

Modeling and Simulation of Chemical Reactors Cooled by Thermosyphons

Thermosyphons is a wickless “heat pipe” that’s capable of performing an impressive heat transfers. In a theoretical study three batch/semi-batch reactor models have been simulated, by the use of MATLAB, to observe the effect of using thermosyphons as an additional cooling method. The effect of using thermosyphons has been evaluated and both the process safety as well as the reaction efficiency have been analyzed. The results have indicated a very positive outcome and that a relatively small number of medium sized thermosyphons can both increase the control of the reaction temperature as well as prevent a runaway reaction in a worst-case scenario.

A runaway reaction (a.k.a. as a thermal runaway) is one of the major risks within the chemistry industry. Two things are required for a thermal runaway and this is at least one exothermic reaction and a reaction rate that grows when the temperature increases. When a chemical reaction is on a runaway the temperature within the reactor is rising, leading to faster reaction and that the exothermic reaction releases more energy into the system. This can be described as a bad cycle where the temperature growth eventually can lead up to a massive explosion and fire or perhaps a leak of hazardous material. In a study that was performed by the U.S Chemical Safety and Hazard Investigation Board (CSB) 167 of serious accidents that had occurred in the United States from 1980-2001 was examined. About 35% of these were a runaway reaction and the most common location was the chemical reactor.

A thermosyphon is a relatively simple tool that consists of a hollow and sealed pipe that’s been partially filled with a fluid. One end of the pipe is then heated at a temperature above the saturation temperature of the fluid while the other end is cooled. This will create a passive loop within the pipe where the fluid evaporates in one end and condensates at the opposite. Due to the massive heat transfer coefficient that’s reached when the fluid is boiling the thermosyphon can transfer a lot of heat from one end of the pipe to the other.

Systems that’s been aided by thermosyphons have proven to be a lot more safe and that a thermal runaway could be prevented even in case the cooling of the original cooling system (the cooling jacket) would cease. Besides this the temperature control of the process has also been greatly improved. The impressive heat transfer prevents the reaction temperature to go very high above the boiling temperature of the fluid within the thermosyphon. This does not only increases the safety of the reaction but also the control of potential side reactions as well. By optimizing the starting temperature, the boiling temperature and the size of the reactor the process can be safer, more selective and keep the production rate up to the desired level.

All in all the thermosyphons appears to be of good use to the chemical industry, especially to processes involving numerous side reaction and where selectivity is of more importance than conversion.