PERÚ Ministerio de la Producción

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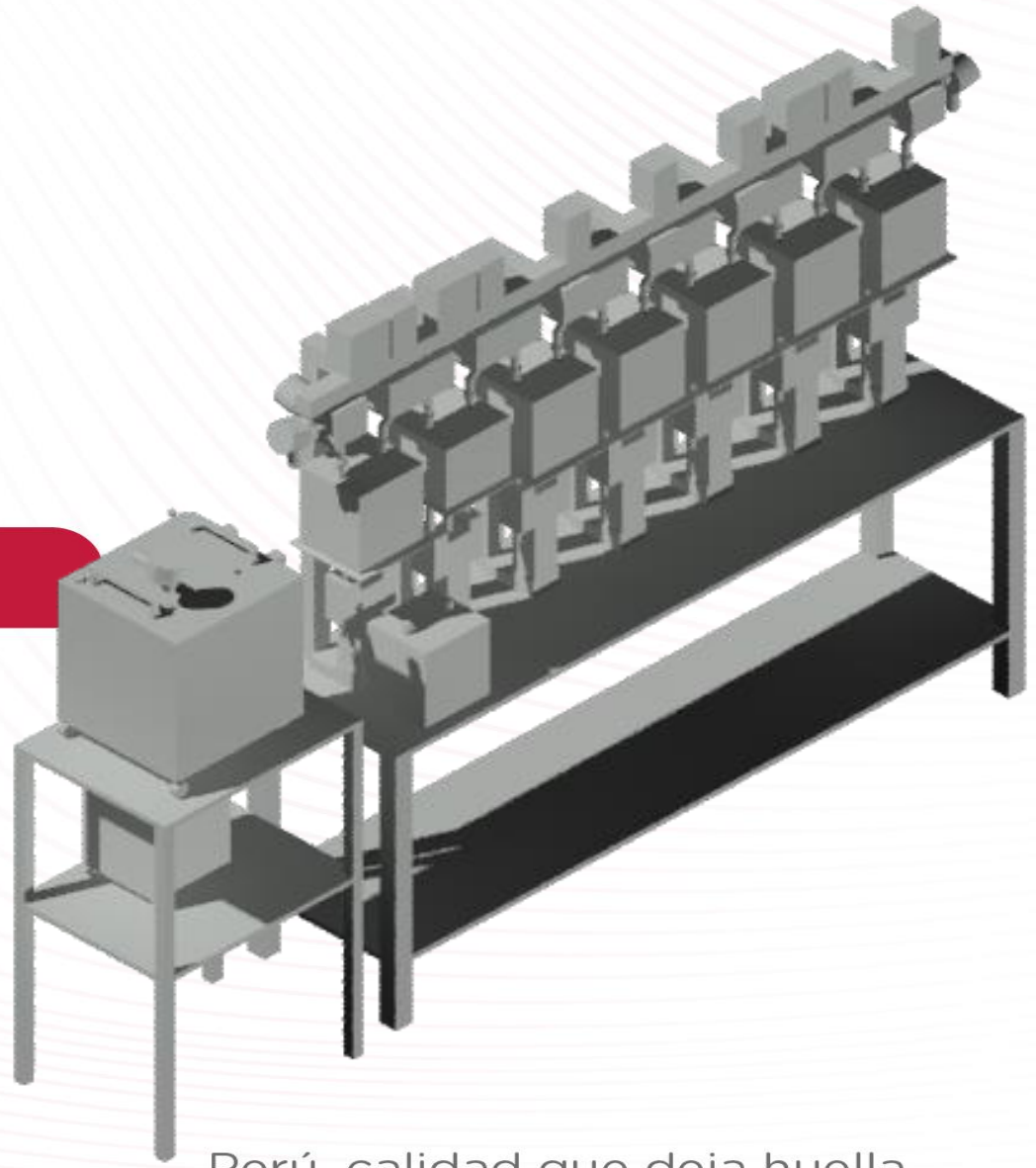
Instituto Nacional de Calidad

Development and automation of a residential gas meter verification bench

Ing. Rubén Gil
Metrologist of Gas Flow Laboratory



Perú, calidad que deja huella.

INACAL – Instituto Nacional de Calidad

Somos el ente rector y máxima autoridad normativa que conduce el Sistema Nacional de la Calidad en el país.

(Adscrito al Ministerio de la Producción)

Nuestra finalidad es promover y asegurar el **cumplimiento de la Política Nacional para la Calidad** con miras a:

EL DESARROLLO Y LA COMPETITIVIDAD DE LAS ACTIVIDADES ECONÓMICAS.

LA PROTECCIÓN DEL CONSUMIDOR.

INACAL SOBRE 4 EJES

NORMALIZACIÓN

- Aprueba las Normas Técnicas Peruanas, no son reglamentos y son voluntarias.
- ESTANDARIZA los procesos productivos, con el objetivo de incrementar la calidad y seguridad de productos y servicios.
- Contribuye a la competitividad, intensifica la competencia e incrementa las exportaciones.

ACREDITACIÓN

- Evalúa la competencia técnica de los organismos de evaluación de la conformidad para dar garantía de un servicio confiable y reconocido nacional e internacionalmente.
- Apoyamos el desarrollo de productos y servicios competitivos en el ámbito nacional e internacional, garantizando seguridad y cumplimiento de estándares de calidad.

METROLOGÍA

- Garantiza la trazabilidad internacional de las mediciones.
- Presta servicios de calibración de equipos e instrumentos de medición a los laboratorios de calibración y a la industria.
- Custodia los patrones nacionales para asegurar la uniformidad de las mediciones en el país.

DESARROLLO ESTRATÉGICO

- Promueve una adecuada gestión e implementación de la Política nacional para la Calidad y el desarrollo de la Cultura de la Calidad.
- Investiga e identifica la demanda y oportunidades de desarrollo de la infraestructura de la calidad, identifica de brechasen materia de calidad y el desarrollo de estrategias de intervención.

Content

1. Objective
2. Normative base
3. Subsequent verification (gas meter)
4. Description of the Test Bench
5. Results

1. OBJECTIVE

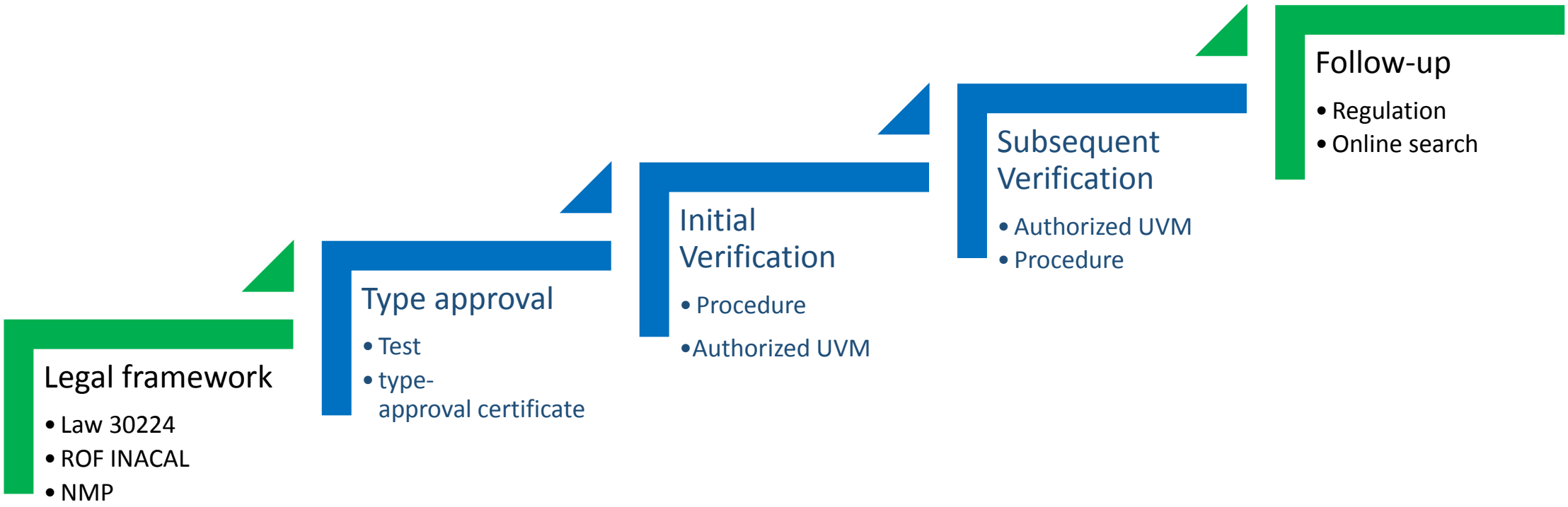
Attend the subsequent verification of the diaphragm type gas meters of sizes G1.6; G2.5 and G4; In accordance with the provisions of the Contrast and Periodic Verification Standard for natural gas meters, established by OSINERGIM.

Kind of gas meter	Flow max. [dm^3/h]	Flow min. [dm^3/h]
G1,6	16	2 500
G2,5	25	4 000
G4	40	6 000

2. NORMATIVE BASE

a) Legal Control of Measuring Instruments

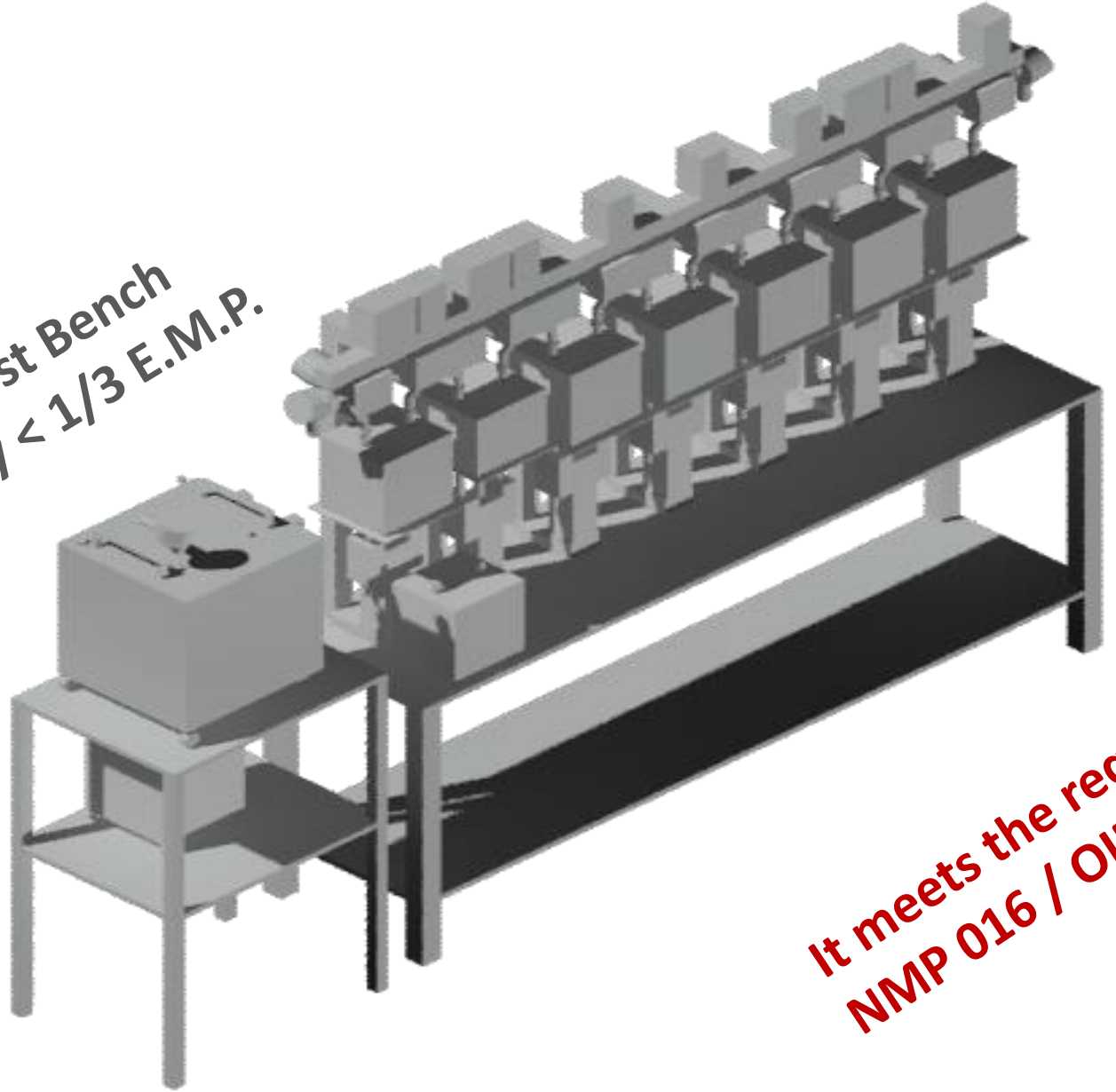
Sequence of operations



3. SUBSEQUENT VERIFICATION

3. SUBSEQUENT VERIFICATION

Gas meter Test Bench
Uncertainty < 1/3 E.M.P.



