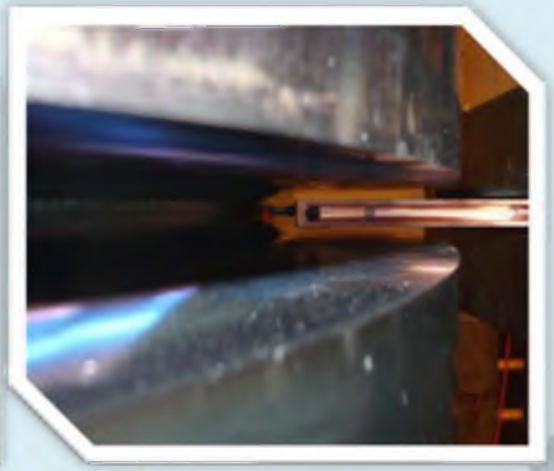
Material service life assessment and testing for welded structures of power equipment at thermal and nuclear power plants

Design of weld assemblies

The laboratory has developed new design principles of turbine units that experience high loads (welded rotors, welded shell parts, diaphragms, welded hollow blades, etc.) using new heat-resistant and highly durable material, as well as combined (dissimilar) welds, that allow significantly streamlining the creation of new products.

Development of welding technology for composite rotors from consisting of various types of steel and alloys

Rotor assembly



The process of narrow-gap welding of the root part

Welding of root parts of rotor welds

Material service life assessment and testing for welded structures of power equipment at thermal and nuclear power plants

Design of weld assemblies

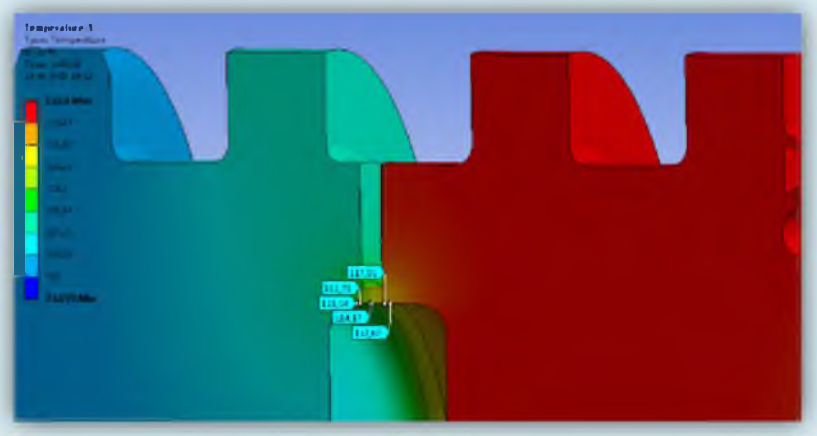
Developed and Introduced Technologies

- The laboratory has developed physical criteria of limits to service life of the equipment made of heat-resistant materials, including dissimilar joints of pearlite-martensitic class.
- The laboratory has developed an evaluation technology for maximum allowable defect sizes in welds of rotors during their production and repair.
- The laboratory has developed a method for evaluating crack resistance of welds on power-generating equipment during its production and repair.
- The laboratory has developed and introduced at domestic factories the rotor welding technology for new-generation nuclear turbines, using state-of-the-art domestically produced and imported materials.
- The laboratory has developed and introduced at domestic factories a welding technology for composite rotor used in turbines with ultra supercritical steam parameters, using state-of-the-art domestically produced and imported materials.
- The laboratory has developed and introduced at domestic factories a welding technology for units and elements of turbines used with ultra supercritical steam parameters, using state-of-the-art materials of P91, E911, P92 class.
- The laboratory has developed and introduced at the domestic factories the low-frequency vibration treatment of welded structures of water turbines – as a replacement for expensive heat treatment.
- The laboratory has developed and introduced the repair technologies that utilize welding (depositing) of rotors, units and elements of nuclear turbines, as well as turbines used with ultra supercritical steam parameters.
- The laboratory has determined the destruction parameters of dissimilar (pearlite-martensitic class steels) welds during long service at ultra supercritical steam parameters.
- The laboratory has determined the limit values of crack resistance at cyclical load ($K_{th)}$ for welded joints of rotor steels: P2MA + P2MA, P2MA + X12CrMoVWNbN 10-1-1, 26XH3M2FA + 26XH3M2FA, used for new-generation nuclear turbines, as well as turbines using at ultra supercritical steam parameters.

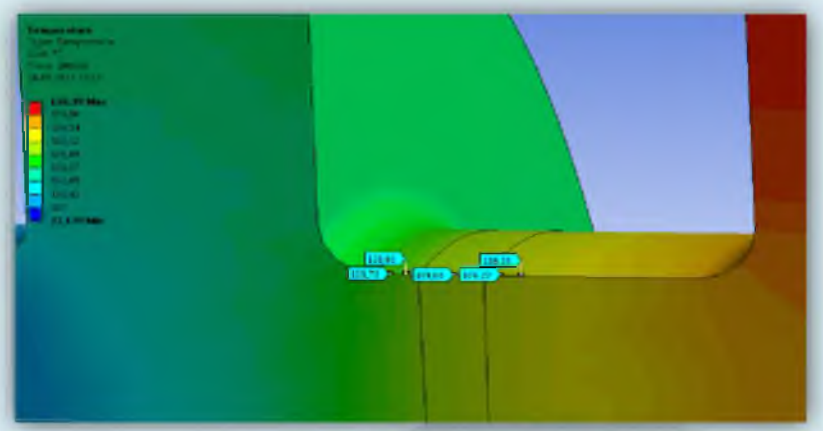
Material service life assessment and testing for welded structures of power equipment at thermal and nuclear power plants

Design of weld assemblies

Evaluation of temperature fields of the rotor at different stages of welding



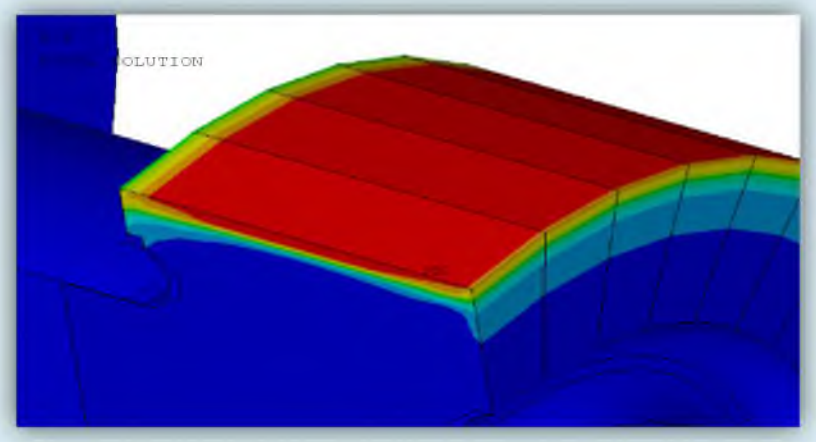
Temperature fields during aging (30 hours) of rotor at the girth weld root zone welding



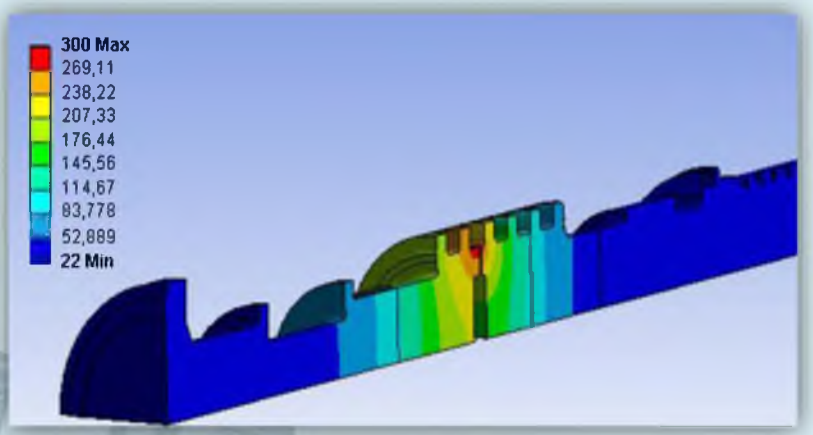
Temperature fields during aging (40 hours) of rotor after welding of the girth weld has been completed

Material service life assessment and testing for welded structures of power equipment at thermal and nuclear power plants

Design of weld assemblies



Residual stress field (stress intensity – σ_i) after depositing, cooling down machining of rotor dummy piston



Temperature field in the composite rotor during heating before welding

Material service life assessment and testing for welded structures of power equipment at thermal and nuclear power plants

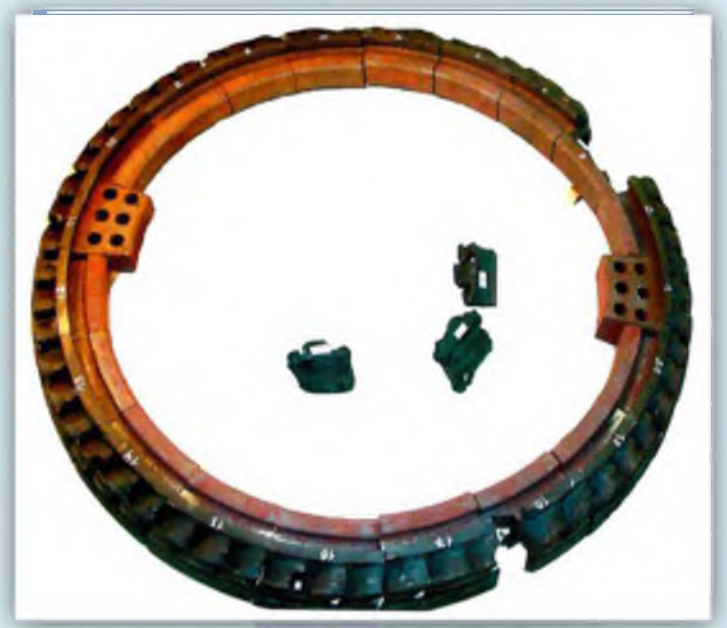
Investigation (Assessment) of Destruction of Power-Generating Equipment

The department conducts investigation of destruction of power-generating equipment elements and units.

The accident investigation includes the following tasks:

- analysis of turbine vibration monitoring data before and during the accident;
- fractographic research of fractures in the control stage and the flow path of the turbine;
- research of quality of the base metal and welds of blade assembly;
- assessment of crack growth kinetics in blades;
- evaluation of type of loads and the amount of destructive stresses in fractures;
- damage source analysis, involving the accident emulation.

The source and sequence of destruction are determined by the above mentioned operations.



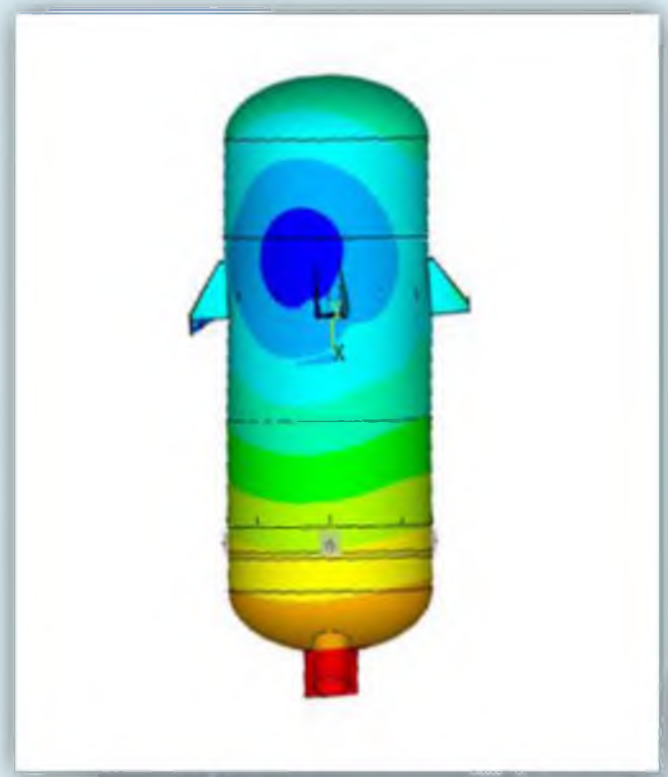
Display of damaged welded blade assemblies of the control stage after deblading.

Material service life assessment and testing for welded structures of power equipment at thermal and nuclear power plants

Strength Evaluation and 3D Modelling

The department performs 3D modelling of welding technologies to optimize the welding technology, streamline the technology development and prevent the formation of crack in the process of welding; forecasting the changes in features of various welding areas.

Distribution of temperature fields in the rotor diaphragm during heat treatment



The shape of natural oscillations of the LPH shell

Development, design and feasibility study for thermal power installations and systems

Main activities of the laboratory:

- thermal testing of power units for nuclear and thermal power plants to plot specified thermal characteristics and determine measures to improve energy efficiency of power units;
- testing of the condensing system to determine the effectiveness of the modernization performed;
- testing of the turbine plant to determine the effectiveness of the modernization performed;
- analysis of operating modes, testing and creation a parameter chart to optimize operation mode of technical water supply system of nuclear power plants;
- analysis of operating modes, testing and creation a parameter chart to optimize the thermal hydraulic mode of heat supply system of nuclear power plants;
- energy survey of power units of thermal and nuclear power plants, manufacturing enterprises;
- optimization of low-potential part of turbine units of thermal and nuclear power plants;
- development of layouts and detail design of installation of heating equipment, pipelines of various systems at power assets and networks, heat and hydraulic evaluation of strength and homing action of existing pipelines, evaluation of hanger-support systems of pipelines and release of data for adjustment, assessment of remaining service life of pipelines and forecasting of schedule and scope of maintenance, examinations of industrial safety;
- energy audits, improvement of processes and equipment operating modes, provision of energy-saving and utilization measures;
- feasibility study and performance evaluation of solutions;
- design analysis of operation modes for individual equipment, systems and power units of thermal power plants, nuclear power plants and industrial facilities;
- development of heat efficiency control systems for power units (selection and organization of measurement procedures, development of methods of source data processing and calculation of integral efficiency indicators, development of software for calculation and monitoring of heat efficiency of the power unit equipment).

Turbine Units Division

Main Departments and Laboratories

- Steam Turbines Department
  - *Industrial Research And Turbine Plant Modernization Laboratory;*
  - *Vibration Laboratory;*
  - *Blade Row Vibration Reliability Laboratory;*
- Turbine Units Research Department
  - *Steam Turbine Research Laboratory;*
  - *Gas Turbine and Combine Cycle Laboratory;*
  - *Compressors Units Laboratory;*
- Hydropower and Hydropower Equipment Department;
- Department on Service Life, Engineering Diagnostics and Repair Technologies of Power Equipment Metal.

Steam Turbines Department

Industrial Research And Turbine Plant Modernization Laboratory

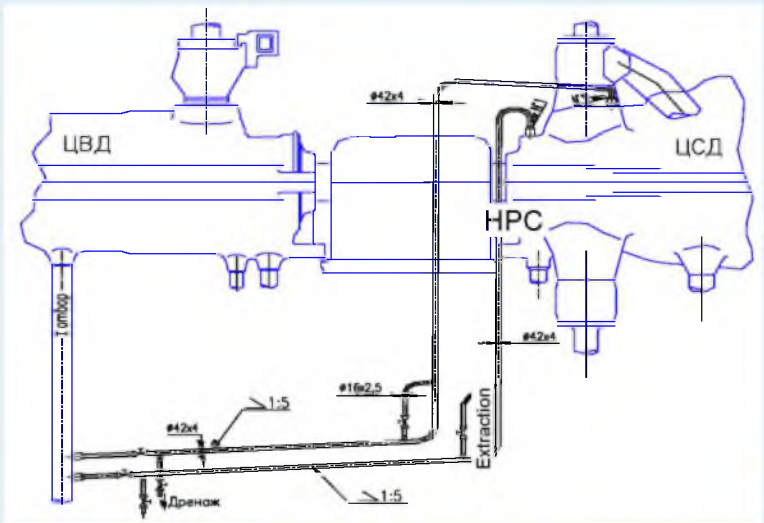
Main activities

- The laboratory conducts research and development of prospective turbine units of thermal and nuclear power plants, industrial research of operating steam turbines, develops and commissions the turbine equipment operation diagnostics system at thermal power plants.
- Among of the significant significant solutions developed by the laboratory is the **Forced Steam Cooling System (FSCS).** The system is designed for extending the service life of turbine units and decrease the progressing bowing of HP and MP rotors in high-power steam turbines. SPPO has been commissioned since 1985 and by now has been installed in **65 turbine units** of various power output in Russia and abroad. Over 30 years of operation have proven the reliability and efficiency of the system.
- The other **system – Mentor** – is an integral part of the unified turbine unit diagnostics system. It allows calculating the efficiency of cylinders and monitor stress in hot elements of high-pressure cylinders (HPC) and intermediate pressure cylinders (IPC).
- Modernization of thermal cycle of turbine units to prevent the abrasive and erosive wear of the blade row in HPC and IPC.
- Modernization of thermal circuits of process heat discharges into the exhaust part of LPC to increase strength of stellite plates of rotor blades in the last stages of K-300 turbines.
- Development of HPC cooling project for the new turbines T-295/335-23,5 to increase their efficiency at low-flow operating modes of turbine units.

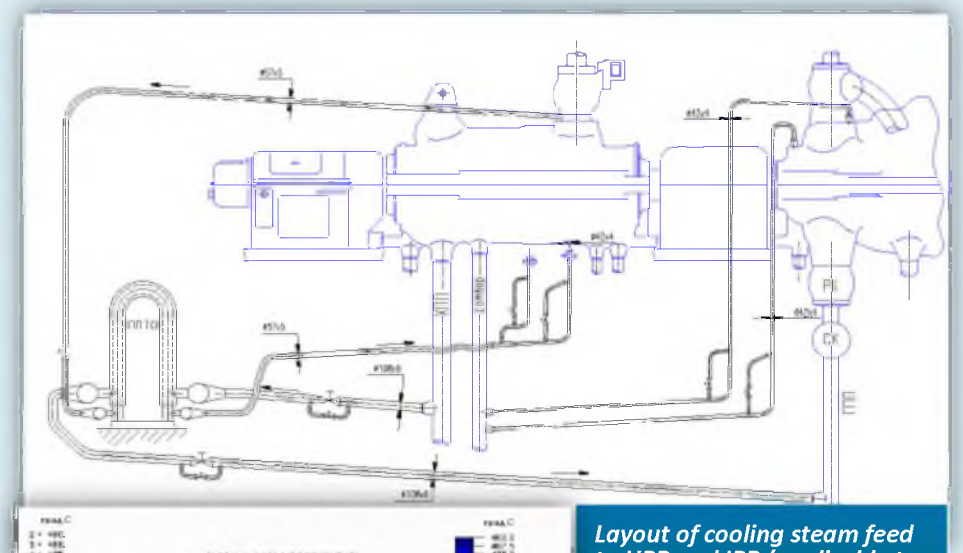
Steam Turbines Department

Industrial Research And Turbine Plant Modernization Laboratory

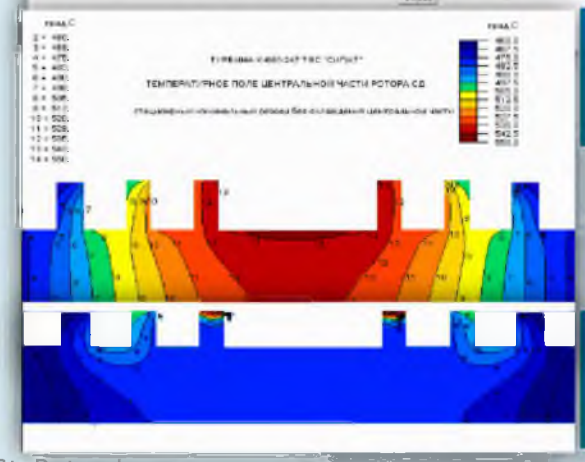
Forced Steam Cooling System (SPPO)



Layout of cooling steam feed to the intermediate pressure rotor (IPR) (applicable for turbines T-100-130, T-250-240, K-200-130, K-300-240, K-500-240)



Layout of cooling steam feed to HPR and IPR (applicable to turbines K-210-130 (LMZ), TPP Maritsa-Vostok-2)



Temperature fields of the IPR of turbine K-660-247 LMZ at the nominal load:
a) – no cooling, b) – with SPPO activated

Steam Turbines Department

Industrial Research And Turbine Plant Modernization Laboratory

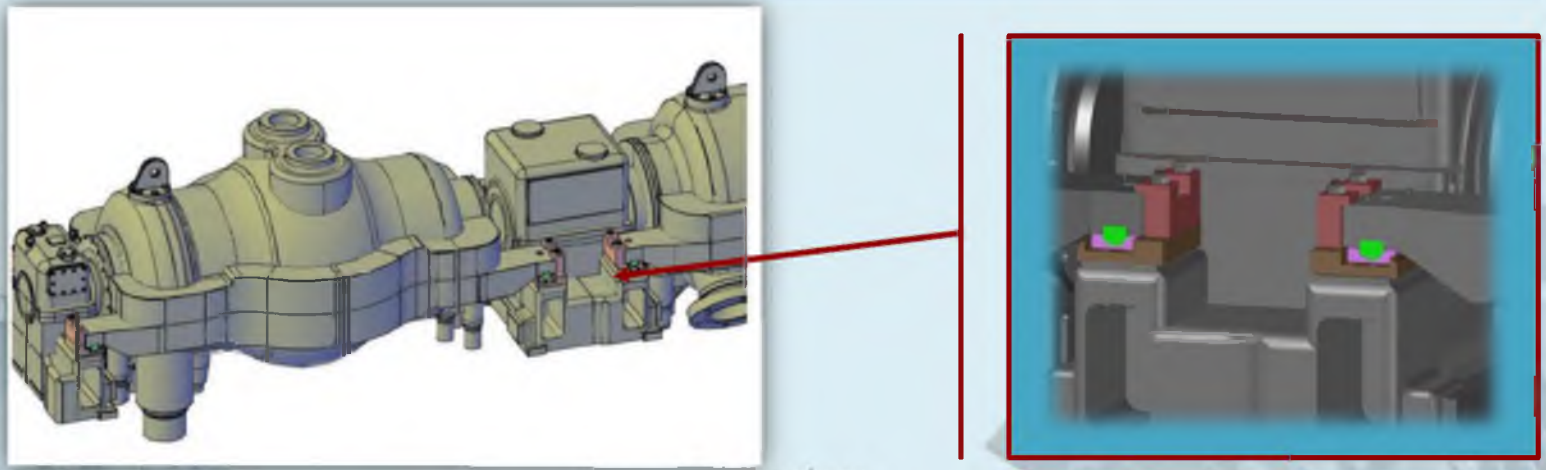
Improvement of Performance Characteristics of Steam Turbines by Modernizing the Cylinder Support System

Modernization of the steam turbine support system is a replacement of conventional solid key by a split-type key.

Modernization purpose: normalization of turbine expansions that allows to improve operational characteristics of turbine plant:

- improve vibration state of turbine in intermittent operation modes;
- normalize expansion ratio of high and intermediate pressure rotors;
- reduce deformation of guide bearing housings and foundation cross beams;
- increase start/stop characteristics of turbine – **reduce the starting time from different thermal conditions.**

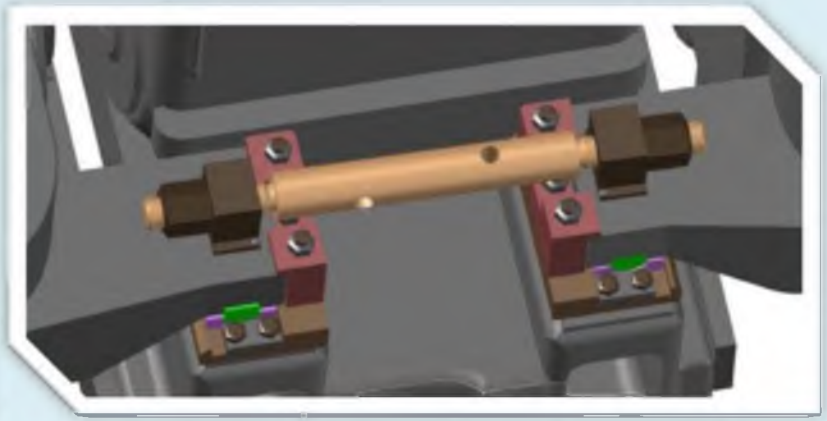
Currently, there are 16 K-200, K-300 turbines in operation equipped with modernized support systems.



Steam Turbines Department

Industrial Research And Turbine Plant Modernization Laboratory

To further improve the expansion characteristics of steam turbines the split-type keys may be supplemented by special devices – pushers



The experience in extended operation of 200–300 MW turbines in industrial applications, where turbines are fit with split-type keys produced by NPO CKTI, is the evidence of significant improvement and normalization of thermal expansions, which result in improvement of performance characteristics. Besides, this improves the vibration characteristics of the turbine in variable-load operation, reduces the deformation of guide bearing housings and torsion of foundation girders, improves free expansion of cylinders and their return to the default position when cooling down.

Steam Turbines Department

Industrial Research And Turbine Plant Modernization Laboratory

Moisture removal from the flow path and labirinths of LPC of K-200-130 turbines

The crucial factor lowering the operating reliability of LPC in K-200-130 turbines consists in erosion damages of blades:

- through erosion of trailing edge by the base of the top tier blades at penultimate (Baumann type) stages, which leads to formation of fatigue cracks and vane ruptures;
- intense erosion wear of blade tips at the last stages, reducing their service life due to the need for replacement, since the chord reduces beyond limits.

The primary source of moisture turned out to be intense condensation of steam on the internal surface of the cone-shaped input baffle at the last stage diaphragm. The baffle is washed on the outside by colder (~ 24 °C less) exhaust steam of the top tier (see the figure).

To prevent erosion damages, the laboratory suggests the following procedures:

- correction of axial clearances Δ in the inter-tier sealing (see the figure at the page 62) or its restoration (see the figure at this slide);
- shielding and draining of internal cone-shaped and cylindrical baffles of the last stage diaphragm (see the figure on this slide).

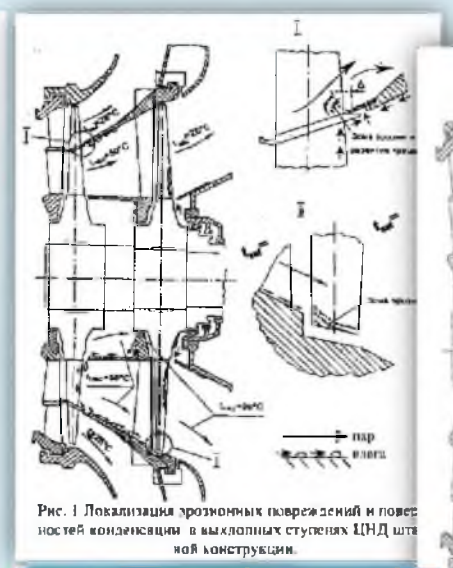
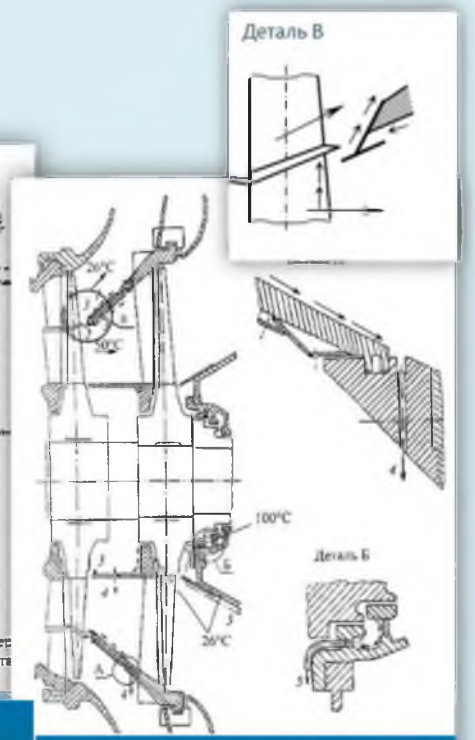


Рис. 1 Локализация эрозионных повреждений и повер
ностей конденсации в выхлопных ступенях ЦНД шта
ной конструкции.

Localization of erosion damages and condensation surfaces at the output stages of a conventional LPC



Erosion-resisting devices in the last stage diaphragm ande the LPC hood in K-200-130 turbine:

1. *Shielded baffle with inter-tier sealing located inside;*
2. *Inter-tier sealing;*
3. *Moisture-collecting collars;*
4. *Drain holes;*
5. *Drain tube;*
6. *Streams of condensate to be drained*

Steam Turbines Department

Industrial Research And Turbine Plant Modernization Laboratory

Remote temperature control of steam emission and air inflows in end seals

In practice, the steaming process is analyzed visually or through assessing the water content in oil, while the air inflows – by the decreasing vacuum in the condenser.

NPO CKTI JSC has developed and successfully implemented on many power plants the method of remote control of steam emission and air inflows in end seals of turbines.

The suggested end seal operation control method is based on measurement and comparison of temperatures of air-steam mixture t_{as}, sealing steam t_s and the ambient air t_a (see the figure).

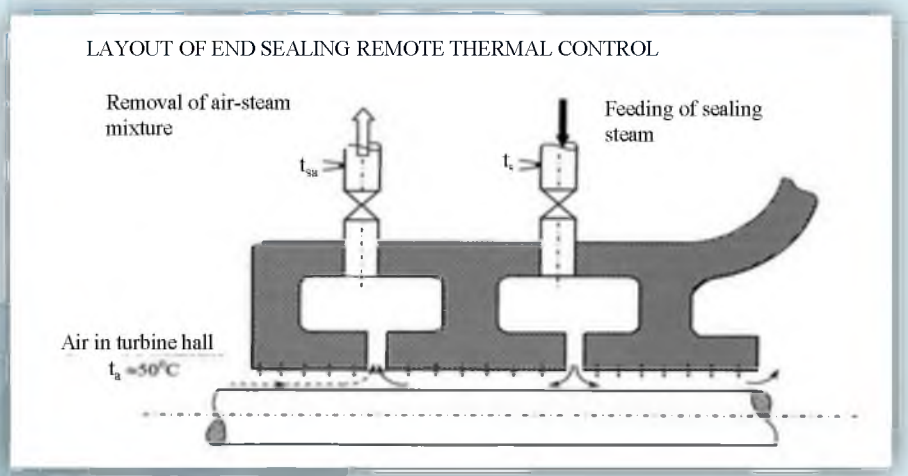
The "**mandatory**" condition of absence of steaming and air inflows: $t_a < t_{as} < t_s$.

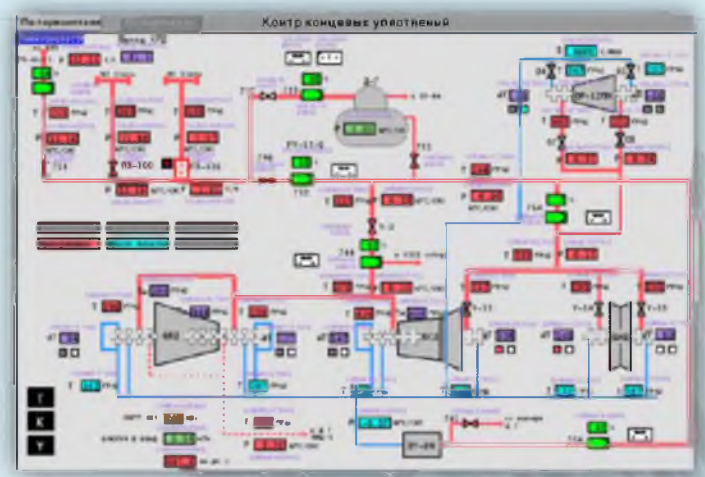
The "**sufficient**" condition looks like this: $t_a + \Delta t_1 < t_{as} < t_s - \Delta t_2$ or $t_п - \Delta t_2 > t_{as} > t_s - \Delta t_3$.

Here, Δt represents settings, the values of which are determined through experiments.

Settings determination method is the **«know how»** of this proposal.

The introduction of end sealing monitoring is expected to decrease the air inflows, which is equivalent to deepening of vacuum by at least 0.1 %.





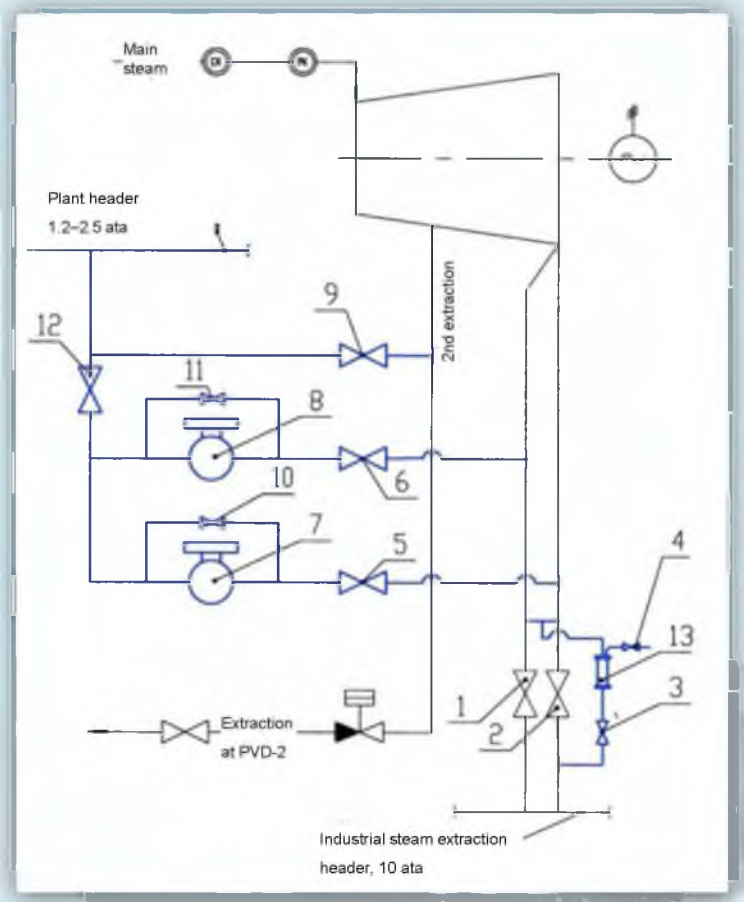
Steam Turbines Department

Industrial Research And Turbine Plant Modernization Laboratory

Modernization of R-type turbine units with the aim to make them work in the cogeneration cycle instead of back pressure mode

Modernization purpose – recommission of reserve R-type turbines that have a large economic life.

