# Impacts of Pressure Differentials between Flash Tanks on Flash Train Performance

**Tran Quoc-Khanh**
Explicit Engineering Pty Ltd, Perth, Western Australia
Corresponding author: tranqk@bigpond.net.au

**Abstract**



The operational performance of a Bayer process digestion facility and the hence overall performance of an alumina refinery are significantly influenced by flash train design and performance. The mechanical and process design of a digestion facility must include the correct number of flash stages to match the range of operating conditions that are likely to be encountered. This will ensure the pressure differentials between flash tanks are within acceptable limits and the facility availability is high. This paper will review a number of digestion facility designs that accommodate maximum digestion temperatures across the range of 145 – 280°C. The design methodologies used to suppress the onset of three-phase flow between flash tanks (including both up-flow and down-flow designs) and the techniques used to minimise erosive wear will be discussed in detail. Finally, recommendations will be provided emphasising considerations that need to be understood when designing bauxite digestion facilities.

**Keywords:** Three-phase mixture velocity; wears; number of flash stages; pressure differentials.

## 1. Introduction

The design of a digestion multistage flash tanks and associated liquor or slurry heat exchangers must consider a number of important criteria, some of these are listed below.

- Minimise energy consumption.
- Maximise refinery productivity.
- Minimise and simplify maintenance requirements.

As the number of flash stages is increased, the amount of vapour evolved at each stage is less, but with an increased saturation temperature. Consequently, it is possible to use these smaller masses of higher grade vapour across an increased number of liquor/slurry heating stages to achieve a higher temperature prior the live steam heaters thereby reducing live steam consumption.

To identify the optimum number of flash tanks, designers must consider both capital and operating costs. A decrease in capital costs can't be consumed by an increase in energy consumption and maintenance costs. The pressure differentials between flash tanks and the hydraulic ability of the flash train must provide the required level of mechanical availability for the range of operating conditions.

## 2. Considerations of Number of Flash Stages

The velocity of a three-phase mixture will increase in response to an increase in the pressure drop between flash tanks and/or in the slurry flow rate. When this occurs at the low pressure end of a high temperature mineral digestion facility, the velocity can become very high because the specific volume of vapour increases dramatically as pressure is reduced.

For a given digestion facility operating under steady state conditions, the pressure differentials between flash tanks are largely governed by the number of operating flash stages and the heat transfer capacity of the associated heat exchangers. Should it be necessary to bypass a flash stage then the overall pressure drop will be taken over fewer stages with commensurately larger pressure drop per stage. This will cause an increase in three-phase velocity between flash tanks and, as a result, destructive erosion occurs if this operating mode is maintained over a long period. The heat transfer surfaces of slurry heat exchangers also foul with time, reducing heat transfer capacity, and as a result affecting the pressure differentials of the flash train. Consequently, the mechanical and process design of a digestion facility must include the correct number of flash stages commensurate with the range of operating conditions that are likely to be encountered, to ensure that the pressure differentials between flash vessels are within acceptable limits, and facility availability is high.

For a given digestion temperature and number of flash tanks the pressure differentials between flash tanks are largely fixed. Where operating conditions differ from those of the original design then the onset of destructive three-phase flow can occur. For example, Bayer process digestion facilities are often designed to operate under the following conditions:

- Flash tanks are routinely taken out of service for maintenance and the slurry is bypassed, as a result the remaining flash tanks must operate under an increased pressure differential that often results in destructive three-phase flow.
- Liquor to digestion slurry flow rates have increased beyond the rates that are associated with the original design. Friction losses between tanks are higher and a destructive three-phase flow regime can result.
- Efforts to reduce capital costs result in a reduced number of flash tanks being employed and as a consequence the pressure differentials between the installed tanks are greater and a destructive three-phase flow can occur earlier in the interconnecting pipe work.

The mechanical and process design must therefore identify the correct number of slurry flash cooling/heating stages to achieve the required heat recovery while operating with pressure differentials between flash tanks that are within the desired limits to enable acceptable performance and plant availability.

### 2.1. High Temperature Digestions

Performance data from nine bauxite digestion facilities, five refineries operating at temperatures between 250 – 280$^{o}$C and four refineries operating at temperatures between 145 - 175$^{o}$C are tabulated in Table 1 below. Typical Flash Tank (FT) operating pressures and pressure differentials are also listed.

The pressure differentials between the digester/holding tubes and first flash stage are particularly high for Refinery 1. Severe erosion of the backpressure control stations can be expected at the refinery.

Pressure differentials between flash tanks are high in Refinery 1 (FT-1 to FT-3) and again destructive three-phase flow can be expected to pipe works between the associated tanks. Similarly, erosive damage to pipe work between FT-2 to FT-4 for Refinery 3 can also be expected.

Despite Refineries 2 and 3 operating at an identical digestion temperature of 270$^{o}$C the pressure differentials under conditions of three-phase flow between flash tanks are expected to be higher for Refinery 3 than those of Refinery 2. This is because Refinery 2 employs more flash tanks

**Table 2: Recommended number of flash tanks.**

| Digestion temperature ($^{o}$C) | Number of Flash Tanks | Notes |
|---|---|---|
| 260 – 280 | 11 + Blow-Off Tank | + The recommended number of flash stages will give a moderate pressure drop between flash tanks so flashing points can be designed to occur inside flash tanks to achieve the design lifetime of the flash tanks.<br>+ The recommended number of stages provides the ability to by-pass a flash tank without significant energy or flow rate loss. |
| 250 | 10 + BOT | |
| 175 | 5 + BOT | + There is low three-phase pressure drop between flash tanks therefore a down-flow or an up-flow design can be selected, and flashing occurs inside flash tanks. However, consideration of flash tank elevation is one of main factors in the design.<br>+ The recommended number of stages provides the ability to by-pass a flash tank without significant energy or flow rate loss. |
| 150 | 4 + BOT | |
| 145 | 3 + BOT | |

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