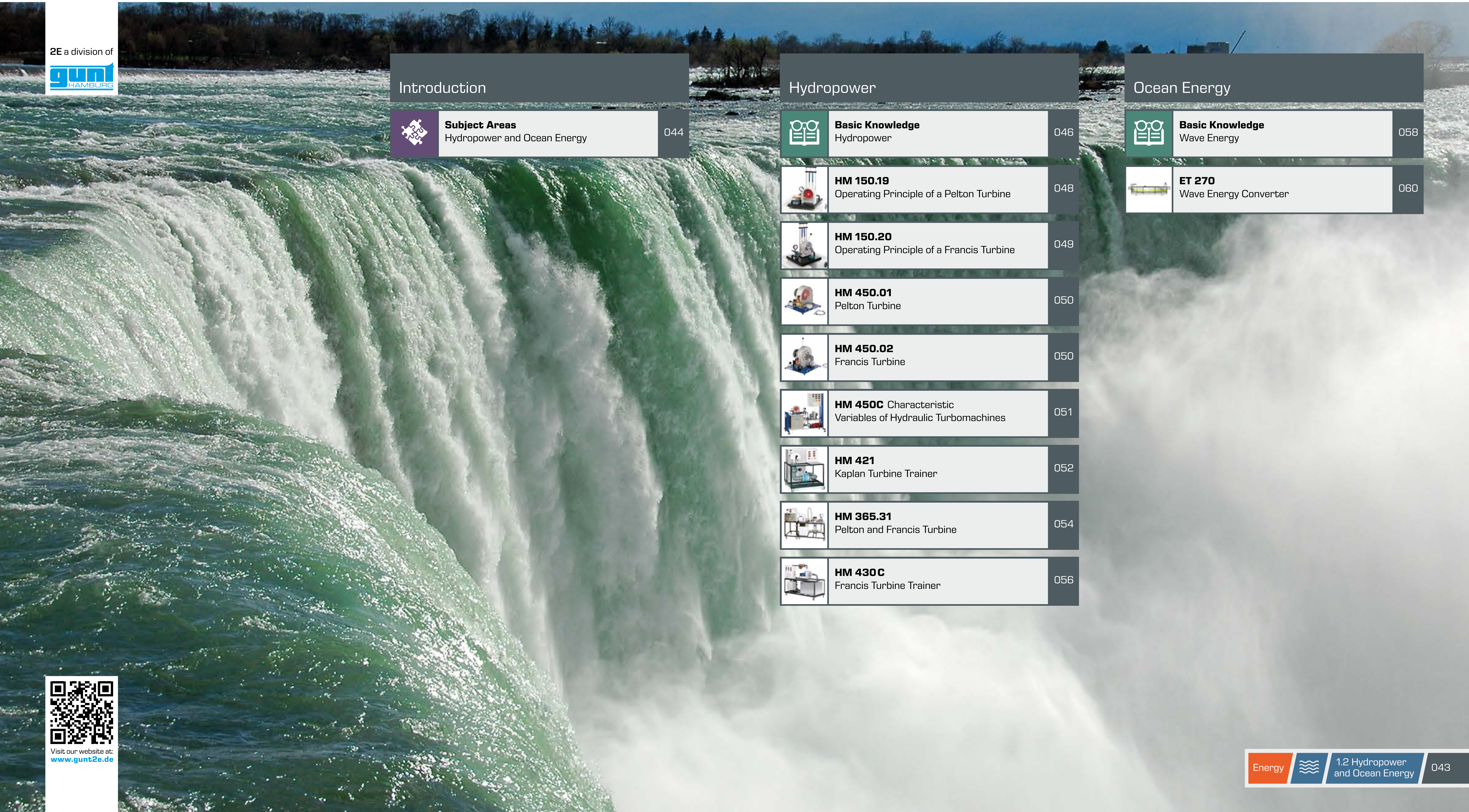
Energy:
Renewable Energies
and Energy Efficiency

Hydropower and Ocean Energy

1.2

2E a division of gunt HAMBURG



Introduction

Hydropower

Ocean Energy

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www.gunt2e.de

Subject Areas

Hydropower and Ocean Energy

Water's natural flowing movements, such as in rivers and reservoirs, can be used in the production of electricity. Furthermore, both the tidal range (the periodic rise and fall of the sea level) and the energy contained in flow and waves can be used in the ocean sector.

Both types of energy conversion are classed as renewable energies. While the typical use of hydropower has been widespread for hundreds of years, using the ocean for energy is in its infancy.

As the table opposite shows, different learning objectives from turbine engineering can be differentiated in the expanded field of hydropower and ocean energy. The corresponding 2E product is listed in the next column.

Additional trainers in the fields of turbines and fluid mechanics in particular can be found in GUNT catalogue 4 "Fluid Mechanics".

Subject Areas	2E Products
Hydropower	
Fundamentals of fluid mechanics: energy conversion in water turbines	**HM 150.19** Operating Principle of a Pelton Turbine **HM 150.20** Operating Principle of a Francis Turbine
Turbomachines: measurements on turbines and pumps	**HM 450.01** Pelton Turbine **HM 450.02** Francis Turbine **HM 450C** Characteristic Variables of Hydraulic Turbomachines
Turbines in run-of-river power stations: river and tidal power stations	**HM 421** Kaplan Turbine Trainer
Comparing turbine types – asynchronous generator drive	**HM 365.31** Pelton and Francis Turbine
How guide vanes affect characteristic turbine curves	**HM 430C** Francis Turbine Trainer
Ocean Energy	
How the guide vanes affect characteristic turbine curves	**ET 270** Wave Energy Converter

Basic Knowledge
Hydropower

Traditional hydropower systems have been in use for hundreds of years as a source of energy for a wide variety of mechanical applications. As such, hydropower represents a renewable energy source that has been successfully used for a long time. Since the beginning of hydropower-generated electricity, the percentage of electrical energy generated in this way has grown to around one quarter of all the electricity used worldwide.

