Description of the research subjects

The Department of Hydraulic Machinery, established on the 1st March 2007, continues research works formerly conducted in the Department of Hydraulic Turbo machinery Tests and Diagnostics and partly in the Department of Cavitation and Hydraulic Machinery Design, which were in organization structure of The Centre for Mechanics of Liquids until the end of February 2007 year. At the present moment Department currying out fundamental and applied research works in the areas of design, operation and diagnostic tests of hydraulic turbomachinery as well as modelling unsteady liquid flows in closed conduit and around bodies.

Development of numerical methods for analysis and design of flow systems of hydraulic turbines and impeller pumps, investigation on mathematical description of phenomena and unsteady processes in hydraulic machines flow systems and improvement in the technique of flow rate measurements in hydrotechnical and hydropower machines and devices are comprise research subjects cultivated in the Department for longer time. These subjects are essential for hydropower engineering and especially for small hydropower plants (SHP) which are renewable energy sources. So far untapped hydropower potential of polish rivers relates in great fraction to the low heads. In order to rationally take the advantage of possessed potential it is necessary to develop relatively high efficient and inexpensive hydraulic turbines constructions. Trying to face the needs of SHP in the Department there is an aspiration to work up an special construction of small hydraulic turbines appropriate for low and ultra low heads which would be characterized by high energy efficiency and very low production cost. This study will be based on modern technique and methodology including three dimensional computations of the liquid flow through turbine blade systems. Until now, collected were abundant practical skills in designing small hydraulic turbines and comprehensive experience of analyzing two dimensional flow through their blade systems, as a basis for new design methods, moreover earlier began works on three dimensional flow analysis are intensively developed .

It is planning to develop own original software for three-dimensional flow modelling by means of vortex singularities method multiple validated in ship propellers applications. In order to better understand phenomena appearing in liquid flow and to confirm reliability of developed computer programs the Departments’s laboratory rigs will be exploited which could be specially modernized and build up within bounds of possibility.

Primary purpose of research works concerning transient phenomena in flow systems of hydraulic turbines and impeller pumps is improvement and development of numerical methods for prediction the course of these phenomena. Practical importance of elaborated methods is related to counteraction unfavorable conditions as excessive pressure changes produced by water hammer effect or induced by vortex shedding under resonance conditions severe increase in vibration amplitude of flown past elements. Such phenomena reduce working life and operational reliability of elements of fluid-flow hydraulic systems and often pose a serious threat of substantial failures. As especially dangerous situations taking place in hydraulic pipeline systems should be consider cases when transient pressure decrease results in appearance of cavitation zones, which are regions of liquid stream discontinuity. Such situations can occur during quick opening/closing of valves or starting/stopping the impeller of pumps or hydraulic turbines,

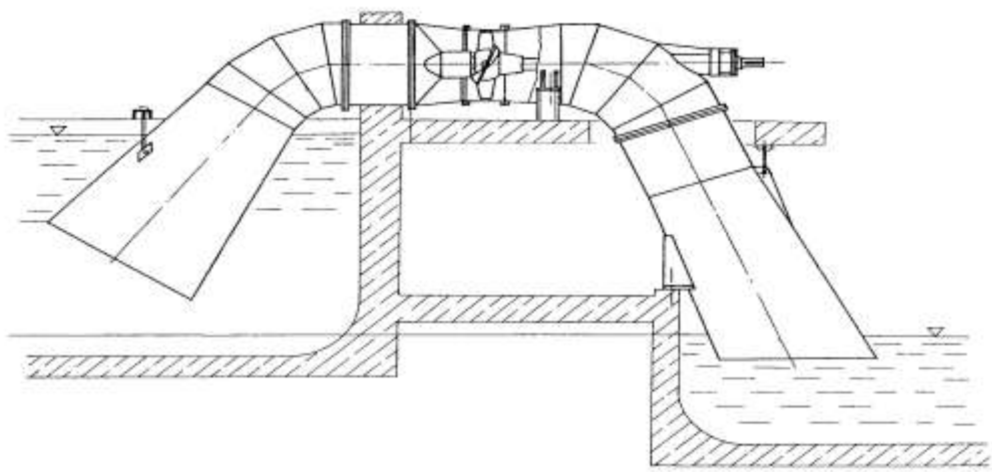
when as a consequence of wave processes produced by water hammer in the closed conduits pressure at some section drops below its critical value, close to liquid evaporation pressure of at a given temperature. Cavitation zones which appear during this process die away after some time. Usually there are multiple emergence and disappearance of these zones. The phenomena occurring under this conditions – i.e. transient cavitation or liquid column

