

University Learning in Schools

Chemistry

The Engineer's Guide to Cleaning up an Oil Company's Mess: Designing a Solution

Lesson 4

Chemical Engineering

Engineering is the application of science and mathematics for the design of equipment and processes to achieve a specific purpose. For example, mechanical engineers design engines to make transport more efficient. Chemical engineers design processes to achieve specific objectives as well. Thus, chemical engineers would be responsible for designing the treatment process for petroleum waste water.

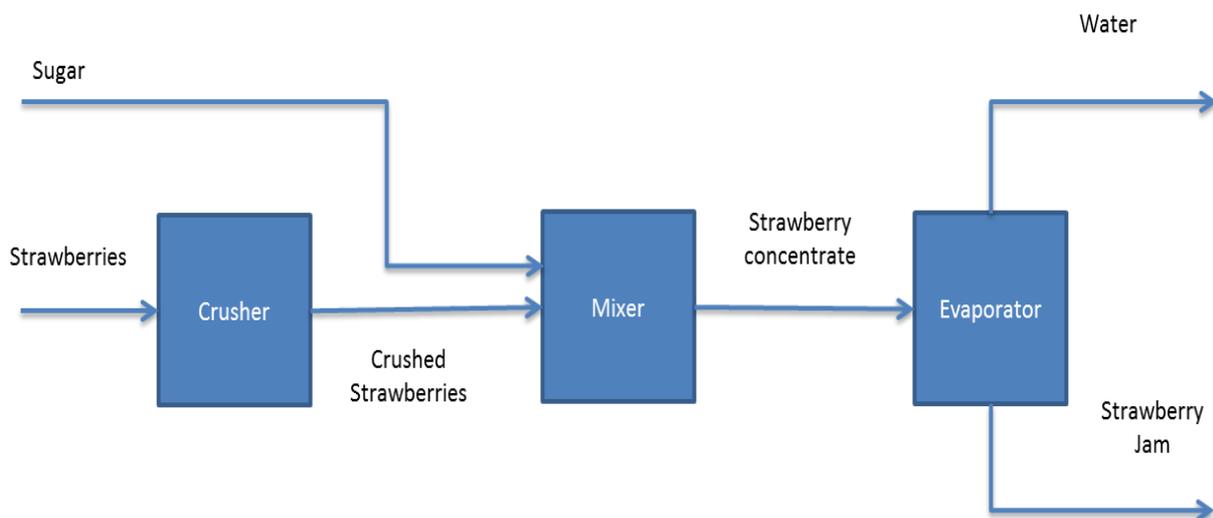
We require a petroleum wastewater treatment design that would be effective at removing pollution while being cost effective at the same time. The first step to designing a chemical process would be to draw it on paper as a block flow diagram



Chemical engineers testing a small scale process

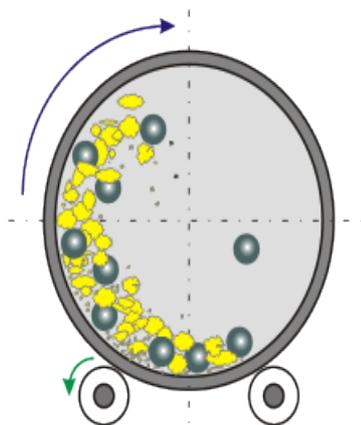
Visualising the process -- Block Flow Diagrams

The block flow diagram is the first step to visualising a process and designing it on paper. It shows all of the major changes that reagents/reactants must undergo before the final product can be made. Below is an example of a process to make strawberry jam.



Strawberry jam process block flow diagram

The above diagram is called a block flow diagram, or a BFD. The arrows represent the movement of material. The blocks represent a piece, or a number of pieces of equipment to bring about a change of material. For example, strawberries are fed to a crusher, which is a piece of equipment which squeezes and presses the strawberries.

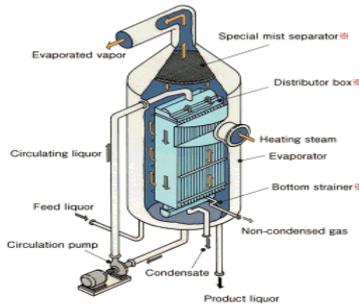


Crusher

The crushed strawberries are then fed into a mixing chamber and uniformly stirred with sugar.



