DESIGNING AND IMPLEMENTING EXPONENTIAL PRESSURE/TEMPERATURE CONTROLLEROFVOLATILE OIL DISTILATION MACHINES

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ABSTRACT

Volatile oilsused as main substancesof perfumes, aromatic foods, therapiesandmedications. At home industry, the volatile oil produced by distillatinga cultivated vegetation and using a simpletechnology,that is a steamer. The steamer works at pressure/temperature about 1 atm/120^{o}C. The process work inefficienregardingto time, fuel, menpower, and product. For improving the efficiency, some variables must be controlled for the process, that are pressure/temperature and duration process. Each variant of the raw materials have a difference characteristic orprocess varibles. Purposes of this research are to designing a simple and low cost the pressure/temperature and duration process controller, but can be adjusted precisely according to the characteristic of the raw material. Expected, using the pressure/temperature and duration process controllerwouldbe more efficience. The analysis show that the controller can be adjusted to follow each curve of distillation characteristic through a variable that is a constant flow rate of water. It very interesting

Key words: distillation, volatile, controller, pressure, temperaturr, duration.

I. AN INTRODUCTION

1.1 Backgraund

Generaly, volatile oils are used as a substance of perfume, aromatic food, aromatic therapy, and medication[5]. Looked at its utility, the volatile oil to be primadona asexport commodity. The volatile oil is produced from some varities of cultivated vegetations. The cultivated vegetations are:pogestemon cablin, andropogon nardus, vetiveria zizanioides, canangium odoratum, santalum album, melaleuca leucadendron, syzygium aromaticum, etc. Weather of subtropicalregionsupports to develop the cultivated vegetations.

Generally, industry doers of volatile oil are home or small industriesand they get aninterest income[1]. For axample: a ton of dry clove leaf distilled use a conventional machine for 12 hours of process distillation will be able to produce 20-25 kgs of clove leaf oil with a price US$230 - US$280. Production cost consist of raw materials, fuels, and manpowers are US$180 in range. It is mean, in once process will give profit at least US$50.00.

Majority, volatile oil produced in simple way, using simple distillation machines by doer small industries in villages near raw material resources[3]. The simple distillation machines made of iron tube without any controller, except using sense and evidentby manpower, mannualy. Without any satisfytechnology will not give product optimally. Besides, not optimally in quantity, also give low quality and it cause low price.

To improve the quantity and quality of product, the efficiency of distillation machines must be increased in ways to completed the machines with some controllers. An opportunity to increase efficiency is manipulate some variables, such as: pressure/temperature and duration of ditillation process.

1.2 Problem Identification

Product of volatile oils collected by distributors to fulfill demands of regional market and export. In fact, it is not enough and neededan product augmentation. An addition of the product attempted in way: 1) increasing distillation frequency, 2) expansion network of purveyor of raw materials and 3) adding menpower[3,4,8].Thiseffortis not sufficient to solve the problem caused by varied constraint. For example: rivalry occured in international marketaffected by: 1) quality of the product, 2) the price tending tofluctuating caused by amount of product not be controlled, and 4) competition of a peer of the producers.

Other posible to increasing the product is to improve efficiency of the machines, that are: improving ratio of the raw material with respect to product, and quickness of the process, in way improving the machine efficiencies.

To improving the machine efficiencies can take advantage ofthe effective technology, that is add a low cost and simple control equipment, but have good performace.

1.3 Intent and Goal

Intent and goal of the designing, realizing, and researching are:

1) Designing a simple controller of a distillation machine which pursue the pressure/temperature curve and duration of the process according to the raw material distilled.
2) Prepare a controller as a effective technology to controlling evaporation chamber of the distillation machine.

1.4 Outline

Designing, manufacturing, and trial the pressure/temperature controller of evaporation chamber of the volatile oil distillation machine which response to pursue a linear or exponetial curve according to raw material characteristic.

1.5 Problemsolving Approaches

Term of controller is not always suggested meaning a difficult thing, a complicated thing, an elaborate thing, or a complex thing. Broadly, the raw material of the valotile oil have 3 approach characteristic curve, that are: 1) linear, 2) covexexponential, and 3) concave exponential. The curve can be pursued by a simple pressure/temperature controller. For this requirement need to design a controller, follow: 1) low cost and simple machine, 2) easy to adjust the response of the contoller, and 3) the controller operate at the best possible and automatically.

