XX Fluid Mechanics Conference KKMP2012,
Gliwice, 17-20 September 2012

# INFLEUNCE OF TYPICAL FLOW DISTURBING ELEMENTS ON THE FLOW RATE IN SELECTED AVERAGING PITOT TUBES

Janusz POSPOLITA[1], Mirosław KABACIŃSKI[2], Sławomir POCHWAŁA[3]
*Opole University of Technology, Opole, Poland[1]; Opole University of Technology, Opole, Poland[2]; Opole University of Technology, Opole, Poland[3].*
e-mail: j.pospolita@po.opole.pl

**Introduction**

The measurements of mass and volume streams are some of the most common procedures in industry. The development of a variety of probes with various measurement characteristics is associated with the progress in measurement techniques and the accompanying progress in electronics and microprocessor technology [1,8]. For many years the dominant group involved flow averaging tubes, in particular Pitot tubes. The measurement technique based on a differential pressure metering was subsequently standardized due to its common use. [9]. The basic advantage of using the above measurement technique involves its applicability in a wide range of temperatures and pressures of the media. The technological advancement in terms of new differential pressure transducers which are capable of generating very small measurement uncertainties as well as other secondary devices affected the extension of the measurement range of flowmeters and led to reducing uncertainty of the measured mass and volume streams. For the case of flow in channels with large diameters (D>800mm), in particular when the medium has a considerable temperature in the range of several hundred $^{o}$C, among the known solutions it is difficult to find an alternative to the classical Venturi tube. In such circumstances an alternative is offered by flow averaging Pitot tubes. The flow averaging probes along with their armature and differential pressure transducers are considered to form a single group called averaging Pitot tubes. Fig. 1 presents the design of such flow averaging tubes.

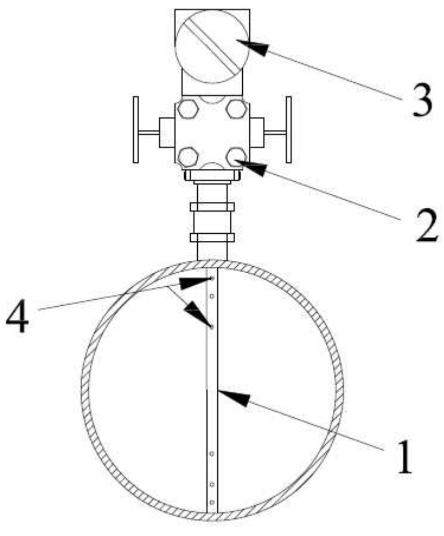


Fig. 1 Averaging Pitot tube, 1- sensor, 2- set of valves, 3- differential pressure transducer, 4- impulse holes.

For the case of flow averaging tubes the relation between the velocity of flow in the pipeline (channel) and differential pressure Δp measure in the averaging chamber takes the form

$$w = K \cdot \sqrt{\frac{2\Delta p}{\rho}}$$

where ρ is the liquid density, and K - flow coefficient.

The selection of a flowmeter beside the metrological properties is guided by its exploitation parameters as well as cost of exploitation [2,3]. There are ways of mounting probes in a pipeline which enable their easy installation and removal without the necessity of stopping the flow in the pipeline – as in WET-TAP [10,11,12], HOT-TAP [13], or FLO-TAP[14] systems. An undoubted advantage of such a solution is associated with the fact the averaging Pitot tubes generate only a slight loss of differential pressure [15] in particular for large pipeline diameters. For the case of averaging Pitot tubes the value of flow coefficient K is relative to the velocity profile in the pipeline. By analogy just as in differential pressure flowmeters, an important role is played by the adequate selection of the probe in the pipeline. It is necessary to ensure that sufficient straight sections of the pipeline are provided before and after the probe. The textbooks regarding metrology of liquid streams [4, 5], flowmeter specifications [8,6] and standards [9], one can find information regarding the adequately long sections of pipelines before and behind a flowmeter in order to ensure the maintenance of a declared measurement uncertainty. Most information in this respect can be found for the case of differential pressure flowmeters. However, such data regarding flow averaging Pitot tubes is relatively scarce. Hence, the decision to undertake the experimental research. The results regarding the impact of typical elements of an installation are also to be found in [7].

