Laboratories of CENEN Association

CENEN-NET
New Generation Nuclear Energy Partnership
Laboratories of CENEN Association

The Laboratories and Facilities of the Academic Members of the CENEN Association
Representatives of individual Departments are responsible for the text describing their laboratories.

Author: CENEN Members
Editor: Jaroslav Zeman,
Faculty of Nuclear Sciences and Physical Engineering, CTU in Prague
Břehová 7, 115 19 Praha 1, Czech Republic
Published by Czech Technical University in Prague
CENEN – Czech Nuclear Education Network

CENEN is a voluntary academic association, whose principal activity is to provide high-quality and sustainable education in the field of nuclear engineering. With the effective cooperation of universities and commercial partners, high quality education can be achieved. The transfer of information between students and academic staff is being improved by organizing workshops, seminars and discussions with experts from the Czech Republic and abroad.

Foreign cooperation is being extended thanks to the inclusion of ENEN, the European Nuclear Education Network, and cooperation with WNU – the World Nuclear University.

The CENEN association was founded on 3rd May 2005, and since then the membership has grown to 17 members from academic institutions, with 4 associated commercial partners.

The CENEN-NET Project

The CENEN-NET project is being addressed within the framework of the Operational Programme ‘Education for Competitiveness’, in relation to priority axis No. 2 – ‘Tertiary education, Research and Development’, and to supported area no. 2.4. – ‘Partnerships and Networks’.

The aim of the project is to deepen cooperation between involved partners in higher education institutions that provide education in the nuclear energy field and are syndicated in the CENEN open academic association. Project participants: Czech Technical University in Prague, Institute of Chemical Technology Prague, University of West Bohemia, VŠB-Technical University of Ostrava, Brno University of Technology, Technical University of Liberec, State Office for Nuclear Safety, CEZ GROUP, ÚJV Řež a.s., ŠKODA JS a.s. and VÍTKOVICE ÚAM a.s.

The core activities of the project cover internships between the units, joint workshops, seminars and conferences, all leading to the strengthening, and especially the making of new contacts from the academic, public and applied spheres, both domestic and international. A key activity is the creation of a Project Support Office, which will assist the CENEN members in the preparation of domestic and international projects.
Project activities are geared mainly to the expansion of CENEN partnerships, through knowledge transfer from the centre to the regions, while facilitating access to the foreign and domestic industrial contacts of Prague-based universities among the regions, and with each other.

The main output of the project is deeper cooperation between universities, industry and the state sector, and the formation of professional contacts. The project target group consists of academics and students in universities outside Prague, who are involved in nuclear energy education. Specifically, this means 7 units comprising Departments and Institutes belonging to 7 different Faculties at 4 Universities (University of West Bohemia, VŠB-Technical University of Ostrava, Brno University of Technology, and Technical University of Liberec).

Information about the project and its undertakings is on the project website: www.cenen.net and that of the CENEN Association: www.cenen.cz.
Academic members of the CENEN Association:

- Czech Technical University in Prague
  - Faculty of Electrical Engineering
    - Department of Electrical Power Engineering
  - Faculty of Nuclear Sciences and Physical Engineering
    - Department of Dosimetry and Application of Ionizing Radiation
    - Department of Nuclear Chemistry
    - Department of Nuclear Reactors
    - Department of Materials
  - Faculty of Civil Engineering
    - Department of Concrete and Masonry Structures
  - Faculty of Mechanical Engineering
    - Department of Energy Engineering

- Masaryk University in Brno
  - Faculty of Social Studies
    - Department of International Relations and European Studies

- Technical University of Liberec
  - Faculty of Mechanical Engineering
    - Department of Power Engineering Equipment

- Brno University of Technology
  - Faculty of Electrical Engineering and Communication
    - Department of Electrical Power Engineering
  - Faculty of Mechanical Engineering
    - Energy Institute
• VŠB – Technical University of Ostrava
  o Faculty of Mechanical Engineering
    ✓ Department of Power Engineering

• Institute of Chemical Technology Prague
  o Faculty of Environmental Technology
    ✓ Department of Power Engineering

• University of West Bohemia
  o Faculty of Applied Sciences
    ✓ Department of Mathematics
  o Faculty of Electrical Engineering
    ✓ Department of Electric Power Engineering and Ecology
  o Faculty of Mechanical Engineering
    ✓ Department of Power System Engineering
The cornerstone of quality education rests on the principle of supplementing lectures and seminars with suitable experimental tuition and hands-on experience. Every department at each of the individual universities has, in its time, assembled a range of laboratories and experimental facilities, intended to broaden theoretical teaching. The opportunity to take part in experiments, and thus to validate theoretical knowledge at a real-world facility, significantly enhances the capabilities of technical college graduates, and hence their competitiveness on the labour market, not only within the Czech Republic, but also on an international scale.

To develop large-scale experimental facilities or to obtain specialized measuring instruments is financially demanding, putting such equipment beyond the reach of many units. Within the CENEN Association, the aim is to make effective use of laboratories and experimental facilities through sharing them and making them available to students from other departments. Thanks to this cooperation, it is possible to extend the number of modern experimental facilities right across the Czech Republic, and thus to raise the standard of graduates being made ready to work in the nuclear industry.

This publication presents an overview of the experimental facilities being run within the CENEN Association framework. These laboratories and specialized workplace are open not only to all students from the CENEN Association member universities, but also to other interested parties from technical colleges in the Czech Republic and abroad.
High Voltage Laboratory

The Laboratory can do voltage testing (up to 200 kV DC and up to 500 kV AC of the industrial frequency and beyond with atmospheric and switching impulse up to 1200 kV amplitude) as well as specialized tests, such as the measuring and evaluation of discharge activity in electrical machinery and equipment, the scanning of frequency characteristics as part of the condition-validation of transformer windings, the testing of surge protection for power and telecommunications equipment in terms of electromagnetic compatibility (EMC) and the mapping of electrostatic precipitator characteristics. The Laboratory undertakes calibration of instruments for high voltage and large current measurement (Rogowski coils, measuring current transformers), tension testing of protective and work means and measuring partial discharge.

Electrical Protection Laboratory

The Laboratory is equipped with electrical protections ranging from older types to the latest models and further safety elements. The Laboratory is equipped with 6 measuring stations, which provide regulated power supplies up to 400 V AC and up
to 220 V DC. Equipment used for measurement in the Laboratory includes, in addition to conventional devices (magneto-electric and ferromagnetic), modern digital instruments and oscilloscopes, interconnected with modern computer technology. Instruments devised for measuring electrical power quality – electrical network analysers (BK 550 Elcom, CIRCUTOR QNA-412, CIRCUTOR CAVA), the OMICRON CMC 256-6 instrument for measuring and testing digital protections devices, and a probe for measuring electrical and magnetic fields are also available here.
**Electrical Generation Power-unit Model**

The Laboratory is equipped with a physical model of the electrical part of a power-plant unit (a synchronous machine powered by a Ward-Leonard control system connectable to the system through a block transformer and a choke). Its purpose lies in teaching power-unit handling, and testing protective systems, transitional phenomena and faults in electricity generating systems. The Laboratory is suitable for tuition and for the training of experts in the electrical power engineering field.

**Lighting Technology Laboratory**

The Laboratory is accredited by the civil aviation authority of the Czech Republic for verifying the lighting-engineering parameters of airport signalling gear. The Laboratory equipment includes: an integrating sphere, goniophotometer, photometric bench, spectrophotometer, contrast meter, reflection meter, luminance meter, etc. Within the Laboratory it is possible to perform computerized and photometric verification of the lighting-engineering quantitative and qualitative parameters of lighting systems, and lighting systems designs, in locations and sites notable
for visually intensive activities, whether in industry, the health sector, schools, offices, etc.
Laboratory of thermoluminescence and gel dosimetry

Thermoluminescence dosimetry is done with a Harshaw-3500 HT reader, primarily designed for dosimeters of the TLD-100 type, but also suitable for other types of dosimeters, e.g. alumino-phosphate glass. The reader allows reading an integral signal and recording of the heating curve.

In addition to its use in dosimetry, the device can be used in solid state physics research. The thermoluminescent signal allows measuring trap concentration and depth in the material band gap, and thus provides valuable information. An example of its successful scientific application is cooperation on scintillator research with the Institute of Physics AS CR.

Gel dosimetry makes it possible to measure the 3D distribution of ionizing radiation doses in a near tissue-equivalent material. The fundamental component is the gel, which fills a container of desired geometry. Under irradiation, the gel changes its properties (density, optical properties), depending on the dose absorbed. The Laboratory is equipped with facilities and raw materials for the preparation of gels, and also has an optical tomograph, allowing the dose to be mapped in all three dimensions at a value range from single units to tens of Gy. Laboratory is equipped with a spectrophotometer also.
X-ray Fluorescence Analysis Laboratory

X-ray fluorescence analysis is a fast, versatile, multi-elemental, non-destructive analytical method, based on measuring the characteristic X-ray spectra excited by ionizing radiation. The Department’s facilities allow measuring of elements with a proton number of 15 and above, in concentrations from about 0.1% and above. Thanks to X-ray optics, it is possible to measure the composition of very small areas in tens of microns, or by means of scanning, to map the 2D layout of elements in the sample.

All the elements are determined in a single measurement, whose duration at any point is never a matter of more than a few minutes. There is no need to modify the sample for measurement purposes and the method causes no harm to the sample.
The Laboratory is equipped with three X-ray devices, an Si PIN detector, an SDD detector, an Si(Li) detector, $^{55}$Fe and $^{238}$Pu radionuclide sources and set-up enabling the scanning of surface objects.

