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SAFETY FLOW MONITORING OF ETHYLENE FLOW IN SUPERCRITICAL STATE USING ULTRASONIC FLOW-MONITORING METHOD

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BEZPEČNÉ MERANIE ETÉNU V SUPERKRITICKOM STAVE POMOCOU ULTRAZVUKOVÉHO PRIETOKOMERA

БЕЗОПАСНЫЙ МОНИТОРИНГ ПОТОКА ЭТИЛЕНА В СУПЕРКРИТИЧЕСКОМ СОСТОЯНИИ С ИСПОЛЬЗОВАНИЕМ УЛЬТРАЗВУКОВОГО МЕТОДА МОНИТОРИНГА ПОТОКА

Abstract
For some production processes is the Ethylene used in supercritical state. It means, a state, where it is neither in liquid nor gas form. The medium is transported using lining with special strong lines under pressures above 2000 bars and temperature above 100 °C. This article reports practical test flow measurement without process interruption using a clamp-on ultrasonic flow meter. Technology for such processes is defined as explosive area, therefore devices and equipment for such conditions to be designed.
Key words: *Supercritical Ethylene, Ultrasonic monitoring, Flow, Safety*

Abstrakt
Pri niektorých výrobných procesoch sa používa etén v nadkritickom stave. To znamená, v stav, kde nie je ani v kvapalnej, ani v plynnej forme. Médium sa prepravuje pomocou hrubostenného potrubia pod tlakom nad 2000 barov a teplotou nad 100 ° C. V tomto článku sa uvádza praktické meranie prietoku merania bez prerušenia technologického procesu pomocou ultrazvukového prietokomeru "clamp-on". Technológia pre výrobné procesy tohto typu je špecifikovaná ako výbušná zóna, preto aj zariadenia musia byť na takéto podmienky prispôsobené.
Kľúčové slová*: Superkritický etén, ultrazvukové meranie, prietok, bezpečnosť*

Абстракт
Для некоторых производственных процессов используется этилен в сверхкритическом состоянии. Это означает, что состояние, в котором он находится не есть ни жидкостью, ни газом. Он транспортируется с использованием обшивки специальнной усиленной арматурой под давлением выше 2000 бар и температурой выше 100 °C.В этой статье описывается практическое измерение тестового потока без прерывания процесса с использованием зажимного ультразвукового расходомера. Технология для таких процессов класифицируется как взрывоопасная, поэтому устройства и оборудование для таких условий должны быть разработаны с учетом взрывопасности.
Ключевые слова: *Сверхкритический этилен, Ультразвуковой контроль, Поток, Безопасность*

Research type: *research paper*

Prolog

The task was to perform a test flow measurement on lining with ethylene under high pressure of 2400 bars and 120°C temperature using a save method without insertion into the process. As the best method has been choosen

the ultrasonic monitoring system from a German producer.Today, acoustic/ultrasonic flowmeters utilize clamp-on and wetted transducers, single and multiple paths, paths on and off the diameter, passive and active principles, contrapropagating transmission, reflection (Doppler), tag correlation, vortex shedding, liquid level sensing of open channel flow or flow in partially-full conduits, and other interactions.[1] This producer has many years experiences in ultrasonic flow monitoring of a large variety of applications. The measuring has been done under supercritical condition of the medium in explosive area Ex Zone 1, where the required safety rules to be kept. The measuring has been performed using ultrasound clamp-on flow meter G608 from German company FLEXIM, GmbH.

Ethylene

Ethene (ethylene) is the building block for a vast range of chemicals from plastics to antifreeze solutions and solvents.[2]Ethylene, the most important basic chemical product, is produced for the following uses: Polyethylene for plastic films, plastic bottles, insulating material; Ethylene dichloride (precursor for PVC) and for solvents (resins, asphalt, bitumen); as precursor for polystyrene (packaging) and as Ethylene oxide (EO) for Monoethylenglycol (MEG). In Europe Ethylene is handled exclusively via pipeline and deapsea vessels.[3]At 27,000 ppm, just a spark can ignite ethylene and cause a deadly explosion.[4]

Ethylene as Supercritical fluid

Any substance is characterized by a critical point which is obtained at specific conditions of pressure and temperature. When a compound is subjected to a pressure and a temperature higher than its critical point, the fluid is said to be supercritical.[5]In the production of the polymer, supercritical ethylene is charged into a high-pressure reactor of proprietary design.[6]

Measuring point

The measuring has been performed in explosive area and must be done under trained personell only. The supervisors have special personal air-monitoring device to monitor the ambient air to avoid work under explosive conditions. The measuring point must be pointed on the proper distance from fittings, valves, boundings or pumps to avoid possible interferences or signal reflections that could disturb the measuring.

