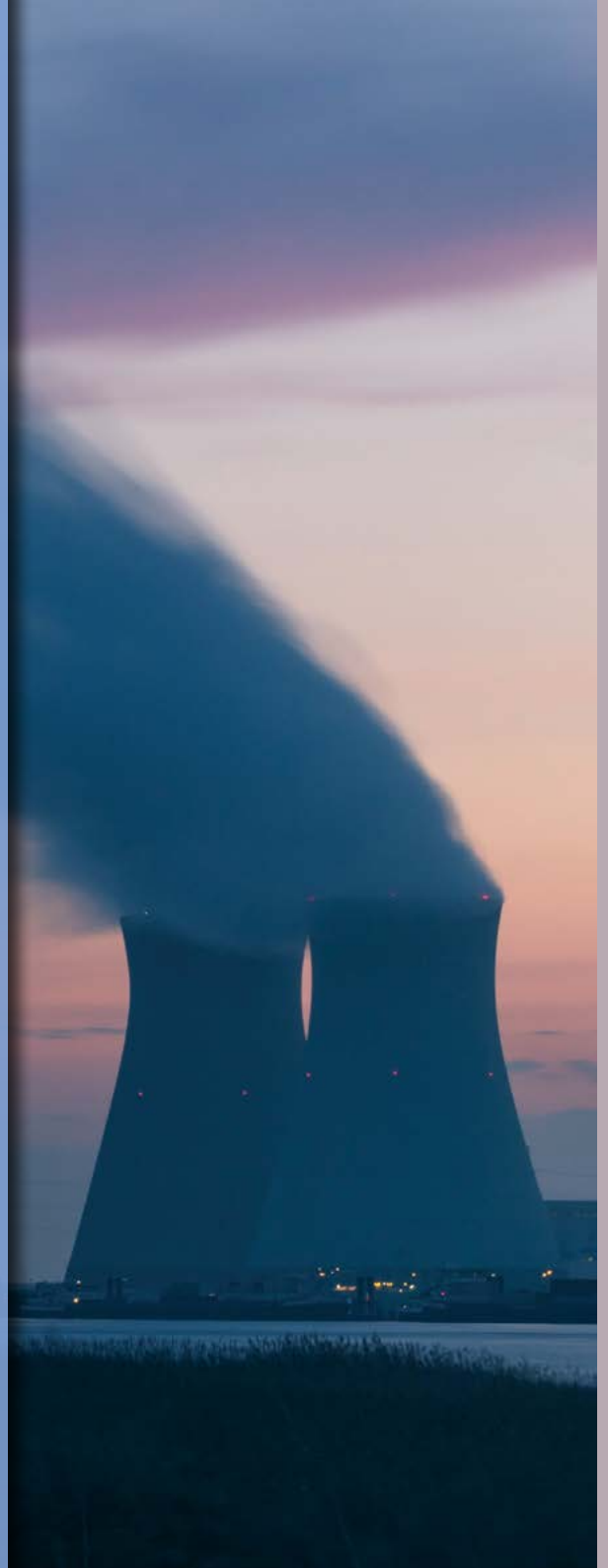
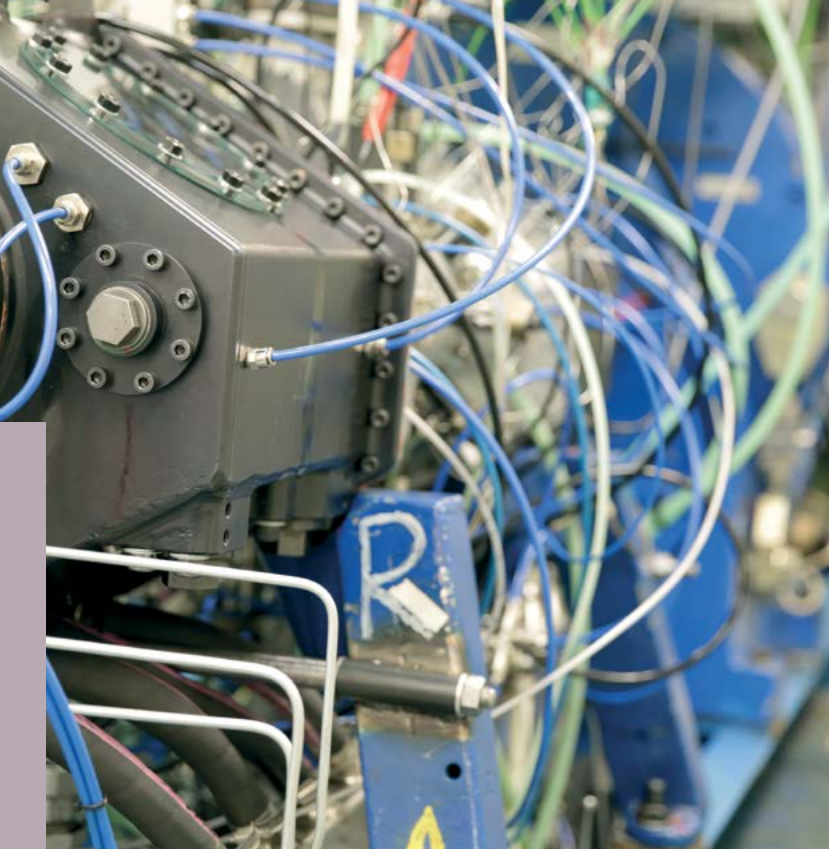


**INSTITUTE OF HEAT  
ENGINEERING**





# RECIPROCATING ENGINE DESIGN TEAM

AT THE WARSAW UNIVERSITY OF TECHNOLOGY

MECHANICAL ENGINEERING; POWER ENGINEERING

#RECIPROCATING ENGINES #DISTRIBUTED GENERATION #GAS FUELS  
#UNCONVENTIONAL FUELS #ENGINE TESTS STANDS #MULTI-FUEL ENGINE

The Reciprocating Engine Design Team working at the Institute of Heat Engineering, Faculty of Power and Aeronautical Engineering, WUT, is the only establishment in Poland to conduct research into entirely novel reciprocating engine designs.

