HyNet North West

VERTEXHYDROGEN

HyNet Hydrogen Production Plant 1 – Technical Note

EPR Response – 9d – BAT for Cooling

Summary

Problem Statement:

With reference to Mineral Oil Refineries BAT conclusion 2, explain which techniques have been used to design the heat integration of the proposed plant.

Response

Background:

With regards to the **LCH™** flowsheet, it is based on Johnson Matthey's (JM) Latest Concept Ammonia (LCA) and Latest Concept Methanol (LCM) flowsheets. As such when the original **LCH** flowsheet was developed, elements of the LCA and LCM flowsheets were used, with the work being conducted under the BEIS Energy Entrepreneurs Fund Competition.

As part of the above work, JM has conducted both a process optimisation and heat integration study in order to optimise the heat recovery within the **LCH** flowsheet. The result of this is a highly integrated flowsheet which recovers as much heat as possible. The only heat rejected from the process is from streams with a low temperature where additional heat cannot be recovered back into the process.

With regards to the CO_2 capture unit, it is based on BASF's latest aMDEA solvents – OASE white©. It has been specifically formulated to enhance hydrogen recovery rate, CO_2 capture rate and use all available heat efficiently. It is integrated with the upstream and downstream sections of the plant.

Techniques Used:

Mineral Oil Refineries BAT Conclusion 2 addresses energy efficiency. It states that in order to use energy efficiently, BAT is to use an appropriate combination of the following techniques:

- ✓ Pinch analysis
- ✓ Heat integration
- ✓ Heat and power recovery
- ✓ Process optimisation
- ✓ Management and reduction of steam consumption
- ✓ Use of energy benchmark
- ✓ Use of combined heat and power
- ✓ Integrated gasification combined cycle (IGCC)

Summary:

Per cost-benefit analysis of the feasibility of district heating for HPP Hynet plant. The HPP does not have a significant source of low-grade heat because of the extent of heat integration incorporated within its design (noting this is key requirement of the BAT Guidance for Hydrogen Production)

Table 3-13 HPP: Comparison Against Hydrogen Production BAT Guidance – Heat Integration and Process Cooling essentially identifies the energy integration elements and their purpose.

Table 3-4: Comparison against energy integration within LCH plant provides heat recovery and power requirement against BAT guidelines.

Table 3-9: HPP Comparison Against Hydrogen Production BAT Guidance – Process CO_2 Capture from Hydrogen Product states: “The Project has adopted a smaller driving temperature in the heat exchangers (5ºC compared with 10ºC). This smaller “pinch point” has maximised heat recovery albeit at the expense of the physical size of the heat exchangers.”

For concluding the above tables details, a number of benchmarking activities which compares the **LCH** flowsheet against other flowsheets was conducted. This reviewed a number of different key performance indicators including:

- ✓ Energy input and output in the form of natural gas and power requirements and hydrogen production rates,
- ✓ Overall process energy efficiency,
- ✓ CO_2 capture and emission flowrates and overall CO_2 capture rate,
- ✓ Raw material costs,
- ✓ CAPEX and OPEX cost analysis,
- ✓ CO_2 taxation and transport and storage costs,
- ✓ Levelized cost of hydrogen,
- ✓ Overall carbon intensity as per the BEIS Hydrogen Standard.

Analysis Areas:

LCH Steam System finalization

The **LCH** process does raise and consume steam via a Saturator Circuit, an Isothermal Shift Converter and a Steam Boiler. All of the steam is used as process steam and as such there is no net import or export of steam from the flowsheet. The steam requirement for the flowsheet is dictated by the required carbon capture rate. The following text explains how the steam system is integrated into the **LCH** flowsheet.

Saturator Circuit Details

The reforming reactions require that steam is added to the feed gas. This is first done by direct contact of the feed gas counter-currently with hot water in a packed tower, then by direct addition of saturated MP Steam, and finally by direct addition of superheated MP Steam.

The de-sulphurised feed gas from the purification enters the base of the Saturator where it is contacted counter-currently with hot water in order to saturate the gas and to provides a significant amount of steam required by the **LCH process**.

Saturated MP Steam from the ITS Steam Drum and superheated MP steam from the MP Steam Superheater are then added to the Saturator overheads to ensure the steam to carbon ratio at the Gas Heated Reformer inlet is at the required value to achieve the required carbon capture rate.