separation – are almost always accompanying by rapid pressure changes which are reasons for a large number of failures and occasionally total damages to the elements of the hydraulic system. Avoidance or partial reduction of such changes could in crucial manner influence upon increase augmentation of working life and operational reliability of flow systems elements. Current knowledge concerning predictability of these phenomena is still unsatisfactory therefore require further investigations.
In its activity the Department holds a wide collaboration with industry. For the most part they are the companies from the hydropower sector for which various research works and practical engineering applications are made. These works encompass efficiency tests of hydraulic turbines and impeller pumps using advanced measurements techniques, design of small hydraulic turbines, investigations and evaluation of dynamic state of hydraulic units with determinations theirs durability and working life, as well as technical expert opinions for hydropower industry and other areas of the economy related to the problems of ascertainment of causes of breakdowns and failures, preparation of devices and equipment for continuous flow rate measurement in hydraulic turbines, preparation of laboratory rigs for investigation on water power phenomena for outer partners.
The whole selection of research topics continued by the Department stem primarily from the thorough diagnose and current needs of the waterpower engineering. Its topicality is confirmed by considerable number of direct contracts with hydropower plants to research and service works, and also large number of technical consultancies and expert opinions which were given to investors and users of small hydro power units and for the others interested in the development of hydro-energetic power industry in Poland. Advanced in theoretical research works and collected experience enable to undertake more and more complicated tasks set by domestic and foreign customers.
Research activity of the Department is perfectly placed in current polish and european scientific and economic trends.

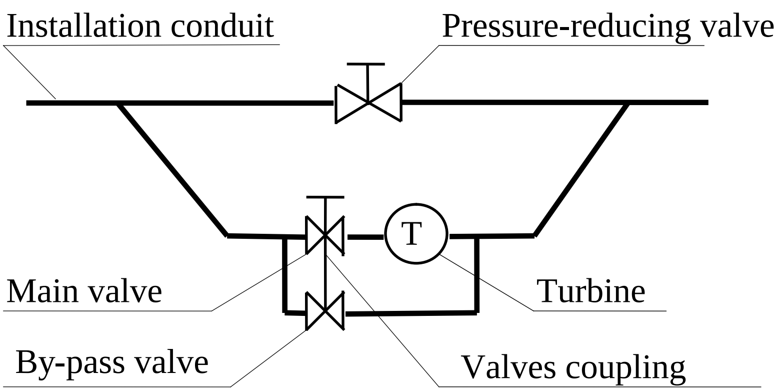
The offers list of research works and expert technical opinions for industry:

CONCEPTS OF INSTALLATION AND DESIGNS OF SMALL HYDRAULIC TURBINES, IMPELLER PUMPS IN TURBINE REGIME

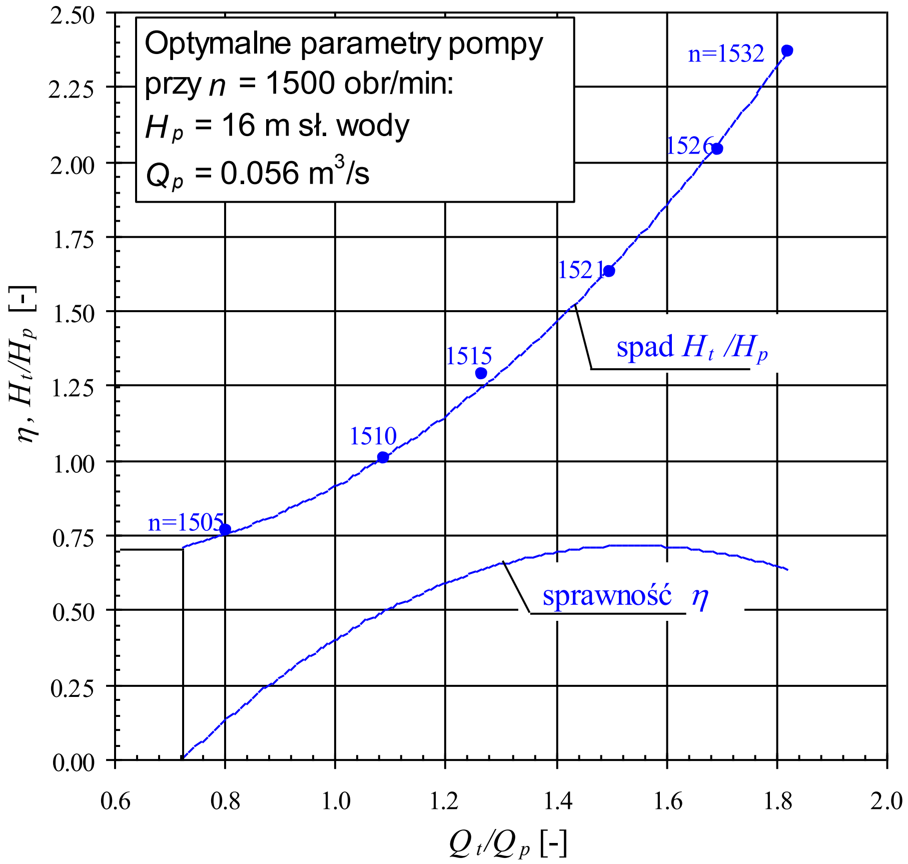
Example 1: The concept of small hydraulic turbine with propeller runner at siphon installation - the Jaracz Hydropower Plant



Example2: Machine for energy recuperation in industrial installations



Schematic diagram of impeller pump application, to run in reverse as turbine, in order to energy recuperation which is losing in industry installation -- energy is wasted at pressure-reducing valve as a consequence of throttling of the flow.