We are involved not only in theoretical analysis (numerical simulations of combustion processes, flows, strength), but also in the design and testing of prototypes, with our own mobile engine test stand handling up to 2,200 kW. For over 20 years we have been designing, building and conducting research into prototypes of engines with a non-standard kinematic system called axial engines. Through our solutions, these engines have a variable compression system with a fairly simple design and pseudoadiabatic combustion chambers, improving engine performance and delivering multi-fuel capabilities, including both liquid and gas fuels.

Thanks to its affiliations with the Faculty of Power and Aeronautical Engineering and strong industry expertise, our Team can design and implement solutions such as engines for large military UCAVs. As part of projects funded by the Ministry of Science and Higher Education (MNiSW) and the National Centre for Research and Development (NCBR) and privately funded projects carried out over the years, we constructed and tested four prototypes (with power outputs ranging from 0.5 kW to more than 1 MW – in the fifth engine that is currently being assembled). In our works we cooperate with industry partners, including the Pimet company, which has allowed us to use its advanced equipment resources, and Horus Energia (the leader of the Polish generator set industry).

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## RESEARCH INFRASTRUCTURE

- mobile container test stand for axial engines comprising all the necessary installations and measurement systems, including:
  - National Instruments data acquisition system
  - dedicated pressure sensors (including indicator sensors, pressure pulse sensors) from global brands (Kistler, Kulite, Imes)
  - eddy current brake (Froude-Hofman) and water brake (Power-Test)
  - torque meters, including HBM's bearing-free torque meters
  - specialised gas composition measuring equipment (Xstream analyser, gas chromatograph)

## SELECTED PROJECTS

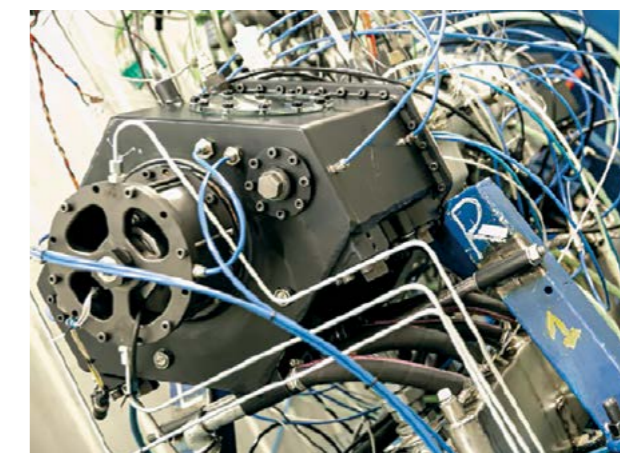
- Investigations of an HCCI high-performance barrel engine for use in distributed power generation systems (NCBR, PBS, 2016–2020)
- Investigations of Homogeneous Charge Compression Ignition in an innovative barrel engine (NCBR, Polish Norwegian Research Programme, 2014–2017)
- Design of a five-cylinder crankless diesel aircraft engine with a capacity of 3,000 cm<sup>3</sup> and cylinder axes parallel to the axis of the motor shaft (Ministry of Science and Higher Education, 2007–2009)
- Design, construction and tests of the PAMAR 2 two-cylinder two-stroke engine with a capacity of 600 cc (private funding, 2005–2007)
- Theory and investigations of a reciprocating internal combustion engine with cylinders parallel to the axis of the motor shaft (Ministry of Science and Higher Education, 2004–2006)

## OFFERED SERVICES

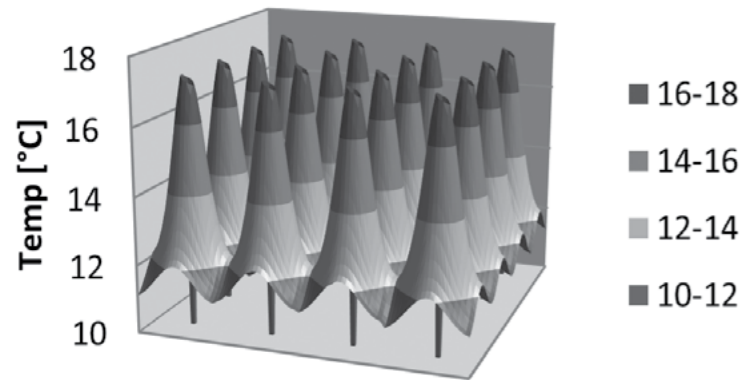
- assessment of the Client's fuel in terms of its applicability for powering internal combustion engines
- tests of an axial engine using fuels provided by the Client
- design and process specifications and implementation of the engine to be powered by the selected fuel
- internal combustion engine designs for distributed power generation systems, military vehicles, UAVs, among other applications

Due to the specific requirements of the industry, the Team is interested primarily in long-term cooperation with Clients in relation to the said services, including with various sectors of industry, particularly:

- distributed power generation – these services are addressed primarily to biogas plants and manufacturing plants whose by-products include gases with low calorific value and variable composition (e.g. waste gasification, tyre disposal, flare gases)
- military – it is possible to design and implement a multi-fuel engine for Polish tanks and tracked vehicles



Temperature distribution in ground - 15 m depth  
after 240h charging



## BUILDING ENERGY SYSTEMS AND RES TEAM AT THE WARSAW UNIVERSITY OF TECHNOLOGY

ENVIRONMENTAL ENGINEERING,  
MINING AND POWER ENGINEERING

#BUILDING ENERGY SYSTEMS #ENERGY INTERACTIVE BUILDINGS  
#SOLAR ENERGY SYSTEMS OF A BUILDING  
#RENEWABLE ENERGY SYSTEMS IN BUILDINGS  
#HEATING AND HUMIDITY PROCESSES #MODELLING MATHEMATICAL  
#NUMERICAL SIMULATION #BUILDING ENERGY RATING  
#BUILDING ENERGY RETROFIT #BUILDING ENERGY PERFORMANCE  
#LIFE-CYCLE ASSESSMENT #MULTI-OBJECTIVE OPTIMISATION

The Team's core is formed by the employees of the Division of Refrigeration and Energy in Buildings, one of the five Divisions that comprise the Institute of Heat Engineering at the Faculty of Power and Aeronautical Engineering, WUT.

