CHEM-E7175 Process safety and sustainability
Exam 16.12.2021; 14 -17

1. (5p) A valve in a chemical plant is replaced by a valve from the warehouse. Unfortunately, the warehouse valve was not constructed of the same material as the original and within a few months corrosion caused the valve to leak, causing a release of toxic material. Which element of risk-based process safety (RBPS) applies to this scenario? Identify and explain the most directly impacted element and other elements that might also be involved.

2. (5p) In a process heat exchanger: Tube to tube-sheet joint failure results in mixing of process fluids and incompatible heat transfer fluids, resulting in a system over pressure and/or the formation and release of a toxic material. Propose design solutions for:
   a. Inherent safety
   b. Passive safety
   c. Active safety

3. (10 points**)**

A company has bought a chemical plant and would like to make it safer.
Study, which are the inherently unsafe parts of the process based on the information given. Apply the inherently safer process design principles and propose safer designs when possible.

Description of process:

A reaction A + B -> D + heat, takes place in a semi batch reactor at 80°C and 101 kPa with a liquid catalyst C. The reaction is quite exothermic and proceeds virtually instantaneously to a complete conversion as long as catalyst C is present. The reaction mass becomes unstable if reactant B is overcharged or catalyst C is left out, which results in a buildup of unreacted reactant B.

If the concentration B becomes too large a rapid and very exothermic reaction
2B -> S + heat, takes place in the temperature 80°C used. The side product S is thermally unstable and decomposes at about 170-180 °C.

The process is operated so that 2m^3 of feed A (concentration 93 wt-%) is first charged to the reactor via a flow control. The agitator is started, and the reactor is heated up to 70°C with steam jacket. Then the catalyst C (about 3 liters) is added by a meter pump. The reactor jacket valves are turned from steam to cooling water. After this, the feeding of reactant B (concentration 90%) is slowly started via flow control. The temperature of reactor is monitored from the temperature measurement and controlled automatically (by TIC) by varying cooling water flow to keep the reactor temperature at 80°C. If the cooling water valve becomes nearly open the reactant B flow rate is reduced.

When all the reactant B (2m^3) is charged to vessel, the reactor is emptied to an intermediate vessel to be distilled later.

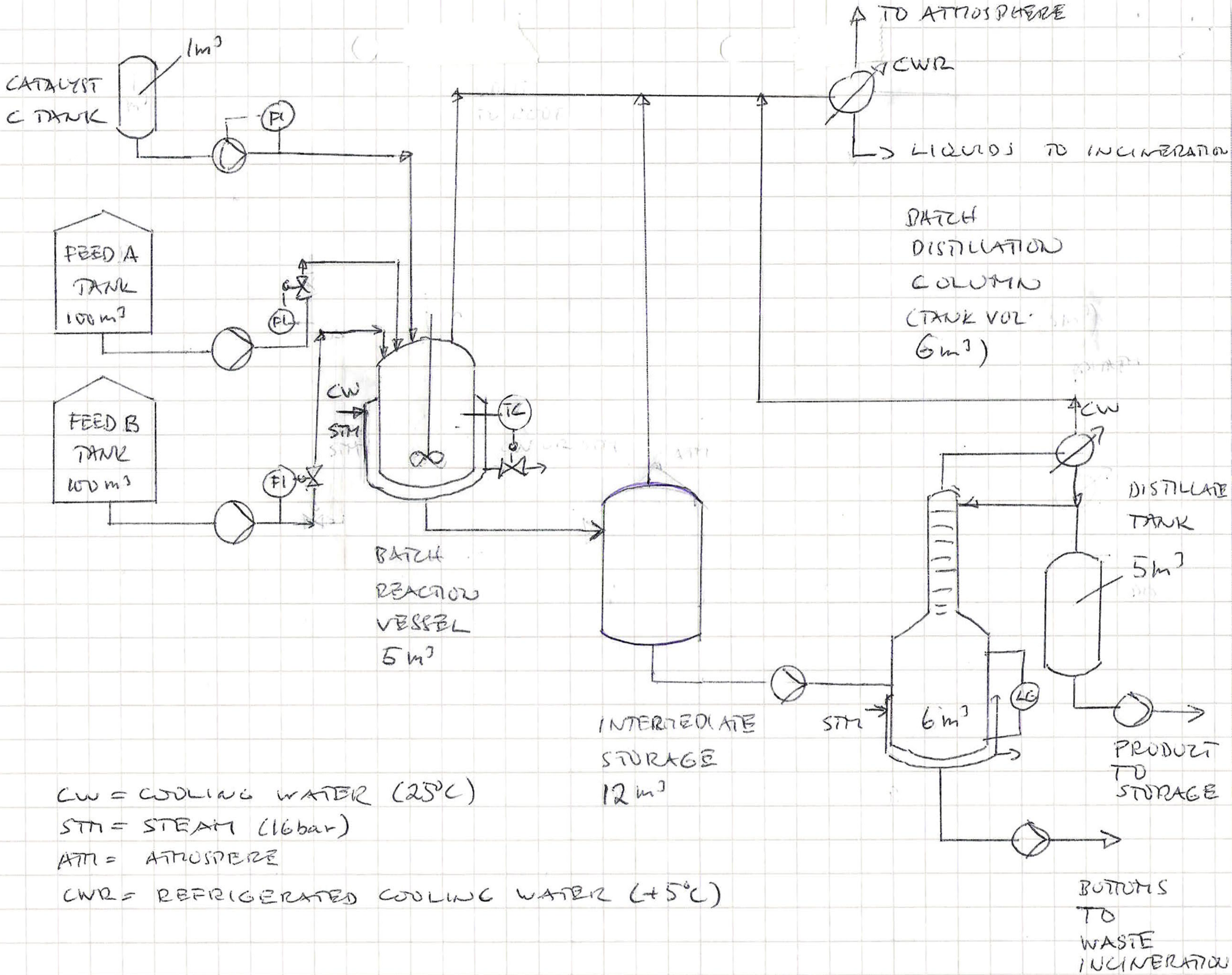
The batch distillation is used for removing the product D from the impurities (feed stock impurities, catalyst remains and possible side product S, which all are low boilers). The catalyst C is not much soluble to product so it could be separated also by settling (gravitation). The batch distillation is operated so the bottom tank of the distillation column is filled from intermediate tank with about 5m^3 of liquid by observing liquid level from level gauge (LG).

After this the steam to column jacket and cooling water to condenser is turned on. The product D is recovered as distillate and the impurities remain in the bottom. The distillation is done at atmospheric pressure and at about 110°C. The distillation is stopped when the bottoms temperature has risen to 130°C. The residues from the bottom are pumped into incineration. The gas vent streams of the process are treated by condensing by refrigerated water (5°C). Essentially all the components can be condensed at that temperature.

Since the components are confidential, the following closely resembling NEPA ratings (0…4, 4 is worst) and boiling points, MF and ERPG-2 values can be used:

Components	Health	Flammability	Reactivity	BP °C	MF	ERPG-2
A =Styrene	2	3	2	145	24	250 ppm
B =acrylic acid	3	2	2	139	24	50 ppm
D =epichlorohydrine	4	3	2	117.9	24	20 ppm
S =phenol	3	2	0	181.7	10	50 ppm

Appendix: A sketch of the process diagram is attached



CW = COOLING WATER (25°C)
STM = STEAM (16bar)
ATM = ATMOSPERE
CWR = REFRIGERATED COOLING WATER (+5°C)