## Layuot of the set-up

The main components of the experimental set-up (Fig. 2a, 2b) include pipelines and a blower which controls the flow rate.

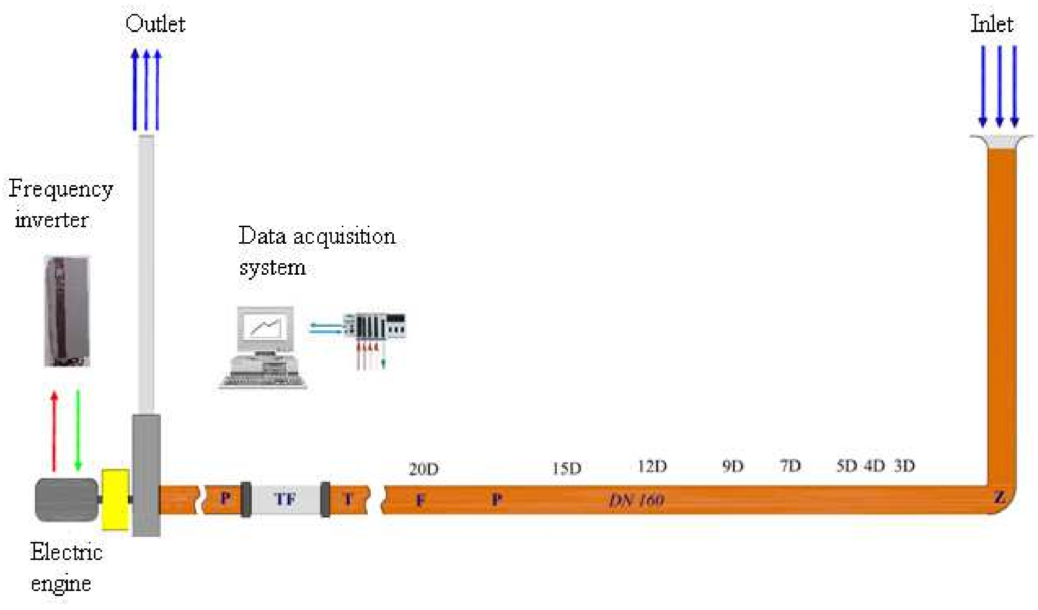


Fig. 2.Layout of the experimental set-up, P- measurement of absolute pressure, T- measurement of temperature, TF- turbine flowmeter, F- tested tube, Z- flow disturbing element

Fig. 2b. Overview of the experimental set-up

The measurement set-up is suitable for calibrating flowmeters by means of a secondary standard. The test stand includes a system of pipelines with the lengths from 104 mm to 381 mm combined by means of collectors. The two parallel pipelines with the diameters of 152 and 305 mm contain reference flowmeters. These are high quality turbine flowmeters with measurement uncertainty of under 0.5 % of the measured value of the stream. Each of the pipelines has a stub pipe (in a form of a band) with the diameter od 2” for installing with flow averaging tubes, or a vortex insertion flowmeter. Each of the pipelines also contains a resistance thermometer and a stub pipe with a cut-off valve for measuring absolute pressure. Due to the adaptability and possibility of modifying the set-up, the research regarded the impact of standard components of an installation affecting disturbance of flow (segmented 90$^o$ bend, system of two segmented 90$^o$ bends situated in various planes) on the flow coefficients of the averaging Pitot tubes.

All subassemblies and measurement devices in the test stand are combined with a computer and a central system for archiving and visualization of the measurement data.

**Methology and results**

The testing was undertaken for three designs of averaging Pitot tube, as presented in Fig. 3.

