INTERSTAGE BRINE FLOW IN MSF CHAMBERS

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Summary

Open channel brine flow in MSF plants is complex, especially in the hot stages with a high interstage pressure drop and, as a consequence, the release of large amounts of vapor in the entrance region of the chamber (directly behind the orifice).

Hydrodynamics and thermodynamics are interdependent and make a prediction of the flow as well as orifice design difficult. This may explain why numerous orifice designs were developed and tested and why a number of empirical equations for orifice design exist.

The chapter discusses the phenomena in open channel flow and compares the quality of some equations proposed for rectangular orifice with and without weir. And advanced system (thermosyphon) is discussed allowing operation at low brine levels and high weir loads but avoiding blowthrough.

1. Introduction

Proper brine flow distribution as well as interstage transport in the flash chambers and its prediction for different loads is vital for an MSF plant. For the condenser tube bundles and waterboxes calculation and control are rather simple whereas the shell side open channel two phase flashing flow - which is characteristic for MSF - is very complex. Especially in the hot stages with a high interstage pressure drop the "explosive" evaporation in the entrance section of the stages is accompanied by release of large amounts of vapor, which has a significant influence on pressure drop. Hydrodynamics and thermodynamics are interdependent and make the local evaporation rates difficult to predict. This may explain why empirically numerous interstage orifice designs were developed and tested: at present almost every manufacturer has an individual design.

General demands for an interstage orifice in MSF are:

1. Keep brine levels within reasonable range at different loads and during startup and shutdown (pressure drop characteristic);
2. induce the interstage pressure drop;
3. avoid blowthrough between two adjacent stages.

It is well-known that the efficiency of flash evaporation is affected by the hydrodynamics in the flash chamber. Low brine levels are desirable as they tend to increase evaporation efficiency (low hydrostatic head and smaller recirculation effects). But depending on the orifice design vapor may pass in the orifice region from the upstream to the downstream stage - commonly called "blowthrough" - if brine levels are too low. Most important is the influence of process conditions (specific weir load and interstage vapor pressure difference) on the effective pressure drop characteristic. As most plants are horizontally arranged the driving forces for interstage brine flow are the vapor pressure difference - i.e. the hydrodynamics are directly coupled to the thermodynamics of heat transfer - and the brine level difference between two adjacent stages. Due to the exponential slope of the vapor pressure curve the interstage vapor pressure difference for a typical MSF plant of 16-20 stages may vary from some 100 mbar in the hot section to less than 15 mbar in the cold section.

2. Open Flow in Horizontal Channels and through Orifices

2.1. Open Channel Flow

The case of single-phase flow open channel flow is characterized by the Froude number

$$\mathrm{Fr} = \frac{v}{\sqrt{gh}} = \frac{\dot{m}'}{\rho h^{1.5}\sqrt{g}}$$

With $\dot{m}'$ as channel velocity specific weir load (kg ms^{-1}). As the chamber width of a typical large MSF plant is more than 10 m, wall effects can be neglected. Thus the flow can be considered as two-dimensional. Some chamber designs have a very slight slope for better draining after a shutdown, although compared to the interstage vapor pressure difference this additional head is small (e.g. 0.01m/stage ≅1 mbar) and not discussed here.

Assuming bulk flow, the energy height of the Bernoulli energy equation is

$$H = h + \frac{v^2}{2g} = h + \frac{\dot{m}'^2}{\rho^2 h^2\, 2g}$$

which is plotted in Figure 1 for three different weir loads (about 280 kg ms^{-1} = 1000 t/mh is the present limit for crossflow plants (Hanbury 1993).