II. THE REVIEW OF RELATED LITERATURE

2.1 Theory of Valotile oil Distillation

The distillation process that is a process to isolate a substanceby evaporate throughwarm upsome liquidand then continued to condensate the steam through a condenser[1]. If some liquid at certain pressure warm up, the increasing temperature will through a boiling point and then go toward a steam phase. Increasing the prerssure in a fix space cause increasing the boiling point of the liquid, and vice versa[2,7].

Quality of volatile depend on eugenol content inherent. Increasingly eugenol content, so increasingly the quality and higher the market value[4,5,6]. The eugenol have to maintained and avoided applicable to over heating. The raw material of volatile oil have a certain temperature limit for distillation process and if the limit passed cause untangled or complete decomposition before reach a minimal boiling point[6]. Very difficult to limit temperature in distillation process through adjuting fire of the heater. Besides that the characteristic of heat change is very slow, also the fire controlling used certain fuel is very tricky. There a easy method to control temperature of evaporate chamber, that using two heater: 1) base heater using any fuel, and 2) fluctuative (controlled) heater using electrical heater. An electrical heater as a superheater to controll temperature steam only and it easy to be controlled.A easiest way to control temperature is to control its pressure and it is cause temperature changing.The distillation process used to isolate volatile oil are majority used conventional technology work principally. That is warm up the raw material and the water at a big chamber sparated by a filter. Steam of the water and volatile oil flowed to condenser through a pipe. Usually, the condenser have a shape as two pools. The distillation used water and steam is chiep relatively and economic.

. The distillation machines majority used are: 1) boiler model, that is the water and raw material sparated, and 2) steam model, that is the raw material inserted in a stainless steel chamber, then the chamber warmed up to certain temperature and its steam used to evaporate the volatile oil inherent raw material and bring it go towards condencer chamber[6,7].

2.2 Gas Pressure and Temperature Law

The atmosphere pressure at surface of sea water is 1 atm or aproach 1 WC (water collum)[9].The gas can be compressed according to Gay Lussac - Avogadro equation[2], that is shown like equation 1:

$$P.V = n.R.T. \qquad 1$$

where:

P : pressure (Pa)
V : volume
n :moles of gas
*R :universal gas constant, 0.082 atm*L/mole*K*
T :temperature in Kelvins

Whiledifferential pressure of liquid can measured from different height. For the water valid a equation 2, follow[9]:

$$P = \rho.g.h \quad (\text{in } N/m^2 \text{or } Pa) \qquad 2$$

where:

ρ: water decity= 1000(kg/m^3)
g : gravity= 9,81 (m^2/s)
h : heigh of water (m)

2.3 Volume Deriving

At figure 1, an object of valume regulator have unique form immersed in a tube, will give an inner space blank.The inner space blank filled water with constant flow rate of liquid, so got changing rate of liquid level as time function. The liquid level changing rate depend of unique form of the volume regulator. An interesting event in this episode is that the liquid level changing proportional regarding water pressure changing at botton.

Then, if derived a mathematic equation of the inner space blank volume, it will result equation 3 and its curve shown like figure 2.

$$v_{(h)} = \pi r_{max}^2 (h - 0.112 h^{\frac{5}{3}}) \qquad 3$$

2.4 Distillation Process Pressure Characteristic

Oil inherent the raw material can not evaporate instantly. To evaprate it, needed longer time, namely: *process duration*. If the water steam flow and contact the raw material shortly and quickly, so have not enough time to evaporate volatile oil inherentthe raw material. To get product optimaly, so the variables to be controlled are: 1) temperature, 2) pressure, and 3) process duration. Process duration shows production rate and measured as ratio of water and volatile oil condenced.

In conventional distillation machines, distillation process apply a constan temperature and pressure, that are the temperature about110^{o}C and the (differential) pressure about 0,1 atm, approximately. At that constant temperature and pressure, the machine work well, but need more longer the process duration, about 12 hours. It means that the process need more time, wasteful fuel, wasteful cost of menpower. Consequently, product price will be more expensive and not competitive in the market.

