A new generation of multi-beam ultrasonic flowmeters

type series SMARTSONIC SC XXXX

(Business and technical report on the state of development project solutions in 2024)

1 to 4-beam flowmeters type SMARTSONIC
dimensions DN32 – DN500

3 to 8-beam flowmeters type SMARTSONIC
dimensions DN100 – DN1200

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1. The intention of developing a new generation of SMARTSONIC multi-beam ultrasonic flowmeters

Based on 25 years of experience in the development, production and sale of more than 10,000 ultrasonic liquid flowmeters of larger dimensions, mainly in the DN32 - DN1200 range, it was decided in 2016 by the management of ELIS PLZEŇ a.s. invest in the development of a new generation of multi-beam ultrasonic flowmeters that can be used to measure the flow and consumption of liquids and gases.

Based on previous experience, we were led to this decision by the knowledge that the ultrasonic principle of flow measurement is extremely promising. Newly developed integrated circuits, guaranteeing the measurement of very short times with extremely high accuracy, make it possible to implement ultrasonic flowmeters in a wide range of dimensions with a measurement range greater than R = 1000. According to the requirements of individual applications (measurement accuracy, resistance to hydraulic disturbances), it is possible to implement appropriate multi-beam flow meters.

This technical progress inspired us to develop completely new generation ultrasonic flowmeters, characterized in particular by a universal system solution enabling the implementation of multi-beam ultrasonic flowmeters for liquids (in the next stage also for gases) for various applications with a relatively small, subsequent scope of development, design and construction work fulfilling the following characteristics and standard technical parameters:

Supply voltage	24V AC/DC	
Dimension range	DN32 to DN1200	
Number of ultrasonic beams used	1 to 8	
Velocity of the measured medium	0 to 10 m/s	
Temperature of the measured medium	-40° C to 150° C	
Pressure of the measured medium	PN6 to PN250	
Kinematic viscosity of the measured medium	0.1 to 400 cSt	
Ambient temperature	-40° C to 60° C	
Environment	normal, with explosion hazard	
Measurement accuracy	1 - beam flow meter	± 1.0%
	3 - beam flow meter	± 0.4%
	5 - beam flow meter	± 0.25%
	8 - beam flow meter	± 0.15%
Electrical outputs	pulse, frequency, current 4 to 20 mA	
Electrical inputs	binary, current 4 to 20 mA	
Communication	RS485 - Modbus RTU	
Measuring range according to OIML 49, EN ISO 4064	R > 1000	
Design	compact, separate	
Protection	IP67	
Expected certifications	CE, MID, OIML, ATEX, IECEx	

2. Current state of applicability of development results to date

At this stage of development, a type series of multi-beam ultrasonic liquid flowmeters SMARTSONIC SC XXXX were developed with the possibility of using the development results for the future development of gas flowmeters.

Hardware

It is developed and verified modularly designed, universal hardware enabling the realization of 1 to 8 beam liquid flowmeters. New, optimized ultrasonic probes and production concepts of measuring sensor bodies have also been developed for different dimensions, the number of ultrasonic beams used and the required applications.

Firmware

A basic universal firmware for flow meters has been developed, enabling the implementation of 1 to 8 beam flow meters in the range of dimensions DN32 - DN1200.

Software

Software of the FLOSET type has been developed, enabling the setting of the required parameters of the evaluation electronics and the calibration of complete flowmeters at the test station via MODBUS RTU communication.

Test functional samples in prototype design

In order to verify the required functions, properties and parameters of the developed flowmeters, 2 pieces of representative functional samples in prototype design with the following dimensions and parameters were designed and manufactured:

- 3-beam flow meter, dimension DN100, type SMARTSONIC SC 4131

- 5-beam flow meter, dimension DN200, type SMARTSONIC SC 6151

3. The technological level of the solution of the development project SMARTSONIC

The technological level of SMARTSONIC series flowmeters is characterized by the following facts:

- **The evaluation electronics** is designed in a modular way for the possibility of implementing one to eight beams flowmeters according to customer requirements and relevant applications. During the development, the latest integrated processors, special IO for measuring very short times and other electronic circuits including the latest component base, exclusively with multi-layer printed circuits and SMD assembly were used, see Fig. No. 1.