Mixer

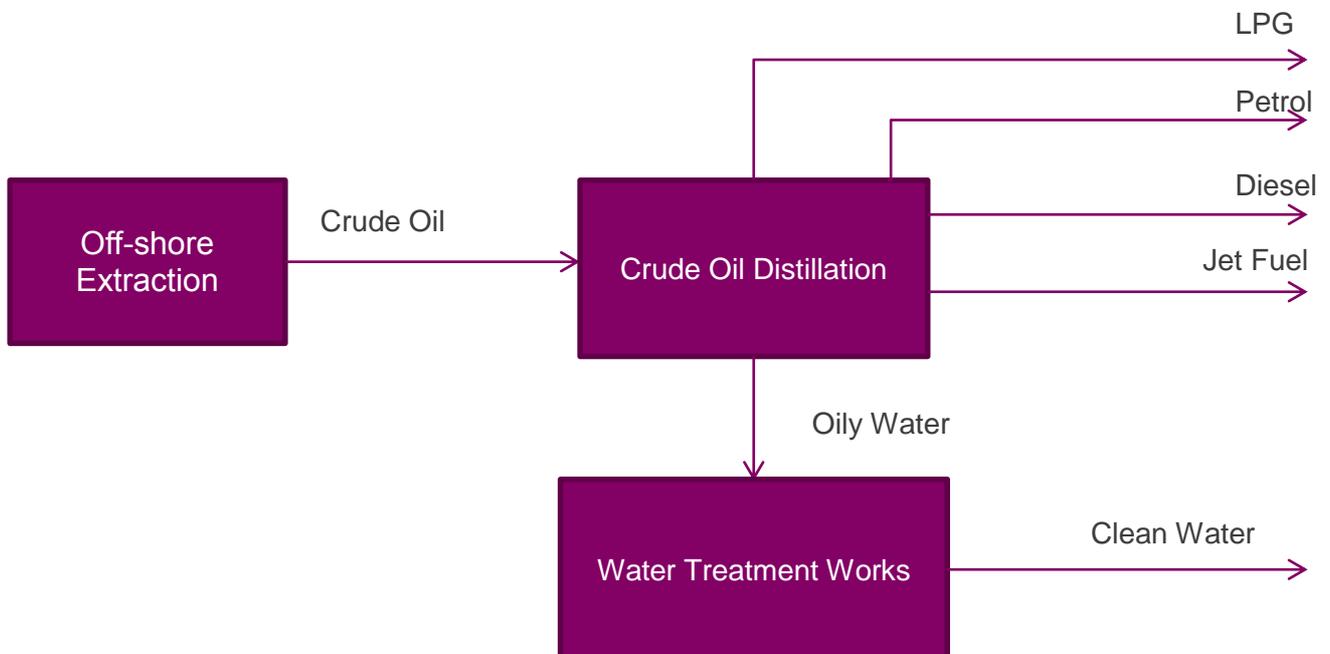


Evaporator

This mixture is then fed into an evaporator, where the water that was contained within the strawberries is boiled off. This is obtained by heating the vessel. The final products are water, and the desired one -- strawberry jam.

The BFD for Fractional Distillation

If we were to represent the process of manufacturing the different fractions of crude oil, it would look something like this:



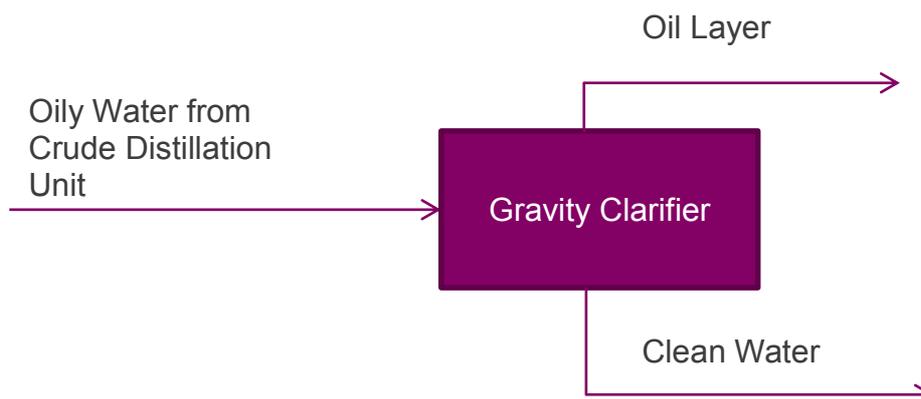
The off-shore extraction block includes all of the processes that are involved in extracting the crude oil from the seabed. This results in our raw product, crude oil, which is sent to the crude distillation process. Again, there are a number of pieces of equipment involved

