Associazione Italiana Strumentisti

Italy Section

MISURE FISCALI

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Auditorium TECNIMONT

Revamping a metering system

SOCRATE

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1.
Introduction

SOCRATE SPA

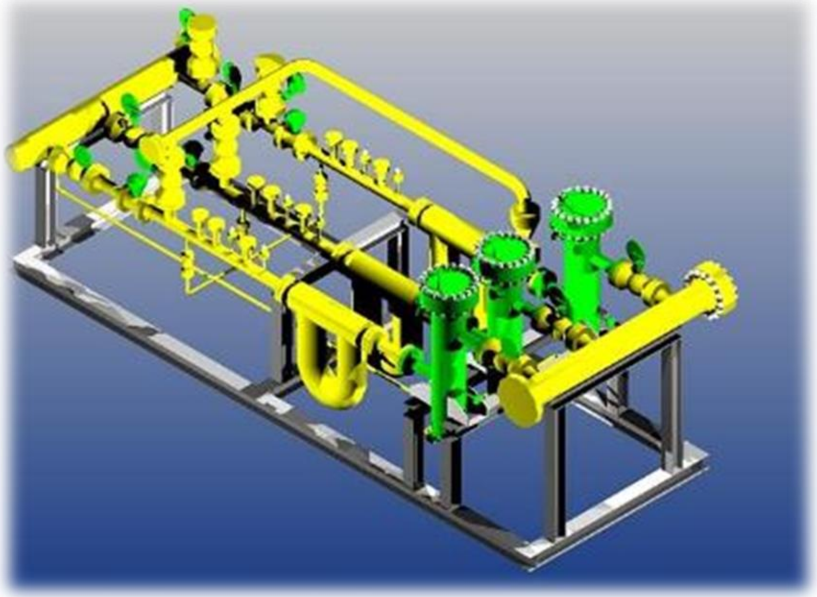
During the last 20 years of activities, SOCRATE SPA has successfully engineered, procured, installed, commissioned and revamped the following products and plants:

- Skid mounted Metering Systems.
- Unidirectional and bidirectional Pipe Provers.
- Product Quality Skids (e.g. analizers, automatic sampling systems).
- Control Systems with dedicated flow computers.
- Sheltered Control Rooms.

SOCRATE SpA is fully qualified to play a role of EPC Contractor, in every step of the process.

Socrate Spa is able to supply turnkey metering systems applying various technologies, (e.g. turbine, ultrasonic, coriolis, pd meters, orifice fitting), including trained in-house resources and dedicated assets.

All metering systems are designed according to the most recent international standards (API, AGA, ISO) and customized to Client requests.



From design to final start-up Socrate Spa is committed to fully satisfy the Client specification in terms of time and quality.

2.
Revamping of a metering system: challenges and constraints

Definitions

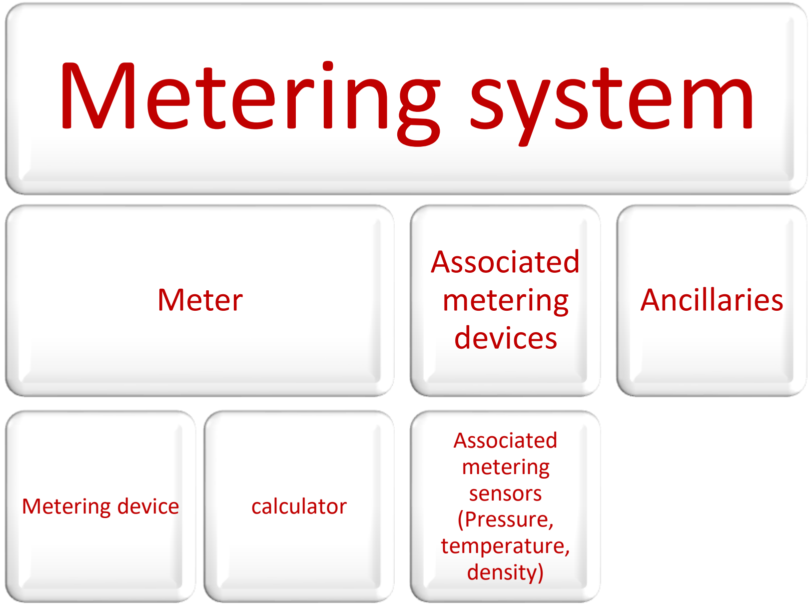
A metering system comprises a meter and its ancillaries.

The principal and essential part of the system is the meter.

The meter is an instrument intended to measure continuosly the quantity of liquid or gas passing through the measuring device at metering conditions.

The associate metering devices are those sensors connected to the calculator in the view of executing corrections\conversions.

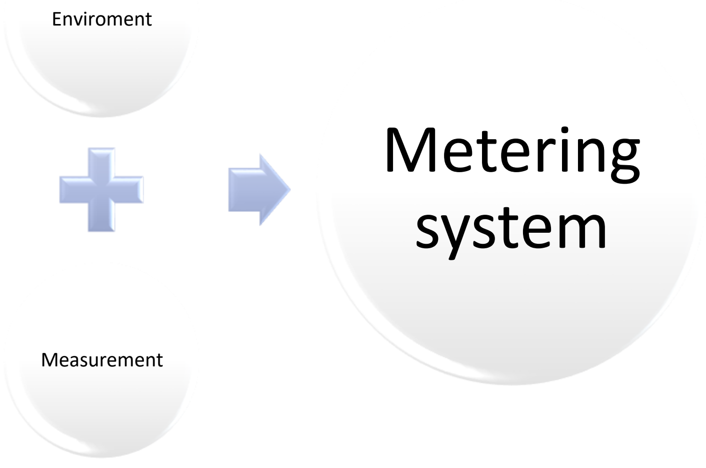
The ancillaries are equipments devoted to perform specific tasks or functions