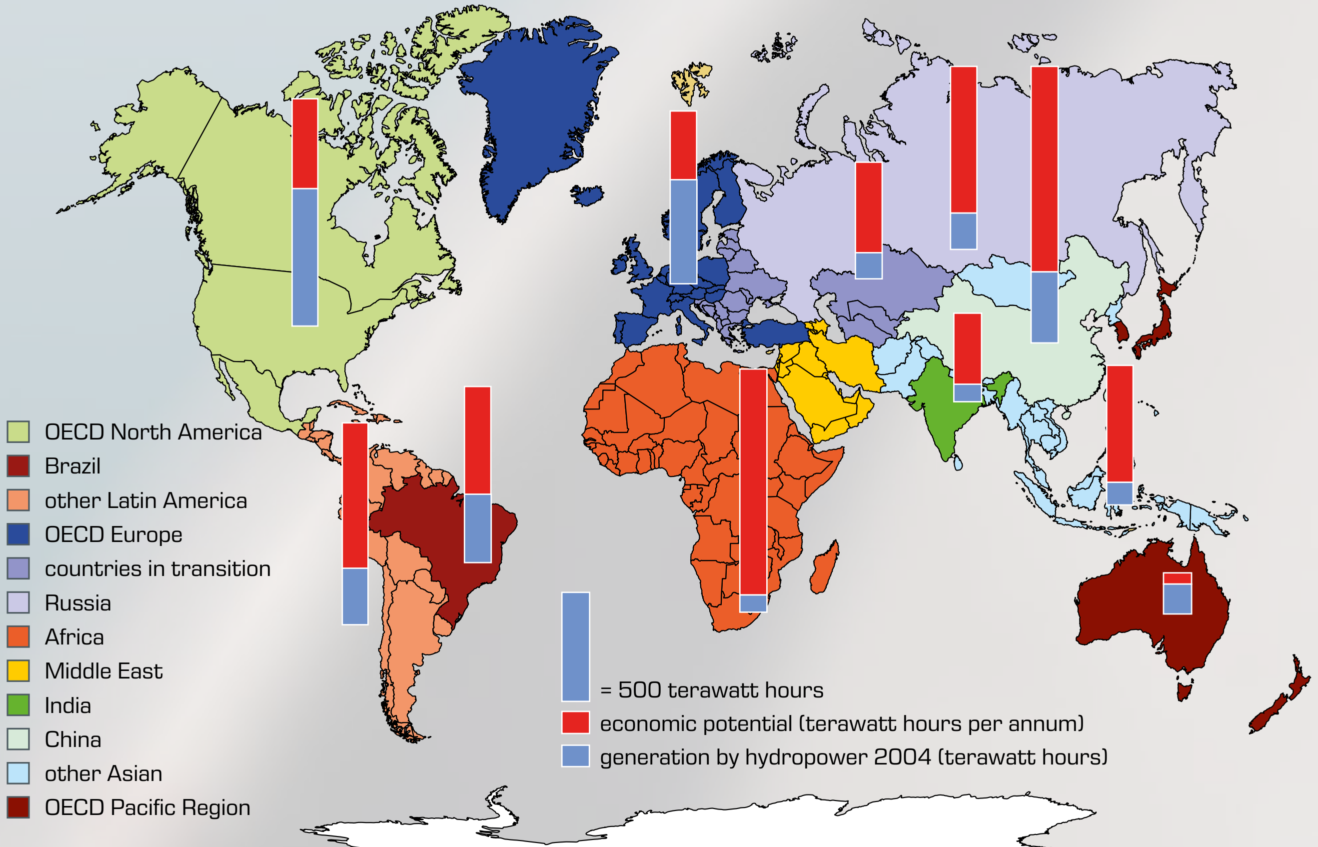
However as the number of turbines in use increases, and with it the necessary retaining dams, the significant drawbacks in the overall ecological balance of this technology has become apparent to some extent. Due to geological conditions, some countries such as Norway (99%), Congo (97%) and Brazil (96%) are able to cover very large proportions of their electrical energy demand with hydropower. By comparison, in Germany only 4% is covered. Brazil is currently home to the world's largest hydroelectric power station, where 18 turbines generate a total output of 12,600 megawatts.

Decentralised power supply through small hydroelectric power stations

In regions without a central power supply, decentralised, small hydroelectric power stations with an output up to about 5 kW offer the possibility of supporting sustainable development in an appropriate manner.

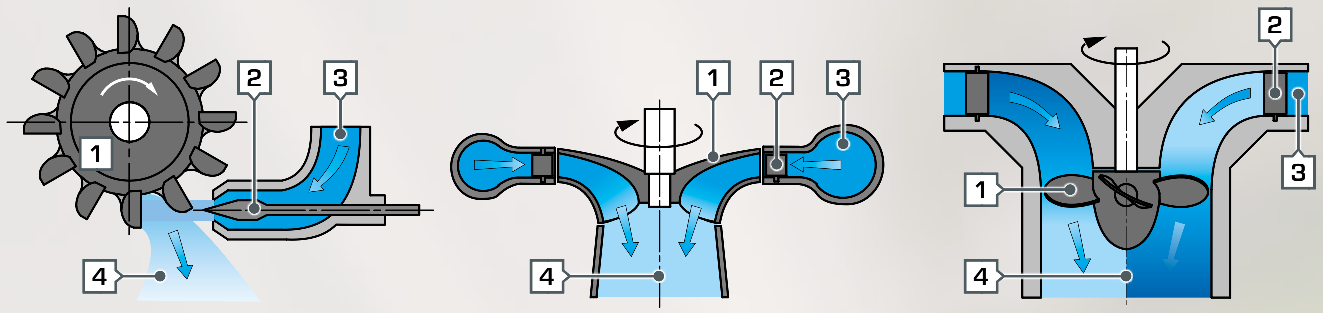
In addition to the typical characteristic variables such as head and flow rate, other aspects such as maintenance issues and accessibility of the installation site are also important to consider when selecting the type of turbine. At heads of 150 m and more Pelton turbines are mostly used. At lower heads on the other hand, Francis or Kaplan turbines are preferred.

Expansion potential for use of hydropower



Source: International Energy Agency, 2006 World Energy Outlook

Turbine types in hydroelectric power stations



Pelton turbine

In the Pelton turbine the water "shoots" out of one or more nozzles onto the vanes of the impeller.

Head: 150 - 2000 m
Flow rate: 0,02 - 70 m³/s
Storage power stations

Francis turbine

The Francis turbine operates with positive pressure. The guide vanes can be adjusted.

Head: 20 - 700 m
Flow rate: 0,3 - 1000 m³/s
Dams

Kaplan turbine

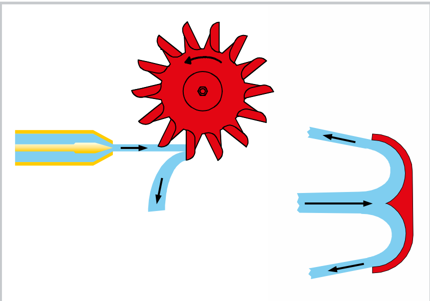
The Kaplan turbine also operates with positive pressure. In this case, guide vanes and impeller vanes can be adjusted.