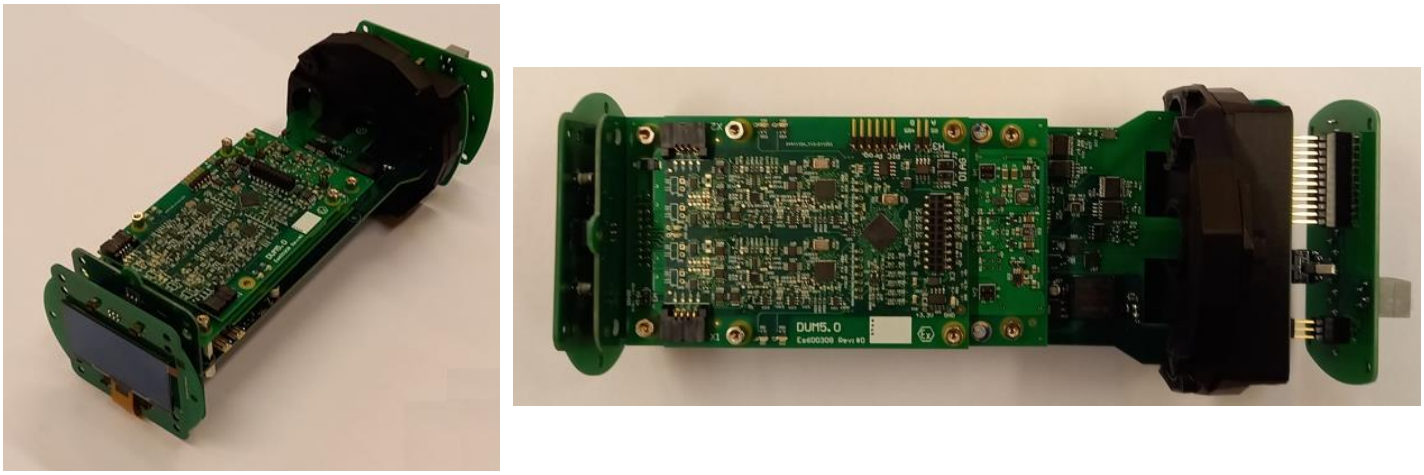

Fig. No. 1 Evaluation electronics block of SMARTSONIC flow meters

- **Ultrasonic probes** are one of the most important elements of ultrasonic flowmeters. They were developed and optimized as part of the SMARTSONIC development project using many years of experience in the development and production of ultrasonic flowmeters. The standard design is designed for temperatures of the measured medium of a maximum of 150˚C, for higher temperatures it is possible to use developed probes up to a medium temperature of 200˚C - see Fig. 2.

Fig. No. 2 A pair of standard ultrasound probes

- Complete ultrasonic flowmeters will be produced in two versions:

  - 1 to 4 beam flowmeters according to Fig. 3

  - 3 to 8 beam flowmeters according to Fig. 4

Fig. No. 3 1 to 4 beam flowmeters

Fig. No. 4 3 to 8 1 to 4 beam flowmeters

4. Results of selected tests performed

A number of tests and measurements were carried out on the above-mentioned functional samples 3 and 5 beam flowmeters in the prototype design of dimensions DN100 and DN200. All tests were performed on our own, metrologically certified test stand type GS 1500/32-800 (see Fig. 1) with the following parameters:

- Dimensions of tested flowmeters ……..DN32 to DN800
- Test flow range …….. 0.05 to 2000 m³/h
- Measuring liquid temperature range …….. 10℃ to 30℃
- Primary standards …… 2 pcs of Mettler Toledo scales, range 12,000 kg and 300 kg
- Secondary standards ……4 pcs of electromagnetic flow meters FLONET FN2015.1

Fig. No. 5 Metrologically certified test stand type GS 1500/32-800

In this presentation, we present the main test results characterizing the most important parameters of the mentioned above 3 and 5 beam ultrasonic flowmeters. For this purpose, the following parameters were tested and evaluated:

- Measurement error depending on the flow rate
- Repeatability of measurements depending on the flow rate
- Measurement range depending on the maximum permissible measurement error

To determine the objective properties of the flowmeters, i.e. the measurement error, to evaluate the repeatability of the measurement and the measurement range, the measurement was performed repeatedly 10 times at each flow rate.