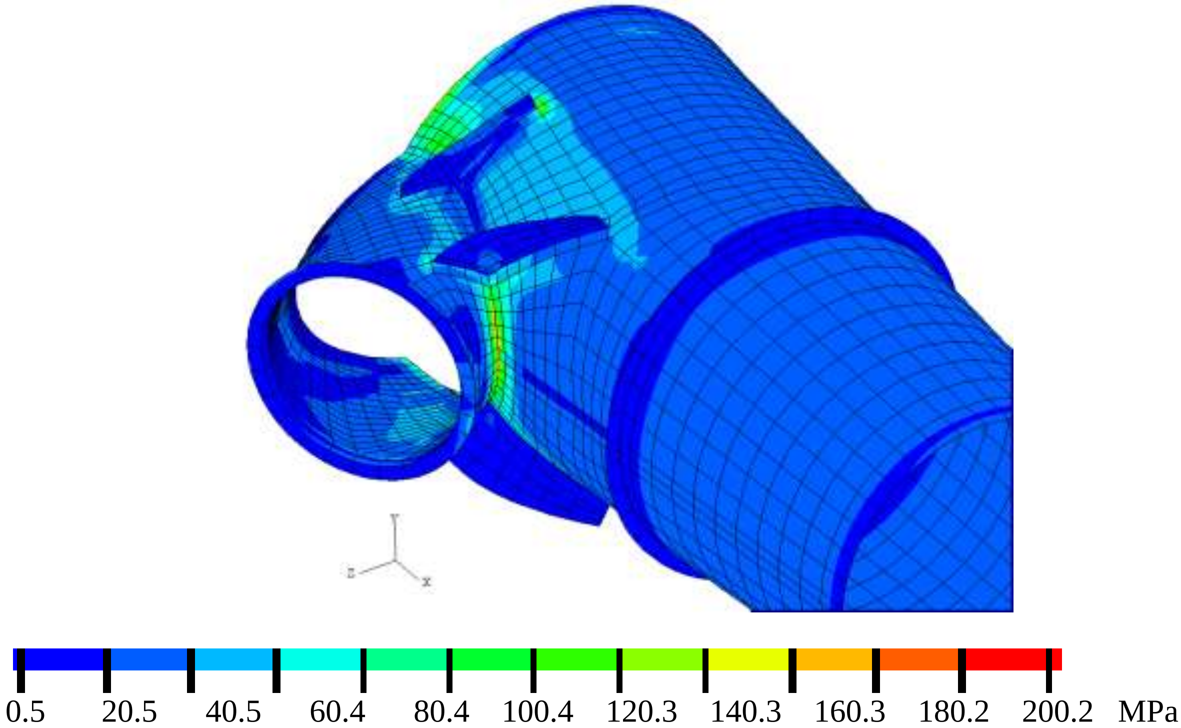


Operation characteristics of pump 150 PJM 250 in turbine regime

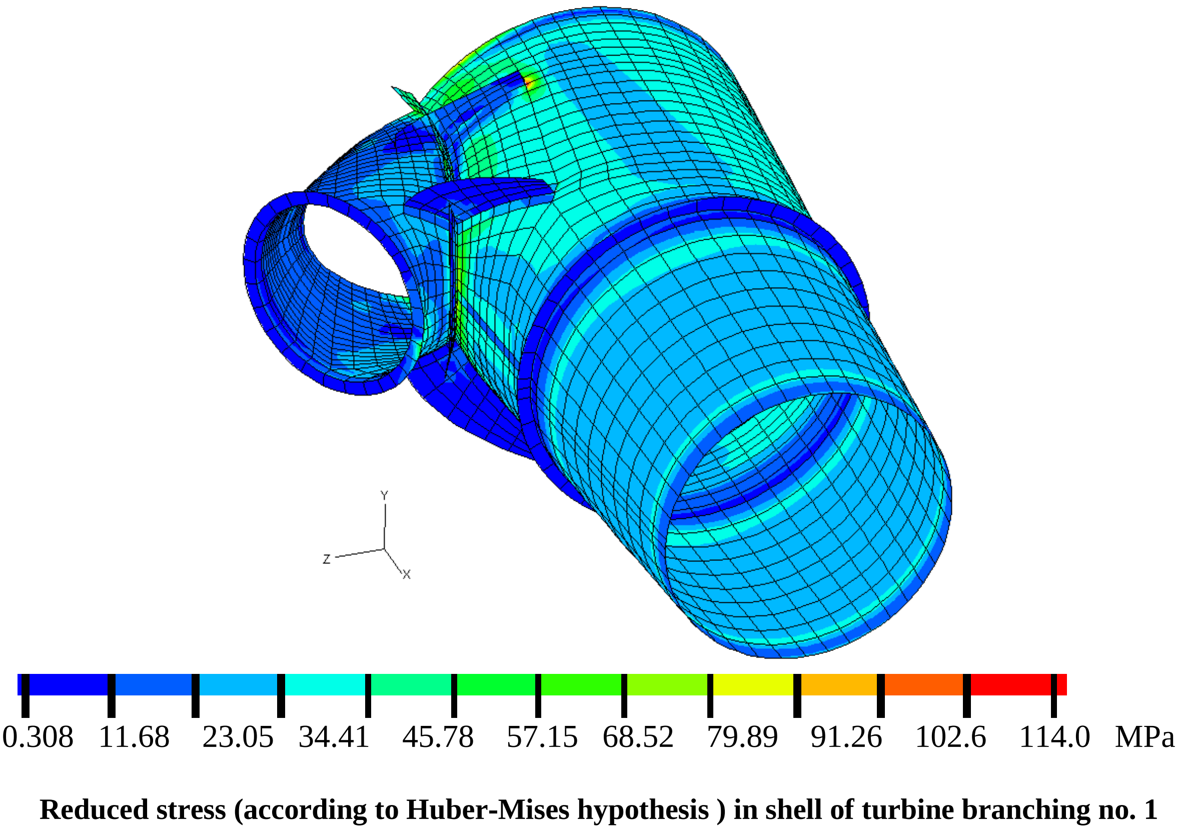
TECHNICAL STATE ASSESSMENTS, TECHNOLOGIES