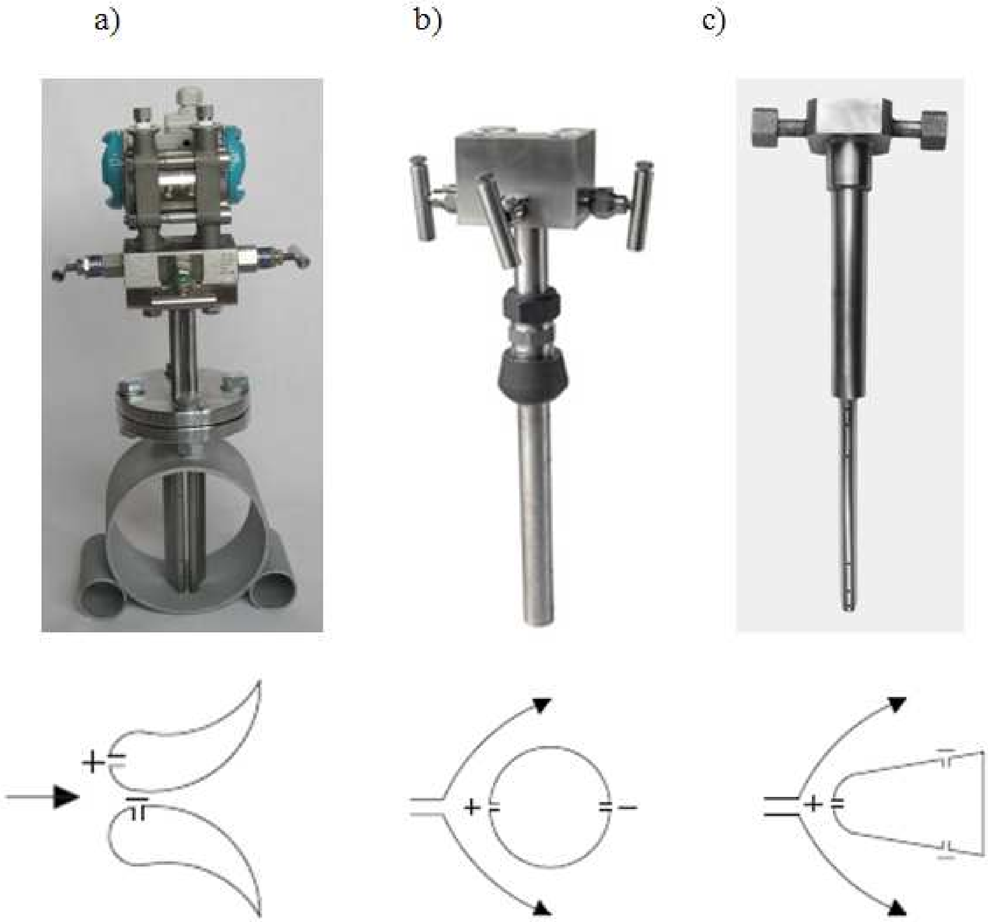


Fig. 3. Tested tubes: a) TWO-PROFILED, b) ACCUTUBE, c) INTROBAR

The flow disturbing element which the was a 90$^o$ segmented bend and a system of segmented bends located in various planes. The measurement of mean velocities was performed in various distances from the flow disturbing elements. They were located at various multiples of the pipeline's diameters (3D, 4D, 5D, 7D, 9D, 12D, 15D and 20D). The probe was located in the plane of the flow disturbing element and in its perpendicular plane. The results of the flowmeter were compared with the value of the stream measured with a reference flowmeter. For various locations and arrangements of the examined flowmeters the K=f(w) characteristics were established

The following figures present selected results of research conducted on the test set-up. The results in Fig. 4 present the characteristics of a two-profiled probe for a single segmented bend in a pipeline with the diameter of 152 mm. The resulting chart is the polynomial approximation of the values of *K*, *w*hich denote the particular points in the measurement series for various distances corresponding to a multiple of the diameter of the pipeline from the flow disturbing element. Figs. 5,6,7 and 8 present the results of the measurement of flow coefficient *K* for the investigated probes for flow velocity of 20m/s for various distances from the flow disturbing element. Figs. 5 to 8 also contain marked boundaries of ±1% and ±3% of variation, which promotes the analysis of the results .

