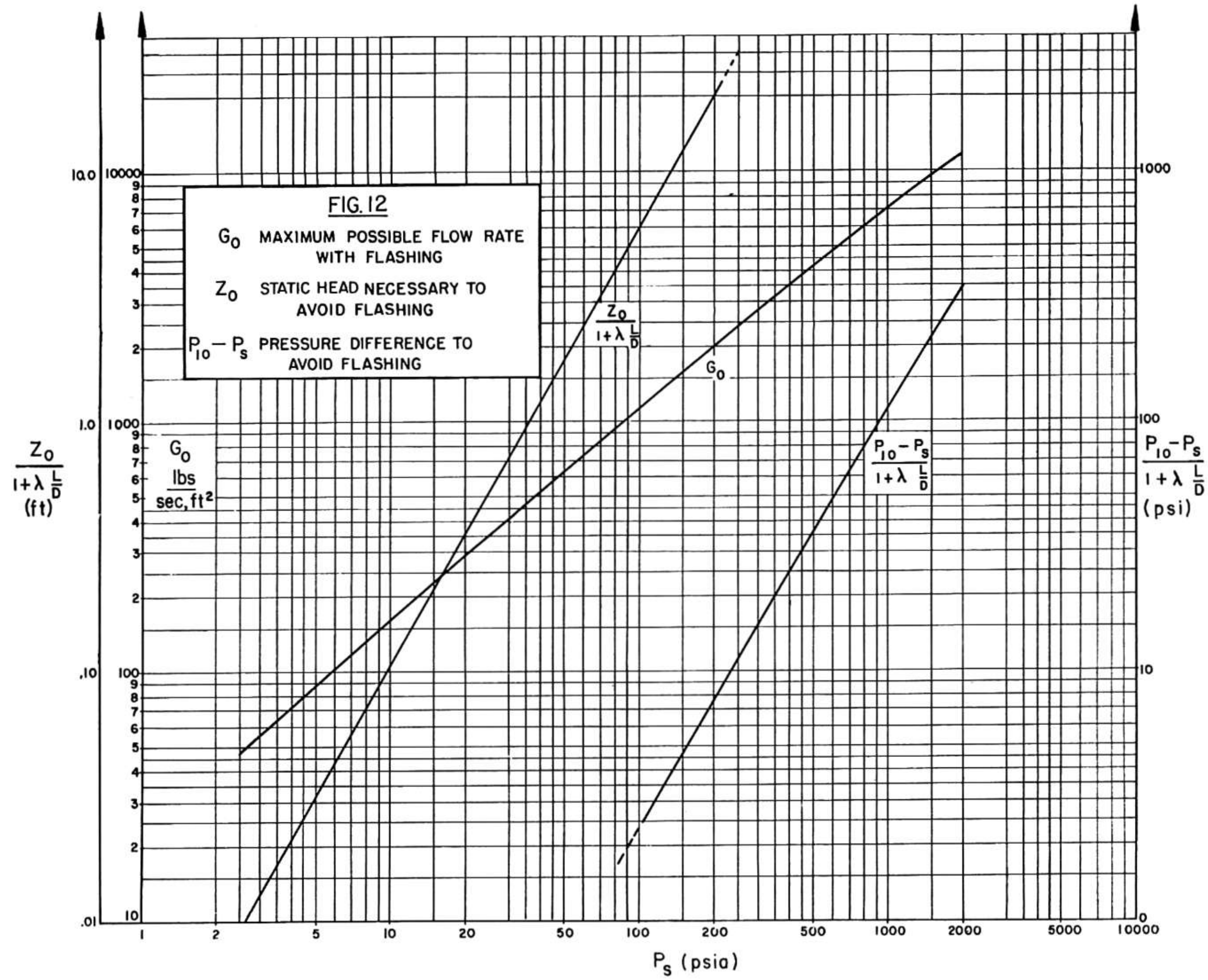

Fig. 12 Parameters for maximum possible flow rate with flashing

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DISCUSSION

H. N. McManus, Jr.[3]

Mr. Sajben has presented an interesting treatment of a complicated problem and is to be complimented.

The assumption by the author of a homogeneous mixture, and the consequent consideration of the acoustic velocity suggests comparison with the work of Heinrich[4] which dealt with flow of foams. Heinrich found that the acoustic velocity was not only a function of pressure and temperature but also a function of vapor-liquid ratio (quality). In fact, the foam acoustic velocity exhibited a minimum for a specific mixture ratio which was much less than the acoustic velocity of the gas.

The form of Equation (13) suggests a similar behavior of

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[4] G. Heinrich, "Über Stromungen von Schaumen," *ZAMM*, vol. 22, April, 1942, pp. 117–118.

acoustic velocity in this model since specific volume is dependent upon pressure, temperature, and, of course, vapor-liquid ratio. It would appear that this dependency on quality presents the possibility of choking at some position other than the pipe outlet for some flow conditions. Hence, a more complicated behavior could be encountered than considered in this work. With this possibility present, it would appear necessary to determine whether the point at which choking was encountered was at the pipe outlet or possibly at some intermediate position in order to determine the critical flow rate.

This writer would be interested in the author's opinion and thoughts on this matter.

Author's Closure

Professor McManus raised a very interesting question concerning the dependence of acoustic velocity on the properties of the vapor-liquid mixture.

For the flow model postulated in the paper the answer may be found by considering Eq. (13), which gives the acoustic velocity as a function of two variables, the steam quality and pressure of the mixture. The temperature is defined by the pressure for the assumed thermodynamic equilibrium.

From the condition for the existence of an extremum:

$$\partial a^2/\partial x = 0,$$

we obtain from Eq. (13) and Eq. (5) after simplifications:

$$2\beta' + v\left(\alpha' + \frac{1}{J}\right) = 0$$

This equation has to be satisfied for a minimum to exist. It is a matter of looking up material properties to show that for water this relation is not satisfied in the range from 0.4 psia up to the critical pressure, and hence a minimum does not exist. For vapor-liquid mixtures of other substances one would have to ascertain whether the above condition is satisfied or not. It is not likely to be satisfied.

It can be shown that for a given flow rate and saturation pressure, the $L_{fv}(P_3)$ function possesses a maximum when the velocity (c_3) equals the acoustic velocity. This indicates that choking occurs at the pipe end.

The quoted work of Heinrich refers to isentropic flows of two-phase, two-component mixtures, like, e.g., air-water mixtures. Other assumptions made by him are identical to those made in the present paper, therefore, the different behavior of the two types of mixtures is due to their physical properties and not caused by different methods of analysis. It points out that caution is necessary in extrapolating results between these two types of flows.