UiT The Arctic University of Norway

Industrial engineering

Three-phase separator simulator introduction

Master's thesis in INE3900 MAI 2022

Table of Contents

1.1 Abstract

In this thesis, the goal is to compare the UIT model in the energy lab to the simulation program Aspen HYSYS. The model in the lab has consist of a three-phase separator tank with a weir, and two-component of water and cooking oil, It was made by two students at UIT in 2018. In this simulation, there will be three different variables to determine the accuracy of the simulation. The flow in and out, the purity and the layer height. The HYSYS simulation of a model used in scares, but valuable information can be achieved. There will be theoretical calculations to confirm the simulations. The challenges are the lack of the phase of gas, additional information on oil has been used, and what are the pressure and temperature. In addition, there are made tasks for the student that have challenges and understand the working of the three-phase process and recreate the model that has been made.

Keywords: Simulation, three-phase separation tank, APSEN HYSYS, MATLAB

1.2 Introduction to three-phases separators

Three-phase tanks are used to separate the mixture of gas, heavy and light liquid, generally, in the petrol and dairy industry, mining[1]—crude oil consisting of gas, water, and oil. The separation is due to the mixture of these three phases having different densities, a lighter constituent like oil and gas compared to water. With time residence these components will separate with the help of gravity and be used for each purpose[2]. The variable that concerns the processes is the amount of flow, constant or changing, pressure of the mixture, and temperature. In separations, this will vary. Therefore it's crucial to go more into detail of the geometry of the tank and establish a working range[3]. To archive, this requires a monitor system to predict and keep the variables in the desired working conditions [4]. The monitor system does not have a conventional solution and depends on various equine techniques to determine the level of oil gas, oil, and water. And the approach is currently used trial and error. These techniques range from using "*externally mounted displacers, differential pressure transmitters, ultrasonic transducers, single-electrode, and multi-electrode capacitance sensors*" [5].

The geometry of a separator tank using gravity has the same behavior depending on the customer's need and the liquid components[6]. Vertical separators are more cost-efficient and use smaller areas when deployed, and handle the buildup of solids such as sand, and dirt. Compared to a horizontal tank. This makes the use of vertical separators more frequently used for smaller operations. For more permanent installation, a horizontal separator is used[7]. The function and difference will be explained in 2.2.

The main activity of this thesis is to evaluate the various levels of the liquid phases inside of the separator, estimate the purity, flow rate and layers make a simulation using the Hysys[8].

1.2.1 Basics of separation tanks

The structure of the separator tank main consists of three sections, intel, gravity, and outlet[9]. The mixture is pumped into this tank can come from sources either on land or at a sub-sea level.

Intel section: The liquid is rapidly changing the direction at a high velocity spreading the mixture such that the fluid is sinking to the bottom of the separator and the gas goes atop, often used feed deflection plate[10]. This is where most of the separation occurs. The liquid is still a mixture of oil and water and needs time for the separator.

Gravity section: The velocity and flow have slowed down and allowed the droplets to be separated from the mixture into the gas zone of the tank. The droplets are small and will float. The separation of water and oil is defined as gravity separation. The two liquids are called immiscible liquids and turn in two phases within the tank because of the difference in density[11]. The time that is needed to separate is called retention time, and sufficient time is needed for this. Another phenomenon is called coalescing separation, where small particles from one of the liquids are separated from a small quantity of liquid, and internal construction is needed for this [12].

Outlet section: As mentioned, the droplet from the liquid is floating in the gas zone of the tank, and for this to form into bigger droplets, a mist extractor is needed that collects all the small size droplets and turns them into larger ones that drop in the liquid allowing them to drop into the mixture again. A weir is also used for separating the oil and water when the oil floats. A wall stops the water allowing oil to pass to stop the turbulence of the mixture and pacify it[13].

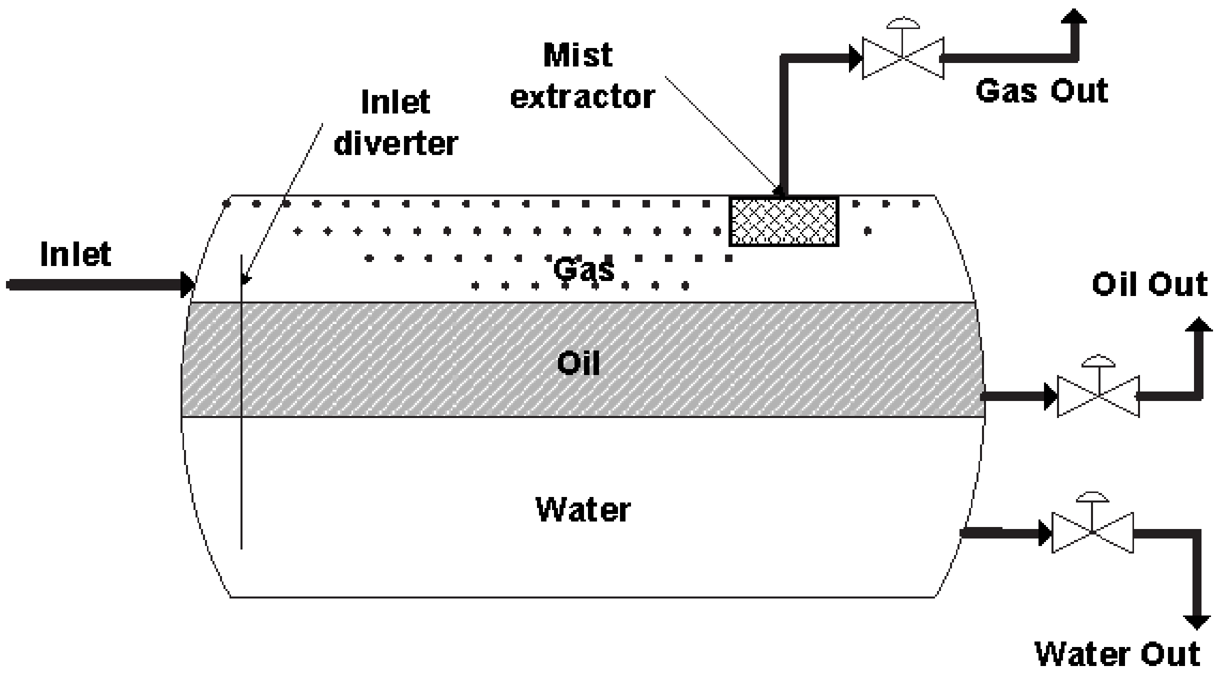

Figure 1: the figure shows the process of separation of gas, oil, and water from a mixture of liquid taken from [14]

1.2.2 Different geometries and designs of separators.

1.2.2.1 Hyrdocyconle separator

Hyrdocyconle separator is a compact tank that doesn't require a large area, and uses are when oil fields are drilling deeper and incoming into the later stages of the production, which is more common now that oil is becoming more scarce. Advantages are the are low cost, operation cost and ease to use. This creates a scenario where the water content is above 15 %, making it difficult for the equipment to process the crude oil[15].

Principle working of a Hydrocyclone crude oil is driven into the tank a the top at a certain pressure and is tangentially fed inlet. Inside the tank, there is a vortex that creates the force from a tangential to centrifugal force, and this increases further down because the area is being restricted. The details phase the heavier particles to the outer edges of the tank and into the underflow outlet, and the lighter practical (oil) is on the inside and moves within the inner core of the separator and excites at the overflow[15-17]. The rise of the droplet are governed by stokes law and assumption:

1. Particles are the same size and spherical
2. No trubolance and lamiar flow.

And the stoke law equation **is** $\boldsymbol{Vs} = \frac{\boldsymbol{g}(\boldsymbol{\rho 1} - \mathbf{p2})\boldsymbol{d}^{\mathbf{2}}}{\mathbf{18}\boldsymbol{\mu}}$

$$v_{S} = terminal\ settling\ of\ the\ solid\ partical$$
$$\rho 1 = destiny\ of\ settling\ partical$$
$$g = gravitational\ accelration$$
$$\rho 2 = destiny\ of\ water$$
$$d = diameter\ of\ water$$
$$\mu = dynamic\ vusisity$$

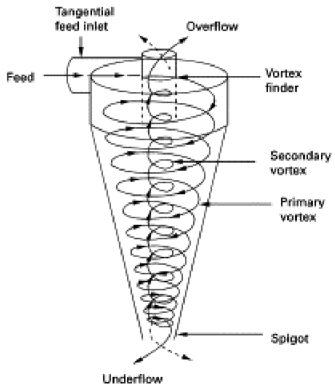

Figure 2 Hydrocyclone source :[18]

1.2.2.2 Parallel piped

The most recent development in the Separation of water and oil is the parallel piped design from NTNU. The design consist of 4 section. First section is the inlet T section that spilts the stream into individual streams, meaning that the heavier phases will be pushed to the sides while the lighter ones will remain in the middle, due to centrifugal forces.Section 2 is the stream divinding the into horizontial stream and have ascending pipes for gas removal. In section 3 the main separation of the liquid liquid separation happens, this in happening due to the density difference and gravitational forces. In section 4 the water mixture in tapped in the bottom of the piped while the oil mixture is driven to the top of it [19]

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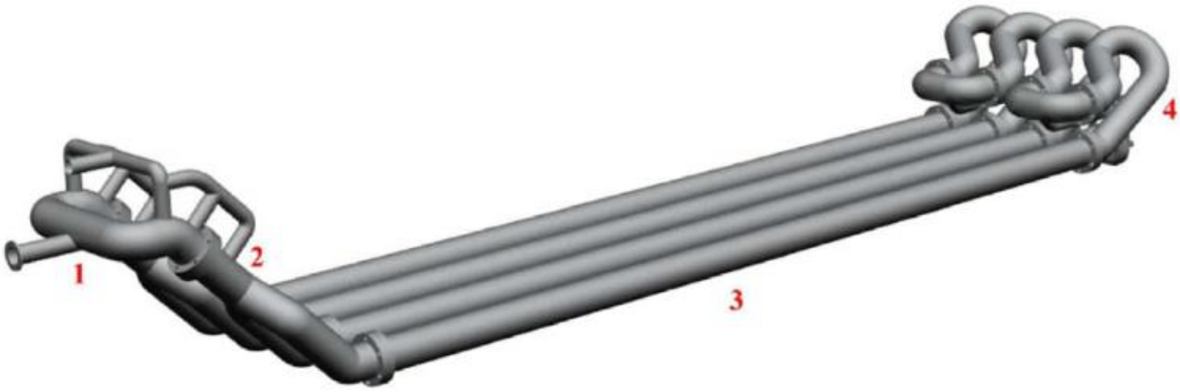


Figure 3 source [19]

1.2.2.3 Vertical separators

A vertical separator is used when, as mentioned, when the liquid has a more slug consistently(contains more solids) and when the area and mobile transportation is crucial. The workings on a vertical are that the mixture goes in an inlet on the side of the tank. Where it is hit by the inlet divider where most of the gas and liquid are separated, there will separate the tank into two layers, one with water and oil. Gas bubbles will rise to the top of the tank into the mist extractor, and droplets in the gas section will form and join the liquids at the bottom [20, 21].

