
Special Research & Development Bureau
for Cryogenic Technologies (SR&DB)
of Technical and Scientific Complex
"B.Verkin Institute for
Low Temperature Physics & Engineering"
INQUIRIES
About the Main Developments of SR&DB for
Nuclear Power Plants

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INTRODUCTION

The Institute for Low Temperature Physics and Engineering (ILTP&E) of the National Academy of Sciences of Ukraine (NASU) was established in 1960 in Kharkov on the initiative of Academician S.P.Korolev, Designer General of ballistic rockets and spacecraft in the USSR. Academician B.I.Verkin was the first director of the ILTP&E. Now the Institute is named after B.I.Verkin.

In addition to fundamental research in low temperature physics, the ILTP&E started wide R&D programs on cryogenic engineering. For this purpose Special Research & Development Bureau (SR&DB) for Cryogenic Technologies was organized in 1971.

The mission of SR&DB is scientific research and developments in the field of cryogenics as well as of space instruments, devices and on-ground testing equipment.

SR&DB has all necessary special scientific, measuring, testing equipment for low temperature, high vacuum R & D in cryogenics, infrared and other optical electronic devices.

Many samples of products and systems developed by the SR&DB in the past are exploited here up to now. Among them are laboratory simulators of space factors, high-vacuum chambers, research apparatuses for material science, equipment for heat transfer research in thermal insulation, liquid and solid cryogens, etc.

SR&DB has about 400 persons on the staff now. Among them are about 50 PhD's and DSc's in physics, engineering and materials science. More than 200 persons are designers and developers in the field of cryogenics, electronics, electrical machinery, medical instrumentation, etc. About 30 persons are specialists in computer calculations and modeling of various processes and systems.

At present the SR&DB occupies a six-storey building (about 2500 sq.meters) on the territory of the ILTP&E in the northern outskirts of Kharkov bordering on the forest and is connected with a railway station and the airport by the city transport and the underground. Kharkov is a large high -potential industrial and scientific center in the north-eastern region of Ukraine with a nearly two million population. In Kharkov were is a state university, several ters of large educational and research institutes.

In SR&DB following research and designing areas are developed in the past and now:

- Development of optical-electronic devices, including infrared radiometers and on-board telescopes, infrared superconducting and non-superconducting bolometers, radiometers, photometers.
- Researches in space and cryogenic materials science, including on-ground simulating of space factors influence on the materials properties; development of laboratory simulating equipment with high vacuum and low temperature conditions realized in large volumes as well as flows of electromagnetic radiation (including hard ultraviolet) and charged particles (protons, electrons).
- Applied superconductivity and its applications in electrical machines (generators, engines, magnet bearings) and electronics, including high sensitive SQUID-detectors of magnetic fields, etc. Research and developments were carried out by SR&DB in the fields of low- as well as high-T_c superconductors.
- Development of SQUID-magnetometers and magnetogradiometers, magnetic screens for geophysics, medicine (for example, for magnetoencephalography) and biology, metrology, military applications.
- Development of cryogenic cooling and cryostatting systems for space equipment, high-sensitivity detectors for various measuring devices, superconducting electrical machines, cryosurgical instruments, storages, cryogenic processing equipment and research apparatuses. Among them are variety of special cryostats for optical, magnetic and other researches; melting and sublimation thermal accumulators; throttle Joule-Thompson type, Stirling-type and pulse-tube cryogenic gas machine coolers.
- Development of radio frequency mass spectrometers for space, sound rockets, aircraft and aerostat carriers applications, ensuring gases contents analysing in atmosphere, including own space vehicle one.
- Development of semi-conductor and glass-metallic resistance thermometers for wide ranges of temperature, pressure, magnetic fields, vibrations intensity and acceleration.

- Studies in the fields of cryogenic heat transfer and liquid hydrodynamics, boiling, solidification and melting of cryogens. Research of microgravity and centrifugal force fields influence on heat transfer and hydrodynamics.
- Development of technologies and equipment for cryogenic processing, storage and transportation of food and drugs raw components, etc.
- Development of new technologies, instruments and software for medicine, including cryosurgery, magnetoencephalography, laser interstitial thermal therapy of tumors.

In 1997 SR&DB are carried out projects for China Peoples Republic, Germany and USA. These projects content is the development of on-ground space factors simulators, low weight cryocooler, cryogenic test equipment for materials science, cryogenic equipment for food and drugs raw components processing. General cost of these projects is about $ 1 M.

In this booklet some proposals of SR&DB in the fields of research and development are presented.

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1. CONTROL, MEASURING AND MONITORING INSTRUMENTS FOR NUCLEAR POWER PLANTS