Head: 2 - 60 m
Flow rate: 4 - 2000 m³/s
Rivers

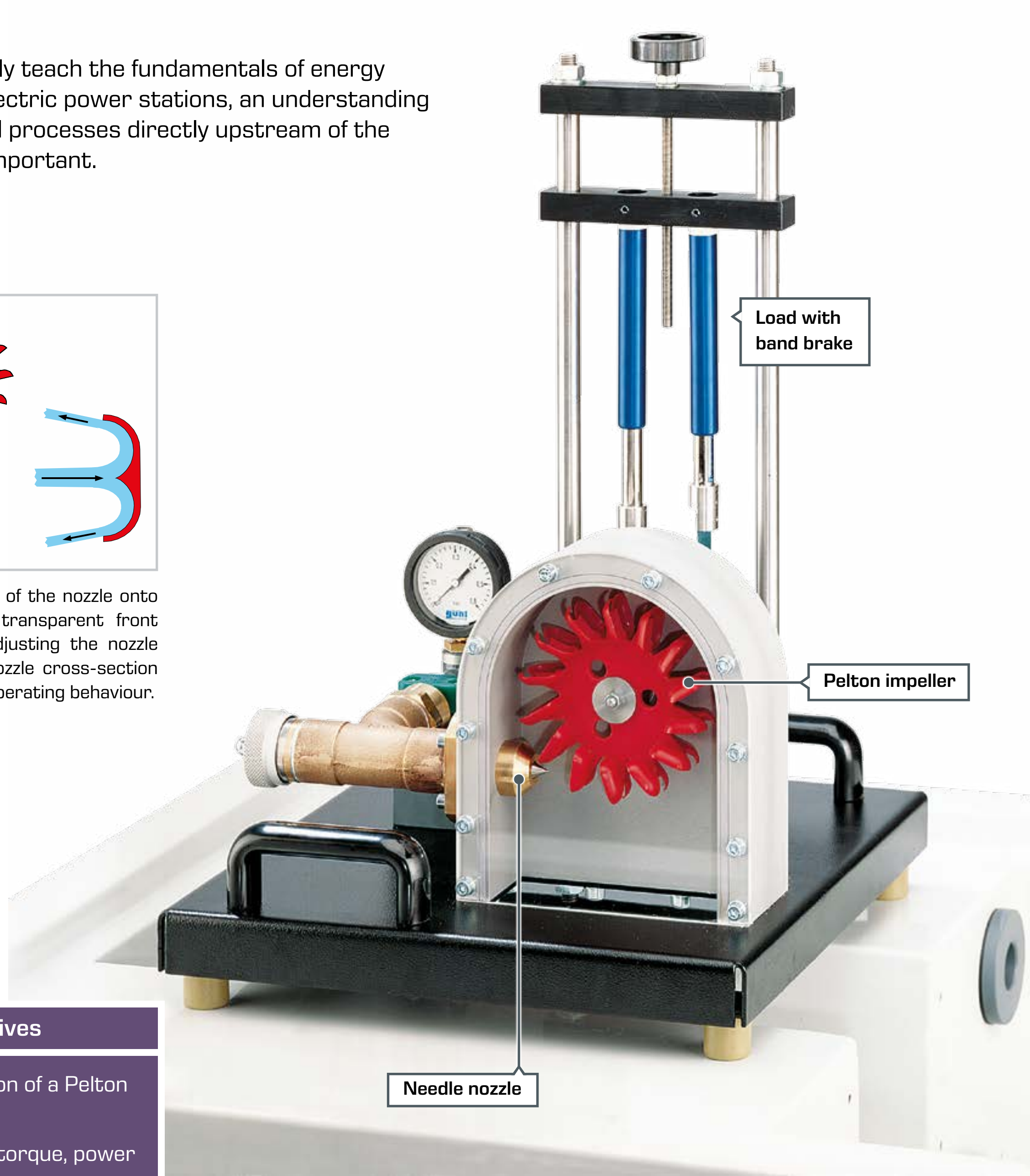
1 impeller   2 guide vanes   3 water inlet   4 water outlet

HM 150.19 Operating Principle of a Pelton Turbine

In order to successfully teach the fundamentals of energy conversion in hydroelectric power stations, an understanding of the fluid mechanical processes directly upstream of the turbine is especially important.



Observe the water flow out of the nozzle onto the impeller through the transparent front panel on HM 150.19. By adjusting the nozzle needle, you can vary the nozzle cross-section and study its effect on the operating behaviour.



Learning objectives

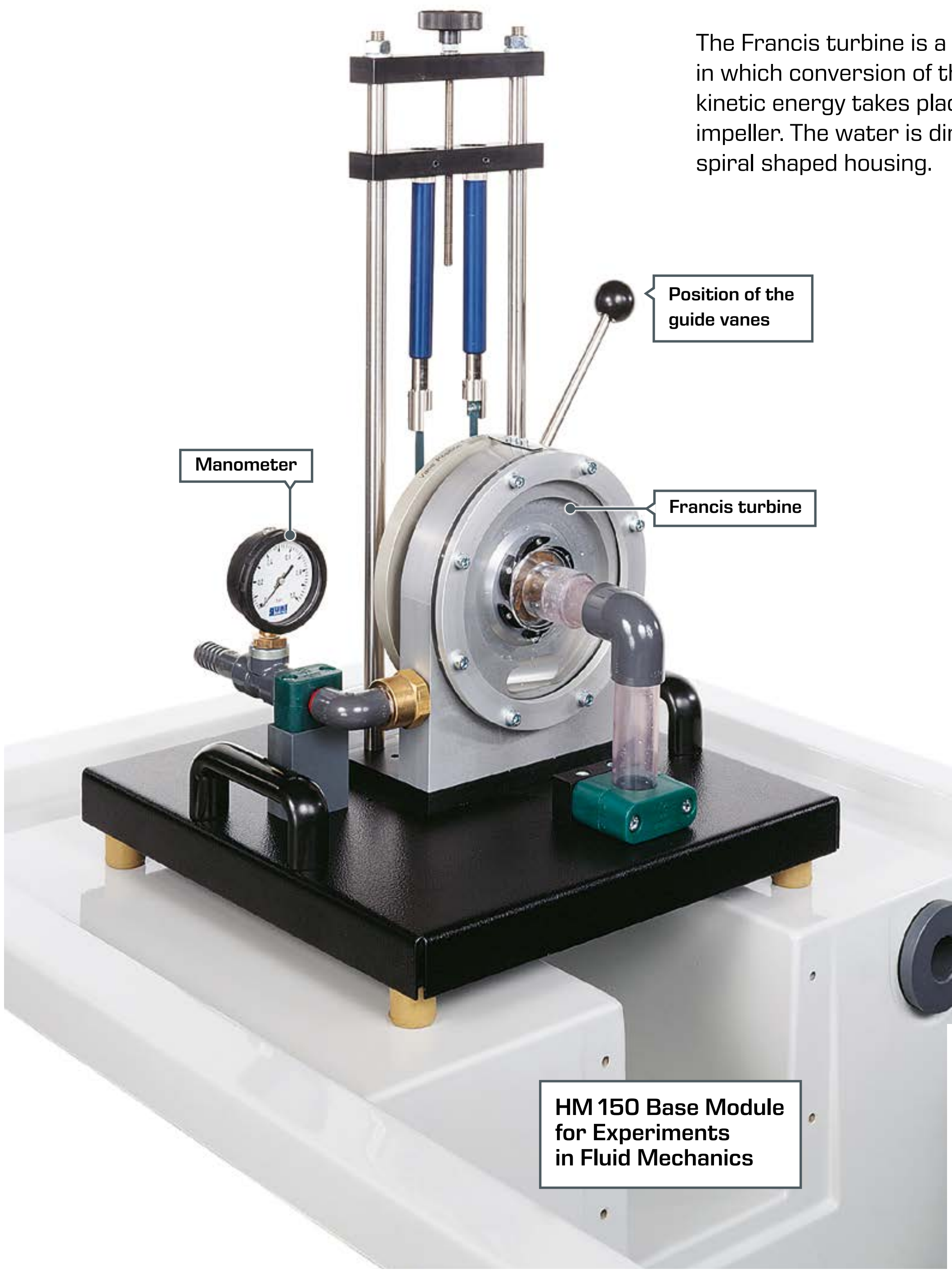
- design and function of a Pelton turbine
- determination of torque, power and efficiency
- graphical representation of characteristic curves for torque, power and efficiency

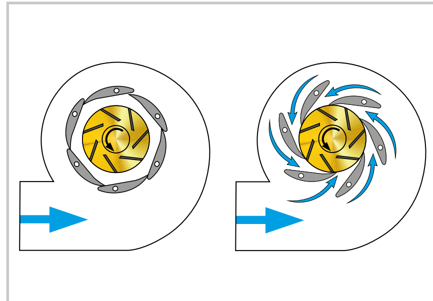
HM 150
Base module

Product No.
070.15019
More details and technical data:
gunt.de/static/s4562_1.php

HM 150.20 Operating Principle of a Francis Turbine

The Francis turbine is a positive pressure turbine, in which conversion of the water's pressure energy into kinetic energy takes place in the guide vanes and in the impeller. The water is directed to the guide vanes via a spiral shaped housing.