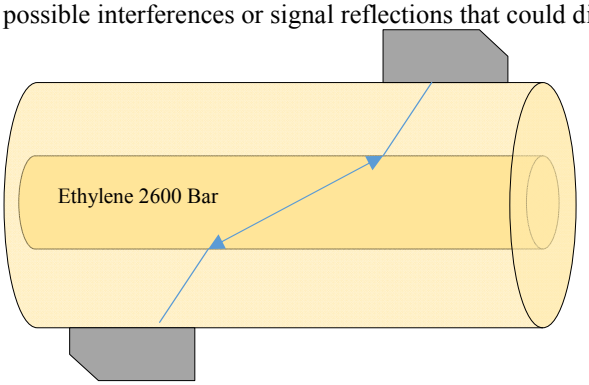


Figure 1 Measuring point of the Ethylene flow test

[1]L.C. Lynnworth, Yi Liu, Ultrasonic flowmeters: Half-century progress report, 1955–2005, Ultrasonics, Volume 44, 2006, Pages e1371-e1378, ISSN 0041-624X, http://dx.doi.org/10.1016/j.ultras.2006.05.046. (http://www.sciencedirect.com/science/article/pii/S0041624X06000849)
Keywords: Ultrasonic; Flowmeters; Multiparameter; Mass flowrate
[2]The Essential Chemical Industry. - [on-line] available on URL:http://www.essentialchemicalindustry.org/chemicals/ethene.html
[3] BASF. Ethylene. - [on-line] available on URL:http://product-finder.basf.com/group/corporate/product-finder/en/brand/ETHYLENE
[4] CATALYTIC GENERATORS. - [on-line] available on URL:http://www.catalyticgenerators.com/ethylene-c2h4/
[5]LE PORTAIL DES FLUIDES SUPERCRITIQUES. - [on-line] available on URL:http://www.supercriticalfluid.org/Supercritical-fluids.146.0.html
[6]McGUIRE, J.T., HAYRAPETIAN V.A. Very high head pump. Flowserve Corporation, Pump division, Veron, California.http://turbolab.tamu.edu/proc/pumpproc/P22/07.pdf

Flow measuring principle

The technique most ultrasonic flow meters use is called transit-time difference. It exploits the fact that the transmission speed of an ultrasonic signal depends on the flow velocity of the carrier medium.[7] The current generation of transit time flowmeters achieve results with 0.5 – 1 % accuracy of full scale.[8] The principle is shown on the following figure.