1.1. LIMIT SWITCHES AND FIXTURE-POSITION-WARNING DEVICES

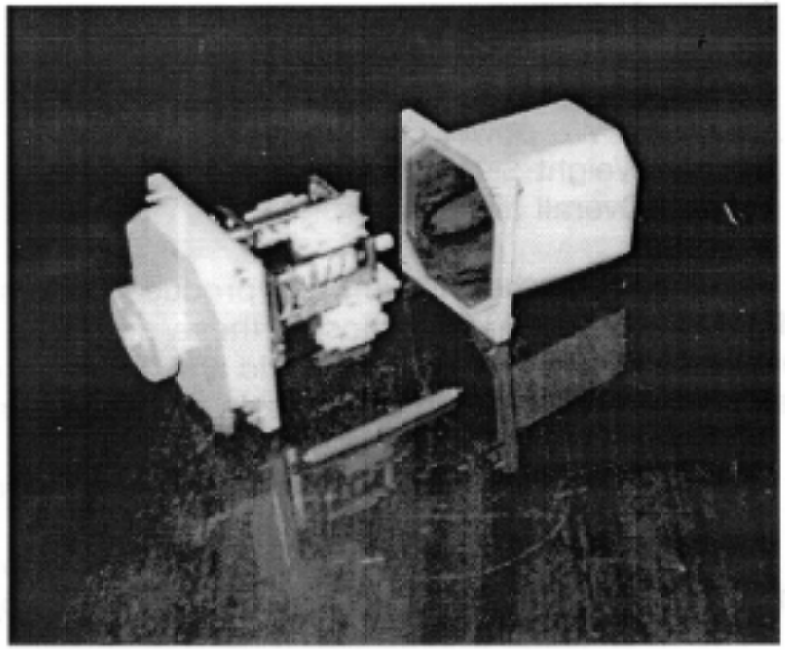
The Special R&D Bureau has developed a series of positioning and limit switches, and locking and regulating fixture- position warning devices (FPWD) intended for performance at nuclear power plants (NPP) and designed for operation within any NPP area, including pressure zones, within a broad performance range, from normal to abnormal leakage levels. A special attention had been giver to maintenance of reliable serviceability of these products in emergency regimes, like with thick air-vapour atmosphere under elevated temperatures and pressures.

A reliable operability of the above devices, multiplied by high accuracy of angular measurements for interaction of rotating shafts and thereof- related contacts, has been achieved by designing a two-module FPWD-structure, whereby:

- the seal-tight transducer module (as one of a FWPD component) operates in a pressure- zone being located directly onto the control and monitoring fixture and
- the relevant electronic block (connected via a cable therewith) is situated in an emergency- free zone of the NPP.

The remarkable precision, along with contact- positioning stability and enhanced serviceability, have been successfully accomplished through denial of the conventional camshaft mechanism. The up-to-date technical resolutions have enabled us to unify the limit switches and fixture-position- warning devices in two modifications:

a) to be operated in a pressure- zone;
b) to be operated in other zones of a NPP.



An exterior of a Fixture Positioning Warning Device designed for operation in any zone of a NPP, pressure zones or/ and emergency conditions included.

PERFORMANCE DATA

Maximum operational temperature:	150 °C
Maximum operational pressure:	0.5 MPa
Rotation- angle range:	
Make 1:	zero to 7.5
Make 2:	zero to 35
Make 3:	zero to 300
Signal current from FPWD rotation angle transducer:	0...5 or 4...20 mA
Characteristic non-linearity of rotation angle transducer:	within 0.5 %
Accuracy & stability of contacts positioning up to action:	within 1%
Non-stop angular-positioning measurements overall error:	within 1%
Failure-free life-time:	up to 250,000 hrs
FPWD power consumption:	up to 7W
Weight :	3.4 kg
Overall dimensions:	140 by 147 by 200 mm

Currently, there have been produced and successfully tested experimental limit- switch and FPWD samples. High reliability characteristics of these products are achieved owing to many years of the SR&DB experience in engineering the on-board scientific and technical equipment for spacecraft, whereby critical performance features, to comply with Customer's demands, have always been such criteria as:

- enhanced life-time and
- failure- proof operation under extremal conditions.

Small-size high-reliability switches and warning devices, developed by the SR&DB, can prove their effective interaction with relevant fixtures in any of NPP applications.

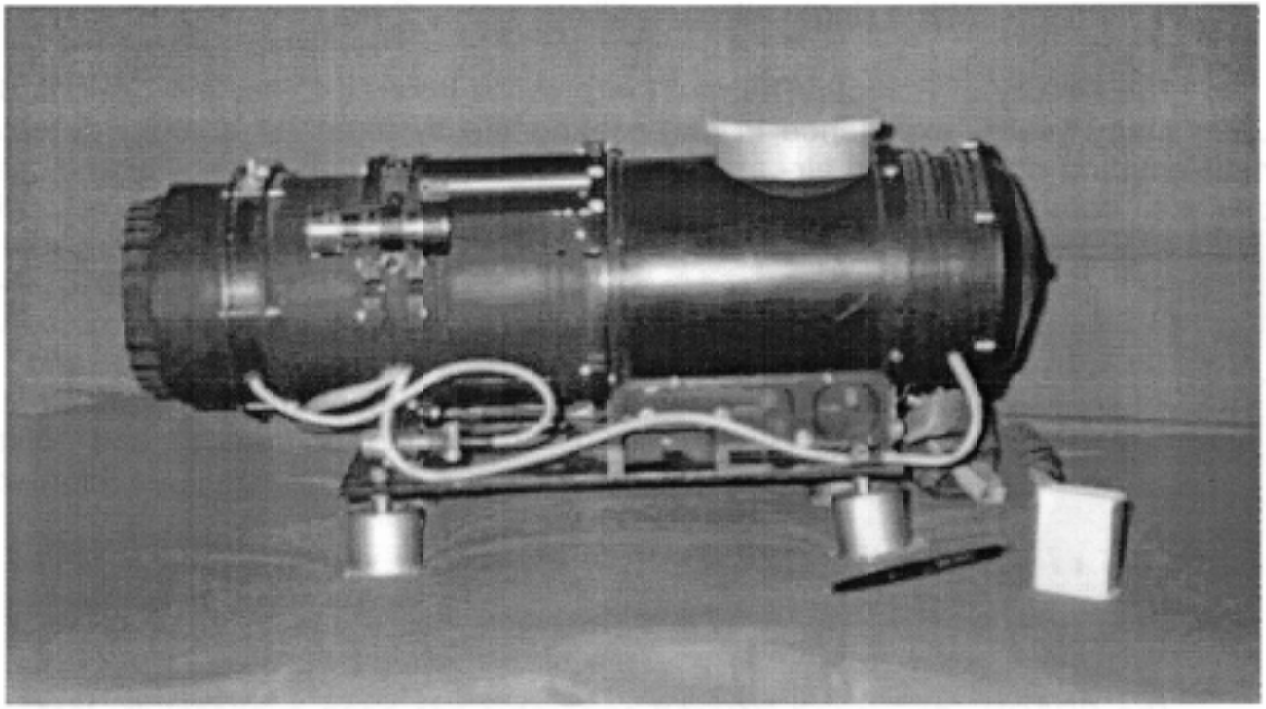
1.2. INFRARED RADIOMETERS FOR REMOTE THERMAL DIAGNOSTICS OF POWER- ENGINEERING EQUIPMENT