You can adjust the alignment of the Francis turbine's guide vanes to optimise performance.

HM 150.19 and HM 150.20 are part of the HM 150 series on fluid mechanics. We recommend using the HM 150 base module for supplying the turbines with water and for measuring the flow rates.

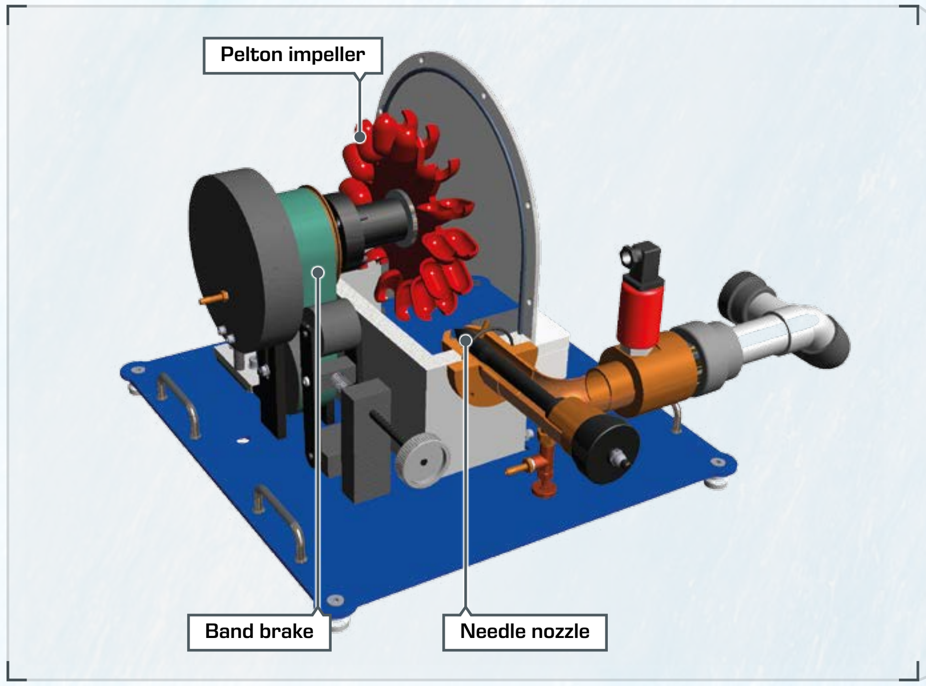
Learning objectives

- design and function of a Francis turbine
- determination of torque, power and efficiency
- graphical representation of characteristic curves for torque, power and efficiency

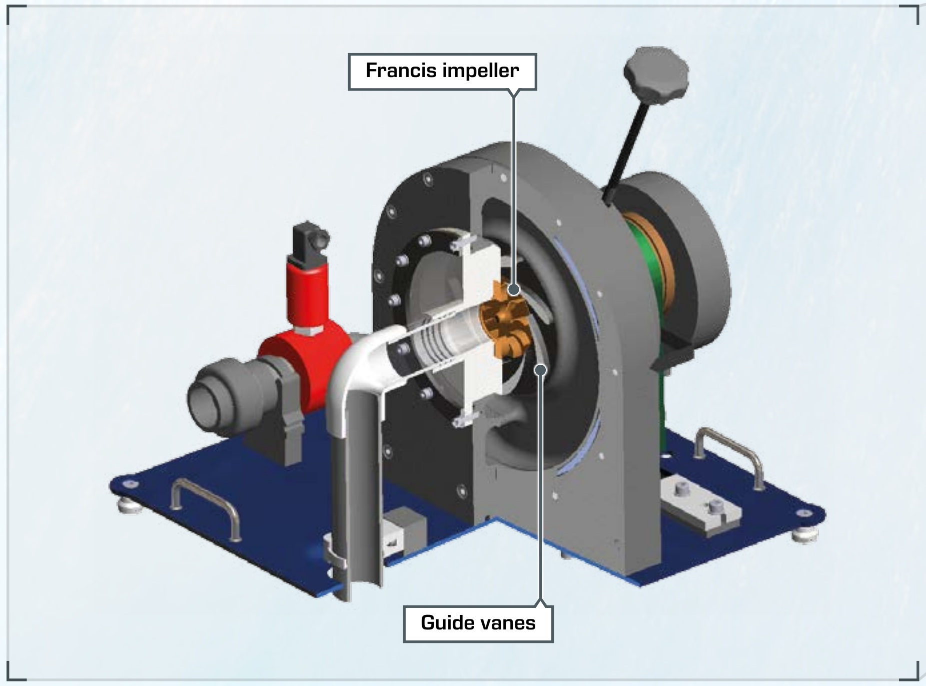
Product No.
070.15020
More details and technical data:
gunt.de/static/s4572_1.php

HM 450.01 HM 450.02 Pelton Turbine Francis Turbine

With HM 450.01 and HM 450.02 you can systematically investigate energy conversion in various turbine types and compare typical properties. Used in conjunction with the HM 450C trainer, you have a fully equipped system for education in the field of turbomachines.



The water exits the Francis impeller axially. The intake capacity, and therefore the performance of the turbine, can be adjusted by rotating the guide vanes.



Learning objectives

- comparison of turbine types
- determining the mechanical power
- influence of nozzle cross-section and/or guide vanes
- plotting characteristic curves
- calculating the efficiency

Product No.
070.45001
More details and technical data:
gunt.de/static/s4202_1.php

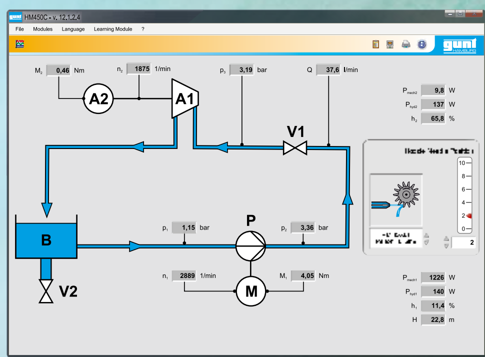
Product No.
070.45002
More details and technical data:
gunt.de/static/s4201_1.php

HM 450C Characteristic Variables of Hydraulic Turbomachines

HM 450C contains a closed water circuit to supply the turbines. Pressure, flow rate, torque and rotational speed are detected electronically and displayed digitally.

The HM 450C software

Measured values can be transferred to a PC via USB. The GUNT software provides you with an extensive range of options for displaying and analysing your data.