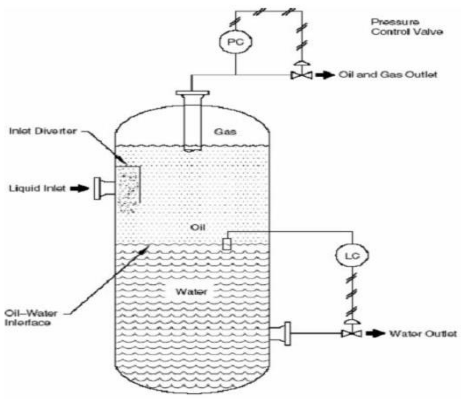


Figure 1: A vertical separator from [18]

1.2.2.4 Advantages and Disadvantages on vertical and horizontal separators

Overview of the advantages and disadvantages of a vertical and horizontal separator

The selection of separators heavily depends on the uses of the tank. This will consist of vertical vs. horizontal tanks. Look at the challenges facing the three-phase separator

Placement/location: Separator location is important for choosing whether the tank will be vertical or horizontal. For operation offshore, the use of a vertical is suited because of the area space and mobile. This can be counter with stacking mounted on top of each other when using a horizontal separator[8].

Solids: With a mixture incoming from a source, it mostly will contain some form of solids. In the horizontal tank, solid piles are situated(repose) at 45 to 60 degrees(angle from the plane to top of the pile) [13], and drains are located and the length of the vessel. Drains needs then to be in close range to each other or installed jets to remove them[14]. Both of these solutions are expensive and not very effective. While in a vertical tank, a dump valve or a drain can be placed in a high elevation and remove the solid before it becomes a pile [8].

Gas/oil ratio: Geometry of a horizontal tank allows for a higher ratio of gas and oil [15]. Volume for gas in a vertical separator is limited and can’t support a high volume of gas but is efficient when it comes to a mixture with low GOR [16].

1.2.2.5 Internal vessel components:

These tanks are equipped with internal components that all have there on uses:

Coalescing plates: are placed in the interface of the water and oil for increasing the size of the droplets, meaning that the setting of the interface is faster and easier. There is a drawback in using these plates: the buildup of sand and other solids. These plates will only be used in a vessel that has a smaller flowrate and smaller size. [22]

Sand jets and drains: as mentioned, the horizontal separators tank with a mixture contains solids that will generate piles at the bottom of the tank and take up volume. To counteract is placing sand jets and drains at the bottom of the tank[2].

Defoaming plates: in crude oil, some impurities cause foam. This foam forms the liquids, and gas are being separated and prohibits the capacity of production. These are placed in the inlet of the tank[23].

Wave Breakers: a plate that has holes distributed and is in a vertical direction in a horizontal tank and horizontal in vertical tanks. In the surge of liquid, depending on the velocity, the plates are placed to break the wave and stop the turbulence [24].

Mist Extractors: A device used for collecting the mist forming in the vessel, the gases in a tank have when separated from the inlet diverter, still have droplets in the form of moisture and hydrocarbons. The purpose is to form these droplets into a size where they drop down into the tank with the help of gravity [25]. Three types are the most common:

- The extractor includes a tight knitted wire with a flat surface between 0,10mm to 0.28mm. these are the most commonly used and considered low cost [26]
- Vane packs force the mist into narrow plates in a snake pattern. They are considered less efficient and require maintenance but are more resilient against plougning. The mixture contains wax, high-speed mist, and slug that can clough-op in mist extractors
- Demisting cyclone is a cycle that uses centrifugal force and separators the liquid and gas. Requires a steady flow with little changes and a high-speed liquid. [27]

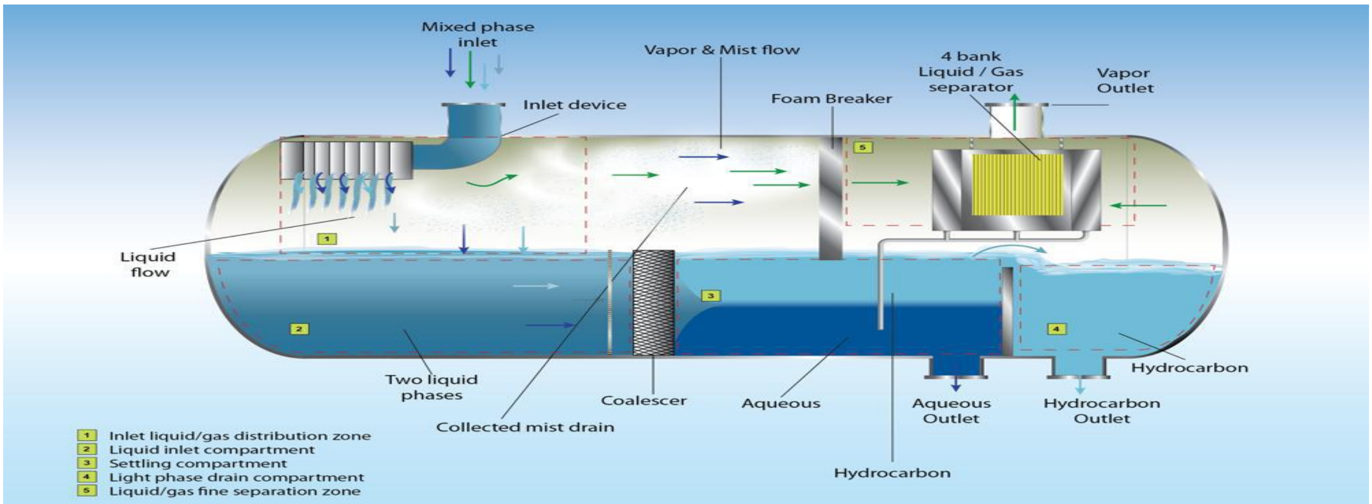


Figure 4 shows all components source: [28]

1.2.3 The equation in separations tanks

A transit balance is to show how a mass changes over time. The quantity can be moles, Mass, momentum, and energy. In a three-phase separator, the most relevant is the mass transit equation. Since the equations presume that the flow, pressure, and temperature are constant in a natural environment, these variables will change and need to be adjusted to find the separator's operating range.

The general basic equation for mass transit is:

$$\frac{\substack{accumaltion\ of\ S\\ within\ a\ system}}{time\ period} = \frac{\substack{flow\ of\ S\\ into\ a\ system}}{time\ period} - \frac{\substack{flow\ of\ S\\ out\ of\ the\ system}}{time\ period} + \frac{\substack{amount\ of\ S\\ generated\ within\ the\\ system}}{time\ period} - \frac{\substack{amount\ of\ S\\ consumed\ within\ the\ system}}{time\ period}$$

S total = Flow in – Flow out + generation – consumption

S stand for:

m = total mass

m_a= Mass of individual species

n_a= moles of individual species

H = enthalpy

U = internal energy

mv= momentum

Total mass = m

Mass balance: $\frac{dm}{dt} = \frac{d(pV)}{dt} = \sum_{t=inlet} \dot{m}_t - \sum_{t=outlet} \dot{m}_j$

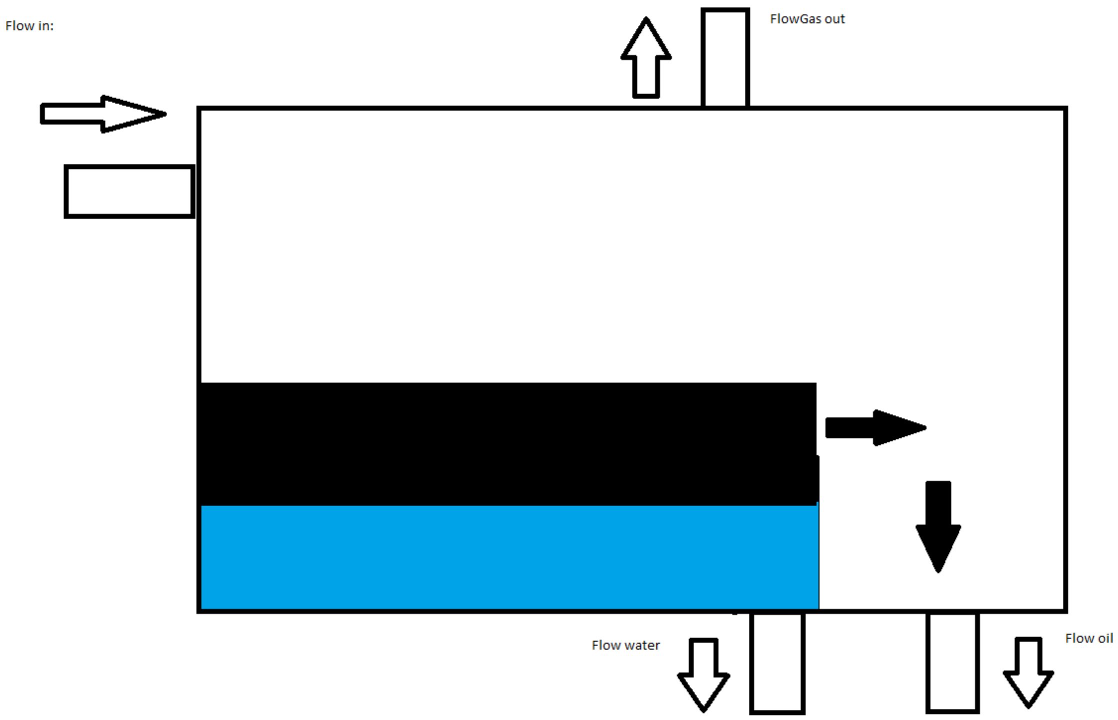
n_a= moles of individual species

energy: $\frac{dm}{dt} = \frac{d(yaN)}{dt} = \sum_{t=inlet} Y_{ai}\dot{n}_i - \sum_{t=outlet} y_{aj}\, \dot{n}_j + r_a V$

The accumulation of S = to the inlet-outlet of a system + generation – consumption. For this equation used, we will overlook the energy and consumption since these are variables of the physics of the mixture, such as turbulence, temperature, flow rate, emulation, etc. For future work in the equation, there will be taking the terms for all the variables[29].

