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**The Problem Statement -**

A facility which imports and stores LPG needs to be converted into a facility which imports and mixes Butane and Propane and produces LPG for a specific composition. This new process has an economic advantage over the previous process of just importing LPG. The import of Butane and Propane is done through a ship which has two compartments for the two liquids, which is transported through pipes(12" diameter and 12.5 Km long) to the storage tanks (As shown in the figure) . The main problem this process causes is the cavitation of the pumps due to evaporation of the cryogenic liquid (propane or butane).

TO COMPRESSOR

HEADER

BUTANE  
-4oC

PUMP

SHIP

PROPANE  
-40oC

**Flow sheet of the process**

The practice that was originally followed can be broken down into two sections, viz.   
 (1)Before the ship docks  
 (2)After the ship docks

**Section 1- Before the ship docks**As we are dealing with cryogenic liquids, we need to pre-cool the pipeline at least till the temperature of the incoming liquid. We have a choice between the two liquids, as to which one do we import first. So for the purpose of explaining the process let's take butane to be the first liquid to be imported. Now it is important to note that, butane is stored at -4oC and propane at -40oC, in both the ship and the storage tank. So the pipelines are cooled to -4oC by pumping butane in a cycle (from the storage tank to the pipes to the tank again).The whole pre-cooling is done so as to prevent the cavitation (of the pump) of the liquid that we are importing.

**Section 2- After the ship docks**The pre-cooling operation takes about 20 hours, after which the ship is docked and butane from the ship is taken in through pumps. The tank in the ship contains 7500tons of both butane and propane . After all of the butane has been imported the valve switches to import propane from the other tank on the ship. This propane at -40oC, makes a contact with the -4oC pipe and the butane in the pipe, vaporizes thus cavitating the pump. The low pressure belts formed during the impeller rotation would turn into knocking of the pump, which can be detrimental to the pump.

It may not be practical to pre-cool it for the second time (with propane) due to time constraints. A solution to this problem can be achieved by using a mixture of butane and propane as the pre-cooling liquid.

**The Solution-**

We use an azeotrope-like mix of propane and butane to pre-cool the pipes. The advantage of doing this will be that as the mixture is azeotrope-like, it behaves almost as a single liquid and has a definite boiling point (between -4oC and -40oC according to the compositions). So say we have a mix of these two at -25oC and we pre-cool the pipes. So below -25oC this mix would stay in the liquid form. After which we can start importing the liquids from the ship. Now importing propane first is really important, because when propane would come in contact with the mix it will cool the mix down and would also increase the propane content in the mix that is present in the pipes. So even if a certain amount of vaporization occurs, it will be very low (not zero) . After emptying the propane tank on the ship completely , the pipes would have a mix that is rich in propane and which have a lower temperature than -25oC. Now butane can be pumped. So when butane comes in contact with the liquid in the pipe, a small amount of vaporization takes place due to temperature difference, and the temperature of the mix keeps increasing as more butane is pumped. As all this is accompanied by an increase in butane fraction in the mix, the azeotrope like mixture is maintained and further vaporization is curbed. We can store the liquids in such a way that one of the storage tanks facilitates the mixture that was used for pre-cooling at the start i.e. stored at -25oC, so that the pre-cooling for the second batch of operation will be easy. As we need LPG out of all this, we can manipulate the vapour amount coming from both the tanks to get 50% of propane and 50% of butane.