KX Low Temperature Digestion Preliminary Engineering

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Abstract

The patented KX heat exchanger, supplied by Sahl Regen, in combination with reduction of environmental heat losses, can reduce energy consumption at Alteo's Bayer process by 70% and reduce CO_2 footprint by 93%; as reported at the AQW conference in April 2024 [1]. Since then Alteo Gardanne and Sahl Regen have completed preliminary engineering with two equipment suppliers to improve the cost estimate of the project and establish how to conduct a pilot project to finalise design parameters, such as reboiler design heat transfer coefficient (HTC). This paper provides details on how Alteo and Sahl Regen scoped and delivered the preliminary engineering to replace the existing Digestion section with a new KX low temperature digestion (KX LTD) and reduce environmental heat losses.

Keywords: KX heat exchanger, Decarbonisation, Emissions, Energy, Environmental heat loss.

1. Introduction

The world is facing an existential challenge in climate change where humanity is currently generating more than 40 billion tonnes of carbon dioxide (CO_2) per year. The United Nations has set a goal to achieve Net Zero by 2050 [2–6]. Strategies to achieve this are to replace fossil fuels with renewable energy, or at least reduce CO_2 emissions complemented with CO_2 capture. The economic challenge to industry, and specifically the chemical industry, is the simple conversion to renewable energy has a high capital cost, and often increases operating cost; there is no return on investment. Sahl Regen is working on both how to reduce CO_2 emissions and capture CO_2. Sahl Regen's KX heat exchanger can assist the chemical industry in significantly reducing and replacing their thermal energy consumption with electrical energy. Thus, reducing CO_2 emissions and their operating costs. Now there is an attractive return on investment while contributing to Net Zero by 2050. Sahl Regen is also developing a complementary project in Senegal to capture CO_2 at scale.

Alteo Gardanne, the world's oldest operating alumina refinery, established 130 years ago, has decided to change its process in 2022 for environmental reasons linked to the storage of bauxite residue. The transformation of the plant involved adapting a part of the Bayer process to dissolve alumina hydrate and re-precipitate it in order to control the quality of its product alumina hydrate, the precursor of high-value commercial alumina. The energy crisis of 2022 and the France 2030 program encouraging manufacturers to reduce their carbon emissions have prompted the Gardanne plant to consider new technological solutions to reduce its gas consumption for steam production. This is how Alteo and Sahl Regen came to collaborate on the project to install Sahl Regen's KX heat exchangers in the plant's new process. Sahl Regen possesses access to the patented KX heat exchanger that can recover heat between scaling slurries with approach temperature less than zero degree centigrade (0 °C).

The Digestion section of the Bayer process currently recovers energy by flashing the digestion slurry to generate process steam which is then condensed to heat the incoming digestor feed, either just the spent liquor or the combined spent liquor and bauxite. This is a robust method to exchange heat between two streams in which at least one stream contains abrasive solids in a scaling liquor. The drawback is the generation of a temperature profile that often requires heating of the digestion slurry by more than 20 °C [7, 8]. An advantage of this method of heat recovery is the removal of water from the process to assist in maintaining the refinery's water balance; although there are alternatives that require considerably less energy.

In 2023, Sahl Regen and Alteo Gardanne completed Conceptual Engineering [1] that established how to:

- In Phase 1 – Reduce energy by 30 % and steam by over 40 %, by:
    - Replacing their existing Digestion with heat recovery by flash, with a KX low temperature digestion (KX LTD) with heat recovery with KX heat exchangers
    - Increasing the heat recovery capacity of their spent liquor / pregnant liquor plate heat exchangers
    - Add MVR evaporation to more than compensate for the loss of evaporation in Digestion, thus, enhancing a net positive water balance sufficient to satisfy future net zero solute emissions to the environment
    - Reducing conductive and evaporative heat losses.
- In Phase 2 – Reduce energy by 70 % and steam by 100 % by:
    - Recovering exothermic heat of precipitation with KX heat exchangers
    - Replacing the spent liquor / pregnant liquor plate heat exchangers with KX heat exchangers
    - Recovering low grade heat from calcination into spent liquor.

The next step was to conduct Preliminary Engineering for Phase 1 with equipment suppliers and design a pilot unit to finalise design parameters for the KX heat exchanger's condenser and reboiler. Sahl Regen developed for Preliminary Engineering PFDs for:

- KX LTD, see Figure 1
- MVR Evaporation, see Figure 2
- Spent Liquor / Pregnant Liquor Plate Heat Exchangers, see Figure 3.

2. KX Heat Exchanger

The KX Heat Exchanger is a combination of a condenser and reboiler with an optional vapour compressor between the two, filled with a heat transfer fluid that can be water or any other refrigerant appropriate for the operating temperature. The condenser can be arranged in a similar fashion to conventional tube digestors. The huge advantage of the KX Heat Exchanger is that it can recover heat at low and even negative approach temperatures. The approach temperature is the temperature difference available for heat transfer between an outgoing stream and its facing ingoing stream; a positive approach temperature is normally required to achieve heat recovery in a conventional heat exchanger.

3. Importance of Balancing Heat Input to Heat Loss from a Refinery

Although, as explained in our previous AQW paper [1] we can recover heat with the KX Heat exchanger to the point where we do not require any steam in Digestion. However, to achieve zero steam in Digestion we must reduce or eliminate net heat losses from the system or recover low grade heat loss from elsewhere in the refinery. Without any reduction of heat losses in the refinery then heat input to the refinery will not change.

7. Strategy and Financing to Deliver Phase 1 and Phase 2

Replacing an existing Digestion section no matter how large is exceedingly expensive on a per tonne of alumina production basis. So how can we make this change commercially viable and what are the drivers? In Europe, they are:

- Reducing energy costs
- Reducing CO_2 emissions and associated costs within the European Union Emission Trading Scheme.

Our analysis shows that Phase1 is commercially very attractive for Alteo, however the capital cost is sufficiently high to make committing to the project with "new" technology challenging. Fortunately, in Europe for innovative projects that can reduce CO_2 emission and improve competitiveness of European industries, we can seek grants and no/low interest loans from programs like Décarb'Ind of ADEME in the French program France 2030, Certificat Économie Énergie (CEE) of France's national electricity provider EDF and the Innovation Fund of the European Union. If successful, this will make our decision to proceed with Phase 1 significantly easier to make.

We at Alteo are taking small incremental steps in the refinery to implement some of the energy recovery modifications like increased spent liquor / pregnant liquor heat recovery to learn how to integrate these modifications to the operating constraints that are specific to the Alteo alumina refinery.

Phase 2 will only be considered and commercially evaluated once Phase 1 is a commercial success. Like Phase 1, Phase 2 could further reduce energy costs significantly. For now, our focus is on Phase1. Phase 2 is for now only an option for the future.

So in summary, our implementation strategy is in 4 phases:

1. Obtain European and French financial support
2. Prepare the land where the KX LTD and MVR Evaporation will be built
3. Install an incremental increase in plate heat exchanger heat recovery capacity
4. Build and operate a KX condenser / reboiler pilot to firm up design HTCs
5. Select vendor for 100 000 t/y Al_2O_3 KX LTD unit and 20 t/h MVR Evaporator
6. Commence construction

8. Conclusions

We at ALTEO and SAHL REGEN have an exciting project, based on a step change in technology to not only reduce CO_2 emissions but also to significantly reduce operating costs. The key to success is to move forward step by step, clearly identifying the key parameters and making the project financially viable.

9. References

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