**Gamma-ray Spectrometry Laboratory**

The Spectrometry Laboratory is equipped with three HPGe detectors in lead shielding. Primarily, these are intended for measuring samples within the Marinelli container geometry, but other geometries are an option. The HPGe detectors are the common non-inverted detectors, suitable for spectrometry of gamma radiation at 50 keV and above. If the need arises to measure lower energies, an Si(Li) detector is available, located in the X-ray fluorescence analysis Laboratory.

**Thermoluminescent dating Laboratory**

For dating items made of ceramics, clay, etc. the thermoluminescent dating method is available. It rest on the premise that the object of study contains material with properties of a thermoluminescent dosimeter with very low fading. Dose accumulated in the material due to irradiation can be measured. Consequently, the age can be calculated with the knowledge of dose rate. A precondition is the erasure of the thermoluminescent signal at some point in history, typically during brick or ceramic item kiln firing, etc. The thermoluminescent dating Laboratory is equipped with facilities for the collection and preparation of samples for thermoluminescent dating and, of course, the instrumentation to determinate the age of historical artefacts.

**Computed Tomography Laboratory**

Currently under construction is a laboratory for a computerized tomograph. The CT will be fitted with a detector, consisting of a CCD camera and a scintillation screen of LuAG:Ce, and potentially a TimePix pixel detector. Both of these detectors allow high spatial resolution to be achieved. The tomograph is intended for displaying smaller objects or details, of around 1 cm or less.
Irradiation hall and Practicum, Dejvice

The Practicum of X-ray physics in Dejvice is equipped with diagnostic set-up no longer in clinical use (a mammograph, a dental X-ray machine, a standard X-ray machine), fully functional nevertheless. These can be used e.g. for image quality and other parameter evaluation purposes. Ionization chambers can be used, to verify X-ray device parameters, and to measure patient dose.

Ionization chambers can also be used in the irradiation hall, which contains a water phantom and a $^{137}$Cs gamma radiation source. Beam profile of this radiation source can be measured using ionization chambers and phantom. The irradiation hall also contains an older $^{252}$Cf neutron source, as well as neutron detectors: a BF$_3$ long-counter and an LiF:Eu scintillator with Bonner spheres, applicable for neutron spectrometry.

Dosimetric Practicum

Available are simple detectors, electronic modules of the NIM and CAMAC systems and 2 oscilloscopes, which are mainly used for tuition, but are versatile enough for other purposes. Specifically, there are crystals of NaI:Tl, plastic scintillators, electronic personal dosimeters, 2 proportional detectors, a YAG:Ce scintillator with vacuum chamber for $\alpha$ spectrometry, a silicon surface barrier detector and vacuum chamber (alpha-spectrometry), GM tube for gamma rays, GM bell detectors, Lucas chambers, radon measuring devices of type RADIM-3, ionization chamber for radon measurement, spectrometric amplifiers, HV bias supply, LV bias supply, coincidence units, single-channel and multichannel analyzers, delay lines, time to amplitude converters, a multichannel scaler, pulse shape analyzer, reference pulse generators, photomultiplier tubes, interconnecting cables, radionuclide sources of ionizing radiation, an emanation source of radon and a range of other, more general apparatus (scales, callipers, etc.).

Other

The Department is also equipped with several devices used for in-situ gamma spectrometry: BGO and NaI:Tl scintillation detectors, several instruments for the measurement of radon, and the ARES system for tomographically determining the specific resistance of rock materials.
The Department is certified and equipped for testing of the long term stability of closed radioactive sources.

The Department operates two older GAMACELL 220 $^{60}\text{Co}$ irradiators with dose rates 4 Gy/h and 60 Gy/h.

Workers utilizing the Monte-Carlo technique have available to them a computing cluster, and the MCNP and Fluka programs.

Using the FRITRA-4 device for the continuous monitoring of radon and its daughter products in a cave.

Measuring dose rates in vicinity of Temelin Nuclear Power Plant.

Gamacell 220 irradiator with extended sample chamber filled by samples.
Department of Nuclear Chemistry, Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague

At the Department of Nuclear Chemistry (DNC) can be found a wide range of instruments and laboratory equipment, divided among ten Laboratories used by four research groups, that may be referred to as „Speciation and Migration”, “Separation and Radioanalytics”, „Radiation Chemistry”and „Radiopharmaceutical Chemistry“.
For more details, see www.jaderna-chemie.cz.

The Instrumental Methods Laboratory serves as the DNC analytical back-office. In addition to standard laboratory equipment (scales, dryers, shakers, pH-meters, centrifuges, thermostats, autoclaves, ...) work here uses numerous investment-intensive analytical instruments and devices (Varian AA240FS and AA280Z atomic absorption spectrometers, an AMA 254 mercury analyzer, a Varian Cary 100 UV-vis spectrometer, a TIM 845 automatic titrator, an HPLC Watrex liquid chromatograph, a CP-9002 gas chromatograph, with ECD and FID detectors, a Reference 600 potentiostat/galvanostat/ZRA with rotary electrode, X-ray diffractometers, TGA, DTA, DSC Lasys Evo thermo-analyzer, a Classic 0415 VAK vacuum furnace, apparatus to determine the nominal surface size of powder materials and a glove box). The Lab also has a workshop with a milling machine, a bench drill press, a table lathe and a bench grinder.

The TRLFS Laboratory (Time-Resolved Laser-Induced Fluorescence Spectroscopy) conducts experimental study of the speciation of uranium and latterly of other elements, which are characterizable by the induced fluorescence of their complexes in the liquid phase, e.g. europium. The main components of this analytical equipment
are an Nd:YAG laser-pumped tuneable laser system, the VIBRANT™ 355 II, an MS257™ spectrograph, and an ANDOR iStar ICCD camera. For the evaluation of acquired data (time-differentiated spectra) were in the laboratory prepared numerous tools, including also application of factor analysis of complex systems of spectra.

In the **Radiation Sources Laboratory** are UV emitters (UV lamp of 120 W power and a UV lamp of 4x25 W power output with an optical bench), a GammaCell source of gamma $^{60}\text{Co}$, a LINAC source of accelerated electrons and pilot flow-through equipment for irradiation of liquid environments with accelerated electrons in flow and circulation modes. Research here is focused, in particular, on utilizing of the nanotechnology to minimize contamination of the environment (radionuclides, heavy metals) and the alternative synthesis of inorganic nano-scintillators. Emitters are also used also for the irradiation of biological materials.

The **Bioradiation Chemistry Unit** enables to work with the Aura Mini (BioAir) laminar box, the Tuttnauer 2540Ms autoclave with chamber volume 23 L, a Lovibond ET 618 (Liebherr) thermostat, a DN45 microscope with image display screen (Lambda Praha) and an orbital shaker, the IKA MS3 basic. Currently the chemical possibilities of protecting of cells against the effects of radiation sources with the purview of modelling of bio-membranes and the surface layer of living cells are studied here.

The **Radiochemical Laboratory** complex contains class II. laboratories equipped with radiochemical fume hoods, contamination meters, a Vacucell-22 vacuum dryer (from Brměnská Medicínská Technika, a.s.), a LYOVAC GT2 lyophilizer (SRK System Technik), an ABU-901 titrator and the basic facilities needed for research and tuition in the area of separation- and analytical radiochemistry.
The **Radiometric Laboratory** is equipped with a gamma-ray spectrometer with high resolution and screening for low-background measurements (ORTEC EG&G – ORTEC USA multi-channel analyzer with PGT PIGC 22 – Princeton Gamma Technologies, USA – coaxial semiconductor detector, 22% efficiency, 1.9 keV resolution for $^{60}\text{Co}$ with $E_\gamma = 1332$ keV, cooled with liquid nitrogen); a gamma-ray spectrometer with high resolution for normal measurements (Canberra GC4019 HPGe 40% detector, ORTEC DSpec Junior 2.0 digital spectrometer, Cryoelectric Canberra II cooling unit); low-energy gamma-ray spectrometer with high resolution (ORTEC 926 multi-channel analyzer and Canberra GL0510P/S detector, cooled with liquid nitrogen); a medium resolution gamma-ray spectrometer (LaBr(Ce) detector and ORTEC DigiBASE/E compact multi-channel spectrometer structurally modified to a submersible probe (to 10 m) with a diameter of 85 mm), single-channel NaI(Tl) based counter systems, the ORTEC OCTETE Plus alpha spectrometer (8- chamber system with PIPS detectors), counter with a proportional detector, liquid scintillation spectrometry – Triathler Standard, Triathler with additional NaI(Tl) well-type counter detector and additional lead shielding, a 3-photomultiplier scintillation spectrometer – the Hidex 300SL (all Hidex Oy, Finland); a NITON XL3t 900S GOLDD Thermo Scientific/HUKOS Ltd. X-ray fluorescence portable analyser; TTi EL302RD electrodeposition and Teflon equipment for alpha spectrometry. The studies and experiments carried out in this laboratory are related to application of separation methods in radiochemistry (e.g. the separation of minority actinides from high-activity waste for their future transmutation – “Partitioning”, the development of new separation materials, in particular solid extractants and composite ion-exchangers, precursor preparation procedures development for advanced nuclear fuel, the separation of radionuclides from liquid radioactive waste, decontamination of soils) and radio-analytical methods focusing on the development of new methods for analysis of hardly to determine radionuclides in radioactive waste or in the environment, and the
preparation of samples for measurement of radionuclides with a long half-life using AMS (Accelerator Mass Spectrometry).