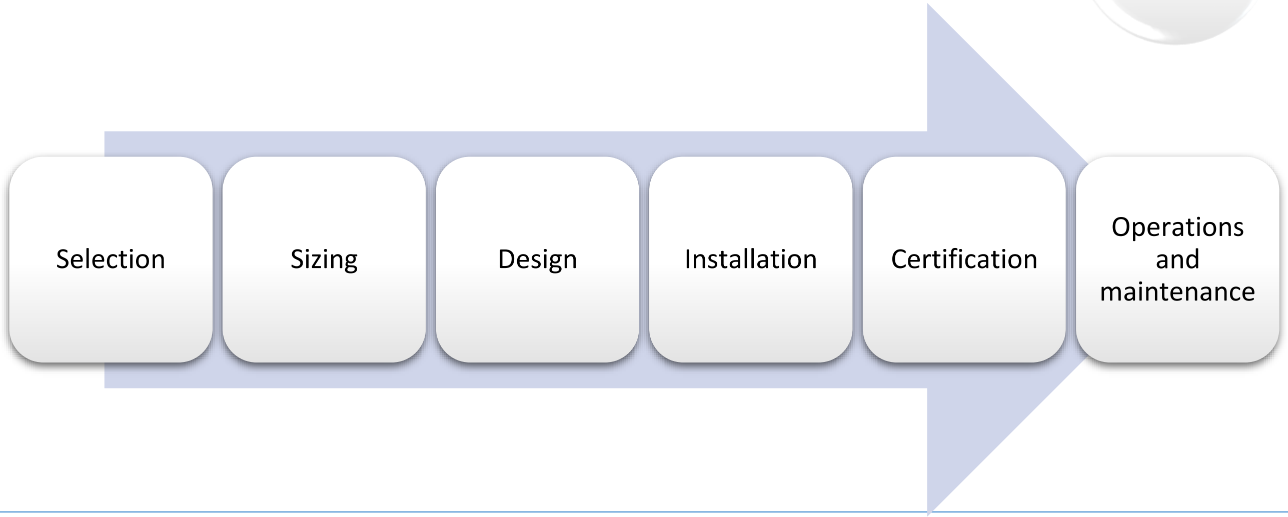
Definition of design constraints

Essentially two type of constrains intervene during sizing, selection and design of a metering systems

- Environmental contraints
- Measurement constrains



These constraints drive all the life cycle of the product setting the “System Requirements”



Environmental constraints

The first type of constraints are related to the environmental context of the installation, in terms of:

- Metrological regulation
- Installation context
- Origin and destination of measured products
- Fluid characteristics and relevant properties
- Safety regulations
- Level of manned activities requirement
- Actual situation (in case of retrofit, revamping, development)
- Time frame and others

Installation context

Apart the International context (variable …) being able to require a particular organization (particularly for commissioning and startup), one of the essential constraints is the system location and installation requirements.

Beyond national or international Regulation, Laws, Standards and other Directives, specificities resulting from practices and "traditions", or from "customer" standards can be imposed.

Specific constraints can appear in the project, in particular in the research of optimal use of existing parts (compatibility, operating conditions, maintenance… after sale).

Specific requirements come primarily from local context and "customer" rules or heritage.

These constraints become of the essence for revamping and retrofitting project.

Actual Situation

Modification of an existing installation for performance improvement, regulatory compliance or process modifications requires a particular approach having to integrate all previously evoked parameters.

The connection of a new system in the hearth of a refinery, on an offshore platform or on a truck does not generate the same issues as the installation of a metering system… in the middle of a desert!

- Straight lines (upstream/downstream)
- System position/elevation
- Access to various devices
- Maintenance and Verification facility (including proving)
- Electric and/or Pneumatic networks
- Others

- In all cases, a very detailed survey is crucial.

Measurement Constraints

The measurement constraints are more technical and define the details of the metering systems, in particular:

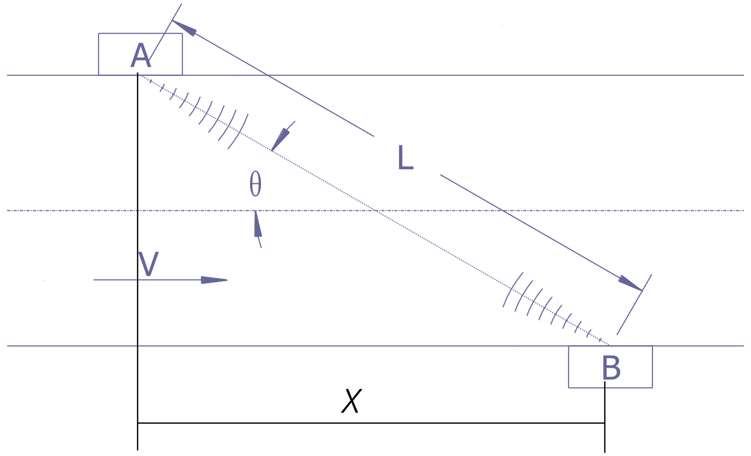
- The design standards to comply with
- The performance level
- The primary element
- Any other additional device or feature
- The operations and the maintenance
- The periodical assessment of the system

3.
Ultrasonic flow meters: an option for system revamping

Flow velocity measurement using transit time ultrasonic flow meter consists in measuring the difference of "travel" time of an ultrasonic wave in the direction of the flow and in the opposite direction.

In the direction of flow, the distance is covered at a speed equal to the speed of sound (celerity) plus the mean flow velocity. In the opposite direction, the same distance is covered at a speed equal to the speed of sound (celerity) minus the mean flow velocity.