- Modernization of R-50-130 turbine units does not only allow its operation according to the cogeneration cycle in a wide load range, but also improves the overall plant economic performance.
- The conducted heat and strength evaluations have allowed determining the optimal conditions of turbine operation from the perspective of its structural reliability and efficiency.
- The modernization allows reaching to the previous operating mode of the turbine, which requires a shutdown for several hours.



Steam Turbines Department

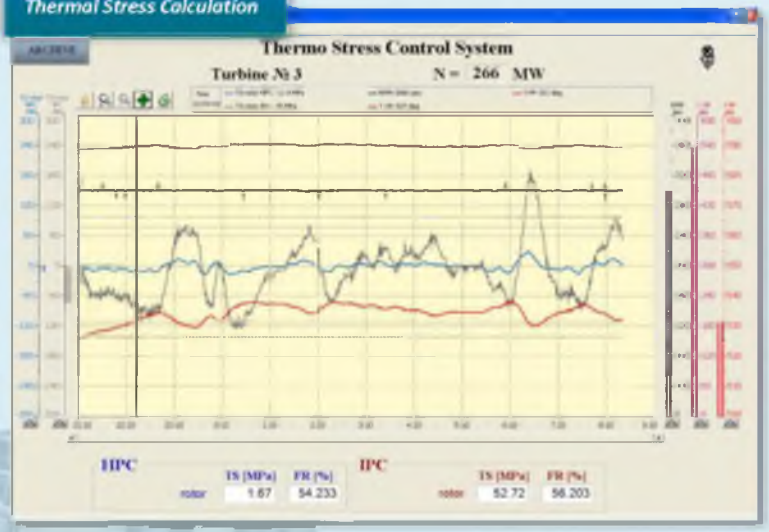
Industrial Research And Turbine Plant Modernization Laboratory

Information Diagnostics System Mentor

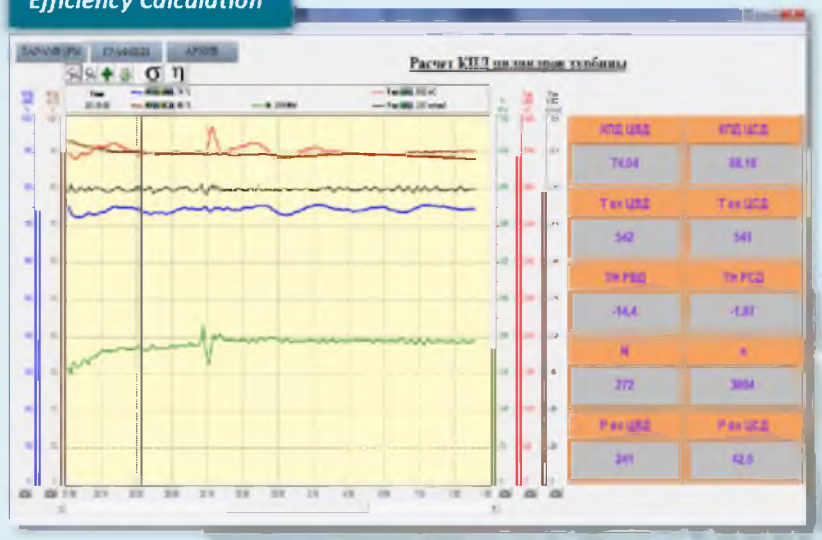
The purpose of Mentor system

- Evaluation and display of optimal start/stop look-ahead schedule for the turbine plant based on its factual thermal condition.
- Diagnostics and analysis by:
  - performance of end sealings;
  - quality of turbine extensions;
  - thermal state of shells and flanges.
- The evaluation of equipment repair and operation quality in all operating modes.
- Display of thermal stress levels in HP and IP rotors and shells.
- Real-time display of thermal stress levels in HP and IP rotors and shells.
- Evaluation of accrued total fault probability rate (service life spent) of HP and IP rotors.
- Selection of optimal boiler operating mode that ensures the optimal boiler efficiency (MEI software).

Thermal Stress Calculation



Efficiency Calculation



Steam Turbines Department

Vibration Laboratory

Works Performed

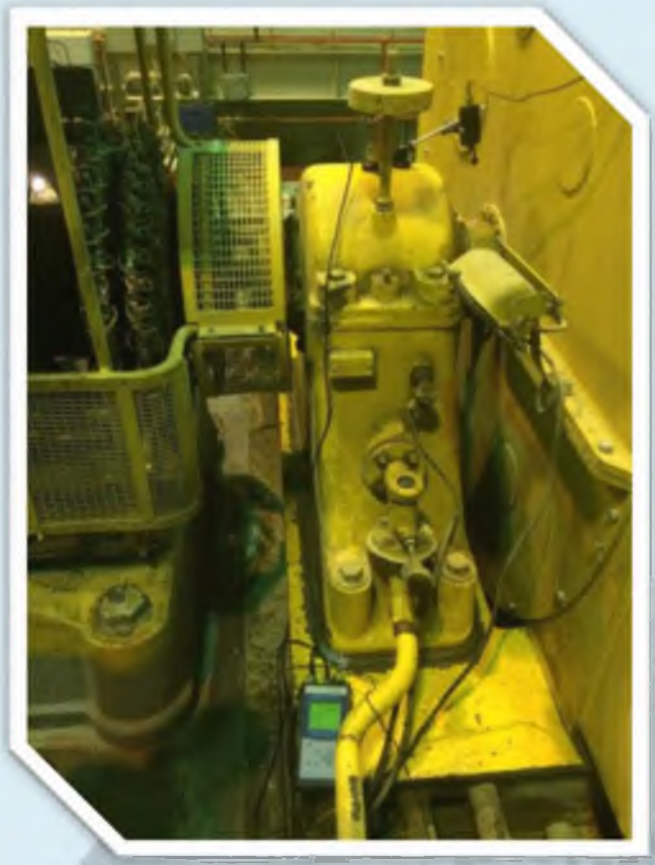
- Vibration measuring diagnostics and vibration alignment of main and auxiliary equipment.
- Manufacturing and supply of turnkey automated vibration diagnostics system VIDAS for main and auxiliary equipment, including the shaft train balancing program.
- Examinations of newly erected and modernized foundations and system of stay and foundation elements for turbine plants after their installation or rehabilitation.
- Test bed examinations and development of designs for full-sized journal (bore inside diameter up to 750 mm) and combined journal-and-thrust guide bearings for turbine plants.

Steam Turbines Department

Vibration Laboratory

Vibration measuring diagnostics and vibration alignment of main and auxiliary equipment

- Vibration measuring diagnostics of increased vibration causes for bearing supports and rotors of steam, gas turbines and auxiliary equipment including operation diagnostics for stay and foundation elements.
- Vibration alignment of units, which brings vibration in compliance with rates set in GOST 55265.2-2012 and GOST 55263-2012, and issue of recommendations on repair including:
  - dynamic balancing of unit rotors at high-speed balancing and overspeed facilities;
  - dynamic balancing of unit shaft train rotors in own guide bearings with elimination of disbalance difficult forms;
  - performance of complex vibration examinations for units in various operating modes using multi-channel portable vibration measuring complex VIDAS.
- Examinations of operation misalignments for units, calculation of dynamic stresses in shaft train rotor journals and static responses of supports, subsequent issue of recommendations concerning unit alignment during repair.



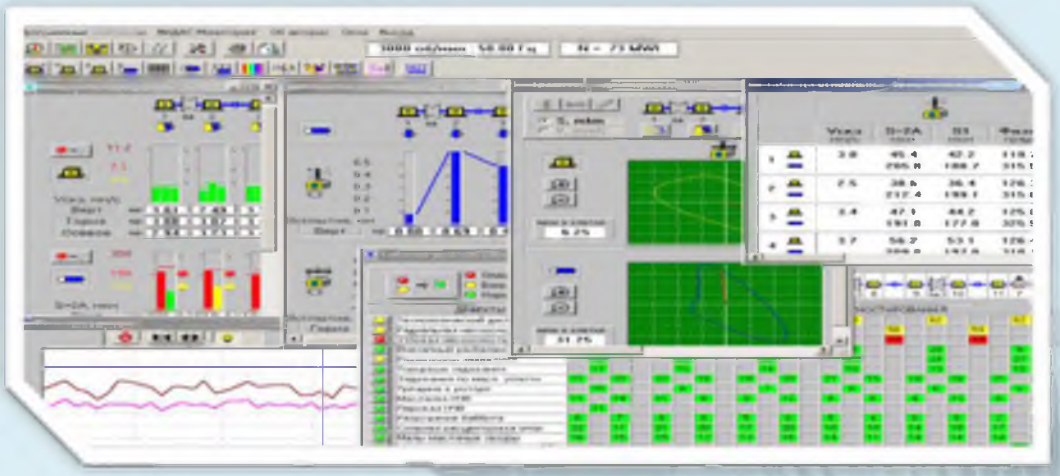
Steam Turbines Department

Vibration Laboratory

Turbine Plant Vibration Measuring Diagnostics System VIDAS

The Purpose of VIDAS System

- Monitoring of vibration parameters, mechanical values and operating parameters.
- Automatic diagnostics of vibration state based on analysis of vibration, thermal-mechanical and operating parameters.
- Works in examination mode (analysis of archive data, spectra, levels, trajectories, vibration modes, etc.).
- Archiving of data on vibration state of turbine plants, thermal-mechanical, operating parameters and results of diagnostics for the whole period of plant operation with the possibility of their subsequent presentation and analysis.
- Determination of optimal arrangement options for balance weights using the program of multiplane dynamic balancing included into the delivery set of VIDAS system.
- Assurance of “remote service (engineering)” with the least help on site needed from NPO CKTI JSC experts and the maximum coverage of generating equipment. The Web-version of VIDAS software was developed in order to ensure full remote service of controlled turbine equipment.



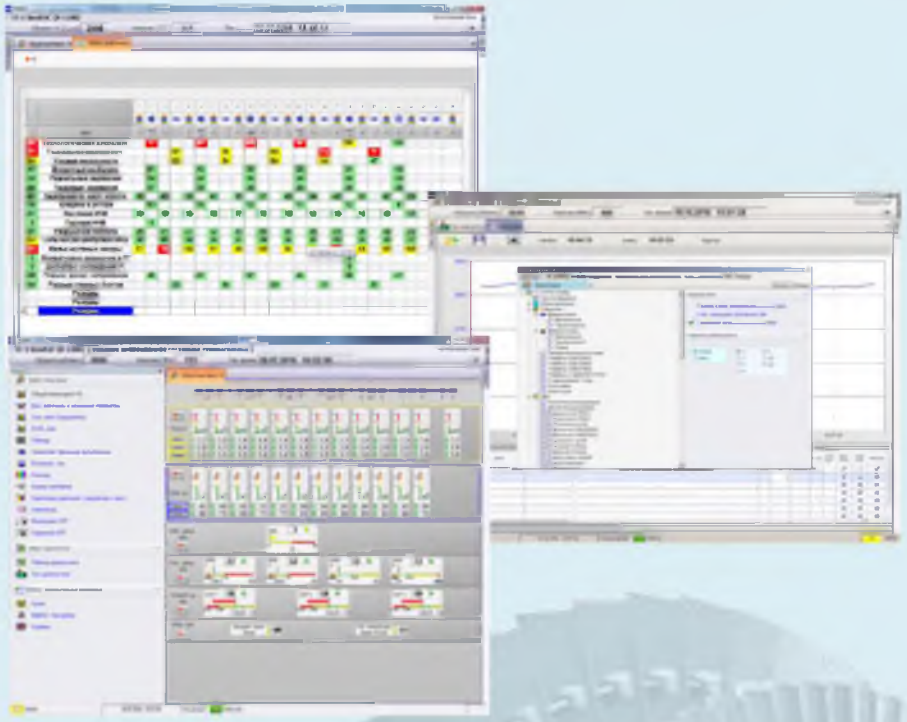
Steam Turbines Department

Vibration Laboratory

Turbine Plant Vibration Measuring Diagnostics System VIDAS

VIDAS system allows determining and localizing a place of occurrence of the following most commonly encountered defects in turbine equipment:

- process disbalance;
- radial misalignment;
- angular misalignment;
- sudden disbalance;
- radial interferences;
- end interferences;
- interferences by oil seals;
- crack in the rotor;
- low-frequency vibration of oil;
- low-frequency vibration of steam;
- babbitt destruction;
- big misalignment of supports;
- low oil clearances;
- turn-to-turn short circuit of generator rotor;
- ventilation disbalance by channels of generator rotor;
- increased dynamic stresses in rotors;
- rupture of tie bolts.



Besides the above mentioned factors, the system can also diagnose various other defects inherent in certain classes of turbine equipment and specific turbine plants.

The algorithms used in the vibration diagnostics system are based on theoretical computation, model studies and full-scale studies, as well as rich experience of NPO CKTI JSC experts gained in the process of vibrational adjustment and operation of steam and gas turbine plants produced by factories in Saint Petersburg, Kharkiv and Ekaterinburg, that operate today in many countries of the world. The diagnostics data is presented in a table format.

Steam Turbines Department

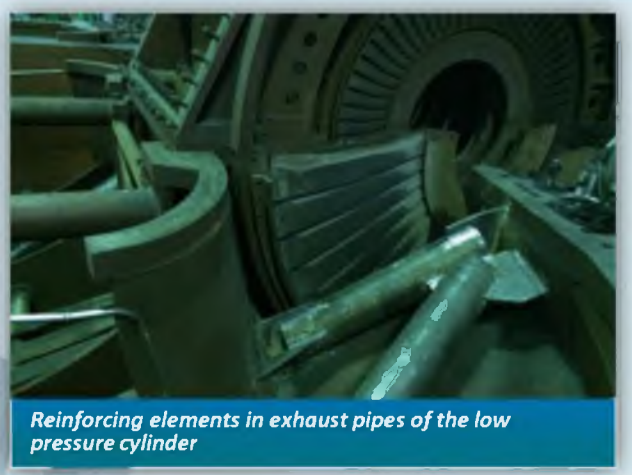
Vibration Laboratory

Examinations of newly erected and modernized foundations and the system of stay and foundation elements for turbine plants after their installation or rehabilitation

Examinations of newly erected and modernized foundations and the system of stay and foundation elements for turbine plants after their installation or rehabilitation a using vibration unit to determine the rigidity of stay and foundation elements and develop recommendations on its increase:

- tests for turbine plant foundation girder twisting after assembly;
- test of foundations and "turbine plant-foundation-base" system of main turbine plants in order to determine the conformity of dynamic compliance of stay elements and plant foundation to the parameters set in RTM 108.021.102-85 and RD 24.033.04-88, as well as the evaluation of quality works on foundation erection and mounting of any serial turbine plant performed by the contractor;
- reinforcement of supporting rotor elements, exhaust pipes and condensers of steam turbines, reinforcement of stay and foundation elements for gas turbines.

Vibrating unit installed on examined foundation



Reinforcing elements in exhaust pipes of the low pressure cylinder

Research of the LPC exhaust manifold conducted using a vibration unit to increase the rigidity of the manifold

Steam Turbines Department

Vibration Laboratory

Test research and development of designs for full-sized journal (bore inside diameter up to 750 mm) and combined journal-and-thrust bearings for turbine plants.

- Testing of newly developed journal and thrust bearings for steam and gas turbines in order to determine their bearing capacity, reliability and efficiency in various operating modes when reproducing their operating conditions under conditions of an operating power plant.
- Testing of various materials of journal and thrust bearing surfaces for steam and gas turbines in order to determine their bearing capacity, reliability and efficiency in various operating modes when reproducing their operating conditions under in an operating power plant.
- Testing of rotating structures (drill pipes, acceleration couplings, etc.) at the non-standard equipment test rig (for rotors of various lengths and diameters).

Test rig for journal bearing with diameters up to 450 mm investigation

Installation of a journal bearing with the face made of new synthetic material on the test rig

Steam Turbines Department

Blade Row Vibration Reliability Laboratory

Main activities of the laboratory:

- Operational diagnostics of rotated blade rows in steam and gas turbines;
- fatigue tests of blades;
- diagnostics of electromagnetic state of turbine equipment and its demagnetization;
- Operational diagnostics of electromagnetic state
- Rotating equipment instrumentation by strain gages
- Development of algorithms, software and hardware for measuring systems

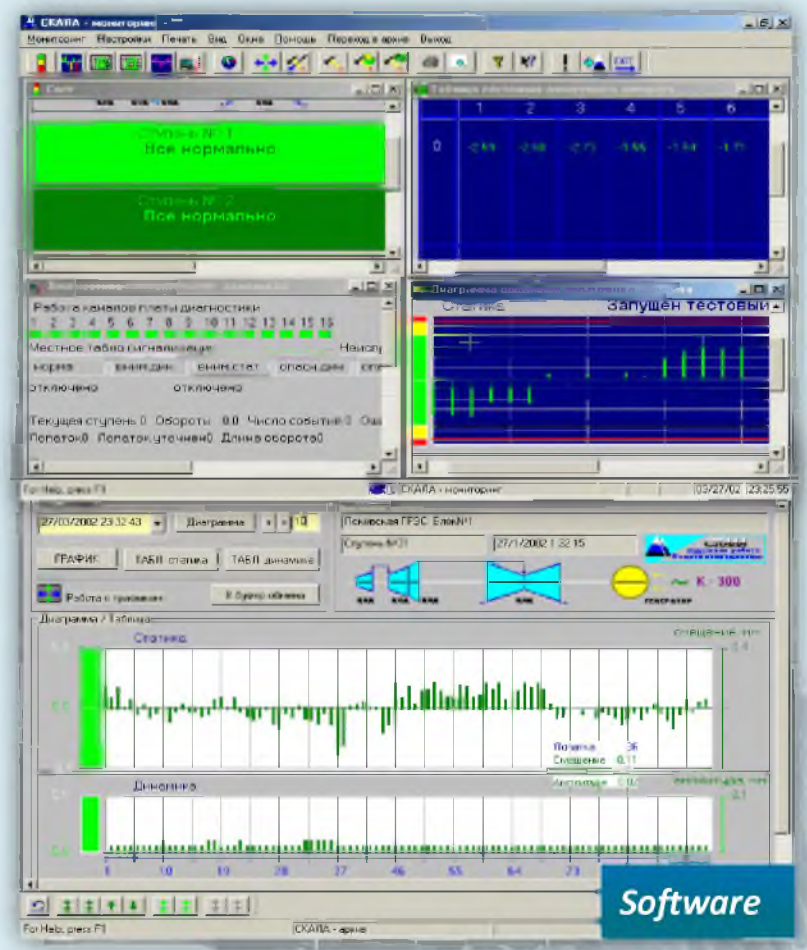
Steam Turbines Department

Blade Row Vibration Reliability Laboratory

Diagnostics of operational state of blading platforms – Automated Blading Control System (ABCS) SKALA

The Purpose of ABCS SKALA

- Continuous monitoring of mechanical state of each stage blade (several stages) in the process of axial turbomachine operation.
- Timely detection of damages in blade system. :
  - cracks in working blades;
  - breaks in wire ties;
  - breaks in the periphery of the blades.
- Continuous monitoring of vibration level of each stage blade (several stages) in the process of axial turbomachine operation.
- Prompt warning of the unit personnel about detected damage of a platform with a description of the damage and indicating the appropriate blade number and step number.



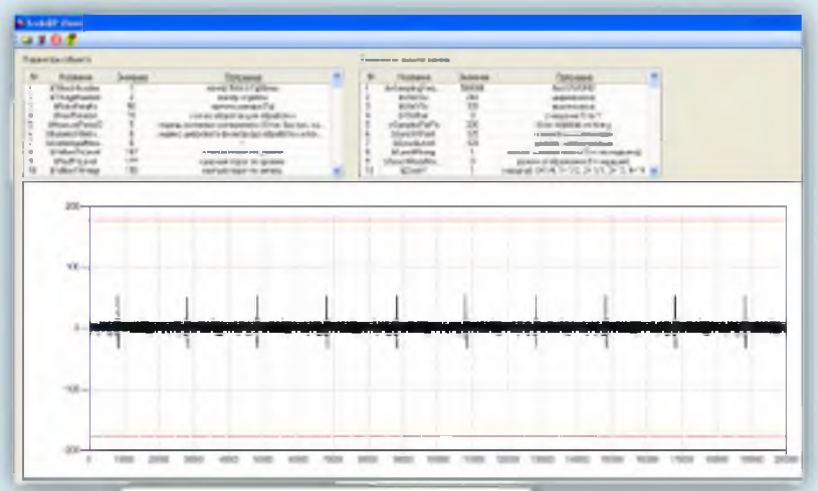
Steam Turbines Department

Blade Row Vibration Reliability Laboratory

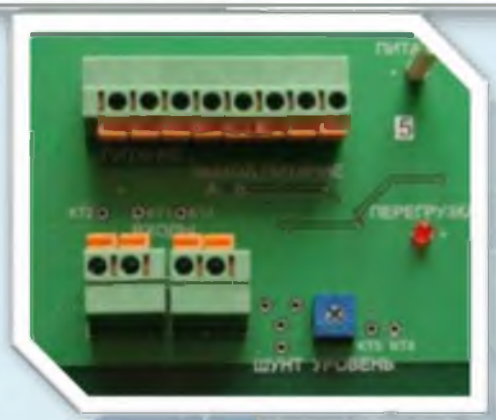
Diagnostics of operational state of blading platforms – Automated Blading Control System (ABCS) SKALA-BP

The Purpose of ABCS SKALA-BP

- Continuous monitoring of mechanical state of platforms at each stages in the process of turbine unit operation.
- Timely detection of damages in blading platforms.
- Prompt warning of the unit personnel about detected damage of a platform.



Controller of ASDP SKALA-BP



Preamplifier

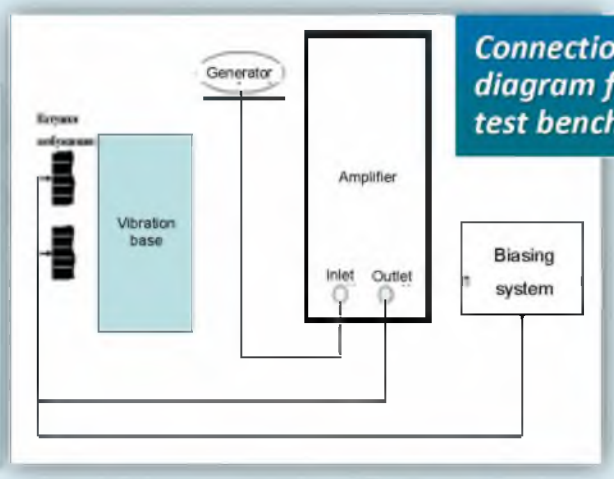
Steam Turbines Department

Blade Row Vibration Reliability Laboratory

Fatigue tests of blades (test rig investigations)

Purposes of Tests

- Evaluation of fatigue strength endurance for blades of steam and gas turbines.
- Evaluation of quality of blade recovery after repair.
- Comparative evaluation of service life for blades made of various materials according to various procedures, etc.



Connection diagram for fatigue test bench

Recording equipment

Steam Turbines Department

Blade Row Vibration Reliability Laboratory

Electromagnetic treatment (demagnetization) of units and parts of the turbine plant in the repair process

Demagnetization is performed to prevent electrical erosion damages of guide bearings from monopolar electromotive forces.

Demagnetization unit

System of Operational Control for Electromagnetic State of Turbine Equipment

The system is designed for continuous operational diagnostics of electromagnetic state for turbine plant and timely detection of the following:

- improper operation of current collector;
- unallowable low resistance of journal insulation of insulated guide bearings;
- unallowable low resistance of insulation of oil films;
- occurrence of rotor current short circuit loops.

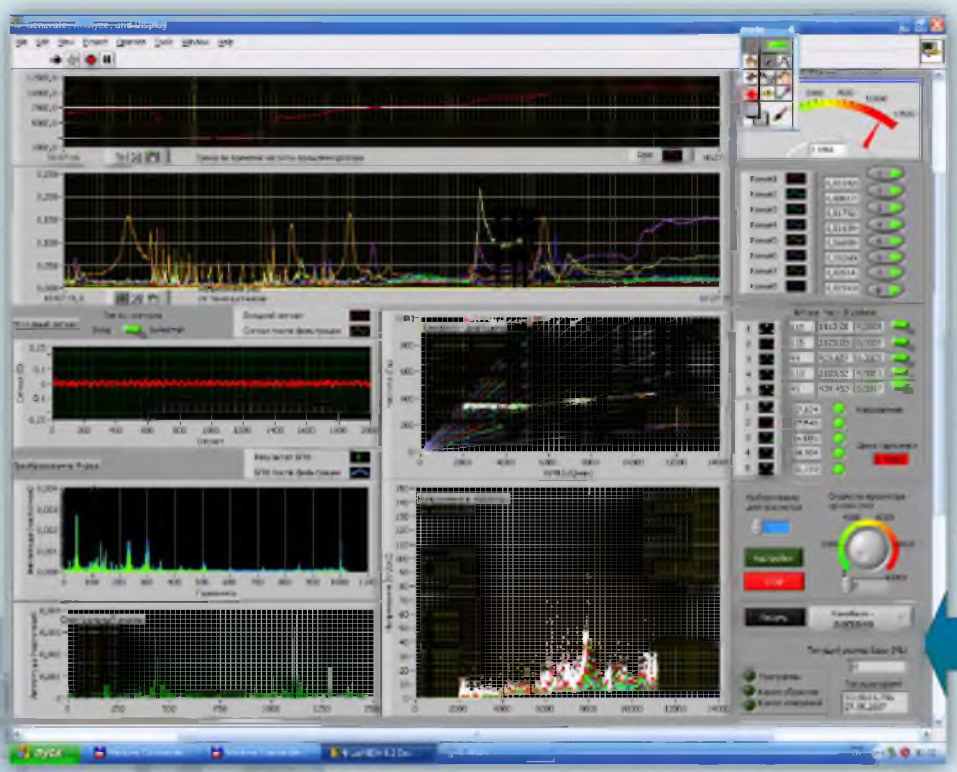
Appearance of electromagnetic state controller

Steam Turbines Department

Blade Row Vibration Reliability Laboratory

Instrumentation of rotating equipment by strain gages for investigation

The laboratory has design a rotating equipment strain gauge testing system. The system is designed for strain gauge testing – evaluation of strain-stress state of an object, evaluation of amplitude-frequency response of blades – using strain gauges.



Software

Current collector

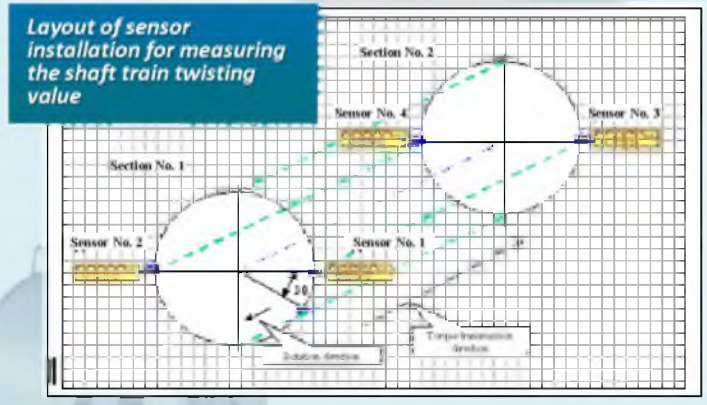
Steam Turbines Department

Blade Row Vibration Reliability Laboratory

Remote temperature measurement system for rotating objects

The department has developed a remote temperature measurement system for moving objects that utilizes proprietary pyrometric sensors.

Proprietary pyrometric sensor



Layout of sensor installation for measuring the shaft train twisting value

Shaft Train Torsion Measurement System

The systems is designed for:

- continuous monitoring of twisting angle of rotor between cross-sections in the process of turbine operation;
- timely detection of damages, such as:
  - circumferential cracks in the rotor body;
  - shaft damages in the diagnosed sections.

The operating principle of the system is based on utilization of discrete phase method and readings of inductive transducers.

This method has advantages over shaft torsion measurement method that utilizes torque measurement couplings, which are based on strain gauge transducers.

Advantages of out shaft train torsion measurement system:

- durability – there are no wear parts;
- simplicity of installation – no need to break the line of shafting;
- the evaluation of twisting takes into consideration such factors as floating and misalignment of shaft in guide bearings, which allows measuring the twisting value within the accuracy of 5 arc minutes.

Steam Turbines Department

Test Rigs of the Laboratory of Blade Row Vibration Reliability

1. ABCS SKALA-BP sensor calibration bed

4. Fatigue test bench (vibration base)

2. ABCS SKALA-BP components adjustment bed

3. ABCS SKALA-BP adjustment bed

5. Fatigue test strain gauge bed

6. Turbine plant electromagnetic state modelling bed

7. Shaft train twisting modelling bed

8. Test bed for checking operability of time-to-failure controllers

Hydropower and Hydropower Equipment Department

Main Activities of the Department

1. Creation of new flow paths of hydraulic turbines in compliance with the demands of the industry, including small and micro hydroelectric power units, as well as creation of new variable speed units.

2. Performance of cavitation tests of water turbine models at the reversible hydraulic unit test rig, NPO CKTI JSC.

3. Performance of vibration tests of water turbine models at the NPO CKTI JSC vibration test rig; test rig validation of the vibration research equipment.

4. Improvement of engineering level of hydroelectrical equipment of active hydroelectric plants, including increase of power and efficiency of operating equipment, extension of hydraulic turbine power and head range.

5. Industrial research of hydraulic turbines of operating hydroelectric plants with evaluation of state and improvement of reliability, including:

- **5.1.** Performance of absolute energy tests of hydraulic turbines with evaluation of absolute efficiency factor of turbines and relative tests in order to obtain precise operation characteristics of operating hydraulic turbines.
- **5.2.** Performance of vibration tests with detection and elimination of causes of vibration.
- **5.3.** Detection and elimination of causes of crack formation in runners and units of hydraulic turbines; performance of turbine strength tests.
- **5.4.** Cavitation research and development of measures aimed to decrease (eliminate) the cavitation erosion of hydraulic turbine flow path.
- **5.5.** Performance of special full-scale research: study of pressure pulsation, transition processes, influence of equipment on dams and hydroelectric plant buildings, dynamic state of penstock, etc.

6. Evaluation of technical state of hydroelectric units with extension of service life and assessment of remaining service life of main units of water turbines.

7. Preparation of specifications for replacement and modernization of equipment that has completed its rated service life.

8. Hydraulic design of new and modernized turbines.

9. Development and supply of portable vibration measurement complexes for testing hydroelectric units.

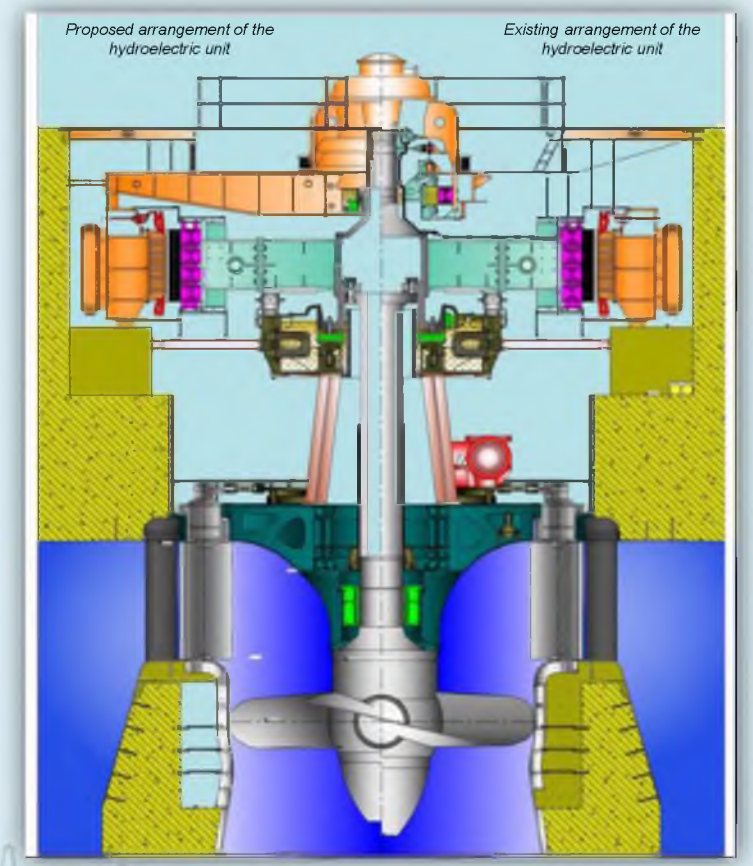
10. Creation and introduction of stationary automated systems of monitoring and diagnostics of technical condition of hydroelectric units, including:

- **10.1.** Development of technical requirements for stationery systems that take into consideration the equipment design.
- **10.2.** Development of algorithms and software for the system of equipment diagnostics and detection and malfunctions at the early stages of their occurrence.
- **10.3.** Supervision of the system commissioning.
- **10.4.** Verification of the system and release of compliance report.