The „Speciation and Migration“ group has the necessary laboratory equipment for characterizing the sorption and retardation characteristics of natural rock materials, the software tools for evaluating of laboratory experimental results and the simulation of contaminant transport in the environment (e.g. PHREEQC, MINTEQ and some GoldSim-based modules) as well as own methodologies and software tools for the management and evaluation of experiments and simulation calculations. Researchers and students from the group study the interactions of selected radionuclides with barrier materials of disposals of radioactive waste and with rock materials. The diffusion of critical radionuclides through the barrier materials is studied experimentally and modelled by some standard methods and also with the help of own codes. Some researchers from this group take part in development of methods and simulation codes for the description of the planned final geological disposal of irradiated nuclear fuel and highly active radioactive waste.

The Radiochemical Practicum is equipped with radiochemical fume hoods, shielded enclosures for stock solutions of radionuclides, a set of contamination meters, a Canberra/Bioscan AR-2000 radio-chromatographical scanner, single-channel scintillation and GM systems, a glove box, an EcoCel 22 dyer, (Brněnská Medicínská Technika, a.s.), a Spectroquant 420 to 150 °C thermo-reactor, submersible thermostats up to 15 L volume, sources for electrophoresis and electrolysis (Consort EV231, Manson DualTracking DPD 3030), a 1000 °C furnace, a neutron AmBe 500 mCi source, a thermostatted Shaker-5 to 75 °C with Peltiér and passive water cooling, a Helios Ypsilon spectrophotometer, a one position ERTEC Magnum 01-04 high-pressure microwave reactor and Lucas chambers for Rn measurement. This is where
most of the DNC practical exercises take place (such as in detection of ionizing radiation, nuclear chemistry, radioanalytical methods, radiochemistry techniques and separation methods).

In the **Radiopharmaceuticals and Labelled Compounds Laboratory** and the Organic Synthesis Laboratory, apparatus is used to label organic substances and prepare radiopharmaceuticals, using a modular analytical HPLC system with autosampler allowing for UV-vis, RI, conductivity and radiometric detection, linked to the Clarity SW. The Laboratory also has at its disposal a TLC Imaging Scanner (AR-2000) linked to WinScan 3 and WinScan 3-2D© SW, a CRC-55 tW ionization chamber and radiochemical fume hoods. The Laboratories also have available all basic laboratory facilities for the synthesis and processing of organic substances on both the micro and macro scales (a double-walled 2.5 L reactor), a Huber TC50E cryostat for low-temperature synthesis, vacuum line with inert branch, an HPLC preparative LKB system with RI detector and fractions collector (separation up to 50 mg/L loading). Laboratories are equipped with central vacuum and inert gas distribution lines (XDS 5). Structurally-analytical section supporting the two Laboratories is comprising of an IR spectrometer, the Nicolet Impact 400D and a single-stage MS spectrometer, the Finnigan SSQ 7000, whilst NMR services are contracted with an external cooperating facility, the Czech Academy of Sciences. The main activity of the Laboratories is developing and optimizing the synthesis of new compounds and potential radiopharmaceuticals, the application of isotopes in biology and medicine, verification of the output quality of labelled compounds and radiopharmaceuticals by means of HPLC, GC and structural analysis of MS (ESI/CID, APCI), IR (ESP, DRIFT), NMR ($^1$H, $^{13}$C, $^3$H).
Training Reactor VR-1

A pool-type zero-power reactor is used primarily for students’ education and the periodic training of nuclear power plant staff. The reactor core features a multitude of vertical channels, allowing operational measuring of power, placing supplementary detectors into the reactor core, or, as required, irradiating small samples. The reactor also includes horizontal channels, fitted with quick-closing valves and measuring boxes for experiments with bundle withdrawal from the reactor core. There is also a pneumatic tube, equipment for the study of delayed neutrons, simulation of bubble boiling, implementation of quick dynamic changes and temperature heating.

The reactor reactor core is variable and changes at least once a year, the design and implementation being done with students’ participation. The reactor core is equipped with different types of neutron detectors, including EMK-310 analyzers, needed for evaluating the measured spectrum. Also available are portable measuring instruments for determining alpha and beta surface contamination and device for the measurement of gamma and neutron dose rate.

At the reactor there are also available, for experimental purposes, EK-10 fuel pins, beryllium and graphite blocks and heavy water.
For education purposes there are several standard tasks prepared, with appropriate methodology, such as:

- Neutron detection
- Study of delayed neutrons
- Basic and advanced reactor kinetics and dynamics
- Measurement of reactivity and calibration curve determination
- Approaching the critical state
- Short-term instrumental neutron activation analysis

In addition to these basic tasks, intended to demonstrate the physical aspects of reactor operation, the reactor is also used for measurement of student works and for research, for example in the field of neutron detection and for security systems.

Regular site visits are arranged for secondary and tertiary education institutions.

**Neutron Laboratory**

The Laboratory offers a set of practical exercises in the study of neutron interaction with matter and the study of neutron source properties. Via these tasks students can experimentally check their lecture-gained theoretical knowledge of nuclear, neutron and reactor physics, nuclear engineering devices, dosimetry and radiation protection.

The Laboratory uses an external AmBe radionuclide neutron source and is thus completely independent of the VR-1 reactor as a neutron source. Available is also a small portable pulsed neutron generator, the Model P385 (supplied by Thermo Scientific), producing neutrons by the D+D fusion reaction. The generator is 690 mm long and 101 mm in diameter, weighing 17 kg in all. The generator can work both
in continuous and pulse modes with frequency up to 20 kHz. Neutrons produced by the generator have an energy level of 2.5 MeV and the maximum yield is around $6 \times 10^6$ n/s.

The Laboratory includes a graphite prism, a water bath with controlled water heating, a manganese bath and apparatus for studying photo-neutron source properties. The Laboratory enables measuring the absolute emission level of radionuclide neutron sources, preparing the photo-neutron source and studying its properties, studying the slowing-down and diffusion of neutrons in water or graphite, i.e. to set the diffusion length and Fermi age of neutrons, the migration area and extrapolated distance.

Also available is apparatus for thermoluminescent measurement, including a TL dosimetry reader, the RA'94, a furnace for dosimeter annealing and TL dosimeters for measuring neutron and gamma radiation.
Spectrometry Laboratory

The Gamma Spectrometry Laboratory holds two semiconductor detectors of high-purity germanium and an inorganic scintillation detector. The main HPGe semiconductor detector, given its energy resolution of 1.8 keV, is suitable for precise gamma-spectrometry measurement. It is permanently encased in a lead-shield box. A portable HPGe detector is used to measure samples in the laboratory, in the reactor hall, or in the neutron laboratory, depending on the type of experiment.

The detectors are used for measuring a variety of gamma spectra of the irradiated samples, particularly measuring neutron field monitors (activation foils) for determining spectral characteristics, and sample isotope composition by activation analysis and the study of reactor VR-1 fuel burn up.

An NaI(Tl) scintillation detector is used to analyze water samples from the VR-1 reactor facility, and can also be used to analyze the activation foils.

Electronic Laboratory

The Electronic Laboratory is used for teaching and practicals in subjects such as Foundations in electronics, the Computer control of experiments and Programmable logic arrays. It is also used for maintaining the control system of reactor VR-1, and the testing and validation of software for nuclear reactor control systems.

Devices worth mentioning include 2 digital oscilloscopes, the HP54641D and Agilent MSOX3012A, Agilent 34410A universal measuring instruments, HP3245A universal supply, HP8110A and HP81110A impulse generators, HP1652B Logic Analyzer, HP33120A and Agilent 33521A function generators, Agilent B2902A current/voltage meter/generator, HPE3631A power supplies. The Laboratory is also equipped with a programming system for programmable memories and single-chip microcomputers, computer equipped with software for the development of programmable logic arrays, and software for the management of measuring equipment and generators.
Nuclear Power-plant Simulator

For a better understanding of the interconnectedness of individual events at a nuclear power plant, the Department has at its disposal reactor operation simulators, for reactor types – VVER-440, VVER-1000, ABWR, CANDU

These are cut-down copies of the respective nuclear power station monitoring systems, allowing students to test the effect of various parameters on the nuclear reactor and vice versa. For example, the effect on cooling of a drop in secondary steam pressure, reactor shutdown after turbine failure, reactor start-up, changes in reactor power, regulation using absorbing clusters, boric acid and so forth.

Computational Tools

To support teaching and for research and development needs the Department of Nuclear Reactors is equipped with computer servers, which together add up to more than 50 processor cores. With these and thanks to the use of the GNU/Linux system it is possible to run calculations remotely in a wide variety of up-to-date computational programs. These include the Monte-Carlo transport software called Serpent, tools for the preparation and processing of nuclear data, NJOY and TALYS, and an extensive suite of computational tools called SCALE which allows a variety of nuclear reactors and shielding calculations. Licensed users have available the Monte-Carlo software MCNP and MCNPX. For students and their work there is, on a bilateral agreement basis, software called MOBY-DICK and ANDREA, used for the analysis of fuel batches at Czech nuclear power plants.

For the calculation of flow and of heat transfer, the Department has SW programs, namely CFD, CCM+ and the COSMOS/M package with modules Hstar for conduction computation and FlowPlus for flow computation. Both can be used for the thermo-hydraulic analysis of the reactor core of the primary circuit and other nuclear power plant facilities. In the field of nuclear fuel thermo-mechanics the software used is FEMAXI-6, FRAPCON/FRAPTRAN and TRANSURANUS, due shortly. Taken together, these software facilities are by their nature able to cover all the necessary analyses, of routine and emergency conditions. Students have available, under cooperation with ŠKODA JS, specialist proprietary software: CALOPEA (aimed at reactor core sub-channel analysis) and STAMOD.
Department of Materials, Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague

The Department of Materials educates engineers in the field of materials physics in the subject of Materials diagnostics, and participates in the education of engineers in the subject of Physics and thermonuclear fusion technology, Mathematical engineering and Mathematical computation. Research activities of the Department, both in fundamental research and within the terms of industrial cooperation are based on a comprehensive approach to the study of faulting in solids and structures, involving physical and metallurgical aspects, the application of fracture mechanics, mathematical modelling of stress and strain fields, research into micro volume breakdown processes as well as the probabilistic approach to studying the reliability of systems. International cooperation by the Department is oriented mainly at the study of materials fatigue faulting. Involved in all these project types are Master's and Doctoral degree programme students.