We offer a wide scope of cooperation: consultations, expert opinions, current state analysis and improvement suggestions, designs for non-standard solutions and training courses.

Our Team's main areas of interest include:

- building energy performance,
- energy performance of internal building systems:
  - heating,
  - cooling,
  - ventilation,
  - water heating,
- use of renewable energy sources:
  - passive and active solar systems, passive and semi-passive systems, active solar heating and cooling systems, PV systems, PV/heating systems – PVT,
  - renewable energy-based integrated multi-source energy systems,
  - systems with PV-coupled heat pumps operating in the heating and cooling cycle,
- other unconventional solutions:
  - short- and long-term heat storage,
  - trigeneration; production of combined cooling, heat, and power in renewable energy-based systems.

### CONTACT

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[www.itc.pw.edu.pl/Pracownicy/Badawczo-dydaktyczni/Jedrzejuk-Hanna](http://www.itc.pw.edu.pl/Pracownicy/Badawczo-dydaktyczni/Jedrzejuk-Hanna)

Our Team also provides solution optimisation for energy performance and LCA, as well as analysis and numerical simulations.

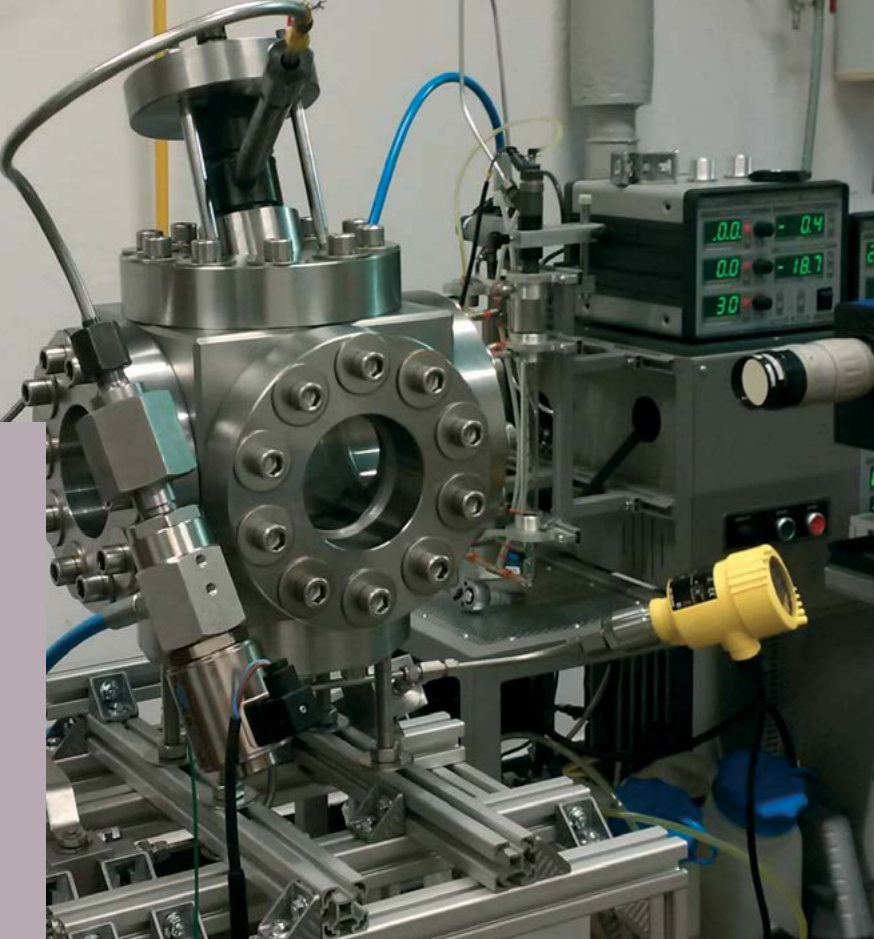
### SELECTED PROJECTS

- Unconventional methods of energy conversion and storage, and material and installation solutions for renewable energy systems to improve the energy-saving effect and energy self-sufficiency of buildings (Innovative Economy Operational Programme, 2010–2013)
- Technical assessment of solar collectors and solar systems. Condition of solar collectors installed at a hospital. Solar collector test. Thermal performance test (2012)
- A study comprising a mathematical model for the selection of an underground thermal energy storage system. GHEx computation tool for simulations of underground thermal energy storage systems (subcontractor, NCBR, 2013)
- Building Integrated Solar Thermal Systems (BISTS) (COST Action KE TU1205, 2013–2017)
- Research on, and preparation for the implementation of, a technology for the production of power and heat in a micronised-biomass powered boiler room (NCBR, BIOSTRATEG, 2015–2019)

### OFFERED SERVICES

- PESTEL/SWOT analysis for energy technologies in a building, including in particular those based on renewable energy sources
- feasibility study concerning the theoretical and technical potential of using renewable energy systems within housing estates, communes and cities; establishment of energy clusters
- expert opinions on energy and financial profitability associated with the use of innovative energy systems based on RES
- energy audits, building thermal performance assessments





# LASER DIAGNOSTICS LABORATORY

AT THE WARSAW UNIVERSITY OF TECHNOLOGY

ENVIRONMENTAL ENGINEERING, MINING AND POWER ENGINEERING; MECHANICAL ENGINEERING

#INJECTION VISUALISATION #MIE SCATTERING  
 #DROPLET SIZE MEASUREMENT #COMBUSTION VISUALISATION  
 #NON-INTRUSIVE FLAME ANALYSIS #RAYLEIGH SCATTERING  
 #LIF #LASER INDUCED FLUORESCENCE #PLIF #CFD MODEL DEVELOPMENT

The Laser Diagnostics Laboratory of the Warsaw University of Technology is focused on investigations of flow, combustion, injection, and mixing processes using non-intrusive measurement methods. Our Laboratory is a part of a broader complex called LATIS (Aircraft Turbine Aerodynamics and Combustion Laboratory), located in the Faculty of Power and Aeronautical Engineering.