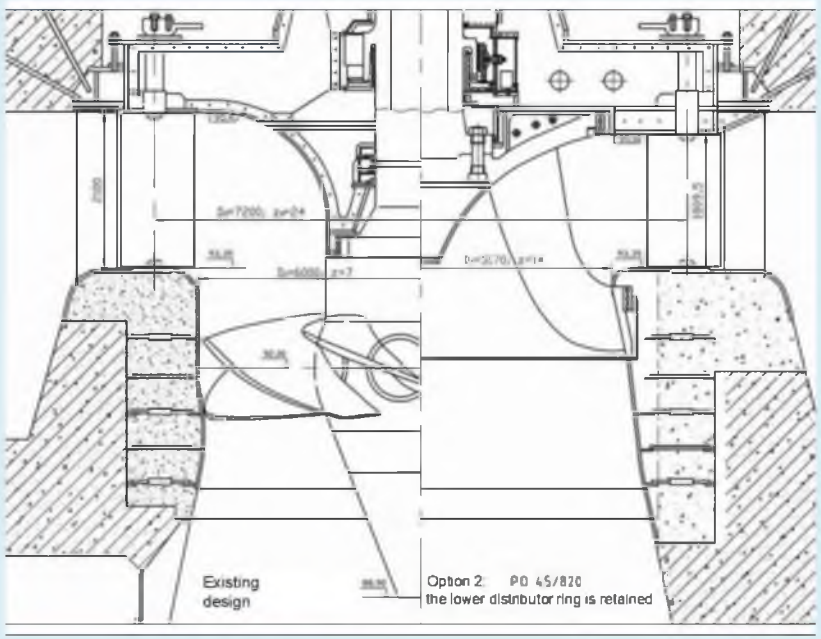
11. Development of standards, regulations, methods of creation, restoration, operation, extension of services life, and research of hydroelectric equipment.

Hydropower and Hydropower Equipment Department

Examples of equipment replacement justification projects



Altering of hydroelectric unit design for Kama Hydroelectric Power Plant

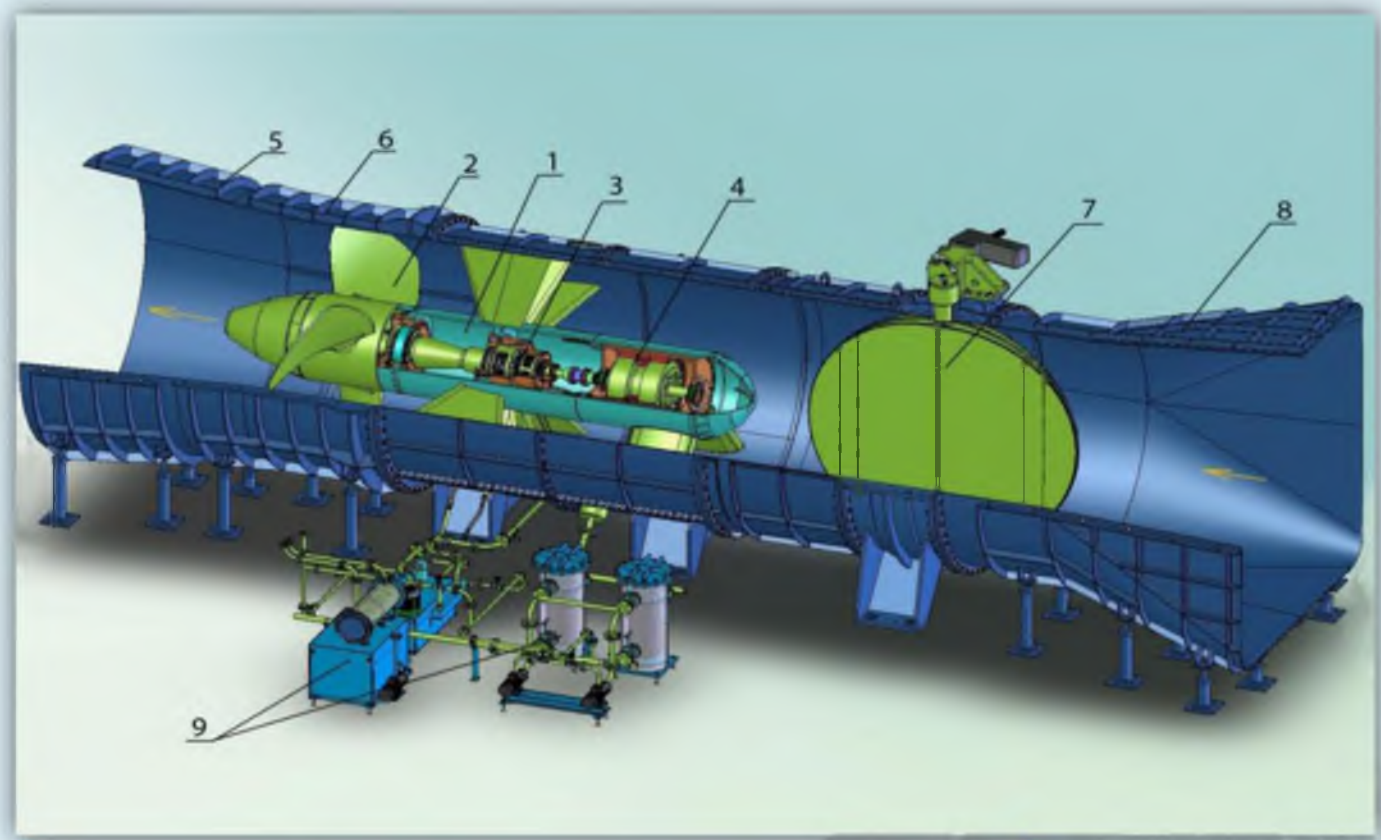


Altering of runner type of Ust-Khantai Hydroelectric Power Plant

Hydropower and Hydropower Equipment Department

An example of creation of new turbine flow path for a small hydroelectric power plant

1. *Water turbine unit*
2. *Runner (D = 2.6 m)*
3. *Multiplier*
4. *Generator*
5. *Suction cone*
6. *Discharge ring*
7. *Butterfly valve*
8. *Feed diffuser*
9. *Lubrication and water cooling systems*



Hydroelectric unit is manufactured for the hydroelectric power plant in Colombia (Mitu)
Power – 600 kW, head – 2.5 m

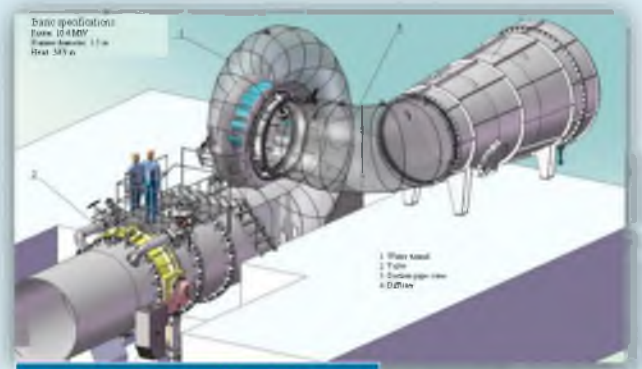
Hydropower and Hydropower Equipment Department

Examples of creation of new hydraulic turbine flow paths for small hydroelectric power plants

Variable-speed hydroelectric unit for Mitu HPP (Colombia)

Pelton wheel

1.8 MW hydroelectric unit at Dzhradzor HPP (Armenia)



Hydroelectric unit of Mendre HPP Power – 10.4 MW

Hydropower and Hydropower Equipment Department

Test Rigs of the Department

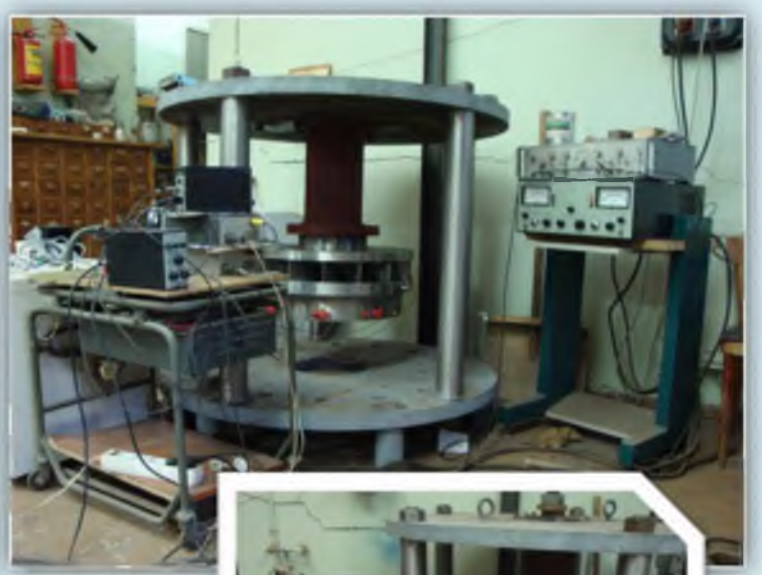
For extension of operating range of radial-axial turbine and evaluation of optimal solution:

- installation of stabilizing devises that break the "twist" below the runner;
- air delivery to the pressure part of the turbine;
- using variable speed.

The department uses **the hydraulic test rig for reversible hydraulic units.** The measurement precision of this test rig complies with the international standards.

Vibration parameters (natural frequencies) are evaluated at the **vibration test rig.**

Reversible hydraulic unit test rig



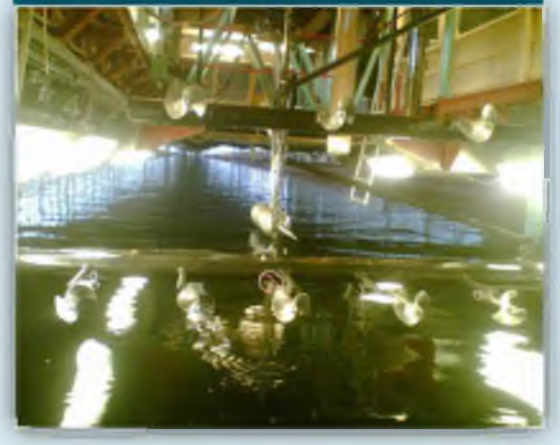
Vibration test rig

Hydropower and Hydropower Equipment Department

Examples Of Industrial Test Of Hydraulic Turbines Of Operating Hydroelectric Power Plants

Absolute Energy Tests

Calibration of hydrometric propellers in the pool



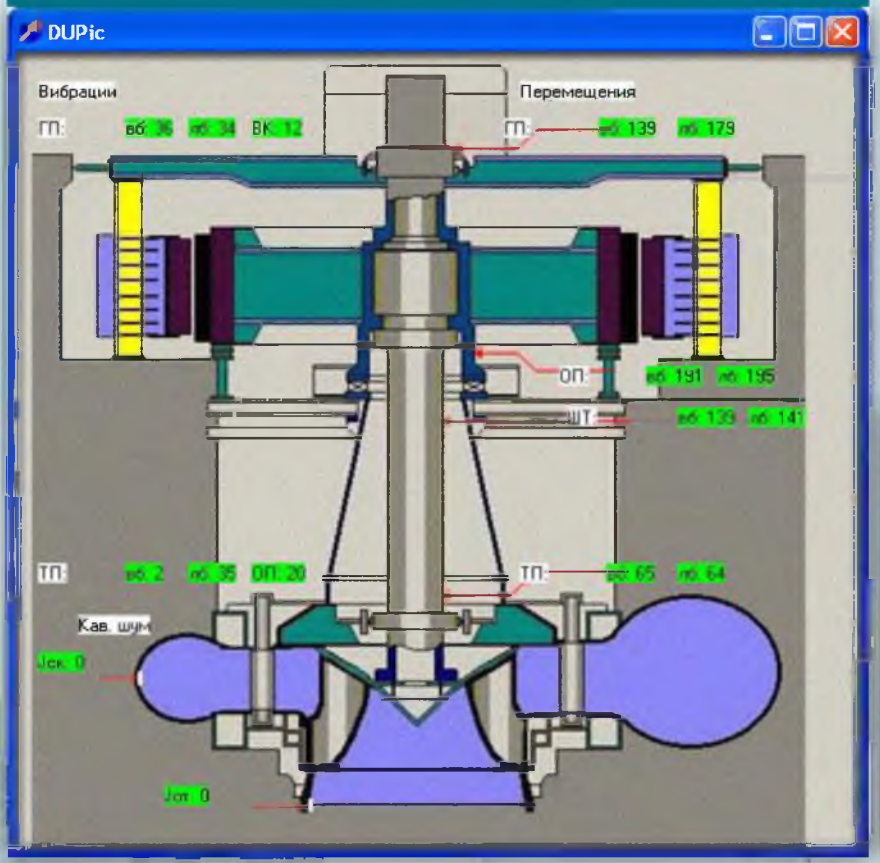
Frame with hydrometric propellers

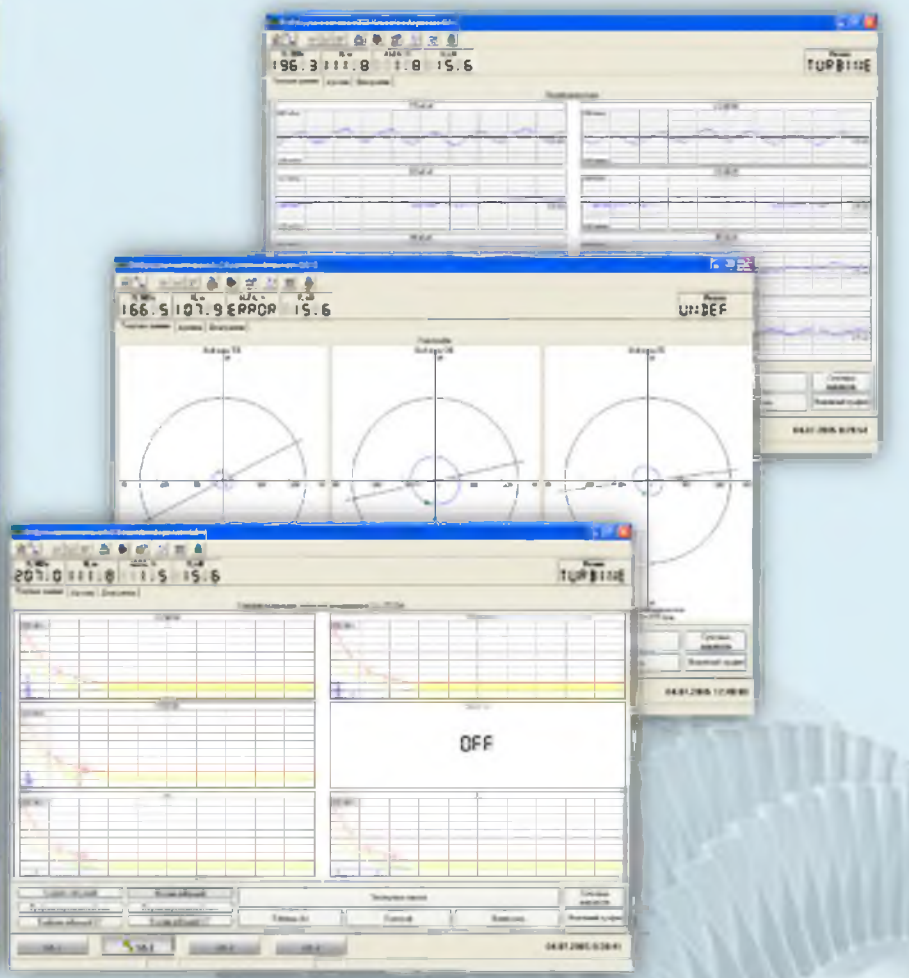
Installation of hydrometric propellers in the penstock

Hydropower and Hydropower Equipment Department

Creation automated systems of monitoring and diagnostics of technical condition of hydroelectric units

Hydroelectric unit vibration monitoring system
Kruonis Pumped Storage Plant (Lithuania)





Turbine Units Research Department

Structural Composition of Department

- Laboratory of Gas Turbine and Combined-Cycle Plants
- Laboratory of Steam Turbine Plant Researches
- Laboratory of Compressor Units, Air Handling and Noise Suppression for Power Generating Equipment

Turbine Units Research Department

Main Activities of the Department

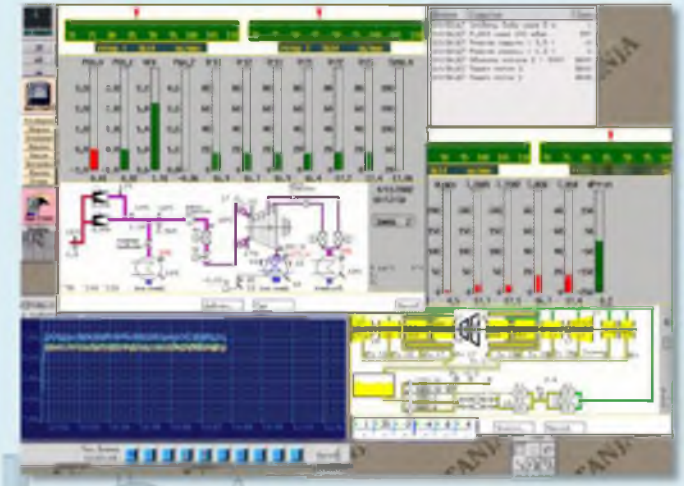
- Experimental and design researches of models for low pressure flow parts on test beds.
- Heat measurement for equipment of power plants and their processing.
- Designing of cooling systems for nozzle and rotor blades, rotors and stays of new turbines.
- Design assessment of service life for elements of existing and modernized gas turbine plants.
- Experimental research of hydraulics and thermal condition of cooled turbine blades on test beds.
- Experimental research of thermohydraulic characteristics of main elements of fluidized bed and turbine in full-scale conditions.
- Designing, production and testing of gas turbine plant air boilers.
- Research of exhaust lines of gas turbine plants and CCGT on test beds and in full-scale conditions. Development of gas flow stabilization methods.
- Design and production of exhaust line elements of gas turbine plant and CCGT.
- Design and production of air inlet path elements of gas turbine plants including volutes.
- Assessment of gas turbine plant projects.

- Development of technical solutions for combined cycle gas turbines (CCGT) of various types. Feasibility studies for CCGT construction.
- Design of thermal circuits for CCGT.
- Development of initial requirements for main thermal and mechanical equipment for CCGT.
- Selection of main and auxiliary thermal and mechanical equipment of CCGT and gas turbine plants and design of non-standard equipment including heat-exchanging equipment and silencers.
- Detailed thermal calculations with determination of energy and technical and economic indices of CCGT at design and off-design modes.
- Evaluation of environmental characteristics (noise levels and heat emission) of thermal and mechanical equipment of CCGT.
- Designing, production and installation of noise and heat insulation of thermal and mechanical equipment of full-scale CCGT.
- Development of import substitution lines and programs related to CCGT and gas turbine plants.

Turbine Units Research Department

Steam Turbine Units Investigation Laboratory

- Steam Turbine Units Investigation lab includes the research test rig designed for tests of low pressure part steam turbine models– Low Pressure Model Turbine (ETND-2). Test facility was built in 1970 and underwent a significant modernization in 1994–1996 and further in 2008 and 2017
- About 20 types of various flow paths of steam turbine LPCs designed by LMZ, Nevsky Factory (Russia), Turboatom Factory (Kharkiv, Ukraine), MAN (FRG), ABB and Alstom (Switzerland) have been tested at this test rig.



ETND-2: monitoring and Control System

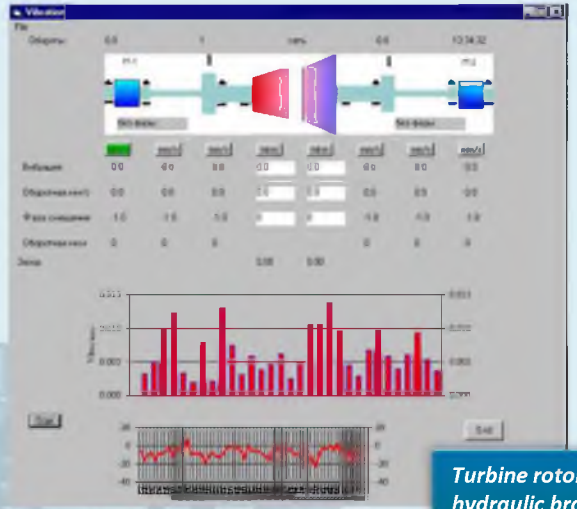
Low Pressure Experimental Turbine (ETND-2)

Turbine Units Research Department

Steam Turbine Units Investigation Laboratory

ETND-2: vibration, deformation and transitions

Plays in the flow path and temperature monitoring of stay elements



Turbine rotor and hydraulic brake vibration control

ETND-2: flow structure research

- 5-channel pneumatic probes.
- Evaluation of pressure and velocities in axial, radial and circumferential directions.
- Up to 3 probes in one section.
- Subsonic and supersonic calibration of probes on steam.
- Automatic 2D probe positioning system.
- Capability of manual probe position selection in the blade channel.

ETND-2: monitoring of stress strain state (using 2D and 3D calculations)

- 2D calculation of temperature and transition fields (by finite-element method).
- The position calculation is based on play measurements.
- Correction of temperature fields through measurement data.
- Real-time analysis capability.

Turbine Units Research Department

Laboratory of Steam Turbine Plant Researches

Test Bed for ETND -2

- From the beginning of 1970s to the middle of 1990s of the XX century on test bed in NPO CKTI researches of flow parts for LMZ, KhTGP, Nevskiy Zavod, as well as MAN
- After fundamental modernization since October of 1997 over 900 tests were performed for ABB, Alstom and GE
- Eleven different models of flow parts with rotor blades of the last stages from 30 to 50 inches were researched within the wide range of modes both for news and modernized turbines

Research Areas

Determination of efficiency

- for the last stage with diffuser (removable element)
- for two last stages with diffuser
- penultimate stage
- group of first stages

Three-dimensional characteristics of flow downstream

- last stage (L-0)
- penultimate stage (L-1)
- third stage from the end (L-2)

Vibration of rotor blades

- for the last stage (by means of strain-gage sensors and tip timing noncontact method)
- penultimate stage (tip timing noncontact method)

Nonstationary flow downstream

- last stage (L-0)
- penultimate stage (L-1)
- guide vane (in gap of the last stage)

Temperature fields

Steam humidity downstream each of three last stages

Turbine Units Research Department

Laboratory of Steam Turbine Plant Researches

Test Bed for ETND-2

Parameters	
Location	St. Petersburg, Russia
Scale	0.25–0.333 for turbine model 50 HZ
Shaft train	Divided shaft
Maximum length of simulated rotor blade	58”
Range of maximum temperatures at inlet	130 °C – 260 °C
Range of maximum pressure at inlet	0.04 bar – 4.5 bar
Steam flow rate	0–30 kg/s
Rotor speed	6.000–12.000 rpm
Minimum pressure at outlet	40.0 mbar
Maximum pressure at outlet	650.0 mbar
Maximum power	15 MW: 2 hydraulic brakes (7.5 & 7.5 MW)
Axial force	up to 120 kN (front rotor)

Rear rotor rotation device for research of ventilation modes (connected)	Power of steam turbine 1.2 MW
Bleeding simulation	2 chambers and pipelines of bleeding
Different types of diffuser	Radial and axial
Configuration of turbine body	Invert
Torque measurement	1x2 force measuring instrument (1 device per each shaft)
Efficiency Measurement	Last stage, penultimate stage, front stages to movable disk
Measured steam flow rate	ISO nozzles (main and for bleeding)

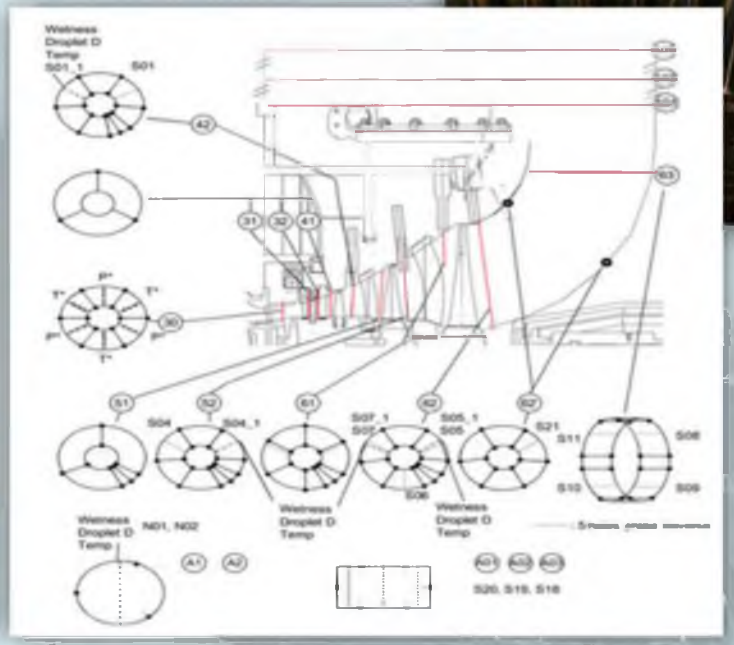
Turbine Units Research Department

Laboratory of Steam Turbine Plant Researches

Test Bed for ETND-2

Turbine Model

- Blades of low pressure stages
- Divided shaft (3–5 last stages on 2 shafts)
- Driven turbine with power of 1.2 MW for idle running of rear rotor stages
- Hydraulic brakes with absorbed power of 7.5 MW on each shaft
- Simulation factor 1:4–1:3 for turbine 50 Hz
- Working medium is water steam



Turbine Units Research Department

Laboratory of Steam Turbine Plant Researches

Test bed for ETND-2. Measuring systems and equipment

All researches shall be anticipated with dynamic balancing and experiments in vacuum chamber
Measuring systems, tools, methods and software are developed and used in LPMT

- ✓ Global data collection system (GLODAS)
- ✓ System of data collection (DAS FLOW) for steady state flow
- ✓ System of data collection for unsteady state flow DAS Unsteady FLOW
- ✓ Humidity measurement system WMS
- ✓ Displacement and deformation measurement system DAS STRUCTURE
- ✓ ANSYS, CFX, SCADA, different DAS/DES, Databases, web applications
- ✓ Special calibration test bed for 5-channel probe

- GLODAS: torque meter, flow rate meter, over 200 static pressure sensors, thermocouples and humidity measurement system (WMS);
- DAS FLOW: traversing with 5-channel probes and humidity probes;
- DAS Unsteady FLOW: movable and fixed sensors of dynamic pressure;
- WMS: 6 optical probes and high-speed video probe;
- DAS STRUCTURE: strain-gage sensors, tip timing noncontact method, sensors of radial clearances and sensors of axial displacements, thermocouples;
- Calibration test bed for 5-channel probe: subsonic and supersonic nozzles, superheated steam or wet steam.

Turbine Units Research Department

Laboratory of Steam Turbine Plant Researches

Test Bed for ETND-2

Standard uncertainty of measured efficiency (1-sigma)

Parameter	U	Unit
Inlet Pt (pressure)	0.0004	бар
Inlet Tt (temperature)	0.28	C
Pressure at outlet Ps	0.00006	бар
Front shaft torque	2.8	Nm
Rear shaft torque	2.7	Nm
Rotation speed	1.6	Об/мин
Steam flow rate	0.0181	кг/с
Losses in bearing	4.00	кВт
Flow part efficiency	0.164	

Turbine Units Research Department

Laboratory of Steam Turbine Plant Researches

Test Bed for ETND-2: Functions

- Designing of models (together with designers of blades)
- Designing of shafts, body and other components, production and quality control
- Installation, introduction into operation and safe operation of turbine
- Research of vibration for blades (110 % – 0 %)
- Research of aeromechanic dampening
- Non-synchronous oscillations
- Aerodynamics (3D flow) / efficiency researches
- Data collection and processing
- Data visualization and their sending to the Customer (web interface)

Turbine Units Research Department

Laboratory of Steam Turbine Plant Researches

Works on aerodynamics of paths and noise suppression

- Design supporting of measures on noise and vibration reduction at gas industry enterprises.
- Gas dynamics and acoustical calculations, development of structural diagrams of process gas discharge silencers.
- Comparative analysis of technical solutions on steam bypass paths in half-speed turbine K-1200-6.8/25 newly designed by LMZ.
- Simulation aerodynamic researches of intermediate- and low-pressure output paths of half-speed turbine K-1200-6.8/25 designed by LMZ.
- Aerodynamic testing for models of LPC exhaust tubes of 1000 MW turbine made by Skoda (the Czech Republic).

Test bed base using air

- High-flow rate aerodynamic test bed.
- Test bed for research of aerodynamics and hydraulic resistances of power-generating equipment.

Turbine Units Research Department

Laboratory of Gas Turbine and Combined-Cycle Plants

Main Activities of The Laboratory

- Designing of cooling systems for nozzle and rotor blades, rotors and stays of gas turbines
- Experimental researches of hydraulics and thermal state of turbine elements including cooled blades on test bed and full-scale conditions
- Designing, production and testing of gas turbine plant air boilers
- Inspection of gas turbine plant during scheduled preventive maintenance, examination of reasons for damageability of elements in gas turbine plants
- Research on test bed and in full-scale conditions, designing and production of elements for exhaust paths of gas turbine plant. Development of gas flow stabilization methods
- Designing, production and research of elements of gas turbine plant air inlet path including volutes
- Performance of various research and development on combined cycle gas turbines including development of technical proposals on CCGT of various types, development of thermal circuits for CCGT, selection of main and auxiliary thermal and mechanical equipment for CCGT and steam-turbine plant
- Designing and production of nonstandard equipment including heat exchange devices and silencers
- Research and designing of antiicing systems for gas turbine plants
- Determination of environmental characteristics (noise levels and heat emission) of thermal and mechanical equipment for gas turbine plant and CCGT
- Designing, production and installation of noise and heat insulation of thermal and mechanical equipment of full-scale gas turbine plants and CCGT

Turbine Units Research Department

Laboratory of Gas Turbine and Combined-Cycle Plants

Gas turbine blade row research bed

Experimental bed is designed for the research of hydraulic features and thermal condition of blade rows of gas turbines.

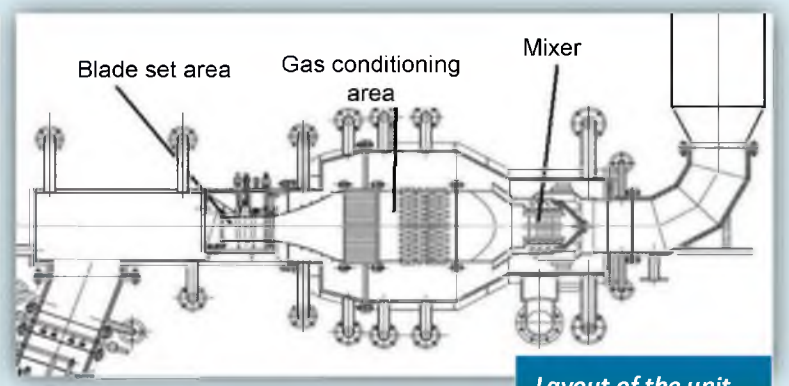
Main element of the bed is the high-temperature gas dynamics unit, which underwent modernization in 2013 – 2016.

Main parameters of the unit: maximum gas temperature – **1100 °C**, maximum gas temperature – **2.5 bar**, cooling air temperature – **20 to 350 °C**. The unit consists of combustion chamber, which receives the compressed air from K-500 compressor (motor power – **3500 kW**, flow – **G = 10 kg/s, P = 6 bar**), gas conditioning zone, work area, replaceable sets of researched and auxiliary blades. The gas conditioning zone is designed for equalizing the gas temperature and pressure fields before the gas enters the work area. It consists of several elements: a mixer, which mixes the flow after it leaves the combustion chamber and the water-cooled elbow (angled at 90°), turbulizer (which consists of several perpendicular rods), honeycomb-type dashpot, which is made if perpendicular panels that form a honeycomb-like structure with the cell size 40 x 40 mm, and a convergent tube.

The work area consists of a water-cooled outer shell and an inner shell with installed sets of prepared experimental and auxiliary blades.

The new liquid-fuel combustion chamber features a refractory liner with combined convection and film cooling and dual-fuel single-stage nozzle with atomizing function. The new combustion chamber features the gas pilot burner (fed from the tank).

The following systems are also featured in the bed: the fuel system that feeds the diesel fuel to the combustion chamber burners, water system that feeds the water to the cooled outer shells of the unit and nozzles that inject water to the combustion projects behind the work area, the system that conditions and feeds the cooling are to the blades, as well as electric heaters.



Layout of the unit

General view of the test bed after modernization

Turbine Units Research Department

Laboratory of Gas Turbine and Combined-Cycle Plants

Exhaust Line Research Test Rig

The department has created a special experimental unit. It was used in research of the exhaust line of PGU-325 unit, which includes GTE-110 gas turbine unit.

The exhaust line of the unit (hereafter EL) consists of the gas turbine diffuser (TD), exhaust manifold (EM) of GTE-110, which is considered a diffuser from the aerodynamic point of view, diffuser of the heat recovery boiler (DHRB), heat recovery boiler (HRB), HRB adaptor.

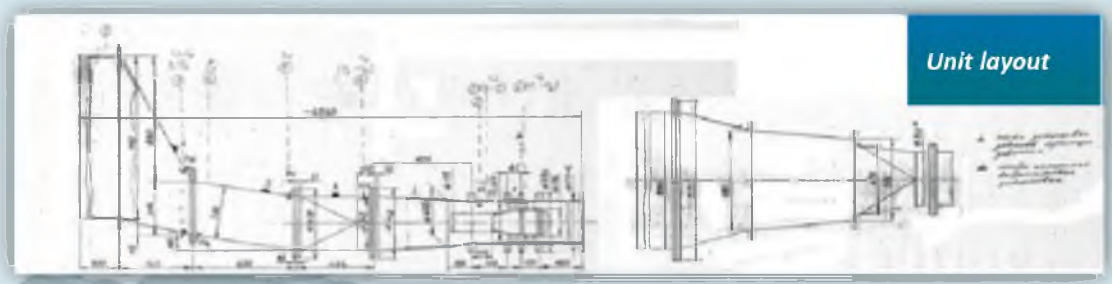
The experiments performed with the unit enabled the following:

- determine the main reason of occurrence of pressure pulsations in the EL gas flow;
- issue recommendations for lowering the pressure pulsations and check them during the experiment;
- determine hydraulic losses in diffusers.

Based on performance of K-500 axial compressor, in order to obtain the required Mach number value in the flow and match the field conditions, the department used the value 11.11 as the condition simulation factor. The layout of the unit is displayed below.

The experimental unit consisted of:

- receiver, inlet docking area, twisting area for three different operating modes of the full-scale unit: idle mode, 50 % of the load, rated mode;
- turbine diffuser models, exhaust manifold model, transition area model, heat recovery boiler diffuser model;
- HRB model with the first tube bundle and equivalent boiler model.