Three-phase separator with constant area and variables:

A model shows a simple version of a three-phase separator with the flow in, flows gas out and flows water and oil out. This example is of a three-phase separator with a content area with a weir



Mass transit equation:

$$\frac{\text{accumaltion of } S \text{ within a system}}{\text{time period}} = \frac{\text{flow of } S \text{ into a system}}{\text{time period}} - \frac{\text{flow of } S \text{ out of the system}}{\text{time period}} + \frac{\text{amount of } S \text{ generated within the system}}{\text{time period}} - \frac{\text{amount of } S \text{ consumed within the system}}{\text{time period}}$$

Removing the generate and consume since the system is determined to have no changing variables.

$$\frac{dm}{dt} = \frac{d(pV)}{dt} = \sum_{t=inlet} \dot{m}_t - \sum_{t=outlet} \dot{m}_j$$

$$\frac{dm}{dt} = \frac{d(axh(t))}{dt} = \sum_{t=inlet} \dot{m}_t - \sum_{t=outlet} \dot{m}_j$$

$$Dm$$

Flow in = q_{in}

Flow water= $c_{v_{water}} A_{exit_{water}} \sqrt{2g(h_{water)} + \frac{\rho_{oil}}{\rho_{water}} h_{hoil\_1}}$

Flow oil= $c_{voil} A_{exitoil} \sqrt{2gh_{oil\_2}}$

If the accumulation of the S (Mass) is inlet-outlet, then the equation is

$$\frac{S}{time\ period} = \ = q_{in} - c_{v_{water}} A_{exit_{water}} \sqrt{2g(h_{water)} + \frac{\rho_{oil}}{\rho_{water}} h_{hoil\_1}} - c_{voil} A_{exitoil} \sqrt{2gh_{oil\_2}}$$

Then applying the mass balance equations for the liquid phase as a unity

$$q_{in} - c_{v_{water}} A_{exit_{water}} \sqrt{2g(h_{water)} + SG_{oil} h_{hoil\_1}} - c_{voil} A_{exitoil} \sqrt{2gh_{oil\_2}} = \frac{\partial Vol_{liq}}{\partial t}$$

Then get the volume of liquid partial derived by time in the system.

And for each phase liquid

$$Q_{water} x Vol_{water} - c_{v_{water}} A_{exit_{water}} \sqrt{2g(h_{water)} + \frac{\rho_{oil}}{\rho_{water}} h_{hoil\_1}} = \frac{\partial Vol_{water}}{\partial t}$$

$$Q_{water} x Vol_{water} - c_{v_{water}} A_{exit_{water}} \sqrt{2gh_{hoil\_1}} = \frac{\partial Vol_{oil}}{\partial t}$$

X represents the state variables of the process. It anticipates more complex systems using vectors and matrices.

Finding the height of the weir :$h_{weir=h_{oil}+h_{water}}$

1.2.3.1 Coalseing droplet from water and oil

The figure shows the most commonly used level for the phases in a separator tank.

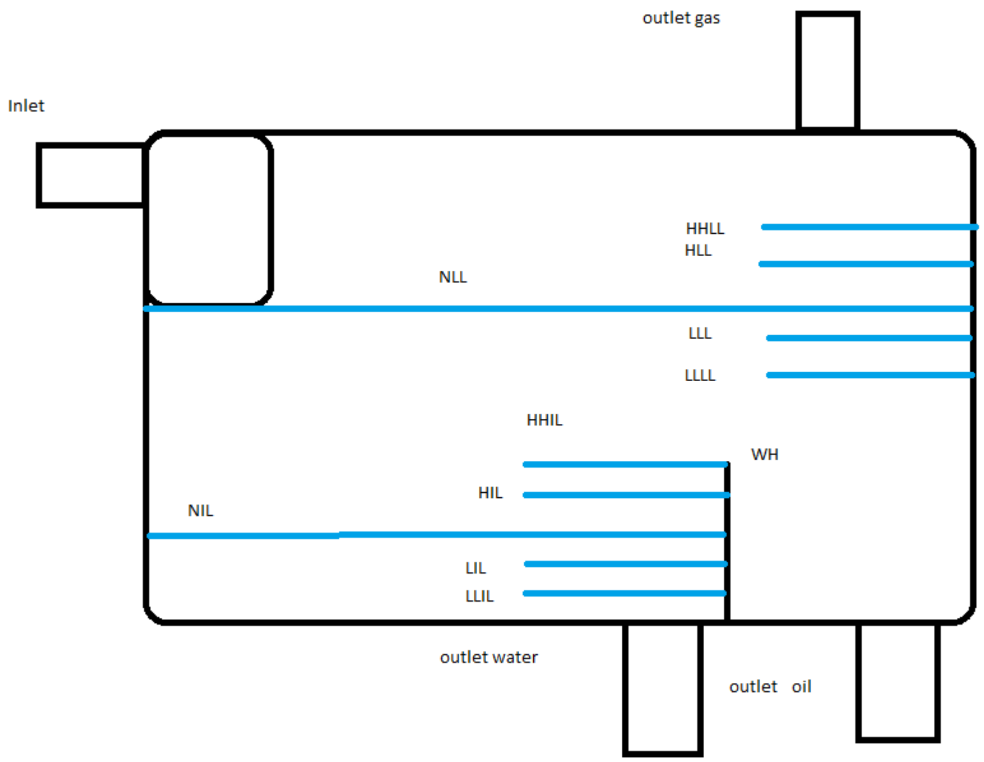


Figure 5 Variables level in a tank

These levels are the typical ones used in a three-phase separator and have slight variations between the American and Norwegian concerning the residence time. The alarm setting on the different levels depends on the steady-state contidons[29].

Coalseing droplets from water and oil. Stokes low is provided for calculating the droplet removal in a tank for most general use:

$$Vt_{100} = \frac{Vh}{H/Le}$$

H: height of the continuous layer

Le: effective separation zone length of a continuous layer

Vt100: the settling of the droplet for 100% removed for both oil and water in the liquid layer

Vh: Velocity of the phases

The velocity can be determined by the droplet can be for the diameter for the size to remove 100% of droplets:

$$Vt = \frac{gd_d^2(Pd - Pc)}{18uc}$$

Vt: Droplet terminal settling velocity

g: gravity

d_d: droplet diameter

Pd: density for droplet

Pc: density for the continuous phase

Uc: viscosity of continuous phase

Assuming that the droplet has been completely removed at this diameter, the smaller diameter droplet of this is in half. The efficanty can is

$$n_{d<100} = \frac{vt}{vt, 100}$$

Vt: Droplet terminal settling velocity

Vt100: the settling of the droplet for 100% removed for both oil and water in the liquid layer

$n_{d<100}$: separation efficiency of droplet smaller the 100

Calculating the efficiency of an inlet without any device but only a correction of the liquid at a 90-degree angle :

$$n = \frac{(p1 - pg)v_g * d^2\varepsilon}{18uD}$$

P1: destiny for liquid

Pg: gas destiny

Vg: velocity for gas

d : droplet size

ε : angle of bend

u: gas viscosity

D: pipe diameter

This equation shows the different variable/parameter that is important to determine when understanding the processes in a three-phase separator tank[29].

1.2.3.2 Study case of using the API units:

The papers found uses the API American petroleum institute static design criteria[30].. The common nominator of these equations depends on stokes law[31].

This study has made a model of each state in a three-phase separator according to the API criteria and simplified the assumption of the process. Then to verify the mathematical model of phases made a simulations model in a production line consisting of a two-phase separator followed by a three-phases[26].

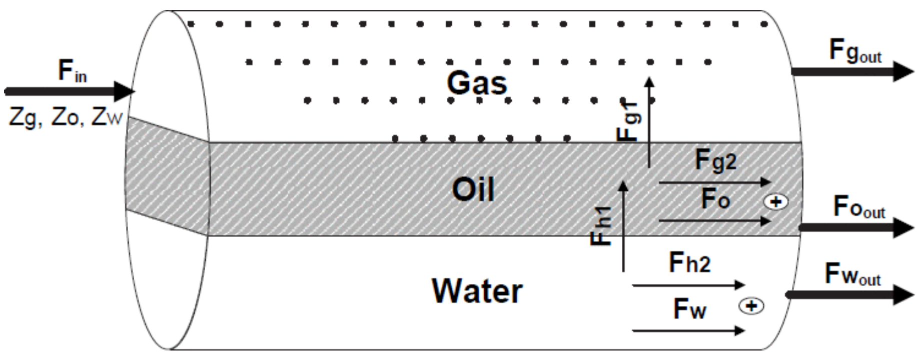


Figure 6 simplified version of a three-phase separator flows source:[32]

This study uses the method in the previous one but expands on it, providing the model with additional dynamics identification of level process[33].

1.2.4 Showcases using MATLAB/Simulink

With Simulink, model and math equations can be to create a virtual representation for many systems involving many engineering fields ranging from mechanical, electro, and hydro[34-36]. This is heavily used in universities for teaching students to compare the results from theoretical to practical, with didactic physical equipment to a simulation model[37].

This allows for generating code from the model after visualizing the equation and system requirements. When making the model for simulation of a three-phase separator with level control, this is the workflow being used.

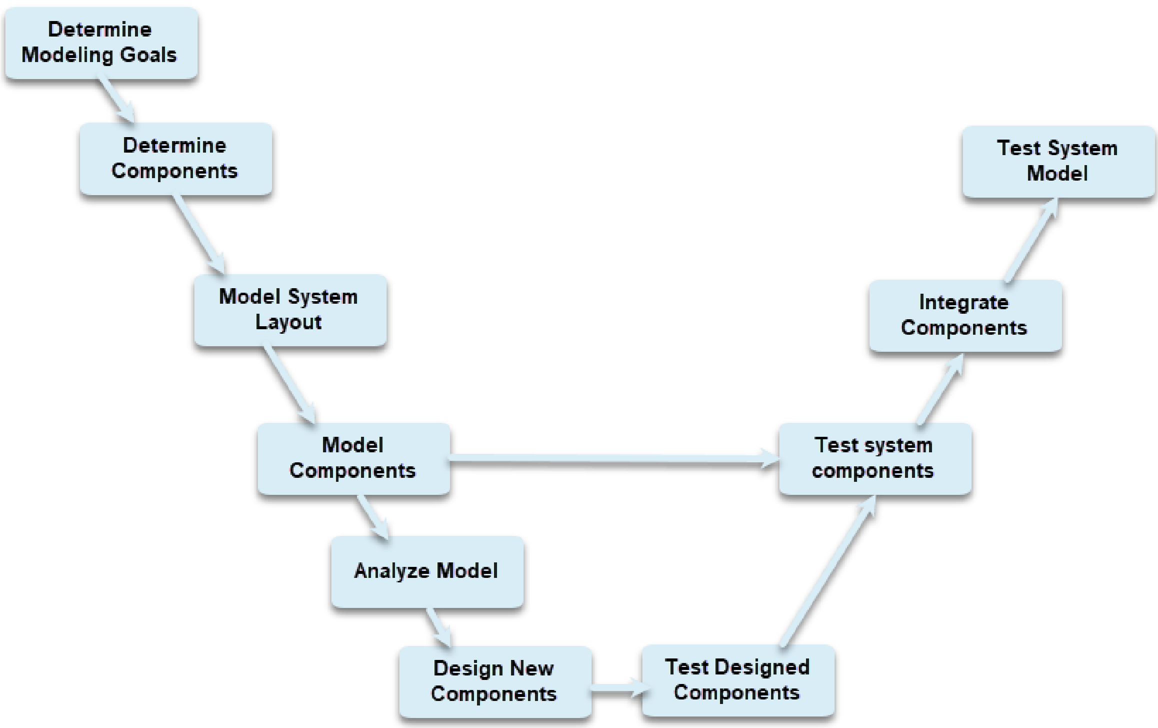


Figure 7 workflow for model-based design Source:[38]

1.2.4.1 Simulink (MATLAB) PID with 2 Tank Simulator

Example for creating a system with two tanks and with a single pumping from a reservoir to determine the PID values.