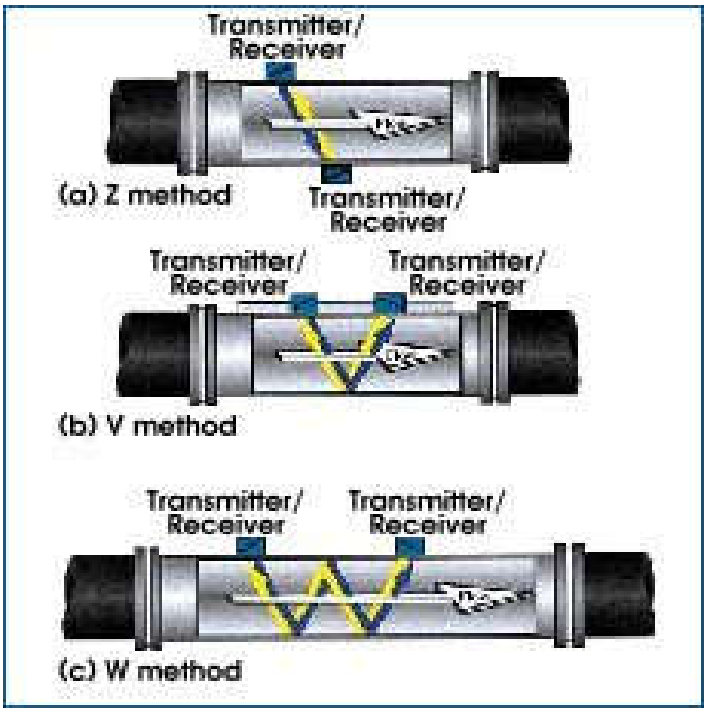


Figure 2 Measuring principle of a ultrasonic flowmeter.[9]

Fluid conditions

The medium, ethylene in supercritical state, has been transported in stainless steel lining with wall thickness of 25 mm. The outer diameter of the pipe is 90 mm.
In such geometry the positioning of the sensors must be very precise. Any small dispossitioningcaused a measuring falldown.
Because of huge vibrations, the sensors to be mounted with a proper mounting system.
In real, the pressure was floating between 2600 bar and 2800 bar, what caused the floating of the flow value.
Using an electronical damping filter implemented in the flowmeter the value has been stabilized.

[7] CHALTRON SYSTEMS. - [on-line] available on URL:https://www.chaltron.com/easterly-wastewater---case-study.
[8]Ultrasonic Flow Management. - [on-line] available on URL:http://www.ufmflowmeters.com/ultrasonic-flow-measurement/.
[9]SENSORS BASIS. Ultrasonic Flowmeter Basics.- [on-line] available on URL:http://www.sensorsmag.com/components/ultrasonic-flowmeter-basics.

Figure 3 Flow monitor FLEXIM G608[10] and flowmeter set[11]

Flow monitor setup

The flow monitor, Designed for industrial use in harsh environments, in gasprocessing and natural gas extraction, chemical industry and in the petroleum industry[12], was setup according to provided parameters of the measuring point, the geometry of the pipe, fluid type and conditions, and data logging. The device is equipped with a datalogger and the measured flow results have been stored into the device memory. Furthermore, the device is able to save so called snaps, what are generally special diagrams allowing the technicians to analyse the signal amplitude, quality and interferencies. This function is then used for better alignment of the device, positioning of the sensors or localization of better measuring point on the line.

Table 1 Flow monitor G608 setup parameters

Outer Diameter	87,06 mm
Wall Thickness	26,00 mm
Roughness	0,0 mm
Pipe Material	Stainless Steel
c-Material	3100,0 m/s
Lining	WITHOUT LINING
Kinem.Viscosity	0,01 mm2/s
Density	0,58 g/cm3
Medium Temperat.	100 C
Trancducer Type	FSP
Sound Path	1 NUM
Transd. Distance	25,7 mm
Damping	10 s
Storage Rate	00:00:10 SAMPLES
Profile corr.	ON
Physic. Quant.	Mass flow
Unit Of Measure	[t/h]/[t]

[10]T&D. FleximFluxus Ultrasonic Gas Flow Meters- [on-line] available on URL:http://www.heattracing.co.uk/sub-product-details/flexim-fluxus-ultrasonic-gas-flow-meters.
[11]BSRIA. - [on-line] available on URL:https://www.bsria.co.uk/instrument/sales/product/flexim-fluxus-f601
[12]FLEXIM. *Portable Ultrasonic Flow Measurement of Gas*. Technical Specification of FLUXUS® G601. Internal document of Flexim GmbH.

