RIFERIBILITÀ DELLA PORTATA IDRICA: TRA IL NUOVO CAMPIONE NAZIONALE E LA CATENA METROLOGICA ITALIANA PER IL TERMICO

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THE INRIM WATER FLOW RATE PRIMARY STANDARD - 1

It is a flow calibration rig based on the **static weighing gravimetric system with flying start-and-finish**, as established by standard EN-ISO 24185

It was designed and built in the **80's** and it still represents a high accuracy water flow calibration facility.

But it showed, of course, a **deep gap** on the side of the efficiency and the reliability of process controls, signals acquisition and computer interface.

- In 2011, INRIM opened a noteworthy upgrading work to plane its extensive renovation, to **get better its structural features and to increasing its metrological performance**.

Ones well know that in a flow rate gravimetric system the ratio of the accumulated water mass to the time interval of water collection provides the value of the mass flow:

$$q_m = k\frac{m + C}{\tau}$$

Where:

m is the mass of fluid indicated by the balance, corrected by the term C accounting for the balance calibration and thermal effects during the measurement;

τ is the time interval during which water was collected,

k a correction factor for the buoyancy exerted on the fluid and for losses due to evaporation and splashing during filling of the reservoir.

C indicates the correction to be applied to readings following calibration of the balance and thermal effects on the measurement.

Consequently the flow rate in volume is:

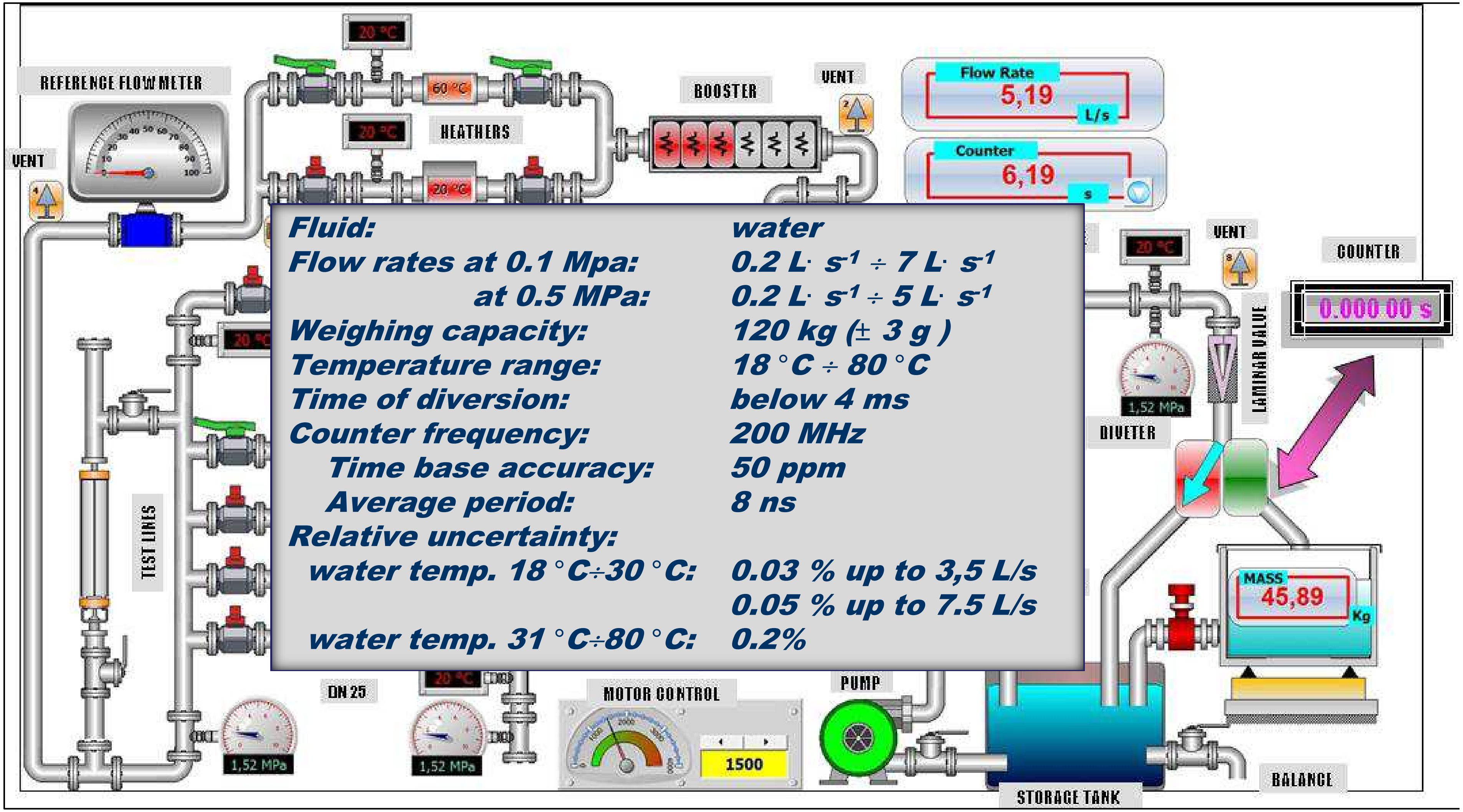
$$q_v = \frac{q_m}{\rho}$$

where

ρ is the density of the fluid at the measurement temperature, expressed in kg/m^3

ISTITUTO NAZIONALE DI RICERCA METROLOGICA

SCHEME OF INRIM WATER FLOW RATE PRIMARY STANDARD



Fluid:	***water***
Flow rates at 0.1 Mpa:	***0.2 L· s⁻¹ ÷ 7 L· s⁻¹***
at 0.5 MPa:	***0.2 L· s⁻¹ ÷ 5 L· s⁻¹***
Weighing capacity:	***120 kg (± 3 g)***
Temperature range:	***18 °C ÷ 80 °C***
Time of diversion:	***below 4 ms***
Counter frequency:	***200 MHz***
Time base accuracy:	***50 ppm***
Average period:	***8 ns***
Relative uncertainty:	
water temp. 18 °C÷30 °C:	***0.03 % up to 3,5 L/s***
	0.05 % up to 7.5 L/s
water temp. 31 °C÷80 °C:	***0.2%***