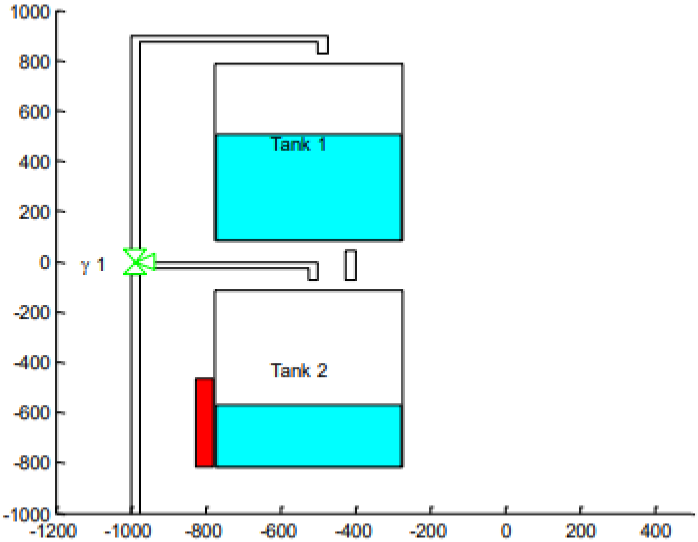


Figure 8 Simulink (MATLAB) PID with 2 Tank Simulator source:[39]

There are two tanks placed on top of each other with a pump from a reservoir and the task is to set a level controller on the second tank such that the pump flow rate is set at a certain level. There is placed a valve in between the tanks but it will not be used.

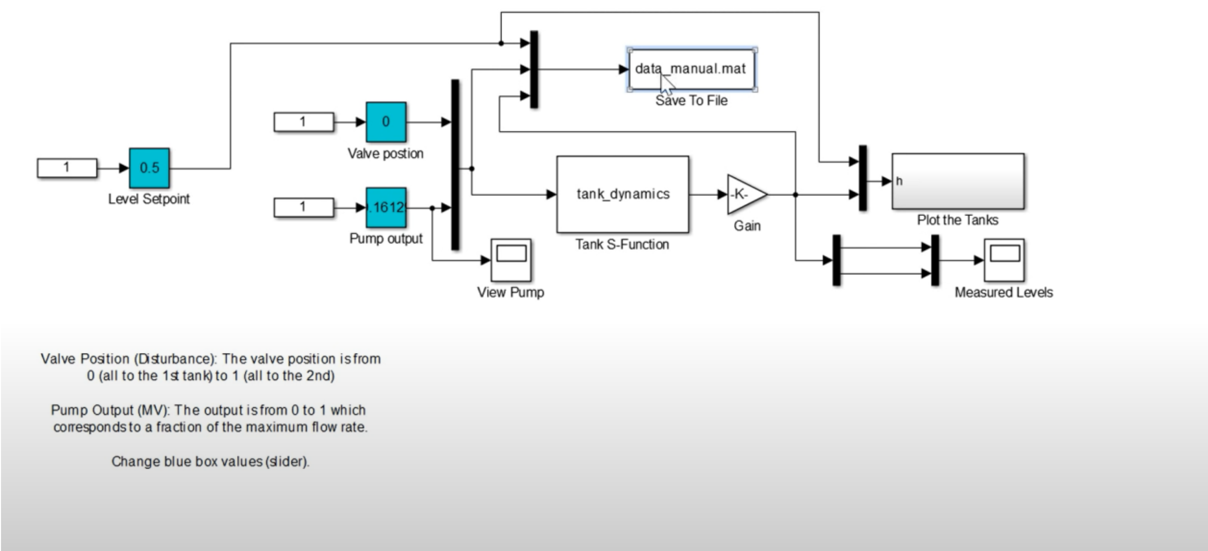


Figure 9 Simulink model of the tanks source:[40]

What is important in this model is the pump is not regulated by a PID controller, but the model is used for finding the k_c , i_τ and t_d value, which in Simulink are $P = k_c$, $I = \frac{k_c}{I_\tau}$ and $D = kc * i\tau$, after obtaining these values, a PID can be placed and regulate the flow rate from the pump to control the level in the 2nd tank[39].

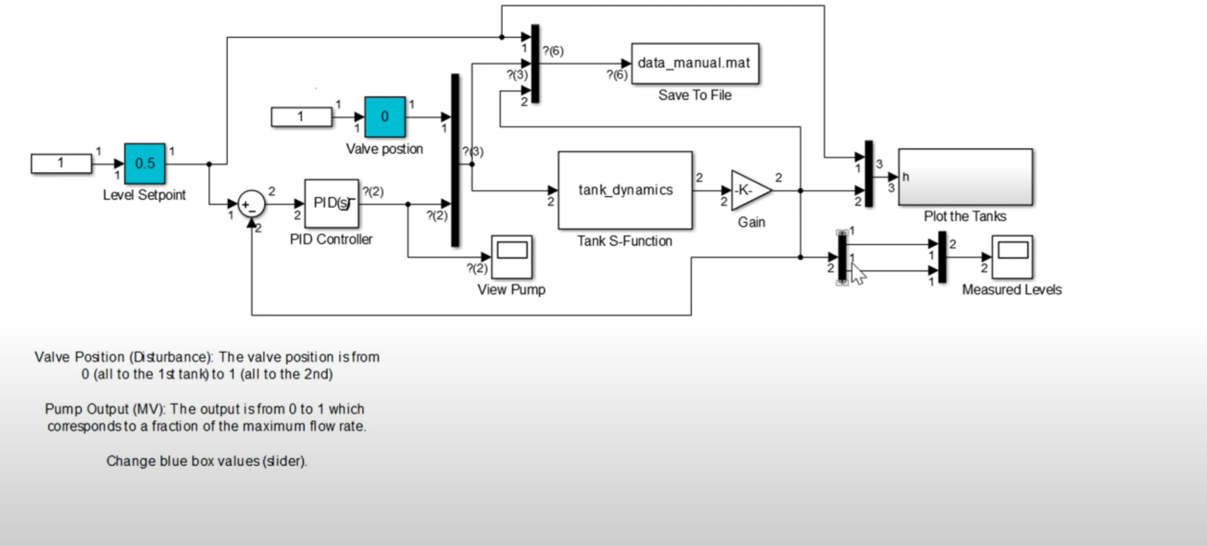


Figure 10 Simulink model after gaining value for PID source: [41]

1.2.4.2 Simulink for second difference equations:

"The differential equations is : $ay'' + by' + cy = 0$

Solving for the function of $F(y, y'') = -ay'' = by' + cy$

Set the y=0 and place the Y" on one side give $y'' = -\frac{by'}{a} - \frac{cy}{a}$*"*

"For a simple Second Order Differential Equations need to add a function that will be able to both Y' and y," and for achieving this, we need to and two integrators in a session of each other. Show the block diagram in Simulink will look like this:"

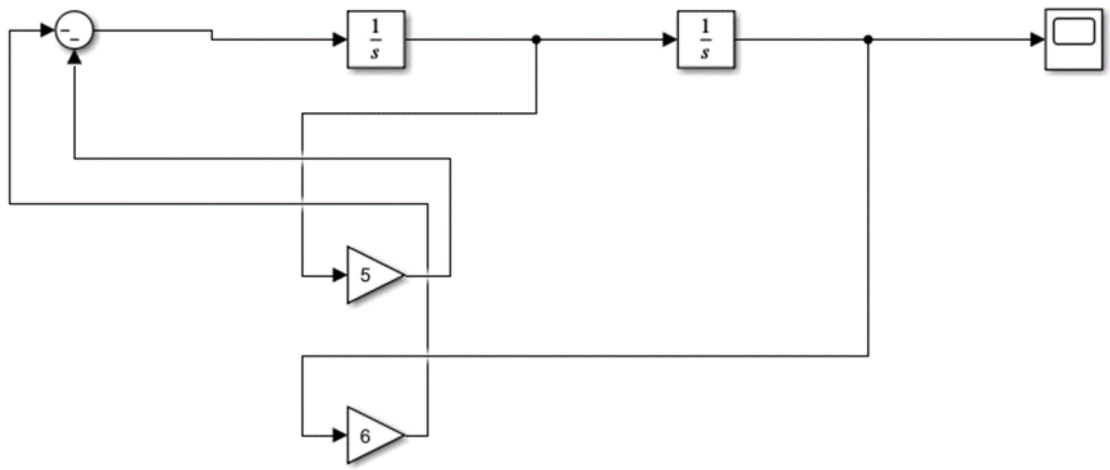


Figure 11 block diagram [42]

"*The initial condition of the integrator is* $y'(0) = 1$ *and second is* $y(0) = 0$

The gain block will work as a constant for y' and y, and in this case, the constant is $5 = y'$ $6 = y$. *and also dividing the* $\frac{b}{a}$ *and* $\frac{c}{a}$

Assuming the form of each is solution is $y = e^{yx}$

The square root of $y^2 + 5y + 6 = 0$ *is* $y = -2$ *and* -3

Gives $y(x) = c1e^{-2x} + c2e^{-3x}$

The initial condition is proven when in the $0 = c1 + c2$ *and* $1 = -2c1 - 3c2$

Using two equations with two unknowns gives :

$$c1 = 1 \text{ and } c2 = -1$$

Show the solution is $y(x) = e^{.2x} - e^{-3x}$ *Simulink gives a similar answer*:[42]"