It meets the requirements of:
NMP 016 / OIML R 137

3. SUBSEQUENT VERIFICATION

Maximum permissible errors (MPE)

Table 2 Maximum permissible errors of gas meters

Flow rate Q	During type evaluation and initial verification			During subsequent verification and In-service *		
	Accuracy class			Accuracy class		
	0.5	1	1.5	0.5	1	1.5
$Q_{min} \leq Q < Q_t$	± 1 %	± 2 %	± 3 %	± 2 %	± 4 %	± 6 %
$Q_t \leq Q \leq Q_{max}$	± 0.5 %	± 1 %	± 1.5 %	± 1 %	± 2 %	± 3 %

* *Note:* National Authorities may decide to implement maximum permissible errors for subsequent or in-service verification.

3. SUBSEQUENT VERIFICATION

11.1.2 Uncertainty

When a test is conducted, the expanded uncertainty[1] of the determination of errors of the measured gas quantity shall meet the following specifications:

- for type evaluation : less than one-fifth of the applicable MPE;
- for verifications : less than one-third of the applicable MPE.

However, if the above-mentioned criteria cannot be met, the test results can be approved alternatively by reducing the applied maximum permissible errors with the excess of the uncertainties. In this case the following acceptance criteria shall be used:

- for type evaluation : $\pm\left(\frac{6}{5}\cdot MPE - U\right)$
- for verifications : $\pm\left(\frac{4}{3}\cdot MPE - U\right)$

  while U≤ MPE

U < 2 % (Qmin a Qt, sin incl.)
U < 1 % (Qt, incl. a Qmax)

4. DESCRIPTION OF THE TEST BENCH

General Characteristics

Dimensions (W x D x H)	**208 cm x 55 cm x 265 cm**
Weight:	**250 kg**
Neumatic:	**10 L/min (a 6 bar)**
Electric:	**220 V 1 P, 60 Hz**
Measurement Interval:	**0,016 dm^3/h a 6 m^3/h**

Banco de Ensayo para Medidores de diafragma

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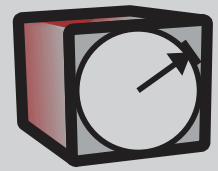


Modelo:	**TB-CORG**
Fabricante:	**INACAL**
Procedencia:	**Perú**
Patrones de Ref.:	**Cámara Húmeda**
Fluido de Ensayo:	**Aire atmosférico**
Fuente de alim.:	**220 V 1 P, 60 Hz**

4. DESCRIPTION OF THE TEST BENCH

Test Bench Parts:

4.1 Hardware

4.1.1 Structure and Neumatic System

4.1.2 Air System Pumping

4.1.3 Acquisition System

4.1.4 Measuring Instruments/Devices

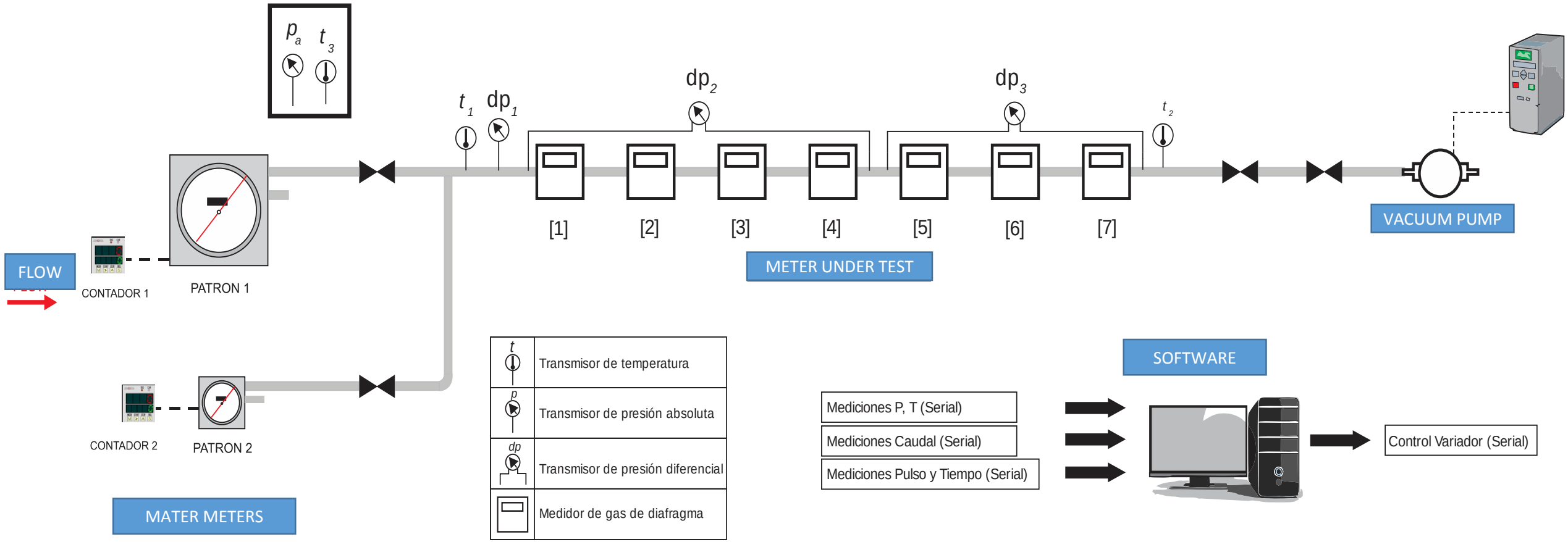
4.2 Software

4.2.1 Grafical User Interface

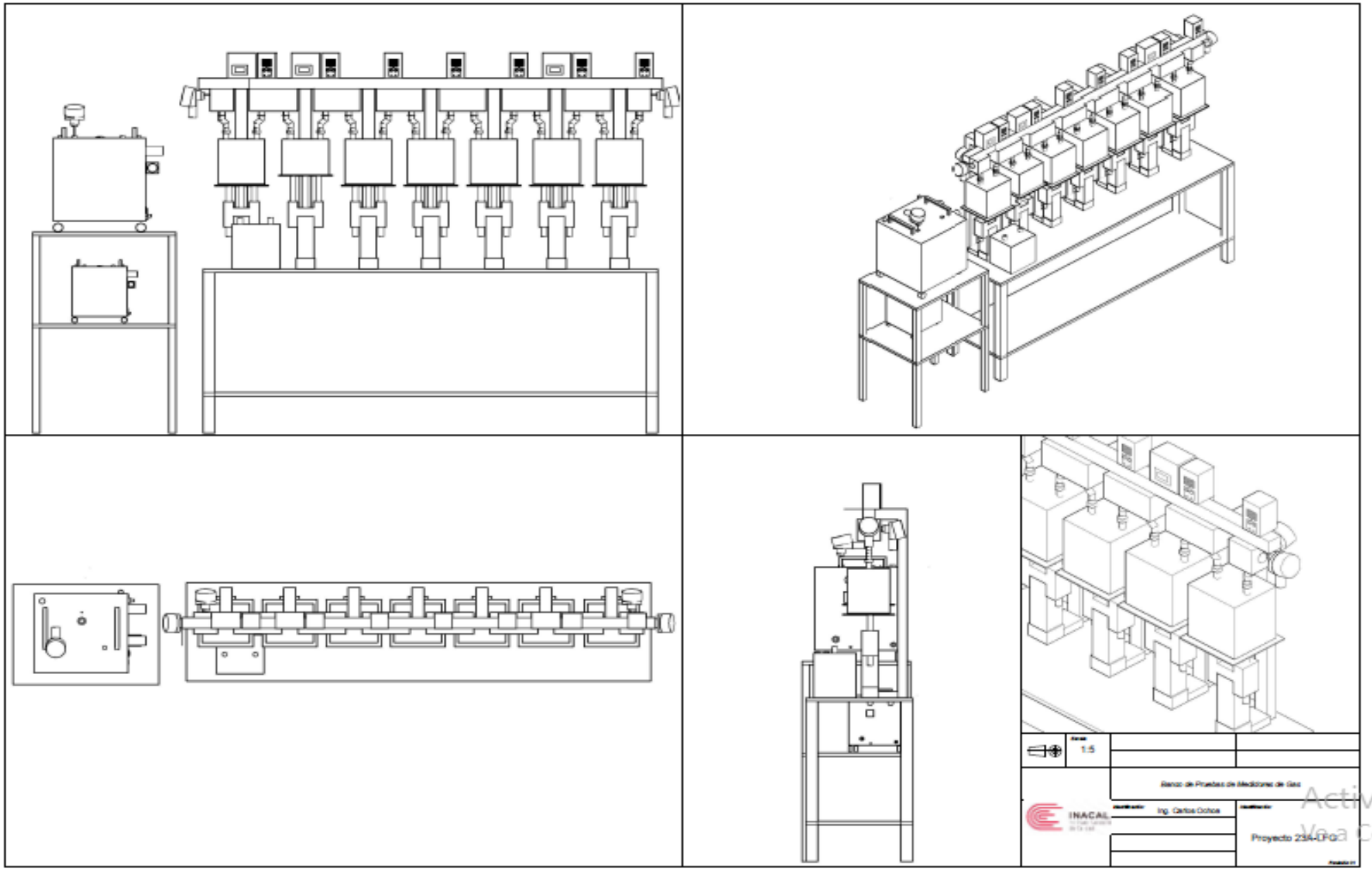
4.2.2 Spreadsheet

4. DESCRIPTION OF THE TEST BENCH

General Scheme of the Gas Meter Test Bench



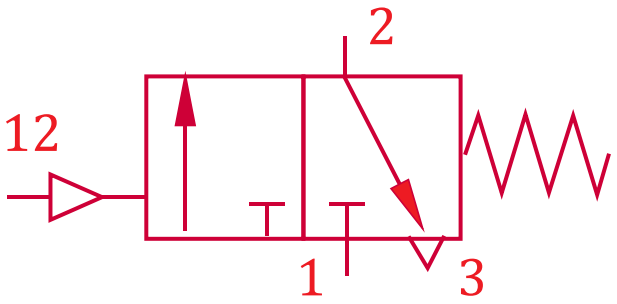
4. DESCRIPTION OF THE TEST BENCH

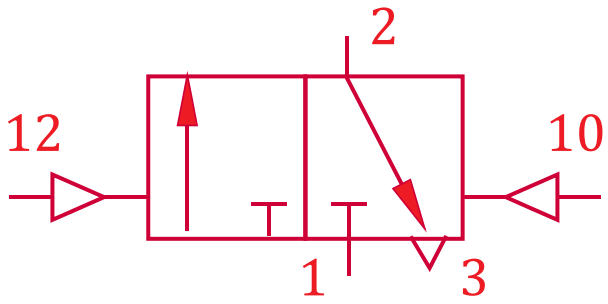


4. DESCRIPTION OF THE TEST BENCH

4. DESCRIPTION OF THE TEST BENCH

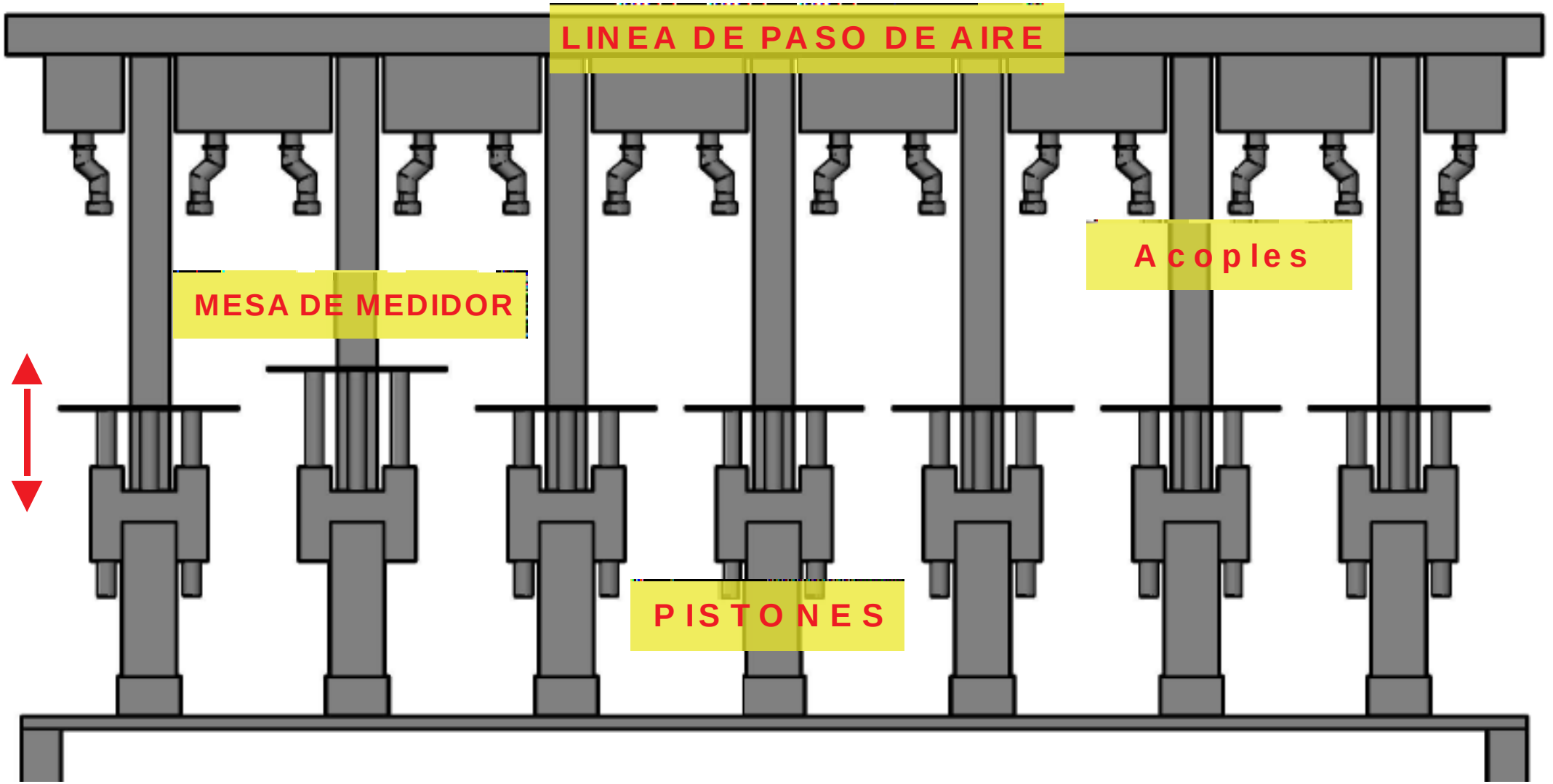
4.1.1 Structure and Neumatic System





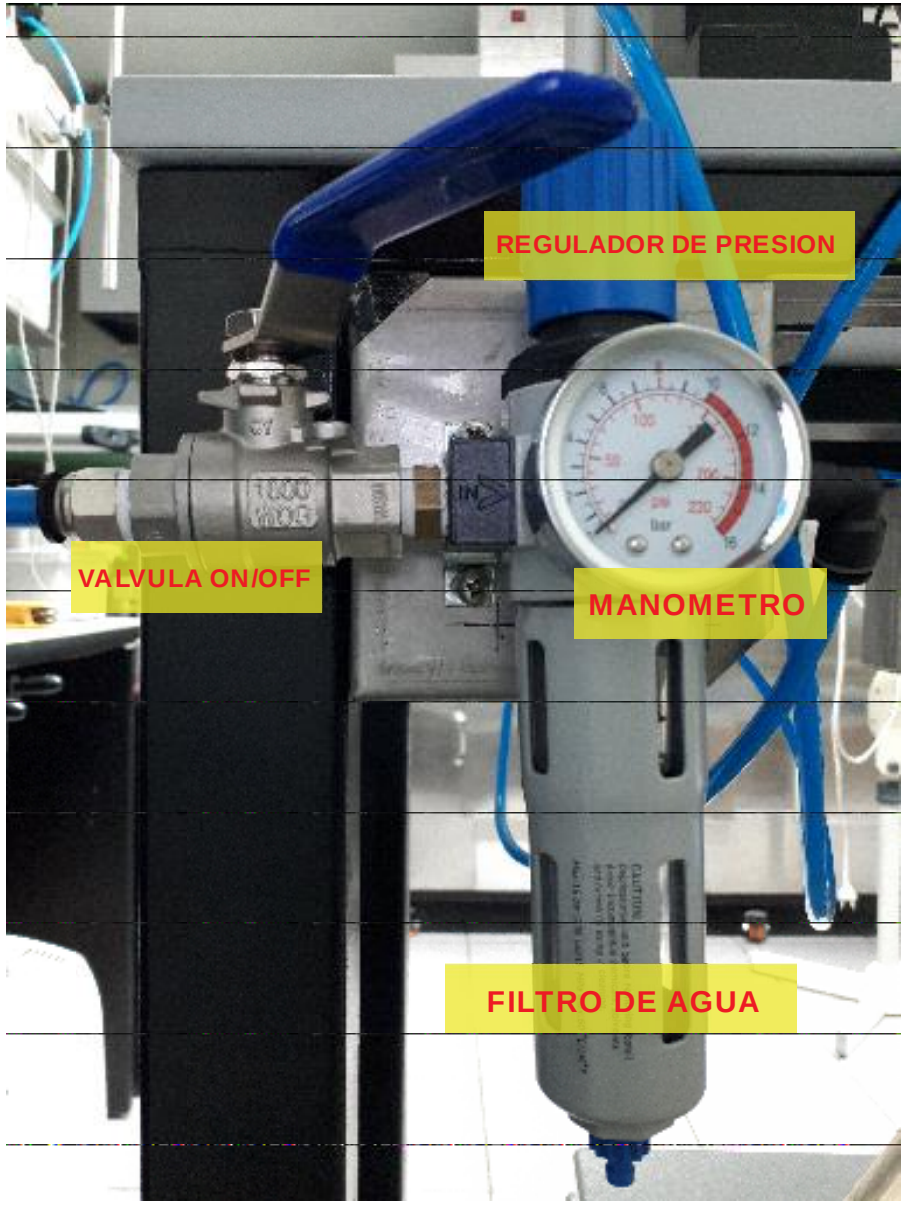
4. DESCRIPTION OF THE TEST BENCH

4.1.1 Structure and Neumatic System



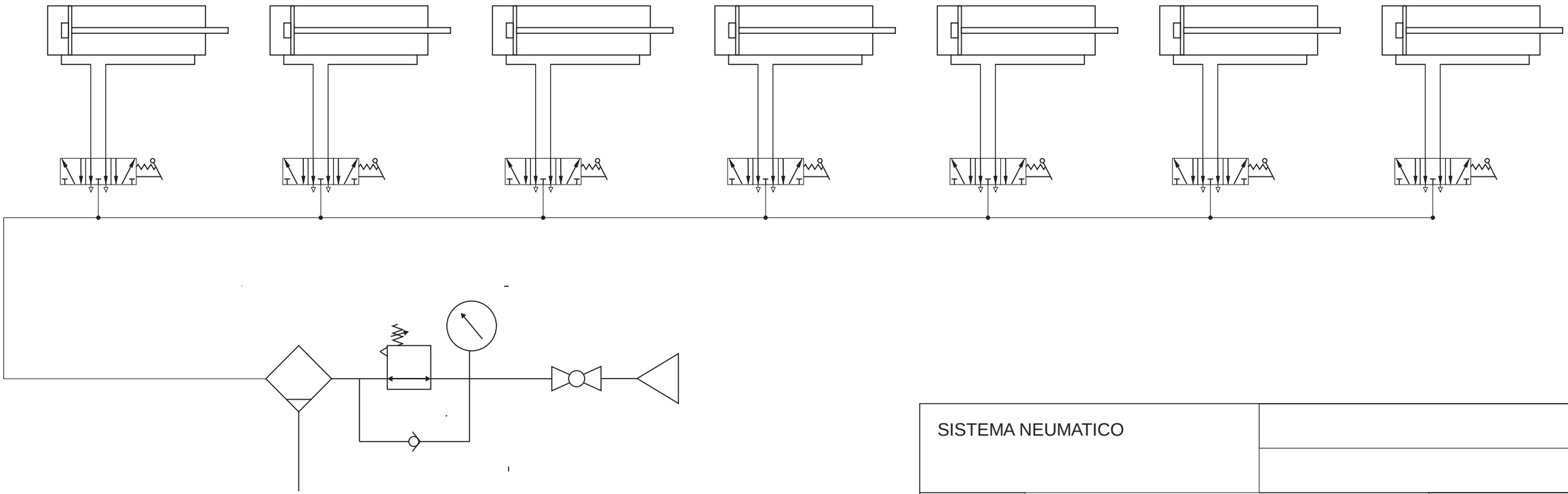
4. DESCRIPTION OF THE TEST BENCH

4.1.1 Structure and Neumatic System



4. DESCRIPTION OF THE TEST BENCH

4.1.1 Structure and Neumatic System



4. DESCRIPTION OF THE TEST BENCH

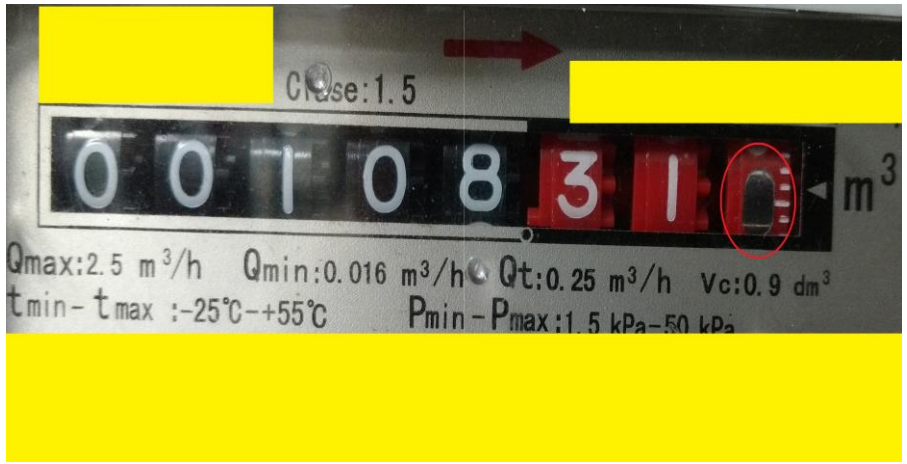
4.1.2 Air System Pumping

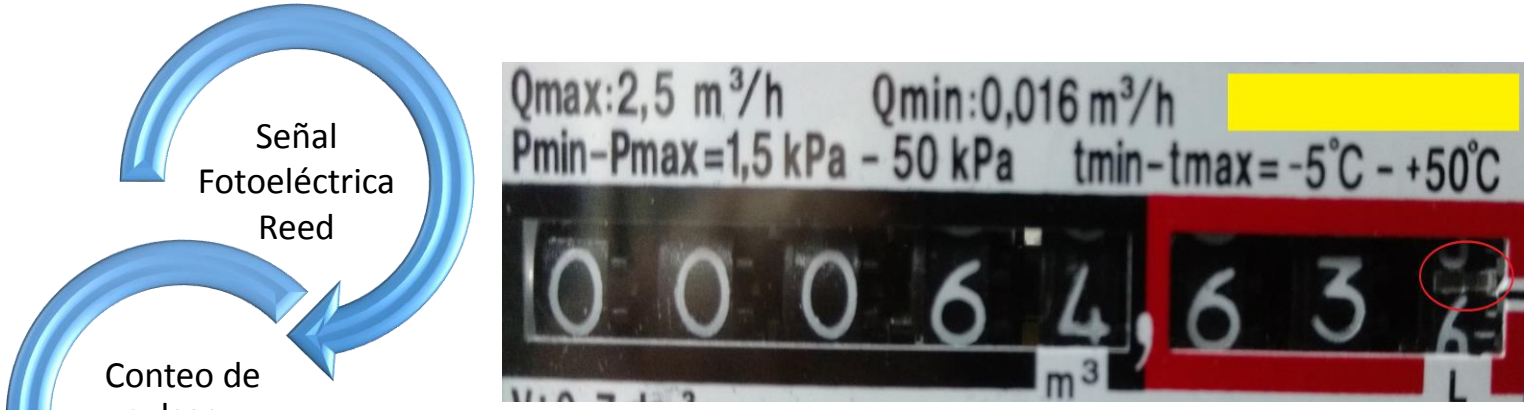
GASFLOW BLOWER			
Potencia	0,37 kW	*Voltaje*	220 V
Frecuencia	60 Hz	*Velocidad*	2840 rpm
Qmax	76 m3/h	*p-max vacío*	-17 kPa
Peso	10,6 kg		

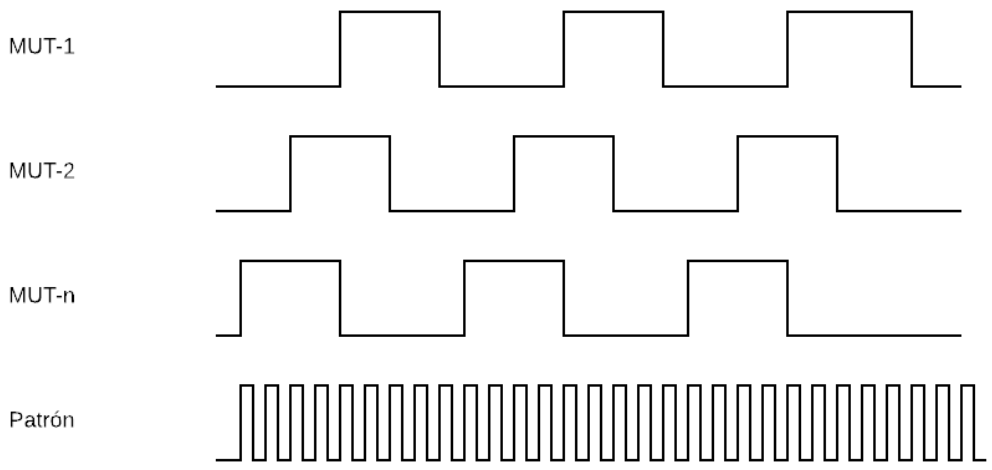
VARIABLE SPEED
VARIABLE SPEED DRIVE
3 Fases - Protocolo MODBUS
0,75 kW - 1 HP - (200-240) V

