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DISCUSSION

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Although the authors described the complexity of phenomena existing in the safety valve vent system, most of those conditions were indeterminable by the authors' one-dimensional method. The authors stated that the velocity at the valve pipe outlet could be either sonic or supersonic, and demonstrated the effect of velocity ratio on the vent pipe area ratio in Fig. 6. However, they failed to determine what velocity ratio should be used by power plant engineers in their design. The possible velocity ratio is rather widely spread, and with a fixed friction parameter (fL/D_1'), errors on area ratio can be as high as 75 percent. It appears that the result of the authors' method is as fortuitous as the result of the Benjamin method, which requires an assumption for nozzle efficiency instead. As indicated in the Author's Closure of the writer's paper [26], the writer recognizes the limitation of the one-dimensional analysis, and has recommended a conservative approach, which assumes sonic velocity to be the maximum velocity attainable at the valve pipe outlet. The writer considers that the flow passage up to the valve orifice is similar to a convergent nozzle. However, beyond the valve seat, the flow changes direction, passes rough contours of the valve, and finally is conveyed through a sharp 90-deg elbow to reach the valve pipe outlet. Since the flow must undergo a 90-deg. change in direction twice with a constant area duct at the tail end, the writer questions whether this can be treated similar to the divergent section of a supersonic nozzle.

In their introduction, the authors pointed out the deficiency of two existing methods. For the Benjamin method, lack of rational selection of nozzle efficiency was mentioned. For the industry developed procedure, the backward calculation was mentioned as a deficiency. However, the writer's opinion relative to the deficiency of two existing methods is somewhat different.

The major deficiency of the Benjamin method is the vent pipe sizing criterion. It compares the velocity pressure of steam leaving the valve pipe with the static pressure at the vent pipe inlet. However, according to fluid mechanics, four basic physical laws must be satisfied, i.e. conservation of mass, conservation of momentum, the first law of thermodynamics, and the second law of thermodynamics. Since the law of conservation of mass and the first law of thermodynamics have been considered by the Benjamin method, the design criteria are to satisfy the second law of thermodynamics and the conservation of momentum. The former requires an increase in entropy or a decrease in total pressure. The latter requires a decrease in momentum. The Benjamin criterion might violate the second law of thermodynamics, and therefore, a vent size selected could be too small. The recent industry developed procedure has accommodated the second law of thermodynamics. However, the writer considers that the conservation of momentum should also be satisfied. From writer's observation, it is often that the momentum criterion determines the minimum vent size rather than the entropy or total pressure criterion.

The authors indicated that flow calculations should be forward, and the backward method currently used would not directly tie together conditions at the vent pipe inlet. However, in writer's opinion, it is not likely that problems can be solved from the upstream downward. For example, if sonic condition exists at the vent pipe outlet discharging to the atmosphere, an abrupt change in static pressure, or a discontinuity in pressure gradient is permissible. If subsonic condition exists, pressure gradient must be continuous to the atmospheric pressure. In any case, the condition at the vent pipe inlet can not be determined without knowing the condition at the vent pipe outlet. Therefore, the calculations are always backward.

The authors are to be congratulated especially regarding the detail descriptions of the phenomena occurring in the safety valve vent system. With their analysis of valve pipe discharge velocity versus vent pipe size, the importance of assuming adequate valve pipe discharge velocity is demonstrated. The paper seems to confirm that the sonic velocity at the valve pipe outlet assumed in the industry developed procedure as well as by the writer is a conservative approach for sizing the vent pipe with confidence.

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Author's Closure

The objective of the authors paper is two-fold; one, to present a qualitative discussion of the flow in a steam safety valve vent system based on the investigations of similar devices in other fields; and two, to examine to what extent modern fluid dynamics can be used to analyze this complex flow problem. Although the end result for practical design purposes remains the one-dimensional approach used by both Mr. Liao and the authors, knowledge of its deviations from reality adds confidence to its application. Thus, knowing that the assumption of sonic velocity at the valve pipe outlet produces a conservative value of the vent pipe area ratio and that an increase in area ratio above the minimum due, for example, to available pipe sizes results in an inflow of air into the vent pipe aids in the evaluation of a given vent system design.

The authors considered the flow downstream of the valve orifice and downstream of the valve pipe outlet to be similar to the flow in an abrupt change in cross-section area. As described in the paper, transition from the smaller to the larger area is by a supersonic free jet. This is not the same as the flow in the divergent section of a supersonic nozzle as Mr. Liao states. Further, supersonic, albeit transient, flow in a 90-degree elbow has been investigated both analytically and experimentally [27, 28].[3] However, using the one-dimensional analysis, the valve pipe outlet velocity can only be determined as being within the limits of the sonic velocity and about 1.7 times the sonic velocity.

Authors are in agreement with Mr. Liao's discussion of the deficiency of Benjamin's method and the need to satisfy all fluid dynamic and thermodynamic laws at each section of the system.

Finally, consider the direction in which the calculations are made. The authors main concern, like the writer's, is that the applicable physical laws are satisfied everywhere. If the mathematical model reflects this requirement, then the choice of direction is based on calculation convenience. However, since downstream conditions cannot directly influence the upstream flow in a supersonic flow, the forward direction appears logical—at least between the valve pipe outlet and the intersection of the free jet and the vent pipe wall.

That the calculation can proceed in a forward direction will now be demonstrated. Assuming sonic velocity, the stagnation to atmospheric pressure ratio at the valve pipe outlet is calculated with the aid of equation (29). For a specified vent to valve pipe area ratio and the limiting condition for no steam blowback, the velocity upstream and downstream of the normal shock is determined from equations (25), (7), and (6). If the thermodynamic limit is exceeded, the area ratio must be reduced until equation (26) is satisfied.

Assuming sonic velocity at the vent pipe outlet, the corresponding stagnation pressure is determined from the valve pipe outlet conditions using equation (28). The outlet static pressure is then calculated using the isentropic relation between static and stagnation pressures. If it is greater than atmospheric pressure, the outlet velocity is indeed sonic. However, if it is less, the outlet static pressure must be atmospheric. The corresponding subsonic velocity is calculated from the conservation of mass, equation (8).

The maximum vent pipe length is the difference between equation (12) evaluated downstream of the normal shock and at the vent pipe outlet. If the calculated length is less than the required length, the vent pipe area must be increased and the calculation repeated. If it is greater, flow conditions within the vent pipe will adjust accordingly and further calculations, i.e., reducing the vent pipe area, are unnecessary.

Authors thank Mr. Liao for his discussion. It is unfortunate that published test data do not exist against which to compare the calculated data.

[3] Numbers in brackets designate Additional References at end of Closure.

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