WATER BALANCES IN HYDROMETALLURGICAL REFINERIES

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Abstract

Water is a valuable and in many areas a scarce resource. Governmental legislation regulates the environmental impact of water usage and wastewater disposal through the issue of licenses. These requirements mean that hydrometallurgical refineries must ensure that water consumption and water disposal is managed on a continuous basis in order to prevent the repeal of their operating license.

Water balances are often overlooked during the design of a hydrometallurgical refinery. Recent changes in environmental legislation have forced both design engineers and operational management to review water use and disposal within these processes.

Unlike concentrators where water can easily be recovered by recycling from tailing dams, water introduced into hydrometallurgical refineries becomes contaminated with soluble metals and thus requires pre-treatment prior to disposal.

This paper discusses the various concerns that need to be considered during design and operation of hydrometallurgical refineries with respect to the water balance.

1 Introduction

Hydrometallurgy is defined as the extraction and reclamation of metals from ores by treating them with aqueous chemical solutions, including extraction by electrolysis and ion exchange. The chemical solutions in hydrometallurgical processes are usually an acid or base dissolved in water.

Often during the design of a new hydrometallurgical refinery, engineers only focus on the metals to be extracted. Little or no cognisance is given to the water present.

Factors making water ideal to use in hydrometallurgical refineries are:

- water is an efficient way to transport particles within and between processes, mixing particles, and supplying reactants to the site of reactions;
- water provides a medium which is suitable vehicle for the selective action of a distributed force field, for example gravity or centrifugal force;
- water forms an essential chemical substance in most processes.

Water is also used to heat in the form of steam or to cool in the form of cooling water. Pollution abatement equipment treating gaseous emissions utilises water as solvent for the scrubbing agent and to retain particulate matter.

The use of water in hydrometallurgical processes has an impact on the environment. An increase in ecotoxicity is expected. Additional impacts include changes in the eutrophication, chemical oxygen demand, and level of suspended solids in natural waters.

This writing attempts to emphasize potential aspects that need to be considered during the design of a new facility. It highlights the thought process to follow, different technologies available, and affects it these are not followed.

2 Water Balance

A water balance over a hydrometallurgical refinery will consist of input and output streams as well as internal recycle streams within the boundary fence.

The input streams, or sources of water ingress, include rainfall, snow, and dew; groundwater entering from the soil; water accompanying the raw material feeds; and dilution water present in reagents. The output streams, or sinks of water, include loss of water to evaporation, flashing, and drifting; seepage of water into soil; discharge of water to natural waterways; water in final and intermediate products; and water associated with solid waste. The internal recycle streams usually include boiler and cooling water blowdowns. In addition, water accumulates in the process in inventory. The various inventories include storage in tankage; runoff to ponds; and excessive dilution of process streams.

Usually the scenario described above is used to estimate the fresh water requirements during the initial mass and heat balances. Although accurate enough for cost budget estimates, additional work is required if the project continuous into the detailed design phase. Difficult commissioning, higher operational costs, expensive and time intensive retrofits might result using this approach during sizing of process equipment.

3 Design Considerations

It is critical that once the flowsheet has been finalised that the mass and heat balance be expanded to include all equipment with all inputs, outputs and utility requirements. This will provide insight on the amount and quality of water required in the various process steps.

Additional aspects need to be considered to estimate a more accurate picture of the water balance in hydrometallurgical refineries. These aspects are used to expand the initial mass and heat balance derived using the typical approach mentioned in section 2. Detailing the interim streams converges the amount of fresh water make-up required to a more believable and better-defined value.

A design method to use is water pinch technology. Pinch technology presents a simple method for systematically analysing the process and surrounding utility systems with the help of the first and second laws of Thermodynamics. The first law provides the energy equation for calculating the enthalpy changes in the streams passing through a heat exchanger. The second law determines the direction of heat flow. That is, heat may only flow in the direction of hot to cold. This prohibits temperature crossovers of the hot and cold stream profiles through the heat exchanger unit.

3.1 Rainwater runoff

It is tempting when laying out a Greenfield refinery to leave wide open expanses between unit process to facilitate future expansion and intra-plant logistics. It is also often deemed good practice to pave or tar open expanses of land within the perimeter of the plant so as to prevent the formation of mud and to minimise housekeeping and maintenance issues.

However, most countries now expect that all rainwater that falls on the refinery footprint is retained inside the fence-line and either used in the process or treated for acceptable drainage either to a natural waterway or a municipal sewer system.

It is therefore beneficial to the operation to carefully consider directing roof gutter flows to a dedicated pond for eventual re-use. Open spaces are better grassed to enable rain water of reasonable quality to sink into the ground. Systems can be utilised whereby the first few minutes of rainfall run off are collected and then, once the plant has been cleansed of any contamination, the balance is allowed to flow to natural water courses.

3.2 Water Ingress

Due to time and cost constraints during the project design insufficient time and effort is put into trying to minimising water input or ingress in to the plant. The plant operations are then forced to live with, or retrofit, whatever decisions were made during the design phases.

Often equipment or process requirements force the engineer to have to include for extra water ingress into the plant. The effects of this on the mass and heat balance are often overlooked. In addition, the engineer often makes assumptions when modelling the mass balance. These assumptions are only confirmed once the equipment or process have been fully defined. Any changes as a result of detailed design need to be incorporated into the model.

In the detailed design phase the engineer must review the "life time costs" of implementing any decision to minimise water ingress into the circuit. For instance the decision to use single mechanical seals or double mechanical seals on slurry pumps. With single mechanical seals, water will be introduced into the circuit on a continuous basis. This water, if the circuit does not balance, will have to be bled from the plant and since it is now contaminated with base metals will have to be treated before being disposed. The capital costs for the installation are less but the future operating costs will be high, especially if a simple treatment process is not used. Alternatively, if double mechanical seals are used there is no water ingress into the circuit, but the initial capital cost is high and the seal maintenance is expensive. In this case a trade-off study should be performed to compare the "life time cost" of using a single mechanical seal versus a double mechanical seal. The cost of the utility circuit and instrumentation requirements for the various circuits should be included in the study.