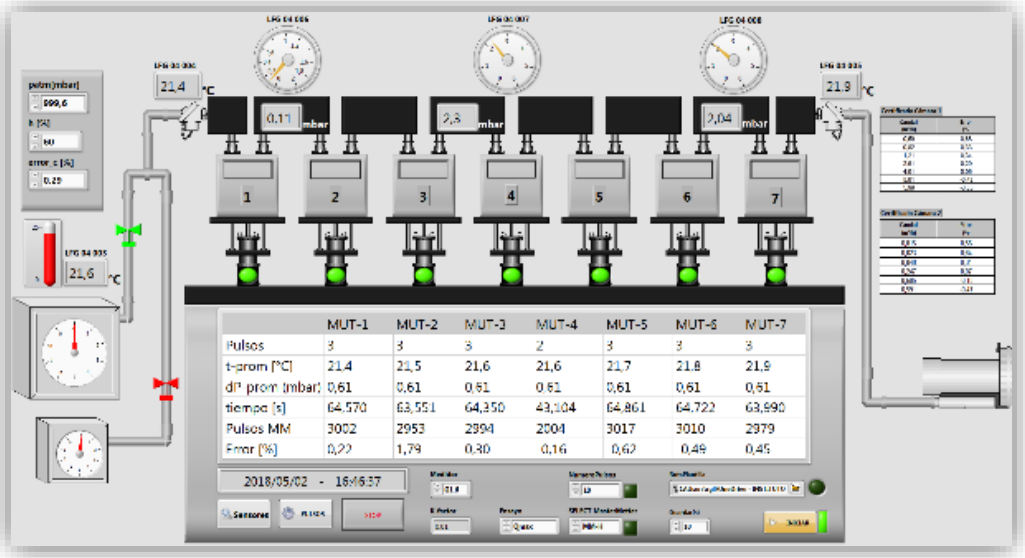
4. DESCRIPTION OF THE TEST BENCH

4.1.3 Acquisition System







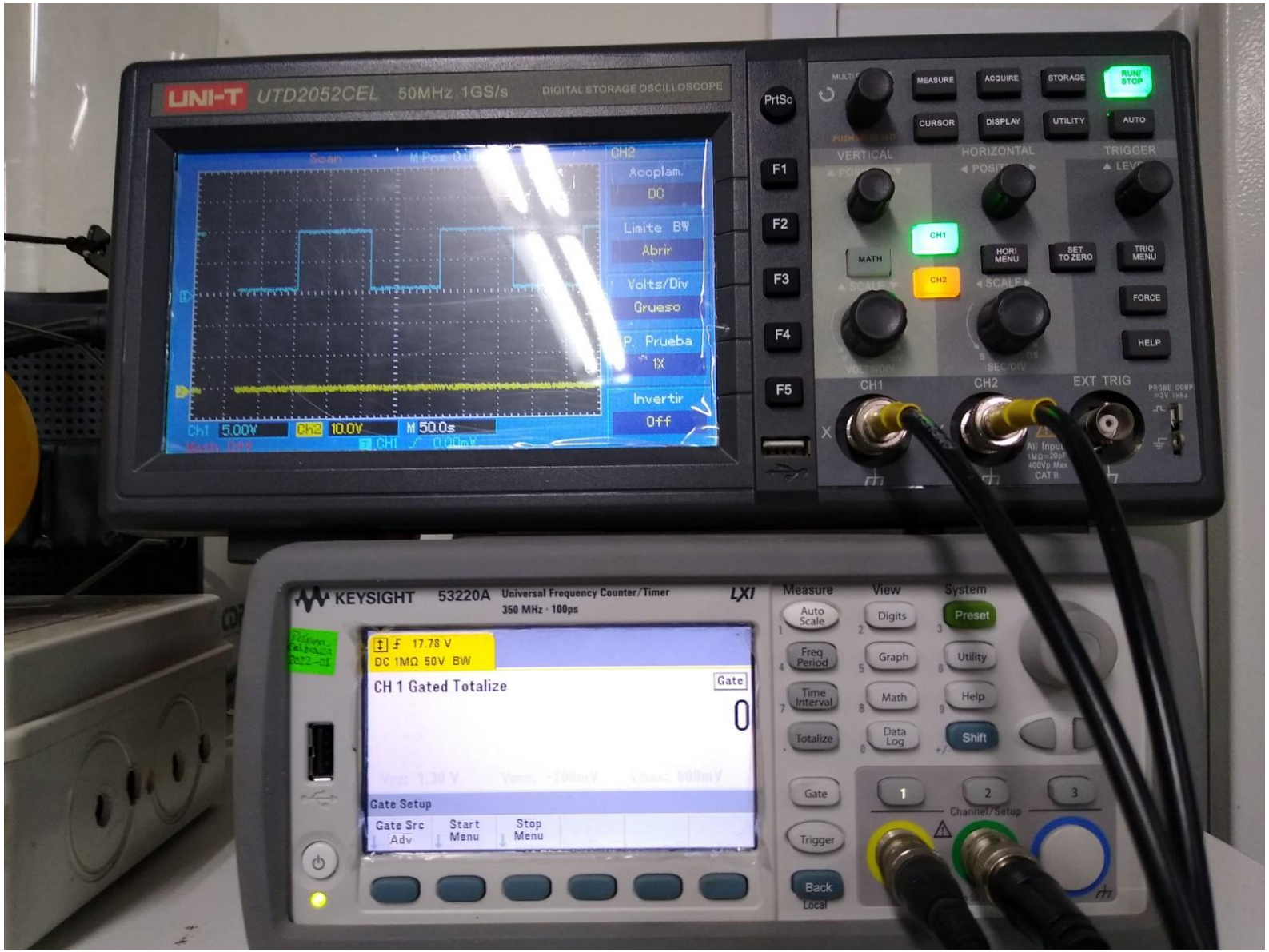


4. DESCRIPTION OF THE TEST BENCH

4.1.3 Acquisition System

4. DESCRIPTION OF THE TEST BENCH

4.1.3 Sistema de Adquisición



4. DESCRIPTION OF THE TEST BENCH

4.1.4 Measuring Instruments/Devices

Instrument of the Test Bench

Instrument	Identification
Wet gas meter, 1 dm^3	LFG-04-011
Wet gas meter, 10 dm^3	LFG-04-010
Temperature sensor [pt100], T1	LFG-04-004
Temperature sensor [pt100], T2	LFG-04-005
Temperature sensor [pt100], T	LFG-04-003
Differential pressure transducer, DP1	LFG-04-006
Differential pressure transducer, DP2	LFG-04-007
Differential pressure transducer, DP3	LFG-04-008
Differential pressure transducer, DP	LFG-02-005
Absolute pressure transducer, Pa	LFG-02-004
Humidity sensor, h	LFG-02-011

4. DESCRIPTION OF THE TEST BENCH

4.1.4 Measuring Instruments/Devices

Master Meters used to test gas meters

X suitable (X) partially suitable

Standard	Type of meter under test (measurement principle)					
	Diaphragm	Rotary piston	Rotary vane	Turbine	Vortex/ swirl	Ultrasonic
Bell prover	X	(X)	(X)	(X)	(X)	(X)
Drum-type meter	X	X	X	X	X	X
Rotary piston meter	X	(X)	X	(X)		
Low-pulsation rotary piston meter	X	X	X	X	X	X
Rotary vane meter	X	X	X	X	X	X
Turbine meter		(X)	X	X	X	X
Sonic nozzle	X	X	X	X	X	X
Piston-cylinder system	X					
Oval wheel meter	X					

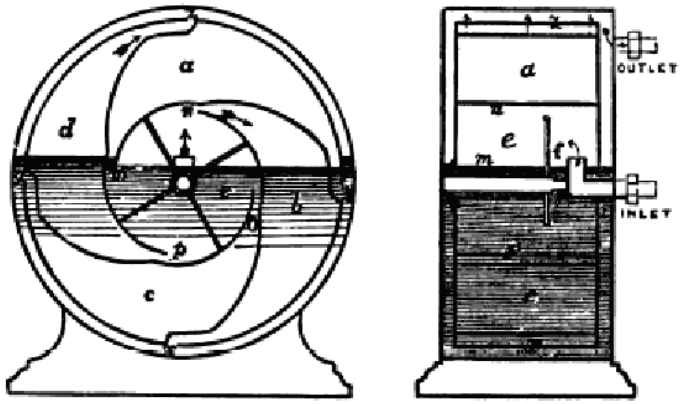
***Information taken from**: PTB Testing Instructions, Volumen 29 (Ed.). 2003. Measuring Instruments for Gas. Braunschweig, Alemania: Physikalisch-Technische Bundesanstalt*

4. DESCRIPTION OF THE TEST BENCH

4.1.4 Measuring Instruments/Devices

a) Wet Gas Meters

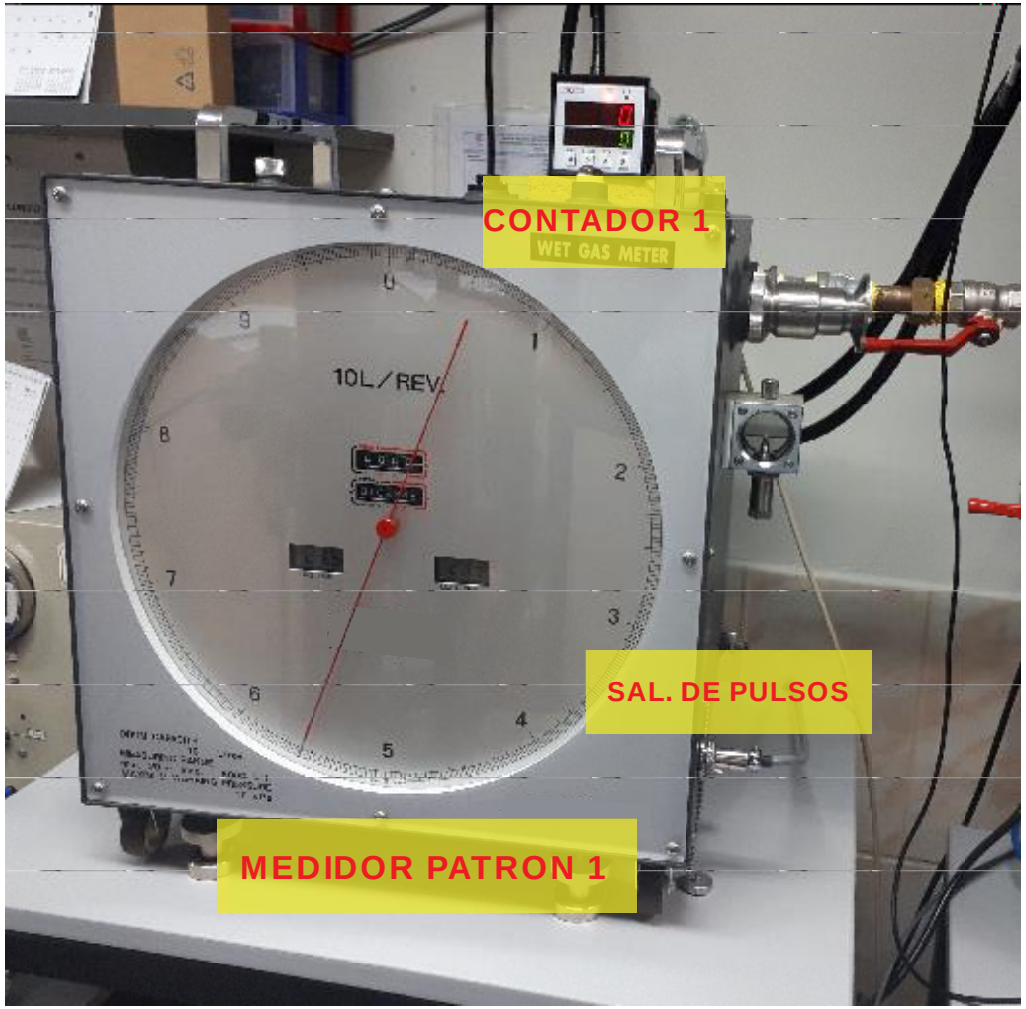
Volumen	Intervalo de medición	K_{fN}
1 dm^3	10 dm^3/h a 400 dm^3/h	0,001 dm^3/p
10 dm^3	40 dm^3/h a 6000 dm^3/h	0,01 dm^3/p