Examples:

- Evaluation of technical state of flow systems of hydraulic turbines
- Extension of working life of flow systems of hydraulic turbines and impeller pumps, for instance by reinforcement the most strained constructional elements of such systems
- Evaluation of strength and working life of derivation pipelines supplying hydraulic turbines
- Evaluation of vibration state of rotating systems of hydraulic units



Case without additional reinforcement. Reduced stress (according to Huber-Mises hypothesis) in shell of turbine branching – outer side, pressure load 415 kPa (for linear-elastic material).



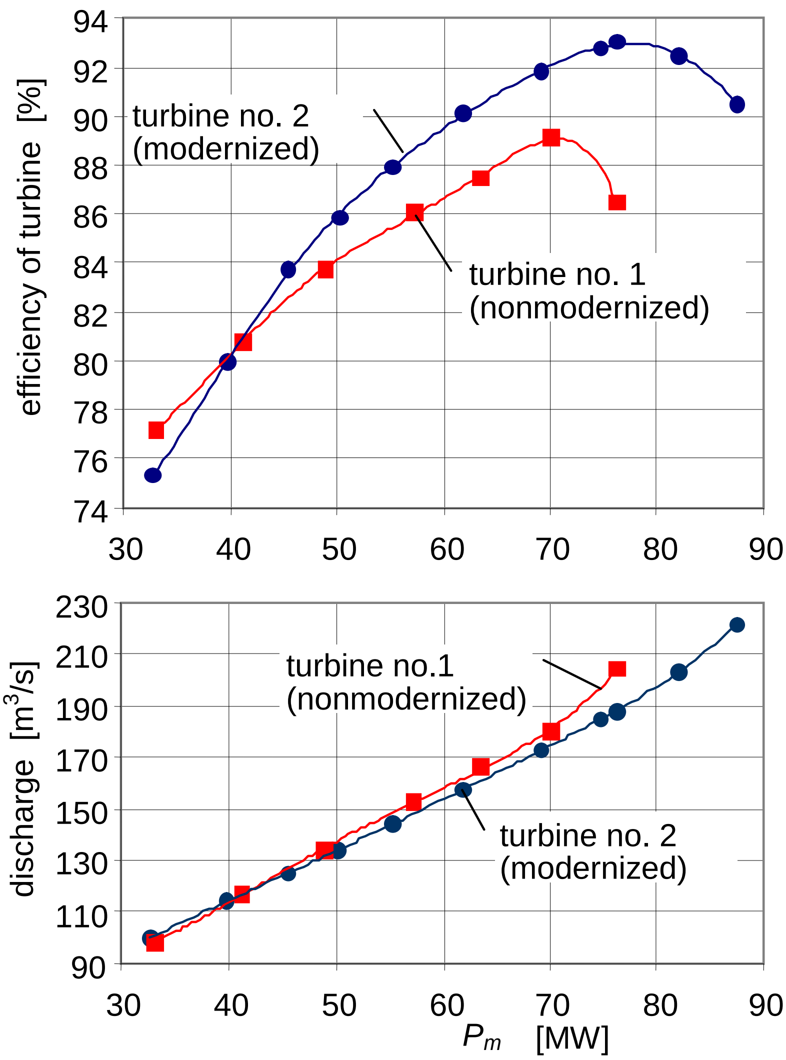
Reduced stress (according to Huber-Mises hypothesis) in shell of turbine branching no. 1 fortified with a fin (for linear-elastic material).

