Mechanical Vapour Recompression applied to Alumina Spent Liquor Evaporation Plants

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Abstract

Mechanical Vapour Recompression (MVR) is a technology that has been widely used for many years in different processes where concentration by evaporation is required. This technology is based on the re-use of the vapour produced by evaporation as the heating medium, after having increased its temperature and pressure by mechanical compression. The main advantage given by MVR compared to classical evaporation is the use of electrical power instead of live steam, which gives lower operating expenses when electrical power is available. There is no need for cooling water and the operating temperature is lower than the one in conventional evaporation plants with Multiple Effects or Multiflash trains, which means lower scaling, higher availability and lower corrosion. While MVR evaporation is widely used in heavy industry such as the Salt industry or Pulp and Paper, it is quite rare to find this technology in an Alumina refinery. Based on a case study of an installed MVR evaporator in an Alumina refinery, we will show the advantages of this technical alternative. Considering its various advantages and the low operating costs, MVR evaporation technology should be really considered during the design of a new alumina refinery or during capacity expansion project of an existing plant.

Keywords: Mechanical Vapour Recompression, Concentration by evaporation.

1. Introduction

There are many evaporation technologies and some of them were developed before the Bayer process of the alumina industry. Evaporation process has always been a part of the Bayer process and development of evaporation technology was done in parallel of the Bayer process one. The improvements were in the equipment (for example Falling Films have replaced Climbing Films types of evaporators) but also in the process in order to obtain better efficiency and lower energy consumption. This explains the presence of many types of evaporation technologies in alumina refineries such as multiflash trains, falling film multiple effects, forced circulation multiple effects and other combined process.

One of the developed evaporation technology is called Mechanical Vapour Recompression. It consists of using the process vapour generated by the evaporation as the heating vapour on the service side of the evaporator heat exchanger(s). For that purpose a compressor machine is used to increase the pressure and saturated temperature of the process side vapour and use these recompressed vapours to exchange heat again with the boiling spent liquor. So live steam is not needed anymore in that case but only electrical power. This technology enables a reduction in energy when integrated at a correct place in the Bayer process.

2. Thermodynamic Principles

Evaporation is the change from liquid phase to gaseous phase of the solvent contained in a liquid solution (the solvent is water and the liquid is the spent liquor in the case of the alumina refineries). The gaseous phase (water vapours) of the solvent is separated by gravity from the liquid phase (Bayer process spent liquor).

2.1. Thermodynamics sequences

The thermodynamic sequence of an MVR evaporation is described in the below enthalpy and entropy diagrams. The sequence is composed of various energy transfers that can be split like described in Table 1.

Table 1. Thermodynamic sequences of MVR evaporation.

Difference of Enthalpy	Corresponding energy
$H_A – H_B$	Energy of solvent vaporisation
$H_R – H_A$	Polytropic work of compression
$H_E – H_R$	Energy of de-superheating
$H_F – H_E$	Heat released by condensation of the vapour

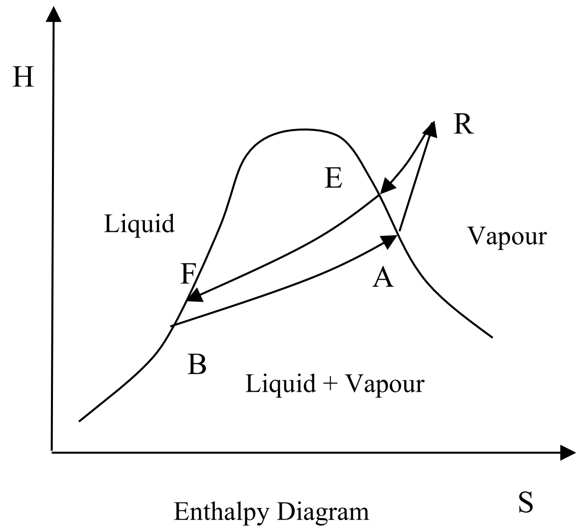

Figure 2. Enthalpy diagram for MVR Evaporation.

The energy needed for the evaporation of the water (H_A-H_B) corresponds approximately to the heat released by the condensation of the heating vapour (H_F-H_E). However a motive force is needed to allow this transfer of energy between the condensing vapours and the boiling liquor.

In evaporation, as in any other heat transfer unit, this motive force is the temperature difference between the hot stream being cooled down or condensed and the cold stream being heated or evaporated (T_E-T_B). No heat transfer can happen without this temperature difference.

Two alternatives have been presented for the increase of the plant capacity:

- Having more surface area for the existing line of evaporation without changing the process flowsheet (this is s the case called "Unit 5 effects + New body in parallel").
- Offering a MVR pre-concentration in front of the existing evaporation line.

The above economical comparison of the operating costs enabled the end user to decide to choose the MVR option because this scenario was offering very good operating costs savings.

4.5. Records and Performances from this MVR Project

The new evaporator was erected independently to the existing one. The shutdown period for the existing line was only for the piping connection, and the production was re-started after only 24 hours.

In the following table we present the initial performances and the new performances after the MVR installation for this evaporation unit:

Table 3. Performances before and after MVR unit installation.

	Existing 5 effects	5 effects + MVR
Evaporation rate	150 tph	180 tph
Steam economy	0,375 t/t	0,260 t/t
Power	10 kW/t	15,8 kW/t
Cooling water	14 t/t	11,8 t/t
Inlet Na_2Oc	150 gpl	150 gpl
Outlet Na_2Oc	250 gpl	260 gpl

The two fans had a total electrical consumption of 1200 kW and an operating speed of 3200 rpm.

5. Conclusion

The Mechanical Vapour Recompression technology has proven its capabilities for energy savings in alumina refineries. The operating costs are minimized by replacing live steam and cooling water by electrical power, and moreover the reduced running temperature also limit significantly the scaling of the heat exchange surfaces. This means that maintenance and availability are improved in comparison with other designs.

If electrical power is available with steady conditions and a competitive price, MVR evaporation technology should be really assessed as a potential solution. It can be used as a booster for capacity with an existing unit during expansion programs; but it can also be the best solution for greenfield projects where the caustic concentration is limited leading to low boiling point elevation.

While MVR has been used for decades in other industries (i.e. Pulp & Paper industry or Salt industry), this technology is also a good fit for the Alumina refineries.