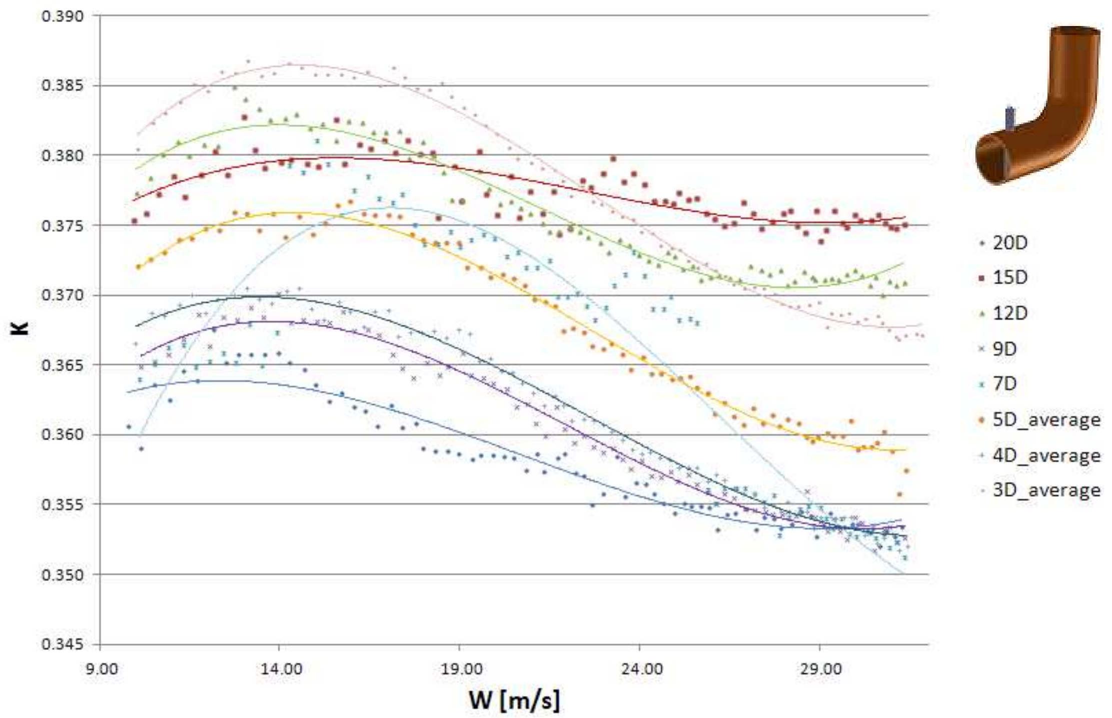


Fig. 4 Characteristic of two-profiled probe for a single segmented bend

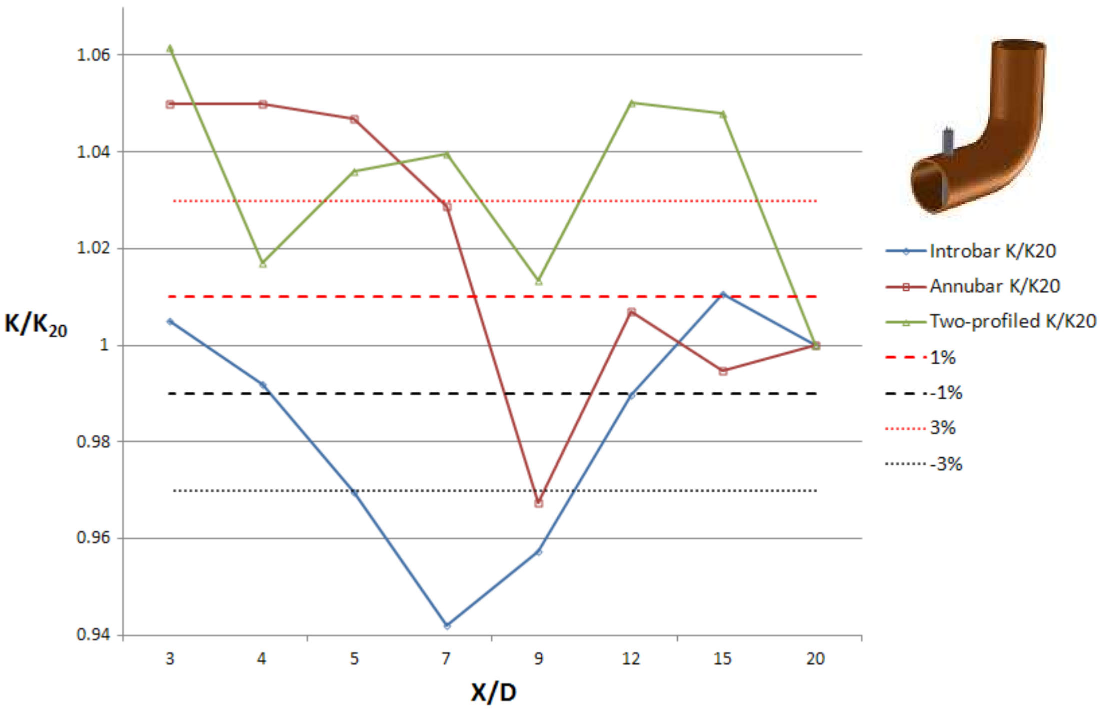


Fig. 5 Variation of flow coefficient K for various distances equal to a multiple of the diameter for the pipeline for the tested probes (for flow velocity of 20m/s for a vertical installation of the probe behind the flow disturbing element)

The above chart presents the results for a single segmented bend and vertical layout of the installed probes. For Introbar and Annubar probes the measurement is already possible for the distance of 12 times the diameter of the pipeline while the value of flow coefficient K referred to the distance of 20 times the diameter of the pipeline is in the range of ±1%.