4.1. Tests of the 3-beam flowmeter SMARTSONIC SC 4131- DN100

Fig. No. 6 Flow meter during tests on the test stand

4.1.1. Dependence of the measurement error on the flow rate

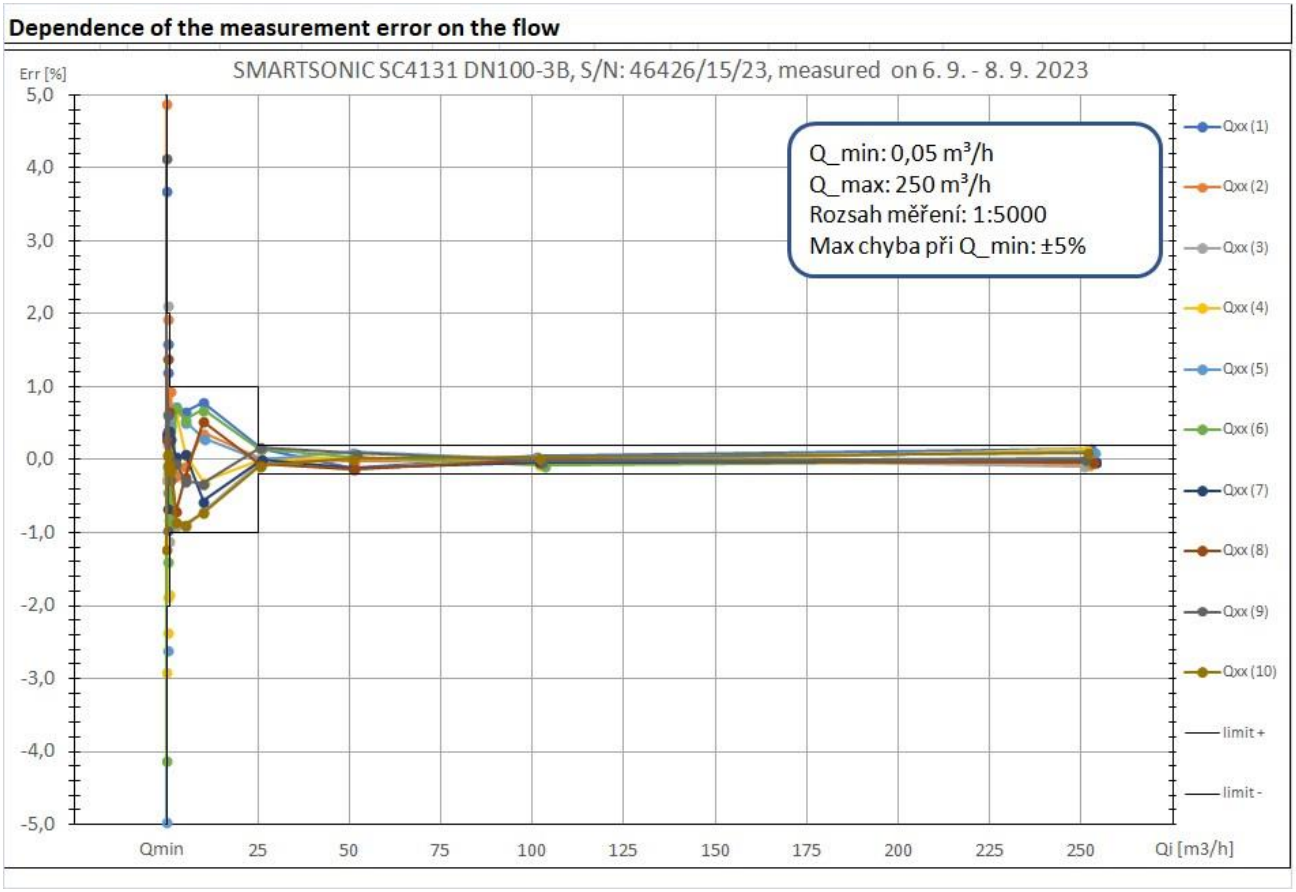

Fig. No. 7 Dependence of the measurement error on the flow rate, measurement range R according to OIML 49