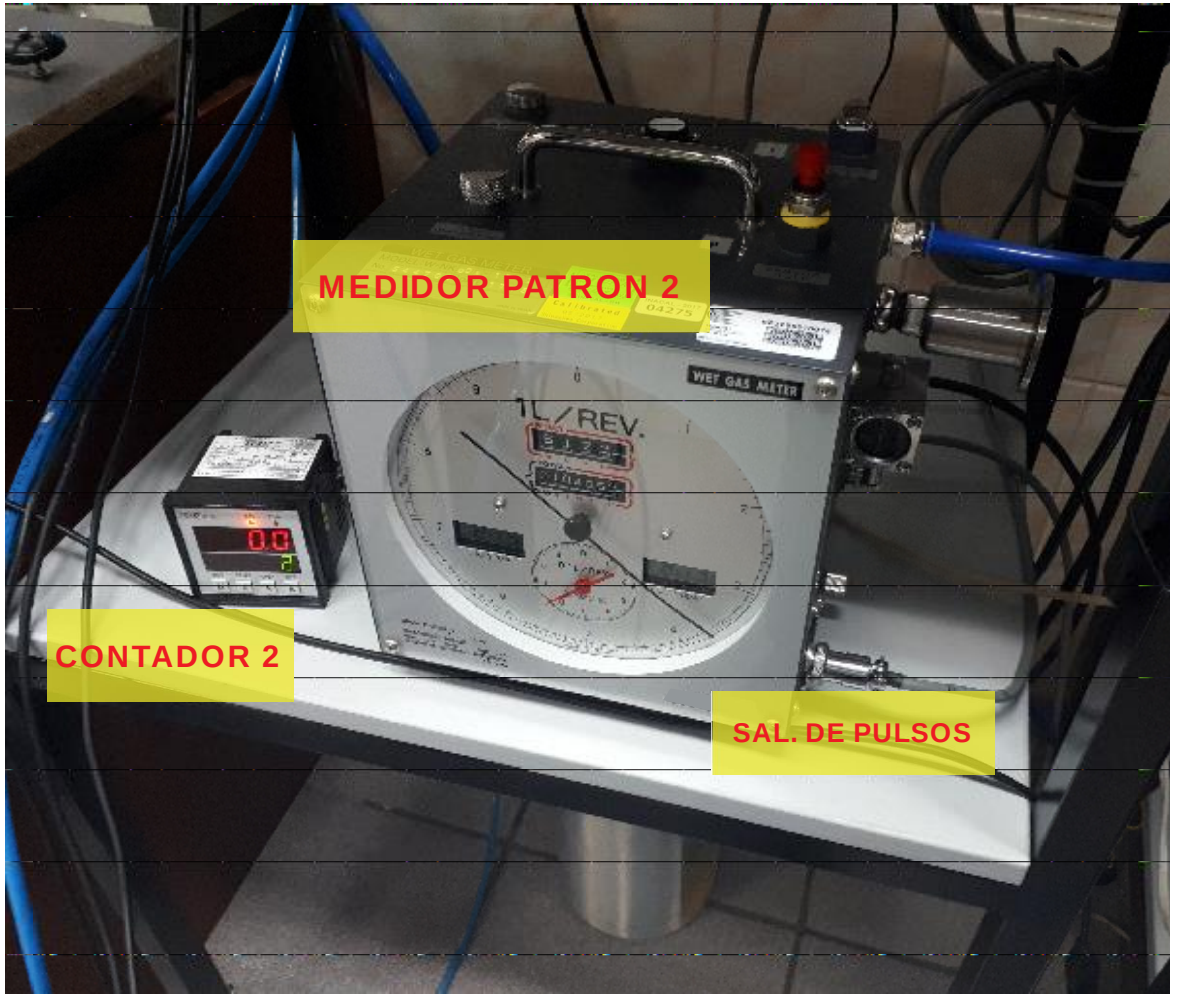


4. DESCRIPTION OF THE TEST BENCH

4.1.4 Measuring Instruments/Devices

a) Wet Gas Meters



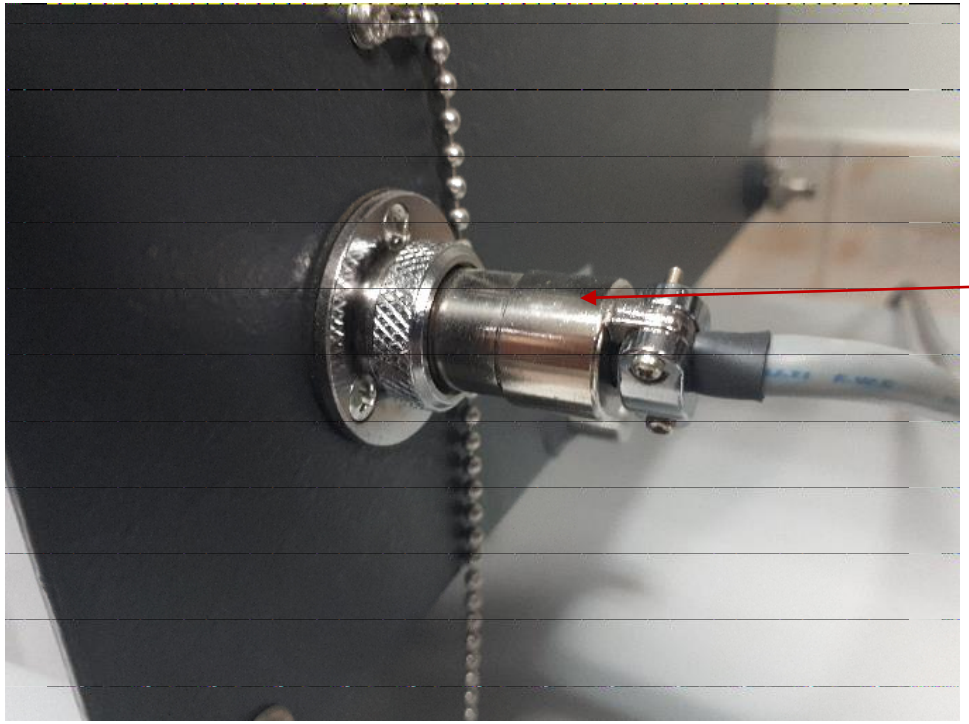


4. DESCRIPTION OF THE TEST BENCH

4. DESCRIPTION OF THE TEST BENCH

4.1.4 Measuring Instruments/Devices

a) Wet Gas Meters



Pulses output

Meter Under Test (10 000 mL = 1 Pulso)
Master Meter 1 (10 mL = 1 pulso)
Master Meter 2 (1 mL = 1 pulso)