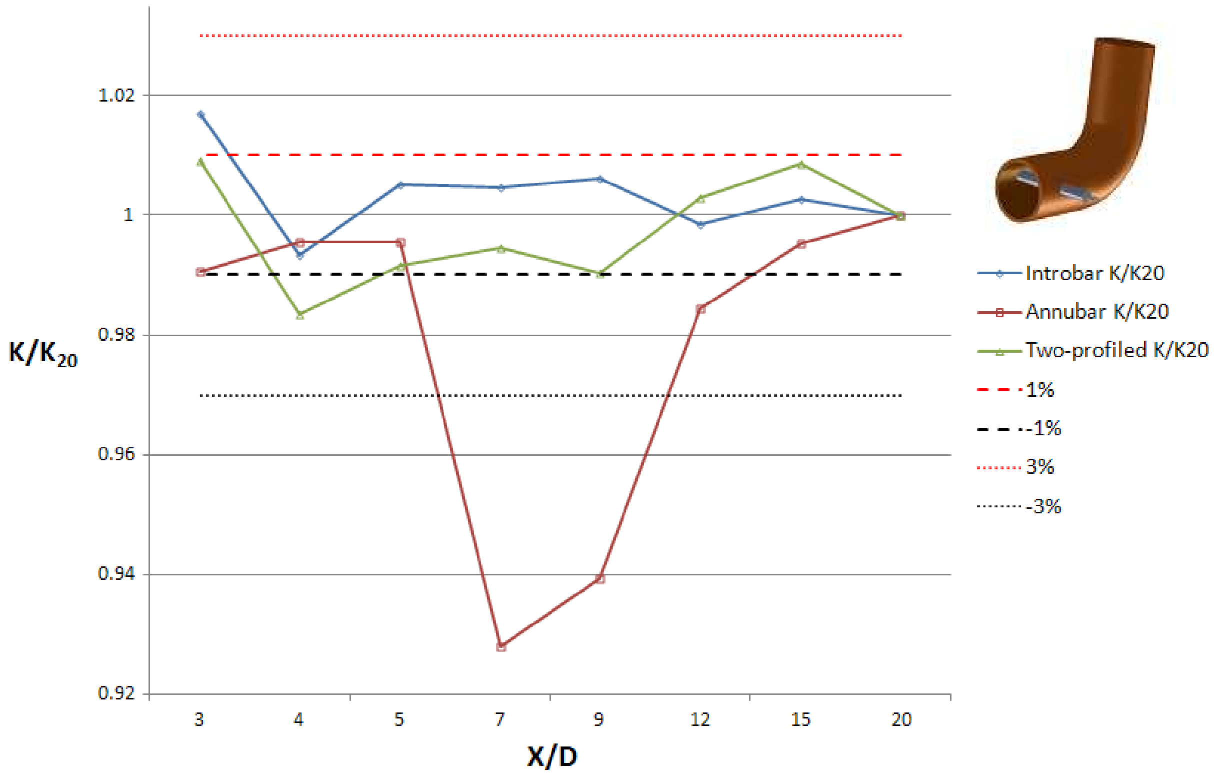


Fig. 6 Variation of flow coefficient K in the distances of multiples of diameter of the pipeline for the examined probes (for flow velocity of 20m/s for a horizontal installation of the probe behind the flow disturbing element)

Fig. 6 presents the variation in the flow coefficient K referred to the value of this coefficient measured in an undisturbed place for a horizontal installation of the pipeline behind the flow disturbing element. From the conducted research it stems that horizontal installation is the best position to install flow averaging Pitot tubes, as for all examined probes considerably smaller variations of the flow coefficient were noted in this position in comparison to the vertical installation. Only for the case of 7 and 9 times the diameter of the pipeline for Annubar probe the variation of this coefficient are below 5%. This plays a fundamental role in the selection of the location of the probe is its installation in order to ensure the reduction of the measurement uncertainty.

The chart below (Fig. 7) presents the relative value of flow coefficient K in the system with two segmented bends situated in various planes for the vertical installation of the probe behind the flow disturbing element. The flow disturbing element in form of a system of segmented bends situated in various planes leads to considerable deformation of the velocity profile. This, in turn, leads to considerable variation in the value of K. Only the two-profiled probe in these flow conditions and location is less sensitive to the disturbance of the velocity profile.