To prevent the build-up of dissolved inorganics in the Saturator circuit, a small blowdown stream is removed and cooled in the Saturator Blowdown Cooler before being mixed with other condensate streams and sent OSBL for effluent treatment.

One benefit of the Saturator approach is that it allows most of the process condensate to be recycled to the process which minimises the amount sent offsite for effluent treatment. The circulation water from the bottom of the Saturator is combined with process condensate from the Oxygen Pre-Heater before being passed to the Saturator Water Pump. The Saturator Water Pump discharge is mixed with make-up condensate from the Process Condensate Pre-Heater and is circulated to Saturator Water Heater No.1 and then Saturator Water Heater No.2 where it is heated by syngas exiting the Isothermal Shift Converter and Gas Heated Reformer respectively before being returned to the top of the Saturator directly above the packing to saturate the feed gas.

Isothermal Shift Details

The hot syngas from the Gas Heated Reformer shell side is first passed to the Saturator Water Heater No. 2 where it is cooled by heating the circulating water in the saturator circuit.

The Isothermal Shift Converter consists of tubes containing copper-based catalyst with water on the shell side to provide cooling by production of saturated MP Steam.

The syngas passes from Saturator Water Heater No.2 to the tube side of the Isothermal Shift Converter where the water gas shift reaction occurs to react carbon monoxide with water to produce hydrogen and carbon dioxide.

The heat of reaction is transferred to the shell side of the converter which produces steam in the ITS Steam Drum. MP Boiler Feed Water (MP BFW) is supplied to the ITS Steam Drum from the BFW Pre-Heater, which is part of the Steam Boiler and the saturated MP steam generated is added to the Saturator overheads.

The exit gas from the Isothermal Shift Converter is cooled in Saturator Water Heater No.1 and then the Process Condensate Pre-Heater. The syngas then enters the Syngas CO2 Regeneration Reboiler which provides the heat load required by the CO2 Removal Unit.

Steam Boiler Details

Demineralised Water is pre-heated in the Demin Water Heater before entering the Deaerator.

BFW is supplied directly from the Deaerator to the water jackets on the Gas Heated Reformer and Autothermal Reformer, where it is used to provide cooling for the refractory lined vessels.

Boiler Feed Water required for steam raising is supplied from the Deaerator by the MP BFW Pump. The MP BFW passes to the BFW Pre-Heater where it is heated before flowing to the MP Steam Drum and the ITS Steam Drum. BFW from the MP Steam Drum is used in the MP Steam Boiler where a small fraction is vaporised and subsequently disengaged from the liquid phase in the MP Steam Drum.

The saturated MP steam from the MP Steam Drum is then split so that some is sent to the Oxygen Pre-Heater to pre-heat the Autothermal Reformer oxygen, a small amount is used as a steam purge in the hot oxygen stream, a small flow is provided to the Deaerator and the remainder is passed to the MP Steam Superheater to be superheated. This superheated steam is then combined with the Saturator overheads and MP Steam from the ITS Steam Drum before passing to the Mixed Feed Pre-Heater.

FW from the ITS Steam Drum is used as a cooling medium on the shell side of the Isothermal Shift Converter where a small fraction is vaporised and subsequently disengaged from the liquid phase in the ITS Steam Drum.

To minimise fouling and corrosion, the BFW is chemically dosed by the BFW Dosing Package, which supplies oxygen scavenger to the Deaerator, amine to the suction of the MP BFW Pump and phosphate to the MP Steam Drum and its Steam Drum.

Post Hydrogen Supply Competition Update

Subsequent to completion of the Hydrogen Supply Competition, JM completed a pinch analysis on the LCH flowsheet and this confirmed that the proposed flowsheet for the HyNet project was the optimal flowsheet, at the power and natural gas prices assumed in that study.

Power Requirements

Since the LCH plant uses all of the steam within the process, there is no steam import or export. As such there is no opportunity for power generation within the flowsheet and the power that the flowsheet requires will need to be imported from the grid.

<u>Further development:</u>

To ensure that the plant has been fully integrated and optimised in terms of heat and power, a further round of value engineering exercises shall be completed within the next engineering phase. This shall focus on bespoke and specific opportunities such as;

- Finalisation of individual loads from vendor data
- Operation synchronisation
- Hydraulic power recovery
- Cooling optimisation
- Removal of equipment such as the Natural Gas inlet compressors

All of which shall drive the plant efficiency higher.