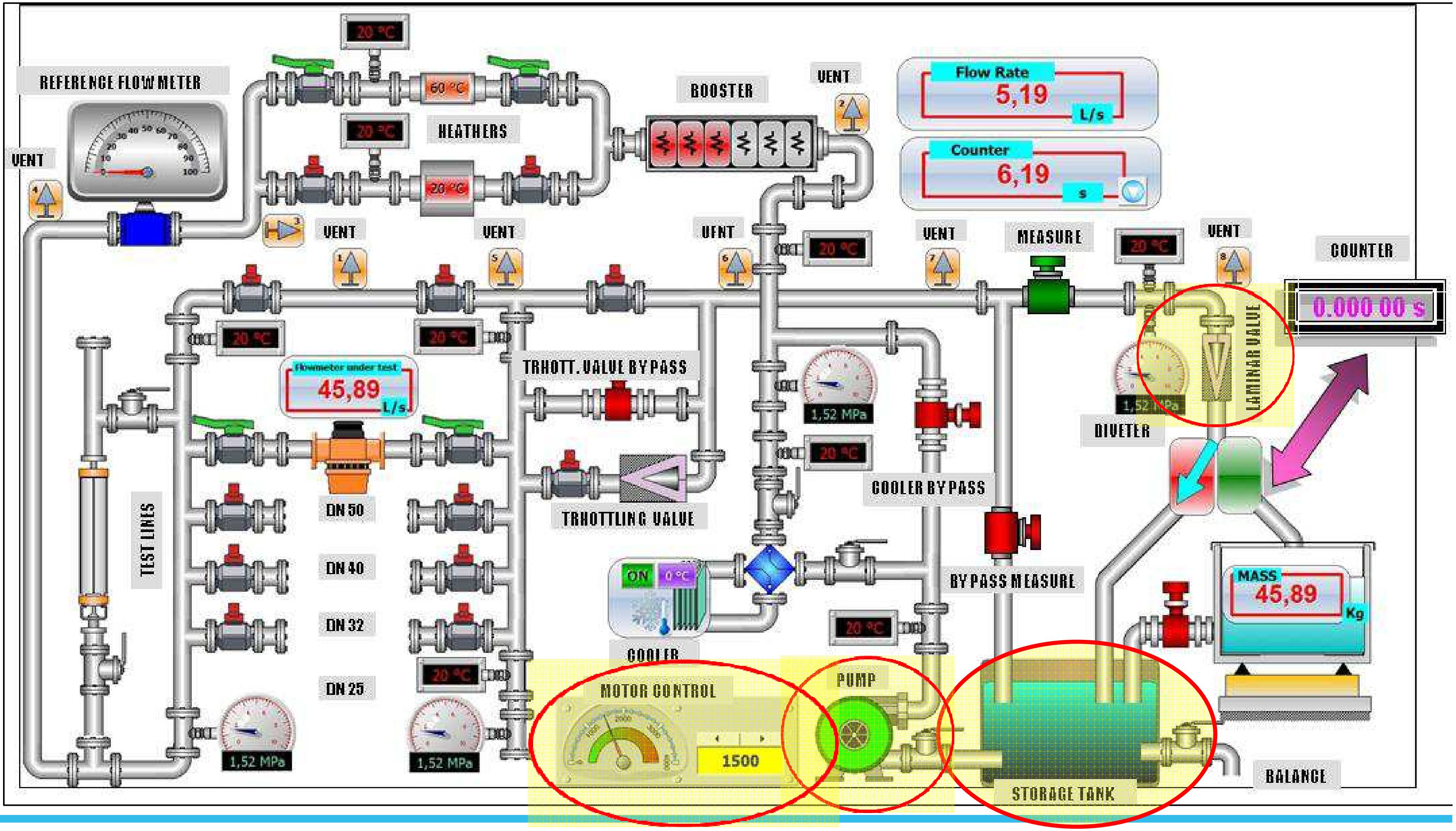
MAIN REVAMPING ACTIVITIES

Major improvements concerned the updating of the measurement rig and its ancillary instrumentation:

- ✓ ***Flow rate range and control***
- ✓ ***Water temperature measurement***
- ✓ ***Pressure control***
- ✓ ***Flow diversion and monitoring***
- ✓ ***Diverter design***
- ✓ ***Measurement procedures and data acquisition and processing***

SCHEME OF INRIM WATER FLOW RATE PRIMARY STANDARD

Flow rate range and control



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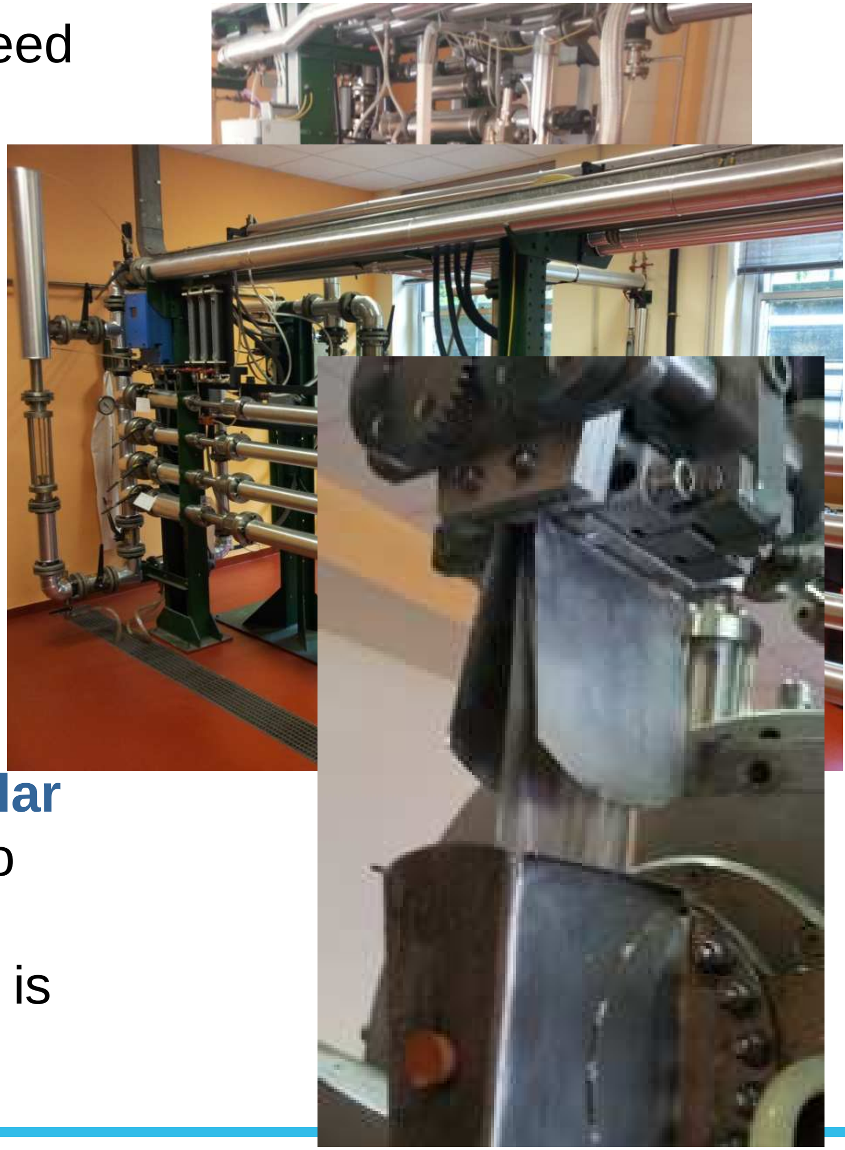
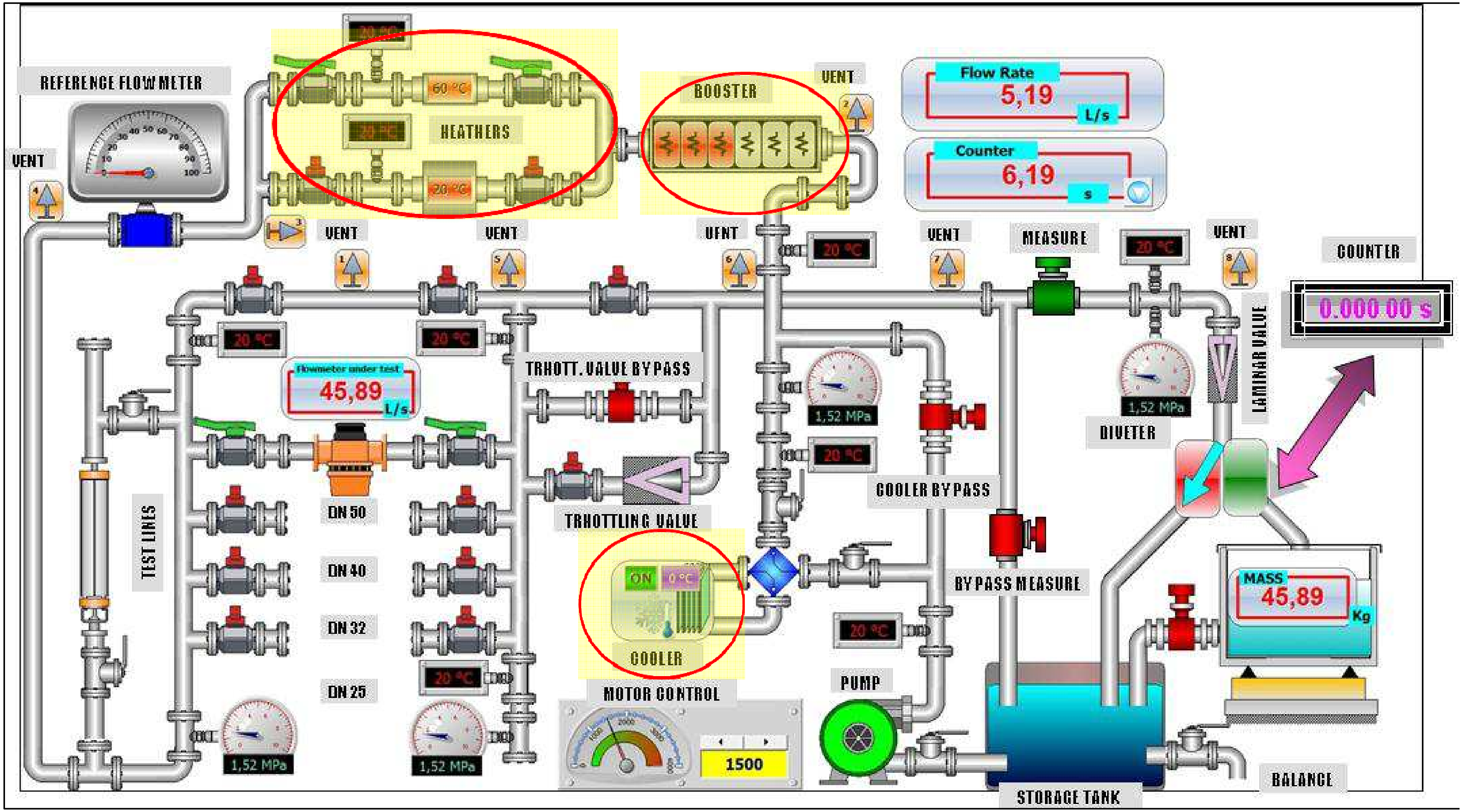
- The flow rate stabilization is guaranteed by a variable-speed **multi stadium centrifugal pump** driven by a control loop for flow rate regulation.



