HAZOP ON THE BTG-BTL REACTOR (ROTATING CONE REACTOR)

Biomass particles are fed to the pyrolysis reactor together with an excess flow of sand, which acts as circulating heat carrier material. The biomass and sand are mixed within the pyrolysis reactor and converted into pyrolysis oil vapors, gas and char. The produced vapours and gasses pass through several cyclones before entering the condenser, in which the vapours are quenched by re-circulated oil.The sand and char are transported to a combustor, where air is added to combust the char and reheat the sand.The hot sand is then transported back to the reactor to close the loop.This system ensures that the excess heat which is produced by the combustion of pyrolysis char and non-condensable gases is captured as steam so it can be utilized in for example a steam turbine system. Some steam will be used for electric power generation and feedstock drying but the excess steam can be sold to a nearby industrial site or district heating grid.

This reaction is exothermic, and a cooling system is provided to remove the excess energy of reaction. If the cooling flow is interrupted, the reactor temperature increases, leading to an increase in the reaction rate and the heat generation rate. The result could be a runaway reaction with a subsequent increase in the vessel pressure possibly leading to a rupture of the vessel. The temperature within the reactor is measured and is used to control the cooling water flow rate by a control valve.

Besides, this reactor has built-in recovery of excess heat in the form of steam which can be used for heating and electricity production. In this case, this power electricity generated can be used to run the total plant. If there is less heat produced, the system would not functioning well and there will be less heating and electricity production.

The HAZOP Analysis has been done and four study nodes of this analysis are the **cooling water line, stirring motor, monomer feed line, and reactor vessel.**

The HAZOP analysis would reveal the following potential process modifications (**special safety features) to be installed in our proposed reactor :**

- Installation of a cooling water flow meter and low flow alarm to provide an immediate indication of cooling loss.
- Installation of a high temperature alarm to alert the operator in the event of cooling function loss.
- Installation of a high temperature shutdown system, that would automatically shutdown the process in the event of a high reactor temperature. The shutdown temperature would be higher than the alarm temperature to provide the operator with the opportunity to restore cooling before the reactor is shutdown.
- Installation of a check valve in the cooling line to prevent reverse flow. A check valve could be installed both before and after the reactor to prevent the reactor contents from flowing upstream and to prevent the backflow in the event of a leak in the coils.
- Periodic inspections and maintenance of the cooling coil to insure its integrity.
- Evaluation of the cooling water source to consider any possible interruption and contamination of the supply.

The installation of a back-up controller and control valve was not essential. The high temperature alarm and shutdown system that are installed, already can prevent a runaway in this event. Similarly, a loss of cooling water source or a plugged cooling line would be detected by either the alarm or emergency shutdown system

HAZARD AND OPERABILITY REVIEW

STUDY NODES	PROCESS PARAMETER	GUIDE WORDS (DEVIATIONS)	CAUSES	CONSEQUENCES	ACTION
Cooling coils	flow	No	1. Control valve fails closed 2. Plugged cooling coils 3. Cooling water service failure 4. Controller fails and closes valve 5. Air pressure fail, closing valve	1. Loss cooling, possible runaway 2. As above 3. As above 4. As above 5. As above	1. Select valve to fail open 2. Install filter with maintenance procedure. Install cooling water flow meter and low flow alarm. Install high temperature alarm alert operator. 3. Check and monitor reliability of water service 4. Place controller on critical instrumentation list 5. Select valve to fail open
		High	1. Control valve fails open 2. Controller fails and open valve	1. Reactor cools, reactant concentration builds, possible runaway on heating. 2. As above	Instruct operator and update procedure.
		Low	Partially plugged cooling line	Diminished cooling, possible runaway	Install filter with maintenance procedure. Install cooling water flow meter and low flow alarm. Install high temperature alarm alert.
		Reverse	Failure in water resulting in the backflow	Loss of cooling, possible runaway	Install cooling water flow meter.
	Temperature	Low	Low water supply	None – controller handles	None
		High	High water supply	Cooling system capacity limited, temperature increases	Install high flow alarm and/or cooling water high temperature alarm.