Several research and development projects have been completed, including one project within the HORIZON 2020 programme. The primary partners are Wärtsilä Finland Oy, one of the world's largest manufacturers of stationary and marine engines; AVL LIST GmbH, the market leader in the development of vehicle powertrains; Katcon Polska Sp. z o.o., one of the key suppliers of exhaust systems for leading automotive companies.

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## RESEARCH INFRASTRUCTURE

- Laser system for flame and aerosol visualisation (methods: PLIF, Rayleigh scattering, shadowgraphy, Mie scattering, SLIPI, LIF/Mie)
- High-speed cameras for time-resolved visualisation
- Long-distance microscope for monitoring liquid stream disintegration and drop size measurement
- Data acquisition systems for recording fast signals
- Computational fluid dynamics (CFD) for single and multi-phase flow, heat transfer, and combustion analysis
- Constant volume chambers with optical access for studies of injection and combustion processes under high pressures and temperatures
- Flow rig with the visualisation section to investigate injection and mixing in flow conditions, and testing aftertreatment systems
- CLD gas analyser for NOx and NH3 measurement

## SELECTED PROJECTS

- KNOCKY Knock prevention and increase of reliability and efficiency of high power gaseous internal combustion engines (Horizon 2020, MSCA-RISE-2015, 2015–2019)
- Clean solutions for conventional and hybrid drives as bridge technologies towards full electrification (NCBR, Ścieżka dla Mazowsza, 2020–2023)
- Mixing process of impinging jets in near- and above the boiling point in quiescent and cross-flow conditions (NCN, SONATA, 2021–2024)
- Flash-boiling atomization in high cross-flow conditions (NCN, OPUS, 2019–2022)
- Development of mixing and urea-water solution conversion unit in SCR systems in order to start production of exhaust system for compression ignition engine that meets the Euro 7 emission standards (NCBR, Smart Growth Operational Programme, 2015–2020)

## OFFERED SERVICES

- measuring droplet size distribution in sprays generated by fuel injectors, fire extinguishing systems, nozzles for drug delivery, nozzles for the application of fertilisers and pesticides, and others
- analysis of aerosols produced by humans through coughing or sneezing
- visualisation of fast-changing processes related to fluid dynamics and solids interactions
- flame analysis, including the determination of the main-reaction zone, pollutants formation, radicals' distribution, and the temperature field
- analysis of gas and liquid mixing processes in practical systems
- verification, development and calibration of combustion injection and flow models

## SELECTED ACHIEVEMENTS

- Recognition of the KNOCKY project in the Innovation Radar programme organized by the European Commission to highlight the most innovative projects funded from the European funds
- Industrial implementation of the developed exhaust aftertreatment systems B20 DTR into series production
- Industrial implementation of the developed exhaust aftertreatment systems B20 DTH into series production



# A TELLITE AND DETONATIVE PROPULSION SYSTEMS LABORATORY

## AT THE WARSAW UNIVERSITY OF TECHNOLOGY

ENVIRONMENTAL ENGINEERING, MINING AND POWER  
ENGINEERING; MECHANICAL ENGINEERING

#AERONAUTICS #COSMONAUTICS #ROCKET PROPULSION  
#PROPULSION SYSTEMS SATELLITE #ROTATING DETONATION #RESISTOJET  
#MONOPROPELLANT #BIPROPELLANT #ROCKET PROPULSION MATERIAL

The Satellite and Detonative Propulsion Systems Laboratory operates in the Institute of Heat Engineering at the Faculty of Power and Aeronautical Engineering of the Warsaw University of Technology.

Thanks to extensive experience and robust infrastructure, our Team can conduct advanced research into solid and liquid rocket propulsion materials, and designs engines in which such materials can be used. Using our test stands for solid propellants, we can draw characteristic curves for normal conditions, under variable temperatures and under acceleration. Through our experience in detonation, including rotating detonation, we are able to carry out tests involving the detonability of fuel-oxidiser mixtures and their use for propulsion, among other applications. And all this is complemented by our ability to develop advanced spacecraft control models using rocket propulsion.

Our Team has been involved in many projects, as part of which it cooperated, or continues to cooperate, with the European Space Agency, the Polish defence industry (MESKO S.A.) and aerospace companies (Alenia Space Polska, Jakusz SpaceTech), among other partners – and the list of cooperating institutions and research centres is constantly expanding. So far, we have worked with such Clients as: Łukasiewicz Research Network – Organic Industry Institute, Jakusz SpaceTech Sp. z o.o. and the Chemical Faculty of the Warsaw University of Technology.

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### RESEARCH INFRASTRUCTURE

- vacuum chambers (for rocket engine tests)
- high-speed camera (up to 600,000 fps), thermal imaging camera
- pressurised fuel systems for rocket engines, including measuring equipment (pressure measurement, mass flow rate, thrust)
- National Instruments measurement systems: DAQ, PXI, including dedicated software
- detonation tubes for investigating the detonation properties of gas mixtures
- detonation chambers for investigating the phenomenon of rotating detonation
- test chambers for investigating the combustion process of solid propellants under controlled temperatures in the range of 0°C to +50°C
- combustion chamber to investigate the impact of gravitational acceleration solid propellant combustion with the remote measurement of pressure in the combustion chamber
- apparatus to produce gas mixtures using the partial pressure method
- test stand to investigate hypergolic combustion with the “drop test” method

### SELECTED PROJECTS

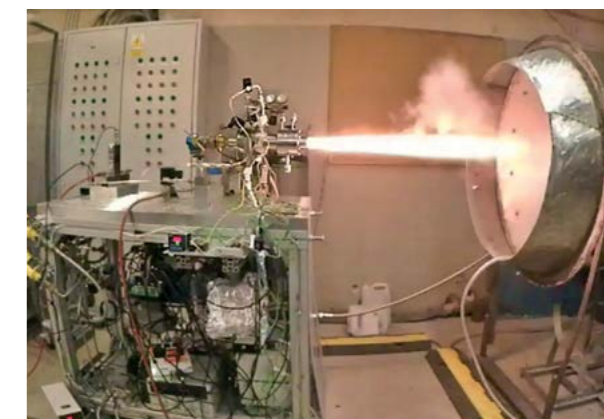
- Development and construction of a demonstrator of executive systems for PB-1 and PB-2 gas-dynamic control systems (MESKO S.A., 2018–2019)
- Design of elements of an executive system for gas-dynamic steering (MESKO S.A., 2017–2018)
- Development of a liquid-propulsion rocket engine technology for applications in next-generation launch vehicles (NCBR, Defence and Security programmes and projects, 2016–2021)
- Development and validation of a laboratory model of a space robot with a resistojet engine system (NCBR, PBS 3, 2015–2017)
- Catalyst bed for 1N class HTP thruster (Jakusz SpaceTech, ESA, 2018–2021)