To improve this matter is make sorter for the distillation process duration until less than 5 to 6 hours. This can be achieved with increasing the pressure/temperature gradually and no hasten feed the steam to condencer, in order togive opportunity evaporate the volatile oil inhrent raw material. In figure 3 shown three types prediction of the distillation process pressure/temperature curve without cause volatile oil decomposition. All three curve are: 1) linear, 2) covex exponential, and concave exponential. Need to know that each pressure/temperaturecurve of different raw material has different shape curve. For example, the dry clove leaf according to curve ”2”, that has end point about 250^{o}C/1 atm upper the pressure atmosphere.

2.5 Temperature Measurement

Boiling point of water depend on space pressure. If continued warm up, liquid – gas phase changing occurred. If the gas continued more warm up will occurred an advanced head known as superheated steam. The Pressure changing follow the temperature changing. The heat steam at the controlled pressure/temperature contact directly to the raw material.In order to maintain the steam temperature so that not exceed temperature cause raw material decomposition, therefore the temperature watched over continuously.

2.6 Water Level Control and Measurement

Water level in the evaporation chamber have to maintained constant. This equipment also used to measure amaunt of water evaporated. Ways, some of water filled automatically to evaporated replaced the water alredy evaporated. Machine need to completed anautomatic water level control.

2.7 Process Duration Measurement.

To evaporate the oil inherent the raw material, the evaporation chamber have to be wormed until at certain temperature and duration[1]. The process duratian imply rapidness of production. If, speed evaporate waterextremely, so will give the steam water only and ratio of product (ratio between volatile oil and water) will be low, and if, speed evaporate water very low, so the process duration wil be slow. Then, if the steam of the water and volatail oil always discharged, it will affect the pressure in the evaporation chamber and it cause evaporate water majority and not sufficient to give opportunity to evaporate the oil inner raw material. To get optimal result in distilation process, so that need to regulate three variables, that are: temperature, pressure, and duration of the process. Optimal process duration controlled using automatic pressure controller and adjusting fuel. But, in this research not yet conclude amount of the fuel, except manually.

2.8 Pressure Contoller of Evaporate Chamber

The controller have to follow the optimal evaporation process characteristic according to the raw material characteristic. The controller must be simple and easy to be adjusted. Then, the controller made and could controll three varables, that are: pressure, temperature, and duration process. The controller using a constant flow rate of water as a reference of all variables. Pressure of evaporation chamber compared to pressure generated by wigth of water.

III. METHOD

3.1. Step of The Research

Initiative and sequences the research enclose: 1) designing and manufacturing, 2) trial, 3) analyzing, and 4) determining specificationof the controller. The reserach flowchart shown like Figure 4

3.2. System Aproach Method and Analysis.

The analysis based on mathematic estimate and result of each the trials. The variables to be measured that are a change of pressure/temperature and time. This are enaught to predict the characteristic of controller. In another word, that the analysis base on:

1) Controller filled the water at constant flow rate, then recordedthe pressure and duration.
2) Drew a curve of the pressure versus duration

From the result of the data analysing can be determined the accurat setting point of the process so that got the most optimal destilation machine..

IV. DESIGNING MACHINE

Priority consideration on the designing are, efficient like difined before, low cost, esay to operated, and have good performace.

4.1 Controller Designing

In the figure 5 shown a sketch of the pressure controller system. The figure is not real scale. The big chamber in the left side is a evaporator tube completed a filter to sparated water and raw material. In the right side shown a pressure controller system.

4.1.1 Linear Controller Designing

In the figure 6 shown an unique shape object and used in a linear pressure controller, In this system used a cylinder form, that is an object shaped like a tube or pipe. In this model, if a constant flow rate of water used to fill inner space blank cause increasing level (high) of water. Rate of level changing is linear and in such manner for height and pressure at botton.Rate of pressure changing can be stated in a mathematic like shown in equation 4.