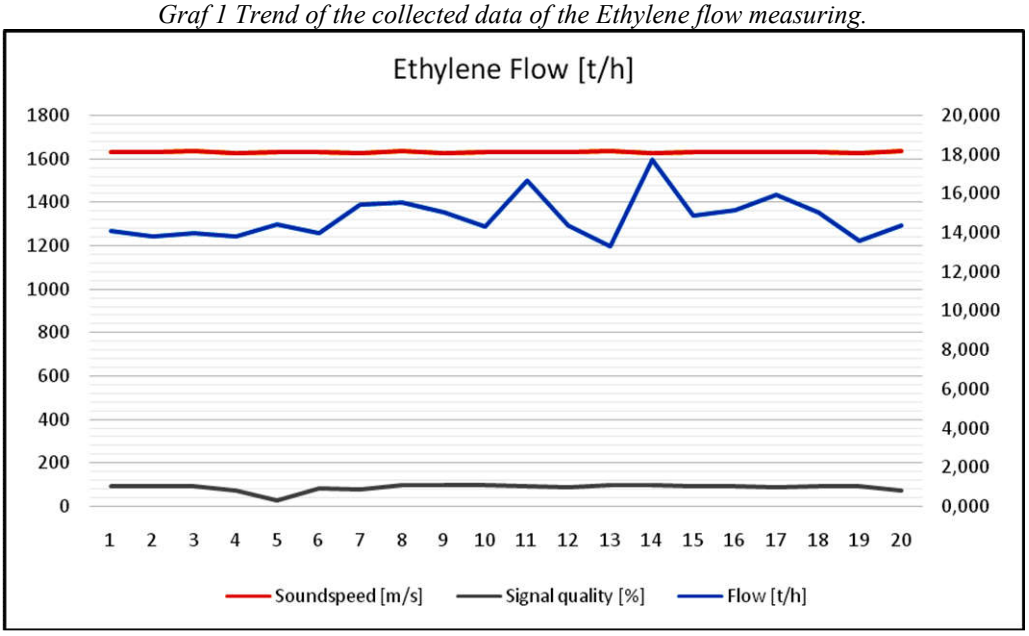
Results of measuring

The data have been collected into the internal memory of the flow monitor. The data were downloaded using a special communication cable of the device set (Figure 3) through RS232 communication protocol to a computer for further processing. The results are shown in Table 2 and Graf 1.

Table 2 Results of the Ethylene flow measuring.

Flow [t/h]	Soundspeed [m/s]	Signal quality [%]
14,083	1628,2	97
13,814	1630,33	96
13,955	1634,02	97
13,810	1624,06	72
14,425	1627,73	27
13,934	1631,4	86
15,420	1626,88	81
15,510	1634,08	99
15,017	1624,89	98
14,295	1627,87	100
16,653	1629,97	95
14,351	1627,63	91
13,283	1633,31	98
17,733	1625,24	100
14,851	1629,75	97
15,134	1632,85	97
15,914	1629,54	90
15,055	1631,46	97
13,567	1624,01	95
14,345	1636,19	72

Graf 1 Trend of the collected data of the Ethylene flow measuring.



Standard deviation determination

The standard deviation has been done using online standard deviation calculator available on portal calculator.net [13].

Table 3 Standard deviation results.

Sample Standard Deviation, s	1.0981293891264
Variance (Sample Standard), s^2	1.2058881552632
Population Standard Deviation, σ	1.0703241319806
Variance (Population Standard), σ^2	1.1455937475
Total Numbers, N	20
Sum:	295.149
Mean (Average):	**14.75745**
Standard Error of the Mean ($SE_{\bar{x}}$):	0.2455491962177

Conclusion

The results analysis shows according to high pressure fluctuation of the medium a stable line of the flow measurement. The pressure has been floating in 200 bar intervals but in 2 seconds (short) and periodical intervals. Using a damping filtering is possible to smooth the flow line and get a stable parameter for further regulation or controlling of the process.

The Ultrasonic methods give a big advantage in engineering praxis because of non-invasive method. This means, the process is not being disturbed by any mechanical action into the process. For such processes under high pressure and temperature, explosive medium, brings this method a safety solution of monitoring the process conditions. Moreover, these types of devices are able to determine the medium inside a process using the sound velocity, monitor concentrations of many kinds of fluids.

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Recenzované dvomi recenzentmi, členmi vedeckej rady konferencie. Za textovú a jazykovú úpravu príspevku zodpovedajú autori.

REVIEW TEXT IN THE CONFERENCE PROCEEDINGS
Contributions published in proceedings were reviewed by two members of scientific committee of the conference. For text editing and linguistic contribution corresponding authors.

[13]Calculator.net. - [on-line] available on URL:http://www.calculator.net/standard-deviation-calculator.html