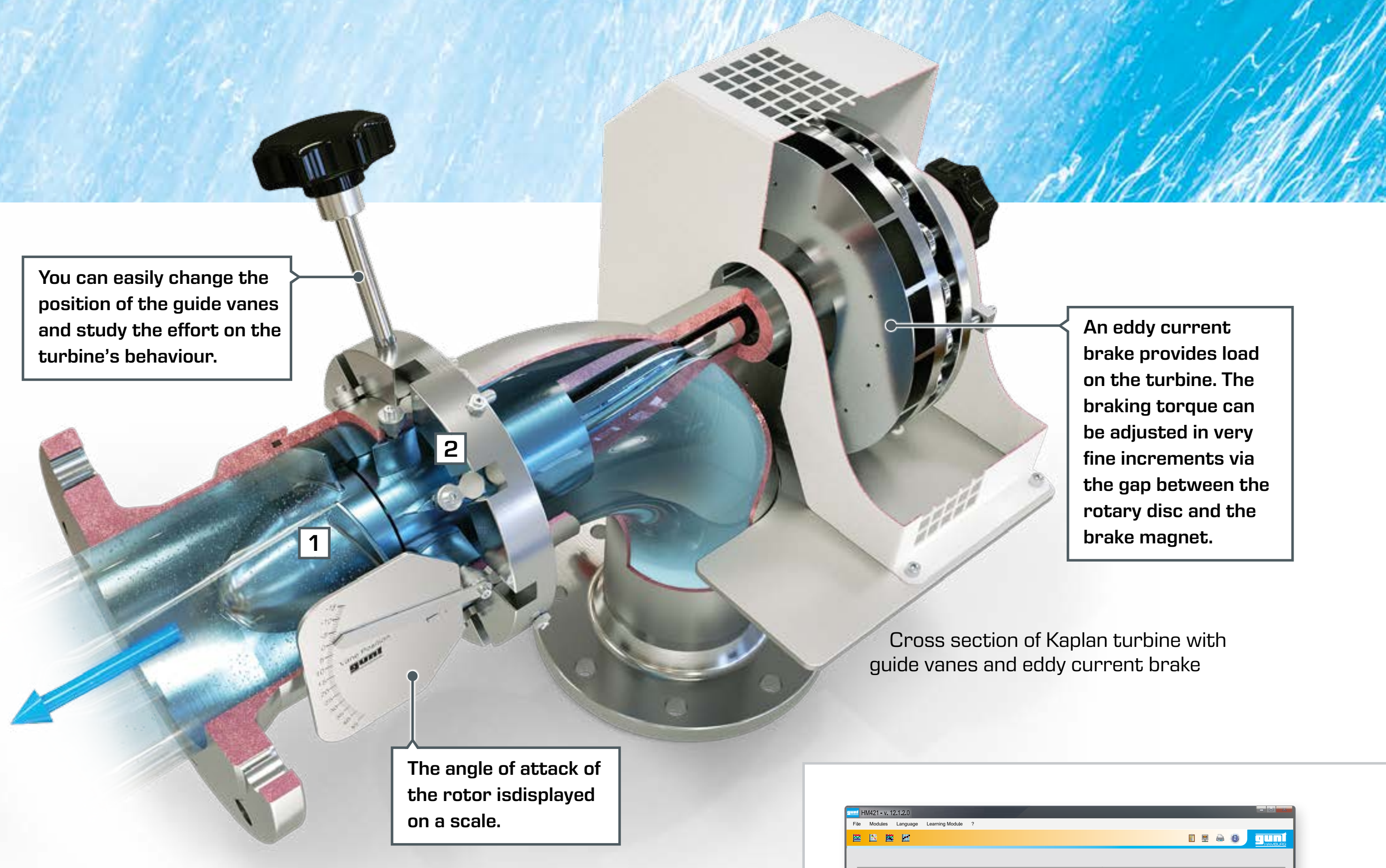
Product No.
070.450C0
More details and technical data:
gunt.de/static/s4242_1.php

HM 421 Kaplan Turbine Trainer

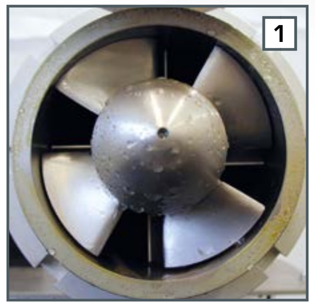
Kaplan turbines are used at low hydraulic heads to generate electricity. Low heads occur for example, in run-of-river power stations and tidal power stations.

HM 421 provides you with a trainer equipped with a Kaplan turbine in a closed water circuit and a submersible pump.

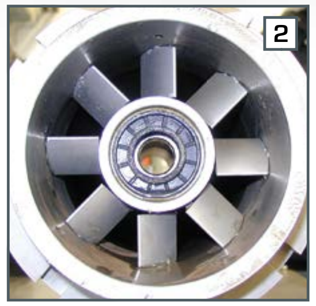
Product No.
070.42100
More details and technical data:
gunt.de/static/s4917_1.php



Cross section of Kaplan turbine with guide vanes and eddy current brake



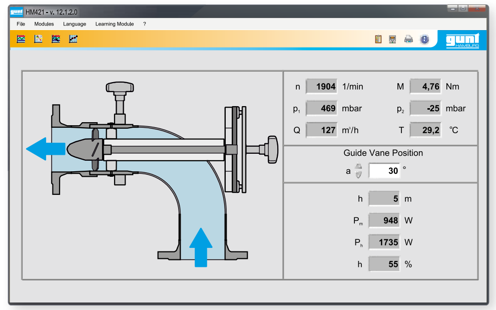
Impeller



Guide vanes

Learning objectives

- measurement of turbine characteristics
- determining power characteristics at different speeds (hydraulic power, mechanical power)
- determining the head
- calculating the turbine efficiency
- how blade position affects power and efficiency



Software

The software for HM 421 allows the most important variables to be captured:

- flow rate
- head
- speed
- torque
- pressure at the inlet and outlet
- temperature

The following variables can be calculated from the measured values:

- hydraulic power
- mechanical power
- efficiency
- head

HM 365.31 Pelton and Francis Turbine

The HM 365 modular system allows you to investigate the characteristic operating behaviour of various turbine types. Water is supplied by the specially designed HM 365.32 supply unit. The energy generated by the turbine is transferred to the asynchronous generator in HM 365. Further information about the additional possibilities can be found in the data sheets for the respective devices.

The **GUNT software** provides an intuitive visualisation of current measurement data in a system diagram and enables continuous data acquisition via a USB connection.
Of course, graphical representations and calculations are also provided for analysis of the measurement data.

HM 365.31: Pelton Turbine

HM 365.31: Francis Turbine

HM 365 has a three-phase asynchronous motor which is used as a generator. Thanks to the possibility of controlling the load via the speed or torque, the turbine being studied can be operated at the optimum operating point with varying hydraulic power.

HM 365.32 is equipped with sensors for pressure and flow rate. A power pump – inside an enclosed water circuit – simulates the gradient of a hydroelectric power station.