Volume of inner space blank is:

$$v_1 = \pi(r_L^2 - r_D^2)\int_0^t dh \qquad 4$$

Where:

v_1 = volume of inner space blank
h = height (level) of water
r_L= radius of outside tube
r_D= radius of inner tube

While volume of water used to fill the inner space blank equal to a constant flow rate times duration of filling in or $v_2 = Qt$. Because $v_1 = v_2$than:

$$h = \frac{Q}{\pi(r_L^2 - r_D^2)} t \text{or}$$

$$P = \rho g \frac{Q}{\pi(r_L^2 - r_D^2)} t \qquad 5$$

4.1.2 Fraction Exponent Controller Designing

In figure 7shown a unique shape object used in a concave exponent controller. The pressure in the botton have an exponent shape, it is mean that the pressure in the botton change exponentialy with respect to time. Relationshipbetween pressure and time shown in equation 6.

$$P = 10^{-6}\,\rho g\left(Q\frac{3}{\pi}\left(\frac{h_{max}}{r_{max}}\right)^2\right)^{1/3} t^{1/3} \qquad 6$$

Where:

h_{max} *: maximum high of liquid*

r_{max} *: maximum radius of the inner space blank*

Then, display a curve using Matlab. All parameters and values used in this programmare real value in international standard unit. The yield shown in figure 7, that are the characteristic curve and the programm to draw the curve.

In Figure 8 shown other model of Fraction Exponent Controller. Relationbetween pressure and time shown in equation 7 and figure 9.

$$A = \frac{\pi r_{max}^2}{0.00001\rho g Q}\left(P - \frac{P^2}{0.00001\rho g h_{max}} + \frac{P^3}{(0.0000173\rho g)^2 h_{max}^2}\right) \qquad 7$$

4.1.3 Origin Exponent Pressure Controller Designing

Origin Exponent Pressure Controller have a characteristic curve like inverse of Fraction Exponent Controller curve. This controller is made by reversethe unique shape object like shown in figure 10. Simplifying mathematic equation shown in equation 8 and 9. Its characteristic curve shown in figure 11.

$$t = \frac{\pi r_{max}^2 h}{Q} - \frac{\pi}{3Q}\left(\frac{r_{max}}{h_{max}}\right)^2 h^3 \qquad 8$$

$$P = 0.0001 r_{max} g h \qquad 9$$

4.2 Water Level Controller Designing

Water Level Controller is mde by take advantage of vocuum tube principle. A transparant vocuum tube completed scale volume indicator and two waterways as inlet and outlet.The outlet connected to water chamber in evaporator chamber. If water level reduce under limit will contrived a air channel towards vocuum tube consequencely soon flow few of water towards the water chamber, then, water level increase and close the air channel.In figure 12 shown the concept.

V. IMPLEMENTATION

5.1 Raw Material Characteristic

In a scientific article published wtih title: Eugenol Extraction from Clove Leaf (by: Nur Hidayati) explain a correlation between pressure and temperaturein the distillation process shown like in figure 13. In the process seen that the distillation process started at about temperature/pressure: 120^{o}C then ended at about 254,46 ^{o}C/1,053 atm[6].Duration process distillation of dry clove leaf needed for 5-6 hours. This data can be used to arrange the pressure controller.

5.2 Controller Application

If used a fraction prone exponent controller, valid to use equation 7 and use simple manipulation (using Matlab) will found a curve like shown in figure 14.

5.3 Analysis

To adjusting with respect to raw material characteristic have to select the unique shape object as volume arrangement.A form of the unique shape object have four characteritics, that is: 1) inner volume, 2) out side volume, 3)reverse inner volume, and 4) reverse out side volume. Although, unique shap object cosist of varying shape, but can be categorized in three form, that are: 1) a linear tube, 2) a cone/prism tube, and 3) a parabolic/exponent side tube. With all the three of unique shape object can be varied according to 12 forms of raw material characteristic. Also, adjusting a dissimilar precede level of water will give different characteristic, so obtainedinfinite amount of the characteristic forms. It show that the contruller equipment designed enough to represent all raw material characteristics.

Other Advantages of this pressure controller that are veri easy to operate and cheap. This is cheap because only parts contact directly to steam made from stainless steel, and other part made using glass or transparent material and they are minority. Majority pard made using pvc or plastic pipe. Cost total is very low compared to the advantages.

