Journal of Hazardous Materials, 8 (1984) 377—380
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

Short Communication

DISCHARGE OF SATURATED LIQUIDS THROUGH PIPES

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(Received November 25, 1983; accepted November 25, 1983)

When a saturated liquid, stored in a pressure vessel in a superheated condition, i.e., at a temperature above its boiling point at atmospheric pressure, is discharged through a pipe, the liquid can flash (partially convert to vapour) during or after its discharge. The mass flux will depend on the amount of flashing which takes place, which in turn depends on the physical properties of the liquid, its storage conditions, etc. It is common practice [1] to characterise the discharge by use of the length/diameter ratio (*L/D*) of the pipe.

However, it has been shown by Fletcher and Johnson [2] that the mass fluxes of both saturated water and Refrigerant 11 through pipes are strongly dependent on the pipe length and independent of *L/D*, at least until decreases in flow rate can be attributed to frictional effects. By plotting $G^2/(C_d{}^2P_1)$ against pipe length (where G is the mass flux, C_d is the discharge coefficient and P_1 is the upstream absolute pressure) experimental data were correlated for each liquid. These correlations showed the same variation with pipe length: for pipe lengths less than 75 mm, $G^2/(C_d{}^2P_1)$ fell more gradually as equilibrium between the phases was approached and friction became the dominant factor in determining the change in mass flux. In the case of Fauske's results [3], on which correlations such as that given in Ref. [1] are based, the length of 75 mm corresponded to an *L/D* of approximately 12, and this has been widely used as the transition point between metastability and thermal equilibrium of the phases. However, the data given in Ref. [2] suggest the simple criterion of a constant relaxation length.

Whilst the range of stagnation pressures used in Ref. [2] for the saturated water data was quite wide (3 to 102 bar), the pipe diameters ranged only from 6.35 to 50.5 mm. Further data from the Marviken critical flow tests on the blowdown of water under saturated initial conditions [4] have now been added and are plotted on Fig. 1 (see also Table 1). These experiments were unique in that they provided data on discharges through pipes up to 500 mm in diameter.

The data added were obtained on the 500 mm diameter pipe; they show good agreement with those previously presented. It should be noted that for L = 730 mm, the value of *L/D* is only 1.46 and that frictional effects would be very small, whereas for the small-diameter pipes considered previously,

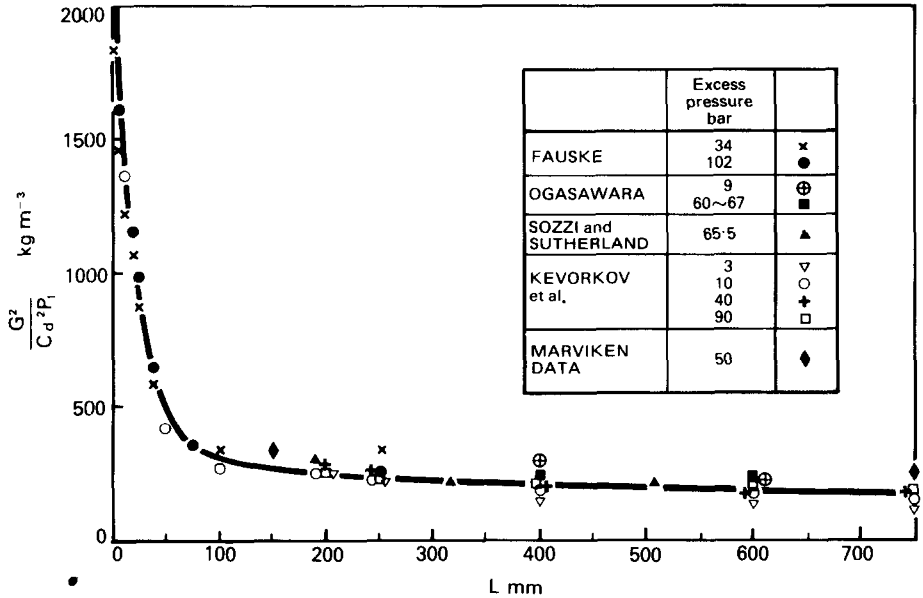

Fig. 1. Discharge of saturated water

TABLE 1

Ranges of variables in discharge of saturated water tests

Source	Pipe diameter (mm)	Pressure (bar)
Fauske [3]	6.35	34, 102
Ogasawara [5]	10.9, 32.9, 50.5	9, 60, 67
Sozzi and Sutherland [6]	12.7	65.6
Kevorkov et al. [7]	14, 25, 37.8	3, 10, 40, 90
Marviken data [4]	500	50

friction could have a significant effect. Higher values of $G^2/(C_d{}^2P_l)$ might therefore be expected for larger-diameter pipes for pipe lengths greater than about 100 mm. The Marviken data also support the observation made by Fletcher [8] that flashing can occur within a pipe for values of L/D less than 1; it is commonly assumed that liquid alone flows through an orifice L/D less than 2. In the Marviken experiments the lowest value of L/D was 0.33; this corresponded to a pipe length of 166 mm. Figure 1 shows that a considerable volume of vapour had been formed and the mass flux was varying only slightly with pipe length.

Suitable data on the discharge of substances other than water and R-11 are sparse. Recent experimental results from Van den Akker et al. [9] on the flashing discharge of Refrigerant 12 at pressures up to 10 bar through pipes of diameters 2, 3 and 4 mm have been replotted on Fig. 2 to show the variation of $G^2/(C_d{}^2P_1)$ with L. (Also plotted are the R-11 results from Fletcher and Johnson [2] for comparison.) These both show the same sort of variation of $G^2/(C_d{}^2P_1)$ with L as is found for water. Again a pipe length of about 75 mm seems to mark the transition point in the variation. The implication of these results, covering liquids of widely varying physical properties and wide variations in pipe diameters and stagnation pressures, seems to be that the relaxation process residence time requirement can be characterised by a simple length criterion (i.e., a length of the order of 75 mm).

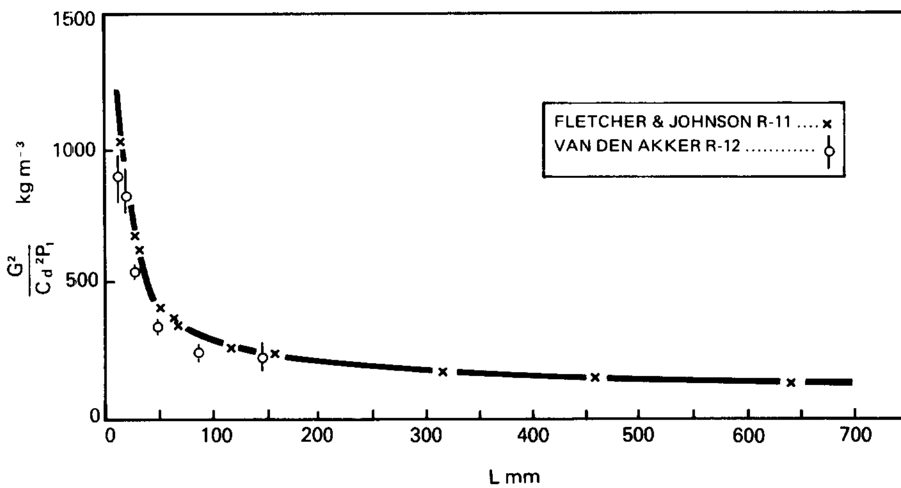

Fig. 2. Discharge of R-11 and R-12.

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