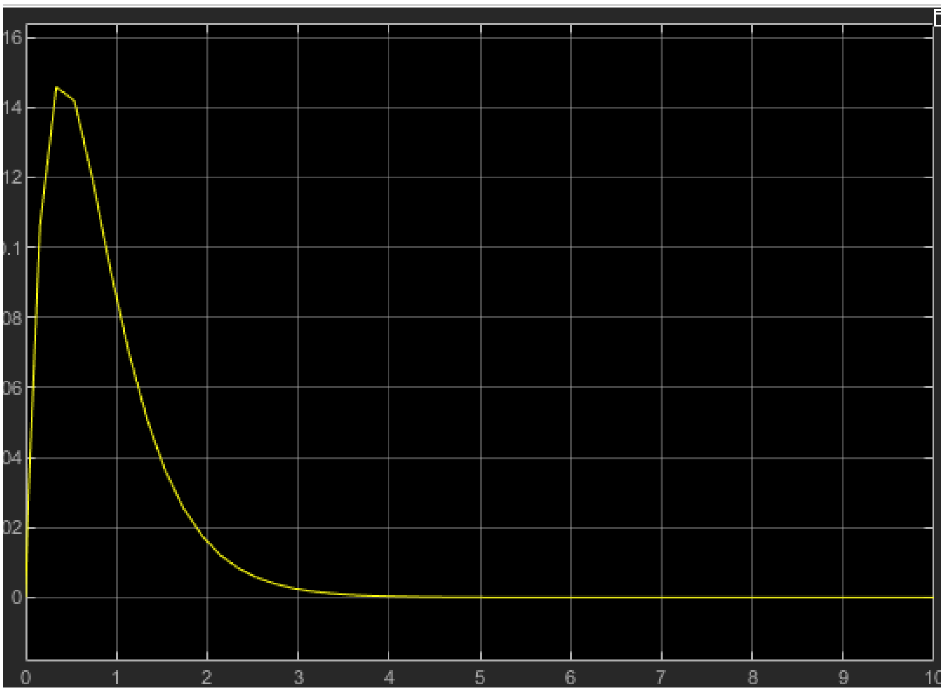


Figure 12 results

1.2.4.3 Single tank system with subsystem

The equations can be put into the Simulink using Matlab to execute a program, but you can also use Simulink to make a subsystem that performs a task. Here we have a subsystem for the integral time. The system has a PID controller with P = 1 I= 1 and D= 0. The mass equation is

$$\frac{dvol}{dt} = 8 - bV$$

The system is set to a constant of 8, and the initial condition of each of the gain blocks at 1

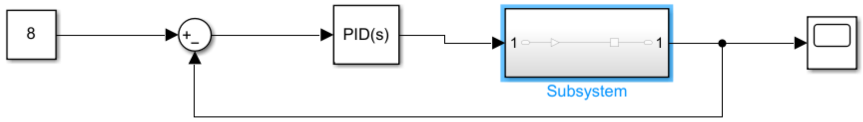


Figure 13 subsystem

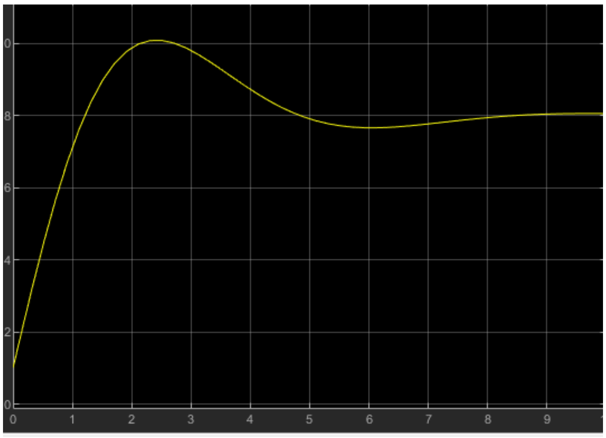


Figure 14 result from subsystem

The result shows that the volume increases to 10 and goes under 8. This is due to the PID controller not being calculated.

A single tank mass transition programming

We can also use Simulink for programming the equations into a separate function such that each product does not have a block.

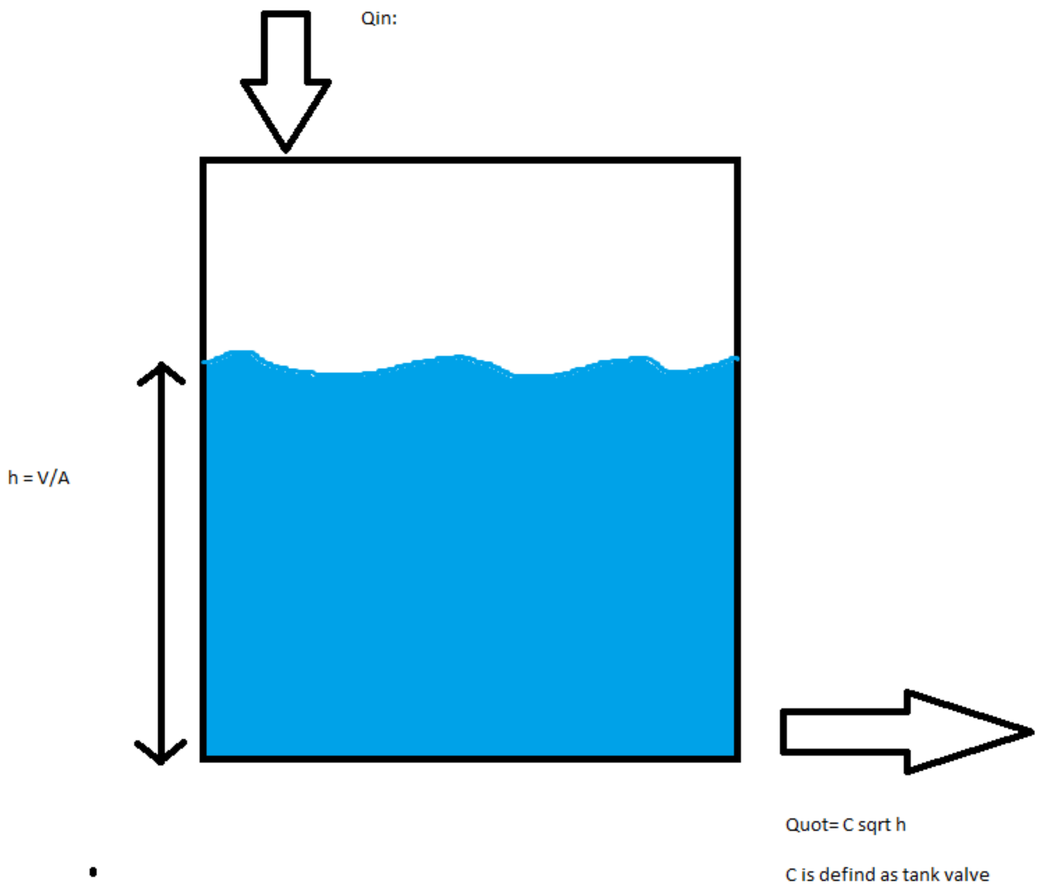


Figure 15 presentation

C= tank valve flow

h= height of water level.

$$\frac{dV}{dT} = Qin - Qout \quad =$$

$$Qout = C\sqrt{h}$$

$$h = \frac{V}{A}$$

The Qout is defined as the valve position to the square of the height of the water

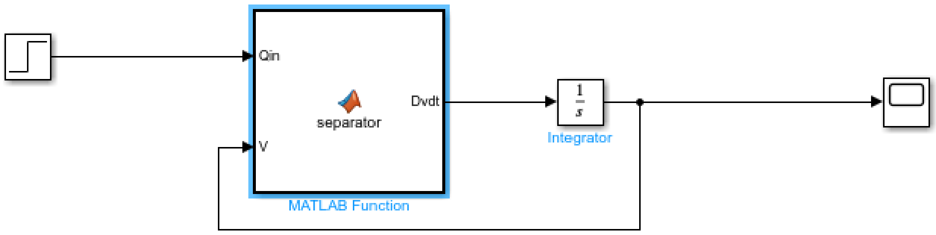


Figure 16 using a fucntio cell for a tank

The equation looks look like this:

```
function Dvdt= separator(Qin, V,d, C, p1)

Axs = p1/d*4^2;

h = V/Axs;

Qut = C*sqrt(h);


Dvdt = Qin -Qut;
```

Figure 17 formula used

The result shows function is working, but the values are not correct since all of the parameters are set to 1. This is done for showing that the function of using “coding” is possible. The parameter can be easily changed for a more complex system.

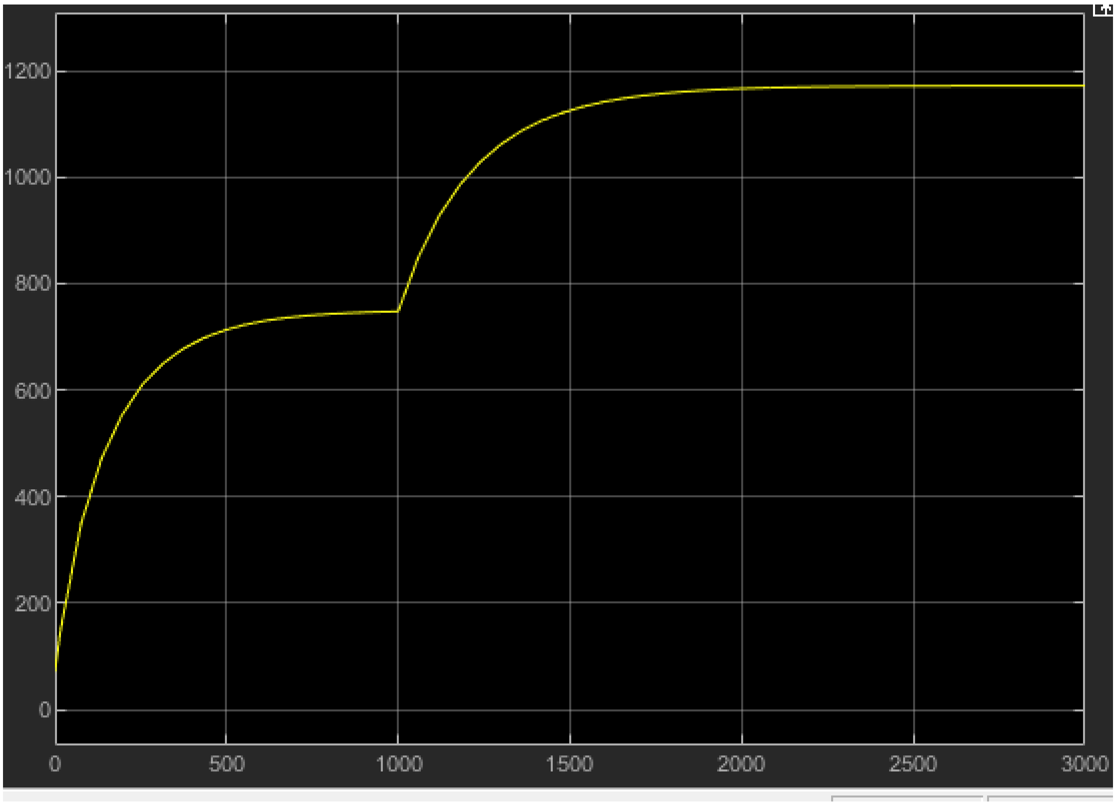


Figure 18 results

The step input time is set to 1000 the Qinn changes from the initial volume of 8 to 10. The tank becomes a steady-state with a volum of ca 780, rises to 1100, and reaches a steady-state again[29].

