KE-107. 6000 Special Course in Plant Design (Process Safety and Security)

Exam 18.12.2009, 8-11 o'clock

You may answer in English, Finnish or Swedish

Theory part (8-9.30):

Lecture etc. material may not be used in this part.
After the theory part return your answer paper.

1. Explain the reasons and learnings from Seveso accident

2. Why computer systems fail

3. What type of hazards DOW F&E index includes (as penalties)

Applied part (9.30-11):

Lecture material may be used in the applied part.

A company has bought a chemical plant and would like to make it safer.
Study, which are the inherently unsafer parts of the process based on the information given. Apply the inherently safer process design principles and propose safer designs when possible. (Evaluate, how hazardous the chemicals used are, by using Dow F&E Index Material Factors and its sub terms).

Description of process:

A reaction

A + B -> D + heat

takes place in a semibatch 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.

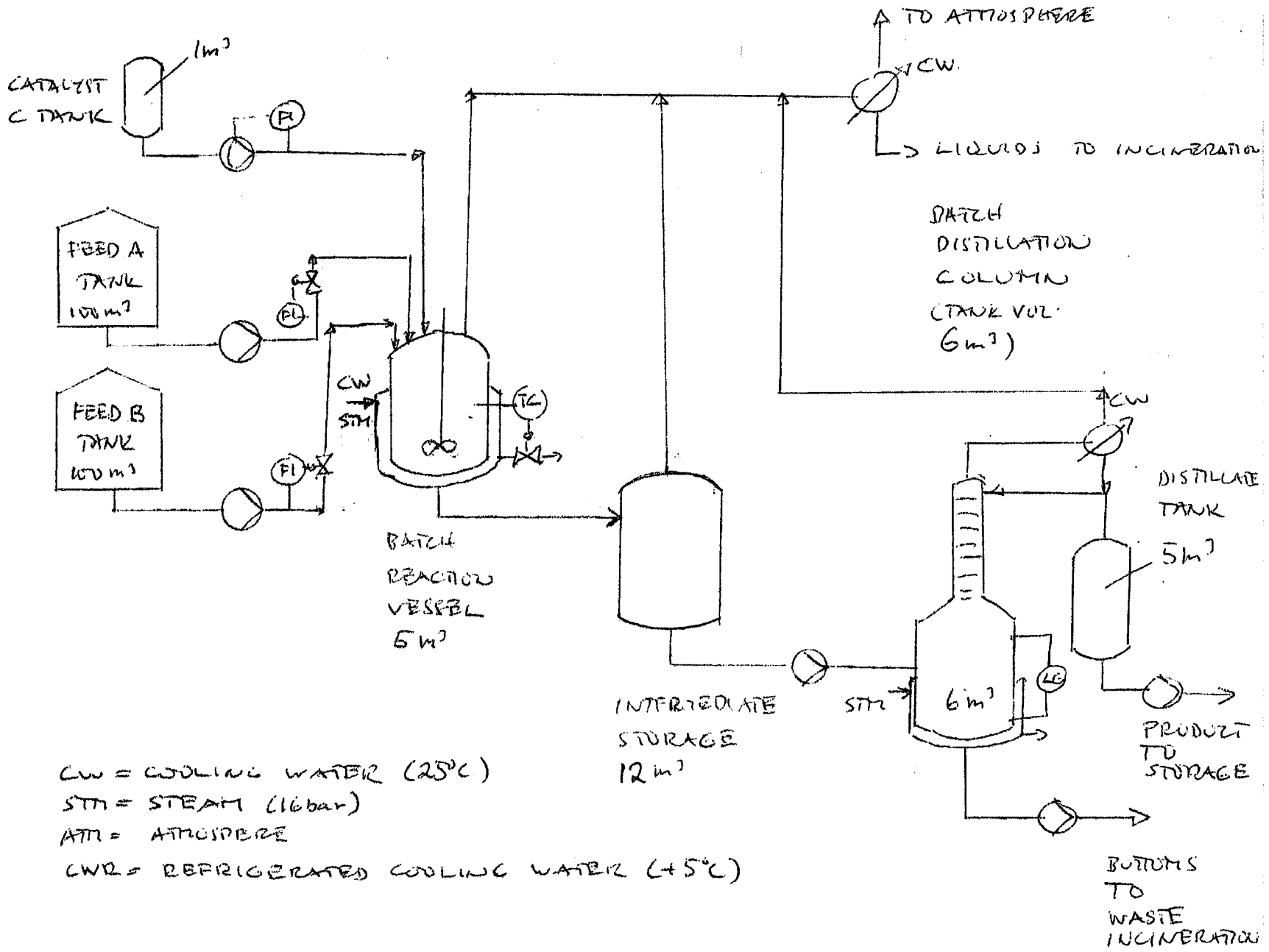
The process is operated so that 2 m^3 of feed A (concentration 93 wt-%) is first charged to the reactor via a flow control. The agitator is started and the reactor is heated up to 70 °C with steam jacket. Then the catalyst C (about 3 litres) is added by a meter pump. The reactor jacket valves are turned 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 (2 m^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 5 m^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 flammability and health values can be used:

					H	F	R
For	A	values of	styrene	Boiling point 145 °C	2	3	2
	B		acrylic acid	140	3	2	2
	D		epichlorohydrine	116	3	2	1
	S		phenol	181	3	2	0

Appendix included: A sketch of the process,
NFPA index values


TO ATMOSPHERE
CW
LIQUIDS TO INCINERATION
CATALYST C TANK
1m³
PI
FEED A TANK 100 m³
FEED B TANK 100 m³
FI
FI
CW
STM
TC
BATCH REACTION VESSEL 5 m³
BATCH DISTILLATION COLUMN (TANK VOL. 6m³)
INTERMEDIATE STORAGE 12 m³
STM
6 m³
LC
CW
DISTILLATE TANK
5m³
PRODUCT TO STORAGE
BOTTOMS TO WASTE INCINERATION
CW = COOLING WATER (25°C)
STM = STEAM (16bar)
ATM = ATMOSPHERE
CWR = REFRIGERATED COOLING WATER (+5°C)