- **Four measurement lines**, with different bores (DN25, DN36, DN42, DN50), provide an adequate pipe section at different flow rates.

A final laminar valve gives **a rectangular shape of the water flow jet** in order to get better the flow deviation.
Thus, an accurate and stable flow rate is guaranteed over the whole range.

Water temperature measurement



Water temperature measurement

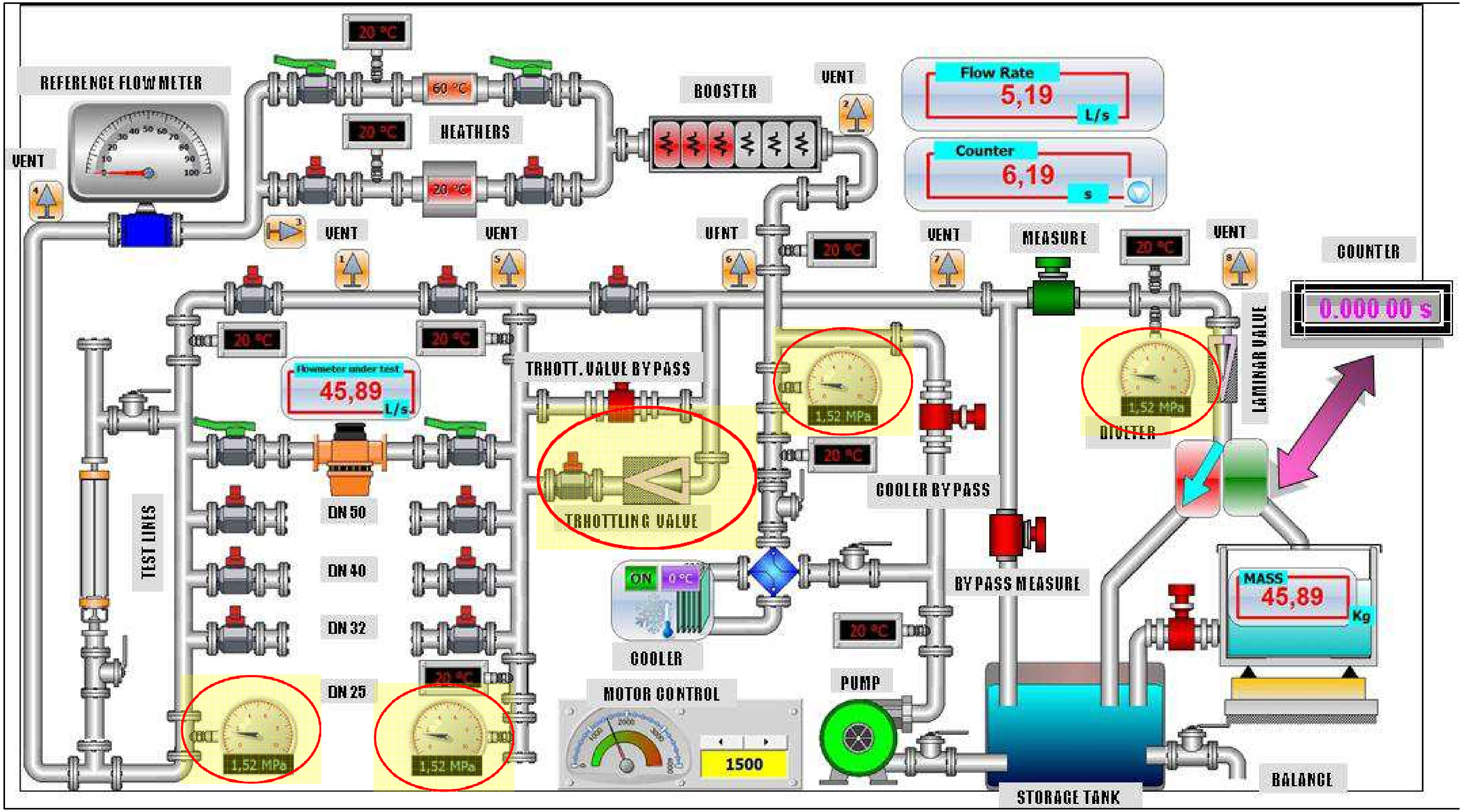
The INRIM standard flow rate is designed to work in a **temperature range from 18 °C to 80 °C**. The desired temperature is obtained by two integrated control loops systems:

- a **cooling circuit** reduces the water temperature down to 18 °C and hampers temperature increase due to the thermal dissipation during tests.

It is made up by a water cooling system that ca reach temperatures as low as 4 °C coupled t the measurement rig by means of a heat exchanger;

- a **programmable three-stage heating circuit** including a set of electrical resistances that dissipate a power precisely programmable by an automatic loop control.