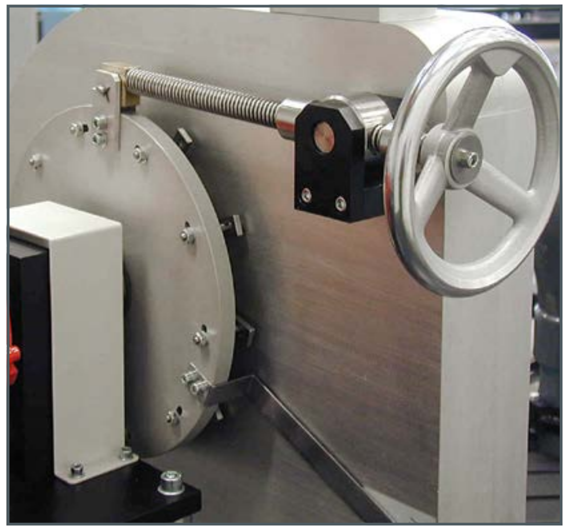
Learning objectives

- comparison of impulse and reaction turbines
- determination of mechanical and hydraulic power
- determination of efficiency
- recording of characteristic curves
- influence of Pelton turbine nozzle cross-section on characteristic values
- influence of Francis turbine guide vane position on characteristic values

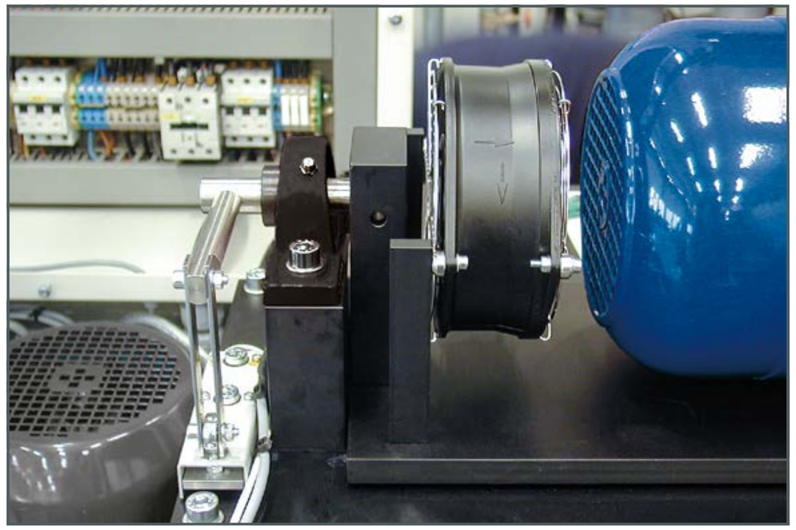
Product No.
070.36531
More details and technical data:
gunt.de/static/s4233_1.php

HM 430C Francis Turbine Trainer

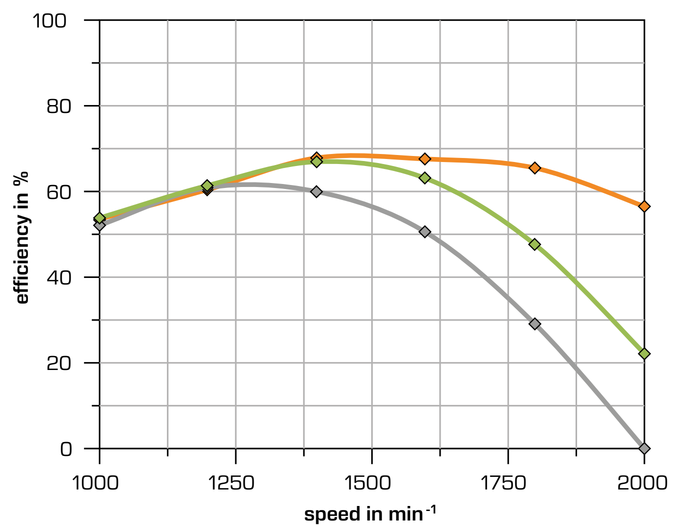
Francis turbines are used for hydropower at medium heads and medium flow rates. HM 430C provides you with the facility for using a DC generator for energy conversion.



You can easily study the behaviour of the turbine with different guide vane positions.



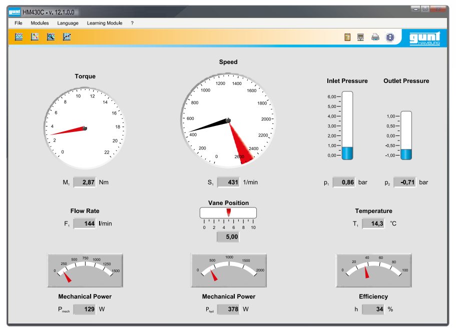
A force sensor detects the torque at the generator's flexible mounting.



The mechanical power emitted, the hydraulic power supplied and the efficiency can all be calculated from the measurement data. The chart shows how the efficiency depends on the speed for three different guide vane positions.

Learning objectives

- investigation of conversion of hydraulic into mechanical energy
- determination of torque and speed of turbine shaft
- determination of mechanical and hydraulic power
- determination of efficiency
- recording of characteristic curves
- investigate the effect of guide vane position
- calculate velocity triangles



Software

The GUNT software displays torque, speed and pressure to monitor the current system state.

Product No.
070.430C0
More details and technical data:
gunt.de/static/s4585_1.php

Basic Knowledge

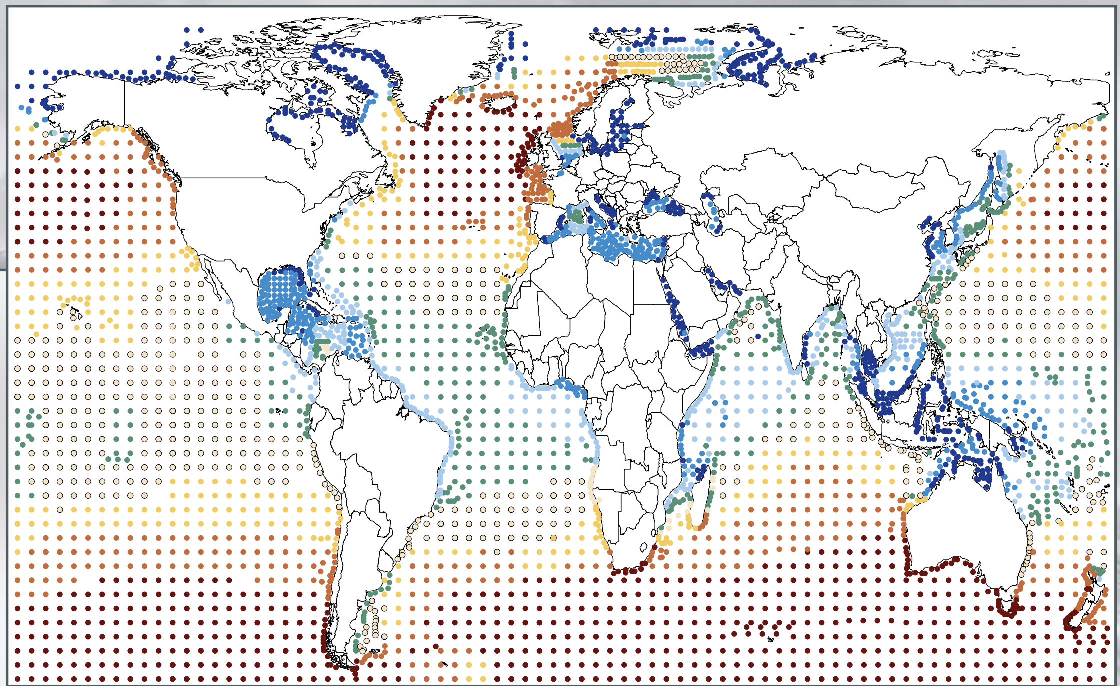
Wave Energy

The ocean's waves contain an inexhaustible reserve of energy. They are caused by wind, gravitational forces and atmospheric pressure differences.