4.1.2. Measuring range R

- R > 100 for a max. measurement error of ± 0,5% at flow rate Qmin 2,8 m³/h
- R > 250 for a max. measurement error of ±1% at flow rate Qmin = 1 m³/h
- R > 1000 for a max. measurement error of ±2% at flow rate Qmin = 0.25 m³/h
- R > 5000 for a max. measurement error of ±5% at flow rate Qmin = 0.05 m³/h

Explanations:

- R – measurement range Qmax/Qmin
- Emax – permissible maximum measurement error in the measurement range R
- 3P, 5P – number of ultrasound beams

4.2. Tests of the 5-beam flowmeter SMARTSONIC SC 6151- DN200

Fig. No. 8 Flow meter during tests on the test stand

4.2.1. Dependence of the measurement error on the flow rate

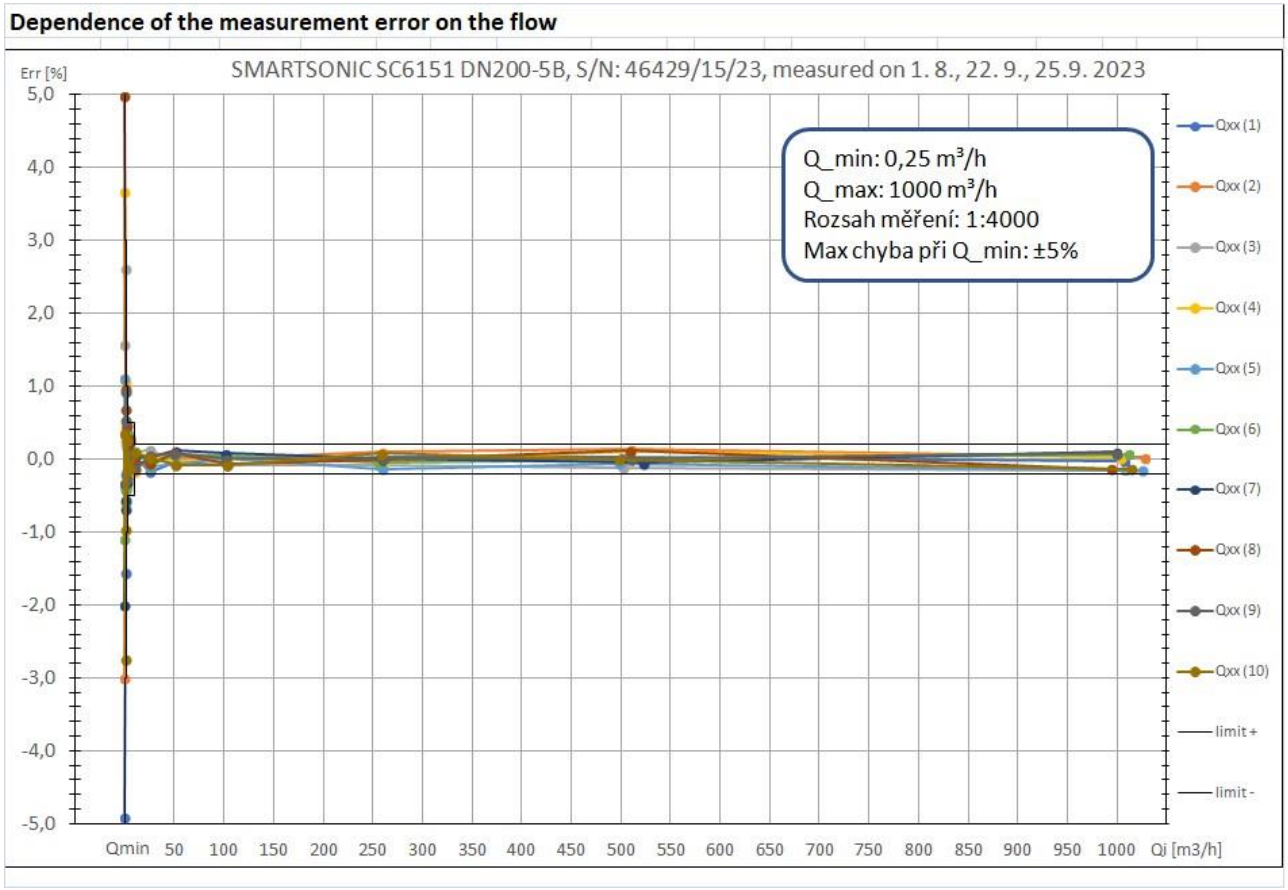

Fig. No. 9 Dependence of the measurement error on the flow rate**,** measurement range R according to OIML 49