PRESSURE CONTROL

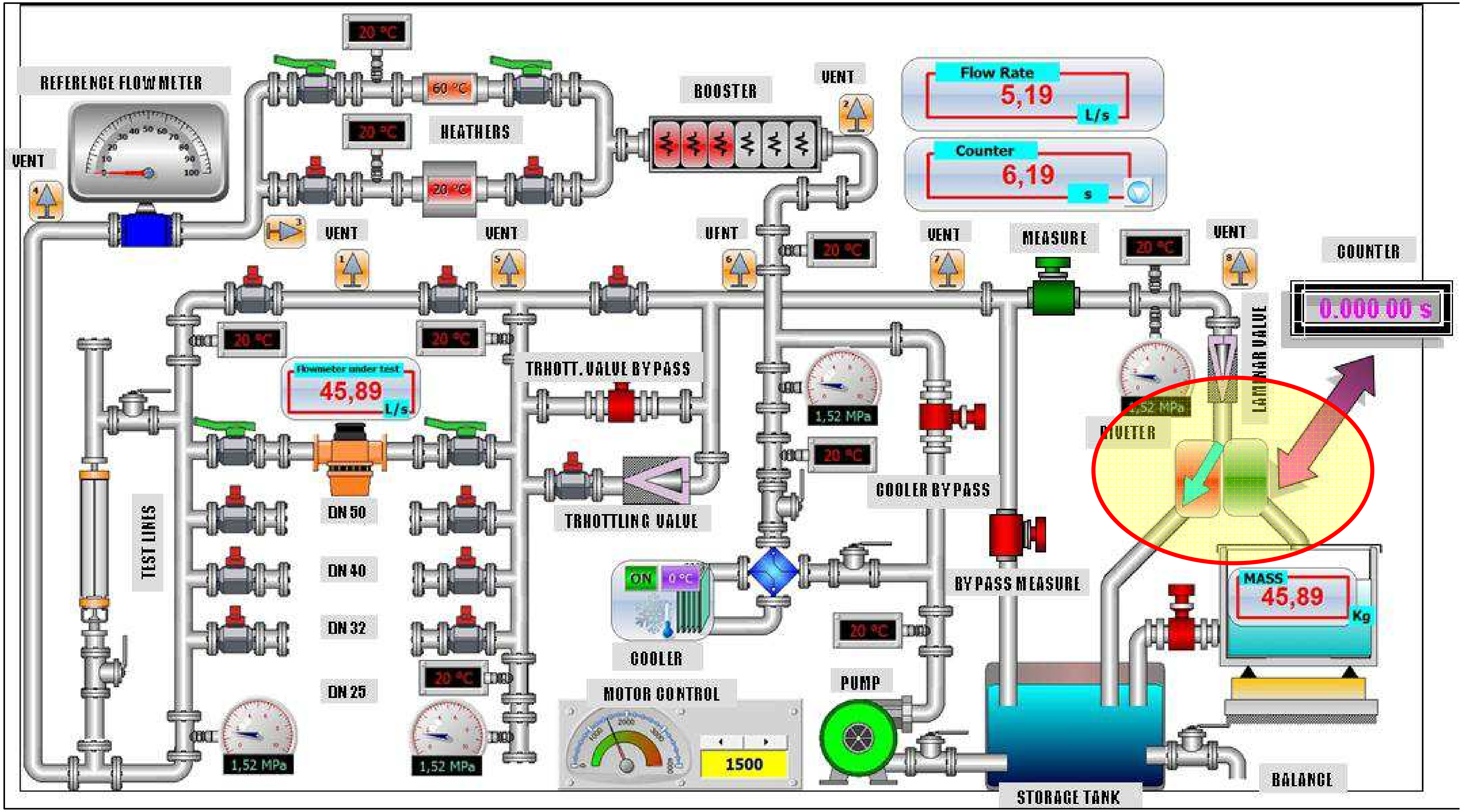


Pressure is controlled by a **throttling valve,** operating in the range from 0.1 MPa to 0.6 MPa.

Four **different pressure transducers** are connected at the output of the pump, at the beginning and the ending of the measurement lines and just before the diverter. They allow to control and to record the value of pressure along the measurement lines.

SCHEME OF INRIM WATER FLOW RATE PRIMARY STANDARD

FLOW DIVERSION AND MONITORING



FLOW DIVERSION AND MONITORING - 1

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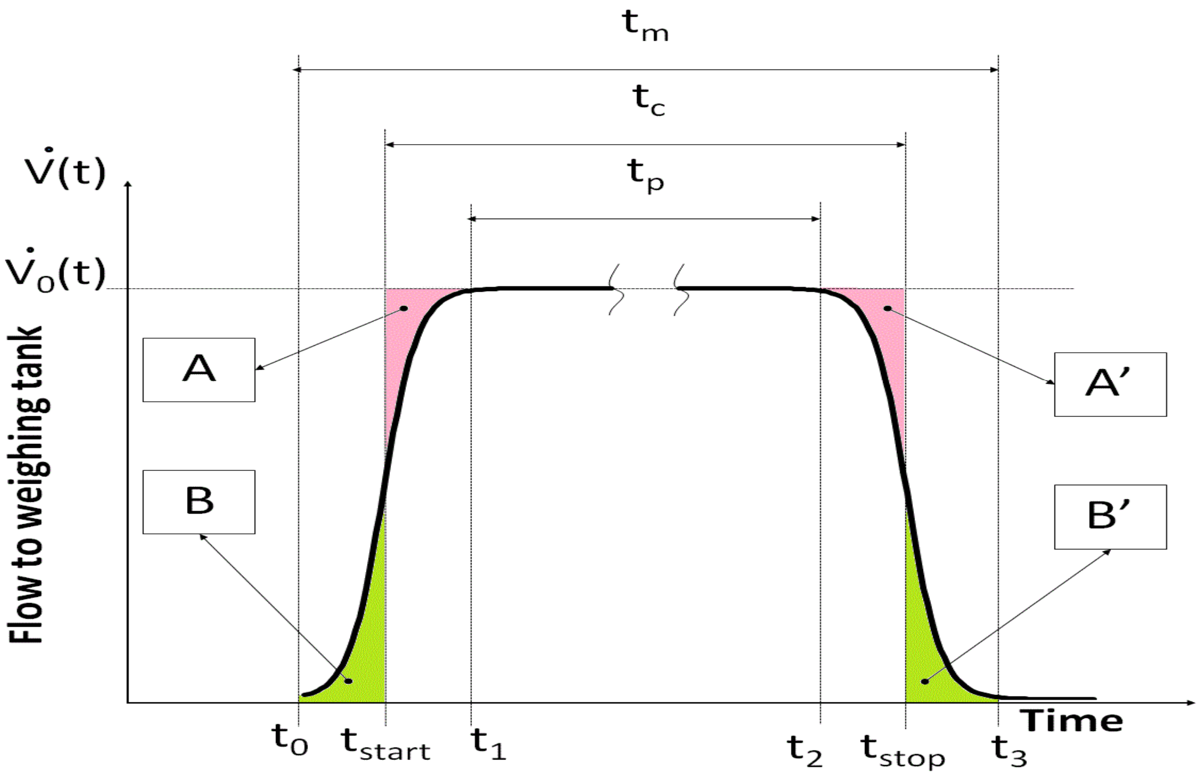
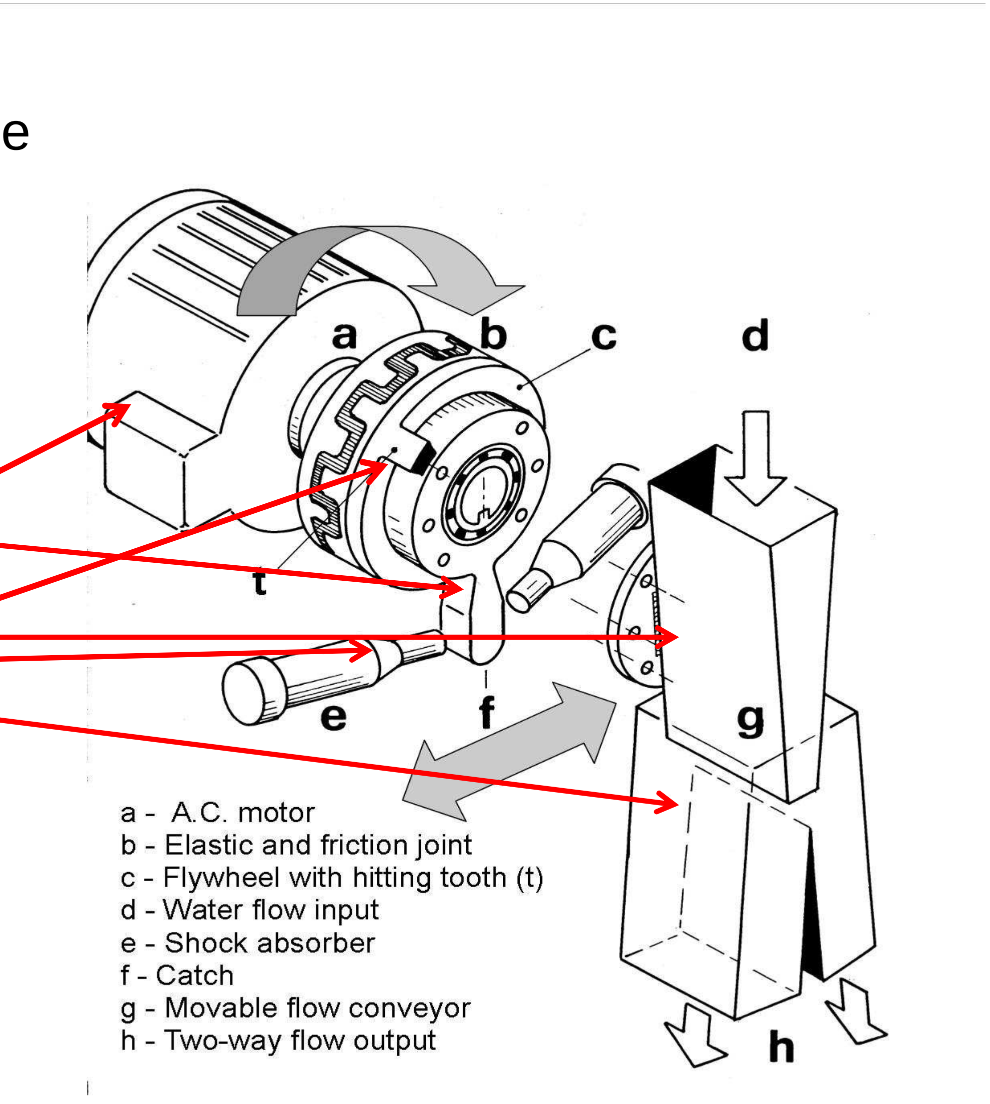