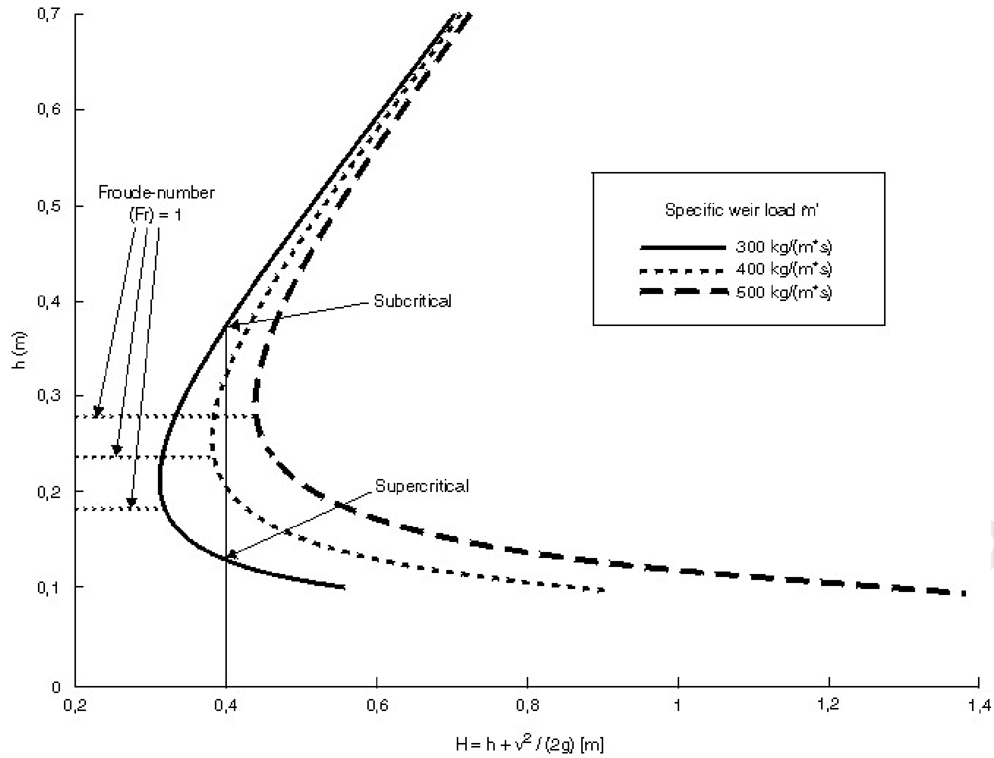

Figure 1. Influence of weir load and water level energy height.

For a given weir load two corresponding brine levels *h* exist. Flow is called supercritical or shooting for Fr > 1 and subcritical or tranquil for Fr < 1. Critical flow occurs at Fr = 1. In horizontal open channel flow without baffles or obstacles only the transition from shooting to tranquil flow can be observed. This phenomenon is called hydraulic jump as shown in Figure 2. Research on hydraulic jumps is reported widely. Some of the work is presented in Section 2.2.

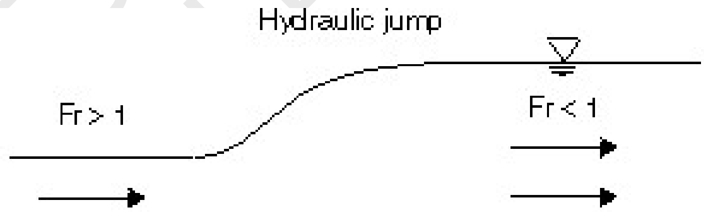

Figure 2. Transition from supercritical flow (hydraulic jump).

There are two important aspects of shooting open channel flow with regard to brine levels.

1. Shooting flow increases stability of brine levels in the Flash stages.
2. Low brine levels increase evaporation efficiency and thus decrease thermodynamic losses of the process.

In contrast to subcritical flow, downstream disturbances such as obstacles or level fluctuations, are not propagated upstream. This fact is important for brine level control in the stages. MSF distillers have many stages at the same elevation and since only the brine level of the last stage being controlled in case of subcritical or submerged flow, all upstream brine levels are affected by the level in the last stage. Especially during commissioning or operation at different loads a frequent problem is to keep the brine levels within reasonable limits. Adjusting the orifice opening position during operation is in most cases impossible (one reported exception: the Port Torres MSF plant was designed with orifice control).

Excessive levels result in high distillate conductivity, increased scaling of the demisters and lower process efficiency due to higher non-equilibrium losses. It was shown (Rautenbach, Schäfer and Schleiden 1996) that the non-equilibrium temperature loss (which is the temperature difference between the brine at stage exit and the vapor phase) is the stage reduced by the boiling point elevation, as a plain rectangular weir is proportional to the brine level in this stage. Reasons for this are the extra hydrostatic head of brine reducing the driving force for evaporation and the increased relevance of submerged flow. But too low levels can result in blowthrough and thus decrease process efficiency.

2.2. Hydraulic Jump

The hydraulic jump area is of particular interest for several reasons:

1. Effective dissipation of the kinetic energy of the brine.
2. Generation of strong turbulences increasing the mass- and heat transfer by intensive mixing perpendicular to the flow direction.
3. Entrainment of large amounts of vapor in the recirculating top roller increasing the effective interphase surface.
4. Ensuring vapor sealing at the orifice between two adjacent stages. In Section 2.3.3 a special orifice design is presented (Tusel, Rautenbach and Widua 1994) providing perfect interstage sealing without an enforced hydraulic jump.

In general the relevance of the first three items increases with increasing Froude number.

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