Unit layout

General view of the unit

Turbine Units Research Department

Works Performed

Starting from 2012, the department has been performing a lot of works aimed to ensure reliable operation of the unique domestically-produced **gas turbine unit GTE-110** by UEC Saturn. The following works have been performed to ensure the turbine operation:

- comprehensive analysis of the unit design, which determined main structural disadvantages of the unit;
- project and modernization of the unique high-temperature test bed designed for testing GTE-110 and GTE-110M blades;
- several series of experimental researches of nozzle guide vanes and blades of one stage of GTE-100 turbine at the gas temperature of 1100 °C;
- based on the design analysis and a set of assessments of blade damages, the department has developed and released blade optimization recommendations.

For the sake of experimental research, full-scale blades on the test bed were fitted with two types of thermocouple with XA labeling: for the main part of the blade – approximately 50 thermocouples in soft siliceous thread insulation saturated with silicone lacquer (thermocouple wire diameter – 0.3 mm); the trailing edge zone is fitted with thermocouple cables that have the outer diameter of 0.5–0.7 mm.

Hot junctions were getting flattened and welded by electric resistance welding to the external surface of the blade at the cable groove end zone. The cable in grooves and hot junctions were getting enclosed by ~0.1 mm think foil, which was getting welded to the blade by electric resistance welding. The air and gas temperature was measured using XA thermocouples in soft insulation with wire diameter of 0.5 mm.

Nozzle guide vanes and blades of GTE-110 turbine equipped with sensors

Turbine Units Research Department

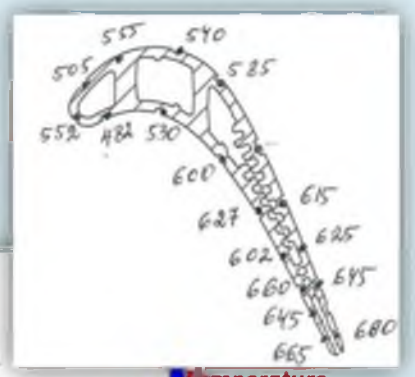
Works Performed

Based on the obtained experimental data on hydraulic and thermal condition of various versions of nozzle guide vanes of GTE-110, we have verified the corresponding design models in 2D and 3D. Using the verified models, we have conducted calculations of hydraulic, thermal, stress and vibrational condition of blades for field environment. The ***Fig. A*** displays a comparison of experimental data on the blade with calculations. The ***Fig. B*** features the results of thermal condition design for one version of GTE-110 blade in a field environment.

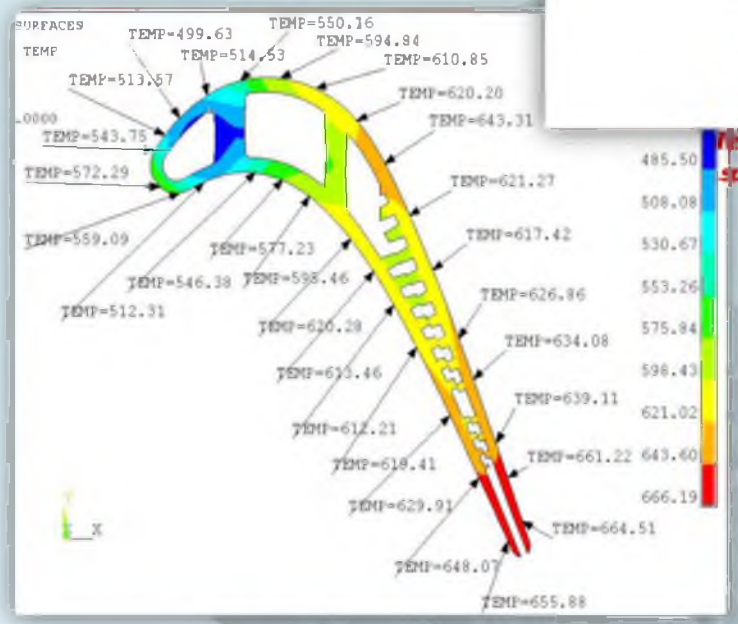
Fig. A. Verification analysis of the mid-section temperature field in the hot blowdown mode

Fourth approximation

λr = 0.57; Tr* = 800 °C; Pr* = 1.56 atm; Gвотн = 1.84 %; Tв = 135 °C



New regions and derating factors for the external Alfa.
2nd iteration of hydraulics and cooling air heating.



Temperature specification 660

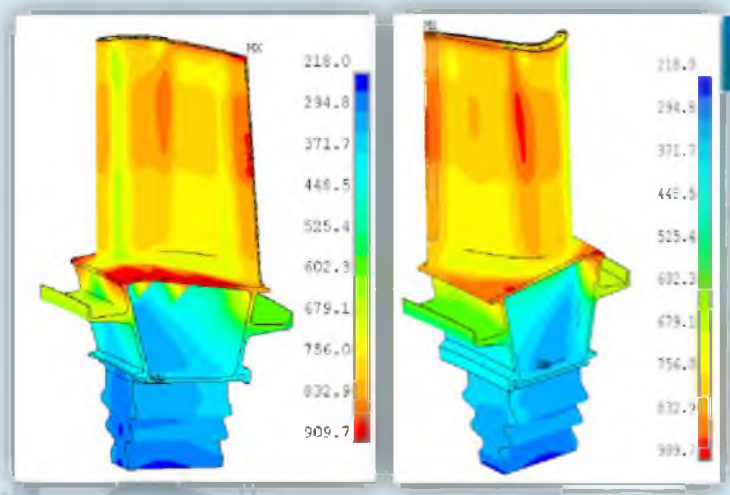
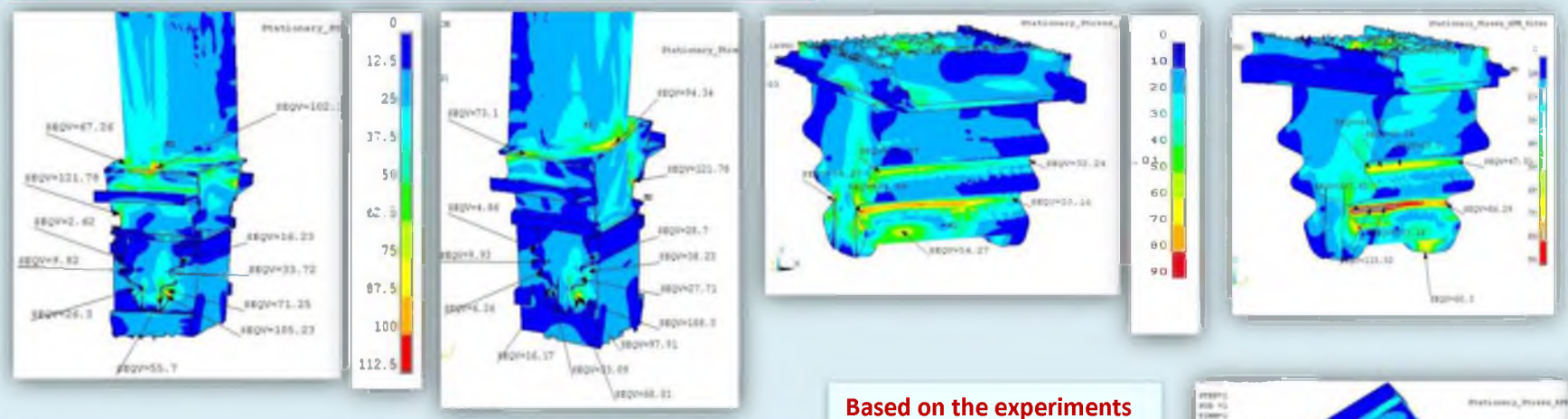


Fig. B.

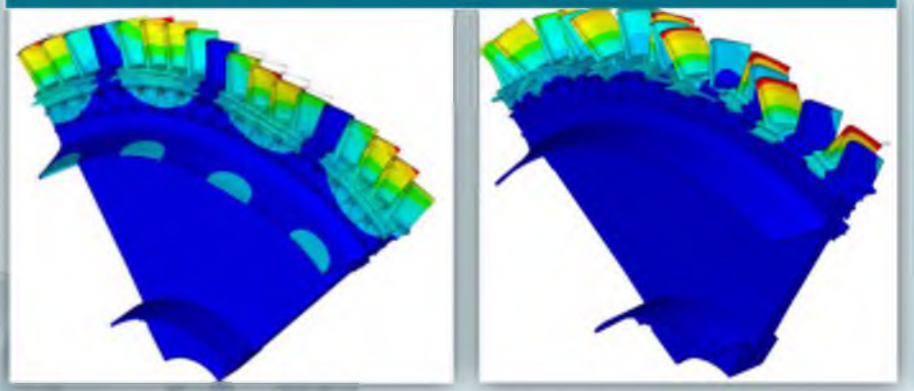
Turbine Units Research Department

Works Performed

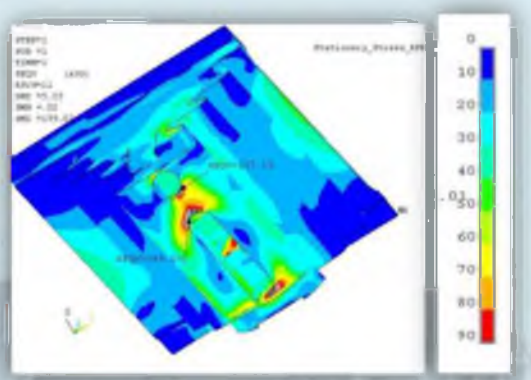
Heat stress condition calculation results in 3D projection of a blade at one stage of the turbine



The results of vibration condition evaluation for the "disc-blades" system of one stage of GTE-110 turbine



Based on the experiments and calculations performed, the department has developed specific suggestions regarding modernization of cooling systems and design of nozzle guide vanes and blades with the aim to extend their service life. The recommendations are included in the full-scale unit.



Turbine Units Research Department

Works Performed

A set of studies aimed to determine the causes of flow pulsations in the exhaust line of GTE-110 unit by UEC Saturn, **which lead to development of pulsation suppression method**

The measurement scheme designed for the research includes several types of primary sensors and secondary equipment:

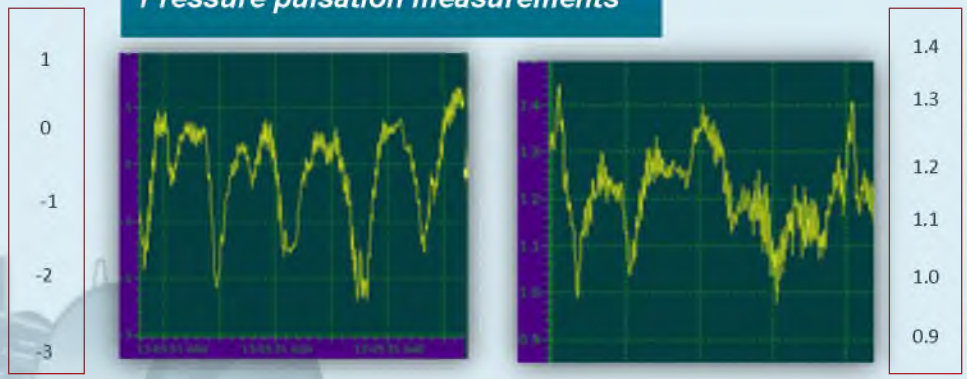
- five-channel ball probe for measuring the speed value and direction in the flow. Secondary equipment – U-shaped differential pressure gauges with water and pressure gauges like Metran-100 DIV and Metran-100 DI;
- Pitot-static tube for measuring the flow parameters in the last measurement section and Metran-100 DIV;
- pressure gauges like Metran-100 DIV for measuring static pressure during the extraction from the unit walls and to ensure operation of the pressure pulsation detection scheme;
- Ditran piezo pressure pulsation sensor and instrumentation complex by National Instruments.

Experimental research was conducted using the Re number in the self-similarity of flow. **(Re > 1.5*10^5)**, and Mach numbers that match the full-scale values. For example, for the rated load mode at the axial flow to the turbine diffuser the tests were performed with the value **M ≈ 0.47** (**Re value was 3.76 × 10^5**).

The pressure pulsation measurement has shown that the main reason of their occurrence is the flow whirling. (see ***Fig. E***)

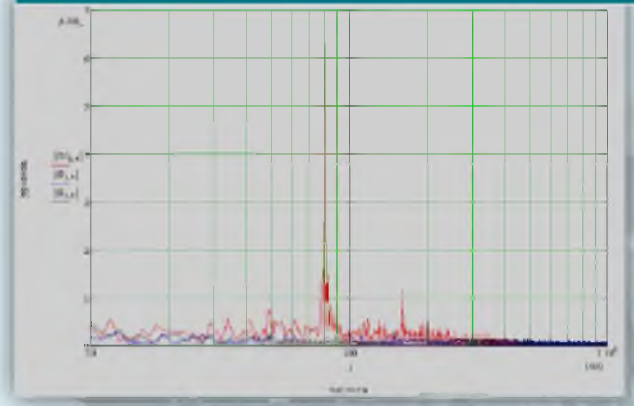
The department has designed a pressure pulsation suppression method in the EL flow that is based on counter-whirling device. (see ***Fig. F***)

Pressure pulsation measurements



Idle mode (sensor P2) **Rater load mode, (sensor P2)**

Flow pressure pulsation suppression in the EL



Turbine Units Research Department

Works Performed

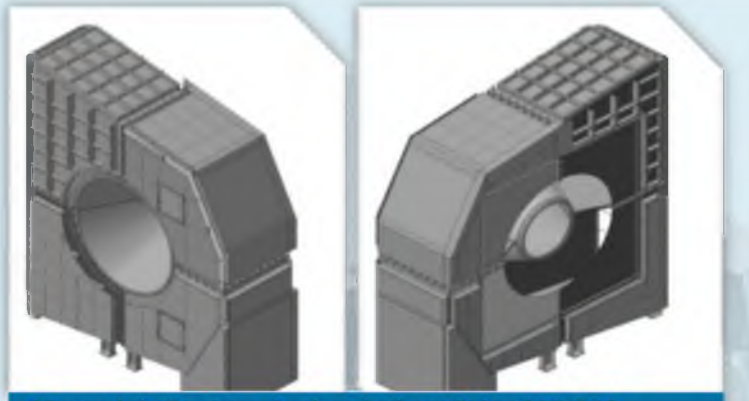
Works performed with 1.25–1.8 MW marine units produced by JSC «Proletarsky Zavod»

- The department has completed a design, production and testing of plate regenerator for the new marine unit GTG-1250 by JSC «Proletarsky Zavod».
- The department has received the industrial utility model patent. **The patent is implemented in the commercial GTU.**

Marine unit GTG-1250 R produced by JSC "Proletarsky Zavod"

Evaluation of environmental characteristics of PGU 325 equipment

- The noise levels have been measure in the turbine hall of PGU 325.
- The main noise sources have been determined.
- The recommendations have been issued with regard to reducing the noise emitted by the heat machinery equipment of the PGU.
- The department has designed modernization of sound insulation of the shelter, exhaust manifold, oil facilities, transmission and gas fuel system pipes. The Detail Construction Documentation has been released for the turbine shell heat insulation. New noise and heat insulation of the turbine shell was mounted on the full-scale unit.



3D model of new noise insulation of the GTE-110 volute.

Отдел исследований турбоустановок

Laboratory of Gas Turbine and Combined-Cycle Plants

Performed Works

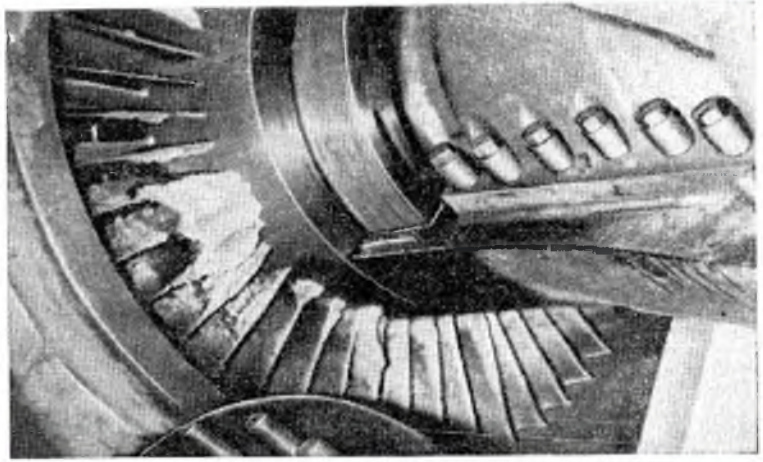
Works on research of antiicing systems for gas turbine plant

- Complex of works on research of antiicing systems for gas turbine plants SGT-800, V 64.3A and ГТ-160 installed at power plants of TGC-1 PJSC in St. Petersburg is performed.

  Recommendations on optimization of algorithms for antiicing systems and their design.

  Economic losses from operation of antiicing systems and reduction of power in units within summer time.

  Proposals on implementation of “Tuman” system implementation.
- Complex of works on research on damaged inlet guide vane of compressors for 2 gas turbine plants SGT-100 installed in power center of Pulkovo Airport. Determination of reasons for blade damaging is icing in the area of inlet guide vanes.



Turbine Units Research Department

Works Performed

Import Substitution Activities

- **The department has developed scientific, engineering and economical programs for import substitution in gas turbine technologies.**
  - We have collected and analyzed the source data and developed various sections of **import substitution programs** for the gas turbine technologies. Works performed:
    - ✓ we have researched the product range and engineering standards of the stationary GTU equipment market;
    - ✓ we have developed propositions for altering technical requirements, types and sizes of certain gas turbines;
    - ✓ we have defined a circle of organizations, enterprises, engineering companies and design bureaus interested in creating domestic stationary GTU;
    - ✓ we have prepared propositions regarding implementation of pilot projects in the field of highly-efficient combined cycle power units;
    - ✓ we have developed an **import substitution program** in the field of gas turbine technologies.
- **The department has developed scientific, engineering and economical programs for import substitution in gas turbine technologies, including:**
  - a forecast of the gas turbine equipment demand in the Russian energy industry till 2030;
  - propositions regarding 100 % domestic GTU production;
  - requirements for design organizations and GTU producers in the field of product life cycle information support;
  - propositions regarding cycle arrangements and requirements for main CCGT equipment;
  - propositions for selecting and applying IT support for managing the **import substitution program.**

Turbine Units Research Department

Laboratory of Compressor Units, Air Handling and Noise Suppression for Power Generating Equipment

Main Activities of The Laboratory

Axial Compressors:

- development of flow parts for multi-stage compressors with subsonic and supersonic stages with subsequent aerodynamic and vibration trial on test beds of NPO CKTI;
- rehabilitation of existing compressors to increase capacity, pressure and efficiency using methods of blading optimization;
- development and research of transonic and supersonic stages on test beds of NPO CKTI;
- research of compressor with injection of water into flow part for compression process intensification;
- research of issues concerning contamination and development of optimum methods for cleaning of flow part in axial compressors;
- inspection of compressors, extension of their service life and delivery of spare parts (rotor blades, guide vanes, etc.) of compressor equipment;
- organization and performance of industrial tests for full-scale compressors by the Customer in the operating places;
- designing, manufacturing and delivery of vessels, filters and other devices subordinate to Rostekhnadzor and Rosatomnadzor.

Turbine Units Research Department

Laboratory of Compressor Units, Air Handling and Noise Suppression for Power Generating Equipment

Main Activities of The Laboratory

Designing and test of many types of **centrifugal compressor equipment** for core industries:

- natural gas blower with various power;
- air compressors and blowers for ferrous industry, cryogenic engineering and general purpose;
- compressors and blowers for chemical, petrochemical and petroleum industry;
- development of flow parts of centrifugal compressors and blowers based on up-to-date designing methods with subsequent updating of aerodynamic designs on test beds of NPO CKTI;
- calculation and theoretical researches of flow parts for centrifugal compressor machines;
- experimental researches and development for models of centrifugal and blower stages;
- modernization of existing compressors in order to improve their parameters, reliability, reduction of power consumptions during operation;
- researches of influence from abrasive and and corrosive wear of elements for flow part for aerodynamic and energy characteristics of centrifugal compressors and blowers and development of efficient protection methods;
- natural gas blower with various power;
- air compressors and blowers for ferrous industry, cryogenic engineering and general purpose

Turbine Units Research Department

Laboratory of Compressor Units, Air Handling and Noise Suppression for Power Generating Equipment

Main Activities of The Laboratory

- inspection of compressors and blowers, flaw detection of their main assemblies, development of recommendations on replacement of their element and delivery of spare parts (impellers, vaned diffusers, seals, bearings) in order to extend service life; perform industrial tests for full-scale compressors by the Customer with issue of recommendations on their further operation;
- diagnostics of compressors and blowers in order to determine remaining service life of their key elements, participate in investigation of reasons for compressor and blower failures and development of methods and conditions for their elimination;
- selection of centrifugal compressor equipment for the specified parameters and the technical requirements;
- performance of **certification tests** for compressors and blowers with issue of conclusions about correspondence with the regulatory document;
- development and delivery of air cooling systems at inlet of gas turbine plant;
- development of authoring system for early warning about approaching of unsteady-state mode of compressors.

Turbine Units Research Department

Laboratory of Compressor Units, Air Handling and Noise Suppression for Power Generating Equipment

Main Activities of The Laboratory

For **air handling devices**:

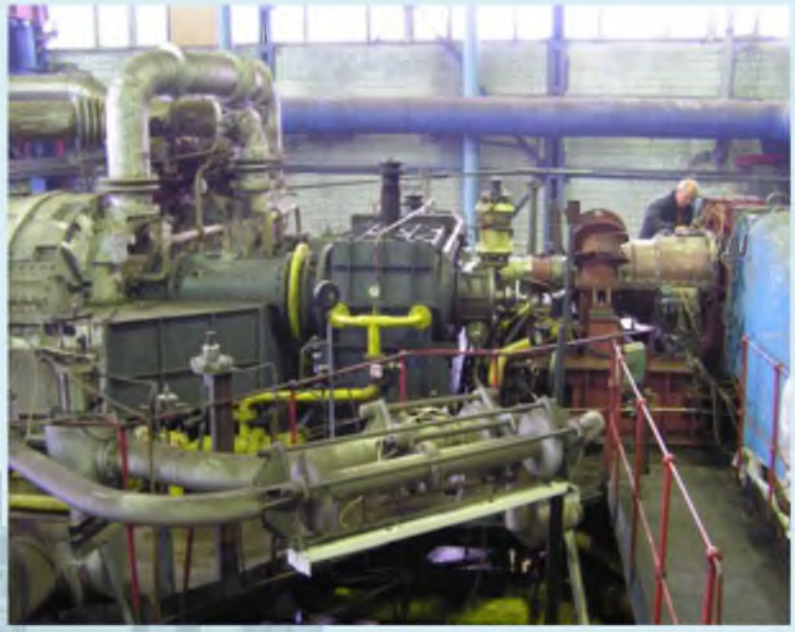
- designing of air cleaning facilities and their production on the basis of its own enterprise;
- performance of investigation tests for model of air inlet path in general or its separate elements, calculation and confirmation of acoustic, thermal and strength characteristics during new construction and rehabilitation of the plants;
- optimal selection of cycle air filtration method for the certain project;
- scientific and technical support for equipment in the place of assembly, erection supervision, warranty

Turbine Units Research Department

Laboratory of Compressor Units, Air Handling and Noise Suppression for Power Generating Equipment

Test bed for axial compressors of gas turbine plant (21206)

For development and research of models for axial compressors three large-scale test-beds are created, which allow testing both separate single stages and compartments from several stages, as well as multi-stage compressors with a great number of stages for high degrees of pressure increase. Researches are performed in complex: gasodynamic characteristics of blading and vibration condition of rotor blades are researched.



The test bed is intended for aerodynamic and vibration tests of large-scale models for axial compressors of gas turbine plant.

- Drive: steam turbine with power of 16 MW.
- Steam flow rate – 80 t/h.
- Steam pressure – 40 kgf/cm^2.
- Maximum speed of rotor for model compressor is up to 14,000 rpm.

Change in operating CC modes from modes of maximum flow rate to the limit of steady operation shall be provided with change of rotor speed from 2,000 to 14,000 rpm and control of loading orifice installed at outlet of compressor.

Turbine Units Research Department

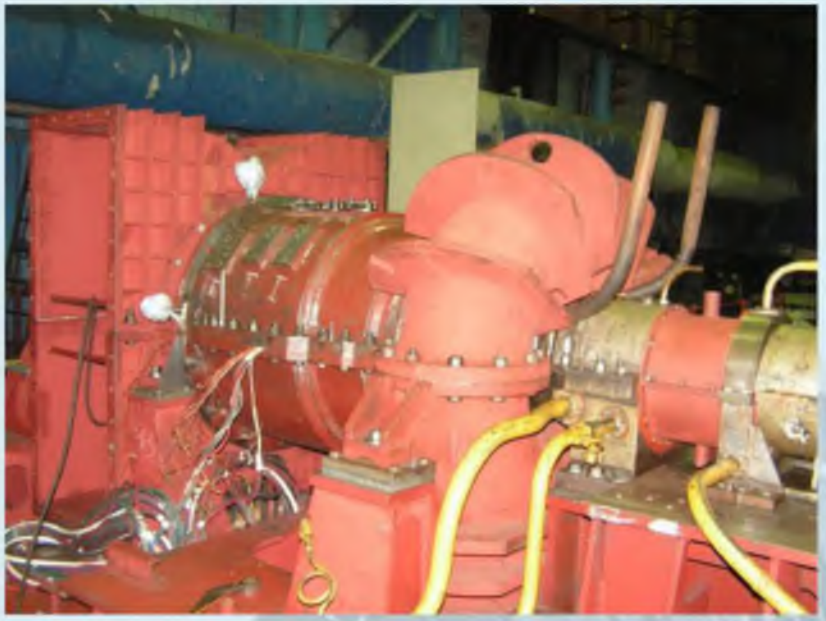
Laboratory of Compressor Units, Air Handling and Noise Suppression for Power Generating Equipment

Works Completed

On test bed No. 21206 the following is tested:

- CC model ГТЭ-150 made by LMZ JSC in scale 1:4.14 (G_m = 36.7 kg/s, π^*_c = 13, n = 12,420 rpm)
- model for first six CC stages ГТЭ-65 in scale 1:2.2332 (G_m = 36.27 kg/s, $\pi^*_{1\text{-}6}$ = 3.74, n=12,151 rpm).

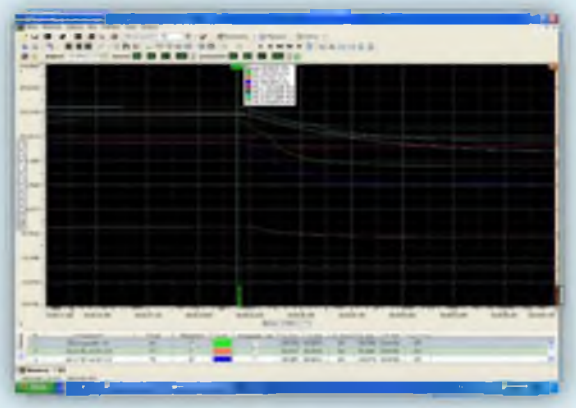
Models of rotor and compartment of compressor for plant GTE-65

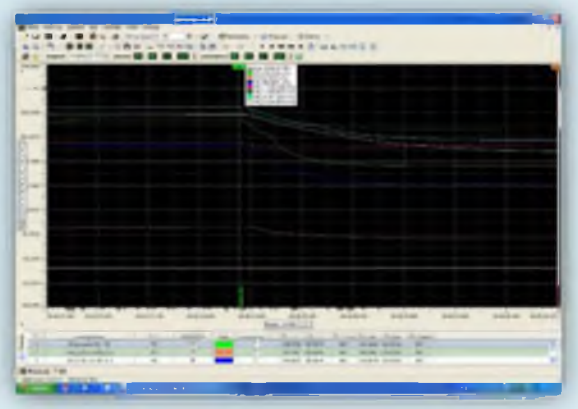


Turbine Units Research Department

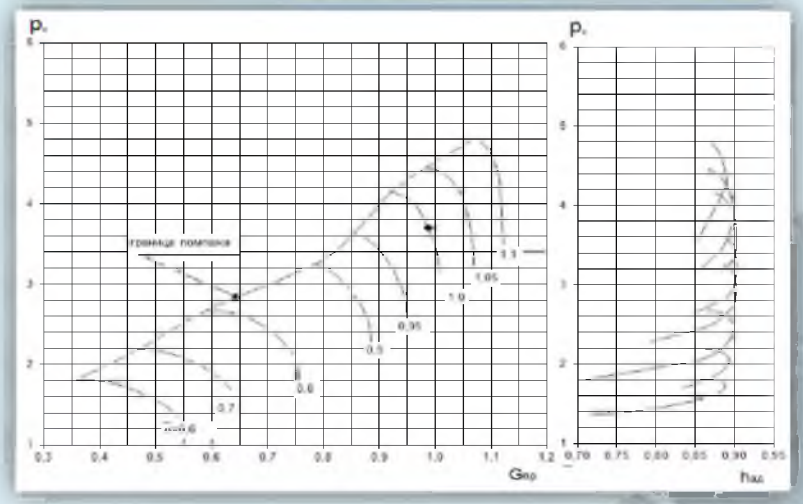
Laboratory of Compressor Units, Air Handling and Noise Suppression for Power Generating Equipment

System of plant operation parameter recording





Characteristics for 5 stages of model at initial angles of blade installation



Turbine Units Research Department

Laboratory of Compressor Units, Air Handling and Noise Suppression for Power Generating Equipment

Test beds for model researches of centrifugal compressors (21202 and 21203)

Test beds are intended for model researches of centrifugal compressors and natural gas blowers.
The drive is dc motors.
One test bed has drive with power of 700 kW and model rotor speed up to 20,000 rpm,
the second test bed has drive with power of 300 kW and model rotor speed up to 17,000 rpm,
The test beds are equipped with drive automatic control system with maintaining of the specified speed, as well as loading orifice with remote control. Models of almost all natural gas blowers of turbine building factories of the country have passed researched on these test beds.

Turbine Units Research Department

Laboratory of Compressor Units, Air Handling and Noise Suppression for Power Generating Equipment

Test bed No. 21201 for compressor tests

The test bed is intended for development and researches of compressor models or compartments at degree of pressure increase up to $\pi^*_c = 5 \div 6$.

The drive of compressor model is steam turbine with power up to 2.5 MW with maximum rotor speed up to 20,000 rpm.

The test bed is equipped with automatic control system of driven turbine and maintaining of the specified speed for compressor model, as well as surge protection and loading orifice with remote control.

Works Completed

On test bed No. 21201 the following was researched: models of compressors LPC ГТ-100, ГТК-10, ГТК-16 and ГТК-25, models of compressors for ferrous industry with turning of guide vanes during tests:

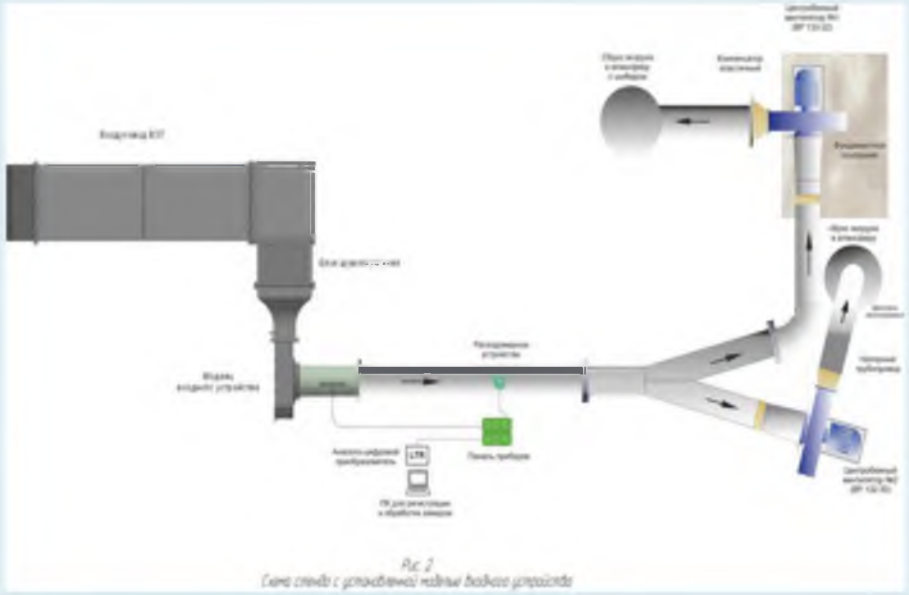
- model of the first 2 stages LPC-II (first stage is transonic);
- model from first three stages of compressor ГТН-25 TMZ (first two stages are transonic).

Turbine Units Research Department

Laboratory of Compressor Units, Air Handling and Noise Suppression for Power Generating Equipment

Test bed No. 21205 is intended to purge air inlet devices for compressors of gas turbine plant

Test Diagram



Model of air inlet path for GTE-110 made by UEC Saturn PJSC

Department on Service Life, Engineering Diagnostics and Repair Technologies of Power Equipment Metal

Main Activities of the Department

- Evaluation of mechanical features of steels and alloys with creation of deformation curves at the temperatures of **20–950 °C**.
- Creep-rupture tests with creation of creep-rupture curves and Larson – Miller parameter curves.
- Creep resistance tests with creation of isochronic creep curves at the temperatures of 600–950 °C. Creation of dependencies of creeping speed on stress at a current stage.
- Heat fatigue tests at different cycles with **T_{max}** up to **1200 °C** (with and without holding at **T_{max}**) of flat corset reference specimen in vacuum with monitoring of specimen surface structure and registration of occurring cracks.
- Technical diagnostics of metal in parts and units of operating equipment (dye penetrant inspections, eddy current tests, metallography of replicas, hardness tests).