The up-to-date methods of non-destructive control enable us to accomplish thermal diagnostics of operating equipment which is typical for presence of:

- either heated working fluids (as liquids or gases),
- or heat emission while performance.

An Infrared (IR) Bandwidth portable device (with cooled high-sensitive receivers, developed by the SR&DB) enables to provide the efficient diagnostics of thermal status for chimneys, power-engineering facilities-thermoinsulation, cooling ponds of NPP etc. These techniques facilitate to detect, prior to oncoming of emergency prerequisites, the interior defects in walls of vessels, piping & tubing, chemical reactors, high-voltage electrotechnic facilities etc.

More particularly, the infrared devices are capable of finding defects related to pressurization failures (like development of micro-cracking, gasket and seal troubles etc). Thus, IR- facilities help to significantly enhance the operational security, thus providing for cost- savings to recover the unpredicted accidental losses.



An Exterior of a Portable Infrared Radiometer with a Cooled Receiver

PERFORMANCE DATA

Measured temperature range:	-10 ... + 1,000^{O}C;
Temperature contrast resolution:	0.1^{O}C/ cm
Operative vicinity of the device to the surveyec object:	300 m
Weight of the Infrared Detector Unit:	
a) IR- chamber:	1.5 kg;
b) Power- supply & Processing block:	5.0 kg
Non-stop performance time, with a single nitrogen filling:	2 hrs

The history of Remote Thermal Diagnostics Infrared-Detection devices development by the SR&DB is based upon many years- experience in engineering the systems for search, detection and follow-up of Earth-located heat-emitting objects from air- and spacecraft carriers. High sensibility and resolution features of the detecting IR-devices, combined with their low weight and enhanced operational reliability, unique methodics of computer processing and operative observation-results analysis, characterize the SR&DB-developed infrared radiometers as highly effective and serviceable, comparatively inexpensive means of remote and safety control for various power-engineering equipment and facilities of nuclear, thermoelectric and district heating plants, high-voltage transmission lines, high-voltage distribution sub-stations etc.

An example of a High-Pressure Steam-Duct IR-Thermogram

The SR&DB- developed infrared apparatus has been successfully tested in many various power-engineering object sites.

1.3. MASS - SPECTROMETRIC FLUID / GAS CHEMICAL CONTENT TECHNOLOGICAL & ENVIRONMENTAL CONTROL APPARATUS

A mass- spectrometric (MS) method enables to provide analytical investigations, in a broad concentration range, for qualitative and quantitative content of substances and mixtures. The SR&DB experts have been developing various MS- devices for application in different branches of industry, medicine, ecological monitoring etc. In Ukraine, these devices are manufactured by Electronic- Microscope Factory in town of Sumi. High level-characteristics of MS- appararus, reliability and small weight of these products, are accomplished due to SR&DB experience gained for many years in development of MS-devices for space-purpose techniques.

The SR&DB has engineered, manufactured and field- tested a mobile MS-set for monitoring of fuel-combustion process completion , and of smoke- gases chemical composition.

A presented here MS- set may be used:

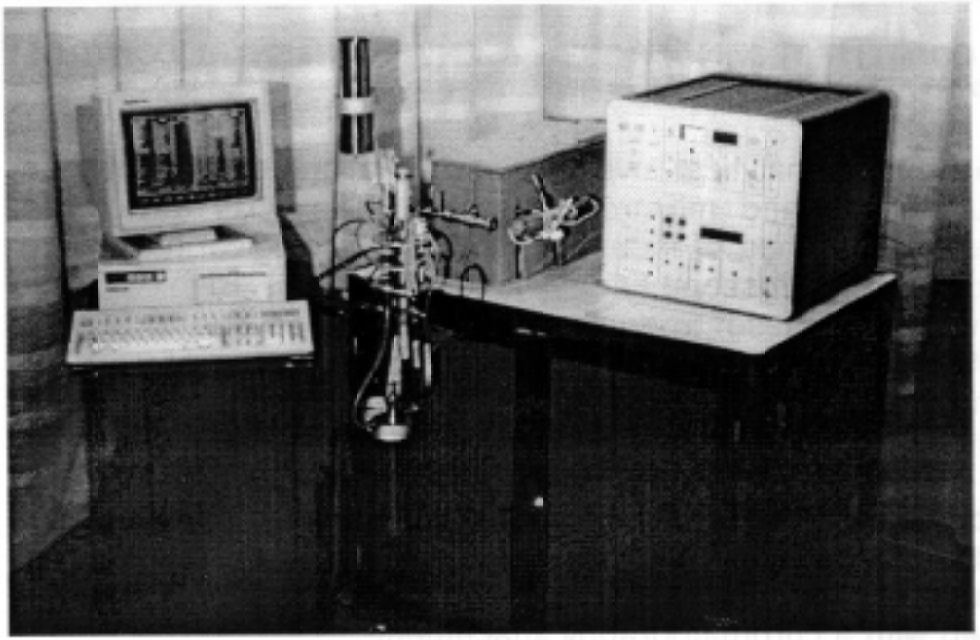
- at Thermal Power Plants to ccntrol the combustion processes for solid, liquid and gaseous fuel;
- for technical and economical efficiency enhancement of District Boiler Stations and
- for ecological monitoring of industrial premises and adjacent territories.