Diameter (mm)	Δt(s)	E(Δt) (s)
100	10^{-6}	10^{-8}
300	$3x10^{-6}$	$3x10^{-8}$



$$t_1 = \int_0^L \frac{dl}{c - v_z(l)cos\theta}$$

$$t_2 = \int_0^L \frac{dl}{c + v_z(l)cos\theta}$$

$$v_{path} = \frac{L(t_1 - t_2)}{2t_1 t_2 cos\theta}$$

Ultrasonic flow meter principle (some details)

More than one acoustic path is normally used.

Disposition of the path can vary from model and from manufacturer.

The most common path integration method is Gaussian Type, however other solution (e.g. Tcheybechev) have been used.

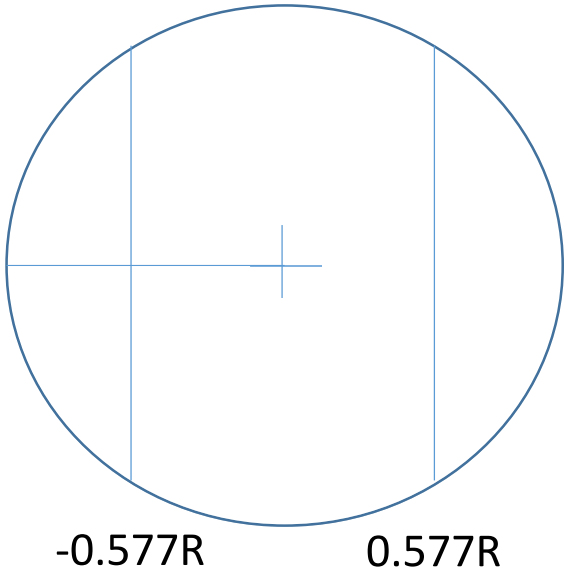
Gaussian integration method leads a proper definition of the chordal positions and their relevant weigths.

E.g. 2 paths:

$$\boxed{\begin{gathered} position = \pm\frac{1}{\sqrt{3}} \\ w_{1,2} = 1 \end{gathered}}$$

$$\boxed{v_{meas} = \sum_{i=1}^{n} w_i v_{path,i}}$$

Path velocities integration rule



The most common number of paths is four, for which

$$x_{1,2} = \pm 0.339981$$
$$x_{3,4} = \pm 0.861136$$

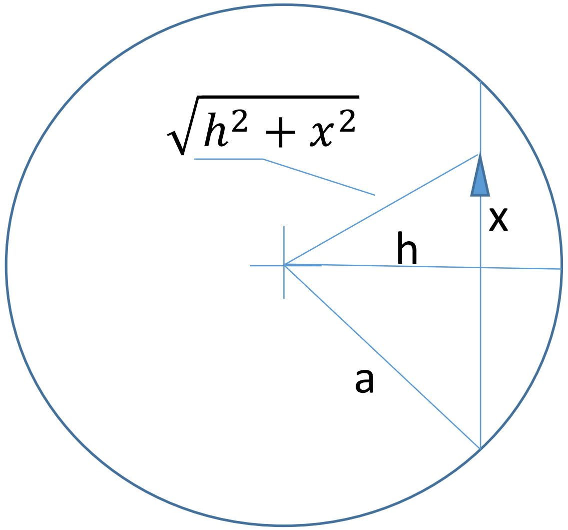
,

$$w_{1,2} = 0.652145$$
$$w_{3,4} = 0.347854$$

Velocity profile may alter the ultrasonic waves flight times, ultimately the measurement accuracy.

$$\Delta t = \frac{2\cot\theta}{c^2}\int_{-\sqrt{a^2-h^2}}^{+\sqrt{a^2-h^2}} V(h^2+x^2)dx$$

$$c^2 = \frac{\gamma P}{\rho}$$ Speed of sound

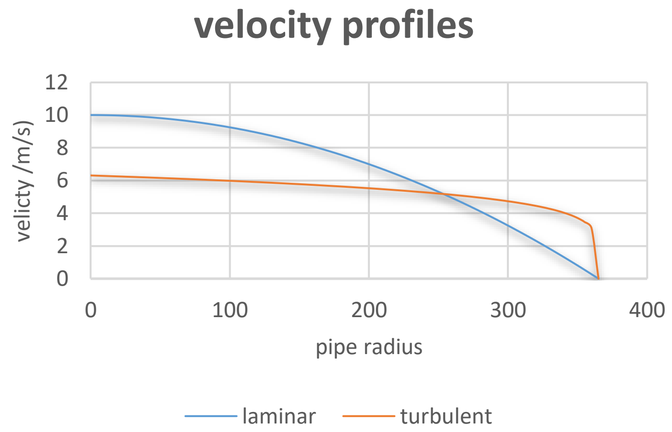


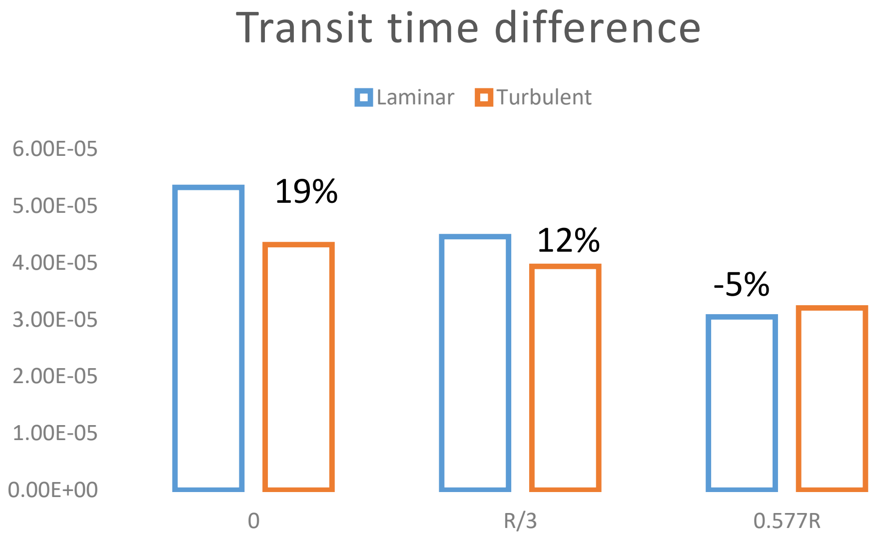
This simple mathematical model was tested with two velocity profiles:

$$V(r) = \frac{(1+2n)(1+n)}{2n^2} V_m (1-\frac{r}{a})^{\frac{1}{n}}$$ Turbulent flow (n=6)

$$V(r) = 2V_m[1-(\frac{r}{a})^2]$$ Laminar flow

Methane in a ID=730 mm pipe
Vm=5 m/s,
P=70 bar





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ISA Italy Section

Ultrasonic flow meter principle – uncertainty contribution due to measurement and calculations

Term	Type and effect	Contribution	NOTES
Transit times	Repeatabilty	Turbulence Incoherent noise Coherent noise Clock resolution Electronic stability Spurious signal detection	
	Systematic	Possible deposit at transducer level Sound refraction Beam reflection	- - Eliminated with calibration or recalibration
Mathematical	Systematic	Inaccuracy of integration model	
Installation	Systematic	Pipe configuration In flow profile (different from calibration) Initial wall roughness and roughness along time Wall deposit Use of Flow conditioner	- - - - Eliminated if USM is calbratated with FC
Meter body	Systematic	Measurement uncertainty of dimensional quantities Out of roundness P&T correction inaccuracy	Eliminated with calibration or recalibration sic Sic
Calibration	Systematic	Calibration laboratory uncertainty and repeatability USM repeatabilty during calibration	

Ultrasonic flow meter principle – uncertainty contribution due to calculation of gas parameter

Term	Type and effect	Contribution	notes
Density	Systematic	Uncertainity and repeatability of the densitometer Density temperature\pressure correction (calibration and inline)	
Compressibility	Systematic	EOS model uncertainty GC (or other analysis) uncertainty	
Pressure	Systematic	Trasnmitter uncertainty Stability of the instrument RFI effects on instrument Enivormnetal condtions (P,T) Mounting Vibration	
Temperature	Systematic	Trasnmitter\element uncertainty Stability of the instrument RFI effects on instrument Enivormnetal condtions (P,T) Mounting Vibration	
Flow computer	Systematic	Calculations Signal acquisition loop	

Uncertainty of the measurement, simplified model

$$(\frac{u_c(q)}{q})^2 = u_{cal}^2 + u_{op}^2 + u_{com}^2 + u_{fc}^2$$

Uncertainty of the inline volumetric flow rate

$$(\frac{u_c(q_s)}{q_s})^2 = u_c^2 + u_p^2 + u_t^2 + u_{z/z0}^2$$

Uncertainty of the standard volumetric flow rate

$$(\frac{u_c(E)}{E})^2 = u_{qs}^2 + u_{Hs}^2$$

Uncertainty of the energy flow rate

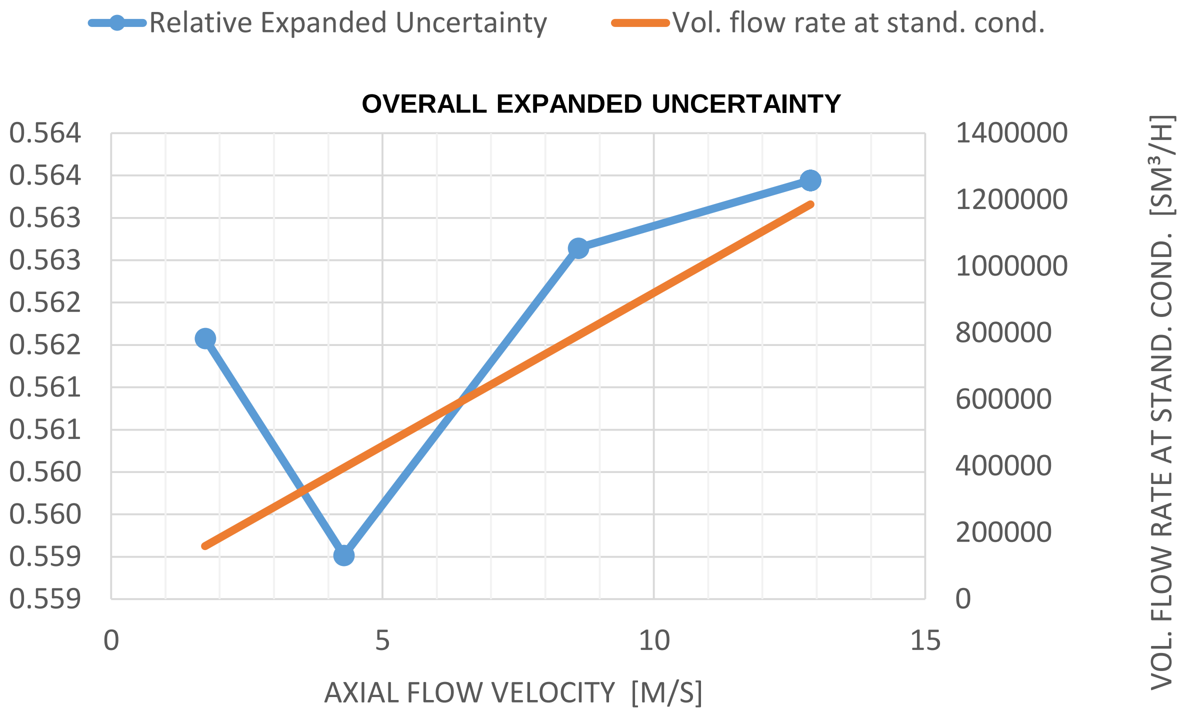
u_{cal} : standard uncertainty of the meter after calibration
u_{op}: standard uncertainty of the meter in operation
u_{com}: standard uncertainty of the signal transmission
u_{fc} : standard uncertainti of the flow computer acquisition and AD conversion
u_P : standad uncertainty of the pressure measurment
u_T : standard uncertaintiy of the temperature measurement
$u_{Z/Z0}$: standard uncertainity of the compressibility factor calculation (EOS and analysis)
u_{HS} : standard uncertainty of the calorific value calculation or analysis