And example of dye penetrant inspection

A crack on the teeth of the HP turbine GTK-10

And example of structures of metals obtained via metallographic replaces

Martensitic

Austenitic

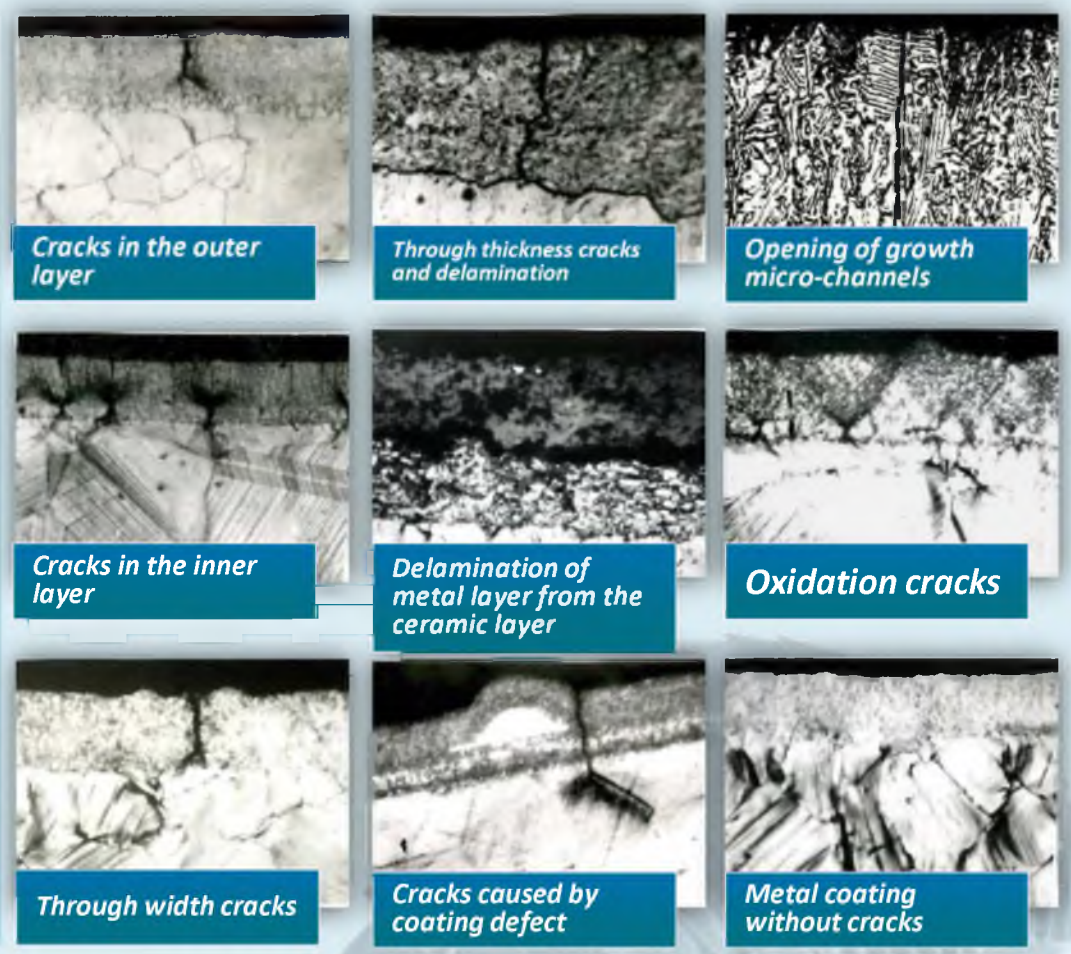
Ferritic-pearlitic

Department on Service Life, Engineering Diagnostics and Repair Technologies of Power Equipment Metal

Main Activities

- Corrosion tests in various media at the temperatures up to **900 °C**.
- Finite element evaluation of materials affected by stress strain at constant and cyclically varying temperatures and loads.
- Design evaluation of heat fatigue resistance of discs and blades of GTU with determination of their strength margin.
- Structural research of steels and alloys by digital optical metallography, electronic microscopy, phase and X-ray diffraction analysis, X-ray spectral analysis.
- Research on how strain ageing influences the kinetics of changes in structure, mechanical features, creep rupture strength, creeping, heat fatigue.
- Repair of steam turbine blades on the rotor in a power plant environment.
- Expert investigations in cases of destruction of blades and guide vanes in steam and gas turbines.
- Industrial safety investigations in the event of prolongation of gas turbine service life.
- Assessment of protective coatings according to NPO CKTI method.
- Estimation of speed with which fatigue cracks, creep cracks and heat fatigue cracks will grow.

Localization of heat fatigue cracks



Department on Service Life, Engineering Diagnostics and Repair Technologies of Power Equipment Metal

Work Completed By The Department In The Past 5 Years

1. Tom-Usinskaya SDPP (State District Power Plant), Novovoronezh NPP, Kemerovo Regional SDPP.

- Repair of blades on steam turbine rotors in the power plant environment.

2. JSC Klimov.

- Research of operability of single-crystal heat-resistant alloys used in turbine blades of helicopter engines under development.
- Optimization of metallurgical technology used in production of blades of HP turbine RD-33MK and its modernization.
- Research of corrosion resistance and heat fatigue resistance of single-crystal alloys ZhS32, VZhM4, VZhM-7, VZhA-21, VZhM5U, VIN.

3. **UEC Saturn.**

- Design of basic material and equipment technologies for combined cycle gas turbines based on high-power gas turbine units:
  - design of modern strength standards for stationary GTU parts;
  - creation of data base of features of heat-resistant steels and alloys used in gas turbine production;
  - development of new methods of non-destructive and destructive testing for evaluation of current condition of coatings and metal of parts and units of GTU after long periods of operation – with the aim to prolongate their service life;
  - creation of experimental service life evaluation method for gas turbine blades, which is based on studying the redistribution of elements in the surface layers of various points of blade body after long periods of operation;
  - improvement of strength evaluation method for gas turbine blades, which have aligned or polycrystal structure, as well as parts of low-emission combustion chamber, considering the influence of coating system.
- Development of measures aimed to eliminate defects of 1st stage blades on GTD-110:
  - optimization of chemical composition of ChS-88U alloy within the limits of alloy certificate;
  - comparative metallographic research of 1st and 2nd stage blades;
  - Metallographic research of defective blades (GTD-110 No. 5 and No. 6)of 1-4 stages of turbine with the aim to confirm the conclusions based on the research of defective blades of GTD-110 No. 3 and No. 4 performed by JSC “VTI”.

4. Gasenergoservis LLC.

- Industrial safety test report after prolongation of service life on GTK-10, GTK-10I, GTK-25I gas turbines.

5. Gazprom Transgaz Sankt-Peterburg LLC.

- Expert’s conclusions on causes of destruction of pipe sections.

Boiler Plant Department

Main Departments and Laboratories

- **Boiler Plant Design, Adjustment and Research Department:**
  - *Boiler Hydraulics, Separation and Boiler Unit Design Laboratory:*
    - *boiler equipment design group;*
    - *boiler hydraulics and separation group;*
    - *boiler unit metal structures group;*
    - *heat equipment lining, refractory brickwork and heat insulation group.*
  - *Fuel preparation and combustion laboratory.*
- **Department of industrial boiler plants and power saving:**
  - *furnace, industrial and heating boiler laboratory;*
  - *industrial power boiler and heat recovery boiler cleaning laboratory.*
- **Water chemistry sector.**

Boiler Plant Design, Adjustment and Research Department

Main Activities of the Department

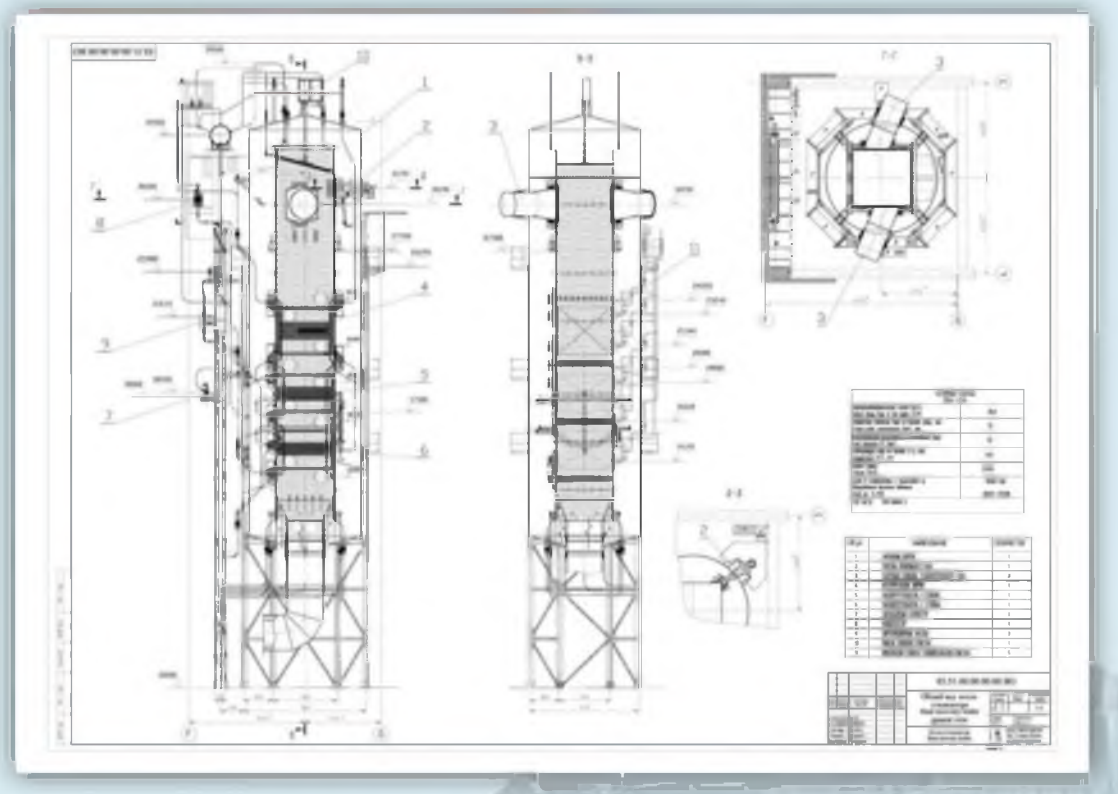
- Design of boiler units of various types and purposes, as well as their elements.
- Design of technologies to increase steam production capacity of boiler plants.
- Setup of boiler plants for lower steam conditions, extension of control range.
- Research and adjustment of hydraulics in various types of boilers and separators of drum boilers.
- Determination of causes of deposits in boiler pipes.
- Chemical heat tests and commissioning of utility boilers, heat recovery boilers, industrial power boilers.
- Thermal (including boilers with circulating fluidized beds), hydraulic, aerodynamic calculations; calculation of wall temperature.
- Research of metal structures, design of new projects and boiler and chimney shell recovery projects.
- Development of refractory brickwork, lining and heat insulation projects for boiler plants of various types and purposes and their elements, designer's supervision of installation, inspection, certification or linings and heat insulation of various boilers, boiler equipment, vessels and pipelines.
- Development and manufacturing of burner devices with various thermal powers, ignition safety devices, fuel nozzles, air valves, crushers, dust separators, screw feeders, fuel dozers and other auxiliary equipment.
- Development of mathematical models for creation of calculation methods aimed at designing boilers with steam production capacity of 220–420 t/h with circulating fluidized beds on low grade coal – for replacement of obsolete boilers.
- Creation of high-productivity crushing equipment and fuel conditioning systems for powerful power units with furnaces and gas generators with circulating fluidized beds, fluidized beds, and layer-type gas generators.
- Optimization of solid fuel gasification technology based on oxygen-steam blast under pressure – as the most prospective technology for creation of powerful combined cycle gas turbines (CCGT) with closed cycle coal gasification.
- Design, adjustment of fuel gasifier.
- Design, adjustment of pulverizing systems.
- Design of gas supply systems.
- Design, adjustment, blowdown on dust separator, dust concentrator, pulverized coal (single-cyclone and multiple-cyclone) collector models.
- Transition of power facilities to combustion of various types of solid, liquid and gas fuels.
- Erection supervision of equipment and operational tests for power units.
- Type and approval tests of burner devices with issue of burner certificate and declaration (certificate) of conformity to TR TS (Technical Regulation of Customs Union).
- Bench tests of power equipment (burners, combustion chambers).
- Burning tests of non-standard fuels.
- Selection of alternative coals for burning on thermal power plants, considering the features of boiler equipment.

Boiler Plant Design, Adjustment and Research Department

Boiler Hydraulics, Separation and Boiler Unit Design Laboratory

Boiler Equipment Design Group

- Activities aimed at creating new equipment.
- Modernization of operating equipment in order to increase reliability of heating surfaces, decrease of allowable load limits, increase of steam quality.
- Aerodynamic, thermal (including boilers with circulating fluidized bed furnace) calculations, calculation of wall temperature via proprietary software (TopHeat, Heat-KS, TSten-K, TSten-R). Thermal calculation in the licensed version of Boiler Designer software.



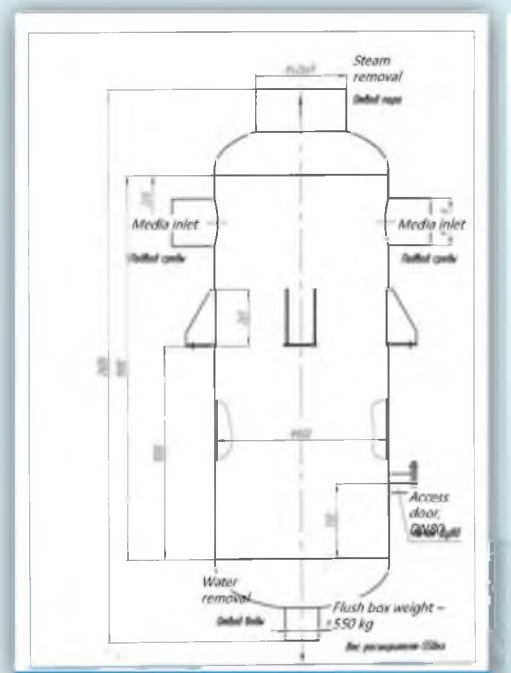
Boiler Plant Design, Adjustment and Research Department

Boiler Hydraulics, Separation and Boiler Unit Design Laboratory

Boiler Hydraulics And Separation Group

Main Activities

- Research and adjustment of hydraulics in various types of boilers and separators of drum boilers.
- Hydraulic calculations of once-through boilers, calculation of natural circulation and separators of drum boilers.
- Assessment of reliability of hydraulics and temperature conditions of heating surfaces in boilers.
- Development of detailed design documentation, production and supply of continuous blowdown flush boxes with corresponding support documentation.
- Development of detailed construction documentation for separators
- Determination of causes of deposits in pipes of various types of boilers.
- Chemical heat tests and commissioning.
- Circulation tests with the aim to verify the operational reliability of evaporating (circulation) circuit of boiler units.



HP flush box

The laboratory team has designed the HP flush box with the diameter of **800 mm** and the height of **2600 mm**. Design parameters of the flush box: pressure – 0.69 MPa. Temperature – **200 °C**, operating parameters: pressure – 0.12 MPa. Temperature – 104 **°C**.

In 2014, the flush box was manufactured by the Non-Standard Equipment Department of NPO CKTI JSC and delivered to the Severnaya Cogeneration Plant-21 of the Nevsky branch of JSC TGC-1 (Unit No. 1), passed the tests, obtained the Certificate of Conformity No. TS RU C-RU.AY04.B/00109 Series RU No. 0219465 and commissioned. In 2016, the flush box was delivered as a part of the Unit No. 2 of Severnaya Cogeneration Plant-21 and commissioned. Also, the order for the production of Unit No. 3 was made.

Boiler Plant Design, Adjustment and Research Department

Boiler Hydraulics, Separation and Boiler Unit Design Laboratory

Boiler unit metal structures group

Main Activities

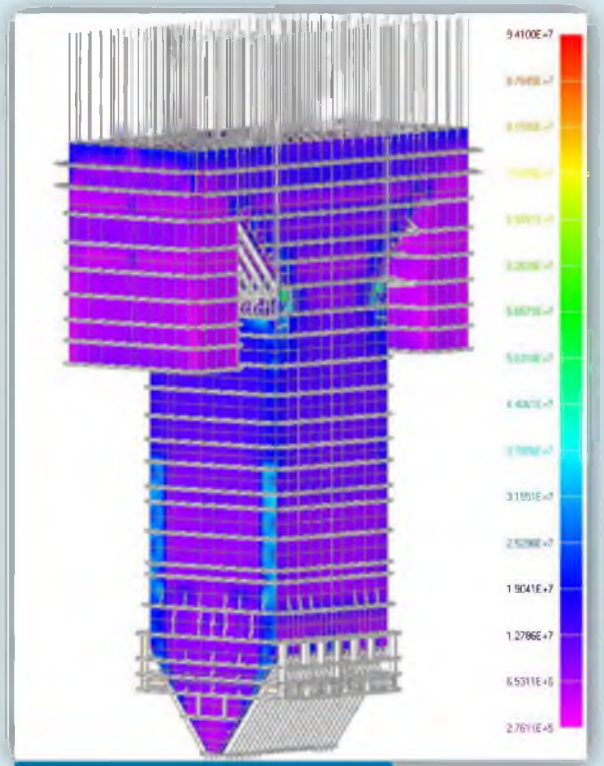
- Design of (rough, technical, detailed) of various metal structures, such as: power equipment frames, industrial power boilers and heat recovery boilers, chimney frames, plate structures (flues, ducts, bunkers, expansion bellows).
- Strength calculations for metal structures and gas-proof boiler chests exposed to operational, climatic and seismic loads.
- Inspection of frames of steam and hot water boilers, auxiliary boiler equipment, chimneys.
- Detection of damages, metal feature analysis of elements damages by heat exposure.
- Expert reports with recommendations on defect elimination.
- Design of restoration projects for damaged metal structures and technical guidance during implementation of these projects.

Industrial power boiler frame and chimney tower

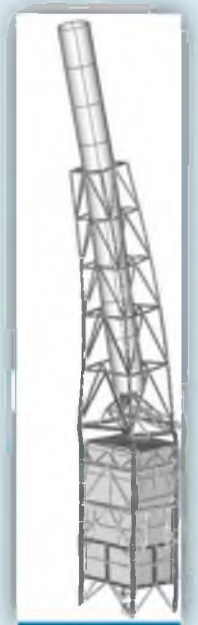
Boiler Plant Design, Adjustment and Research Department

Boiler Hydraulics, Separation and Boiler Unit Design Laboratory

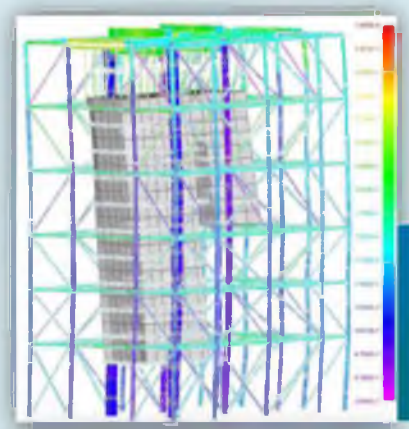
Boiler unit metal structures group



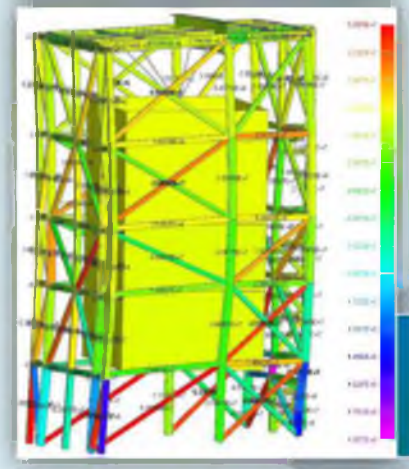
Gas-proof chest of P-67 boiler



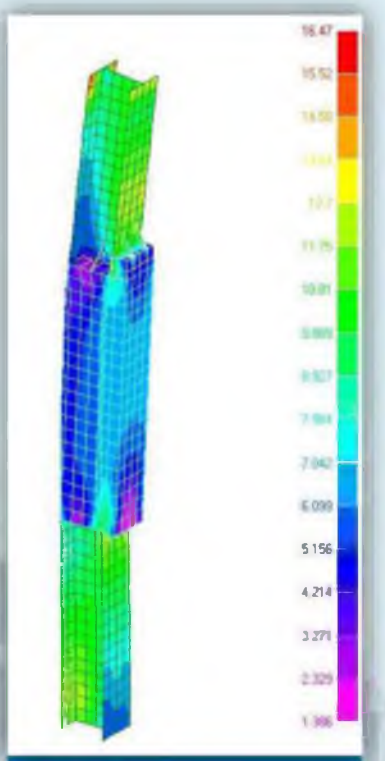
Calculation of seismic load on P-151 boiler



Calculation of seismic load on U-shaped boiler



Calculation of seismic load on P-151 boiler



Calculation of column reinforcement for TP-87 boiler

Boiler Plant Design, Adjustment and Research Department

Boiler Hydraulics, Separation and Boiler Unit Design Laboratory

Heat equipment lining, refractory brickwork and heat insulation group

- Implementation of refractory brickwork, lining and heat insulation projects for redesigned boiler units of various types and purposes of their elements.
- Implementation of refractory brickwork, lining and refractory brickwork restoration projects for the entire boiler plant or separate areas distinguished by low strength (boiler arches of any design, including studded burner arches covered by refractory mixture, manholes, ceilings, unshielded lining surfaces, etc.).
- Inspection of refractory brickwork of power boilers and heat insulation of pipelines, report on condition of heat insulation.
- Certification of heat insulation with the aim to reduce heat loss and increase efficiency of the equipment.

Boiler Plant Design, Adjustment and Research Department

Fuel Preparation And Combustion Laboratory

Main Activities Of The Laboratory

The fuel preparation and combustion laboratory takes leading positions in research, design, production of modern-class power-generating equipment and power units, as well as improvement of combustion systems designed for liquid and gas fuels for industrial power boilers, various types of furnaces, combustion chambers of gas turbine units and other facilities.

NPO CKTI JSC has designed standard schemes of highly-efficient low-toxicity combustion, which include:

- ***using specialized new generation low-toxicity burners;***
- ***low-excess air combustion;***
- ***staging of oxidizing medium (when burning natural gas);***
- ***recirculation of exhaust gas.***

By their features, the burners produced by NPO CKTI JSC compete with the best domestic and imported analogs. Each burner can be custom designed and produced to match the demands of each facility.

Burners with central gas distribution tube are used for various types of burners in a wide range of power capacities. Burners of this type with power capacity of 4 to 20 MW are installed in the furnace chamber walls (wall mounting, single-front, opposed, stacked configuration, etc.). Burners of this type are reliable and easy to operate. They ensure proper burnout and moderate emissions.

Oil-gas burners GMU-m with central gas distribution.

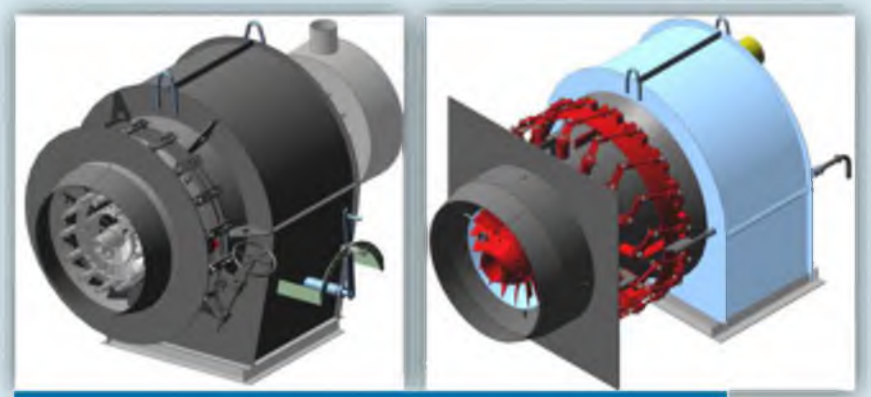
Burners with adjustable tubular gas feed are installed primarily in burners with steam production capacity of more than 75 t/h. Availability of adjustable gas distribution function, as well as air feed mode adjustability (redistribution of air flow to separate channels of the burner) allows changing the length and configuration of flame (the manner of temperature distribution in the flame core), influence the emission characteristics of the flame. **Adjustment** (multiple location arrangements of gas distribution nozzles of three calibers) **allows significantly reducing the emission of NOx, CO, soot**, influence the temperature of superheated steam. The laboratory has developed technical recommendations regarding installation angles of gas nozzles, which enable certain flame configurations.

The adjustment may be implemented by the NPO CKTI JSC experts during commissioning.

Boiler Plant Design, Adjustment and Research Department

Fuel Preparation And Combustion Laboratory

Oil-gas burner GMU-m with tubular gas distribution



Oil-gas burner GMU-m with adjustable blade row

NPO CKTI JSC has designed state-of-the-art burner devices for highly efficient low-toxicity combustion of blast-furnace gas, coke gas other types of associated gas in metallurgy.

Also, one of the example of using the NPO CKTI JSC burners in metallurgy is the introduction of powerful versatile pilot burner for sulfur furnace at the sulfuric acid production shop (Phosphorit plant (Eurochem Group), Leningrad Oblast, Phosphorit industrial zone).

Gas burner for burning blast-furnace and natural gases

Combined flat-flame gas burner for burning blast-furnace, coke and natural gases.

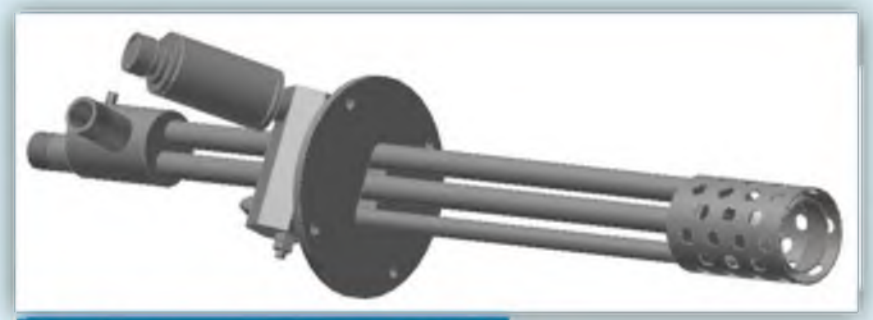
Boiler Plant Design, Adjustment and Research Department

Fuel Preparation And Combustion Laboratory

The burners are equipped with igniters and flame monitoring sensor.

As of today, ignition control devices ZZU-ZG-01 are used in many facilities of various types. For example, our ignition devices has been used for 10 years in igniting the burners of **Rostral Columns in Saint Petersburg.**

The igniter works according to the "flame-transition pipe" – it does not have a high-voltage electrode and stands out of electric igniters by combustion stability, safety, reliability and durability in operation. The spark unit is installed directly into the igniter.



Ignition control device ZZU-ZG-01

Operation of ignition control device in Rostral Columns

Boiler Plant Design, Adjustment and Research Department

Fuel Preparation And Combustion Laboratory

- First, installation on burners in the boiler is supervised, then, operational tests of power units are performed.
- After installation of burners in boiler flame-out tests are performed with various pressures of gas and air.
- NPO CKTI JSC designs and produces fuel nozzles, air valves and other auxiliary equipment and metal structures.
- Optimization of solid fuel gasification technology based on oxygen-steam blast under pressure – as the most prospective technology for creation of powerful combined cycle gas turbines (CCGT) with closed cycle coal gasification.

  Experimental facilities of the laboratory allow it to perform a wide range of scientific works, which a prerequisite for design of modern-class combustion chambers and burner devices.
- Trial operation of NPO CKTI JSC-designed solid fuel gasification unit in the pressurized oxidizer flow has confirmed a capability to obtain a high-calorie syngas suitable for using in gas turbine combustion chambers.
- NPO CKTI JSC experts have participated in design of practically all domestic gas turbine units. We have constantly been improving our testing facilities, creating new test bays for newly designed modern units.
- Design of burner installation on the boiler with distribution of waterwall tubes for the new burner arches.
- Design of gas supply systems.

Dust distributor

Gasification bed, a cabinet for oxygen or nitrogen racks.

Burner module with premixed gas/air function

Combustion chamber designed for starting a boiler that works with fluidized bed

Combustion chamber

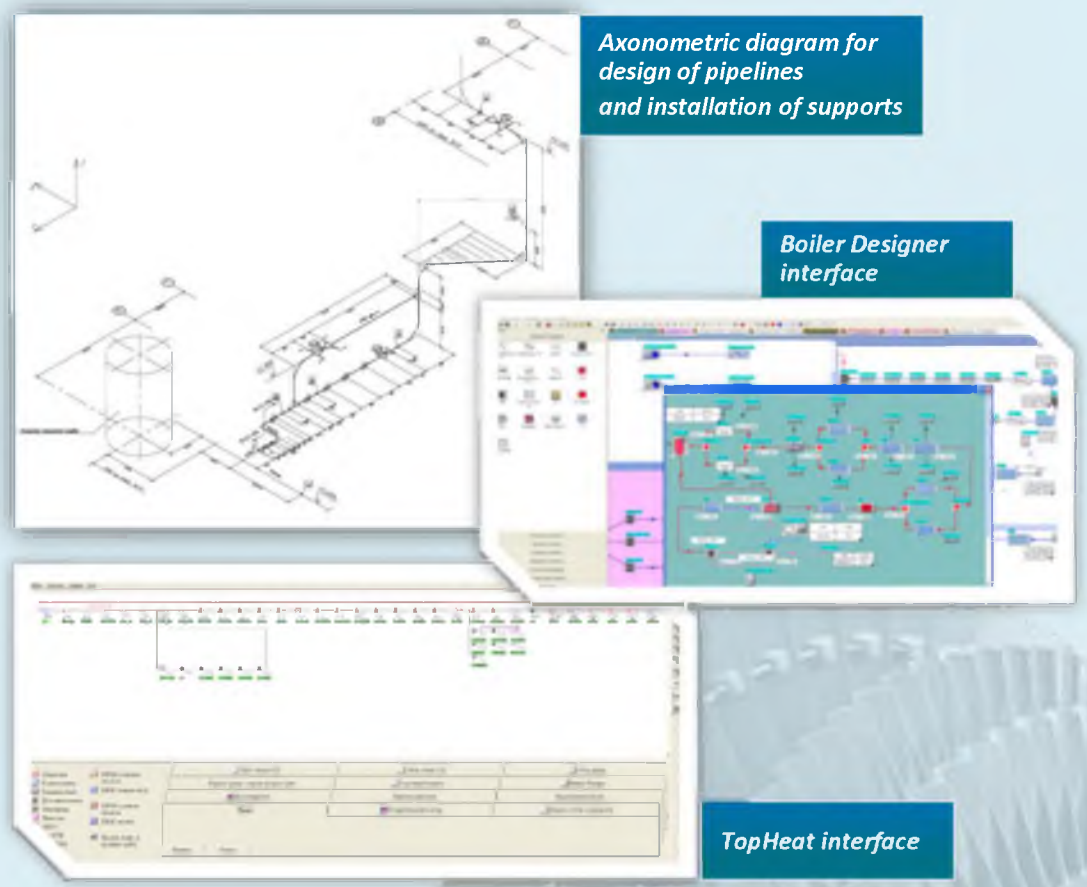
Burner for combustion chamber

Boiler Plant Design, Adjustment and Research Department

Fuel Preparation And Combustion Laboratory

Laboratory Software Base

- **TopHeat** – power boiler thermal design software (proprietary).
- **Heat-KS** – thermal design of boilers with fluidized bed and circulating fluidized bed (proprietary).
- **TSten-K** – temperature design of convective heating surfaces (proprietary).
- **TSten-R** – temperature design of radiant heating surfaces (proprietary).
- **Boiler Designer** – software for creation of controlled all-mode mathematical models of heat and power facilities.
- **Autodesk AutoCAD** – 2D and 3D computer-aided design system.
- **Askon COMPAS 3-D** – 2D and 3D computer-aided design system.
- **Kontur** – circulation design.
- **D-Pipe** – design strength analysis of pipelines at heat and nuclear power plants.



Axonometric diagram for design of pipelines and installation of supports

Boiler Designer interface

TopHeat interface

Boiler Plant Design, Adjustment and Research Department

Fuel Preparation And Combustion Laboratory

Works Completed

- Design of standard projects of boilers with circulating fluidized bed boilers for 225 MW power units with subcritical steam conditions (production capacity – 640 t/h, P = 13.7 MPa, t = 565 °C) and 330 MW units supercritical steam conditions (production capacity – 965 t/h, P = 24.2 MPa, T = 565 °C), development of testing program and operating manual for pilot plant with circulating fluidized bed; design of software for thermal design of boilers with circulating fluidized bed.
- Conversion of Igumnovskaya Cogeneration Plant into a boiler house and readjustment of boilers No. 8–9 for lower steam conditions – to supply heat energy to **Sintez OKA-ENERGO LLC** and other chemical cluster enterprises at Dzerzhinsk, Nizhny Novgorod Oblast.
- Design of fire suppression system for boiler back-end surfaces of boilers No. 2, 3, 4, 6 of Zakamskaya Cogeneration Plant – 5 as a part of conversion of power boilers of the cogeneration plant into oil burning equipment. As a part of this project, the laboratory has designed the fire suppression system for tubular air preheaters which utilizes water as the fire-prevention medium.
- Retrofitting of hazardous industrial facility – **Cogeneration PlantMondi Syktyvkar JSC** – installation of new continuous blowdown flush box. Syktyvkar, Komi Republic.
- Retrofitting of CKTI-75-39F2 boiler of plant No. **10 at cogeneration plant of SC "CHEPETSKY MECHANICAL PLANT"** with conversion into natural gas burning equipment. Glazov, Udmurt Republic.
- Retrofitting of **Simon Carves** boiler No. 3**, NLMK Group,** as a part of restoration of convection part performed with the aim to lower the temperature of flue gases and increase its cost efficiency.
- Modernization of continuous boiler blowdown system for Riley Stoker-type boilers at plant No. 2 and CKTI-75-39-F2-type boiler of plants No. 3–5 at the cogeneration plant of **JSC EnSer. Miass**, Chelyabinsk Oblast.
- Introduction of two-stage evaporation system at plant No. 5 of CKTI-75-39-F2 type at the cogeneration plant of **JSC EnSer** as a part of retrofitting project aimed to eliminate the causes of damage of waterwall pipes at saline sections of the boiler. Miass, Chelyabinsk Oblast.
- Retrofitting of heat recovery boiler of the first processing line of Melting Shop No. 1, **JSC "Metallurgical plant n/a A. K. Serov"** – replacement of spring-loaded safety relief valve with pulse safety device aimed to make the boiler comply with modern industrial safety requirements. Serov, Sverdlov Oblast.
- Retrofitting of TP-87 boiler of plant No. 9, **West-Siberian Cogeneration Plant**, aimed to introduce the combustion of secondary gases – byproducts of metallurgical production **at EVRAZ ZSMK.** Novokuznetsk, Kemerovo Oblast.