Another version of this MS-portable set is furnished with a chromatography attachment.

PERFORMANCE DATA

Range of analyzed mass numbers:	1...500 atomic mass units
Sensitivity:	0.0001 (0.08) vol.% (mg/ m^3)
Analysis time per 1 sample:	60 sec
Consumed power:	1,600W
Weight:	80 kg
Overall dimensions:	800 by 900 by 900 mm

The SR&DB has engineered a specialized mock-up version of a Nuclear Power Plant- application MS- system for control of 1st- Contour heat- carrier composition, to provide a non-stop automatic measurement of: boric- acid concentration; Boron-10 / Boron-11 isotope ratio in a heat carrier; gas content of heat-carrier-dissolved hydrogen, oxygen, ammonia, argon etc. The MS- monitoring unit is automatically controlled by a built-in or a remote computer.



A Mock-up sample of a specialized Mass- Spectrometric computerized System to control the #1- Contour heat carrier composition.

PERFORMANCE DATA

Measurement range for boric acid concentration:	0...50 g/ l
Sensitivity:	0.1 g/ kg
Measurement accuracy:	4%
Dynamic Boron-10/ Boron-11 measurement range:	100
Reaction:	60 s
Gas- component measurement range vol.%:	0.01...100
Consumed power:	3,000
Weight:	140 kg
Overall dimensions:	
a) Analytical electronic block:	920 by 1000 by 100 mm
b) Hydrocommutator:	1200 by 200 by 300 mm

The potential of MS- devices, engineered by the SR&DB, is perspective for many further developments with purpose of facilitating multiple technological and ecological monitoring tasks for Nuclear Power Plants.

1.4. PERSPECTIVE DEVELOPMENTS OF MEASUREMENT INSTRUMENTS

1.4.1. ACOUSTIC CONTACTLESS FLUID-LEVEL METERS. During power- engineering equipment operation, it's important to provide a dynamic control for tank or vessel- fluids (like water, heat carriers, fuel) level, rapidly changeable due to specific technological conditions. A fluid may be hot and corrosion- aggressive, which is critical against usage of conventional float-level meters or sight glasses.

In order to apply the automated level-control and technological process control systems, there are required contactless measurement methodics with electric output signal provision.

The SR&DB has developed acoustic (ultrasonic) resonance level-meters for contactless in-vessel fluid- level measurements with high (0.25%)- accuracy, quick action and interference security. Physically, the ultrasonic level-meter performance is based upon:

- excitation of gas column over fluid level and
- measurement of the gas-column resonance frequency,

which depends on said gas column height.

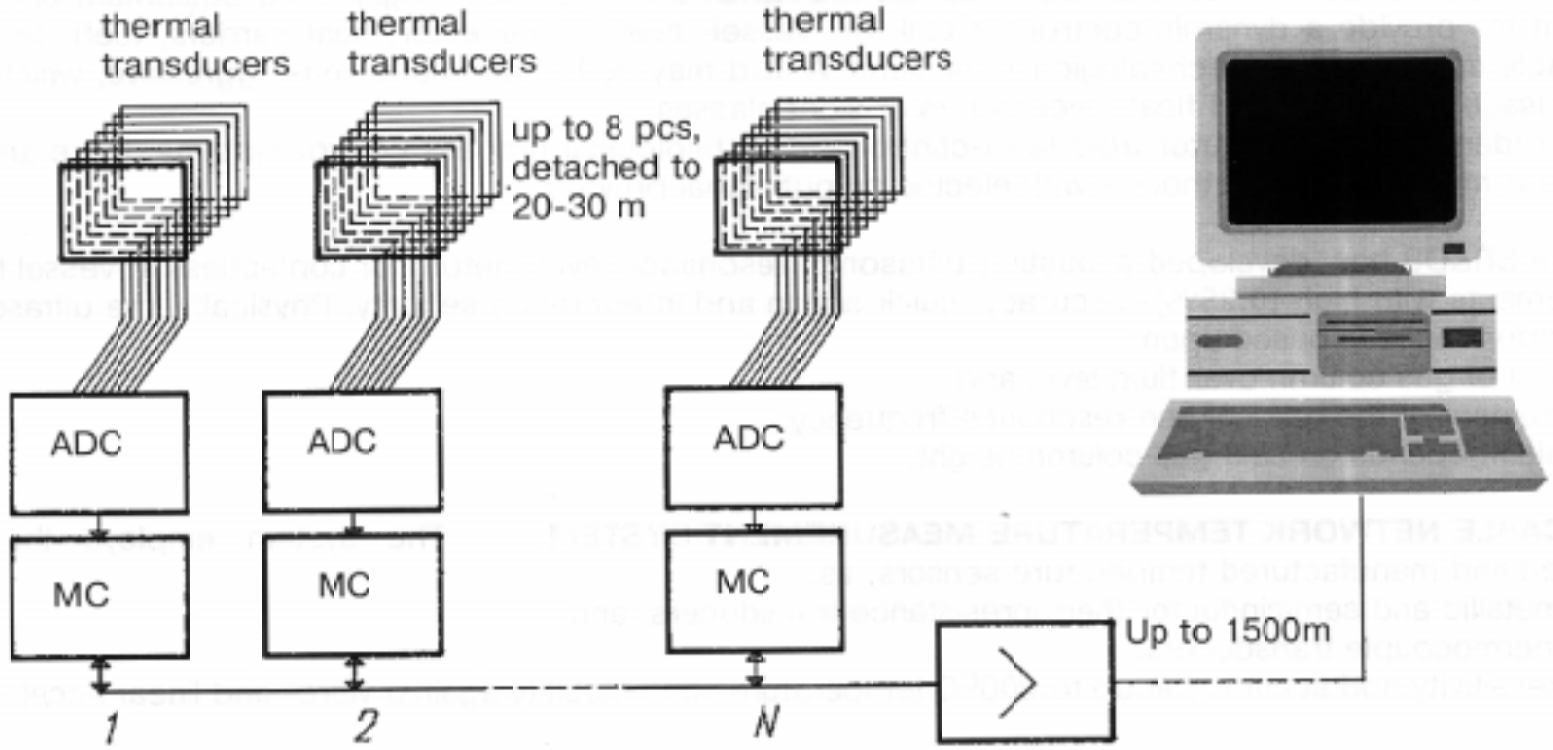
1.4.2. CABLE NETWORK TEMPERATURE MEASUREMENT SYSTEM. The system employs the SR&DB-developed and manufactured temperature sensors, as:

- metallic and semiconductor thermoresistance transducers, and
- thermocouple transducers,

of high sensitivity and accuracy at up to 200^{O}C temperatures and stability against vibro- and linear accelerations up to 300g.

The miniature thermometers (provided with auto-calibration function to discrete phase- transition points typical for some special alloys, wherein the transducer body houses several capsules with said alloys) can be a basis for further perspective thermometering systems of long- performance lifetime, without changing the first-stage transducers.

A measurement complex- installation for cable network temperature control, located in semi-basement of a Nuclear Power Plant - Power Unit, may include up to several hundred transducers detached up to 1500 meters away. A usage of analog/ digit transformation method for primary information signals ensures a two-lead network communication.



ADC - Analog - to - Digit Converter
MC - Micro Controller
> - Communication Line (up to 1,500 m) Amplifier

Scheme of a Cable-Network Temperature- Change Measurement- System located in Power- Unit semi-basements at a Nuclear Power Plant.

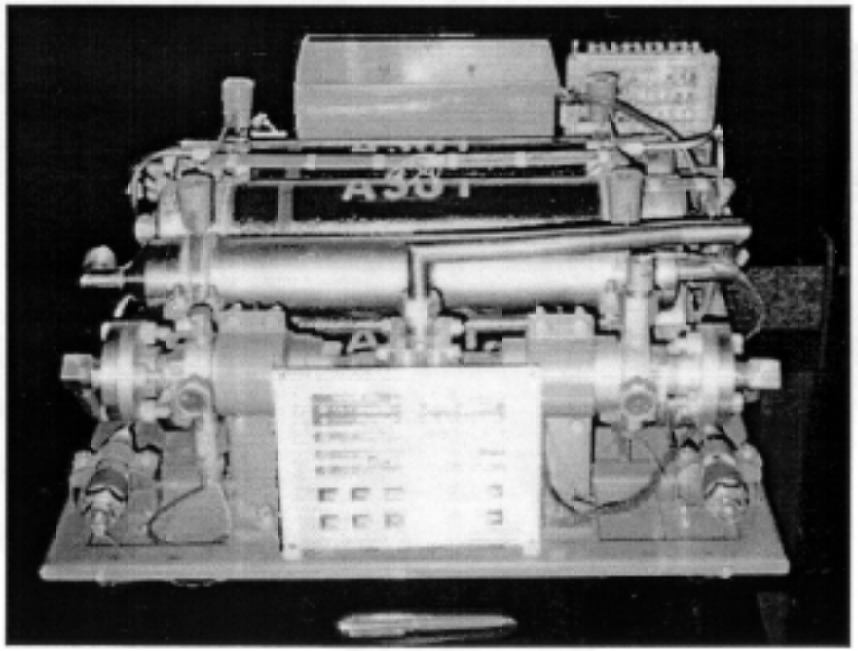
2. EQUIPMENT FOR SAFETY MAINTENANCE SYSTEMS OF NPS

2.1. AUTOMATED FIRE-ARRESTING SYSTEM

Purpose of the system is the automated fire-arresting of Nuclear Power Stations automated control systems, electrical equipment cabinets and racks with the use of gaseous nitrogen, which is safe for human and has no harmful action on equipment being protected