Strengthening fin at pipeline branching

INVESTIGATION OF POWER PROPERTIES (EFFICIENCY MEASUREMENTS) AND DYNAMIC STATE OF HYDRAULIC UNITS IN HYDROPOWER PLANTS

Examples:

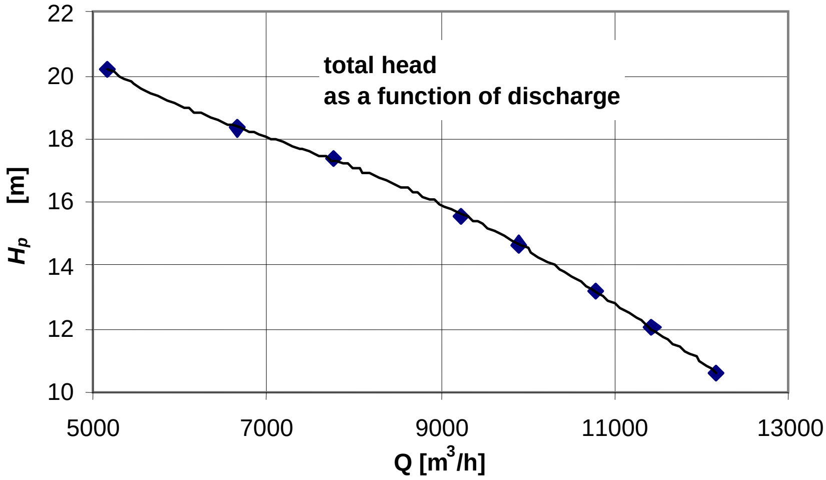
- Field guaranty and acceptance tests (efficiency measurements) of hydraulic turbines
- Efficiency measurements of hydraulic turbines
- Commissioning tests of hydraulic units after construction, modernization or overhaul
- Dynamic state tests of hydraulic units – measurements and evaluation of vibration level in constructional elements, noise level and pressure pulsation under various operation conditions

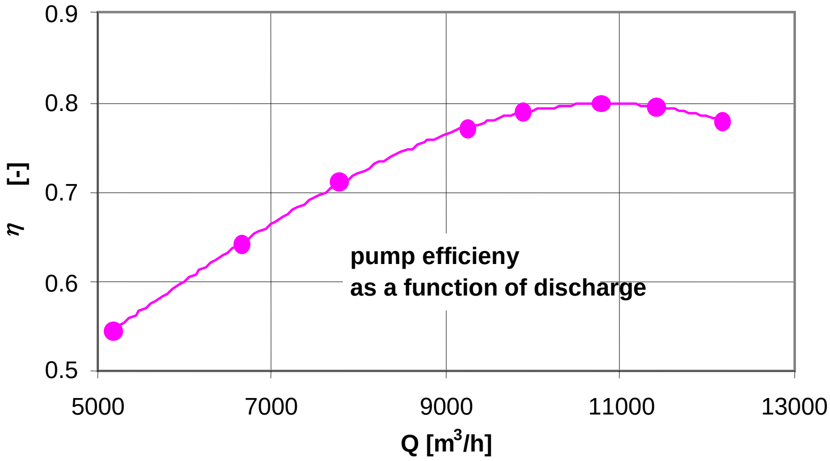


Power characteristic of hydraulic turbines determined for one effective head on the basis of test conducted using Gibson method

OPERATION INVESTIGATIONS OF PUMPING SETS -- EFFICIENCY AND FLOW RATE MEASUREMENTS

- pump systems and pumping stations of cooling water in conventional and heatpower plants
- preheated water pumps in heatpower plants
- flow systems on marine ships





Operation characteristics of network water pump determined in one of the heatpower plant (ultrasonic method of flow rate measurement)

TECHNICAL EXPERT OPINIONS

Determination of breakdown and failure causes of hydraulic machinery and devices (cavitation failure, damages caused by destructive effect of water hammer, resonant phenomena, and others).

Examples:

- determine the causes of excessive hydraulic unit shaft vibration
- determine the causes of shaft cracking of impeller pumps
- recognize the causes of penstock rupture
- recognize the causes of cracking of cut-off valves housing in various hydraulic flow systems
- control and calibration of ultrasonic flowmeters installed in derivation pipelines of hydropower plants and other hydrotechnical objects

Disrupted penstock in the Łapino Hydropower Plant

Main scope of works :

In order to evaluate the technical state of the penstock after the failure and to determine the causes of its burst, the case was subject to an extensive investigation, covering among others:

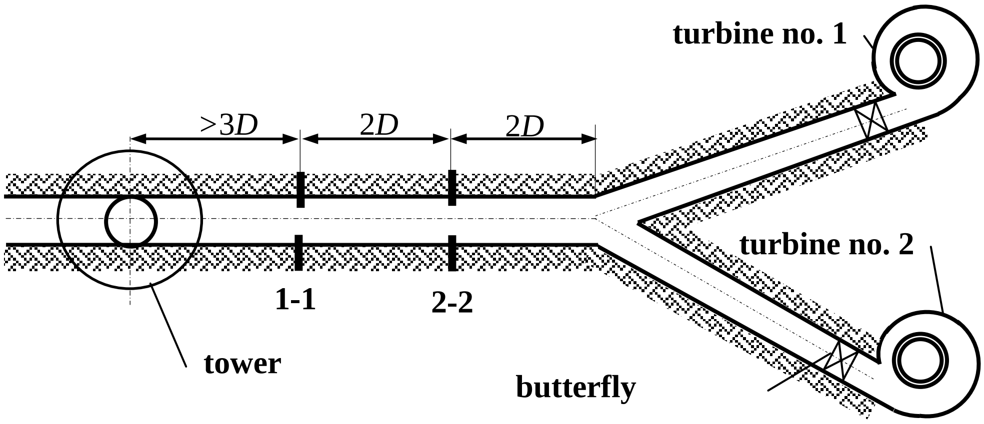
- non-destructive tests of the preserved penstock shell with a particular focus on the weld joints,
- material tests of the broken penstock shell,
- analysis of the stress in the shell of the broken penstock section,
- analysis of hydraulic transients under conditions of failure,
- elaboration of guidelines for repair of the penstock and further operation of the power plant.