in this step, such as pumps, mixers, furnaces, reactors, distillation columns, etc. The process yields different products, together with oily waste water.

The oily waste water will be sent to the waste treatment works, where there will be, once again, a number of equipment pieces involved in transforming the oily wastewater into clean water. We are going to attempt to design these steps, and also rate if our designs will work to meet the treatment specifications that we want.

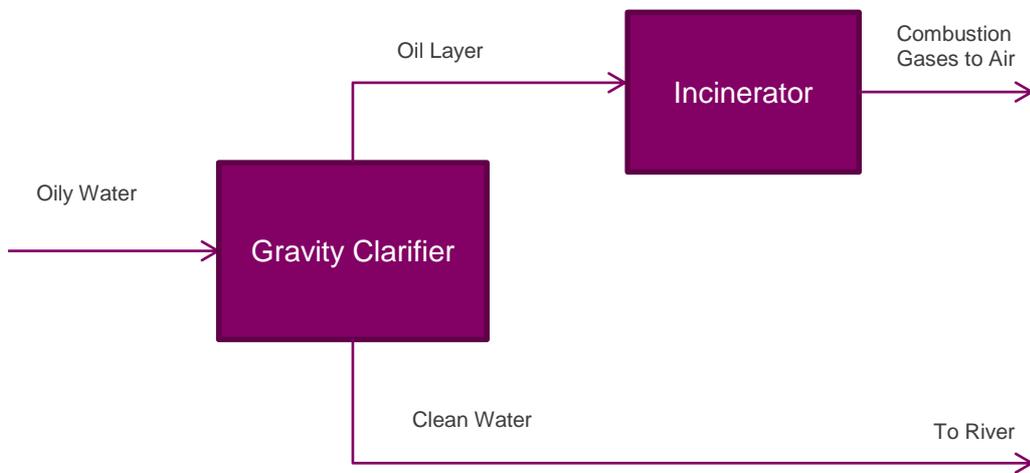
BFD for the use of a Gravity Filtration Unit

One of the most basic designs for separating oil and water is a gravity separation unit. As we learned in the previous lessons, a gravity separation unit simply needs to be large enough to allow for the oil to settle on the top of the water. If our oily water goes into this unit, we will have a top component of oil, and a bottom component containing water.