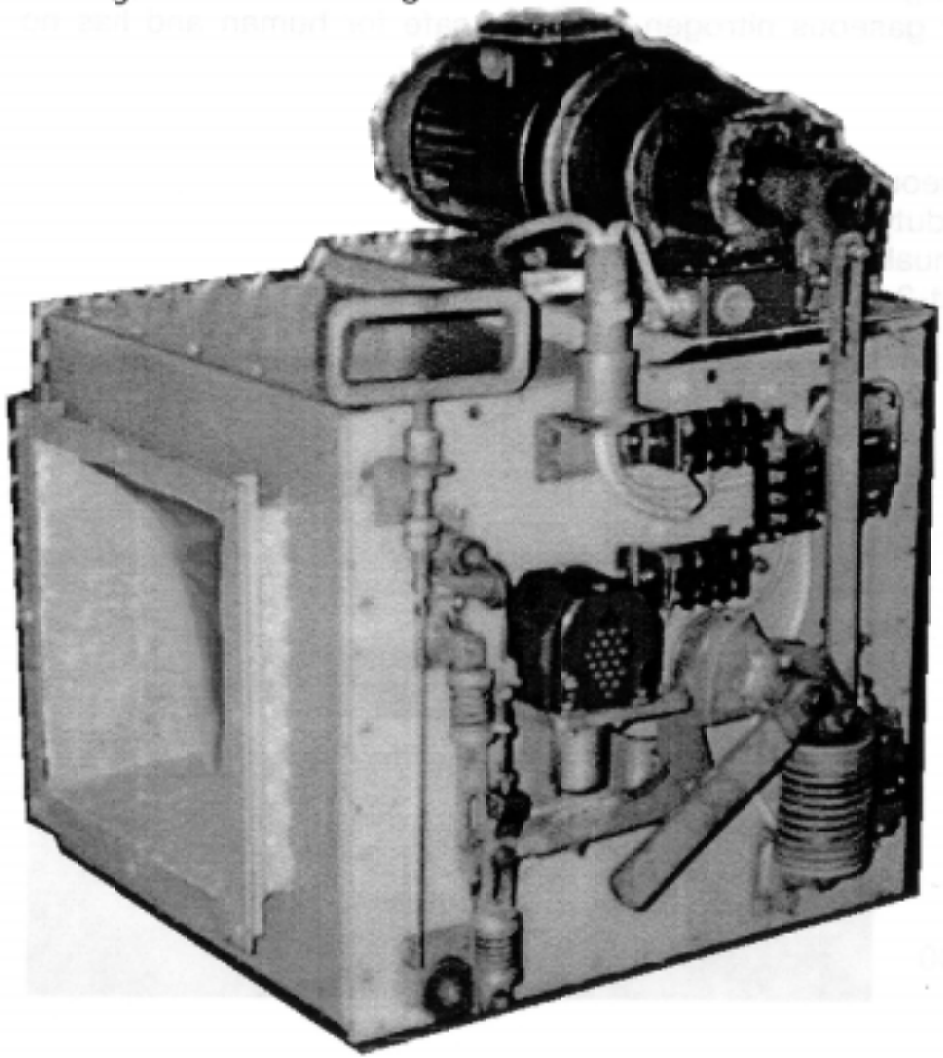
PERFORMANCE DATA

Basic fire-fighting medium	Gaseous nitrogen
System operating modes	On duty and fire-fighting
Transition from on-duty mode to fire-fighting mode	Manually or automatically
Fire alarm type	Agat-3
Fire alarm temperature setting, ^{0}C	80
Air smoke content which corresponds to fire alarm operation, dB/m	0,2
Duration of ejection of 90% of the fire-fighting substance from the balloon after system starting, sec	30
Fire-fighting substance temperature entering the cabinet, ^{0}C	-5
Power consumption in on-duty mode, W	50
System lifetime in on-duty mode with periodical tests, years	10
System service life after nitrogen refilling after operation and change of explosive charge, cycles	15
System mass, kg	50
Overall dimensions, mm	600x600 x 300
Price, $ USA	5000
Term of manufacturing, month	3



2.2. FIRE- ARRESTING SEISMIC- PROOF VALVES SYSTEM

There are developed 4 dimensional versions of the Fire- Arresting Valves- Units (FAVU) intended for automated blocking of fire- scattering



- through ports in fire - prevention partitions, or
- via air- ducts in ventilation systems at Nuclear Power Plant premises and constructuions.

The FAVU system will automatically close its valves within maximum 4 sec after fire-alarm warning or at functioning of easy-melting (fire-warning) locks.

Besides this, valves of a FAVU may be closed or opened :

- from a remote distance (via electric drive actuated by a control pulse), or
- manually (through wire ropes).

Thanks to application of special materials, the fire durability of a FAVU system amounts to minimum 90 minutes at about 1,000^{O}C environmental temperature.

Exterior of a Fire- Arresting Valves- Unit (of 400 by 400 mm pass-way cross-section), intended for automated blocking of fire scattering via air- ducts in a NPP ventilation system.

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PERFORMANCE DATA

FAVU fire- response temperature: 72° C

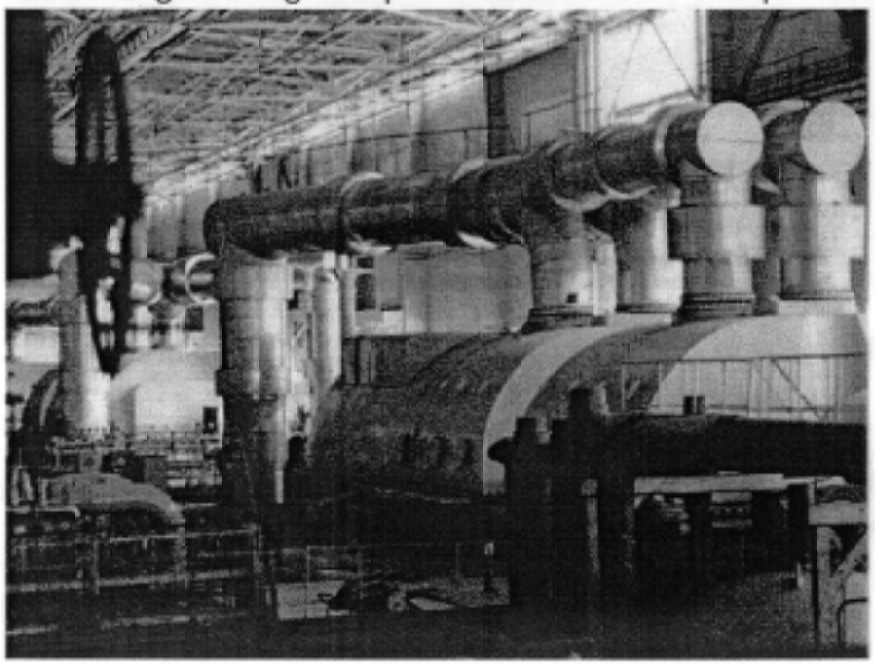
Pass-way cross-sections of each (of 4) FAVU dimensional versions:

a): 250 by 250;
b) 300 by 300;
c): 400 by 400;
d): 500 by 500 mm

Weight and dimensions of each of 4 versions, respectively:

a):	67;	540 by 506 by 620;
b);	75;	580 by 556 by 670;
c):	94;	620 by 656 by 770;
d):	115 kg	690 by 756 by 870 mm

FAVU design is based upon multiple SR&DB experience in engineering of specialized fixtures for space & rocketry flight-objects, stable against great impact- and vibration- overloads, that occur in active orbit sections.



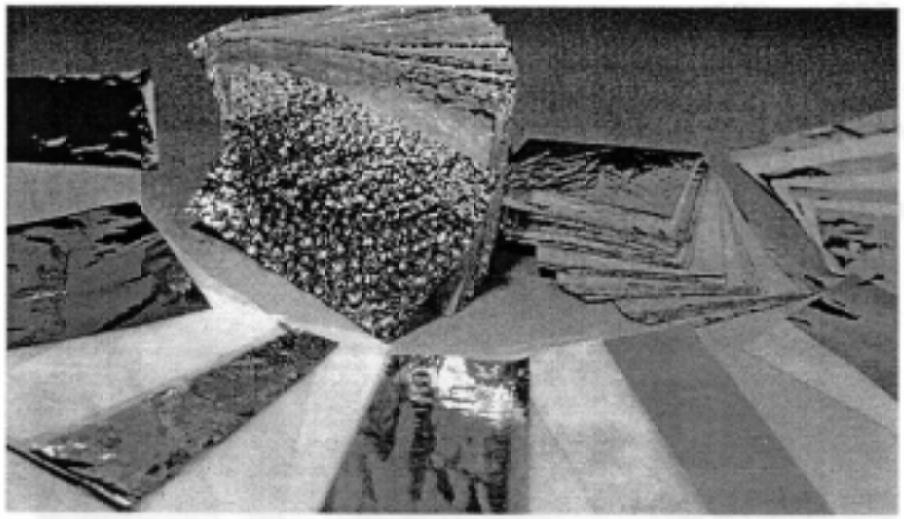
The special FAVU- structure design provides for high reliability and efficiency of fire- arresting valves even under exterior impacts as, for example, at explosions, earthquakes and other disastrous situations.

Such means of security enhancement for power-engineering equipment, and, first and foremost, for service personnel, may be used in nuclear power plants, in power-distribution sub-stations, in power-engineering system control centers etc.

3. THERMOSTRESSED POWER -ENGINEERING SYSTEM COOLING EQUIPMENT

3.1. DETACHABLE HOT- PIPELINE THERMO- INSULATION

Thermal insulation of a Nuclear Power Plant hot pipelines reduces power losses ard increases the total efficiency of power engineering equipment. At the same time, its features and design should meet multiple demands, besides the thermo-resistance requirement. These demands include: low cost, operational feasibility, ability for easy assembly/ disassembly, personnel sanitary security, stability against radiation, vibrations, desactivation.



Examples of High- Temperature Composite Thermo-Insulation Mullito- Silice Fiber Material

To satisfy such demands, the SR&DB has developed easy-detachable multi-usage thermo-protection sections (to apply for 1st and 2nd Contour pipelines, and for Nuclear Power Plant thermal fixtures), with use of high-temperature composite thermo- insulation material (conditionally: VCTM) based on mullito-silice fibers produced in Ukraine. The proposed thermal protection is specific for improved thermal and sanitary characteristics, as compared to conventional types, made as mineral-glass thermoinsulation mats.

Said sections are welded-carcass structures intended for quick assembly with hinge-locks. Thanks to low weight of section units, a team of several workers can operatively provide a quick job of control inspection for welded joints or other critical sites of the NPP equipment.

Having substantially better- than- conventional thermal and operational characteristics, the SR&DB- developed thermo- insulation cost, per average 1 m^2 of a pipeline surface, is :

- slighly prevailing over traditional mineral- glass matted material, or
- ten times less expensive than steel- foil thermal insulation provided by the "Atommash" enterprise, Russia.

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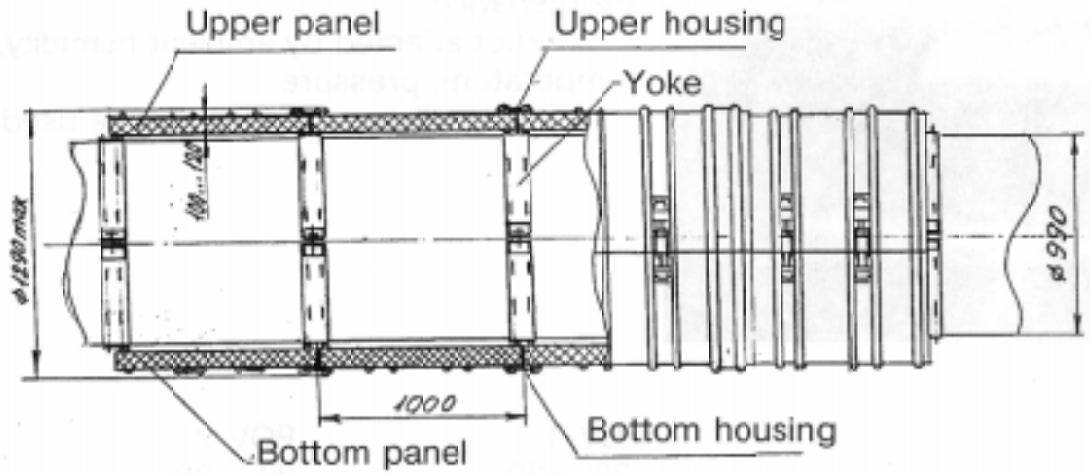
PERFORMANCE DATA