The International Energy Agency estimates the possible global contribution of wave energy to the power supply at more than 10 %.

The main challenge in constructing wave power stations is not least that of designing systems that can withstand the sometimes destructive natural conditions. The integration of chamber systems following the principle of the oscillating water column (OWC) has proven promising in existing coastal defence structures.

Annual average power of ocean waves (kW/m)



The map shows the average annual wave power. It assumes power along a coastline or along a wave crest. The power densities are specified in kW/m. It should be noted that high powers can be found at latitudes far from the equator and on the west coasts of the continents.

Source: Centre for Renewable and Sustainable Energy Studies, Stellenbosch University

Linear wave theory provides an estimate for the energy flow of a wave:

$$P \sim T * H^2$$

We can see that the power **P** is linearly dependent on the period length **T** and quadratically dependent on the height of the wave **H**.

Distribution of the wave energy supply

Seconds			Minutes	Hours	
0,1	1	30	5	12	24

Energy content

Wind

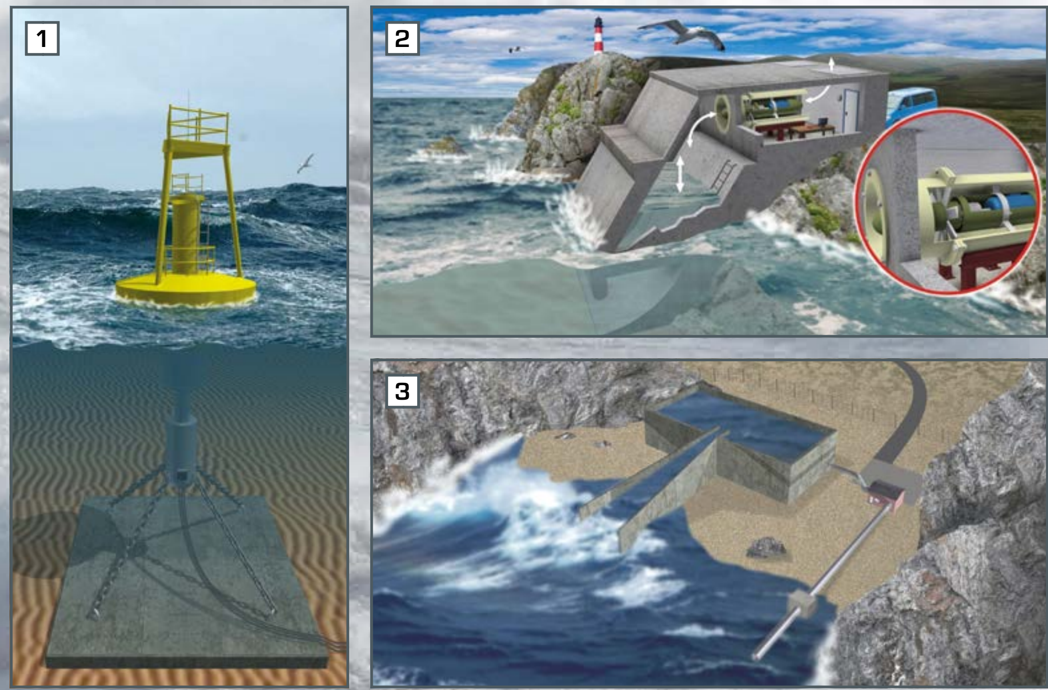
Tides

Storms / Earthquakes

Distribution of wave energy over the period length

When designing systems to use wave energy, the distribution of the wave energy supply is particularly important. Results from global studies show that the largest percentage of wave energy can be assigned to a period length between 1 and 30 seconds.

Basic mechanical principles for using wave power

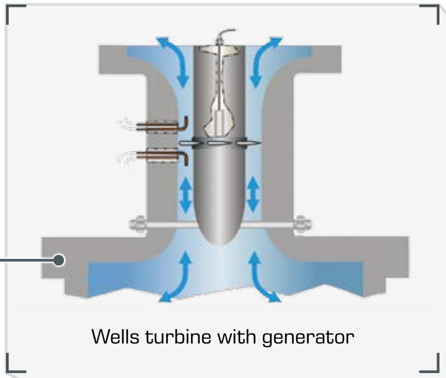


Systems for using wave energy which have been proposed in the past and also partially put into practice can be classified in the following categories according to the underlying principle:

1. floating systems
2. chamber systems (OWC)
3. overflow systems

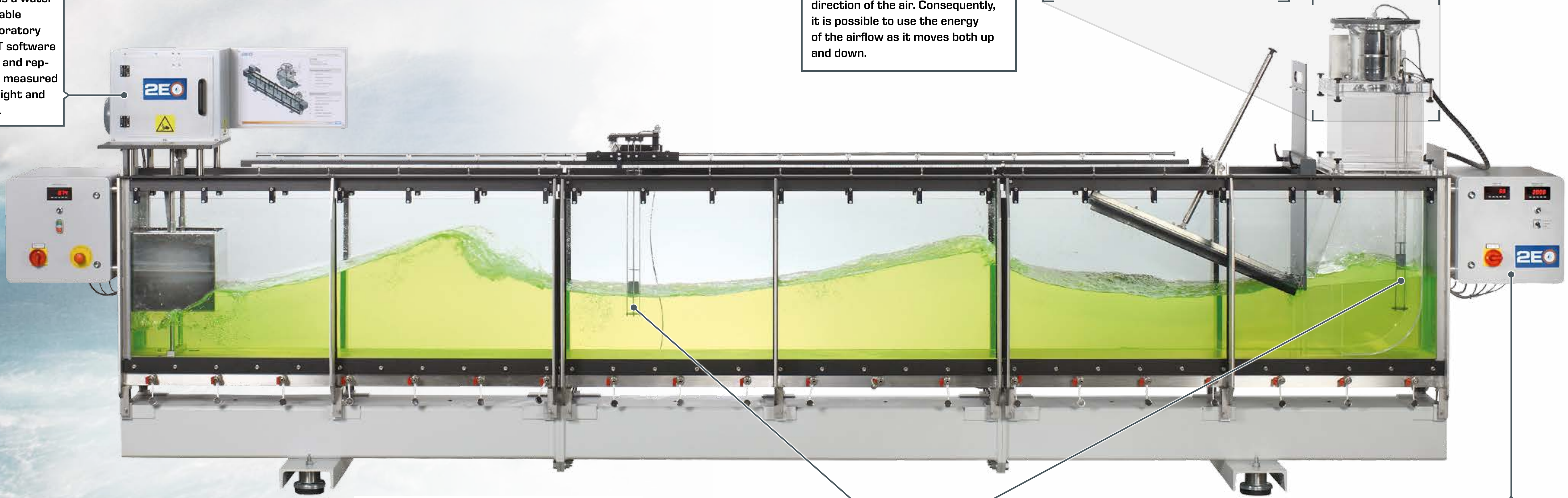
ET 270 Wave Energy Converter

Wave power stations use the energy of ocean waves to generate electricity. Systems designed according to the principle of the oscillating water column (OWC) are fitted with a chamber which opens out below sea level. At the other end is a turbine. The continuous wave motion produces an oscillating water column within the chamber, which causes the air mass above it to move. The airflow generated in this way drives the turbine, which generates electricity via a generator.