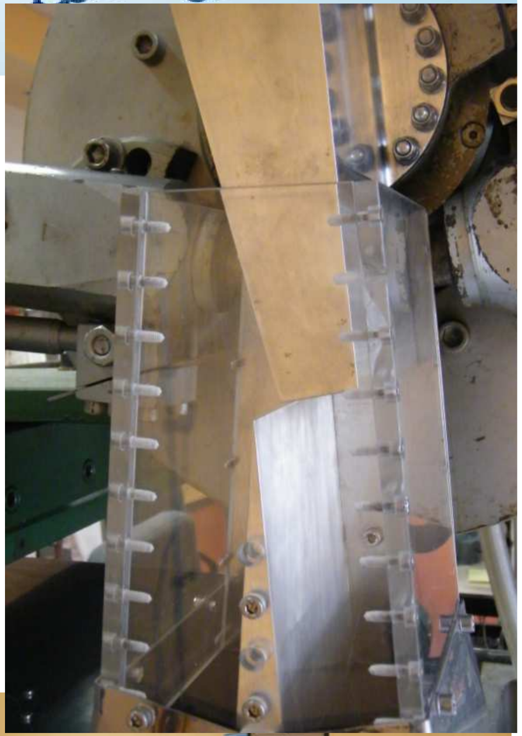
The diverter's design has been optimized to match a **good repeatability with an elevated transient symmetry**.

Furthermore, in order to minimize the flow diversion errors a system was designed to **reduce the transition time down to 4 ms**:

4. when the diverter crosses the verticality. an optoelectronic signal switches on or off the counter, to start or finish the measurement time respectively.



FLOW DIVERSION AND MONITORING - 3

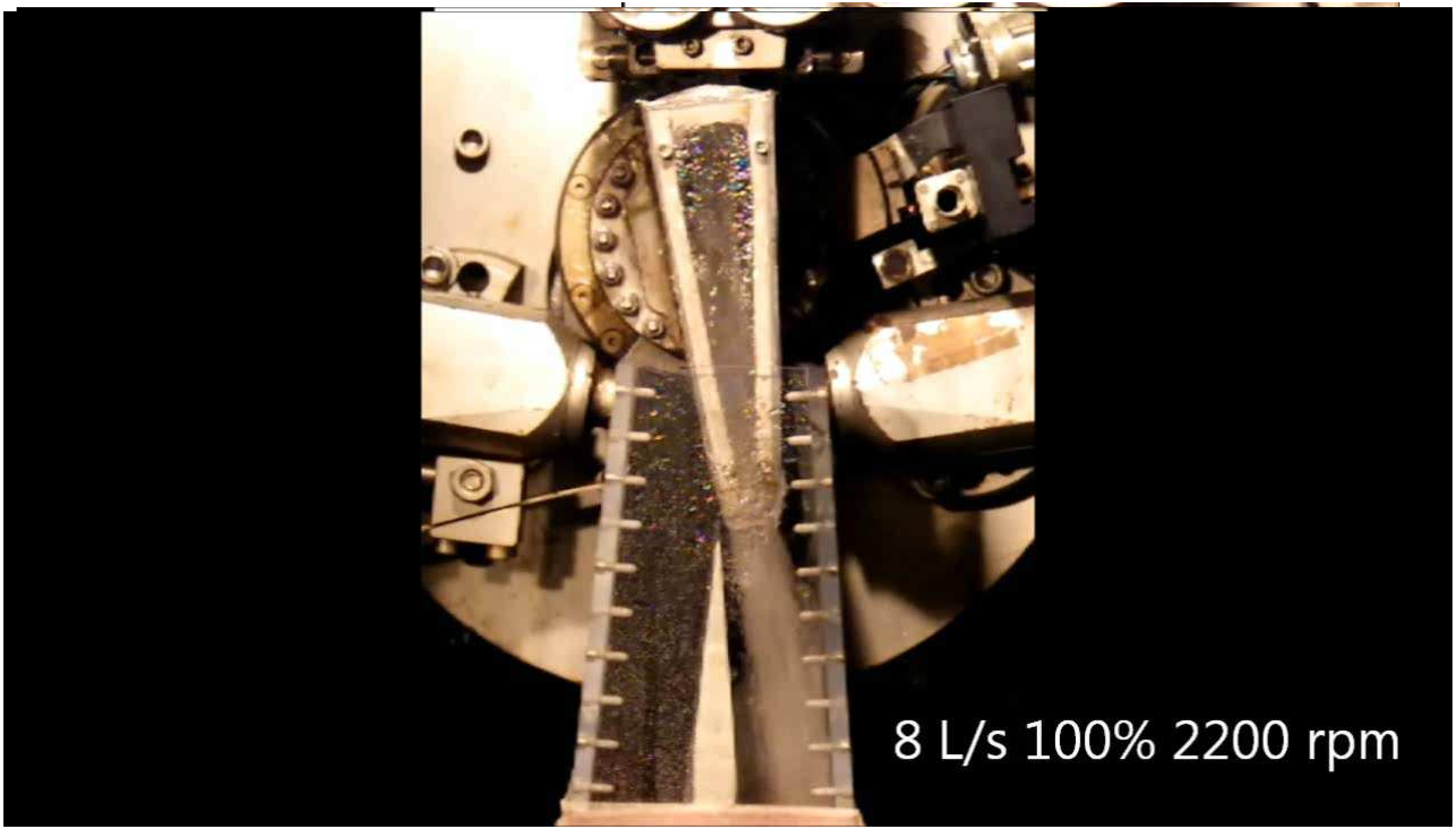


In order to verify the water flow behavior during diversion it was decided:

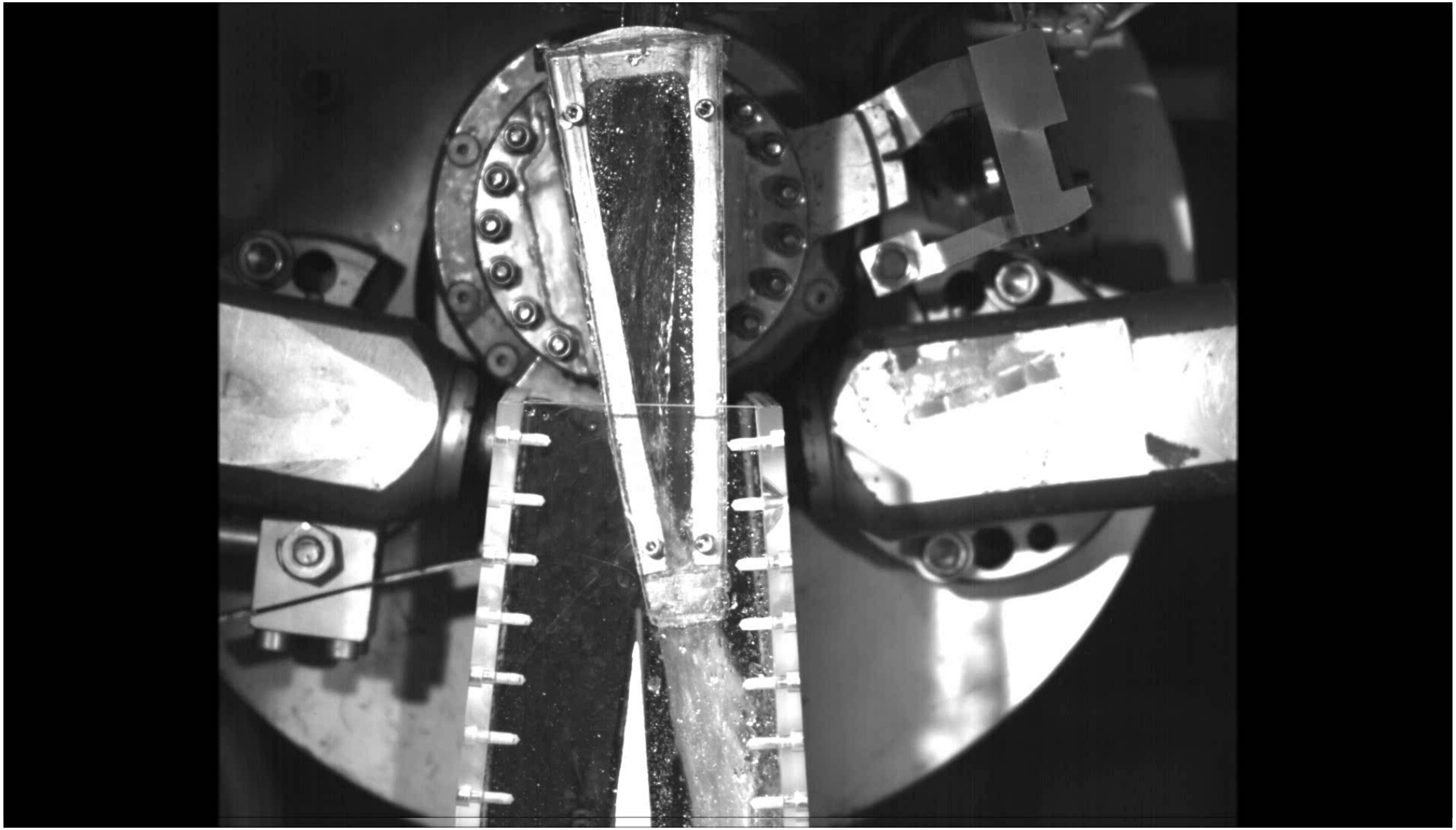
1.to adopt a **see-through collector** in order to have, in every step of the measurements, a direct and real-time monitoring of the flow performance.