4.2.2. Measuring range R

- R > 100 for a max. measurement error of ± 0,2% at flow rate Qmin = 10 m³/h
- R > 400 for a max. measurement error of ± 0,5% at flow rate Qmin = 2,5 m³/h
- R ≥ 1000 for a max. measurement error of ±1% at flow rate Qmin = 1 m³/h
- R ≥ 2000 for max. measurement error ±3% at flow rate Qmin = 0.5 m³/h
- R ≥ 4000 for max. measurement error ±5% at flow rate Qmin = 0.25 m³/h

Explanations:

- R – measurement range Qmax/Qmin
- Emax – permissible maximum measurement error in the measurement range R
- 3P, 5P – number of ultrasound beams

4.3. Main conclusions from the conducted tests

The tests carried out show that the developed flow measurement system achieves top technical parameters. In comparison to standard flowmeters of various principles used, it is mainly about achieving very high measurement accuracy in a wide range of measured flow with dimensions ranging from approximately DN32 up to dimensions without principled technical limitation larger than DN1200. Functional samples meet the expected basic parameters.

5. Expected areas of application for the use of SMARTSONIC series flowmeters

The newly developed multi-beam ultrasonic liquid flowmeters of the SMARTSONIC series achieve high technical parameters and can be used in several applications.

It is advisable to use them especially in those applications where it is problematic to achieve the required technical parameters when measuring the flow of liquids with existing flowmeters. These are especially applications where the following technical requirements are critical:

- flow measurement of not only electrically conductive but also electrically non-conductive liquids, e.g. demineralized, chemically treated or distilled water, various chemical liquids including crude petroleum and processed liquids, etc.
- requirement for high measurement accuracy
- requirement for a large measurement range, e.g. R > 1000
- requirement for flow measurement at high liquid temperatures T>150˚C
- requirement for flow measurement at high liquid pressures PN>100 bar

These requirements are often found in the following industries in particular:

- Water industry
- Energy
- Heating industry
- Heat and cold energy measurement
- Pharmaceutical industry
- Chemical and petrochemical industry
- Oil industry
- Other light and heavy industry

6. Brief evaluation of the current state of the SMARTSONIC development project

- as part of the SMARTSONIC development project, essential parts of the entire system, including the functionality of complete flow meters, were developed and verified by basic tests. In particular, the following were verified on functional samples in prototype design:
- correct conceptual design of multi-beam flowmeters
- development of all main parts of flowmeters, i.e. modular evaluation electronics, ultrasonic probes and measuring ultrasonic sensors using the most modern components, elements and technologies
- development of all main parts of flowmeters, i.e. modular evaluation electronics, ultrasonic probes and measuring ultrasonic sensors using the most modern components, elements and technologies
- the main parts of the firmware and software enabling all the basic measuring functions of the flowmeters, including electrical outputs and MODBUS RTU communication
- verified complete manufactured 2 pieces of functional samples in the prototype design of multi-jet flowmeters confirming the achievement of the main specified parameters of the flowmeters (accuracy, repeatability and measurement range)
- design documentation of functional samples in prototype design

7. Expected stages for the completion of the SMARTSONIC development project, the introduction of repeated production for application on the world market

7.1. Implementation of recommended documentation modifications resulting from prototype tests

7.2. Completion of selected firmware and software features

7.3. Proposal of the final design and design of the flowmeters

7.4. Processing of complete production documentation

7.5. Processing of commercial and technical documentation

7.6. Prototype tests

7.7. Production of prototypes of flowmeters for certification purposes (CE, ATEX, MID, OIML, IECEx, PED)

7.8. Implementation of certifications¨

9/2024