FLOW RATE MEASUREMENTS IN HYDROPOWER PLANTS

Examples:

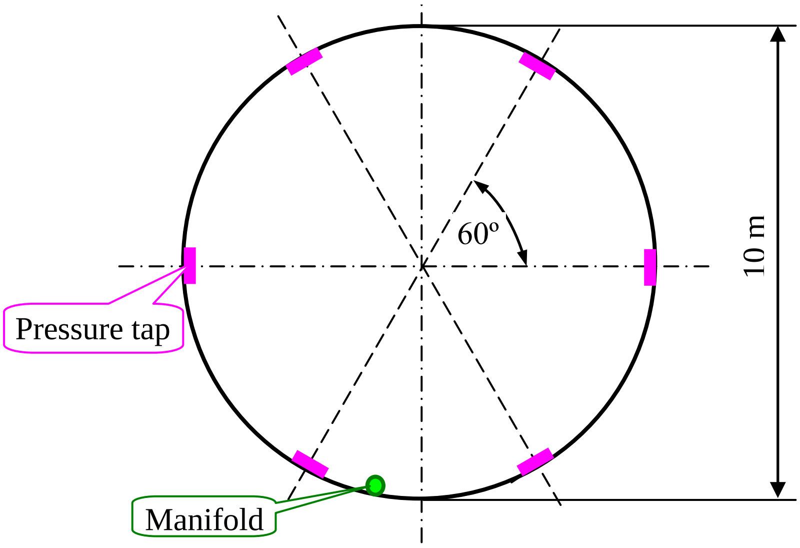
- preparation and application of the water hammer method (Gibson method) for flow rate measurement in flow systems of hydraulic turbines and pump-turbines
- development, fitting up and starting up the devices for continuous water flow rate measurement in hydraulic turbines (Winter-Kennedy method and ultrasonic method)

Example of water hammer method (Gibson method) application

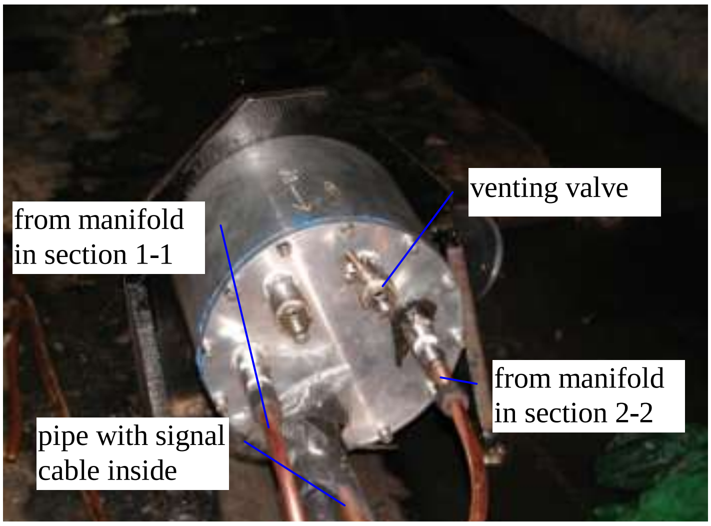


Schematic diagram of supply system of turbines under investigation with marked hydrometric sections using (which were used) in Gibson method

