Velocity Gradient Corrections to Superpipe Data

M.V. Zagarola*and A.J. Smits
Department of Mechanical and Aerospace Engineering
Princeton University, Princeton, N.J. 08544-0710

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The following information is summarized from [1], where further details can be found. The streamline displacement by a Pitot probe, which causes the probe to measure a velocity other than the value at its geometric center, requires a correction which is known as the velocity gradient correction. The correction Δy is usually written as a correction to the probe position, where

$$\frac{\Delta y}{D_{probe}} = \varepsilon,$$

where D_{probe} is the outer diameter of the Pitot probe (in these data, $D_{probe} = 0.902\,mm$), and Δy is the correction that needs to be added to the wall distance y.

We recommend the correction proposed by Chu [2], where

$$\varepsilon = 0.18\left(\alpha - 0.17\alpha^3\right),$$

and

$$\alpha = \frac{1}{U_c}\left.\frac{dU}{dy}\right|_c \frac{D_{probe}}{2},$$

where the subscript c indicates the quantity evaluated at the center of the Pitot probe.

This correction only has a small effect on the profiles (in our case, less than 0.15% on the average velocity, less than 0.6% on von Kàrmàn's constant, and less than 2% on the additive constant in the log-law). Other corrections, such as that proposed by MacMillan [3] lead to much greater differences, which we feel to be incorrect.

* *Currently: Creare Inc., P.O. Box 71, Hanover, NH 03755*

References

[1] M.V. Zagarola. Ph.D. Thesis, Princeton University, 1996.

[2] S.H. Chu. *Progress in Aerospace Sciences*, 16:147–223, 1975.

[3] F.A. MacMillan. *Reports and Memoranda No. 3028, Ministry of Supply, London*, Feb 1954.