Ultrasonic flow meter principle – uncertainty

USM CALIBRATION RESULT (after correction)

Q_i/Q_p [%]	Q_i [m^3/h]	Deviation [%]	CMC [%]	U_{tot} [%]
74.7	19411	0.00	0.17	0.21
49.9	12965	0.04	0.17	0.20
24.8	6458.8	0.03	0.17	0.19
10.0	2607.2	0.00	0.17	0.20

Measurand	U%(95%)
USM (calibration)	0.21 – 0.20
Pressure	0.16
Temperature	0.0487
Compressibility factor (model and analysis)	~ 0.34
Installation effects	0.16



Typical uncertainty (U) for an ultrasonic meter run is 0.5 – 0.7 %

4.
Case study

BAUMGARTEN SITE

Operators: EUSTREAM, TAG

6 x 30” LEFM 380Ci installed in parallel at the BAUMGARTEN Border Station in Austria replacing existing Orifice Stations

BAUMGARTEN receives 1/3 of Russian gas into Europe and distributes this within the Austria network and towards Northern Italy

Application challenge: Only 10 available upstream and flow conditioners were to be avoided due to pressure drop and compression costs

Cameron LEFM 380Ci is an OIML R137 Class 0.5 device with a minimum of 5D and no flow conditioner

ARNOLDSTEIN STATION

Major Import Station accepting gas from Austria into Northern Italy

Operator: TAG

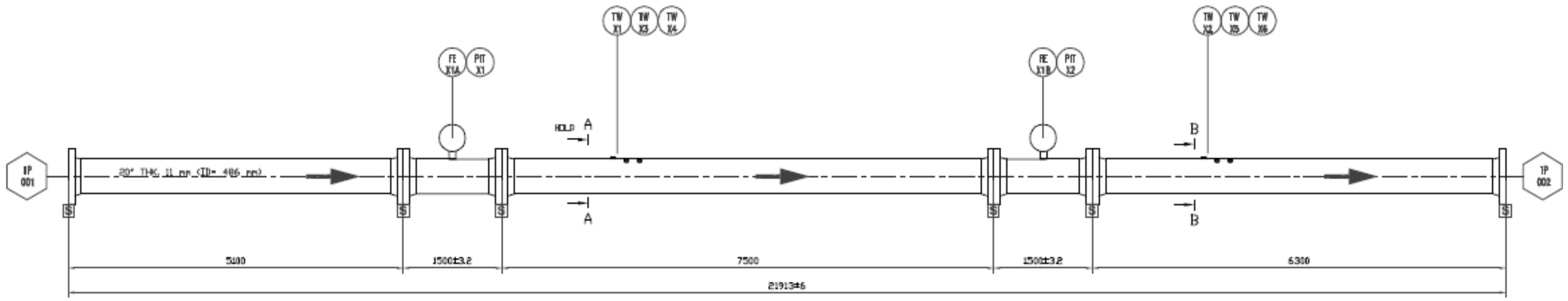
Onshore Austria

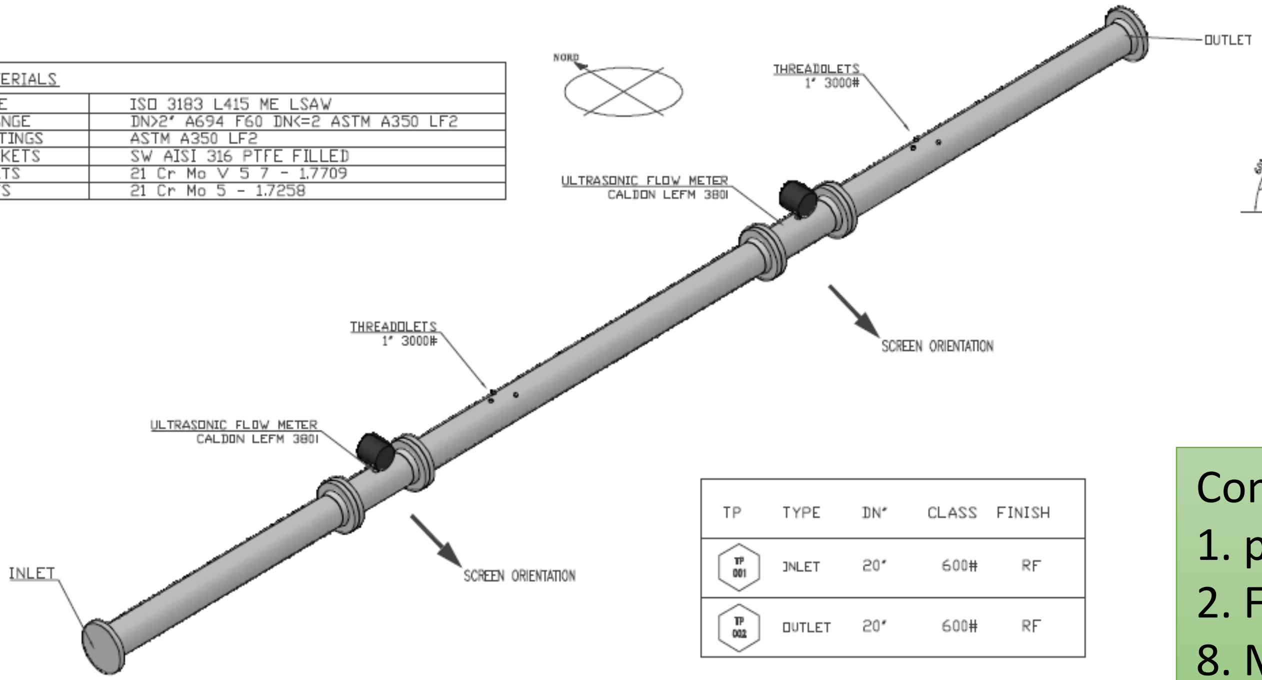
16 off 20” Cameron LEFM 380Ci mounted in series within an 8 stream system configuration