1.2.5 Three-phase separators in didactic equipment.

A motivation for this thesis is to create a simulator using MATLAB/Simulink with the current equipment in the lab. Lectures encourage the student to be passive, and students are most more learning benefits of "learning by doing." And in some cases leading the student to drop out of the courses[43, 44]

UIT three-phase separator model

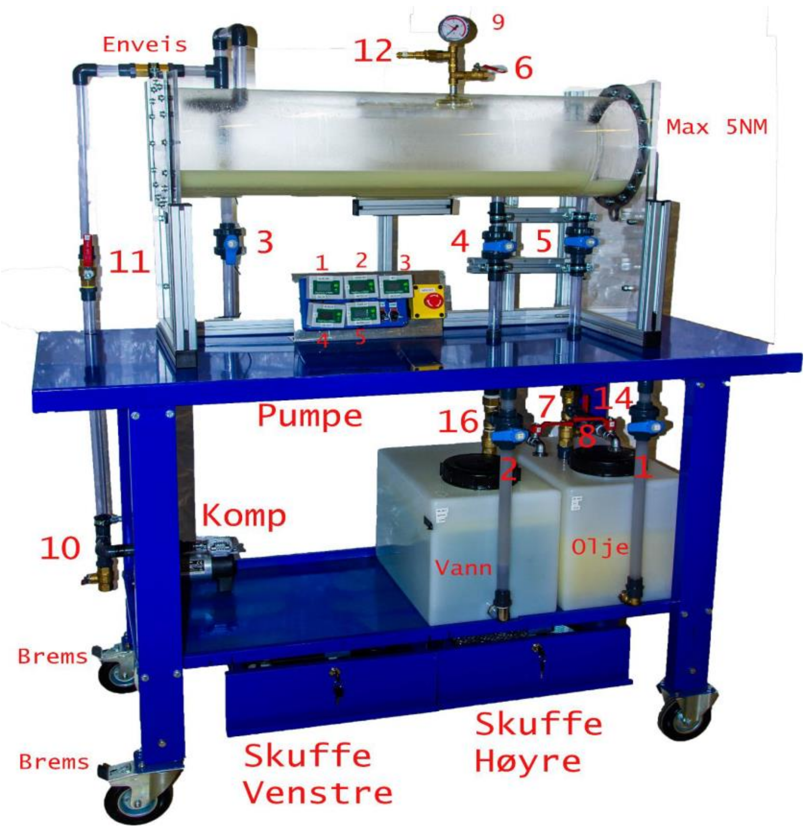


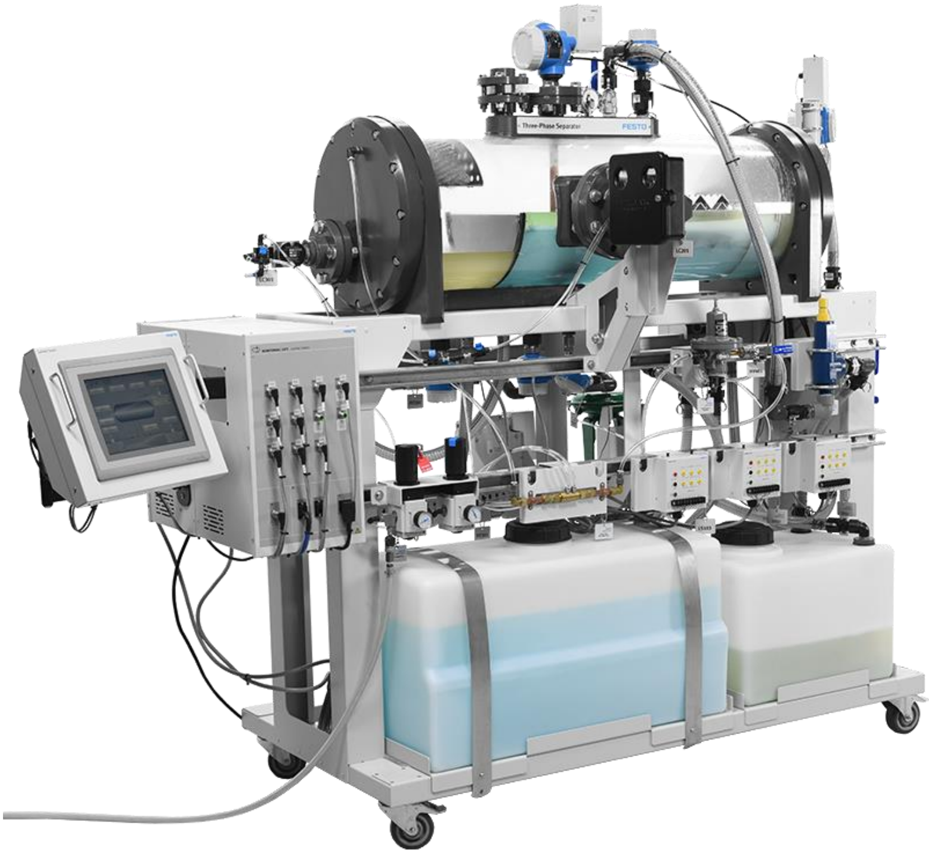
Figure 19 three-phase separator from UIT

The vessel consists of a pump that pumps it from two containers of oil and water into the tank. The mixture hits the walls of the tank that act as an inlet diviner—filling up the tank with the mixture. In the tank, it has an outlet for letting the gases out. After the mixture is settled into a layer, the oil will flow over the weir and back into the container. Each of the pipes going into and out of the tank has a regulated valve that can be regulated, thus acting like a Coefficient for comparing to the equations.

Every pipe going into and out of the containers also have a pressure gauge and flowmeter for accurate reading of the flow, which is displayed in real-time for reading the results.

As a physical model, it's a simplified version of a three-phase separator tank. It lacks much of the equipment used in a real production tank and does not have software for simulating the process or configuring it.

Labvolt three-phase separator:



- Figure 20 abvolt three-phase separator source:[29]

Labvolt three phases separator model shows all the steps as close to a real-production have. An inbuilt automatic valve that is controlled by the HART communications protocol. It has an inlet divider, coalescing plates, mist extractor, and pressure valve. The system is monitored by a computer for watching, level control, and result of different parameters [29].

UOP30-3-phase separator

It is a separator with two different separator tanks, which are interchangeable but come in weir and bucket weir configurations. It uses ArmSOFT desktop software where the users can monitor the flow rate of water, oil feed rate, oil flow rate, water flow rate, water feed rate, the temperature of the vessel, and airflow rate. The feed rate can be changed while the separator is on or off[45].

Figure 21 OUP30 source: [36]

Comparison of the separators:

There are minor differences in the separator that can be purchased from the market. It has been given two examples which are more of [46, 47]. A common factor is that they are all automatic valves that can be adjusted with a monitor system, in the system flow rate can be changed while the vessel is on. All of the data is being logged and can be reviewed. In the equipment of the tank, there are differences. Some of them have mist exstator, coalescing plates, and wave breakers. With the tank that UIT has, these are much more complicated and provide a more realistic environment for teaching.

1. Three-phase model in the laboratory

The master thesis is divided into 2 parts:

1. Model in the three-phase separator in Autodesk inventor and a flowchart from Aspen HYSYS consisting of the model in the laboratory.

3. Tasks for students in rely on the model in the laboratory.

The physical model in the laboratory consists of a three-phase separator from two vessels.

1.3 Model in the laboratory

The model in the laboratory is developed by two students previous in UIT for purpose of teaching the students about the inner working of the three-phase separator. The model has a simple weir solution here the two-component in the model consist of two liquids of regular cocking oil and water (H20). The experiment that is conducted is normally the purity and height of the layers.

The two liquids are mixed in a one-way pipe into the separator into an inlet diverter, unlike the equipment used in the oil industry where you normally will find a wall or a weave. The model uses a wall of the model. The model uses straight walls instead of curved walls. One deficit is also that it uses cooking oil instead of oil with a viscosity of crude oil. The cooking makes emulation in the whole tank instead of having layers of oil and water.

The range of the parameter are:

Flow rate: 3.0 - 100.0 liter/min

Temperatur: 0 – 80 grader Celsius

Pressure: Maximum 8.0 kg/cm2

Each pipe flow in and out for 100 mm in diameter and can handle a flow of 100 litre/min. the mixture will be a perfect 50/50 between the oil and the water due to a control sensor in the mixture pipe.

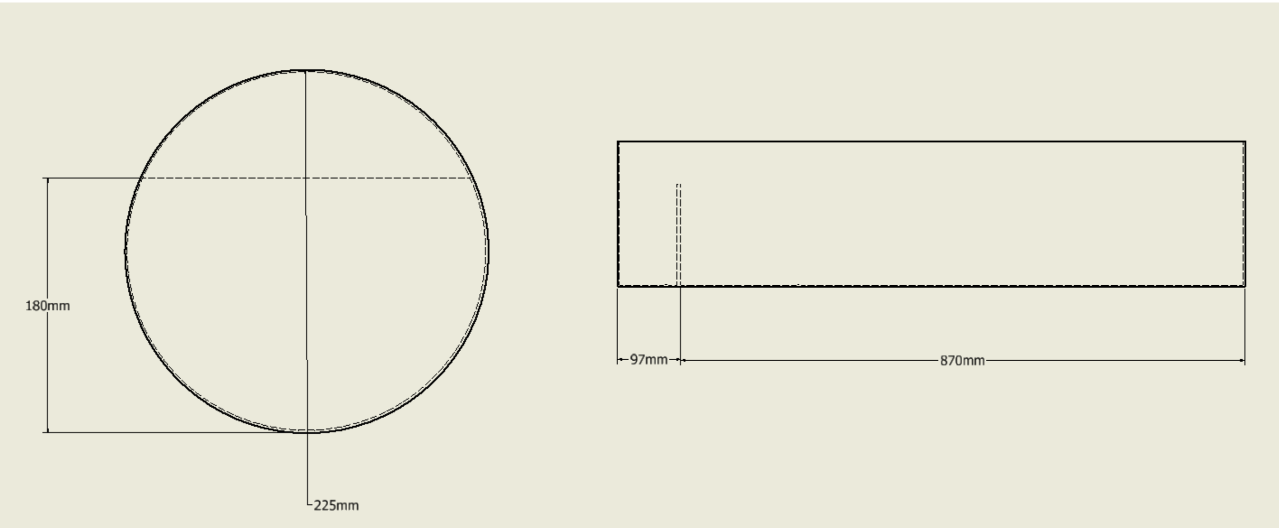


Figure 22 dimension of the tank in mm

The diameter of the tank is 225mm after the weir and 870mm before it, the diameter is 225mm and the height of the weir is 180mm.