Working T inside thermoinsulation sections:	320^{O}C
Average exterior T of thermoinsulation sections, with 50^{O}C ambient temperature:	60^{O}C
Specific thermal efficiency from section surface:	133 W/ m^2
Thickness of a thermo-insulation layer:	100 mm
Expected life-time:	30 years
Weight of a thermo-insulation section:	40 kg maximum
Outside surface area:	1.8 m^2



Scheme of a Multiple- Usage Thermal Protection Section to be Applied at 1 & 2 Contours and Fixtures of a NPP

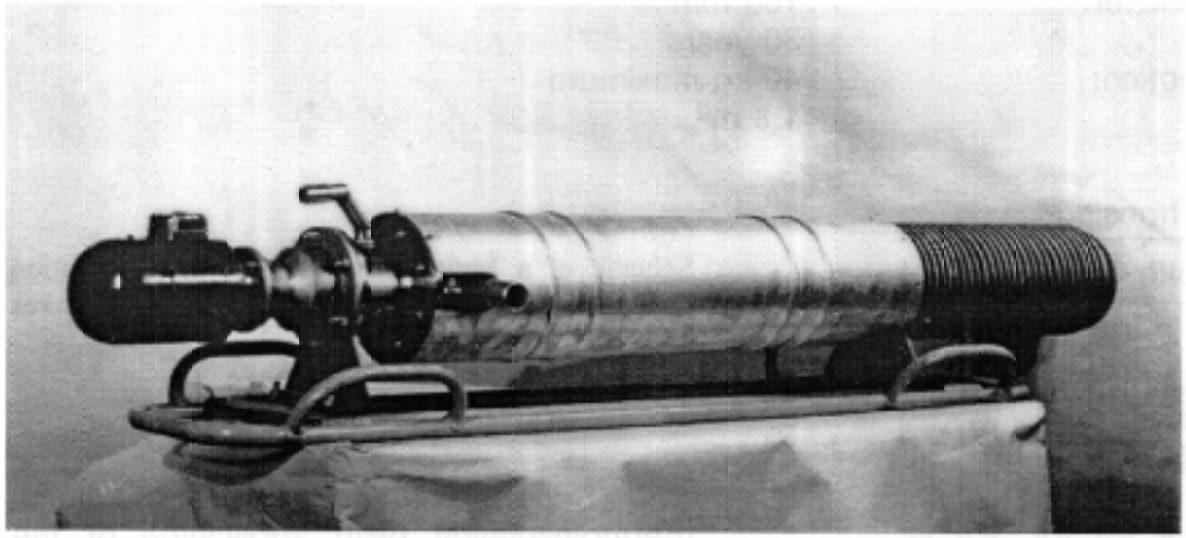
Superb characteristics of sectional thermoinsulation (with application of the new material) are available thanks to SR&DB substantial thermophysic- science potential, and many years experience in engineering for high-efficiency, light- weight and reliable thermoinsulation structures for space- application, and for specialized high-temperature facilities.

New approaches to creation of thermoinsulation structures, as implemented by the SR&DB developments, may be utilized for heat-losses reduction, as well as for improvement of serviceability and security for pipelines and power- engineering equipment of Nuclear Power plants.

2.2. PULSE TUBE AIR COOLERS

Coolers are intended for air conditioning, including mine working spaces, cooling agricultural, medical and pharmaceutical objects, agricultural products freezing, natural gas components separation etc. It matches best analogues in world.

Pulse tube coolers advantages are:



- free of electric power (only compressed air operation)
- ecologically safe
- simple to operate, no operation maintenance
- not affected by ambient humidity, temperature, pressure
- other than air gases can be used

PERFOMANCE DATA

Pulse tube cooler model	POV-1	POV-2
Ambient temperature, ^{0} C	-20..+30	20..+30
Cooling capacity, kW	2	9
Temperature difference between air inlet aid outlet, ^{o} C	40	60
Compressed air consumption, m^3 /min	2	5
Compressed air pressure, MPa	0,4 - 0,6	0,4...0,7
Outlet air pressure, MPa	0,1	0,1
Overall dimensions, mm	∅160 x 1500	∅550 x 660
Mass, kg	20	40

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CONCLUSION

1. The Special R&D Bureau in Cryogenic Technologies at B. Verkin Institute for Low Temperature Physics and Engineeting at National Academy of Sciences, Ukraine, has a strong scientific and technological basis, along with multiple-years experience in development and engineering of devices, facilities and equipment for space application, to satisfy with:
   - strictest requirements of high reliability and efficiency,
   - low power consumption level and
   - mass- dimensional characteristics.

2. The SR&DB has been successively using its scientific and technological basis with all available potential for development of new devices, facilities and equipment to meet interests of the Fuel- and- Power Complex of Ukraine (the nuclear power plants as well), with application of up-to-date materials and technologies.

3. High- qualification experts and specialists of the SR&DB are ready and enthusiastic to face further updated technology tasks specified by the Nuclear Power Engineering in Ukraine.