The Department includes a fractographic unit, bearing the status of an authorized Czech aviation industry and research test centre.

Graduates in the Materials diagnostics subject are fully ready for comprehensive original work in materials research, in the development and deployment of new technologies and in finding solutions to the problems the systems longevity and reliability in a diversity of mechanical engineering, energy and transport sectors. Graduates have the mathematical and physical grounding supporting their range of knowledge in solid state physics, applied mechanics of continua, fracture and computational mechanics. During the course, emphasis is put on the experimental methods of researching materials in macro- and micro volume, studying the underlying nature and manifestations of faulting processes, and on the use of probabilistic and statistical techniques.

A graduate’s profile is such as to be broadly deployable in fundamental and applied research or in research and development activities in industrial practice.

Fractografic Laboratory:

- 3 drilling JEOL electron microscopes: JSM 5510 LV, JSM840 A, JSM 50 A
- Energy-dispersive micro-analyzer
Metallographic Laboratory:

- Metallographic sample preparation, automatic polisher, electrolytic polisher
- Light microscopes with digital output
- 3D surface reconstruction using stereo pairs

3D surface reconstruction using stereo pairs
Micro-hardness Measurement Laboratory

- Nano-indentor with micro-indentor module
- Micro-hardness testing devices

Mechanical Testing Laboratory:

- INOVA JAMES 50 modernized hydraulic pulsator
- High-frequency resonant pulsator (SF-test)
- Tension tests, Charpy impact test, hardness measurement
INOVA pulsator

SF-test

Instrumented Charpy hammer

Inspekt 100 kN Universal testing machine
Department of Concrete and Masonry Structures, Faculty of Civil Engineering, Czech Technical University in Prague

All the Laboratories at the Faculty of Civil Engineering focus on research into and verification of the properties of construction material, which therefore includes the materials used in nuclear power constructions. Studied here are the geological conditions crucial to the foundations of strategic constructions. Of further interest are building materials such as concrete and steel, including when under extreme conditions of prolonged heating, fire, chemical attack. Also examined is the flow of water, the understanding of which is crucial when designing production plant cooling systems. Below are listed the individual Laboratories, related to nuclear energy.

Experimental Centre

This Centre acts as an accredited workplace in the field of building structures and materials testing. It carries out scientific-research experimentation and provides professional support services for construction companies both in the Laboratory and on-site. As part of education students get acquainted here with the basic methods of experimental research into the mechanical properties of building materials and structures.
Experimental Geotechnics Centre

This Centre deals with solving technical and practical issues in the mechanics of rocks and soils, and monitors special-interest ground and underground building structures such as underground storage tanks and repositories of spent fuel.

Chemical and Technological Laboratory

This Laboratory deals with determining the physical and chemical properties of materials such as stone, quarry aggregates, binders etc.

Laboratory of Transport Processes

This Laboratory, just as the chemical and technological Laboratory, deals with determining the physical parameters of construction materials in a simulated environment using air conditioning chambers. As part of the tuition here students become familiar with e.g. the issues of building material diffusivity and materials behaviour under extreme heat conditions.

Micromechanical Laboratory

This Laboratory is engaged in comprehensive research into silicate binders, primarily on the basis of cement and fly-ash detritus from power plants. The Laboratory’s high-tech facilities include three nano-indentors, an environmental scanning electron microscope with micro-analyzer and electron diffraction, an atomic force microscope, a polarizing microscope and an isothermic calorimeter. Here, students can get to know
about phase state changes in silicate binders at the micro level, during their exposure to extreme conditions.

Water-management Laboratory

This Laboratory serves model-based research of hydraulic phenomena pertaining to water-management structures, water flows, water pipes, sewage water treatment, etc.
Gaslift Experimental facilities

Experimental equipment made of plexiglass for the monitoring of two-phase air-water flows. The equipment is used for measuring flow stream velocity (by using conductometers) and the visualization of flow using high speed cameras.
Experimental facilities for on-wire boiling crisis research

The apparatus is used for verifying correlates of crisis at atmospheric pressures. Handles water up to boiling temperature. Allows for using different wire types. Investigating the role of surface roughness and purity.

Experimental facilities to simulate flooding and flow-reversal

The apparatus is used for verifying correlates of flooding and flow direction reversal. This phenomenon is very important for the emergency cooling of the reactor core in nuclear reactors. The apparatus operates at atmospheric pressure and room temperature.

Equipment for verifying the Temelín Nuclear Power Plant barbotage tank collector

The equipment serves for parameter-verification of the new collector for the barbotage tank in Temelín. Pressure increases and the behaviour of two-phase flow in the tank have to be verified.
Experimental facilities for simulating tank level regulation

The facilities serve determining the level in the tank, and its regulation by means of a pump displacement choke valve. The closed regulatory circuit consists of a level sensor, a PID controller and an electrically controlled choke valve as the actuator. The control valve on the top tank outflow pipe is used to set the rate of tank level drop, with the ability to monitor the response of the control circuit to liquid uptake changes.

Neutron Camera

An aluminium, watertight device for scatter neutron tomography for nuclear reactor utilization. Manufactured from 6061 aluminium and welded together in a protective atmosphere, using 99.9999% shielding. This allows installing the detector of both thermal and fast neutrons, and use both with and without the chamber. Tested for 15 m depth.

Functional 1:1 model of the LWR reactor pressure vessel

A functional 1:1 model of the LWR reactor vessel is used to study radiative properties at the iron-air boundary. It offers adjustable geometry and composition, in a waterproof and non-corrosive implementation.
Equipment for verifying the Temelin NPP barbotage tank collector

Experimental equipment for simulating tank level regulation
Department of Power Engineering Equipment, Faculty of Mechanical Engineering, Technical University of Liberec

CFD Laboratory

Department of Power Engineering Equipment has several licenses for the commercial program Fluent (Ansys) for Computational Fluid Dynamics simulation. This program is used primarily to teaching and also to resolve some projects. Apart from the Fluent commercial program, the Open Foam program is also used, as well in-house developed code for incompressible fluid flow simulation with DDES turbulent models, particularly for simulating the flow of conducting fluids in a rotating magnetic field.

Visualization of oil flow in toothed gearing

In terms of cooperation with companies, the Department has been growing its research in the area of visualization and simulation of oil flow in gearboxes. This covers monitoring the lubrication of mechanically stressed parts, e.g. the bearings and where gears mesh. The impact of gear-teeth cavitation was also surveyed.

Measuring equipment to determine air-conditioner flow characteristics

The Department has a relatively long history of cooperation with companies specializing in the manufacture of air-conditioners (GEA - Heat Exchanger, 2VV, Recutech). The Department has various devices for the determination of flow characteristics in air conditioning systems.

Measurement of ejector flow characteristics

The measuring track for determining flow characteristics in an ejector is intended mainly for basic research into the dependencies of flow characteristics (velocity, pressure, volume, air suction) as a function of the input speed of the ejector nozzle, nozzle geometry, etc.
**Visualization of oil flow in toothed gearing**

**Measuring equipment to determine air-conditioner flow characteristics**

**Ejector**

**Ejector - detail**

**Measuring equipment for the optimization of hot water storage tanks**

This equipment is designed primarily for optimizing the internal geometry of the tank, so as to avoid thermal stratification in the tank and so that thermal charging and discharging should take the shortest time.

**Thermoacoustic motor**

In order to explore the application opportunities of thermoacoustic motors, the Department has built a working model. Research is done on the basic characteristics and properties of the device itself, which, in addition to classic thermal exchange makes use of the static resonance of contained air.
High-speed aperture track

The Department has available a small-scale aperture track to determine the characteristics of small ventilators.

Turbocompressor

The Department has available measuring tracks for exploring the characteristics of high speed flows. The principal component of the device is a digitally driven turbocompressor with a nominal power output of $3500 \text{ m}^3/\text{h}$ and overpressure of 1.5 bar.

Visualisation of high-speed flow through Schlieren technique apparatus

The Department has facilities for high-speed flow visualization using the schlieren technique. The simulated channel with nozzle is modelled from a sheer material (glass, plexiglass, ...) and through this channel polarized light is passed, which shows dark regions on the screening in areas where high pressure gradients arise during flow – especially due to shockwave impacts.

Visualization using a shallow bath

This is the visualization of flow in modelled channels on a smooth plate by using small, light-coloured particles, scattered onto a dark shallow liquid flowing over a smooth, slightly inclined plate.
To measure the impact – mechanical wear and tear of solid materials by cavitation, an ultrasonic cavitation generator is deployed. The Department is particularly engaged in fundamental research into the behaviour of cavitation bubbles – the emergence and disappearance of cavitation bubbles and their influence on a solid wall as well as their mutual interaction. In addition to generating cavitation bubbles by means of ultrasound, an electrical discharge based generator is also available.
Laboratory measurements of the thermomechanical properties of materials

The most interesting examples of measuring instruments for determining the thermomechanical values of materials, are of two types – rotary and vibratory viscosimeters. Two types of calorimeters for solid and liquid fuels, with pure oxygen driven combustion, a lambdameter for determining the material’s thermal conductivity.