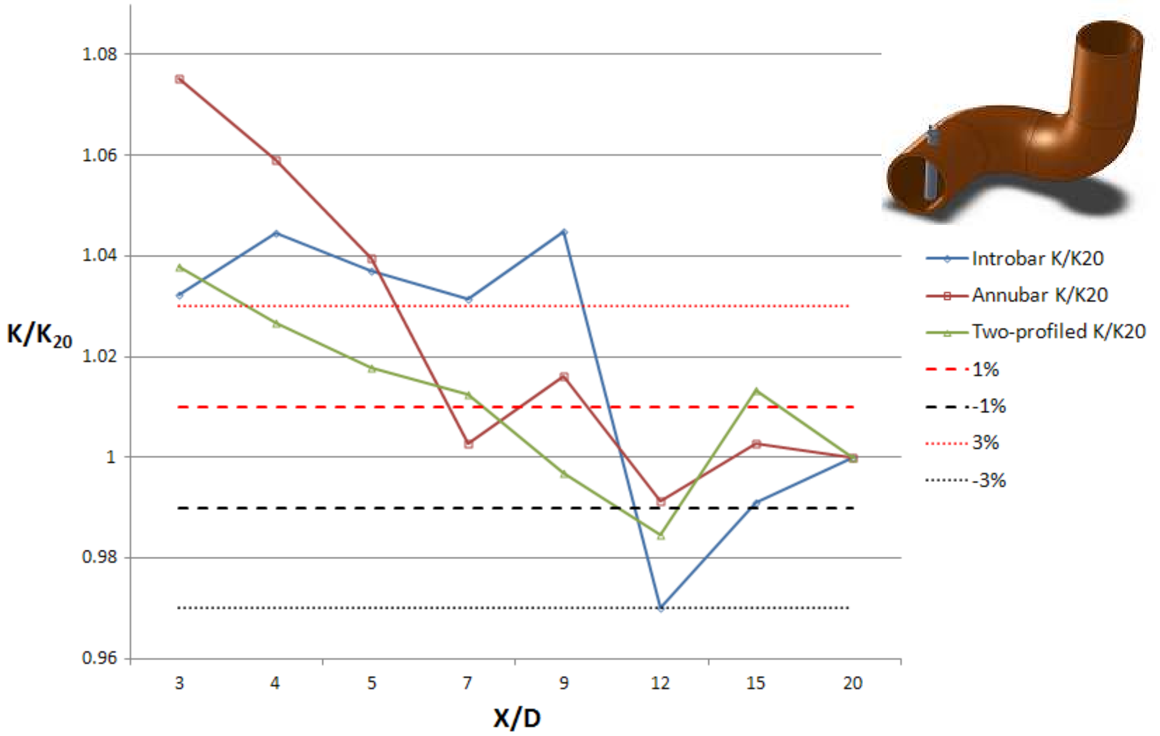


Fig. 7 Variation of flow coefficient K for various distances equal to multiples of the diameter for the pipeline for the tested probes (for flow velocity of 20m/s and vertical installation of the probe behind the flow disturbing element)