VI. CONCLUSION AND SUGGESTION

6.1 Conclusion

From the result of designing, analysing, and implementing the pressure and water level controller, then, can be concluded like follow:

1. All type of the pressure/temperature characteristic curve for all raw material distilled can be followed by the controller.
2. The Controller is very cheap and easy to manufactured, opeation, maintanance, and repair.

6.2 Suggestions

Disadvantages of the controller eguipment is not completed an automatc fuel regulator, so it tricked manually. It require trial and error to adjust the fuel consumption untill the best possible. Amaunt of bubler flow in the controller indicate the energyconsumption, so can be used as a reference to adjust the fuel consumption. Optimal process depend on the correct adjusting the fuel consumption.

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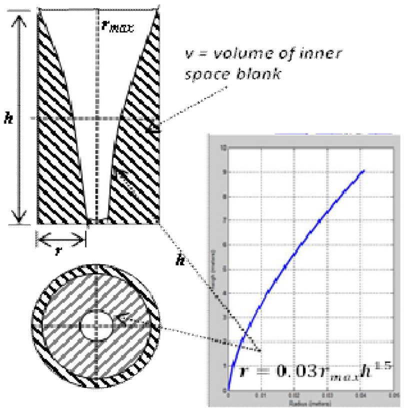


Figure 1. Volume Deriving

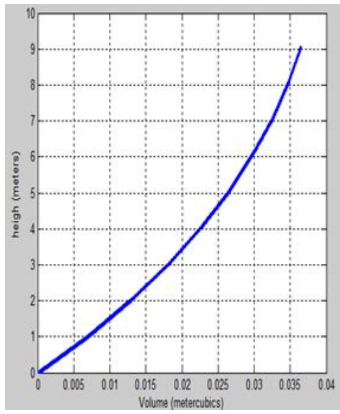


Figure 2. Volume v.s. High

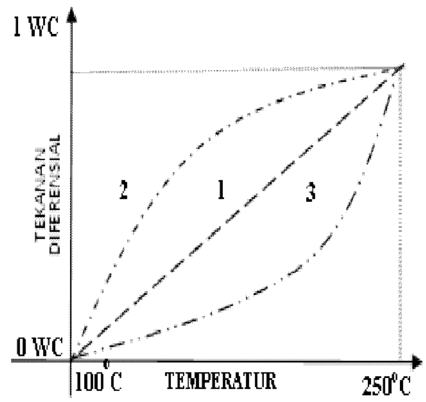
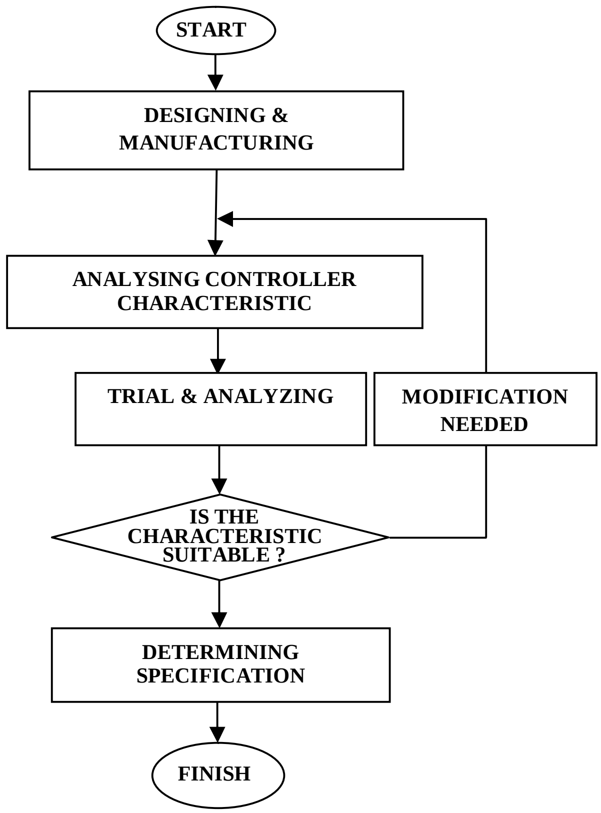