1 mL

10 mL

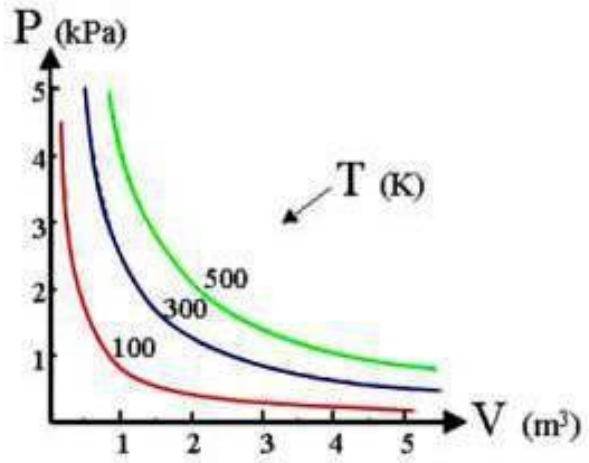
10 000 mL

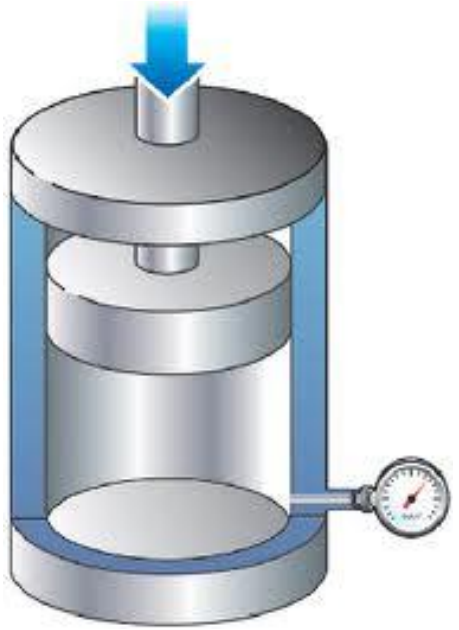
4. DESCRIPTION OF THE TEST BENCH

4.1.4 Measuring Instruments/Devices

b) Differential pressure transducer

ISOTERMAS

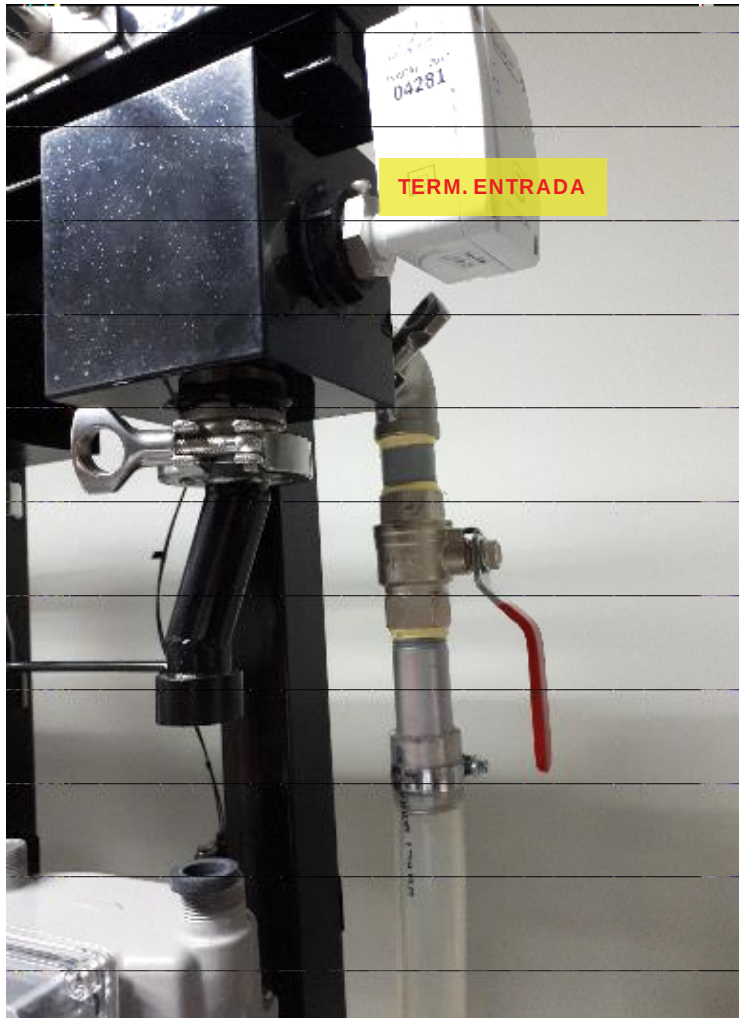


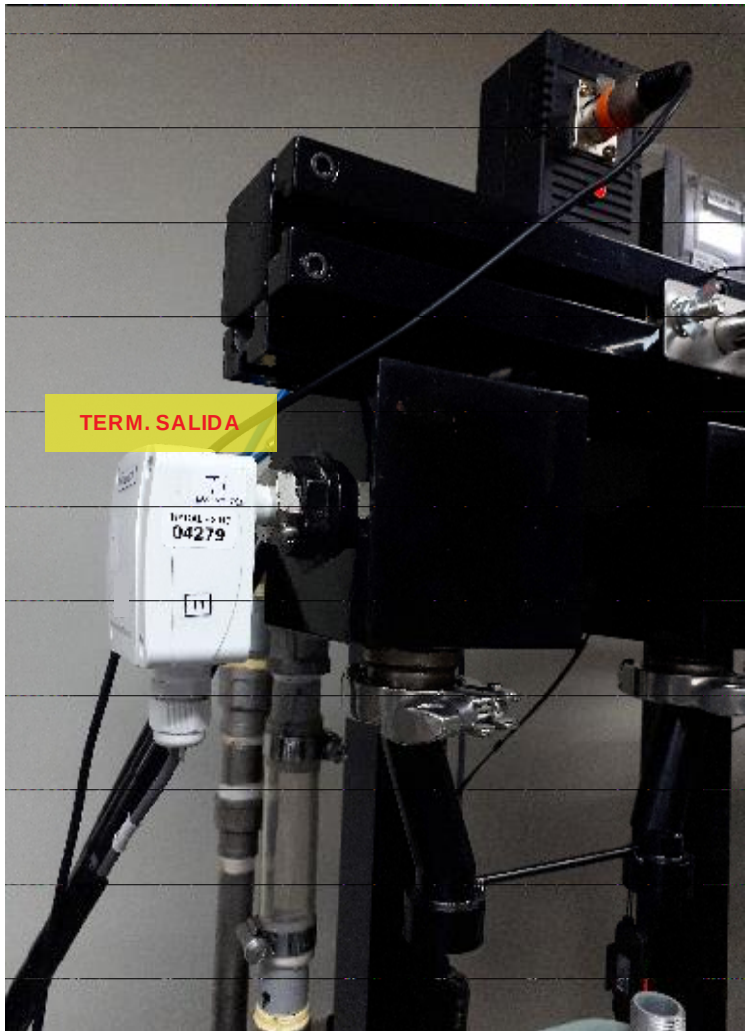


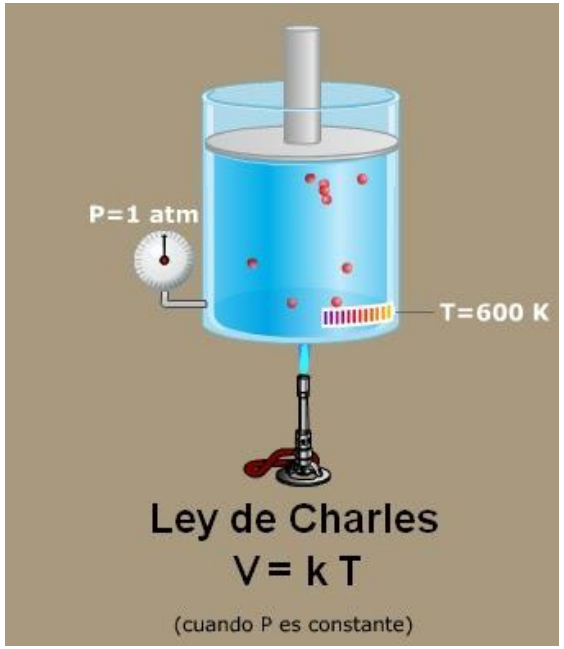
4. DESCRIPTION OF THE TEST BENCH

4.1.4 Measuring Instruments/Devices

c) Temperature sensor





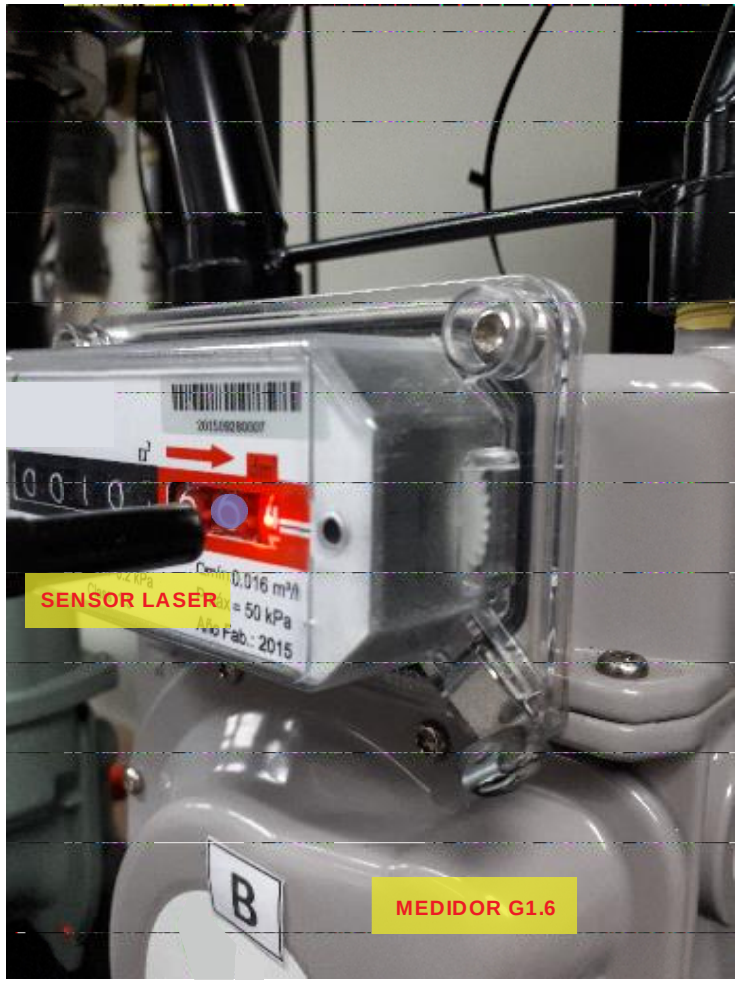


4. DESCRIPTION OF THE TEST BENCH

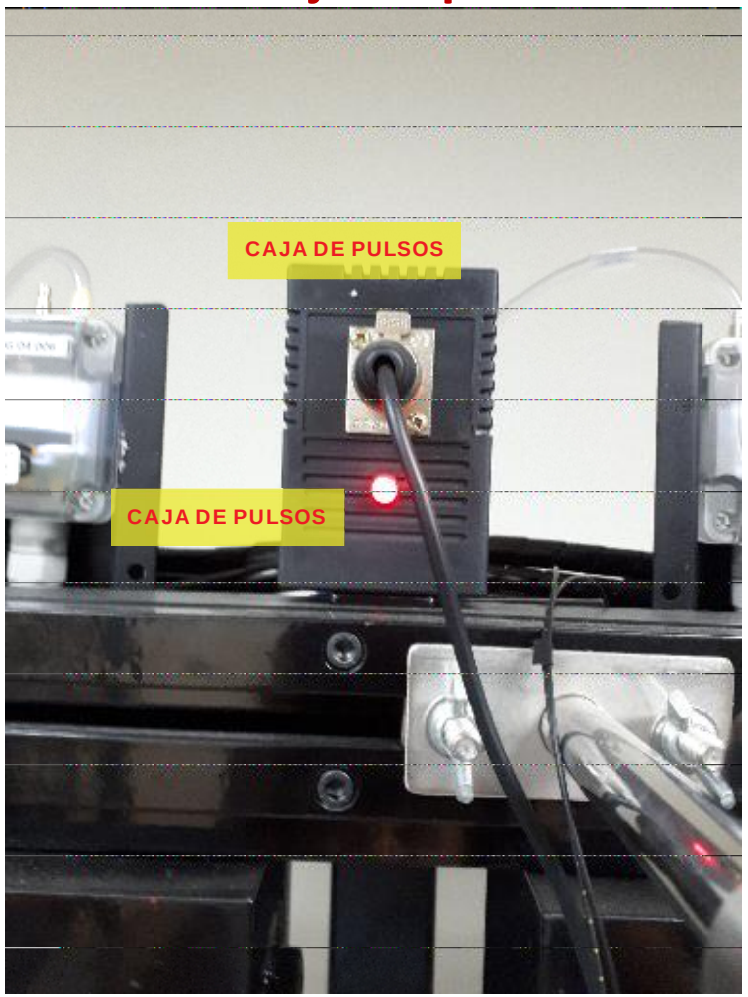
4.1.4 Measuring Instruments/Devices

c) Pulse Sensor and Pulse Box

Sensor de pulso

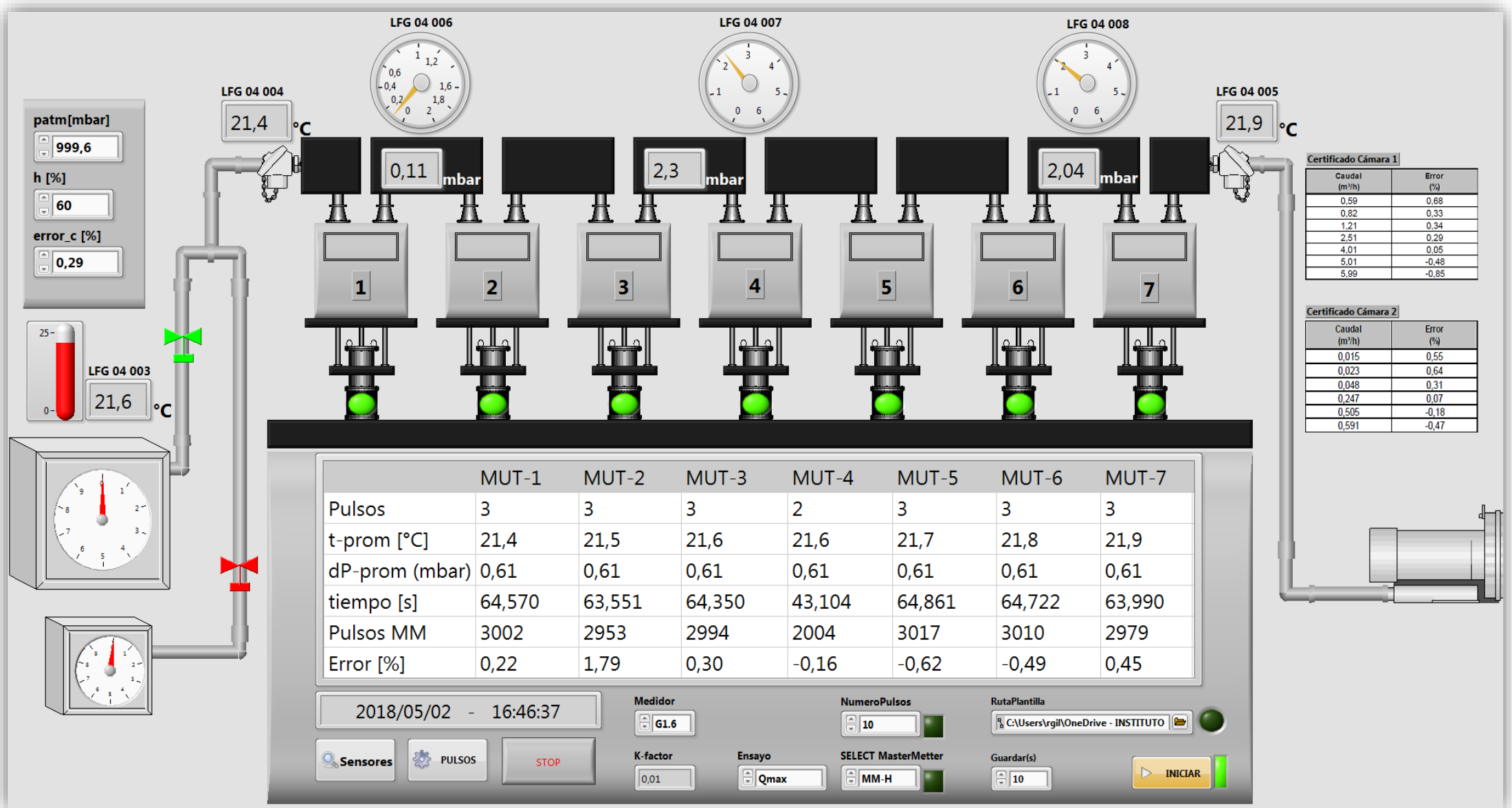


Caja de pulso



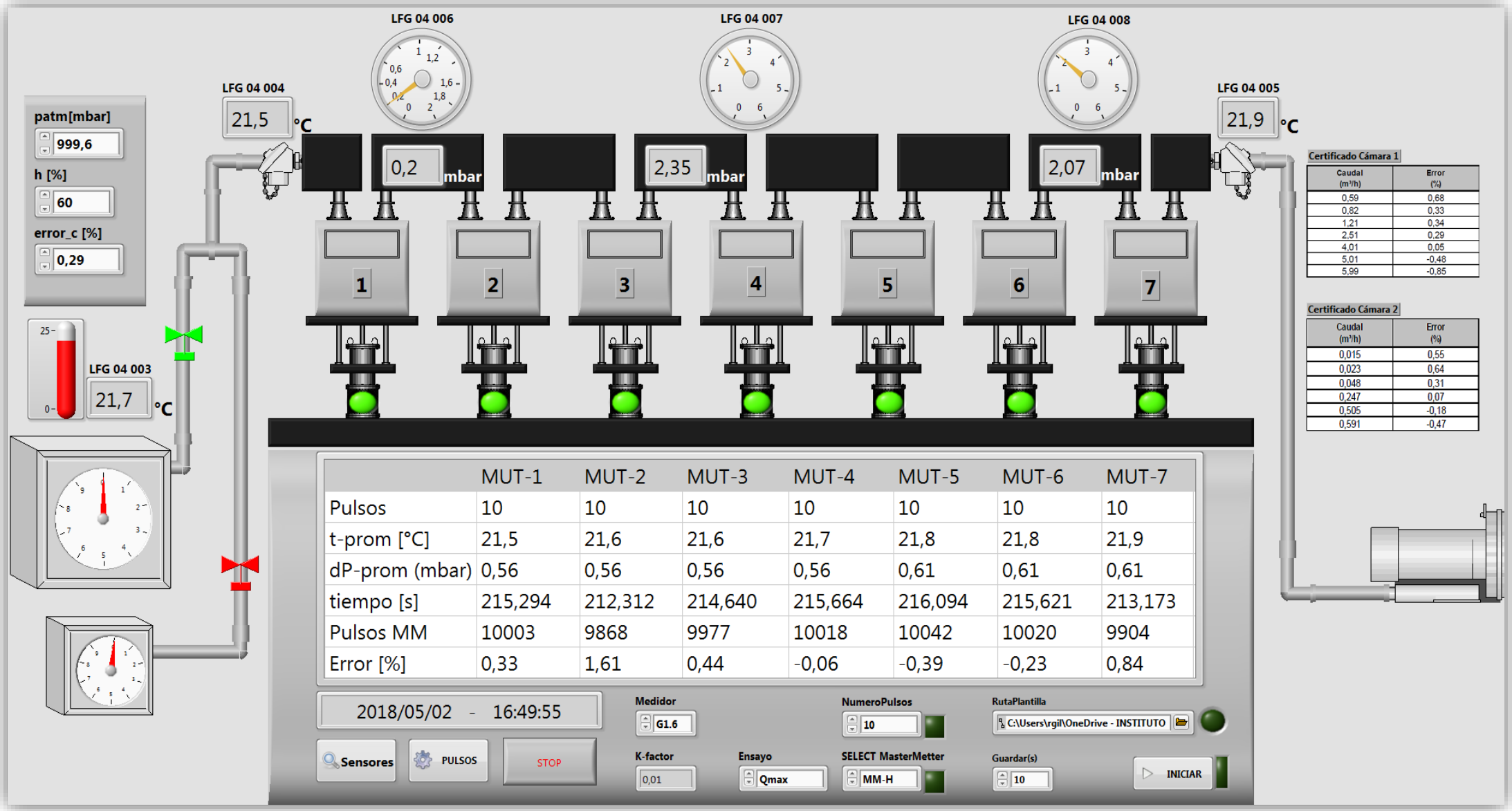
4. DESCRIPTION OF THE TEST BENCH

4.2 Software



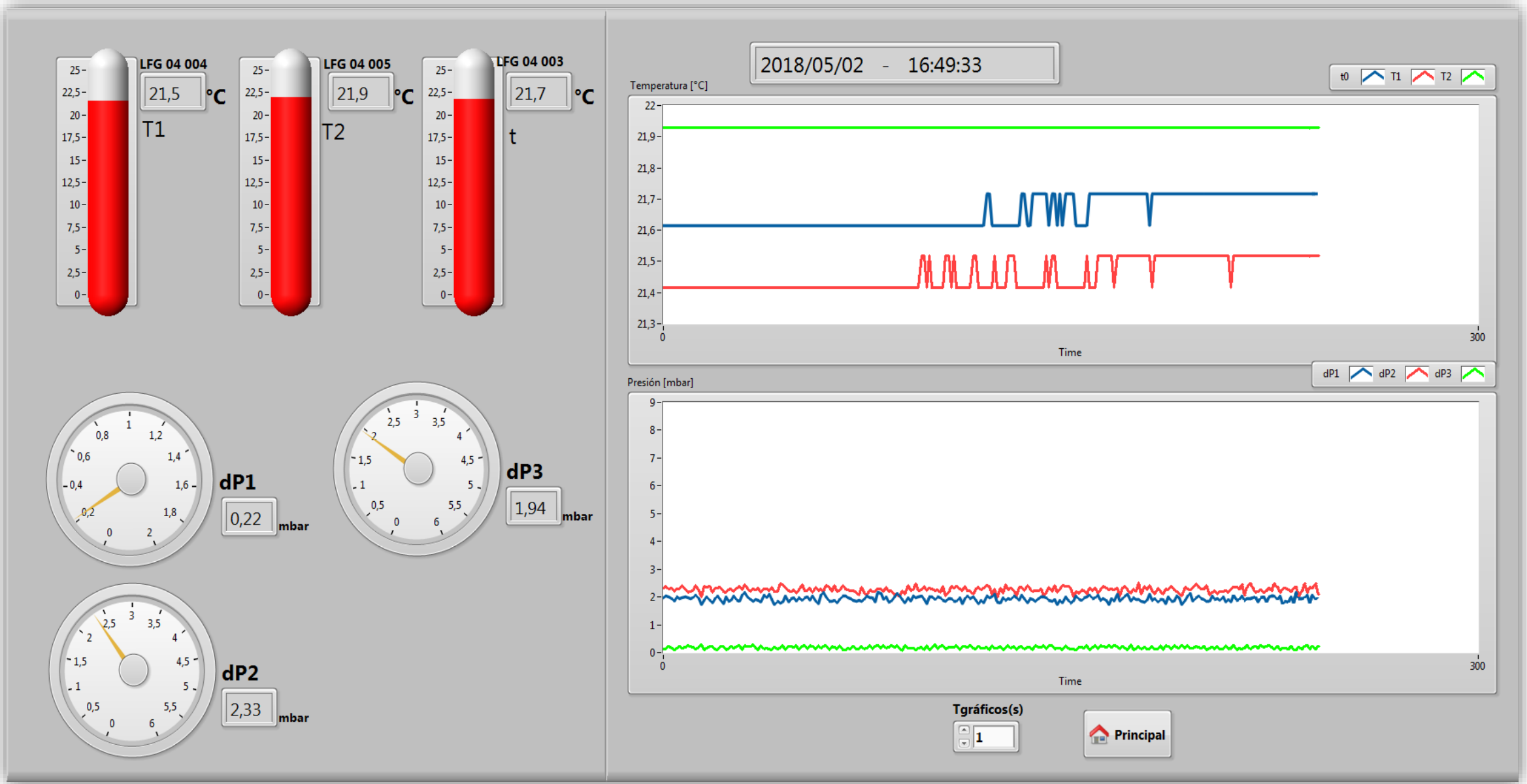
4. DESCRIPTION OF THE TEST BENCH

4.2 Software



4. DESCRIPTION OF THE TEST BENCH

4.2 Software



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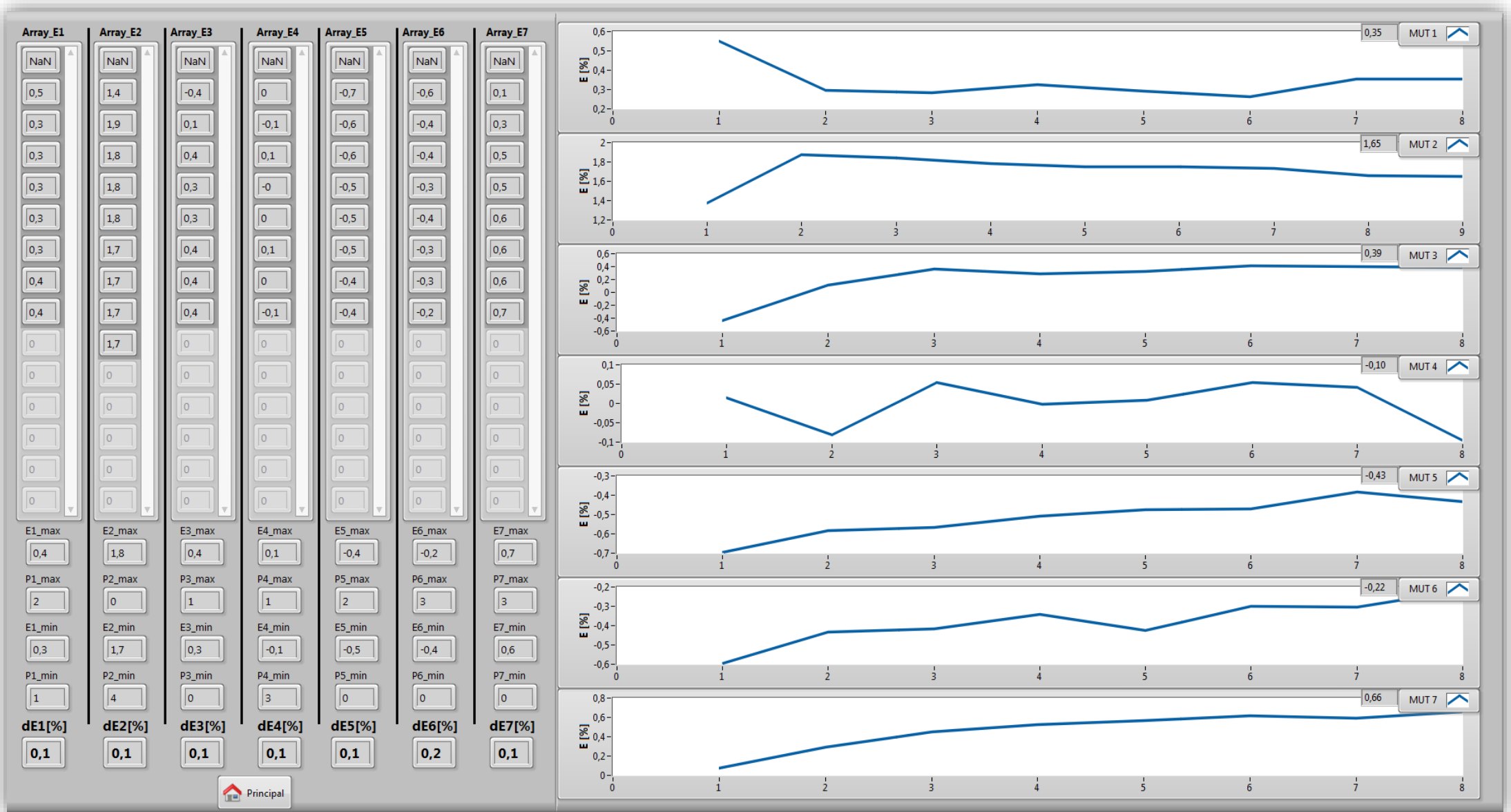
4.2 Software



4. DESCRIPTION OF THE TEST BENCH

4.2 Software

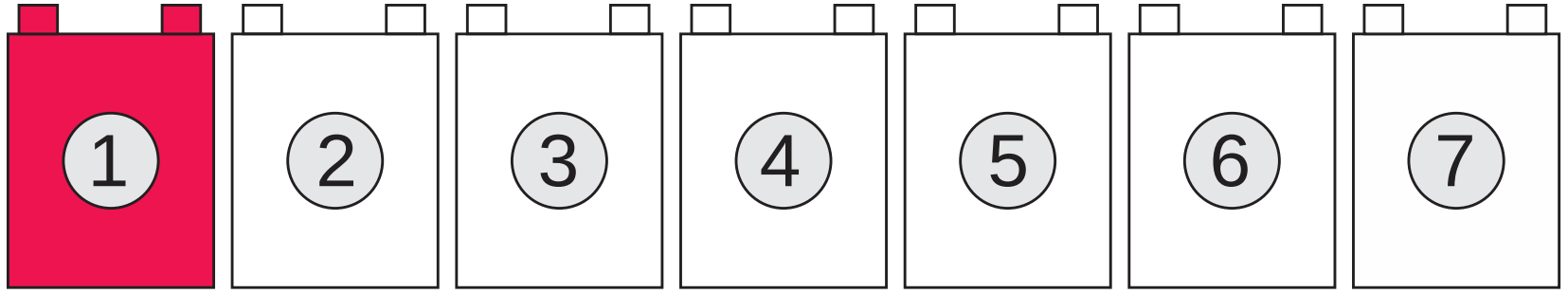