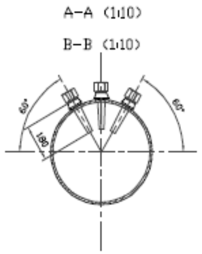
Picture of meters being installed and insulation added

MAIN PROJECT CONSTRAINTS

#	Type	Description
1	Measurement	Pay&check UFM configuration Class 0.5 OIML
2	Measurement	Class 0.5 OIML R137
3	Measurement\Environmental	Data transfer via DSFG bus, typical of german world
4	Enviromental	Maintain calibration setup in installation
5	Environment	Respect the tie-in dimensions, i.e. fit overall length of the line.
6	Environment	Materials as per end user heritage
7	Environment	Lead time in accordance with plant shut down
8	Environment	maximize availability of the measurement







MATERIALS	
PIPE	ISO 3183 L415 ME LSAW
FLANGE	DN>2" A694 F60 DN<=2 ASTM A350 LF2
FITTINGS	ASTM A350 LF2
GASKETS	SW AISI 316 PTFE FILLED
BOLTS	21 Cr Mo V 5 7 - 1.7709
NUTS	21 Cr Mo 5 - 1.7258

TP	TYPE	DN"	CLASS	FINISH
TP 001	INLET	20"	600#	RF
TP 002	OUTLET	20"	600#	RF

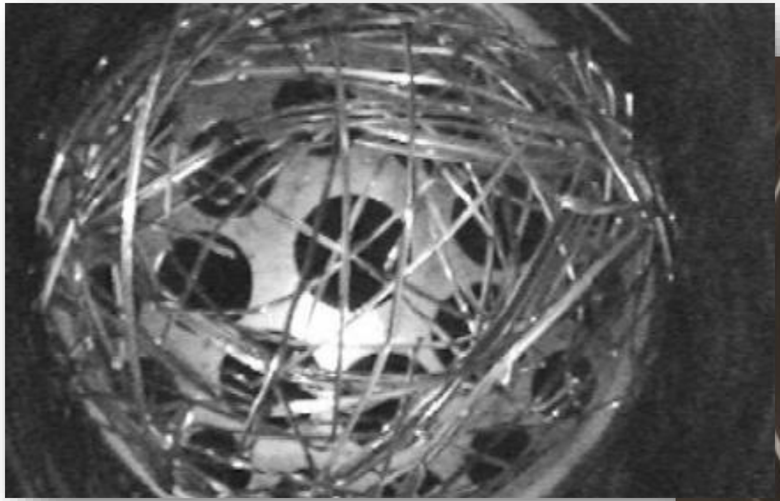
Constraint respected:
1. pay&check
2. Fit the available space
8. Maximize maintenability

Flow conditioner and calibration issues

No flow conditioner used

- No maintenance concerns
- No additional pressures losses
- *Only the meter itself need be returned to the lab for calibration*

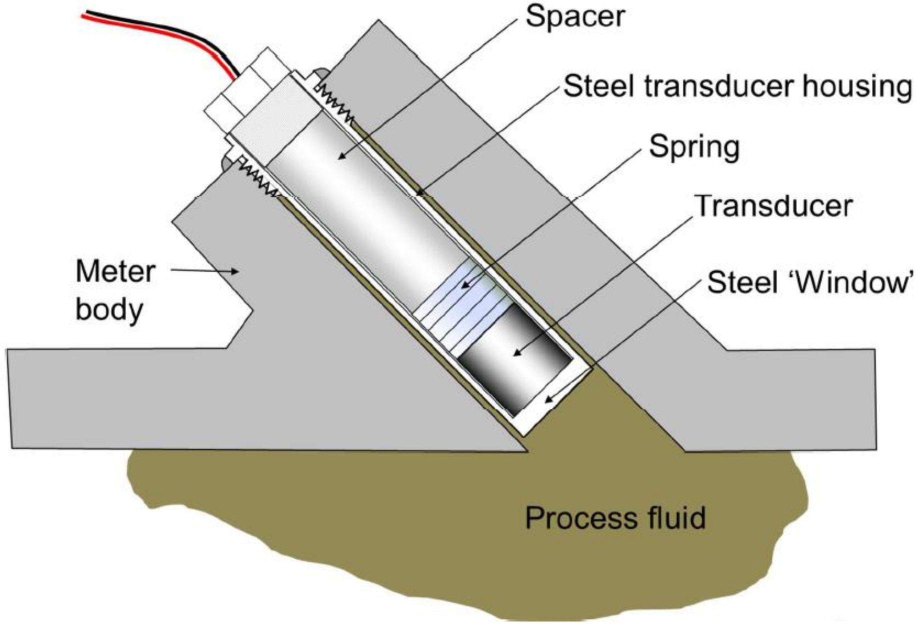
If a flow conditioner is to be used the meter should be calibrated along with its flow conditioner in the correct location and orientation.
This set up should be **carefully maintained in the field…**