### OFFERED SERVICES

- tests of the regression rate of a solid propellant in temperatures in the range of -40°C to +50°C
- tests of the regression rate of a solid propellant for various rates of acceleration given to the test material grain in room temperature
- tests of self-ignition delay in hypergolic mixtures
- construction of test stands to investigate solid propellants
- measurement of thrust in engines powered by solid propellant materials (up to 500N)
- tests of coldgas, resistojet and monopropellant rocket engine solutions
- tests of detonation properties for fuel-oxidiser mixtures in the gaseous state
- experiments involving detonation engines

### PATENT

- Laboratory stand to test the properties of solid propellants (P.434707)





# HYDROGEN TECHNOLOGIES TEAM

AT THE WARSAW UNIVERSITY OF TECHNOLOGY

ENVIRONMENTAL ENGINEERING, MINING AND POWER ENGINEERING

#FUEL CELLS #HYDROGEN #HYDROGEN TECHNOLOGIES  
 #ELECTROLYSIS #HIGH-PERFORMANCE ENERGY CONVERSION  
 #ORC #ENERGY STORAGE #CIRCUITS FOR SUPERCRITICAL PARAMETERS

Our Research Team consists of employees of the Faculty of Power and Aeronautical Engineering of the Warsaw University of Technology (WUT) and the Faculty of Chemical and Process Engineering (WUT).

The members of our Team are currently involved in several research projects financed, among others, by the National Centre for Research and Development. In these projects we focus on the subject of fuel cells.

The Team has accumulated extensive experience in implementing diverse projects with business partners. Moreover, we have the qualifications and capabilities required to issue expert opinions and secure patents for our solutions.

Our Team's industry partner is Fuel Cell Poland Sp. z o.o., a spin-off of the Warsaw University of Technology. Our Clients include companies such as PKN Orlen S.A., TAURON Polska Energia S.A., etc.

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## RESEARCH INFRASTRUCTURE

- test stand for high-temperature fuel cells
- test stand for impedance spectroscopy measurements
- gas chromatograph
- optical microscope for surface analysis
- controlled atmosphere furnace
- ball mills
- tape caster
- vacuum mixers

## SELECTED PROJECTS

- Modular system based on Molten Carbonate Fuel Cells with tailored composite membranes designed for specific flue gas compositions oriented into CCS integration with an industrial power plant (POLNOR CCS2019, 2020–2023)
- High-performance carbonate fuel cells (NCBR, 2015–2018)
- TENNESSEE: Industrial design of carbonate fuel cells and ceramic electrolyzers providing integrability with power-to-gas systems (Tauron Wytwarzanie, 2018–2023)
- Innovative carbon-ceramic composite materials as CO<sub>2</sub> capture and utilisation technologies for sustainable power generation (NCBR, 2017–2020)

## OFFERED SERVICES

- fuel cell certification
- PV cell certification
- battery certification
- impedance measurements
- gas composition measurements

## PATENTS

- CO<sub>2</sub> separation and fuel recirculation unit for MCFC cells (PAT.236053)
- Method of electrolyte regeneration in carbonate fuel cells (PAT.234555)
- Test stand for electrochemical measurements in a molten salt environment under high temperatures (P421492)
- Cathode with a multi functional layer for molten carbonate fuel cells (P430869)
- Sealing for high temperature fuel cells (P422085)



## RATIONAL USE OF ENERGY TEAM AT THE WARSAW UNIVERSITY OF TECHNOLOGY

ENVIRONMENTAL ENGINEERING,  
MINING AND POWER ENGINEERING

#ENERGY AUDIT #ENERGY PERFORMANCE AUDIT #ENERGY PERFORMANCE  
#ENERGY MANAGEMENT #ELECTRICITY MANAGEMENT #REACTIVE POWER  
#SMART GRIDS #RATIONAL UDE OF ENERGY #ELECTROTHERM #PUMPS  
#COMPRESSED AIR #POWER TRANSMISSION SYSTEMS  
#PROSUMER #ELECTRICAL INSTALLATIONS

The Rational Use of Energy Team at the Faculty of Power and Aeronautical Engineering (WUT), the Institute of Heat Engineering.

Our team conducts research on potential energy improvements of energy performance in smart grids and electrical installations. Moreover, we develop concepts for a more rational use of energy in industry and buildings, investigate the energy demand structure in different groups of recipients, and also perform analyses in the context of current energy and climate policies.

Our services are addressed to all industries that are interested in the economical and rational use of energy resources, grid operators: industrial entities, service providers, including small and medium-sized enterprises, building managers, as well as public agencies and institutions.

So far we have provided services for: Stoen Operator Sp. z o.o. and PKN Orlen S.A., as well as SMEs.