2.to supervise the diverter commutation by a **continuous high speed camera** (1200 frame/s), to detect any anomalous behavior that could lead to systematic and hidden errors.

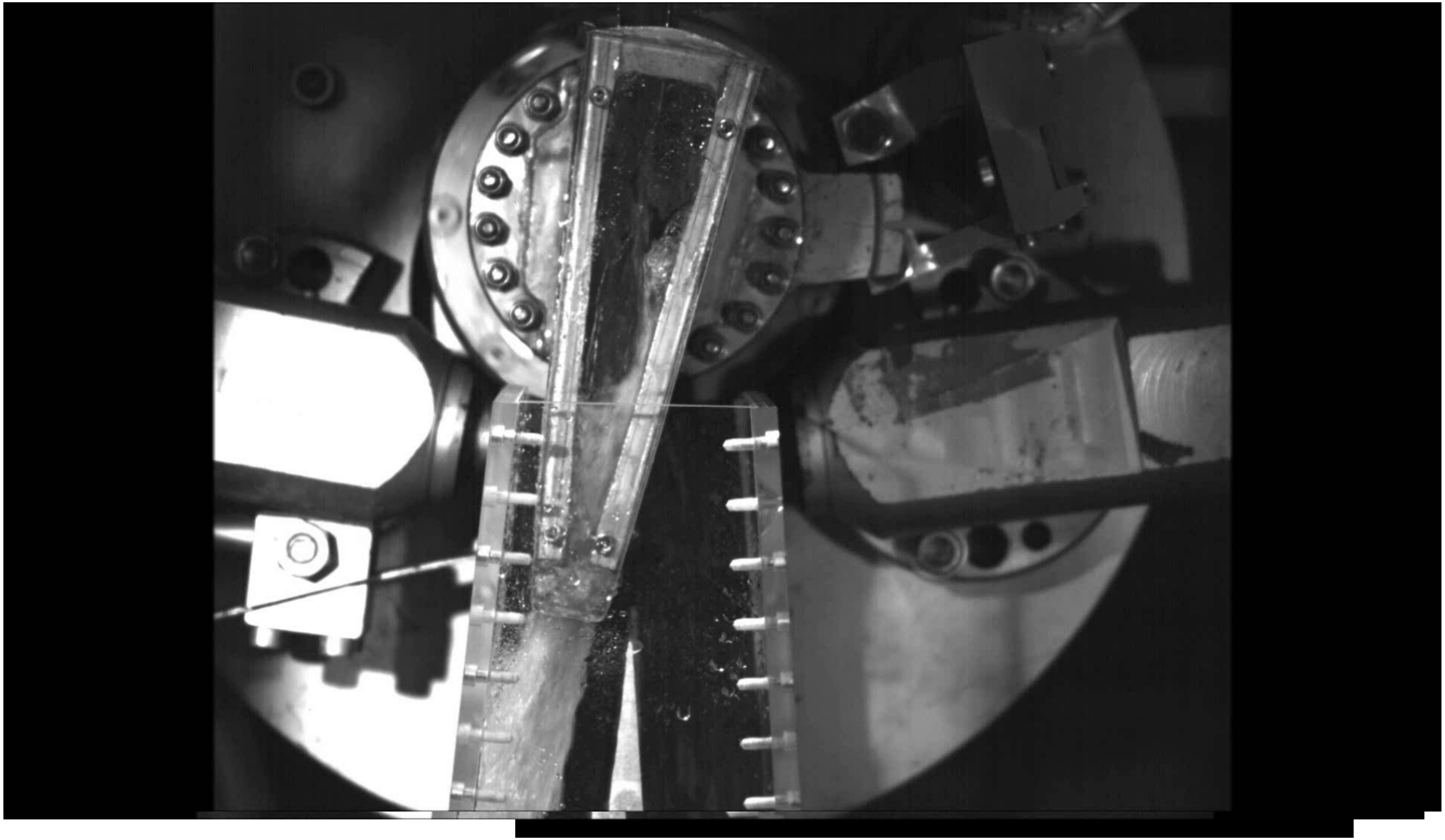
FLOW DIVERSION AND MONITORING - 3



FLOW DIVERSION AND MONITORING - 4

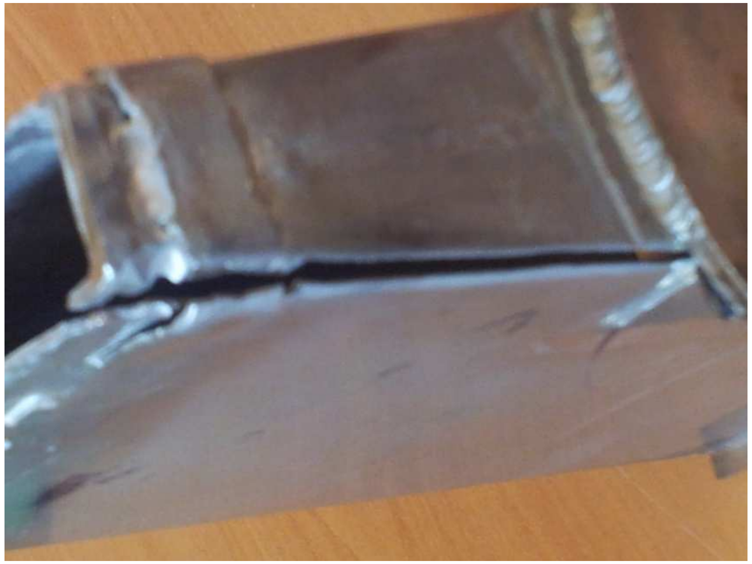


FLOW DIVERSION AND MONITORING - 5



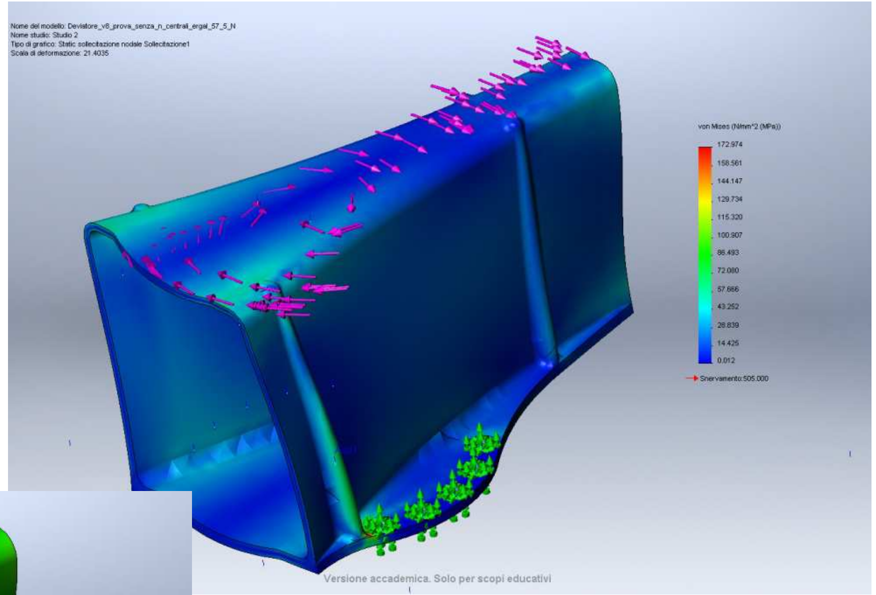
FLOW DIVERSION AND MONITORING - 6

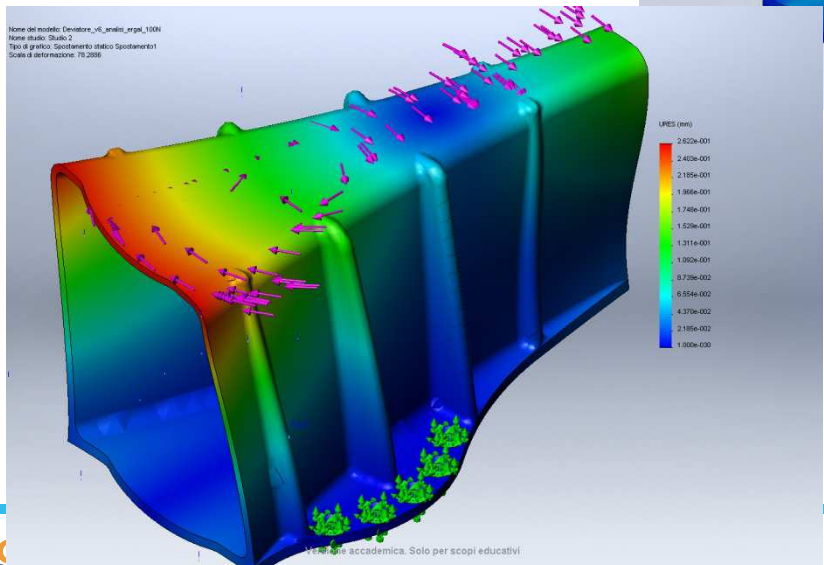
A very high commutation speed of diverter involves **elevated values of kinetic energy** with subsequent considerable mechanical stress on the welded stainless steel.