Laser Anemometry Laboratory

The Laser Anemometry Laboratory has at its disposal speed measuring apparatus based on Laser Doppler Anemometry (LDA) and vector field flow visualization methods using the proportional–integral–derivative (PID) technique. In addition to the laser device, software for processing, visualization, e.g. to determine the values of the vector field is also available.
Department of Electrical Power Engineering, Faculty of Electrical Engineering and Communication, Brno University of Technology

Electrical Power Generation Laboratory

The laboratory is focused on the area of electrical power and the operation of electrical machinery. It has seven aggregates (motor generators) used for laboratory measurements to demonstrate the role of a synchronous generator in a distribution or isolated network. During laboratory measurements students familiarize themselves with governace of electrical machinery and the basic principles of operation of synchronous generators in networks.

As part of research into renewable resources and their synergistic possibilities the Department has several renewable sources of electricity. There is a small installation of polycrystalline photovoltaic panels on the roof, complemented by a pyranometer for the accurate measurement of incident radiation. There are also two wind turbines on the roof; the first type is a classical wind power generator based on the lift principle, the second is of Savonius type wind turbine based on the drag principle. Measurements and the energy produced are sent from these devices to the solar lab, housing lead acid storage batteries and a heat pump. Further storage battery facilities are on the ground floor of building B in the Technical 12 area. A special – Vanadium–redox battery type is used whose capacity depends on the solution volumes of vanadium and sulphuric acid where the produced energy is accumulated. As a backup energy source, a cogeneration unit is connected into this closed system, which is equipped, moreover, with an accumulator tank, so that it can accumulate the heat and energy produced by the cogeneration unit.

Solar Laboratory

The Solar laboratory has experimental models of photovoltaic solar cells using a variety of silicon technologies. They are also represented in the form of entire panels. For the purposes of measuring photovoltaic and solar technologies, instruments are on hand for measuring radiometric and photometric values, with positioning systems and various other systems for automated measurement in laboratory and outdoor conditions. These solar systems are complemented with a heat pump model.
Non-conventional transformation and Electro-thermic techniques Labs

The laboratory is equipped for basic research and education on the subject of non-conventional energy transformations usable in the energy field. This primarily covers electrochemical, thermoelectric, thermochemical, as well as thermomechanical, electromechanical. The laboratory is equipped with modern types of low-temperature membrane fuel cells and electrolyzers, using hydrogen as the fuel. Furthermore, there are older KOH based fuel cells. Also available are thermoelectric (Peltier) cells of different sizes, a demonstration unit with a Stirling engine or an experimental model of the Savonius wind turbine. In the energy storage subject-area, the laboratory has various types of battery accumulators from lead to the modern LiFePO₄ cells and sachets of thermochemical storage media. The Electro-thermic laboratory is equipped with apparatus to investigate the phenomena involved in calorimetry, heat transfer and the calculations concerned with heating systems based on closed heat cells. The laboratory also enables the calibration of temperature sensors during thermal measurement and verifying the effectiveness of diverse thermal heating. The laboratory is equipped for the contactless measurement of high temperatures on the fibre pyrometer principle, with thermocouple and resistor thermometers, a vacuum dryer, calorimeter and last but not least the RAYTEK contactless radiation thermometer.
Electrical Networks Laboratory

The Electrical networks Laboratory has a range of models of various electrical networks, ranging from a voltage level of 400 kV to model distribution networks for 400 V, as well as having available several models of compensator units, enabling the simulation of a variety of such network states as are readily found in practice at its disposal. The laboratory has also a model of a DC network for investigation of network short-circuit situations. The compensator models currently available in the laboratory are manual stepped, automatic stepped and automatic continuous SCV regulators.

Electrical Protection Laboratory

The Electrical protections laboratory is used for demonstration of historical and contemporary methods of protection of electrical equipment when extraordinary conditions, which could damage or destroy a protected device, arise in the electricity network. The laboratory is focused in particular on the protection of devices found in transmission and distribution networks, i.e. generators, transformers, and outdoor cable lines. For this reason the laboratory is equipped with the older types of classic relay-based remote protections, but also modern numerical and digital protections including several test signal generators.

Diagnostics, Electrical Power quality and EMC Laboratories

The Diagnostics laboratory focuses on basic diagnostic procedures, which include recognising the root causes of faults, fault definition and interplay. Issues explored include device status detection by means of noise emission diagnostics, detection of the internal state of the winding of electrical rotary machines by means of shock pulses, fault diagnostics of cable lines with a refractometer, search for incipient failures using thermo-cameras and diagnostics of rotary machine vibration using an accelerometer.
The Electrical power quality laboratory serves to explore the different types of low frequency interference, the electromagnetic compatibility of appliances in the low frequency range and the chances of retroactive interference from appliances. It also specializes in measurement of various aspects of low frequency electromagnetic disturbance propagated along power lines, related to electrical power quality. Within this laboratory one can address the conditions for supplying high-quality electrical power, the mechanisms and sources of low frequency interference mechanisms propagated along power lines and the principles and procedures to ensure the compatibility of appliances with the power network.

Ionizing Radiation Laboratory

The Ionizing radiation laboratory is used to obtain basic knowledge of the different types of ionizing radiation. This laboratory enables investigation of properties of various types of ionizing radiation and of the possibilities of shielding and protection against spreading of ionizing radiation. For the different types of measurements, the laboratory is equipped with a set of measurement and personal dosimeters, and for determination of the weight of samples there are accurate scales with 0.0001 g precision. Laboratory is also equipped with all the necessary resources for the handling of insignificant sources of ionizing radiation, allowing the practical exploration of all standard handling procedures with the various emitter types, under laboratory conditions. For these purposes the laboratory has LaBr\(_3\) (Ce) gamma spectrometers with a 1x1x1 inch crystal and a 4x4x4 inch NaI (TI) crystal, a RadEye HEC alpha/beta radiation detector, a RadEye BR-20 ER multi-purpose surface contamination detector, a set of personal dosimeters and two Kern precision scales with internal calibration, at its disposal.
The Electrical power quality and EMC laboratory

Appliance for measurement of asynchronous motor with frequency converter

KERN precision scales, RadEye HEC
alpha/beta radiation detector

NaI (Tl) gamma spectrometer

High-voltage Laboratory

The Department runs a High Voltage Laboratory within the Science and technology park dedicated to Professor List. This laboratory offers facilities for equipment testing and research in the high-voltage subject area, with the aid of a high voltage transformer, providing up to 300 kV with 1 A current. Other state-of-the-art devices include a shock pulse generator of up to 1,000,000 V. This generator is equipped with a cut-off discharger, ensuring curtailing of the test impulse. The High-voltage laboratory is equipped with high-quality screening, so that it does not affect external devices, but mainly so that external noise does not interfere with the progress of the tests themselves. Thanks to this shielding, the laboratory can also be used to investigate the subject area of partial discharges.

High-voltage generator and measuring capacitors

The charging 100 kV unit (left of scene), shock pulse generator (middle of scene), cut-off spark gap discharger (rear right of scene), measuring capacitor (front right of scene).
Energy Institute, Faculty of Mechanical Engineering, Brno University of Technology

Fuel characteristics analysis

Laboratory apparatus allows gauging, for liquid and solid fuels, the moisture content, calorific value, flash-point temp., flare-up temp., viscosity, softening temp., melting and creep of ash, fuel malleability, pressed fuel mechanical strength, and granularity profile of small solid factions.

Laboratory apparatus:

- IKA C200 calorimeter
- KERN MLS halogen dryer scales
- VENTICELL drying oven
- BSL hydraulic laboratory press
- 0116E electric observation furnace
- Fuel ignition measuring device
- Solids flammability-temperature measurement device
- VISCO STAR plus digital rotary viscosimeter
- Minimum ignition temperature of suspended coal dust measurement device

Testing and development of low-output boilers, stoves and solid fuel heaters

The Combustion Laboratory has a monitoring nook for complete measuring of local solid fuel heaters, up to cca 50 kW rating. The nook enables measuring to valid European norms and national regulations. The nook is equipped with a cooling circuit to absorb produced heat with direct effectiveness gauging, and has various flue attachments to regulate flue draw rate, flue gas temperature, and composition, which can be measured in on-line and off-line modes.

During monitoring the heater is situated on a weighbridge, so as to accurately track the depletion of fuel to the nearest 20 g. Monitoring can include the measurement of surface
temperatures on touchable surfaces and the heating of surrounding surfaces using a detection plate. All data are recorded via a modular monitoring program, allowing detailed processing of acquired measurement data. Based on the findings, modifications can be proposed to improve the parameters of the devices tested.

**Thermal Imaging measurement**

Thermal imaging technology and thermo-gravimetric measurement has been used with success for quite some time in a wide variety of disciplines and sectors. These days, thermal imaging technology is very often used in thermal profile diagnostic analysis of buildings and constructions. This technology has a wide range of other practical uses in engineering, electrical engineering as well as in the energy sector. A thermal camera can readily show the building’s surface temperatures, and so identify surface overheating (elevated temperature) locations, e.g. electrical wiring and radiation areas.

The Laboratory enables measurement with an FLIR SC 660 camera. The FLIR infrared cameras of the SC series allow for on-line capture and recording of changes in temperature fields in real time and for data evaluation, which makes it possible to perform comprehensive measurements to obtain the required data. The measured data are then analyzed using programs for the maximal processing and analysis of results.

**Thermal machinery measurement stand**

The testing nook for small steam devices is designed for testing steam engines and related equipment (motors, turbines, valves, etc.). The test Laboratory has an external source of steam and facilities to take care of the residual heat.