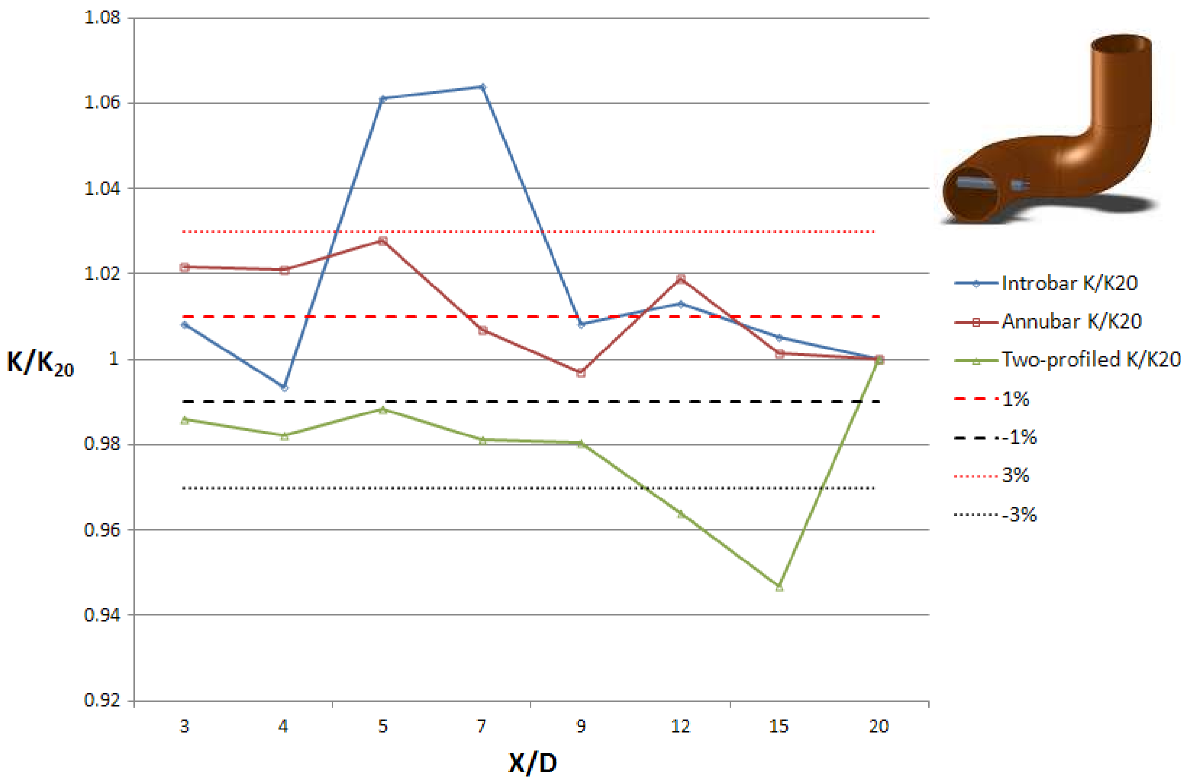


Fig. 8 Variation of flow coefficient K for various distances equal to multiples of the diameter for the pipeline for the tested probes (for flow velocity of 20m/s and horizontal installation of the probe behind the flow disturbing element)

