Dividing Equation [15] by [16]

$$\frac{ds}{dL} = \frac{\frac{P_1}{K_1}(1-q)}{\frac{P_1}{K_1}[K_1-(1-q)]} = \frac{(1-q)}{K_1-(1-q)} \quad [17]$$

Setting Equation [17] equal to [14] and solving for a_b, another of the basic equations results

$$a_b = \frac{K_2(1-q)}{K_1-(1-q)} \quad [3]$$

The initial area is the area at zero flow when $q = 0$

$$a_0 = \frac{K_2}{K_1-1} = \frac{A_C - A_D}{\frac{A_C}{A_R} - 1} \quad [4]$$

Discussion

J. A. Perry, Jr.[3] The design of an integral pneumatic square-rooting flow-measuring instrument meets many problems which at first may not be apparent.

In the field of flow measurement a seemingly infinite variety of devices has been developed to extract the square root of the differential impulse received from a primary element. Square-rooting devices probably can be divided into two general categories. The first is the integral device such as this, the Le Deaux bell, or the electrical-resistance-rod type. The other is the non-integral or remote square-rooting type. This type receives the differential impulse from the measuring element and then by means of a cam or some other device extracts the square root.

The most obvious purpose for desiring a straight-line impulse is to be able to record flow on an evenly divided chart. Another reason is for totalizing flow. Obviously a totalizer must count at a rate proportional to the flow and not proportional to the differential head across an orifice.

Another reason for desiring a linear-flow impulse, and the major need for which this transmitter was designed, is for flow control. An ideal flow control would have a measuring impulse with an equal response throughout the range of operation. Mathematically, the output impulse of the square-root transmitter described by the author can be stated as, $I = CW$, where I is the pneumatic impulse and W is the flow. The change in impulse for a change in flow is

$$\frac{dI}{dW} = C$$

This means that at all rates of flow the transmitter output will change equally for equal changes in flow. However, the output of a conventional differential transmitter is $I = CW^2$. Here the change in impulse for a change in flow is

$$\frac{dI}{dW} = 2CW$$

Now, the impulse change is not constant but varies at every rate of flow—an undesirable characteristic.

The practical result of the foregoing equations is that a flow controller receiving an impulse from the square-root transmitter can be stabilized equally well at all rates of flow. However, if the controller receiving an impulse from a differential transmitter were stabilized at high flows, it would be sluggish at low flows. If it were stabilized at low flows, it would be unstable at high flows. Of course, since unstability cannot be tolerated, the only choice is the former.

A particular case which illustrates the usefulness of this device is in a three-element feedwater control. Here the controller receives the combined impulse of feedwater flow, steam flow, and drum level. If the two flow functions were of the differential type, the relationship of the change in drum level to the change in flow would differ at every rate of flow. However, by use of the square-root-type transmitter this relationship is constant, and effective drum-level control can be obtained from full load on down to very low loads.

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Author's Closure

The author appreciates Mr. Perry's mention of the simplified stabilizing procedure in the field when the instrument described above is used.

The amount of effort put into the development of square-root extracting devices by designers through the years confirms Mr. Perry's appraisal of their value.