Boiler Plant Design, Adjustment and Research Department

Fuel Preparation And Combustion Laboratory

Works Completed

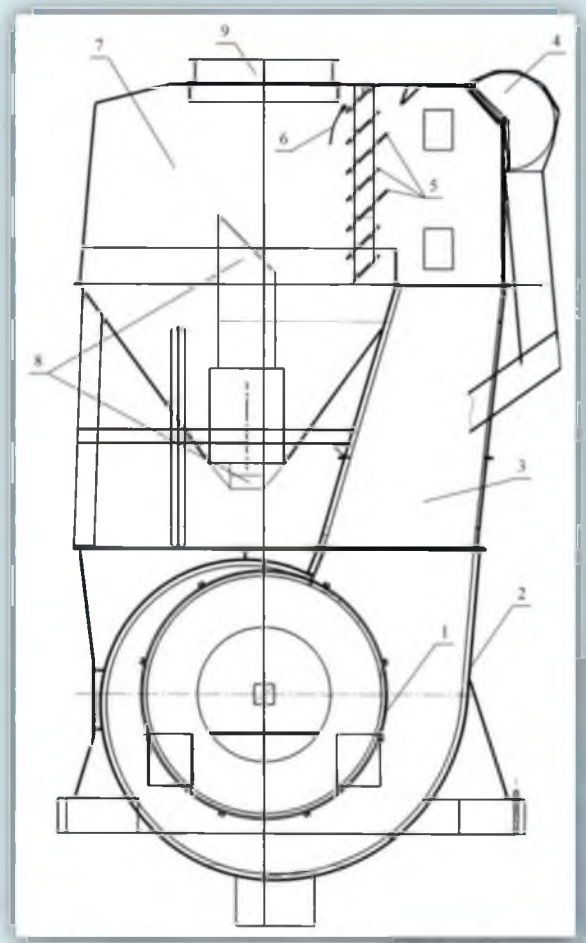
- Reestablishment of optimal hydraulic mode of LP steam/water circuit for heat recovery boiler KGT-45/6,7-450-15/0,9-270, gas turbine power plant, **Novy Urengoy Gas and Chemical Complex,** VIS Group. The project included selection of circulation pumps required for this circuit, design of pipeline hanger-support system of HP and LP circuits. Novy Urengoy, Yamal-Nenets Autonomous Okrug.
- Retrofitting of E-220-9,8-540GD boilers at **Utility Cogeneration Plant of NLMK Group** – surface extension of second-stage water economizer, which lowered the temperature of flue gases and raised efficiency. Lipetsk.
- Retrofitting of boiler, plant No. 6 (TP-230-2), **Cogeneration Plant of NLMK Group** – surface extension of second-stage water economizer to lower the temperature of flue gases and raise efficiency. Lipetsk.
- Retrofitting of boilers at plants No. 6 and 7 (BKZ-210-140), **Steam-Air-Thermal Power Plant of PAO Severstal** – surface extension of second-stage water economizer and setup of condensate and feed water injection system, which extended the load range and lowered the temperature of flue gases behind boilers and raised efficiency. Cherepovets, Vologda Oblast.
- Experimental burning of coal from Zheronsky coal deposit in the boiler plant BKZ-420-140 PT-2. Development of experimental system for monitoring circulation reliability and thermal conditions. Experimental burning of pure coal from Zheronsky coal deposit within the operating steam load range, including circulation tests and thermal conditions. Ust-Ilimsk, Irkutsk Oblast.
- Drum replacement as a part of retrofitting of boiler at plant No. 14 (TP-82), **Omsk Cogeneration Plant-3** with the aim to lower air suction, improve thermal features of the boiler, lower fuel oil consumption, increase the reliability of firing-up process.
- Design of technical solutions for restoration of intermediate pressure evaporating circuit in the heat recovery boiler of PGU-410 unit, **Krasnodar Cogeneration Plant. Taganrog**.
- Hydrodynamic research (of circulation and separation) of small-size low and medium power boilers with steam production capacity of 50.75 and 100 t/h, pressure of 1.4 and 3.9 MPa, to analyze the structure of circulation circuits and separation devices inside the drum and to issue recommendations on raising their reliability in operation. **PJSC "Krasny Kotelshchik",** Barnaul branch.
- Correction of Detailed Design Documentation for HP boilers F7701-F7901 by Hohenthurm. **OOO Novy Urengoy Gas Chemical Complex, OAO VNIPIneft, Novy Urengoy, Yamalo-Nenets Autonomous Okrug.**
- Establishment of minimum load E-2 of steam boiler BKZ-75-39FB. **Vilnius, Lithuania.**
- Development of operating manual for boiler units of plants Nos. 21, 22, Pr-228/47-7,86/0,62-515/230 (PK-59), power unit No. 2. Pravoberezhnaya Cogeneration Plant, **Saint Petersburg.**
- Hydraulic analysis of boiler unit P-49 with the aim to find out the cause of pipe damageability and develop a set of activities to eliminate these causes. Inspection of hydraulic and thermal conditions of front waterwall of P-49 boiler in operation, building 7A **Nazarovskaya Regional SDPP. Nazarovo.**
- Introduction of boiler chemistry system at the branch of **Nevinnomyssk Regional SDPP, Enel Russia. Nevinnomyssk.**
- Restoration project of 67-boiler aimed to set up operation at lower parameters within 30-120 t/h range – to supply energy to the department**Shekinskaya Regional SDPP, branch of PJSC "Quadra – Power Generation". Sovietsk.**
- Design of drum separators with the diameter of 1600 mm and circulation analysis for the boiler TP-100, **Lugansk TPP, OOO DTEK Vostokenergo. Lugansk, Ukraine.**
- Development of detailed design of separators for steam boilers F-06-5101/5102, **Klaipėdos Nafta, Klaipeda, Lithuania.**

Boiler Plant Design, Adjustment and Research Department

Fuel Preparation And Combustion Laboratory

Works Completed

- For JSC "TYAZHMASH", the laboratory has developed technical solutions regarding design of powerful coal mills with capacity of 80 to 120 t/h for Chinese power plants (Yimin TPP, Jiutai TPP, etc.), Laos (Honsha TPP), India (Neyveli TPP) etc.
- The laboratory has developed technical solutions on the design of static and dynamic separators for MVS-265Ts mills designed for producing a finished product from the ground cement clinker.
- The laboratory has developed a small-size separator for hammer mills to process high-volatile bituminous and brown coals. The aforementioned separators form a part of boilers in 210 MW and 215 MW units of Gusinoozyorskaya Regional SDPP, boilers of Blagoveshenskaya Cogeneration Plant, boilers with production capacity of 420 t/h, boilers of Nazarovskaya Regional SDPP with production capacity of 270 t/h, etc.
- This equipment was designed based on mathematical modelling and state-of-the-art software with evaluation of full-scale models. The example can be seen at illustrations of static centrifugal separator for MVS-265 manufactured for Barh TPP(India).



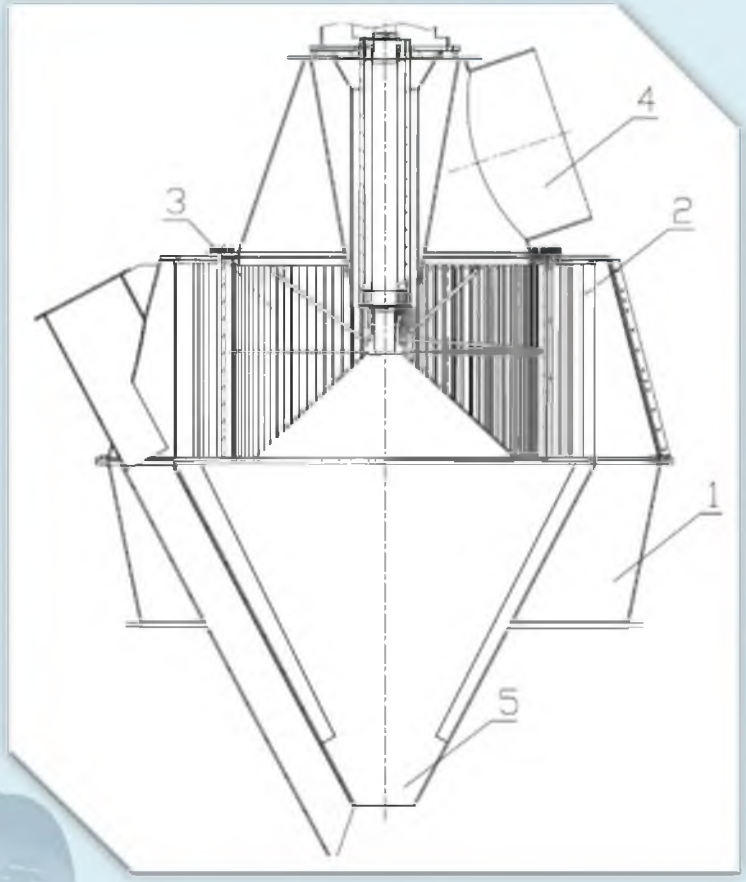
1. Rotor
2. Mill body
3. Separator feed manifold
4. First stage of under-milled fuel return
5. Static guide blades
6. Control valve
7. Separation chamber
8. Second stage of under-milled fuel return
9. Outlet manifold for processed dust

The image features a coal mill with inertial separator manufactured for Honsha TPP (Laos). These separators form a part of boilers for 600 MW power units

Boiler Plant Design, Adjustment and Research Department

Fuel Preparation And Combustion Laboratory

Works Completed



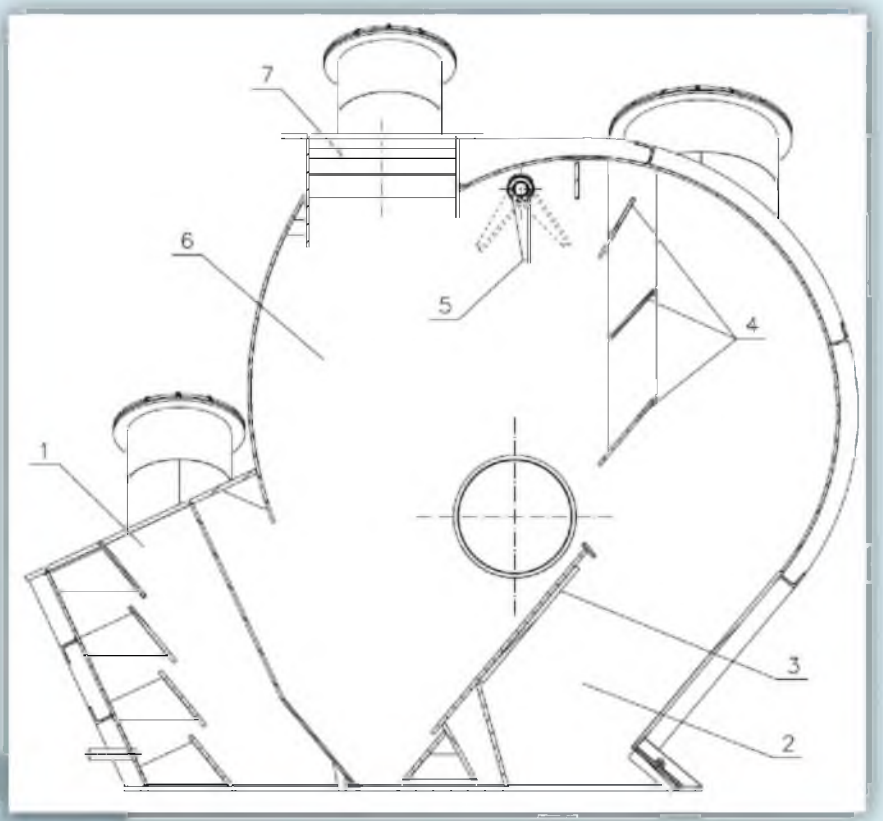
1. Annular inlet for milled product
2. Static guide blades,
3. Rotor with blades
4. Outlet manifold for processed product
5. Under-milled product return bunker

The image features a dynamic separator for MVS 265Ts mill designed for producing a finished product from the ground cement clinker.

Boiler Plant Design, Adjustment and Research Department

Fuel Preparation And Combustion Laboratory

Works Completed



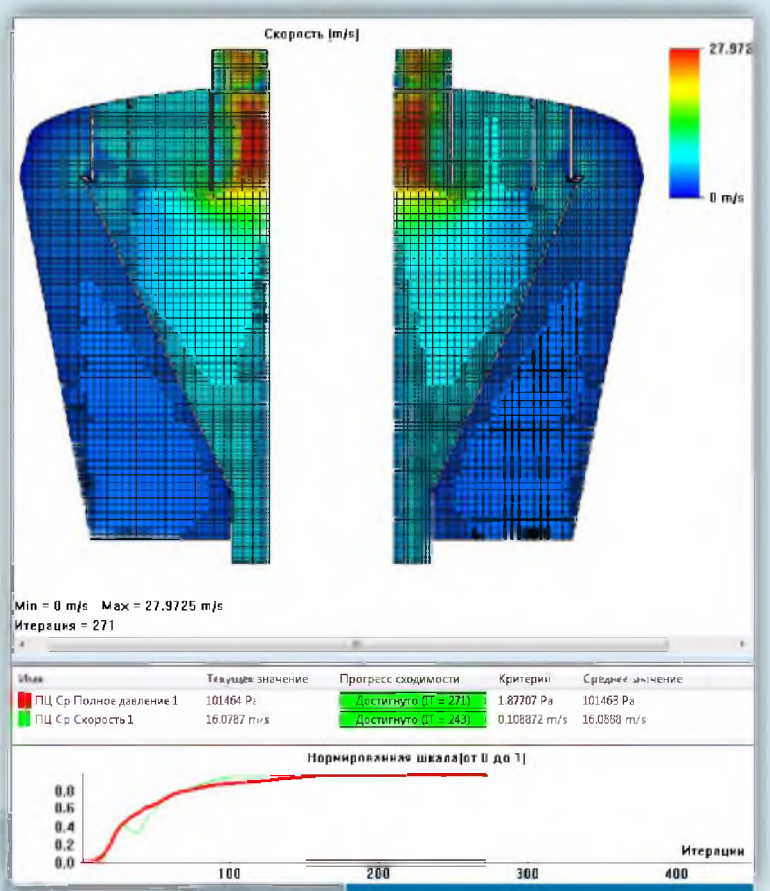
1. Inlet manifold for fuel and drying agent,separator inlet manifold
2. Baffle plate
3. Static guide blades
4. Control valve
5. Separation chamber
6. Separator outlet manifold

The image features small-size inertial separator for hammer mills

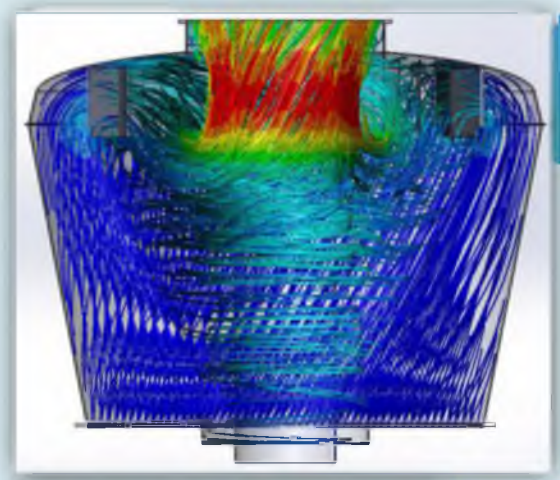
Boiler Plant Design, Adjustment and Research Department

Fuel Preparation And Combustion Laboratory

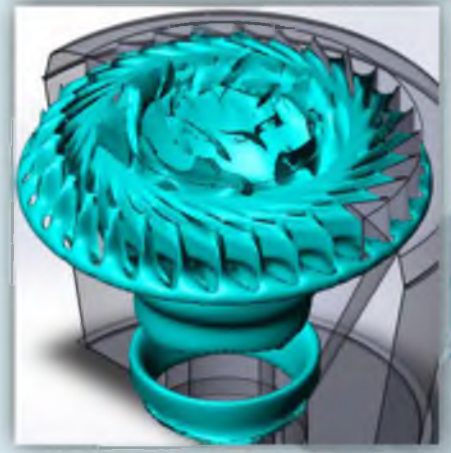
Works Completed



The model design process in the gas-hydrodynamic research



The results of calculations of air-dust mixture streamlines in the separator

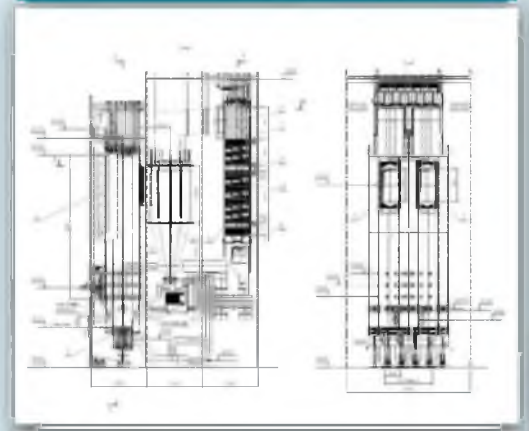


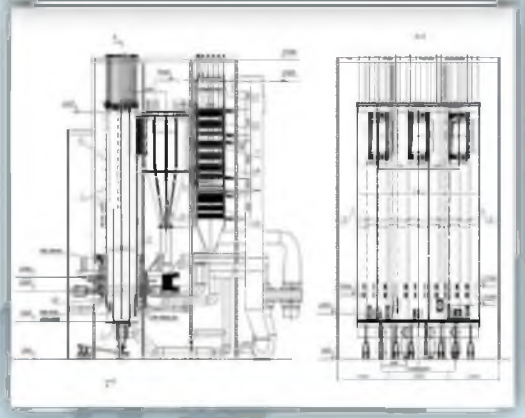
High-speed isosurface of air-dust stream in the zone where the stream gets away from the separator guide vanes, which was used to further optimize the shape of the above mentioned guide vanes.

Boiler Plant Design, Adjustment and Research Department

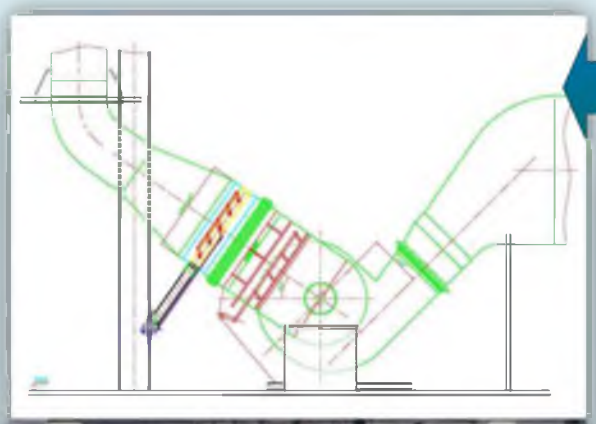
Fuel Preparation And Combustion Laboratory

Engineering design of boilers with circulating fluidized bed furnace on request by Minenergo (Ministry of Energy of the Russian Federation)



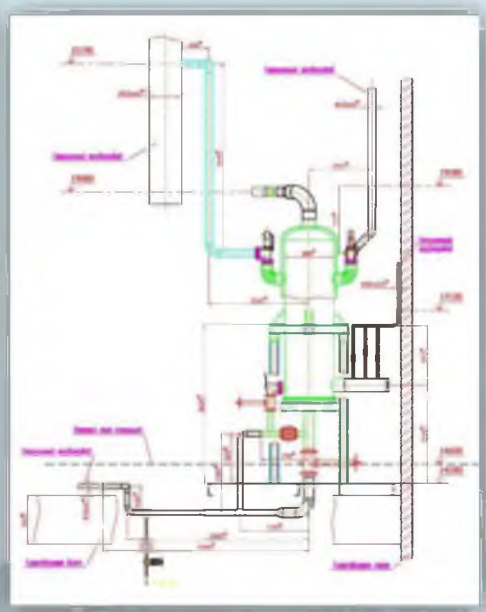


Works Completed



Installation of 06 PGVU 299-80 valves with actuators in the induced draft fan rarefaction path as a part of retrofitting of 67-SP boiler.

HP steam boilers F7701, F7801, F7901



Installation of continuous blowdown flush box with process piping

Department of Industrial Boiler Plants and Power Saving

Furnace, Industrial And Heating Boiler Laboratory

Main Activities Of The Laboratory

Creation and improvement of boiler equipment for industrial, public and small energy needs, burner devices and combustion chambers for gas and liquid fuels, process fuels, gas and liquid compounds, low-calorie gas and liquid multicomponent industrial waste, furnace devices for burning solid fuels (in the regular layer and using a fluidized bed burning technology) related to steam and hot water industrial boilers and power units:

- development of detailed design documentation for industrial steam and hot water boilers for solid, liquid and gas fuels, domestic and vegetative waste – for their production in house and by other enterprises;
- design of waste treatment and industrial boiler equipment for various industries (metal, chemical, oil processing, petrochemical, etc.);
- design of waste treatment, industrial power and energy saving equipment based on research in energy savings, energy combining and data on development of various industrial sectors;
- design, supervision of production and installation, adjustment of waste treatment equipment for sewage sludge burning factories;
- research and development of prospective elements of waste treatment equipment (such as heat pipes, cyclone furnace, etc.);
- development of regulatory documents;
- certification testing.
- modernization of operating furnaces;
- participation in development of energy technology systems that strongly rely on heat and combustible waste products.

Department of Industrial Boiler Plants and Power Saving

Furnace, Industrial And Heating Boiler Laboratory

The laboratory has qualified specialists in research and development, years of experience in design and production in cooperation with factories representing the industry of industrial steam and hot water boilers, heat recovery boilers, furnaces and other industrial thermal equipment.

Works Performed

- All works related to creation and restoration of any LP and IP boilers.
- Extension of service life of steam boilers.
- Resetting of boilers to water-heating mode.
- Resetting of heating equipment to lower steam conditions, as well as lower and higher steam production.
- Readjustment of boilers for burning other types of fuels.
- Improvement of environmental indicators of boilers.
- Thermal, aerodynamic, strength and other calculations of boilers.
- Examination of industrial safety of projects and equipment.
- All types of tests, including certification tests.

Department of Industrial Boiler Plants and Power Saving

Furnace, Industrial And Heating Boiler Laboratory

Low and intermediate-power boilers with fluidized bed furnace units for burning low-grade and biological fuels

Fluidized bed *is the technology designed to ensure high process and environmental performance when burning low-grade fuels, including biofuels (peat, various types of wood waste).*

KE-10-14 boiler with fluidized bed furnace for burning wood waste

Under assembly

After commissioning

Start-up devices

Combustion liners of diesel fuel start-up chambers

Start-up device of KE-25-24-350 boiler

Fuel feed units

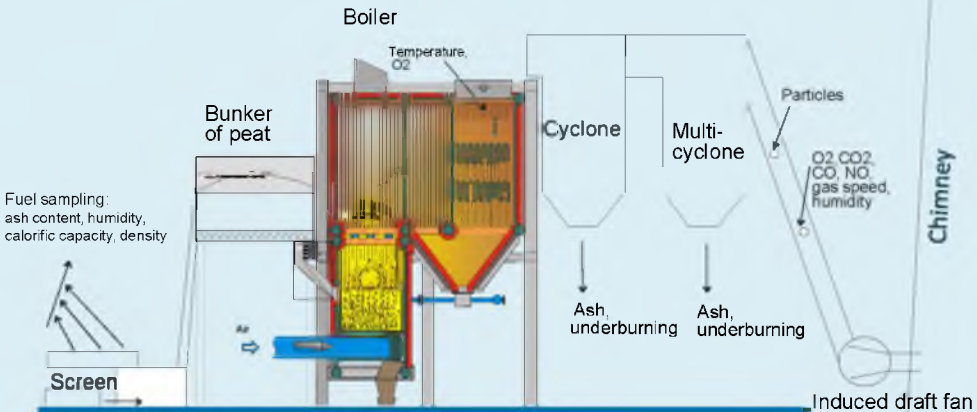
Mechanized fuel warehouse

Feed bin with feeder

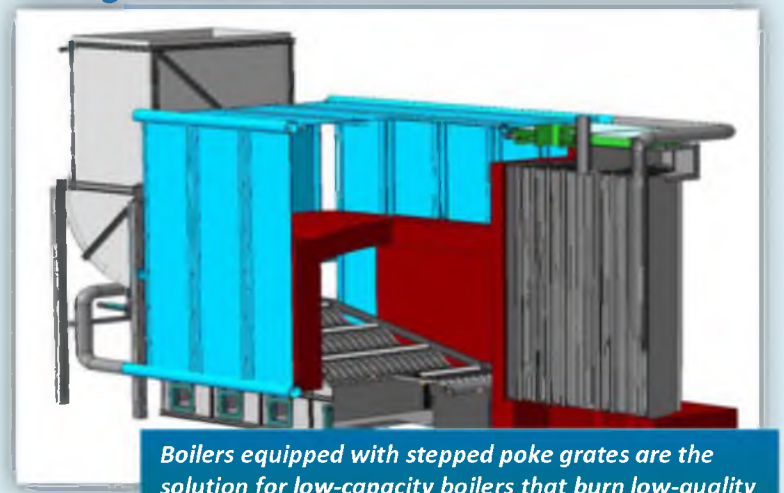
Department of Industrial Boiler Plants and Power Saving

Furnace, Industrial And Heating Boiler Laboratory

Low and intermediate-power boilers with fluidized bed furnace units for burning low-grade and biological fuels

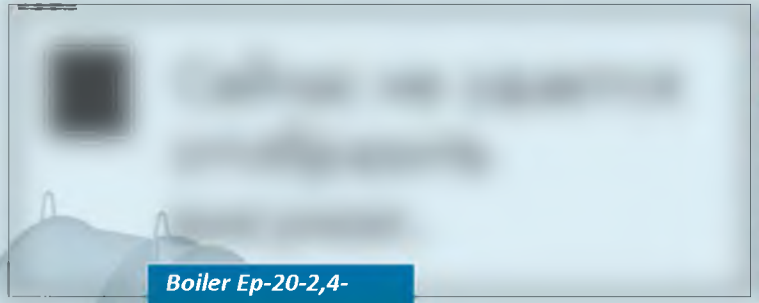


Milled peat and wood waste burning boiler KVD-5,5-125, AS «ELVESO», Jüri, Estonia

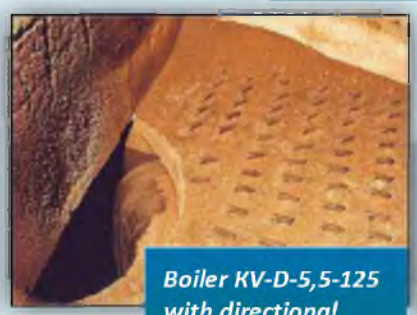


Boilers equipped with stepped poke grates are the solution for low-capacity boilers that burn low-quality biofuel

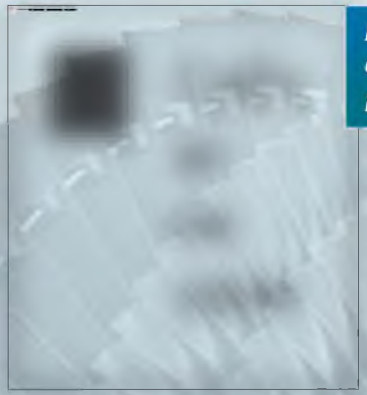
Fluidized bed grates



Boiler Ep-20-2,4-350, bubble type, in production



Boiler KV-D-5,5-125 with directional bl... bubble caps



Boiler grate chest Ep-20-2,4-350

Department of Industrial Boiler Plants and Power Saving

Furnace, Industrial And Heating Boiler Laboratory

Fuel combustion technology in the high temperature fluidized bed (HTFB)

NPO CKTI JSC has designed and put into production a range of HTFB furnace devices for installation under steam and hot water boilers with heat capacity of 3 to 58 MW. HTFB furnaces by NPO CKTI JSC comply with the strictest reliability, mechanical strength and operability requirements.

General view of boiler KV-P-58, 2-150 heat capacity of 58.2 MW – first boiler of a new series of hot water boilers created by NPO CKTI JSC in cooperation with Public Corporation «Dorogobuzhkotlomash».

1. Furnace device (narrow angled mobile stoker grate)
2. Fuel feed unit
3. Limestone feed system
4. Furnace chamber
5. First stage separator (labyrinth type)
6. Convection part
7. Second stage separator (multi-cyclone)
8. Ash reinjection device
9. Piping system

HTFB furnace with thermal capacity of 7.56 MW

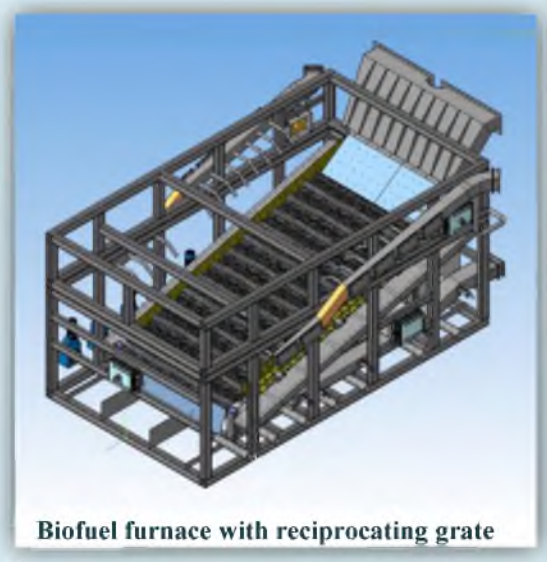
Department of Industrial Boiler Plants and Power Saving

Furnace, Industrial And Heating Boiler Laboratory

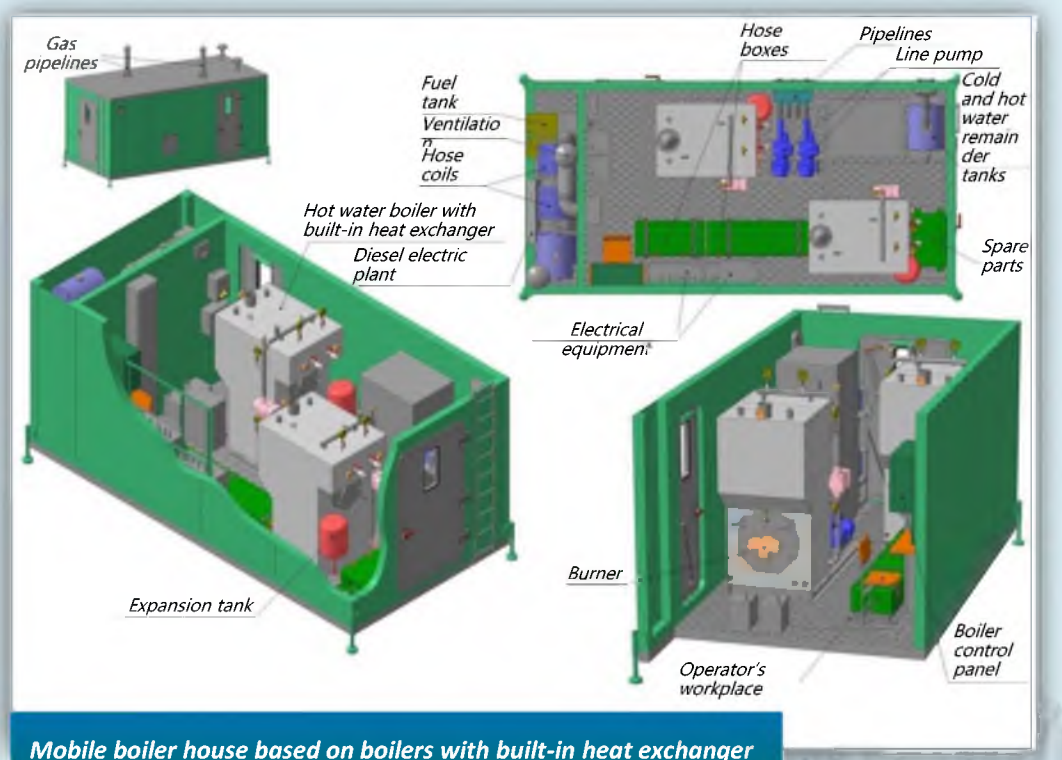
Low and intermediate-power boilers by NPO CKTI JSC with fluidized bed furnaces

The furnace with reciprocating grate was designed for installation under the steam boiler with saturated steam production capacity of 12 t/h. Litter waste is used as a fuel.