Fig.8 presents a similar situation for the probes installed in the respective horizontal plane in relation to the plane of the lower bend. In this case the value of flow coefficient K also vary considerably. Relatively, this value changes to the smallest degree for the case of Annubar probes – just in the range of ±3%. Concurrently, two-profiled probe displays considerable changes in the value of K even at a distance of a dozen diameters from the system of bends.

## Conclusions

The impact of the liquid on the probes in the tested system is a complex phenomenon. An important role is associated not only with the disturbance of the velocity profile but also with the flow averaging effect. In particular this concerns two-profiles probe. The location of the impulse holes oalso plays a role in the process, as in the research it was different for each of the probes. This factor can help explain the various curves in the charts for each of the probes.

The conducted research made it possible to state metrological conclusions. The results indicate that not only the distance from the flow disturbing element but also the plane in which a probe is installed, plays a role in the recorded measurement uncertainty of the flow averaging Pitot tubes. From the conducted conclusion can be made that for the case of a system with a single bend the horizontal location is a better plane for installing flow averaging Pitot tubes. For all examined probes in this location considerable smaller variation of the flow coefficient K were noted in comparison to the vertical one.

## References:

[1] Baker R.C.: An introductory guide to flow measurement, Alden Press, Oxford, 1989
[2] Kabza Z., Pospolita J.: Metrological anslysis of flowmeters with averaging Pitot tubes [in Polish], Prace Naukowe Politechniki Warszawskiej, Konferencja, Vol. 4, Warszawa, 1995.
[3] Waluś S.: Metrological optimization od measuring liquid streams by means of averaging Pitot tubes [in Polish], monograph, Politechnika Śląska, Gliwice 2000.
[4] GONDEK A.: Averaging Pitot tubes [in Polish],. Politechnika Krakowska, Kraków 2009
[5]HOGREFE W. et al. *Guide to Flow measurements*, Bailey- Fischer & Porter GmbH Göttingen 1995.
[6] INTROL, Part catalogue, Katowice 2009
[7] D. Węcel, T. Chmielniak, J. Kotowicz, Experimental and numerical investigations of the averaging Pitot tube and analysis of installation effects on the flow coefficient, Flow Measurement and Instrumentation, 2008
[8] Miller R.W.: Flow measurement engineering handbook, Mc Graw Hill Book Company, 1983
[9] PN-EN ISO 5167-1: Measurements of liquid stream by means of differential pressure flowmeters. Flanges, nozzles, Pitot tubes installed in full circular pipelines [in Polish], March 2000
[10]Chwastek C., Kabaciński M., Pospolita J.: Metrological properties and applicability of averaging Pitot tubes and micro-scale differential pressure [in Polish], Pomiary Aparatura Kontrola
[11] Introl – Part catalogue, measurement and control apparatus, Katowice 2000
[12]Kabaciński M., Pospolita J.: Numerical research into averaging Pitot tubes, Pomiary Automatyka Robotyka, 4/2001
[13] Howe W. H., Houghen J. O., Lipták B. G., Ptáćnik M.: Pitot Tubes, Averaging, and Duct Section Units, w: Flow Measurement, Editor –in- Chief B.G. Lipták, Chilton Book Company, Radnor 1993.

[14] ITABAR Flow Sensor for Gases, Steam and Liquids, Technical documentation, Intra Automation GmbH, 1995
[15] Waluś S.: Probes for measuring velocities in sampling flowmeters [in Polish], VI Scientific Conference Optoelectronic and Electronic Probes, Gliwice, 13-16 June2000; Prace Komisji Metrologii Oddziału PAN w Katowicach, Seria: Konferencje No. 2, Gliwice 2000, Vol.  I, pp. 279-284.