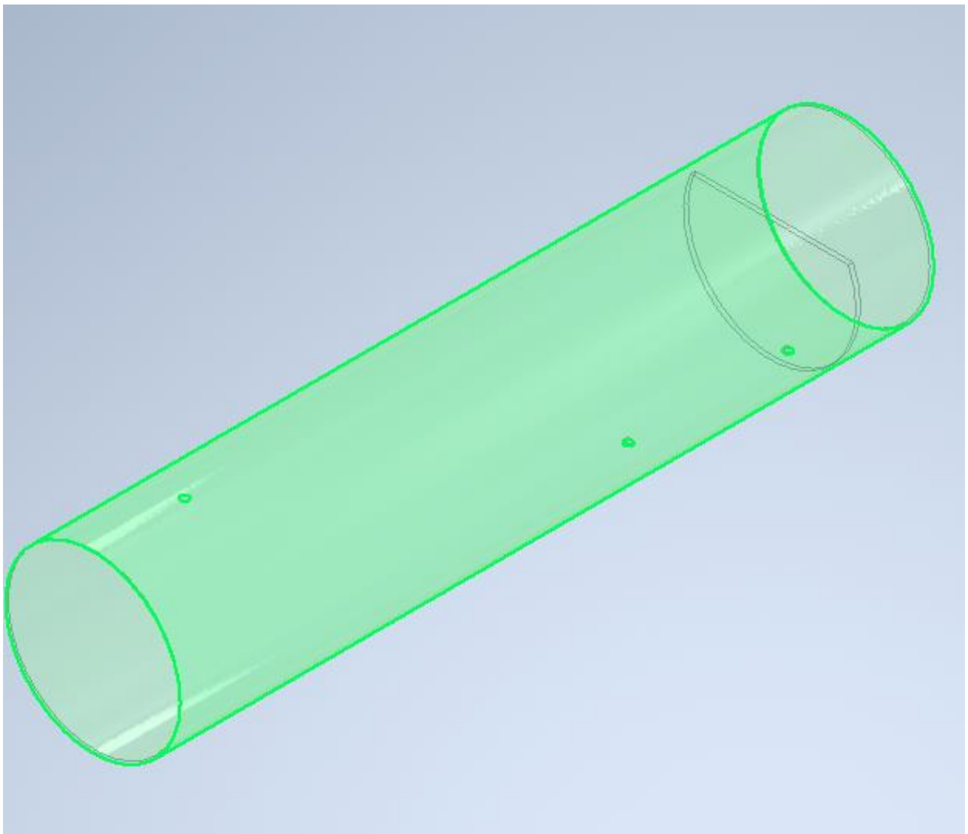


Figure 23 inventor drawing of the tank vessel

The volume of the tank model is: $v = 3{,}97e - 002m^3$.

When performing the test on the model it's going to be most optimal if the layer of water and oil is at 50%/50%.

There is a parameter that will be measured, and that is:

- Flow in water
- Flow in oil
- Mixture flow
- Flow out oil
- Flow out water
- Purity

These are the primary parameter that will be used to determine the correlation between the model and the HYSYS simulation. Also, the flow is in gallons/min.

The pressure inside of the tank is set to be 0,5 bar and this is controlled by a compressor in the model. This is due to the tank being made of Plexiglass and passing this will make it crack. Normally in petroleum, the pressure is naturally by the gas coming from the reservoir.

One of the challenges with this model in terms of acting like a three-phase separator is the model only has two-phase, the valve on top is for regulation of the pressure inside of the tank, not exceeding 0,5 bar. I will treat it as a three-phase separator in HYSYS and change it if it results do not behave like a three-phase in the simulation program.

Figure 24 picture of the model in the experiment

Figure 25 valve from the vessel of oil and water for determining the speed of the program.

For the distribution of 50% water and 50% oil, the flow is needed to be 1.5 Gallons/minute for both. This will show the flow for the mixture as 3.25 gallons/minute in the display. And the flow out of each water and oil will be 1.5 gallons/minute.

Figure 26 the display of the model when the 50/50 distribution

The oil doesn't have a description of what type it is, the only thing that is present is that is cooking oil, so for replacement of the oil, I will be using olieacid since olive oil is 75 % alieacid and without any data on the oil I have to use what is processed to be accurate.

For calculating and simulation the model there will be assumed that the flow, area and compositions are not changing and are constant.

1.3.1 How is the experiment conducted?

The two valves 1 and 2(figure 25) are open to the fullest, this will make the flow be 1.5 g/m for both oil and water, and for the mixture 3.25 g/m. the mixture shows a variance of -+ 0,3g/m. When the mixture reaches the weir edge the process is done and waiting on the separation to start. When the oil and water have separated the process can go continuously with a reduced liquid volume, which will say that the speed of the inlet needs to be reduced to achieve.

Model of the simple three-phase separator in HYSYS.

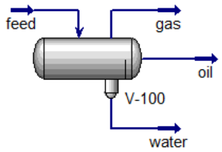
It is called a simple model because the tank will be simulated the model in the lab. The lab model lacks pressure gadgets, 2and temperature gadgets and overflowing. This makes the task of simulation difficult. The purity also must be with the model.

The model in the HYSYS will be using a standard(v-100) three-phase simulator with a feed of two liquids. The pressure is assumed to be the same as inside of the tank will say 0.5 a bar

The flow rate of both liquids will be 1.5 Gallons/minute which converts to 409,5 l/h = 0,0819kg/s. The oil used is linolenacid.

For choosing the fluid package that will be used, the choice was between Peng-Robinson, CPA or SRK. In general, all of these use a cubic equation of a state-based property package that is appropriate for these kinds of separation between water and hydrocarbons.

V-100		
Separator Type	Three Phase	
Vessel Temperature	20,00	C
Vessel Pressure	10,00	bar
Vapour Molar Flow	0,0000	kgmole/h
Liquid Molar Flow	6,074e-004	kgmole/h
Duty	0,0000	kW
Vapour Molar Flow	0,0000	kgmole/h
Liquid Molar Flow	6,074e-004	kgmole/h



Compositions				
	feed	gas	oil	water
Comp Mole Frac (H2O)	0,5000	1,0000	0,0003	1,0000
Comp Mole Frac (LinolencAcid)	0,5000	0,0000	0,9997	0,0000

Material Streams					
		feed	gas	oil	water
Vapour Fraction		0,0000	1,0000	0,0000	0,0000
Temperature	C	20,00	20,00	20,00	20,00
Pressure	bar	10,00	10,00	10,00	10,00
Molar Flow	kgmole/h	1,214e-003	0,0000	6,074e-004	6,070e-004
Mass Flow	kg/h	0,1800	0,0000	0,1691	1,094e-002
Liquid Volume Flow	barrel/day	2,943e-002	0,0000	2,778e-002	1,654e-003
Heat Flow	kW	-0,1374	0,0000	-8,930e-002	-4,815e-002

Figure 27 HYSYS results

1.4 Calculations of the tank

The calculations are made such that the h=hweir and that the mixture is not surpassing the height of the weir. The length of the calculation is the size of the gravity section of the tank. (From the wall to the weir). The units that will be used are metric: m, m/s. The Conversion of the flow is then 1,5 g/m = 1 gallon per minute ≈$0{,}0675\,\mathrm{kg/s}$:

Using the data from the simulation for flow out and flow in

Flow out oil = $c_{voil} A_{exitoil} \sqrt{2gh_{oil\_2}}$

Flow out water = $c_{v_{water}} A_{exit_{water}} \sqrt{2g(h_{water}) + \frac{\rho_{oil}}{\rho_{water}} h_{hoil\_1}}$

Finding the height of the water layer inside the separator tank this formula is taken from the book [10]:

A simple model of the separator tank will get the layer of

Av = $L * f(h) = L2 * \sqrt{}$(h(2r − h) = 0.870 $* f(h) =$

$0.870m * 2 * \sqrt{}(0.225m(2 * 0{,}171\text{m} - 0{,}225\text{m}) = 0{,}482m^2$ area of the mixture

L=length of separator h=height of mixture = hweir r= radius of tank av= area of the liquid

Using the same equations for the height of the water and oil:

$$hw, o \frac{1}{\rho o, w * Av}(qio.w - qoutw, o)$$

$$\rho_{mix} = \frac{2 \times \rho_1 \times \rho_2}{\rho_1 + \rho_2}$$

This is assuming the Ho > Hweir

Height of the layers: hweir:180 L:870

Calculated:

Mixture:	Height water:	Height oil:
50%water/50%oil	9,7cm	8,3cm
65%water/35%oil	11,4cm	6,6cm
80%water/20%oil	14,9cm	3cm
35%water/65%oil	7,9cm	10cm

What is observed:

Mixture:	Height water:	Height oil:
50%water/50%oil	11,5cm	6cm

65%water/35%oil	13cm	4,9cm
80%water/20%oil	14,9cm	3cm
35%water/65%oil	7,9cm	10cm

.

Finding the flow for each of the distribution of components:

50%water/50%oil = 3,25gallons*% of water and oil

Mixture:	Water:(gal/min)	oil:(gal/min)
50%water/50%oil	1,63	1,63
65%water/35%oil	2,11	1,14
80%water/20%oil	2,6	0,65
35%water/65%oil	1,14	2,6

The flow is adjusted using the valve 1 and valve 2 as shown in the fig

Purity:

Each sample is weighed to be 75ml water is taken out and weighed for finding the purity of the sample on the flow out oil side: $\frac{amout\ of\ oil}{amout\ of\ water}$

Mixture: 50%water/50%oil	Purity 90%
65%water/35%oil	87%
80%water/20%oil	85%
35%water/65%oil	92%

For getting the most accurate the residence time is about one hour, this is not standard residence time, but the mixture is almost 100% emulsion.

1.4.1 Comparing the results of the simulation, model, and simulation:

The simulation is almost too perfect in its assumptions of the separation between oil and water. They have created many attempts of finding which package to use, the use of CPA is because of the low-pressure process. But the unknown in the process makes it very difficult to simulate the process with accurate results.

1. The difference between what is observed and calculated is significant, this is most likely because of that the tank fills first up with water from the tank and adjusting the valves to match the flow needed for the component, is not done properly because it takes time for the sensor to register the flow difference.

2. The flow of oil out simulation is too high with a mass fraction of 0,9392 linolenacid, into 0,0602 H_2O. This is most likely because of the molar weight of the liquids.