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### RESEARCH INFRASTRUCTURE

- power quality analysers
- electrical installation meters
- electrical equipment safety meter
- laboratory multimeters
- illuminance and luminance meter
- ultrasonic and electromagnetic flow meters
- pressure meters for liquids
- pyrometers
- optical revolution counters
- industrial torque meters
- sound level meters
- compressed-air system meters
- pump and pump system meters

### OFFERED SERVICES

- energy audits and energy performance audits (active and reactive power consumption, pump systems, compressed air systems, heat generation and distribution systems)
- analysis and measurements of electricity flow and power quality parameters
- testing systems and devices for impact on power quality
- power consumption and demand analysis
- investigations of power consumption and generation management models, development and identification of modification scenarios
- concepts for upgrading pump and ventilation systems, including their power transmission systems, and compressed air systems, to reduce power consumption and improve reliability
- investigating the soundness and energy, economic and environmental effects of high-performance cogeneration

### SELECTED PROJECTS

- Development of a method to assess the possibility of having SMEs restore buildings according to sustainable development criteria ("Scientists for the Mazovian economy – Bioenergia Cluster for the Region", CBI, project co-funded by the European Union under the EFS, 2012–2014)
- Investigations of a diffusion model for renewable energy production technologies and smart energy consumption measurements (EU, Horizon 2020, INNOPATHS, 2017–2020)
- Analysis of the real demand for power in residential and residential-retail buildings based on data from measurement systems (commissioned by Innology Stoen Operator, 2019)
- Analysis of coincidence factors for residential buildings during national quarantine based on data from measurement systems (commissioned by Innology Stoen Operator, 2019)
- Investigation and application of complete centrifugal-pump curves to improve their reliability and the energy efficiency of fluid transport, particularly in the power generation industry (Ministry of Science and Higher Education, 2010)
- Identification of potential energy savings due to a new approach to adjusting the performance of flue gas fans integrated with boilers at the Elektrociepłownia Polskiego Koncernu Naftowego ORLEN S.A. combined heat and power station in Płock (PKN Orlen S.A., 2019)

### PATENTS

- Current source inverter control and protection system (PAT.204310B)
- Power supply unit system (PAT.205020B1)
- Stream straightener and aligner installed ahead of the rotor of a two-stream centrifugal pump (PAT.215467)



# POWER ENGINEERING AND ENERGY STORAGE TEAM

AT THE WARSAW UNIVERSITY  
OF TECHNOLOGY

ENVIRONMENTAL ENGINEERING, MINING AND  
POWER ENGINEERING

#MEASUREMENTS OF EMISSIONS FROM POWER GENERATION UNITS

#POWER CALCULATIONS FOR BOILERS

#POWER CALCULATIONS FOR POWER GENERATION SYSTEMS

#EXERGETIC ANALYSIS FOR POWER GENERATION UNITS

The Team's members are affiliated with the Faculty of Power and Aeronautical Engineering (WUT), the Institute of Heat Engineering and the Division of Power Engineering.

Our Team's core activities involve scientific research, projects and expert opinions on subjects related to broadly defined heating power engineering and electricity storage technology.

Our Team provides both specialised analysis requiring advanced software (e.g. numerical fluid mechanics software) and advice on technical solutions (feasibility studies, energy audits). Emission and power parameter tests for fuel burning plants are an important part of our activities. Our Clients have included large power companies (Enea S.A. and PKN Orlen S.A.), smaller local producers (PEC Siedlce, OPEC Grudziądz, MPEC Olsztyn) and technology companies.

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## RESEARCH INFRASTRUCTURE

- GASMET DX 4000 gas composition analyser, including instrumentation
- specialised thermal imaging camera
- set of aspirated thermocouples to measure distributions of boiler flue gas temperatures
- set of devices for non-invasive monitoring of flows in power generation units
- numerical fluid mechanics software (e.g. Ansys Fluent)

## SELECTED PROJECTS

- Development of a predictive system controlling an SNCR system designed to reduce NOx emissions for coal-fired grate boilers (NCBR, 2017–2019)
- Exergetic analysis for a 500 MW rated power generation unit (ENEA Wytwarzanie Sp. z o.o., 2020)
- Economic and technical appraisal for a project involving the use of an alternative fuel from municipal waste to produce heat for the heating system of the city of Grudziądz (OPEC-INEKO Sp. z o.o., 2017)
- Profitability study for the incorporation into existing structures of frequency converters adjusting flue gas fans at EC PKN ORLEN combined heat and power station in Płock (Orlen S.A., 2018)
- Feasibility study of a project involving the utilisation of waste head to dry biomass fuels to be used by EC Mondi Świecie S.A. combined heat and power station (Mondi Świecie S.A., 2018)

## OFFERED SERVICES

- energy- and exergy-based specialised power calculations for power generation units
- power and emission calculations for power generation units
- studies of waste and biomass use for power generation purposes
- feasibility studies and expert opinions on upgrades and expansions for power generation units
- studies of interoperability between energy storage facilities and power generation systems (e.g. RES systems)
- model-scale studies of power generation units (boilers, turbines) with the use of numerical fluid mechanics
- advising on, and designing of, air pollution control systems for boilers (e.g. SNCR, SCR)

## PATENTS

- A method for improving the efficiency of an adiabatic liquid-air energy storage system by using an additional steam module (PAT.236372)
- Liquid-air energy storage and energy recovery system with a steam circuit (patent / license number: 236371)
- Method and installation of the selective non-catalytic reduction of nitrogen oxides in grate boilers (patent/license number: 506/2017)
- Liquid air energy storage facility with an oxygen separating unit (PL233789)
- Injection lance to supply reagents to power generation boilers (PL236482)





# GASEOUS DETONATION LABORATORY

AT THE WARSAW UNIVERSITY OF TECHNOLOGY

ENVIRONMENTAL ENGINEERING, MINING AND POWER ENGINEERING

#COMBUSTION #DEFLAGRATION #COMBUSTION PROCESSES  
 #EXPLOSIVENESS PARAMETERS #EXPLOSION LIMITS  
 #COMBUSTIBILITY LIMITS #DETONATION #GASEOUS MIXTURES  
 #NUMERICAL SIMULATIONS #HYDROGEN

The Gaseous Detonations Laboratory operates within the Division of Aircraft Engines at the Faculty of Power and Aeronautical Engineering (WUT).

Our Laboratory deals with broadly defined combustion processes, with special focus on detonative combustion and the process of transition from deflagrative to detonative combustion. Our Team also investigates basic parameters of gas fuel and liquid fuel combustion.

Our Laboratory owns many unique test stands, including detonation tubes, impact tubes, single punch compression machines and test stands for investigating high-pressure hydrogen stream combustion.