Facility benefits:

- Analysing device turbulent steam flows
- Gauging device heat losses, or conversely, device efficiency
- Gauging device consumption characteristics
Thermoelectric applications

Thermoelectric devices are used for the direct conversion of low and intermediate potency waste-heat into electricity. This transformation, unlike normal energy-producing equipment, takes place in solids, where carriers of electric charge take the place of the working “fluid”. A characteristic feature of these devices is their operating without chemicals and moving parts, their simplicity, reliability and long life. Given the increasing cost of fuels and the interest in environmentally friendly technology, there is a growing trend to use thermoelectric devices and thermoelectricity from waste heat, as sources of electrical power.

The Lab is equipped with experimental measuring apparatus, for determining the operating parameters of thermoelectric generator modules and evaluating their suitability for given thermoelectric applications.

Biofluid 2 experimental gasification unit

The Biofluid 2 experimental stand is an atmospheric fluidized gasifying generator. Suitable fuels are biomass, in the form of pellets, shreiddings or wood chips, and some types of waste. The equipment serves in researching the process of biomass and waste gasification, and the purification and combustion of low-calorific-value gases.

Facility benefits:

- Researching the gasification process in a fluidized bed
- Researching the suitability of gasification media – air, water vapour, oxygen
- Researching the catalytic purification of energy gases
- Developing combustion chambers and burners for low-calorific-value gas
Using biomass for energy purposes

**GEMOS 110 kW experimental combustion unit**

This experimental combustion unit is suitable for testing new alternative fuels, developing and testing measuring and control systems for combustion plants, researching into oxic combustion and emissions reduction related to the combustion of biomass and waste.

**Equipment benefits:**

- Testing new fuels and determining the optimal conditions for their combustion
- Researching complete (“omic”) combustion, reducing emissions from the combustion of biomass and waste
- Testing boiler control systems, exhaust gas cleansing systems
Evaluation of heat transfer in power equipment components

The Unit is equipped with measuring apparatus for the experimental determination of heat transfer through water-sprinkled pipe-works, which are a key component of heat absorption circuits. The evaluation can be carried out at or below atmospheric pressure. The lowest attainable vacuum pressure in the test chamber is 2.5 kPa of absolute pressure. Additional experimental equipment makes it possible to determine the coefficient of heat transfer at the surface of rotating objects. This device is used e.g. to determine the coefficient of heat transfer in different portions of steam turbine rotors. Specific measurements are aimed at the steam labyrinth seals.
Compressors and pumps Laboratory

Experimental Unit. 4 compressors, 3 pumps, aperture track, options for visual measurement and automated data collection. Honeywell pressure transducers, type K thermoelectric temperature sensors, Pt100 resistive sensors, pressure dew point sensors, etc. Frequency converter, Metra brand electrical power supply measurement. Data collection systems – from ADAM Advantech, National Instrument.

Solar Laboratory – 20 kW photovoltaic power plant

Experimental / monitoring Unit. 4 x solar collectors, 1 x photovoltaic Si-amorphous 40 Wp panel, 1 x photovoltaic Si-monocrystal 20 kWp power plant. 2 x CM11 Kipp & Zonen pyranometer, (global/diffusion), SD6 detector of direct sunlight, anemometer, Siemens MassFlow mass flow-meter, temperature and pressure transducers. Yokogawa WT210 digital wattmeter. ENA330/BK-ELCOM power quality analyser. ADAM Advantech automated data capture system.

Wind tunnel

An experimental Unit. A wind tunnel with measuring section diameter of 500 mm, airflow speed 20 m/s. The fan has a frequency converter controlled electric motor. A digital differential micro-manometer, the Airflow MEDM 500 an Ahlborn barometer, a Prandtl probe, temperature sensors. The wind tunnel is used primarily for gauging pressure losses.
Contactless temperature measurement

Flir ThermaCAM SC 2000 thermal imaging camera – parameters: 320x240 pixel detector, measuring accuracy ± 2 °C, resolution 0.08 °C, spectral sensitivity 7.5 to 13 µm.

A Flir SC 640 (2010 model) thermal imaging camera – parameters: 640x480 pixel detector, measuring accuracy ± 2 °C, resolution 0.03 °C, spectral sensitivity 7.5 to 13 µm, temperature range -40 °C to 2000 °C. Interchangeable objective lens (12° and 24°). Advanced measurements of surface temperatures, thermal diagnostics, heat loss verification, etc.

Infrared thermometers up to 3000 °C.

Calorimetric measuring track

For measuring the effectiveness of air-to-water heat exchangers (air-glycol+water), but primarily for the measurement of compact heat exchangers with glycol/water automatic fluid module, the following criteria must be met:

Sample size of 100x100 mm. Mass air flow measuring apparatus with measurability range 4 – 100 m³/h and 30 – 800 m³/h. Uncertainty of mass flow measurement not exceeding 1.2 % of rdg. Compliance with ISO 5167 standard and other relevant gauge standards.

The fluid circuit must be designed to provide manageable flow of fluid, aiming to transfer from the heat exchanger sample under measurement, a heat output of some 5 kW, proportionally regulable.
Energy Research Centre small boilers Testing Unit

Experimental Unit. Automated data capture, fully equipped testing Laboratory (flow meters, temperature and pressure sensors, humidity sensors, scales, analysis of combustion gases, etc.)

ERC Heat pump, small polygon

An experimental / monitoring Unit. Automated data capture, mass flow meters – Siemens MassFlow (2 x boreholes, 1 x heating system), temperature sensors and pressure sensors, including pressure and temperature sensing of the cooling circuit.

Measurement of the temperature response of the rock mass in the heat pump primary circuit.

Heat pumps, large polygon

A monitoring Unit. Automated data capture. Monitoring heat pump operation, including thermal response of rock mass in the primary circuit of borehole pit no. 4.

Advanced Innovation Technologies Centre – Experimental air-conditioning Laboratory (CPIT)

Unit for the numerical modelling of physical phenomena and LCA analysis.

An experimental Unit. A fully equipped Testing Laboratory of refrigeration, air-conditioning and air-to-air or air-to-water heat pumps. Two independently adjustable air-conditioning chambers (temperature, humidity) where evaporators or condensers can be situated. Automated data capture.

The Unit is equipped with computer stations for the mathematical modelling of physical and chemical processes with the use of CFD and DEM software. Also included is software for life-cycle assessment (LCA).

Combustion and flow parameters measuring Unit

TESTO 335 flue gas analyzer + sampling probe, Prandtl tube, Easy Emission software, Testo 316-1 gas detector, Testo 319-1 endoscope, Testo 606-2 hygrometer, 830-T2 thermometer set
Solid fuel combustion research Laboratory

The Unit is duly equipped to research alternative solid fuel combustion. The test room has a Verner (25 kW) boiler, cooling medium pipe-works and cooling units. Included are gauges for the comprehensive determination of parameters along the flue gas track (including fly-ash collection) as well as the parameters of the cooling circuit.

The Unit for Operation and diagnostics of thermal energetic devices has the following facilities:

**IVECO emissions measuring truck**, equipped with Hartmann & Braun and Siemens emission analysers, working on the infrared spectrum absorption principle, for determining the concentration of CO, SO₂, NOₓ as well as an analyzer working on the principle of paramagnetic properties of oxygen, for determination of concentration of O₂, as well as an FID analyser for the measurement of CₓHᵧ.

**Two Fiat Ducato monitoring vans**, equipped with apparatus for specialized measurements and the measurement of solid pollutants.

**Specialized devices for the energy sector**, such as special chilled probes with up to 6 m operating length, for measuring speed-, concentration- and temperature fields within combustion chambers, preparation for the SNCR denitrification method, apparatus for the diagnosis of milling circuits and coal powder sampling, a National Instruments measuring system, thermal imaging diagnostics with a thermal imaging camera, Rosemount and Yokogawa pressure sensors with Field Bus digital communications, speed probes (Prandtl, wedge, cylindrical), propeller and thermal anemometers for measuring flow, wide range temperature measurements, R, B, S, K, thermocouples, high-precision Pt thermometers allowing continuous recording of measured values and apparatus for dew point measurement.
The **Expert Group on power machinery, renewable and alternative energy sources** is primarily focused on activities leading to the streamlining and efficiency enhancement of energy production plants and power machinery, to reduce their energy consumption and energy losses. The group is equipped for this work with:

*Two measuring systems*, from Solartron Schlumberger and Advantech, for the automatic monitoring, visualization, and recording of the physical values measured (temperatures, pressures, flow rates, etc.) by means of their Honeywell hyperbaric, differential and absolute pressure sensors, as well as temperature sensors, which can be precision class 1 sheath thermocouple thermometers, resistance thermometer probes, two-wire Pt100 resistance thermometers of precision class A, or the black ball thermometer. Two portable *ultrasonic flow meters* made by Panametrics and Krohne, for measuring flow rates of liquids in circular section pipelines from ø 25 up to 3000 mm. Relative humidity sensors, and a sensor for pressurized air dew point measurement. Solar radiation intensity sensors and a digital detector of direct sunlight.
The Department of Power Engineering has several laboratories equipped with a variety of apparatus necessary for comprehensive research in the field. The organisational division of laboratories and their facilities corresponds to the Department’s scientific research activities: water – analysis and treatment of water with ion-exchange and membrane separation methods; materials – electrochemistry, corrosion protection and materials; fuels – biomass processing, analysis of wastes and fuels; alternative energy sources – effectiveness of bio-fuel use, quality of bio-fuel agglomeration.