Biofuel furnace with a reciprocating grate



Biofuel furnace with reciprocating grate

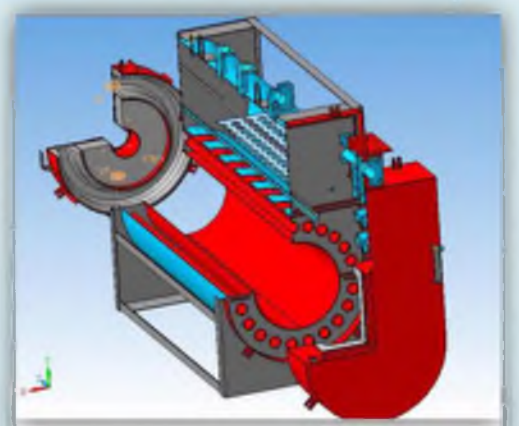


Mobile boiler house based on boilers with built-in heat exchanger

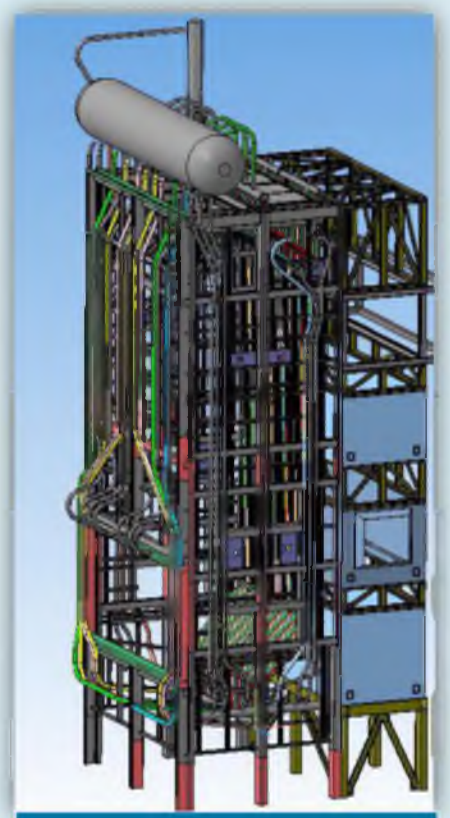
Department of Industrial Boiler Plants and Power Saving

Furnace, Industrial And Heating Boiler Laboratory

Low and intermediate-power boilers by NPO CKTI JSC with fluidized bed furnaces



Shell-type steam boiler KP 0,12 (steam production capacity – 0.2 t/h)



E-50 3,9 440 steam boiler for burning wood waste

Steam boiler installation E-50 3,9 440

Piping of E-50 3,9 440 boiler drum

Department of Industrial Boiler Plants and Power Saving

Furnace, Industrial And Heating Boiler Laboratory

Low and intermediate-power boilers by NPO CKTI JSC with fluidized bed furnaces

No.	Facility	Boiler	Qty	Unit thermal power, MW	Fuel	Year commissioned
1.	Kietaviškės, Lithuania AB Dominga Hardwood	KE-10-14	1	6	Wood waste	2004
2.	Marijampolė, Lithania, «Marijampolės, RK	KE-25-24-350	1	16	Wood waste	2005
3.	Plunge, Lithuania, AB Plunges Bioenergija	KE-25-24-350	1	16	Wood waste	2006
4.	SInyachikha, Sverdlovsk Oblast, plywood factory, ZAO Fankom	KE-25-24-350	1	15	Wood waste	2006
5.	Maksatikha, Tver Oblast, Maksatikhinsky DOK	GM-50-1	1	32	Wood waste	2006
6.	Vileyka, Belarus, Vileyskaya Mini-Cogeneration Plant based on RK-3 MES	KE-25-24-350	1	16	Wood waste	2007
7.	Verkhnyaya Sinyachikha, Sverdlovsk Oblast, plywood factory, ZAO Fankom	Ep-20-2,4-350	1	15	Wood waste	2008
8.	Beloozyorsk, Belarus, Open Joint Stock Company “Beloozersky Energomehinichesky Zavod”	E-30-3,9-440	1	19	milled peat, wood waste, lignin, brown and bituminous coal	in production

Department of Industrial Boiler Plants and Power Saving

Furnace, Industrial And Heating Boiler Laboratory

Low and intermediate-power boilers by NPO CKTI JSC with fluidized bed furnaces

No.	Facility	Boiler	Qty.	Unit thermal power, MW	Fuel	Year commissioned
9.	Kedrovy, Krasnoyarsk Krai	KV-TS-10	4	11.63	Coal from Irsha-Borodinsky deposit	2005
10.	Anadyr, Chukotka National Okrug	KV-RF-7.56	5	7.56		2005
11.	Zaplyusye, Pskov Oblast	DKVR-6.5-13	1	7.0	Kuznetsky 1CC coal	2005
12.	Kyzyl, Chuvash Republic	KV-RF-11.63-115	4	11.63	Products from Kyzyl-Tashtyg deposit	2010
13.	Shalym, Kemerovo Oblast	DKVR-10-13	1	7.0	Bituminous coal from Kuznetsk Basin, (Kyrgayskaya mine)	2011
14.	Tashtagol, Kemerovo Oblast	DKVR-6.5-13	1	5.5	Bituminous coal from Kuznetsk Basin, (Kyrgayskaya mine)	2013
15.	Gramoteino, Kemerovo Oblast	KV-RF-29 150 (CKTI)	1	29	Bituminous coal from Kuznetsk Basin, (D grade) 0–6 mm size coal (DSSh grade).	2014

Department of Industrial Boiler Plants and Power Saving

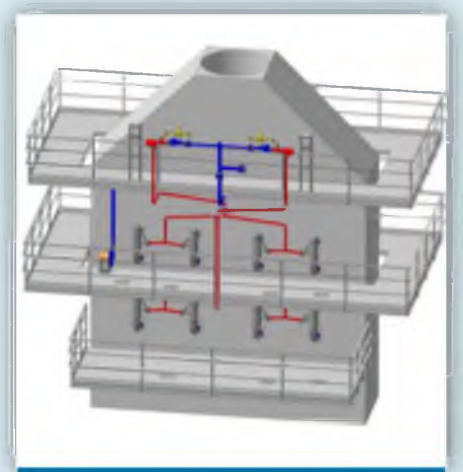
Industrial power boiler and heat recovery boiler cleaning laboratory

Activities Of The Laboratory

Design, research and modernization of pulse cleaning devices (gas pulse cleaning (GPC) and pneumatic pulse cleaning (PPC)) of heating surfaces of boilers and power equipment, including cleaning devices for outdoor design in various climatic conditions.

Works Performed and Equipment

Design, production, supply and commissioning of pulse cleaning devices for Russian and foreign heat energy and oil processing industries.



3D model of GPC system on the furnace

GPC system on IZOMALK-2 unit, JSC Gazpromneft – Omsk Refinery, 2011

GPC system on the heat recovery boiler, LUKOIL Neftokhim Burgas AD, Bulgaria, 2014

Water Chemistry Sector

Main Activities Of The Sector

- Organization of steam turbine plant element protection (turbine plant flow path, high pressure heaters) in the area of phase transfer due to erosive and corrosive wear.
- Chemical flushing of flow part in the turbine of power unit with supercritical pressure from water-insoluble deposits in process.
- Increase of corrosion reliability for steam heat exchangers of Thermal Power Plant.
- Optimisation of water chemistry for high pressure drum boilers. Resetting of boilers to the non-hydrazine water chemistry.
- Refusal to use of high-toxic chemical reagent hydrazine-hydrate relating to the 1st hazard class – to comply with modern environmental safety standards.
- As a result of implementation of water chemistry without hydrazine the following occurs: reduction of operating costs for production of steam and lowering of electric energy prime cost; increase of environmental safety for operation of equipment at thermal power plants.
- Optimisation of water chemistry for power units with supercritical pressure.
- Chemical heat tests of steam and heat water boilers, heat recovery boilers, deaeration and water treatment units with compilation of Parameter Tables, Water Chemistry Guidelines that comply with requirements set in RD 10-179-98 and RD 10-165-97 (Rostekhnadzor). Optimization of water chemistry.

  Similar operations for HP and SCP boilers in compliance with SO 153-34.20.301 (RD 34.20.301) and RD 153-34.1-37.313-00 (OAO RAO UES).

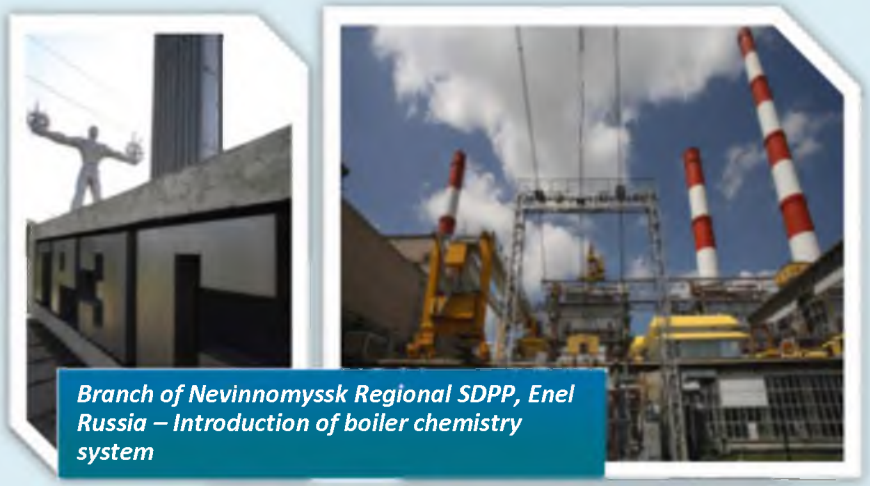
- Technical audit of water chemistry. Analysis of damage causes in boiler, turbine and heat exchange equipment of all types operating at different water chemistry conditions and makeup water treatment methods.

  The results:
  - preparation of Reports on water chemistry condition;
  - water chemistry effectiveness assessment;
  - development of recommendations on optimization of water chemistry, extension of service life of equipment, improvement of environmental characteristics;
  - development of recommendations on optimization of water chemistry in case of non-deaeration cycle arrangements, at which SCP power unit water undergoes oxygenated treatment;
  - development of recommendations on optimization of chemical monitoring of water chemistry.
- Development of preservation, chemical purification technology for heat and power equipment considering its operating modes and water chemistry applied.
- Optimization of water chemistry in water cycle of cogeneration plants.

  The results:prevention of scale formation and corrosion of water cycle equipment.
- Optimization of water chemistry on steam/water path of CCGT, closed and open CCGT cooling circuits.

Water Chemistry Sector

Works Completed



Branch of Nevinnomyssk Regional SDPP, Enel Russia – Introduction of boiler chemistry system

CCGT Cogeneration Plant "GSR TETs", Kolpino, heat chemical tests of equipment at power unit No. 1

Examples of water chemistry monitoring devices

Advanced Development Department

Activities of the Department

1. Design of equipment for subsea hydrocarbon process systems.
2. Development of prospective technologies in various sectors of economy.
3. Testing of power equipment of various classes and purposes at universal **test bed BVAI.441400.001**.
4. Cooperation with FUCHINO Co Ltd. based on the Cooperation Agreement.

Works Performed

- Research and development activities – design of SPS (subsea process system) equipment connection system.
- Research and development activities – development of subsea landing head system and tools for installation and maintenance of its elements; manufacture and testing of development models.
- Testing of pumping units, testing of steam turbines with power capacity up to 40 MW.
- Testing of attachments to turbines with power capacity up to 12 MW. Stress tests of turbines with power capacity up to 40 MW via hydrodynamometer by FUCHINO Co Ltd.
- Valving tests.
- Reengineering of valves, runners of pumping units, other equipment.
- Hydraulic design of pipelines, systems, etc.
- Consulting on test bed equipment selection.
- Rough design of test beds using hydrodynamometers by FUCHINO Co Ltd.
- Supply of hydrodynamometers by FUCHINO Co Ltd. to Russian customers; installation and commissioning on the equipment.

Advanced Development Department

BVAI.441400.001 – test bed for testing of power equipment of various classes and purposes.

Test bed BVAI.441400.001 for conducting energy producing equipment of various classes and purposes is designed for scientific research, development and testing of energy-producing equipment and samples of industrial products in compliance with the requirements set in GOST, OST, NP, MU, specifications (TU), testing programs and methods (PM) for certain products, etc. **Technical features of the test bed are displayed at the Table on the slide 139.**

The test bed is suitable for testing the following equipment:

- hydraulic dynamometers and hydraulic brakes with power capacity **up to 12 MW**;
- steam turbines with effective power **up to 40 MW** and main steam flow rate of **no more than 120 t/h**;
- heat exchangers with the power **up to 60 MW;**
- hydraulic equipment with **water feed up to 9000 m3/h;**
- electric pumps with electric **power up to 1.25 MW** (voltage up to 0.6 kV);
- electric pumps with electric **power up to 3 MW** (voltage up to 6 kV);
- electric pumps with electric **power up to 650 kW** (voltage up to 0.4 kV);
- valves with diameter up to DN 400 (operating medium flow rate through the device up to 5 m/s) for evaluating hydraulic and cavitation characteristics and confirming the service life;
- water hammer protection equipment.

Test bed BVAI.441400.001

Advanced Development Department

BVAI.441400.001 – test bed for testing of power equipment of various classes and purposes.

Technical Characteristics of the Test Bed

Technical data, parameters	Units of measurement	Values	Notes
Rated power of tested steam turbine (ST), N	MW	up to 40.0	
Superheated steam pressure, P_{sh}	MPa	3.9	$P_{sh\ crit}$ up to 4.2
Superheated steam temperature, t_{sh}	^0C	440	$t_{sh\ crit}$ up to 470
Superheated steam flow rate, G_{sh}	t/h	111	$G_{sh\ max}$ up to 125
Cooling water flow, G_{cool}	m^3/h;	Up to 9000	
Temperature of cooling (fluvial) water, t_{cool}	^0C	+1 to +20	
Oil pressure in the lubrication system of ST, P_{loil}	MPa	0.05–0.1	When the lubrication system is delivered along with ST, the parameters may be different
Oil pressure in the ST control system, P_{coil}	MPa	0.8	
Temperature of oil on ST, t_{oil}	^0C	40 ± 5	$t_{oil\ crit}$ up to 110
Cooling water flow rate per hydrodynamometer, $G_{cool.hd}$	m^3/h;	Up to 1800	
Weight-lifting capacity of overhead crane	t	32/5	
Area occupied by main equipment	m2	380.7	
Total area of test bed facilities	m2	1352.4	

Advanced Development Department

BVAI.441400.001 – test bed for testing of power equipment of various classes and purposes.

Test bed BVAI.441400.001

General information about the test bed.

BVAI.441400.001 test bed includes:

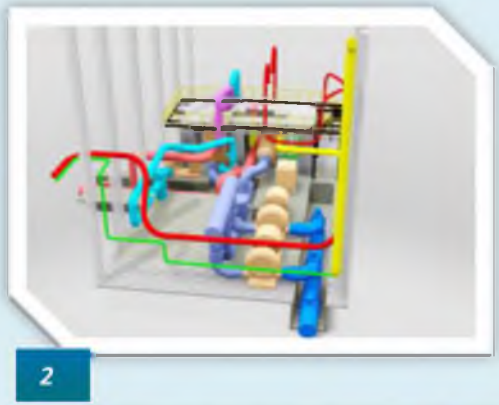
- power suppression system of BVAI.441542.001;
- Turbodrive of BVAI.620415.001;
- Steam pipeline system 166/14.003-TS;
- Condensate return system 166/14.003-TS;
- Test bed equipment cooling system BVAI.441421.001;
- Test bed power supply system 14-077-EOM1;
- Automated control system of BVAI.420336.001;
- Utility systems of BVAI.425500.001;
- handling equipment of BVAI.481214.001.

Advanced Development Department

Test Bed Development Perspectives

There are design studies aimed at increasing the parameters of tested equipment.


1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6

Advanced Development Department

Cooperation with FUCHINO Co Ltd.

CF-type hydrodynamometers

Large-size hydrodynamometer CFSR-30.0

Large-size hydrodynamometer CFSR-26.0

Advanced Development Department

Cooperation with FUCHINO Co Ltd.

CF-type hydrodynamometer

General technical characteristics and sizes of CF-type hydrodynamometer

Type	Max. PS	Max. kW	rpm. max.	A (m/m)	B (m/m)	C (m/m)	D (m/m)	E (m/m)	F (m/m)	Weight, kg
CF-9.0	10,000	7,500	1,200	2,400	1,700	2,500	1,193	950	1,550	10,000
CF-10.0	12,000	9,000	1,100	2,600	1,900	2,700	1,193	1,000	1,750	13,000
CF-11.0	14,000	10,000	1,000	2,700	2,000	2,800	1,193	1,050	1,820	16,000
CF-12.0	16,000	12,000	900	2,800	2,100	2,850	1,193	1,100	1,850	17,000
CF-13.0	20,000	15,000	800	2,900	2,250	2,900	1,193	1,150	1,920	18,000
CF-14.0	22,000	16,000	730	3,000	2,400	3,350	1,193	1,250	2,200	19,000
CF-15.0	25,000	18,000	680	3,400	2,600	3,600	1,432	1,350	2,400	20,000
CF-16.0	28,000	20,000	600	3,450	2,800	3,900	1,432	1,400	2,500	28,000
CF-18.0	30,000	22,000	500	3,500	2,900	4,120	1,432	1,500	2,615	40,000
CF-20.0	36,000	26,000	400	4,160	3,160	4,600	1,790	1,700	2,960	60,000
CF-22.0	40,000	30,000	370	4,300	3,160	4,700	1,790	1,800	3,150	65,000
CF-24.0	46,000	34,000	340	4,400	3,500	5,000	1,790	2,000	3,405	90,000
CF-26.0	50,000	37,000	320	4,700	3,500	5,200	1,969.5	2,000	3,520	110,000
CF-28.0	60,000	45,000	280	5,300	4,000	5,700	2,148	2,100	3,800	130,000
CF-30.0	65,000	48,000	260	5,400	4,400	5,700	2,148	2,100	4,000	150,000
CF-32.0	70,000	52,000	250	5,700	4,700	5,700	2,435	2,100	4,200	180,000
CF-34.0	80,000	59,000	240	6,200	6,200	7,400	2,864.8	2,100	4,400	210,000
CFW-32.0	100,000	75,000	240	5,700	7,400	8,400	2,435	2,100	4,200	210,000
CFW-33.0	150,000	110,000	200	5,900	7,600	8,600	2,864.8	2,100	4,300	230,000
CFW-35.0S	170,000	125,000	200	6,200	6,200	9,000	2864.8	2,100	4,500	240,000
CFW-36.0	200,000	150,000	200	6,400	6,400	9,300	3008	2,100	4,600	280,000

Advanced Development Department

Cooperation with FUCHINO Co Ltd.

CFT-type hydrodynamometer

CFT 8.0 hydrodynamometer

General technical characteristics and sizes of CFT-type hydrodynamometer

Type	Max. PS	Max. kW	rpm Max.	A (m/m)	B (m/m)	C (m/m)	D (m/m)	E (m/m)	F (m/m)	Weight, kg
CFT – 5.0	14,000	10,000	10,000	1,800	1,400	1,500	650	900	1,400	8,000
CFT – 5.5	16,000	12,000	9,000	2,000	1,600	1,650	700	1,000	1,600	10,000
CFT – 6.0	20,000	15,000	8,500	2,200	1,700	1,800	800	1,050	1,700	12,000
CFT – 7.0	27,000	20,000	7,000	2,600	2,000	2,100	900	1,200	2,000	18,000
CFT – 8.0	40,000	30,000	6,000	2,900	2,300	2,400	1,000	1,400	2,200	26,000
CFT – 9.0	60,000	44,000	6,000	3,200	2,300	2,600	1,200	1,400	2,200	26,000
CFT – 10.0	80,000	60,000	5,000	3,500	2,500	2,800	1,400	1,600	2,400	32,000
CFT – 12.0	100,000	74,000	4,000	3,800	2,700	3,000	1,600	1,800	2,600	40,000

Advanced Development Department

Cooperation with FUCHINO Co Ltd.

CFT-type hydrodynamometer

CFT 9.0 hydrodynamometer

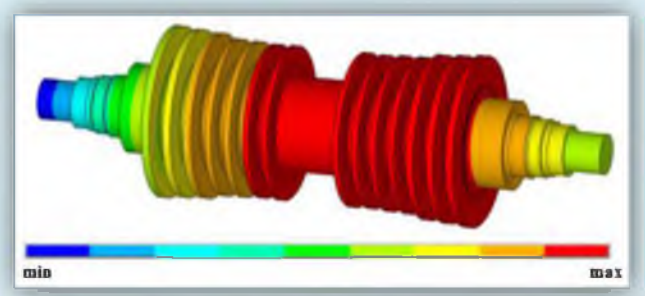
Monitor of the CFT-9.0 control system

Power Equipment Durability and Service Life Department

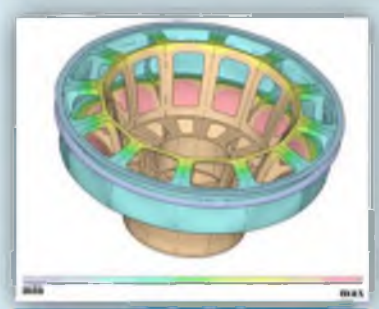
TPP, NPP and HPP Turbine Strength Laboratory

Main Activities Of The Laboratory

- Design and experimental justification of strength and service life of turbine equipment for TPP, NPP and HPP using state-of-the-art versatile software solutions and non-destructive testing methods.
- Extension of reliable and safe operation of power equipment beyond the design service life.
- Justification of equipment serviceability despite defects and damages after long time in operation.
- Assurance of seismic strength of turbine equipment, including the equipment for newly design thermal and nuclear plants;
- Participation in design of new turbine equipment of TPP, NPP and HPP.



Distribution of movements in the HP rotor of K-1000-60/1500 turbine during seismic stress



Distribution of vertical movements in the head cover of a powerful water turbine

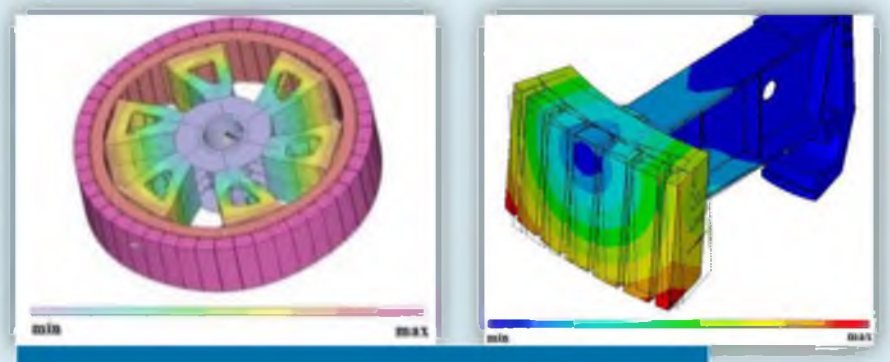
Crack in the blade root at the 4th stage of HP rotor of K-500-65/3000 turbine

Power Equipment Durability and Service Life Department

TPP, NPP and HPP Turbine Strength Laboratory

Main Activities Of The Laboratory

- Investigation and assessment of causes of accidents and damages of power equipment at power plants and industrial facilities.
- Development and revision of regulatory documents that regulate the issues od design, production and operation of turbines of TPP, NPP and HPP.
- Development and introduction of modern approaches, engineering methods and design programs that correspond with the laboratory profile.
- Development of strength and service life assessment methodology for power equipment with extra long service life, considering its current condition.



Visualization of various form of natural oscillations (full model and rotor spoke with a fragment of rotor rim)

The band defect at the 6th stage of PT-60-130/13 turbine.

Power Equipment Durability and Service Life Department

TPP, NPP and HPP Turbine Strength Laboratory

2016–2017 References

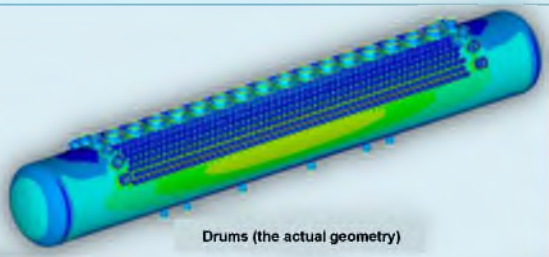
- Complex research of technical condition and assessment of remaining service life of hydropower units at **Bratsk Cogeneration Plant** *(2011–2016).*
- Evaluation of technical condition and assessment of remaining service life of hydropower units at **Irkutsk Cogeneration Plant** with instrumentation research *(2011–2016).*
- Works aimed at evaluation of technical condition, assessment of remaining service life and its extension for turbine units TG-7,8 of power unit No. 4, **Leningrad Nuclear Power Plant** *(2012–2016).*
- Service life extension of steam turbine TGU-3, turbine generator TGU-3, transformer T-3 35/10 kW, **Pauzhetskaya Geothermal Power Plant** *(2013–2016).*
- Inspection and calculations for main steam pipeline of P30-100/41-1 turbine, ammonia unit AM-70, specification of its interaction with steam pipeline of shop 51, **Mineral Fertilizer Plant, KCKK Branch of Uralchem Group** *(2014–2016).*
- Evaluation of technical state and resource of steam turbines, **Kola NPP** *(2015–2016).*
- Participation in development of GOST 3618-2016 “Stationary steam turbines and turbogenerators. Types and basic parameters”, **PJSC “Krasny Kotelshchik”** *(2015–2016).*
- Participation in development of GOST “Stationary steam turbines for electric generators of thermal electric stations. General technical requirements”, **PJSC “Krasny Kotelshchik”** *(2015–2016).*
- Assessment of technical condition and remaining service life of turbine units TG-1,2, power unit No. 1, **Smolensk NPP** *(2016).*
- Design-based justification of seismic strength of Taman TPP turbine unit equipment, **PJSC “Power Machines”** *(2016).*
- Design and experiment-based research of service life and fatigue strength of blading of HPC and LPC in turbine unit K-800-130/3000, power unit No. 4, **Beloyarsk NPP**, considering the detected defects (*2016–2017*).
- Evaluation of technical condition and assessment of remaining service life of valves and turbine equipment of power unit No. 2, Armenian NPP (*2016–2017*).
- Assessment of metal condition monitoring programs and assessment of structures, systems and components of second circuit equipment, power unit No. 5, **Kozloduy NPP** (*2016–2017*).
- Extension of service life of LMZ HP rotors HTGZ IP rotors of K-500-240 turbine, Ekibastuz Regional SDPP-1, **Korund LLP, KBI Energy LLP** (*2016–2017*).

Power Equipment Durability and Service Life Department

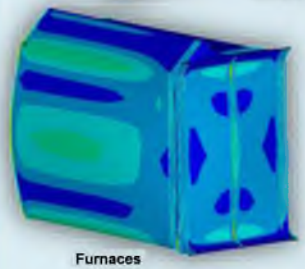
Pipeline and Boiler Strength Laboratory

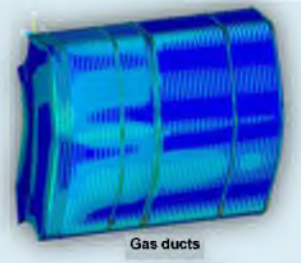
Main activities

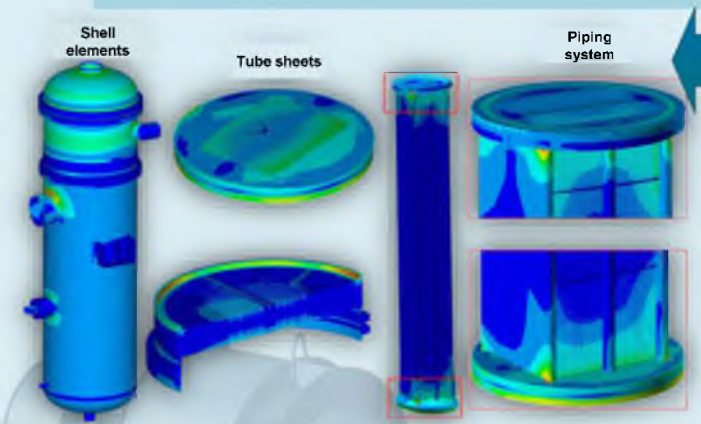
- Modelling of polydimensional heat and stress strain state of equipment under the exposure to static and dynamic loads.
- Modelling of stress strain state of equipment under seismic load.
- Modelling of stress strain state of pipes, molded elements, pipelines and supports of any complexity.
- Full-scale high-temperature time-to-rupture tests.
- Industrial safety research.
- Development of new generation normative documentation for Rostekhnadzor facilities.



An example of modelling stress-strain state of boiler equipment

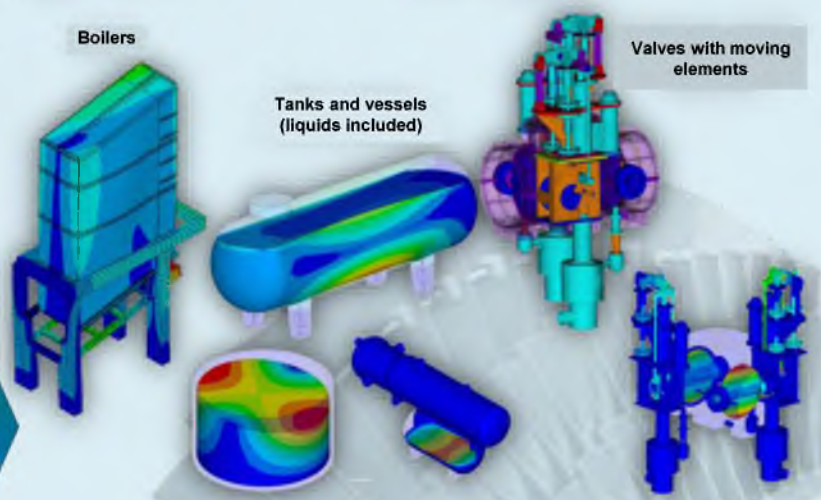






An example of modelling stress-strain state of heat-exchanging equipment

An example of modelling of stress strain state of equipment under seismic load

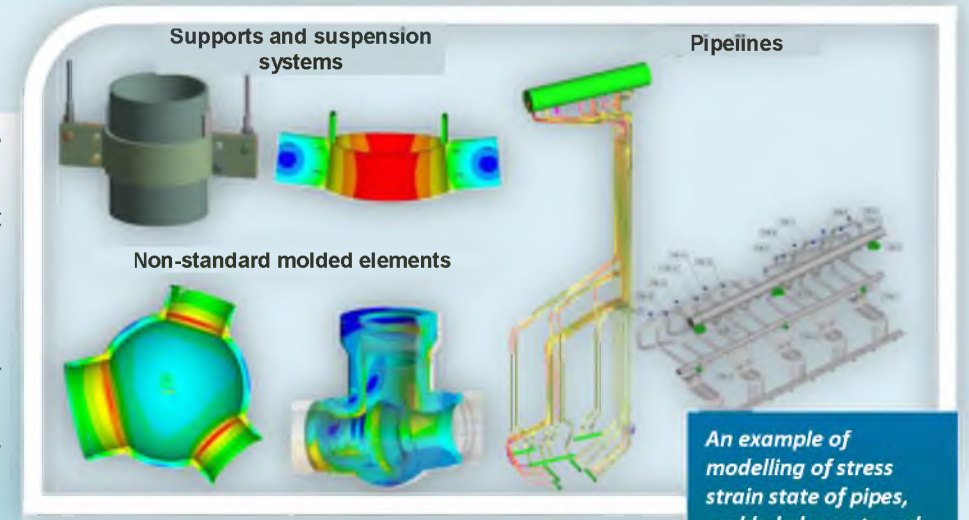


Power Equipment Durability and Service Life Department

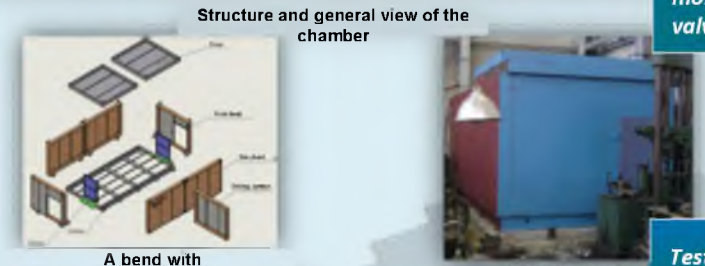
Pipeline and Boiler Strength Laboratory

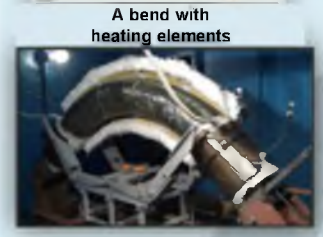
Works Performed

- Design and experiment-based justification of strength and service life of heat machinery equipment.
- Extension of reliable and safe operation of power equipment beyond the design service life.
- Justification of equipment serviceability despite defects and damages after long time in operation.
- Assurance of seismic strength of heat machinery equipment for newly design thermal and nuclear plants.
- Design of new heat-exchanging equipment for operation at new generation TPP and NPP.
- Investigation and assessment of causes of accidents and damages of power equipment at power plants.
- Development and revision of regulatory documents that regulate the issues od design, production and operation of boilers and pipelines.
- Development and introduction of modern approaches, engineering methods and design programs.
- Development of strength and service life assessment methodology for power equipment considering its current condition.
- Development of actual stress-strain state assessment methods for automated monitoring systems.



An example of modelling of stress strain state of pipes, molded elements and valves





Test bed equipment

Power Equipment Durability and Service Life Department

NPP Equipment Strength Laboratory

- Development of strength calculation methods programs for equipment of nuclear power and research installations.
- Development and improvement of RD on strength in nuclear power industry, considering the operating experience and modern design methods.
- Strength calculations of heat machinery equipment for NPP under construction, including calculations for selecting the main dimensions and all stages of strength calculations.
- Extension of service life of heat machinery equipment and pipelines of NPP power units that have exhausted their design service life.
- Experimental justification of power-generating equipment strength.
- Evaluation of ductile and brittle failure resistance and low-cycle fatigue resistance of full-scale elements and models of power-producing equipment, as well as materials on natural thickness samples using large testing machines.
- Experimental research of strength and service life on models and full-scale samples with in case of various damage mechanisms and industrial and operational defects.
- Testing of full-scale elements of power equipment and pipelines, including the test monitoring (strain gauging, temperature profiling, vibration measurement).
- Hydraulic tests of HP equipment and its elements, as well as pipelines and their elements.
- Measurement of vibrations in safety-critical pipelines of NPP in all operating modes.

Test Beds of the Department

Skoda ZZ-8000 tensile testing machine

Max. Force – 8,000 ton; Stroke – 200 mm; Sample section area – 200,000 mm²; Max. sample length – 3,000 mm; Max. sample weight – 5 ton

MUP-100 tensile testing machine

Maximum force – 100 t

Power Equipment Durability and Service Life Department

NPP Equipment Strength Laboratory

References and the largest customers

- **Branches of Rosatom Group:**
  - **Smolensk NPP;**
  - **Kursk NPP;**
  - **Leningrad NPP;**
  - **Beloyarsk NPP;**
  - **Novovoronezh NPP.**
- **NIKIET JSC.**
- **OJSC VNIIAES.**
- **KomplektEnergo LLC.**
- **KSB LLC.**
- **PJSC Power Machines.**
- **LLC «Belenergomash – BZEM»**
- **CJSC ATM.**

The laboratory has worked on extension of service life of main heat machinery equipment and pipelines that have exhausted their design service life (including the the equipment of reactor shop, turbine hall, chemical shop, support building) for the following nuclear plants:

- **Smolensk NPP (power units 1, 2);**
- **Kursk NPP (power units 3, 4);**
- **Leningrad NPP (power units 3, 4);**
- **Beloyarsk NPP (power unit 3).**

The laboratory has conducted strength calculations of main heat-exchanging equipment (LPH, HPH, deaerator, FAPD and control valves) for nuclear plants under construction:

- **Kudankulam NPP, power units 3, 4;**
- **Leningrad NPP 2;**
- **Novovoronezh NPP 2;**
- **Beloyarsk NPP (BN-800);**
- **Beloyarsk NPP, power units 1, 2.**

The laboratory has designed the pipeline parts for prospective power unit BN-1200.