23,4	23,4	23,5	0,02	0,88	0,77	998,00				
tn / °C	tp1 / °C	tp2 / °C	dp1 / mbar	dp2 / mbar	dp3 / mbar	patm / mbar	Zp / p	Zn / p	Δt / s	MUT
23,2	23,4	23,5	0,01	0,86	0,77	998	6	5958	408,749	1
23,2	23,4	23,5	0,00	0,78	0,87	998	6	5912	405,181	2
23,3	23,4	23,5	0,01	0,7	0,8	998	6	6012	412,843	3
23,2	23,4	23,5	0,02	0,93	0,81	998	6	5971	410,114	4
23,3	23,4	23,5	0,02	0,97	0,87	998	6	5982	410,531	5
23,3	23,4	23,5	0,01	0,98	0,69	998	6	5981	410,536	6
23,3	23,4	23,5	0,03	0,94	0,92	998	6	6009	412,545	7
23,3	23,4	23,5	0,04	0,82	0,75	998				
23,4	23,4	23,5	0,01	0,87	0,84	998				
23,4	23,4	23,6	0,02	0,98	0,6	998				
23,4	23,4	23,6	0,04	0,93	0,83	998				
23,4	23,4	23,6	0,03	0,79	0,72	998				
23,5	23,4	23,6	0,02	0,95	0,66	998				
23,5	23,4	23,6	0,01	0,79	0,75	998				
23,5	23,4	23,6	0,03	1,06	0,84	998				
23,5	23,5	23,6	0,03	0,8	0,71	998				
23,5	23,5	23,6	0,03	0,79	0,75	998				
23,5	23,5	23,6	0,02	0,79	0,91	998				
23,5	23,5	23,6	0,00	0,98	0,74	998				
23,5	23,5	23,6	0,01	0,94	0,57	998				
23,6	23,5	23,6	0,04	0,86	0,75	998				
23,6	23,5	23,6	0,03	0,92	0,79	998				
23,6	23,5	23,6	0,06	0,84	0,77	998				
23,6	23,5	23,6	0,01	0,87	0,72	998				