Makeup of reagents at higher concentrations in water and then diluting down with process solution prior to feeding into the process. This is especially applicable with reagents like flocculent which can be made up at 0.5% concentration to hydrate the flocculent and then diluting down to 0.025% with process solution prior to feeding to the thickener.

3.3 Internal Water Recycle

During the design phase it is essential that the usage and recycle of different quality waters be scrutinised in order to minimise the fresh water feed into the plant. One unit operation's effluent can be considered as feed or makeup solution for another.

An example of such a scenario is a reverse osmosis plants, which produce demineralised water that may be required in certain sections of the plant where water purity of the water is important. The brine produced is often regarded as an effluent with its attendant disposal costs. However, the possible should be investigated whether the brine could be used as reagent makeup water in a section of the plant where impurities are not a problem.

Other examples of recyclable "effluents: include:

- cooling water blow down;
- steam blow down;
- and contaminated condensate disposal.

3.4 Interim Streams

Parameters often forgotten on the detailed analysis of mass and heat balances over individual process circuits include:

- tanks should allow for heat losses and evaporation;
- pumps should allow for gland seal water if required;
- blowers should allow for cooling water;
- evaporation circuits should allow for bleeds to prevent impurity build up;
- allowance should be made for floor and equipment wash waters;
- bleeds to maintain impurity levels within a circuit should be identified;
- backwash or wash cycles on filters should not be ignored;
- cooling water and steam generation circuits should be included complete with blow down requirements;
- and an allowance should be made for cloth washing circuits on belt filters.

Importantly the client and engineering design company must fully understand the necessity of expanding and including these mass and heat flows. The cost of including these minor streams at the design phase is minimal compared to the potential problems that will be experienced later by commissioning and operational personnel.

3.5 Recovery scenarios

The treatment of process-derived water streams in order to either re-use the resulting water or in order to allow excess water to flow safely to natural water courses, is now also an integral part of the design of new refining circuits. This has been driven both by the tightening of environmental legislation and the imposition of substantial penalties (sometimes even closure) as well as the significant increases in costs in raw water brought about by exponential growth in world-wide industrial and residential requirements.

Typically, rainwater and process water are constricted in separate open ponds. These ponds allow both storage in the event of un-seasonal or excessive rainfall occurrence as well as allowing the subsequent water treatment plant to be provided with a more consistent flow. The water treatment plant generally consists of a sequence of unit processes designed to remove the various contaminants from the water and to produce an appropriately pure stream for use or disposal. Examples of unit processes and their purposes are detailed in Table 1.

Table 1: Examples of unit operations and their purposes.

Unit process	Purpose
Clarifiers	Coagulation of small solids by means of density difference
Coagulators & after settlers	Removal of large amounts of organic contaminants
Cartridge filters	Removal of various size fractions of minute solid particles
Activated carbon columns	Removal of dissolved and entrained organics
Ion exchange	Removal of metal and earth cations and anionic complexes into a concentrated stream for further processing
Hydrolysis processes	Removal of metal contaminants at elevated pH
Ultra & micro filtration	Removal of finest solid particles
Reverse osmosis	Concentration of salts by osmosis leaving a good quality water stream
Crystallisation	Complete removal of dissolved salts into solid product to produce recyclable water

3.6 Evaporation Circuits

Evaporation and flashing circuits are often required in metallurgical refining circuits in order to either balance the water requirements in the process, to drive off water to produce crystals or to cool superheated solutions to boiling point.

Plants constructed in previous years often failed to design for the optimisation of energy requirements in these circuits as well as to facilitate the reuse of valuable clean water streams emanating from these unit processes.

Energy can be conserved in evaporation circuits by the use of the residual energy in the process vapours driven off in the evaporation process. This can be accomplished in two ways:

- using the energy in the process vapours (often evaporated under vacuum) to provide the motive force for the evaporation of solution in a second or third evaporator effect;
- and using an element of the energy in the process vapour in addition to new steam in thermo-compressors to enhance evaporation.

Careful control of level in the evaporator bodies with regular cleaning of the demister pads enables both the steam and process condensate streams to be used as raw water stock for the process. Often they are of a quality that can be used as feed-water to demineralised water plants and eventually as boiler feed-water.

Flashing circuits often vent to atmosphere where both the energy and the contained water vapour are lost. Condensate capture and purification circuits need to be considered when large scale flashing from elevated temperatures are an inherent element of a refining circuit.

3.7 Control and Accounting Water Usage

During the design phase of the project the design engineer must also take cognisance of the fact that whilst the process may not call for flow measurement of water around the plant it is a very important parameter for operations to be able to account and control the indiscriminate use of water within the plant. Either each water line should be fitted with a flow measurement device or at the very least the main header into each of the sections of the plant should be installed with flow measurement device to record the flows into that section. In this way operations can set up a procedure to account for and control the flow of water into the plant. This should be monitored on a daily basis to ensure that water is not being used unnecessarily in the plant.

4 Conclusions

Water balances in hydrometallurgical refineries are often not given the focus they deserve. In the design of a new plant, lack of understanding of the water balance, might decrease the initial capital outlay, but result in difficult commissioning and higher operational costs. If problems persist after start-up, expensive retrofits might lead to excessive plant downtime. Considering all influencing aspects during design will save time and money. In addition, tightening of environmental legislation laws requires adoption of the “zero liquid effluent” philosophy.

5 References

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