Our Laboratory has implemented a number of scientific projects funded under domestic and foreign grants. We have cooperated with partners such as Shell Research Ltd UK, Karlsruhe University of Technology, Ulster University, University of South-Eastern Norway and the Central Institute for Labour Protection – National Research Institute.

Our Team is interested in cooperating with other research institutes and partners from the petrochemical and "hydrogen" industries.

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[www.itc.pw.edu.pl/Pracownicy/Badawczo-dydaktyczni/Rudy-Wojciech](http://www.itc.pw.edu.pl/Pracownicy/Badawczo-dydaktyczni/Rudy-Wojciech)

## RESEARCH INFRASTRUCTURE

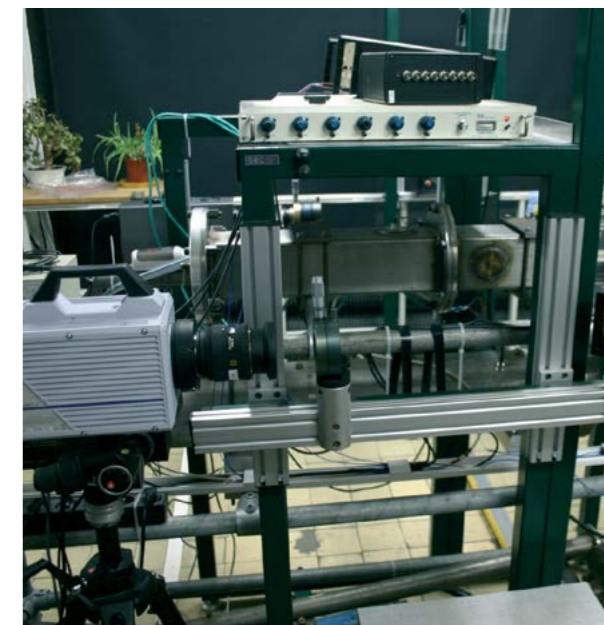
- detonation tubes (up to 6 metres long) along with necessary measurement instrumentation (with a sampling frequency of up to 10 MHz)
- 20-litre test container as per PN-EN 1839 and PN-EN 15697 standards
- 0.4-litre high-pressure transparent chamber to test laminar burning velocity
- test chamber to investigate the process of hydrogen and hydrogen mixture self-ignition
- Pensky–Martens closed-cup flash-point tester as per ASTM D 93
- high-pressure impact tube
- single punch compression machine
- numerical software: Cantera, OpenFoam, ANSYS

## SELECTED PROJECTS

- HYSAFE – Safety of Hydrogen as an Energy Carrier (EU, 6th Framework Programme, Network of Excellence, 2004–2009)
- GENFUEL – Addressing fundamental challenges in the design of new generations FUELS (EU, 7th Framework Programme, Marie-Curie Action Project, Industry-Academia Partnership Pathways, 2014–2018)
- LACOMEKO: HYKA – DETHYD – Detonations in partially confined layers of hydrogen-air mixtures (EU, 7th Framework Programme, 2010–2011)
- Determining flash points and explosion
- points for selected liquid fuels, and investigating the impact of these parameters on the storage and transport safety of liquid fuels (NCBR, 2010–2013)
- Investigating the mechanism of transition from deflagrative to detonative combustion for a mixture of methane, hydrogen and air (Ministry of Science and Higher Education 2006–2009)

## OFFERED SERVICES

- testing services for broadly defined combustion, expert opinions
- testing of basic combustibility (explosiveness) and detonability parameters of gases and vapours
- measurement of detonation cell sizes, run-up distances, superpressures and propagation velocity
- testing of flame/detonation flame arresters and active fire suppression systems in pipelines
- investigating the phenomenon of hydrogen self-ignition during high-pressure leakage
- numerical simulations using commercially available and proprietary numerical codes: 3D, 2D, 0-D





# THERMOPHYSICAL PROPERTIES MEASUREMENT LABORATORY

AT THE WARSAW UNIVERSITY  
OF TECHNOLOGY

ENVIRONMENTAL ENGINEERING, MINING AND POWER ENGINEERING;  
MECHANICAL ENGINEERING; MATERIALS ENGINEERING

#SPECIFIC HEAT #THERMAL CONDUCTIVITY #HEAT PROCESSES #MEASUREMENTS  
OF THERMOPHYSICAL PROPERTIES #THERMOPHYSICAL MEASUREMENTS  
#EXPERIMENTAL TESTS #MEASUREMENTS OF HYGROTHERMAL PROPERTIES  
#SORPTION CURVES #THERMAL DIFFUSIVITY #WATER VAPOUR PERMEABILITY

The Laboratory operates within the Division of Thermodynamics of the Institute of Heat Engineering at the Faculty of Power and Aeronautical Engineering (WUT).

Our Laboratory conducts measurements of thermophysical properties, hygrothermal properties and heat and mass transfer processes.

We perform measurements as part of research projects and assignments from other scientific and industrial entities operating in Poland and abroad.

Our contractors represent the Łukasiewicz Research Network – the Institute of Aviation, the Air Force Institute of Technology (AFIT), PKN Orlen S.A., Veolia Energia Warszawa S.A. and Jenbacher (Austria).

## CONTACT

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## RESEARCH INFRASTRUCTURE

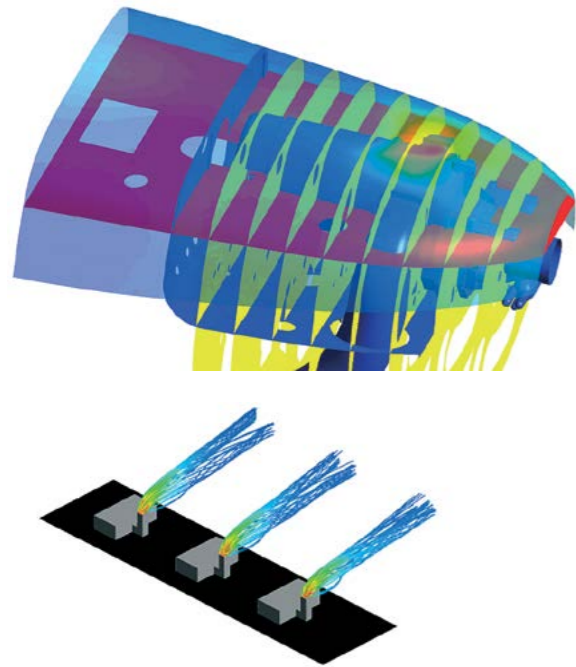
- LFA 447 Nanoflash system from Netzsch
- LFA 457 Microflash system from Netzsch
- DSC 404 F1 calorimeter from Netzsch
- DSC-7 calorimeter from Perkin-Elmer
- Parr 6120 EF bomb calorimeter
- plate-type system for thermal conductivity measurements
- KBK-200WL climatic chamber from Wamed
- KKS 240 TOP+ climatic chamber from POL-EKO APARATURA
- CAP2000+ high-torque high-temp viscosimeter from Brookfield
- drying chambers up to 250°C
- test stand for investigating drying in building materials and small civil engineering structures
- test stand for investigating heat and moisture processes in building materials