4. DESCRIPTION OF THE TEST BENCH

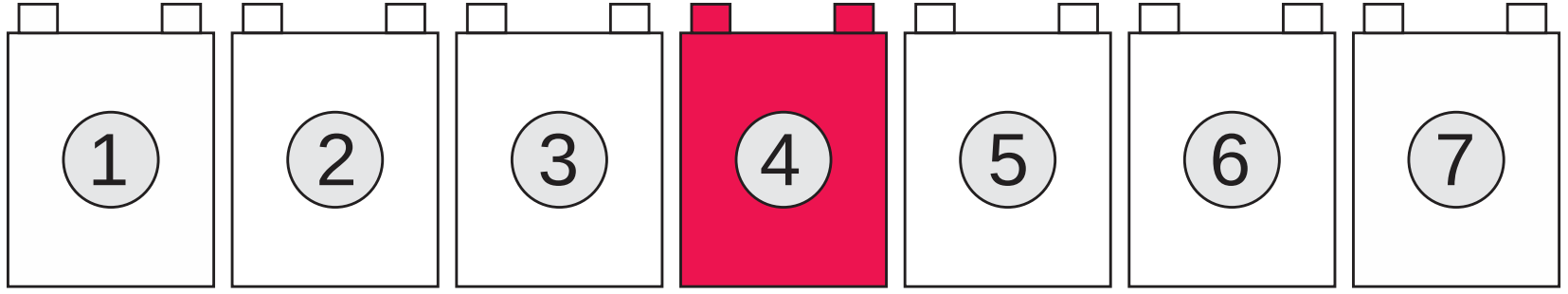
5. RESULTS

Results Consistency Test

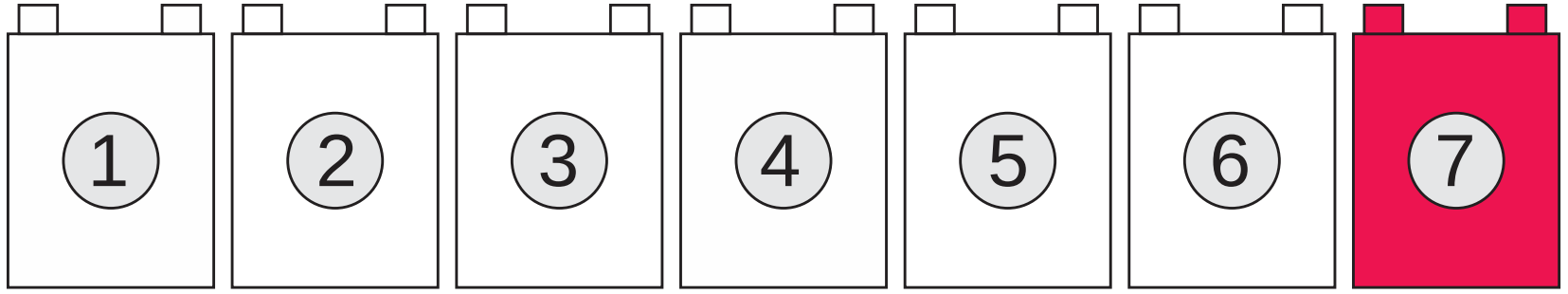
Medidor Posición 1



Medidor Posición 4



Medidor Posición 7



5. RESULTS

Results Consistency Test

Medidor / Medición	A	B	C	D	F	G	metrex
Posición	1	2	3	4	5	6	7
1	0,30	1,57	-0,01	-0,52	1,76	0,75	0,78
2	0,30	1,45	-0,15	-0,54	1,59	0,48	0,48
3	0,31	1,60	0,01	-0,41	1,78	0,59	0,59
Promedio	**0,30**	**1,54**	**-0,05**	**-0,49**	**1,71**	**0,61**	**0,62**
Repetibilidad	0,0	0,1	0,2	0,1	0,2	0,3	0,3

Medidor / Medición	A	B	C	D	F	G	metrex
Posición	2	3	4	5	6	7	1
1	0,41	1,39	-0,29	-0,47	1,76	0,51	0,75
2	0,26	1,47	-0,17	-0,48	1,66	0,47	0,67
3	0,43	1,44	-0,17	-0,48	1,60	0,35	0,83
Promedio	**0,37**	**1,43**	**-0,21**	**-0,48**	**1,67**	**0,44**	**0,75**
Repetibilidad	0,2	0,1	0,1	0,0	0,2	0,2	0,2

Medidor / Medición	A	B	C	D	F	G	metrex
Posición	3	4	5	6	7	1	2
1	0,45	1,70	0,32	-0,26	1,60	0,63	0,27
2	0,38	1,65	0,17	-0,41	1,48	0,54	0,41
3	0,52	1,77	0,24	-0,35	1,59	0,74	0,28
Promedio	**0,45**	**1,71**	**0,24**	**-0,34**	**1,55**	**0,64**	**0,32**
Repetibilidad	0,1	0,1	0,2	0,2	0,1	0,2	0,1

5. RESULTS

Software Validation

According to ISO 17025, software validation is required. In our case, the Excel template performs the calculations and the software acquires the sensor data and sends it to the template. Then the validation is done to excel and the validation to our software consists of corroborating the data transfer

5. RESULTS

Reproducibility Test

$$E_N = \frac{e_{ref} - e_{TB}}{\sqrt{U_{ref}^2 + U_{TB}^2}}$$

Criterio de Aceptación

$|E_N| \leq 1$ Successful Result

$|E_N| > 1$ Unsuccessful Result

E_N Normalized Error

e_{ref} Reference Bank Error (nozzles)

e_{TB} Test Bench Error (wet gas meter)

U_{ref} Reference Bank Uncertainty(nozzles)

U_{TB} Test Bench Uncertainty(nozzles(wet gas meter)

5. RESULTS

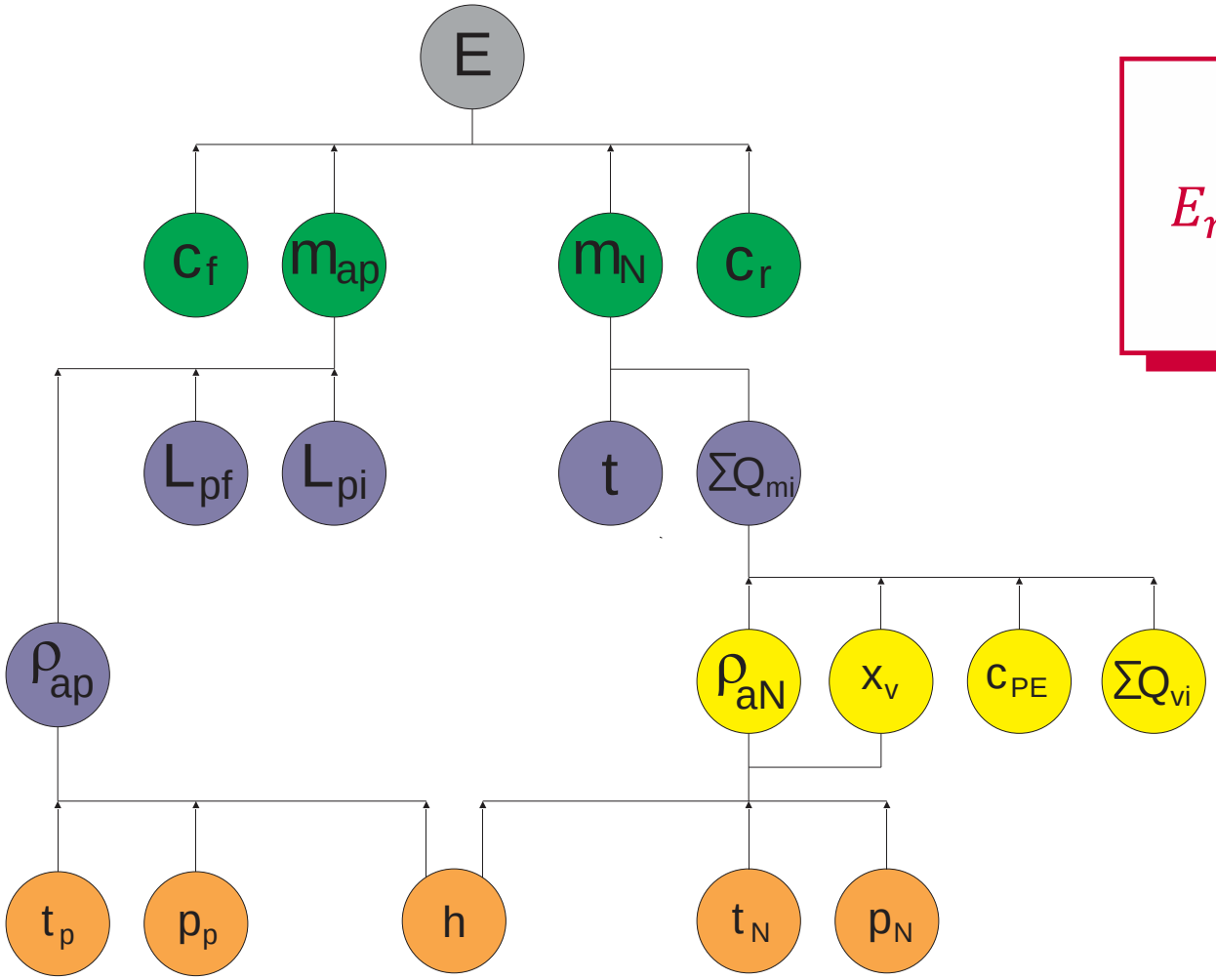
Reproducibility Test

Medidor de Referencia	Caudal [dm^3/h]	Error Banco Ref. [%]	Error Banco Nuevo [%]	U Banco Ref. [%]	U Banco Nuevo [%]	$\lvert E_N \rvert$
GasMeter A	2500	-0,2	-0,30	0,35	0,6	0,2
	500	0,7	0,46	0,45	0,6	0,3
	16	0,7	0,50	0,55	0,7	0,2
GasMeter B	2500	0,9	0,90	0,35	0,6	0,1
	500	1,5	1,37	0,45	0,6	0,2
	16	0,7	0,55	0,55	0,7	0,1
GasMeter D	2500	-1,1	-1,20	0,35	0,6	0,2
	500	-0,2	-0,01	0,45	0,6	0,2
	16	0,4	0,28	0,55	0,7	0,1
GasMeter M	2500	0,0	-0,40	0,35	0,6	0,5
	500	1,0	1,24	0,45	0,6	0,3
	16	0,5	0,77	0,55	0,7	0,3

The absolute value in all cases is less than 1.

5. RESULTS

Estimation of Uncertainty



$$E_{mi} = \left(\frac{\rho_{pi}}{\rho_n}\right) \cdot \left(\frac{K_{fp} \cdot Z_{pi}}{K_{fN} \cdot Z_{ni}}\right) \cdot \left(1 + {}^{f_N}/_{100}\right) - 1$$

5. RESULTS

Estimation of Uncertainty

entrada X_i			x_i	U_i	Probabilidades		Estándar $u_i(xi)$	Sensibilidad c_i	a la U $u_i(y)$
Densidad del Aire en el MUT	kg/m^3	ρ_{pi}	1,1683	0,0020	Normal	2	0,0010	0,87	0,0009
Densidad del Aire en el Patrón	kg/m^3	ρ_n	1,1688	0,0034	Normal	2	0,0017	-0,87	-0,0015
Error del Medidor Patrón	%	f_N	0,29	0,47	Normal	2	0,24	0,01	0,0024
Pulsos del MUT	pulsos	Z_{pi}	15	0,02	Uniforme	$\sqrt{12}$	0,01	0,07	0,0004
Pulsos del Patrón	pulsos	Z_{ni}	14944	2	Uniforme	$\sqrt{12}$	0,58	-6,9E-05	-0,00004
Reproducibilidad	-	Crepr.	0	0	Normal	2	0	1	0,0000
Repetibilidad	-	Crep.	0	0,002	Normal	2	0,001	1	0,0010
Consistencia	-	Ccons.	0	0,004	Normal	2	0,002	1	0,0020
								$u_c = \sqrt{\sum (u_i(y))}$	0,0037
								k	2
								U	0,0074

5. RESULTS

Establishment of the Calibration and Mesurement Capacities of the Test Benchm in the range from 16 dm^3/h to 2500 dm^3/h.

Q		U
i	[dm^3/h]	[%]
Qmin	16	1,1
0,2 Qmax	500	1,0
Qmax	2500	0,7

SI QUEREMOS UN PAÍS CON CALIDAD,
TENEMOS QUE PRODUCIR Y CONSUMIR RESPONSABLEMENTE.

Seamos Peruanos de Calidad
¡SÉ PARTE DEL CAMBIO!