Electrochemistry, corrosion protection and materials

For research in the field of electrochemistry, corrosion protection and materials, three laboratories at the Department of Power Engineering are fitted out – Experimental loops, the Electrochemical laboratory and the Materials and Corrosion laboratory.

Experimental loops

The laboratory is equipped with tensile testing (breaking) machines and a number of experimental loops with autoclaves, to study corrosion and the mechanical properties of materials, under simulated real-world industrial conditions, i.e. high temperatures, pressures, mechanical stresses, exposed to variously corrosive environments. Also, the laboratory is equipped with devices allowing both in-situ monitoring of experimental progress, and thus of the corrosion behaviour of the material, but also ex-situ analysis.

*Instron 1362*: A mechanical breaking machine with Baskerville autoclave, for tests of corrosion cracking or fatigue under conditions of high temperatures and pressures (up to 300 °C and 15 MPa). Autoclaves can serve standalone sample exposure without mechanical stressing.

*Cortest*: A mechanical breaking machine designed for slow deformation tests, (SSRT – Slow Strain Rate Test). The tensile testing machine can be supplemented with an autoclave, which allows the test to be done in the required environment under pressure.

*SCW autoclave*: An experimental loop with SCW (Super Critical Water) autoclave allowing for the exposure of samples in so called supercritical boiler conditions, i.e. up to 600 °C and 30 MPa. The facilities can cater for long-term exposures.
**Cortest autoclave**: An experimental loop equipped with autoclave for the exposure of samples in water at temperatures of up to 290 °C and 10 MPa pressure. Having a custom sample holder (working electrode) the setup offers in-situ electrochemical reading, notably EIS and ECNM.

**Gamry PC4/750**: An integrated electrochemical multi-system (potentiostat, galvanostat, ZRA) that enables a wide range of electrochemical readings. Due to its high sensitivity it is suitable for EIS and thanks to its ZRA also for ECNM.
Electrochemical Laboratory

The laboratory is engaged in the study of corrosion and corrosion protection across a broad range of the energy, fuel and chemical industries. Experimental facilities allow for routine corrosion tests (to ISO and ASTM standards), aimed at taking readings under demanding experimental conditions, – e.g. the study of corrosion in very low conductivity environments (corrosion and inhibition of corrosion in glycol solutions), corrosion under precisely defined hydrodynamic conditions, the study of local corrosive attack, galvanic corrosion, the study of the corrosion characteristics of protective layers (passive and oxidizing films, layers and coatings of organic and inorganic nature). In addition to a range of electrochemical techniques, optical microscopy is also applied to the study of surfaces.

Materials and Corrosion Laboratory

Here, scientific research activities, and thus laboratory facilities, are aimed toward the design and optimization of materials’ solutions in the various environments of energy production and chemical plants, including the development and testing of surface treatments and coatings, made by physical or chemical means. Instrumentation makes possible the testing of materials’ properties in temperatures of up to 1000 °C in air, in gases and in salt- and alkali melts; In liquid environments up to their boiling point temperatures, which can also include aggressive solutions such as acids, alkalis or oxidants. Tests comply with domestic / international (ISO, ASTM) standards.

The Gamry PCI4/750 is integrated electrochemical multi-system offering many electrochemical techniques, apart from measurement under controlled potential or current conditions, it includes Zero Resistance Amperometer functionality. Its high sensitivity allows use for Electrochemical Impedance Spectroscopy and thanks to the ZRA for Electro-Chemical Noise Measurement.

Vallen Systeme AMSY 5: An Acoustic Emission measurement system – dual-channel with parametric input, piezoelectric sensors, this system is designed for the detection of discrete AE events as well as noise, especially under laboratory conditions.

Water analysis, ion-exchangers:

The analytical laboratory is equipped with several devices which are particularly necessary for research in the field of analysis and treatment of water with ion-exchange and membrane separation methods.
**Dionex ICS 1000**: An ion chromatograph equipped with an analytical pre-column and a column with a stationary phase for the analysis of anions. Apparatus sensitivity is enhanced by the inclusion of a suppressor.

**Anion analysis**: fluorides, chlorides, nitrites, bromides, nitrates, phosphates, sulphates

**ICP-OES Optima 2000**: An optical emission spectrometer with inductively coupled plasma, allowing the determination of 68 periodic table elements. The detection thresholds of the various elements differ, with some at a detection threshold of 3 µg.dm\(^{-3}\).

**SpectrAA 220 Varian**: A double-beam atomic absorption and emission spectrometer i.e. comparing 2 beams obtained by splitting a radiation source using rotating mirror segments. One beam passes through the absorbing environment with the second (reference) passing by.
- Atomic absorption: Ca, Mg, Cu, Zn, Cd, Pb, Cr, Ni, Cr, Mn, Fe, Co, ...
- Atomic emission: K, Na

**Cecil CE 2041**: A spectrometer for visible and ultraviolet regions of the spectrum, measuring wavelengths from 190 nm to 990 nm. Enables detection of e.g. nitrates, ammonium ions, fluorides, phosphates, sulphates, silicates, aluminium, nitrates, organic aromatic substances, etc. Also enables measuring changes of absorbance with time and of wavelength spectra scanning.

**Analysis of waste, fuels and bio-fuels**

This laboratory studies the combustion of biomass, alternative fuels and waste, which involves analyzing the fuels, and modelling the combustion processes. In addition to the listed facilities, the Laboratory also has an AS 200 sifting device (for sifting, mesh analysis and creation of a dissemination curve), an SM2000 mill (for grinding and homogenization of all the samples for analysis, ranging from biomass, coal, plastics, paper, to small scale sheet metal material) and an LH 06/13 furnace (up to 1345 °C).

**IKA C 2000**: A calorimeter equipped with a KV500 standalone water condenser designed for determining the gross calorific value and calorific value of solid and liquid fuels.

**GA 60**: A portable flue gas analyzer equipped with an additional flue gas condenser and heated probe. It can determine the concentrations of CO, CO\(_2\), O\(_2\) and NO\(_x\) in flue gas.

**Alternative Energy Sources Laboratory**

**SDT Q600**: Simultaneous thermal analysis, up to temperatures of 1500 °C. DSC calorimetry – detection of thermodynamic changes by measuring heat energy needed to compensate for the difference in temperatures between sample and reference substance. The technique provides qualitative and quantitative data on endothermic and exothermic processes. TGA thermo-
gravimetry – detection of weight changes (as a function of temperature) by plotting the thermogravimetric curve and its first derivative, to better resolve between separate processes.

Niton XL3t: A manual X-ray fluorescence analyzer with a desktop mounting bracket, non-destructive elemental analysis of periodic table elements from Mg onward. A wide range of uses: in geochemical and mining exploration, the composition analysis of alloys, scrap metal, additional materials in welds, for the detection of heavy metals in toys, jewellery, plastics, RoHS

Nicolet iS10: An FTIR spectrometer designed for the mid-infrared range 7800-350 cm⁻¹. Spectral resolution of 0.4 cm⁻¹, scan speed of 1 scan per second. An ATR (attenuated total reflectance) attachment for measuring samples with highly absorptive to infrared radiation. Omnic control software. Molecular spectroscopic detection of powders, liquids and gases

MWS-2: Pressure decomposition, mineralization of solid and liquid samples using microwave radiation. Contactless measurement of the dissolution mixture temperature in Teflon containers – the ability to use any mixture of acids (H₂SO₄, HF, etc.)

**Within the central Laboratories the following methodologies are available:**

*Surface roughness tester, Mitutoyo series SJ 400: Surface roughness and profile measurement, evaluation software, evaluating according to different standards.*

*XPS Omicron Nanotechnology, ESCA Probe P: A system for surface analysis with a monochromatized X-ray source, equipped with two ion cannons, compensation charging of samples and a variety of other components.*

A universal instrument for the analysis of surfaces, including the determination of their depth profiles.

**Issues most often addressed:**

- Catalyst oxidation status
- Organic material surface conditions
- Corrosion layers
- Layers under development for chemical sensors
- Materials for electronics, taking advantage of concentration profile measurement
Department of Electric Power Engineering and Ecology, Faculty of Electrical Engineering, University of West Bohemia

Energy engineering

The energy engineering laboratories are used for the laboratory research of new technologies in the fields of production, distribution and redistribution of electricity or heat, as well as the mathematical modelling and optimization of energy-intensive industrial systems. In the subject area of electric power production it focuses on computation, modelling of coal-and gas fired power stations or of the secondary circuit of nuclear power stations, from the viewpoint of optimization of energy efficiency, dynamics and the quality of regulation of own power consumption by the electricity generating plants. An important subject domain for this group is the modelling and optimization of hydroelectric plants specializing in optimizing the management of parallel running turbines.

Other pillars of the laboratories’ research programme are the simulation and modelling of electric distribution and transmission networks, short-circuit calculations, reliability calculations and security, especially in the nuclear energy field. The group’s portfolio encompasses creating computational computer models of mechanical and electromechanical structures including the simulation of operational and adverse states of constructions and rotary machines.

The Electro Technical Laboratory - ETL (accredited testing laboratory No. 1090)

The laboratory offers a range of tests in the electro-technical field. For the vast majority of them, the ETL is accredited by the Czech Accreditation Institute according to the ČSN EN ISO 17025 standard. ETL has available specialized equipment for performing these tests and experts experienced in their implementation. The Electronic systems EMC laboratory provides precertification measurement of EMC for electronic systems according to the prevailing set of standards, in particular of line-propagated emitted interference in the 30 MHz to 1 GHz range, and of electromagnetic resilience.

- Measurement of suppression device characteristics.
- Consulting and expert activities on Electronic systems EMC.
ETL laboratory protocols on tests carried out can be used as a basis for demonstrating compliance pursuant to Act No. 22/97 Coll., as well as for the use of the CE conformity marking.