A new Diverter design

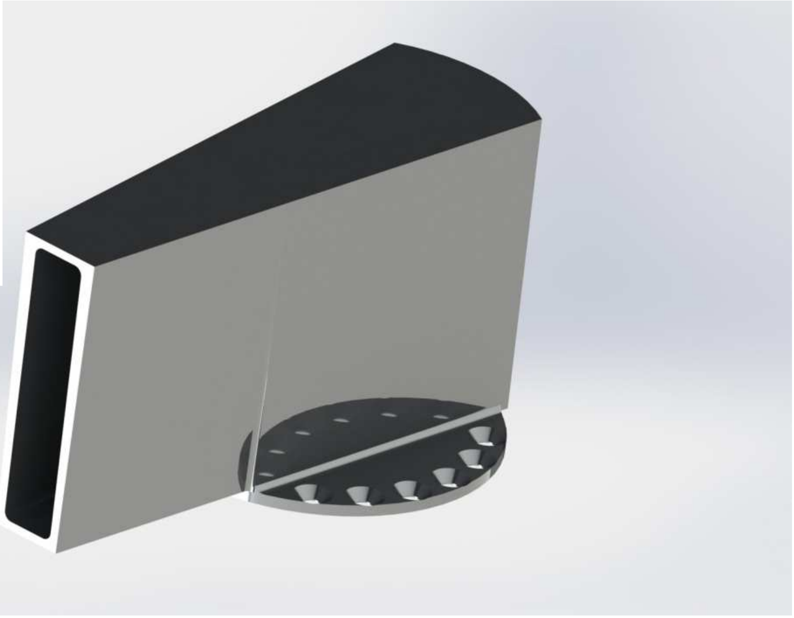
This structural problem required the **shunt system to be redesigned**. Numerical analysis and tests were performed on various geometrical shapes, **in order not to enhance acceleration stresses maintaining movement velocity**.





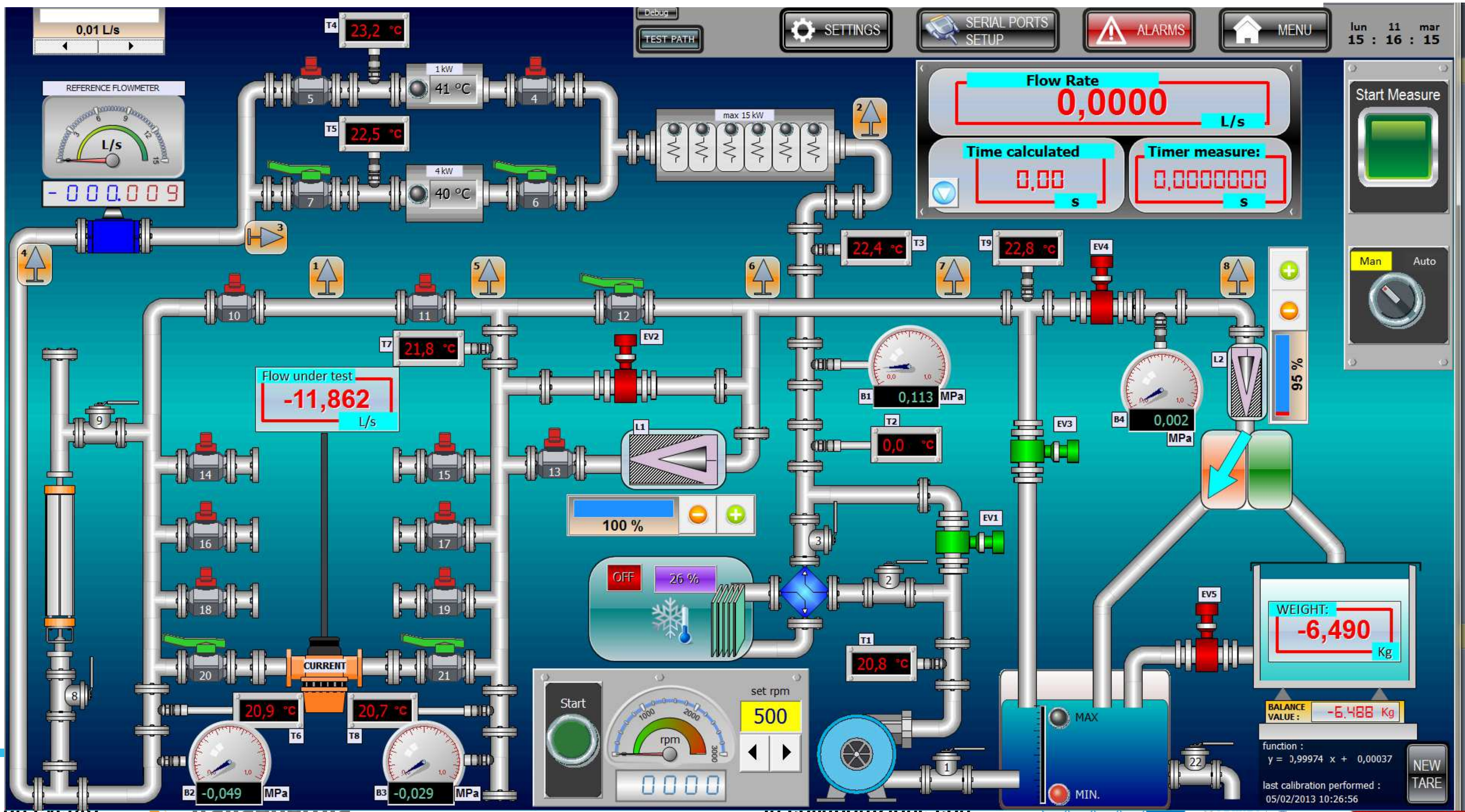
New Diverter design

The problem was solved by using the ERGAL7050 alloy (2.6 Cu; 3.1 Mg; 6.7 Zn), that has a density of 2.7 g/cm^3 versus 7.9 g/cm^3 of steel.
Hence a thicker diverter was built (greater elasticity), **maintaining the same total weight.**



Human-machine interface and data presentation.