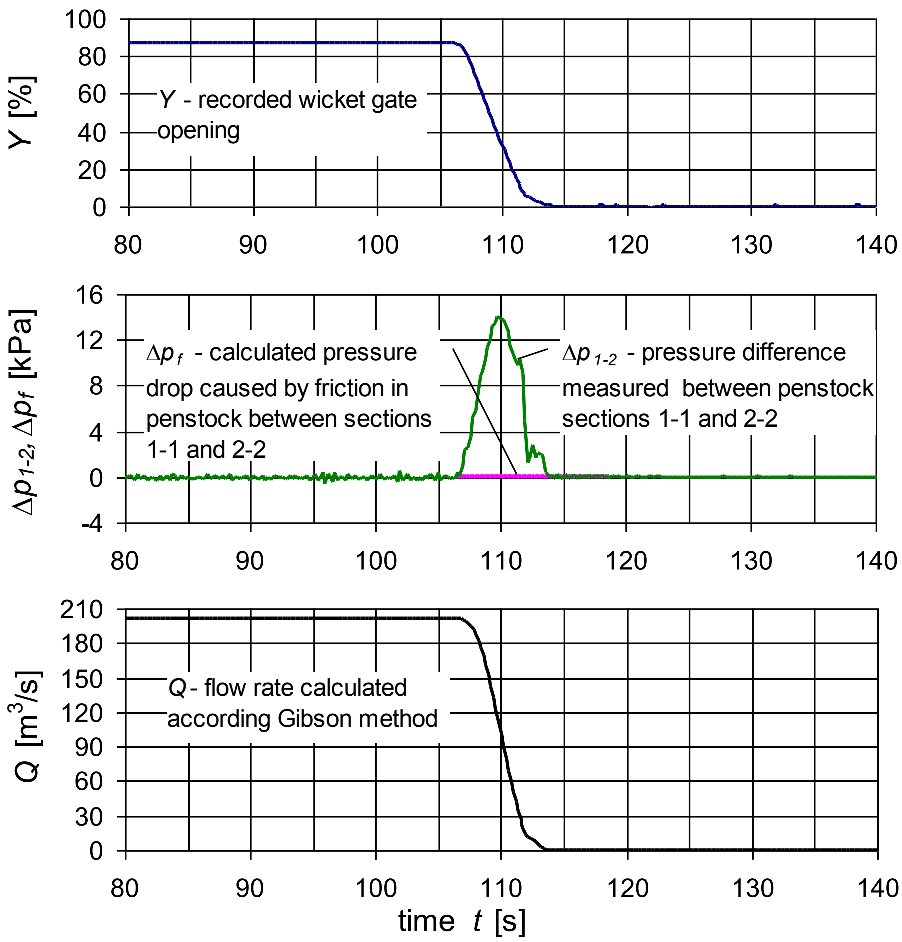
Section 1-1 and 2-2



Localization of pressure taps at each pipeline section 1-1 and 2-2.



Waterproof housing with pressure difference transducer installed inside.



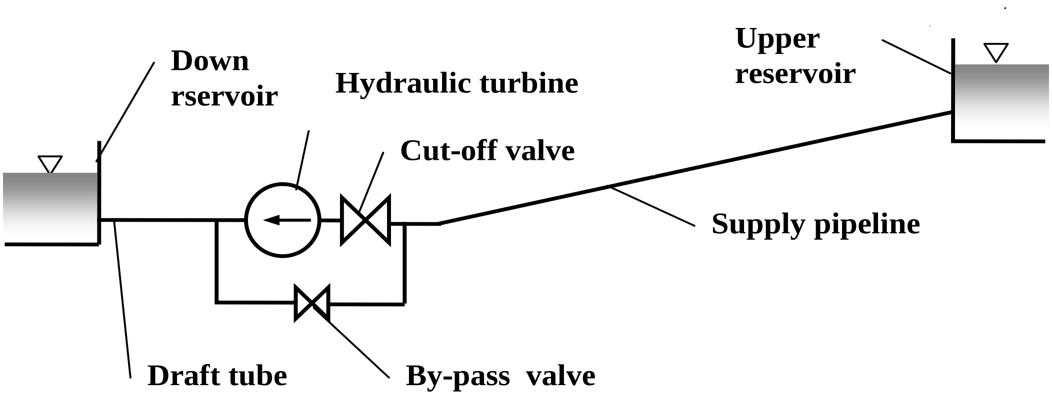
Recorded and calculated time changes of values related to flow discharge measurement by means of Gibson method

COMPUTATIONS OF WATER HAMMER PHENOMENA IN FLOW SYSTEMS OF HYDRAULIC TURBOMACHERY

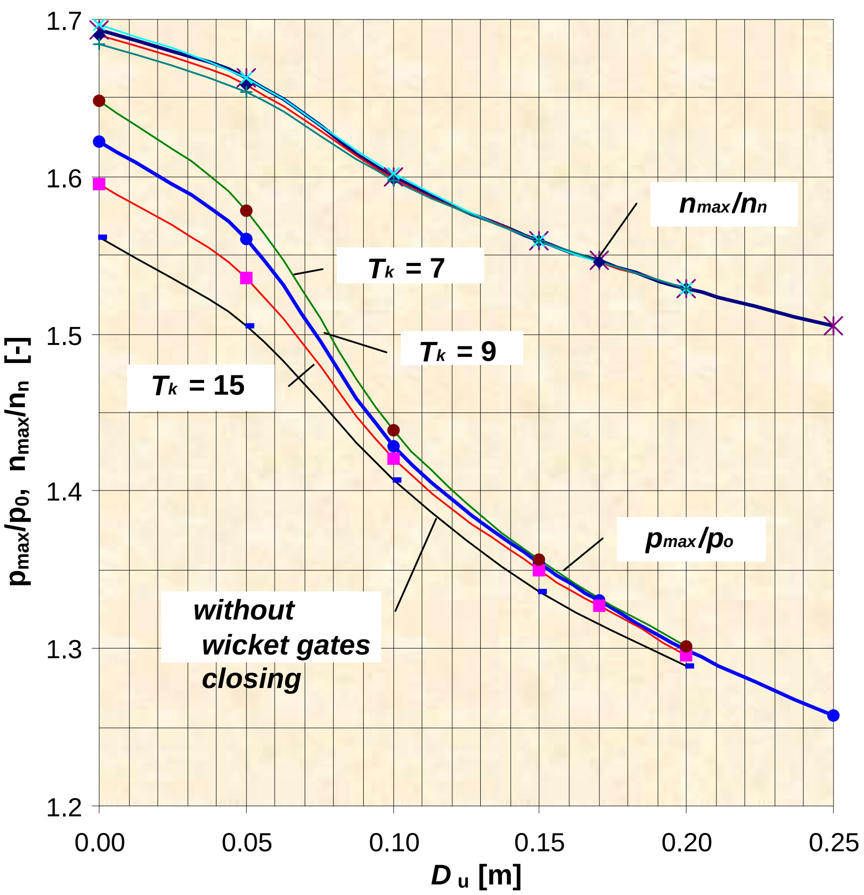
Examples:

- optimisation of the wicket gate closing procedure in order to protect supply pipeline form the excessive pressure increase, and turbine generator from the excessive rotational speed increase,
- analysis of various methods of the water hammer effects (mitigation or attenuation) in order to choice the most advantageous technical solution,
- reduction of the excessive pressure pulsation produced by water hummer in fluid-flow system of pumps and turbines,
- control of transient states of hydraulic machines in order to counteract the unfavorable effects of water hammer.

Exemplary analysis of by-pass valve application in order to diminish water hammer level



Schematic diagram of by-pass valve application in hydraulic turbine system

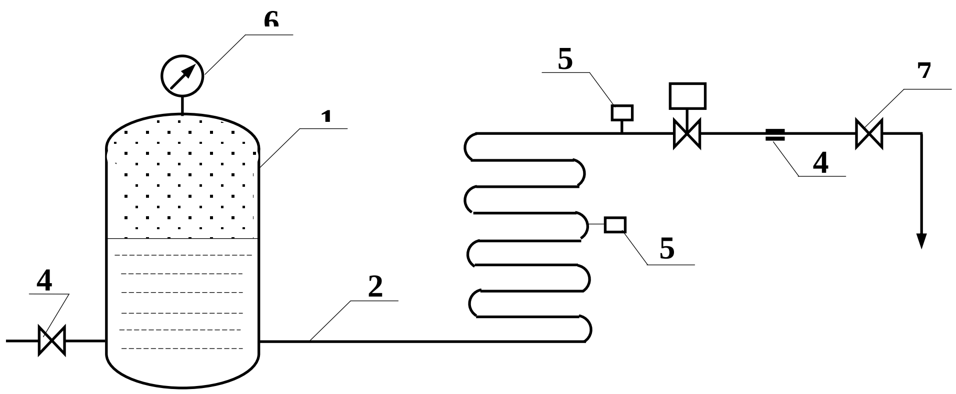


Maximum pressure in pipeline (p_{max}) and maximum rotational speed (n_{max}) versus by-pass valve diameter D_u for various closing times of wicket gates T_k

CONSTRUCTION OF LABORATORY RIGS

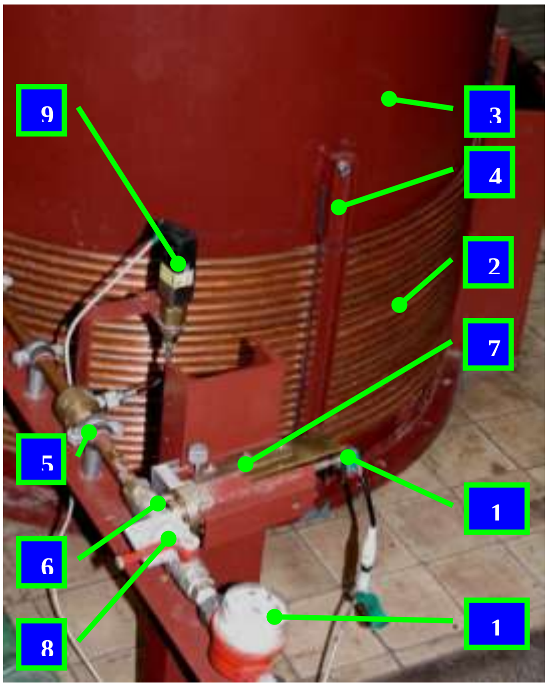
Example:

Small size laboratory test rig for studying hydraulic transient in pipe systems with measurement equipment.



Schematic diagram of laboratory rig for water hammer phenomena investigation

1. Water-air reservoir, 2. Long pipeline winded up on the reel, 3. Quick closing valve, 4. Control valve, 5. Static pressure transducers, 6. Manometer or pressure gage transducer with display unit, 7. Electromagnetic flowmeter.



Partially view of laboratory rig for investigation on pressure wave propagation in closed conduit

2 – measurement pipeline (copper), 3 – steel reel, 4 – C-shape bar to fasten pipeline, 5 – supports of measurement pipeline, 6 – cutoff valve (ball valve), 7 – spring drive of cut-off valve, 8 – control valve, 9 – pressure transducer, 10 – turbine flowmeter, 11– potentiometric transducer to record closing of cut-off valve.