Figure 3. Prediction of the Pressure/Temperature Characteristic



Gambar 4. Step of The Research Flow Chart

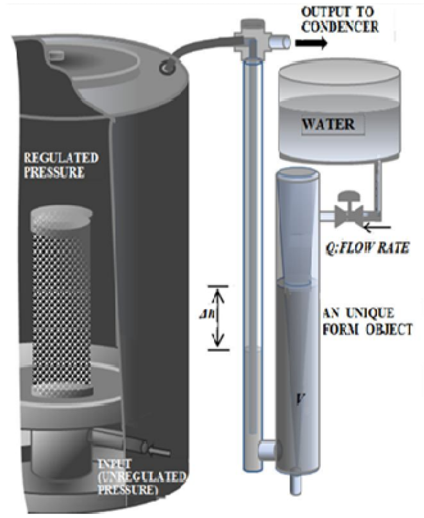


Figure 5. Pressure Controller System

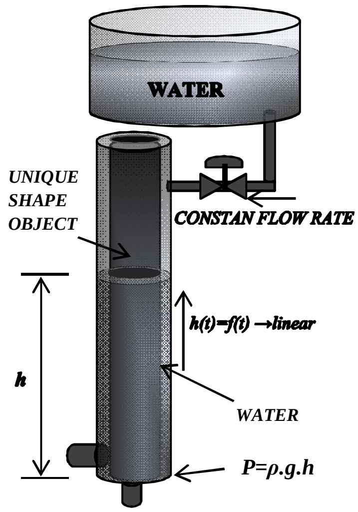


Figure 6. Linear Pressure Controller

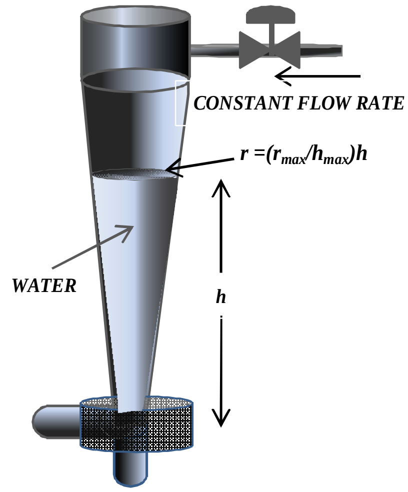
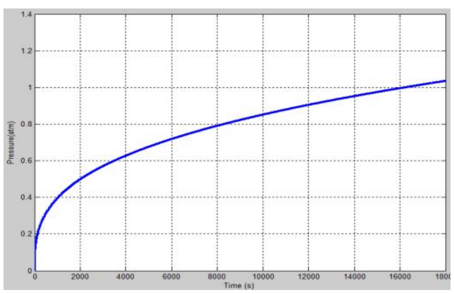


Figure 7. Fraction Laid Back Exponent Controller




```
duration=5*60*60;t=[0:duration];% process duration= 5
jam
pi   = 3.14;  atm=0.1*10.^(-5);
rho  = 1000;    % water density    = 1000 kgs/m3
g    = 9.81;              % gravity        = 9,81
mmeters/s2
Q    = 1.61*10.^(-9); % flow rate= 1.61 mls/s
hmax = 10;          % max water level = 10 meters
rmax = 0.05;       % max.radius   . = 5 centimeters
h = ((Q*3/pi)*(hmax/rmax).^2).^(1/3)*t.^(1/3);
P    =atm*rho*g*h; plot (t,h,'b','LineWidth',2);
xlabel('Time (s)'); ylabel('Pressure (atm)');
```