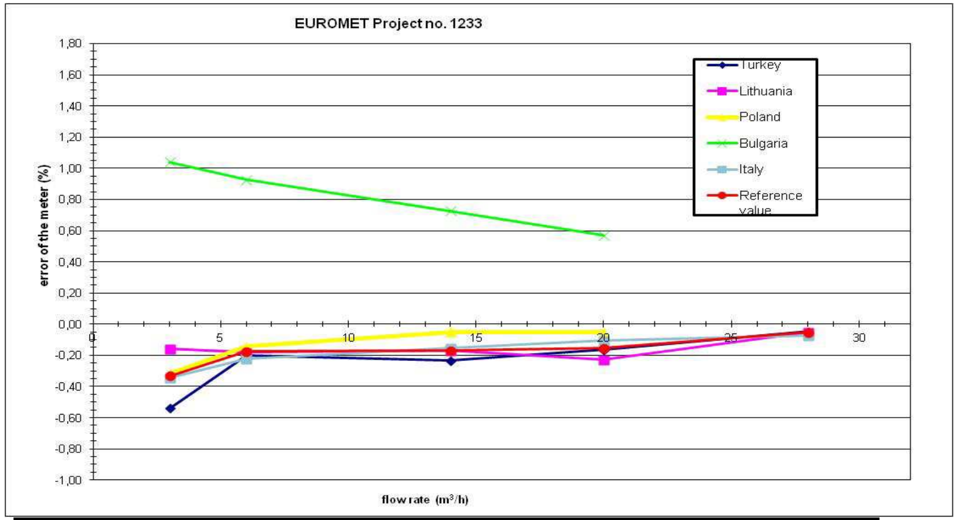
All the graphic symbols are **active keys** to actuate devices, and to sense their status and the actual measured values



In the period between September 2012 and February 2013 a **comparative study,** as part of the EURAMET project n° 1233 “**Inter-comparison of water meter reference standard**”, was carried out.
The tests were performed in the flow range from 3 m^3/h to 28 m^3/h.

A reference Coriolis mass flowmeter was used in five European NIMs
- *Tubitak UME, Turkey,*
- *Lithuanian Energy Institute,*
- *Central office of Measurement, Poland,*
- *INRIM, Italy,*
- *Bulgarian Institute of Metrology*,

to **compare calibrations recorded** by National Standards water flow rate.



[redacted]

$$Q = \int_{t_0}^{t_1} q_m \Delta h dt$$

Where

q_m is the mass flow rate of the energy conveying liquid passing through the heat meter

Δh is the difference between the specific enthalpies of the energy conveying liquid at the flow and return fluid conditions in the heat exchange circuit

t is the time

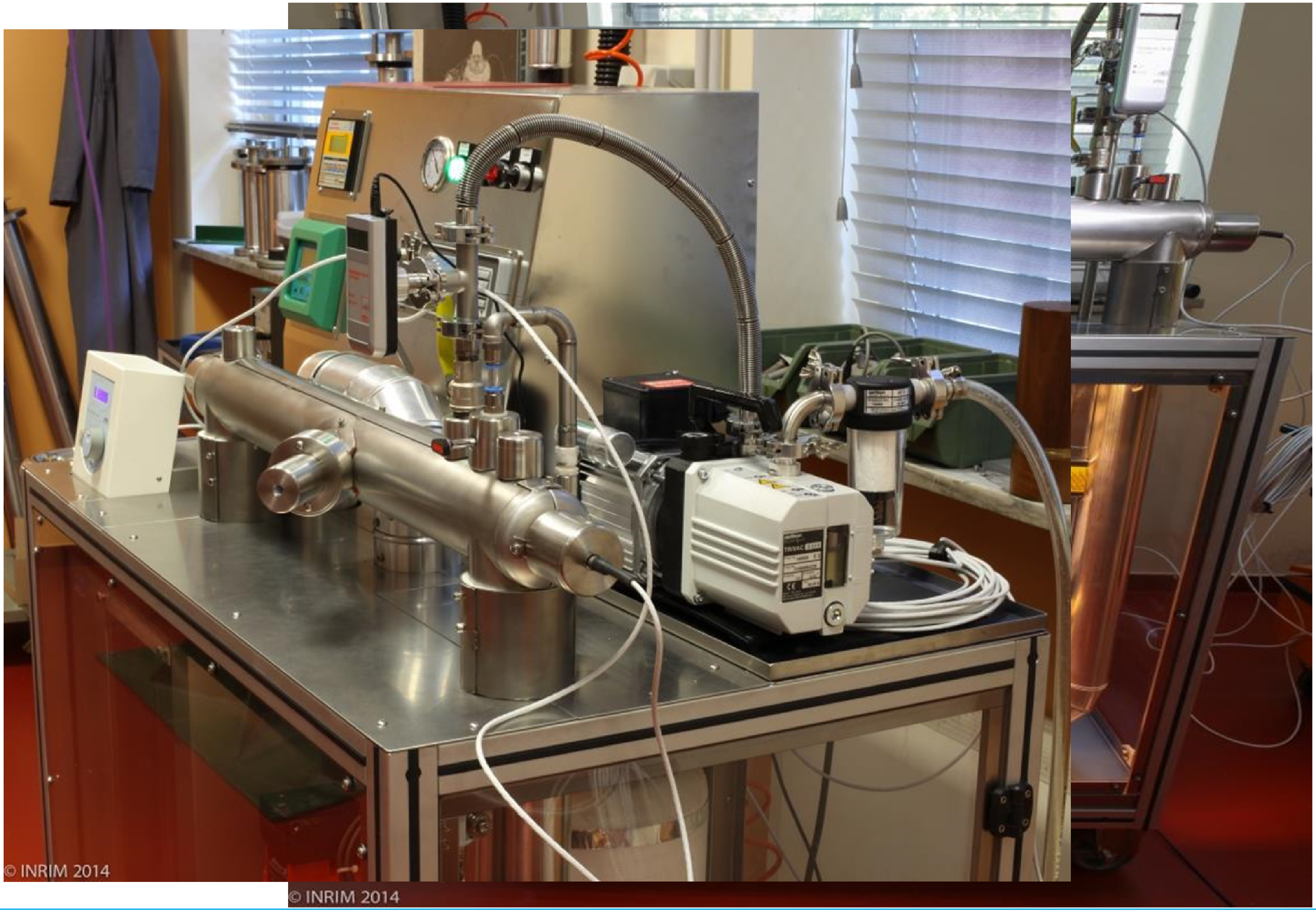
Using water as system heat conveying liquid, then thermodynamic properties must be calculated according to the *Industrial Standard for the Thermodynamic properties of Water and Steam* ***(International Association Property Water Steam -IF 97)*** using the International Temperature Scale of 1990 (ITS-90).

THE INRIM WATER FLOW RATE PRIMARY STANDARD

THE NATIONAL THERMAL ENERGY STANDARD

NATIONAL METROLOGICAL CHAIN FOR THERMAL ENERGY CALIBRATION

Thermal energy reference standard



THE INRIM WATER FLOW RATE PRIMARY STANDARD

THE NATIONAL THERMAL ENERGY STANDARD

NATIONAL METROLOGICAL CHAIN FOR THERMAL ENERGY CALIBRATION

FIRST EUROPEAN THERMAL-HYDRAULIC MOCKUP FOR THE VALIDATION OF HEATING COSTS ALLOCATORS

INRIM Thermal hydraulic mockup

NORTH AND SOUTH WALLS: THERMAL-HYDRAULIC ANALYSIS

GRAZIE PER L’ATTENZIONE