3. The process of the flow rate of the liquids, which is 0,169 kg/h for oil

1.5 Task for students

For the student to challenge themselves and learn by doing instead of sitting passively listening g to lectures is important to see the workings of a three-phase separation and do the theory the before, since there is only one model in the laboratory there will be set to grp of 5 persons. The first part will include questions general to the three-phase separator and the last will be to make a model in HYSYS to match the model in the laboratory. This will be in a task form.

Question:	Answer:
1. Explain the three sections in a three-phase separator	Intel section: The liquid is rapidly changing the direction at a high velocity spreading the mixture such that the fluid is sinking to the bottom of the separator and the gas goes atop, often used feed deflection plate. This is where most of the separation occurs. The liquid is still a mixture of oil and water and needs time for the separator. Gravity section: The velocity and flow have slowed down and allowed the droplets to be separated from the mixture into the gas zone of the tank. The droplets are small and will float. The separation of water and oil is defined as gravity separation. The two liquids are called immiscible liquids and turn in two phases within the tank because of the difference in density. The time that is needed to separate is called retention time, and sufficient time is needed for this. Another phenomenon is called coalescing separation, where small particles from one of the liquids are separated from a small quantity of liquid, and internal construction is needed for this. Outlet section: As mentioned, the droplet from the liquid is floating in the gas zone of the tank, and for this to form into bigger droplets, a mist extractor is needed that collects all the small size droplets and turns them into larger ones that drop in the liquid allowing them to drop into the mixture again. A weir is also used for separating the oil and water when the oil floats. A wall stops the water allowing oil to pass to stop the turbulence of the mixture and pacify it.

2. what is the advantage and disadvantages of the vertical and horizontal separator?	Overview of the advantages and disadvantages of a vertical and horizontal separator The selection of separators heavily depends on the uses of the tank. This will consist of vertical vs. horizontal tanks. Look at the challenges facing the three-phase separator Placement/location: Separator location is important for choosing whether the tank will be vertical or horizontal. For operation offshore, the use of a vertical is suited because of the area space and mobile. This can be countered with stacking mounted on top of each other when using a horizontal separator. Solids: With a mixture incoming from a source, it mostly will contain some form of solids. In the horizontal tank, solid piles are situated(repose) at 45 to 60 degrees (angle from the plane to the top of the pile) [13], and drains are located and the length of the vessel. Drains needs then to be in close range to each other or installed jets to remove them. Both solutions are expensive and not very effective. While in a vertical tank, a dump valve or a drain can be placed at a high elevation and remove the solid before it becomes a pile [8]. Gas/oil ratio: The geometry of a horizontal tank allows for a higher ratio of gas and oil [15]. Volume for gas in a vertical separator is limited and can't support a high volume of gas but is efficient when it comes to a mixture with low GOR.

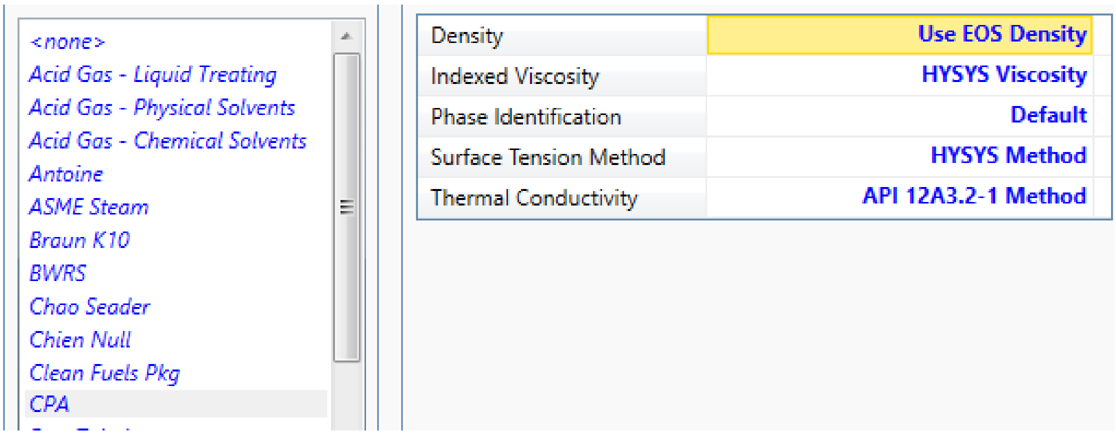
The model in HYSYS:

Step1.What components?

Component	Type	Group
H2O	Pure Component	
LinolencAcid	Pure Component	

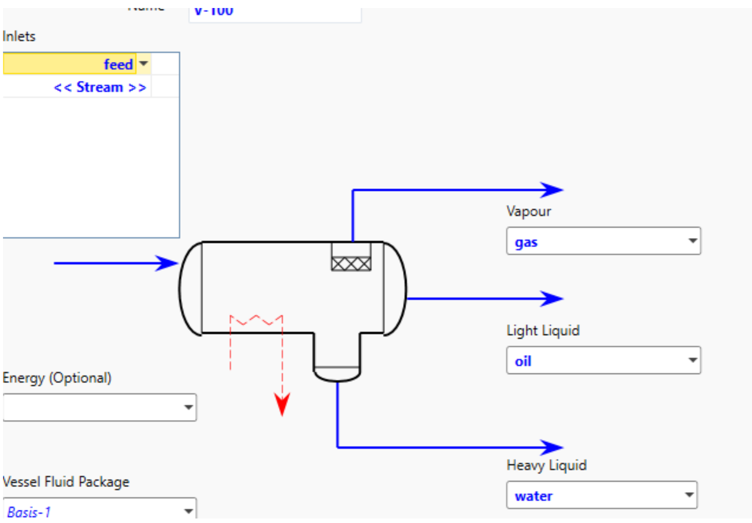
First, pick the components H2O and linolencacid, the reason why you pick the linolencacid, is because sunflower oil is 75% linolenacid.

Step2. What fluid packages?



The package that will be picked is CPA because the process is a low-pressure process between water and oil.

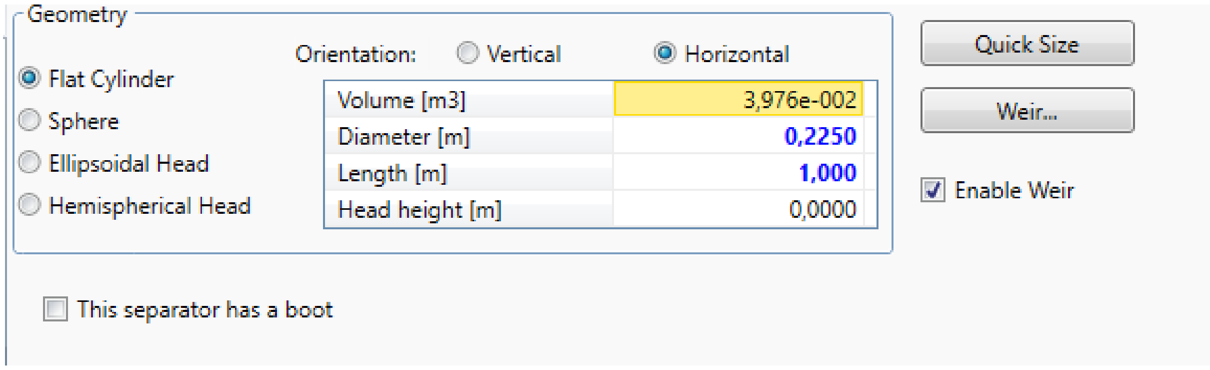
Step3. Pick the three-phase separator and add a feed stream and three product streams.



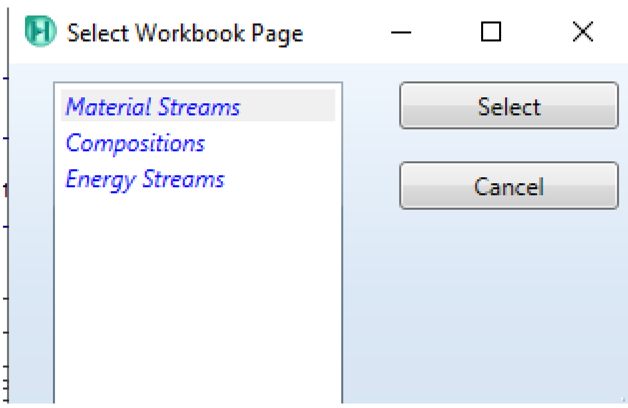
Step4. Add temperature to 10 C and the pressure to 1bar and mass flow to 1,5 g/min and the worksheet should look like this:

Name	feed	oil	gas	water
Vapour	0,0000	0,0000	1,0000	0,0000
Temperature [C]	10,00	10,01	10,01	10,01
Pressure [bar]	1,000	1,000	1,000	1,000
Molar Flow [kgmole/h]	5,319e-003	3,233e-004	0,0000	4,996e-003
Mass Flow [kg/h]	0,1800	9,000e-002	0,0000	9,000e-002
Std Ideal Liq Vol Flow [barrel/day]	2,840e-002	1,479e-002	0,0000	1,361e-002
Molar Enthalpy [kJ/kgmole]	-3,013e+005	-5,349e+005	-2,862e+005	-2,862e+005
Molar Entropy [kJ/kgmole-C]	49,75	-7,606	53,47	53,47
Heat Flow [kW]	-0,4452	-4,804e-002	-0,0000	-0,3972

Step5. Change the geometry of the tank from a boot separator to a separator with a weir. Also, the 50% to 75% use of the tank, add the diameter of 225mm and 1-meter length, in the weir height to 180mm and distance 900mm



Step6. To show results right-click the process wall and show the worksheet of the streams



1.6 the Discussion

The model in HYSYS does not represent the model in the UIT. Are many factors that may point to why first the information that is given on the oil component is lacking and therefore hard to choose one without having a reference. The model lacks a pressure gadget so for the model in HYSYS it was chosen to set them to 1 bar, there have been many attempts of changing the pressure without any effect on the results. The residence time is not been calculated because the model has an emulsion of 100%. There is perhaps a contamination of the oil and water vessel, where people have not cleaned the model and oil has come into the water vessel. The lack of a third phase makes it hard because the three-phase separator has in its equation to predict the flow of gas. The package can be set to only have a liquid to liquid separation but the solver then does not calculate a separation happening. A lot of the work has been lost because of spending time making the model in HYSYS

1.7 Conclusion

The project has produced a model and a blueprint for the student in UIT to learn using HYSYS in the lectures. It teaches the students which components to use and which fluid packet to choose. Also how to change the geometry from a boot separator to a separator with a weir.

1.8 Further work

Further work is needed is to add a pressure gadget to the three-phase separator and add a gas phase to the model. It needed to change the oil to oil and then represent an oil used in the petroleum business. The viscosity is too similar to water and makes a 100% emulsion even if the flow rate is slowed down.

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