## SELECTED PROJECTS

- New construction materials with improved thermal conductivity (TERMET) (NCBR, Innovative Economy Operational Programme 2009–2014)
- Development of an innovative test stand system for testing personal protective equipment (INNOOS) (NCBR, 2013–2016)
- Development of an innovative wall drying and insulation technology (DRYWALL) (NCBR, Innovative Economy Operational Programme 2017–2020)
- Manufacturing technology of building products made of ecological high performance fibre composites with encapsulated PCM for the NZEB application (NCBR, 2020–2023)

## OFFERED SERVICES

- measurements of thermophysical properties:
  - thermal diffusivity
  - specific heat
  - thermal conductivity of solids and liquids
  - determination of enthalpy and temperature of phase changes
  - determination of higher heating value for solid and liquid fuels
- measurements of hygrothermal parameters (e.g. of building materials)
  - sorption curves
  - water vapour permeability
- investigation of heat and mass transfer processes using dedicated experimental stands (e.g. material drying processes, energy conversion and energy storage)



# HEAT AND MASS EXCHANGE ANALYSIS TEAM

AT THE WARSAW UNIVERSITY OF TECHNOLOGY

ENVIRONMENTAL ENGINEERING, MINING AND POWER ENGINEERING;  
MECHANICAL ENGINEERING; CHEMICAL ENGINEERING

#NUMERICAL COMPUTATIONS #COMPUTATIONAL FLUID MECHANICS  
#COMPUTATIONAL HEAT EXCHANGE #HEAT AND MASS EXCHANGE  
#THERMAL CONDUCTIVITY #CONVECTION #THERMAL RADIATION  
#MULTI-PHASE FLOWS #PHASE CHANGE #ALLOY CRYSTALLISATION  
#HEAT EXCHANGERS #ENERGY CONVERSION AND STORAGE  
#CONTROL VOLUME METHOD #FINITE ELEMENT METHOD

Our Team works within the Division of Thermodynamics of the Institute of Heat Engineering at the Faculty of Power and Aeronautical Engineering (WUT).

We carry out computations and analysis related to issues around heat and mass exchange in various processes, devices and systems using commercially available computational software and open-source codes, as well as proprietary computational software. Moreover, we develop proprietary models dedicated to specific problems (e.g. heat and mass exchangers) and implement new models (e.g. moisture transport, phase changes) into existing software. Our Team is also involved in research projects (including NCN, NCBR, FP7 AND H2020 projects) and assignments from other scientific and industrial and scientific entities.

Our Team has cooperated with many WUT faculties (including the Faculty of Mechatronics, the Faculty of Materials Engineering and the Faculty of Automotive and Construction Machinery Engineering) and has completed assignments from entities such as: the Institute of Fluid-Flow Machinery at the Polish Academy of Sciences, the Łukasiewicz Research Network – the Institute of Aviation, Warbud S.A., Enea Sp. z o.o., SILTEN Terbud Sp. z o.o., Enea Badania i Rozwój Sp. z o.o., PKN Orlen S.A., PGNiG GAZOPROJEKT S.A., WSK „PZL-Rzeszów” SA, and ALSTOM Power Sp. z o.o.

## CONTACT

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## RESEARCH INFRASTRUCTURE

- SuperMicro four-CPU PC, 256 GB RAM, four Intel Xeon CPUs, 40 cores
- SuperMicro four-CPU PC, 256 GB RAM, four Intel Xeon E CPUs, 24 cores
- SuperMicro two-CPU PC, 64 GB RAM, two Intel Xeon CPUs, 12 cores
- ANSYS CFD software (ANSYS Academic Research, ANSYS Academic Associate) licenses, including commercial licenses
- CAD/CAM/CAE (NX) software licenses, including commercial licenses
- compilers and numerical libraries (including Intel Parallel Studio, Intel C++ Composer, Intel MKL, Microsoft Visual Studio), including commercial licenses

## SELECTED PROJECTS

- Efficient Systems and Propulsion for Small Aircraft ESPOSA (EU, 7th Framework Programme, 2011–2015)
- Development of an innovative wall drying and insulation technology (NCBR, 2017–2020)
- Development of a new generation of jet pump-based water separators (assignment from ENEON Sp. z o.o as part of an NCBR project, 2018–2021)
- Technology for the manufacture of construction materials made from environmentally friendly high-performance fibrous composites with PCM microcapsules for NZEB applications (NCBR, as part of M-era.net 2, 2020– 2023)
- An innovative system for the generation of heat energy from large underground civil engineering structures (assignment from Warbud S.A. as part of an NCBR project, 2020–2023)

## OFFERED SERVICES

- computational analysis of heat and mass exchange processes
- operational parameter analysis of heat equipment and system components
- support at the stage of designing and developing heat equipment and systems
- optimisation of energy transport processes in equipment and systems
- thermal optimisation of equipment and systems (e.g. heat and mass exchangers, cooling systems, etc.)
- specialised computation-based opinions (e.g. to estimate whether equipment and machinery components, thermal insulation, etc. are built correctly)
- inverse problems (including the determination of heat exchange conditions or thermophysical properties using indirect measurements)
- computational determination of effective thermal-moisture properties