We perform test either in their entirety according to the relevant technical standard or in part according to the customer's specification, which is particularly advantageous for product verification in the pre-production stage.

We carry out test in accordance with these technical regulations:

- Czech harmonised technical standards
- Czech technical standards
- The European EN standards
- International IEC standards
- National technical standards
- Customer technical stipulation
- Special methodologies

Many of the tests can be performed directly at the customer site. We also offer the use of ETL measuring apparatus, including staffing, to carry out the tests in the presence of customer representatives.

The laboratory is equipped with shielded free-field room with a measuring distance of 3 m and 18 GHz frequency reach, a 9 kHz - 1 GHz measuring receiver, a set of antennas with a range of 30 MHz - 2.7 GHz, a 9 kHz - 3 GHz spectrum analyzer, a single-phase artificial power network of 16 A/150kHz - 30 MHz, an RF amplifier 15 W/150 kHz - 1 GHz, a three-phase network quality analyzer and a 5/50 ns EFT generator.
LV switching and control devices Laboratory

The electrical instruments unit conducts testing of switches, circuit breakers, LV relays. These tests are important for verifying the correct operation of protection and switching equipment.

Device tests:
- Selected tests on information technology equipment according to ČSN EN 60950-1.
- Selected tests on switches according to ČSN EN 60947 standards.
- Testing of circuit breakers, relays and switching equipment

Megger power supply source used: 0-500A /3.5V; 0-125A /14V and 0–25A/ 70V.

Electro-thermic technology Laboratory

The unit offers consultancy, consultation and professional activities in the subject area of electro-thermic techniques. The Group focuses mainly on the computational modelling of thermal processes, the issues of heating buildings and the measurement and evaluation of thermal conditions.

Services offered:
- Designing solutions to problems in the subject area of electro-thermic techniques:
  - Induction heating, design of inductive warming of mechanized tooling equipment, modelling and simulation of phenomena during electromagnetic induction warming,
  - Resistance warming, electric heating.
- Designing systems for monitoring the thermal fields of real devices.
- Optimizing the heating of industrial, commercial and civic buildings.
- The computational simulation of thermal, electromagnetic and deformational fields, simulation calculations of thermal conditions.
- Contactless measurement of surface temperatures (to determine heat loss or radiant efficiency of electrical panels).
  - Kleiber pyrometer: detection range 300 to 2300 °C, spectral range 1.58 to 2.5 μm, measuring distance 400 to 3000 m.
- Omegascope pyrometer: detection range -18 to 900 °C, measuring distance 132 mm up to 59 m.
- Optris LS infrared thermometer: detection range -35 to 900 °C, measuring small objects down to 1 mm.
- Linn HTG 3000 high-frequency generator
  - Frequency range 0 to 400 kHz, power range 0 to 3 kW.
  - Used for e.g. melting of non-ferromagnetic and rare well-conductive metals.
- FRQET5 induction heating unit
  - Working frequency range 5 - 25 kHz, nominal current 16 A rated voltage 400 V.

Acoustics

The Acoustics unit is dedicated long-term to the measurement of equipment noise emission, sound frequency, acoustic power output measurement, sound source localization, vibration measurement, electroacoustics and building construction acoustics.

- Frequency analysis of sound in the audible spectrum.
- Measurement of acoustic power output.
- Localization of sound sources using acoustic intensity.

Electroacoustics

- Measurement of speaker parameters (according to ČSN IEC 60268-5)
Design and parameter measurement of sound-distribution systems
Measurement of directional characteristics

**Anechoic chamber**

- Meets the requirements of ČSN EN ISO 3745
- Dimensions of 5 x 4 x 6.4 m
- Lower frequency limit 90 Hz
- Volume 128.3 m³

**Building acoustics**

- Measurement the sound transmission loss values in construction projects
- Mapping the paths of sound propagation in buildings
- Measuring reverberation time

**Reverberation chamber**

- Meets the requirements of ČSN EN ISO 354
- Regulation of temperature and humidity 15 - 30 °C, 35 – 90 % RH
- Analyzer Brüel & Kjaer PULSE (4 channels)
- Handheld decibel meters Brüel & Kjaer 2260 and 2231
- Microphones for free-field and diffusion field
- Probes for acoustic intensity measurement Brüel & Kjaer 3599
Department of Power System Engineering, Faculty of Mechanical Engineering, University of West Bohemia

Hall Laboratory

This Laboratory has a single-speed air turbine, a calibration line and a demonstrator of two-phase flow.

Calibration line

A subsonic aerodynamic track, which is primarily used to calibrate pneumatic probes and for teaching purposes. A three-phase engine of 10kW rated output powers a ventilator fan that sucks air from the Laboratory and blows it into the stabilising pipeline. At the end of the 5.5 m long pipe is the nozzle. The special sinusoidal shape of the nozzle, designed by Doc. Ing. Václav Konečný, CSc., provides a very uniform output air velocity field. Regulation of the calibration velocity is done by constriction in the fan intake. Velocity can be smoothly adjusted in the range of 20 – 110 m/s.

The orientation device, in which the calibrated probe is firmly fixed, is controlled by two stepper motors that allow orienting the probe in the horizontal and vertical planes with a minimum increment of 0.09°.

VT400 Air turbine

This is a single-stage air turbine, located in the compressor intake.

The turbine is used for both scientific-research activities and teaching purposes. It is possible to measure the air velocity field beyond the distributor and the circulating
blades, to determine the overall turbine stage effectiveness and evaluate its
dependence on partial admission, axial clearance, etc.

Currently underway is a research project of how propeller blade shape affects stage
flow and overall effectiveness.

Axial distance between guide blades and moving blades is 20.5 mm. For measuring
the velocity field beyond the RL a five aperture probe is used – located 11 mm beyond
RL. To move the probe, a traverser is deployed, allowing movement along
the radial (above the tip and below the heel of the blade) circumventing
the circumference (2 channels) and
the automatic orienting of the probe into
the air stream. To determine stage
effectiveness, measurements are made
of temperatures and static pressures
entering and leaving the turbine, its
speed and torque. Mass air flow is
determined via a precision nozzle with
collection in the neck.

ZVVZ APW 1200 axial fan

Experimental apparatus used to research axial fan flow. This is research into
instabilities in fan operation, i.e. if the fan is or passes into a mode characterized by
large instabilities. This research helps to better understanding of processes in out-of-
specification modes of fan operation, studying the vibrations generated by these
occurrences, exploring options to suppress or override the effect of instabilities.
The experimental equipment will also provide air propulsion in a proposed wind
tunnel.

Two-phase flow demonstrator

This device is used to research the intensification of natural flow with “Gas-Lift”. The
purpose of the research programme is to determine the effect of feeding gas into
a liquid on its resulting flow. This technology could be used to dissipate heat from
IV. generation reactors, especially when using fluoride salts. The aggressiveness
of these salts along with high temperatures (approx. 700 to 800 °C) causes problems
with selection of suitable materials for primary circuit pumps. Using “Gas-Lift” addresses this problem. In addition, using helium would rid the fuel-cooling mix of certain fissile products, such as xenon.
UL136 Laboratory

The Laboratory is focused on research into fluid-bound flexible body system vibrations, elicited by a flowing medium (air), i.e. of tube bundles and blade cascades, with the additional provision here of an output diffuser model.

Wind tunnel for blade cascade vibration measurement

The equipment serves the study of blade cascade oscillations. Tasks are investigated experimentally using specially designed blades. These are the end portions of blades from the last stage of a low-pressure turbine rated at 1000 MW. Research is focused on the propagation and attenuation of vibrations in the blade cascade. Four of the total eight blades are connected to vibro-nodes, which are special devices allowing movement of the blades. Two vibro-nodes are deployed to elicit blade vibration, the other two being deployed to capture the forces resulting from the fluid flow and the abovementioned vibration.

Wind tunnel for tube bundle vibration measurement

This experimental device is similar to the previous stand, except that instead of using blades, the aerodynamic forces are measured on a tube bundle. The task is investigated experimentally on physical mock-ups, where the non-linearities of aerodynamic forces meet with the non-linearities of the construction. During the measurement, it is necessary to acknowledge the fluid flow relationship between the oscillating tubes, while their mechanical bonding is incidental. As regards the foremost bundle tubes, especially when it comes to tangential flow, the phenomenon of self-elicited vibration is compounded by a strong turbulent wake, which needs to be separated out.
Output diffuser model

This experiment serves in the search for possibilities how to reduce losses in the turbine output diffuser. Its purpose is to determine the effect of opening the diffuser and of surface treatments on the effectiveness of this device. Being studied are options to influence the flowing fluid’s burble at the diffuser wall. The velocity field in the measured region is determined primarily by the PIV method.

The essence of the PIV method of measurement lies in illuminating the sampled space with an intense pulsed laser beam. Microscopic particles are released into the measured area (oil or water bubbles, or polystyrene balls). A sensitive camera samples the particle positions during individual pulses and based on their correlations, the shift and direction of motion of the particles are determined. Knowing the shift and time, we can express the speed vectors and then construct vector velocity maps.

An alternative is to use apparatus for flow visualization. The intensity of the flashes is increased, and flow field is sampled by a classic digital camera. This is able to capture the flow pattern, but cannot provide velocity information. In many cases such visualization is quite sufficient.

Detail of output diffuser
Release of this publication was supported by:


Operational Programme ‘Education for Competitiveness’, priority axis No. 2 – ‘Tertiary education, Research and Development’, area no. 2.4. – ‘Partnerships and Networks’.