The equipment certificates of Leningrad NPP chemical shop have been restored.

Power Equipment Durability and Service Life Department

TPP and NPP Valve Strength and Service Life Laboratory

Main Activities Of The Laboratory

- Development of regulatory documentation on valving reliability.
- Extension of service live of valving in nuclear plants, nuclear icebreakers, storage units, etc.
- Justification of valve operation safety in case of deviations from nuclear power regulations.
- Justification of selection of valves subject to mandatory diagnostics in operation according to NP-068.
- Justification of selection of valve subject to to maintenance, repair and technical examination according to PNAE G-008.

Works Performed in 2013–2016

- Participation in evaluation of technical condition, assessment of remaining service life of safety class 2, 3 and 4 valves installed on the power unit No. 2 of **Kalinin NPP**.
- Preparation of feasibility study documents for PSE-3. Development of missing certificates for valves of power unit No. 3 of **Kursk NPP.**
- Inspection, assessment of technical condition and remaining service life of equipment and pipelines in power units 2, 3 of **Smolensk NPP.** Inspection, assessment of technical condition and remaining service life of valves DN 800 in repeated force circulation circuit, power unit No. 3, **Smolensk NPP.**
- Extension of service life of elements and equipment. Inspection, assessment of technical condition and remaining service life of valves in power units of **Smolensk NPP.**

Power Equipment Durability and Service Life Department

TPP and NPP Valve Strength and Service Life Laboratory

Works Performed in 2013–2016

- Extension of service life of power unit No. 2 of Smolensk NPP. Inspection, assessment of service life, justification of serviceability of valves within the extended service life period of power unit of **Smolensk NPP**.
- Assurance of safe operation and management of long-term performance of valves in Separate Storage of Spent Fuel No. 5 of **Novovoronezh NPP.**
- Support of operations aimed to ensure safe operation of systems, in particular, general purpose of power unit No. 4 of **Kursk NPP.**
- Extension of service life of power unit No. 2 of Smolensk NPP. A set of works aimed to ensure safe operation of safety-critical systems of power unit No. 2, **Smolensk NPP.**
- Inspection, assessment of technical condition and justification of remaining service life of valves in power unit No. 5 of **Novovoronezh NPP.**
- Inspection, assessment of technical condition and justification of remaining service life of valves in power unit No. 5 of **Kozloduy NPP.**
- Comprehensive inspection of valves in power unit No. 2 of **Armenian NPP.**
- A set of operations aimed to determine technical condition and evaluate the remaining service life of repeated force circulation circuit valves in power units 1 and 4 of **Leningrad NPP.**
- A set of operations aimed to determine technical condition and evaluate the remaining service life of safety class 1, 2, 3 valves in power units 1 and 2 of **Kursk NPP.**
- Service life extension justification of elements of power units 3 and 4 of **Novovoronezh NPP.**

Power Equipment Durability and Service Life Department

Laboratory of Non-Destructive Testing and Acoustic Emission Inspection

Main Activities Of The Laboratory

- Non-destructive testing by visual inspection control.
- Non-destructive testing by ultrasonic method.
- Non-destructive testing by liquid penetrant method.
- Non-destructive testing by eddy current method.
- Non-destructive testing by magnetic particle method.
- Non-destructive testing by acoustic emission method.
- Non-destructive testing by ultrasonic thickness measurement.
- Non-destructive testing by hardness measurement.
- Inspection of axial channel of turbine rotor by visual inspection, ultrasonic testing and eddy current testing.
- Development of guidance and regulatory documents.
- Diagnostics of facilities in test bed conditions and in operation.

Laboratory Test rigs

Acoustic emission diagnostics system SDAE-16

Ultrasonic flaw detector Sonatest D-10

Ultrasonic flaw detector Sonatest D-10

Ultrasonic thickness gauge Sonatest T-GAGE IV MM

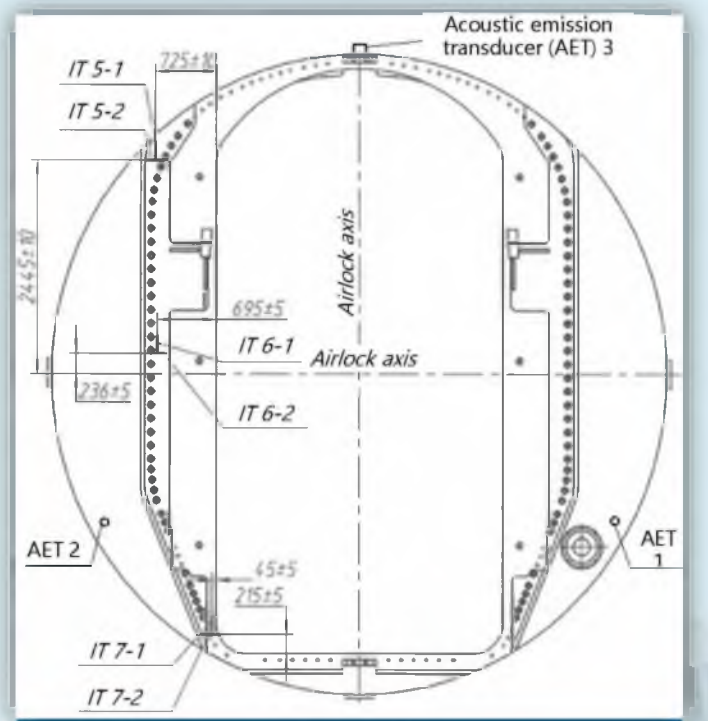
Hardness gauge

Power Equipment Durability and Service Life Department

Laboratory of Non-Destructive Testing and Acoustic Emission Inspection

Works Performed

- Monitoring of new generation space nuclear reactor model during long thermal cycle tests.
- Development of method and project of regulatory and technical documentation for acoustic emission testing of welding of critical structures in shipbuilding.
- Detection of flaws in boiler and pipeline equipment.
- Detection of flaws in turbine equipment.
- Diagnostics of Leningrad NPP equipment lock at the production stage.
- Participation in development of two STO standards: STO RusHydro 02.03.93-2013 *«Water turbines. Testing of metal of blades and runner chambers. Methodology guidelines»* and STO RusHydro 02.03.107-2013 *«Hydroelectric power plants. Non-destructive testing of fasteners of critical hydroelectric units. Methodological Guidelines»*.



Acoustic emission testing as a part of pneumatic testing of transportation airlock AKTsSh 622.00.00.00.000

CGPP belonged to NPO CKTI JSC

Central power plant of city tramlines **was established in 1906–1907** to supply electricity to the city tramway network – as a part of construction of first tramway line.

In 1913–1916, the plant underwent the first significant modernization related to extension of tramway network in Saint Petersburg.

On July 28, 1918, the plant along with others was nationalized and started getting managed by Petrograd commune.

On May 17, 1919, the central city tramway power plant became a part of newly organized Association of State Power Plants (OGES) as GES No. 4 (State Power Plant). **In 1922,** OGES was converted into the Petrograd Electric Power Plant Trust "Petrotok", and in April 1924, it became the Leningrad Association of State Power Plants "Elektrotok", in July 1932, it became Lenenergo.

In 1920s, GES No. 4 participated in resolution of issues related to implementation of GOELRO plan: it partakes in local fuels adoption experiments. In March 1921, for the first time in the Soviet Union, professor T. F. Makaryev tested his own invention – shaft-chain furnace.

In 1929, GES No. 4 was among the first power plants of the city to start supplying heat to buildings of Leningrad. In the same year, GES No. 4 started supplying steam to an external facility – a steam pipeline connected the plant with the Botkin Hospital.

In 1932–1936, CKTI employees experimented at GES No. 4 on burning milled peat and fluidized slate in new cyclone furnaces created by professor T. F. Makaryev.

City Electric Railroad Power Plant

Central City Railroad Power Plant.
View from the Kremenchugskaya street, 1907

Westinghouse Electric Corporation delegation.
2nd on the right – Ya. K. Gakkel

Generator hall interior, 1907

CGPP belonged to NPO CKTI JSC

In 1936–1939, GES No. 4 served as a base to CKTI employees for design and construction of the first semi-industrial plant in the world that works by the binary principle and utilizes liquid metal coolant.

In 1938, GES No. 4 was excluded from Lenenergo and handed over to the Central Boiler and Turbine Scientific Research and Design Institute (CKTI). The plant got the new name – State Experimental Power Plant CKTI (GEES CKTI).

In 1938—1941, specially equipped GEES CKTI test beds were used for experimental research of turbine aerodynamics, circulation and processes inside boiler, heat exchange and aerodynamics of boiler units, binary cycles, steam separation, furnaces.

In August 1941, in the beginning of the Great Patriotic War GEES CKTI was included into Lenenergo again due to the evacuation of the institute.

In 1942, the plant adapted production of 50 Hz electricity and started working in parallel with Lenenergo system.

During the blockade, the plant kept supplying heat and electricity to the Botkin Hospital, Haass Hospital, the adjacent residential buildings.

In 1944, the plant was returned to CKTI. After the war, the power plant undergoes restoration and serves as an experimental base for CKTI.

Since 1950s up to this day, CKTI Cogeneration Plant has been supporting the experimental research conducted by CKTI (since 1976 – NPO CKTI), as well as supplying heat and electricity to several industrial and municipal facilities of Cmolninsky and Nevsky districts of Leningrad (today, Central and Nevsky districts of Saint Petersburg).

Senior Enginer of CKTI A. A. Kanaev is taking readings of recorders installed on the experimental binary plant, GES No. 4, 1937

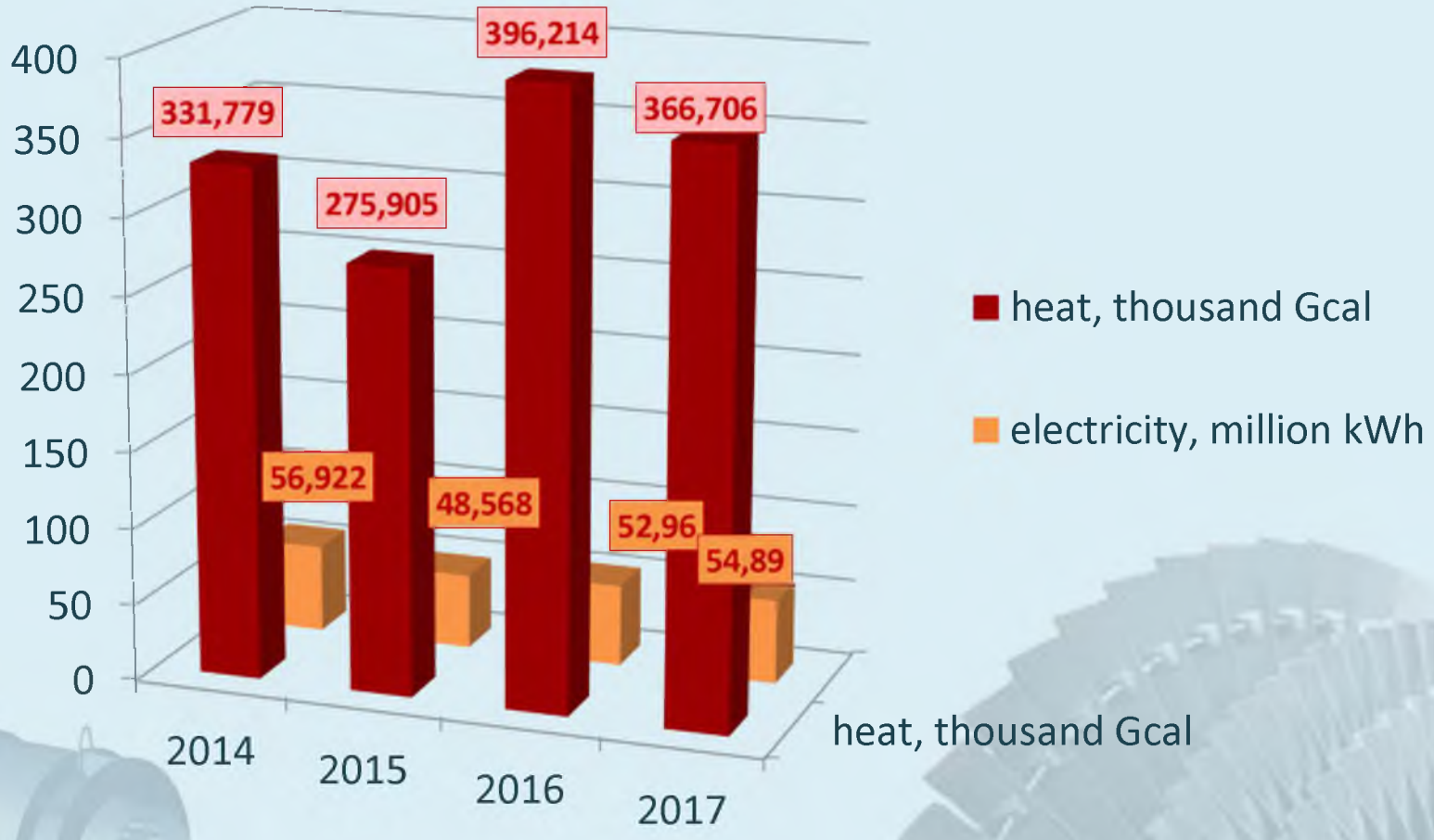
1985. The workers of Steam Turbine Aerodynamics Laboratory are preparing the model of ETND-2 turbine for testing

CKTI TK-3-13 system

A layout of districts receiving electricity and heat from the CKTI Cogeneration Plant

CGPP belonged to NPO CKTI JSC

Heat and electricity supplied within three years, 2014–2017

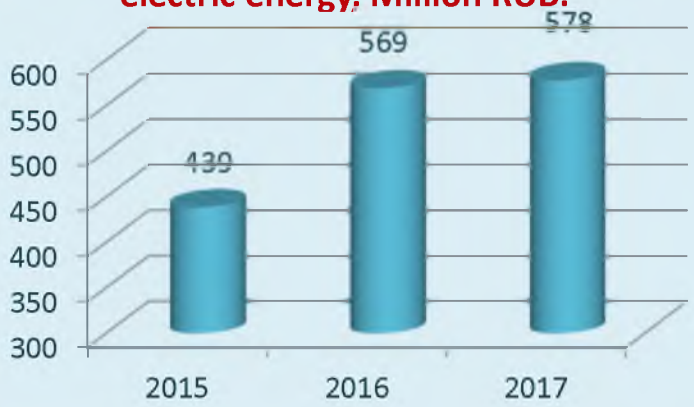


Operating Performance of the Cogeneration Plant in 2017

Main consumers of CKTI Cogeneration Plant

Consumer	Electric power supplied, %	Heating power supplied, %
JSC PSC	74,3%	
Power Supply Management Board, JSC Russian Railways	0,5%	
T4 Business Center	5,4%	
Rusenergosbyt LLC	3,6%	
JSC Etalon LenSpetsSMU	2,9%	4,0%
others	13,3%	
TGC-1 PJSC		54,2%
Heat and Water Supply Management Board, JSC Russian Railways		26,1%
others		15,7%

Revenue from sales of heat and electric energy, Million RUB.



The main fuel used at the Cogeneration Plant is natural gas (supplied by Gazprom Mezhregiongaz Saint-Petersburg LLC); the reserve fuel is heating oil (the required winter for CKTI Cogeneration Plant is 3.676 thousand tons).

Equipment: 3 turbine generators (6 MW each), 8 boiler units (including: 7 steam 1 one hot water boiler).

According to boiler certificate data, summary heating power of boilers is **425 t/h** or **386 Gcal/h**. According to parameter tables, the actual summary power of boilers is **375 t/h** or **338 Gcal/h.**

CGPP belonged to NPO CKTI JSC

Boiler Shop

District heating plant (DHP)

DHP control panel

Major Customers of NPO CKTI JSC

1. PJSC RusHydro and the branches
2. PJSC Irkutskenergo
3. PJSC Power Machines
4. JSC TyazhMash
5. Voith, Austria
6. Kruonis Pumped Storage Plant, Lithuania
7. Rosenergoatom Concern JSC
8. Rosatom Group
9. The Central Design Bureau for Marine Engineering «Rubin»
10. Doosan Škoda Power
11. Belarus NPP
12. Fortum Power and Heat Oy
13. Bushehr NPP, Iran
14. BGK Engineering Company, Iran
15. Unipro PJSC
16. TGC-1 PJSC
17. PJSC Mosenergo
18. Inter RAO Group
19. Gasenergoservis LLC

Major Customers of NPO CKTI JSC

20. AS Vitkovice Power Engineering
21. AS Eesti Energia Narva Elektrijaamad
22. Tianwan NPP
23. JSC Rusatomservis
24. JSC Atomstroyexport (JSC ASE)
25. JSC «NPF CKBA»
26. Armalit JSC
27. Mondi Syktyvkar JSC
28. Mechel-Energo LLC
29. POLYKRAFT group (Safonovo Heating Solution)
30. All-Russian Scientific Research Institute of Experimental Physics
31. All-Russia Thermal Engineering Institute
32. UEC Saturn PJSC
33. State Research Center CNIITMASH
34. Vorkutaugol JSC
35. Severstal PJSC
36. AEM-Technology JSC
37. LLC «Belenergomash – BZEM»
38. Kudankulam NPP, India
39. Loviisa NPP, Finland
40. JSC «REP Holding»
41. Pulkovo Airport OJSC
42. JSC Klimov

Environment Protection

The environmental conditions around OJSC NPO CKTI facility are satisfactory.

The company conducts the environment protection activities in compliance with the environmental regulations of the Russian Federation and the Government of Saint Petersburg, as well as environmental standards.

The Environment Protection Department cooperates with **certified testing laboratory** in monitoring of natural and sewage water according to the "Water Body Supervision Program." The testing laboratory is certified according to the international system of State Standards – ISO (Certificate No. РОСС RU. 0001. 512425 – valid through December 3, 2018).

NPO CKTI JSC has developed and implements Industrial Environmental Monitoring program to ensure the enterprise complies with all requirements and provisions set in design and regulatory documentation aimed to lower environmental risks and gradually decrease the harmful impact on the environment.

The Environment Protection Department solves all environmental problems related to atmospheric emissions, storage and disposal of waste; the Department has sanitary protection area projects for both sites; also, the department timely develops new Allowable Discharge Standards and Waste Disposal and Generation Targets. The certified testing laboratory has all the required equipment and instrumentation. In its work, the certified testing laboratory is guided by environment protection activity plans, scheduled water body supervision program, which are all coordinated with and approved by the municipal organizations that perform supervision of company's environmental activities.

ФЕДЕРАЛЬНАЯ СЛУЖБА ПО АККРЕДИТАЦИИ

АТТЕСТАТ АККРЕДИТАЦИИ ИСПЫТАТЕЛЬНОЙ ЛАБОРАТОРИИ (ЦЕНТРА)

№ РОСС RU.0001.512425

Открытому акционерному обществу «Научно-производственное объединение по исследованию и проектированию энергетического оборудования им. И.И. Ползунова», ИНН 7825660956

191167, г. Санкт-Петербург, ул. Атаманская, д. 3/6

Испытательная лаборатория

191167, г. Санкт-Петербург, ул. Атаманская, д. 3/6

ГОСТ ИСО/МЭК 17025-2009

03 декабря 2013 г. — 03 декабря 2018 г.

М.А. Якутова

EHS (Enviromental Healthy Safety)

The management of NPO CKTI JSC fully assumes the responsibility for creation of safe operating conditions and assurance of industrial safety.

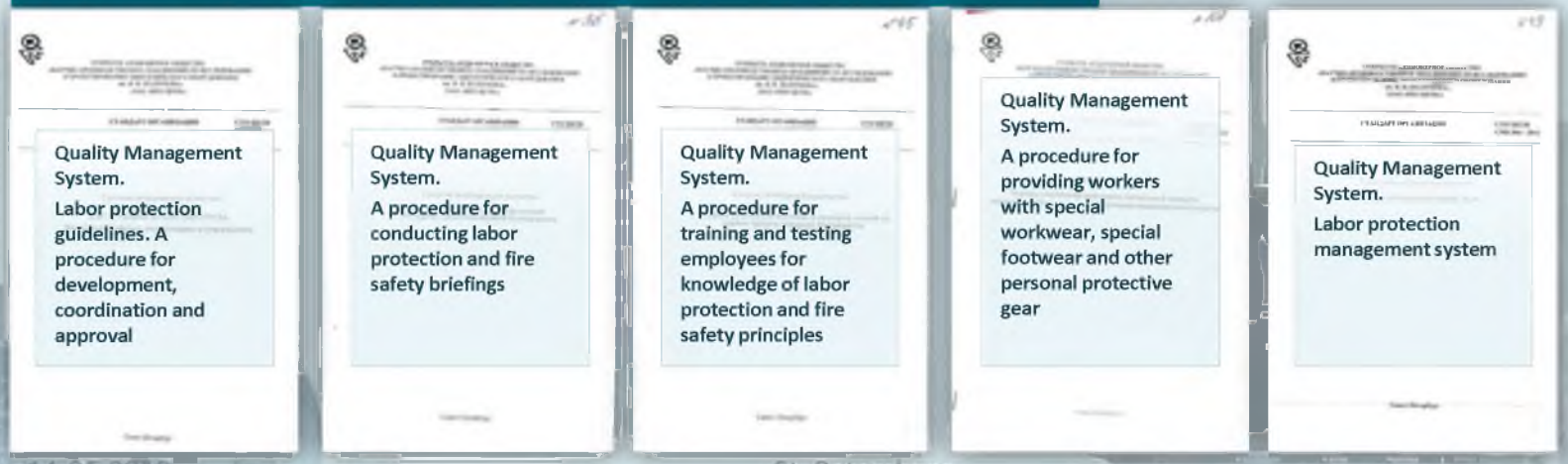
The enterprise has incorporated the labor protection system and organized supervision of safe operation of hazardous industrial facilities.

All labor protection and industrial safety requirements set by the law of the Russian Federation are observed.

The workers are trained and tested for knowledge of labor protection and industrial safety principles.

The company utilizes a special assessment of labor conditions, which provides all conditions set by the Labor Code and compensations for the employees stipulated by the collective labor agreement.

Organization Standards That Regulate the Labor Protection



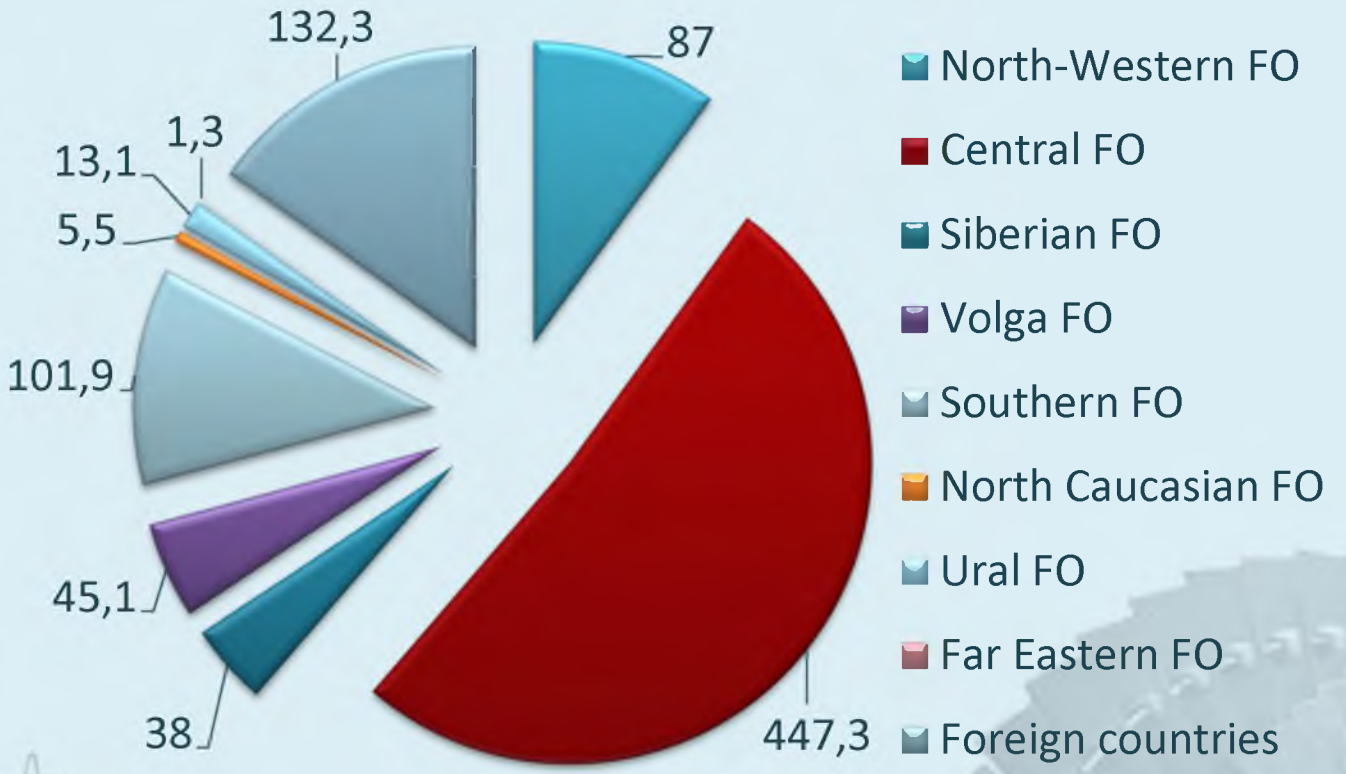
Economic Performance of NPO CKTI JSC in a five-year period, 2013–2017

Key Financial Indicators for the Past Five Years

Key Financial Indicators	2013	2014	2015	2016	2017
Authorized capital	39	39	39	39	39
Net asset value	478,632	553,511	594,464	614,646	628 775
Total current assets	577,547	707,973	889,928	696,368	722 522
Total short-term liabilities	352,431	482,857	633,785	511,898	514 053
Net working capital	225,116	225,116	256,143	184,470	208 469
Revenue (without VAT)	1,481,621	1,369,285	1,191,801	1,938,303	1 539 830
Net profit	95,033	75,623	40,953	32,482	14 110
Current ratio	1.6	1.5	1.4	1.4	1,4
Financial leverage	0.97	0.95	1.15	0.85	0,84
Balance sheet total	944,070	1,079,823	1,278,766	1,137,508	1 159 083

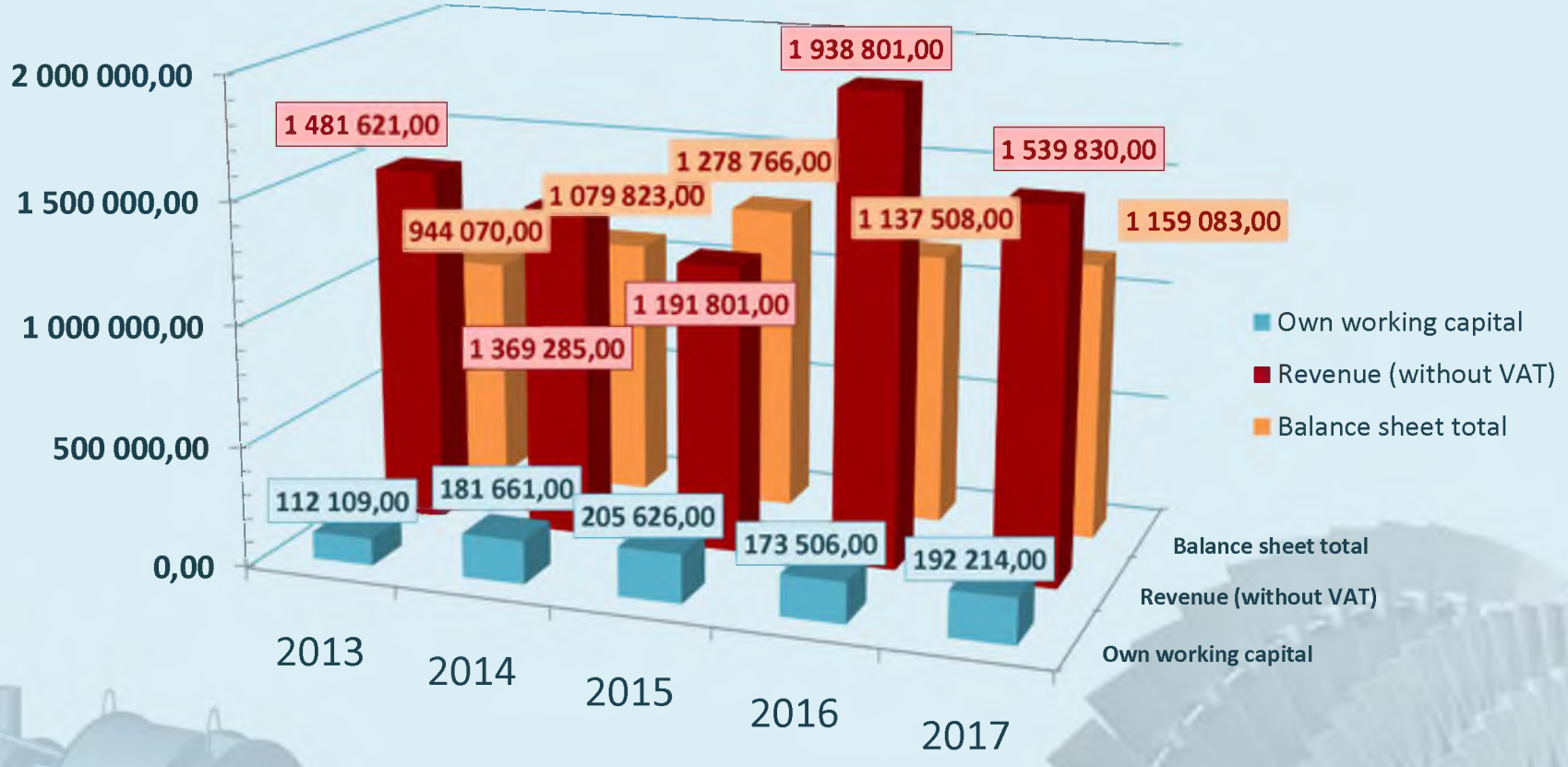
Economic Performance of NPO CKTI JSC in a five-year period, 2013–2017

Revenue Share by Federal Okrugs



Economic Performance of NPO CKTI JSC in a five-year period, 2013–2017

Financial Dynamics



International Economic Activity of NPO CKTI JSC

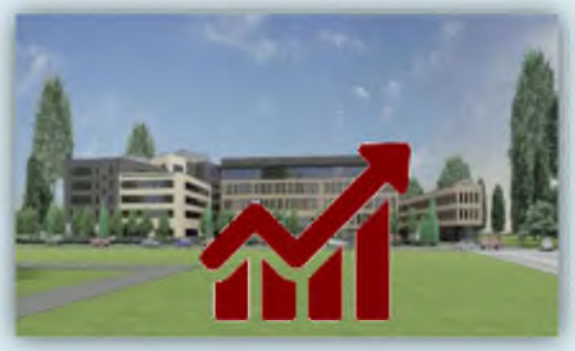
NPO CKTI JSC has years of experience in cooperation with American, Western and Eastern European, Japanese, Chinese, South Korean companies and organizations. We have also established a business connection with Baltic and CIS countries.

We sustain our partnership with the following companies:

Alstom Power Ltd., *Switzerland*;
General Electric, Bechtel, *USA;*
Mitsubishi Heavy Industries Ltd., IHI, **FUCHINO Co Ltd.**, *Japan*;
Siemens AG, BBS GmbH, *Germany*;
EDF, *France;*
JNPC, Fujuan, *China;*
Entegro Ltd., *Greece;* **REK Bitola,** *Macedonia;*

Energico OY, Fortum Power and Heat Oy, *Finland;*
Slovenské energetické strojarne AS, *Slovakia;*
Skoda Power AS, *Czech Republic;*
«Brikel», *EAD*;
Energoremont--Varna-Invest, **Kozloduy NPP, Maritsa – East,** *Bulgaria;*
AS Narva Elektrijaamad, VKG Oil AS, *Estonia;*
Latvenergo, (Daugavas HES), *Latwia;*
Kauno Energetikos Remontas, *Lithuanian Regional SDPP;*
Kruonis Pumped Storage Plant, *Lithuania;*
KUdankulam NPP, Sipat TPP, Barh TPP, *India;*
Bushehr NPP, *Iran;*
Ust-Kamenogorsk HPP, *Kazakhstan,* as well as leading companies of *Ukraine, Belarus, Moldova, Tajikistan,* etc.

Subsidiary Enterprise – Moscow Division of CKTI



The enterprise was founded as a small business entity for implementing power and power engineering industry projects withing the competence of NPO CKTI JSC.

Main Activities of MO CKTI LLC

Московское Отделение ЦКТИ

- Cooperation with federal government, state development institutions and industrial associations with the aim to create industrial development programs and implement scientific and investment projects with various forms of state support and participation.
- Implementation of representative functions, participation in expert committees.
- Organization and holding of meetings, industrial conferences and briefings related to power engineering industry issues.
- Consulting on the following issues:
  - expert support on participation in implementation of state programs and projects supported by the state;
  - development of strategies and industrial development programs, propositions on implementation of state industrial policy, enterprises of the industry;
  - Development of feasibility studies and business plans, justifications of investment.
- Energy surveys and development of complex programs aimed to increase energy efficiency of industrial enterprises and modernization programs.
- Expert assessments of various design documentation considering technical, economic, environmental aspects and industrial safety requirements.
- Engineering and design work.
- Implementation of complex modernization projects in power management of industrial enterprises, prolongation of equipment service life.
- Development of engineering aspect of complex construction projects and modernization of power-generating capacities.

THANKS FOR ATTENTION

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