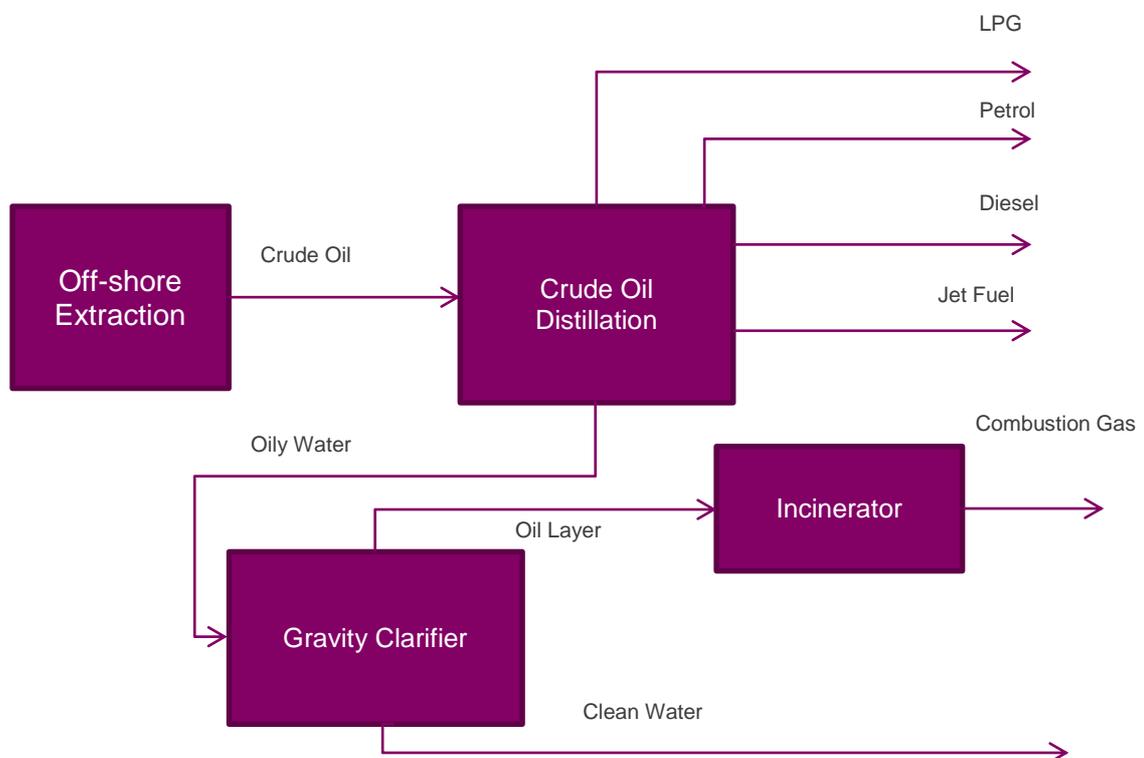
The clean water can now be disposed of into the environment (if it meets regulations). If it does not, it may require further treatment via a biological or chemical method. The oil layer would need to be disposed of via incineration. Some of this oil can be sold as bunker oil fluid, but not many people want to buy this.

Let's add the incineration unit to the process.



The combustion gases formed during the incineration processes are released into the atmosphere. This would count towards the environmental impact that our process has. Generally, we would like to clean the water without having to burn the by-products.

We have now designed a petroleum water treatment process, which can be combined into the crude distillation process.



The same line of thought can be applied to both the biological process and the chemical process.

For the biological process, oily water emerging from the crude distillation unit would be fed into a bioreactor. The only stream emerging from the reactor would be treated water. This is fed into a disinfection unit. In here, the treated water is fed with chlorine to destroy residual bacteria. The disinfected water can be discharged into a river.

For the chemical process, oily water emerging from the crude distillation unit is fed into an oxidation reactor. Either ozone or hydrogen peroxide is fed into the reactor, which has an embedded UV light. This produces hydroxyl radicals which react with the pollutants within the water. The clean water emerging from the reactor may be discharged into a river.

Homework

Chemical Engineering

Chemical engineers are responsible for designing processes for the manufacture of chemicals, or for the accomplishment of a specific objective such as water treatment. Research and list 4 examples of the work that chemical engineers can do.

Block Flow Diagrams

Draw the following block flow diagrams [1]:

a) Gas adsorption or gas scrubbing is a commonly used method for removing environmentally-undesirable species from waste gases in chemical manufacturing and combustion processes. The waste gas is contacted with a liquid solvent in which the potential pollutants are highly soluble and the other species in the waste gas are relatively insoluble. Most of the pollutants go into solution and emerge with the liquid effluent from the scrubber, and the cleaned gas is released into the atmosphere. The liquid effluent from the scrubber may be discharged to a waste lagoon. Draw the BFD.

b) Seawater containing 3.5 wt% salt passes through a series of 5 evaporators. Roughly equal amounts of water are vaporized in each evaporator, and all of these streams are fed to a condenser, which produces a fresh stream of product water. The brine produced from one evaporator is fed to the subsequent evaporator, except that produced from the 5th evaporator. This is sent to another facility which uses this solution as a draw solution for forward osmosis. Draw the BFD.

[1] R. Felder and R. Rousseau, Elementary principles of chemical processes, 3rd ed., New York: John Wiley, 2000.

Petroleum Waste Water Treatment

- a) Draw the BFD of the chemical and biological treatment process.
- b) Draw a combined physical + chemical process.
- c) Draw a combined physical + biological process.