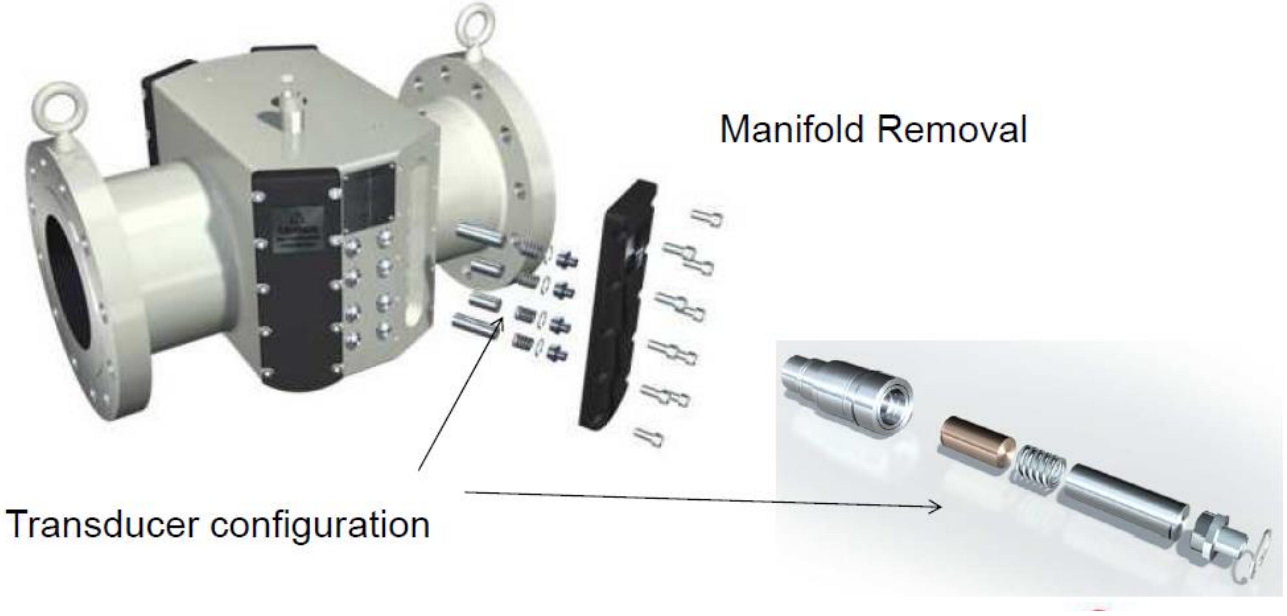


Installing a flow conditioner at any position in the meter run upstream of the USM will cause a change of the meter's indicated flowrate. This change depends on many factors (e.g. flow conditioner type, meter type, position relative to the USM, flow perturbation upstream of the flow conditioner, etc…)… To avoid this additional uncertainty, the best option is that the USM is calubrated with the actual flow conditioner and meter tube as one package (USMP)