Wells turbine with generator

Modelled on large-scale power stations, ET 270 also uses a Wells turbine. This type of turbine functions regardless of the flow direction of the air. Consequently, it is possible to use the energy of the airflow as it moves both up and down.

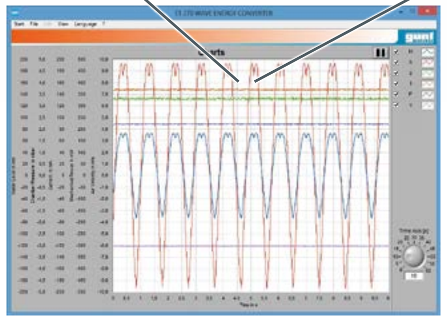


In addition to the usual components of an OWC wave power station, ET 270 contains a water channel with a controllable wave generator for laboratory experiments. The GUNT software enables the acquisition and representation of relevant measured values such as wave height and speed of the generator.

The speed of the Wells turbine can be specified by controlling the generator. As a result, it is possible to adjust the most efficient operating point for energy recovery.

Learning objectives

- familiarisation with wave power plants
- understanding of energy generation from wave motion
- measurement of wave motions
- familiarisation with the Wells turbine
- optimisation of operating behaviour



Software

Measurement of the wave height

Product No.
061.27000
More details and technical data:
gunt.de/static/s5372_1.php

Energy

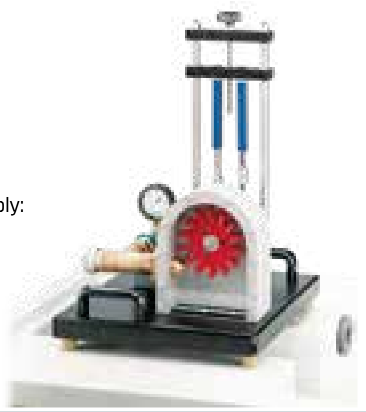
Hydropower and ocean energy

HM 150.19
Operating principle of a Pelton turbine

Model of an impulse turbine with adjustable nozzle; determination of efficiency

Recommended for water supply: HM 150 Base module for experiments in fluid mechanics

Order No.: 070.15019

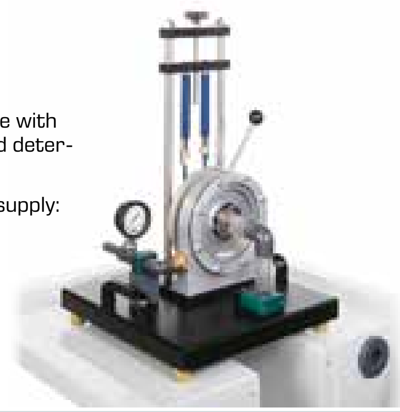


HM 150.20
Operating principle of a Francis turbine

Model of a reaction turbine with adjustable guide vanes and determination of the efficiency

Recommended for water supply: HM 150 Base module for experiments in fluid mechanics

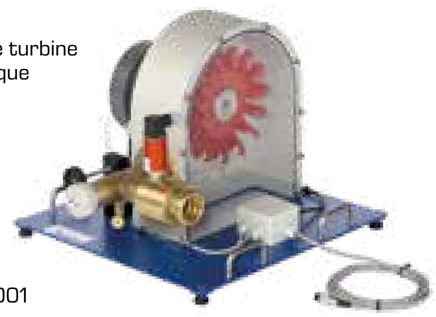
Order No.: 070.15020



HM 450.01
Pelton turbine

Model of an impulse turbine with speed and torque measurement

Order No.: 070.45001



HM 450.02
Francis turbine

Model of a reaction turbine with speed and torque measurement; adjustable guide vanes

Order No.: 070.45002

HM 450C
Characteristic variables of hydraulic turbomachines

Determination of output and efficiency of turbines and pumps; demonstration of a pumped storage plant

Order No.: 070.450C0

HM 421
Kaplan turbine trainer

Four-bladed Kaplan turbine with guide vane adjustment for varying power

Order No.: 070.42100

HM 430C
Francis turbine trainer

Characteristics of a powerful Francis turbine with adjustable guide vanes

Order No.: 070.430C0

HM 365.31
Pelton and Francis turbine

Comparison of impulse and reaction turbines

Order No.: 070.36531

HM 365.32
Turbine supply unit

Water supply for HM 365.31

Order No.: 070.36532

HM 365
Universal drive and brake unit

Core component for experiments on various driving and driven machines

Order No.: 070.36500

Trainer for turbines with Pelton turbine HM 365.31, supply unit HM 365.32 and brake unit HM 365

ET 270
Wave energy converter

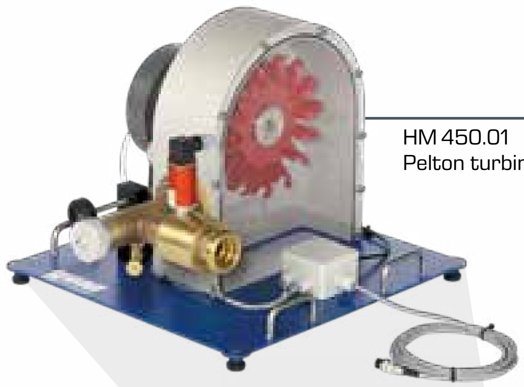
Turbine unit with Wells turbine and electric generator; configurable wave generator

Order No.: 061.27000

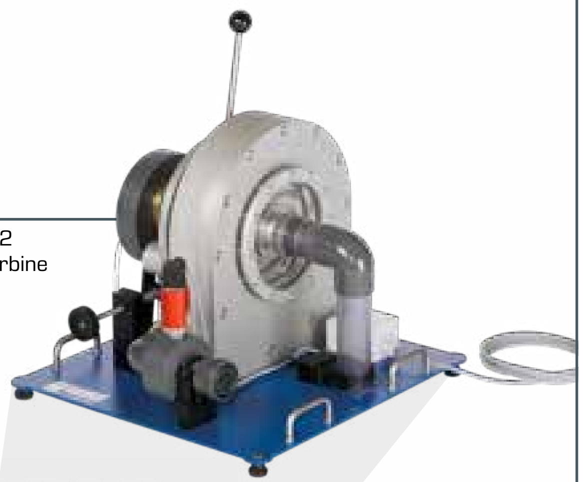
Hydropower

HM 450C
Characteristic variables of hydraulic turbomachines

The trainer HM 450C is able to operate pump and turbine at the same time. Relevant measured values are recorded contemporaneously at both turbomachines. Thus the trainer can be used as a **pumped storage plant**.

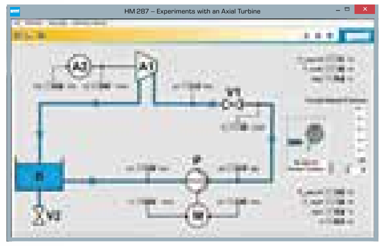


HM 450.01
Pelton turbine



HM 450.02
Francis turbine

HM 450C
Trainer with
water turbines



Needle nozzle and impeller of the Pelton turbine

Adjusting knob for the needle nozzle

Position of the guide vanes in the Francis turbine

Vanes and impeller of the Francis turbine

HM 288
Experiments with a reaction turbine

HM 289
Experiments with a Pelton turbine

HM 291
Experiments with an action turbine

HM 290
Base unit for turbines

HM 287
Experiments with an axial turbine