Figure 7. Fraction Laid Back Exponent Controller Curve

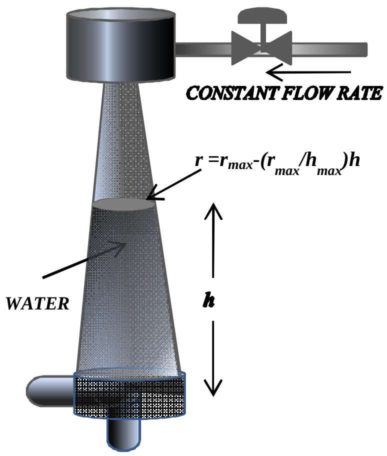


Figure 8. Fraction Prone Exponent Controller

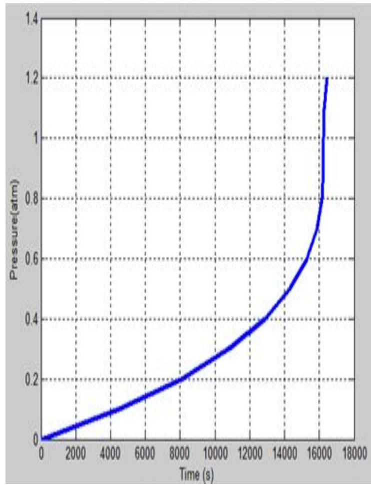


Figure 9. Fraction Prone Exponent Controller Curve

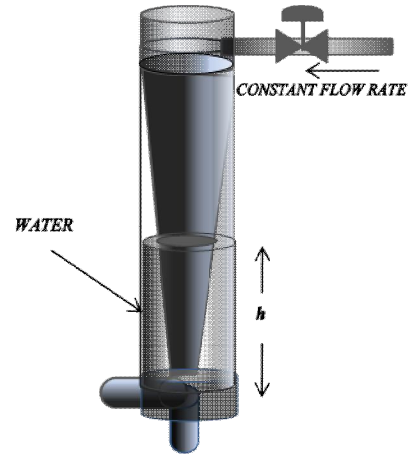
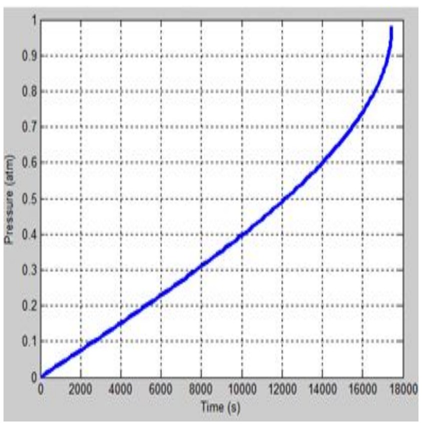


Figure 10. Origin Exponent Pressure Controller



Gambar 11. Curve Characteristic of Origin Exponent Pressure Controller

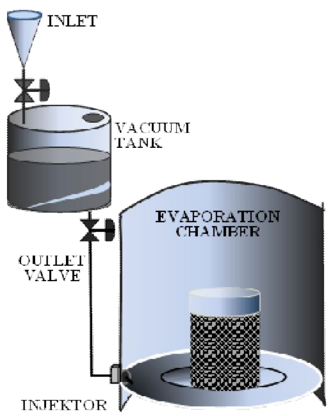


Figure 12. Water Level Controller

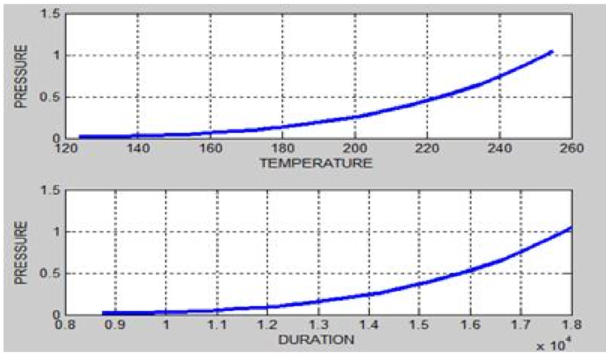
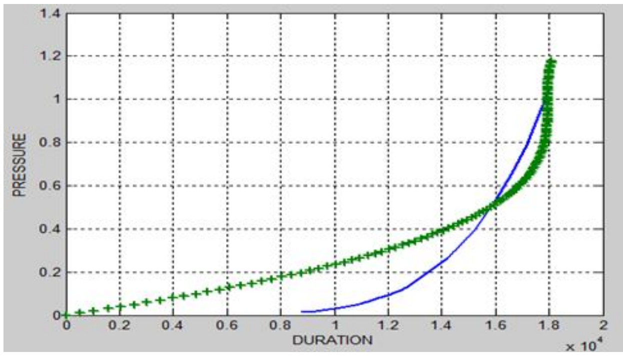


Figure 13. Temperature and Pressure Curve of Clove Leaf Oil Distillation [10]



Gambar 14. Fraction Prone Exponent Controller Applied to Dry Clove Leaf Distillation