ex ISO 17089-1

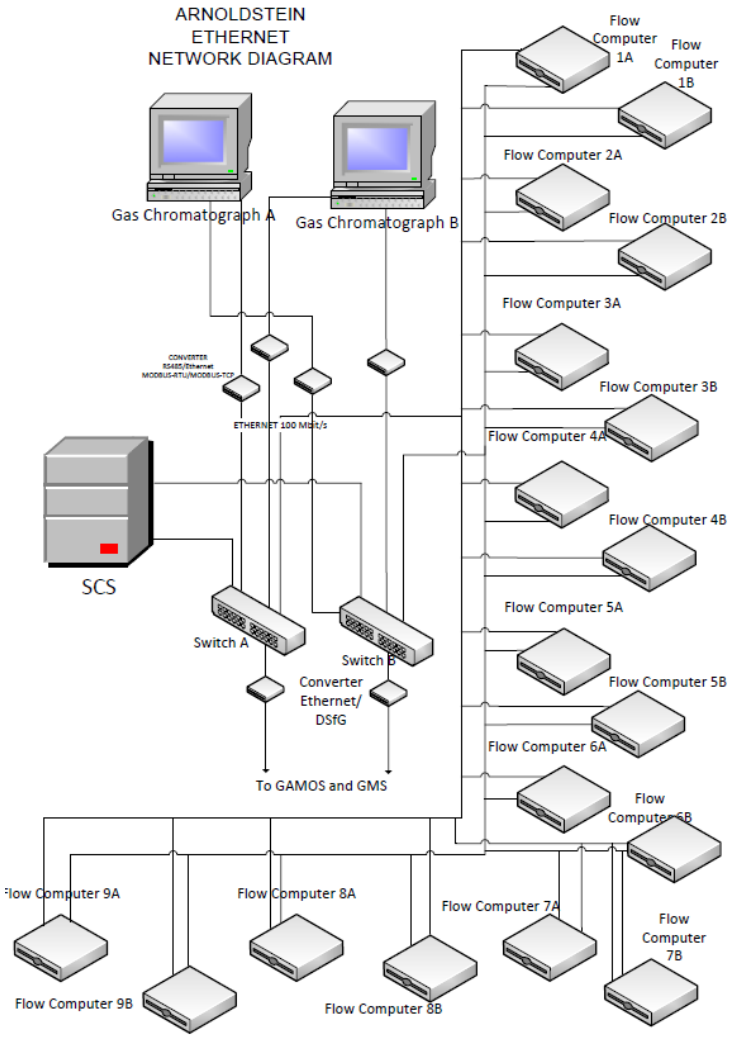
TRANSDUCER ARRANGMENT IN USED UFM

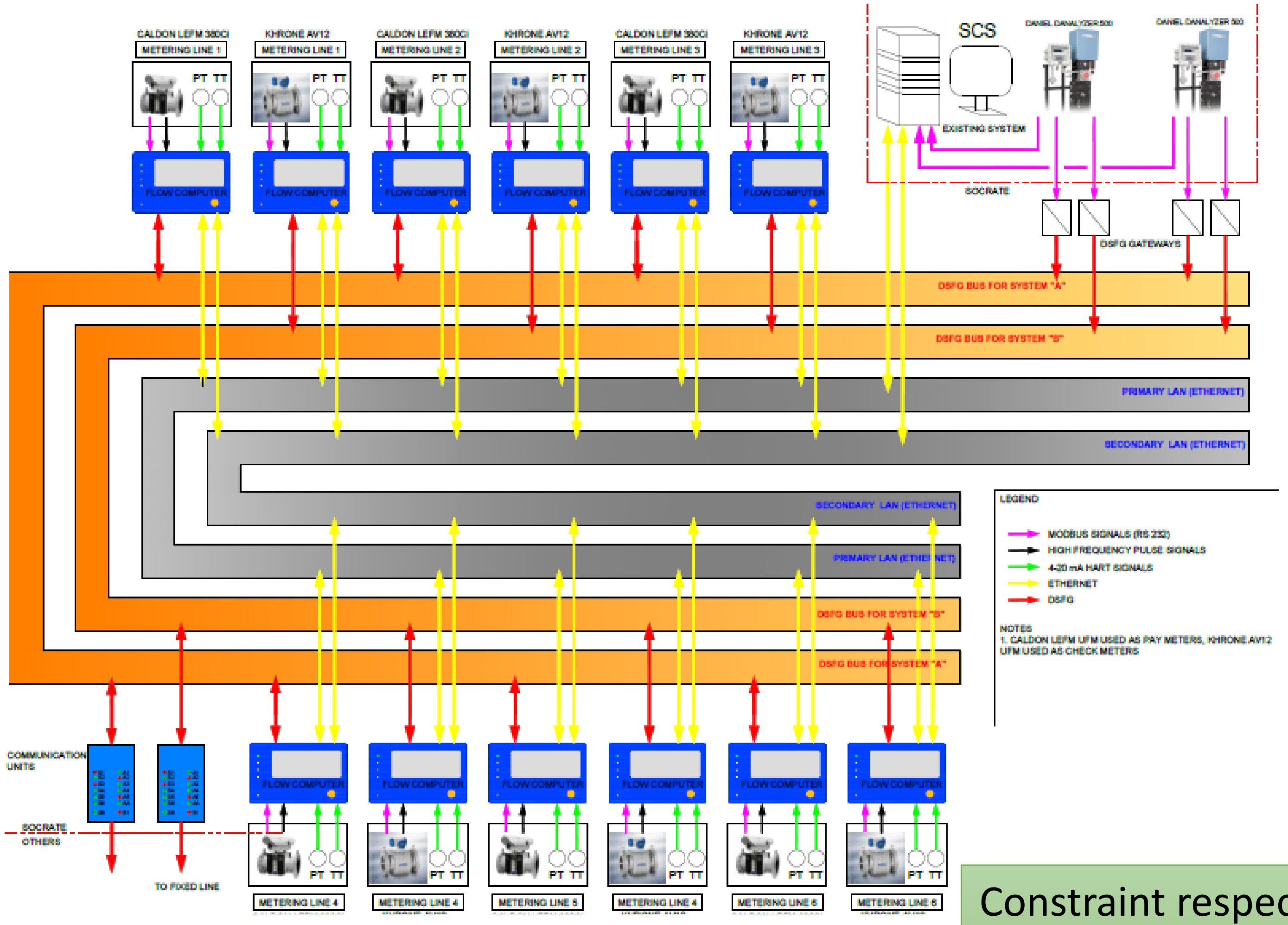




Constraint respected:
2. OIML 0.5 Class
8. Maximize measurement availabilty and maintenabilty

Revamping a metering system– case study





Constraint respected:
3. Dsfg bus DT

Constraint respected:
4. Maintain calibration setup in field installation

?

Keep Internal conditions along time

Corrosion alters
meter performance!

Application of special corrosion and adhesion resistance coatings can help preserve the original condtion without alteiring its performance.

The coating can be applied to both the body and the transducer housing

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CALDON LEFM 380 Ci

- 8 paths design
- Flow conditioning not required
- Unique transducer arrangement
- Internal coating
- OIML R137 Class 0.5

NMi

Certificate of conformity

Certificate number : CPC-12200428-01
Page 1 of 1

Issued by	NMi Certin B.V. Hugo de Grootplein 1 3314 EG Dordrecht The Netherlands
In accordance with	- OIML R 137-1&2:2012 "Gas meters"
Applicant	Cameron 1000 McClaren Woods Drive Coraopolis PA 15108, Pennsylvania United States
Submitted	**An Ultrasonic gas meter**
	Manufacturer : Cameron Type : Caldon LEFM 380Ci
Characteristics	Destined for the measurement of : gas volume Accuracy class OIML R137-1&2:2012 : Class 0,5 Accuracy class MID : Class 1 Mechanical environment class : M2 Electromagnetic environment class : E2 Temperature range : -40°C / +70°C